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7. Abstract

A multiphase program was initiated in 1994 to test commercially available melter technologies for the vitrification of the low-level waste (LLW) stream from defense wastes stored in underground tanks at the Hanford Site in southeastern Washington State. Phase 1 of the melter demonstration tests using simulated LLW was completed during fiscal year 1995. This document is the final report on testing performed by GTS Duratek Inc. in Columbia, Maryland. GTS Duratek (one of the seven vendors selected) was chosen to demonstrate Joule heated melter technology under WHC subcontract number MMI-SVV-384215. The report contains description of the tests, observations, test data and some analysis of the data as it pertains to application of this technology for LLW vitrification. The document also contains summaries of the melter offgas reports issued as separate documents for the 100 kg melter (WHC-SD-WM-VI-028) and for the 1000 kg melter (WHC-SD-WM-VI-029).

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Phase I Hanford LLW Melter Tests

Final Report

prepared by

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August 1995

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BIF-MMT	-	Boiler and Industrial Furnace Multiple Metals Train
CEM	-	Continuous Emission Monitor
CFR	-	Code of Federal Regulations
CUA-VSL	-	Vitreous State Laboratory of The Catholic University of America
DCP	-	Direct Current Plasma
DI water	-	Deionized Water
DOE	-	Department of Energy
DOT	-	Department of Transportation
DSSF	-	Double-Shell Slurry Feed
DWPF	-	Defense Waste Processing Facility
EPA	-	Environmental Protection Agency
ES	-	Engineering-Science
HEPA	-	High Efficiency Particulate Arrestor
LLW	-	Low-Level Waste
OEM	-	Original Equipment Manufacturer
PCT	-	Product Consistency Test
PLC	-	Programmable Logic Controller
PNL	-	Pacific Northwest Laboratory
SEM-EDS	-	Scanning Electron Microscopy Coupled with Energy Dispersive X-Ray Spectroscopy
SRL-EA	-	Savannah River Laboratory Environmental Assessment (Reference Glass)
THC	-	Total Hydrocarbon Concentration
USGS	-	United States Geological Survey
WHC	-	Westinghouse Hanford Company

EXECUTIVE SUMMARY

Approximately 230,000 m^3 of defense nuclear wastes is stored in underground tanks at the U.S. Department of Energy site in Hanford, Washington. Retrieval and pretreatment of this material will lead to a low-level waste (LLW) stream that contains sodium nitrate and nitrite salts in a highly alkaline liquid/slurry; vitrification has be selected as the remediation technology for this waste. Westinghouse Hanford Company (WHC) has been evaluating alternative vitrification technologies for this purpose.

GTS Duratek, Inc. and the Vitreous State Laboratory of The Catholic University of America (CUA-VSL) performed melter tests under the WHC program using a simulant of the Hanford LLW stream. The tests were conducted on two melter systems, the DuraMelter™ 100[*] and the DuraMelter™ 1000, at CUA-VSL between September 1994 and January 1995. These tests successfully met the objectives detailed in the test plan that was prepared for this project.

The Hanford LLW simulant was successfully vitrified using the DuraMelter™ 100 and 1000 systems at sustained feed rates of nearly twice the nominal rates for these systems. The slurry feed systems efficiently regulated the transfer of the mixture of Hanford LLW simulant and chemical additives to the melters. Approximately 610 kg and 10,700 kg of glass was produced in the DuraMelter™ 100 and 1000 tests, respectively; the corresponding volumes of LLW simulant consumed were 740 l and 8000 l, respectively. All glasses produced as crucible melts and in continuously-fed DuraMelters™ far exceeded the stated leach resistance requirements.

Emission monitoring by both an outside contractor and the VSL staff demonstrated the effectiveness of the off-gas systems and provided the additional data necessary to complete the mass balances for the process. The results indicated good retention of the constituents of the LLW simulant in the glass product. Final particulate and metal emissions from the process were all below measurable and regulatory limits. There was good agreement between direct measurements of melter particulate and metal concentrations and those calculated from data on the accumulations of constituents in the off-gas system (quencher and scrubber liquids, baghouse dust, etc.). Methods were demonstrated that considerably reduced nitrogen oxide emissions.

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[*] DuraMelter is a trademark of GTS Duratek, Inc.

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1.0 INTRODUCTION

Approximately 230,000 m^3 of defense nuclear wastes are in storage in underground tanks at the U.S. Department of Energy, Hanford site in Washington State. Retrieval and pretreatment of these wastes will convert the major fraction to a liquid low-level radioactive waste stream consisting mainly of sodium nitrate and nitrite salt in a highly alkaline liquid/slurry. Vitrification has been selected as the treatment technology for this waste stream. Westinghouse Hanford Company (WHC) is conducting tests of several alternative vitrification methods for this waste. Seven vendors were selected to perform Phase 1 testing on a non-radioactive surrogate material.

This report presents the results and observations obtained from the melter tests using Hanford LLW simulant performed by GTS Duratek, Inc. and the Vitreous State Laboratory of The Catholic University of America (CUA-VSL). These tests were performed on GTS Duratek DuraMelter™ 100* and DuraMelter™ 1000 systems at CUA-VSL between late September of 1994 and January of 1995. The tests successfully met the objectives detailed in the Test Plan (WHC-SD-WM-VI-020, Revision 0); the test on the DuraMelter™ 100 system was completed several days before the September 30 Tri-Party Agreement Milestone.

1.1 TEST OBJECTIVES

The primary objectives of the test were:

- Conduct "proof-of-principle" tests to demonstrate that the DuraMelter™ vitrification systems can process a simulated, highly alkaline, high nitrate/nitrite, LLW feed and produce a glass of consistent quality.
- Demonstrate a practical and reliable feed system capable of consistent mixing and delivery of LLW simulant and glass former feed materials to the melter, and to provide control of product glass composition.
- Demonstrate the ability to produce a durable, consistent, homogeneous glass with a target composition (product quality).
- Determine any specific requirements for feed preparation, secondary waste, and off-gas treatment systems.
- Provide a descriptive chronology of events during the tests.

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* DuraMelter is a trademark of GTS Duratek, Inc.

- Describe general operating behavior during the tests including upsets and operating problems.
- Determine quantity of feed processed and processing rates.
- Collect mass balance data across the melter for potentially volatile components such as Cs, Na, B, K, Mo, to determine partitioning of these components between the glass, condensed deposits, off-gas entrained particulates, and scrub solutions. Mass balance data was also needed for elements of radiological interest, including Cs, Sr, and Tc (Mo will stand in for Tc).
- Make off-gas measurements of NOx and SOx concentrations, flow rates, and quantities and composition of entrained particulates.
- Collect data to assess melt characteristics including phase separation, foaming events, cold-cap behavior, etc.
- Collect samples of the glass product throughout the tests for assessment of glass composition consistency and uniformity as well as leach resistance testing.
- Perform pre-test and post-test inspection of the equipment. To the extent possible, inspection will identify solids buildup, deposits, plugging, corrosion, erosion, refractory wear, electrode wear, and equipment damage.
- Provide samples collected according to the sampling plan described below to WHC and/or WHC-designated laboratories for analysis and archiving. Feed, product glass, off-gas scrub solutions, and off-gas sampling was performed every few hours after reaching steady-state operation.
- Perform a test of sufficient duration to achieve the test objectives stated above, and of sufficient duration to process at least three times the melter system glass inventory. In no event should the test duration be less than 24 hours continuous processing time.

1.2 SCOPE OF TESTING

This effort included pretest work, one test on the DuraMelter™ 100 vitrification system, and one test on the DuraMelter™ 1000 vitrification system, as described below.

The use of the two DuraMelter™ systems provided approximately a factor of ten scaling (nominal glass production rates of 100 and 1000 kg/day, respectively) in the data sets. In addition, the operation of the DuraMelter™ 100 provided information which was useful in optimizing the operation of the DuraMelter™ 1000. The smaller size of the DuraMelter™ 100 allowed the testing of various operating conditions at a minimal cost compared to that for the DuraMelter™ 1000. Experience has shown that the smaller system is large enough that the general behavior is similar to the larger system and is, to a great extent, scalable. Therefore, what was learned from the smaller system was directly applied to the larger system.

The DuraMelter™ 100 was successfully operated with a slurry feed and consequently, the same approach was used for the larger system. Several feed additives were evaluated with respect to their effects on emissions during the turnover stage on the DuraMelter™ 100. From these tests, urea was selected as the primary additive to reduce NOx emissions.

Although the two melters are very similar in design, the power supply for the smaller melter has greater connected power relative to melter volume than the power supply for the larger system. This would have allowed higher relative production rates to be investigated in the smaller system than in the larger system in the event that the connected power was the controlling factor. However, production rates of over twice the nominal values were comfortably demonstrated with the LLW feed and higher rates were almost certainly achievable.

1.2.1 Pretest Work

Pretest work included glass formulation development based on the composition of the LLW simulant. A series of crucible melts was made and each was characterized for key processing characteristics relevant to the DuraMelter™ systems (including melt viscosity, electrical conductivity and liquidus temperature).

PCT leach tests were also conducted to ensure that the selected composition met the WHC requirement for a normalized sodium release of below 1 $g/m^2/d$. The results, obtained by this lab and that of an independent analysis made at PNL, show the glass to be well within this criterion.

Other pretest work included procurement and modification to the feed systems to ensure that the specific requirements for these tests would be met. Also, sampling stations for off-gas sampling were installed.

1.2.2 DuraMelter™ 100 Test

The smaller size of the DuraMelter™ 100 system together with the fact that the feed system was previously configured for a slurry feed made rapid initiation of testing viable. Data from this test provided a valuable basis for the larger scale (and more costly) test on the DuraMelter™ 1000 system to ensure that maximum benefit from the DuraMelter™ 1000 test was obtained. The DuraMelter™ 100 test was about five days in duration and generated about 600 kg of glass, half of which was generated during the steady state run. This allowed a three-melter-volume turnover of glass to reach the target composition followed by a further three-melter-volume turnover at steady-state. Higher than nominal production rates were achieved, particularly for the steady state run. Overall glass production rates were 185 and 106 kg/day for the steady state and turnover runs, respectively. While the test durations were shorter than originally planned, the quantity of glass produced was sufficient to achieve a total of six melter-volume turnovers. Note that the basis for the nominal production rate of the DuraMelter™ 100 was a typical borosilicate glass slurry feed producing about 400 g glass per liter of feed; production rates considerably greater than this proved possible in practice.

A limited number of samples from this test (sample splits) were analyzed at CUA-VSL since a rapid turnaround time was available. This allowed maximum use of the results from the DuraMelter™ 100 system test in the final detailed planning of the DuraMelter™ 1000 test.

1.2.3 DuraMelter™ 1000 Test

The same basic approach was used for the DuraMelter™ 1000 tests, i.e., the steady state portion of the test followed a turnover period corresponding to three melter volumes of glass. While for the DuraMelter™ 100 system the glass inventory in the melter was approximately equal to the nominal daily production rate (~100 kg), for the DuraMelter™ 1000 it was considerably larger; the approximate inventory was about 2600 kg and the nominal daily production rate was about 1000 kg. The turnover portion of the run was spread out over a month between 12/12/94 and 1/14/95 due to other contractual obligations and holidays. The melter was drained to the lowest glass level possible for operations (about 1700 kg) before the onset of turnover feeding to expedite the turnover. As a result, only 7000 kg of glass production was required to assure the mandatory three turnovers. Once this was achieved, approximately 3700 kg of glass were produced over two days resulting in a production rate of approximately 1800 kg/day for the steady-state period. This was considerably shorter than the projected four days at the nominal production rate.

2.0 MELTER SYSTEM DESCRIPTION

Tests were performed using two melters at the VSL which were similar in basic design but approximately a factor of ten different in nominal throughput capacity: the DuraMelter™ 100 and DuraMelter™ 1000 vitrification systems. Each consists of a feed system, a melter system, and an off-gas system. The basic features of the melters are described below. Figures 2.0a and 2.0b show schematic diagrams of the DuraMelter™ 100 and 1000 systems indicating data and sample collection points.

2.1 GENERAL FEATURES

The tests conducted on the DuraMelter™ 100 system made use of the existing capability to feed a slurry stream to the melter. The DuraMelter™ 1000 system was originally configured to accept bagged, dry feed and was therefore modified to resemble the DuraMelter™ 100 with respect to feed introduction. The slurry feed was prepared from the LLW simulant and the requisite quantities of chemical additives in batches in the system's mix tank; each completed batch was then transferred to the feed tank. The feed blend was then pumped continuously to the melter through a water-cooled feed line. The feed rate was measured from the flow rate; an additional cumulative measure was obtained from the feed tank level and total feeding time.

The nominal glass residence time for the DuraMelter™ 100 and DuraMelter™ 1000 system is approximately 1 and 2.6 days, respectively, depending on the glass production rate. It has been established that the behavior of melters of this type is well approximated by a simple well-stirred tank model, as can be shown by compositional spike data (while we have made such measurements on similar melters in the past, these measurements were not made in the present tests). In this approximation, a step change in feed composition leads to an exponential approach of the glass pool composition to the new composition; the exponential decay constant, given by the ratio of the melter inventory to the glass production rate, then provides the natural measure of the residence time. The nominal residence times given above then follow from the melter inventory (approximately 100 and 2600 kg glass for the DuraMelter™ 100 and DuraMelter™ 1000, respectively) and the nominal glass production rate (approximately 100 and 1000 kg glass for the DuraMelter™ 100 and DuraMelter™ 1000, respectively). At higher production rates, the residence time will be correspondingly shorter. Actual residence times ranged between 8 and 24 hrs for the DuraMelter™ 100 tests and was 1.4 days for the DuraMelter™ 1000 tests.

The glass product was poured directly into preweighed, unpainted 5-gallon steel pails or 55-gallon drums. Each of these bore a unique identification number. The pails or drums of glass were allowed to cool and then weighed. Samples for analysis and testing were collected directly from the pour stream using the grab-sample technique described below. The weight of these samples was also recorded.

2.2 FEED SYSTEMS

The LLW simulants were shipped to CUA-VSL in 55-gallon drums. The material was stored for the minimum possible time before use and during storage, the contents were mixed periodically after receipt in an attempt to avoid precipitation and sedimentation. The LLW simulant was used directly with no pretreatment beyond extensive mixing. The material was pumped using a drum pump/stirrer directly to the vitrification system as described below.

A slurry feed system was employed for the runs on the DuraMelter™ 100 and the DuraMelter™ 1000 systems. The DuraMelter™ 100 was originally equipped with a liquid slurry feed nozzle while the DuraMelter™ 1000 was equipped with a chute to accommodate bagged, solid feed. This resulted in a few straightforward modifications to the DuraMelter™ 100 while numerous modifications were required for the DuraMelter™ 1000. The earlier runs on the smaller melter provided invaluable information for the feed system of the larger melter.

2.2.1 DuraMelter™ 100

This melter and its associated glove-box feed system were radioactive prior to the Hanford runs and therefore a new independent feed system was installed to minimize contamination. The slurry feed method was employed according to the following sequence:

a. The 55-gallon drums containing waste simulant were stirred or recirculated as necessary to minimize possibility of gelation or precipitation (at least weekly).

b. One drum of simulant at a time was placed in the DuraMelter™ 100 feed preparation area, fitted with a recirculation drum pump system attached to the drum cover and, after thorough stirring, the requisite quantity of simulant was pumped into the mixing tank.

c. In the mixing tank the simulant was combined (mechanically stirred) with chemical additives to yield a final feed slurry containing up to about 70% total solids (i.e., soluble plus insoluble solids), as calculated from the LLW simulant composition and the amount of additives; pretests demonstrated that this material could be pumped without any additional water. The chemical additives were preweighed and mixed in ~30 kg batches, contained in a plastic bag. One bag of additives was added to the hopper of a vibratory feeder for every 20 liters of simulant transferred. The entire contents of the hopper were then added gradually to the mix tank while stirring constantly. After mixing thoroughly, the feed was pumped into a continuously-agitated feed tank.

d. The feed was metered from the feed tank into the melter by means of a peristaltic pump, through a water-cooled nozzle mounted on the top of the melter. The inlet to this pump was connected to a recycle line through which feed flowed rapidly in a loop from the feed tank, through a recycle pump to the feed pump (mounted on top of the melter), and back to the feed tank. The feed rate was controlled by monitoring the sludge level in the feed tank and adjusting the rotation speed of the pump accordingly. The level of the feed was measured periodically to obtain average feed rates over intervals of about 4 hours. In addition, the speed setting on the feed pump was calibrated to the actual measured flow rate (volume delivered in a timed interval) to permit real-time adjustments to be made.

2.2.2 DuraMelter™ 1000

This melter was not originally equipped with a liquid feed system and modification was required to provide one. A slurry feed system which closely paralleled the approach used for the DuraMelter™ 100 system was used. The major difference was the batch size that was used (the 55-gallon drums were replaced by 500-gallon tanks) and the method of delivering the dry chemicals to the mix tank (a hopper with a screw feed system was used). The contents of the mix tank and the feed tank were continuously agitated. A recycle loop to a feed pump at the top of the melter was used in a similar fashion to that described for the DuraMelter™ 100 system.

2.3 MELTER SYSTEMS

2.3.1 DuraMelter™ 100

The DuraMelter™ 100 is a Joule-heated ceramic-lined melter with a nominal glass melting rate of 100 kg/day. The actual melting rate depends on the type of feed supplied, the properties of the resultant glass, the melter temperature, the rate of bubbler-induced mixing employed, and other operational parameters chosen. A schematic diagram of the melter is shown in Figure 2.3.1a.

The footprint of the melter is approximately a 3 feet by 3 feet square to which the discharge chamber, a 1.5 feet by 2 feet appendage, is added. The melter shell is about 4 feet in height and rests on an approximately 2-foot tall stand bringing the top of the melter to about 6 feet. The glass contact refractory is a Monofrax® K3* refractory which forms a 14" by 14" melt pool. The normal glass depth is maintained at about 15" and the K3 refractory extends several inches above that level. Two 1" thick flat plate Inconel 690** electrodes cover opposing walls of the melt chamber. The surface area of a single electrode is 162 square inches. The resultant melt volume is about 2500 cubic in. (41 liters). This represents about 100 kg capacity for a typical glass specific gravity of 2.5 g/cm^3. The melter plenum sides are lined with Zirmul®*** refractory and the plenum roof has an Inconel protective sheet. There are about 15" of air space between the melt surface and the plenum ceiling.

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* Monofrax is a trademark of Carborundum, Co.

** Inconel is a trademark of INCO Alloys International, Inc.

*** Zirmul is a trademark of North American Refractories, Co.

The melt refractory is held within an Inconel shell which prevents the leakage of molten glass into layers of insulating refractory fiber between the inner shell and outer stainless steel shell. The inner shell has penetrations for electrode busses, drain and discharge ports. These are designed to prevent glass leakage.

The melter has two drains that exit through the bottom. One is a direct bottom drain from the floor of the melt tank. It is sealed by frozen glass and can be activated by applying heat from a wire resistance heater. This drain is used if it is desired to completely drain the melter. A second drain exiting the bottom has a drain pipe which extends above the normal level of the glass. It can be used to drain a floating secondary phase from the glass surface. The normal glass discharge is through a side exit port to a riser and pour trough. This, along with an air lance, forms an air lift. The air lift discharge is activated by bubbling air through the air lance inserted in the discharge riser. Glass drains from the trough through a flanged opening to a metal container sealed to the flange.

Glass samples can be collected in a variety of ways depending on the quantity of glass desired. If a small amount of glass is desired, it may be collected by terminating the discharge riser bubbling and, as the glass flow tapers off, closing a gate valve located just above the discharge chamber flange. When the flow has stopped, the gate valve can be opened and the glass solidified on the top of the slide is collected. The gate material itself is clean (and can be cleaned before and after use), corrosion-free, and is not in contact with any grease or lubricant. If a larger sample is required, the glass can be collected in a suitable crucible within a larger container using the air lift to start and stop the glass discharge.

The melter employs air bubbling to promote mixing and to increase the melting rate. The bubbler is designed to produce a curtain of bubbles rising from the melter floor between the two electrodes. In addition to mixing, the bubbling of air tends to keep the melt well oxidized.

The heat for glass melting is provided primarily by Joule heating in the melt. The melter is equipped with resistance heaters in the plenum space for starting the melter and for increasing the plenum temperature, if desired. The melter has a large number of thermocouples in the melt, in the plenum space, in the discharge chamber and at various locations in the melter refractory.

The top of the melter is equipped with a number of ports. These provide access for feed, for viewing, for off-gas discharge etc. The normal method of feeding is slurry feeding through a water-cooled feed pipe mounted through the top of the melter. The melter can also accommodate dry feed.

The power to the melter electrodes (40 kW designed power) is controlled by a programmable process controller. It can be configured to control in several ways depending on the desired operating conditions. Normally the temperature of a thermocouple in the melt is the parameter used to control the melt process. The glass tank is small enough that the response time of the glass temperature is relatively short and temperature is a reasonable choice for process control. The output of the process controller adjusts the on-time of an SCR power controller to determine the applied electrical power. The response to changing demands due to feeding, cold cap variation etc. is automatic. The process controller is configured with alarms which alert the operator to abnormal conditions in temperature or power. The controller can be programmed to reduce the melter power to a safe level if a potentially hazardous condition exists. The upper safe operating temperature for the glass melt is about 1200°C due to the use of Inconel electrodes.

A computer-based data acquisition system is used to display and record important melter operating conditions such as melter power and temperatures at critical locations in the melter. Data is recorded on disk and periodically printed out. Manual readouts are also available for these parameters. The computer is also programmed to act as a backup process controller in case of malfunction of the dedicated controller.

2.3.2 DuraMelter™ 1000

As discussed above, the DuraMelter™ 1000 is similar in design to the DuraMelter™ 100 but is more than an order of magnitude larger in terms of size and glass production capacity. The nominal glass production capacity is 1000 kg/day but may be higher depending on feed, glass type, and operating conditions. It is a Joule-heated melter with Inconel 690 electrodes and thus has an upper operating temperature of about 1200°C. A schematic diagram of the melter is shown in Figure 2.3.2.a.

The footprint of the melter is approximately 6 3/4 ft by 6 3/4 ft with a 2 ft. by 4 ft. discharge chamber appended to one end. The melter shell is 9 ft. tall. The refractory design of the glass tank and plenum area is similar to that of the DuraMelter™ 100 with the exception that the plenum area walls are constructed of Monofrax® H refractory. The surface of the glass pool is about 42" on a side. The glass depth is nominally 38". The resultant melt volume is approximately 67,000 cubic in. (1100 liters). This represents more than 2.5 metric tons of glass capacity for the tank. Each of two opposing walls of the tank have a pair of flat plate electrodes. The bottom electrodes are 12" by 42" and the top electrodes are 10" by 42", giving an electrode area per pair of about 925 sq. in. There is about 35" of air space above the melt surface. Under normal operating conditions the melt level would be between about 1-5 inches above the top of the electrodes, but this is adjustable.

As in the DuraMelter™ 100, the refractories are contained in an inner shell with penetrations for drains and electrode busses. The melter has a bottom drain which can be used to drain the melter completely. The normal discharge is via an air lift. Discharge and sampling are accomplished in a manner similar to that of the DuraMelter™ 100. There are provisions for a surface drain to remove floating secondary phases but it is not presently installed.

There are various ports on the top plate of the melter which will accommodate a variety of feed mechanisms, as is discussed elsewhere. These ports are also used for thermocouple wells, plenum heaters, the bubbler assembly and viewing ports that are installed. The melter is also provided with an inclined chute for feeding bulk materials such as bagged material. The chute has an inner insulated heat shield door and two air lock doors to facilitate safe charging of materials. The doors are pneumatically operated.

The power to the melter electrodes (200 kw designed power) is controlled by programmable process controllers. The thermal mass of the DuraMelter™ 1000 is relatively large and the time constants for temperature control of the melt are very long (hours). It is convenient to control the process temperature by configuring the process controller to control power and adjusting the power setpoint as needed to maintain the desired operating temperature. Alarms can be set to detect out-of-range temperatures or power in the melter. The top and bottom electrode pairs are powered from separate but same-phase circuits and have independent controllers. It is possible to skew the power supplied to the top or the bottom of the melt pool by adjusting the power to each pair independently. Backup process controllers are installed to be used in case of failure of the main controllers.

A computer data acquisition system is used to record and display selected melter operating parameters in a similar fashion to the DuraMelter™ 100.

2.4 OFF-GAS SYSTEMS

The existing off-gas systems for both the DuraMelter™ 100 and DuraMelter™ 1000 are considered functionally identical as applied to the process of vitrification of WHC simulated waste. Both consist of a melter exhaust film cooler, evaporative quencher, packed bed scrubber, air reheater, heated air dilution port, air-jet bag filter and HEPA filter units. Both off-gas systems were designed to treat particulate, aerosol, and acidic gaseous emissions other than NOx. No equipment modifications were planned to provide for treatment of nitrogen oxides. However, experiments were performed on the effects of reducing agents added to the feed to diminish NOx emissions. These were successful and NOx emissions control is discussed in detail in Section 6.0.

Both off-gas systems were operator assisted, controlled by ladder logistic alarm levels. Process control alarm levels are handled by Programmable Logic Controllers (PLC, Allen-Bradley 250 family), while the critical parameters (temperature, pressure and current/voltage) are continuously monitored by sensors directly interfaced to a PC. Non-critical parameters are displayed only but can be, in most cases, easily interfaced for continuous monitoring.

Liquid volumes in the DuraMelter™ 100 quencher and scrubber sumps are about 250 l and 1000 l, respectively. There is only one liquid reservoir on the DuraMelter™ 1000 system and it has a capacity of approximately 1000 liters.

2.5 OFF-GAS MONITORING AND SAMPLING

Off-gas monitoring and sampling was performed by both CUA-VSL staff and a certified air monitoring laboratory (Engineering-Science (ES), Inc., 10521 Rosehaven St., Fairfax, VA 22030). Monitoring was performed in two distinct modes: Continuous emission monitoring (CEM) of the gaseous compounds NO, NO_2, SO_2, O_2, CO, and total hydrocarbon concentration (THC) and standard isokinetic sampling for metals and particulates. The methods used by VSL and ES for particulates and metals air sampling were identical whereas methods for monitoring gaseous components were very different. VSL staff also periodically monitored HCl and NH_3 during the 1000 kg/day steady state run.

VSL CEM monitoring was handled by various OEM probes (ENERAC Inc., FCI Fluid Components Inc. etc.) equipped with RS232 data transmission modules. All probes were guaranteed by their manufacturers to meet all relevant requirements of 40 CFR 60 Appendices A & B. Measurement of concentrations employed compound specific sensors which operate electrochemically or use the Hall effect. Dilution and permeation drying techniques were used for sample conditioning upstream of the sensors. Calibration was performed according to OEM procedures and, whenever possible, cross-checked against Engineering Science data.

CEM monitoring conducted by ES followed standard EPA protocol described in CFR 40. This includes Method 6C for SO_2, Method 7C for NOx, Method 10 for CO and Method 25A for THC. Two sample streams were extracted from ducts and transported through heated lines to a mobile CEM trailer. One of the streams was conditioned to remove entrained particles and moisture before reaching a stainless steel manifold. During the 100 kg/day tests, only the THC analyzer was in the second stream which did not receive this treatment. On the basis of the results from the 100 kg/day tests, it was discovered that the chemiluminescent analyzers used by ES for NOx measured ammonia as NOx (it was subsequently confirmed by separate calibration checks that this interference was NOT present for CEM system used by VSL). This resulted from gaseous ammonia being converted to NO in the high- temperature stainless steel catalytic converter. To eliminate this positive interference in the DuraMelter™ 1000 tests, the gas stream was bubbled through a 10% sulfuric acid solution to remove the ammonia. The SO_2 and THC analyzers were not attached to this sample stream since the sulfuric acid would strip out the analytes of interest.

Particles and metals runs were collected at the melter exhaust and at the HEPA filter exhaust. These runs were conducted by modifying EPA's Boiler and Industrial Furnace Multiple Metals Train to accommodate the physical constraints of the sample locations. The BIF train was modified so that the exhaust gas from the melter would be sampled as representatively as possible. The modifications included the substitution of a cooled Inconel probe followed by an unheated filter, for the conventional heated probe/filter. The sampling was single-point sampling with the isokinetic sampling rates selected from the velocity estimated from measurements made significantly upstream in the off-gas system. The melter exhaust duct was not configured to allow a strict conformance with the sample point selection criteria established in 40 CFR Part 60, Appendix A, Method 1. This may impact the representativeness of the collection of particulate matter. Sampling of particulates and metals after the HEPA filter was done in strict adherence to Method 1A for sampling site selection, Method 2A for measuring gas volume, Method 4 for determining moisture content of the air, and Method 5 for particle collection. Samples collected were analyzed for Na, K, Cs, B, Mo, Sr, and Cr by an outside laboratory (subcontracted by ES), and in some instances also by VSL.

The bulk of the sampling was performed during the steady state runs. The measurements made during melter turn overs were made by VSL staff for NO, NO_2, SO_2, O_2, and CO with the ENERAC CEM system. These measurements were made mostly after the HEPA filter to determine the effectiveness of alternative methods for reducing NOx and SO_2 emissions. During the steady state run, VSL staff made the same measurements it did during the melter turnovers, particle/metals sampling at the melter and HEPA outlet, and additional NO, NO_2, SO_2, O_2, and CO downstream of the DuraMelter™ 1000 mist eliminator. During DuraMelter™ 100 steady state test, ES performed was NOx, SOx, CO, O_2, and THC at four sample points (Melter Exhaust, Post-Quench, Post-Mist Eliminator, HEPA Filter Exhaust) and particle/metal sampling at both the melter and HEPA exhaust outlets. ES did the same for the DuraMelter™ 1000 steady state run except there was no Post-Quench sampling site. In addition to the will be monitored periodically for criteria pollutants (NOx, SOx, CO), O_2 and THC.

Figure 2.0.a Schematic Diagram of DuraMelter™ 100 System Showing Sampling Points (S1-S8) and Data Collection Points (D1-D17)

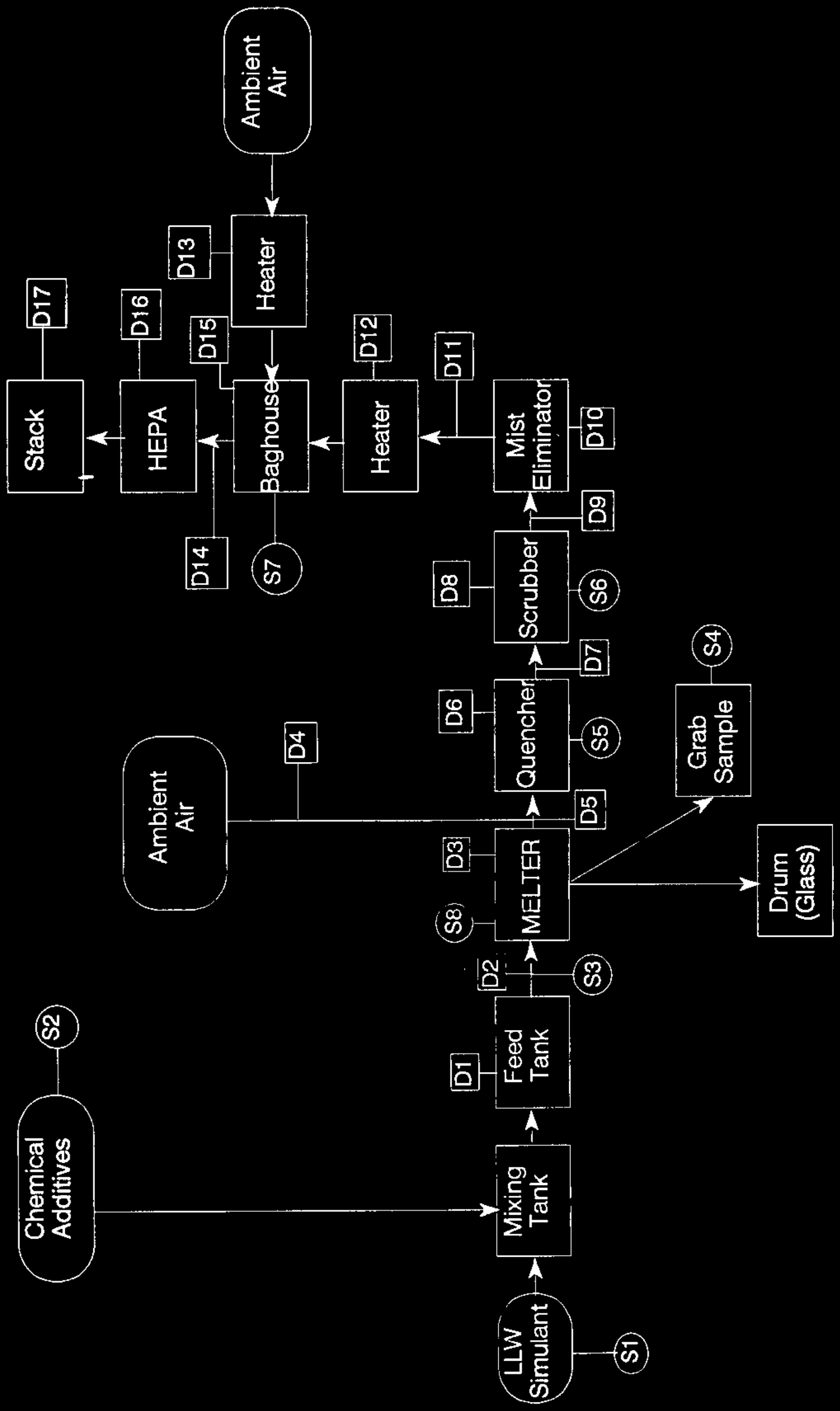


Figure 2.0.b. Schematic Diagram of DuraMelter ™ 1000 System Showing Sampling Points (S1-S10) and Data Collection Points (D1-D17)

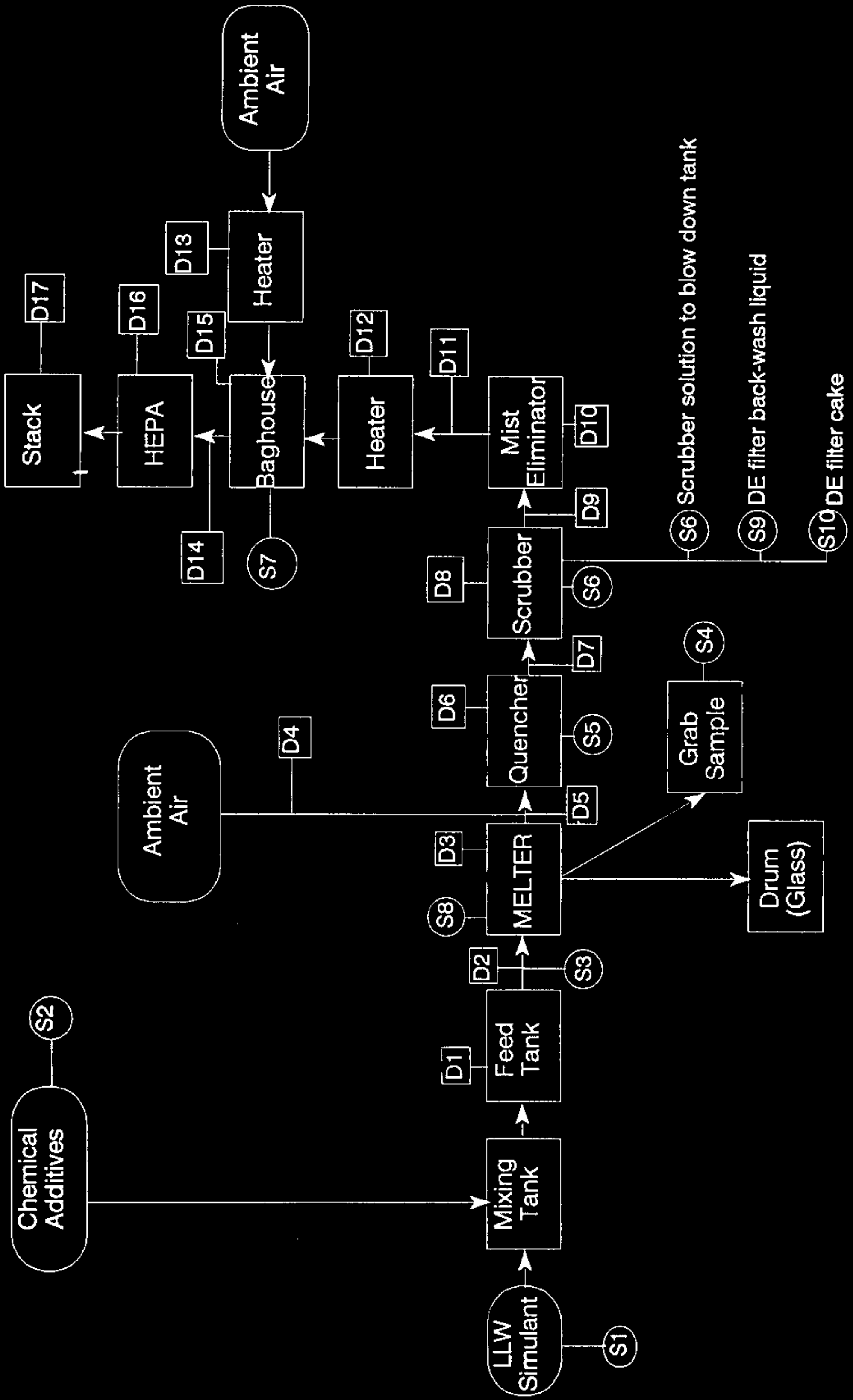


Figure 2.3.1.a. Schematic Diagram of the DuraMelter™ 100 System

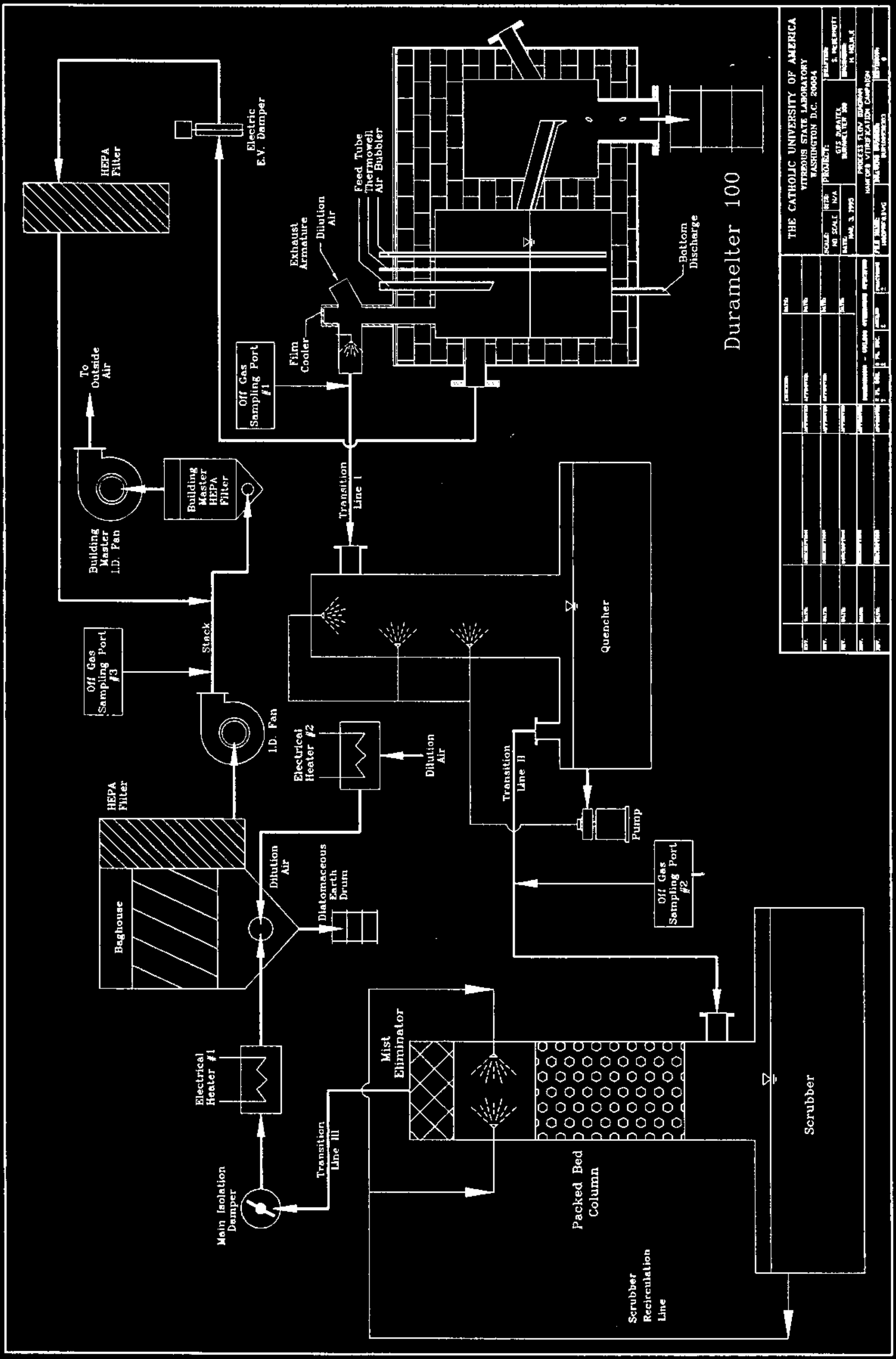
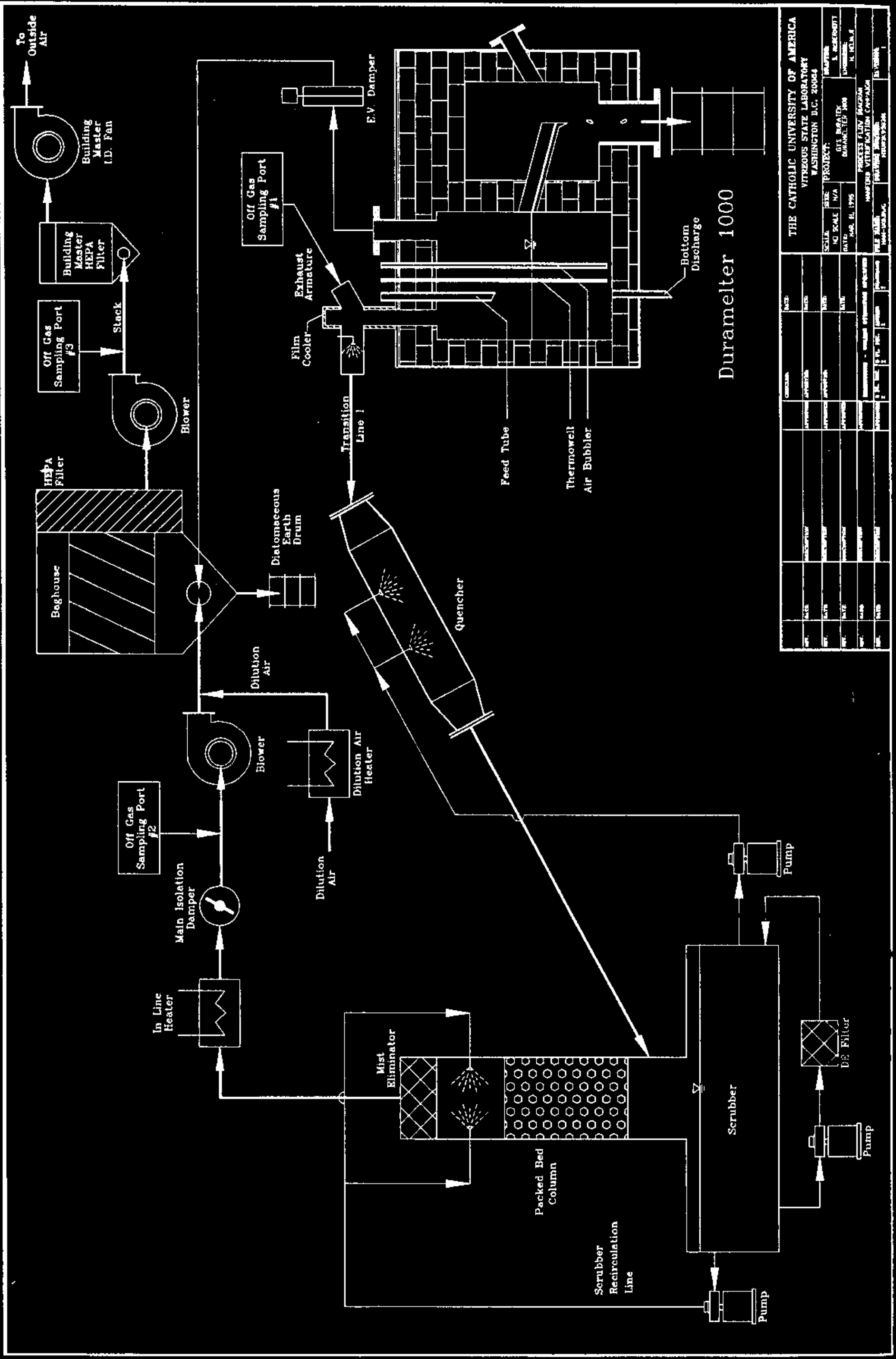


Figure 2.3.2.a. Schematic Diagram of the DuraMelter™ 1000 System



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3.0 GLASS FORMULATION

A series of formulations consisting of glass-forming additives and chemicals representing the DSSF stream were prepared. Each glass was tested to provide the information needed to select the glass composition to be used for the DuraMelter™ tests. The desired target glass was to have the following characteristics: Waste oxide loading of 25 wt% (corresponding to sodium oxide of approximately 20 wt%); viscosity below 100 poise at melt temperatures between about 1100 and 1150°C; electrical conductivity between about 0.3 and 0.5 Siemens/cm at melt temperatures between about 1100 and 1150°C; liquidus temperature below about 950°C; and normalized PCT release rates for sodium below 1 $g/m^2/day$. All of the five glasses that were tested met these criteria. Glass HAW4 was selected from this group based upon its expected slightly higher processing rate and good PCT performance.

Each of the five glasses was prepared by melting the batch of chemicals at 1150°C in a fireclay crucible for one hour. The additives examined were combinations of Al_2O_3, B_2O_3, CaO, K_2O, SiO_2, TiO_2, and ZrO_2. Boria, potassia, and silica were held relatively constant at 6%, 3% and 42%, respectively. Table 3a gives the composition of the LLW simulant on an oxide basis together with the target and analyzed glass compositions. Liquidus temperatures were estimated by heat treating the glasses at constant temperature for typically 20 hrs. Scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS) analysis was used to determine the amounts and types of crystallization, if any.

Melt viscosity was determined by measurement of the torque on a rotating spindle inserted in the melt. Electrical conductivity was measured using a high-temperature conductivity cell. The data obtained from these measurements are summarized in Table 3.b and depicted in Figures 3.b and 3.c. Minimum values were observed for HAW-3 and HAW-4.

The standard PCT leaching procedure was performed on all five glasses. Normalized concentrations of boron, silicon and sodium are compared to those of the SRL-EA glass (standard glass for the Savannah River Defense Waste Processing Facility, DWPF) in Figures 3.d, 3.e, and 3.f, respectively. The corresponding data for the normalized leach rates are shown in Figures 3.g, 3.h, and 3.i. In all cases the test glasses showed considerably better leach resistance than the standard glass. Leach rates were as much as two orders of magnitude lower than the stated maximum of 1 $g/m^2/day$.

On the basis of these data, glass HAW-4 was selected as the formulation to be used for the DuraMelter™ runs. The glass-forming additives required for each of the DuraMelter™ runs are given in Table 3.d together with the chemical source of each.

Table 3.a
Simulant and Glass Formulations in Oxide Form

Glass Name	DSSF Simulant	HAW1		HAW2		HAW3		HAW4		HAW5	
Oxide		Target	Analyzed	Target	Analyzed	Target	Analyzed	Target	Analyzed	Target	Analyzed
Al_2O_3	12.73	9.18	8.66	9.18	8.94	7.68	7.94	6.18	5.75	8.18	7.80
B_2O_3		6.19	6.84	6.19	6.78	6.19	6.48	6.19	6.53	6.19	6.61
BaO		0.00		0.00		0.00		0.00		0.00	
BiO	0.06	0.02		0.02		0.02		0.02		0.02	
CaO	0.01	7.88	8.41	6.75	7.26	7.88	8.21	7.88	8.33	5.88	6.42
Cr_2O_3	0.16	0.04		0.04		0.04		0.04		0.04	
Cs_2O	0.59	0.15		0.15		0.15		0.15		0.15	
Fe_2O_3	0.02	7.51	7.30	9.01	8.33	9.01	8.22	7.51	7.94	7.51	7.32
K_2O	5.76	3.69	3.01	3.69	2.75	3.69	3.09	3.69	3.14	3.69	3.07
Li_2O	0	0.00		0.00		0.00		0.00		0.00	
MgO	0.01	0.00		0.00		0.00		0.00		0.00	
MnO_2	0.01	0.00		0.00		0.00		0.00		0.00	
Na_2O	75.41	18.85	20.62	18.85	21.73	18.85	21.04	18.85	20.74	18.85	21.40
NiO		0.00		0.00		0.00		0.00		0.00	
P_2O_5	0.75	0.19	0.31	0.19	0.35	0.19	0.37	0.19	0.32	0.19	0.34
PbO	0	0.00		0.00		0.00		0.00		0.00	
SiO_2		41.25	41.97	41.25	41.38	41.25	41.47	42.25	42.42	42.25	42.15
SO_3	0.84	0.21		0.21		0.21		0.21		0.21	
SrO	0.43	0.11		0.11		0.11		0.11		0.11	
TiO_2		0.00		0.00		0.00		1.00	1.08	1.00	1.12
U_3O_8	0.08	0.02		0.02		0.02		0.02		0.02	
ZrO_2		4.13	2.78	3.75	2.45	4.13	3.09	5.13	3.67	5.13	3.69
Cl	1.3	0.33		0.33		0.33		0.33		0.33	
F	1.3	0.33		0.33		0.33		0.33		0.33	
SUM	99.460	100.05	100.00	100.05	100.00	100.05	100.00	100.05	100.00	100.05	100.00

Table 3.b
Viscosity and Conductivity Data for Hanford Glasses

Glass Name	HAW1	HAW2	HAW3	HAW4	HAW5
Viscosity, Poise					
1050°C	113.7	99.6	87.8	94.9	135.7
1100°C	68.9	65.2	59.9	56.46	80.31
1150°C	46.1	45.6	43.1	34.84	49.32
1200°C	33.1	33.6	32.2	22.21	31.3
Conductivity, S/cm					
1050°C	0.35	0.38	0.35	0.33	0.37
1100°C	0.44	0.45	0.41	0.40	0.44
1150°C	0.53	0.54	0.48	0.48	0.521
1200°C	0.64	0.63	0.55	0.57	0.61

Table 3.c
Summary of Leaching Results

Normalized concentration, g/L																		
Days	HAW1			HAW2			HAW3			HAW4			HAW5			SRL-EA		
	B	Na	Si	B	Na	Si	B	Na	Si	B	Na	Si	B	Na	Si	B	Na	Si
7	0.731	1.54	0.341	1.169	1.81	0.481	1.241	2.17	0.485	0.895	1.928	0.382	1.062	1.88	0.464	17.1	13.4	3.93
28	1.116	2.24	0.473	1.579	2.73	0.634	1.525	3.08	0.621	1.093	2.642	0.463	1.541	2.62	0.6	20.4	15.7	4.37
56	1.226	2.3	0.51	1.792	2.94	0.689	1.663	3.15	0.655	1.23	2.754	0.527	1.789	2.72	0.638	24.8	18.5	4.89
120	1.451	2.78	0.583	2.123	3.49	0.762	2.036	3.8	0.755	1.512	3.582	0.626	2.419	3.68	0.767	52.8	34.8	7.28
180	1.618	3.23	0.659	2.513	4.04	0.833	2.167	4.17	0.798	1.59	3.684	0.662	2.746	4.22	0.836	58.7	40.5	7.82
Normalized leach rate, g/m^2/day																		
3.5	0.104	0.22	0.049	0.167	0.26	0.069	0.177	0.31	0.069	0.128	0.275	0.055	0.152	0.27	0.066	2.44	1.91	0.56
17.5	0.032	0.06	0.014	0.045	0.08	0.018	0.044	0.09	0.018	0.031	0.075	0.013	0.044	0.08	0.017	0.58	0.45	0.13
42	0.015	0.03	0.006	0.021	0.04	0.008	0.02	0.04	0.008	0.015	0.033	0.006	0.021	0.03	0.008	0.3	0.22	0.06
88	0.008	0.02	0.003	0.012	0.02	0.004	0.012	0.02	0.004	0.009	0.002	0.004	0.014	0.02	0.004	0.3	0.2	0.04
150	0.005	0.01	0.002	0.008	0.01	0.003	0.007	0.01	0.003	0.005	0.012	0.002	0.009	0.01	0.003	0.2	0.14	0.03

Table 3.d
Complete Formulation of the Hanford Feed for the DuraMelter™ 100 Runs

Recipe	Vendor	Purity	Factor	Wt. (kg)	Wt. (lbs)
Al_2O_3	Pechiney	0.997	1	361.083	796.06
H_3BO_3	US Borax	0.999	0.563	1312.147	2892.80
$CaCO_3$	Minerals Tech.	0.986	0.56	1695.161	3737.21
Fe_2O_3	NOAH	0.995	1	903.618	1992.15
K_2CO_3	Armand	0.996	0.68	397.659	876.69
SiO_2	US Silica	0.997	1	4784.270	10547.56
TiO_2	RGC Minerals	0.942	1	126.753	279.44
$ZrSiO_4$	RGC Minerals	0.988	0.67222	920.119	2028.52
SUM				10500.810	23101.782
DSSF sim				10442.047	22972.5034
Total				20942.856	46074.2832

Figure 3.a. Glass Formulation Variation of Key Components

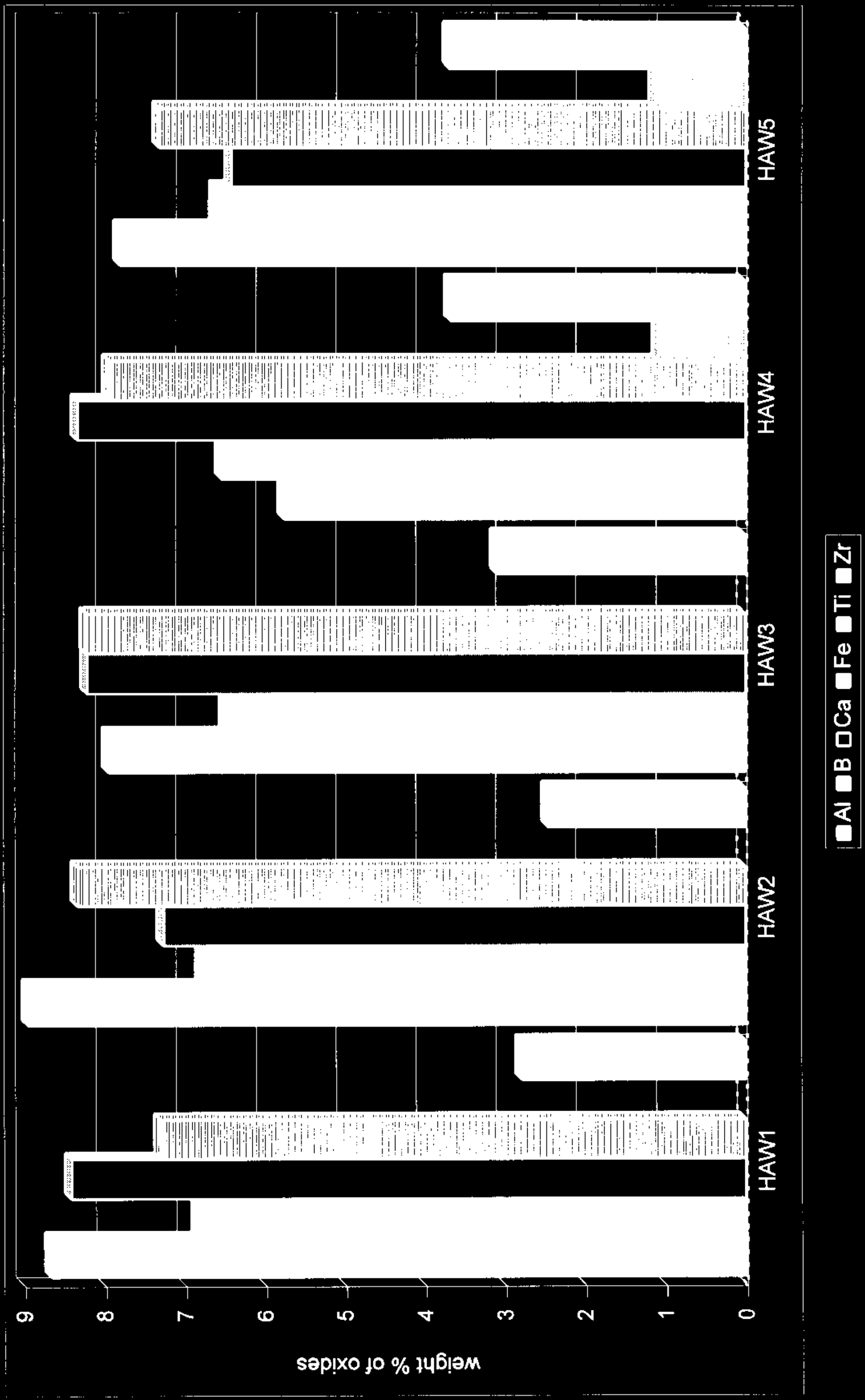


Figure 3.b. Viscosity Variation with Temperature

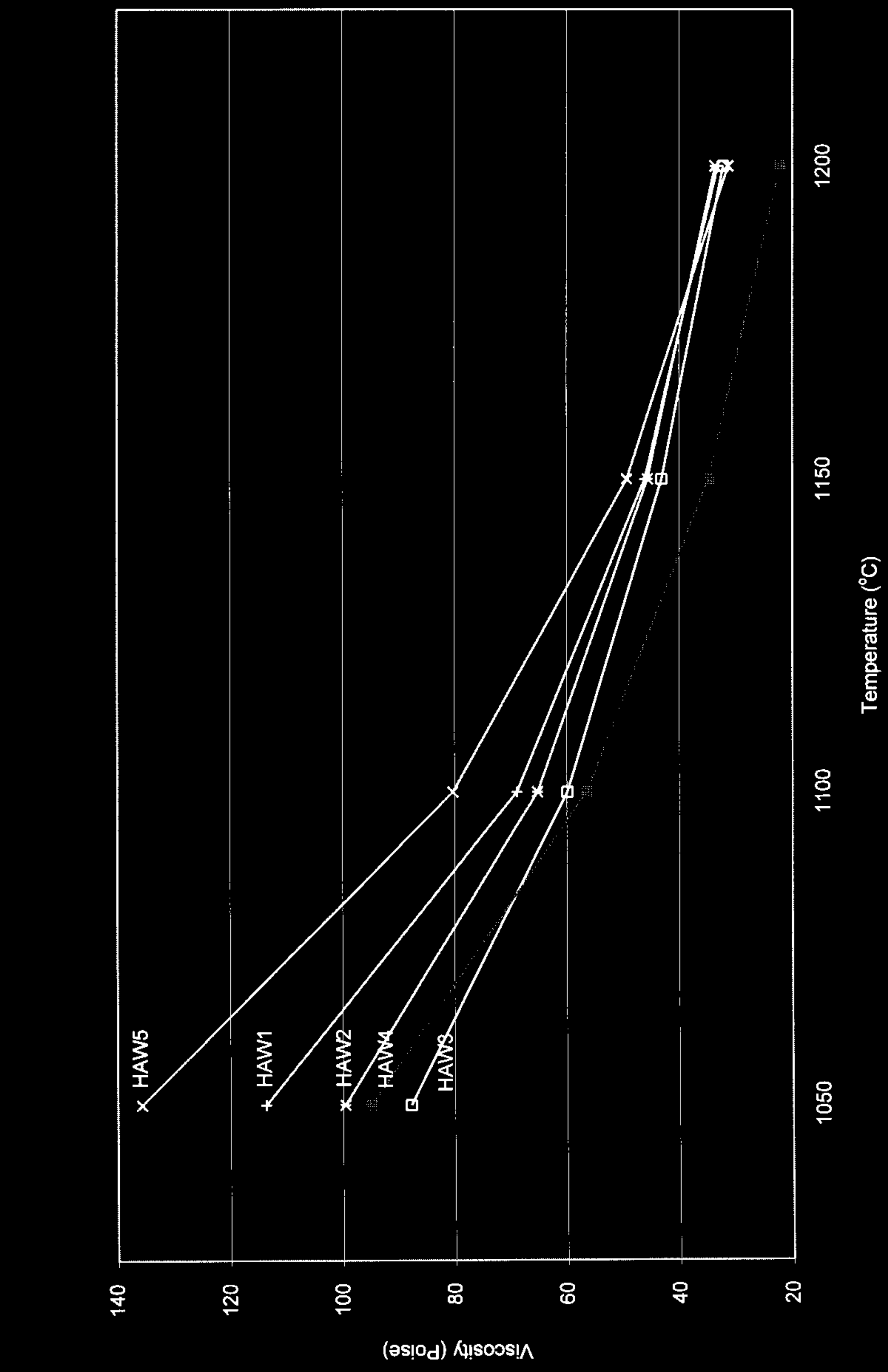


Figure 3.c. Conductivity Variation with Temperature

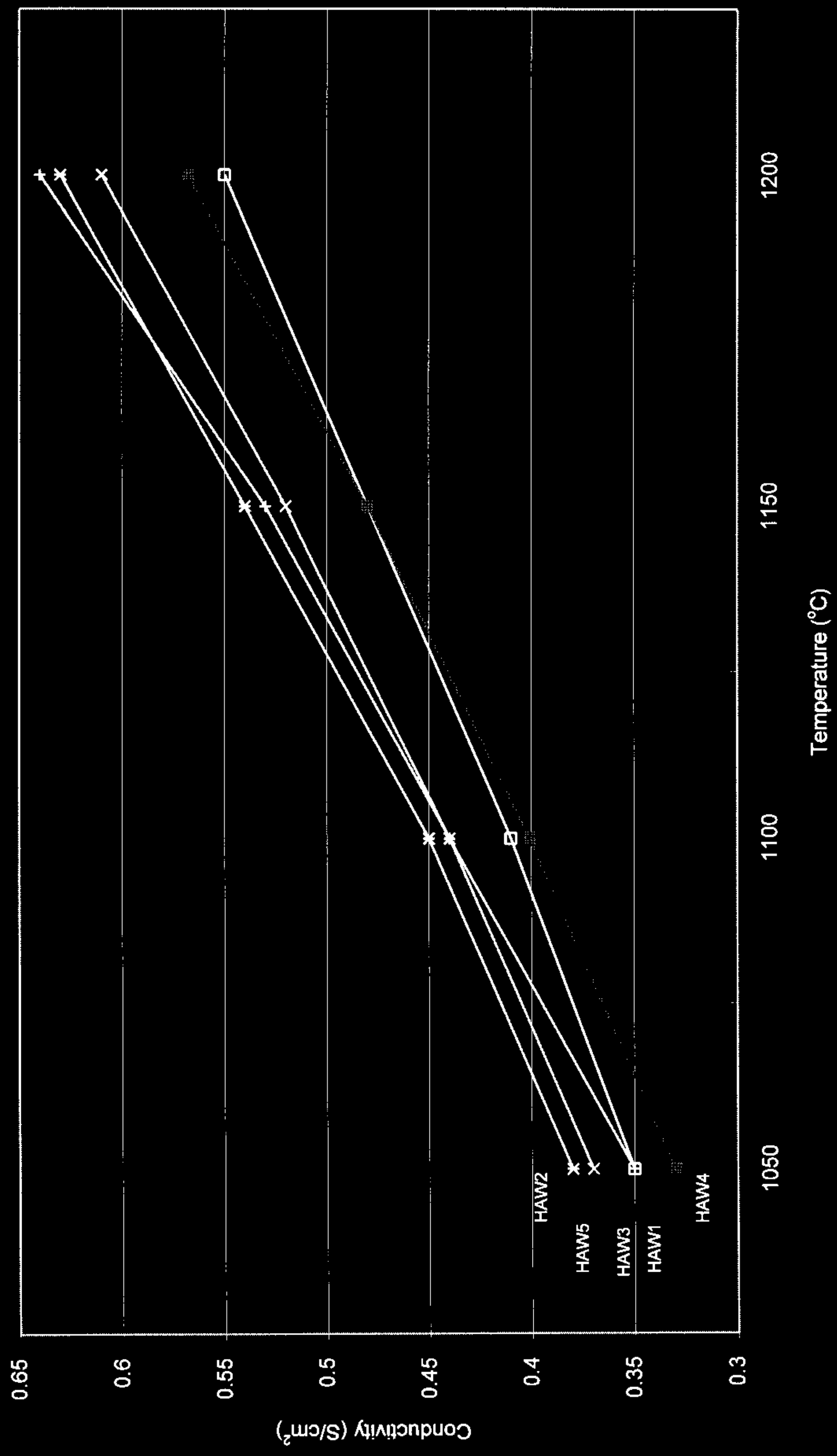


Figure 3.d. PCT Data for Hanford Glasses Comparison with SRL-EA Glass (Boron Concentrations)

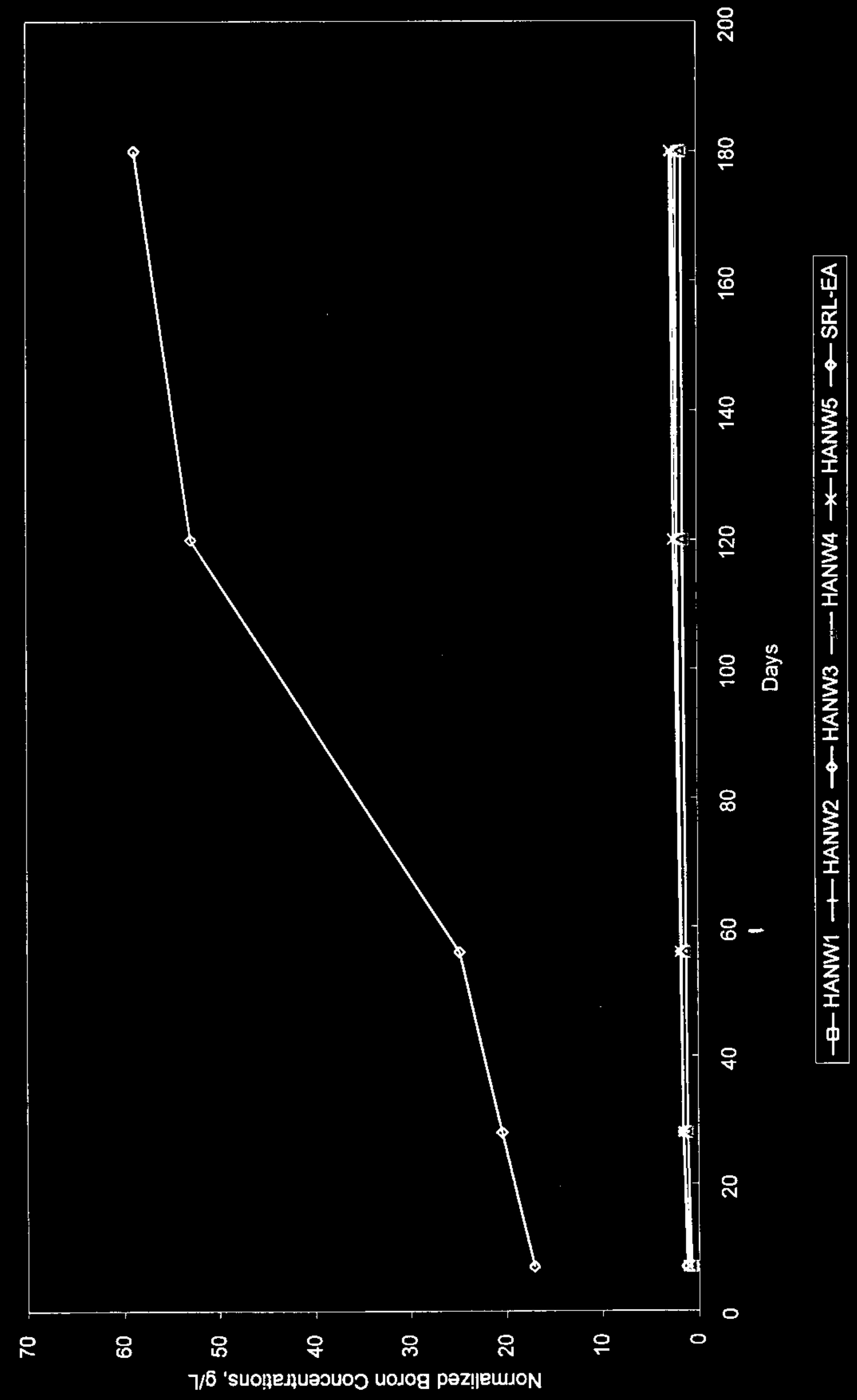


Figure 3.e. PCT Data for Hanford Glasses Comparison with SRL-EA Glass (Silicon Concentrations)

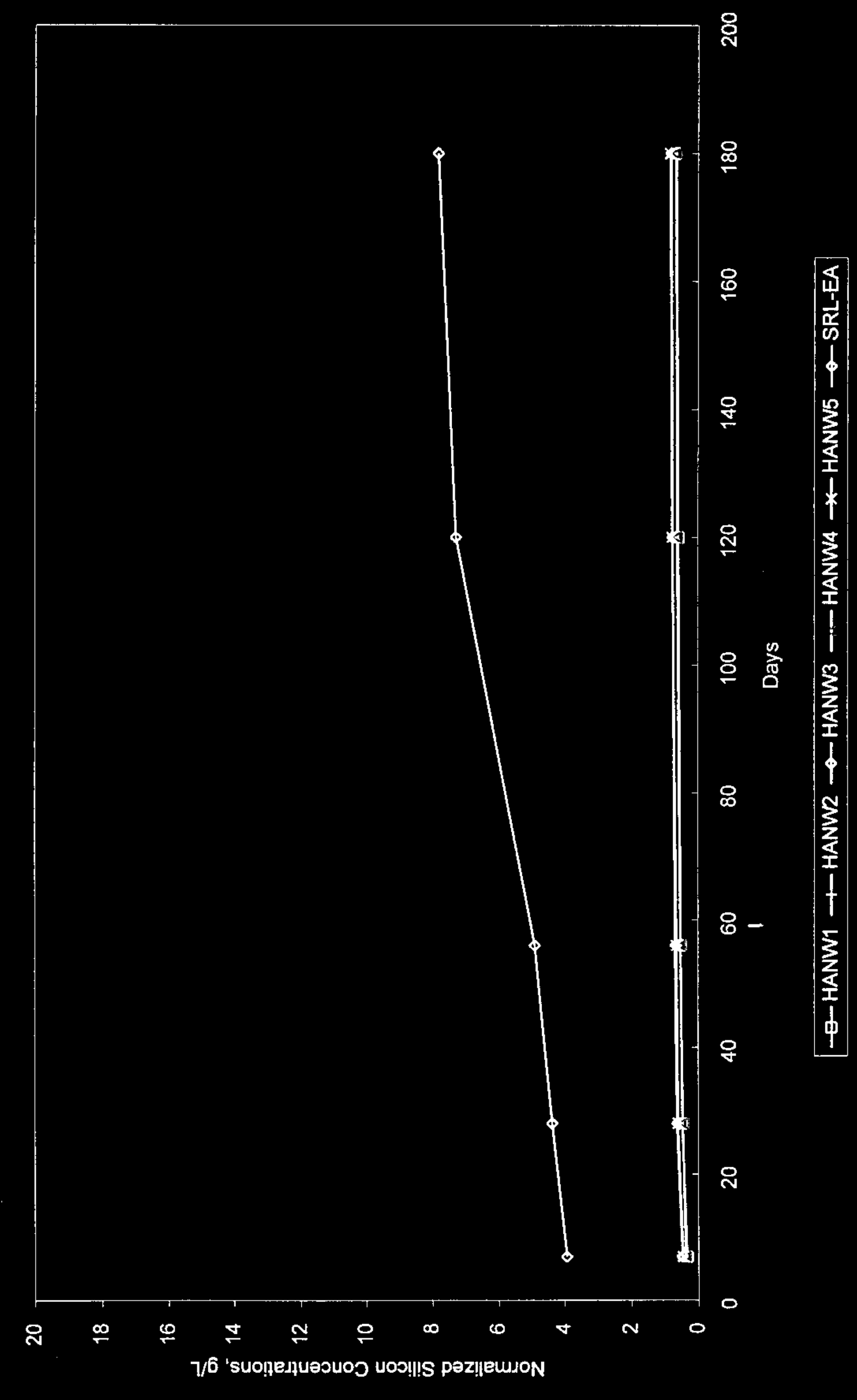


Figure 3.f. PCT Data for Hanford Glasses Comparison with SRL-EA Glass (Sodium Concentration)

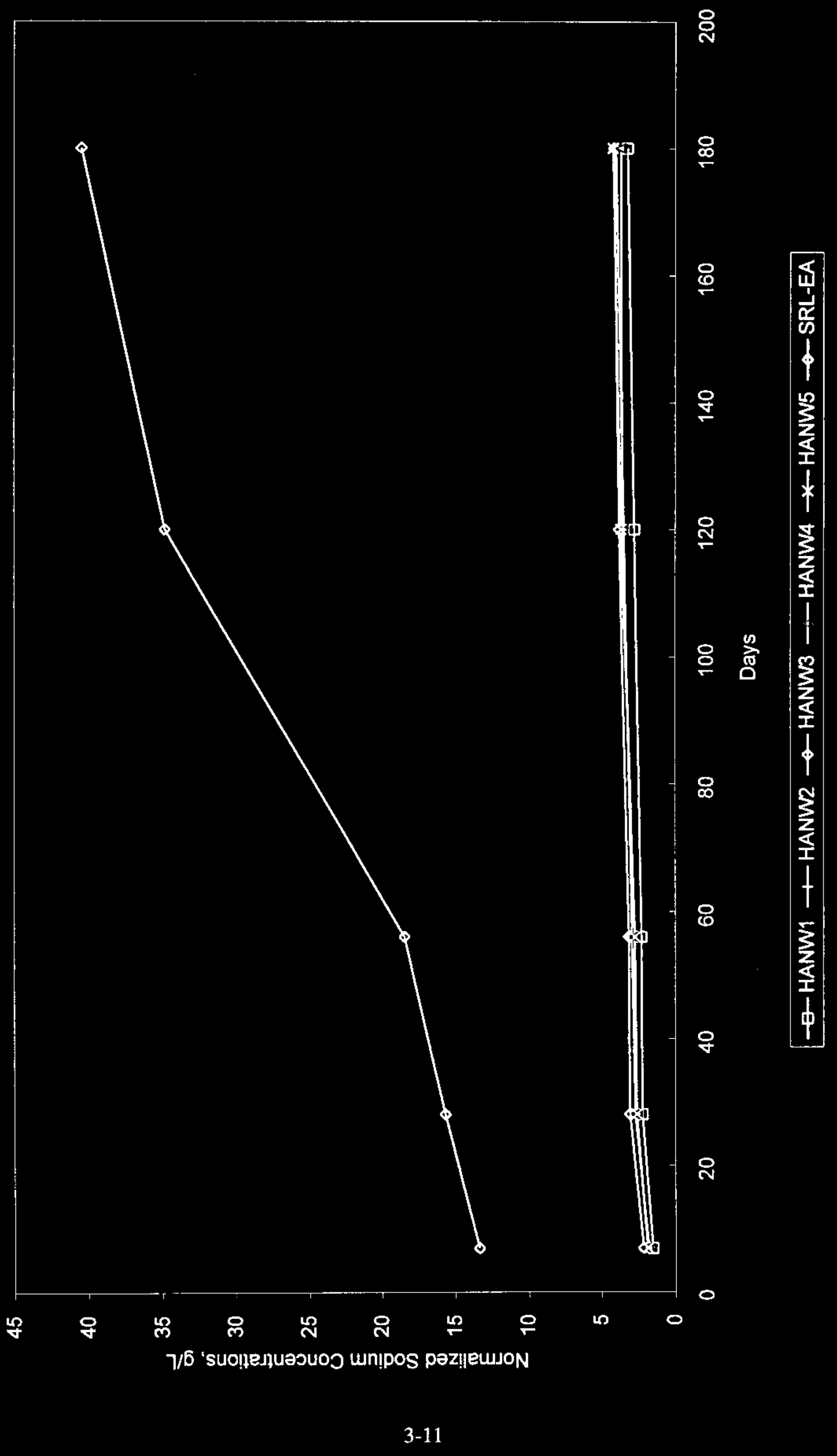


Figure 3.g. PCT Data for Hanford Glasses Comparison with SRL-EA Glass (Boron Leach Rate)

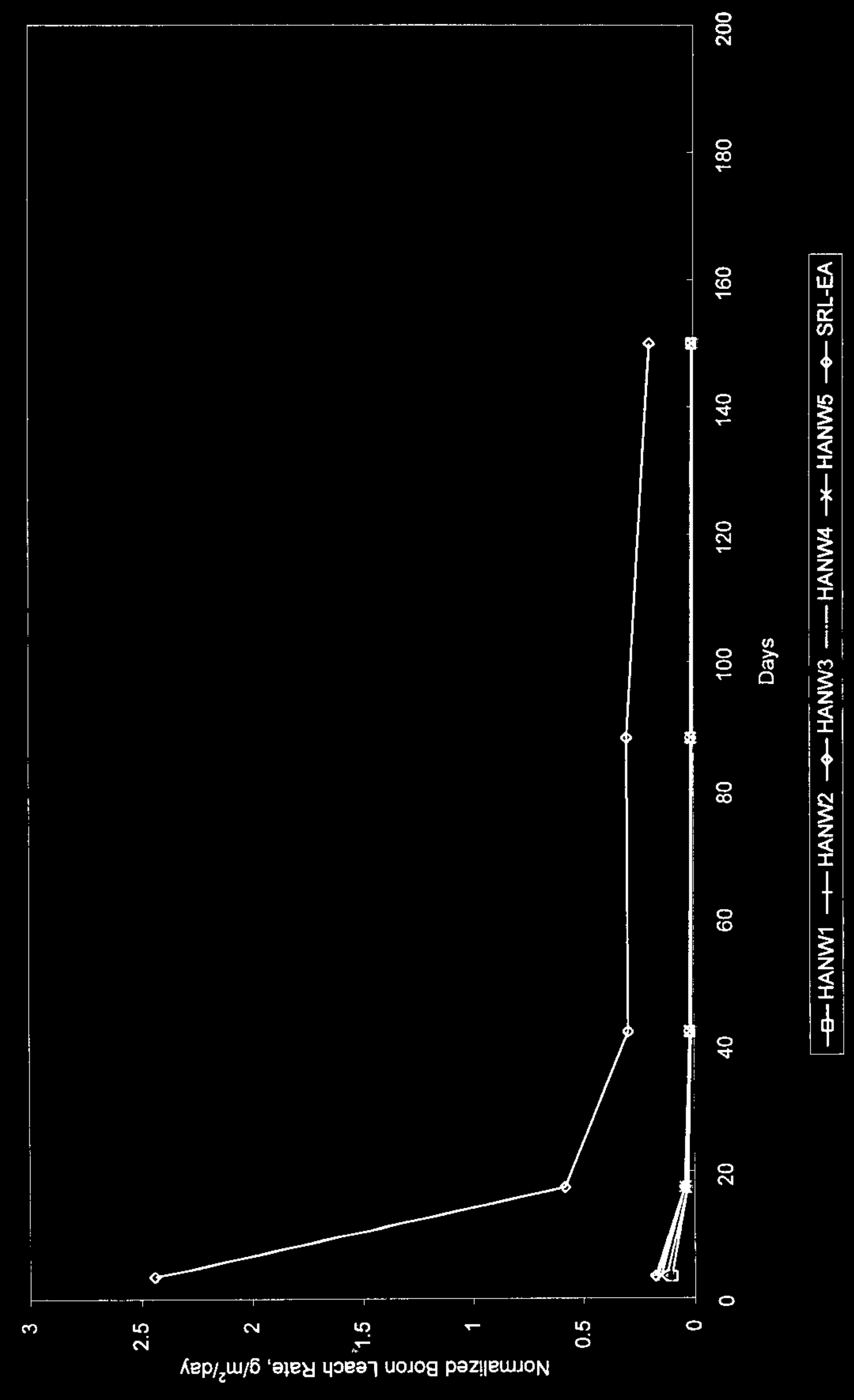


Figure 3.h. PCT Data for Hanford Glasses Comparison with SRL-EA Glass (Silicon Leach Rate)

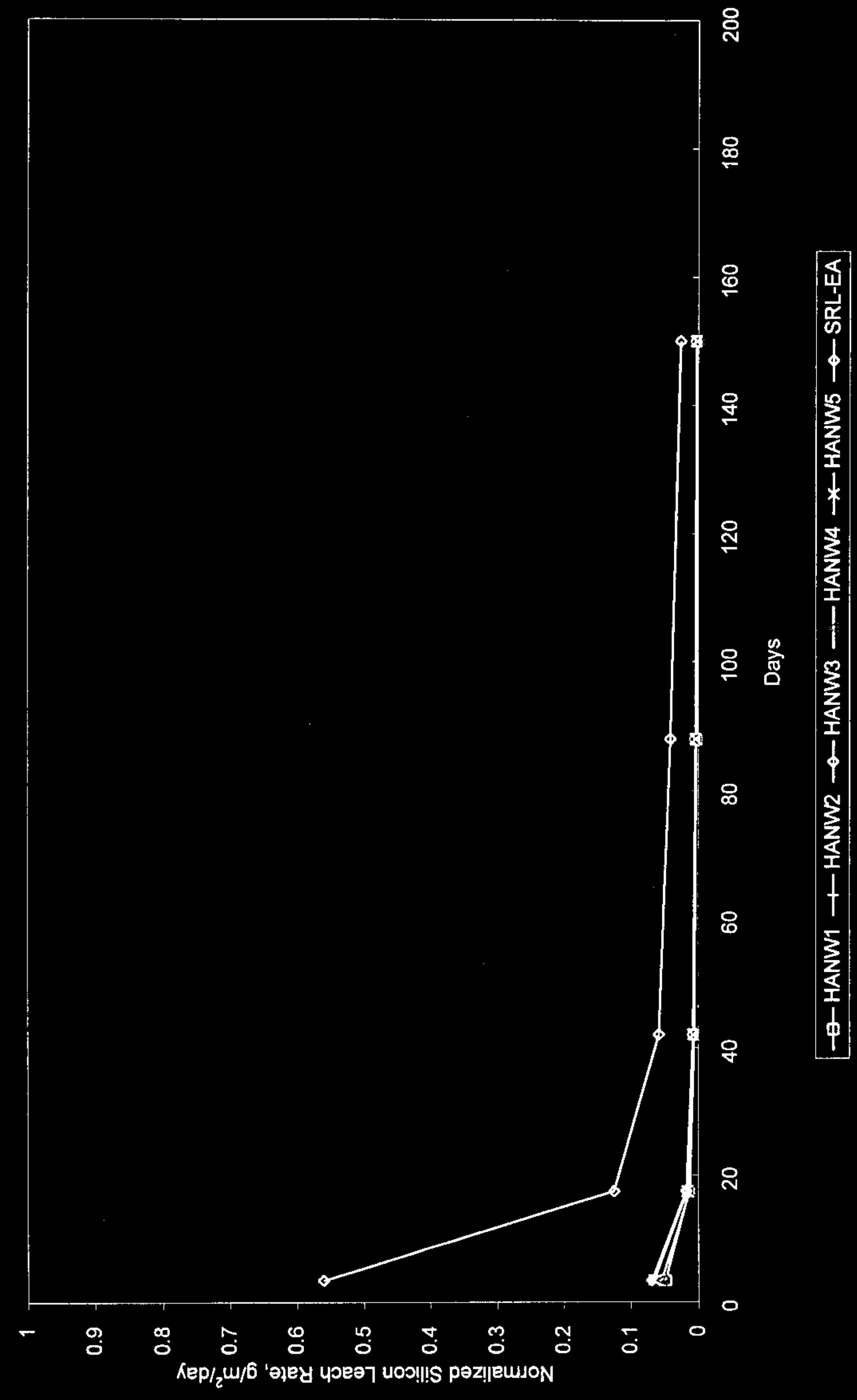
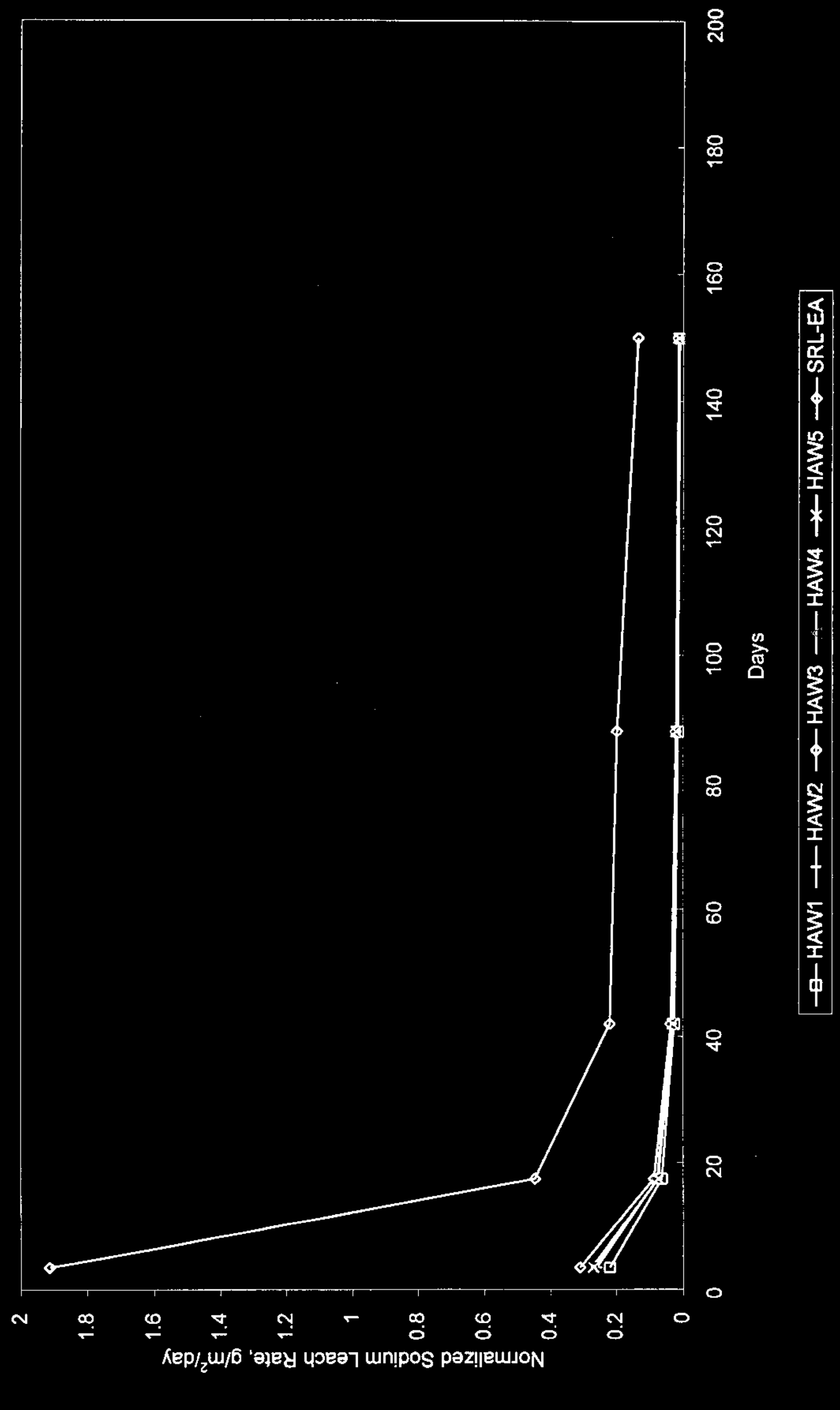


Figure 3.i. PCT Data for Hanford Glasses Comparison with SRL-EA Glass (Sodium Leach Rate)



4.0 DURAMELTER™ 100 RUNS

4.1 PRETEST MELTER CONDITIONS

The DuraMelter™ 100 system had been used previously to process a variety of simulated and actual low-level radioactive wastes. Prior to performing the melter tests on Hanford simulated wastes, the system was on standby mode with a high-iron borosilicate glass in the tank. The approximate composition (wt%) of the glass in the DuraMelter™ 100 prior to the introduction of any Hanford LLW feed was: Al_2O_3 = 5%; B_2O_3 = 20%; CaO = 7%; Fe_2O_3 = 4%; MgO = 5%; Na_2O = 11%; SiO_2 = 44%; others = 8%. This glass was flushed (three turnovers, as described above) with the Hanford simulated waste feed to remove the standby glass before the body of the steady-state tests. Areas of the melter plenum were probably contaminated with minimal amounts of material from previous melts but this would not be expected to contribute substantially to off-gas carryover. Records of previous melt feeds are available.

4.2 CHRONOLOGY OF EVENTS

The DuraMelter™ 100 runs were conducted between September 21-24, 1994 and September 26-29, 1994 for turnover and steady state portions, respectively. Complete run chronologies are given in Tables 4.2.a and 4.2.b.

4.3 QUANTITY OF FEED PROCESSED AND GLASS PRODUCTION

Approximately 306 kg and 304 kg of glass were produced in the turnover and steady-state periods, respectively. Approximately 370 liters of feed was consumed in each of these runs. Detailed information on feeding rates and times as well as glass pouring can be found in the run chronologies given in Section 4.2. All of the feed batches used in the DuraMelter™ 100 runs were nominally identical; each batch was labelled with the prefix "HAWF" followed by a number. A description of characteristics of the resulting feed slurry is given in Table 4.3.a. Complete sample descriptions and nomenclature are given in Section 4.5.

The average feed rates for the steady state and turnover runs were 9.5 and 5.2 liters per hour, respectively. Cumulative feeding curves are given in Figures 4.3a and 4.3b. The average glass production rates for the steady state and turnover runs were 7.7 and 4.4 kg per hour, respectively. This results in a measured overall conversion ratio of 1.2 liters of feed per kg of glass produced to be compared with the calculated value of 1.17 liters feed/kg glass (Table 4.3.a). The actual cumulative glass production is compared with the calculated value (from the cumulative amount of feed and the calculated conversion ratio) in Figures 4.3c and 4.3d. The comparison indicates good accounting for all the feed and glass.

Another method for checking feed and production rates is monitoring changes in glass composition over time. A total of six glass samples were analyzed by PNL. These analyses were compared with the projected composition of the glass based on the composition and amount of feed introduced into the melter using the standard well-stirred tank approximation. The results are depicted in Figures 4.3e, 4.3f, 4.3g, 4.3h, 4.3i, 4.3j, 4.3k, 4.3l, and 4.3 m for aluminum, boron, calcium, iron, potassium, magnesium, sodium, silica, and zirconium, respectively. The target compositions based on feed closely match the compositions of the analyzed glasses. This was particularly true after the initial 300 kg of glass had been produced. Notice that during this steady state period, the composition of the glasses asymptotically approaches the nominal target composition.

Glass production rates, by any measure, were always above the nominal 100 kg/day production rate. The overall average feed rate is, of course, larger if periods of non-feeding are factored out in the calculation. For example, the average production rate for the steady state run using total time was 188 kg/day whereas it was 223 kg/day when periods of non-feeding were excluded. Figures 4.3n and 4.3o illustrate the average glass production rates for the turnover and steady-state periods using both methods of calculating average production rates.

Since there was some residual radioactivity in the starting glass inventory in the melter from previous runs, the activities of the glass samples were measured for shipping purposes. The gross radioactivity of these glasses was measured using an Eberline ESP-1 detector. The detector was calibrated with a standard source. For the glass produced in the turnover run, the radioactivity decreased significantly with time in a manner which is well represented by the conventional well-stirred tank model, as shown in Figure 4.3p; these results are consistent with the composition data discussed above. While the radioactivity measurements are rather rough (a hand-held monitor was used without corrections for geometry, etc.), they do serve to demonstrate the general turnover effect and are consistent with the nominal melter inventory (100 kg), as shown in Figure 4.3p. The radioactivities of all glasses produced (including the earliest glass samples) are below the limit set by DOT (Reference: 49CFR.173.416). Therefore, all glasses were classified as "non-radioactive" samples for shipping purposes.

4.4 ENERGY CONSUMPTION

The primary consumption of energy in the DuraMelter™ 100 system is through the electrodes, the lid heaters, and the discharge heaters. The energy consumption for each of these was computed from the products of the respective voltages and currents. The average values obtained over the steady-state period were 20, 8, and 5 kW for the electrodes, lid heaters, and discharge heaters, respectively. The total average power usage was therefore 33 kW. This results in a power consumption rate of approximately 4.3 kWhr per kg glass produced.

The glass temperature was held relatively constant by controlling the power to the electrodes, as needed, in response to changes in the glass level and cold cap extent; variations in the electrical parameters, as well as other parameters, over the run are illustrated in Figures 4.4.a - 4.4.c. The voltages across the discharge heaters and the plenum heaters were held relatively constant at 96 volts and 71 volts, respectively.

4.5 IDENTIFICATION, DESCRIPTION, AND SAMPLING TIME FOR ALL SAMPLES COLLECTED FOR ANALYSIS OR ARCHIVAL

An elaborate system for sample naming was developed by WHC for these tests. The method, depicted in Figure 4.5a, involves a ten-character string which includes information such as vendor, project phase, analyzing lab, and sample type identifications. Collection of samples during the runs proved to be very labor intensive in that it involved preparing paper work (chain-of-custody and log book entries) and corresponding sample containers, sampling, distributing samples, labelling, recording and, finally, shipping. Figures 4.5b and 4.5c illustrate the 16 and 17 different sampling times during the turnover and steady period, respectively. Tables 4.5a and 4.5b provide names and descriptions of all of the samples that were taken.

Samples were stored in clean, labelled and suitably sized, plastic containers with snap-on or screw-on caps. Liquid sample containers were sealed in plastic bags and overpacked in 5-gallon or 55-gallon steel drums (according to the quantity) filled with loose absorbent; solid samples were packaged similarly. Sample containers were grouped and segregated in labelled 4-mil plastic bags to facilitate identification. All samples were assigned unique names (combinations of alpha-numeric characters), as discussed above, that were recorded on the sample container label and in the appropriate logbook. The logbook entries included all other pertinent sampling information (time, date, location, special conditions, operator, etc.) for that sample. Samples were shipped per Federal, State, and Local regulations.

4.6 DESCRIPTION OF OPERATING BEHAVIOR INCLUDING UPSETS, FAILURES, OPERATING PROBLEMS AND UNEXPECTED BEHAVIOR

The DuraMelter™ 100 runs proceeded very smoothly with no major upsets or surprises. The minor problems that were encountered related to the feed and off-gas systems rather than the melter and were successfully solved over the course of the runs (primarily during the turnover period); we would not consider any of these problems to represent obstacles to scale-up of the DuraMelter™ systems.

Some aspects of the feed were somewhat unusual including the high solids content and high alkalinity. As discussed in Section 2.2.1, a new feed system was installed for these runs which, when coupled with the new feed, necessitated some testing. The turnover run was used to debug the feed system and identify further minor improvements. During this period improved procedures for mixing the chemical additives with the simulant were also developed.

The test plan included direct sampling of melter exhaust. Unlike the situation for final off-gas system emissions, the DuraMelter™ 100 system was not designed for this procedure. As a result, modifications were required to the transition line from the melter. An opening of approximately 3 inches was required in the 6 inch transition line to accommodate the probe. The space between the probe and the opening was filled with a fibrous refractory blanket, however significant air leakage still occurred. This resulted in pressure drops and lower temperatures in the transition line. Material deposited in this area that subsequently had to be removed. The elimination of direct sampling of melter exhaust or designing a system with a better seal between around the probe would reduce or negate this problem.

A sulfate layer formed on the glass surface after the completion of the Hanford runs. This occurred several days after the melter was placed on idling mode. Idling occurred at the reduced temperature of approximately 1050°C and with significantly reduced glass bubbling. This observation is rather surprising since the targeted SO_3 content in the final glass was only 0.21 wt%. While an SO_3 solubility study was not performed on this particular glass formulation, this amount is well within the solubility limit of typical borosilicate glasses of this kind. This suggests that the LLW simulant may have contained more sulfur than was targeted. Mass balance calculations, discussed below, also indicate the presence of more sulfur in vitrification products than was provided by the nominal feed which supports this suggestion. The sulfate layer was removed from the melt surface by reduction to gaseous SO_2 by feeding an aqueous sugar solution into the melter.

4.7 DATA FOR MEASURED RUN PARAMETERS

Run parameters such as temperatures, pressures, flow rates and concentrations were recorded during the runs. The data for these parameters are collected in the following tables: Table 4.7.a for turnover melter conditions; Table 4.7.b for steady state melter conditions; Table 4.7.c for turnover off-gas system conditions; Table 4.7.d for steady state off-gas conditions; Table 4.7.e for turnover nitrogen air emissions; Table 4.7.f for steady state nitrogen air emissions; Table 4.7.g for melter transition line conditions; Table 4.7.h for post HEPA filter stack conditions; and Table 4.7.i for Engineering Sciences and VSL CEM emissions data. The data are also presented graphically in the following figures: Figure 4.7.a shows cation concentrations in the quencher solutions during turnover; Figure 4.7.b shows anion concentrations in the quencher during turnover; Figure 4.7.c shows cation concentrations in the scrubber during turnover; Figure 4.7.d shows anion concentrations in the scrubber during turnover; and Figure 4.7.e shows nitrogen emissions during the steady-state period.

Melter and off-gas system conditions were held relatively constant throughout the runs, as was intended (Figures 4.4.a - 4.4.c). Glass temperatures remained steady at approximately 1160°C after the first few hours of operation. Plenum temperatures fluctuate with feed rate, bubbling rate and cold cap. Negative pressure (with respect to atmospheric) is maintained in the melter for safety reasons. Scrubber temperatures were manipulated as a trade-off between accumulating the minimum amount of water during the run and maintaining low humidity at the baghouse; heated dilution air is introduced into the bag house to help prevent moisture condensation. Pressure differentials across the bag house and HEPA filter were used to monitor filter quality and to determine times for bag house conditioning.

A total of eight scrubber samples and eight quencher samples from the turnover period were analyzed at VSL. Boron, potassium, and sodium were determined by using DC Plasma Spectroscopy. Nitrite and nitrate were measured by using ion chromatograph and selective electrodes. Addition of hydrogen peroxide into either the scrubber or quencher was found to significantly increase the concentrations of nitrate and decrease concentrations of nitrite in the off-gas system solutions (scrubber and quencher), however, the effect on NOx removal was relatively small. Furthermore, the initial additions of hydrogen peroxide to the scrubber produced intense foaming which is operationally undesirable and also reduces the effective peroxide concentration.

Off-gas emissions data were collected by both Engineering Sciences and VSL. The two sets of data were in good agreement for metals and particulates but significant differences were found in the NOx data. Both labs show post HEPA filter metal emissions below detection levels for all metals and particulate concentrations well below the required 0.03 grain/dscf. Comparable moisture and metal concentrations were measured at the melter exit as well. However, ES reported NOx values one to two orders of magnitude greater than VSL measured values. Subsequent to the DuraMelter™ 100 test, a literature review conducted by VSL revealed that the method used by ES, chemiluminescence using a stainless steel catalyst, actually reads a large fraction of any ammonia that is present as NOx. The urea additions to the feed generated a significant quantity of ammonia in the exhaust stream which contributed to this effect. ES recognized this and documented the positive interference in their report. Later tests conducted at VSL confirmed that the CEM chemical sensor technique used to obtain the VSL data was immune to this interference.

4.8 MASS BALANCES

Establishing material mass balances was a major objective of these tests. To compute material balances, compositional analyses were required of the following: feed, quencher and scrubber solutions, glasses, bag house powders, and emissions. Also, complete and accurate data pertaining to feed rates, glass production, air flow rates, liquid volumes, and bag house conditioning were needed. The great majority of this information was available for this report, however some extrapolations and approximations were required from the available data, as noted below, in order to complete the analysis.

Fourteen feed samples were taken during the steady state run, three of which were analyzed by PNL; these samples were taken 573, 723, and 1413 minutes into the run. The results of the PNL analyses are given in Table 4.8.a. The average values (as well as the target values) were used in mass balance calculations. Deviations in the reported values could have resulted from actual compositional variations in the feed, sampling, and analytical variations from either sample dissolution or analysis. These variations introduce uncertainty into the mass balance calculations. Analysis of all 14 feed samples would provide an improved estimate of the true average feed composition. There is, however, quite good agreement between the target composition and the average of the PNL analyses with the exceptions of cesium, phosphorous and zirconium; analysis of zirconium in slurries is often problematic due to its relative insolubility. In general, the glass forming elements and compounds which volatilize from the glass melt, such as those containing nitrogen, were present in the relative proportions expected on the basis of the target composition.

Seventeen glass samples were collected during the steady state run; however, only three were analyzed by PNL and USGS. The results for these analyses, in addition to those for the three turn over glasses, are given in Table 4.8.b. The deviation between the PNL and USGS analyses for most elements was well below 10% with the exception of boron (approximately 10%) and zirconium. As illustrated in Section 4.3, the product glass was found to be very close to the target composition with the exception of zirconia. Additional analyses of feed and glass samples, and perhaps including other analytical laboratories, would be helpful in elucidating these discrepancies. VSL analysis of a glass sample taken at the end of the turnover run indicated that the glass contains approximately 4.5 wt% zirconium oxide.

Fourteen pairs of quencher and scrubber samples were taken during the steady state run; however, only three pairs were analyzed by PNL. The results of these analyses are given in Table 4.8.c. Increases in elemental concentrations over time can be attributed to carryover from the melter, whereas decreases can be attributed to dilution and loss by misting from the liquid reservoirs. The liquid volumes were kept relatively constant at 250 liters for the quencher and 1000 liters for the scrubber by transferring solution from the scrubber where moisture condenses to the quencher where liquid evaporates. DI water was added to the quencher in place of the scrubber water when there was not enough scrubber water available. Excess liquid accumulated in the scrubber was periodically transferred to a blow down tank. Accumulation of any precipitate (other than that which was naturally suspended in the liquids (due to the active agitation) and therefore accounted for in the samples) was assumed to be insignificant due to the low concentrations and limited duration of the runs. Operating for longer time periods, without changing the quencher solution, would require quantifying and analyzing any precipitate that accumulated.

Diatomaceous earth was used as a coating to condition the bag house filters. A sample of the spent diatomaceous earth was taken from the bag house at the end of the steady state run. All of the spent diatomaceous earth that was accumulated during the turnover run was removed before commencing the steady state run. Eight kilograms of diatomaceous earth was added to the system and *approximately* 11 kg (unfortunately, however, this number is not well known) of spent diatomaceous earth was recovered at the end of the steady state. The PNL and USGS analyses of both the spent and unused material are shown in Table 4.8.d. There is good agreement between the two laboratories for most elements with exception of silicon. The raw diatomaceous earth consists primarily of silicon with lesser amounts of aluminum, sodium, iron, and calcium. During melter operation, deposits develop on the diatomaceous earth consisting mainly of alkali metals, boron, and halogens.

Data selection and assumptions were required to complete the steady state mass balance calculations. Data from PNL was the most extensive and was used whenever possible in order to reduce the effects of any lab-to-lab analytical biases. Two methods were used to calculate the amount of each feed component introduced into the melter: (a) The product of average analyzed feed composition in Table 4.8.a and the total amount of feed, and (b) The product of target feed composition and the total amount of feed. Accumulations in the quencher and scrubber were calculated by extrapolating the accumulations rates determined from the analyses given in Table 4.8.c to the entire run. This extrapolation was predicated on the assumption that since melter feed rates were uniform throughout the run, so were the carry-over rates from the melter.

Because of the uncertainty in the mass of material removed from the baghouse, the amount of material accumulated in the bag house during the run was calculated by normalizing the analytical results for the unused and the spent diatomaceous earth samples (Table 4.8.d) to the same silica content, subtracting the results for the unused sample from those for the spent sample, and multiplying the result by the total mass of the spent material. Post HEPA filter emissions were all below the detection limits (Table 4.7.h); however, the maximum possible masses emitted were determined as the product of detection limit concentration, the air flow rate, and the total run time.

The accumulation of material as glass was calculated as the product of the total mass of glass produced and the average steady state glass composition plus a small correction due to the change of composition of the glass in the melter over the run. This change was estimated by subtracting the composition of the glass at the end of the turnover run from that of the last available steady-state glass (approximately two-thirds of the way into the run) and multiplying by the nominal size of the glass pool (100 kg). An improved estimate could have been obtained if the composition of the glass at the end of the run and exact glass melter levels were known. This estimate, although a slight underestimate, does not greatly affect the overall mass balance calculation in that changes in the composition of the glass pool during steady-state were very small.

The results from mass balance calculations are given in Tables 4.8.e and 4.8.f. The agreement between the feed data and the glass production data are very good, particularly considering the number of analyses and assumptions involved. Using PNL feed analyses, the difference between the amount fed and the amount recovered is less than ten percent for Al, B, Ca, Fe, K, Mn, Mo, Na, Si, and Sr. Between 94 and 100% of the mass of these elements was retained in the glass. Similar results for most elements are also achieved using the target feed, however, in that case most of the elements exceed 100% recovery somewhat. A comparison of the percent deviations from the two methods of calculation indicate the level of uncertainty in such mass balance calculations. Small differences in analytical results (either the feed or the individual constituents of the feed) can lead to quite different results.

The measured amounts of cesium, sulfur, titanium and, to a lesser extent, potassium did not balance well with the respective amounts fed into the melter. The eleven to sixteen percent of the titanium not recovered may have been due to the underestimation of changes in the glass pool. Titanium was absent from the glass at the beginning of the Hanford run and was still approaching its low target value; small errors in estimates of the glass pool changes and average glass composition results have a larger effect on the mass balance for such components. It is perhaps worth noting that of the other three components which gave the poorest mass balances (Cs, S, and K) Cs and K are relatively volatile and there is evidence that the actual amount of sulfur in the LLW simulant was greater than targeted.

The fractional amount of each feed constituent exiting the melter was quantified using two independent methods: In the first, the average measured emission rates were divided by the average feed rates; in the second, the total mass of material in the off-gas system was divided by the total mass fed into the melter. The results of these calculations are given in Table 4.8.g. The methods show good agreement for many of the elements except for potassium. Given the many difficulties involved in obtaining representative sampling at the melter exhaust, the agreement was better than expected.

4.9 GLASS DURABILITY

Two of the glasses produced during the steady state run were subjected to the PCT leach test procedure by the USGS. The results obtained are presented in Tables 5.9.a together with data from the DuraMelter™ 1000 run, and depicted in Figure 4.9a. Leach rates for the glasses produced from the DuraMelter™ 100 were well below the that of SRL-EA standard glass. The normalized average leach rates for sodium were approximately one order of magnitude less than the 1 $g/m^2/day$ goal. These results are very similar to those reported in Section 3.0 for the crucible melt glasses. Thus, very leach resistant glasses were successfully produced in the continuously fed melter tests.

4.10 CORROSION TESTS

Since none of the melter components were new, coupons were used to determine any reactions between the Hanford feed and glass with the melter materials, including refractories and metals. Coupons were tested in contact with the glass, in the plenum space, and at the glass air interface. Photographs of the coupons before and after the run are given in Figures 4.10.a - 4.10.l.

Corrosion tests were performed on coupons of the following melter materials: Inconel 690, Inconel 601, K-3 brick, and Zirmul® brick. The Inconel 690 and K-3 coupons were of sufficient length to be exposed to the glass, the glass air interface and plenum atmosphere alone. The Inconel 601 and Zirmul® coupons were exposed to plenum atmosphere. The Inconel coupons were obtained from our inventory. Archive samples were supplied which were cut from the same stock. The brick coupons were cut from surplus bricks remaining from melter construction. Archive samples were provided from the identical bricks.

On visual inspection upon completion of the tests, there did not appear to be any sign of corrosion of any of these coupons. The coupons were supplied to the analytical labs designated by WHC but no detailed data are presently available.

4.11 SUMMARY AND CONCLUSIONS

The DuraMelter™ 100 was successfully operated to demonstrate the vitrification of Hanford LLW simulant. The objectives detailed in the test plan were met during the two stages of the test, turnover and steady-state. The slurry feed system employed was suitable and reliable for controllable transfer of a mixture of Hanford LLW simulant and chemical additives to the melter. The sustained feed rate was twice that originally planned. Melter retention for most elements was close to 100%. The amount of material emitted from the process was below detectable limits for all metals. Urea was effective in reducing NOx concentrations in the off-gas.

Table 4.2.a
Run Chronology (Turnover) (7 sheets)

Clock Time	Run Time (min)	Turnover Run
		9-21-94
830		Glass sample taken (100-5-7A)
1735	0	Computer clock set to Zero
2020	165	Feed tank level - 24.5 cm
2030	175	Glass sample taken (100-5-7B)
2042	187	Feed Started
2100	205	Feed/Scrubber/Quencher/Glass Samples Taken
2227	292	Feed tank level - 12.5 cm, Feed Rate = 100 ml/min, Glass sample taken (100-5-7C)
2315	340	Feed tank level - 10.5 cm, Quencher Level - 2" below High mark
2320	345	Water added to Quencher up to the level - 3/4" below High mark
		9-22-94
33	418	Feed tank level - 8 cm
40	425	Feed rate - 100 ml/min
47	432	Quencher level was 2.5" below high mark
130	475	Feed tank level - 6 cm, glass sample (100-5-11A) taken
200	505	Feed/Scrubber/Quencher samples taken
214	519	Feed rate - 92.4 ml/min
232	537	Feed tank level - 4 cm, Glass sample taken
237	542	DI Water added to Quencher to level 1" below the mark
340	545	Feeding Stopped
345	550	Scrubber Solution ANC=0.22, Glass sample taken (100-5-11B), Glass Temperature set to 1050°C
845	850	Scrubber tank level 19 cm below top
1000	925	Mix HFWF4 + 20 liter DSSF3
1130	1015	Mix HFWF5 + 20 liter DSSF3

Clock Time	Run Time (min)	**Turnover Run**
1200	1045	25 liter 50% H_2O_2 added to the Scrubber
1244	1089	Transferred HAWF4+HAWF5 from Mixing tank to Feed tank, new feed tank level was 36 cm
1350	1155	Foaming in Scrubber, Water leakage from Scrubber
1435	1200	A Scrubber solution sample was taken after adding H_2O_2 (92241435S)
1635	1320	Feeding resumed, Feed rate - 100 ml/min, Feed tank level - 35 cm
1730	1375	Scrubber and Quencher samples taken (92241730S+92241730Q)
1815	1420	Feed Rate - 120 ml/min
1830	1435	Scrubber and Quencher samples taken (92241830S+92241830Q)
1900	1465	8.3 gallon of 50% NaOH solution added to Scrubber
1945	1510	Glass sample taken
1955	1580	Glass discharged for five minutes, 10 Liter of H_2O_2 added to Quencher, 5 liter of H_2O_2 added to Scrubber
2000	1585	Scrubber/Quencher samples taken
2020	1605	10 liter H_2O_2 added to Quencher
2035	1620	Feed tank level - 22.5 cm
2100	1645	Glass sample taken (100-5-19)
2130	1675	Feed tank level - 20.5 cm. Water added to Quencher up to 1.5 cm below high mark.
2200	1705	10 liter H_2O_2 added to Quencher, 5 liter H_2O_2 added to Scrubber
2230	1735	Water added to Quencher
2240	1745	Glass started to drain by itself, Air lift activated to drain 3" in container.
2330	1795	Feed tank level - 14 cm, Mixing tank level - 25.5 cm
9-23-94		
10	1835	Closed water line to the heat exchanger. Transferred water to the Quencher.
25	1850	Feed tank level - 11.5 cm, Mixing tank level - 25.5 cm.
30	1855	Feed tank level - 22.0 cm.
125	1910	5.3 Kg Urea added to feed tank.

Clock Time	Run Time (min)	Turnover Run
135	1920	4.2 Kg Urea added
145	1930	Glass sample taken (100-5-20A)
150	1935	4.8 Kg Urea added to feed tank
230	1975	Feed rate - 90 ml/min, reset to 120 ml/min
235	1980	There was water under Scrubber, should be checked for a leak
310	2015	Feed Line unclogged, feed was OK
340	2045	Transferred 5 cm (in height) water to Quencher
355	2060	Scrubber/Quencher samples taken
410	2075	Feed sample taken, 1 liter fed per 11 minutes
422	2087	Feed tank level - 19 cm
430	2095	Discharged 4 inch of glass
435	2100	Scrubber N = 0.43. Cold cap 20%, increased feed speed to "yellow" 5
505	2130	Feed tank level - 14.5 cm
516	2141	Turn on heat exchanger, transferred 4 cm from scrubber into Quencher
551	2176	Feed level = 14.5 cm
600	2185	North right discharge heater burnt out. Discharged glass.
730	2275	Stopped feeding. Worn out, Teflon feeding line replaced.
910	2375	Feed and glass (100-5-21A) sample taken
930	2395	Resumed feeding, Feed level = 7 cm
950	2415	Glass sample taken.
1048	2473	9 cm water transferred from Scrubber to Quencher.
1123	2508	Feed level - 4 cm
1220	2565	Feed level - 2 cm before transfer. Stopped feeding. 156 oz starch added. New feed level before (adding starch) = 15.4, after = 17 cm. Mix tank level = 3.4 cm
1320	2625	Transferred 8 cm liquid from Scrubber to Quencher
1345	2650	Scrubber water shift to city water

Clock Time	Run Time (min)	Turnover Run
1346	2651	Resumed feeding
1346	2651	Feed sample taken, feed rate - 100 ml/min
1410	2675	Feed rate increased (from yellow 2 to yellow 4)
1430	2695	Feed stopped, it was difficult to pump to melter. After 17 liters water added, was still difficult to pump.
1450	2715	Feed level = 15.5 cm
1500	2725	Discharged glass and changed containers (100-5-26A)
1700	2845	300 liters of scrubber water transferred to the blow down tank
1800	2905	Prepared feed batch 8, 9, & 10. Mix tank height = 38.5 cm, No starch added.
1840	2945	Feed tank level - 45 cm
1955	3020	Resumed feeding
2000	3025	Scrubber and Quencher samples taken
2015	3040	Feed sample taken, feed rate - 118 ml/min
2030	3055	Resumed feeding. Transferred DI water to quencher for 5-1 cm below H
2045	3070	Feed tank level - 23.0 cm
2130	3115	Feed Rate - 125 ml/min. Increased to - 160 ml/min. Bubble 12 Feed tank level = 21 cm
2140	3125	Transferred 6 cm DIW to quencher up to 1 cm below High mark
2200	3145	Cold cap 90%. Increased bubbler to 18
2230	3175	Cold cap: 90%. Bubbler 18 Feed tank level = 17.8 cm, Add 3.8 Kg Urea
2248	3193	Feed on, feed rate = 164 ml/min
2310	3215	Bubbler reduced to 10, transferred DIW to quencher from 6 to up to 1 cm below High mark.
2315	3220	Cold cap 85%, bubbler 16
2330	3235	Mix tank level = 9.5 cm
2336	3241	Feed tank = 15.5 cm
2345	3250	Poured 1 inch glass

Clock Time	Run Time (min)	**Turnover Run**
		9-24-94
5	3270	Drained glass, feed rate = 158 ml/min
10	3275	Feed tank level = 14 cm
15	3280	Added 3 Kg Urea, stirred for 10 min
50	3315	Changed to second drum of DSSF simulant and stirred
100	3325	Feed tank level = 12 cm
110	3335	Transferred 20 Liter DSSF to mix tank
120	3345	Added HAWF11 to mix tank
210	3395	Feed tank level = 7.8 cm
215	3400	Feed rate = 198 ml/min
220	3405	Mix tank level = 23 cm, Added 10.2 Kg Urea
230	3415	Glass taken (100-5-29A)
300	3445	Transferred 5 cm DIW to Quencher
310	3455	Added urea 16.2 Kg to mix tank, level = 27 cm, increased volume 17% (27/23)
325	3470	After transfer, 2 cm left in mix tank
330	3475	Feed tank level= 28 cm
335	3480	Feed rate = 196 ml/min
405	3510	Feed rate 195 ml/min, Discharged glass
430	3535	Feed level = 24.5 cm
500	3565	Discharged glass (100-5-29B)
515	3580	Cold cap 90%, bubbler= 25, transferred solution from scrubber to blowdown tank
530	3595	Feed level = 19.5 cm
615	3640	Discharged glass for 5 min
630	3655	Feed level = 16 cm
700	3685	Cold cap was getting thicker and was closing. Reduced feed rate to yellow 1
805	3750	Stopped feeding to clean bag house

Clock Time	Run Time (min)	Turnover Run
805	3750	Sample taken, feed rate = 179 ml/min, feed levels: feed tank = 7.5 cm, mix tank = 1.4 cm
815	3760	Discharged glass (100-5-30A), changed container
856	3801	Started feed
857	3802	Pressure reading after bag house reconditioning Melter DP = 1.0"(DIS 3701), scrubber sump DP = 0.7" (DDS 3701), melter transition DP = 2.0" (PD 3701), Bag house DP = 2" (DDS 3704), HEPA DP = 0.7" (DDS 3703)
900	3805	150 liters scrubber water was transferred to blow-down tank
920	3825	Opened the third nozzle on the quencher at 10 psi to aid in scrubbing particulate emitted from melter
1028	3893	Feed level in feed tank down to 3.2 cm
1030	3895	Couldn't sustain feed rate due to low level in feed tank. Feeding was erratic, water was pumped with feed to keep the feed tube open
1040	3905	HAW 12 & 13 added to mix tank
1115	3940	Mix tank level = 27 cm, previous level = 1.4 cm 16.4 Kg urea added
1120	3945	9 cm water transferred to Quencher
1215	4000	Transferred sludge from the mix tank to feed tank, prepared feed, level in mix tank = 31.6 cm, volume expansion due to urea = 19%
1220	4005	After transfer, feed tank = 29.7 cm, mix tank = 2.3 cm
1226	4011	Feed sample was taken, feed rate = 195 ml/min
1230	4015	Scrubber and quencher solutions taken, feed sample taken
1245	4030	Discharged glass
1320	4065	7 cm of water transferred to quencher
1416	4121	Feed level in feed tank = 20 cm, feed rate = 4.85 cm/hr w/urea Feed rate = 16.5 Kg/hr of feed w/o urea Estimate of power consumption 14-21 KW, avg. 17.5 KW
1440	4145	Glass discharged (100-5-33A)

Clock Time	Run Time (min)	**Turnover Run**
1450	4155	Feed stopped, feed line was washed with 15 gallons of DI water
1615	4240	Glass temp. reached the preset level of 1090°C. Melter put on idling mode
		(emergency) and off-gas system halted.
		End of Turnover Period Operation !

Table 4.2.b
Run Chronology (Steady State) (6 sheets)

Clock Time	Time (min)	Steady-State Run
		9-26-94
920		Temp. set point to reach 1160 C in 1 hr 20 min. Prepared to place Coupons in the melter The coupons would be introduced gradually to the plenum space and then lowered into the glass
1018		K3 was introduced into the port opening, bottom should extend just into plenum space plenum temp. was 1040°C
1025		Mix tank = 46.5 cm, feed tank = 16.5 cm
1040		Lowered the coupon so Zirmul was about 1" below flange
1050		Coupons were positioned in melter, were visible from viewpoints.
1342	0	
1412	30	Feed rate = 190 ml/min
1430	48	Transferred DI water to Quencher from 8 to 1 cm below High mark (Water was transferred from one of the top nozzles).
1510	88	Transferred scrubber solution to the blowdown tank from level of plastic elbow to 12 cm.
1610	148	Drained glass for 3 min before taking glass sample
1620	158	Transferred 6 cm of DI water to Quencher
1628	166	12 cm of scrubber water was transferred to blowdown tank. 173 liters
1720	218	Transferred sludge from mixing tank to feed tank. feed tank level from 4.3 cm to 45.5 cm
1745	243	Noticed a mound of cold cap was forming under the feed tube. Glass level dropped about 1 inch below cold cap when it was drained. As a result the heat transfer to the cold cap was reduced greatly. (Don't drain too much at one time. Drain more frequently but less glass once/hr Increase bubbling rate before draining 40 cm/h)
1830	288	Glass and off-gas liquid samples were taken.
1845	303	8 cm DI water was transferred to the Quencher.

Clock Time	Time (min)	**Steady-State Run**
1913	331	Feeding stopped to dissolve the mound from the feed tube. Bubbling had been up to 80 SCFH for the past 45 min So feeding water for 4 min and stopped water for 3 min before mound dropped down to melt
1920	338	Feeding resumed at the same rate
1935	353	Bubbling back to 16 SCFH
1936	354	9 cm of scrubber solution was transferred to blowdown tank.
2016	394	Drained for 30 seconds
2020	398	Removed glass (100-5-43A)
2025	403	Drained glass into new bucket for 1-1/2 minutes
2106	444	Started air jet for 10 minutes, feed stopped.
2125	463	Resumed feed
2145	483	Started to drain glass
2245	543	Started to drain glass
2325	583	The solution in scrubber was lowered down to the point of 8 cm, which was transferred to the blowdown tank.
2350	608	Drained the glass
		9-27-94
35	653	Mixing tank level = 49 cm.
58	676	Discharged glass for 1-1/2 minutes (100-5-45)
145	763	Discharged glass
150	768	Stopped feeding
154	772	Started air jet for 10 minutes, 2 kg DE went in.
215	793	Resumed feeding
320	858	Transferred solution from the scrubber to the blowdown tank, level was 15 cm.
321	859	Discharged glass
340	878	Transferred 31 liters of DI water to Quencher.
415	913	Drained Glass

Clock Time	Time (min)	**Steady-State Run**
445	943	Transferred solution from the scrubber to the blowdown tank, the level was 12 cm.
500	958	Discharged glass (100-5-45B)
515	973	pH of Scrubber at 11.6, NaOH needed.
545	1003	Glass/Feed/Scrubber/Quencher samples taken
550	1018	Resumed feed
640	1068	Transferred 6 cm DI water into Quencher through the transition line
710	1098	Discharged Glass (100-5-45C)
715	1103	1-1/3 gallon of NaOH added to the scrubber, pH=13.23
720	1108	Started to spray DI water into the transition line, due to high dP in Quencher.
734	1122	Feed rate was reduced to yellow 1.
738	1126	Feeding stopped
759	1147	Cleaned deposit from the film cooler and initial section of the transition line.
854	1202	Started to feed
935	1243	Discharged glass for sampling
955	1263	Glass/Feed/Scrubber/Quencher samples taken
1010	1278	Decreased feed rate to yellow 1, Bubbling rate set to 40.
1020	1288	Feed rate resumed to yellow 4.
1035	1303	Transferred solution from Scrubber to Blowdown tank
		Transferred 7 cm DI water to Quencher
1100	1328	Transferred 14.5 cm solution from Scrubber to Blowdown tank
1205	1393	Both flow rate sensors read significant increases (~50%) when ES introduce their probes into the melter exhaust line. (This confirmed the origin of previously observed spikes in flow rates from yesterday's new data)
1225	1413	Stopped feeding, bubbler hose needs repair.
1242	1430	Resumed feed
1255	1443	Discharged glass (100-5-48A)

Clock Time	Time (min)	Steady-State Run
1310	1458	Added 7 cm of DI water to Quencher
1342	1490	Turned feed off, Purged baghouse
1345	1493	Discharged glass (100-5-48B)
1356	1504	Started feeding
1405	1513	Transferred 1.5 gallon of NaOH to Scrubber, pH=13.57 after transfer.
1430	1538	Discharged glass
1510	1578	Added 10 cm of DI water to Quencher
1555	1623	Stopped feeding, needed to replace with new sludge.
1620	1648	Discharged Glass (100-5-50A)
1635	1663	Replaced Glass Bucket
1700	1688	Drained glass for 1 minute
1715	1703	Glass/Feed/Scrubber/Quencher samples taken
1720	1708	Drained glass
1730	1718	Added 5.5 cm of DI water to Quencher
1815	1763	Scrubber flow sensor gave erratic results (because it was wet), sensor was pulled out of line, dried and replaced.
1858	1806	Stopped Feeding, Dip-sample taken from glass sample pool through cold-cap (sample point S8)
1902	1810	Baghouse jets activated
1913	1821	Baghouse jets stopped, 2 kg DE deposited into the baghouse.
1940	1848	Added 6 cm of DI water to Quencher
1958	1866	Dip sample taken of cold cap
2000	1868	Resumed feed
2008	1876	Feed tank level = 21.5 cm
2010	1875	Discharged glass
2110	1938	Added 6 cm of DI water to Quencher
2115	1943	Discharged glass, glass sample taken
2145	1973	Mixing tank level = 31.5 cm

Clock Time	Time (min)	**Steady-State Run**
2215	2003	Discharged glass (100-5-52A)
2245	2033	Feed Stopped, Baghouse jet activated
2300	2048	Samples taken
2305	2053	Baghouse jets stopped, 2 kg of DE added
2310	2058	Discharged glass
2315	2063	Added 7 cm of DI water to Quencher
2345	2093	Discharged glass
		9-28-94
25	2133	Discharged glass
42	2150	Feed Stopped, Baghouse jet activated
55	2163	Resumed feed, baghouse jets off, 2 kg DE added.
113	2181	Added 6.5 cm of DI water to Quencher
120	2188	Discharged glass
130	2198	Transferred 10 cm solution from scrubber to blowdown tank
140	2208	Removed bucket (100-5-54A)
205	2233	Drained glass
233	2261	Feeding was off, Purged baghouse
235	2263	Samples taken
245	2273	Feeding was back on
255	2283	Drained glass for 1 minute
320	2308	Added 6.5 cm of DI water to Quencher
340	2328	Drained glass
420	2368	Drained glass for 5 minutes, (100-5-54B)
445	2393	Feeding stopped
1117	2785	Temp. was set to 1100°C for further glass drainage, but there was no need for further drain after inspection.
1128	2796	Coupons were lifted above the glass level to let them drip, Plenum temp. was 970°C.

Clock Time	Time (min)	Steady-State Run
1143	2811	Coupons removed, (some cracking sounds heard as the pieces cool. There were visible cracks in the K3, none in the Zirmul)
		The weld wire appeared intact, the Inconel 690 appeared OK.
1145	2813	DE have been removed from baghouse, A new can was installed to catch DE from baghouse
1206	2834	Air jet was activated
1220	2848	Air jet was secured and catch bucket full of DE was removed.
1225	2853	New DE was deposited on the bags.
1630	3098	A sample of the glass pool was taken by inserting a Hyanes alloy HR252 (high Ni-Cr alloy, very similar to Inconel 601) rod into the glass pool and withdrawing it.
End of Hanford 100 kg/d campaign!!!		

Table 4.3.a.
Slurry Feed Characteristics

(1) Oxide Waste Loading (nominal* without urea)	25 wt%
(2) Total Solids Content (nominal* without urea)	70 wt%
(3) Total Oxides Content (nominal* without urea)	57.5 wt%
(4) Density before Urea Addition (measured at VSL)	~1.75 g cm^{-3}
(5) Oxide Yield (calculated from (3) and (4))	994 g/l
(6) Urea Content (steady state)	250 g/l
(7) Volume Increase on Addition of Urea (measured at VSL)	18%
(8) Density with Urea (calculated from (4), (6), and (7))	1.69 g cm^{-3}
(9) Volume of Feed per kg of Glass (calculated from (3), (4), and (7))	1.17 l/kg
(10) Density of Feed (with urea) Measured at WHC	1.75-1.78 g cm^{-3}

* Nominal values were calculated from the proportions and characteristics of the simulant and additives

Table 4.5.a
Turnover Sampling During DuraMelter™ 100 Hanford Runs

Date	Time	Run Time	Feed[a]	Glass[b]	Scrubber[c]	Quencher[c]
9-21-94	2100	205	D1F3-001	D1G4-001	D106-001	D105-001
	2200	265	D1F3-002	D1G4-002	D106-002	D105-002
9-22-94	200	505	D1F3-003	D1G4-003	D106-003	D105-003
	345	610	NST	D1G4-004	D106-004	D105-004
	1600	1345	D1F3-005	NST	D106-005	D105-005
	2000	1585	D1F3-006	D1G4-006	D106-006	D105-006
	2400	1825	D1F3-007	D1G4-007	D106-007	D105-007
9-23-94	230	1,975	D1F3-008	NST	NST	NST
	400	2065	D1F3-009	D1G4-009	D106-009	D105-009
	800	2305	NST	NST	D106-010	D105-010
	930	2395	D1F3-010	NST	NST	NST
	1000	2425	NST	D1G4-010	NST	NST
	1410	2675	D1F3-011	D1G4-011	D106-011	D105-011
	2000	3025	D1F3-012	D1G4-012	D106-012	D105-012
	2400	3265	D1F3-013	D1G4-013	D106-013	D105-013
9-24-94	400	3505	D1F3-014	D1G4-014	D106-014	D105-014
	800	3745	D1F3-015	D1G4-015	D106-015	D105-015
	1230	4015	D1F3-016	D1G4-016	D106-016	D105-016
	1430	4135	D1F3-017	D1G4-017	NST	NST
	1500	4165	NST	NST	D106-017	D105-017

Note: a. Feed samples were shipped to Quanterra, PNL, WHC 222-S, and USGS.
b. Glass samples were shipped to PNL, Geo. Tech., and USGS.
c. Quencher and Scrubber samples were shipped to Quanterra, PNL, and Geo. Tech.
NST - No Sample Taken

Table 4.5.b
Steady State Sampling During DuraMelter™ 100 Hanford Runs

Date	Time	Run Time	Feed[a]	Glass[b]	Scrubber[c]	Quencher[c]
9-26-94	1412	30	D1F3-018	D1G4-018	D106-018	D105-018
	1600	138	D1F3-019	D1G4-019	D106-019	D105-019
	1815	273	D1F3-020	D1G4-020	D106-020	D105-020
	2030	408	D1F3-021	D1G4-021	D106-021	D105-021
	2315	573	D1F3-022	D1G4-022	D106-022	D105-022
9-27-94	145	723	D1F3-023	D1G4-023	D106-023	D105-023
	545	963	D1F3-024	D1G4-024	D106-024	D105-024
	940	1198	D1F3-025	D1G4-025	D106-025	D105-025
	1315	1413	D1F3-026	D1G4-026	D106-026	D105-026
	1705	1643	D1F3-027	D1G4-027	D106-027	D105-027
	1900	1758	NST	D1G4-028	NST	NST
	1958	1816	NST	D1G4-029	NST	NST
	2100	1878	D1F3-030	D1G4-030	D106-030	D105-030
	2300	1998	D1F3-031	D1G4-031	D106-031	D105-031
9-28-94	245	2223	D1F3-032	D1G4-032	D106-032	D105-032
	430	2328	D1F3-033	D1G4-033	D106-033	D105-033
	1630	3048	NST	D1G4-034	NST	NST

Note:
a. Feed samples were shipped to Quanterra, PNL, WHC 222-S, and USGS.
b. Glass samples were shipped to PNL, Geo. Tech., and USGS.
c. Quencher and Scrubber samples were shipped to Quanterra, PNL, and Geo. Tech.
NST - No Sample Taken

Table 4.7.a
DuraMelter™ 100 Operational Data for Hanford Turnover Run

Date	Time	Temperature (°C)			Negative Pressure (inches water)	Cold Cap (%)	Bubbler (scfh)
		Plenum	Glass	Discharge			
9/21/94	1900	837	926	1012	1.5	0	4
	2325	1068	939	1103	1.5	20	10
9/22/94	0110	747	962	1096	1.4	5	10
	0230	783	965	1086	1.4	20	10
	0625	705	932	847	1.4	0	NA
	1600	647	1081	898	1.0	0	5
	1650	640	1114	900	1.0	60	16
	1850	551	1157	916	0.9	80	8
	2130	580	1164	1071	1.0	75	16
	2355	589	1163	1079	1.0	85	16
9/23/94	0200	775	1166	1110	0.8	30	16
	0430	840	1169	1045	0.6	20	5
	0600	730	1168	1000	0.8	40	5
	1030	796	1156	1009	0.6	10	3
	1340	859	1143	998	0.8	0	16
	1555	926	1161	743	0.5	0	10
	2030	881	1176	543	0.5	10	12
9/24/94	0030	627	1167	1046	0.8	80	19
	0415	593	1165	1043	0.7	90	20
	0615	616	1168	1050	0.7	90	26
	0923	717	1165	990	0.8	80	26
	1130	871	1165	1026	0.6	0	26
	1330	656	1163	1049	0.8	80	25
	1500	610	1164	1045	0.7	NA	25
Avg.		735	1112	988	0.9	38	14
Range		551-1068	926-1169	543-1110	0.5-1.5	0-90	4-26

NA = Not Available

Table 4.7.b
DuraMelter™ 100 Melter Operational Data for Hanford Steady State Run

Date	Time	Temperature (°C)			Negative Pressure (inches water)	Cold Cap(%)	Bubbler (scfh)
		Plenum	Glass	Discharge			
9/26/94	1200	977	1288	859	1.0	0	7
	1415	818	1157	984	0.8	10	16
	1440	656	1159	1003	0.9	85	25
	1550	579	1159	1025	0.8	90	24
	1705	787	1161	1039	0.6	60	24
	1730	732	1147	1051	1.0	60	27
	2140	591	1159	1039	1.1	80	26
	2340	640	1164	1057	0.9	85	23
9/27/94	0130	688	1163	1068	0.4	80	31
	0400	659	1159	1063	0.8	70	32
	0640	697	1162	1065	0.7	50	37
	0800	832	1164	1085	0	90	2
	0900	788	1161	1077	1.0	30	29
	1010	504	1162	1032	1.3	90	40
	1144	642	1157	1042	1.0	80	40
	1330	650	1154	1048	0.9	80	40
	1355	655	1159	1042	1.2	90	30
	1535	611	1162	1061	0.8	80	30
	1856	640	1158	1065	1.6	NA	NA
	2200	664	1155	1055	1.0	70	40
9/28/94	0130	660	1159	1090	0.6	60	NA
Avg.		689	1165	1040	0.9	67	28
Range		591-977	1154-1288	859-1090	0-1.1	0-90	2-40

NA = Not Available

Table 4.7.c
DuraMelter™ 100 Off-Gas Operational Data for Hanford Turnover Run

Date	Time	Scrubber				Baghouse		HEPA Filter	
		Air Temp Quencher Entrance (°C)	Scrubber Inlet Temp (°C)	Scrubber Liquid Temp (°C)	Pressure differential across scrubber tower (inches water)	Air Temp (°C)	Pressure Differential (inches water)	Pressure Differential across HEPA filter (inches water)	Dilution Air Temp (°C)
9/21/94	1900	NA	NA	NA	1.2	39	2.4	1.0	NA
	2325	NA	NA	NA	1.1	38	2.8	0.8	NA
9/22/94	0110	NA	NA	NA	1.1	39	3.1	0.8	NA
	0230	NA	NA	NA	1.1	39	3.3	0.8	NA
	0625	NA	NA	NA	1.2	40	3.7	0.8	NA
	1600	297	53	13	0.3	51	1.0	0.5	93
	1650	290	54	12	2.2	53	1.2	0.6	91
	1850	261	54	14	0.3	52	1.8	0.6	86
	2130	264	57	15	2.0	51	2.4	0.6	92
	2355	253	57	13	2.0	50	2.6	0.6	90
9/23/94	0200	325	58	47	1.3	65	2.8	0.6	88
	0430	354	60	57	1.4	70	2.7	0.5	85
	0600	343	60	26	2.3	63	2.9	0.6	89
	1030	357	60	18	1.8	57	4.1	0.6	88
	1340	368	59	19	3.0	53	5.2	0.6	88
	1555	396	61	33	0.3	60	5.7	0.5	84
	2030	381	63	32	2.6	50	2.3	0.7	79
9/24/94	0030	273	58	32	1.7	48	4.0	0.6	85
	0415	253	57	41	1.8	52	4.5	0.6	78
	0615	NA	57	33	1.5	48	5.9	0.6	80
	0923	336	59	32	1.4	49	2.6	0.6	78
	1130	340	56	31	1.6	48	4.1	0.6	92
	1330	286	58	33	1.5	48	5.2	0.6	86
	1500	287	59	33	1.4	48	6.0	0.6	84

NA = Not Available

Table 4.7.d
DuraMelter™ 100 Off-Gas Operational Data for Hanford Steady State Run

Date	Time	Scrubber				Baghouse		HEPA Filter	Dilution Air to Baghouse
		Air Temp Quencher Entrance (°C)	Scrubber Inlet Temp (°C)	Scrubber Liquid Temp (°C)	Pressure differential across scrubber tower (inches water)	Air Temp (°C)	Pressure differential (inches water)	Pressure differential (inches water)	Temp (°C)
9/26/94	1200	398	41	22	3.6	49	2.0	0.6	102
	1415	380	61	23	3.2	57	3.9	0.5	87
	1440	336	60	21	3.4	54	4.2	0.5	81
	1550	279	58	18	3.0	52	4.1	0.5	85
	1705	255	57	17	2.7	48	4.3	0.5	95
	1730	344	59	17	3.5	43	3.8	0.5	87
	2140	279	58	16	4.0	35	1.8	0.5	38
	2340	276	56	14	3.5	45	2.7	0.5	91
9/27/94	0130	297	61	14	3.0	42	5.6	0.5	89
	0400	305	59	13	4.0	45	2.7	0.5	95
	0640	311	59	13	4.1	43	4.8	0.4	83
	0800	57	14	8	-0.2	46	1.9	0.3	120
	0900	340	56	9	2.5	50	4.0	0.5	77
	1010	279	57	13	2.4	46	4.2	0.5	85
	1144	292	57	13	2.1	41	4.9	0.4	93
	1330	291	56	16	1.8	39	7.3	0.5	96
	1355	299	58	9	2.1	37	2.6	0.5	99
	1535	265	56	11	1.5	43	4.0	0.4	92
	1856	283	58	11	1.4	37	NA	0.3	85
	2200	316	59	13	2.0	38	6.6	0.4	85
9/28/94	0130	308	59	12	1.4	40	5.4	0.4	86
Avg.		304	56	21	2.0	48	3.7	0.6	87
Range		57-398	14-61	8-57	-0.2-4.1	35-70	1.0-7.3	0.3-1.0	38-120

NA = Not Available

Table 4.7.e
Air Nitrogen Emissions from DuraMelter™ 100 During the Hanford Turnover Run

Date	Run Time (min)	NO (ppm)	NO_2 (ppm)
9-22-94	1345	0	0
	1387	520	142
	1392	541	133
	1394	574	155
	1399	1527	752
	1429	1348	524
	1433	1370	545
	1437	1391	509
	1442	962	386
	1468	1592	687
	1469	1542	705
	1509	1664	789
	1562	1864	1018
	1575	1005	410
	1600	876	350
	1611	1020	443
	1631	1077	478
	1715	1075	518
	1819	1065	466
9-23-94	1878	802	274
	1900	798	295
	1921	438	87
	1948	276	29
	1971	34	0
	2037	187	7
	2083	166	4
	2168	281	22
	2467	203	9
	2683	254	14
	3062	736	248
	3125	928	411
	3161	1296	706
	3199	655	181
	3211	771	250
	3237	860	322
9-24-94	3273	853	321
	3312	561	127
	3354	530	111
	3388	486	95
	3413	622	144
	3457	693	170
	3494	208	26
	4045	229	22
	4109	194	14
	4137	378	46

Table 4.7.f
Air Emissions from DuraMelter™ 100 During the Hanford Steady State Run

Date	Time	Run Time (min)	NO (ppm)	NO_2 (ppm)
9-26-94	14:30:14	48	294	31
	15:11:08	89	277	26
	15:32:00	110	276	33
	19:16:25	334	288	38
	20:30:06	408	307	47
	21:55:17	493	247	23
	23:29:18	587	139	10
9-27-94	00:05:20	623	108	6
	02:32:56	770	249	24
	10:02:40	1220	143	10
	10:25:03	1243	172	11

Table 4.7.g
Melter Emissions

	Vitreous State Lab	Parsons Engineering Science Inc.	
		Average of Tests	Range of 3 Tests
Moisture (%)	6.08	6.70	5.98 - 8.11
O_2 (%)	20.5	20.3	19.9 - 20.5
Stack Gas Volumetric Flow Rate (acfm)	197	177	173 - 183
Stack Gas Volumetric Flow Rate (dscfm)	88	79	77 - 82
Isokinetic Ratio (%)	95.3	103.6	100.4 - 107.4
Sample Volume (dscf)	40.036	37.529	36.661 - 38.152
Particulate Matter Concentration (gr/dscf) Emission Rate (lb/hr)	 0.3540 0.2669	 0.4300 0.2870	 0.2050 - 0.7509 0.1436 - 0.4964
Boron Concentration (ug/dscf) Emission Rate (lb/hr)	 467 7.6E-03	 1125 1.2E-02	 455 - 1957 4.9E-03 - 2.0E-02
Chromium Concentration (ug/dscf) Emission Rate (lb/hr)	 31.40 5.11E-04	 35.1 3.6E-04	 14.47 - 60.02 1.57E-04 - 6.12E-04
Caesium Concentration (ug/dscf) Emission Rate (lb/hr)	 612.28 7.11E-03	 624 6.73E-03	 329 - 932 3.7E-03 - 9.50E-03
Molybdenum Concentration (ug/dscf) Emission Rate (lb/hr)	 43.30 7.05E-04	 57.40 5.90E-04	 21.70 - 99.50 2.36E-04 - 1.01E-03
Strontium Concentration (ug/dscf) Emission Rate (lb/hr)	 18.53 3.03E-04	 19.0 1.95E-04	 5.96 - 37.14 6.45E-05 - 3.78E-04
Potassium Concentration (ug/dscf) Emission Rate (lb/hr)	 2368 3.86E-02	 1818 1.88E-02	 1168 - 2448 1.27E-02 - 2.49E-02
Sodium Concentration (ug/dscf) Emission Rate (lb/hr)	 3596 5.86E-02	 3866 4.0E-02	 1826 - 6111 2.0E-02 - 6.23E-02

Table 4.7.h
HEPA Filter Outlet Emission

	Vitreous State Lab	Parsons Engineering Science Inc.	
		Average of Tests	Range of 3 Tests
Stack Temperature (F)	102	98	90 - 103
Moisture (%)	2.96	2.68	2.61 - 2.74
O_2 (%)	20.5	20.8	20.6 - 20.9
Stack Gas Volumetric Flow Rate (acfm)	222	211	201 - 227
Stack Gas Volumetric Flow Rate (dscfm)	195	188	181 - 201
Isokinetic Ratio (%)	99.0	98.9	94.7 - 103.5
Sample Volume (dscf)	38.907	41.270	40.127 - 42.111
Particulate Matter			
Concentration (gr/dscf)	0.0021	0.0024	0.0018 - 0.0028
Emission Rate (lb/hr)	0.0054	0.0040	0.0028 - 0.0047
Boron			
Concentration (ug/dscf)	< 40.0	< 125	< 125
Emission Rate (lb/hr)	< 1.00E-03	< 3.1E-03	< 3.1E-03
Chromium			
Concentration (ug/dscf)	< 2.0	< 0.12	< 0.11 - < 0.15
Emission Rate (lb/hr)	< 5.00E-05	< 2.98E-06	<2.6E-06-<3.5E-06
Cesium			
Concentration (ug/dscf)	< 0.5	< 0.97	< 0.95 - < 1.0
Emission Rate (lb/hr)	< 1.00E-05	< 2.4E-05	<2.3E-05-<2.6E-05
Molybdenum			
Concentration (ug/dscf)	< 0.5	< 0.37	< 0.23 - < 0.47
Emission Rate (lb/hr)	< 1.00E-05	< 9.33E-06	<5.6E-06-<1.1E-05
Strontium			
Concentration (ug/dscf)	< 2.0	< 0.08	< 0.07 - < 0.10
Emission Rate (lb/hr)	< 5.00E-05	< 2.09E-06	<1.9E-06-<2.5E-06
Potassium			
Concentration (ug/dscf)	< 3.0	< 40	< 40
Emission Rate (lb/hr)	< 7.00E-05	< 6.6E-04	< 6.6E-03
Sodium			
Concentration (ug/dscf)	< 60.0	< 70	< 70
Emission Rate (lb/hr)	< 2.00E-03	< 1.4E-03	< 1.4E-03

Table 4.7.i
Results from CEM Off-Gas Emissions Analysis for the Hanford DuraMelter™ 100 Steady State Run

Date	Time (Labs)	NOx(ppm)	SO_2 (ppm)	CO (ppm)
9-26-94	15:32:00(VSL)	309	0	24
	17:20:00(ESI)	584	0.2	19.5
	21:55:17(VSL)	270	0	6
	22:15:00(ESI)	974	1.5	5.9
9-27-94	00:05:20(VSL)	114	0	0
	00:32:00(ESI)	860	5.7	55.9
	10:25:03(VSL)	183	0	12
	12:01:00(ESI)	1336	3.6	43.6

Table 4.8.a
PNL Analysis of Feed Used in DuraMelter™ 100 Hanford Runs
(wt%)

Sample No.	Target*	D1F3-022P2	D1F3-023P3	D1F3-026P4	Average	Stand. Dev.
Al_2O_3	3.02	3.15	3.03	2.99	3.06	0.07
B_2O_3	2.99	3.05	2.62	3.24	2.97	0.26
CaO	3.84	4.18	3.95	4.27	4.13	0.13
Cr_2O_3	0.02	0.03	0.02	0.03	0.03	0.00
Cs_2O	0.07	0.13	0.13	0.13	0.13	0.00
Fe_2O_3	3.66	3.82	3.74	3.76	3.77	0.03
K_2O	1.86	2.29	1.80	2.61	2.23	0.33
MgO	0.00	0.05	0.03	0.06	0.05	0.01
MoO_3	0.07	0.08	0.07	0.08	0.08	0.00
Na_2O	8.85	8.36	8.51	9.06	8.64	0.30
P_2O_5	0.09	1.03	0.98	1.01	1.01	0.02
SO_3	0.10	0.10	0.10	0.11	0.10	0.00
SiO_2	19.36	20.72	20.08	19.62	20.14	0.45
SrO	0.05	0.06	0.06	0.06	0.06	0.00
TiO_2	0.51	0.51	0.54	0.40	0.48	0.06
ZrO_2	2.50	0.06	0.08	0.16	0.10	0.04
Cl	0.17	0.16	0.17	0.16	0.16	0.00
NO_3^-	5.75	5.81	5.78	5.79	5.79	0.01
NO_2^-	2.19	2.32	2.38	2.38	2.36	0.03

NA = Not Analyzed

▪BaO, LiO_2, and NiO were all below detection limits

*Based on 10 molar simulant analysis provided to VSL and additives.

Table 4.8.b
PNL and USGS Glass Analysis from DuraMelter™ 100 Hanford Runs (wt%)

Sample No.	DIG4-										Steady State Target
	002P	009P	017P	022P2	022U2	022U2	023P3	023U3	023U3	026P4	
Al_2O_3	4.74	5.17	6.34	6.71	6.39	6.39	6.36	6.44	6.45	6.36	6.14
B_2O_3	18.47	11.84	7.82	7.37	6.5	6.41	7.05	6.28	6.28	6.53	6.15
BaO	0.31	0.15	0.06	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0
CaO	6.93	7.84	8.34	8.7	8.36	8.35	8.5	8.37	8.35	8.33	7.8
Cr_2O_3	0.31	0.24	0.19	0.21	0.2	0.2	0.19	0.19	0.19	0.14	0
Cs_2O	N.A.	N.A.	N.A.	N.A.	0.1	0.1	N.A.	0.11	0.11	N.A.	0.15
Fe_2O_3	4.62	6.43	7.37	7.78	7.4	7.4	7.7	7.46	7.45	7.66	7.5
K_2O	4.41	6.1	6.48	2.47	3.38	3.34	3	3.37	3.36	3.75	3.68
Li_2O	0.04	0.02	0.01	BDL	N.A.	N.A.	BDL	N.A.	N.A.	0	0
MgO	3.93	1.99	0.82	0.61	0.56	0.6	0.53	0.51	0.51	0.41	0
MnO_2	0.05	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0
MoO_3	0.03	0.1	0.14	0.15	0.13	0.13	0.14	0.13	0.13	0.15	0.15
Na_2O	11.64	15.53	17.64	18.02	17.5	17.3	18.1	17.4	17.5	17.85	18.82
NiO	0.18	0.12	0.08	0.06	0.06	0.05	0.07	0.05	0.05	0.04	0
P_2O_5	BDL	BDL	BDL	0.06	0.2	0.2	0.04	0.2	0.21	0.05	0.19
SO_3	0.2	0.22	0.22	0.21	0.15	0.17	0.21	0.15	0.15	0.22	0
SiO_2	39.49	40.05	40.66	42.51	42.9	42.8	41.95	43	42.9	40.99	42.23
SrO	0.03	0.08	0.1	0.12	0.1	0.1	0.12	0.1	0.1	0.12	0.11
TiO_2	0.21	0.61	0.82	0.89	0.89	0.89	0.9	0.91	0.91	0.88	1
ZrO_2	1.44	1.3	3.05	3.62	3.67	3.62	3.79	3.85	3.83	3.93	5.09
Cl	N.A.	N.A.	N.A.	N.A.	0.11	0.11	N.A.	0.12	0.12	N.A.	0
F	N.A.	N.A.	N.A.	N.A.	0.09	0.07	N.A.	0.07	0.07	N.A.	0
Total	96.89	97.7	100.06	99.53	98.78	98.32	98.69	98.78	98.74	97.45	98.41
Fe(II)/Total Fe	0.0027	0.0026	0.0874	0.077	0.1652	0.1802	0.1044	0.2235	0.2268	0.074	

N.A. = Not Analyzed
BDL = Below Detection Limit

Table 4.8.c
PNL Analysis of Quencher and Scrubber Solutions from DuraMelter™ 100 Hanford Runs (moles/liter)

	Quencher Samples			Scrubber Samples		
	D1O5-022P2	D1O5-023P3	D1O5-026P4	D1O6-022P2	D1O6-023P3	D1O6-026P4
Al	6.48e-04	8.76e-04	7.07e-04	3.74e-05	1.35e-04	1.68e-04
B	5.67e-03	7.74e-03	4.74e-03	2.88e-04	3.64e-04	5.89e-04
Ba	1.38e-06	1.53e-06	1.97e-06	2.91e-07	1.02e-06	1.24e-06
Ca	1.10e-03	1.26e-03	1.55e-03	3.04e-05	4.89e-05	7.89e-05
Cr	6.35e-05	8.08e-05	4.83e-05	6.92e-06	1.48e-05	1.90e-05
Cs	2.03e-06	2.63e-06	5.12e-06	2.03e-06	2.63e-06	5.12e-06
Fe	7.97e-04	1.04e-03	9.47e-04	1.79e-06	7.16e-06	1.40e-05
K	2.73e-03	4.68e-03	4.97e-03	9.41e-04	3.15e-03	4.15e-03
Mg	8.76e-05	1.25e-04	1.82e-04	3.91e-05	1.59e-04	2.06e-04
Mn	1.09e-06	3.28e-06	2.37e-06	BDL	1.27e-06	1.46e-06
Mo	2.58e-05	4.04e-05	3.10e-05	2.71e-06	6.36e-06	8.96e-06
Na	9.28e-03	1.30e-02	1.02e-02	1.76e-01	2.26e-01	2.33e-01
Ni	BDL	9.54e-06	8.52e-06	BDL	1.01e-05	1.41e-05
P	8.37e-03	1.04e-02	3.79e-03	1.34e-03	1.75e-03	4.16e-03
S	BDL	2.71e-05	BDL	8.11e-05	1.21e-04	1.89e-04
Si	2.42e-05	2.85e-05	3.06e-05	6.48e-05	1.40e-04	1.53e-04
Sr	5.82e-06	5.25e-06	8.45e-06	3.24e-07	7.99e-07	1.03e-06
Ti	2.92e-06	8.35e-07	2.09e-06	6.26e-07	3.34e-06	4.18e-06
Zr	BDL	BDL	BDL	BDL	3.29e-06	4.06e-06
TOC*	1.44e+02	1.92e+02	2.28e+02	2.37e+01	2.88e+01	3.82e+01
TIC**	5.25e+02	5.74e+02	5.46e+02	1.29e+03	1.59e+03	2.37e+03
CL^-	2.63e-03	3.93e-03	6.66e-03	2.39e-03	3.39e-03	3.38e-03
F^-	2.83e-03	3.47e-03	6.64e-03	BDL	BDL	BDL
NO_3^-	2.76e-04	4.11e-04	9.23e-04	1.30e-04	1.81e-04	1.81e-04
NO_2^-	6.22e-04	9.47e-04	1.24e-03	1.26e-03	2.01e-03	2.88e-03
PO_4^{---}	BDL	8.21e-05	BDL	BDL	BDL	BDL
SO_4^{--}	4.51e-04	6.46e-04	9.79e-04	6.07e-05	8.37e-05	1.22e-04

BDL = Below Detection Limit
*Total Organic Carbon (mg/liter)
**Total Inorganic Carbon (mg/liter)

Table 4.8.d
PNL and USGS Analysis of Baghouse Diatomaceous Earth from the DuraMelter™ 100 Hanford Runs (wt%)

Sample No.	D1O7-000 (Blank)			D1O7-002 (End of Steady State Run)		
Analysis Labs.	PNL	USGS		PNL	USGS	
Al_2O_3	4.11	4.31	4.32	3.35	3.94	3.98
B_2O_3	0.05	0.02	0.01	1.1	0.84	0.86
BaO	0.02	0.03	0.03	0.02	0.02	0.02
CaO	0.48	0.46	0.45	0.42	0.42	0.43
Cr_2O_3	BDL	BDL	BDL	0.09	0.07	0.09
Cs_2O	N.A.	BDL	BDL	N.A.	0.27	0.29
Fe_2O_3	1.69	1.74	1.76	1.52	1.61	1.58
K_2O	BDL	0.34	0.33	1.88	1.85	1.83
MgO	0.25	0.22	0.21	0.19	0.2	0.2
MnO_2	0.01	0.01	0.01	0.02	0.01	0.01
MoO_3	BDL	BDL	BDL	0.03	0.02	0.02
Na_2O	4.38	3.86	3.87	5.69	5.04	5.05
P_2O_5	BDL	0.08	0.07	0.02	0.09	0.09
SO_3	BDL	BDL	BDL	0.6	0.45	0.4
SiO_2	84.1	87.9	87.9	66.11	78.7	78.8
SrO_2	0.01	0.01	0.01	0.01	0.01	0.01
TiO_2	0.21	0.24	0.23	0.19	0.21	0.21
ZrO_2	0.02	0.01	0.01	0.1	0.01	0.01
Cl	N.A.	0.02	0.02	N.A.	1.75	1.7
F	N.A.	0.02	0.02	N.A.	0.62	0.46
Fe(II)/Total Fe	N.A.	0.09	0.09	N.A.	0.03	0.03

N.A. = Not Analysis
BDL = Below Detection Limit
▪Li_2O and NiO were below detection limits

Table 4.8.e
Distribution of Components from the DuraMelter™ 100 Hanford Steady State Run (grams)

	Feed		Glass	Quencher Solutions	Scrubber Solutions	Baghouse Diatomaceous Earth	Total in Off Gas Systems	Stack Emissions*
	Target	Analysis						
Al	19488	19746	19842	40.49	52.40	15.91	108.79	n.c.
B	19315	19186	19208	250.25	27.78	141.14	419.16	<88
Ca	24826	26701	25988	31.21	10.91	5.69	47.81	<132
Cr	96	151	n.c.	4.76	6.55	0.03	11.35	<4.4
Cs	537	969	612	0.60	1.82	113.28	115.70	<0.88
Fe	23665	24376	23897	67.49	4.51	25.52	97.53	<1.3
K	12033	14427	11699	319.92	1095.72	219.43	1635.07	<1.3
Mn	65	65	62	1.26	3.15	3.07	7.47	n.c.
Mo	451	495	468	7.42	5.61	5.12	18.14	<0.88
Na	57,193	55836	55688	400.72	n.c.	299.25	699.96	<132
S	668	668	686	14.57	33.55	59.99	108.12	n.c.
Si	125065	130104	127879	0.90	47.49	0.00	48.39	n.c.
Sr	343	388	374	0.24	0.60	0.33	1.16	<4.4
Ti	3317	3122	2777	0.58	2.28	3.32	6.17	n.c.

n.c. = not calculated.
*All measurements were below detection limits

Table 4.8.f
Distribution of Components from the DuraMelter™ 100 Hanford Steady State Run based on PNL Feed Analysis (%)

	Glass	Quencher Solutions	Scrubber Solutions	Baghouse Diatomaceous Earth	Total Off Gas Systems	Deviation
Al	100.48	0.21	0.27	0.08	0.55	+1.03
B	100.11	1.30	0.14	0.74	2.18	+2.29
Ca	97.33	0.12	0.04	0.02	0.18	-2.49
Cr	NC	3.16	4.35	0.02	7.53	NC
Cs	63.15	0.06	0.19	11.69	11.94	-24.91
Fe	98.04	0.28	0.02	0.10	0.40	-1.56
K	81.09	2.22	7.59	1.52	11.33	-7.58
Mn	96.59	1.94	4.87	4.75	11.56	+8.15
Mo	94.49	1.50	1.13	1.03	3.66	-1.85
Na	99.73	NC	NC	0.54	NC	+0.26
P	2.39	2.18	5.47	0.03	7.68	-89.93
S	102.82	2.18	5.03	8.99	16.20	+19.02
Si	98.29	0.00	0.04	0.00	0.04	-1.67
Sr	96.59	0.06	0.15	0.08	0.30	-3.11
Ti	88.93	0.02	0.07	0.11	0.20	-10.87

NC = Not Calculated.

Table 4.8.g
Elemental Feed Rates and Retention in the Melter

	Direct Sampling of Melter Exhaust	Sum of Total Mass in Off Gas System
Sodium		
Feed Rate (g/min)	25.1	
% Melter Escape	1.5	1.4
Potassium		
Feed Rate (g/min)	6.5	
% Melter Escape	3.3	12.3
Boron		
Feed Rate (g/min)	8.6	
% Melter Escape	0.9	2.4
Chromium		
Feed Rate (g/min)	0.087	
% Melter Escape	7.6	6.4
Strontium		
Feed Rate (g/min)	0.17	
% Melter Escape	1.1	0.3
Molybdenum		
Feed Rate (g/min)	0.23	
% Melter Escape	2.1	3.8
Cesium*		
Feed Rate (g/min)	0.21 - 0.38	
% Melter Escape	13.8 - 25.0	14.9 - 26.9

* - range of values represent differences between analyzed and target cesium concentrations.

Figure 4.3.a. Cumulative Feed for DuraMelter™ 100 Steady State Run

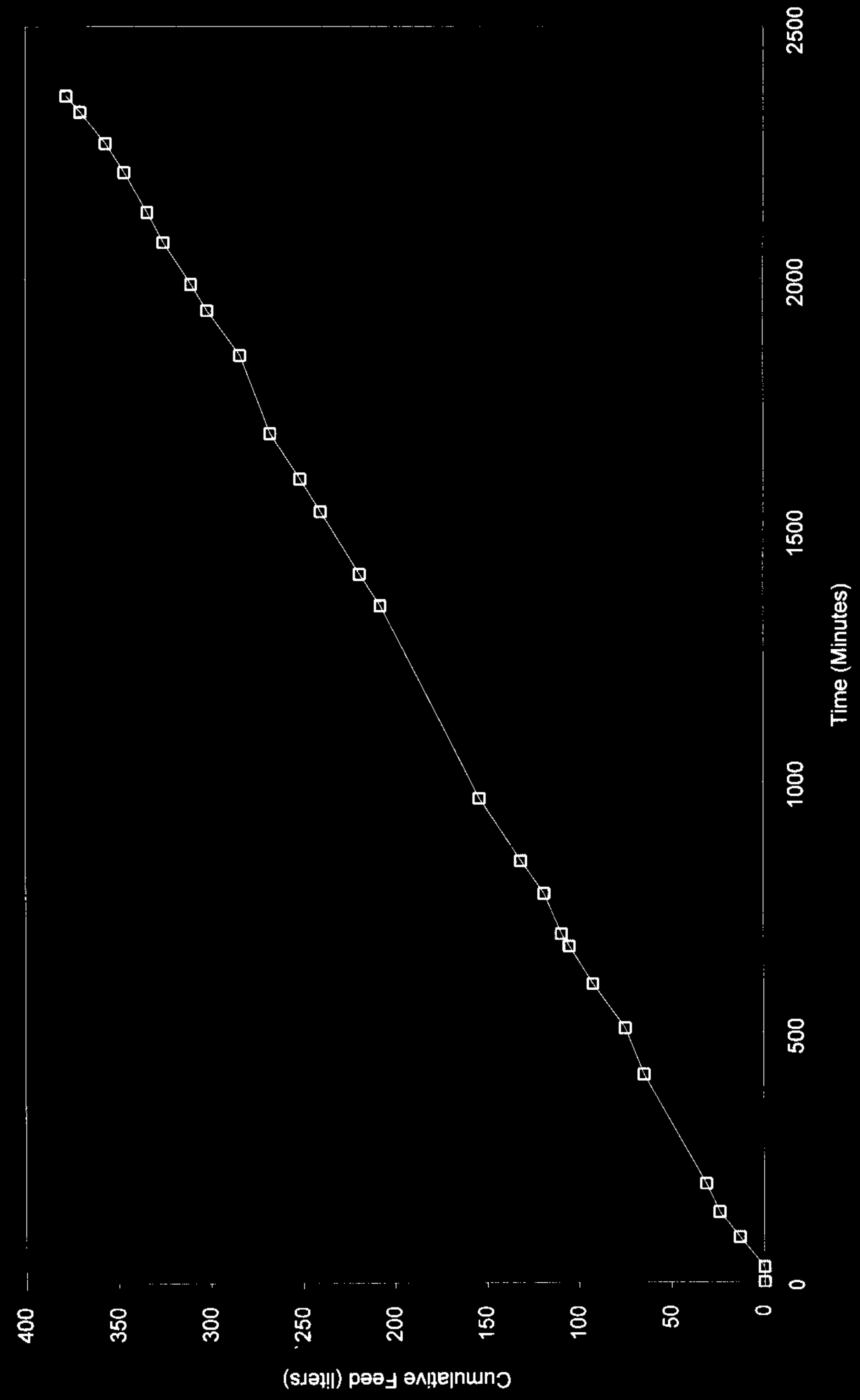


Figure 4.3.b. Cumulative Feed for DuraMelter™ 100 Turnover Run

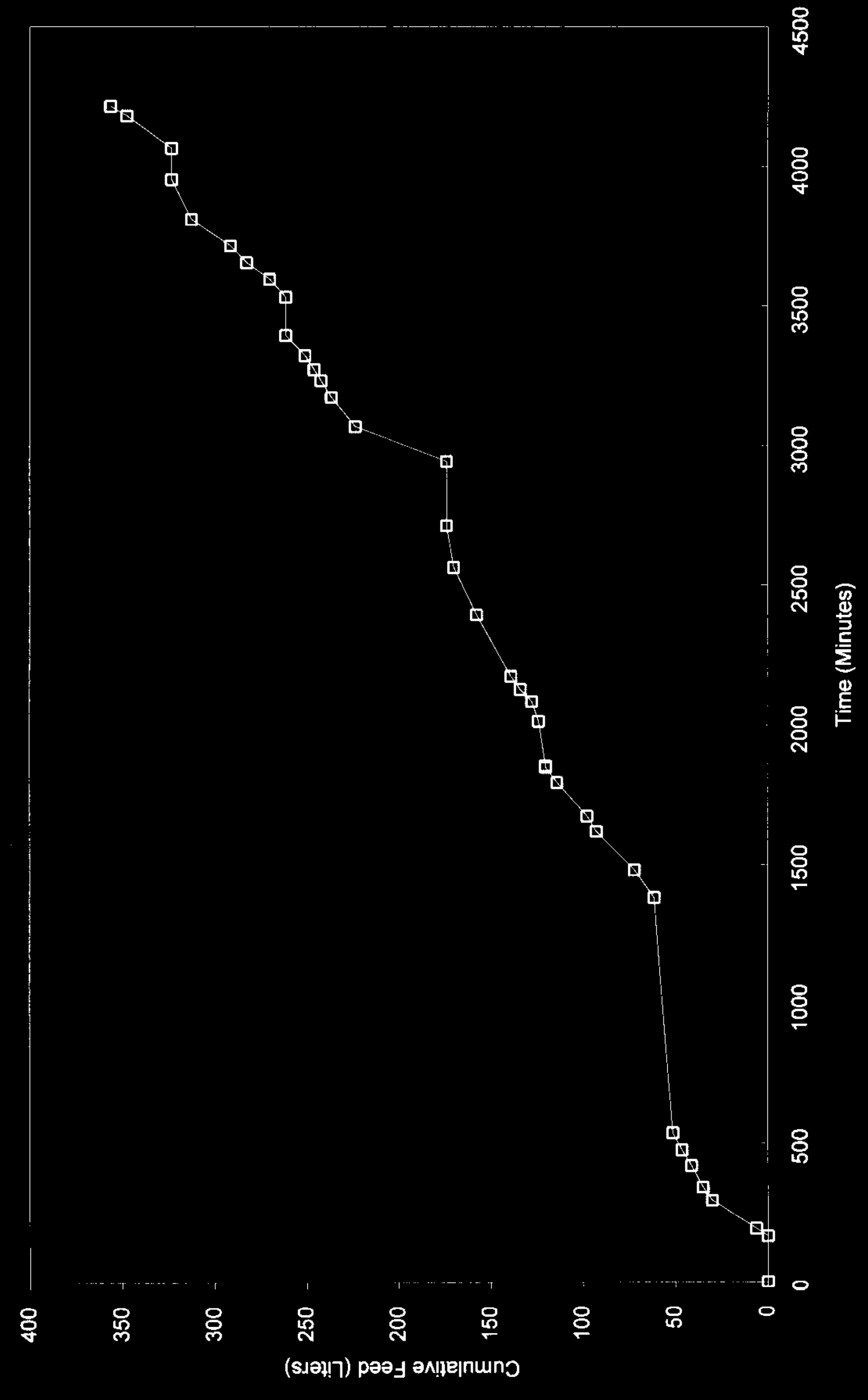


Figure 4.3.c. Glass Production from DuraMelter™ 100 Steady State Run

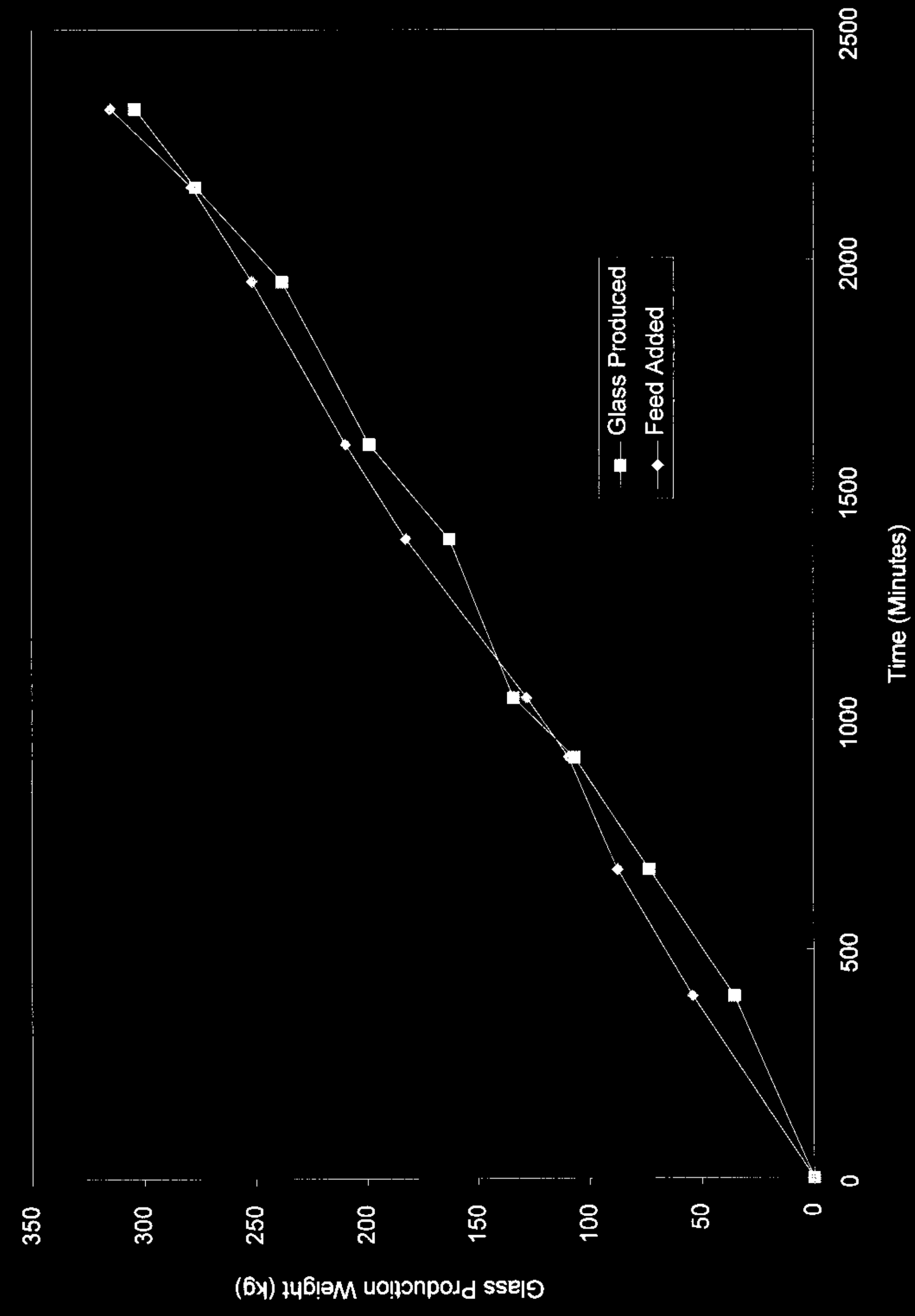


Figure 4.3.d. Glass Production from DuraMelter™ 100 Turnover Run

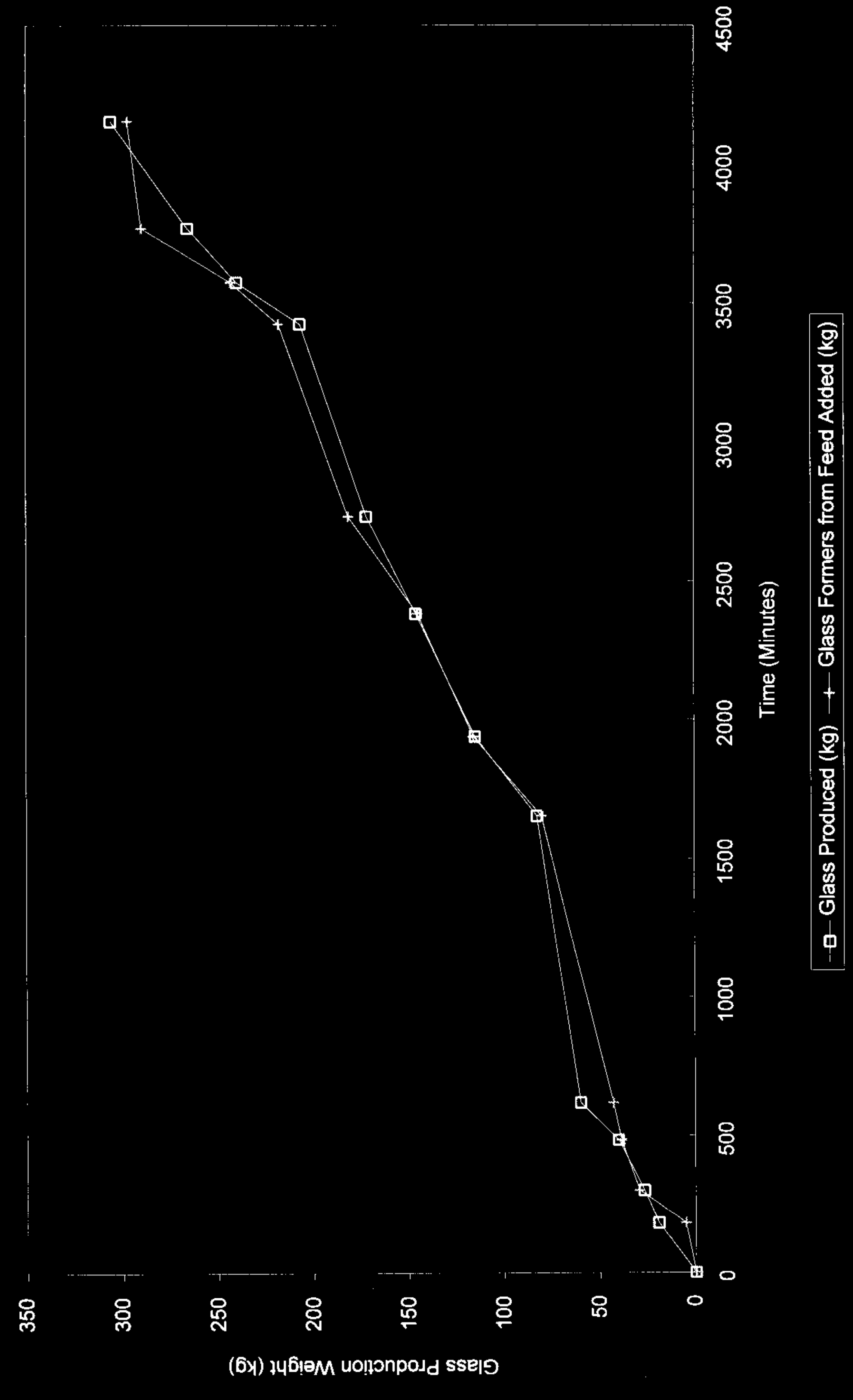


Figure 4.3.e. Aluminum Concentration Changes in Glass During DuraMelter™ 100 Runs

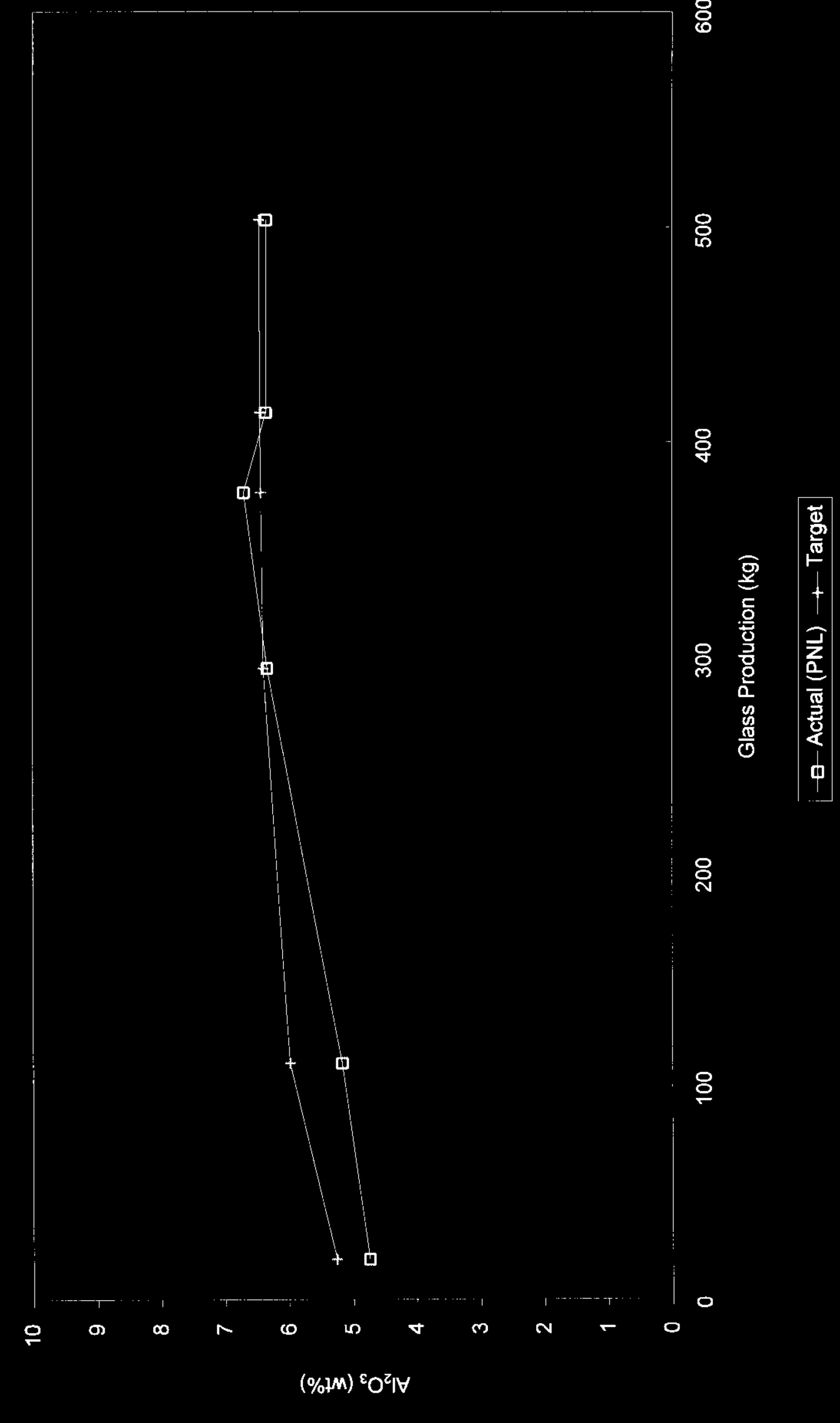


Figure 4.3.f. Boron Concentration Changes in Glass During DuraMelter™ 100 Runs

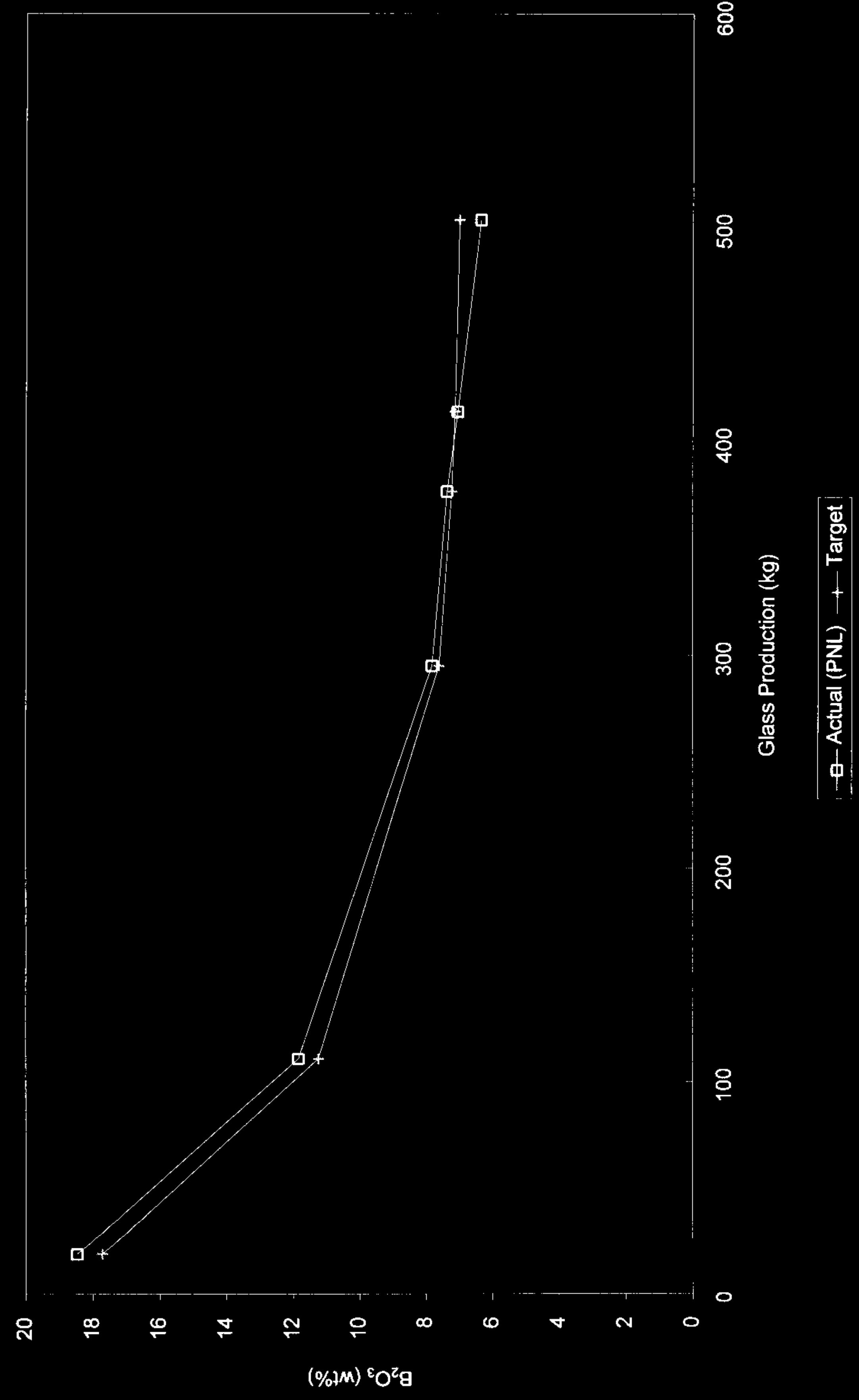


Figure 4.3.g. Calcium Concentration Changes in Glass During DuraMelter™ 100 Runs

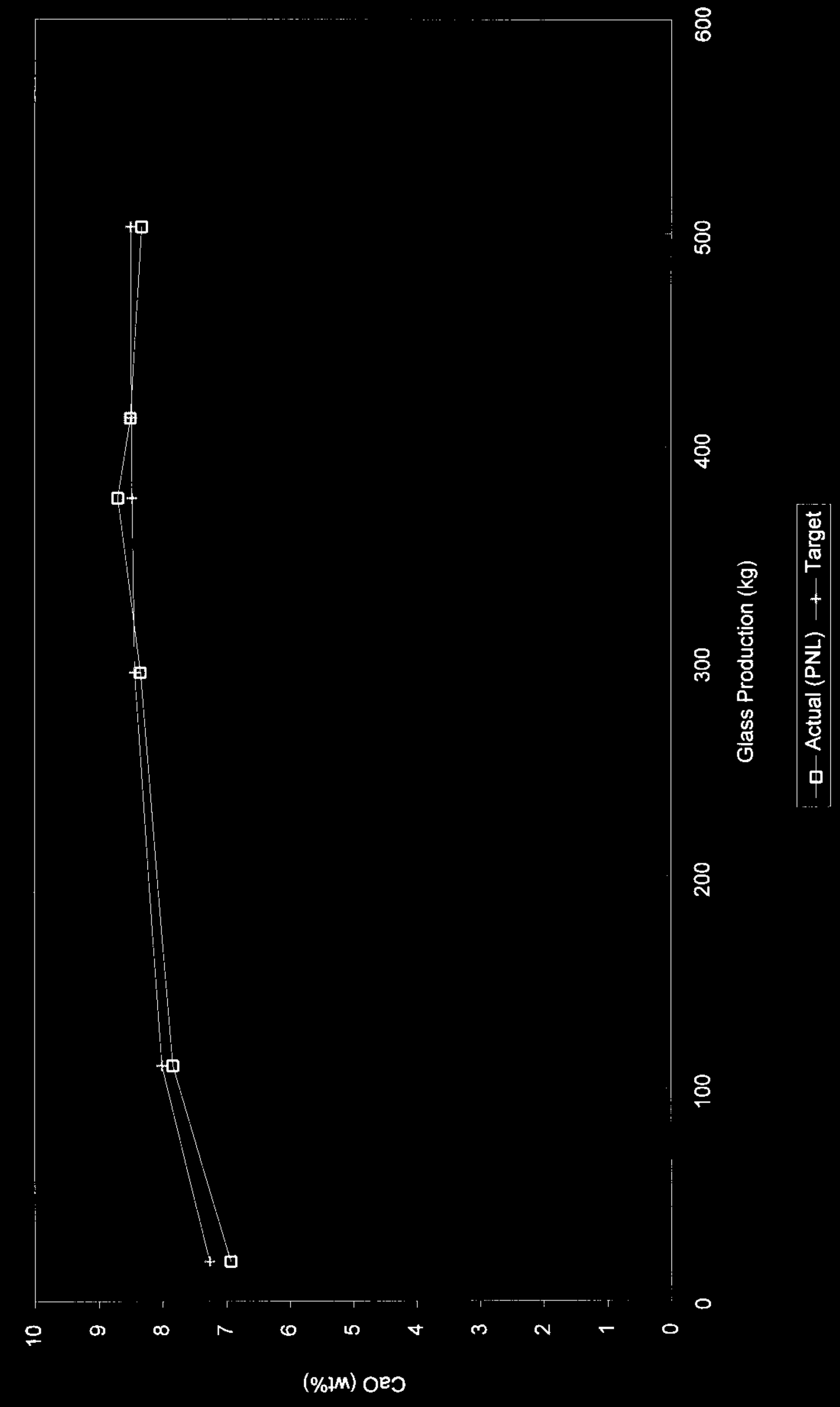


Figure 4.3.h. Iron Concentration Changes in Glass During DuraMelter™ 100 Runs

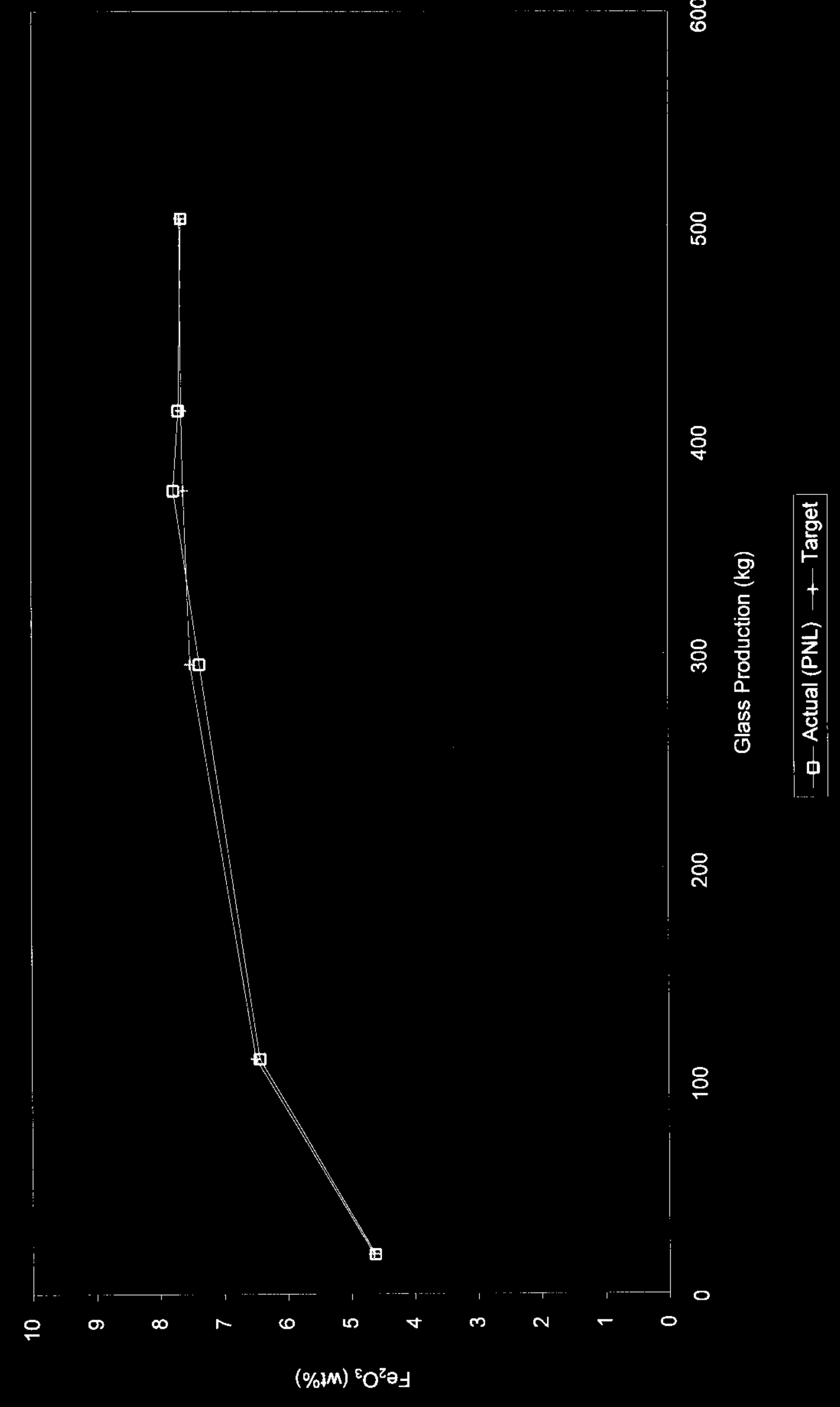


Figure 4.3.i. Potassium Concentration Changes in Glass During DuraMelter™ 100 Runs

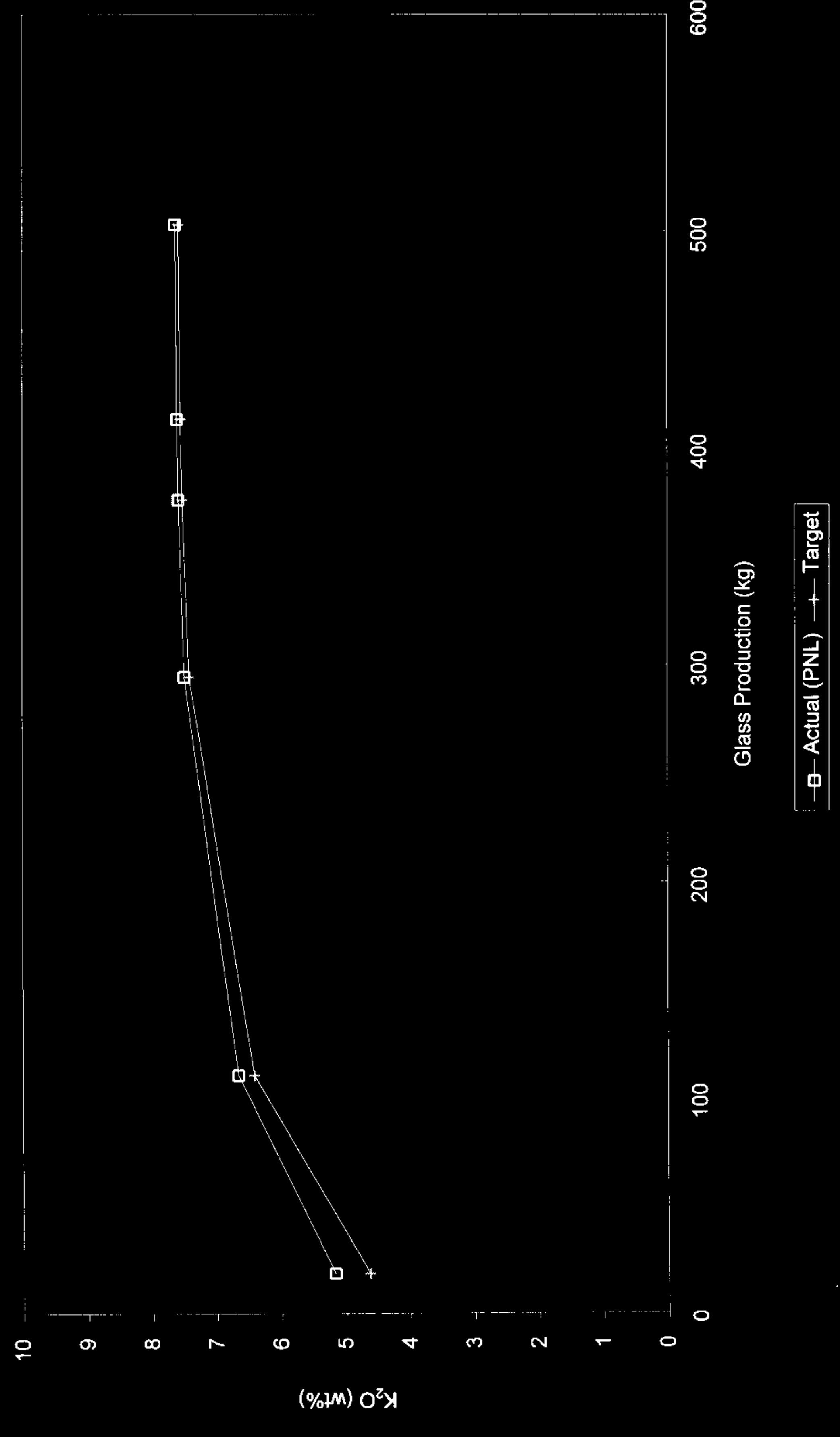


Figure 4.3.j. Magnesium Concentration Changes in Glass During DuraMelter™ 100 Runs

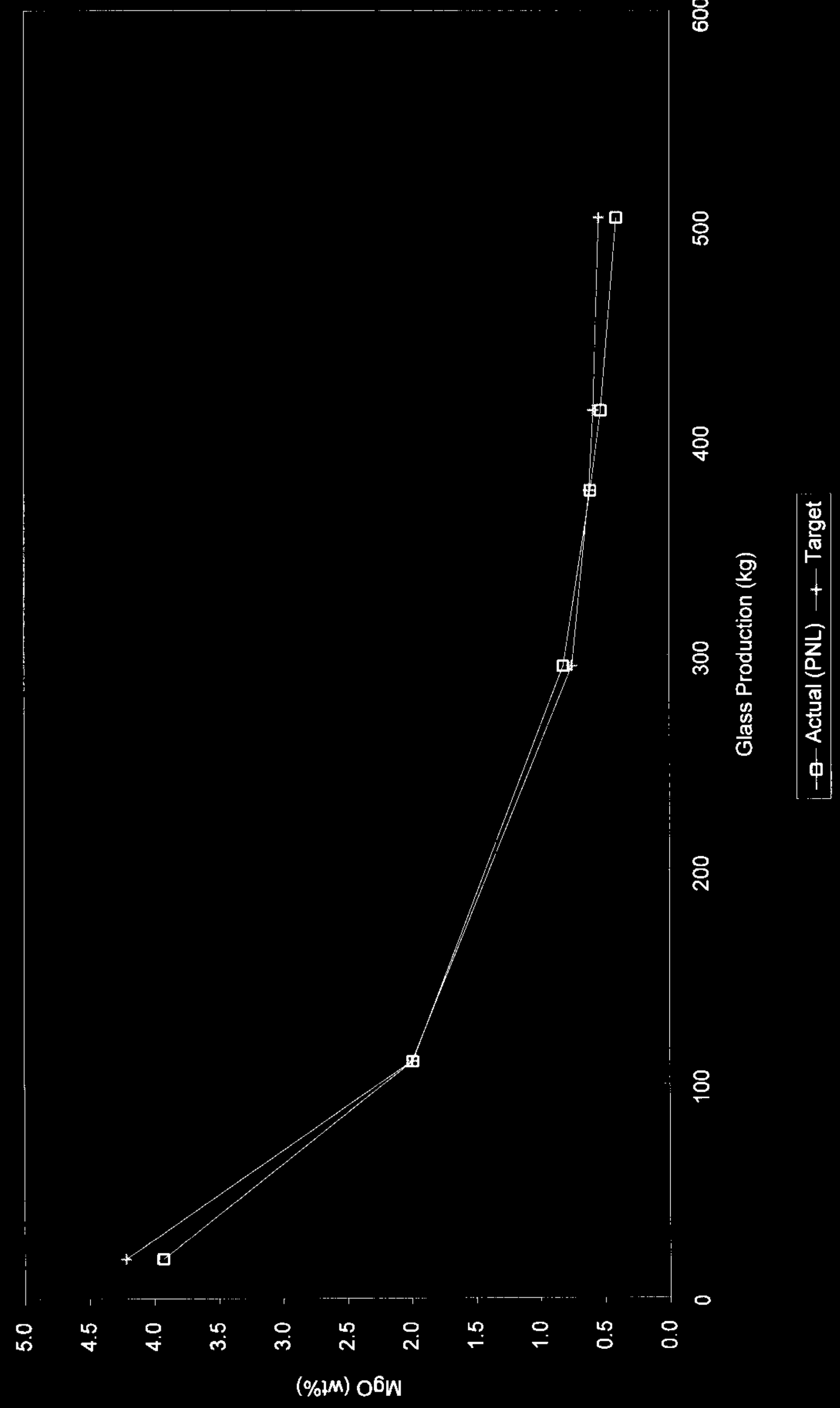


Figure 4.3.k. Sodium Concentration Changes in Glass During DuraMelter™ 100 Runs

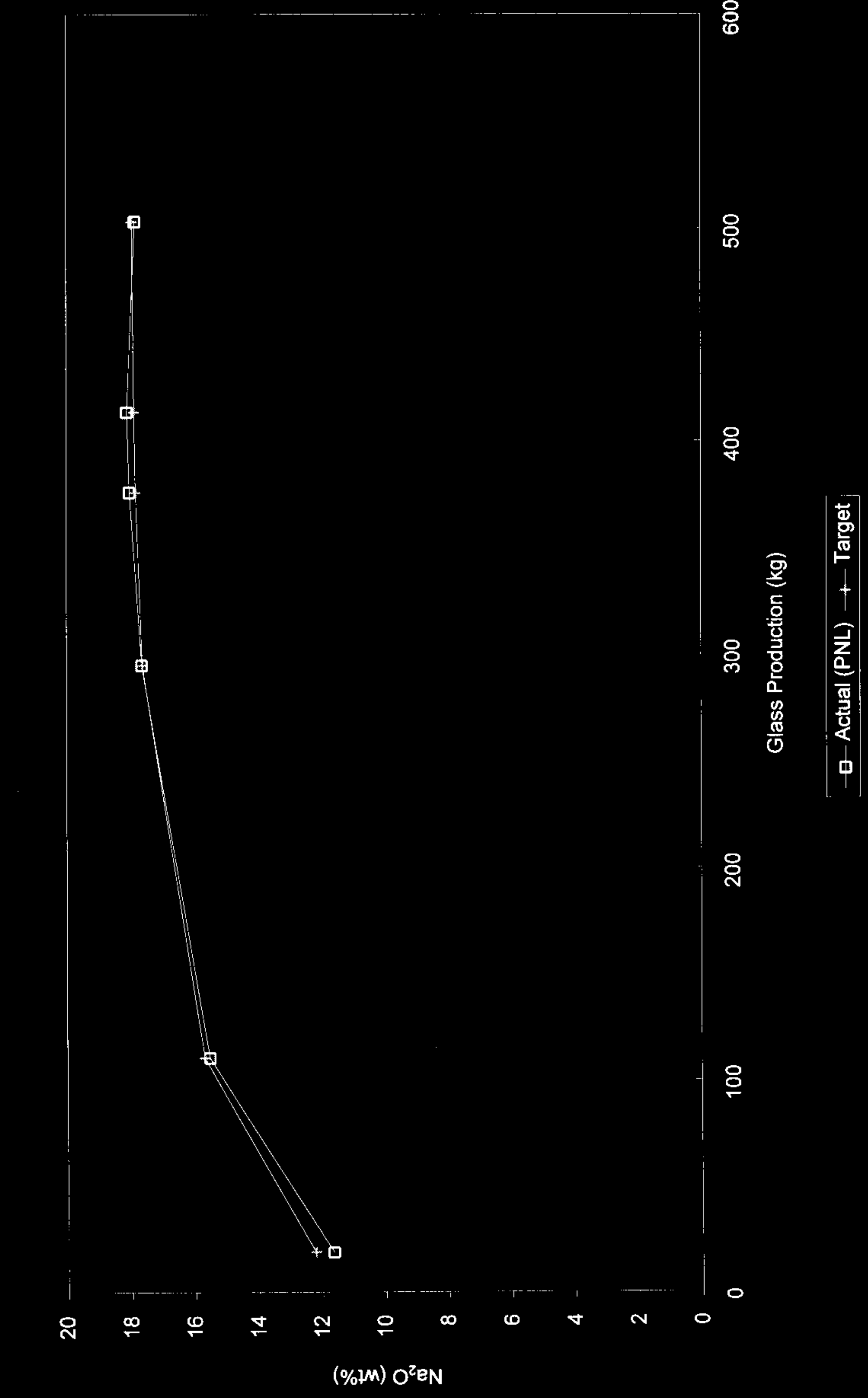


Figure 4.3.1. Silicon Concentration Changes in Glass During DuraMelter™ 100 Runs

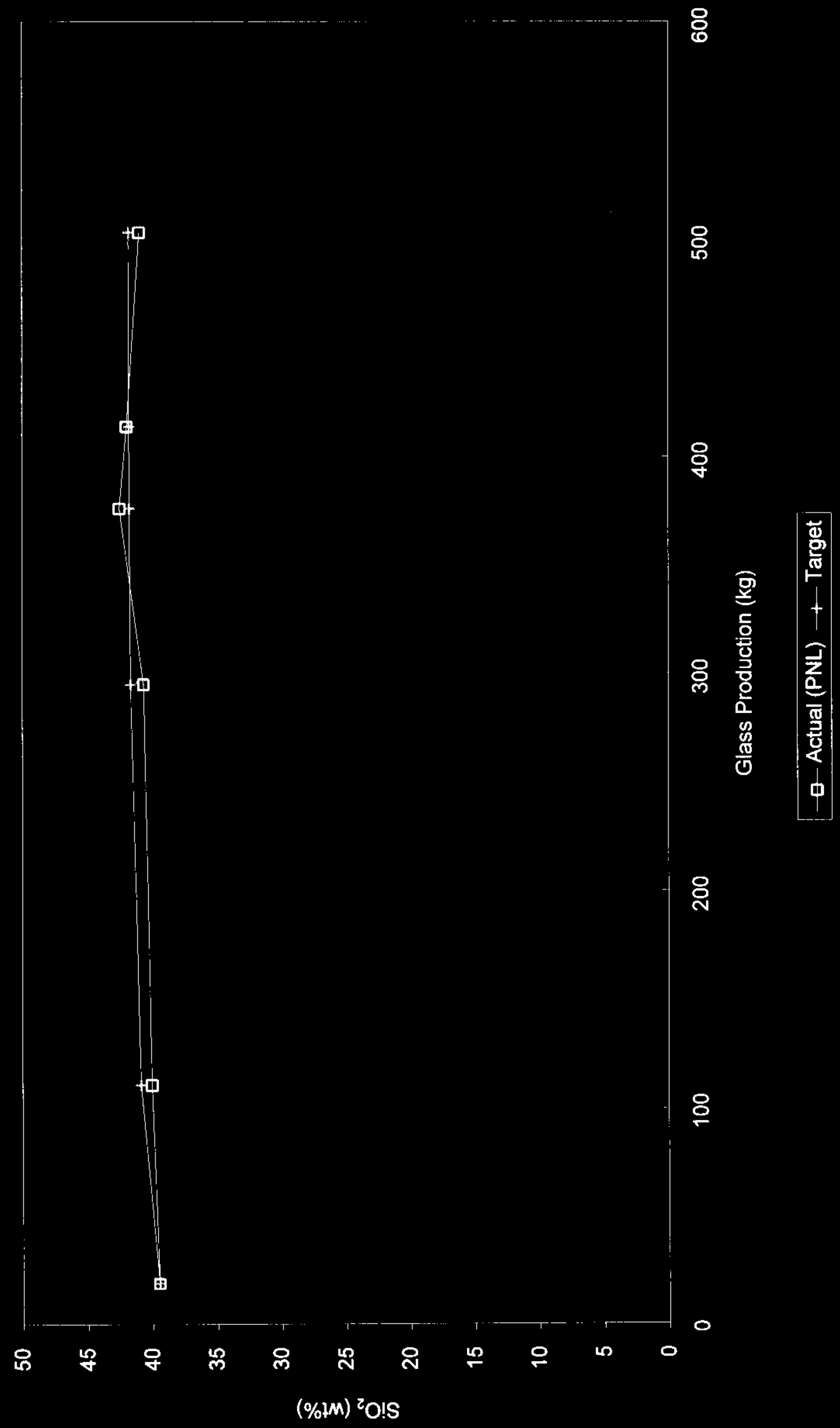


Figure 4.3.m. Zirconium Concentration Changes in Glass During DuraMelter™ 100 Runs

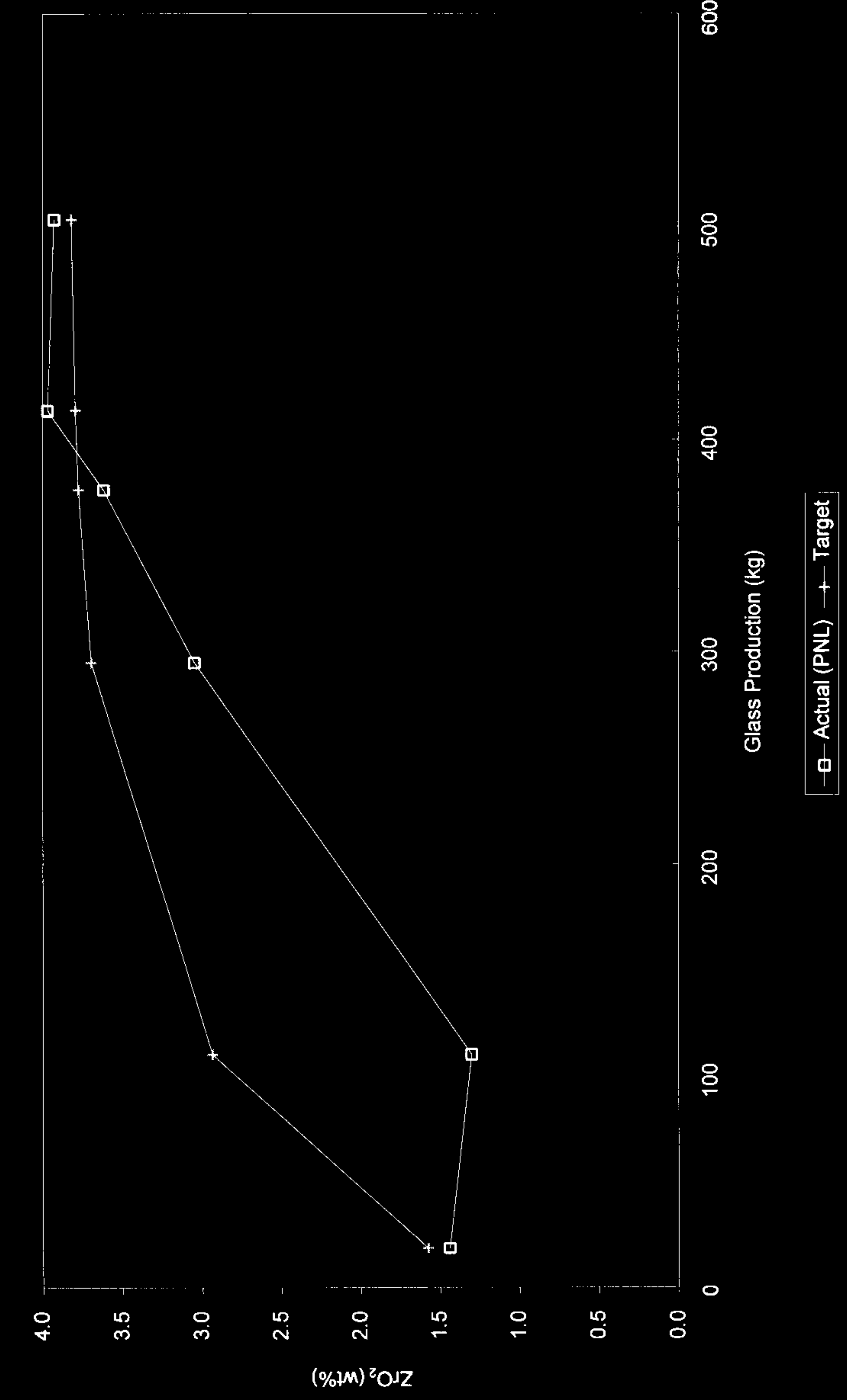


Figure 4.3.n. Glass Production Rates from Hanford DuraMelter™ 100 Turnover Run

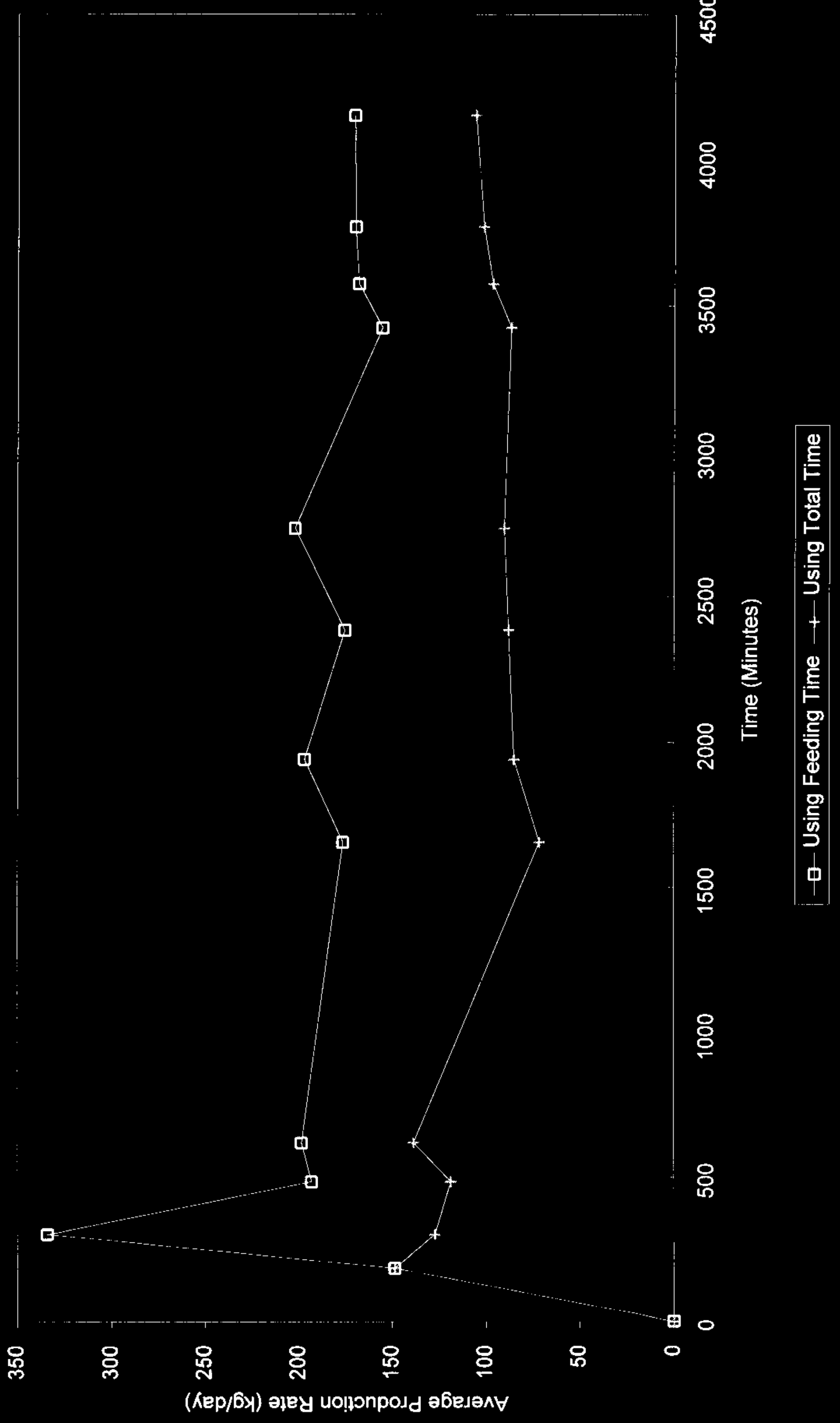


Figure 4.3.o. Glass Production Rates from Hanford DuraMelter™ 100 Steady State Run

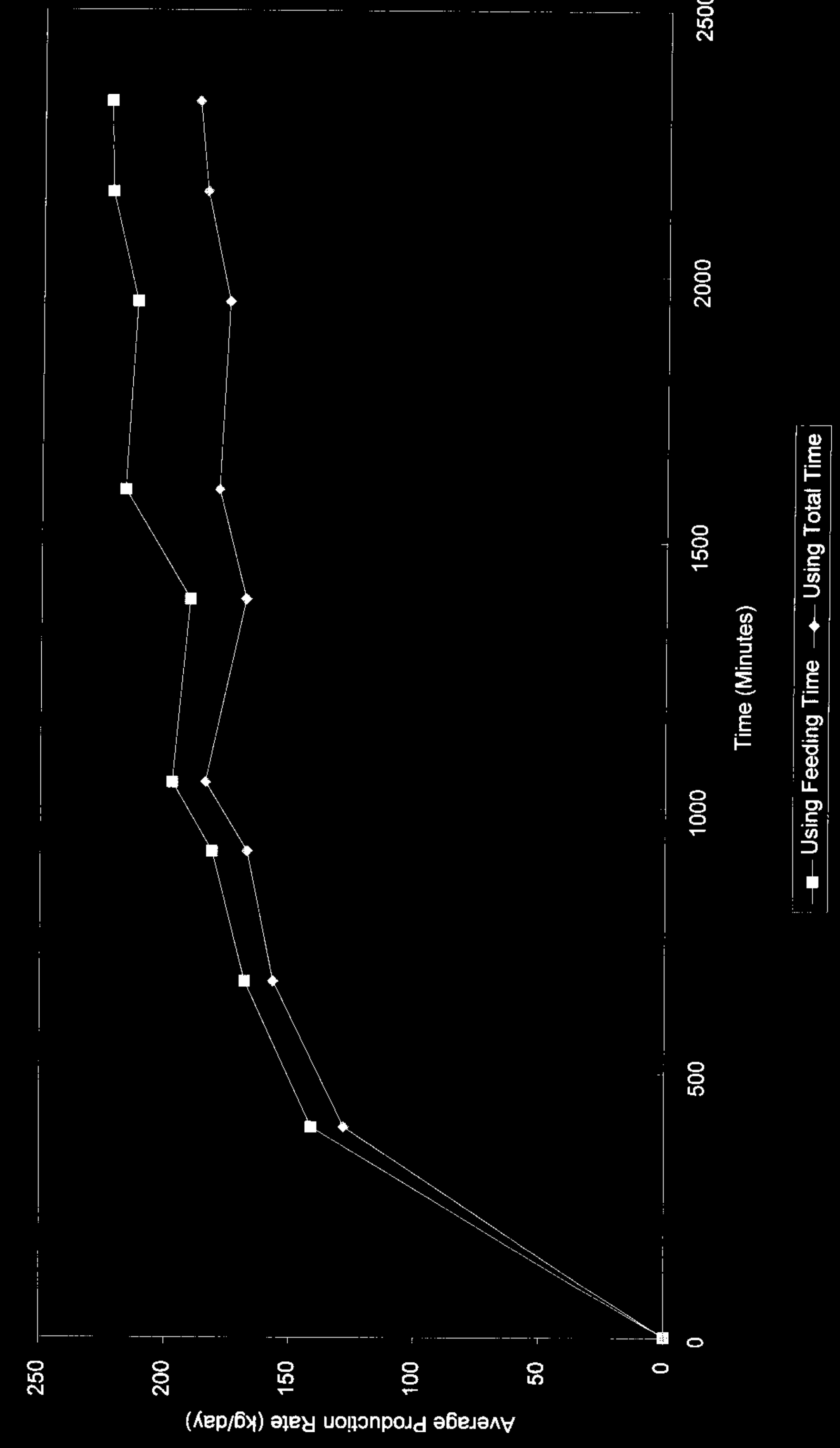


Figure 4.3.p. Count Rate Variation of Glass Produced from Hanford DuraMelter™ 100 Runs

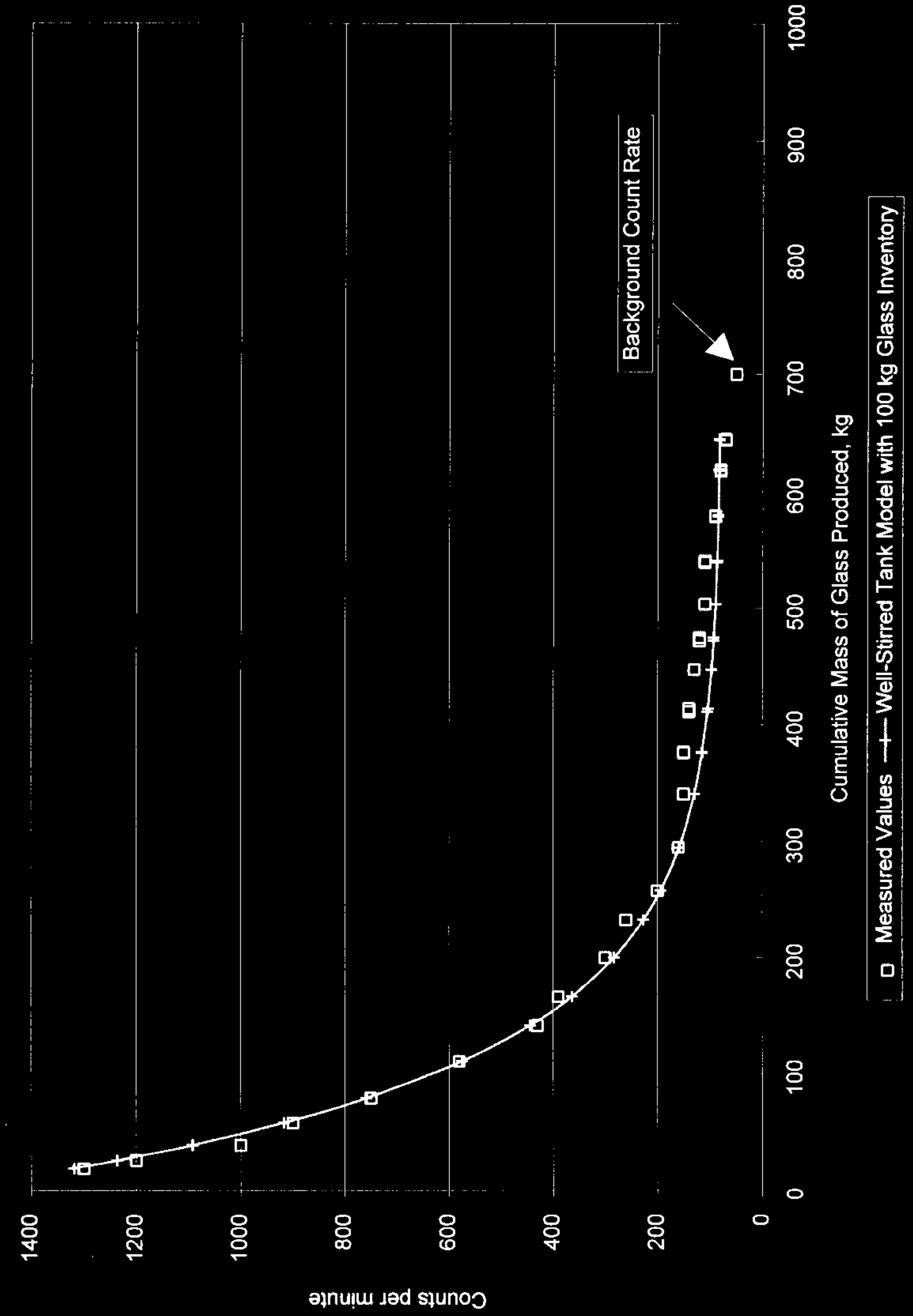


Figure 4.4.a. DuraMelter™ 100 Steady State Period

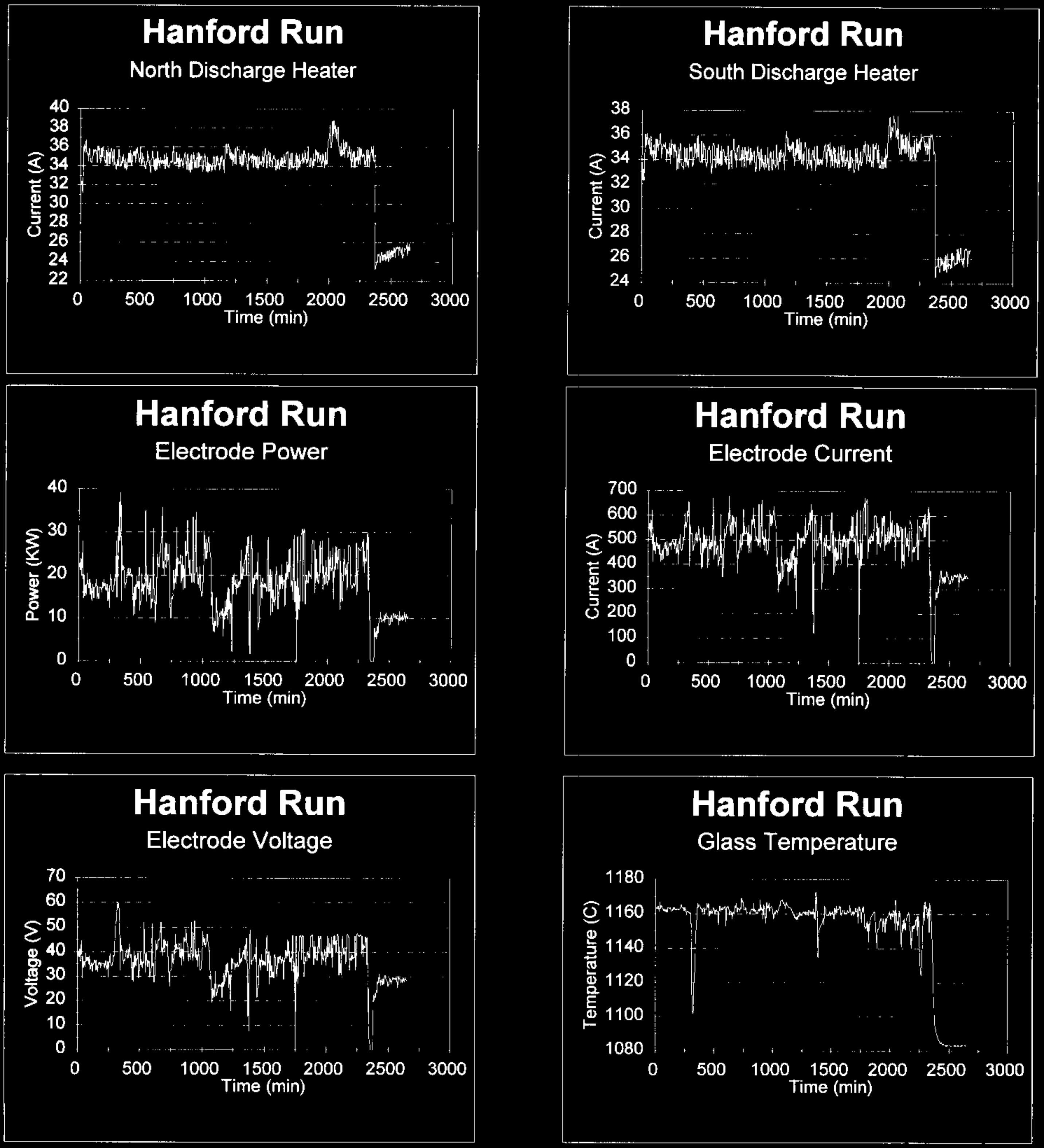


Figure 4.4.b. DuraMelter™ 100 Steady State Period

Figure 4.4.c. DuraMelter™ 100 Steady State Period

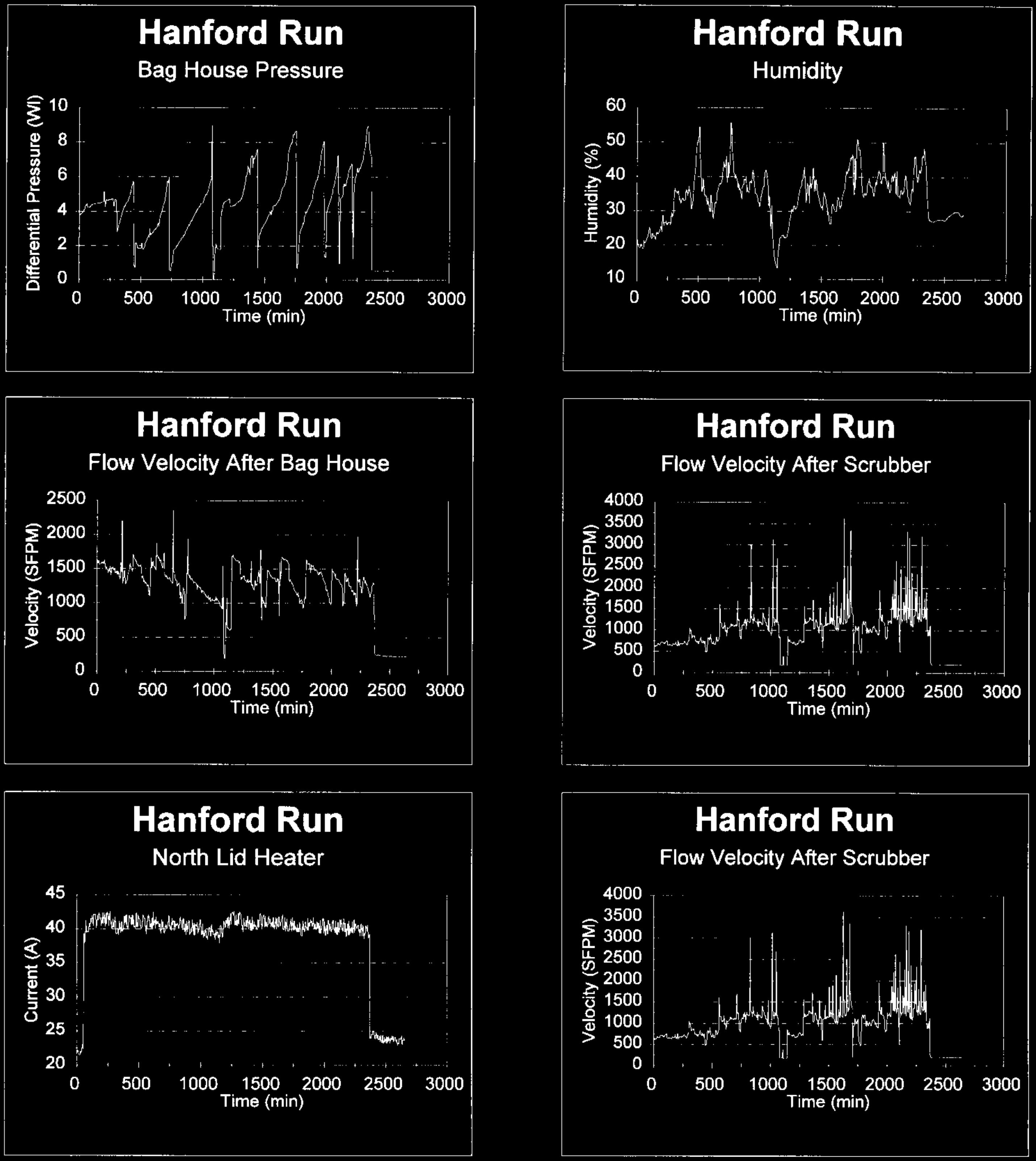


Figure 4.5.a. Melter Project: Sample Numbering Scheme, Duratek/VSL

D	1	F	1	-	0	0	1	Q	A
Vendor Identification	Phase Identifier	Sample Type	Sample Point Number	Hyphen	Serial	Sample	Number	Lab ID	Sample Set ID
Duratek	*Phase I*	*Feed Sample*	*Sample Point 1*		*Sample*	*Number*	*1*	*Quanterra*	*All Sample Points*

Vendors

D = Duratek

Sample Type and Point

F3 = Feed, Mixed
G4 = Glass
O5 = Quencher
O6 = Scrubber
S1=Simulant

Lab ID

C = Corning
G = Archive (GEL)
P = PNL
Q = Quanterra
U = USGS
W = 222-S
V = VSL

Sample Set ID

A, B, C = All Sample Pts. (Starting on Monday)
Blank = Selected Pts.

Figure 4.5.b. Sampling Schedule from DuraMelter™ 100 Turnover Run

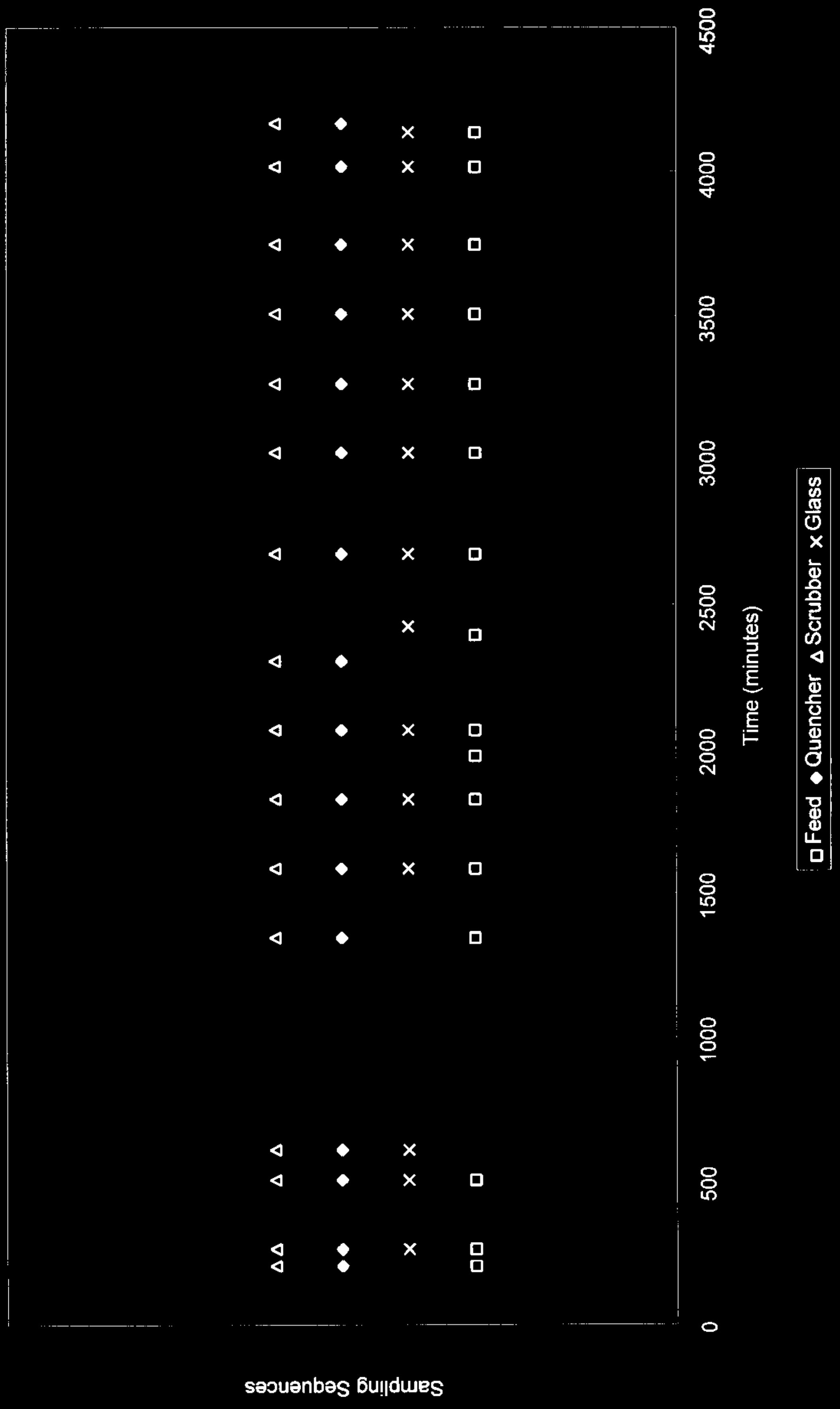


Figure 4.5.c. Sampling Schedule from DuraMelter™ 100 Steady State Run

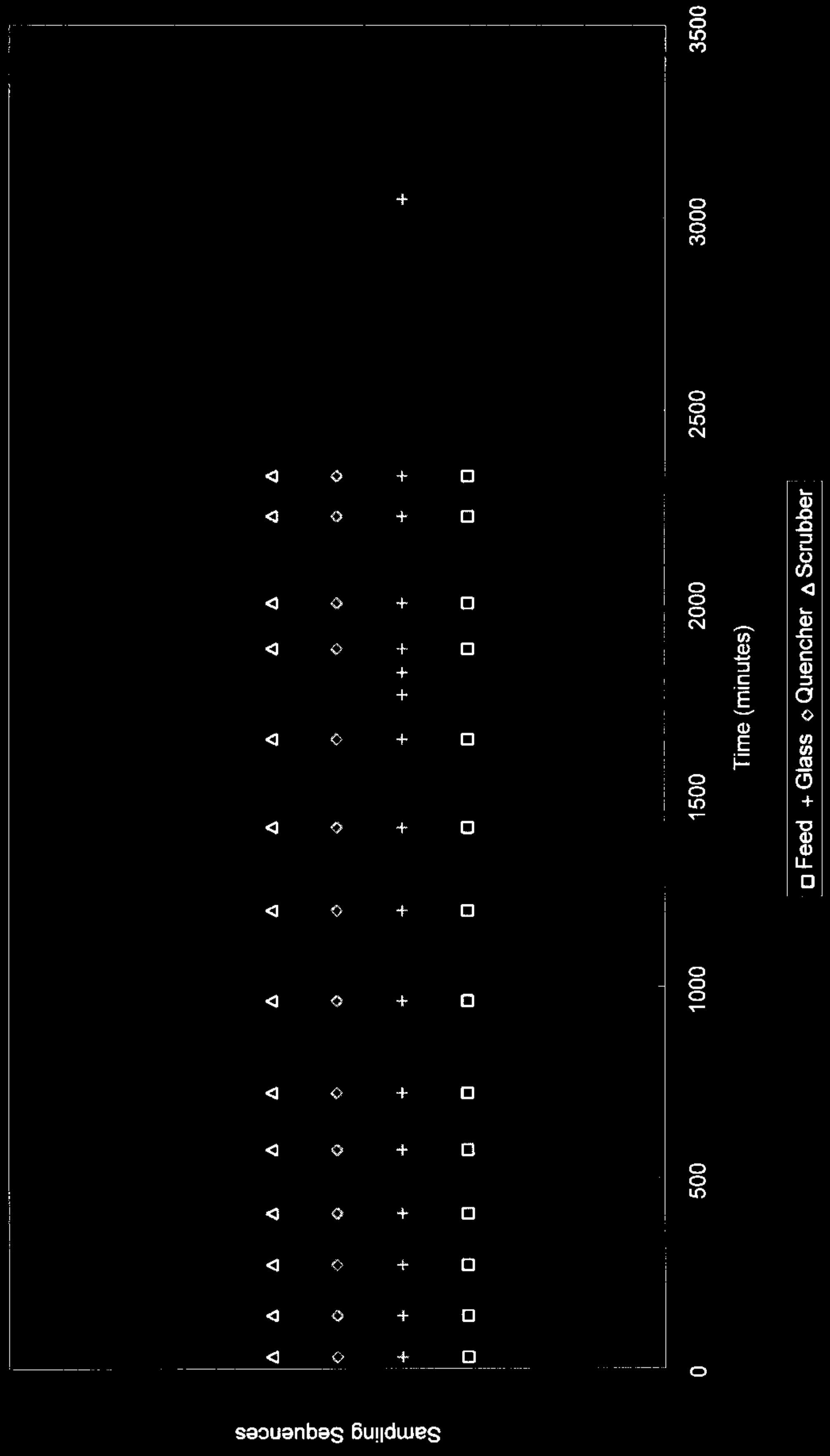


Figure 4.7.a. Cation Concentrations in Quencher Solutions During DuraMelter™ 100 Turnover Run

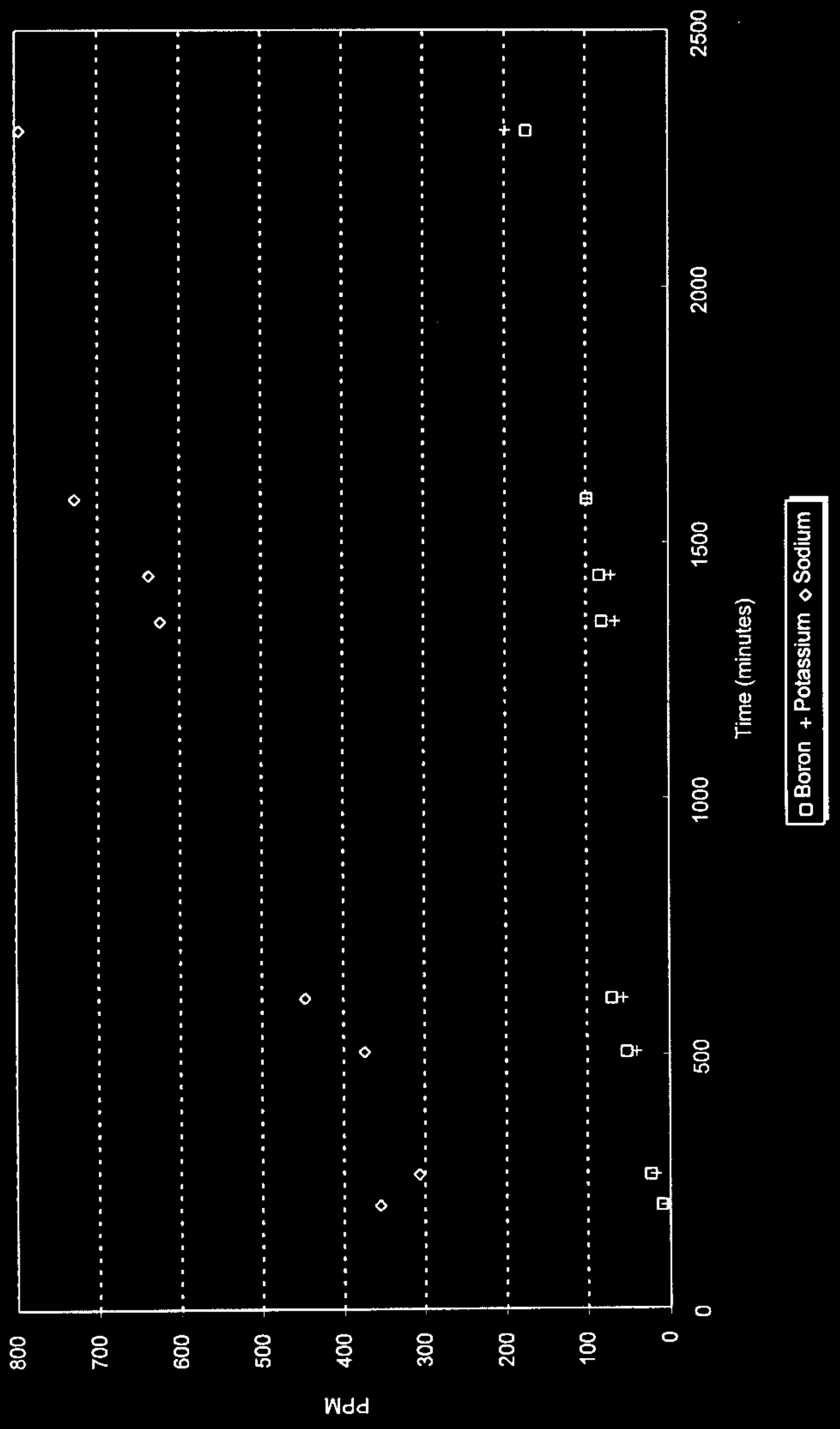


Figure 4.7.b. Anion Concentrations in Quencher Solutions During DuraMelter™ 100 Turnover Run

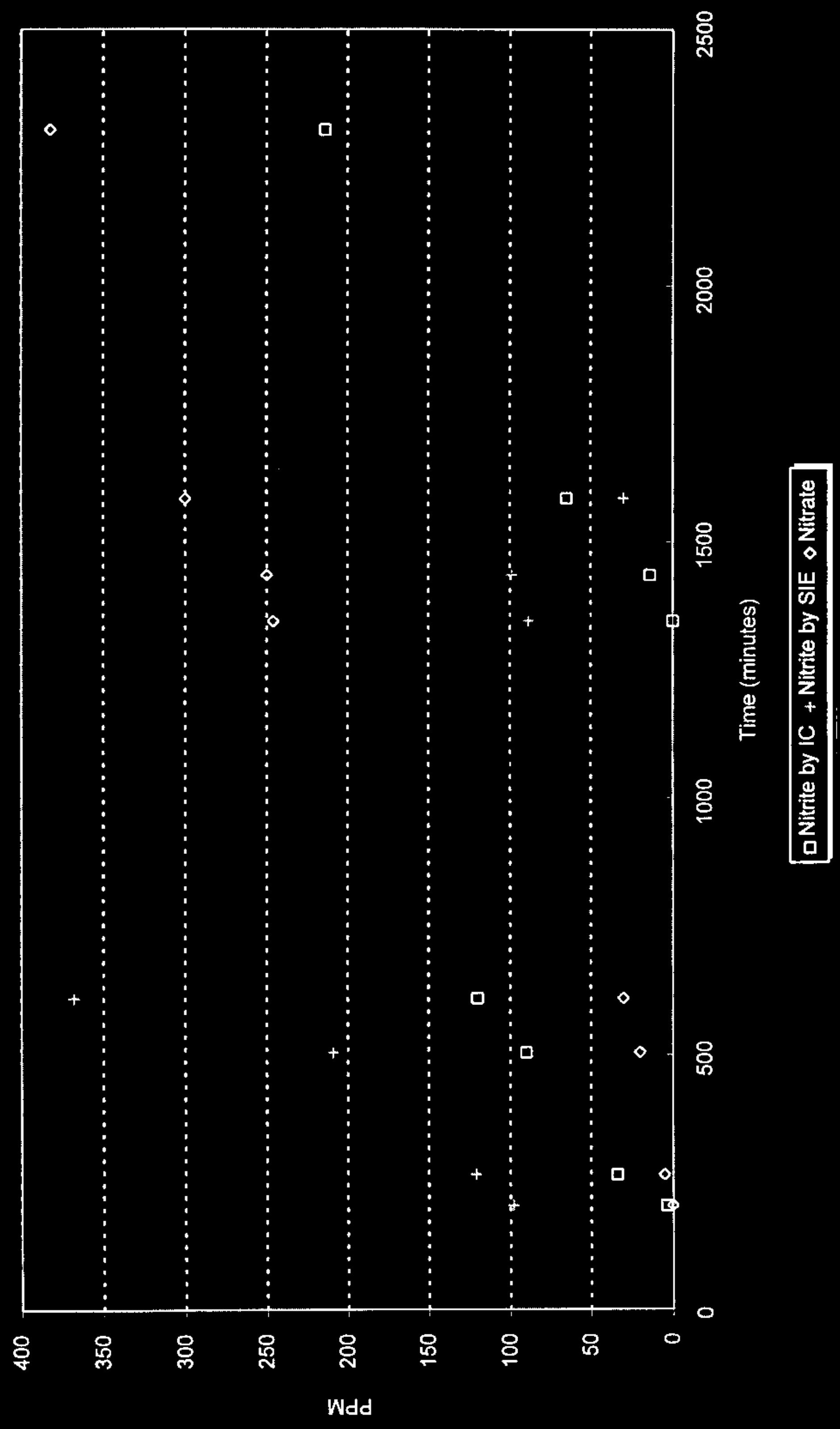


Figure 4.7.c. Cation Concentrations in Scrubber During DuraMelter™ 100 Turnover Run

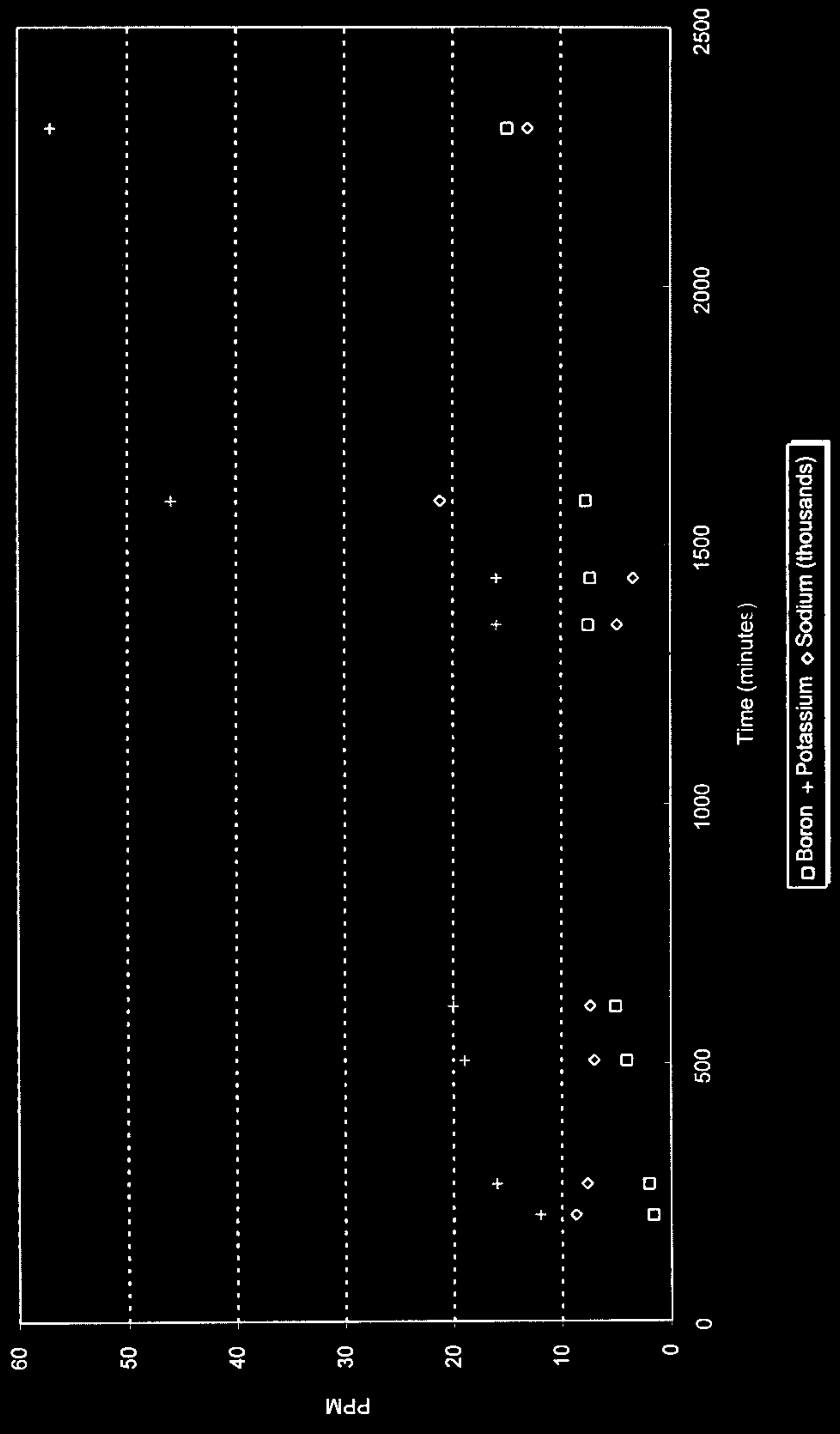


Figure 4.7.d. Anion Concentrations in Scrubber During DuraMelter™ 100 Turnover Run

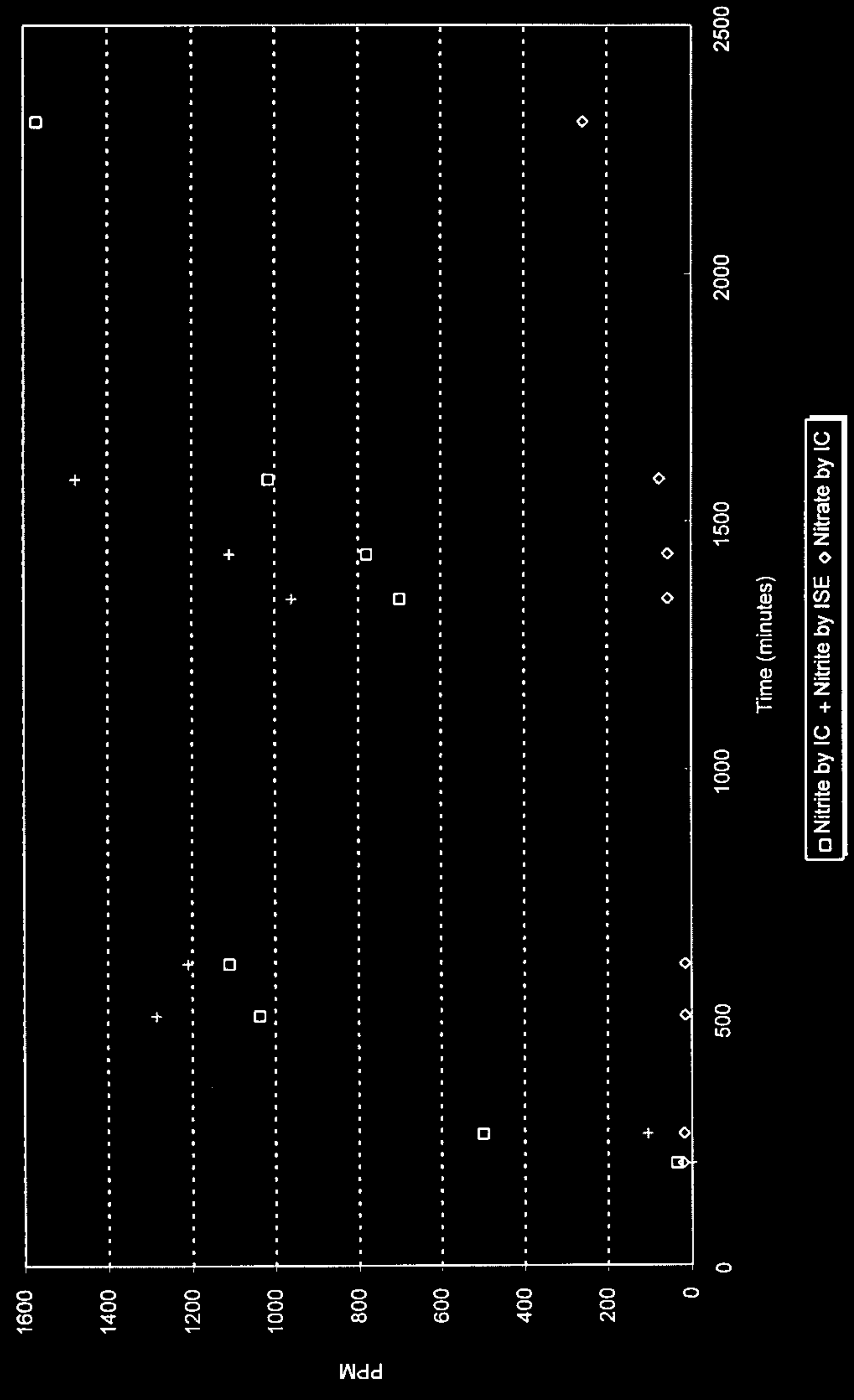


Figure 4.7.e. Nitrogen Emissions from DuraMelter™ 100 Steady State Run

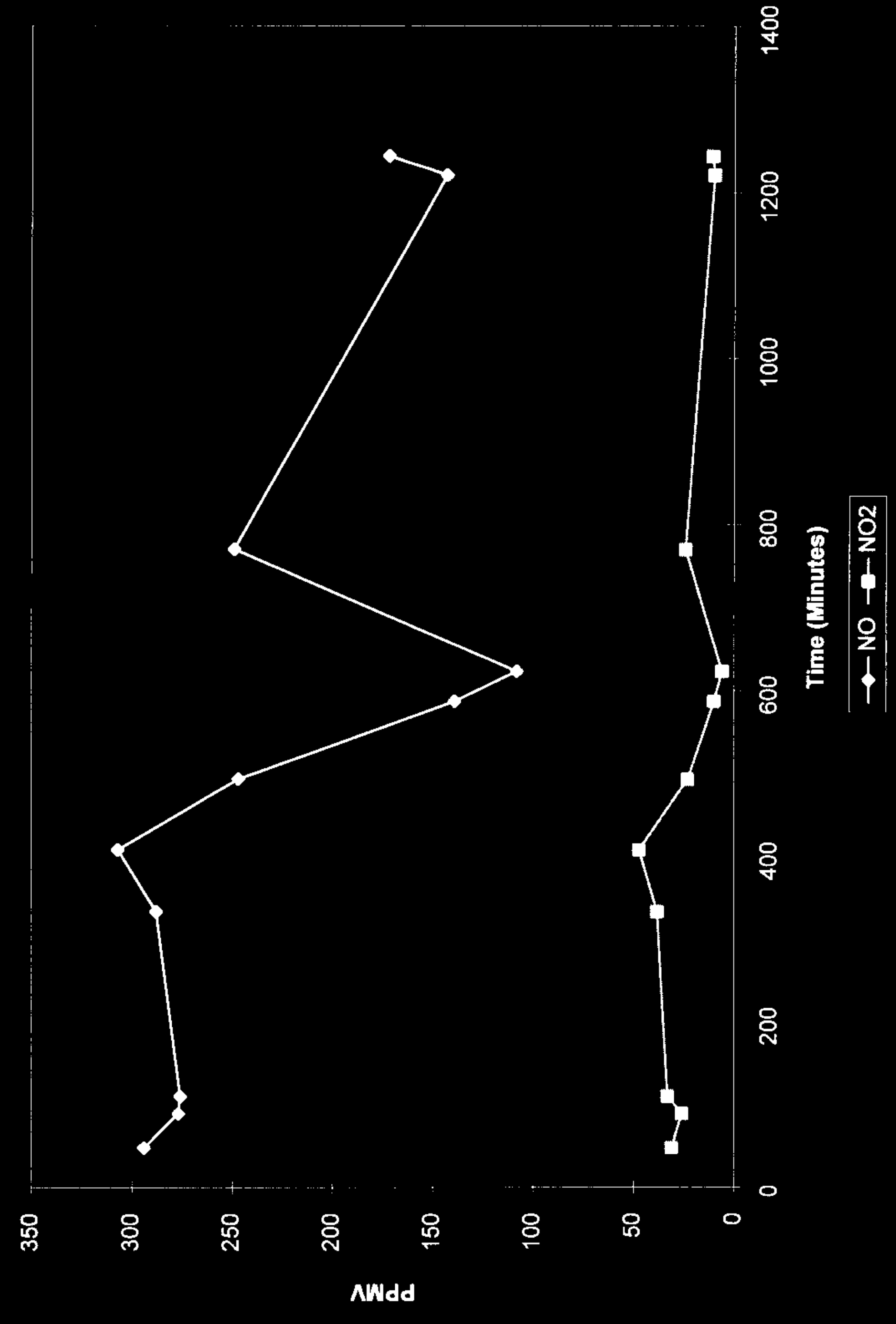
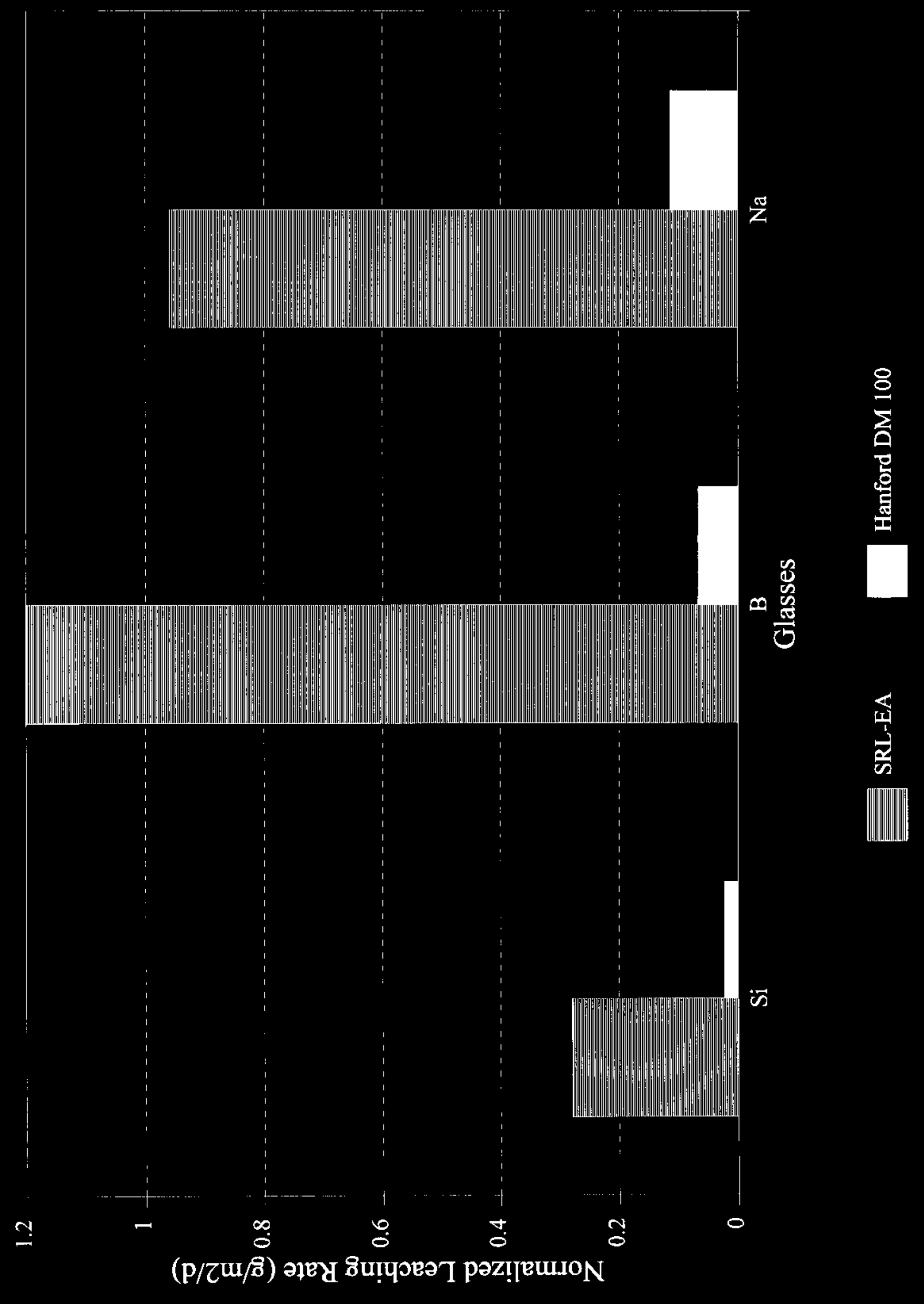


Figure 4.9.a. PCT of Hanford DuraMelter™ 100 Glass, 7-Days, T=90°C, S/V=2000 m^{-1}



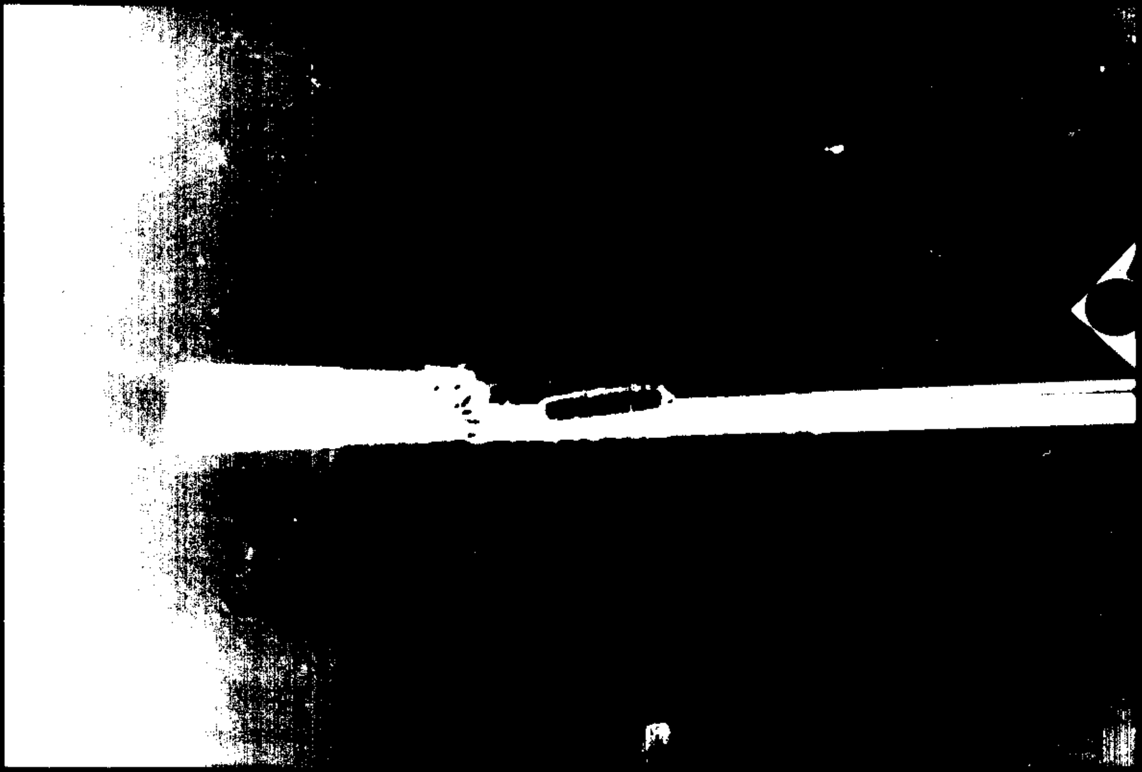


Figure 4.10.a: The corrosion coupon arrangement for the 100 Kg melter run. The view shows a Zirmul coupon (cream colored) at the top held in place by Inconel 72 weld wire. The group at the bottom includes an Inconel 690 bar and a K-3 refractory coupon held in place by Inconel 72 weld wire. The coupons are suspended from an Inconel 601 tube. The position of the coupons was such that in the melter the Zirmul would be in the plenum space and the Inconel and K-3 coupons would extend above and below the air glass interface.

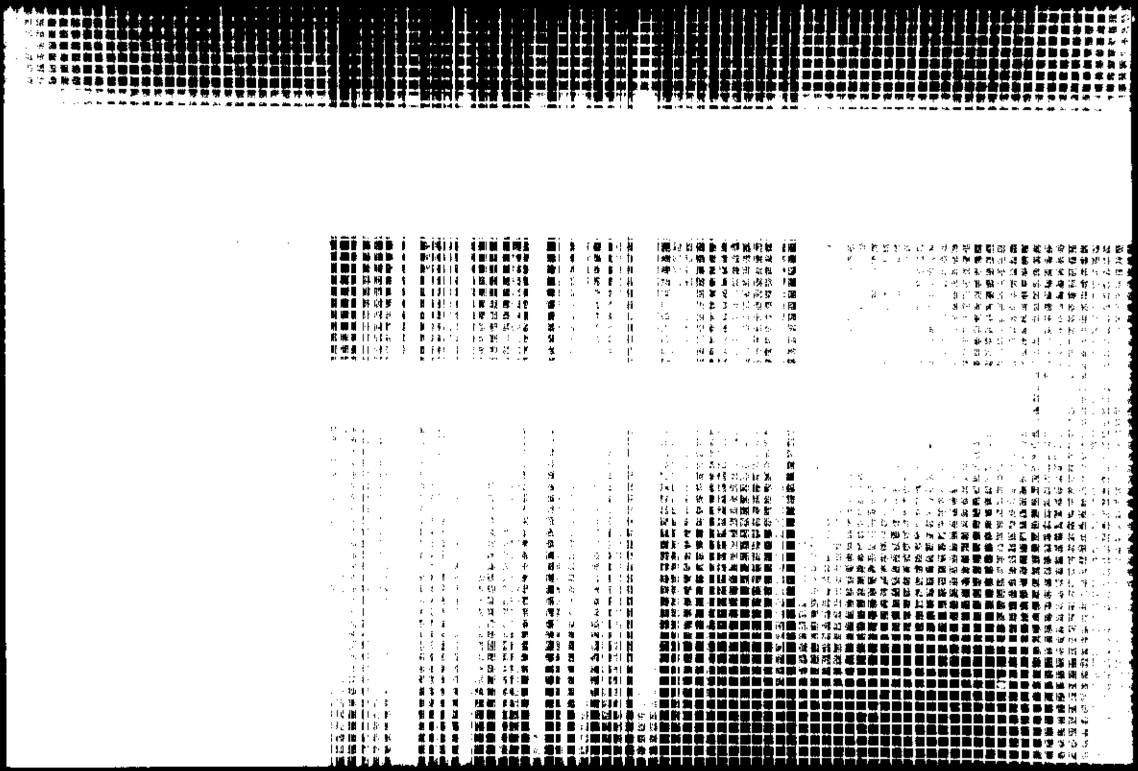


Figure 4.10.b: The Inconel 690 coupon before the test

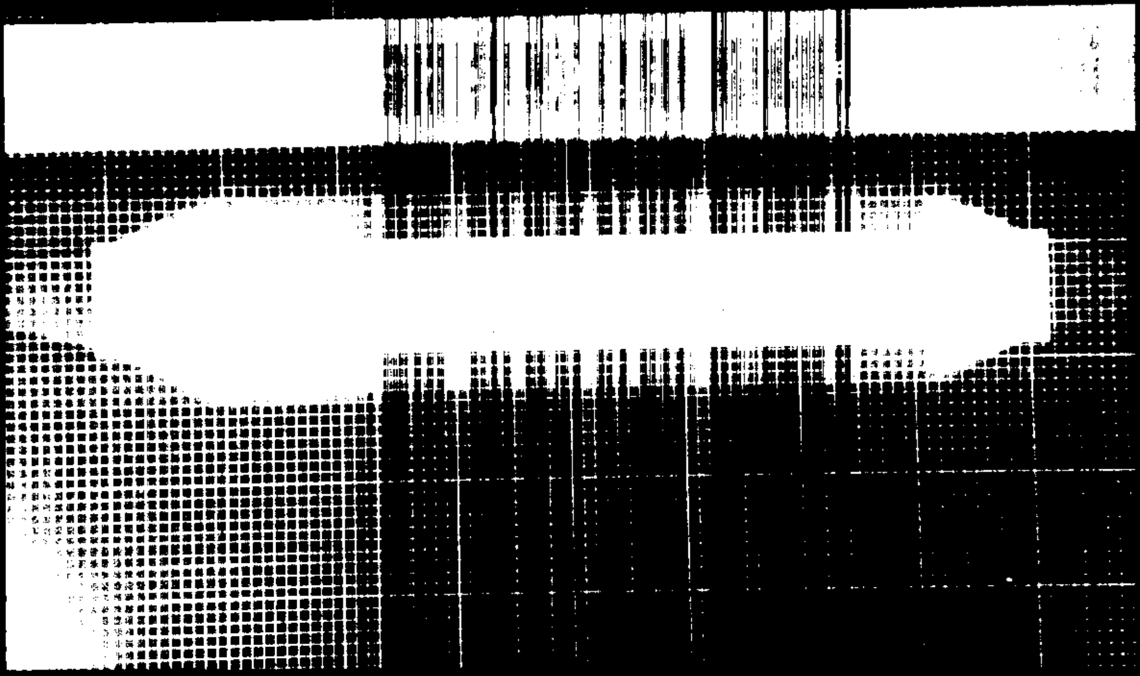


Figure 4.10.c: The K-3 coupon before the test.

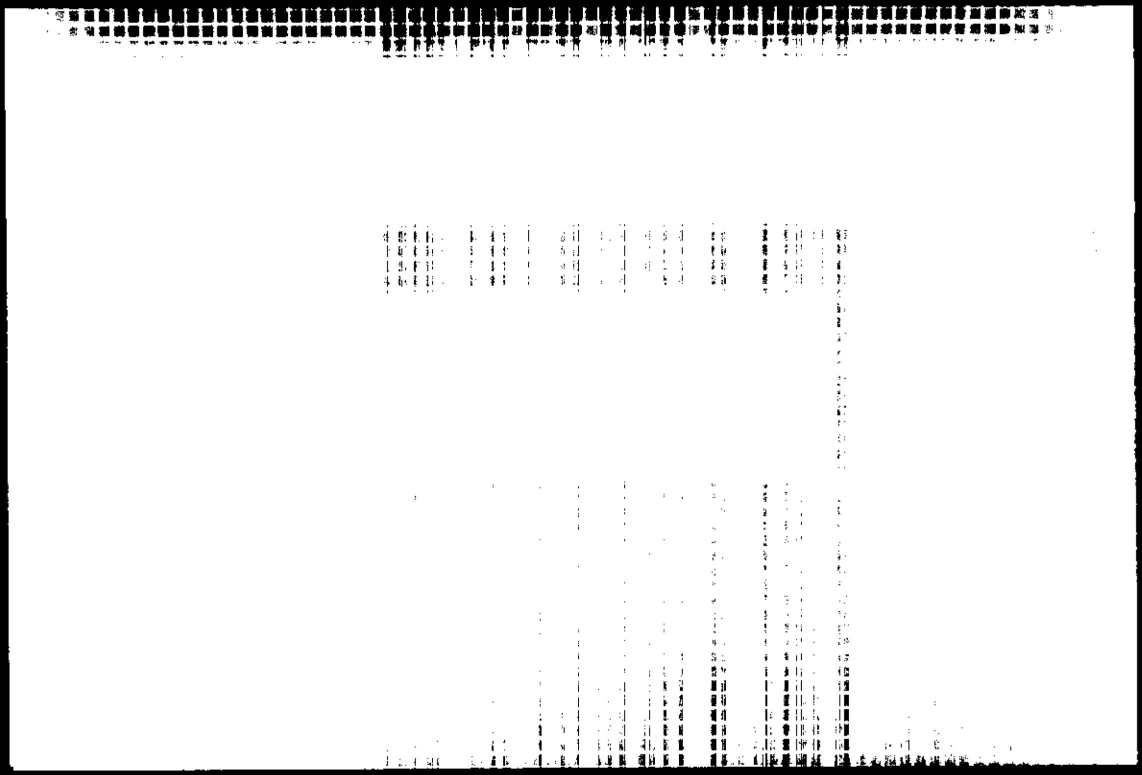


Figure 4.10.d: The Zirmul coupon before the test.

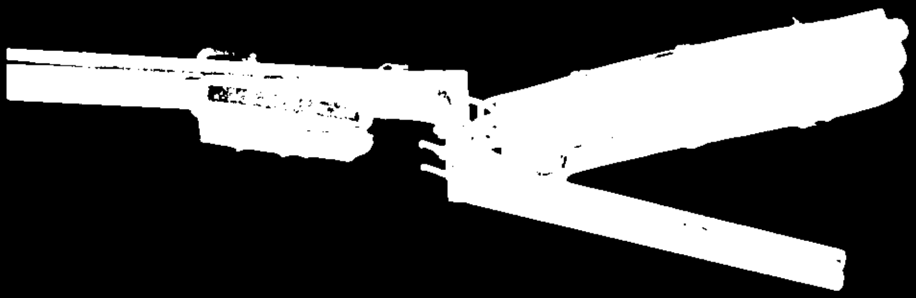
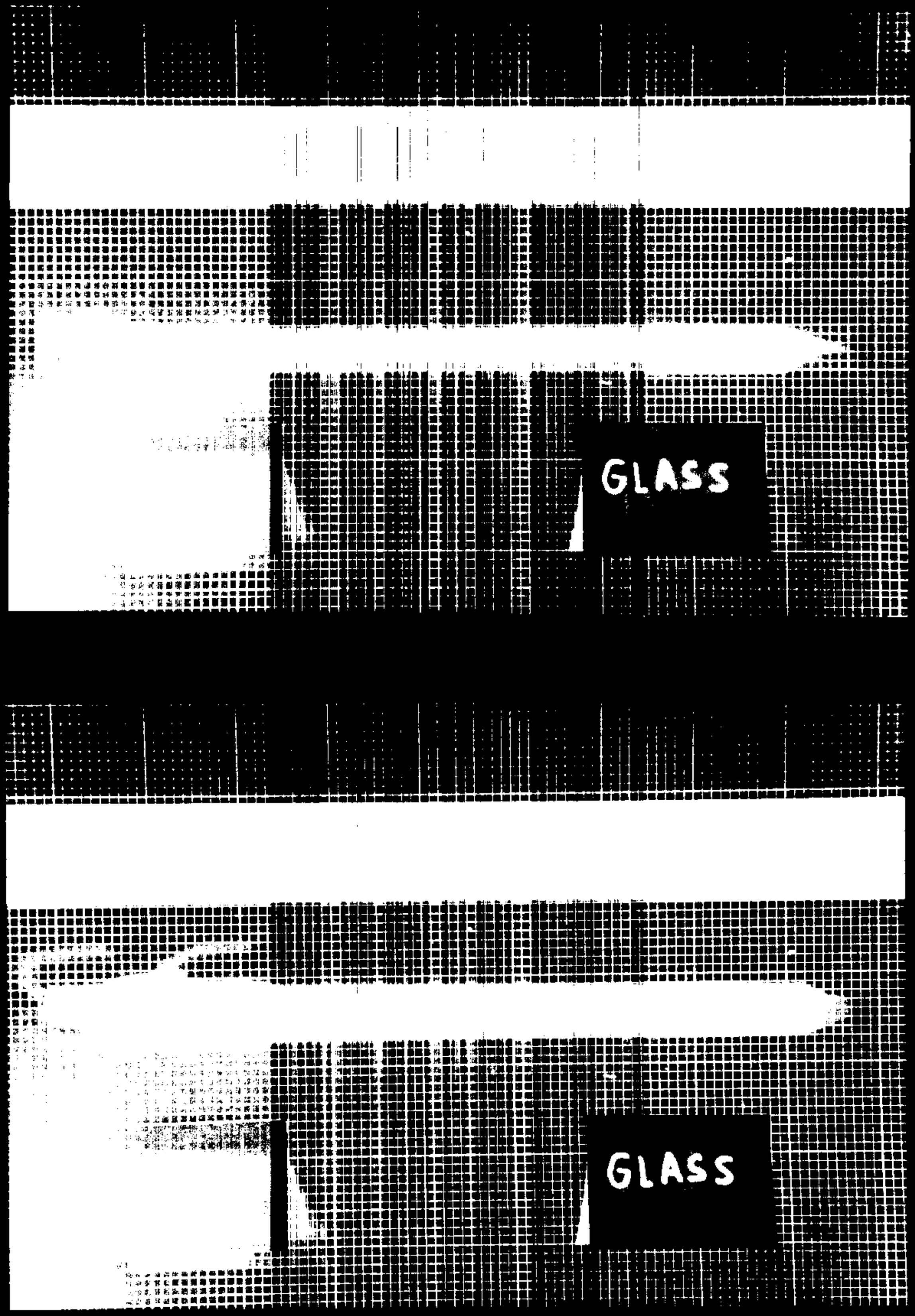


Figure 4.10.e: The corrosion coupon assembly after the 100 Kg melter run.



Figures 4.10.f and g: Two views of the Inconel 690 coupon after the test. The ends in the air and glass are labeled.

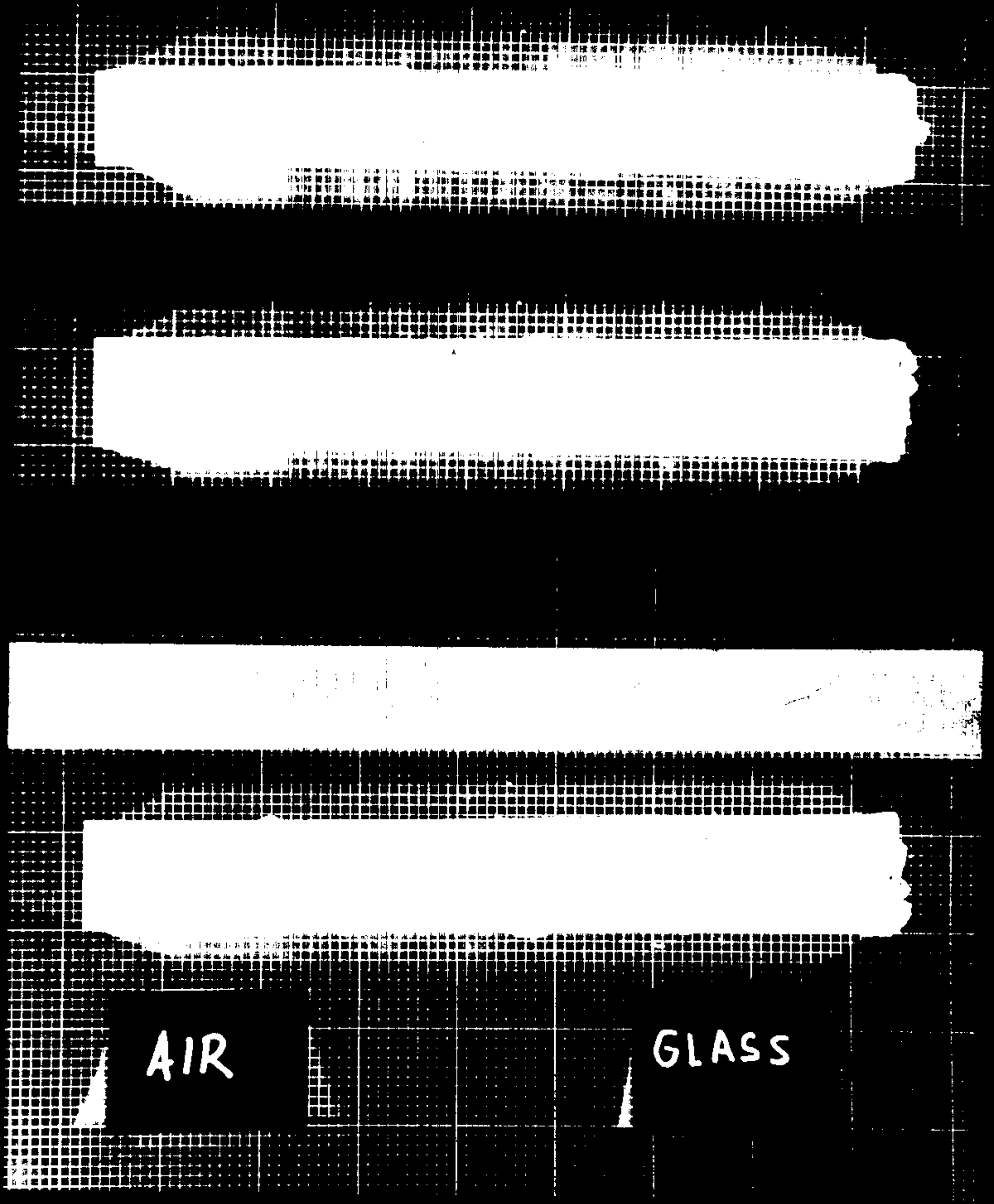
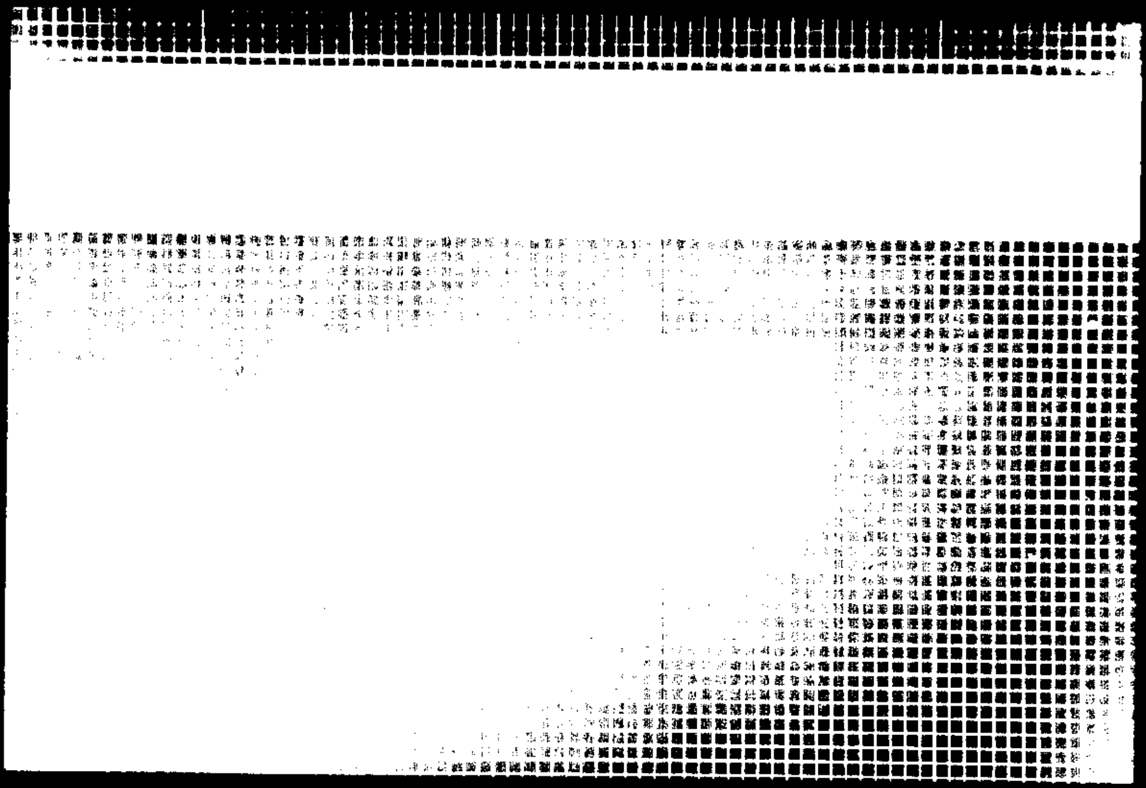


Figure 4.10.h, i, and j: Three views of the K-3 coupon after the test. The ends in the air and glass are labeled. One can see the positions where the Inconel 72 weld wire contacted the coupon.



Figures 4.10.k and l: Two views of the Zirmul coupon after the test.

5.0 DURAMELTER™ 1000 RUNS

5.1 PRETEST MELTER CONDITIONS

The pretest conditions of the DuraMelter™ 1000 were similar to those of the DuraMelter™ 100 except that only non-radioactive glasses had been melted previously in the DuraMelter™ 1000; a list of previous feed types is available. The approximate composition (wt%) of the glass in the DuraMelter™ 1000 prior to the introduction of any Hanford LLW feed was: Al_2O_3 = 4.5%; B_2O_3 = 17%; CaO = 8.5%; Fe_2O_3 = 6%; MgO = 7%; Na_2O = 9%; SiO_2 = 41%; others = 7%. The melter was flushed with Hanford simulated waste feed (three turnovers, as described above) to establish the starting conditions for the test.

5.2 CHRONOLOGY OF EVENTS

The turnover run was split into three runs in order to make and test minor modifications to the system. The holidays and the schedules of WHC observers also contributed to the decision to conduct the run at three different times. The first turnover period took place on December 13, 14, and 15 largely to shakedown the new feed system. The second turnover period took place between December 17 and 20, 1994 and was used to test several alternatives for off-gas NOx reduction. The third turnover period took place between January 12 and 15, 1995 and was used to complete the compositional turnover of the glass pool. It also provided a final test of the system prior to steady state operations.

The steady-state run was conducted on January 19, 20 and 21. Operations proceeded very smoothly due in part to the experience accumulated during the DuraMelter™ 100 tests and the turnover periods. A complete run chronology for the steady state run is given in Table 5.2.a.

5.3 QUANTITY OF FEED PROCESSED AND GLASS PRODUCTION

Approximately 7000 and 3700 kg of glass were produced in the turnover period and steady-state portions of the run, respectively. The relationship between feed and glass production for all the DuraMelter™ 1000 runs is depicted in Figure 5.3.a. There was a significant difference between the feed amount and the glass output in the first and second turnover runs due to changes in the glass level in the melter; prior to the first turnover, the level was significantly below the normal melter pool level (to expedite the compositional turnover) and, consequently, the glass output was significantly smaller than the amount of glass formed from the feed added. During the third turnover and the steady-state periods, excellent mass balances were achieved.

Unlike the drums of simulant used during the DuraMelter™ 100 runs, there was significant drum-to-drum variation in the nature of the simulant. The drums of simulant were grouped into three different categories based on the observed rheology and the extent of precipitation. The different batches and sub-types of LLW simulant and the feed batches in which they were used are shown in Table 5.3.a.

A description of average feed slurry characteristics is given in Table 5.3.b. Approximately one-fourth of the urea concentration that was used in the DuraMelter™ 100 steady-state run was used in the DuraMelter™ 1000 steady state run. As discussed previously, the addition of urea to the feed causes a significant volume increase which must be taken into account (18% for the DuraMelter™ 100 steady state run). While this increase was smaller for the DuraMelter™ 1000 run due to the reduced urea concentration, there was an additional volume increase in this case due to the effect of added water. Water was added to the feed batches to facilitate mixing and to flush lines at various points. The net result of these two effects is, coincidently, again an 18% increase in volume over that for the target feed mix without added urea or water.

Approximately 4500 and 3500 liters of combined LLW surrogate and additives were fed to the melter during the steady-state and third turnover runs, respectively. The average feed rates for the two runs were 1.55 and 1.2 liters per minute for the steady state and third turnover runs, respectively. Cumulative feeding curves are given in Figures 5.3b and 5.3c. The average glass production rates for the two runs were approximately 1800 and 1600 kg per day for the steady state and turnover runs, respectively. This resulted in an actual conversion ratio of 1.22 liters feed per kg glass produced which compares well with the expected conversion ratio of 1.17 liters feed/kg glass; using the latter value, the cumulative observed glass production and theoretical glass production are compared in Figures 5.3d and 5.3e. The comparison indicates good accounting for all the feed and glass. Only one half of one percent of the total glass formers fed to the melter were not directly identified. This small difference could be attributed to the drum to drum variability of the DSSF simulant, the heels left in the mixing and feed tanks and/or accounting for the net glass volume change in the melter over the run. Detailed information on feeding rates and times as well as glass pouring were given in the run chronologies discussed in Section 5.2. Complete sample descriptions and nomenclature are given in Section 5.5.

Glass production rates, by any measure, were always above the nominal 1000 kg/day production rate. The overall average production rate is, of course, larger if periods of non-feeding are factored out in the calculation. For example, the average production rate for the steady-state run using total time was 1800 kg/day whereas it was 1900 kg/day when periods of non-feeding were excluded. Figures 5.3f and 5.3g illustrate the average glass production rates for the third turnover and steady-state periods using both methods of calculating average production rates.

5.4 ENERGY CONSUMPTION

The major consumption of energy in the DuraMelter™ 1000 system is through the electrodes, the lid heaters, and the discharge heaters. The total energy consumption for the steady-state period was computed by summing the products of the measured voltages and currents for each of these. The average values obtained were 115, 12, and 18 kW for the electrodes, lid heaters, and discharge heaters, respectively. This gives a total average power consumption of 145 kW or a power consumption rate of approximately 2 kWhr per kg glass produced during the steady-state run.

Glass temperatures were maintained relatively constant by controlling the input powers, primarily to the electrodes, in response to varying power demands as a result of changing glass levels and cold caps. The variations are illustrated in Figures 5.4.a - 5.4.c, together with those for other measured run parameters.

The overall power required to produce a kilogram of glass from this feed in the DuraMelter™ 1000 was less than half that of the DuraMelter™ 100. The fraction of the total power supplied to melter from the lid heaters and discharge heaters is considerably smaller for the larger melter, as also is the effect of thermal losses.

5.5 IDENTIFICATION, DESCRIPTION AND SAMPLING TIME FOR ALL SAMPLES COLLECTED FOR ANALYSIS OR ARCHIVAL

Samples were named using the same system as that described for the DuraMelter™ 100 runs. Fewer samples were taken during the DuraMelter™ 1000 runs for several reasons. The DuraMelter™ 1000 off-gas system only had one liquid reservoir which reduced the number of liquid samples accordingly. Also, WHC personnel suggested that, with the benefit of the data from the DuraMelter™ 100 runs and the general need for analytical economy, samples be taken at longer intervals, particularly during the turnover run. Figure 5.5.a illustrates the different sampling times during the steady-state period. Tables 5.5a and 5.5b provides names and descriptions of all of the samples that were taken for outside analysis.

5.6 DESCRIPTION OF OPERATING BEHAVIOR INCLUDING UPSETS, FAILURES, OPERATING PROBLEMS AND UNEXPECTED BEHAVIOR

The DuraMelter™ 1000 runs proceeded very smoothly with no major upsets or surprises. The minor problems that were encountered related to the feed and off gas systems rather than the melter and were successfully solved over the course of the runs (primarily during the turnover period); we would not consider any of these problems to represent obstacles to scale-up of the DuraMelter™ systems.

Some aspects of the feed were somewhat unusual including the high solids content and high alkalinity. As discussed in Section 2.2.1, a new feed system was installed for these runs which, when coupled with the new feed, necessitated some testing. The turnover run was used to debug the feed system and identify further minor improvements. During this period improved procedures for mixing the chemical additives with the simulant were also developed.

The test plan (WHC document number WHC-SD-WM-VI-020) included direct sampling of the melter exhaust. Unlike the situation for final off-gas emissions, the DuraMelter™ 1000 system was not designed for this procedure. As a result, modifications were required to the transition line from the melter. The only available sampling location was an angled section immediately after the film cooler. An opening was made at this point and a stainless steel cap was used to reduce the air leakage around the sampling probe. The DuraMelter™ 1000 was more susceptible to the accumulation of transition line deposits than the DuraMelter™ 100 due to the geometry of the transition and the fraction of dilution air. As a result, material still deposited in this area despite the improved seal around the probe. Eliminating direct sampling of melter exhaust or redesigning the system specifically for such sampling would reduce or negate this problem.

The DuraMelter™ 1000 does not have a quencher sump and the quench liquids flow directly into the scrubber (by contrast, the quencher on the DuraMelter™ 100 was specifically designed for solids collection and removal). As a result, collected solids accumulated in the scrubber sump. To address this potential problem, filters were installed in a recirculation line to remove particles and precipitates from the scrubber liquids. As the scrubber solutions were circulated through the filters, particulate material accumulated on diatomaceous earth as a filter cake. This new system was debugged during the turnover runs.

As with the DuraMelter™ 100 runs, a sulfate layer formed on the glass surface after the completion of the Hanford runs. This occurred several days after the melter was placed on idling mode. Idling was at the reduced temperature of approximately 1050°C and with significantly reduced glass bubbling. This observation is rather surprising since the targeted SO_3 content in the final glass was only 0.21 wt%. While an SO_3 solubility study was not performed on this particular glass formulation, this amount is well within the solubility limit of typical borosilicate glasses of this kind. This suggests that the LLW simulant may have contained more sulfur than was targeted. Mass balance calculations, discussed below, also indicate the presence of more sulfur in vitrification products than was provided by the nominal feed which supports this suggestion. The sulfate layer was removed from the melt surface by reduction to gaseous SO_2 by feeding an aqueous sugar solution into the melter.

5.7 DATA FOR MEASURED RUN PARAMETERS

Run parameters such as temperatures, pressures, flow rates and concentrations were recorded during the runs. The data for these parameters are given in the following tables: Table 5.7.a for steady-state melter conditions; Table 5.7.b for steady-state off-gas conditions; Table 5.7.c for post HEPA steady-state NOx, SO_2 and CO air emissions; Table 5.7.d for pre HEPA steady-state NOx, SO_2 and CO air concentrations; Table 5.7.e for melter transition line conditions; Table 5.7.f for post HEPA filter stack conditions; Table 5.7.g for HCl and NH_3 emissions; Table 5.7.h for VSL analysis of sulfuric acid scrubbing solutions collected by Engineering Sciences; and Table 5.7.i for steady-state CEM data. In addition, graphical displays of data are presented in the following figures: Figure 5.7.a shows additions of sodium hydroxide to the scrubber during the steady-state run; Figure 5.7.b shows melter cold cap percentages during the steady-state run; Figure 5.7.c shows ammonia concentrations in the scrubber during turnover; and Figures 5.7.d - 5.7.m show air emissions during steady state.

Melter and off-gas system conditions were relatively constant throughout the steady state run (Figures 5.4.a -5.4.c). The glass temperatures remained steady at approximately 1120 - 1130°C after the first few hours of operation. The plenum temperatures fluctuated with bubbling rate, cold cap, and feed rate variations. The pressure in the melter is maintained negative (with respect to atmospheric) for safety reasons. Scrubber temperatures were manipulated as a trade-off between accumulating the minimum amount of water during the run and maintaining low humidity at the baghouse; heated dilution air is introduced into the bag house to help prevent moisture condensation. Pressure differentials across the bag house and HEPA filter were used to monitor filter quality and to determine times for bag house conditioning.

Engineering Sciences and VSL emissions data for metals and particulates were in good agreement. Both labs show post HEPA filter metal emissions below detection limits for all metals and particulate concentrations well below the required 0.03 grains/dscf. At the melter exit, a particularly challenging sampling point, comparable moisture and cesium concentrations were measured by both labs. However, VSL particulate and metal concentrations measurements at the melter exit were approximately twice those of ES. It should be noted, however, that the two sets of data were not collected at the same time in the run; it is quite likely that the difference was a result of the increased bubbling near the end of the run when VSL staff sampled melter emissions. Prior work with DuraMelters™ has demonstrated this kind of relationship between bubbling rate and particulate emissions.

The ES emissions sampling train included a sulfuric acid scrubbing solution to remove ammonia from the gas stream since it was found previously that ammonia interferes with the measurement of NOx by chemiluminescence. The sulfuric acid scrubbing solutions were obtained from ES for analysis by VSL for several reasons. One was to investigate the possibility of a negative bias that might be created for the ES NOx measurements since any nitrate or nitrite observed in the scrubbing solutions was present as NO_2 in the original gas stream and therefore the downstream detector would be exposed to less than the total NO_2 concentration. Another reason was to estimate ammonia concentrations at the three locations. Sulfuric acid solutions should quantitatively remove the ammonia from the gas streams and therefore the total amount analyzed in solution will be directly related to the concentration in the gas and the volume of air that passed through the scrubbing solution. Lastly, analysis of these solutions permits an estimate of particulate fluorides and chlorides to be made. Acidic gases such as HCl and HF would not have been trapped in this strongly acidic scrubbing solution, however particulates such as NaCl might have been retained. The scrubbing solutions were provided to VSL along with the length of time exhaust air was pulled through them at the rate of 14 liters/min. VSL measured the volume of each solution, the ammonia concentrations using an ion specific electrode, and the anion concentrations using ion chromatography.

The results from these analyses of the scrubbing solution are given in Table 5.7.h. Significant amounts of NO_2 were apparently removed from the gas stream prior to the gas stream reaching the detector. However, comparison between ESI and VSL NOx values suggests the amount of NOx removed in the scrubbing solutions was small; in fact, the VSL values were less than the ESI values even though the gas analyzed by VSL was not passed through scrubbing solutions. It is possible that the NH_3 was not completely scrubbed out; however, this could not entirely account for the discrepancy between the VSL and ESI results. Further study of NOx interferences is required. The ESI SO_2 measurements tended to be high because the line was not heated.

The ammonia concentration in the melter exhaust measured in this way agrees well with an extrapolation of the third turnover scrubber data depicted in Figure 5.7.c. Ammonia was removed quantitatively from the melter emissions by the scrubber while the pH was below 11. Once the pH was maintained above 11, the scrubber no longer removed ammonia efficiently, in fact ammonia actually evaporated from the scrubber. During the initial 10-hour feeding period the scrubber accumulated ammonia at a rate of 0.4 kg/hr. This extrapolates to a gas concentration of approximately 2500 mg/m^3; this was only twenty percent higher than the value calculated from the data from the sulfuric acid scrubbing solutions. The ammonia data for final emissions shown in Table 5.7.g were obtained by VSL using an electrochemical sensor; these results are approximately six times higher than those calculated from the sulfuric acid scrubbing solution data. Further testing with the electrochemical ammonia sensors and the scrubbing solution technique would be required to corroborate either of these measurements.

Particulate halide salts were only detected at the melter exhaust location, as would be expected. VSL measurements using electrochemical sensors showed the presence of HCl in the final emissions but no chloride was detected in the sulfuric acid scrubbing solution. This supported the notion that particulate chlorides, not HCl, were detected in the acid scrubbing solutions. Relating the particulate emissions to the rates at which these ions were fed into the melter showed only approximately five and one percent of the total chloride and fluoride exited the melter as chloride and fluoride particulate salts, respectively. A portion of the fluoride and chloride fed into the melter was retained in the glass, however significant amounts probably exited the melter as HF and HCl. An effective system for removing acid fumes from the melter exhaust is therefore required when producing glass from this feed.

5.8 MASS BALANCES

Establishing material mass balances was a major objective of these tests. To compute material balances, compositional analyses were required of the following: feed, quencher and scrubber solutions, glasses, bag house powders, and emissions. Also, complete and accurate data pertaining to feed rates, glass production, air flow rates, liquid volumes, and bag house conditioning were needed. The great majority of this information was available for this report, however some extrapolations and approximations were required from the available data, as noted below, in order to complete the analysis.

Four feed samples were taken during the steady-state run, three of which were analyzed by Corning. The samples were taken at the beginning, 890 and 1730 minutes into the run. The results of the Corning analyses are given in Table 5.8.a. The normalized values for the Corning analyses are compared with target and actual recipe compositions in Table 5.8.b. Deviations in the reported values could have resulted from actual compositional variations in the feed, sampling errors, or analytical variations from either sample dissolution or analysis. These variations introduce uncertainty into the mass balance calculations. Good agreement exists between the target composition and actual recipe for all the components, as would be expected. Unfortunately, the

Corning feed analysis does not match either the target or actual composition for many of the components, most notably aluminum, boron, calcium, silicon, and strontium. Analysis of slurries is often problematic due to the problems associated with obtaining a representative sample from a multi-phase mixture. The analyses of glasses produced in the steady-state run demonstrated that the target composition was successfully reached and maintained throughout the run (Figures 5.8.a and 5.8.b). The recipe composition, not the Corning feed analysis, was therefore used in the mass balance calculations. Additional analysis of feed and glass by other analytical laboratories may be helpful in eliminating this discrepancy.

Ten glasses were sampled during the steady state-run, five of which were analyzed by Corning. Two of the five were also analyzed by USGS and one by PNL for comparison purposes. The results for these analyses are given in Table 5.8.c. Good agreement exists between the three labs for most elements. The deviation between PNL and USGS was well below 10% for all of the major constituents. As noted above, the product glass and target composition are very similar. One of the aluminum and both of the calcium analyses from Corning were significantly lower than the corresponding data from the other labs; these are two of the elements which were in question for the feed analysis.

Close to fifty scrubber samples were taken during the steady-state run; ten of these samples were analyzed by PNL. The results of these analyses are given in Table 5.8.d. Typically, increases in element concentrations over time would be attributed to carry over from the melter, whereas decreases would be attributed to precipitation and misting from the liquid reservoirs. There was no discernable or systematic trend in the data from the PNL analyses that could be convincingly associated with either of these phenomena. Concentration changes either up or down were as much as several orders of magnitude between adjacent data points. Any conclusions that can be drawn from these data are therefore subject to considerable uncertainty.

The volume of liquid in the scrubber sump was kept relatively constant at 1000 liters by transferring any accumulated solution into a blowdown tank. The sump liquids were strongly agitated and it was therefore assumed that any precipitates that were formed were sufficiently well suspended to be captured in the sump liquid recirculation filtration unit. Filter cakes from the recirculation filter were removed, weighed, and analyzed.

Some data selection and assumptions were required in order to complete the steady-state mass balance calculations. The average of the five glass analyses from Corning was used for the glass composition. The feed composition and quantity was calculated using the total amounts of chemicals and DSSF simulant consumed. The amount of material accumulated in the scrubber during the run was determined by calculating the net increases in concentration over time and multiplying by the volume. As noted above, the scrubber solution analyses show no reasonable trend. For this reason, only the data from the first two analyses were used due to the minimal amount of liquid transfer during this time and the low initial concentrations. This extrapolation was predicated on the assumption that since melter feed rates were uniform throughout the run, so too would be the carryover rates from the melter.

The amount of material accumulated in the bag house during the run was calculated by normalizing the unused and spent diatomaceous earth sample analyses to the same silicon value and then subtracting the values for the unused sample from those of the spent sample and multiplying by the total mass. The same approach was used for the filter cake taken from the scrubber filter unit. Data for these is presented in Table 5.8.e. Post HEPA filter emissions were all below detectable limits (Table 5.7.f), however the maximum possible masses emitted were determined as the product of lowest detectable concentration, air flow rate, and total run time.

The results from the mass balance calculations are given in Tables 5.8.f, 5.8.g, and 5.8.h. The overwhelming majority of the material fed into the melter became glass. Less than two percent of any element other than chromium and cesium was detected outside of the glass. Less than ten percent of the recovered cesium was detected in the off-gas system. Chromium is a special case in that it comes not only from the feed but also from the refractory components of the melter as well. Chromium retention in the melter therefore rarely follows the same trends as other elements. The necessary analytical data for Cl, F, S, and P were either not available or of dubious quality (particularly for quencher and scrubber solutions and even for the LLW simulant itself) and it was therefore not possible to complete the mass balance for these species; some volatilization of these species to the off-gas would be expected, however.

In general, the agreement between feeding data and glass product data was not as good as that for the DuraMelter™ 100 run. Half the elements measured gave deviations of less than ten percent; however, deficiencies between 9.5 and 17 percent existed for Ca, Cs, Fe, Mo, Ti, and Zr. Most of these deficiencies can be attributed to the glass analyses; since the overwhelming majority of all of the material is found in the glass, a small discrepancy in the glass analysis can sway the whole mass balance very significantly. As discussed in Section 5.3, the total material balance (simple mass in versus mass out) agreed to less than half a percent. The glass analyses, however, only account for approximately 95 percent of the total solid. As a result, five percent of the total glass is therefore not accounted for when using these analyses. One could, of course, arbitrarily renormalize these analyses to 100%; we have elected not to do this, however. Comparing target glass compositions with the Corning analyses shows deficits for Ca, Cs, Fe, Mo, Ti, and Zr. These were the elements which gave poor recoveries when the Corning glass composition was used for mass balance calculations.

The fractional amount of the feed material that exited the melter (other than as glass) was quantified using two independent methods. One was to divide the measured emission rates (Table 5.7.e and 5.7.g for ammonia) by the average feed rates. The other was to divide the total sum of material in the off-gas system by the total mass of material fed into the melter. The results of these calculations are given in Table 5.8.h. The table also compares the results of the VSL and ES melter exhaust sampling measurements. The methods agreed within a factor of two for all elements except for strontium. Given the numerous sampling limitations encountered while sampling melter exhaust gases, the agreement was better than expected. DuraMelter™ 1000 retention rates for all elements were greater than that of the DuraMelter™ 100. As observed in past DuraMelter™ comparisons, the larger plenum space in the DuraMelter™ 1000 make it more difficult for particles to escape. Both DuraMelter™ 100 and 1000 values for strontium from direct sampling of melter emissions were higher than those from summing total masses in the off gas system. Since direct emission values from different labs were in good agreement, this result suggests that either the PNL analyses for bag house and scrubber strontium are systematically low or that strontium has somehow precipitated out of scrubber solutions in such a way that it has gone undetected.

An incomplete data set was obtained for the chloride, fluoride, and sulfate. Missing and unreliable scrubber solution analysis data resulted in an inability to calculate the amounts of these components in the scrubber solutions. Despite these limitations, some noteworthy conclusions can be drawn. Using the amount of chloride in the DSSF simulant, the USGS average glass analysis of 0.185%, and the average emission measurement of 55 ppmv, approximately 56% of the chloride was retained in the glass and approximately 32% left the system through the stack. The twelve percent that was unaccounted for was probably contained in the scrubber solution. Using the amount of fluoride in the DSSF simulant and the USGS/Corning average glass analysis of 0.13%, approximately 77% remained in the glass. Calculations from the Corning analysis of the bag house DE showed that less than two percent of the total fluoride was deposited there. Final emissions measurements for fluorides were not made; however, previous DuraMelter™ runs with high-fluoride feeds resulted in no measurable stack emissions of fluorides. It is likely, therefore, that the unaccounted for fluoride was probably in the scrubber solutions.

Unlike fluoride and chloride, there was considerable evidence for additional sulfur in the feed. Calculations based on the USGS analysis of the glass indicated there was approximately three times as much sulphur in the glass as there should have been on the basis of the nominal feed composition. The original analysis of the DSSF sulfur content was suspect throughout the DuraMelter™ runs. Sulfur emissions as SOx are considerably reduced when urea is added to the feed; however, from the turnover runs in which urea was not used, the total emissions during these runs accounted for more sulfur than was nominally present in the feed. The only element with a large surplus in the DuraMelter™ 100 steady-state mass balance calculations was sulfur. Finally, the unexpected sulfate layers found on top of the glass pool at the end of the both of the runs also suggests the presence of additional sulfur in the feed.

Sodium hydroxide was added to the scrubber at an average rate of approximately 1 mol/min or 0.63 mol/ liter of feed processed (Figure 5.7.a). The combined halogen feed rate to the melter was less than 0.3 mol/min and over half of the halogens remains in the glass. Thus, the large majority of the acidic components (which consume the sodium hydroxide that was added to the scrubber) generated during glass production must come from nitrogen and sulfur compounds. While, in principle, an acid balance (or anion-cation balance with the measured pH) is possible, the solution analyses do not appear to be of sufficiently good quality for this.

5.9 GLASS DURABILITY

A sample of the glass produced during the steady-state run was subjected to the PCT leach test procedure by Corning. The results obtained are given in Table 5.9a and depicted in Figure 5.9a. The average USGS PCT test results for the DuraMelter™ 100 glasses are provided for comparison. Leach rates for the DuraMelter™ 1000 glass were well below the that of SRL-EA standard glass and the normalized average leach rates for sodium were more than one order of magnitude below the 1 g/m^2/day goal. These results were very similar to those reported in Section 3.0 for the crucible melt glasses and the DuraMelter™ 100 glasses. A notable exception is the sodium data for which Corning reported a considerably lower value than that previously found for essentially the same glass. While it is important to resolve this discrepancy, the sodium leach rate was either 10 or 25 times lower than the target value; thus, very leach resistant glasses were made both at the crucible melt and continuously fed melter scale.

5.10 SUMMARY AND CONCLUSIONS

The DuraMelter™ 1000 has been successfully operated to demonstrate the vitrification of Hanford LLW simulant. The objectives detailed in the test plan were met during the two stages of the test, turnover and steady-state. The slurry feed system employed was suitable and reliable for the controllable transfer of a mixture of Hanford LLW simulant and chemical additives to the melter. The feed rate that was achieved and sustained was nearly twice that originally planned. An excellent material mass balance was achieved for the steady-state run which shows minimal carry over from the melter.

Table 5.2.a
Run Chronology for DuraMelter™ 1000 Steady State Run (9 sheets)

Date/ Time	Accumulated Time	Events
1-17-1995		
1200		White sump filter was back washed with 30 gallons of city water; sample was taken
		The filter was opened up and cleaned. Filter was covered with brown reddish color coating on the top of DE over the filter.
		Cleaning done on the other sump filter too.
1645		Bag House #1 exchanged for new filters
		First layer of HEPA filter changed
		2 kg of DE introduced into Bag House #1
1-18-1995		
1100		3 fuses were blown in the discharge fuse panel. They were replaced and the discharge chamber was made operational.
1500		There were 12" leftover in feed tank.
		Batch #8 was prepared in the mixing tank and transferred to the feed tank.
		After transfer the level in the feed tank was 59.5"
		The scrubber was rinsed and wet vacuumed to pick up sediments then filled with DI H_2O.
		Bag house #2 was reconditioned.
		DE samples were taken from Bag house #1 and #2.
		Samples were archived from the end of the previous run.
1-19--1995		
0600		Prepared system for start.
0700		Started feeding as scheduled.
0707		Feed level in the feed tank was 59.0"
		Feed setting in pump=4.0 /each. Pump dial - setting at 4 (40% of full range)
0710	0	Started recording of Electric Data
0724	14	Feed rate was 1.8 l/min, cold cap was forming, approximately 50%
0740	30	Enerac was switched before baghouse, NO_x = 32 ppm.
750	40	Linear velocity in the duct (6"OD) after dilution was 2900 L/FPM. (before dilution)
		Counted to SCFM was 470 SCFM. Converted to SCFM
0803	53	Enerac was switched back to the Post HEPA location NO_x=17 ppm.

Date/ Time	Accumulated Time	Events
0815	65	0.5 Gal NaOH 50% added to scrubber (pH from 12.4 to 14.06)
0845	95	Note: At the back of the melter over the glass pool, small occasional flames observed, Organic combustion?
0855	105	NO_x=7 ppm in the stack.
0856	106	0.5 Gal 50% NaOH added
0930	140	0.25 Gal 50% NaOH added.
0945	155	Feed tank level - 48.5 in , feed rate=2.02 lit/min.
1000	170	Discharged glass.
		Transferred 5 cm from sump scrubber to blowdown.
1025	185	0.75 Gal 50% NaOH added to scrubber
1026	186	Enerac was switched to stack position.
1045	205	Feed tank level - 45.0 in., Feed rate = 1.77 lit/min.
1055	215	Transferred 4 cm from scrubber to blowdown
1100	220	0.5 Gal 50% NaOH transferred.
1134	254	Enerac switched to duct from the stack. (Post HEPA filter)
		NO_x readings were high.
1137	257	Enerac switched back to stack.
1140	260	Feed level in the tank was 42.0" , Feed rate=1.66 lit/min.
1201	281	Transferred 4.5 cm from scrubber to blowdown.
1150	270	0.5 Gal 50% NaOH added to scrubber.
1210	290	Briefly disconnected Enerac Probe.
		Enerac was back in the stack.
1215	295	Discharged glass.
1220	300	0.5 Gal of 50% NaOH was added to the scrubber.
1250	330	Feed level 38.5".
1255	335	0.5 gal 50% NaOH added.
1315	355	Scrubber sample taken. 5 cm solution transferred to blowdown tank, 0.5 Gal 50% NaOH added.
1350	390	Discharged glass, HAN-89A net wt.424.6 kg
1352	392	Feed tank level - 35.5", Feed rate=1.47 lit/min.
		setting on the feed pumps increased to 4.3/each. Dial setting at 43%
1355	395	0.5 Gal of 50% NaOH added to the scrubber.

Date/ Time	Accumulated Time	Events
1428	428	Transferred 4.5 cm from scrubber to blowdown.
1430	430	1 Gal of 50% NaOH added to the scrubber.
1445	445	NO_x measurement device was being adjusted.
		Reading at this time was not valid until further notice.
1500	460	Discharged glass.
1501	461	Feed tank leyel - 30.75 in. feed rate=2.09 lit/min.
1505	465	1 Gal of 50% NaOH added to scrubber.
1530	490	NO_x measurement device back in operation .
1535	495	4.5 cm transferred from scrubber to the blowdown.
1536	496	1.5 Gal of 50% NaOH was added to the scrubber.
1600	520	1 Gal of 50% NaOH was added to the scrubber.
1601	521	Feed tank level - 27 in. feed rate = 1.9 lit/min.
1610	530	Glass discharged.
1640	560	Scrubber sample taken, 5 cm of scrubber solution transferred to blowdown.
1647	567	Linear velocity before the baghouse was 2950 sfpm (6" duct).
1650	570	2 Gal of 50% NaOH was added to the scrubber.
1656	576	Feed tank level was 23.5" feed rate was 1.93 lit/min
1715	595	1 gal of 50% NaOH was added to the scrubber.
1730	610	Discharged the glass.
1802	642	Feed tank level - 20", feed rate was 1.61 lites/min
1820	660	0.5 Gal 50% NaOH transferred.
1830	670	Discharged glass for 2 min.
1845	685	0.6 Gal 50% NaOH was transferred.
1850	690	5 cm solution transferred from scrubber to blowdown.
1900	700	Started to discharge glass in a new drum.
1910	710	0.8 Gal 50% NaOH was transferred
1924	724	Feed tank level - 16", feed rate was 1.52 lit/min.
1943	743	Completed transfer, feed tank depth was 53", mix tank depth 10.5" at end.
1950	750	5.0 cm solution was transferred from scrubber to blowdown.
1951	751	2.0 Gal 50% NaOH was transferred to reagent tank (or holding tank)
2020	780	Discharged glass.

Date/ Time	Accumulated Time	Events
2036	796	Feed tank level was 52".
2038	798	HCl=70 ppm NH_3=230 ppm. Post HEPA
2040	800	1.5 Gal 50% NaOH was transferred
2109	829	HCl=60 ppm NH_3=230 ppm. Post HEPA
2120	840	5.0 cm solution was transferred from scrubber to blowdown.
2140	860	HCl=70 cm NH_3=230 ppm. Post HEPA
		1.0 Gal 50% NaOH solution was transferred.
2200	880	HCl=30 PPM NH_3=170 PPM CO=35 PPM SO_2=0 NO=247 PPM Post HEPA
		Cold Cap =80% Tplean=672 Tblow=Tc=1137 power 61/69 Plenum Temp. TC3 = 672°C Glass Temp. TC5 = 1137 Total power to electrodes 61 + 69 = 130 kV
2210	890	HCl=40 ppm NH_3=250 ppm. Post HEPA
2220	900	1 Gal 50% NaOH was transferred.
2230	910	Setting dial on both, feeding pumps put to 4.5" (or 45%), Feed tank depth or level was 47.25".
2234	914	HCl=80 ppm NH_3=240 ppm. Post HEPA
2240	920	Discharged glass.
2312	952	1.0 Gal 50% NaOH was transferred, 5 cm solution was transferred from scrubber to the blowdown.
2315	955	Blowdown level was 36" in both tank.
2322	962	Feed tank level was 43".
2325	965	HCl=70 ppm NH_3=110 ppm Post HEPA
2355	995	HCl=30 ppm NH_3=170 ppm Post HEPA
		1 Gal NaOH was transferred to scrubber sump
1-20-1995		
0030	1030	HCl=80 ppm NH_3=70 ppm Post HEPA
0035	1035	Transferred 1.5 Gal 50% NaOH.
0042	1042	Discharged glass HAN 93A, 432.8 kg.
0043	1043	Transferred 5 cm solution from scrubber to blowdown
0100	1060	HCl=50 ppm NH_3=80 ppm Post HEPA
0125	1085	Increased recirculation rate slightly.
0130	1090	HCl=60 ppm NH_3=80 ppm Post HEPA
0135	1095	Transferred 1.2 Gal 50% NaOH.

Date/ Time	Accumulated Time	Events
0200	1120	HCl=50 ppm NH_3=0 Post HEPA
0235	1155	HCl=30 ppm NH_3+80 ppm . Post HEPA
0236	1156	Transferred 4.5 cm solution from scrubber to the blowdown.
0240	1160	Transferred 1.0 Gal 50% NaOH
0255	1175	HCl=80 ppm NH_3=0 Post HEPA
0306	1186	Feed pump #2 was secured at 1:25. Feed pump #1 dial setting was increased to 5.5 (55%), Feed line 2 which had been shut down since 1:25 was turned back on. Pump dial setting at 4.5 for both pumps.
0320	1200	Discharged glass
0325	1205	Transferred 1 Gal 50% NaOH to scrubber sump.
0335	1215	HCl=20 ppm NH_3=0 Post HEPA
0343	1223	Bag house 1 had 7" p changed to bag house 2.
0348	1228	Transferred 5.0 cm solution from scrubber to blowdown.
0430	1270	Changed to bag house 1 p=5.8"
		Transferred 1 Gal 50% NaOH.
0435	1275	HCl=20 ppm NH_3=0 CO=31.8 PPM SO_2=0 NO=134.0 PPM NO_2=11.0 PPM NO_x=159.0 ppm Post HEPA
0440	1280	Changed to bag house #2.
445	1285	Started to prepare a new screw feeder for feed line #2. Electric motor driver was replaced.
		Feed pump was off from 4:20 to 4:45
0455	1295	Discharged glass.
0505	1305	Transferred 5.0 cm solution from scrubber to blowdown.
0515	1315	Scrubber recirculation pump #1 stopped working, changed to recirculation pump #2.
0530	1330	Discharged glass .
0600	1360	Discharged glass HAN93B, 455 kg.
0640	1380	Transferred 1 Gal 50% NaOH, transferred solution from scrubber to blowdown.
0715	1415	Transferred 0.75 gal NaOH to scrubber sump.
0820	1480	Feed tank level in the tank was 19" .
0830	1490	Transferred 5 cm solution from scrubber to blowdown.
0835	1495	Transferred 1.5 Gal 50% NaOH.
		Feeder #2 was changed to a back up system that belongs to DuraMelter 10. D-10 screw feeder drive was used for feed line #2.

Date/ Time	Accumulated Time	Events
		At about 0630 coupling of the feeder #1 broke, and feeding from pump #1 was stopped.
		Feed rate was increased in line #2. to compensate for line #1, setting was at 6.5 on pump #2. coupling was fixed and line #1 was activated at 0720.
		Feed rates on both pumps were set at 4.5/each. Dial setting - 5.
0840	1500	Started to transfer feed from the mixing tank to the feed tank.
		Level of the mixing tank : before transfer =56.5"
0845	1505	Bag house #1 was activated, #2 was secured.
0850	1510	Feed tank level - 53.5"
0900	1520	22" was left in the mixing tank after transfer.
0930	1550	Discharged glass
0940	1560	Transferred 5 cm solution from scrubber to blowdown.
0945	1565	The feed tank level - 50.25", feed rate was 1.79 lit/min .
0950	1570	Enerac was in the duct before HEPA filter.
		Notes: NO_x readings in the stack were low (60-80 ppm).
		Transferred 1.25 Gal 50% NaOH
1000	1580	The velocity in the duct(6") before the baghouse was 2900 SFPM, melter obsolete pressure i
1002	1582	Flexible shaft coupling line 1 to the DC motor got loose again.
		Emergency Vent (EV) was activated around 10:00 AM.
1010	1590	EV activated, recovered
1035	1615	Transferred 1 Gal 50% NaOH
1038	1618	Feed augers were jammed, cleaned and reactivated, feeding was stopped for about 8 minutes.
1050	1630	Transferred 5 cm solution from scrubber to blowdown.
1115	1655	Feed tank level was 45.5", feed rate was 1.60 lit/min.
1130	1670	Both screw feeders were replaced, feeding stop for 10 min.
1205	1705	Blowdown tank was drained.
		Transferred 3.5 Gal of 50% NaOH.
1207	1707	Transferred 5 cm solution from scrubber to blowdown.
1229	1729	Feed tank level - 41.25" feed rate was 1.75 lit/min.
1230	1730	Screw feeder repaired.
1245	1745	Discharged glass

Date/ Time	Accumulated Time	Events
1330	1790	Feed pump #1 stopped for 5 min to inspect the feed tube angle.
1340	1800	Feed tank level - 39", feed rate was 0.96 lit/min
1400	1820	Transferred 5 cm solution from scrubber to blowdown.
1405	1825	Quencher inlet sprayed for 4 min DP of the film cooler and Quencher both dropped.
1415	1835	Transferred 1.5 Gal 50% NaOH.
1440	1860	Feed tank level - 37.5". feed rate was 0.76 lit/min.
1500	1880	Feed stopped
1520	1900	Discharged glass
1540	1920	Transferred remaining feed to feed tank,
1600	1940	Feed tank level before transfer was 36.5 in..
1610	1950	Feed tank level after transfer =53".
1620	1960	Transferred 3.5 Gal 50% NaOH.
1640	1980	Transferred 5 cm solution from scrubber to blowdown.
1700	2000	Started to discharge glass, bag house 1 secured, 2 activated, resumed feeding
1705	2005	Enerac was in the stack of bag house #2
		Notes: Film cooler was inspected, deposit build up near the end in the plenum, deposits were dislodged backing to the melter.
		Feed augers were pulled out, repaired, new end plugs were used to reassemble them.
		New coupling were used to connect flex shafts vs the DC drivers.
1740	2040	Feed mixing tank level - 3".
		Feed tank level - 51.5", feed rate was 1.14 lit/min .
1742	2042	Feed pump setting was set st 4.5/ea. Dial setting.
1837	2097	Feed tank level - 38.5".
1855	2115	Transferred 4.5 cm solution from scrubber to the blowdown.
1904	2124	Feed tank level was 46.5", feed rate was 1.82 lit/min .
1925	2145	Added 1 Gal 50% NaOH to the scrubber.
1945	2165	Discharged glass.
2000	2180	Feed tank level - 43.5" .
2030	2210	Added 1 Gal 50% NaOH to the scrubber.
2045	2225	Discharged glass. HAN99A, 420.3 kg.
2100	2240	Feed rate at 5.0 in scale. Dial setting.

Date/ Time	Accumulated Time	Events
2130	2270	Added 1 Gal 50% NaOH to the scrubber.
		Total feed level used so far was 159"(4849.5 lit). total glass made was 3900 kg, so 0.804 kg/lit. Glass to feed conversion is 0.8041 g/lit
2212	2312	Large cold cap was thick,"hot region as a continuous region across "Ts=1107(glass top) 1107°C plenum T6=701 C.
2225	2325	New drum placed under discharge chamber.
2230	2330	Discharged glass.
2235	2335	Added 1 Gal 50% NaOH to the scrubber.
2301	2361	Discharged glass, cold cap was 98%, Plenum temp. TC6 - 638°C.
		CO=58 ppm NO=573 ppm NO2=224 ppm NO_x=799 ppm.
2330	2390	Feed tank level - 32.25".
2335	2395	Transferred 6 cm solution from scrubber to blowdown.
1-21-1995		
0025	2445	Discharged glass.
0045	2465	Transferred 4.5 cm solution from scrubber to blowdown.
0100	2480	System had a very stable process rate at 1.77 lit/min (2549 lit/day or 2049 kg/day), electrode power at 54 kw/58 kw or 2688 kwh/day so electrode's power consumption is at 1.31 kwh/kg of glass.
0155	2535	Discharged glass HAN99B 405.5 kg.
0205	2545	Transferred 4.5 cm solution from the scrubber to the blowdown .
0230	2570	Discharged the glass to the new barrel
0310	2610	Transferred 5 cm solution from the scrubber to the blowdown.
		Discharged glass.
0322	2622	Stable condition with feed rate = 2.07 lit/min .
0340	2640	Added 1 Gal 50% NaOH to the scrubber.
0405	2665	Discharged glass.
0445	2705	Added 1 Gal 50%NaOH to scrubber.
0450	2710	35" drained from blowdown tank.
0535	2755	Discharged glass
0545	2765	Transferred 5 cm solution from scrubber to blowdown tank
0615	2795	Glass sample was taken.
0626	2806	Feed tank level - 7.75", feed rate was 1.62/min.
0640	2820	Added 0.6 Gal 50% NaOH.

Date/ Time	Accumulated Time	Events
0710	2850	HAN-100A, 443.5 kg.
		Transferred 5 cm solution from scrubber to the blowdown.
0712	2852	Added 1 Gal 50% NaOH.
0733	2873	Feed tank level - 3.5".
0734	2874	Discharged glass, feed rate was 1.93 lit/min .
0750	2890	Added 1.5 Gal 50% NaOH.
0800	2900	Feeding stopped.
		Recirculation pump started to cavitate, feed level before stopping the pump was 2.5" at 0750, feed rate was 1.8 Lit/min.
0810	2910	Approximately 35-40 gallons of RO water was pumped to recirculation lines, cleaned all lines.
		Water was collected in the feed tank.
		Scrubber sump filter was not changed or backwashed during the steady state run.
		Initial scrubber sump filter pressure was 10-12 psi and at the end of run was increased to only 16 psi.
0855	2955	Discharged glass, HAN-101A.
0950	3010	The cold cap was dissolved, system prepared for idle mode.
		Electrode power was set at 20 kw/ea plenum and discharge heater are secured.
		Glass sample, scrubber sump sample, bag house #2, DE sample, sump filter DE sample were taken at the end of cold cap dissolve in the glass.
1050	3070	9" of liquid in both blowdown tanks were drained.
1100	3080	System was idle, bag house #1 was on, all samples were taken.
1-23-1995		
1420	4722	The level of glass in the melter was measured, it was 29.5", above this mark , there was 3'' of yellow material, the sample was taken.
		Operation checklist copies are attached to page 149-156
		Enerac readings (printout) are pages 137-147.

Table 5.3.a
DuraMelter™ 1000 Feed Batches

	Amount of Simulant used in batching (kg)					Glass
Feed Batch#	Drum A	Drum B	Drum C	Drum D	Total	Target (kg)
1	282	282	150		714	820
2	282	282	282	282	1130	1300
3	282	282	282	282	1130	1300
4	282	282	282	282	1130	1300
5	282	282	282	282	1130	1300
6	282	282	282	282	1130	1300
7	282	282	[illegible]		735	840
TURNOVER REACHED for melter initial level = 1.7 tons						
8	282	282	282	282	1130	1300
9	282	282	282	282	1130	1300
10	282	282	282	282	1130	1300

NOTES:

During this campaign, a total of 37 drums (55 gallons) of LLW simulant were used.
The DSSF simulant was prepared in two different batches at Optima.
The first batch (of which we received 13 drums) is marked in white cells.
The second batch (of which we received 24 drums) is shaded in grey.
Some of the drums of the second batch contained significantly more precipitated material than the others; those are marked by dashed outline of the cells.
Each feed batch prepared used up to 4 drums of simulant (Drums A through D) in addition to the chemical additives.

Table 5.3.b
Slurry Feed Characteristics

(1) Oxide Waste Loading (nominal* without urea)	25 wt%
(2) Total Solids Content (nominal* without urea)	70 wt%
(3) Total Oxides Content (nominal* without urea)	57.5 wt%
(4) Density before Urea Addition (measured at VSL)	~1.75 g cm^{-3}
(5) Oxide Yield (calculated from (3) and (4))	994 g/l
(6) Urea Content (steady state)	66 g/l (250 g/gal)
(7) Volume Increase on Addition of Urea and Water (measured at VSL)	18%
(8) Volume of Feed per kg of Glass (calculated from (3), (4), and (7))	1.17 l/kg
(9) Feed Density (with urea and water) Measured at WHC	1.82 to 1.89 g cm^{-3}

* Nominal values were calculated from the proportions and characteristics of the simulant and additives

† It was not possible to calculate a density of this feed as was done for the 100 kg run because the amount of water added when flushing lines etc. is not known.

Table 5.5a
Sampling Schedule from DuraMelter™ 1000 Hanford Turnover Run

Date	Time	Feed	Glass	Chemicals/ RO Water	Bag House
12-13-94	1300	D2F3-101	D1G4-101		
	1700			D1S2-101,D1S2-102, D1S2-103,D1S2-104, D1S2-105,D1S2-106, D1S2-108	
12-14-94	1600			D1S2-109	
	2200	D1F3-102			
12-17-94	1620	D1F3-103			
12-18-94	2120	D1F3-104			
12-19-94	1300			D1S2-110	
	1600				D1O7-100 (blank DE)
	510	D1F3-105			
	1703	D1F3-106			
12-20-94	900	D1F3-107	D1G4-102		
	1526		D1G4-103		
	1800		D1G4-104		
1-12-95	1820	D1F3-108			
	2110		D1G4-105		
1-13-95	1230	D1F3-109			
1-14-95	125	D1F3-110			
	1145		D1G4-106		

Table 5.5b
Sampling Schedule from DuraMelter™ 1000 Steady State Run (3 sheets)

Date/ Time	Run Time	Glass	Feed	Scrubber	Bag House/Filter Cake/Backwash	Simulant
1-18-95	1500					D1S1-101
1-19-95						
710	0	D1G4-107	D1F3-111	D106-101		
1000	170			D106-102		
1055	225			D106-103		
1201	291			D106-104		
1208	298			D106-105		
1315	365			D106-106		
1350	400	D1G4-108		D106-107		
1428	438			D106-108		
1535	505			D106-109		
1635	565			D106-110		
1725	615			D106-111		
1735	625			D106-112		
1850	700			D106-113		
1950	760			D106-114		
2000	770	D1G4-109		D106-115		
2100	830			D106-116		D1S1-102
2120	850			D106-117		
2200	890		D1F3-112			
2245	935			D106-118		
2315	965			D106-119		
2330	980	D1G4-110		D106-120		
1-20-95						
43	1053			D106-121		

Date/ Time	Run Time	Glass	Feed	Scrubber	Bag House/Filter Cake/Backwash	Simulant
236	1166			D106-122		
340	1230			D106-123		
420	1270				D1O7-101	
503	1313			D106-124		
530	1340	D1G4-111				
629	1399			D106-125		
830	1520			D106-126		
900	1550		D1F3-113			
940	1590			D106-127		
1050	1660			D106-128		
1135	1705			D106-129		
1145	1715	D1G4-112				
1205	1735			D106-130		
1207	1737			D106-131		
1400	1850			D106-132		
1500	1910					D1S1-103
1630	2000			D106-133		
1730	2060	D1G4-113	D1F3-114		D1O7-102	
1850	2140			D106-134		
2015	2225			D106-135		
2200	2270			D106-136		
2335	2365			D106-137		
2345	2375	D1G4-114				
1-21-95						
45	2435			D106-138		
200	2510			D106-139		
305	2575			D106-140		

Date/ Time	Run Time	Glass	Feed	Scrubber	Bag House/Filter Cake/Backwash	Simulant
410	2640			D106-141		
435	2665			D106-142		
450	2680			D106-143		
545	2735			D106-144		
615	2765	D1G4-115		D106-145		
705	2815			D106-146		
755	2865			D106-147		
810	2880	D1G4-116				
1030	3020			D1O6-148	D1O7-103, D1O9-101	
1050	3040					
1-23-95						
1530	4760				D1O10-101	

Table 5.7a
DuraMelter™ 1000 Operational Data for Hanford Steady State Run

Date	Time	Temperature (°C)				Abs. Pressure (inches water)	Cold Cap (%)	Bubbler (cfh)
		Glass	Plenum	Discharge	Melter Exhaust Air			
1/19/95	0700	1069	984	1066	230	-1.2	0	100
	0800	1108	864	1088	414	-1.8	80	100
	0920	1126	799	1062	359	-2.2	85	100
	1010	1119	777	1091	556	-1.6	85	100
	1110	1115	724	1111	541	-1.4	90	100
	1300	1131	702	1089	390	-2.2	95	120
	1430	1124	689	1099	451	-2.0	90	120
	1530	1115	670	1093	469	-2.0	90	80
	1705	1097	662	1094	426	-1.8	75	120
	1910	1121	696	1098	393	-2.0	80	120
	2010	1142	716	971	345	-2.5	75	120
	2200	1136	695	997	386	-2.5	90	120
	2335	1131	733	977	488	-1.8	70	120
1/20/95	0158	1139	710	974	480	-3.1	80	NA
	0415	1109	724	1047	468	-2.5	80	120
	0645	1117	765	1039	474	-1.6	80	120
	0835	1120	765	1055	491	-1.8	80	140
	0945	1109	746	1103	512	-2.6	90	140
	1105	1116	740	1164	481	-2.0	90	140
	1300	1116	702	1146	532	-3.0	80	140
	1700	1136	893	1118	343	-2.0	NA	120
	1815	1132	825	997	574	-2.0	70	120
	2130	1102	747	1035	558	-2.2	80	120
	2310	1098	643	1110	462	-2.0	99	160
1/21/95	0100	1109	702	1084	447	-2.4	90	170
	0300	1109	714	1082	471	-2.6	85	170
	0500	1097	672	1076	433	-3.2	90	170
	0635	1101	697	1088	445	-3.0	80	170
	0820	1116	686	1081	403	-2.8	70	170
Avg.		1116	739	1070	449	-2.2	80	128
Range		1069-1142	662-984	974-1164	230-574	-1.2- -3.2	0-99	100-170

NA = Not Available

Table 5.7.b
DuraMelter™ 1000 Off-Gas Operational Data for Hanford Steady State Run

Date	Time	Scrubber			Baghouse Diff. Pressure (inches water)
		Temp. (°C)	Diff. Pressure (inches water)	Spray recirc. flow (gal/min)	
1/19/95	0700	21	1.0	2.1	2.8 (1)*
	0800	21	1.2	2.1	3.3 (1)
	0920	22	1.2	2.1	3.5 (1)
	1010	22	1.2	2.1	3.6 (1)
	1110	23	1.5	2.1	3.8 (1)
	1300	22	2.0	2.1	4.0 (1)
	1430	23	2.0	2.1	4.2 (1)
	1530	23	2.0	2.1	4.2 (1)
	1705	23	2.0	2.1	4.3 (1)
	1910	21	2.0	2.1	4.3 (1)
	2010	21	2.3	2.1	4.4 (1)
	2200	22	2.2	2.1	5.0 (1)
	2335	21	2.0	2.1	4.6 (1)
1/20/95	0158	19	2.0	2.2	NA
	0415	20	2.0	2.2	3.2 (2)
	0645	20	2.0	2.2	3.2 (2)
	0835	20	2.0	2.2	3.8 (1)
	0945	22	2.0	2.2	5.0 (1)
	1105	23	2.0	2.0	5.3 (1)
	1300	24	3.0	2.0	5.9 (1)
	1700	21	2.0	2.0	2.8 (2)
	1815	21	2.0	2.1	3.5 (2)
	2130	21	2.5	1.8	3.8 (2)
	2310	20	2.0	2.0	4.0 (2)
1/21/95	0100	20	2.0	1.8	4.2 (2)
	0300	22	2.0	2.0	5.0 (2)
	0500	21	2.5	1.8	5.5 (2)
	0635	22	2.8	1.8	5.4 (2)
	0820	21	2.6	1.8	5.6 (2)
Avg.		21	2.0	2.1	4.2
Range		19-24	1.0-3.0	1.8-2.2	2.8-5.9

NA = Not Available
*(#) - denotes which baghouse was used

Table 5.7c
Post HEPA Off-Gas data from DuraMelter™ 1000 Steady-State Run (ppmv) (4 sheets)

Time	Run Time	Date	CO	SO_2	NO_X	NO	NO_2
07:10:00	0	01/19/95					
07:26:06	16	01/19/95	0	3	27	22	5
07:56:16	46	01/19/95	6	0	289	257	27
08:06:22	56	01/19/95	8	0	47	38	11
08:16:37	66	01/19/95	0	0	12	12	0
08:26:40	76	01/19/95	3	1	16	13	4
08:36:43	86	01/19/95	30	3	51	44	9
08:46:44	96	01/19/95	0	0	54	54	2
10:27:26	197.5	01/19/95	29	5	46	47	0
10:37:26	207.5	01/19/95	21	7	32	32	0
10:47:28	217.5	01/19/95	30	2	106	104	0
10:57:30	227.5	01/19/95	36	9	75	75	0
11:07:34	237.5	01/19/95	29	0	297	259	39
11:17:37	247.5	01/19/95	36	0	424	354	76
11:37:45	267.5	01/19/95	24	0	607	638	147
11:47:48	277.5	01/19/95	29	0	349	290	65
11:57:51	287.5	01/19/95	44	0	394	327	65
12:26:52	1756.5	01/20/95	71	0	623	499	128
12:36:57	1766.5	01/20/95	33	0	271	239	33
12:47:02	1776.5	01/20/95	47	0	117	110	6
12:57:07	1786.5	01/20/95	42	0	364	318	48
13:07:12	1796.5	01/20/95	52	0	339	295	45
13:17:17	1806.5	01/20/95	51	0	344	298	49
13:27:22	1816.5	01/20/95	28	0	46	45	0
13:37:27	1826.5	01/20/95	26	0	413	357	55

Time	Run Time	Date	CO	SO_2	NO_X	NO	NO_2
13:47:31	1836.5	01/20/95	29	0	83	81	0
13:57:36	1846.5	01/20/95	39	0	327	288	41
14:07:41	1856.5	01/20/95	32	0	717	572	142
14:17:46	1866.5	01/20/95	23	0	65	65	3
14:27:50	1876.5	01/20/95	23	0	58	56	0
14:37:56	1886.5	01/20/95	22	0	345	308	38
14:48:00	1896.5	01/20/95	20	0	369	328	37
14:58:05	1906.5	01/20/95	28	0	N.A.	N.A.	N.A.
15:08:10	1916.5	01/20/95	26	0	N.A.	N.A.	N.A.
15:18:16	1926.5	01/20/95	44	0	N.A.	N.A.	N.A.
15:28:24	1936.5	01/20/95	48	0	N.A.	N.A.	N.A.
15:38:32	1946.5	01/20/95	26	0	N.A.	N.A.	N.A.
15:48:37	1956.5	01/20/95	12	0	237	196	41
15:58:42	1966.5	01/20/95	36	0	1041	749	294
16:08:47	1976.5	01/20/95	19	0	409	341	68
19:19:29	2167	01/20/95	13	0	112	100	9
19:49:51	2197.5	01/20/95	20	0	56	55	1
19:59:57	2207.5	01/20/95	24	0	114	101	14
20:10:01	2217.5	01/20/95	18	0	206	183	24
20:40:17	2247.5	01/20/95	19	0	15	16	0
20:50:21	2257.5	01/20/95	22	0	286	248	39
21:00:26	2267.5	01/20/95	27	0	32	32	0
21:10:31	2277.5	01/20/95	27	0	84	79	6
21:20:36	2287.5	01/20/95	63	0	199	171	32
21:30:41	2297.5	01/20/95	34	0	458	372	89
21:40:46	2307.5	01/20/95	34	0	69	65	5
21:50:50	2317.5	01/20/95	29	0	236	207	30

Time	Run Time	Date	CO	SO_2	NO_X	NO	NO_2
22:00:55	2327.5	01/20/95	32	0	65	62	3
22:11:00	2337.5	01/20/95	41	0	98	91	7
22:21:05	2347.5	01/20/95	52	0	36	36	0
22:31:09	2357.5	01/20/95	68	0	239	207	31
22:41:14	2367.5	01/20/95	28	0	279	236	44
22:51:19	2377.5	01/20/95	92	0	707	524	189
23:01:24	2387.5	01/20/95	58	0	797	574	224
23:11:28	2397.5	01/20/95	57	0	828	588	239
23:21:35	2407.5	01/20/95	69	0	1148	769	381
23:31:40	2417.5	01/20/95	44	0	571	437	136
23:41:46	2427.5	01/20/95	48	0	535	651	127
23:51:51	2437.5	01/20/95	51	0	749	558	191
00:01:56	2447.5	01/21/95	68	0	813	604	208
00:22:04	2467.5	01/21/95	63	0	687	551	205
00:32:08	2477.5	01/21/95	142	31	707	670	208
00:42:13	2487.5	01/21/95	82	3	898	648	247
00:52:18	2497.5	01/21/95	94	0	728	552	170
01:02:23	2507.5	01/21/95	67	0	892	649	244
01:12:28	2517.5	01/21/95	61	0	944	678	265
01:22:33	2527.5	01/21/95	116	0	662	501	172
01:32:38	2537.5	01/21/95	73	0	897	655	243
01:42:46	2547.5	01/21/95	58	0	1117	786	331
01:52:51	2557.5	01/21/95	38	0	682	534	146
02:02:58	2567.5	01/21/95	59	0	1003	721	288
02:13:03	2577.5	01/21/95	75	0	828	623	205
02:23:09	2587.5	01/21/95	90	0	987	723	256
02:33:14	2597.5	01/21/95	78	0	732	566	162

Time	Run Time	Date	CO	SO_2	NO_X	NO	NO_2
02:43:20	2607.5	01/21/95	91	0	1000	705	301
02:53:24	2617.5	01/21/95	37	0	455	377	80
03:03:30	2627.5	01/21/95	69	0	530	412	115
03:13:36	2637.5	01/21/95	39	0	755	580	174
03:23:41	2647.5	01/21/95	40	0	408	339	67
03:33:46	2657.5	01/21/95	75	1	744	529	229
03:43:51	2667.5	01/21/95	30	0	291	255	34
03:53:56	2677.5	01/21/95	38	0	198	176	20
04:04:02	2687.5	01/21/95	43	0	432	354	78
04:14:06	2697.5	01/21/95	138	0	996	746	245
04:24:12	2707.5	01/21/95	57	0	618	487	134
05:15:15	2758.5	01/21/95	79	24	851	560	292
05:25:20	2768.5	01/21/95	68	5	644	457	186
05:35:25	2778.5	01/21/95	56	5	951	621	330
05:45:30	2788.5	01/21/95	47	0	777	517	260
10:48:20	3091.5	01/21/95	8	0	37	37	0
Average			50	1	472	365	114

Table 5.7d
Pre-HEPA Off-Gas Data from DuraMelter™ 1000 Steady-State Run (ppmv) (6 sheets)

TIME	Accum. Time	DATE	CO	SO_2	NO_X	NO	NO_2
07:10:06	0						
07:35:43	25	01/19/95	0	1	86	70	2
07:36:07	26	01/19/95	2	0	236	212	9
07:46:13	36	01/19/95	5	0	192	155	42
08:56:45	106	01/19/95	81	0	52	44	8
09:06:48	116	01/19/95	149	0	258	244	19
09:16:51	126	01/19/95	121	0	53	48	5
09:26:55	136	01/19/95	167	3	158	119	7
09:36:58	146	01/19/95	81	0	214	218	17
09:47:06	156	01/19/95	500	32	1478	934	603
09:57:09	166	01/19/95	119	0	969	757	212
10:07:13	177	01/19/95	142	0	658	536	131
10:17:25	187	01/19/95	145	0	330	298	39
10:20:07	189.5	01/19/95	200	0	215	203	15
11:27:42	257.2	01/19/95	89	111	2342	1558	765
12:07:54	297.2	01/19/95	42	0	650	507	142
12:18:00	307.2	01/19/95	73	0	979	687	298
12:28:03	317.2	01/19/95	19	0	643	497	145
12:38:11	327.2	01/19/95	24	0	690	524	165
12:48:14	337.2	01/19/95	30	0	682	526	154
12:58:18	347.2	01/19/95	26	0	449	368	87
13:08:28	357.2	01/19/95	31	0	687	533	152
13:18:31	367.2	01/19/95	43	0	516	421	95
13:28:34	377.2	01/19/95	43	0	446	371	73
13:38:37	387.2	01/19/95	36	0	286	250	36
13:48:41	397.2	01/19/95	39	0	577	465	107
13:58:44	407.2	01/19/95	44	0	808	611	196
14:08:54	417.2	01/19/95	54	0	746	566	181

TIME	Accum. Time	DATE	CO	SO_2	NO_X	NO	NO_2
14:18:58	427.2	01/19/95	74	0	1028	736	292
14:28:59	437.2	01/19/95	49	0	947	698	245
14:39:06	447.2	01/19/95	57	0	1148	801	349
15:49:49	517.2	01/19/95	64	0	1264	871	394
15:59:56	527.2	01/19/95	60	0	1095	777	320
16:10:04	537.2	01/19/95	70	0	1034	744	291
16:20:07	547.2	01/19/95	85	0	1202	856	344
16:30:16	557.2	01/19/95	72	39	1480	1011	470
16:43:08	570.2	01/19/95	71	138	1618	1089	530
16:53:18	580.2	01/19/95	80	105	1224	851	376
17:03:25	590.2	01/19/95	84	75	1190	848	343
17:13:34	600.2	01/19/95	84	172	1882	1287	588
17:23:41	610.2	01/19/95	88	101	1373	949	423
17:33:49	620.2	01/19/95	89	123	1730	1173	503
17:43:58	630.2	01/19/95	85	99	1142	861	326
17:54:05	640.2	01/19/95	72	70	1213	868	348
18:04:11	650.2	01/19/95	47	34	1017	749	267
18:14:19	660.2	01/19/95	41	26	1025	748	279
18:24:24	670.2	01/19/95	47	34	1140	824	317
18:34:32	680.2	01/19/95	87	50	1280	902	382
18:44:39	690.2	01/19/95	58	37	1147	828	317
18:54:47	700.2	01/19/95	72	39	1063	773	290
19:04:57	710.2	01/19/95	72	155	1078	1039	292
19:15:06	720.2	01/19/95	47	96	1239	885	354
19:25:13	730.2	01/19/95	61	100	1471	1045	426
19:35:23	740.2	01/19/95	185	252	2252	1459	809
19:45:32	750.2	01/19/95	109	174	1655	1129	529
19:55:40	760.2	01/19/95	45	93	1292	949	343
20:05:43	770.2	01/19/95	44	32	879	681	200
20:15:46	780.2	01/19/95	72	1	654	525	133

TIME	Accum. Time	DATE	CO	SO_2	NO_X	NO	NO_2
20:25:49	790.2	01/19/95	42	0	806	635	169
20:35:56	800.2	01/19/95	35	0	858	673	182
20:46:03	810.2	01/19/95	27	0	819	642	176
20:56:03	820.2	01/19/95	28	0	1037	782	253
21:06:06	830.2	01/19/95	25	0	691	553	139
21:16:10	840.2	01/19/95	24	0	710	568	141
21:26:14	850.2	01/19/95	31	0	585	471	119
21:36:23	860.2	01/19/95	81	0	720	565	164
21:46:26	870.2	01/19/95	43	0	439	374	69
21:56:29	880.2	01/19/95	31	0	297	267	30
22:06:34	890.2	01/19/95	47	0	471	408	60
22:16:37	900.2	01/19/95	57	0	501	427	74
22:26:40	910.2	01/19/95	46	0	559	472	92
22:36:43	920.2	01/19/95	49	0	732	590	142
22:46:49	930.2	01/19/95	51	0	747	593	153
22:56:56	940.2	01/19/95	53	0	666	556	119
23:06:59	950.2	01/19/95	45	0	594	493	102
23:17:02	960.2	01/19/95	41	0	537	447	92
23:27:05	970.2	01/19/95	35	0	425	366	61
23:37:09	980.2	01/19/95	48	0	486	416	67
23:47:12	990.2	01/19/95	49	0	456	394	61
23:57:13	1000.2	01/19/95	90	0	1220	895	325
00:07:18	1010.2	01/20/95	69	0	962	730	236
00:17:25	1020.2	01/20/95	78	0	1128	840	288
00:27:35	1030.2	01/20/95	70	0	1012	763	251
00:37:39	1040.2	01/20/95	78	0	993	755	236
00:47:46	1050.2	01/20/95	45	0	678	545	135
00:57:49	1060.2	01/20/95	62	0	626	499	95
01:07:52	1070.2	01/20/95	49	0	1211	879	330
01:17:55	1080.2	01/20/95	37	0	896	688	211

TIME	Accum. Time	DATE	CO	SO_2	NO_X	NO	NO_2
01:27:59	1090.2	01/20/95	32	0	763	604	158
01:38:05	1100.2	01/20/95	37	0	959	727	230
01:48:08	1110.2	01/20/95	37	0	848	657	191
01:58:11	1120.2	01/20/95	29	0	750	596	152
02:08:14	1130.2	01/20/95	30	0	711	567	141
02:18:26	1140.2	01/20/95	34	0	350	286	73
02:28:35	1150.2	01/20/95	25	0	492	418	75
02:38:42	1160.2	01/20/95	29	0	534	433	107
02:48:43	1170.2	01/20/95	36	0	1008	766	244
02:58:49	1180.2	01/20/95	39	0	361	314	47
03:08:52	1190.2	01/20/95	21	0	226	206	22
03:18:55	1200.2	01/20/95	83	0	623	517	102
03:28:59	1210.2	01/20/95	34	0	259	240	18
03:39:04	1220.2	01/20/95	34	0	228	210	21
03:59:11	1250.2	01/20/95	11	1	92	80	19
04:29:21	1280.2	01/20/95	31	0	240	214	28
08:40:41	1531.2	01/20/95	6	0	43	34	9
08:50:44	1541.2	01/20/95	11	0	17	17	0
09:00:49	1551.2	01/20/95	17	0	93	90	7
09:10:53	1561.2	01/20/95	19	1	48	51	0
09:20:56	1571.2	01/20/95	19	0	67	67	0
09:30:59	1581.2	01/20/95	24	1	84	84	0
09:41:00	1591.2	01/20/95	78	0	657	566	77
09:55:51	1606	01/20/95	147	0	232	214	22
10:05:58	1616	01/20/95	90	0	218	1081	13
10:16:07	1626	01/20/95	90	0	919	803	201
10:26:12	1636	01/20/95	32	0	155	107	48
11:06:25	1676	01/20/95	62	0	309	262	37
11:16:28	1686	01/20/95	61	0	149	108	43
12:16:42	1746	01/20/95	19	0	171	158	8

TIME	Accum. Time	DATE	CO	SO_2	NO_X	NO	NO_2
17:05:38	2035	01/20/95	10	0	170	157	11
17:15:38	2045	01/20/95	13	0	257	224	31
17:25:39	2055	01/20/95	5	0	69	68	0
17:35:51	2065	01/20/95	8	0	100	94	5
18:28:53	2118	01/20/95	42	0	318	263	60
20:30:07	2239	01/20/95	68	0	174	141	33
00:11:59	2461	01/21/95	266	298	2196	1157	1030
05:55:34	2804.5	01/21/95	278	73	1645	892	758
06:05:42	2814.5	01/21/95	188	128	1220	668	557
06:15:50	2824.5	01/21/95	112	43	677	403	275
06:25:53	2834.5	01/21/95	163	79	977	554	421
06:36:03	2844.5	01/21/95	229	54	831	479	353
06:46:06	2854.5	01/21/95	231	69	909	521	388
06:56:09	2864.5	01/21/95	207	63	875	499	375
07:06:13	2874.5	01/21/95	183	42	775	445	330
07:16:15	2884.5	01/21/95	187	21	644	394	250
07:26:19	2894.5	01/21/95	175	0	516	318	199
07:36:22	2904.5	01/21/95	153	0	384	240	144
07:46:25	2914.5	01/21/95	164	0	343	216	127
07:56:28	2924.5	01/21/95	171	0	365	230	135
08:06:32	2934.5	01/21/95	170	0	423	261	162
08:16:35	2944.5	01/21/95	143	0	525	320	205
08:26:38	2954.5	01/21/95	118	0	534	322	211
08:36:41	2964.5	01/21/95	60	0	936	547	386
08:46:50	2974.5	01/21/95	45	379	990	1306	410
08:57:00	2984.5	01/21/95	35	595	N.A.	1553	N.A.
09:07:11	2994.5	01/21/95	44	615	N.A.	1645	N.A.
09:17:22	3004.5	01/21/95	72	690	2498	1487	1074
09:27:33	3014.5	01/21/95	66	579	2199	1298	940
09:37:43	3024.5	01/21/95	58	387	1864	1080	784

TIME	Accum. Time	DATE	CO	SO_2	NO_X	NO	NO_2
09:47:53	3034.5	01/21/95	53	244	1528	935	595
09:58:00	3044.5	01/21/95	47	106	1167	767	401
10:08:08	3054.5	01/21/95	30	0	475	412	62
10:18:11	3064.5	01/21/95	29	0	388	360	30
10:28:14	3074.5	01/21/95	15	0	135	137	0
10:38:17	3084.5	01/21/95	11	0	69	70	0
10:48:20	3094.5	01/21/95	8	0	37	37	0
Average			65	38	674	516	189

Table 5.7.e
Measured Off-Gas Emissions Data at Melter Outlet

	Vitreous State Lab	Parsons Engineering Science Inc.	
		Average of Tests	Range of 3 Tests
Moisture (%)	15.46	16.3	10.1 - 21.7
Stack Gas Volumetric Flow Rate (dscfm)	99	99	99
Sample Volume (dscf)	40.45	41.418	37.966 - 43.343
Particulate Matter			
Concentration (gr/dscf)	0.458	0.31	0.26 - 0.39
Emission Rate (lb/hr)	0.399	0.27	0.22 - 0.34
Boron			
Concentration (ug/dscf)	1054.7	721	551 - 924
Emission Rate (lb/hr)	1.38E-02	9.45E-03	7.21E-03 - 1.21E-02
Chromium			
Concentration (ug/dscf)	67.7	59.1	53.86 - 63.20
Emission Rate (lb/hr)	8.87E-04	7.73E-04	7.05E-04 - 8.28E-04
Cesium			
Concentration (ug/dscf)	885.5	937	781 - 1046
Emission Rate (lb/hr)	1.16E-02	1.2E-02	1.0E-02 - 1.4E-02
Molybdenum			
Concentration (ug/dscf)	99.1	55.74	50.38 - 58.55
Emission Rate (lb/hr)	1.30E-03	7.30E-04	6.60E-04 - 7.67E-04
Strontium			
Concentration (ug/dscf)	69.2	12.08	9.25 - 14.77
Emission Rate (lb/hr)	9.07E-04	1.58E-04	1.21E-04 - 1.93E-04
Potassium			
Concentration (ug/dscf)	2379	273	0 - 820
Emission Rate (lb/hr)	3.12E-02	3.6E-03	1.27E-02 - 2.49E-02
Sodium			
Concentration (ug/dscf)	4419	1764	1420 - 2328
Emission Rate (lb/hr)	5.79E-02	2.3E-02	2.0E-02 - 6.23E-02

Table 5.7.f
Measured Off-Gas Emissions Data at HEPA Filter Outlet

	Vitreous State Lab	Parsons Engineering Science Inc.	
		Average of Tests	Range of 3 Tests
Moisture (%)	1.4	1.2	1.0 - 1.4
O_2 (%)	20.5	20.7	20.7
Stack Gas Volumetric Flow Rate (acfm)	616	651	627 - 672
Stack Gas Volumetric Flow Rate (dscfm)	576	588	565 - 606
Isokinetic Ratio (%)	98.6	96.8	92.9 - 99.1
Sample Volume (dscf)	88.152	83.407	78.965 - 85.924
Particulate Matter Concentration (gr/dscf) Emission Rate (lb/hr)	0.000297 0.00146	< 0.00002 < 0.0002	< 0.00002 < 0.0002
Boron Concentration (ug/dscf) Emission Rate (lb/hr)	< 10.0 < 1.57E-04	< 10 < 8.9E-04	< 10 < 8.9E-04
Chromium Concentration (ug/dscf) Emission Rate (lb/hr)	< 10.0 < 1.57E-04	< 2.0 < 1.8E-04	< 2.0 < 1.8E-04
Cesium Concentration (ug/dscf) Emission Rate (lb/hr)	< 1.0 < 3.00E-05	< 2.0 < 1.8E-04	< 2.0 < 1.8E-04
Molybdenum Concentration (ug/dscf) Emission Rate (lb/hr)	< 1.0 < 3.00E-05	< 2.0 < 1.8E-04	< 2.0 < 1.8E-04
Strontium Concentration (ug/dscf) Emission Rate (lb/hr)	< 10.0 < 1.57E-04	< 2.0 < 1.8E-04	< 2.0 < 1.8E-04
Potassium Concentration (ug/dscf) Emission Rate (lb/hr)	< 10.0 < 1.57E-04	NA	NA
Sodium Concentration (ug/dscf) Emission Rate (lb/hr)	< 10.0 < 1.57E-04	< 10 < 8.9E-04	< 10 < 8.9E-04

NA - Not Available at this time.

Table 5.7.g
HCl and NH_3 Emissions from the DuraMelter™ 1000 Hanford Steady State Run

Date	Time	Concentration (ppm)	
		HCl	NH_3
1/19/95	2000	90	400
	2038	70	230
	2109	60	230
	2140	70	200
	2200	30	170
	2210	40	250
	2234	80	240
	2325	70	110
	2355	30	170
1/20/95	0030	80	70
	0100	50	80
	0130	60	80
	0200	50	< 1
	0235	30	80
	0255	80	< 1
	0335	20	< 1
	0435	20	< 1
Avg.		55	136
Range		20-90	< 1-400

Table 5.7.h
VSL Analysis of ES Sulfuric Acid Scrubbing Solutions

		Melter Exhaust	Mist Eliminator Exhaust	HEPA Filter Exhaust
Liters of Air through Sulfuric Scrubbing Solution		1512	1148	2534
Total Mass (mg)	NH_3	2925	1053	53
	NO_2	388	312	37
	F	18	< 1	< 1
	Cl	126	< 1	< 1
Air Concentration (mg/m^3)	NH_3	1934	917	21
	NO_2	195	209	11
	F	12	< 1	< 1
	Cl	83	< 1	< 1

Table 5.7.i
CEM Data for DuraMelter™ 1000 Steady State Campaign

Date	Time (Lab)	Location	NOx(ppm)	SO_2(ppm)	CO(ppm)
1/19/95	1344 (ESI)	Melter	6445	5.4	414
	1259 (ESI)	Post Mist Eliminator	2116	678	229
	1258 (VSL)		449	0	26
	1216 (ESI)	Post HEPA	648	243	35.3
	1227 (VSL)		623	0	71
1/19/95	1922 (ESI)	Melter	4099	76.7	151
	1805 (ESI)	Post Mist Eliminator	3761	204	210
	1804 (VSL)		1017	34	47
	1712 (ESI)	Post HEPA	1106	245	85.7
	1158 (VSL)		394	0	44
1/19/95	2306 (ESI)	Melter	465	NA	22.8
	2204 (ESI)	Post Mist Eliminator	2077	NA	168
	2207 (VSL)		471	0	47
	2132 (ESI)	Post HEPA	496	NA	36.8
1/20/95	1307 (ESI)	Melter	2911	NA	248
	1219 (ESI)	Post Mist Eliminator	1952	NA	179
	1217 (VSL)		171	0	19
	1116 (ESI)	Post HEPA	579	NA	36.7
	1227 (VSL)		623	0	71
Average	ESI*	Melter	3480	NA	209
	ESI	Post Mist Eliminator	2477	NA	197
	VSL#		674	38	65
	ESI	Post HEPA	707	NA	49
	VSL		472	1	50

* - Average of four data points.
\# - Average of all the data points given in Tables 5.7c and 5.7d.

Table 5.8.a
Corning Feed Analysis from Hanford DuraMelter™ 1000 Steady State Run (wt%)

	Dried Slurry			Wet Slurry		
Sample No.	DIF3-111C(d)	DIF3-112C(d)	DIF3-114C(d)	DIF3-111C(s)	DIF3-112C(s)	DIF3-114C(s)
Al_2O_3	1.03	0.98	0.97	0.70	0.69	0.68
B_2O_3	5.59	4.68	4.91	3.83	3.27	3.46
CaO	2.51	2.68	2.53	1.72	1.87	1.78
Cr_2O_3	0.05	0.05	0.05	0.03	0.04	0.03
Cs_2O	0.10	0.09	0.11	0.07	0.06	0.07
Fe_2O_3	4.37	5.34	4.92	3.24	3.73	3.46
K_2O	2.70	2.66	2.88	1.85	1.85	2.03
MnO_2	0.10	0.10	0.09	0.07	0.07	0.06
MoO_3	0.09	0.09	0.10	0.06	0.07	0.07
Na_2O	15.20	13.30	13.90	10.40	9.27	9.80
P_2O_5	0.14	0.16	0.11	0.10	0.11	0.08
SiO_2	32.30	34.90	33.00	22.10	24.30	23.20
SrO	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.34	0.63	0.77	0.23	0.44	0.54
ZrO_2	2.91	4.16	4.27	1.99	2.90	3.00
Total	67.42	69.82	68.61	46.39	48.66	48.27

Table 5.8.b
Normalized Corning Feed Analysis from DuraMelter™ 1000 Steady State Run (wt%)

Sample No.	Slurry			Actual	Target
	DIF3-111C(d)	DIF3-112C(d)	DIF3-114C(d)	Recipe	
Al_2O_3	1.53	1.40	1.41	6.23	6.18
B_2O_3	8.29	6.70	7.16	6.19	6.15
CaO	3.72	3.84	3.69	7.88	7.80
Cr_2O_3	0.07	0.07	0.07	0.04	0.04
Cs_2O	0.15	0.13	0.16	0.15	0.15
Fe_2O_3	6.48	7.65	7.17	7.54	7.50
K_2O	4.00	3.81	4.20	3.71	3.68
MnO_2	0.14	0.14	0.13	0.00	0.00
MoO_3	0.13	0.13	0.15	0.15	0.15
Na_2O	22.54	19.05	20.26	18.30	18.97
P_2O_5	0.21	0.23	0.16	0.19	0.19
SiO_2	47.91	49.99	48.10	42.50	42.23
SrO	<0.01	0.00	0.00	0.11	0.11
TiO_2	0.50	0.90	1.12	1.00	1.00
ZrO_2	4.32	5.96	6.22	5.13	5.09
Total	100	100	100	99	99.1

Table 5.8.c
Corning, USGS, and PNL Glass Analysis from DuraMelter™ 1000 the Hanford Steady State Run (wt%)

Sample No.	DIG4-108C5	DIG4-109C6	DIG4-110			DIG4-112C8	DIG4-115		Target
			Corning	USGS	PNL		Corning	USGS	
Al_2O_3	6.19	6.21	6.24	6.42	7.6	6.26	6.28	6.5	6.18
B_2O_3	6.57	6.51	6.46	6.21	5.97	6.42	6.33	6.09	6.15
BaO	0.011	0.011	0.011	0.015	0.01	0.011	0.011	0.0134	0
CaO	7.088	7.108	7.1	7.77	7.72	7.02	6.94	7.84	7.8
Cr_2O_3	0.14	0.15	0.138	0.175	0.17	0.13	0.115	0.1533	0.04
Cs_2O	0.11	0.11	0.11	N.A.	N.A.	0.11	0.11	N.A.	0.15
Fe_2O_3	6.33	6.26	6.26	6.25	6.05	6.25	6.19	6.23	7.5
K_2O	3.39	3.43	3.45	3.38	2.77	3.45	3.46	3.4	3.68
MgO	0.403	0.345	0.31	0.335	0.27	0.245	0.19	0.225	0
MnO_2	0.115	0.12	0.12	0.102	0.09	0.12	0.12	0.106	0
MoO_3	0.13	0.13	0.13	0.133	0.13	0.13	0.13	0.135	0.15
Na_2O	17.7	17.7	17.7	17.8	17.3	17.6	17.6	17.6	18.97
NiO	0.028	0.025	0.022	0.023	0.05	0.02	0.017	0.0178	0
P_2O_5	0.29	0.29	0.29	0.255	0.26	0.27	0.26	0.225	0.19
SO_3	N.A.	N.A.	N.A.	0.537	0.56	N.A.	N.A.	0.574	0.21
SiO_2	41	41.2	40.8	42.3	40.7	40.6	42.2	42.5	42.23
SrO	0.11	0.11	0.11	0.115	0.12	0.11	0.11	0.113	0.11
TiO_2	0.87	0.83	0.828	0.83	0.77	0.845	0.9	0.9	1.0
ZrO_2	4.64	4.55	4.52	4.43	4.33	4.56	4.76	4.42	5.09
Cl	N.A.	N.A.	N.A.	0.18	N.A.	N.A.	N.A.	0.19	0.35
F	0.16	0.15	0.14	0.15	N.A.	0.12	0.09	0.09	0.29
Total	95.22	95.21	94.75	97.29	94.9	94.23	95.7	97.31	99.95

N.A. = Not Analysis.
All Data were from Corning, excepting those specified.

Table 5.8.d
PNL Analysis of Scrubber Solution from the DuraMelter™ 1000 Hanford Steady State Run (mole/l)

Sample No.	D1O6-1 01P	D1O6-1 06P	D1O6-113P	D1O6-119P	D1O6-1 25P	D1O6-1 30P	D1O6-1 34P	D1O6-1 43P	D1O6-1 46P	D1O6 -148P
Al	0.00022	0.00089	0.0006	0.0007	0.00032	0.0036	0.0005	0.0003	BDL	4e-04
B	0.00033	0.00673	0.0084	0.0089	0.0145	0.012	0.0189	0.0175	0.0176	0.018
Ca	0.00013	0.00016	0.0006	BDL	0.00005	0.00135	5e-05	BDL	BDL	4e-04
Cr	BDL	0.00016	0.0002	0.0002	0.00021	0.00021	0.0003	0.0003	0.0002	2e-04
Cs	0.00002	0.00028	0.0004	0.0005	0.00079	0.00063	0.0011	0.0011	0.001	0.001
Fe	0.00002	0.00004	4e-05	6e-05	0.00004	0.00251	4e-05	6e-05	1e-04	1e-04
K	BDL	0.00356	0.0048	BDL	0.00775	0.00005	0.0111	0.0073	0.0066	0.012
Mo	2.4e-06	0.00007	0.0001	9e-05	0.00013	0.00011	0.0002	0.0002	0.0002	2e-04
Na	0.192	0.6	1.12	1.28	1.62	1.3	1.88	1.78	1.7	1.69
P	0.0077	0.109	0.226	0.316	0.322	0.0171	0.336	0.352	0.417	0.365
S	BDL	0.00091	0.0012	0.013	0.00214	0.00269	0.0032	0.0031	0.0033	0.003
Si	0.00009	0.00082	0.0009	0.0007	0.00078	0.00192	0.0005	0.0015	0.0009	9e-04
Sr	0.00096	BDL	0.0708	0.0867	0.108	0.0867	0.126	BDL	0.114	0.126
TOC*	2.6	N.A.	25	21	22	54	15	N.A.	26	25
TIC□	84	N.A.	6200	7600	9500	7600	11000	N.A.	10000	11000
CL$^-$	0.00239	N.A.	0.0132	0.016	0.00369	0.00003	0.0047	N.A.	0.043	0.043
F$^-$	BDL	N.A.	N.A.	0.0254	0.00664	BDL	0.0035	N.A.	N.A.	0.003
NO_3^-	0.00026	N.A.	0.0002	0.0004	0.0009	0.0117	0.0018	N.A.	0.0007	7e-0N o
NO_2-	0.00219	N.A.	0.173	0.16	0.0159	0.129	0.0151	N.A.	0.142	0.142
SO_4^{--}	0.0001	N.A.	0.0008	0.001	0.00159	0.00157	0.0024	N.A.	0.0027	0.003

N.A. = Not Analysis;
BDL = Below Detection Limitations.
*TOC = Total Organic Carbon (mg/liter)
□TIC = Total Inorganic Carbon (mg/liter)

Table 5.8.e
Corning Analysis of Filter Cake, Baghouse Diatomaceous Earth and Filter Backwash from DuraMelter™ 1000 Steady State Run (wt%)

	Filter Cake		Baghouse DE				Backwash
Sample No.	D1O10-101C(d)	D1O10-101C(s)	D1O7-100C (Blank)	D1O7-101C	D1O7-102C	D1O7-103C	D1O9-101C
Al_2O_3	1.12	0.42	4.29	2.55	4.41	3.61	0.004
B_2O_3	0.92	0.35	0.042	1.09	0.22	0.62	0.03
BaO	0.009	0.003	0.021	0.106	0.06	0.017	BDL
CaO	3.95	1.5	0.48	0.6	0.47	0.59	0.0005
Cr_2O_3	0.046	0.017	0.006	0.18	0.027	0.11	0.00081
Cs_2O	0.14	0.05	BDL	1.37	0.46	1.09	0.01
Fe_2O_3	6.37	2.41	0.97	4.9	1.97	1.87	BDL
K_2O	1.12	0.42	0.72	5.17	2.15	4.16	0.03
MgO	0.265	0.1	0.69	0.2	0.603	0.22	0.0006
MnO_2	0.11	0.04	0.0091	0.03	0.013	0.012	BDL
MoO_3	0.01	BDL	BDL	0.07	0.02	0.05	0.0011
Na_2O	7.85	2.98	4.3	9.5	4.8	8.3	3.27
NiO	0.009	0.003	0.008	0.027	0.0063	0.0038	BDL
P_2O_5	0.07	0.03	0.17	0.25	0.17	0.08	BDL
SiO_2	59.9	22.7	86.5	41.2	78.7	65.6	0.093
SrO	0.003	0.001	0.0075	0.012	0.01	0.01	0.0001
TiO_2	0.14	0.05	0.21	0.11	0.2	0.16	0.0002
ZrO_2	0.081	0.031	0.0028	0.0038	0.0043	0.0062	BDL
F	0.09	N.A.	0.04	1.25	0.23	0.52	0.01
H_2O	N.A.	62.1	N.A.	N.A.	N.A.	N.A.	94.0
Total	82.12	93.19	98.42	68.54	94.5	87	97.45

BDL = Below detection limitations
N.A. = Not Available

Table 5.8.f
Mass Distribution from DuraMelter™ 1000 Hanford Steady State Run (kg)

	Feed	Scrubber	Baghouse	Filter-Cake	Glass	Emissions*
Al_2O_3	241.322	0.332	0.071	0.015	243.204	NC
B_2O_3	239.850	2.185	0.103	0.012	254.169	<0.06
CaO	305.237	0.010	0.034	0.049	260.732	NC
Cr_2O_3	1.577	0.119	0.017	0.001	n.c	<0.03
Cs_2O	5.736	0.347	0.157	0.002	4.290	<0.002
Fe_2O_3	292.351	0.015	0.378	0.084	244.062	NC
K_2O	143.814	1.053	0.541	0.015	134.004	<0.03
MoO_3	5.855	0.088	0.008	0.000	5.070	<0.002
Na_2O	709.228	n.c	0.746	0.103	688.740	<0.03
SiO_2	1646.976	0.426	n.c	n.c	1605.240	NC
SrO	4.206	n.c	0.001	0.000	4.290	NC
TiO_2	38.807	0.295	0.001	0.002	33.329	NC
ZrO_2	198.608	0.120	0.000	0.001	179.634	NC

*All values below detection limits
NC = Not Calculated

Table 5.8.g
Elemental Distribution from DuraMelter™ 1000 Hanford Steady State Run (wt%)

	Scrubber	Baghouse	Filter-Cake	Glass	Total	Deviation
Al_2O_3	0.14	0.03	0.01	100.78	100.95	0.95
B_2O_3	0.91	0.04	0.01	105.97	106.93	6.93
CaO	0.003	0.01	0.02	85.42	85.45	-14.55
Cr_2O_3	7.58	1.08	0.04	n.c	n.c	n.c
Cs_2O	6.05	2.74	0.03	74.79	83.62	-16.38
Fe_2O_3	0.01	0.13	0.03	83.48	83.65	-16.35
K_2O	0.73	0.38	0.01	93.18	94.30	-5.70
MoO_3	1.51	0.13	0.002	86.59	88.23	-11.77
Na_2O	NC	0.11	0.01	97.11	97.23	-2.77
SiO_2	0.03	0.000	n.c.	97.47	97.49	-2.51
SrO	n.c.	0.02	0.001	101.99	102.01	2.01
TiO_2	0.76	0.003	0.005	85.89	86.65	-13.35
ZrO_2	0.06	0.000	0.001	90.45	90.51	-9.49

n.c. = not calculated

Table 5.8.h
Elemental Feed Rates and Retention in the Melter

	Direct Sampling of Melter Exhaust		Sum of Total Mass in Off Gas System
	VSL	ES	
Sodium			
Feed Rate (g/min)	157.6		
% Melter Escape	0.3	0.1 - 0.15	0.1
Potassium			
Feed Rate (g/min)	37.0		
% Melter Escape	0.6	0 - 0.2	1.1
Boron			
Feed Rate (g/min)	22.3		
% Melter Escape	0.5	0.2 - 0.4	1.0
Chromium			
Feed Rate (g/min)	0.3		
% Melter Escape	2.3	1.8 - 2.1	8.7
Strontium			
Feed Rate (g/min)	1.1		
% Melter Escape	0.6	0.08 - 0.1	0.02
Molybdenum			
Feed Rate (g/min)	1.2		
% Melter Escape	0.8	0.4 - 0.5	1.6
Cesium			
Feed Rate (g/min)	1.6		
% Melter Escape	5.5	4.9 - 6.5	8.8
Ammonia			
Feed Rate (g/min)	68.5		
% Melter Escape	7.9	NC	NC

Table 5.9.a
PCT Analysis of Hanford Glass

		USGS Analysis of DuraMelter™ 100 Glass	Corning Analysis of DuraMelter™ 1000 Glass	SRL-EA
PCT Leachate Conc. (ppm)	pH	11.5	11.5	11.7
	B	18.25	14.5	578
	Si	61.75	55.5	850
	Na	202.5	66	1620
	K	20.5	18	2.7
Normalized Leaching Rate ($g/m^2/day$)	B	0.07	0.05	1.2
	Si	0.02	0.02	0.28
	Na	0.11	0.04	0.96
	K	0.05	0.05	0.41

Figure 5.3.a. Glass Production from the DuraMelter™ 1000 Run (12/12/94-1/21/95)

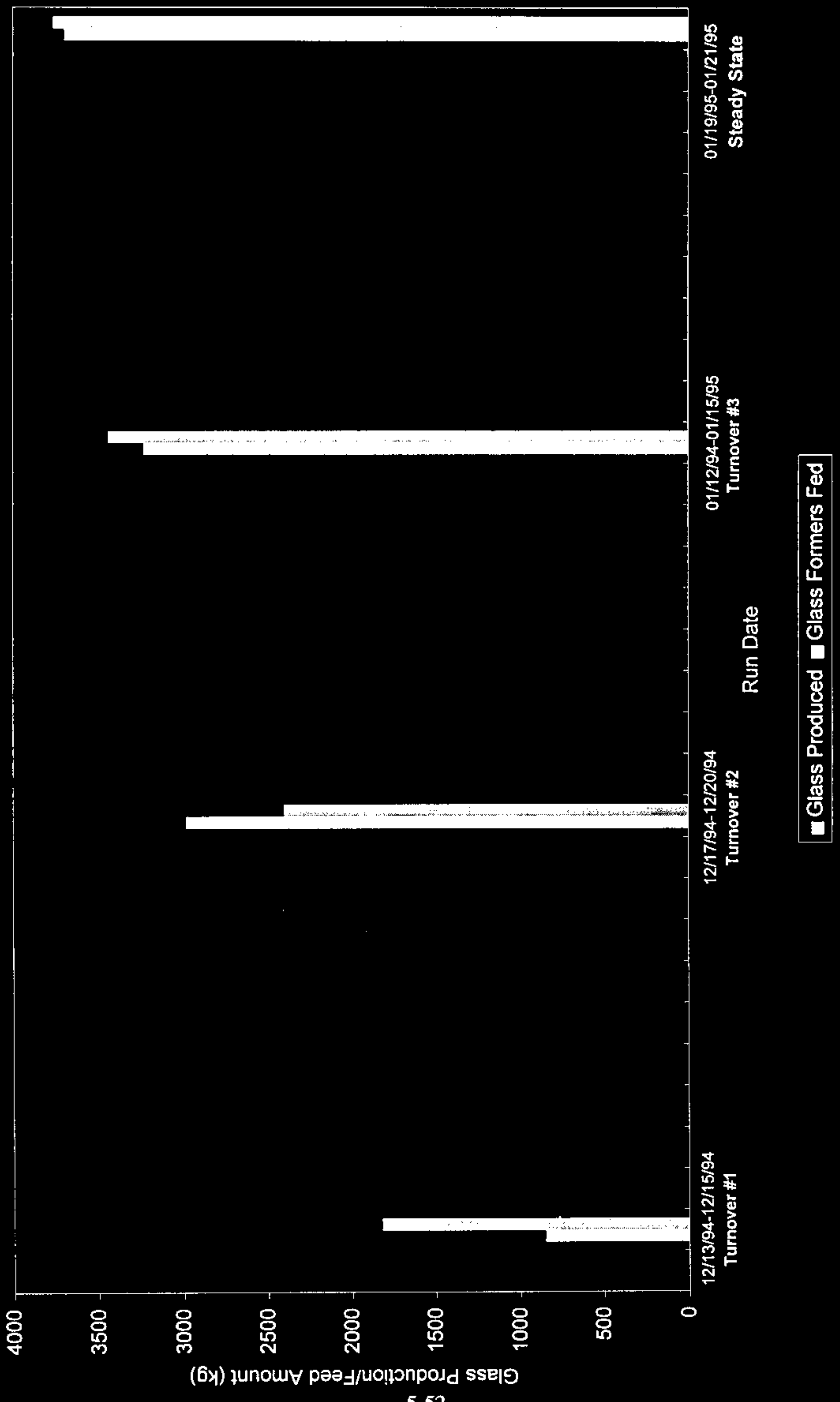


Figure 5.3.b. DuraMelter™ 1000 Accumulated Feed
Hanford Steady State (1/19/95-1/21/95)

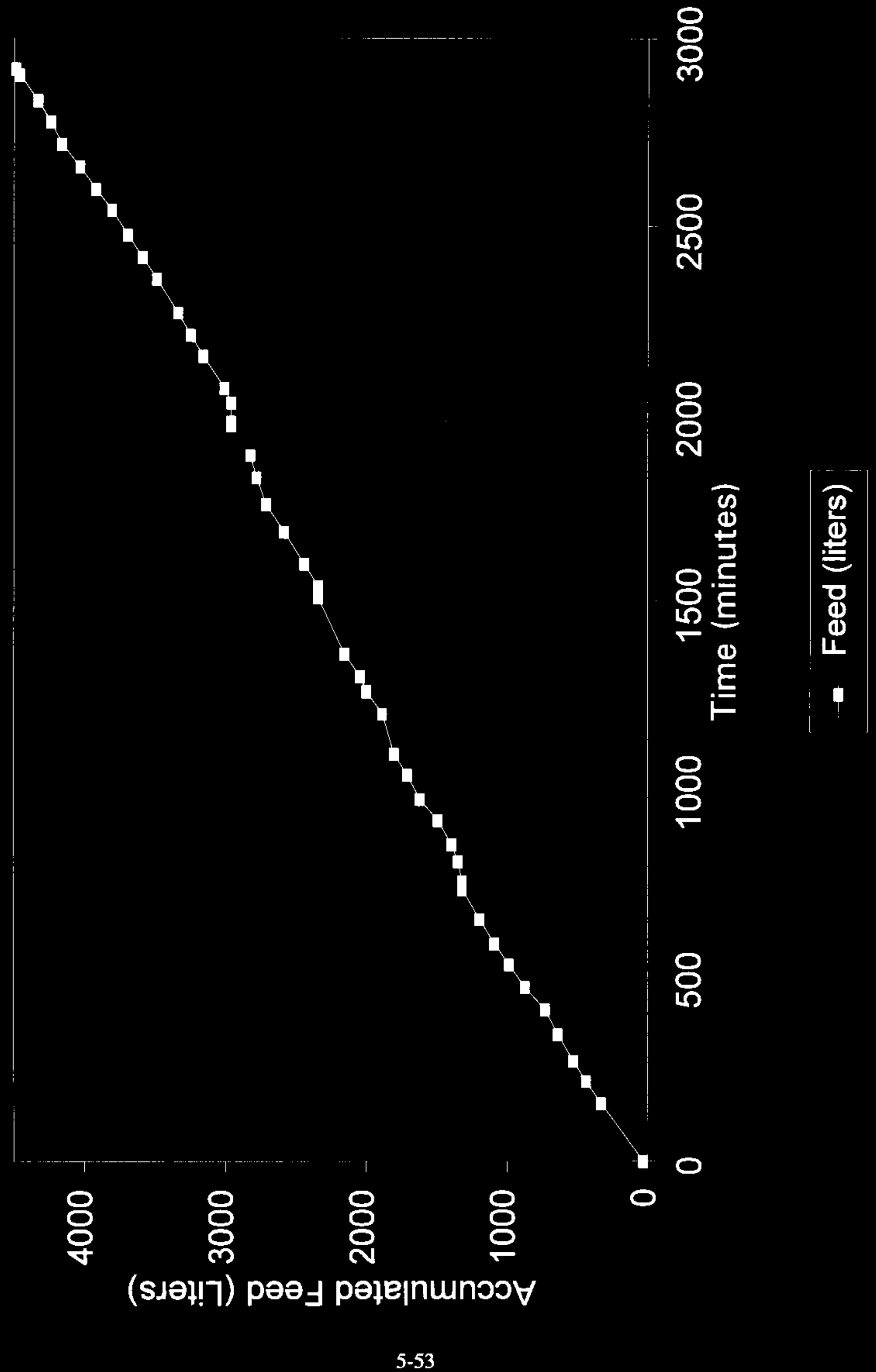


Figure 5.3.c. DuraMelter™ 1000 Accumulated Feed Hanford Turnover (1/12/95-1/14/95)

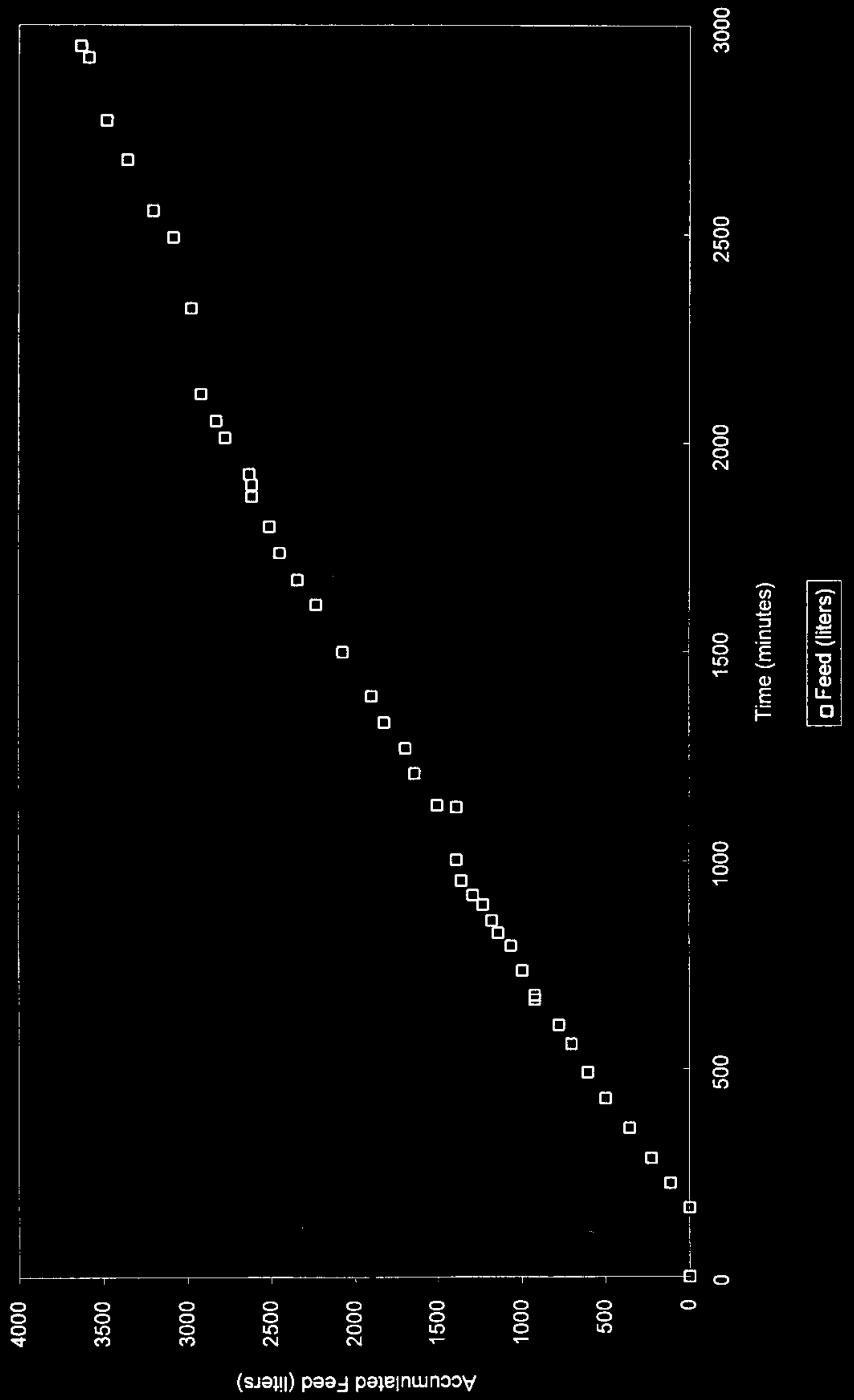


Figure 5.3.d. DuraMelter™ 1000 Glass Production Hanford Steady State (1/19/95-1/21/95)

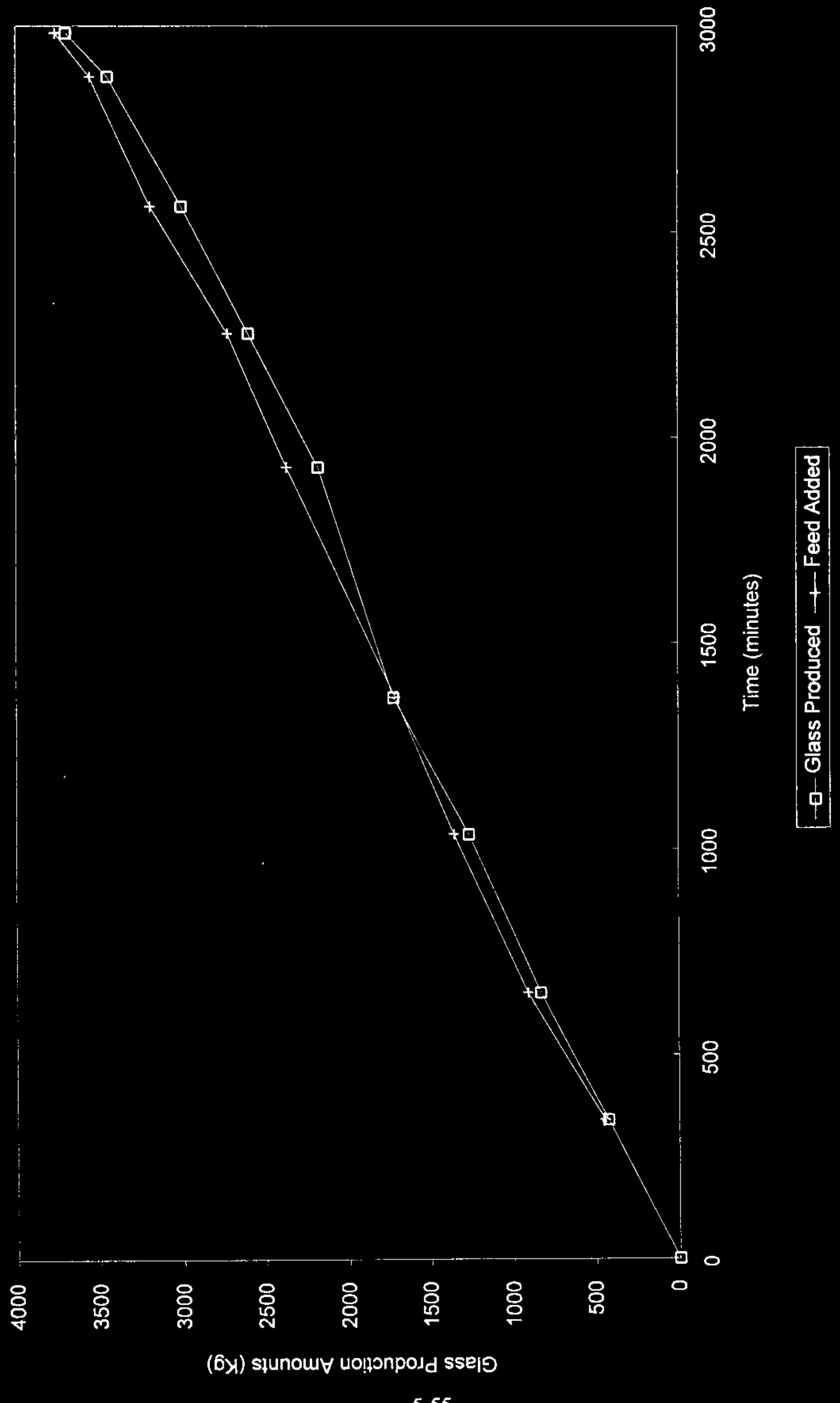


Figure 5.3.e. DuraMelter™ 1000 Glass Production
Hanford Turnover (1/12/95-1/14/95)

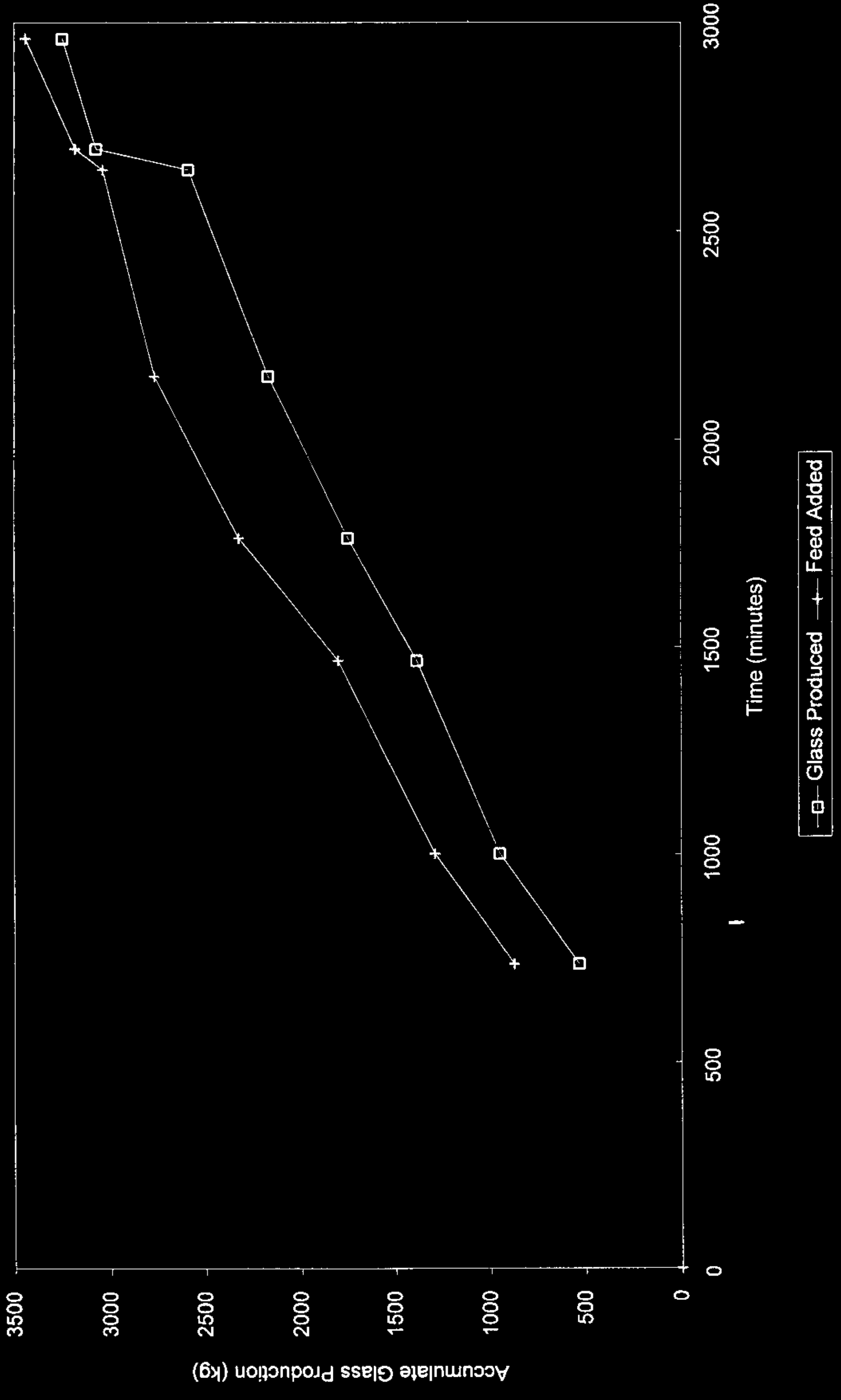


Figure 5.3.f. DuraMelter™ 1000 Glass Production Rate
Hanford Turnover (1/12/95-1/14/95)

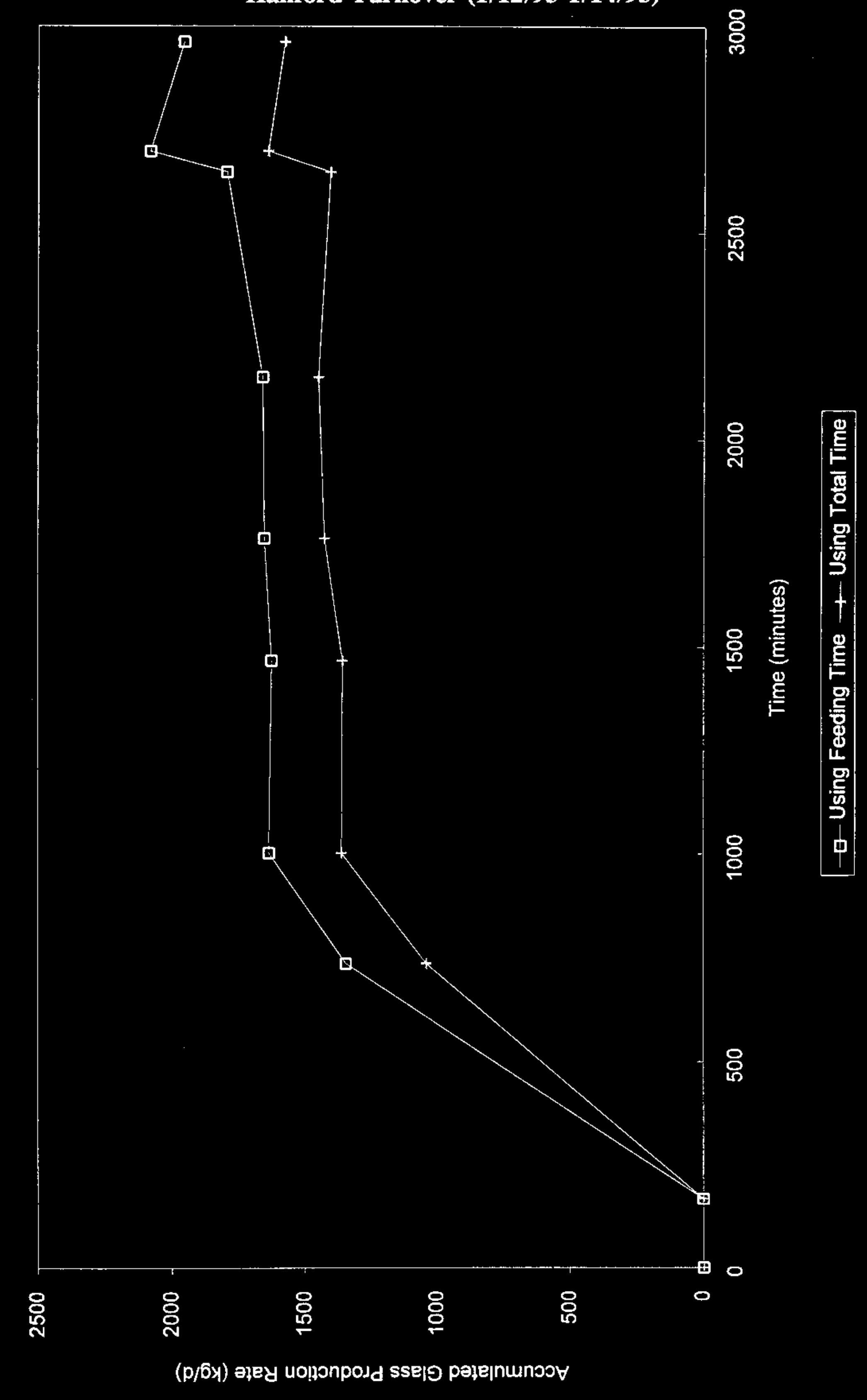


Figure 5.3.g. DuraMelter™ 1000 Glass Production Rate
Hanford Steady State (1/19/95-1/21/95)

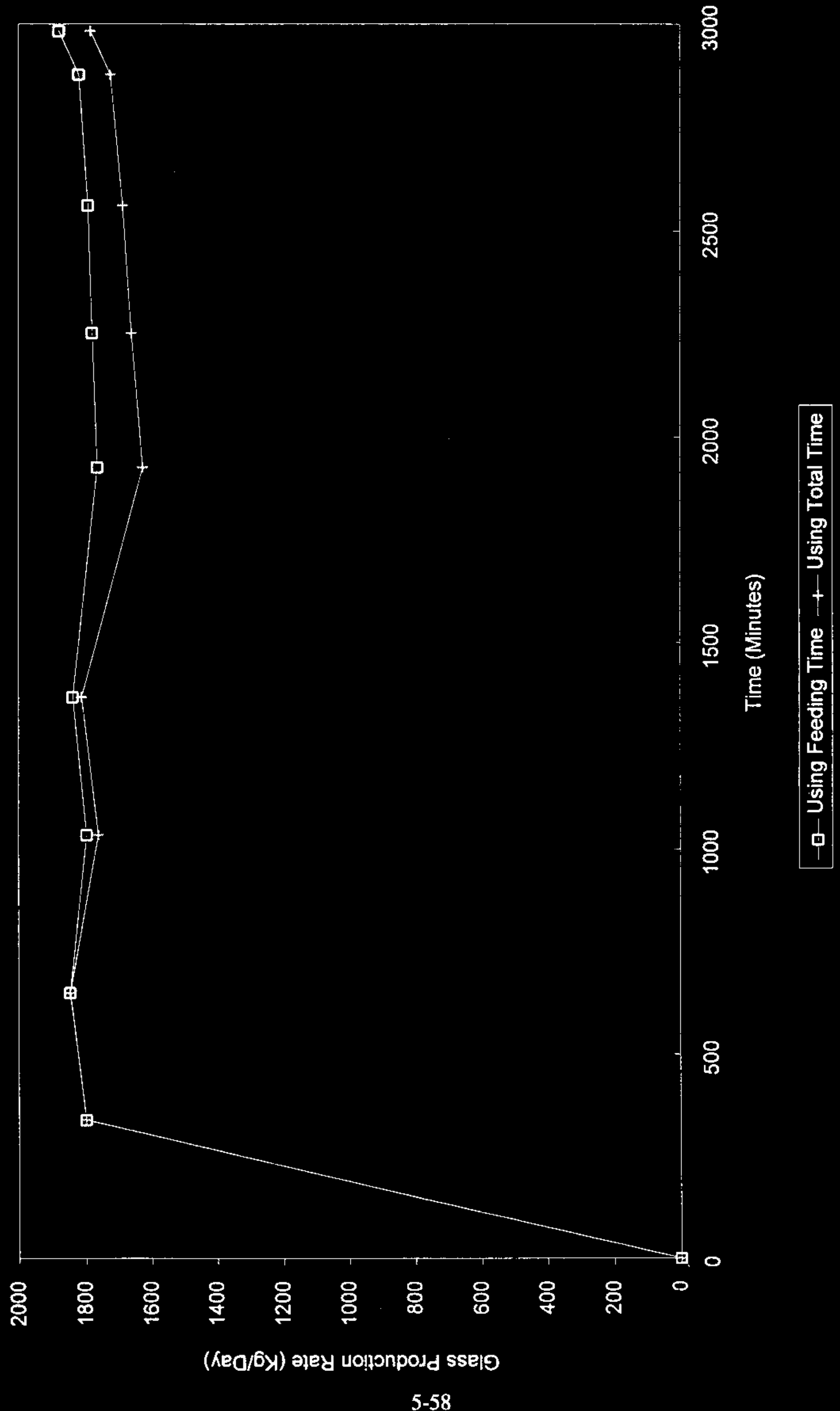


Figure 5.4.a. DuraMelter™ 1000 Steady State

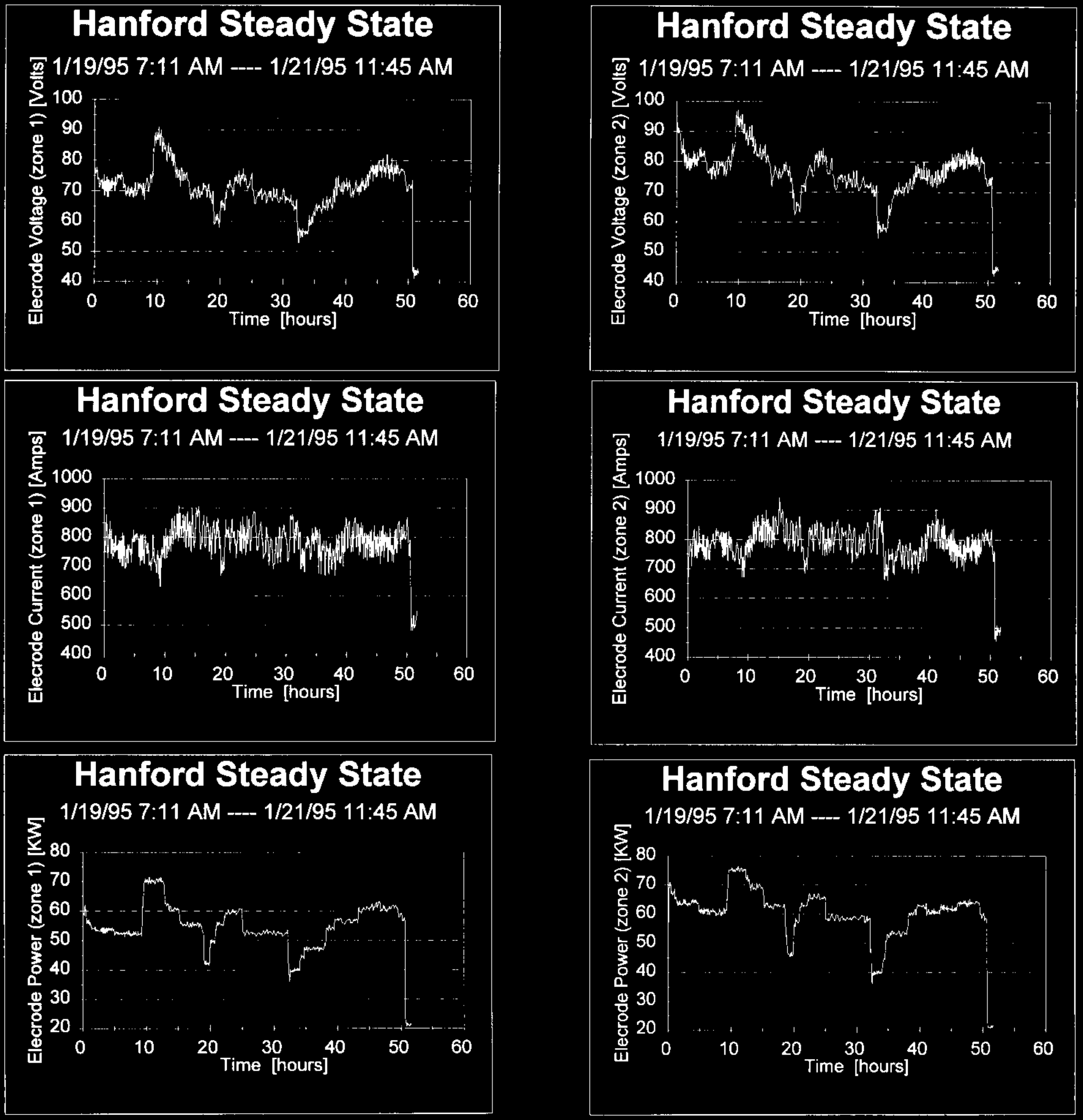
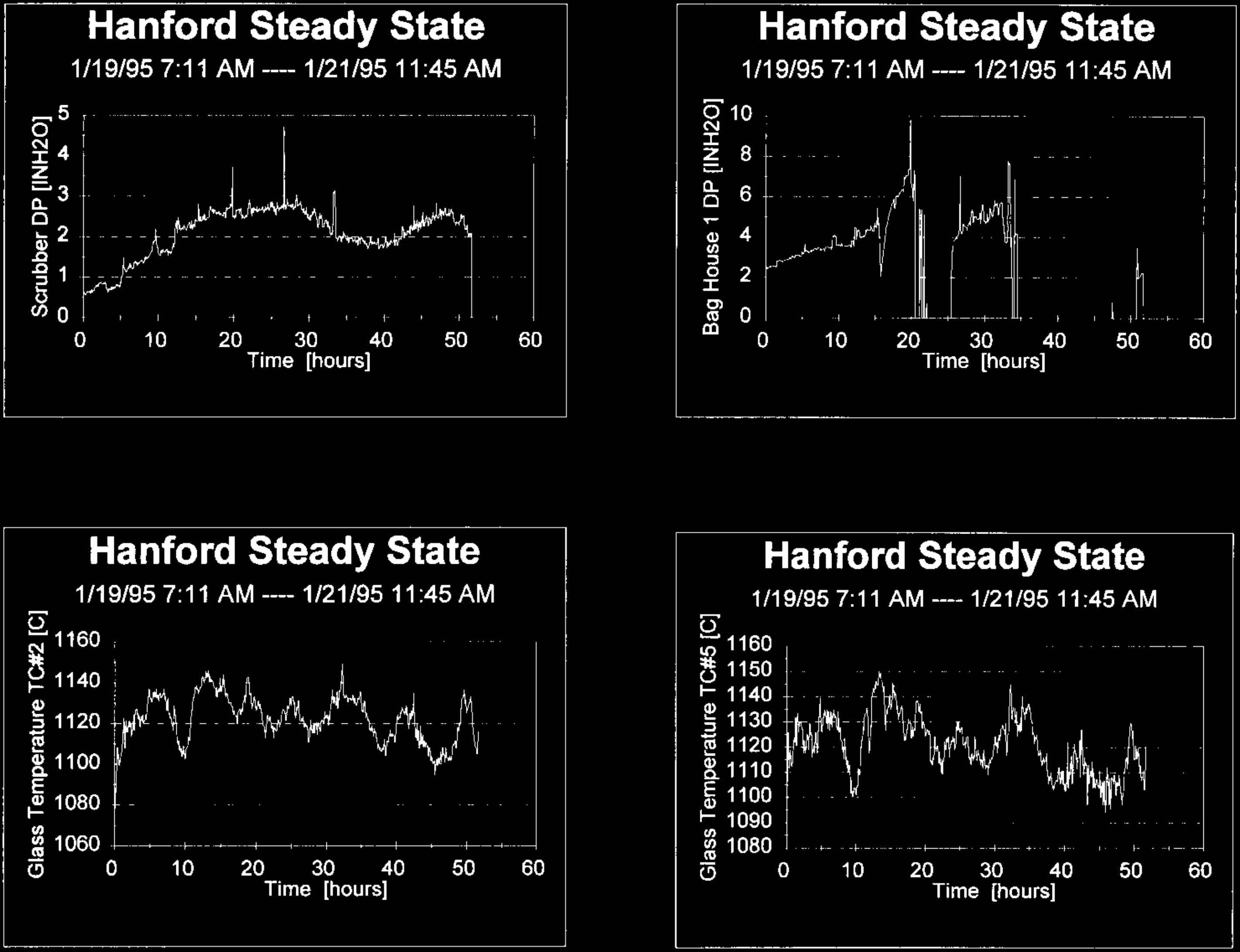


Figure 5.4.b. DuraMelter™ 1000 Steady State



Hanford Steady State

1/19/95 7:11 AM ---- 1/21/95 11:45 AM

Figure 5.4.c. DuraMelter™ 1000 Steady State

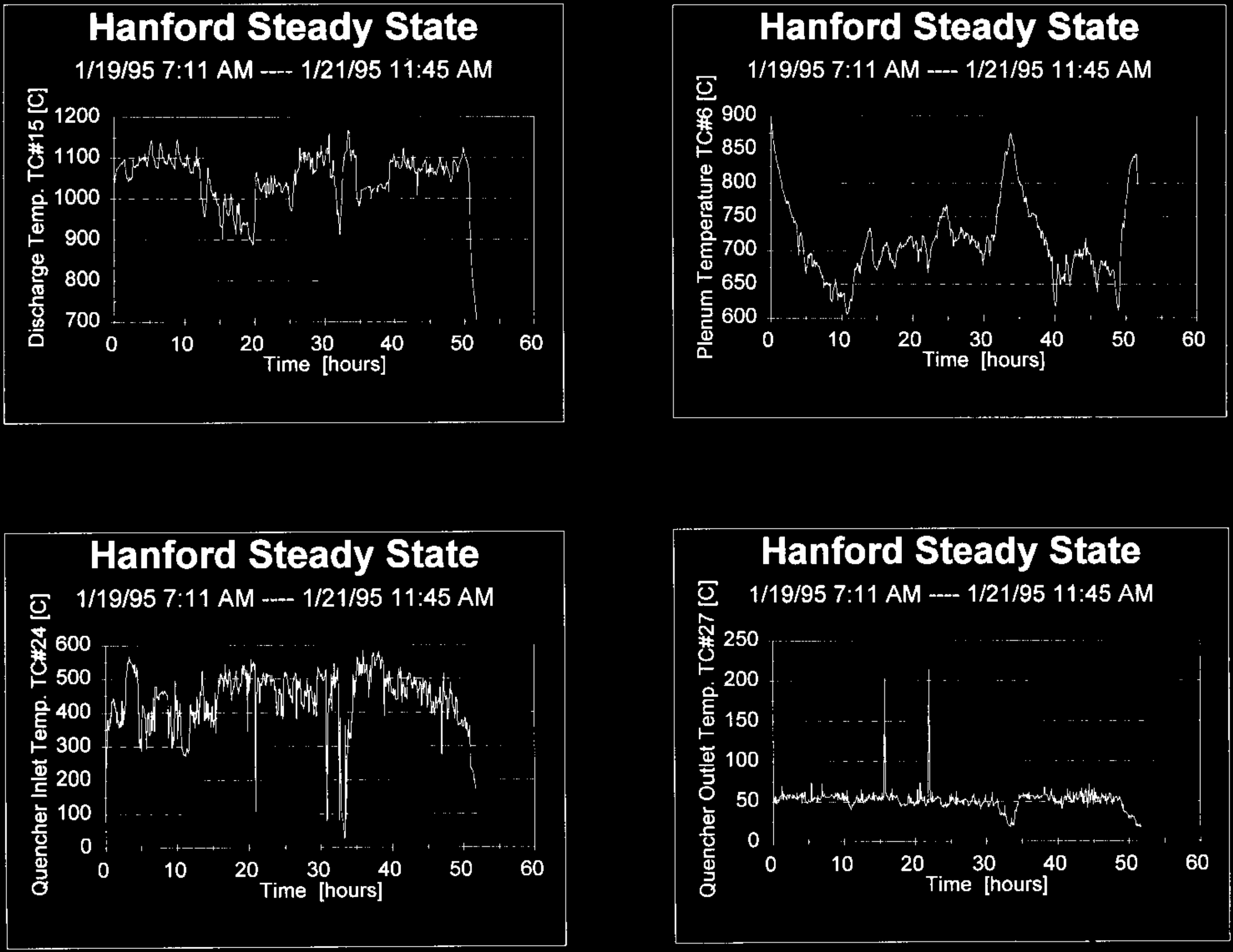


Figure 5.5.a. Sampling Sequence DuraMelter™ 1000 Steady State Run

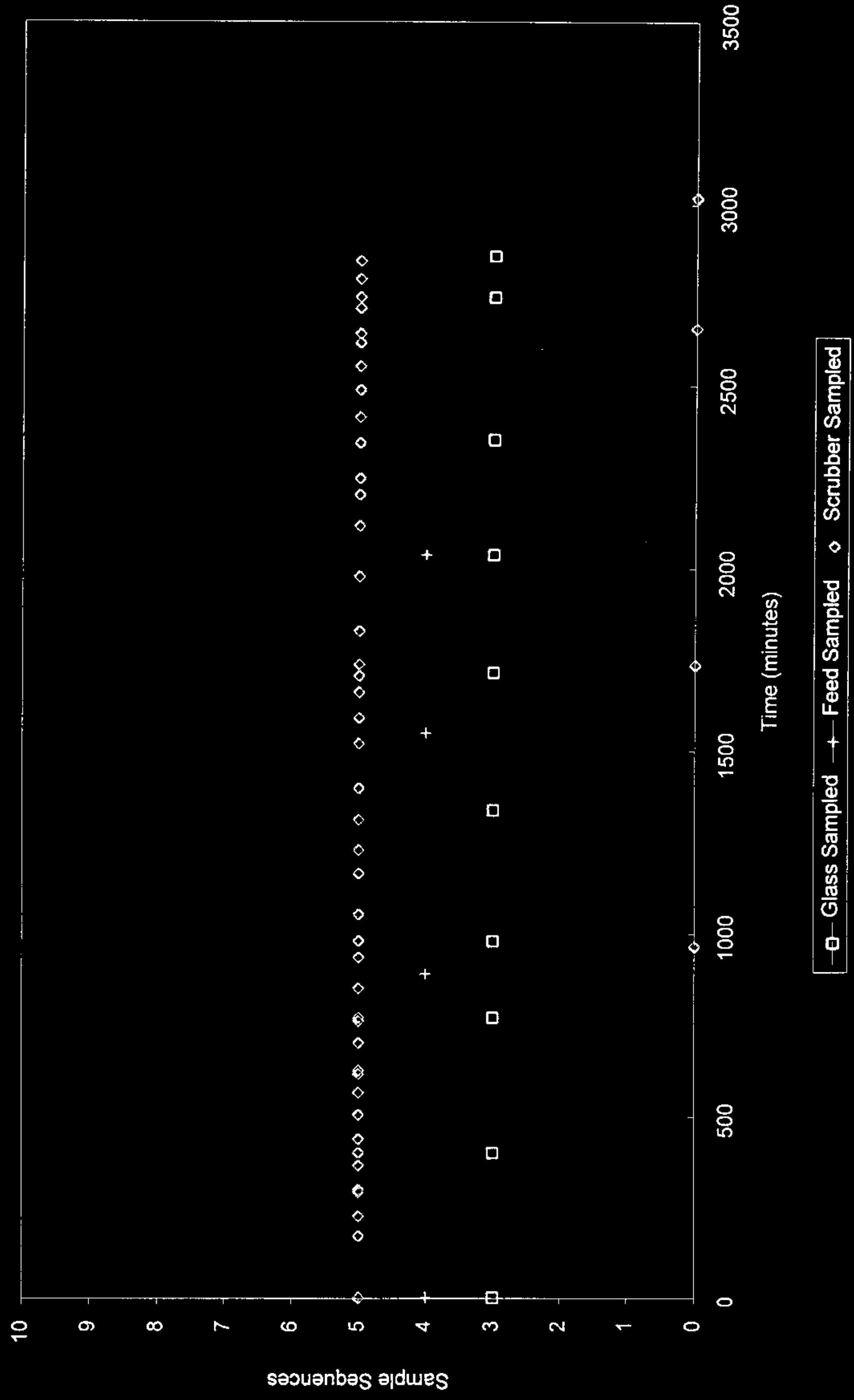


Figure 5.7.a. NaOH Added/Removed to Scrubber DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

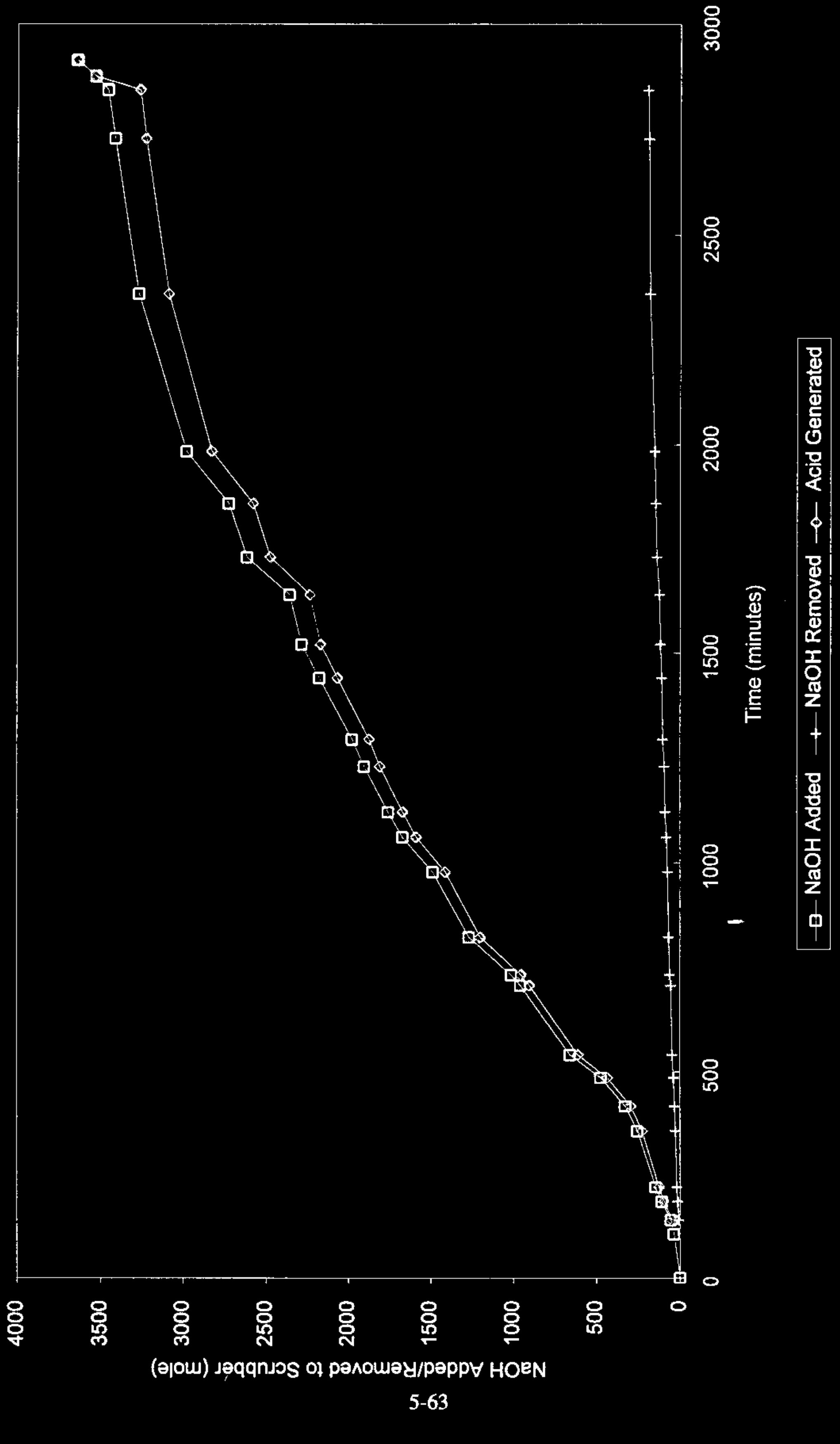


Figure 5.7.b. Cold Cap DuraMelter™ 1000
Hanford Steady State (1/19/95-1/21/95)

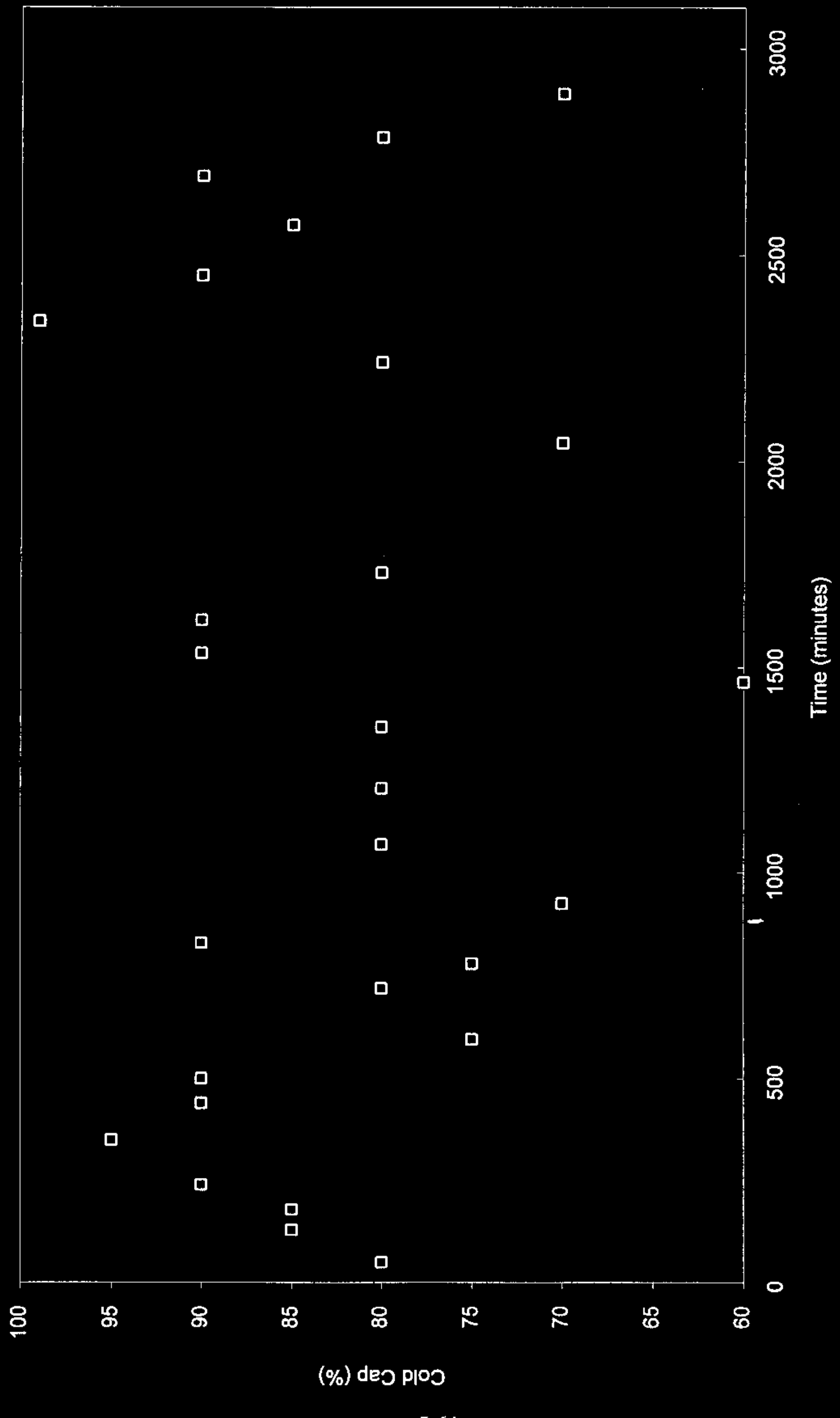


Figure 5.7.c. Ammonia in Scrubber Solution, DuraMelter™ 1000
Hanford Turnover (1/12/95-1/14/95)

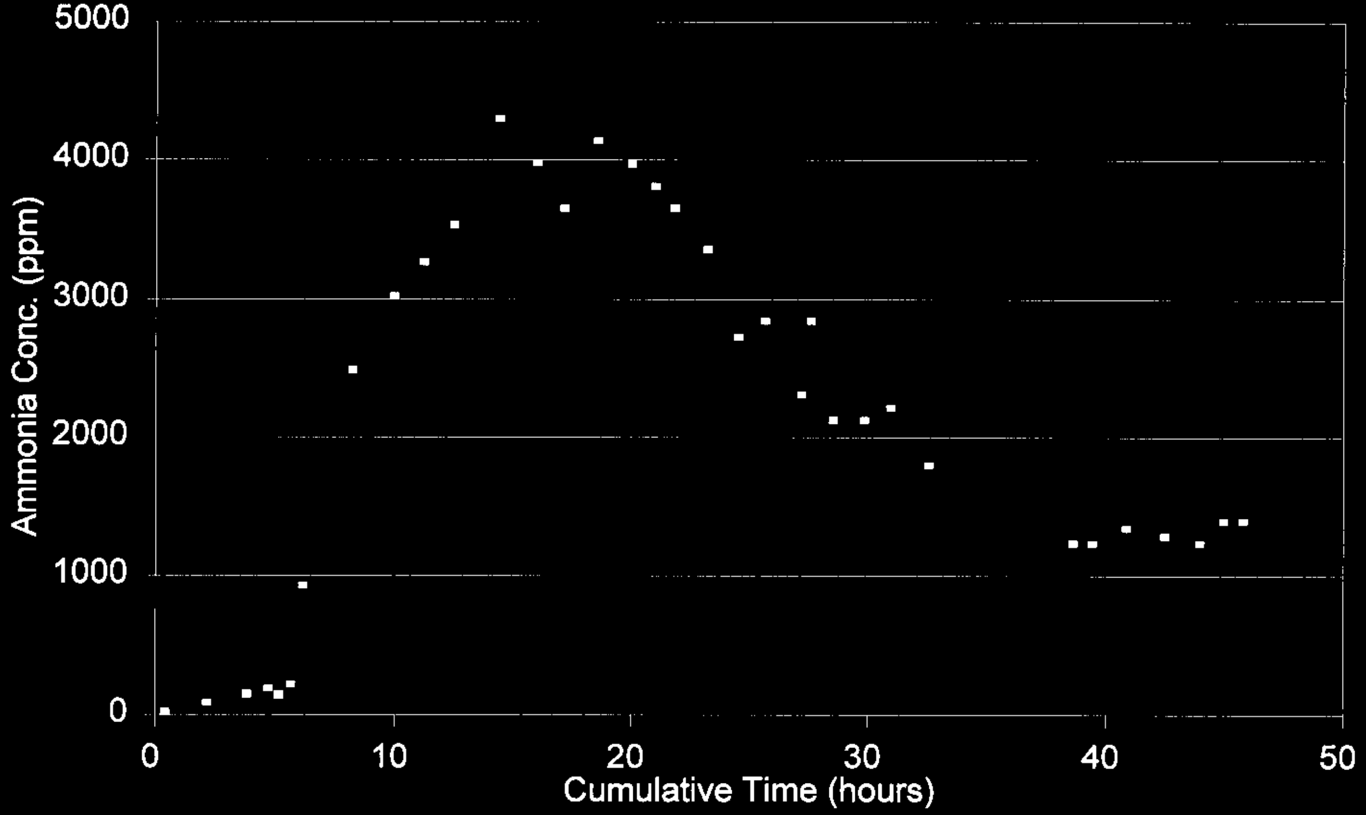


Figure 5.7.d. [NO] in Offgas Before HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

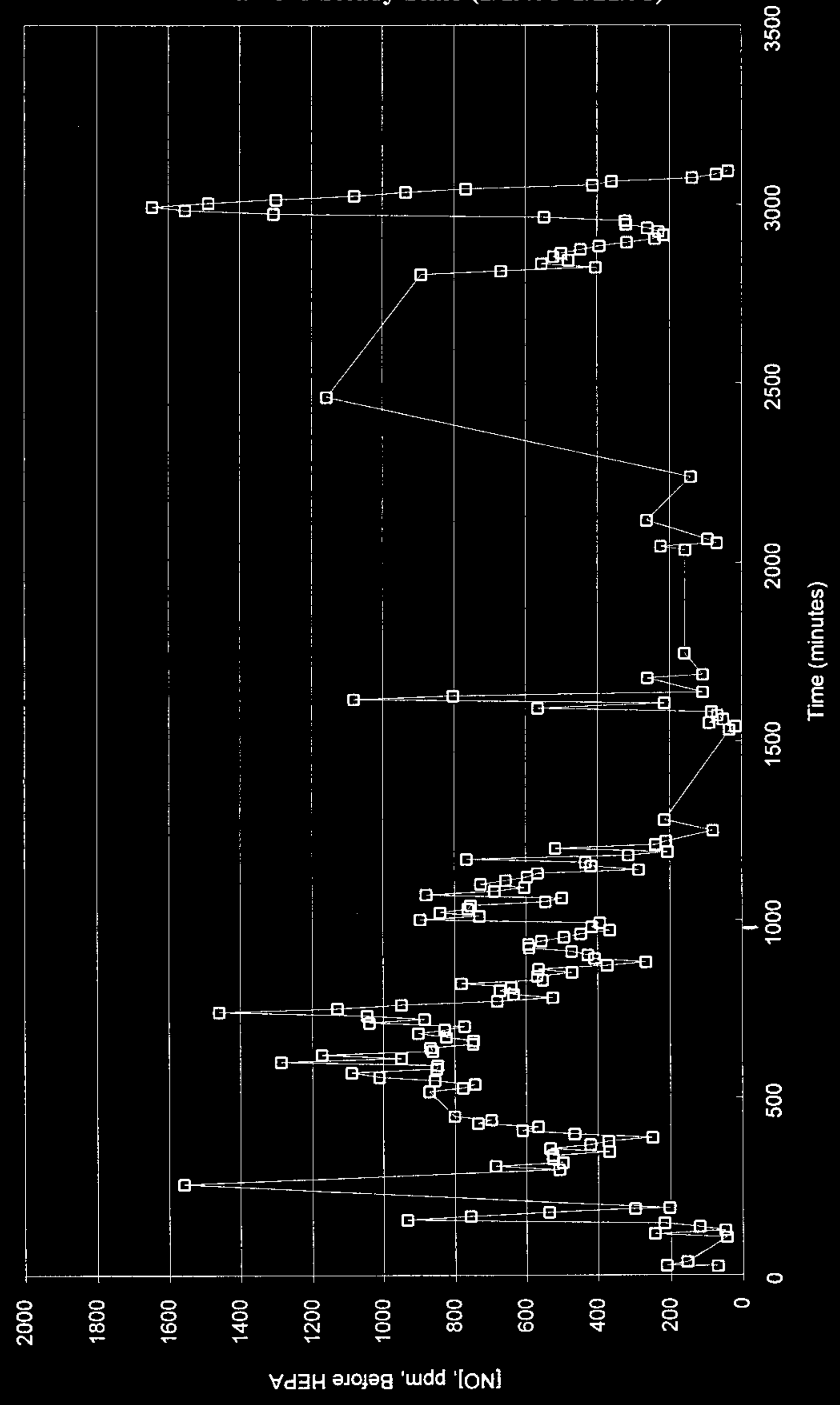


Figure 5.7.e. [NO] in Offgas After HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

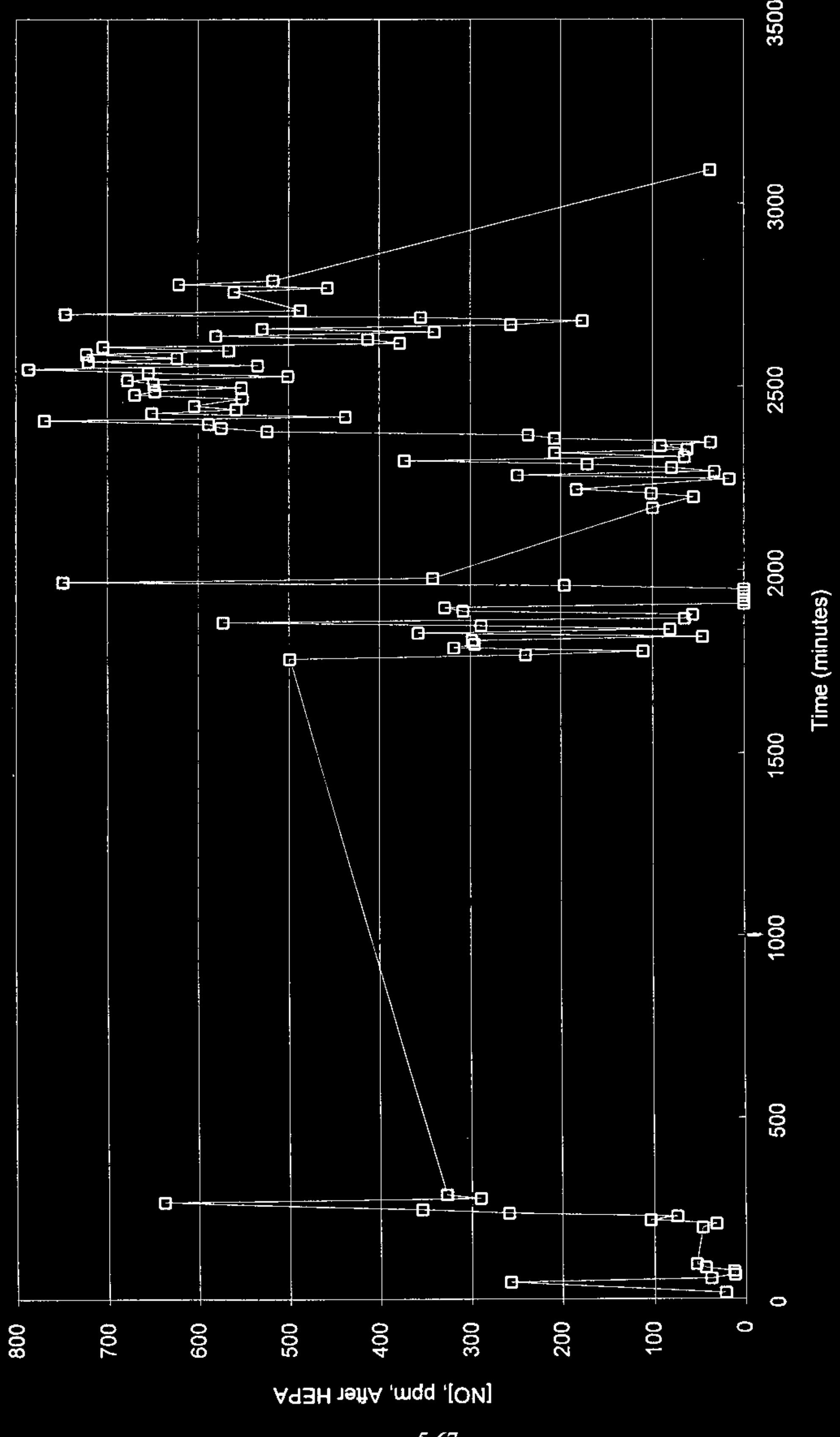


Figure 5.7.f. [NOx] in Offgas After HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

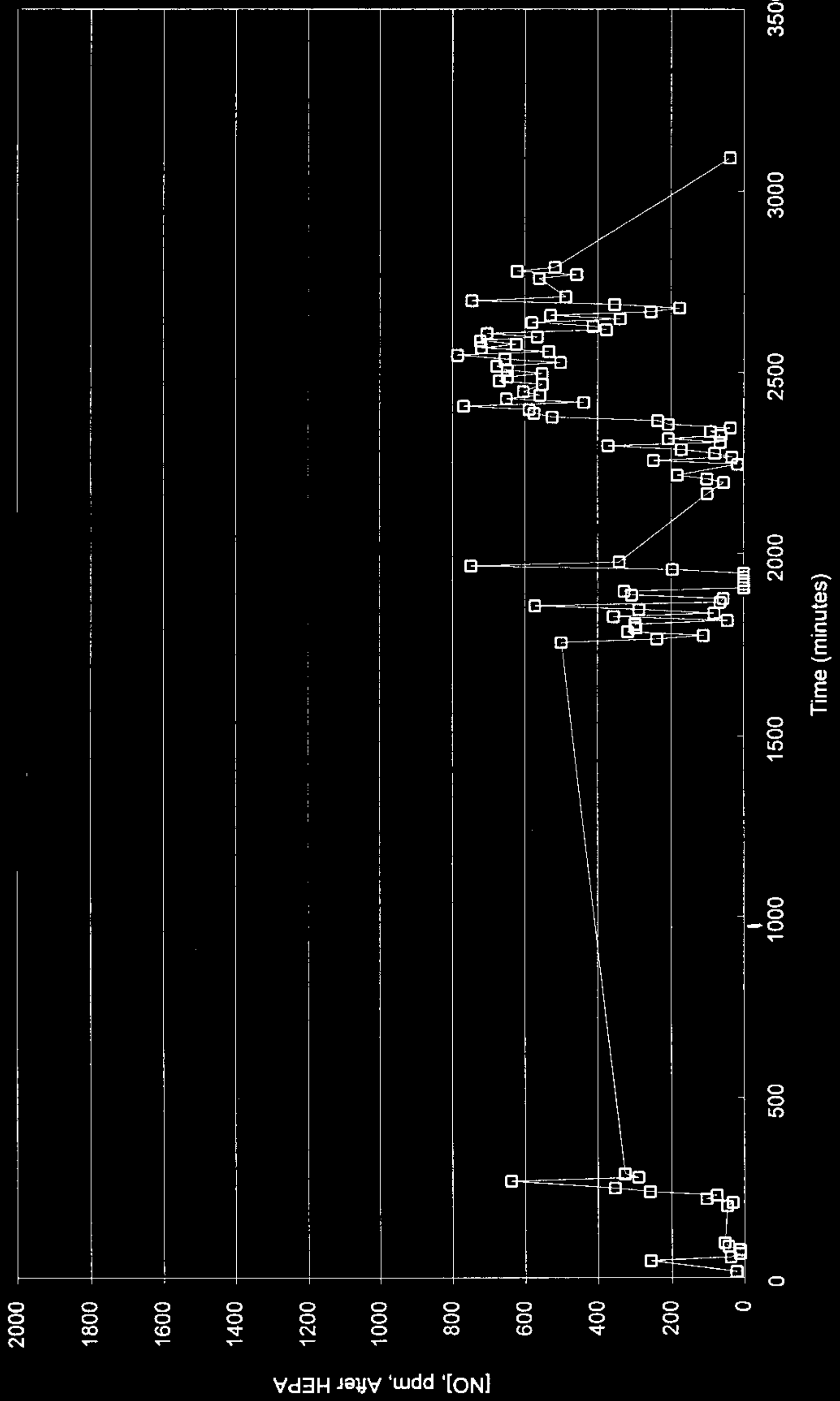


Figure 5.7.g. [NOx] in Offgas Before HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

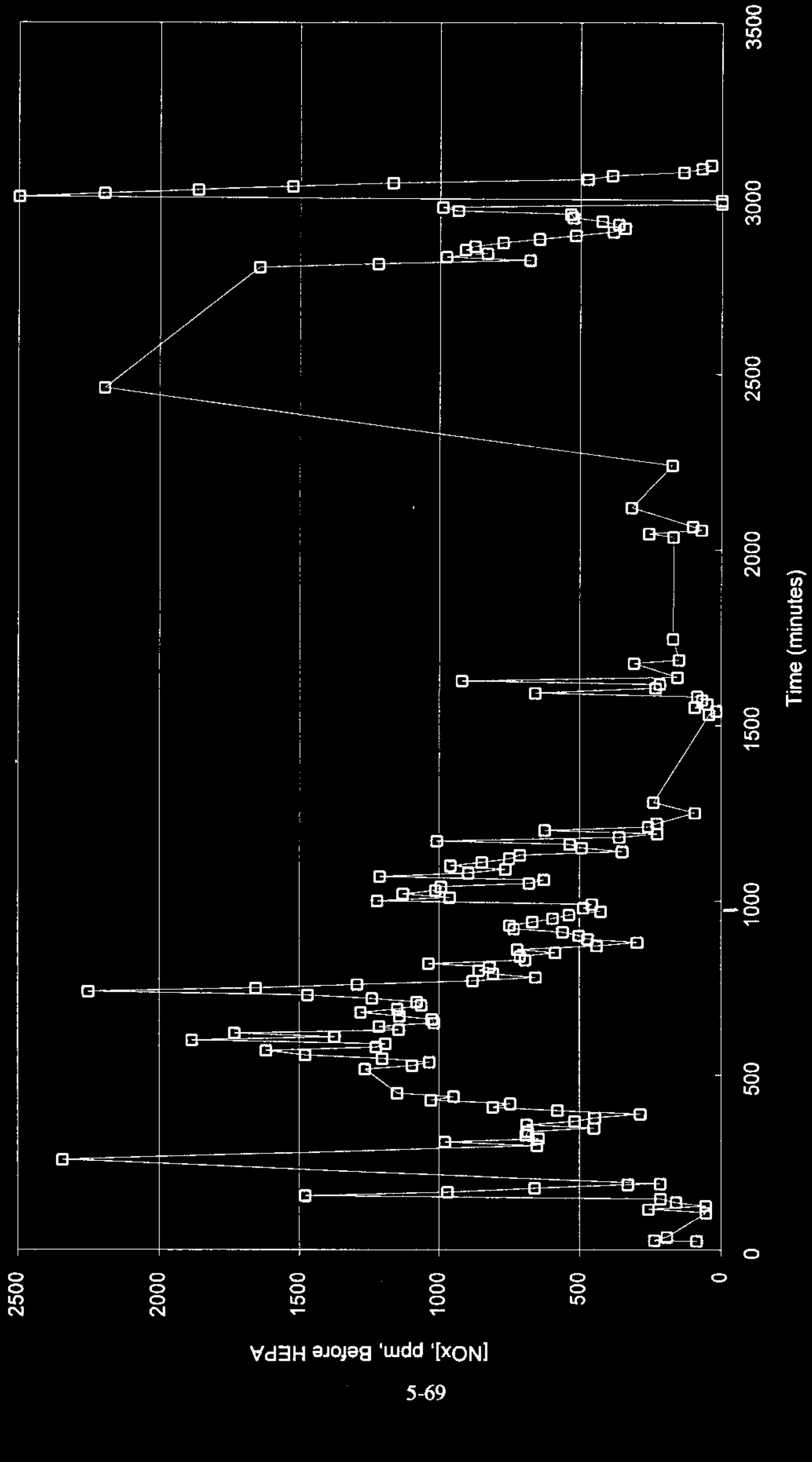


Figure 5.7.h. $[NO_2]$ in Offgas After HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

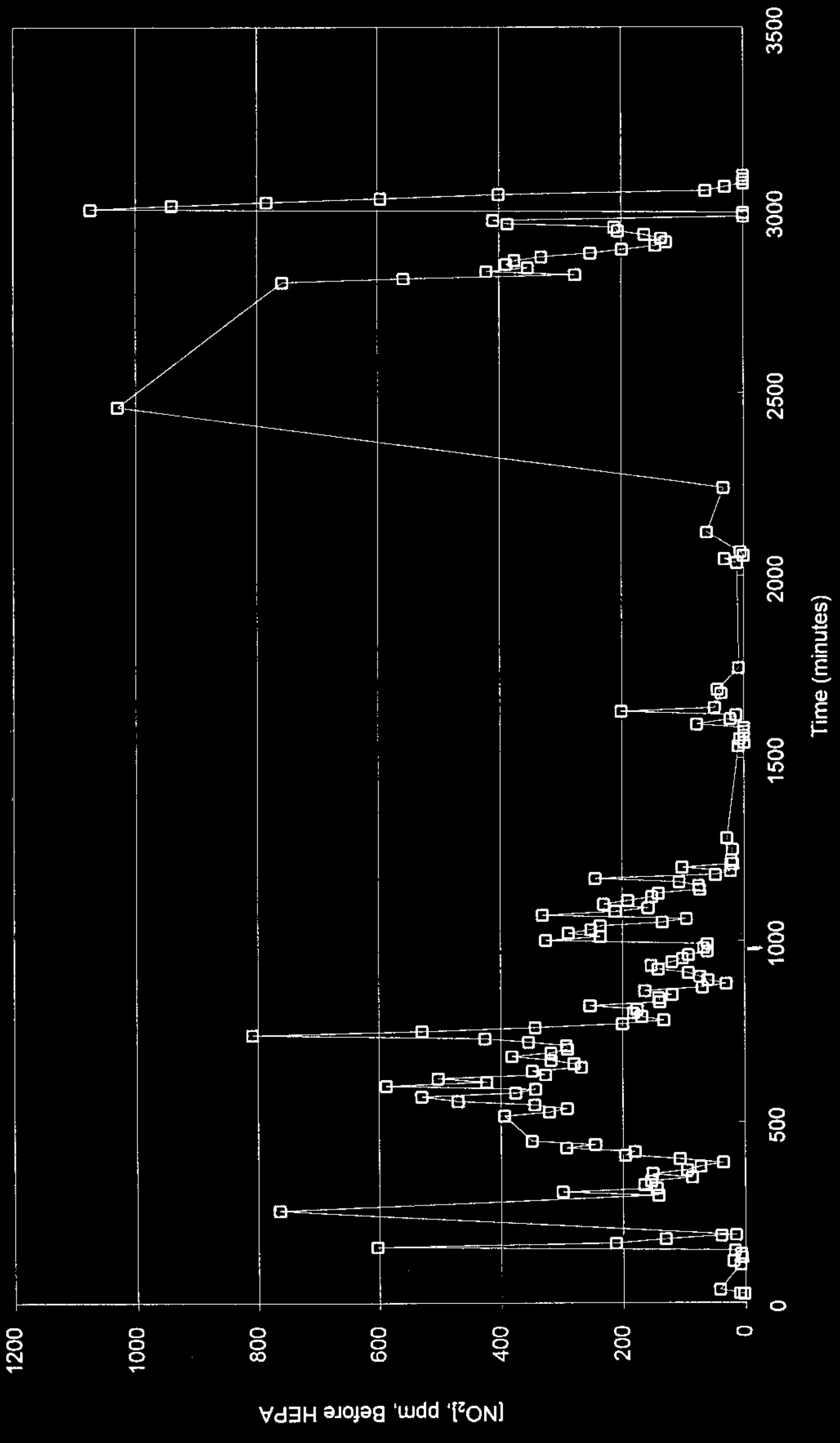


Figure 5.7.i. [NO_2] in Offgas Before HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

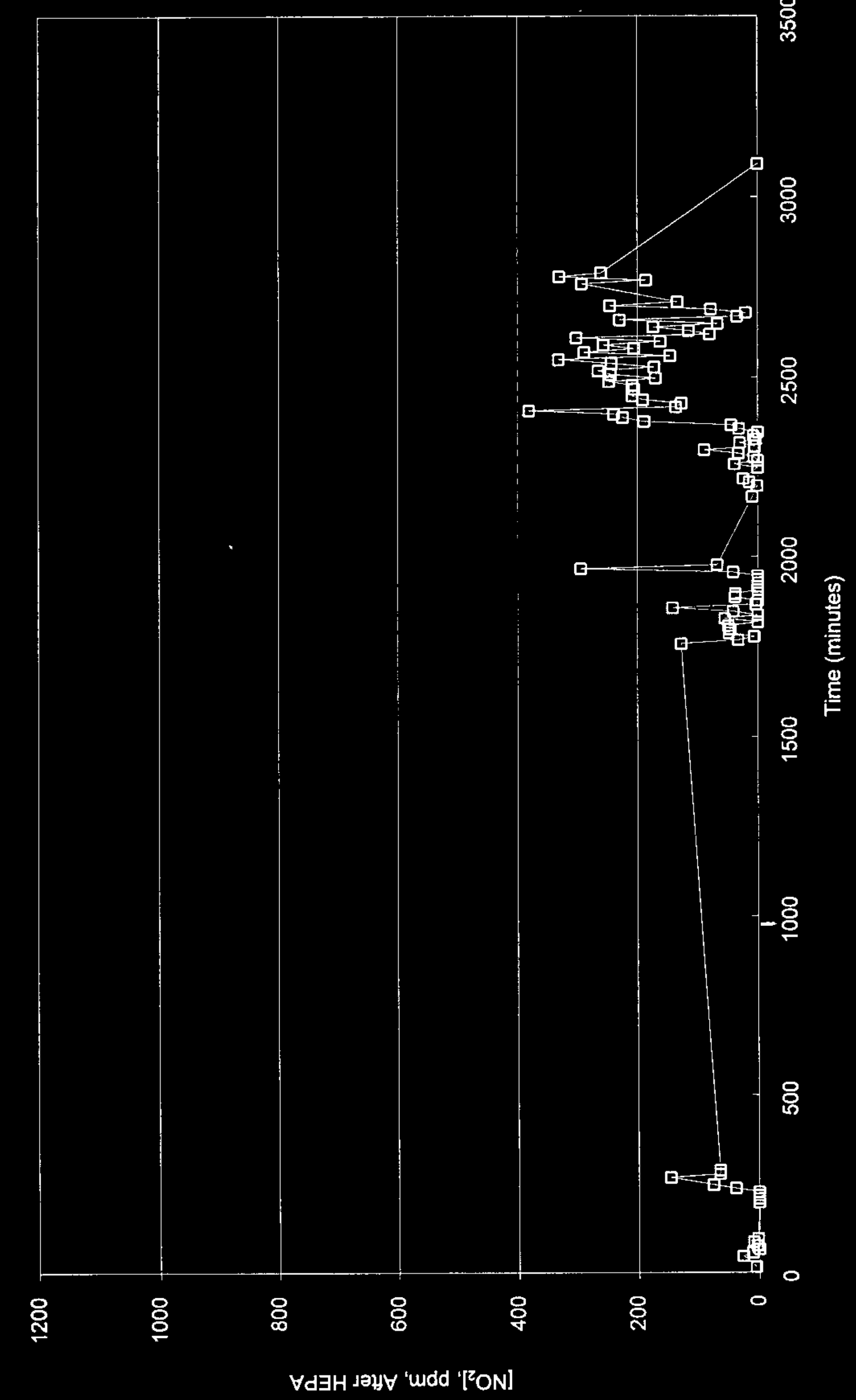


Figure 5.7.j. [CO] in Offgas Before HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

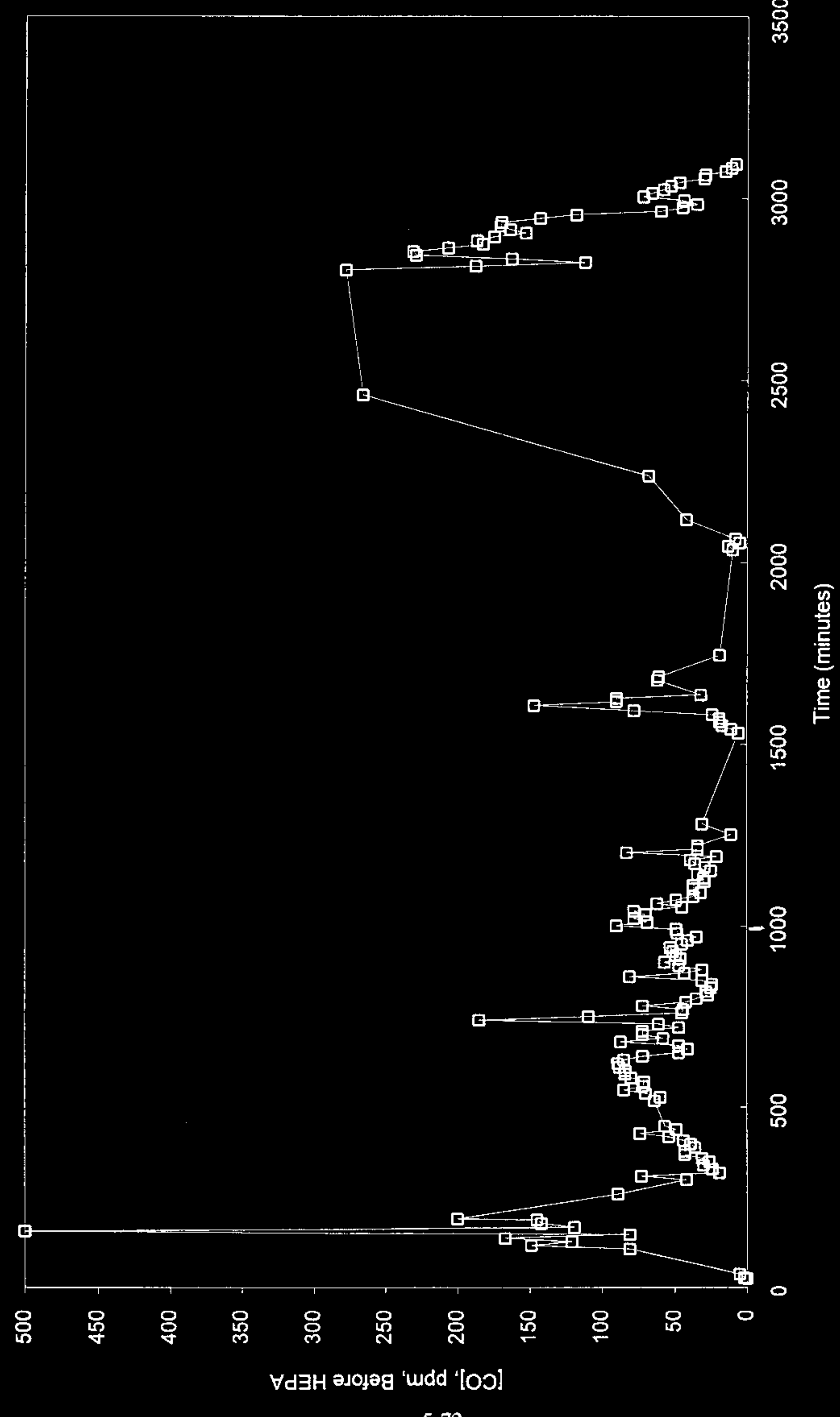


Figure 5.7.k. [CO] in Offgas After HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

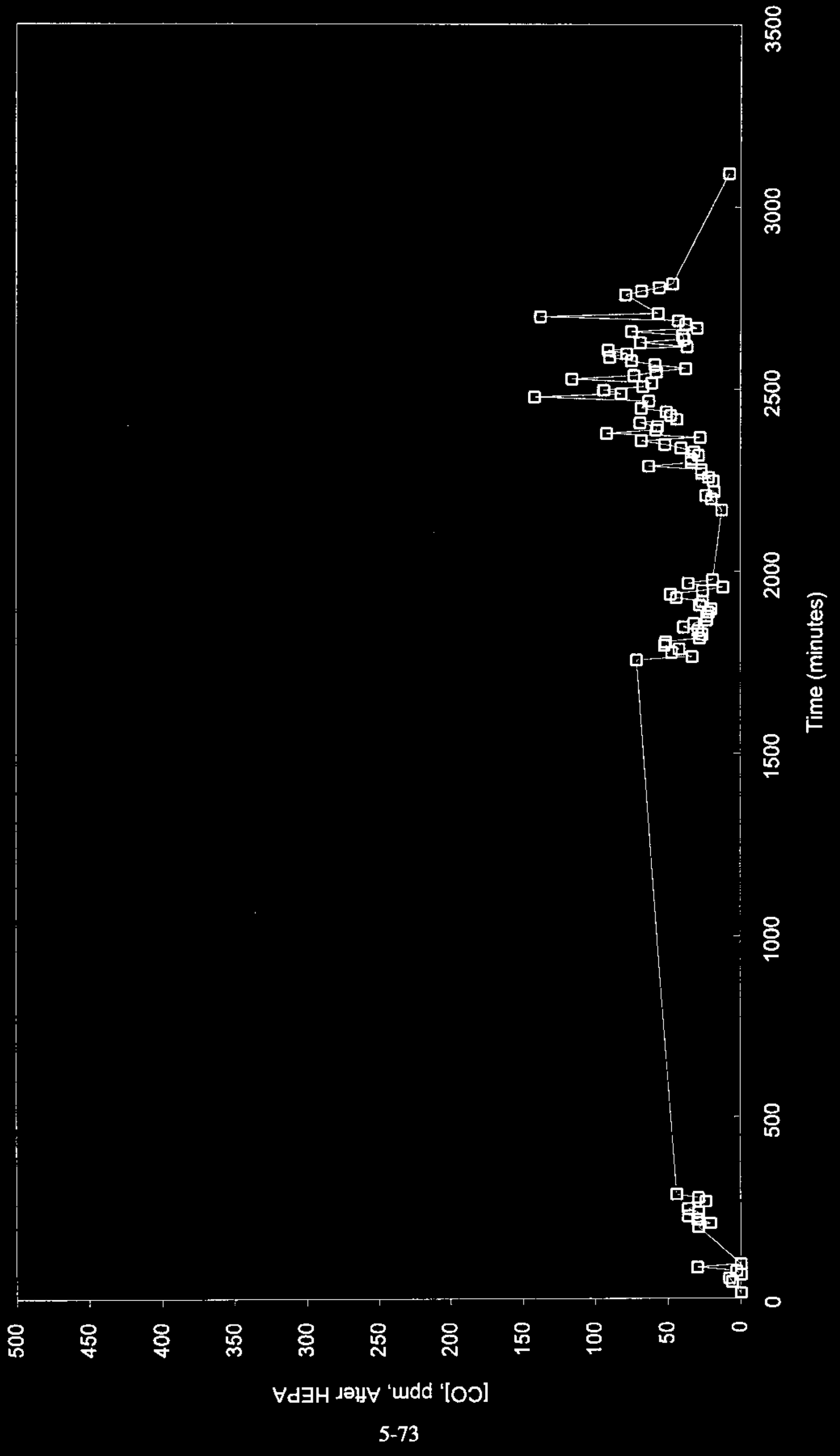


Figure 5.7.1. $[SO_2]$ in Offgas Before HEPA, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

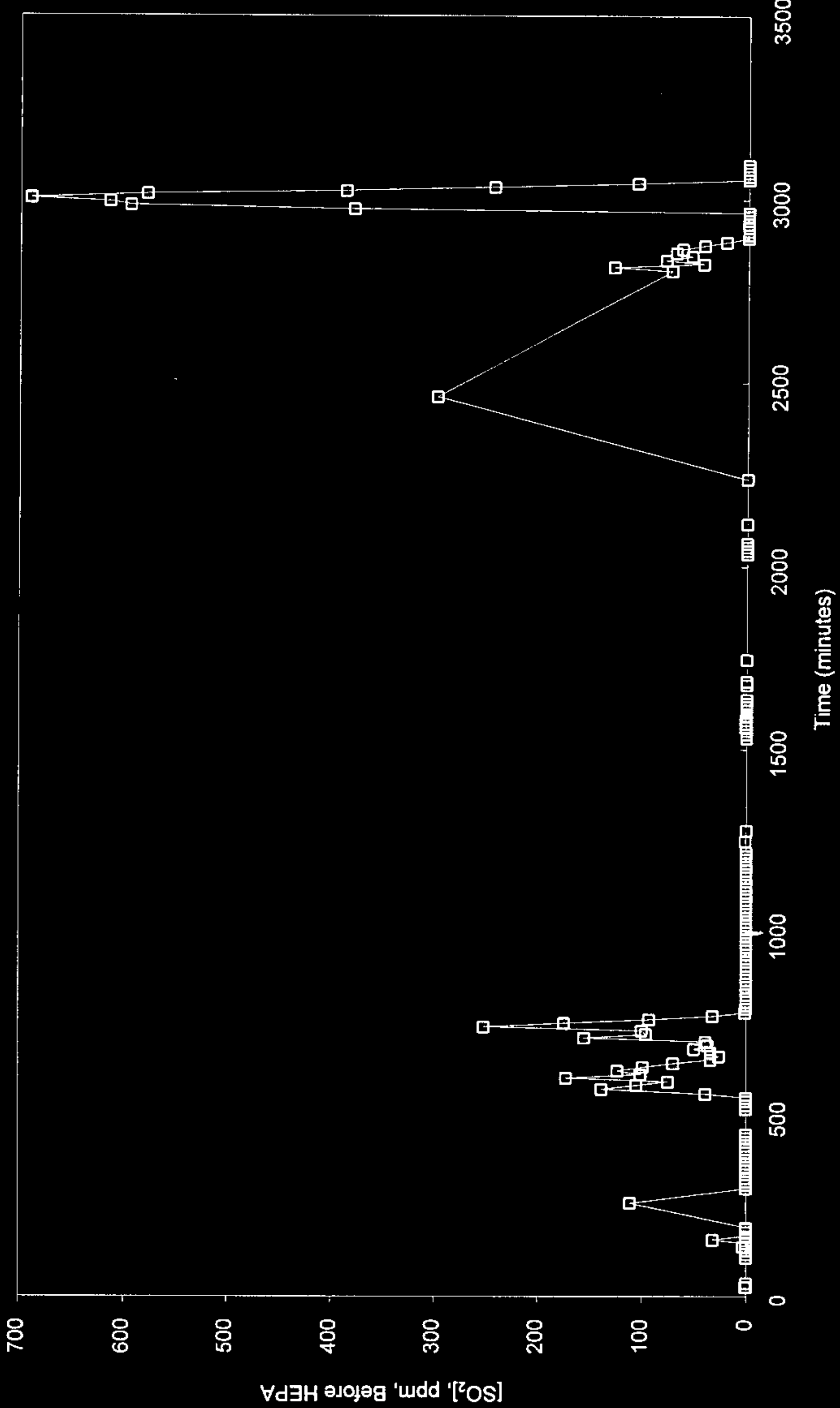


Figure 5.7.m. [SO_2] in Offgas After HEPA, DuraMelter™ 1000
Hanford Steady State (1/19/95-1/21/95)

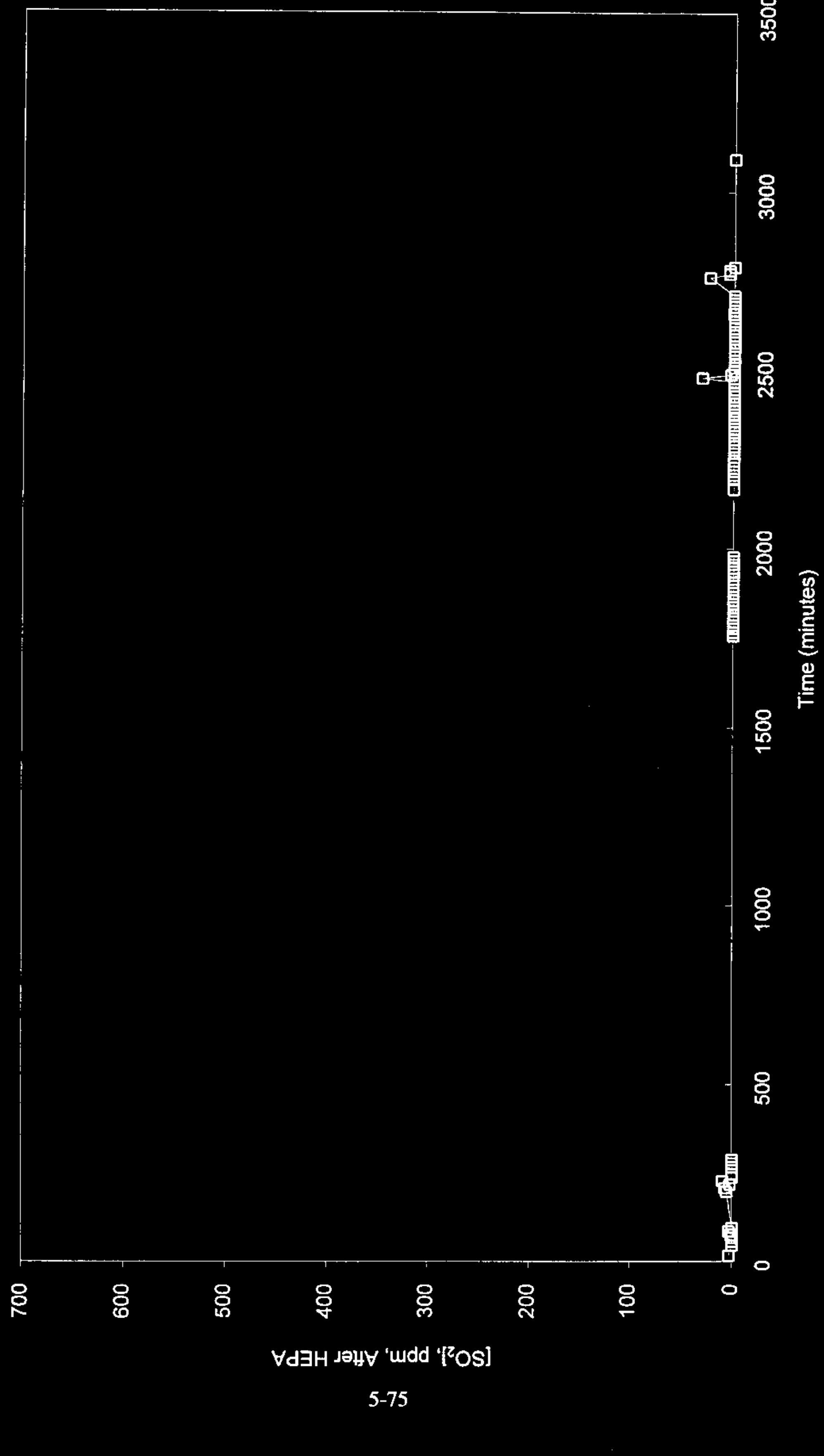


Figure 5.8.a. Composition, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)

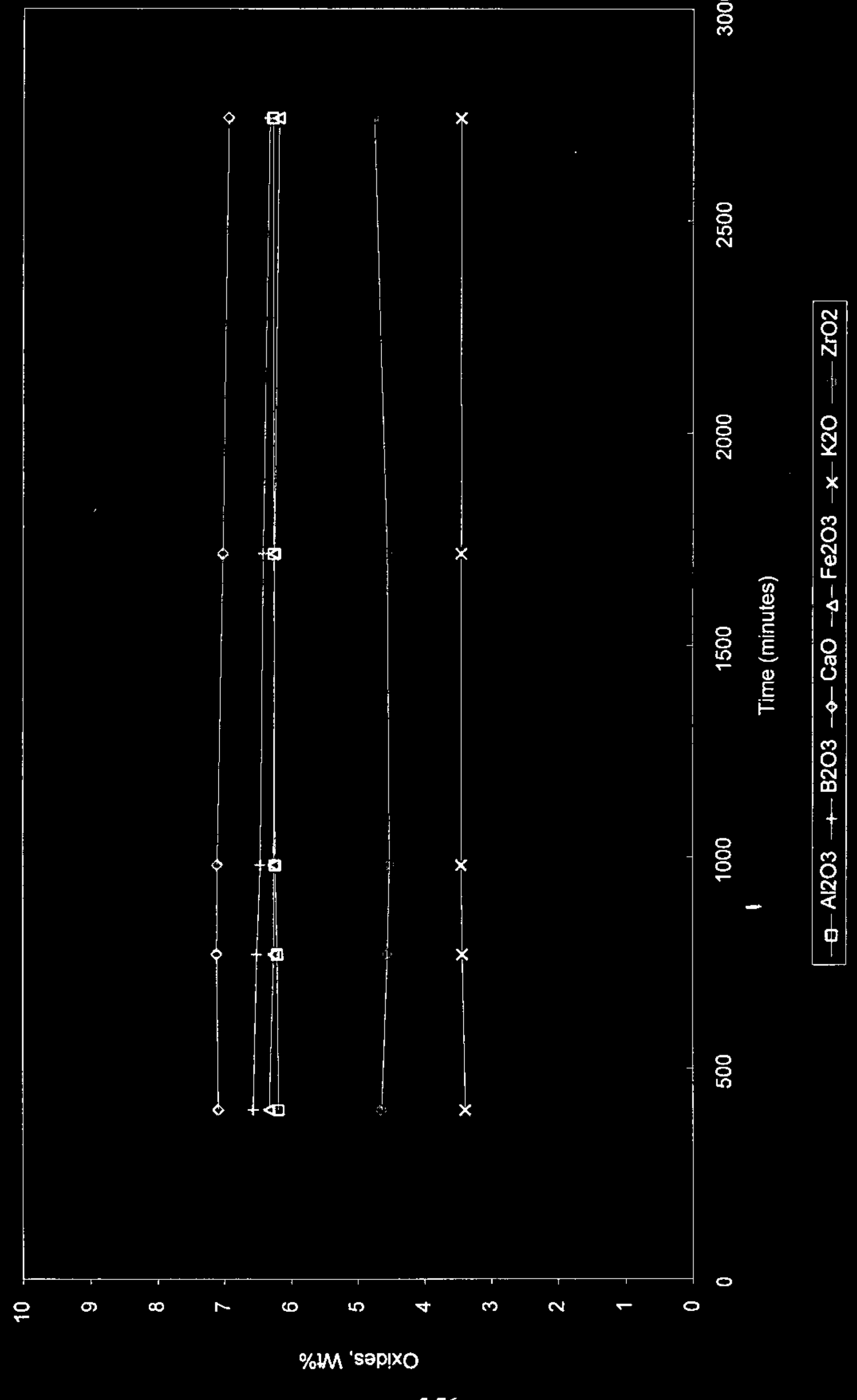


Figure 5.8.b. Composition, DuraMelter™ 1000
Hanford Steady State (1/19/95-1/21/95)

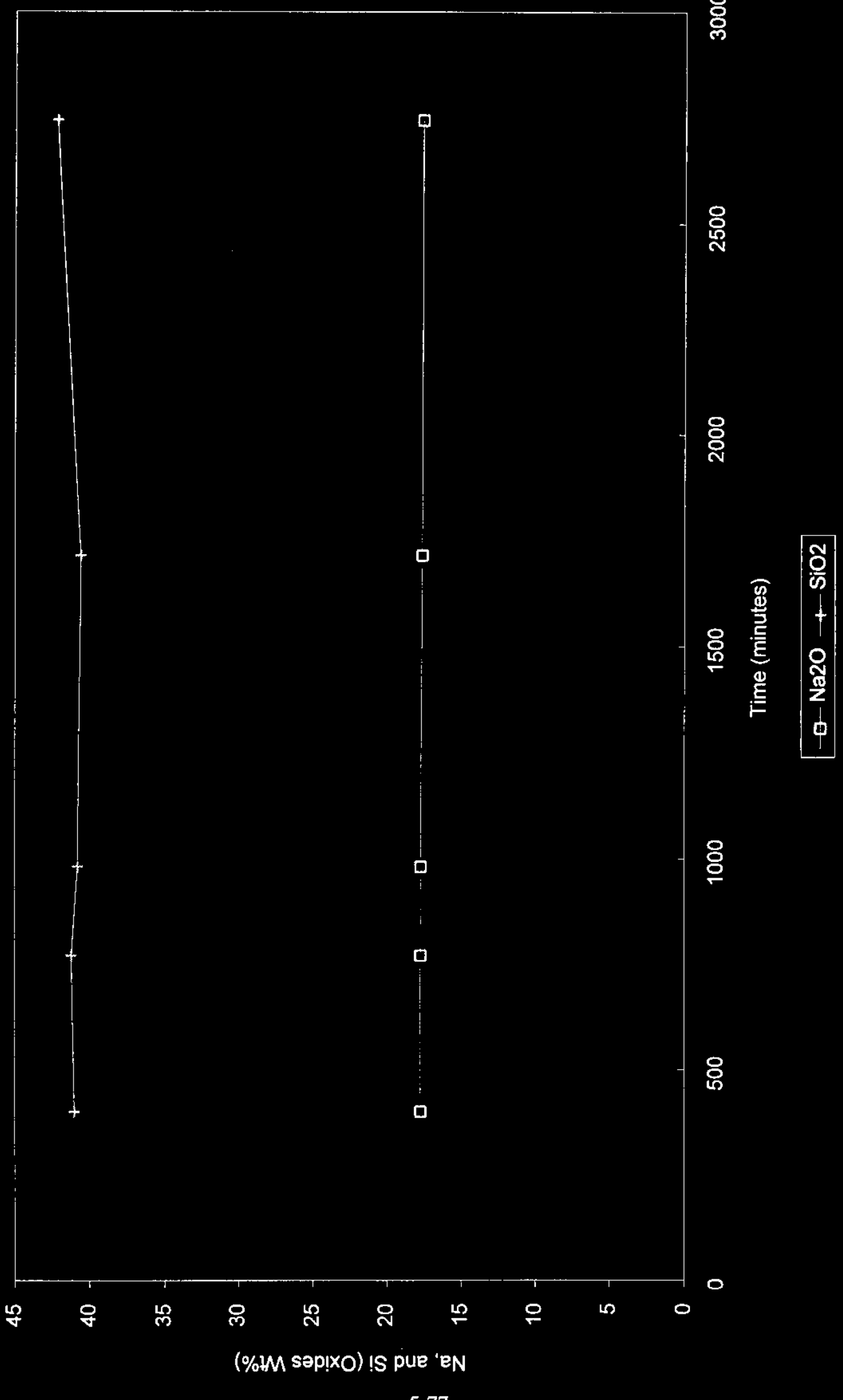
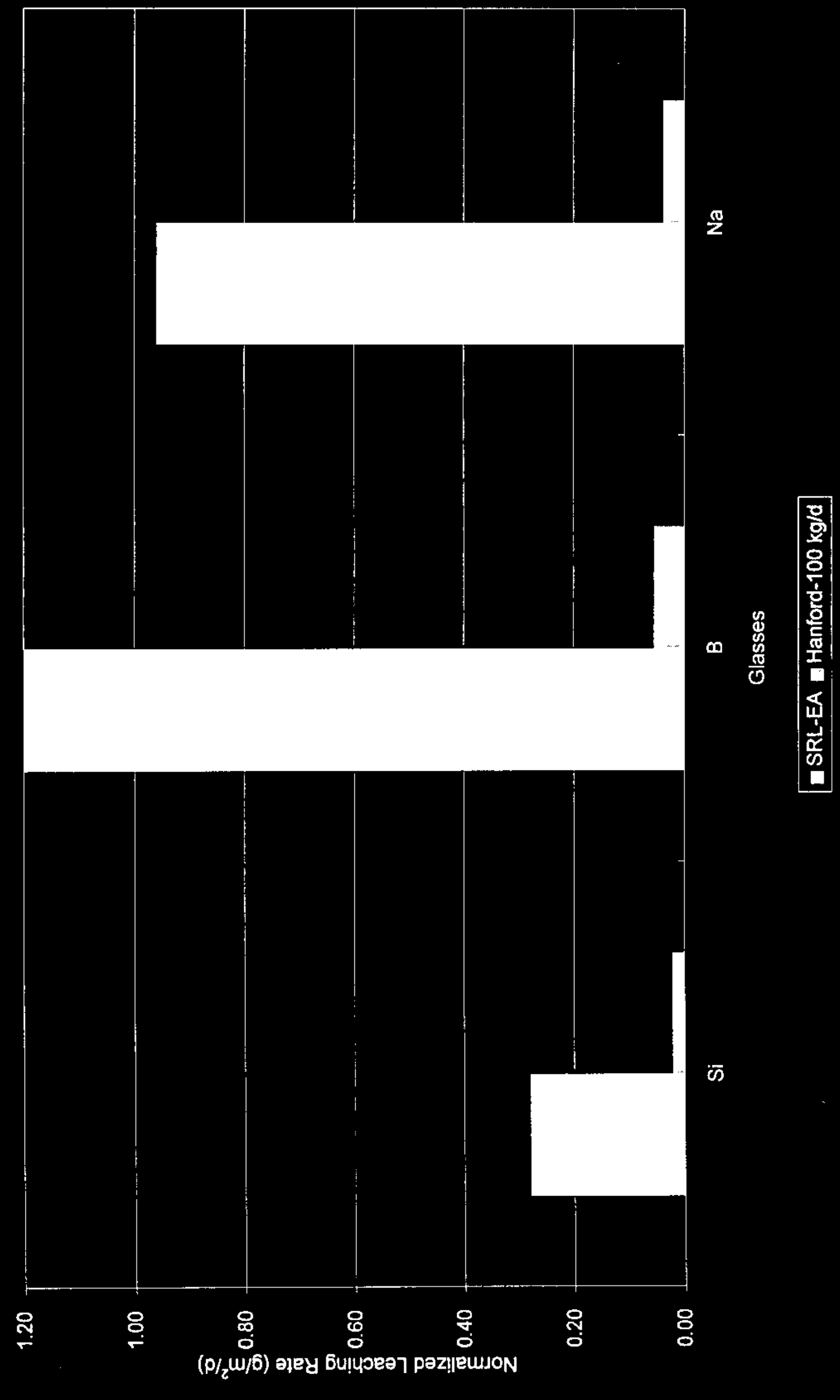


Figure 5.9.a. PCT, 7 Days, T=90°, S/V=2000 m^{-1}, DuraMelter™ 1000 Hanford Steady State (1/19/95-1/21/95)



6.0 NOx EMISSION CONTROL

6.1. INTRODUCTION

The LLW stream at Hanford, like many nuclear and mixed waste streams, contains significant amounts of nitrogen in the form of nitrates or nitrites. There is therefore the potential for the release of large quantities of NOx if all of the nitrogen were released in this way during the vitrification process. Scientists at the Vitreous State Laboratory (VSL) have investigated several approaches to these problems for a variety of applications. The most extensive testing was performed for GTS Duratek in support of the design and construction of their DuraMelter™ vitrification facility for M-Area mixed wastes on-site at Savannah River. These wastes also contain large amounts of nitrates and nitrites. In this particular application, however, there is an additional constraint that liquids released from the vitrification process are permitted to contain only very low levels of nitrites.

The investigations of various NOx treatment options were performed in several sets of experiments: bench-scale experiments using standard gases; DuraMelter™ 10 runs with actual Savannah River M-area feed; DuraMelter™ 100 runs with Hanford DSSF simulant and additives; detailed DuraMelter™ 1000 runs with diluted Hanford DSSF simulant and additives; and additional DuraMelter™ 1000 runs with Hanford DSSF simulant and additives. The focus of this report is, of course, on the results from the Hanford DuraMelter™ runs, however, a brief summary of the major conclusions from other previously reported tests are given to provide the appropriate background.

6.2. BENCH-SCALE EXPERIMENTS

Bench-scale experiments were conducted with standard gases to identify the important parameters associated with liquid scrubbing of NOx laden gases. NOx removal over 50% was demonstrated with liquid scrubbing alone. This process is highly dependent on the residence time of the gases in the scrubber column. The solution pH was observed not to be a significant factor between pH 3 and 13 and had only a slight effect above pH 13. The scrubber solution temperature was observed to affect NOx removal in that the lower the temperature the greater the amount of NOx removal. Spraying hydrogen peroxide into the gas stream at vaporizing temperatures was observed to reduce NOx emissions by an order of magnitude. The ENERAC 2000 system that was used for Hanford CEM measurement by VSL was also checked for potential interferences of the NOx reading by ammonia; no detectable effects were observed.

6.3. TEST TO SUPPORT SAVANNAH RIVER M-AREA VITRIFICATION SYSTEM DESIGN

Between October 10-12, 1994 over 40 kg of glass was produced from actual Savannah River M-Area waste using the DuraMelter™ 10. Various amounts of urea were added to the feed to determine the effect on NOx emissions. Overall NOx emissions were reduced by a factor of 5 to 10 depending melter conditions such as cold cap and melter temperatures. This reduction was achieved at a urea-to-feed-nitrate ratio of approximately 0.5. Higher concentrations of urea in the feed did not result in significant further reductions of NOx emissions. Based on these results, the urea-to-feed-nitrate ratio of about 0.5 was selected for subsequent DuraMelter™ 1000 runs.

6.4. DURAMELTER™ 100 HANFORD RUNS

In September of 1994, over 600 kg of glass was produced using the VSL DuraMelter™ 100. The nitrate-rich Hanford LLW simulant was approximately 50 weight percent of the feed, resulting in a nitrogen content of 2.2 weight percent. The primary goal of the work was to demonstrate that Hanford LLW simulant could be vitrified in such a system, not to determine operating parameters most conducive to NOx emission reduction. However, experiments were conducted to determine the effect of urea as a feed additive on NOx reduction.

Two additives (starch and urea) were tested during the turnover run for their effects on off-gas emissions. The effect of hydrogen peroxide additions to quencher and scrubber liquids was also tested. The criteria pollutants, NO_2 and NO were periodically monitored with the ENERAC system. The addition of urea significantly decreased the emission concentrations of NOx (NO and NO_2) in the off-gas, as shown in Figures 6.4.a-6.4.c (values were shown tabulated previously in Table 4.7.e). On the other hand, the addition of starch had relatively little effect on the concentration of NOx in the off-gas. However, the period of time was very short for the starch test due to its very significant impact on feed rheology; the feed became progressively thicker after the addition, to the point where it was no longer pumpable. The addition of hydrogen peroxide to the quencher and scrubber solutions did not have any effect on reducing NOx emissions. Furthermore, the initial additions of hydrogen peroxide gave intense foaming which was operationally undesirable.

Urea was added in various amounts to the feed to examine its effects on NOx reduction. Its effect was not correlated to cold cap or bubbling rate although cold caps between 80 to 100 percent were generally maintained. Figures 6.4.d and 6.4.e show the effect of urea additions on NOx emissions. NOx emissions were reduced by an order of magnitude at the highest feed rate.

Based on the results from the turnover period and the DuraMelter™ 100 test, urea was added to the feed for the entire steady-state period to control NOx production. The concentrations of NO and NO_2 in the off-gas were given in Table 4.7.f and depicted in Figure 4.7.e. To maximize NOx removal, a two molar urea-to-feed nitrate stoichiometry was used. The excess urea resulted in an unquantified but presumably substantial NH_3 concentration in the exhaust gases. Subsequent experiments demonstrated that much smaller concentrations of urea were equally effective in reducing NOx emissions.

6.5. DURAMELTER™ 1000 DILUTED HANFORD FEED TESTS

6.5.1. Methods and Overview

On December 17, 18, and 19, 1994 several experiments were conducted using the DuraMelter™ 1000 to determine optimum conditions for the reduction of NOx emissions. A three-fold volume dilution of the Hanford simulant feed was used in order to achieve the same feed nitrogen content as for the Savannah River M-Area feeds. The dry chemicals, the DSSF simulant, and water (purified by reverse osmosis) were combined in 500-gallon tanks and fed into the melter. The dilution resulted in an elemental nitrogen concentration of 13 g/liter or 1.06 weight percent.

Data were collected from these experiments under a variety of melter conditions including various plenum temperatures, cold caps, feeding conditions (such as times and rates), scrubber conditions (such as liquid types and volumes), and off-gas conditions (such as air flow rates and contaminant concentrations). The glass temperature was maintained at 1100 (±20) °C. Measured emissions and melter conditions are given in Table 6.5.1. Feed rates were monitored by calibrating the feed pump and observing the drop in feed level in the feed tank.

EPA Test Methods 1A and 2C were used to locate off-gas sampling points and to measure velocity with a standard pitot tube, respectively. Each velocity determination was the average of two perpendicular 12 point traverses. The density of air (as a function of temperature and humidity) at the sampling locality was calculated to be 0.071 lb/cf. This value was then used to calculate velocity. Measurements of NO, NO_2, SO_2, NOx, O, O_2, and stack temperature were made with an ENERAC 2000 system. This is the same device used in all measurements of these parameters at VSL. Gas concentrations are given in ppmv or volume percent.

6.5.2. Effects of Plenum Temperature and Cold Cap

The first set of experiments were performed to determine the effect of plenum temperature and cold cap on NOx emissions. These experiments were conducted during the first nine hours of run time and no urea or peroxide was used. The data are provided in Table 6.5.1. and depicted in Figure 6.5.2.a. The fraction of elemental N emitted as NOx (not including that from the urea) is a convenient measure of process effectiveness in that emissions are normalized to feeding rates and the weight of oxygen is factored out. This was calculated by dividing the mass of elemental nitrogen leaving the system as NOx (air volume X NOx concentration that is corrected to a nitrogen basis) by the amount being fed into the melter (feed nitrogen concentration X feed rate) at a given point in time. There was no clear connection between plenum temperature and NOx emissions. The amount of elemental nitrogen leaving as NOx averaged approximately 50% and ranged between 25 and 80 percent with no clear correlation to cold cap or plenum temperature. The results show that the thermal conversion to innocuous N_2 alone already provides a significant reduction over the theoretical maximum NOx emissions.

6.5.3. Effects of Urea and Hydrogen Peroxide

A second set of experiments was performed to determine the effect of urea and hydrogen peroxide in reducing NOx emissions. Both approaches were found to be very effective. The data from these experiments are summarized in Table 6.5.1 and depicted in Figures 6.5.3.a and 6.5.3.b. A concentrated (50%) hydrogen peroxide solution was pumped at 175 ml/min and sprayed against the flow of the exhaust gases in the quencher. The melter was fed at a rate of 2 liters/min resulting in a 1:1 molar ratio of peroxide to feed nitrate. Urea was added to the feed to achieve a 5:12 weight ratio (0.5 stoichiometry) of urea to feed nitrate.

The vast difference between spraying peroxide on the exhaust gases as opposed to water is illustrated in Figure 6.5.3.a; notice the low NOx values at the beginning of the run when peroxide was sprayed and the high values when water was sprayed with or without peroxide. The two points at approximately 50% N as NOx correspond to the baseline value for the thermal conversion alone. Depending on the cold cap, peroxide reduced the N-as-NOx percentage from the 50% baseline to 20%. The values above 100% relate to the destruction of the cold cap; for example, NOx was released from unmelted feed on top of the melt pool even when feeding was stopped. The conversion of NOx to N_2 was reduced if the temperature of the quenched gases was reduced by the spraying of water in addition to peroxide. The spaying of hydrogen peroxide on exhaust gases was therefore effective at reducing NOx emissions only at high temperatures.

Urea additions to the feed reduced emissions to as low as 5% of the total nitrogen fed into the melter. The effectiveness of the urea in reducing NOx emissions was affected by the extent of the cold cap (Figure 6.5.3.c). As the cold cap increased to 100%, the NOx emissions increased by a factor of four. This trend was reversed as the cold cap was destroyed.

Small concentrations of CO were released when urea and peroxide were used as depicted in Figure 6.5.3.b. It is likely that small amounts of carbon monoxide were produced from the breakdown of urea ($CO(NH_2)_2$). The mechanism for the CO production when peroxide was used is unclear.

6.6 DURAMELTER™ 1000 EXPERIMENTS WITH HANFORD FEED

Experiments using Hanford LLW feed were conducted prior to the diluted feed experiments on December 13 and 14, 1994 and afterwards on December 19 and 20, 1994. The earlier experiments were conducted to test the feed system and establish an emissions baseline for the high-nitrogen Hanford feed. The second set of experiments was conducted to provide more data on hydrogen peroxide quenching, particularly when the feed contains urea.

The first set of experiments demonstrated that either higher concentrations of nitrate in the feed or the decreased water-to-nitrate ratio decreased overall NOx emissions. These experiments were conducted with cold caps between 50 and 65 percent and moderate bubbling rates. No peroxide or urea were used, yet 50 to 70 of the nitrogen was decomposed to N_2 in the plenum area. It is not possible to separate the effects of nitrate concentration and the water-to-nitrate ratio because water was used to dilute the Hanford feed.

The last set of experiments further demonstrated the effectiveness of hydrogen peroxide and urea at reducing NOx emissions. Data for these experiments are given in Table 6.6 and depicted in Figures 6.6.a and 6.6.b. Figure 6.6.a illustrates the dramatic effect of combining both hydrogen peroxide and urea on emissions. NO and SO_2 are shown in the Figure because they both remain on-scale on the ENERAC for the entire experiment. The results show that while urea additions to the feed are both simple and effective, NOx emissions from melting a urea-containing feed can be further reduced by using hydrogen peroxide to quench the exhaust gases. This reduction, however, is only an additional 20% of the baseline NO concentration.

In these experiments, an 80% cold cap was maintained while the glass pool was bubbled vigorously. The result was reduced NOx emissions. This was in contrast to the prior urea run in which large cold caps contributed to an increase in NOx emissions. Apparently, vigorous bubbling or the lack of a cold cap provides higher reaction temperatures which facilitate nitrate decomposition to N_2 rather than NOx.

Emissions data for the steady-state portion of the run were in good agreement with those for the urea portion of the last turnover run. The average NO concentration during the steady-state run (Figures 5.7.d and 5.7.e and Tables 5.7.c and 5.7.d) was 365 ppmv as compared to approximately 400 ppmv during the urea portion of the experiments. Carbon monoxide concentrations ranged between 30 to 80 ppmv during urea feeding for both runs. Sulfur dioxide emissions were always virtually absent during periods of urea feeding.

6.7. NITROGEN MASS BALANCES

Data was gathered during the diluted Hanford feed experiments to determine the distribution of nitrogen between scrubber liquids and the various kinds of emissions. Scrubber solution volumes were combined with VSL concentration data to calculate the nitrogen accumulation in scrubber liquids. Elemental nitrogen emitted as NOx values from Table 6.5.1 were time weighted and averaged to determine the total mass of nitrogen emitted as NOx over the given periods of time. These values were subtracted from the amount of nitrogen fed into the melter to determine the amount of nitrogen decomposed to N_2. The results are given in Table 6.7.a along with results obtained from feeding the more concentrated material.

Large portions of the nitrates fed into the melter were thermally decomposed to N_2 in all of these time periods. The major factors affecting this process appear to be feed concentration of nitrate and the presence of urea. The amount of nitrogen trapped in scrubber liquids was relatively constant. The efficiency of the scrubber was relatively constant also (Table 6.7.b) over the range of conditions tested.

The ratio of nitrate to nitrite in the scrubber liquid was drastically affected by solution pH. Nitrite is stable in basic solutions and is only converted to nitrate, at any reasonable rate, upon acidification. Unfortunately, acidification alone results in a significant release of NO_x as shown in Table 6.7.b.

Calculations from the DuraMelter™ 1000 steady-state and third turnover runs show that approximately eight percent of the ammonia (as urea) fed into the melter exits into the off-gas system. This value would not be valid for diluted Hanford feed or for urea-to-nitrate molar ratios other than 0.5. Emission measurements of ammonia indicated that less than twenty percent of this ammonia is emitted from the off-gas system. This figure would be drastically reduced with an acid scrubber. Spent diatomaceous earth samples from the bag house during the turnover period were analyzed at VSL to investigate the potential for ammonium nitrate formation. The measured ammonia values were below 0.5% in all cases and were always significantly lower than the nitrate concentrations.

Excellent NOx emission control was achieved during the DuraMelter™ 1000 steady-state run. Calculations from average feed and emission rates (Tables 5.7.c and 5.7.d) show that less than 9 percent of the elemental nitrogen fed into the melter was emitted as NOx over that run. If scrubbing efficiencies of 20 to 30 percent are assumed, 89 percent of the elemental nitrogen fed into the melter was decomposed to diatomic nitrogen. SO_2 emissions were practically eliminated.

6.8 CONCLUSIONS

Forty to fifty percent of the nitrogen entering the DuraMelter™ 1000 as diluted Hanford surrogate feed was decomposed to N_2 in the plenum area with no additional engineering controls. This was demonstrated very clearly with the DuraMelter™ 1000. Once the cold cap was stabilized, factors such as plenum temperature, size of the cold cap, and feed rate show little effect on this process. The nitrogen content of the feed (or the ratio of water to nitrogen) does have an effect in that the greater the percentage of nitrogen in the feed the greater the percentage that is decomposed to N_2.

The addition of urea to the feed can increase thermal decomposition of nitrates to greater than 80 percent. The effectiveness of this can be reduced if there is an extensive cold cap; however, if a cold cap of approximately 80% is maintained with vigorous bubbling, maximum decomposition can still be achieved. Several different urea/nitrate ratios were tested. Effective decomposition of nitrates was achieved at weight ratios as low as 5/12. Potential problems with urea, such as ammonia release and ammonium nitrate accumulation in the bag house, can be eliminated with an acid scrubber.

At high temperatures, hydrogen peroxide is effective in reducing NOx emissions. The vapor-phase reaction involves oxidation of NO to NO_2 and NO_2 to nitric acid. NO cannot be removed by liquid scrubbing and therefore even conversion of NO to NO_2 results in overall NOx emission reduction. This was demonstrated with extensive bench-scale experiments and DuraMelter™ 1000 runs. Although peroxide is effective in reducing NOx emissions, it requires a dedicated delivery and monitoring system.

Bench-scale experiments demonstrated that significant removal of NOx (primarily NO_2) by spraying exhaust gases in a packed bed column is possible, but highly dependent on residence time. Using residence times feasible in the scrubber tower of the DuraMelter™ 1000, 6-11% of the nitrogen fed into the melter was removed by the scrubbing liquids; this corresponds to the capture of about 25% of the NOx reaching the scrubber. A greater proportion of the nitrogen that enters the melter is removed because 40-70% has already been converted to N_2 in the plenum. The pH of the scrubbing liquids does not exert a marked effect on scrubbing efficiency. It does however determine the final nitrite/nitrate ratio in the scrubbing liquids. Nitrite/nitrate ratios in acid scrubbing liquids are 0.01 and 6 in basic solutions.

Table 6.5.1
Conditions and Emissions for DuraMelter™ 1000 Run; Dec. 17-19, 1994

Date	Time	Cum Time (hrs)	NOx ppm	SO_2 ppm	NO ppm	NO_2 ppm	NOx/SO_2	CO ppm	Feed rate (l/min)	% N as NOx	plenum °C
12/17	1945	0.75	16	0	10	6	1.15	0	2.0	0	970
	2037	1.62	1881	1640	1106	775	1.23	0	2.0	51.0	926
	2130	2.5	1870	1526	1145	725	1.32	0	2.0	51.2	882
	2147	2.78	2211	1674	1309	902	1.32	0	2.0	60.0	840
	2203	3.05	1879	1428	1154	725	1.40	0	2.0	51.5	750
	2235	3.58	1321	941	893	428	1.32	13	2.0	37.1	708
	2313	4.22	1327	1007	836	491	1.35	0	1.0	73.1	790
	2342	4.7	1383	1025	879	504	1.32	0	1.6	47.7	872
12/18	0002	5.03	2139	1622	1183	956	1.32	0	1.6	71.5	875
	0021	5.35	1497	1070	911	586	1.40	0	1.5	54.5	893
	0039	5.65	2154	1667	1186	968	1.29	0	1.5	76.7	906
	0048	5.8	750	467	542	208	1.61	0	1.5	28.6	934
	0107	6.12	1200	916	794	406	1.31	0	1.5	44.6	930
	0145	6.77	686	462	506	180	1.48	0	0.8	49.2	960
	0204	7.07	785	546	559	226	1.44	0	0.8	55.8	961
	0224	7.4	596	362	438	158	1.65	0	0.8	42.7	968
	0245	7.75	913	592	615	298	1.54	0	0.8	64.0	906
	0302	8.03	632	374	449	183	1.69	0	0.8	44.9	835
	0311	8.18	471	239	336	135	1.97	0	0.8	33.5	824
	0323	8.38	730	474	227	730	1.54	0	0	0	0
	0335	8.58	158	9	135	27	17.56	0	0	0	0
	0339	8.65	68	0	60	8	0	0	0	0	0
	2130	11.5	over	1455	1400	over	2.06	0	variable		840
	2200	12	1180	643	785	350	1.84	0	variable		0
	2215	12.25	1950	1196	1223	728	1.63	15	variable		778
	2233	12.55	1183	479	402	774	2.47	15	2.2	31.6	756
	2236	12.6	975	355	332	676	2.75	7	2.2	27.0	0
	2240	12.67	1094	480	377	725	2.28	11	2.2	29.7	0
	2248	12.8	970	412	333	650	2.35	11	2.2	26.4	730
	2250	12.83	1000	427	327	653	2.34	12	1.77	32.7	0
	2255	12.92	940	421	335	587	2.23	13	1.77	31.1	0
	2300	13	1459	855	819	640	1.71	15	1.77	53.7	703
	2305	13.08	1329	693	765	564	1.92	12	1.77	49.2	0
	2310	13.16	674	170	296	378	3.96	9	1.77	23.5	0
	2315	13.25	564	136	249	306	4.15	11	1.77	19.5	689
	2320	13.33	859	376	522	321	2.28	11	1.77	31.8	0
	2330	13.5	1900	887	1047	777	2.14	13	1.77	67.5	700
	2340	13.67	1320	670	856	472	1.97	17	1.77	50.5	0
	2359	13.98	1476	560	866	534	2.64	15	1.35	69.1	0

Table 6.5.1 Continued

Date	Time	Cum Time (hrs)	NOx ppm	SO_2 ppm	NO ppm	NO_2 ppm	NOx/SO_2	CO ppm	Feed rate (l/min)	% N as NOx	plenum °C
12/19	0010	14.16	1800	725	1076	760	2.48	17	1.35	89.5	661
	0012	14.2	1360	483	875	477	2.82	9	1.35	67.5	0
	0020	14.33	1640	670	1048	607	2.45	15	1.35	82.2	0
	0025	14.42	2033	940	1230	830	2.16	19	1.35	100.8	0
	0030	14.5	1879	808	1160	724	2.33	20	1.35	92.9	0
	0048	14.8	2340	1036	1460	1059	2.26	29	1.35	122.4	0
	0100	15	2375	1015	1405	1000	2.34	19	1.3	121.6	631
	0105	15.08	1435	356	980	529	4.03	7	1.3	78.3	631
	0112	15.2	1410	504	1050	575	2.80	7	1.3	84.2	632
	0118	15.3	989	163	686	303	6.07	7	1.3	52.2	632
	0125	15.42	1170	344	720	323	3.40	11	1.3	55.0	643
	0150	15.83	over	795	1676	over	3.77	0	1.5	100.0	666
	0200	16	over	860	1570	over	3.49	0	1.5	100.0	701
	0205	16.08	2488	890	1415	1110	2.80	0	1.5	109.6	0
	0210	16.16	2330	838	1374	1374	2.78	0	1.5	116.3	0
	0215	16.25	1912	594	1187	772	3.22	0	1.5	86.6	0
	0220	16.33	1812	575	1136	680	3.15	0	1.5	80.9	760
	0230	16.5	1309	263	843	490	4.98	0	1.5	59.6	770
	0240	16.67	1079	154	772	305	7.01	0	1.5	49.8	0
	0245	16.75	913	91	669	225	10.03	0	1.5	41.8	780
	0258	16.97	574	0	299	276	0	0	1.5	24.5	785
	0305	17.08	973	286	603	335	3.40	0	1.5	42.1	0
	0312	17.2	506	0	195	315	0	0	1.5	20.5	0
	0315	17.25	960	318	600	369	3.02	0	1.5	43.1	0
	0320	17.33	1058	390	660	397	2.71	0	1.5	47.1	0
	0322	17.37	1168	481	808	369	2.43	0	1.5	53.7	0
	0323	17.38	1142	439	770	332	2.60	0	1.5	50.6	0
	0410	18.18	575	0	200	365	0	0	1.27	26.5	0
	0415	18.25	905	219	660	232	4.13	0	1.27	49.1	0
	0420	18.33	586	0	143	451	0	0	1.27	26.4	839
	0425	18.42	175	0	61	122	0	0	1.27	8.5	0
	0430	18.5	101	0	60	40	0	0	1.27	5.2	0
	0446	18.77	121	0	94	28	0	0	1.27	6.8	0
	0450	18.83	113	0	86	26	0	0	1.27	6.2	0
	0500	19	114	0	91	22	0	0	1.27	6.4	824
	0508	19.13	200	0	173	29	0	15	1.27	11.6	0
	0515	19.25	141	0	121	21	0	7	1.27	8.2	811
	0520	19.33	163	0	145	21	0	4	1.27	9.6	0
	0525	19.42	206	0	183	24	0	4	1.27	12.0	790
	0530	19.5	128	0	117	19	0	13	1.27	7.8	0
	0535	19.54	333	68	299	37	4.90	19	1.27	19.6	0
	0545	19.75	688	292	580	110	2.36	23	1.27	39.5	684
	0602	20.03	535	140	459	72	3.82	25	1.27	30.6	641
	0623	20.38	540	343	445	65	1.57	29	2.2	17.0	631
	0635	20.54	1186	766	958	270	1.55	27	2.2	39.6	644
	0638	20.63	933	586	766	176	1.59	31	2.2	30.8	0
	0640	20.67	814	519	686	130	1.57	31	2.2	26.9	660
	0700	21	551	382	485	74	1.44	25	1.6	25.6	643
	0716	21.27	288	219	266	21	1.32	29	1.6	13.4	0
	0733	21.55	251	220	236	14	1.14	35	1.6	11.8	0
	0752	21.87	251	236	234	17	1.06	37	3.1	6.1	0
	0810	22.17	289	284	266	14	1.02	33	3.1	6.8	0
	0820	22.33	143	170	146	7	0.84	27	3.1	3.7	0
	0835	22.54	1015	1040	834	215	0.98	43	3.1	24.2	0
	0856	22.93	2611	1582	1656	955	1.65	19	3.1	56.5	0

over - the ENERAC upper limit for NO_2 is approximately 1000 ppm

Table 6.6
Emissions Data (ppm) During DuraMelter™ 1000 Run; Dec. 13-14, 1994

Date	Time	Run time (hr)	NO_x	SO_2	NO	NO_2	CO	Conditions
12/19/94	1905	0.08	940	260	532	408	0	H_2O_2
	1910	0.17	1066	328	556	508	0	H_2O_2
	1915	0.25	1111	339	474	637	0	H_2O_2
	1920	0.33	1410	569	729	681	0	H_2O_2
	1921	0.35	1389	549	668	721	0	H_2O_2
	1923	0.38	1367	528	649	718	0	H_2O_2
	1926	0.43	2199	1052	1164	1035	0	water
	1927	0.45	over	1088	1420	over	0	water
	1936	0.6	1332	356	548	784	0	H_2O_2
	1937	0.62	1203	310	509	694	0	H_2O_2
	1940	0.67	1596	614	737	859	0	H_2O_2
	1942	0.7	1106	354	440	766	0	H_2O_2
	1945	0.75	1083	320	363	720	0	H_2O_2
	1947	0.78	1047	325	313	734	0	H_2O_2
	1950	0.83	1404	597	544	860	0	H_2O_2
	1955	0.92	1146	419	310	836	0	H_2O_2
	1957	0.95	over	1293	1250	over	0	water
	1959	0.98	over	1192	1251	over	0	water
	2002	1.03	over	1068	1187	over	0	water
	2008	1.13	1154	264	375	779	0	H_2O_2
	2010	1.17	1283	419	463	820	0	H_2O_2
	2015	1.25	1247	391	361	786	0	H_2O_2
	2020	1.33	1208	459	368	840	0	H_2O_2
	2022	1.37	1259	509	378	881	0	H_2O_2
	2026	1.43	2165	1123	1142	1023	0	water
	2027	1.45	over	1207	1225	over	0	water
	2030	1.5	over	1077	1254	over	0	water

TABLE 6.6 CONTINUED

Date	Time	Run time (hr)	NO_x	SO_2	NO	NO_2	CO	Conditions
12/20/94	0128	2.47	over	1420	1531	over	0	water
	0135	2.58	1508	525	540	968	29	H_2O_2
	0137	2.62	over	947	941	over	32	H_2O_2
	0143	2.72	1649	613	640	1009	35	H_2O_2
	0147	2.78	1886	876	801	1085	41	H_2O_2
	0148	2.8	over	836	749	over	43	H_2O_2
	0151	2.85	over	823	717	over	29	H_2O_2
	0155	2.92	over	1275	1536	over	0	water
	0158	2.97	over	1020	1615	over	0	water
	0223	3.38	over	1170	1260	over	0	water
	0224	3.4	over	1095	1255	over	0	water
	0225	3.42	over	1061	1276	over	0	water
	0232	3.53	over	1815	1307	over	0	water
	0237	3.62	over	767	1653	over	21	urea
	0241	3.68	over	648	1274	over	50	urea
	0243	3.72	over	895	1618	over	11	urea
	0246	3.77	979	0	602	372	53	urea
	0248	3.8	913	0	600	313	51	urea
	0250	3.83	1094	41	720	374	80	urea
	0252	3.87	757	0	511	246	53	urea
	0255	3.92	324	0	216	108	61	H_2O_2/urea
	0257	3.95	257	0	174	83	83	H_2O_2/urea
	0258	3.97	187	0	95	92	68	H_2O_2/urea
	0259	3.98	178	0	85	93	75	H_2O_2/urea
	0300	4	146	0	100	46	61	H_2O_2/urea
	0301	4.02	181	0	78	103	55	H_2O_2/urea
	0302	4.03	156	0	63	93	48	H_2O_2/urea
	0303	4.05	186	0	71	115	41	H_2O_2/urea
	0327	4.45	342	0	251	91	33	water/urea
	0330	4.5	611	111	515	96	251	water/urea
	0332	4.53	342	0	248	94	54	water/urea
	0334	4.57	352	0	264	88	77	water/urea
	0335	4.58	263	0	190	73	67	water/urea
	0336	4.6	518	119	395	123	31	water/urea
	0338	4.63	379	0	287	92	58	water/urea
	0342	4.7	439	0	154	285	35	urea
	0346	4.77	397	0	176	221	47	urea
	0349	4.82	327	0	91	236	41	urea
	0355	4.92	211	0	76	135	48	urea
	0358	4.97	321	10	162	159	53	urea

over - the upper limit of the ENERAC is approximately 1000 ppm for NO_2

Table 6.7.a
Mass Distribution of Nitrogen

Date	Run Time (hr)	Feed		Percent of Total Elemental N			Conditions
		Conc. (g/l)	Total Mass (kg)	In Scrubber Solutions	Emitted as NO_x	Emitted as N_2	
Dec 13,1994*	3.5	39	9.6	9.4	34.4	56.2	No Urea
Dec 14,1994*	11	39	51	8.0	20.0	72.0	No Urea
Dec 18,1994	6.6	13	5.2	10.8	51.3	37.9	No Urea
Dec 19,1994	4	13	4.3	6.7	20.9	72.4	Basic Scrubber, Urea in Feed

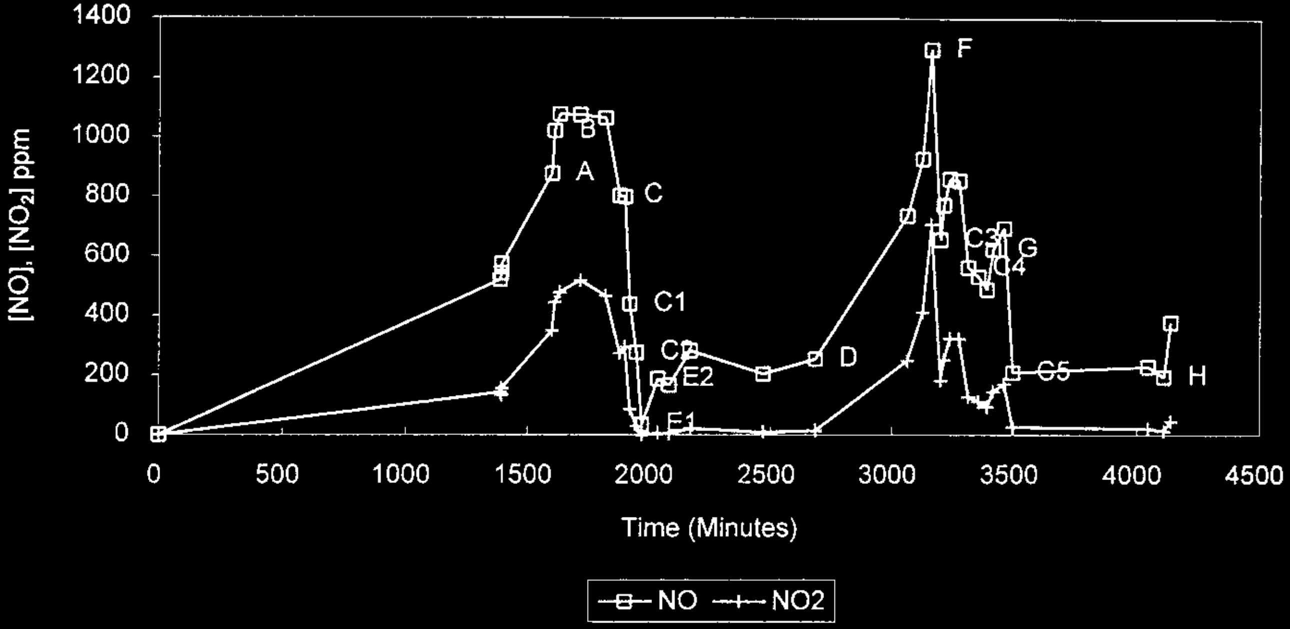
* NO_x values not time averaged, delta p from pitot tube not adjusted for RH% + temp, hence, 10% error possible.

Table 6.7.b
Summary of Scrubber Efficiency

Date	Run Time (hr)	Scrubber					Emissions exiting Scrubber NO/ NO_2	Conditions
		Total Mass N (kg)	Elemental Nitrogen Captured	Scrubbing Efficiency	Nitrate/ Nitrite	Elemental Nitrogen as NO_x emitted upon Acidification		
Dec 13,1994*	3.5	0.9	9.4 %	26.9 %	105	0.09 %	1	Acid Scrubber
Dec 14,1994*	11	4.1	8.0 %	28.7 %	105	0.09 %	1	Acid Scrubber
Dec 18,1994	6.6	0.6	10.8 %	18.6 %	0.17	9.4 %	0.5	Basic Scrubber
Dec 19,1994	4	0.3	6.7 %	25.3 %	0.17	5.8 %	0.25	Basic Scrubber, Urea Feed

* NO_x values not time averaged, delta p from pitot tube not adjusted for RH% + temp, hence, 10% error possible.

Figure 6.4.a. Final Air Emissions, [NO], [NO$_2$], DuraMelter™ 100 Hanford Turnover (9/22/94-9/24/94)



A	After Adding 10 l Peroxide to Quencher
B	After Adding 10 l Peroxide to Scrubber
C	After Adding 5 kg Urea into feed tank
C1	After Adding 4.2 kg Urea
C2	After Adding 4.8 kg Urea
C3	After Adding 4.8 kg urea
C4	After adding 3 kg Urea
C5	After adding 100% of planned Urea
E1	No Feed
E2	Renew feeding
D	Adding Starch
F	No Urea
G	Increasing Feed Rate to 198 ml/min
H	Maxium Cold Cap

Figure 6.4.b. Final Air Emissions, $[NO+NO_2]$, DuraMelter™ 100 Hanford Turnover (9/22/94-9/24/94)

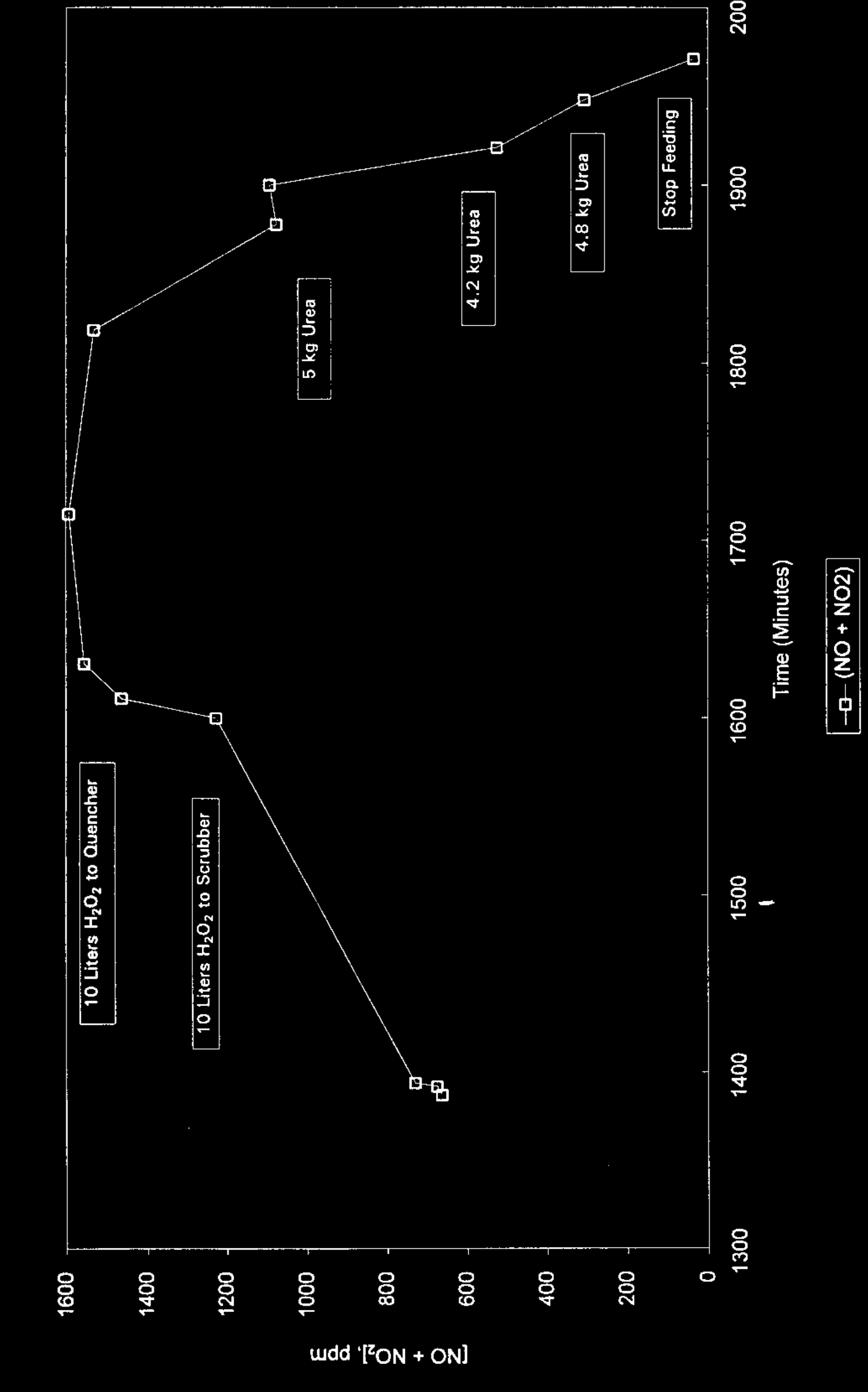


Figure 6.4.c. Final Air Emissions, [NO+NO$_2$], DuraMelter™ 100 Hanford Turnover (9/22/94-9/24/94)

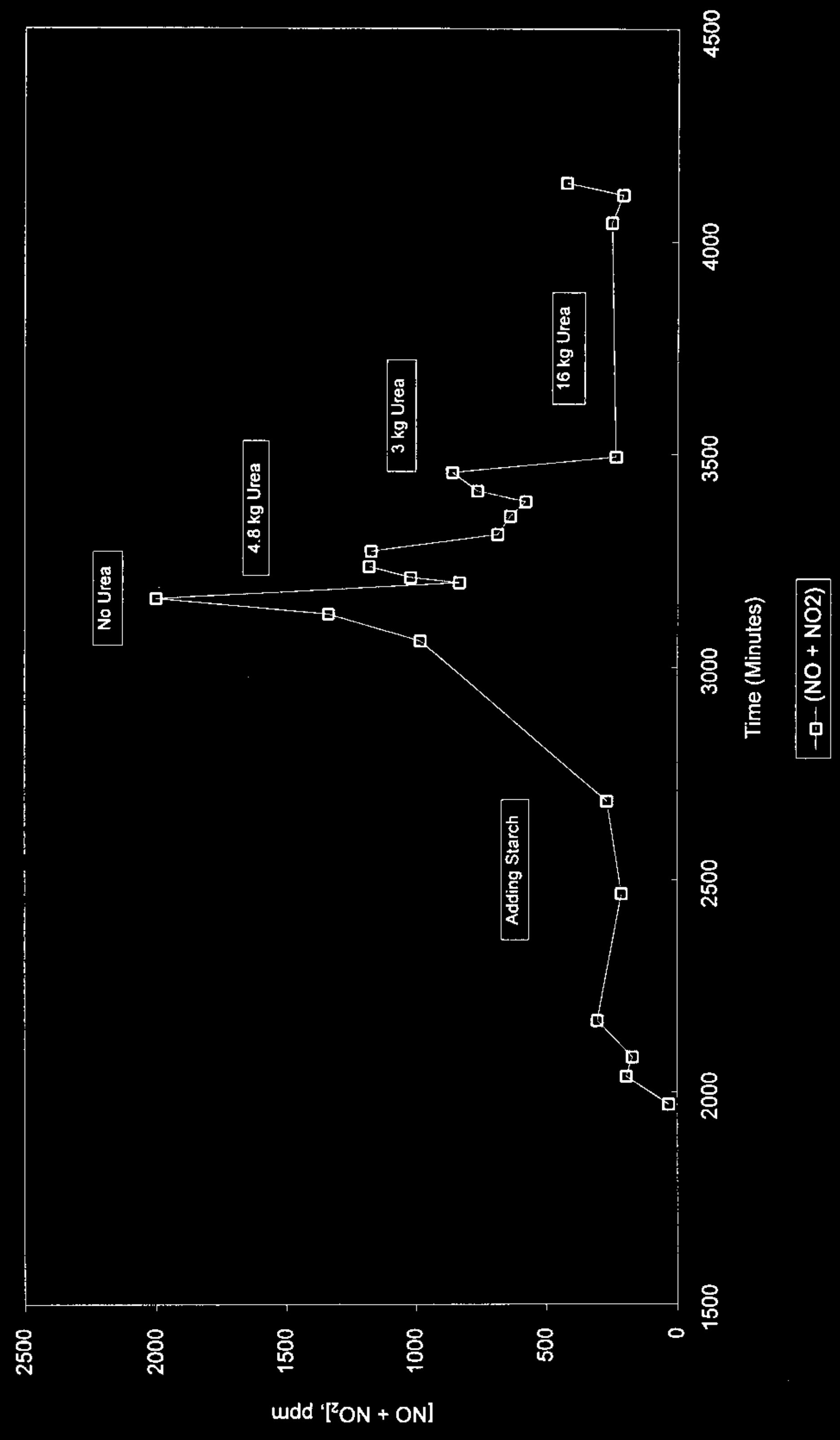


Figure 6.4.d. Effect of Urea on NOx, Test 2, DuraMelter™ 100

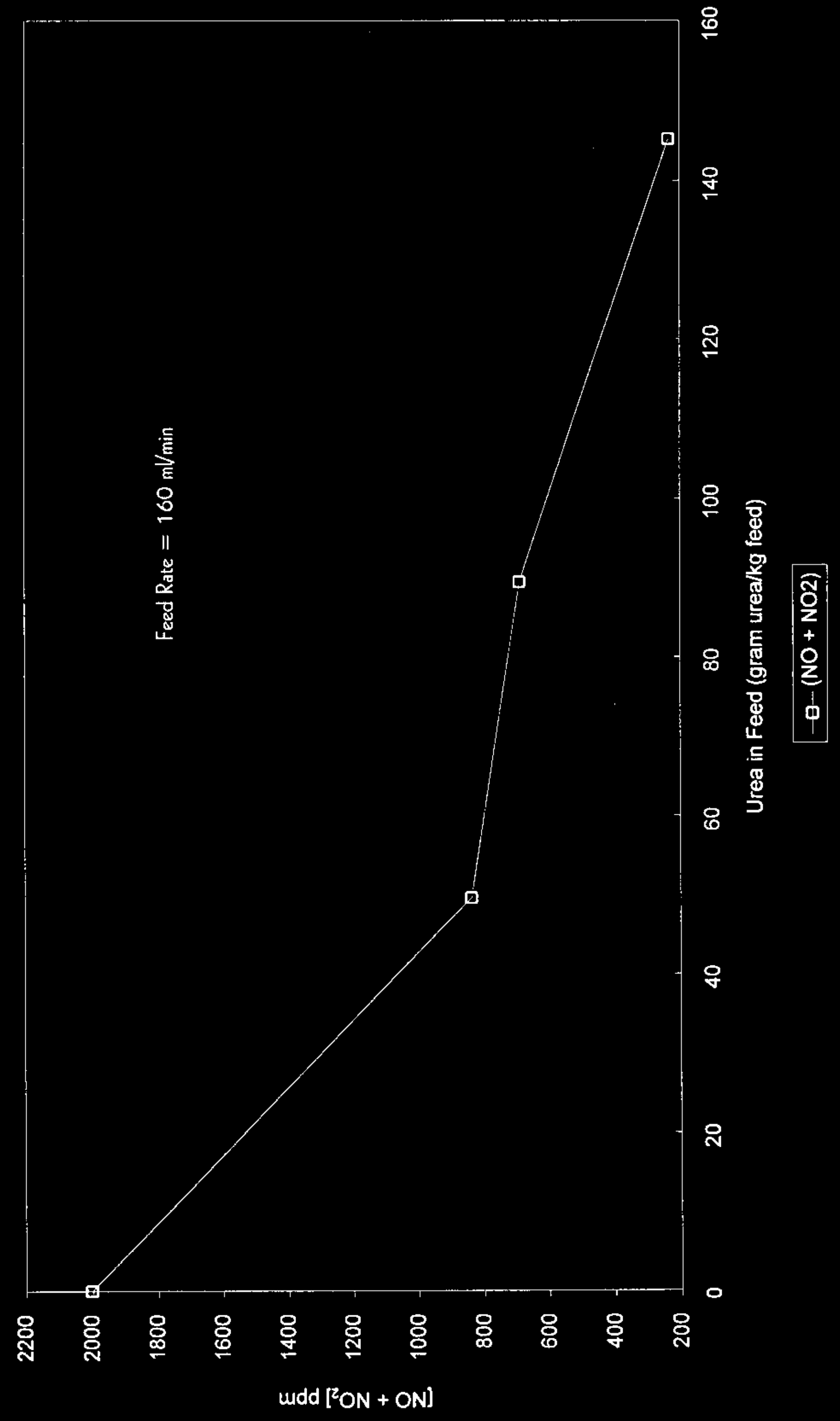


Figure 6.4.e. Effect of Urea on NOx, Test 1, DuraMelter™ 100, (9/23/94)

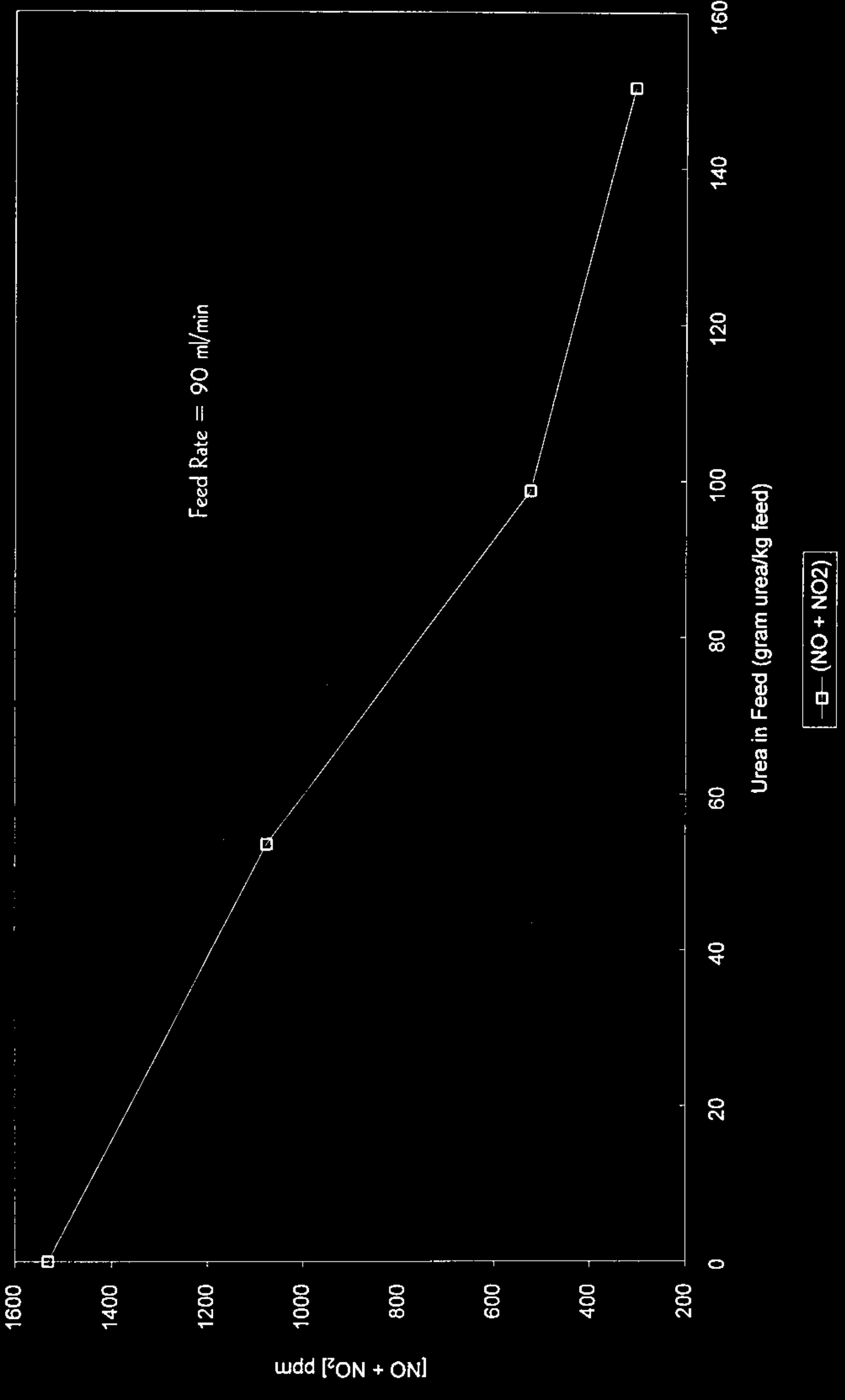


Figure 6.5.2.a. NOx Emissions from DuraMelter™ 1000 Using Diluted Hanford Feed (12/17/94-12/18/94)

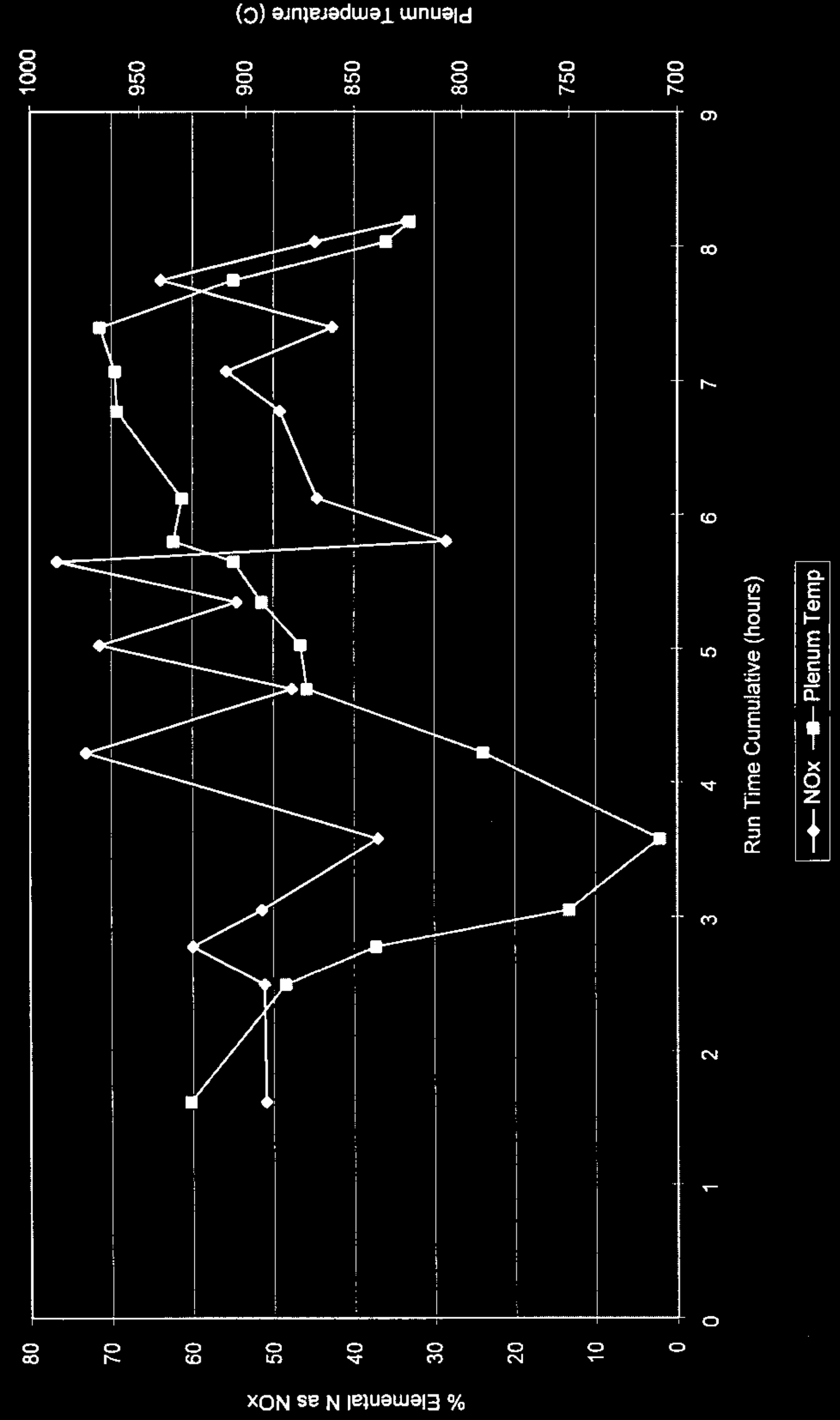


Figure 6.5.3.a. NOx Emissions from DuraMelter™ 1000 Using Hanford Feed Diluted by 3 (Vol) (12/18/94-12/19/94)

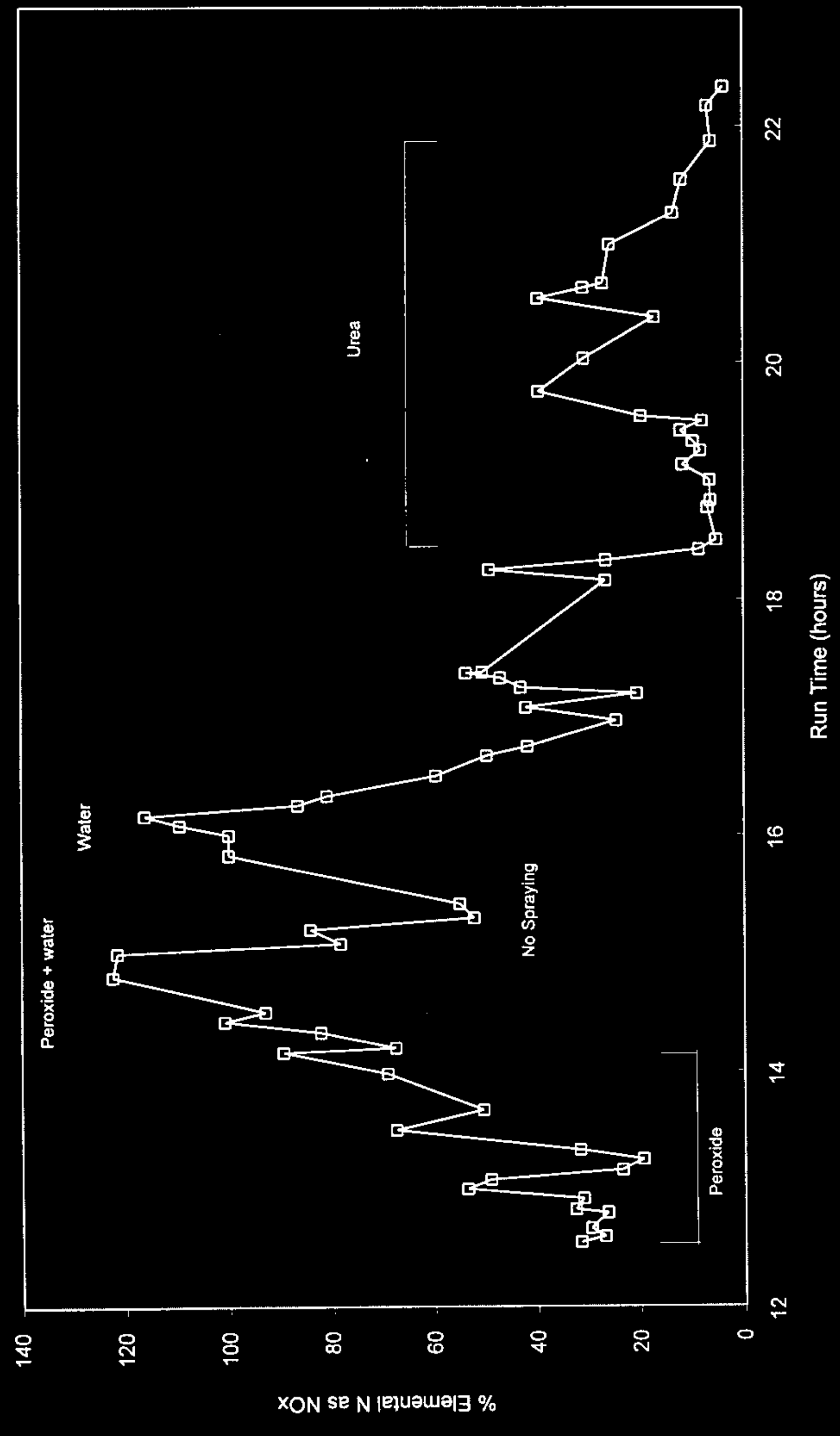


Figure 6.5.3.b. CO Emissions from DuraMelter™ 1000 Using Diluted Hanford Feed (12/17/94-12/19/94)

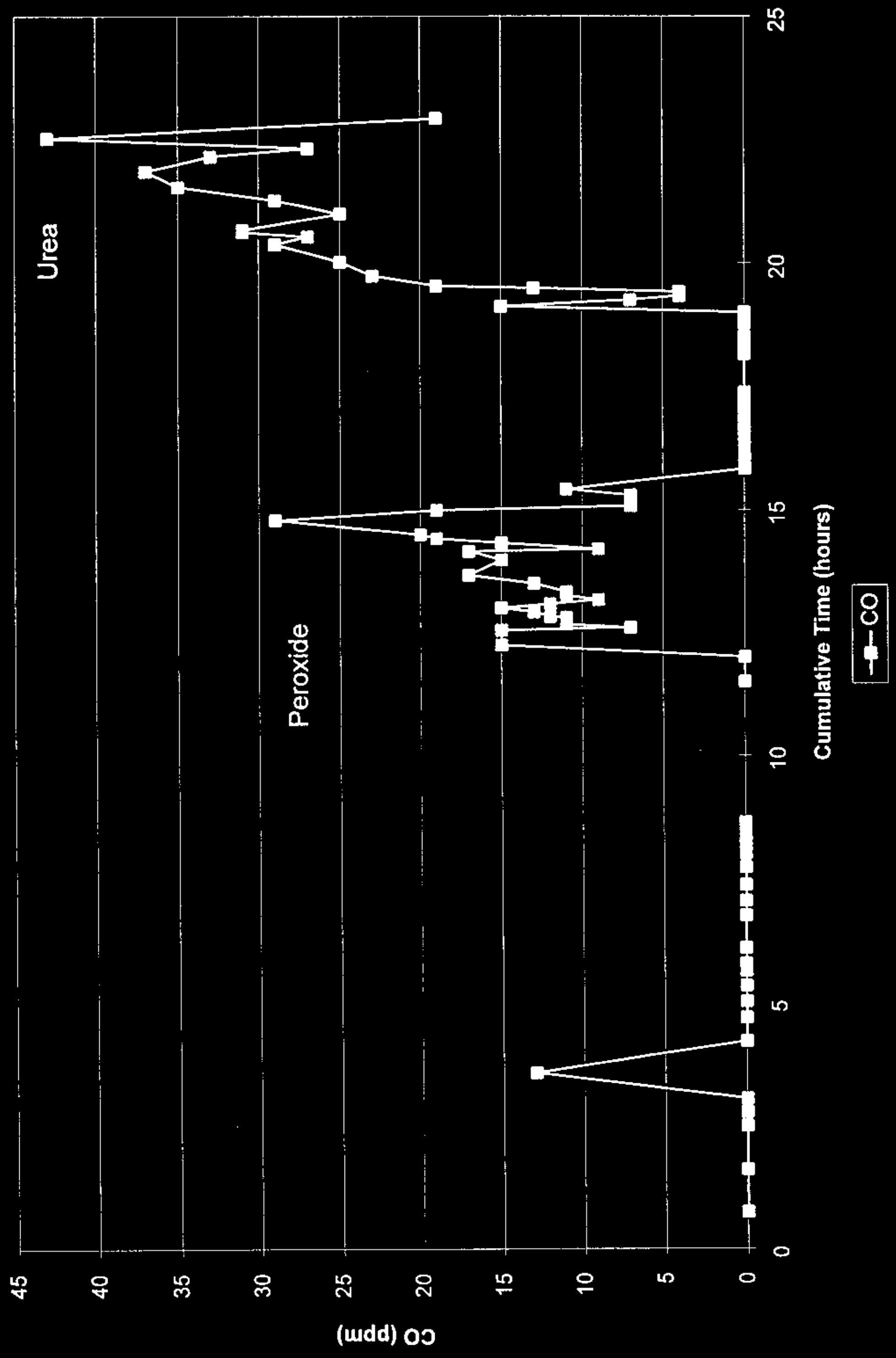


Figure 6.5.3.c. NOx Emissions and % Cold Cap from DuraMelter™ 1000 Using Hanford Feed Diluted by 3 (Vol) Urea Run (12/19/94)

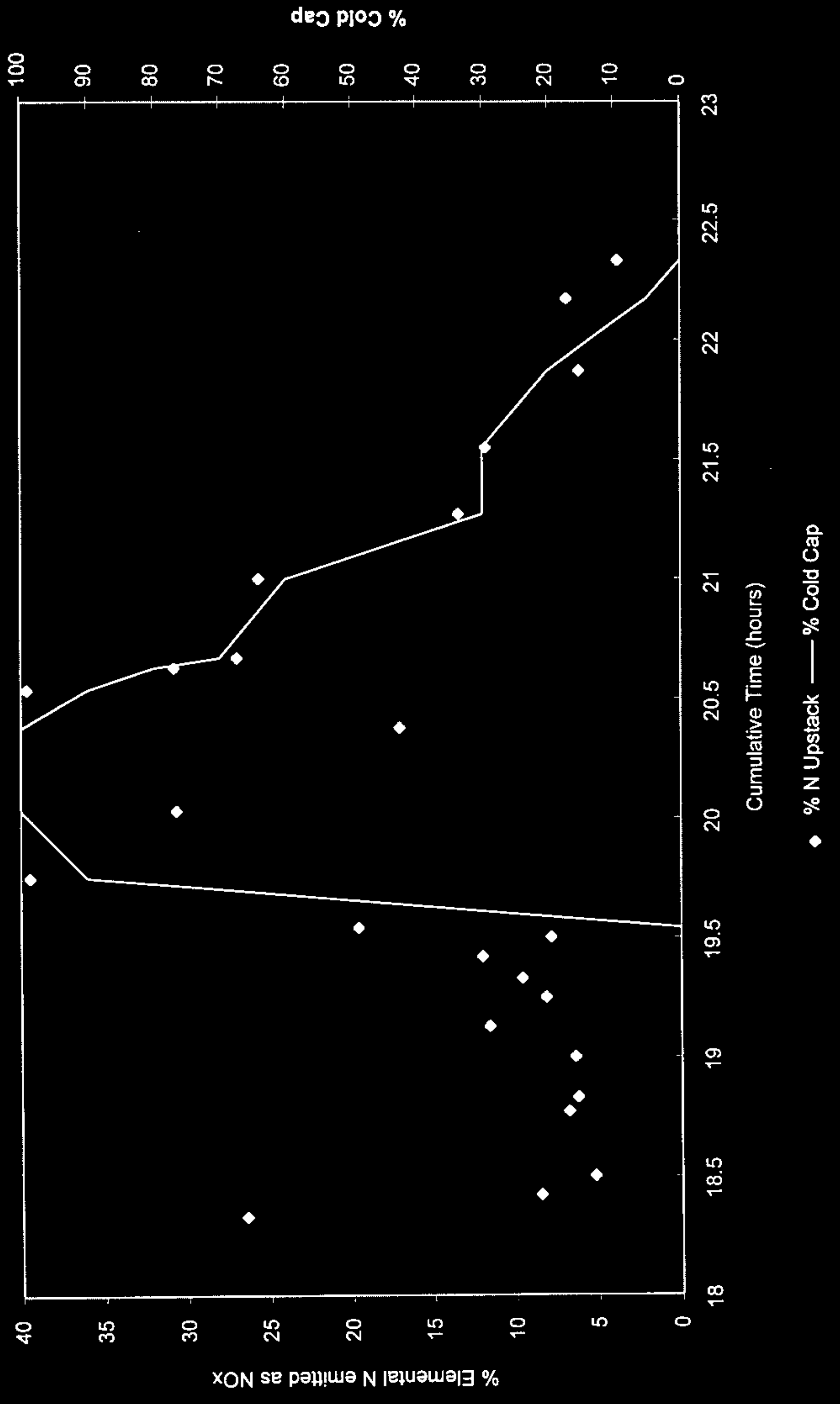


Figure 6.6.a. [NO] and [SO_2] Emissions from DuraMelter™ 1000 Using Hanford Feed (12/19/94-12/20/94)

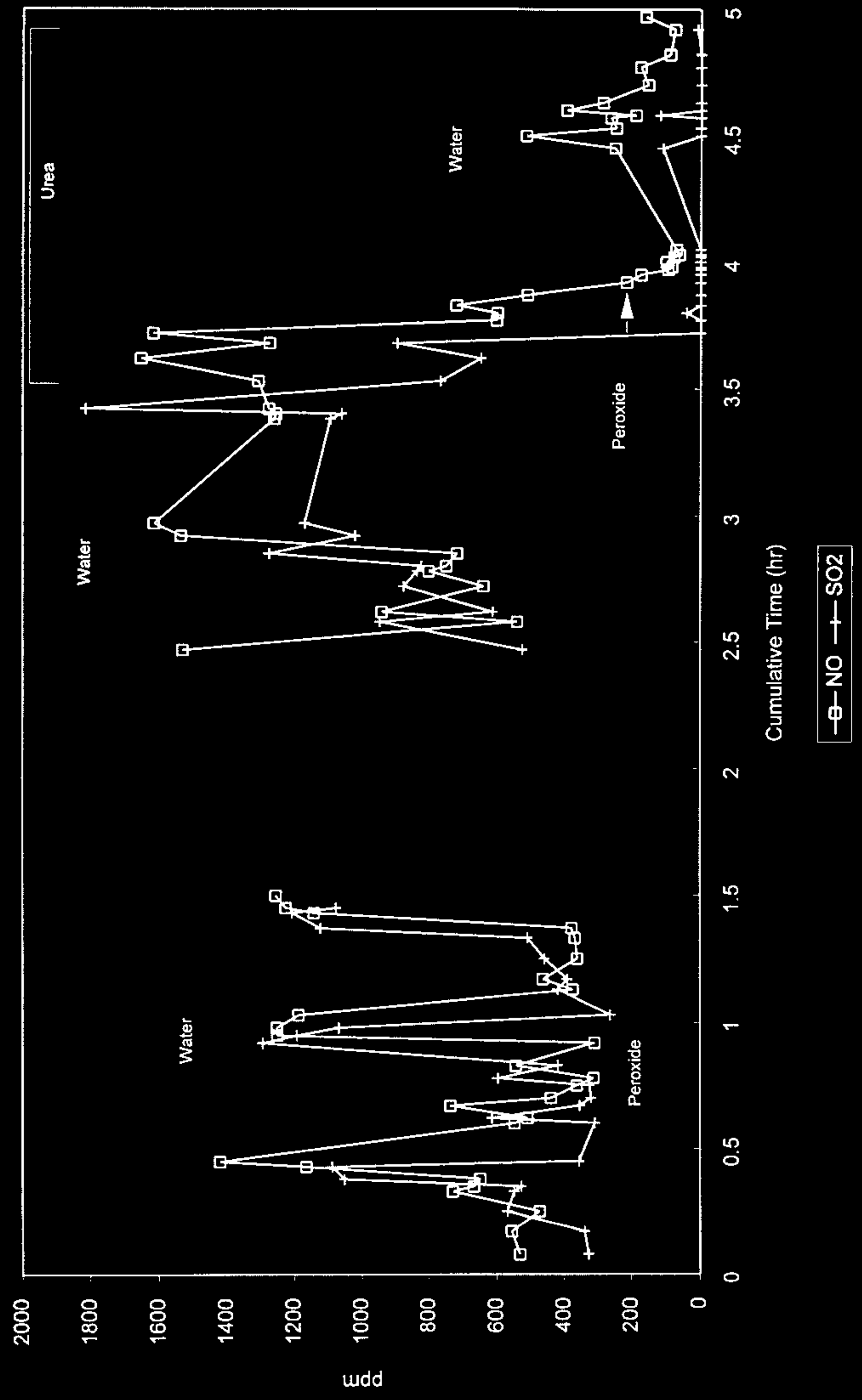
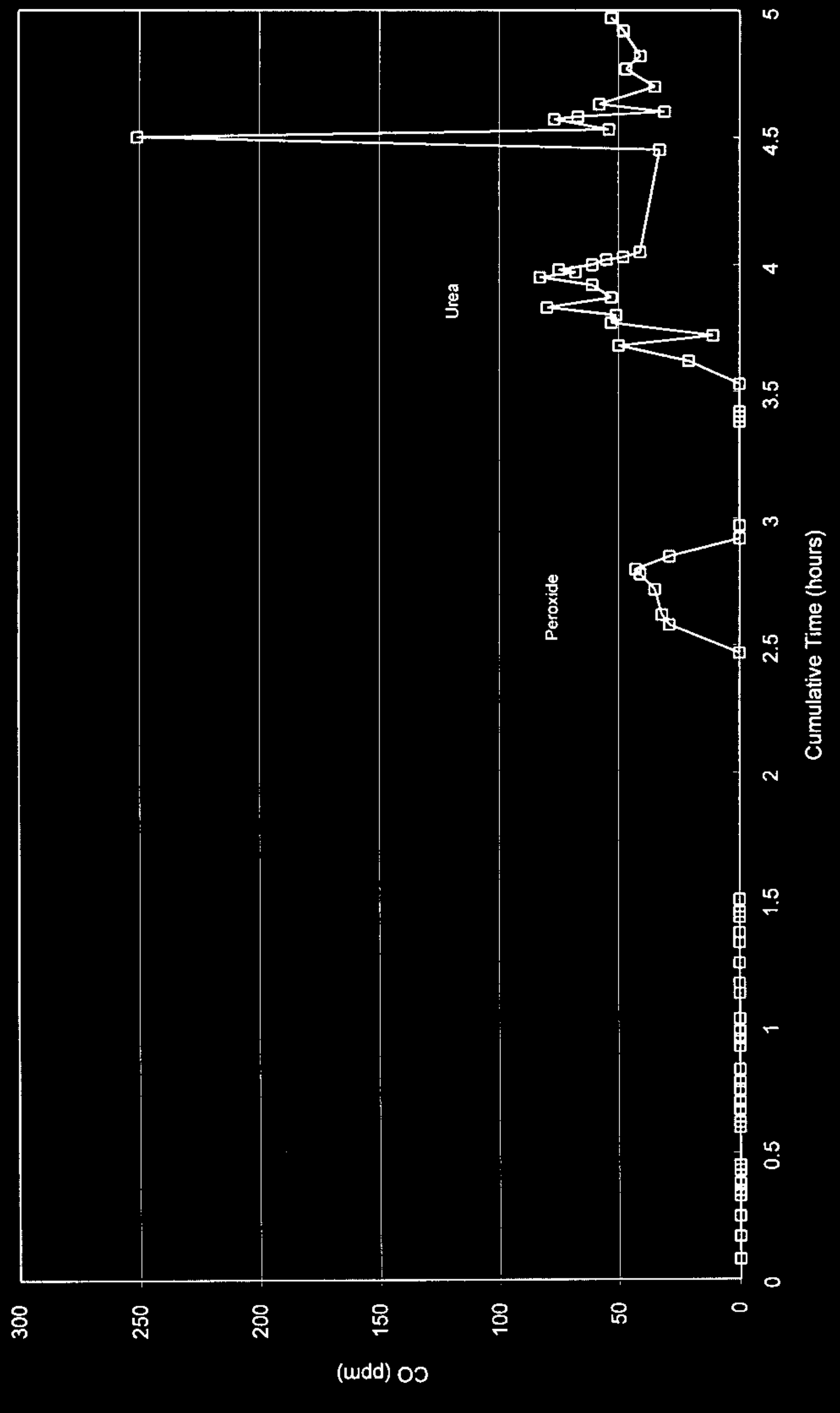


Figure 6.6.b. [CO] Emissions from DuraMelter™ 1000 Using Hanford Feed (12/19/94-12/20/94)



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7.0 SUMMARY AND CONCLUSIONS

The DuraMelters™ 100 and 1000 were successfully operated to demonstrate the vitrification of Hanford LLW simulant. The objectives detailed in the test plan (WHC-SD-WM-VI-020) for both DuraMelter™ campaigns were met during the turnover and steady state runs. The slurry feed system employed was suitable and reliable for controllable transfer of a mixture of Hanford LLW simulant and chemical additives to the melter. Feed rates of nearly twice those originally planned were achieved and sustained. Excellent material balances were achieved for the steady state runs. All glasses produced as crucible melts and in continuously fed DuraMelters™ far exceeded the stated leach resistance requirements.

Emissions monitoring by an outside contractor and VSL staff demonstrated the effectiveness of the offgas systems and provided the additional data need to complete the mass balances for the process. Final particulate and metal emissions from the process were all below measurable and regulatory limits. There was good agreement between direct measurements of the melter particulate and metal concentrations and those calculated from the data on the accumulations of constituents in the offgas system (quencher and scrubber liquids, baghouse dust, etc.). Methods were demonstrated that considerable reduce the nitrogen oxide emissions.

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APPENDIX I
Parsons Engineering Science Off-Gas Monitoring Summary Report for the DuraMelter™ 100 Run

NOTE: Appendix I contains only the first part of the DuraMelter™ 100 offgas monitoring report as prepared by Parsons Engineering Science Inc. The full report including field data and calculations is issued as a separate document "GTS Duratek, Phase 1 Hanford Low-Level Waste Melter Tests: 100-kg Melter Offgas Report" (WHC-SD-WM-VI-028).

PERFORMANCE TEST REPORT FOR THE 100 KG MELTER

PREPARED FOR:

VITREOUS STATE LABORATORY

CATHOLIC UNIVERSITY OF AMERICA

WASHINGTON, D.C. 20064

PREPARED BY:

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FAIRFAX, VIRGINIA 22030

726517

DECEMBER 1994

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EXECUTIVE SUMMARY

Source testing was conducted on the 100 kg melter operated by Catholic University's Vitreous State Laboratory. The testing was conducted during a pilot-scale study involving the vitrification of sludge. Particulate matter emission rates were highest at the melter exhaust and averaged 0.29 lb/hr. At the HEPA filter exhaust, the particulate matter emission rate averaged 0.004 lb/hr. Metals concentrations and emissions rates were measured at the melter exhaust and at the HEPA filter exhaust. The highest metals concentrations were observed in the melter exhaust while the HEPA filter exhaust was virtually clean with most metals reported by the laboratory as non-detectable. Sodium was the most prevalent metal in the melter exhaust (3866 μg/dscf).

Continuous emissions monitoring results for NO_x, SO_2, CO, and THC identified NO_x as the pollutant most prevalent at all of the sampling locations (melter exhaust, post-scrubber, post-demister, HEPA filter). The highest NO_x measurement observed was at the post-scrubber and was 5234 ppmv. However, NO_x measurements were biased by the presence of high concentrations of ammonia in the exhaust gas. Ammonia converts to NO when subjected to the NO_x measurement systems heated converter. NO_x measurements will be biased by 80 percent of the ammonia concentration in the gases to be measured.

Other pollutants were not present in significant quantities when compared to the NO_x concentrations. CO, THC, SO_2 were generally observed at levels below 100 ppmv. Baseline concentrations of NO_x, SO_2, CO, and THC at all locations were below 2 ppmv.

SECTION 1

INTRODUCTION

This sampling and analysis report has been prepared by Parsons Engineering Science, Inc. (Parsons ES) for a source assessment program conducted on an experimental glass melter, operated by the Vitreous State Laboratory (VSL) of the Catholic University of America. The Director of the VSL is Dr. Pedro Macedo. This pilot-scale melter (100 kg) is located in Hannon Hall, Catholic University of America, Washington D.C., 20064. Process sampling results are presented and summarized in this report. Collected data will be used by the VSL as part of the performance evaluation program for the 100 kg melter.

During this source assessment, Parsons ES monitored the melter at different locations of the process and air pollution control system. Emission rates of sodium (Na), potassium (K), cesium (Cs), strontium (Sr), molybdenum (Mo), boron (B), and chromium (Cr) were measured. Particulate matter emission rates were also measured. Parsons ES periodically monitored several gas streams for nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), oxygen (O_2), and total hydrocarbons (THC).

The physical design and layout of the 100 kg melter prevents strict adherence to the source test methodologies prescribed by 40 CFR Part 60, Appendix A for compliance monitoring. Therefore, we modified the EPA Reference Methods of 40 CFR Part 60 and utilized other EPA source test methods to conduct a source assessment program of the 100 kg melter; these modifications were made to allow collection of samples in the most representative manner as possible, given the nature of the physical constraints of the system layout.

The 100 kg melter source assessment was conducted by a Parsons ES field crew of two engineers and two senior technicians with the assistance of VSL operators, on September 26 and 27, 1994. Analysis of samples for metals content was performed by Triangle Laboratories, Inc.

SECTION 2

SOURCE DESCRIPTION

The 100 kg melter is an electrically-powered melter designed to vitrify certain types of hazardous materials of varied natures. During this testing, a surrogate sludge was fed to the melter to simulate the low-level radioactive or mixed waste for which this melter is being designed. Once the desired glass composition in the melter was obtained, the melter operated continuously for approximately three days, during which time the surrogate sludge was pumped into the unit. Source testing occured during the first twenty-seven hours of the melter demonstration.

The exhaust from the melter is treated by an air pollution control system. Exhaust air leaves the melter at temperatures between 500 and 800° C and passes through a quench and then to a caustic scrubber. Two demisters follow the caustic scrubber and after the gas passes through them, it is re-heated before being sent to a baghouse for final particle removal. Final gas cleaning is accomplished with a HEPA filter. A small volume of ambient air is added to the exhaust air prior to the HEPA filter to control the humidity and maintain HEPA filter performance.

SECTION 3

SAMPLING LOCATIONS

Four sampling locations were selected by the VSL for the source assessment of the 100 kg melter. These locations are the melter exhaust, post-quench, post-demister, and HEPA filter exhaust.

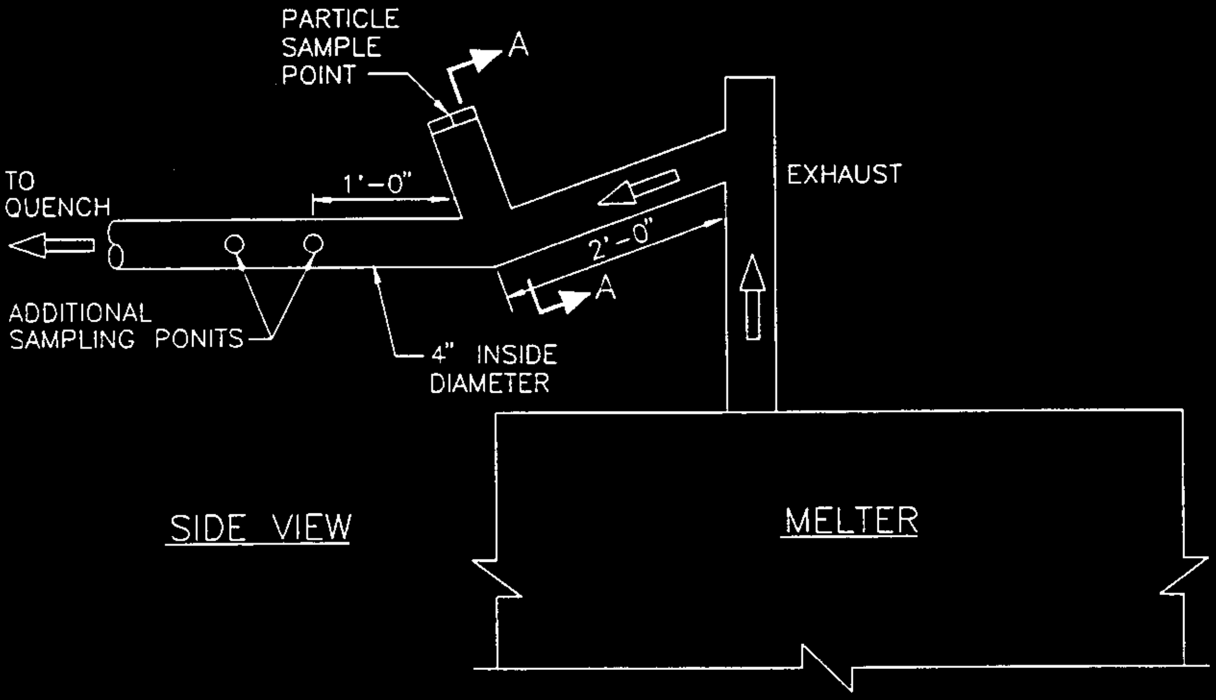
The melter exhaust sampling location is pictured in Figure 3.1. A pipe "T" fitting was modified for use as a sampling port in the four-inch i.d. Inconel® pipe that ducts exhaust gas from the melter. The main sampling port is located at a bend, approximately two feet downstream from the melter exhaust stack. Due to the melter equipment arrangement, there are no sampling locations that meet the criteria for isokinetic sampling as described in EPA Reference Method 1 or 1A. Also, the small duct diameter precludes sampling traverses. Instead, a single point nominally in the center of the gas flow, was selected for the sampling nozzle location. An auxiliary sample point was installed downstream of the main sampling point for the collection of NO_x, SO_2, THC, CO, and O_2.

Sampling at the post-quench was performed at a sampling port located just down stream of the quench (Figure 3.2). A small tap suitable for sampling NO_x, SO_2, THC, CO, and O_2 was installed in the six-inch i.d. stainless steel pipe. This location was only used for extraction of samples for the CEM system.

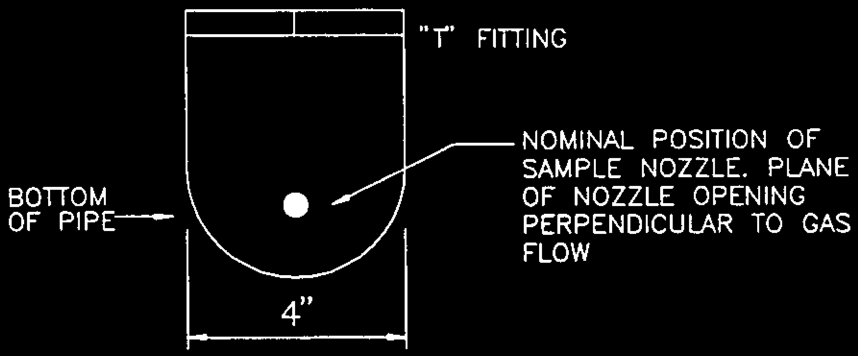
Sampling at the post-demister was performed at a sampling port located just down stream of the demister (Figure 3.3). A small tap suitable for sampling NO_x, SO_2, THC, CO, and O_2 was installed in the eight-inch PVC pipe, prior to the reheat. Like the post-quench, this location was only used for CEM sampling.

The HEPA filter exhaust was sampled at the exhaust pipe after it leaves the filter and before it passes through the induced draft fan (Figure 3.4). The main sample location was selected as required by EPA Reference Method 1A. The exhaust duct is a 5-inch diameter steel pipe with a sampling port for isokinetic sampling located eight diameters downstream from the nearest disturbance and approximately four diameters upstream from the nearest disturbance.

FIGURE 3.1
MELTER EXHAUST



SIDE VIEW



VIEW A-A

FIGURE 3.2
POST-QUENCH

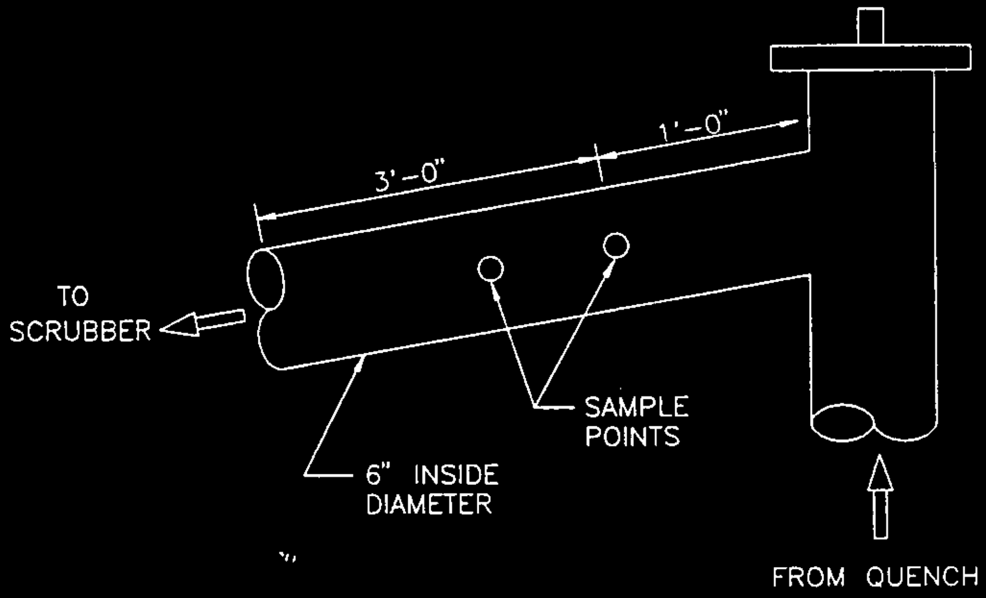


FIGURE 3.3
POST-DEMISTER

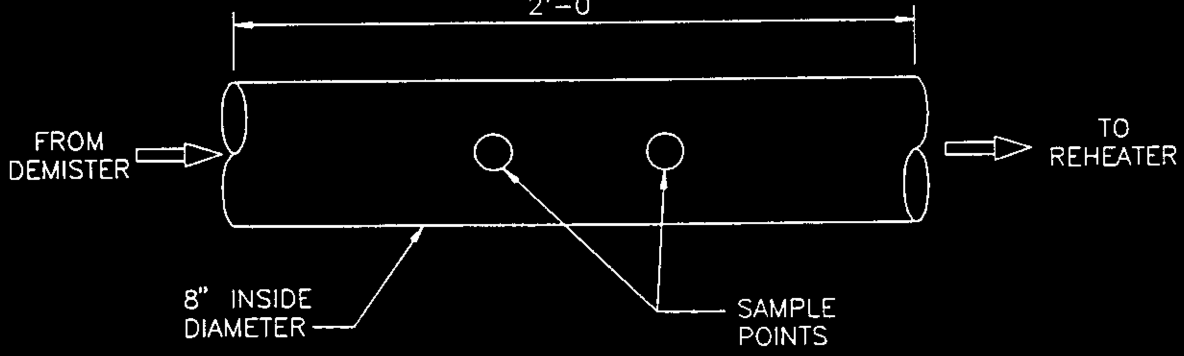
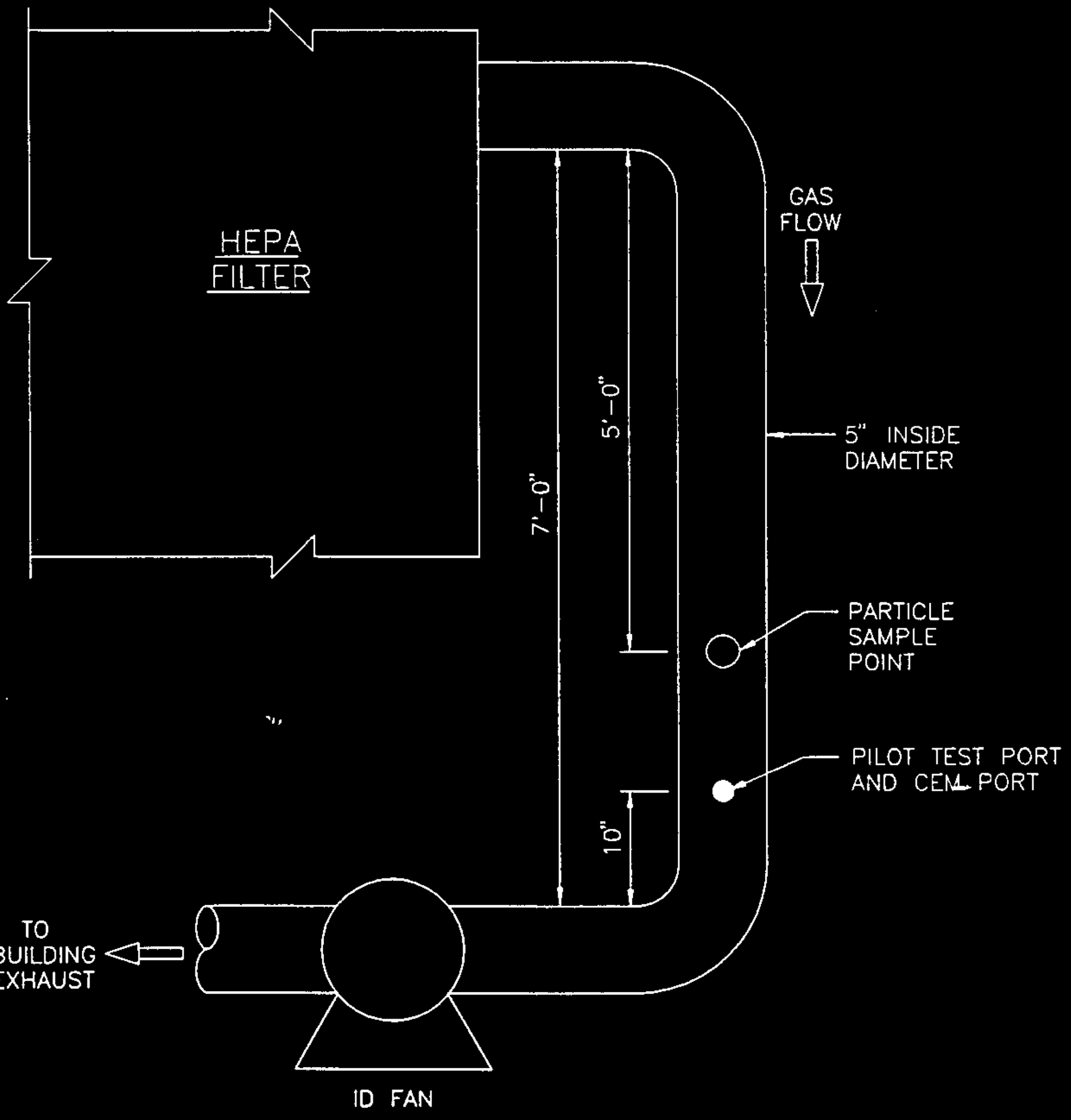


FIGURE 3.4
HEPA FILTER EXHAUST



A pitot tube port was installed downstream of the main sampling port for velocity measurements with a standard pitot tube. As with the Melter Exhaust, a single sample point nominally in the center of the exhaust gas flow, was selected for the sampling nozzle.

The pitot tube port also served as an auxiliary sampling port for non-isokinetic sampling.

SECTION 4

TEST PROGRAM AND SAMPLING METHODS

As stated previously, the purpose of this source assessment program is to provide emissions data for the VSL's 100 kg melter. This test program collected emissions data from four sampling locations: the melter exhaust, the post-quench, post-demister, and HEPA filter exhaust. Particulate matter and metals samples were collected from the melter exhaust and HEPA filter exhaust locations. From all four locations, NO_x, SO_2, THC, CO, and O_2 were measured. Figure 4-1 is the sampling matrix for the source assessment program.

Particulate Matter and Metals Sampling

Particulate matter and metals were collected at the Melter Exhaust with a modification of the multiple-metals method from the *Methods Manual for Compliance with the BIF Regulations (EPA/530-SW-91-010)*. The BIF metals methods was used in conjunction with EPA Method 1A at the HEPA Filter Exhaust sampling location.

With the BIF Metals Method, particulate and gaseous emissions are isokinetically withdrawn from the stack and collected on a quartz fiber filter and in an impinger solution. Metals in the particulate phase are captured on the filter and vapor-phase metals are collected in the impinger solution. This source assessment program used two impingers each containing 100 ml of a 5% nitric acid/10% hydrogen peroxide solution. The various fractions of the sampling trains are digested prior to analysis by inductively-coupled argon plasma (ICAP) spectroscopy. Generally, this method is used for the sampling and analysis of trace metals. Except for chromium, the metals targeted in this source assessment program are not usually selected for emissions monitoring. However, the selected analytical methodology, ICAP, provides the sensitivity and precision desired.

Prior to metals analysis of the sample filter, the filter was weighed to measure the mass of particulate matter collected.

As mentioned previously, the BIF Metals method was modified to accommodate the sample point configuration at the melter exhaust. Since the exhaust gas temperature

FIGURE 4-1

SAMPLE MATRIX FOR VSL 100 KG MELTER

Sample Location	Parameter	No. of Sample Runs	Sample Train ID	Sample Method
Melter Exhaust	Metals (Na, K, Cs, Cr, Mo, B, Sr)	3	1	Modified BIF-MMT
	Particles	3	1	Modified BIF-MMT
	NO/NOx, SOx, CO, O2, THC	Continuous	NA	EPA Methods for CEMS
Post-Quench	NO/NOx, SOx, CO, O2, THC	Continuous	NA	EPA Methods for CEMS
Post-Demister	NO/NOx, SOx, CO, O2, THC	Continuous	NA	EPA Methods for CEMS
Stack	Metals (Na, K, Cs, Cr, Mo, B, Sr)	3	2	Modified BIF-MMT
	Particles	3	2	Modified BIF-MMT
	NO/NOx, SOx, CO, O2, THC	Continuous	NA	EPA Methods for CEMS

exceeded the softening temperature of a conventional glass probe, the sampling nozzle and sampling probe were made from Inconel®. An equipment blank was collected from the nozzle/probe assembly to check for the possibility of contamination from the equipment.

A summary of the BIF Metals Method is presented in the appendices. Also included in the appendices are the summaries of EPA Reference Methods 1 and 5. These are the standard methods upon which the BIF Metals Method draws for the isokinetic and particle sampling guidelines. The source test protocol provides greater detail of the sampling methods.

CEM

At each of the four sampling locations, the exhaust gas was sampled and analyzed for NO_x, SO_2, THC, CO, and O_2. Stack gas samples for analysis by continuous emissions monitors were extracted from a single point at each sample location. Monitoring at each location was conducted on a rotating schedule that reflected the requirements of the VSL staff. Generally, monitoring was conducted at each location for 10 to 15 minutes of every hour during the testing. Two sample streams were extracted from the stack and transported to the mobile CEM laboratory through the use of self-regulating heated sample lines, which are designed to maintain gas temperature of 250 °F above the ambient temperature. One of the streams was conditioned to remove entrained particles and moisture and then sent to a stainless steel sampling manifold. Continuous samples for the oxygen, carbon monoxide, nitrogen oxide, and sulfur dioxide analyzers were extracted from the manifold, and the excess gases were vented to the atmosphere. The second stack gas stream was not conditioned, and was sent directly to the continuous hydrocarbon analyzer which analyzed the total hydrocarbon content of the sample with a flame ionization detector.

Instrument responses to calibration standards and sample gases were analyzed and recorded by a PC-driven data acquisition system (DAS). The DAS consists of an analog-to-digital signal converter and a personal computer which analyzed the instrument responses and converted the analog signals to the appropriate engineering units. The analyzer responses were read and recorded at thirty-second intervals on the PC's hard disk drive and on a computer print-out.

Stack Gas Oxygen Content

The oxygen content in the effluent gas was measured by a Horiba PMA-200 Paramagnetic Oxygen Analyzer in accordance with the procedures in EPA Method 3A. O_2 was analyzed on a dry basis and the instrument responses were recorded by the DAS. The PMA-200 has two operating ranges, 0 - 10, and 0 - 25 percent oxygen. During this test, the instrument was operated on the 0 - 25 percent range and calibrated with oxygen standards containing approximately 17.7 and 11.2 percent oxygen. Prior to each day of testing, the instrument was calibrated by introducing a zero gas and the upscale calibration standards directly to the analyzer. The sample line bias was checked by introducing the zero gas and the mid-range calibration standard into the sampling system immediately downstream of the probe. The oxygen measurement system response and drift was determined at the conclusion of each sampling run by introducing the zero and upscale calibration standard into the measurement system downstream of the probe.

Stack Gas Nitrogen Oxides Content

The nitrogen oxides content in the effluent gas was measured by a Thermo Environmental Model 10 $NO/NO_2/NO_X$ chemiluminescence analyzer in accordance with the procedures in EPA Method 7E. NO_X in the sample gas is converted to NO and detected by the chemiluminescent reaction with ozone. This analytical procedure is subject to interference from NH_3. There was an unanticipated elevated amount of NH_3 in the exhaust from the source tested. NH_3 concentrations were estimated to be as high as 2,000 ppmv which is significant since as much as 80 percent of that concentration can bias the NO_X measurements. NO_X was analyzed on a dry basis and the instrument responses were recorded by the DAS. The Model 10 has eight operating ranges, 0 - 2.5, 10, 25, 100, 250, 1,000, 2,500, and 10,000 ppm nitrogen oxides. During this test, the instrument was operated on the 0 - 250 ppm range and the zero to 1,000 ppm range and calibrated with nitric oxide standards containing approximately 225 and 150 ppm nitrogen oxide. The instrument was calibrated by introducing a zero gas and the upscale calibration standards directly to the analyzer. The sample line bias was checked by introducing the zero gas and the mid-range calibration standard into the sampling system immediately downstream of the probe. The nitrogen oxides measurement system response and drift were subsequently determined at the conclusion of each sampling run by introducing the zero and upscale calibration standard into the measurement system downstream of the probe.

Stack Gas Total Hydrocarbon Content

The THC content in the effluent gas was measured by a J.U.M. VE-7 Total Hydrocarbon Analyzer in accordance with the procedures in EPA Method 25A. Hydrocarbons in the sample stream were measured continuously by a Flame Ionization Detector. THC was analyzed on a wet basis and the instrumentation responses were recorded by the DAS. The VE-7 has five operating ranges, 0 - 10, 100, 1,000, 10,000 and 100,000 ppm hydrocarbons, and is calibrated using propane standards that correspond to approximately 30, 60, and 85 percent of the full-scale response. The VE-7 was operated at the 0-100 ppm range. Prior to testing, the instrument was calibrated by introducing a zero gas and the upscale calibration standards into the sampling system directly downstream of the sample probe. The THC measurement system response and drift were determined at the conclusion of each sampling run by introducing the zero and upscale calibration standard into the measurement system downstream of the probe.

Stack Gas Sulfur Dioxide Content

SO_2 measurements were made using the procedures outlined in EPA Method 6C. Method 6C is based on absorption of ultraviolet radiation by the SO_2 molecule. The amount of light absorbed is dependent upon the concentration of the compound present. The UV light beam is split after the light source, with one part passing through the sample cell, and the other part passing through the reference cell, which is filled with a non-absorbing gas. Each beam then passes through a narrow band pass filter into photomultiplier tubes for creation and amplification of the signals. The amount of absorbed light (found by difference in signal intensity) is proportional to the amount of absorbing species present.

The SO_2 analyzer used is a Horiba that operates on the principle of UV absorption. The analyzer has full-scale ranges of 0 to 100 and 0 to 500 ppm. SO_2 standards are SO_2 in air and are selected to correspond to approximately 55 and 85 percent of the instrument span range.

Summaries of the sampling methods are provide in the appendices.

Sampling Schedule

The source assessment program was conducted over two days, on September 26 and September 27, 1994. Three metals and three particle runs were conducted at both the melter exhaust and at the HEPA filter exhaust. Each metals sampling run lasted for approximately one hour. Metals samples were collected simultaneously at each location.

Exhaust samples each of the four sampling locations were directed to continuous emissions monitoring instruments at 15 minute intervals. After monitoring for approximately 15 minutes at each location , the exhaust from the next location was sampled. During each run, the first location monitored was the HEPA filter exhaust. The next location from where sample was drawn was the post-demister, then the post-scrubber, and finally the melter exhaust.

SECTION 5

QA/QC PROCEDURES

The main quality assurance and quality control (QA/QC) procedure for the 100 kg melter source assessment is the adherence to the test protocol. By following the approved source test protocol, complying with the applicable QA procedures for each sampling and analysis method, and documenting changes to the protocol, the quality of resulting performance test data can be evaluated.

Sampling Equipment

Further QA/QC is provided for by the routine calibration and maintenance of the stack testing equipment. All stack sampling equipment to be used in this testing effort is periodically calibrated according to the methodologies and frequencies established in the EPA Quality Assurance Manual. Routine maintenance dictated by the Quality Assurance Manual and good engineering practice ensures quality performance of the sampling equipment. Prior to field use, source test equipment is checked for proper performance and valid calibrations. Upon completion of a source test program, sampling equipment calibrations are re-checked to assess equipment performance during the source test.

Meter Boxes

Meter boxes used for source testing are subjected to multi-point calibrations once each year, or after repairs are made to the dry gas meter, orifice, or thermocouples. Meter boxes are assigned a unique ID number, and a calibration performed on meter boxes are recorded in the notebook. The dry gas meter and orifice are calibrated at five flow settings ranging from an orifice pressure of 0.5" WC to 4.0" WC. The meter box calibration factor (gamma,) is calculated for each flow setting and checked to ensure that no individual gamma differs from the average by more than 0.02. Similarly the ΔH@ value of the orifice is calculated for each flow setting and checked to ensure that no individual value differs from the average by more than 0.15. Dry gas meter thermocouples are checked against a mercury-in-glass thermocouples are considered unacceptable and are repaired or replaced if they do not read within 5.4°F at each of the calibration points.

Pitot Tubes

Standard pitot tubes are checked for conformance to the dimensional criteria described in Method 2 as they are received, and assigned a pitot tube coefficient, C_p, of 0.99. The pitot tube is checked prior to and at the conclusion of each sampling program for which the pitot tube is used.

Thermocouples

Stack temperature thermocouples are permanently attached to the sampling probes and are checked as received for accuracy. The thermocouples are checked against a mercury-in-glass thermometer at three temperatures: ice-point, ambient, and boiling H_2O point. Calibration and maintenance data for each stack thermocouple are recorded in the appropriate sampling probe notebook. Probe liner, filter box, sample gas, and condenser thermocouples are checked for accuracy at three water temperatures: icepoint, ambient, and boiling point. Parsons ES recognizes that the temperature of the probe liner, heated sample box, and sample gas temperature are generally maintained at temperatures of approximately 250°F. Since these temperatures are not used to calculate stack gas parameters or correct sample volumes, the calibration procedure is considered adequate when weighed against the danger of working with boiling oil. Each thermocouple is assigned a unique identification number and a notebook for recording calibration and maintenance data.

Sampling Nozzles

Parsons ES maintains a full range of sampling nozzles to conduct isokinetic sampling at a variety of exhaust gas velocities. Nozzles are stored in padded metal boxes to prevent damage during storage or transport. The internal diameter of the nozzle is measured using a set of dial, electronic, or vernier micrometer. The diameter used to calculate the nozzle area is determined from the average of three measurements of the nozzle in three different diameters. The nozzle is not used if an individual diameter differs from the average by more than 0.004 inch.

Summary (Table)

A summary of sampling equipment with corresponding calibration procedures, frequencies, and acceptance criteria can be found in Table 5-1.

Analytical Balances

Analytical balances are professionally cleaned and calibrated annually by certified balance technicians provided by the manufacturer. Following this professional calibration, a document is provided by the manufacturer, stating the model number, serial number and date of calibration. Additionally, a sticker noting the technician's name and the date of calibration is attached to the balance.

Each time the balance is used, a calibration check is performed using a set of Class S weights. The results of each calibration are recorded in a notebook which remains with the balance being used.

Continuous Emissions Monitors

The quality of collected CEM data is ensured by the adherence to the calibration and maintenance programs specified by the instrument manufacturers and in the EPA Reference Methods used during the monitoring. Calibration procedures are provided in greater detail in the appendices.

TABLE 5-1

CALIBRATION OF SAMPLING EQUIPMENT

Apparatus	Acceptable Limits	Frequency and Methods of Measurements	Corrective Action
Wet Test Meter (64 ft^3/hr cap.)	Y=1.00±0.01 for calibration range 7.5 to 65 ft^3/hr	Initially and annually by bell prover	Return to service center for corrective maintenance
Dry Gas Meter	Y tolerance for individual values ± 0.02 from average Y value	Calibration initially and annually against calibrated wet test meter at 0.50, 0.75, 1.0, 1.5, 2.0, and 4.0 in H_2O	Repair or replace as needed, recalibrate over full range of flow settings
	$Y_f = Y_i \pm 0.05Y_i$	Post-test calibration check after field use	Repair or replace as needed, recalibrate over full range of flow settings
	ΔH@ tolerance for individual values ± 0.20 from average ΔH@ value	Calibration initially and annually against calibrated wet test meter at 0.50, 0.75, 1.0, 1.5, 2.0 and 4.0 H_2O	Repair or replace as needed, recalibrate over full range of flow settings
Stack Thermocouple	1.5% of absolute temperature as indicated by ASTM mercury-in-glass thermometer	Initially and annually at ice-point, and boiling water point. Temperatures extrapolated to 1500°F	Adjust, determine calibration factor, or reject
Filter Heater Thermocouple	± 5.4°F as indicated by ASTM mercury-in-glass thermometer	Initially and annually at ice-point and boiling water point	Adjust, determine calibration factor, or reject
Condenser Outlet Thermocouple	± 2°F as indicated by ASTM mercury-in-glass thermometer	Initially and annually at ice-point and boiling water point	Adjust, determine calibration factor, or reject

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TABLE 5-1

CALIBRATION OF SAMPLING EQUIPMENT

(CONTINUED)

Apparatus	Acceptable Limits	Frequency and Methods of Measurements	Corrective Action
Dry Gas Meter Thermocouples	± 5.4°F as indicated by ASTM mercury-in-glass thermometer	Initially and annually at ice-point and boiling water point	Adjust, determine calibration factor, or reject
S-type Pitot Tube Assemblies	$C_p = 0.84$	Initially and after field usage be geometric calibration procedures	Realign or replace
Standard Pitot Tube	$C_p = 0.99$	Initially and after field usage be geometric calibration procedures	Realign or replace
Probe Nozzle	Tolerance 0.004 in. for three measurements, 120° apart	Prior to each field test	Reshape and resharpen, then recalibrate
Analytical Balance	± 0.1 mg with Class S wts.	Annually serviced by field tech.	Adjust and repair as needed
		Adjusted prior to each use with Class S wts. (60.0000 g or 100.0000 g)	Adjust as needed to calibrate weight, call for factory service as needed.

SECTION 6

RESULTS AND DISCUSSION

This section provides the sampling results and discussion of the collected data. Results are presented in tables and summarized in the text. Field data, laboratory reports, and computer calculations are presented in the appendices.

Exhaust gas characteristics were observed to be very different at each sample location. The greatest differences were noted between the melter exhaust and the HEPA filter exhaust. Melter exhaust had a much higher particle mass loading than the HEPA filter exhaust. These differences are large enough that sample analysis and data evaluation procedures had to vary for the two locations. For example, the probe washes collected from sample trains used at the melter exhaust contained high concentrations of particle matter in the nitric acid portion of the rinsate. This was not observed for the HEPA filter exhaust samples. Therefore, part of the analytical procedure for the melter exhaust samples was a filtration of the nitric acid rinsate and gravimetric analysis of the particle mass retained on the filter. This procedure was not necessary for the HEPA filter exhaust samples because the particle concentrations and emission rates are extremely low.

HEPA filter exhaust samples were so clean that analytical results for many of the metals were below the instrument detection limits, just as the method reagent blanks. This is a difference from the results observed for the melter exhaust which had measurable concentrations of metals. Final results from the two sample locations were therefore treated differently. The melter exhaust samples were blank corrected while the HEPA filter exhaust samples that were below instrument detection limit were not. The reason for this was to avoid reporting "zero" emissions from the HEPA filter exhaust. A conservative approach is to consider the blanks as zero and then use the instrument detection limit for the metals results that the laboratory reported as non-detectable. Emission rates and concentrations are then reported as "less than" a value.

In the appendices to this report are the details of the analytical procedures and data handling procedures used in this project.

Particulate Matter Concentrations and Emission Rates

Particulate matter sampling results are provided in Tables 6.1 and 6.2. Table 6.1 provides the emission rates for the melter exhaust sampling location and Table 6.2 shows the HEPA filter exhaust sampling results.

The average particulate matter concentration and emission rate measured at the melter exhaust location was 0.43 gr/dscf and 0.29 lb/hr, respectively. At the HEPA Filter Exhaust location, the measured concentrations and emission rates averaged 0.0024 gr/dscf and 0.0040 lb/hr, respectively. The maximum emission rate measured was 0.50 lb/hr for Run #3 at the melter exhaust. The greatest grain loading observed, 0.75 gr/dscf, was also for Run #3 and from the melter exhaust location.

Because of the heavy particle loading in the melter exhaust and the possibility of incomplete sample recovery, an equipment blank was collected during the test program to evaluate the bias introduced by the sample train cleaning procedure. The equipment blank constituted a full sample train designated for use at the melter exhaust location. It was carried to the sample location, and then recovered and analyzed like a regular sample. The front half portion of the equipment blank showed a net weight gain of 0.0226 grams or 4.5% of the smallest sample weight observed for the Melter Exhaust (Run #2). This slight bias has not been applied to the melter exhaust sample results shown in Table 6.1. What the field blank demonstrates is that there is some bias (+ or –) in the particulate measurements due to the sampling methodology.

Another source of bias in the melter exhaust particulate emission rate measurements has been introduced because the melter exhaust sampling location does not meet either EPA Method 1 or EPA Method 1A isokinetic sampling location criterion. The velocity profile at this location is not well-characterized so an evaluation of the bias must begin with the melter exhaust system. Melter exhaust gas exits the furnace in a four-inch internal diameter pipe at a flowrate of roughly 177 acfm with an approximate velocity of 35 f/s.

The sample location is located at a disturbance, as described in Section 3, and six pipe diameters upstream of the sample location is another disturbance. Furthermore, the surface area of the sample nozzle exposed to the gas flow is large enough to introduce disturbance to

TABLE 6.1

SUMMARY OF TEST RESULTS FOR PARTICULATE MATTER AND METALS VITREOUS STATE LABORATORY 100 KILOGRAM MELTER EXHAUST

Sample Run No.	1	2	3	Average
Date	9/26/94	9/26/94	9/27/94	
Time	17:20	22:13	00:30	
Stack Temperature (°F)	609	609	609	609
Moisture (%)	5.98	6.03	8.11	6.70
O_2 (%)	20.5	19.9	20.5	20.3
Stack Gas Volumetric Flow Rate (acfm)	183	173	176	177
Stack Gas Volumetric Flow Rate (dscfm)	82	77	77	79
Isokinetic Ratio (%)	100.4	103.1	107.4	
Sample Volume (dscf)	37.774	36.661	38.152	37.529
Particulate Matter:				
Concentration (grains/dscf)	0.2050	0.3340	0.7509	0.4300
Emission Rate (lb/hour)	0.1436	0.2210	0.4964	0.2870
Boron				
Concentration (µg /dscf)	455	963.4	1956.7	1125
Emission Rate (lb/hour)	4.9E-03	9.81E-03	1.99E-02	1.2E-02
Chromium				
Concentration (µg /dscf)	14.57	30.7	60.0	35.1
Emission Rate (lb/hour)	1.57E-04	3.12E-04	6.12E-04	3.6E-04
Cesium				
Concentration (µg /dscf)	329	610	932	624
Emission Rate (lb/hour)	3.7E-03	6.21E-03	9.50E-03	6.73E-03

TABLE 6.1
(CONTINUED)

SUMMARY OF TEST RESULTS FOR PARTICULATE MATTER AND METALS VITREOUS STATE LABORATORY 100 KILOGRAM MELTER EXHAUST

Sample Run No.	1	2	3	Average
Molybdenum				
Concentration (µg /dscf)	21.7	50.9	99.5	57.4
Emission Rate (lb/hour)	2.36E-04	5.19E-04	1.01E-03	5.90E-04
Strontium				
Concentration (µg /dscf)	6.0	13.82	37.14	19.0
Emission Rate (lb/hour)	6.45E-05	1.41E-04	3.78E-04	1.95E-04
Potassium				
Concentration (µg/dscf)	1168	1838	2448	1818
Emission Rate (lb/hour)	1.27E-02	1.87E.02	2.49E-02	1.88E-02
Sodium				
Concentration (µg/dscf)	1826	3661	6111	3866
Emission Rate (lb/hour)	2.0E-02	3.73E-02	6.23E-02	4.0E-02

TABLE 6.2

SUMMARY OF TEST RESULTS FOR PARTICULATE MATTER AND METALS VITREOUS STATE LABORATORY HEPA FILTER EXHAUST

Sample Run No.	2	3	4	Average
Date	9/26/94	9/26/94	9/27/94	
Time	10:09	00:32	12:01	
Stack Temperature (°F)	90	103	102	98
Moisture (%)	2.61	2.74	2.70	2.68
O_2 (%)	20.9	20.6	20.9	20.8
Stack Gas Volumetric Flow Rate (acfm)	201	206	227	211
Stack Gas Volumetric Flow Rate (dscfm)	181	182	201	188
Isokinetic Ratio (%)	103.5	98.4	94.7	
Sample Volume (dscf)	42.111	40.127	41.573	41.270
Particulate Matter:				
Concentration (grains/dscf)	0.0018	0.0028	0.0027	0.0024
Emission Rate (lb/hour)	0.0028	0.0044	0.0047	0.0040
Boron				
Concentration (µg/dscf)	<125	<125	<125	<125
Emission Rate (lb/hour)	<2.9E-03	<2.96E-03	<3.2E-04	<2.1E-03
Chromium				
Concentration (µg/dscf)	<0.15	<0.11	<0.11	<0.12
Emission Rate (lb/hour)	<3.49E-06	<2.60E-06	<2.86E-06	<2.98E-06
Cessium				
Concentration (µg/dscf)	<0.95	<1.0	<0.96	<0.97
Emission Rate (lb/hour)	<2.3E-05	<2.4E-05	<2.6E-05	<2.4E-05

TABLE 6.2
(CONTINUED)

SUMMARY OF TEST RESULTS FOR PARTICULATE MATTER AND METALS VITREOUS STATE LABORATORY HEPA FILTER EXHAUST

Sample Run No.	2	3	4	Average
Molybdenum				
Concentration (µg/dscf)	<0.23	<0.47	<0.41	<0.37
Emission Rate (lb/hour)	<5.57E-06	<1.14E-05	<1.10E-05	<9.33E-06
Strontium				
Concentration (µg/dscf)	<0.10	<0.08	<0.07	<0.08
Emission Rate (lb/hour)	<2.46E-06	<1.85E-06	<1.96E-06	<2.09E-06
Potassium				
Concentration (µg/dscf)	<40	<40	<40	<40
Emission Rate (lb/hour)	<1.8E-04	<8.8E-04	<9.1E-04	<6.6E-4
Sodium				
Concentration (µg/dscf)	<70	<70	<70	<70
Emission Rate (lb/hour)	<1.2E-03	<1.2E-03	<8.3E-01	<1.4E-03

the flow of exhaust gas past the sampling nozzle. This suggests that the turbulent flow has eddies that can disrupt streamlines and bias the sample collection of particles with varying diameters.

Isokinetic sampling is designed to collect sample gas through the sampling nozzle at the same velocity the gas has in the stack. If the stack gas velocity is constantly changing at the sample nozzle due to eddies or an otherwise unsteady flow, than the sampling rate for collecting particulate matter may not be correct during some periods of testing. If gas samples are not collected at the isokinetic rate then the particulate matter measurements will be biased. The direction of the bias, whether it increases or decreases measured emission rates, depends on whether the particulate matter samples were collected at a rate greater or lesser than the desired isokinetic sampling rate. The bias direction also depends on the sizes of the particles being sampled. If you are collecting samples at a faster rate than required, then the larger diameter particles will be under-represented in the measurement.

Also, the melter exhaust flowrate was not observed to vary significantly, suggesting that the main cause of varying velocities at the nozzle location would be eddies in the gas flow. Smaller diameter particles are generally over represented in the collected samples if the sample collection rate is greater than isokinetic.

Metals Concentrations and Emission Rates

Tables 6.1 and 6.2 show the exhaust gas metals concentrations and emission rates. Emission rates and concentrations for the melter exhaust are shown in Table 6.1. Na, K, B, and Cs are present in the highest concentrations and have the greatest emission rates. The average emission rate for these compounds was 4.02 E-02 lb/hr, 1.88E-02 lb/hr, and 1.2E-02 lb/hr, and 6.43E-03 lb/hr. Concentrations of Na, K, B, Cs averaged 3,866 ug/dscf, 1818 ug/dscf, 1125 ug/dscf, and 624 ug/dscf. The Na concentration is 14.4% of the total suspended particle (TSP) concentration; the K concentration is 7.48% of the TSP concentration; B is 3.97% of the TSP particle concentration; and Cs is 2.4%. Cr, Mo, and Sr were found in the melter exhaust samples, but at significantly lower concentrations relative to Na, K, B, or Cs.

The metals concentrations measured at the melter exhaust may be biased by the sample location for the same reasons that particle concentrations may be biased. Metals that are associated with particulate matter may have been overestimated or underestimated due to the physical dimensions of the sampling location, as described previously.

Exhaust gas samples collected after the HEPA filter contained mainly Na, K, and B (Table 6.2). The Na, K, B concentrations averaged <70 ug/dscf, <40 ug/dscf, and <125 ug/dscf. These averages have been blank corrected by subtracting the blank from the sample value and then taking the negative result and multiplying it by two and using the absolute value as a sample result. The calculated concentrations are then reported as "less than" values. It is likely that any Na, B, or K found in the HEPA filter exhaust is due to the glass filter and reagents, since the blank levels and sample levels are close in values.

The concentrations of Sr, Mo, Cr, and Cs are small compared to the concentration of the other metals. Sr, Mo, Cr, and Cs are present in the samples at concentrations that are either less than the detection limit or less than the reagent blank value. Emission rates and concentrations of Sr, Mo, Cr, and Cs presented in Table 6.2 are based on analytical results reported as less than the detection limits and they have not been blank corrected. This method of calculation provides an overestimate of the emission rates and concentrations.

Continuous Emissions Monitoring Results

Table 6.3 provides a summary of the CEM measurements made at each sample location. Exhaust gas from the melter was measured at each location prior to introducing any feed to the melter. These measurements are refered to as "baseline" measurements or concentrations. Baseline concentrations of NO_x, SO_2, CO, and THC were measured in the melter exhaust as less than ppmv. Measured NO_x concentrations ranged from 584 ppmv to 1336 ppmv, at the HEPA filter exhaust. NO_x concentrations at the melter exhaust varied from 2552 ppmv to 3610 ppmv. (As discussed previously, these measurements were biased upwards because of sample matrix interference). SO_2 concentrations ranged from a minimum of 0.2 ppmv at the HEPA filter exhaust to a maximum of 67.2 ppmv, at the Melter Exhaust. THC concentrations varied from 5.2 ppmv at the HEPA filter exhaust to a maximum of 32.4 ppmv at the melter exhaust. Measured CO concentrations were observed as high as 116 ppmv at the Post-Demister. O_2 concentrations did not change significantly from the 20.9% considered representative of ambient concentrations.

TABLE 6.3

CATHOLIC UNIVERSITY
CEM DATA SUMMARY
100 Kilogram Melter

Run #1

Date	Time	Location	O_2 (%)	CO (ppm)	Concentration NO_x (ppm)[1]	SO_2 (ppm)	THC (ppm)
9/26	18:06	Melter	21.0	38.3	3218	4.7	16.8
9/26	17:59	Post Scrubber	20.9	70.0	2573	3.8	25.6
9/26	17:39	Post Demister	20.9	40.1	886	2.0	11.2
9/26	17:22	HEPA Filter	21.1	19.5	584	0.2	5.3

Run #2

Date	Time	Location	O_2 (%)	CO (ppm)	Concentration NO_x (ppm)[1]	SO_2 (ppm)	THC (ppm)
9/26		Melter	N.D.*	N.D.*	N.D.*	N.D.*	N.D.*
9/26	22:47	Post Scrubber	20.3	94.0	3430	5.9	22.5
9/26	22:33	Post Demister	20.5	113.0	2051	7.2	21.3
9/26	22:18	HEPA Filter	21.0	5.9	974	1.5	5.2

Run #3

Date	Time	Location	O_2 (%)	CO (ppm)	Concentration NO_x (ppm)[1]	SO_2 (ppm)	THC (ppm)
9/27	01:12	Melter	20.4	97.0	2552	67.2	32.4
9/27	00:58	Post Scrubber	20.6	99.0	5234	18.9	28.2
9/27	00:45	Post Demister	20.8	116.0	2417	55.5	21.1
9/27	00:33	HEPA Filter	21.1	55.9	860	5.7	12.5

Run #4

Date	Time	Location	O_2 (%)	CO (ppm)	Concentration NO_x (ppm)[1]	SO_2 (ppm)	THC (ppm)
9/27	12:46	Melter	20.4	78.7	3610	19.7	18.0
9/27	12:36	Post Scrubber	20.8	4.5	3171	6.4	8.6
9/27	12:27	Post Demister	20.7	67.0	3055	28.8	10.3
9/27	12:15	HEPA Filter	20.8	43.6	1336	3.6	7.8

Baseline

Date	Time	Location	O_2 (%)	CO (ppm)	Concentration NO_x (ppm)[1]	SO_2 (ppm)	THC (ppm)
9/26	13:34	Melter	20.9	0.2	0.0	0.0	1.4
9/26	13:28	Post Scrubber	20.9	0.3	0.0	1.1	1.6
9/26	13:23	Post Demister	20.7	0.1	0.0	2.0	2.5
9/26	13:16	HEPA Filter	20.7	0.0	0.0	0.1	1.7

---

* N.D. denotes no data.

[1] The NO_x concentrations are biased by the high concentration of NH_3 present in the melter exhaust. The values are approximately 80 percent too high.

The design of the melter's air pollution control system had an impact on the pollutant concentrations observed at the HEPA filter exhaust. Ambient air is mixed with process exhaust prior to its passing through the HEPA filters, diluting the exhaust gas with ambient air prior to its being measured by the CEM system. The reduced values of NOx, CO, SO2, and THC observed at the HEPA filter exhaust are due to the dilution by the ambient air.

NO_x measurements collected at each location were biased upwards because of sample matrix interference with the NO_x analyzer. Furthermore, during the testing of the 100 kg melter, some differences between the Parsons ES CEM data and the VSL portable analyzer were noted. There was no immediately apparent reason for these differences. Since then, we have reviewed the data, discussed the instrumentation response with manufacturers' technical representatives, and come to some conclusions regarding the data. Basically, the oxygen, carbon monoxide, sulfur dioxide, and total hydrocarbon data are valid as collected and show that the melter emissions were seldom constant, changing over time, sometimes, quite rapidly.

Of most concern, and the most obvious differences between the portable and Parsons ES CEM instruments, were the NO_x readings. Apparently, although we do not have any of VSL-collected data, the VSL results were sometimes an order of magnitude lower than the Parsons ES data at the HEPA filter exhaust. Some readings obtained by Parsons ES were as high as 2500 ppmv, before correction for drift and calibration error and almost 3500 ppmv after correction. The tremendous range of observed reading (0-5200 ppmv) creates its own set of problems relating to analyzer calibration at the proper range. These problems were remedied after the high readings were observed. It now appears, from discussions with VSL personnel and manufacturer personnel, that much of disparity between Parsons ES and VSL data may come from NH_3.

Parsons ES uses a TECo Model 10 chemiluminescence analyzer with a stainless converter for the NO_2 to NO conversion. The manufacturer states that this converter will also convert NH_3 to NO at 80-85% efficiency up to 2000 ppm by volume NH_3. Further, the relatively high concentration of NH_3 would essentially contaminate the converter for some period of time. According to Dr. Matlack, it is entirely possible to have 2000 ppm or higher of NH_3 in the flue gas. We do not have sufficient data to determine the interference level any more precisely than this.

There are several possibilities for doing so, however. The NOx analyzer can be run by bypassing the converter. This is usually done to differentiate between NO and NO2, so the presence of large concentrations of NH_3 in the gas stream would have an unknown effect on the chemiluminescence reaction and on the components themselves. We could also put an ammonia scrubber ahead of the analyzer and compare the scrubbed with the unscrubbed results. A proper experiment would need to address other interferences and analyte removal or conversion processes. The third possibility is to use a NOx analyzer with a molybdenum converter. The MolyCon converts only 5-6% of the ammonia to NO and thus would reduce but not eliminate the interference problem.

APPENDIX II
Parsons Engineering Science Off-Gas Monitoring Summary Report for the DuraMelter™ 1000 Run

NOTE: Appendix II contains only the first part of the DuraMelter™ 1000 offgas monitoring report as prepared by Parsons Engineering Science Inc. The full report including field data and calculations is issued as a separate document "GTS Duratek, Phase 1 Hanford Low-Level Waste Melter Tests: 1,000-kg Melter Offgas Report" (WHC-SD-WM-VI-029).

PERFORMANCE TEST REPORT FOR THE 1000 KG MELTER

PREPARED FOR:

VITREOUS STATE LABORATORY

CATHOLIC UNIVERSITY OF AMERICA

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727107

MARCH 1995

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EXECUTIVE SUMMARY

Source testing was conducted on the 1000 kg melter operated by Catholic University's Vitreous State Laboratory. The testing was conducted during a pilot-scale study involving the vitrification of sludge. Uncontrolled particulate matter emission rates (melter exhaust) averaged 0.27 lb/hr. After the HEPA filter, the average particulate matter emission rate was below particle detection limits (approximately 2μg/dscf). Metals concentrations and emissions rates were measured at the melter exhaust and at the HEPA filter exhaust. As expected, the highest metals concentrations were observed in the melter exhaust prior to the air pollution control devices. The HEPA filter exhaust was virtually clean with metals reported by the laboratory as non-detectable. Sodium was the most prevalent metal in the melter exhaust (1762 μg/dscf).

Continuous emissions monitoring results for NO_x, SO_2, CO, and THC, identified NO_x as the pollutant most prevalent at all of the sampling locations (melter exhaust, post-demister, and HEPA filter). The highest average NO_x measurement observed was at the melter exhaust and was 6445 ppmv. Sample gas was passed through an ammonia scrubber prior to being analyzed for NO_x. This reduced the bias caused by the ammonia present in the stack gas.

Other pollutants were not present in significant quantities when compared to the NO_x concentrations. THC and SO_2 were generally observed at levels below 100 ppmv and 250 ppmv, respectively. The highest average CO concentration observed was 414 ppmv.

SECTION 1

INTRODUCTION

This sampling and analysis report has been prepared by Parsons Engineering Science, Inc. (Parsons ES) for a source assessment program conducted on an experimental glass melter, operated by the Vitreous State Laboratory (VSL) of the Catholic University of America. The Director of the VSL is Dr. Pedro Macedo. This pilot-scale melter (1000 kg) is located in Hannon Hall, Catholic University of America, Washington D.C., 20064. Process sampling results are presented and summarized in this report. Collected data will be used by the VSL as part of the performance evaluation program for the 1000 kg melter.

During this source assessment, Parsons ES monitored the melter at different locations of the process and air pollution control system. Emission rates of sodium (Na), potassium (K), cesium (Cs), strontium (Sr), molybdenum (Mo), boron (B), and chromium (Cr) were measured. Particulate matter emission rates were also measured. Parsons ES periodically monitored several gas streams for nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), oxygen (O_2), and total hydrocarbons (THC).

The physical design and layout of the 1000 kg melter prevents strict adherence to the source test methodologies prescribed by 40 CFR Part 60, Appendix A for compliance monitoring. Therefore, we modified the EPA Reference Methods of 40 CFR Part 60 and utilized other EPA source test methods to allow collection of samples in the most representative manner possible, given the nature of the physical constraints of the system layout.

The 1000 kg melter source assessment was conducted by a Parsons ES field crew of two engineers and two senior technicians with the assistance of VSL operators, on January 19 and 20, 1995. Analysis of samples for metals content was performed by Triangle Laboratories, Inc.

SECTION 2

SOURCE DESCRIPTION

The 1000 kg melter is an electrically-powered melter designed to vitrify certain types of hazardous materials of varied natures. During this testing, a surrogate sludge was fed to the melter to simulate the low-level radioactive or mixed waste for which this melter is being designed. Once the desired glass composition in the melter was obtained, the melter operated continuously for approximately three days, during which time the surrogate sludge was pumped into the unit. Source testing occured during the first twenty-seven hours of the melter demonstration.

The exhaust from the melter is treated by an air pollution control system. Exhaust air leaves the melter at temperatures between 500 and 800° C and passes through a quench and then to a caustic scrubber. A demister follows the caustic scrubber and after the gas passes through the demister, it is re-heated before being sent to a baghouse for final particle removal. Final gas cleaning is accomplished with a HEPA filter. Ambient air is added to the exhaust air prior to the HEPA filter to control the humidity and maintain HEPA filter performance.

SECTION 3

SAMPLING LOCATIONS

Three sampling locations were selected by the VSL for the source assessment of the 1000 kg melter. These locations are the melter exhaust, post-demister, and HEPA filter exhaust.

The melter exhaust sampling location is pictured in Figure 3.1. A pipe fitting was modified for use as a sampling port in the ten-inch i.d. pipe that ducts exhaust gas from the melter. The main sampling port is located at an intersection, approximately two and half feet downstream from the melter exhaust stack. Due to the melter equipment arrangement, there are no sampling locations that meet the criteria for isokinetic sampling as described in EPA Reference Method 1 or 1A. Also, the small duct diameter precludes sampling traverses. Instead, a single point nominally in the center of the gas flow, was selected for the sampling nozzle location.

Sampling at the post-demister was performed at a sampling port located just down stream of the demister (Figure 3.2). A small tap suitable for sampling NO_x, SO_2, THC, CO, and O_2 was installed in the four-inch PVC pipe, prior to the baghouse. This location was only used for non-isokinetic, CEM sampling.

There are two identical HEPA filter systems available for the exhaust gas after it passes through the demister. Only one of the systems can be operated at any given time. The No. 1 or 2 HEPA filter exhaust was in operation and was sampled at the exhaust stack after the gas leaves the filter (Figure 3.3). The main sample location was selected as required by EPA Reference Method 1A. The exhaust duct is a 8-inch diameter steel pipe with the two sampling ports for isokinetic sampling located approximately four duct diameters downstream from the nearest flow disturbance and five diameters upstream from the nearest disturbance. Both ports were located in the same stack cross-sectional plane, and were offset 90 ° to each other. Two pitot tube ports were installed downstream of the main sampling port for velocity measurements with a standard pitot tube. The velocity traverse ports were located 59 inches (7.37 duct diameters) downstream of the outlet of the exhaust

FIGURE 3.1
MELTER EXHAUST

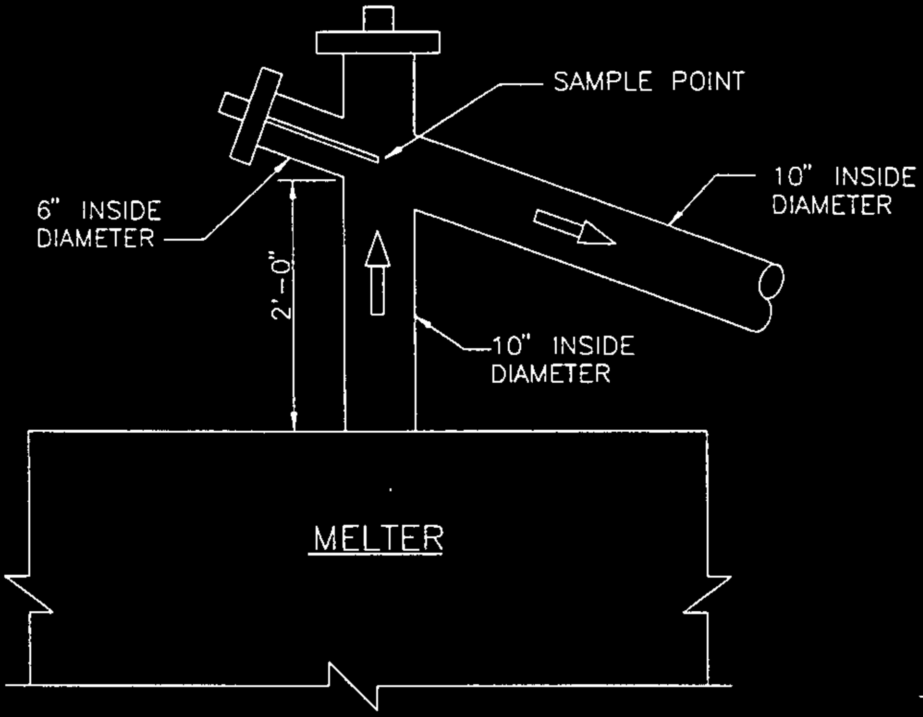

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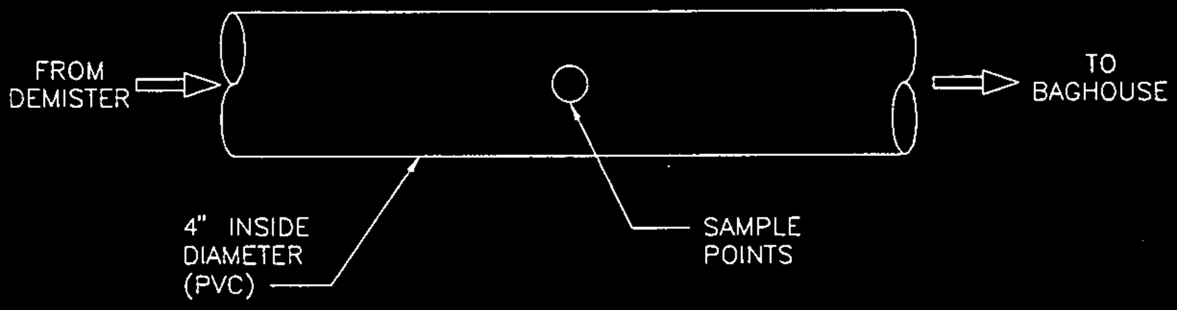
FIGURE 3.2
POST-DEMISTER



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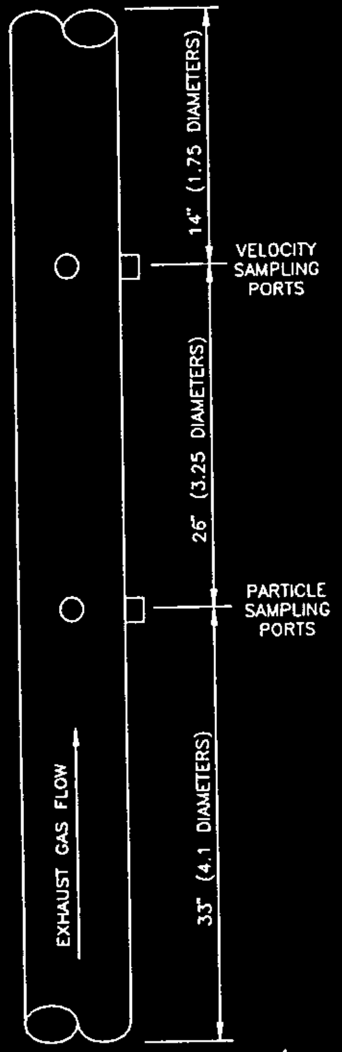

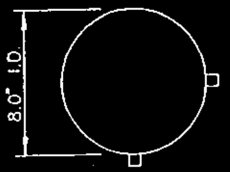

12-POINT TRAVERSE

TRAVERSE POINT ID	DISTANCE FROM INSIDE WALL OF STACK (IN.)
1	0.50
2	0.54
3	0.94
4	1.42
5	2.0
6	2.84
7	5.15
8	6.0
9	6.6
10	7.1
11	7.5
12	7.5

FIGURE 3.3
VITREOUS STATE LABORATORY,
CATHOLIC UNIVERSITY OF AMERICA
SAMPLE PORT LOCATIONS AND TRAVERSE POINT LAYOUTS

27107F03

fan, and fourteen inches (1.75 duct diameters) upstream of the bend in the duct. The sample and velocity traverses were conducted concurrently using a twenty-four point matrix. Each sample matrix consisted of two twelve-point sample traverses.

An auxiliary sampling port was used for non-isokinetic sampling, immediately downstream of the main sampling location.

SECTION 4

TEST PROGRAM AND SAMPLING METHODS

As stated previously, the purpose of this source assessment program is to provide emissions data for the VSL's 1000 kg melter. This test program collected emissions data from three sampling locations: the melter exhaust, post-demister, and HEPA filter exhaust. Particulate matter and metals samples were collected from the melter exhaust and HEPA filter exhaust locations. From all three locations, NO_x, SO_2, THC, CO, and O_2 were measured. Table 4-1 is the sampling matrix for the source assessment program.

Particulate Matter and Metals Sampling

Particulate matter and metals were collected at the Melter Exhaust with a modification of the multiple-metals method from the *Methods Manual for Compliance with the BIF Regulations (EPA/530-SW-91-010)*. The BIF metals methods was used in conjunction with EPA Method 1A at the HEPA Filter Exhaust sampling location.

With the BIF Metals Method, particulate and gaseous emissions are isokinetically withdrawn from the stack and collected on a quartz fiber filter and in an impinger solution. Metals in the particulate phase are captured on the filter and vapor-phase metals are collected in the impinger solution. This source assessment program used two impingers each containing 100 ml of a 5% nitric acid/10% hydrogen peroxide solution. The various fractions of the sampling trains are digested prior to analysis by inductively-coupled argon plasma (ICAP) spectroscopy. Generally, this method is used for the sampling and analysis of trace metals. Except for chromium, the metals targeted in this source assessment program are not usually selected for emissions monitoring. However, the selected analytical methodology, ICAP, provides the sensitivity and precision desired.

Prior to metals analysis of the sample filter, the filter was weighed to measure the mass of particulate matter collected.

TABLE 4-1
SAMPLE MATRIX FOR VSL 1000KG MELTER

Sample Location	Parameter	No. Of Sample Runs	Sample Train ID	Sample Method
Melter Exhaust	Metals (Na, K, Cs, Cr, Mo, B, Sr)	3	1	Modified BIF-MMT
	Particles	3	1	Modified BIF-MMT
	NO/NO$_x$, SO$_2$, CO, O$_2$, THC	Continuous	NA	EPA Methods for CEMS
Post-Demister	NO/NO$_x$, SO$_2$, CO, O$_2$, THC	Continuous	NA	EPA Methods for CEMS
Stack	Metals (Na, K, Cs, Cr, Mo, B, Sr)	3	2	Modified BIF-MMT
	Particles	3	2	Modified BIF-MMT
	NO/NO$_x$, SO$_2$, CO, O$_2$, THC	Continuous	NA	EPA Methods for CEMS

As mentioned previously, the BIF Metals method was modified to accommodate the sample point configuration at the melter exhaust. Since the exhaust gas temperature exceeded the softening temperature of a conventional glass probe, the sampling nozzle and sampling probe were made from Inconel®. An equipment blank was collected from the nozzle/probe assembly to check for the possibility of contamination from the equipment.

A summary of the BIF Metals Method is presented in the appendices. Also included in the appendices are the summaries of EPA Reference Methods 1 and 5. These are the standard methods upon which the BIF Metals Method draws for the isokinetic and particle sampling guidelines. The source test protocol provides greater detail of the sampling methods.

CEM

At each of the three sampling locations, the exhaust gas was sampled and analyzed for NO_x, SO_2, THC, CO, and O_2. Stack gas samples for analysis by continuous emissions monitors were extracted from a single point at each sample location. Monitoring at each location was conducted on a rotating schedule that reflected the requirements of the VSL staff. Generally, monitoring was conducted at each location for 20 minutes of every hour during the testing. Two sample streams were extracted from the stack and transported to the mobile CEM laboratory through the use of self-regulating heated sample lines, which are designed to maintain gas temperature of 250 °F above the ambient temperature. One of the streams was conditioned to remove entrained particles, NH_4 and moisture and then sent to a stainless steel sampling manifold. Continuous samples for the oxygen, carbon monoxide, and nitrogen oxide analyzers were extracted from the manifold, and the excess gases were vented to the atmosphere. The second stack gas stream was not conditioned, and was sent directly to the continuous hydrocarbon analyzer and the sulfur dioxide analyzer.

Instrument responses to calibration standards and sample gases were analyzed and recorded by a PC-driven data acquisition system (DAS). The DAS consists of an analog-to-digital signal converter and a personal computer which analyzed the instrument responses and converted the analog signals to the appropriate engineering units. The analyzer responses were read and recorded at thirty-second intervals on the PC's hard disk drive and on a computer print-out.

Stack Gas Oxygen Content

The oxygen content in the effluent gas was measured by a Horiba PMA-200 Paramagnetic Oxygen Analyzer in accordance with the procedures in EPA Method 3A. O_2 was analyzed on a dry basis and the instrument responses were recorded by the DAS. The PMA-200 has two operating ranges, 0 - 10, and 0 - 25 percent oxygen. During this test, the instrument was operated on the 0 - 25 percent range and calibrated with oxygen standards containing approximately 17.7 and 11.2 percent oxygen. Prior to each day of testing, the instrument was calibrated by introducing a zero gas and the upscale calibration standards directly to the analyzer. The sample line bias was checked by introducing the zero gas and the mid-range calibration standard into the sampling system immediately downstream of the probe. The oxygen measurement system response and drift was determined at the conclusion of each sampling run by introducing the zero and upscale calibration standard into the measurement system downstream of the probe.

Stack Gas Nitrogen Oxides Content

The nitrogen oxides content in the effluent gas was measured by a Thermo Environmental Model 10 $NO/NO_2/NO_x$ chemiluminescence analyzer in accordance with the procedures in EPA Method 7E. NO_x in the sample gas is converted to NO and detected by the chemiluminescent reaction with ozone. This analytical procedure is subject to interference from NH_3. Elevated concentrations of NH_3 were anticipated in the exhaust from the source tested. The conversion of NH_3 to NO can be 80 - 85%, NH_3 in the exhaust gas was scrubbed using a scrubber with sulfuric acid. NO_x was analyzed on a dry basis and the instrument responses were recorded by the DAS. The Model 10 has eight operating ranges, 0 - 2.5, 10, 25, 100, 250, 1,000, 2,500, and 10,000 ppm nitrogen oxides. During this test, the instrument was operated on the 0 - 1,000 ppm, 0 - 2,500 ppm, and 0 - 10,000 ppm range and calibrated with nitric oxide standards containing 861 and 442 ppm nitrogen oxide. The instrument was calibrated by introducing a zero gas and the upscale calibration standards directly to the analyzer. The sample line bias was checked by introducing the zero gas and the mid-range calibration standard into the sampling system immediately downstream of the probe. The nitrogen oxides measurement system response and drift were subsequently determined at the conclusion of each sampling run by introducing the zero and upscale calibration standard into the measurement system downstream of the probe.

Stack Gas Total Hydrocarbon Content

The THC content in the effluent gas was measured by a J.U.M. VE-7 Total Hydrocarbon Analyzer in accordance with the procedures in EPA Method 25A. Hydrocarbons in the sample stream were measured continuously by a Flame Ionization Detector. THC was analyzed on a wet basis and the instrumentation responses were recorded by the DAS. The VE-7 has five operating ranges, 0 - 10, 100, 1,000, 10,000 and 100,000 ppm hydrocarbons, and is calibrated using propane standards that correspond to approximately 30, 60, and 85 percent of the full-scale response. The VE-7 was operated at the 0-100 ppm range. Prior to testing, the instrument was calibrated by introducing a zero gas and the upscale calibration standards into the sampling system directly downstream of the sample probe. The THC measurement system response and drift were determined at the conclusion of each sampling run by introducing the zero and upscale calibration standard into the measurement system downstream of the probe.

Stack Gas Sulfur Dioxide Content

SO_2 measurements were made using the procedures outlined in EPA Method 6C. Method 6C is based on absorption of ultraviolet radiation by the SO_2 molecule. The amount of light absorbed is dependent upon the concentration of the compound present. The UV light beam is split after the light source, with one part passing through the sample cell, and the other part passing through the reference cell, which is filled with a non-absorbing gas. Each beam then passes through a narrow band pass filter into photomultiplier tubes for creation and amplification of the signals. The amount of absorbed light (found by difference in signal intensity) is proportional to the amount of absorbing species present.

The SO_2 analyzer used is a Horiba AIA 23® that operates on the principle of UV absorption. The analyzer has full-scale ranges of 0 to 100 and 0 to 500 ppm. SO_2 standards are SO_2 in air and were selected to correspond to approximately 55 and 85 percent of the instrument span range.

Summaries of the sampling methods are provide in the appendices.

Sampling Schedule

The source assessment program was conducted over two days, on January 19 and January 20, 1995. Three metals and three particle runs were conducted at both the melter exhaust and at the HEPA filter exhaust. Each metals sampling run lasted for approximately one hour. Metals samples were collected simultaneously at each location.

Exhaust samples at each of the three sampling locations were directed to continuous emissions monitoring instruments at 20 minute intervals. After monitoring for approximately 20 minutes at each location , the exhaust from the next location was sampled. During each run, the first location monitored was the HEPA filter exhaust. The next location from where sample was drawn was the post-demister, and finally the melter exhaust.

SECTION 5

QA/QC PROCEDURES

The main quality assurance and quality control (QA/QC) procedure for the 1000 kg melter source assessment is the adherence to the test protocol. By following the approved source test protocol, complying with the applicable QA procedures for each sampling and analysis method, and documenting changes to the protocol, the quality of resulting performance test data can be evaluated.

Sampling Equipment

Further QA/QC is provided for by the routine calibration and maintenance of the stack testing equipment. All stack sampling equipment to be used in this testing effort is periodically calibrated according to the methodologies and frequencies established in the EPA Quality Assurance Manual. Routine maintenance dictated by the Quality Assurance Manual and good engineering practice ensures quality performance of the sampling equipment. Prior to field use, source test equipment is checked for proper performance and valid calibrations. Upon completion of a source test program, sampling equipment calibrations are re-checked to assess equipment performance during the source test.

Meter Boxes

Meter boxes used for source testing are subjected to multi-point calibrations once each year, or after repairs are made to the dry gas meter, orifice, or thermocouples. Meter boxes are assigned a unique ID number, and a calibration performed on meter boxes are recorded in the notebook. The dry gas meter and orifice are calibrated at five flow settings ranging from an orifice pressure of 0.5" WC to 4.0" WC. The meter box calibration factor (gamma,) is calculated for each flow setting and checked to ensure that no individual gamma differs from the average by more than 0.02. Similarly the ΔH@ value of the orifice is calculated for each flow setting and checked to ensure that no individual value differs from the average by more than 0.15. Dry gas meter thermocouples are checked against a mercury-in-glass thermocouples are considered unacceptable and are repaired or replaced if they do not read within 5.4°F at each of the calibration points.

Pitot Tubes

Parsons ES purchases standard pitot tubes that conform to the design criteria specified in Method 2. Upon receipt, Parsons inspects the pitot tubes for proper construction. The standard pilot tubes are assigned a pitot tube coefficient, C_p, of 0.99.

Thermocouples

Stack temperature thermocouples are permanently attached to the sampling probes and are checked as received for accuracy. The thermocouples are checked against a mercury-in-glass thermometer at three temperatures: ice-point, ambient, and boiling H_2O point. Calibration and maintenance data for each stack thermocouple are recorded in the appropriate sampling probe notebook. Probe liner, filter box, sample gas, and condenser thermocouples are checked for accuracy at three water temperatures: icepoint, ambient, and boiling point. Parsons ES recognizes that the temperature of the probe liner, heated sample box, and sample gas temperature are generally maintained at temperatures of approximately 250°F. Since these temperatures are not used to calculate stack gas parameters or correct sample volumes, the calibration procedure is considered adequate when weighed against the danger of working with boiling oil. Each thermocouple is assigned a unique identification number and a notebook for recording calibration and maintenance data.

Sampling Nozzles

Parsons ES maintains a full range of sampling nozzles to conduct isokinetic sampling at a variety of exhaust gas velocities. Nozzles are stored in padded metal boxes to prevent damage during storage or transport. The internal diameter of the nozzle is measured using a set of dial, electronic, or vernier micrometer. The diameter used to calculate the nozzle area is determined from the average of three measurements of the nozzle in three different diameters. The nozzle is not used if an individual diameter differs from the average by more than 0.004 inch.

Summary (Table)

A summary of sampling equipment with corresponding calibration procedures, frequencies, and acceptance criteria can be found in Table 5-1.

TABLE 5-1

CALIBRATION OF SAMPLING EQUIPMENT

Apparatus	Acceptable Limits	Frequency and Methods of Measurements	Corrective Action
Wet Test Meter (64 ft^3/hr cap.)	$Y = 1.00 \pm 0.01$ for calibration range 7.5 to 65 ft^3/hr	Initially and annually by bell prover	Return to service center for corrective maintenance
Dry Gas Meter	Y tolerance for individual values ± 0.02 from average Y value	Calibration initially and annually against calibrated wet test meter at 0.50, 0.75, 1.0, 1.5, 2.0, and 4.0 in H_2O	Repair or replace as needed, recalibrate over full range of flow settings
	$Y_f = Y_i \pm 0.05Y_i$	Post-test calibration check after field use	Repair or replace as needed, recalibrate over full range of flow settings
	ΔH@ tolerance for individual values ± 0.20 from average ΔH@ value	Calibration initially and annually against calibrated wet test meter at 0.50, 0.75, 1.0, 1.5, 2.0 and 4.0 H_2O	Repair or replace as needed, recalibrate over full range of flow settings
Stack Thermocouple	1.5% of absolute temperature as indicated by ASTM mercury-in-glass thermometer	Initially and annually at ice-point, and boiling water point. Temperatures extrapolated to 1500°F	Adjust, determine calibration factor, or reject
Filter Heater Thermocouple	± 5.4°F as indicated by ASTM mercury-in-glass thermometer	Initially and annually at ice-point and boiling water point	Adjust, determine calibration factor, or reject
Condenser Outlet Thermocouple	± 2°F as indicated by ASTM mercury-in-glass thermometer	Initially and annually at ice-point and boiling water point	Adjust, determine calibration factor, or reject

TABLE 5-1

CALIBRATION OF SAMPLING EQUIPMENT

(CONTINUED)

Apparatus	Acceptable Limits	Frequency and Methods of Measurements	Corrective Action
Dry Gas Meter Thermocouples	± 5.4°F as indicated by ASTM mercury-in-glass thermometer	Initially and annually at ice-point and boiling water point	Adjust, determine calibration factor, or reject
S-type Pitot Tube Assemblies	$C_p = 0.84$	Initially and after field usage be geometric calibration procedures	Realign or replace
Standard Pitot Tube	$C_p = 0.99$	Initially and after field usage be geometric calibration procedures	Realign or replace
Probe Nozzle	Tolerance 0.004 in. for three measurements, 120° apart	Prior to each field test	Reshape and resharpen, then recalibrate
Analytical Balance	± 0.1 mg with Class S wts.	Annually serviced by field tech.	Adjust and repair as needed
		Adjusted prior to each use with Class S wts. (60.0000 g or 100.0000 g)	Adjust as needed to calibrate weight, call for factory service as needed.

Analytical Balances

Analytical balances are professionally cleaned and calibrated annually by certified balance technicians provided by the manufacturer. Following this professional calibration, a document is provided by the manufacturer, stating the model number, serial number and date of calibration. Additionally, a sticker noting the technician's name and the date of calibration is attached to the balance.

Each time the balance is used, a calibration check is performed using a set of Class S weights. The results of each calibration are recorded in a notebook which remains with the balance being used.

Continuous Emissions Monitors

The quality of collected CEM data is ensured by the adherence to the calibration and maintenance programs specified by the instrument manufacturers and in the EPA Reference Methods used during the monitoring. Calibration procedures are provided in greater detail in the appendices.

SECTION 6

RESULTS AND DISCUSSION

This section presents the results of the sampling program and provides discussion of the collected data. Raw field data, laboratory reports and calculations are presented in the appendices.

As expected, the uncontrolled exhaust from the melter and the cleaned exhaust exiting the HEPA filter exhibited widely different characteristics. Melter exhaust samples demonstrated very high particle loading and high metals concentrations, while the HEPA filter exhaust samples usually resulted in analytical data at or near detection limits. Accordingly, different sample recovery and data handling techniques were used for the two locations.

Nitric acid probe washes collected from the melter exhaust sample trains were so laden with particles that these rinsates were filtered and subjected to gravimetric analysis prior to metals digestion. This extra procedure was not necessary for nitric acid rinses taken from the HEPA filter sample trains, since these did not contain particles.

A modification was also made in the choice of rinsate used for melter exhaust sample recovery. In Parsons ES's previous investigation at Catholic University's Vitreous State Laboratory, it was found that probe rinses performed with acetone (as prescribed by EPA Method 5) were ineffectual for particle recovery due to the vast quantity and unusual nature of the particulate matter in the melter exhaust. Therefore, during this sampling program, only nitric acid probe rinses were performed on melter exhaust sample trains. However, the normal procedure (acetone rinse followed by nitric acid rinse) was performed on HEPA filter exhaust sample trains.

As mentioned above, the HEPA filter exhaust samples had such low concentrations of metals and particulate that much of the laboratory results were near or below analytical detection limits. There were many cases in which blank samples actually resulted in higher analyte concentrations than the HEPA filter exhaust samples. To treat these situations as conservatively as possible, the following data handling procedures were implemented: 1)

Whenever a laboratory result was listed as "less than detection limit," the detection limit value was used for calculation purposes; 2) all results (melter and HEPA filter) were blank-corrected by subtracting the blank results from the corresponding sample results; 3) when a blank-corrected result was a negative number, the result was considered to be less than ("<") two times the absolute value of the negative result.

PARTICULATE MATTER CONCENTRATIONS AND EMISSION RATES

Particulate matter sampling results for the melter exhaust and HEPA filter exhaust are given in Tables 6.1 and 6.2 respectively.

The average particulate matter concentration and emission rate measured at the melter exhaust location was 0.31 grains/dscf and 0.27 lb/hr respectively. The particulate matter concentration measured at the HEPA filter exhaust was below detection limits. The maximum emission rate and grain loading (0.34 lb/hr and 0.39 grains/dscf) was measured in the melter exhaust during Run #2.

The melter exhaust sampling location does not meet with EPA Method 1 or EPA Method 1A isokinetic sampling criteria. The melter exhaust sampling point is located at a flow disturbance, as described in Section 3. This situation contributes to unpredictable flow characteristics in the gas stream and can bias the collection of particle samples.

However, a review of the 100 kg Melter performance results (December 1994) by VSL personnel compared the air sampling results to the products found in the scrubber discharges and HEPA filter duct. The review indcated that the air sampling results matched well with the emission rates expected based on a mass balance analysis. This suggests that the bias in particle collection may not be too great. Particles emitted from the melter are probably being exhausted as fume or fine particles and being sampled more as a gas and not as a particle.

TABLE 6.1

SUMMARY OF TEST RESULTS FOR PARTICULATE MATTER AND METALS VITREOUS STATE LABORATORY 1000 KILOGRAM MELTER EXHAUST

Sample Run No.	2	3	4	Average
Date	1/19/95	1/19/95	1/20/95	
Time	17:25	21:10	09:50	
Stack Temperature (°F)	752	752	752	752
Moisture (%)	10.1	21.7	17.1	
O_2 (%)	20.6	19.0	19.1	19.6
Stack Gas Volumetric Flow Rate (acfm)	N/A	N/A	N/A	N/A
Stack Gas Volumetric[1] Flow Rate (dscfm)	99	99	99	99
Isokinetic Ratio (%)	N/A	N/A	N/A	
Sample Volume (dscf)	43.343	42.946	37.966	41.686
Particulate Matter:				
Concentration (grains/dscf)	0.39	0.29	0.26	0.31
Emission Rate (lb/hour)	0.34	0.25	0.22	0.27
Boron				
Concentration (μg /dscf)	924	689	550	721
Emission Rate (lb/hour)	1.2E-02	9.0E-03	7.2E-03	9.4E-03
Chromium				
Concentration (μg /dscf)	63.1	53.8	59.9	58.9
Emission Rate (lb/hour)	8.3E-04	7.1E-04	7.9E-04	7.7E-04
Cesium				
Concentration (μg /dscf)	982	779	1044	935
Emission Rate (lb/hour)	1.3E-02	1.0E-02	1.4E-02	1.2E-02

[1] Based on velocity traverses conducted at the post-scrubber location.

TABLE 6.1
(CONTINUED)

SUMMARY OF TEST RESULTS FOR PARTICULATE MATTER AND METALS VITREOUS STATE LABORATORY 1000 KILOGRAM MELTER EXHAUST

Sample Run No.	2	3	4	Average
Molybdenum				
Concentration (μg /dscf)	57.4	50.0	58.1	55.2
Emission Rate (lb/hour)	7.5E-04	6.5E-04	7.6E-04	7.2E-04
Strontium				
Concentration (μg /dscf)	14.7	12.2	9.2	12.1
Emission Rate (lb/hour)	1.9E-04	1.6E-04	1.6E-04	1.6E-04
Potassium				
Concentration (μg/dscf)	819	NA	NA	
Emission Rate (lb/hour)	1.07E-02	NA	NA	
Sodium				
Concentration (μg/dscf)	2326	1418	1542	1762
Emission Rate (lb/hour)	3.0E-02	1.9E-02	2.0E-02	2.3E-02

NA - Not Analyzed: Due to laboratory analytical error, these results are not available

TABLE 6.2

SUMMARY OF TEST RESULTS FOR PARTICULATE MATTER AND METALS VITREOUS STATE LABORATORY HEPA FILTER EXHAUST

Sample Run No.	1	2	3	Average
Date	1/19/95	1/19/95	1/19/95	
Time	12:25	17:25	21:09	
Stack Temperature (°F)	106.8	107.6	108.3	107.6
Moisture (%)	1.00	1.45	1.27	1.24
O_2 (%)	20.7	20.7	20.7	20.7
Stack Gas Volumetric Flow Rate (acfm)	593	565	606	588
Stack Gas Volumetric Flow Rate (dscfm)	655	627	672	651
Isokinetic Ratio (%)	92.9	99.1	98.4	96.8
Sample Volume (dscf)	84.332	78.965	85.924	83.407
Particulate Matter:				
Concentration (grains/dscf)	<0.00002	<0.00002	<0.00002	<0.00002
Emission Rate (lb/hour)	<0.0002	<0.0002	<0.0002	<0.0002
Boron				
Concentration (μg/dscf)	<10.0	<10.0	<10.0	<10.0
Emission Rate (lb/hour)	<8.9E-04	<8.9E-04	<8.9E-04	<8.9E-04
Chromium				
Concentration (μg/dscf)	<2.0	<2.0	<2.0	<2.0
Emission Rate (lb/hour)	<1.8E-04	<1.8E-04	<1.8E-04	<1.8E-04
Cessium				
Concentration (μg/dscf)	<2.0	<2.0	<2.0	<2.0
Emission Rate (lb/hour)	<1.8E-04	<1.8E-04	<1.8E-04	<1.8E-04

TABLE 6.2
(CONTINUED)

SUMMARY OF TEST RESULTS FOR PARTICULATE MATTER AND METALS VITREOUS STATE LABORATORY HEPA FILTER EXHAUST

Sample Run No.	1	2	3	Average
Molybdenum				
Concentration (μg/dscf)	<2.0	<2.0	<2.0	<2.0
Emission Rate (lb/hour)	<1.8E-04	<1.8E-04	<1.8E-04	<1.8E-04
Strontium				
Concentration (μg/dscf)	<2.0	<2.0	<2.0	<2.0
Emission Rate (lb/hour)	<1.8E-04	<1.8E-04	<1.8E-04	<1.8E-04
Potassium				
Concentration (μg/dscf)	<10	<10	<10	<10
Emission Rate (lb/hour)	<8.9E-04	<8.9E-04	<8.9E-04	<8.9E-04
Sodium				
Concentration (μg/dscf)	<10.0	<10.0	<10.0	<10.0
Emission Rate (lb/hour)	<8.9E-04	<8.9E-04	<8.9E-04	<8.9E-04

Metals Concentrations and Emission Rates

Tables 6.1 and 6.2 show the melter and HEPA filters exhaust gas metals concentrations and emission rates. For the melter exhaust Na, K, B, and Cs are present in the highest concentrations and have the greatest emission rates. The average emission rate for these compounds was 2.3E-02 lb/hr, 9.4E-03 lb/hr, and 2.2E-02 lb/hr. Concentrations of Na, K, B, Cs averaged 1,762 ug/dscf, ug/dscf, 721 ug/dscf, and 935 ug/dscf. The Na concentration is 8.5% of the total suspended particle (TSP) concentration; B is 3.57% of the TSP concentration; and Cs is 4.4%. Cr, Mo, and Sr were found in the melter exhaust samples, but at significantly lower concentrations relative to Na, K, B, or Cs.

The metals concentrations measured at the melter exhaust may be biased by the sample location for the same reasons given in the previous section for particulate sampling bias. Metals that are associated with particulate matter may have been overestimated or underestimated due to the physical dimensions of the sampling location, as described previously.

Exhaust gas samples after the HEPA filter all had metals concentrations below the detection levels. Table 6.2 reports these results as either <2 μg/dscf or <10 μg/dscf. These detection levels are those reported by the VSL analysts for their results. The detection levels reported by Triangle Laboratories for these results are slightly lower. However, to remain consistent with the work conducted by VSL, the higher detection level is reported in the summary table, Table 6.2.

Continuous Emissions Monitoring Results

Table 6.3 provides a summary of the CEM measurements made at each sample location. Measured NO_x concentrations ranged from 496 ppmv to 1106 ppmv at the HEPA filter exhaust. NO_x concentrations at the melter exhaust varied from 465 ppmv to 6445 ppmv. THC concentrations varied from 1.1 ppmv at the melter exhaust to a maximum of 8.5 ppmv at the HEPA filter exhaust. Measured CO concentrations were observed as high as 248 ppmv in the melter exhaust. O_2 concentrations did not change significantly from the 20.9% considered representative of ambient concentrations.

TABLE 6.3

CATHOLIC UNIVERSITY
CEM DATA SUMMARY
1000 Kilogram Melter

Run #1					Concentration		
Date	Time	Location	O_2 (%)	CO (ppm)	NO_x (ppm)	SO_2 (ppm)	THC (ppm)
1/19	13:44	Melter	18.9	414	6445	5.4	1.1
1/19	12:59	Post Demister	19.1	229	2116	678	10.0
1/19	12:16	HEPA Filter	20.7	35.3	648	243	4.6

Run #2					Concentration		
Date	Time	Location	O_2 (%)	CO (ppm)	NO_x (ppm)	SO_2 (ppm)	THC (ppm)
1/19	19:22	Melter	20.6	151	4099	76.7	3.7
1/19	18:05	Post Demister	20.7	210	3761	204	8.2
1/19	17:12	HEPA Filter	20.7	85.7	1106	245	8.5

Run #3					Concentration		
Date	Time	Location	O_2 (%)	CO (ppm)	NO_x (ppm)	SO_2 (ppm)	THC (ppm)
1/19	23:06	Melter	19.0	22.8	465	N/A	5.9
1/19	22:04	Post Demister	20.0	168	2077	N/A	8.0
1/19	21:32	HEPA Filter	20.7	36.8	496	N/A	3.5

Run #4					Concentration		
Date	Time	Location	O_2 (%)	CO (ppm)	NO_x (ppm)	SO_2 (ppm)	THC (ppm)
1/20	13:07	Melter	19.1	248	2911	N/A	N/A
1/20	12:19	Post Demister	20.1	179	1952	N/A	N/A
1/20	11:16	HEPA Filter	20.6	36.7	579	N/A	N/A

* N/A denotes no data collected.

Measured SO_2 concentrations varied from location to location. The observed variability can be attributed to process changes but it is probably due to the hysterisis of sulfate compounds in the sampling line. As described in Section 4, the SO_2 analyzer was sampling hot and wet gas. Eventually this biased the SO_2 sampling system.

During previous testing at the Vitreous State Laboratory, NO_x measurements collected at each location were biased upwards because of sample matrix interference with the NO_x analyzer. Parsons ES uses a TECo Model 10 chemiluminescence analyzer with a stainless converter for the NO_2 to NO conversion. The manufacturer states that this converter will also convert NH_3 to NO at 80-85% efficiency up to 2000 ppm by volume NH_3. Further, the relatively high concentration of NH_3 would essentially contaminate the converter for some period of time.

In the report submitted to Catholic University for the previous investigation, Parsons ES recommended several methods for handling ammonia interference in NO_x analysis. These methods were employed in the investigation described herein.

Parsons ES placed a sulfuric acid solution in-line prior to the NO_x analyzer in order to scrub NH_3 from the sample gas. Furthermore the analyzer was periodically operated in the converter bypass mode (NO mode) in order to reduce and evaluate the ammonia bias.

Prior to the source test, Parsons ES constructed an ammonia scrubber and evaluated the systems impact on the sampling system. Calibration gases with known values of NO_x and SO_2 were passed through the ammonia scrubber and analyzed by our instruments. Our test results indicated that the Scrubber had no impact on the NO_x and NO values as measured by our NO_x /NO analyzers. However, SO_2 removal was apparent. Therefore, sample gas for the SO_2 analyzer was not passed through the ammonia scrubber.

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