PNWD-3437
WTP-RPT-122, Rev. 0

Test Summary: WTP Flowsheet Evaluation of Mercury- Containing Hanford Waste Simulant

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**Battelle Memorial Institute

April 2004

Prepared for Bechtel Hanford Incorporated
under Contract 24590-101-TSA-W000-00004

LEGAL NOTICE

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Test Exceptions: None
R&T Focus Area: HLW Vitrification
Test Scoping Statement(s): B-91

4/28/04
for W. Tamosaitis

ACCEPTED FOR
PROJECT USE

Battelle—Pacific Northwest Division
Richland, Washington 99352

Completeness of Testing

This report describes the results of work and testing specified by Test Specification 24590-PTF-3PI-MEVV-00001, Rev. A and Test Plan TPR-RPP-WTP-252. The work and any associated testing followed the quality assurance requirements outlined in the Test Specification/Plan. The descriptions provided in this test report are an accurate account of both the conduct of the work and the data collected. Test plan results are reported. Also reported are any unusual or anomalous occurrences that are different from expected results. The test results and this report have been reviewed and verified.

Approved:

Gordon H. Beeman, Manager
WTP R&T Support Project

4/23/04
Date

Summary

Mercury is found in the Hanford tank farm wastes. The chemistry of mercury under thermal processing conditions suggests that several different chemical species of mercury can be formed. The physical properties of those species provide different pathways for the mercury in the Waste Treatment Plant (WTP), which require different abatement schemes to control mercury releases.

Under current WTP operating conditions, the portion of the mercury that is scrubbed from the process exhaust will be periodically recycled to the Pretreatment Plant where it will be chemically adjusted, concentrated, and further partitioned between high-level waste (HLW), low-activity waste (LAW), the liquid effluent retention facility/effluent treatment facility (LERF/ETF), and pretreatment's vessel vent (VV) streams. The noncondensable mercury fraction in the melter's off-gas stream, on the other hand, will be actively abated using activated-charcoal sorption beds that form the initial processing component in the melter's secondary off-gas processing system. Without adequate abatement, mercury vapor, depending on its concentration, can threaten both catalytic unit operations in the Plant's secondary off-gas system and clean-air emission limits for mercury as well as other catalytically-abated, regulated volatiles (organics and NO_x).

Beyond process clean-air limits, there is a possibility that the mercury content of the LERF/ETF streams could exceed those facility's discharge limits. Consequently, partitioning fractions and chemical species produced by vitrification and subsequent pretreatment operations need to be quantified to determine off-gas design criteria that will mitigate the threat of excessive airborne and aqueous plant releases.

Toward this end, experimental evaluations were conducted to elucidate the vitrification flowsheet behavior of a mercury-containing Hanford-waste simulant (C-104/AY-101) under representative WTP operating conditions using a range of mercury, halogen, and reductant concentrations as testing variables. Specifically, Battelle—Pacific Northwest Division's Research-Scale Melter (RSM) was used to conduct seven separate processing campaigns over a ~120-h period that involved selected combinations of three mercury, two halogen, and two reductant feed concentrations. In addition, the secondary aqueous waste stream generated by the melter's quench-scrubber was used in a separate, post-melter test evaporator study to project mercury partitioning in LERF/ETF and VV streams.

To be meaningful, experimental testing conditions were designed to simulate as closely as practical those key WTP conditions that may affect mercury speciation. For vitrification and process condensate evaporator tasks, the key process conditions identified, their associated target values, and the average values achieved during testing are summarized in Table S.1. All operational constraints were successfully achieved except for the evaporator concentration factor which, nevertheless, is well within the conceptual design operating range (1.25 to 5) of vacuum evaporators.

To satisfy the technical objectives of this mercury-flowsheet-testing task as discussed above, continuous emission monitoring (CEM) for volatiles (H_2, O_2, CO, CO_2, NO, NO_2, SO_2, volatile organics, and gaseous forms of mercury) in the unquenched melter exhaust was conducted during all seven test conditions evaluated during this 5-day, 24-h-per-day, process-evaluation study. Beyond the CEM studies, four discrete U.S. Environmental Protection Agency Method-29 sampling campaigns were conducted to characterize the melter-effluent source and the chemical species of effluent mercury in particular. Secondary waste streams were also routinely sampled to further elucidate the fate and behavior of mercury and all other waste-simulant species.

Table S.1. C-104/AY-101 Flowsheet Evaluation Test Conditions

	Parameter	Target	Actual	
Melter				
	Glass melt temperature, ^{o}C	1,150	1,150	
	Plenum temperature range, ^{o}C	400–450	422	
	Post film cooler temperature, C°	200–250	222	
	Melter-EVS off-gas residence time, s	1	1	
	Specific Glass Agitation Flow, scfm/m^2	1.0–2.0	0.99	
	Glass Production Rate, MT/d/m^2	0.4–0.8	0.64	
	Glass Fe^{+2}/Fe^{total} ratio	≤0.3	0.055	
Evaporator			**pH=8.4**	**pH=13**
	Boiler Temperature, °C	49 ± 10	47–49	48-49
	Reflux Condenser, °C	49 ± 10	47–49	49
	Condenser Temperature, °C	30 ± 5	30	30
	Vacuum, Torr	60–100	71-90	67-85
	Scaled Inleakage Rate, Scc/min	8-9	8.75	8.5
	Concentration Factor	2	1.7	2.7

Because the performance of the mercury CEM was flawed during C-104/AY-101 melter-flowsheet evaluations, correlations existing between the parameters of the test (Hg, Cl, and reductant concentrations) and the melter-effluent characteristics of mercury, if any, were not directly identifiable using continuous monitor results alone. However, when the continuous monitoring information was combined with off-gas sampling results and waste-stream compositional data, an apparent correlation between feed chloride content and the melter's mercury-effluent source term was revealed. Specifically, these combined data suggest that when significant chlorine is present in a mercury-containing feed stream that is vitrified under WTP processing conditions, the formation of $HgCl_2$ is both thermodynamically and kinetically favored. With an Hg:Cl molar ratio of ~0.1, conversion to chemically combined mercury was essentially complete, whereas a 0.4 molar ratio produced a mixed mercury-effluent source with an appreciable elemental component. On the other hand, for test segments with feed Hg:Cl molar ratios in excess of 2.5, the elemental form was found to be the dominant melter mercury-effluent source. These results suggest that when mercury-containing melter feed with a very low Hg:Cl molar ratio is vitrified under WTP processing conditions, a chemically combined ($HgCl_2$) mercury-effluent source results; otherwise, depending on the magnitude of the Hg:Cl molar ratio, a mixed or totally elemental source will dominate the melter mercury source term. Mercury CEM sampling results downstream of the Ejector Venturi Scrubber (EVS) and high-efficiency mist eliminator (HEME) off-gas treatment devices were consistent with corresponding melter-source-term results previously discussed.

Although the apparent relationship between the Hg:Cl molar ratio and the melter's mercury source term observed during the current test should be generally true and independent of waste-batch identity, any waste constituent capable of affecting the chemical states of the reactants (halogens) can alter the melter's off-gas source term. Thus, if gas-phase reactions are responsible for the formation of halogenated mercury, any substance capable of forming refractory nonvolatile compounds with the halides under vitrification conditions, for example, will affect reactant availability and the resultant yield of halogenated mercury compounds. As a result, unique features of the melter feeds being processed need to be examined in addition to Hg:Cl molar ratios before conclusions can be drawn regarding the likely composition of mercury off-gas effluents.

Post-test evaluation of the melter's secondary waste streams has shown that ~70% of the mercury fed to the melter penetrated the off-gas system's quench scrubber and accumulated in the HEME's deep-bed filter, suggesting a primarily elemental mercury effluent source. Indeed, 76% of the total mercury processed during Research-Scale Melter (RSM) testing occurred during the last two test segments when the melter's mercury-effluent source was predominantly in the elemental state. Of the 27% of mercury collected in the quench-scrubber's condensate, only 9% of the quench-scrubber's mercury inventory was found to be soluble.

The addition of sugar reductant had no discernable influence on processing rates, although it did measurably affect the glass-oxidation state and nitrate reduction. The major effluent gases observed during all phases of melter testing were CO_2 and NO. The combustible gas CO was barely detectable (<2 ppm), except when sugar was added to the feed, and H_2 was not detectable (<10 ppm) under any of the test-processing conditions. Throughout all phases of processing, the CO concentration (by volume) averaged only 1.7 ppm, and the maximum concentration recorded, 0.0019%, occurred during the processing of feed containing 5 g of sugar/L of feed. These concentrations are well below the lower flammability limit (15.5 vol%) of this combustible gas.

Melter partitioning of individual feed constituents, derived from both off-gas sampling and secondary waste-stream analysis, revealed that with the exception of boron, mercury, sulfur (feed impurity detected only in off-gas), and the halogens, essentially all feed constituents (excluding, for example, C, N, and H_2O) were found to be primarily in a condensed state downstream of the film cooler. Overall, the element-specific decontamination factors (DFs) recorded during RSM testing are reasonably close to general expectations and are generally consistent with previous RSM testing results. The very reasonable mass closure demonstrated for most of the feed constituents for which complete analytical data exist suggests that the current melter test has successfully characterized the C-104/AY-101 vitrification flowsheet.

Representative glass samples generated under worst-case, high-mercury testing conditions were subjected to the U.S. Environmental Protection Agency's Toxicity Characteristic Leach Procedure test (TCLP 1992) to demonstrate land-disposal suitability of the simulated waste glass produced during RSM testing. The concentrations of all hazardous analytes, except for Ba and Cr (for which estimates are provided), were found to be below instrument detection limits, and all were below their respective universal treatment standard (UTS) limits. The extremely low mercury concentrations found in the glass presents no adverse leaching problems that would preclude the glass-vitrification product from conforming with all existing Resource Conservation and Recovery Act land-disposal limits (40 CFR 268).

To project HLW/LAW, LERF/ETF, and VV Hg partitioning during pretreatment secondary-waste concentration, representative samples of the quench-scrubber's condensate/scrubbing liquor were vacuum evaporated and concentrated with and without initial pH adjustment. Of the two tests conducted, the results obtained from the pH-adjusted (13) evaluation are considered to be most representative of projected WTP evaporation conditions. The analyses of evaporator condensate and off-gas sample solutions suggest that the mercury partitioning to the Pretreatment Plant's condensate collection and VV systems could be greater than the current WTP design value for the contract maximum mercury feed rate (Cramer 2001). Specifically, the observed evaporator mercury DF (~22) for the unblended RSM condensate is significantly less than the corresponding reference concentrator DF of 997 projected for a blended evaporator feed stream. Of the partitioned mercury, 5.4% was collected in the overhead condensate fraction with the remaining 94.6% being carried off by the gaseous exhaust (vessel vent system). The chemical nature of the evaporator's mercury off-gas source term was evaluated by observing the mercury distribution across the off-gas chemical scrubbers employed during the laboratory-scale tests. The results obtained suggest a mixed volatile oxide/elemental mercury source term (25% / 75%), dominated by the elemental form (3×). Post-test analyses of the mercury remaining in the evaporator concentrate after both the pH=8.4 and pH=13 tests demonstrated that most (86% and 93%, respectively) of the mercury present was associated with undissolved solids. If representative, this result suggests that all but 7% to 14% of the mercury present in WTP evaporator bottoms will be recycled to the HLW melter, with the remainder contributing to the LAW stream.

Since the Pretreatment Plant's evaporator influent stream will be composed of more than just the secondary, aqueous waste generated by HLW melters, the mercury-partitioning results (i.e., mercury DF) established by the above laboratory-scale evaporator tests may not be totally representative of actual plant operations. All factors that can affect the chemical composition of mercury in the evaporator's influent stream need to be considered before accurate Pretreatment Plant projections of mercury off-gas and solution concentrate behavior can be established.

Acronyms/Abbreviations

APEL	Applied Process Engineering Laboratory
BNI	Bechtel National, Inc.
CEM	continuous emissions monitor
DF	decontamination factor
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ETF	Effluent Treatment Facility
EVS	Ejector Venturi Scrubber
Fd	feed
FIA	flame ionization analyzer
FY	Fiscal Year
GC	gas chromatograph
HEME	high-efficiency mist eliminator
HEPA	high-efficiency particulate air (filter)
Hi	High
HLW	high-level waste
Idle	melter non feeding period
IR	injection rate
LAW	low-activity waste
LERF	Liquid Effluent Retention Facility
LFCM	Liquid Fed Ceramic Melter
Lo	Low
LOD	loss on drying
LOI	loss on ignition
MACT	Maximum Achievable Control Technology
MOG	melter off-gas
Mx	maximum
NA	not applicable
ND	not detected
NDIR	non-dispersive infrared

ORP	Office of River Protection
PLC	Programmable Logic Controller
PNWD	Battelle—Pacific Northwest Division
POG	process off-gas
ppm	parts per million (by volume)
QA	quality assurance
QAPjP	quality assurance project plan
RCRA	Resource Conservation and Recovery Act
Red	reductant
RSM	Research-Scale Melter
SBS	submerged-bed scrubber
scfm	standard cubic foot per minute
SCR	silicon-controlled rectifier
SRTC	Savannah River Technology Center
ShakeDwn	melter/off-gas system operational alignment activity
StDev	standard deviation
TCD	thermal conductivity detector
TCLP	toxicity characteristic leach procedure
THC	total hydrocarbon
UDS	undissolved solids
UTS	Universal Treatment Standard
VOC	volatile organic compound
VV	Vessel Ventilation
WTP	Waste Treatment Plant
WTPSP	Waste Treatment Plant Support Project
----	not applicable/available/detected/measured

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The following Battelle—Pacific Northwest Division (PNWD) and Bechtel National Inc. (BNI) staff are recognized for key contributions to this vitrification flowsheet evaluation.

- Task Execution

  The successful completion of the recent Research-Scale Melter (RSM) flowsheet evaluation of simulated, mercury-containing Hanford waste formulation is due entirely to the combined skills and personal commitments of the test contributors. PNWD operators and support staff had to shoulder a greater than anticipated work load due to the presence and needs of commercial service providers that participated in this melter test. With only two qualified staff per shift, it was the resourcefulness and perseverance (and sweat) of the shift personnel, Bill Buchmiller, Jim Davis, Steve Halstead, Chuck Hymas, Harry Smith, and John Tixier, Jr., that allowed the testing schedule to be maintained and successfully completed in a totally safety-conscious and environmentally-responsive manner.

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1.0 Introduction

Mercury is found in the Hanford tank farm wastes. The Best Basis Inventory[a] suggests that tank-farm wastes contain approximately 2000 kg of mercury. A study of mercury's effect on the Waste Treatment Plant (WTP) process (Cramer 2001) suggested that vapor-state mercury is likely to interfere with catalytic off-gas treatment devices and to exceed clean-air release limits if vapor-state emissions were left unabated. However, an examination of process alternatives and flowsheet changes designed to mitigate these potential problems require an accurate knowledge of the partitioning behavior of mercury; unfortunately, the distribution of mercury compounds through the WTP is not well understood.

The chemistry of mercury under thermal processing conditions suggests that several different chemical species of mercury can be formed. The physical properties of those species provide different pathways for the mercury in the WTP, which require different abatement schemes to control mercury releases. Most of the incoming mercury should go directly to the high-level waste (HLW) melter where it will vaporize and become part of the melter off-gas. The chemical nature of the mercury effluent as it enters the WTP's off-gas quencher, the submerged-bed scrubber (SBS), will establish how it partitions and affects unit off-gas treatment operations and secondary waste streams in the WTP.

Under current Plant operating conditions, the portion of the mercury that is scrubbed from the process exhaust will be periodically recycled to the Pretreatment Plant where it will be chemically adjusted, concentrated, and further partitioned between HLW, low-activity waste (LAW), the Liquid Effluent Retention Facility/Effluent Treatment Facility (LERF/ETF), and the pretreatment's vessel vent (VV) streams. On the other hand, the noncondensable mercury fraction will penetrate the WTP's primary off-gas treatment system and, depending on its magnitude, can threaten vitrification plant catalytic unit operations and clean-air emission limits for mercury as well as other regulated volatiles for which catalytic abatement processes are used. As a result, activated carbon absorbers have been subsequently added to the melter off-gas system designs to protect the catalytic units and reduce mercury emissions to below the Maximum Achievable Control Technology (MACT) standards. However, mercury-vapor speciation and corresponding influent rates are not well understood. In addition, there is a possibility that the mercury content of the LERF/ETF streams, discussed above, could exceed those facility's discharge limits. Consequently, partitioning fractions and chemical species produced by vitrification and subsequent pretreatment operations need to be quantified to determine off-gas design criteria that will mitigate the threat of excessive airborne and aqueous plant releases.

This summary report documents the experimental evaluations that were expressly conducted to elucidate the vitrification flowsheet behavior of a mercury-containing Hanford-waste simulant under representative WTP operating conditions using a range of mercury, halogen, and reductant concentrations as testing variables. Specifically, Battelle—Pacific Northwest Division's (PNWD's) Research-Scale Melter (RSM) was used to conduct seven separate processing campaigns over an ~120-h period that involved selected combinations of three mercury, two halogen, and two reductant feed concentrations. In addition, the secondary aqueous waste stream generated by the melter's quench-scrubber was used in a separate, post-

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[a] Go to the following link for the Best Basis Summary database: http://twins/data/getLookupFields3.exe?table=tcd.dbo.v_best_basis_summary&whatsnew=Best+Basis+Inventory. This page has all 177 tanks across the top, and down the left are all of the best basis standard constituents, which would include mercury, in kilograms. The total, 1840 Kg, is shown at the right.

melter-test evaporator study to project mercury partitioning in LERF/ETF streams. The results of these experimental efforts will now be discussed.

2.0 Test Objectives

The major objectives of this test were to characterize the off-gas behavior of mercury under representative WTP vitrification processing conditions over selected waste-loading ranges of mercury, halogen, and reductant and to project mercury-partitioning characteristics during simulated secondary-waste pretreatment concentration operations using condensate generated during the vitrification test conditions. The activities conducted to accomplish these objectives included:

1. Designing experimental testing conditions to simulate as closely as practical those key WTP conditions that may affect mercury speciation. For vitrification testing, the key process conditions identified and their associated target values include:
    - a glass temperature of 1150°C
    - forced-air glass agitation at 1 to 2 $\mathrm{scfm/m^2}$, using two bubblers
    - a plenum temperature of 400°C under steady-state processing
    - a post film-cooler temperature of 200°C to 260°C
    - a melter/quench-scrubber off-gas transit time of 1 second
    - a steady-state specific glass production rate between 0.4 and 0.8 $\mathrm{MT/d/m^2}$
    - a glass with $\mathrm{Fe^{+2}/Fe^{tot}} \leq 0.3$.

    For the laboratory-scale mercury evaporator partitioning studies, the key evaporator operational parameters selected included:
    - a vacuum of 60 to 100 Torr
    - a 49°C evaporator feed temperature
    - a 30°C condenser temperature
    - a scaled 8 to 9 Scc/min simulated inleakage rate
    - a feed pH of 8.4 and 13(a)
    - a feed concentration factor of 2.

2. Performing a research-scale melter test to sample and characterize mercury speciation in off-gas and condensate streams over a range of vitrification process conditions involving feed concentrations of mercury, chlorine, and reductant. This off-gas characterization objective was accomplished by:
    - conducting quasi-continuous determinations of vapor-state concentrations of elemental and oxidized (e.g., $HgCl_2$) forms of mercury before and after each off-gas processing device
    - taking periodic secondary waste-stream supernatant samples for subsequent off-line analyses

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(a) Since Site evaporators utilize a pH range of 7 to 10, but pH=13 is considered WTP prototypic, two evaporator tests were conducted at pH=8.4 and at pH=13.

- collecting and analyzing all quench-scrubber undissolved solids (UDS) and supernatant fluids at the conclusion of testing
- characterizing the melter-effluent source term using a mercury-specific (40 CFR 60, Appendix A, Method 29) sampling train.

3. Sampling and characterizing mercury speciation in evaporator condensable and noncondensable streams when concentrating mercury-containing condensate solutions generated during the vitrification testing phase. Projecting partitioning behavior of mercury under simulated pretreatment evaporation operations was accomplished by:
   - collecting a representative sample of the melter's quench-scrubber waste stream to be concentrated
   - making appropriate pH and chemical adjustment to the condensate fraction
   - performing concentration under the above evaporator reference conditions
   - collecting condensate fraction
   - scrubbing the noncondensable condenser exhaust stream with sequential chemical traps (H_2O_2/HNO_3 and $KMnO_4$/H_2SO_4) designed to selectively trap oxidized and elemental forms of mercury, respectively
   - determining the mercury content of the evaporator condensate and chemical-trap solutions.

In addition to and in support of the above-discussed primary objectives, the compositions and masses of all process influent and effluent streams were also characterized, allowing glass leachability to be assessed and a melter mass balance to be derived. To accomplish this:

- Continuous emission monitors were used to monitor melter noncondensable flue-gas emissions
- Samples of feed, glass, and all aqueous streams generated from off-gas treatment devices were periodically collected in support of post-test analyses and subsequent flowsheet characterization.

3.0 Melter Test Program

As discussed in Section 2, waste-composition ranges of mercury, chlorine, and reductant were chosen as test parameters in the vitrification flowsheet evaluations. High (Hi) and low (Lo) concentration values of each of these variables were established on the basis on waste-tank compositions and likely staging strategies. In addition to Hi/Lo values, an engineering maximum (Mx) condition for mercury was also evaluated.

To satisfy the technical objectives of this mercury-flowsheet-testing task, seven test conditions were identified for evaluation requiring ~5 days of continuous, 24-h-per-day melter operation. A target test-condition matrix defining the technical activity schedule is shown in Table 3.1. This matrix is designed to satisfy the test objectives described in Section 2.

Table 3.1. Target Test Matrix for the June 2003 RSM Testing Campaign

Test Condition Levels (Hg/Cl/Redox)	Glass Fe^{+2}:Fe^{tot} Ratio	Reductant Additive	Feed Rate Target	Cl-Fd Oxide Wt%	Hg Oxide Wt%	Off-Gas Samples	Duration	Cumu-lative hours[(a)]
#1 Lo/Lo/Lo	Not Detectable (ND)	None	Highest optimum at 90% to 95% Cold-Cap Coverage 0.4–0.8 MT/d/m^2 1.0–1.5 L/h	0.009	0.05	---	18	18
#2 Lo/Hi/Lo						---	18	36
#3 Lo/Hi/Hi	≥20% ≤30%	Sucrose ~5 g/L		0.06		---	6	42
#4 Hi/Lo/Lo	ND	None		0.009	0.15	X	18	60
#5 Hi/Hi/Lo	Not Detectable	None		0.06		X	18	78
#6 Mx/Hi/Lo					0.95	X	18	96
#7 Mx/Hi/Hi	≥20% ≤30%	Sucrose ~5 g/L				X	6	102

(a) The 18 hours of contingency time allows for startup, feed-adjustment activities, and unscheduled delays.

3.1 Test-Parameter-Range Selection

To establish a solid basis for the Hg and Cl concentration ranges to be used during RSM testing, an evaluation was conducted of the 84 waste batches that have been identified under the River Protection Project's System Plan Case-3 that will allow completion of all tank-waste vitrification activities by 2028 (ORP 2003). The results of this evaluation are discussed below.

3.1.1 Mercury

It was determined that, except for the beginning and ending phases of processing, most waste batches exhibit a fairly consistent HgO content. The average HgO waste content, 0.19 wt%, would correspond, at 30 wt% waste loading, to a feed concentration of ~0.05 wt%, which is an analytically reasonable choice for the low-Hg-concentration parameter. On the other hand, the highest batch Hg concentration, 0.5 wt%, corresponding to a feed concentration of 0.15 wt%, was a logical choice for the high concentration value to be used during RSM flowsheet tests.

In addition to the Hi/Lo mercury conditions described above, a design maximum condition (Mx) was also established on the basis of creating a sufficient melter mercury off-gas flux to allow mercury-vapor-saturation conditions (30°C) to exist at the outlet of the HEME for:

- a 0.8 $MT/d/m^2$ glass-production rate
- quencher and high-efficiency mist eliminator (HEME) decontamination factors (DFs) of 6 and 3.5, respectively.

The equivalent oxide concentration of mercury in the melter feed stream that satisfies these conditions at a projected noncondensable off-gas flow rate of 5 scfm is 0.95 wt%, which became the adopted mercury Mx value.

3.1.2 Chlorine

To determine the Hi/Lo candidate values for chlorine, waste-batch-composition data for chlorine were similarly examined. It is clear from this evaluation that the median value of 0.03 wt% is representative of the chlorine content of most of the Case-3 batches (ORP 2003) and, therefore, appeared suitable as a low-value test parameter. If the Case-3 batch maximum for chlorine of 0.19 wt% is used for the upper bound, a suitable Cl:Hg molar ratio range of 7 to 0.5 will be established. Since this is also representative of the span of molar ratios exhibited by Case-3 batches, it also appeared appropriate to choose 0.06 wt% and 0.009 wt% as the Hi/Lo chlorine values for melter-feed-test parameters.

3.1.3 Reductant

The glass redox state, which is measured by the Fe^{+2}:Fe^{Tot} ratio, is determined by the relative concentrations of oxidizing and reducing agents in the melter feed stream. Oxalate reductant in the baseline feed (see Section 5) is not expected to create a Fe^{+2}:Fe^{Tot} ratio above its detection limit of about 0.01. However, since reductant levels can be varied to improve process throughput, it is important to determine the influence of reductant levels, if any, upon the off-gas distribution Hg chemical species. Consequently, during part of the test, sucrose was added to the melter-feed stream in sufficient quantities (~5g/L) to produce a measurable Fe^{+2}:Fe^{Tot} ratio that is considered safe (≤0.3) from a glass-durability standpoint.

3.1.4 Test-Condition Duration

The ability of the Table 3.1 test series to accomplish all planned test objectives depends on how rapidly the melter-glass bath, the cold-cap, and the off-gas respond to step changes that occur for each of the different test conditions. The target operating conditions based on RSM design parameters and melter test specification conditions are summarized in Table 3.2.

Table 3.2. Target RSM Operating Conditions

Parameter	Target
Melt surface area, cm^2	182
Melt volume, L	1.4
Glass specific gravity (20°C)	2.6
Glass inventory, kg	3.6
Minimum expected glass rate, $MT/d/m^2$	0.40
Minimum expected glass rate, kg/h	0.30
Maximum expected glass rate, $MT/d/m^2$	0.80
Maximum expected glass rate, kg/h	0.61
Minimum expected feed rate, L/h(a)	0.55
Minimum expected feed rate, kg/h(b)	0.77
Maximum expected feed rate, L/h(a)	1.11
Maximum expected feed rate, kg/h(b)	1.55
Maximum melter glass turnover rate, h	12.0
Minimum melter glass turnover rate, h	6.0
Glass Fe^{+2}:Fe^{tot} ratio	≤0.3
Specific glass agitation flow, $scfm/m^2$	1.0 to 2.0
Glass agitation flow rate, sL/min	0.52 to 1.0
Glass melt temperature, °C	1,150
Plenum temperature range, °C	400 to 500
Plenum pressure, inches water	-0.5 to -1.5
Post film cooler temperature range, °C	200 to 250
Air inleakage rate, scfm	1
Post Film-cooler off-gas flow rate, acfm	10.5
Melter-EVS off-gas residence time, s	1
Initial scrub solution volume, L	60
Initial scrub solution pH	7

(a) Based on a feed oxide loading of 550 g-ox/L.
(b) Based on a feed density of 1.4 kg/L.

At a given set of operating conditions, some operating time is needed to allow time for the melt-bath composition to approach a new equilibrium after step changes in the feed composition that affect the melt composition. Based on the RSM molten-glass volume and the acceptable production-rate-range previously discussed, a 6- to 12-h melt-cavity turnover frequency is suggested. Since up to three bath-volume turnovers are needed to achieve steady-state composition of the melter's glass inventory, a minimum of 18 processing hours, at a 0.8 $MT/d/m^2$ production rate, will be needed to reach true steady-state processing conditions after a feed-stream change has occurred.

However, the above considerations only pertain to feed constituents that are incorporated in the glass product. Because mercury glass partitioning is vanishingly small, changes in its feed concentration will have no impact upon steady-state melter-glass composition. Similarly, since changes in feed-reductant concentrations affect existing as well as newly produced melter glass, changes in melter-glass oxidation state occur over much shorter periods (3 to 6 hours) than the time required to produce three melter turnovers. Although changes in chloride concentrations will affect melter-glass composition and impact the time required to attain steady-state processing conditions, the impact of glass composition, if any, upon the melter's mercury emission source will be derivable from the trending data generated by the quasi-continuous measurements that will be conducted.

Thirty hours were originally allowed for the first test condition to provide sufficient time to:

- establish processing stability
- purge the melter of its startup glass
- record emission results under representative processing conditions.

However, since it was possible to replace the RSM's existing glass inventory with representative C-104/AY-101 glass supplied by Bechtel National, Inc. (BNI), the period for the first test condition was reduced to 18 hours.

Six hours has been allowed for establishing the impact of the changes in reductant concentrations. As discussed above, this time is not based on melter-glass turnovers, but is nominally based on time needed to:

- make the feed change
- change the oxidation state of melter glass
- characterize the system response to the change
- accumulate adequate continuous off-gas monitoring data.

All other test conditions are scheduled for 18-h periods.

3.2 Test-Matrix Glass Composition

The test-parameter conditions detailed in Table 3.1 will be established by adding appropriate quantities of mercury, chlorine, and/or sucrose to an invariant HLW simulant feed batch representing ~30 wt% C-104/AY-101 feed formulation to be discussed in Section 5. Since mercury and reductant are not incorporated in the glass to any significant extent, and the chlorine content of the glass remains at trace levels under all conditions, the glass composition is expected to remain nominally invariant throughout all phases of testing.

4.0 Experimental Equipment Description

Experimental equipment used to support the objectives of this flowsheet evaluation task includes the RSM processing system and a laboratory-scale evaporator. The RSM facility was used to model WTP's HLW processing conditions to determine the chemistry and resultant off-gas fate and behavior of waste-constituent mercury. The redistribution of mercury in the RSM's secondary waste between HLW, LAW, LERF/ETF, and off-gas streams was subsequently evaluated under WTP pre-treatment (concentration) conditions using a laboratory-scale evaporator. The equipment to be used in these evaluations is described below.

4.1 RSM System Description

PNWD's RSM facility is located in the Applied Process Engineering Laboratory (APEL) building in Richland, Washington. Figure 4.1 is a photograph of the RSM system as it nominally appeared during melter testing, and Figure 4.2 schematically illustrates the system components and their relationships to one another. Because mercury was part of the C-104/AY-101 vitrification flowsheet evaluation test, a temporary enclosure was constructed around the RSM to contain and exhaust any melter emissions created by inadvertent melter pressurizations. A plan and elevation view of this enclosure is illustrated in Figure 4.3, while interior and exterior photographs of a similar, previously constructed walk-in hood appear in Figure 4.4 and Figure 4.5, respectively.

The RSM processing system provides a continuous, Joule-heated vitrification capability, which is key for

- developing process flowsheets
- characterizing relationships between feed composition and the properties of the final glass produced
- establishing the fate and behavior of process effluent.

This melter system's capability to produce glass in a continuous manner is also essential for modeling the behavior of a full-scale system. Moreover, the size of the RSM allows the impacts of process variables upon melter performance or glass quality to be quickly and efficiently evaluated without undue expense or waste generation.

4.1.1 Melter

The RSM itself is a small Joule-heated melter that is capable of processing melter feed on a continuous basis. The body of the RSM is an Inconel® closed-ended cylinder lined with Alfrax® refractory and containing a Monofrax® K3 refractory melt cavity. An Inconel® overflow tube discharges molten glass into a stainless steel canister. An electric kiln surrounds the melter body and minimizes heat loss from the melter body during operation, and auxiliary heaters are used to heat the melter's discharge section to facilitate pouring of the glass. The stainless steel glass receipt canister sits inside a clam-shell furnace maintained between 700°C and 900°C to promote uniform canister filling. A platform scale, forming part of a hydraulic jack assembly that supports the canister inside the furnace, allows glass-canister accumulations to be monitored as necessary. Two top-entering Inconel® 690 electrodes (7.6-cm square × 0.64-cm thick [3-in. square × ¼-in. thick]), that are suspended in the glass, supply Joule-heating power to the RSM. The electrode's connecting tubular busbars also serve as thermowells that allow continuous measurement of the glass-pool temperatures. Beyond the pair of electrodes and the exhaust port, the melter lid also provides melter access for a pair of glass agitation bubbler (Inconel®) tubes and a water-cooled feed nozzle. Figure 4.6 provides a cross-sectional view of the melter vessel, illustrating its refractory makeup, while Table 4.1 summarizes the RSM's dimensions and other operational features.

Figure 4.1. Photograph of the Research-Scale Melter Demonstration Unit

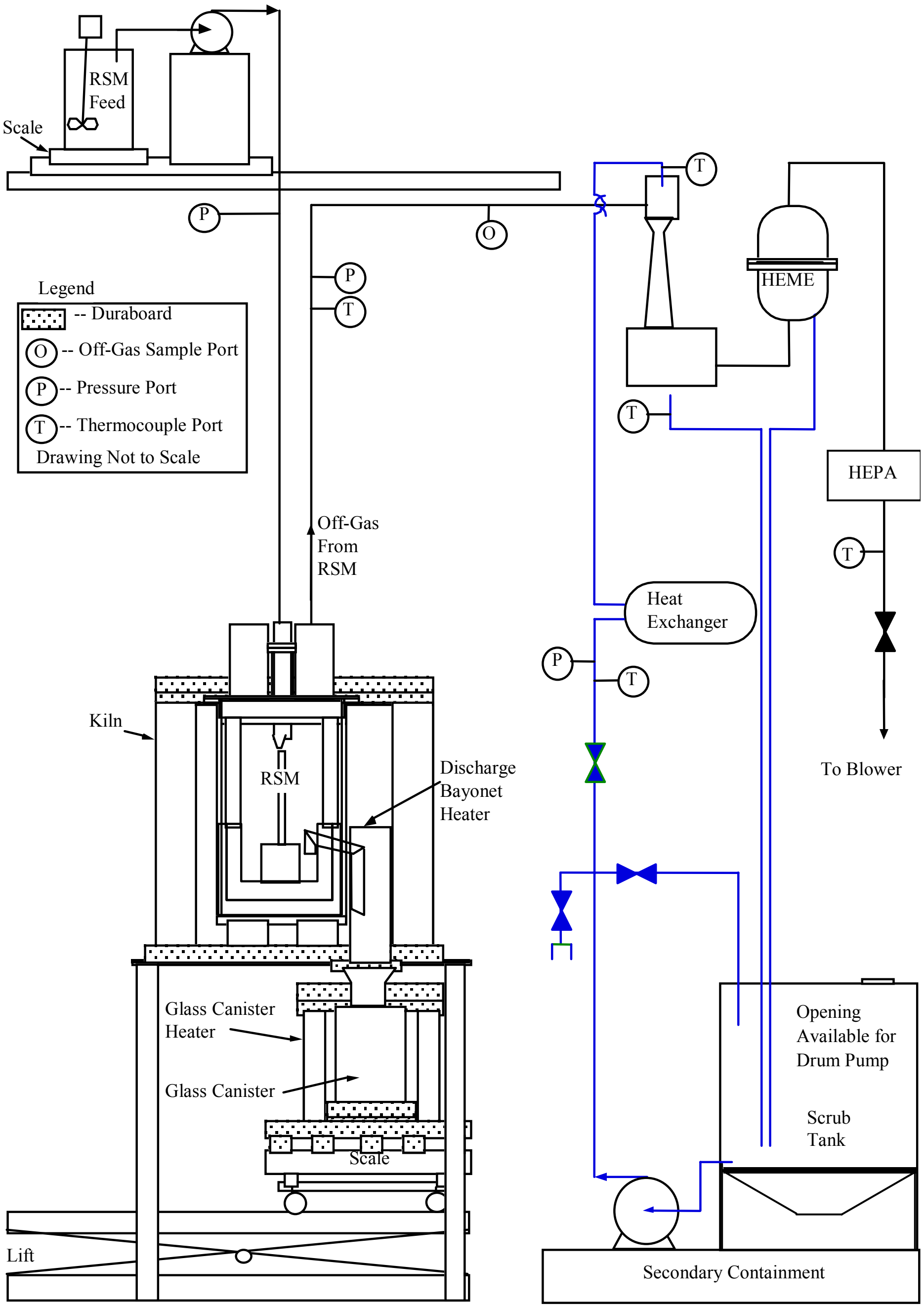

Figure 4.2. Schematic of the Research-Scale Melter Processing System

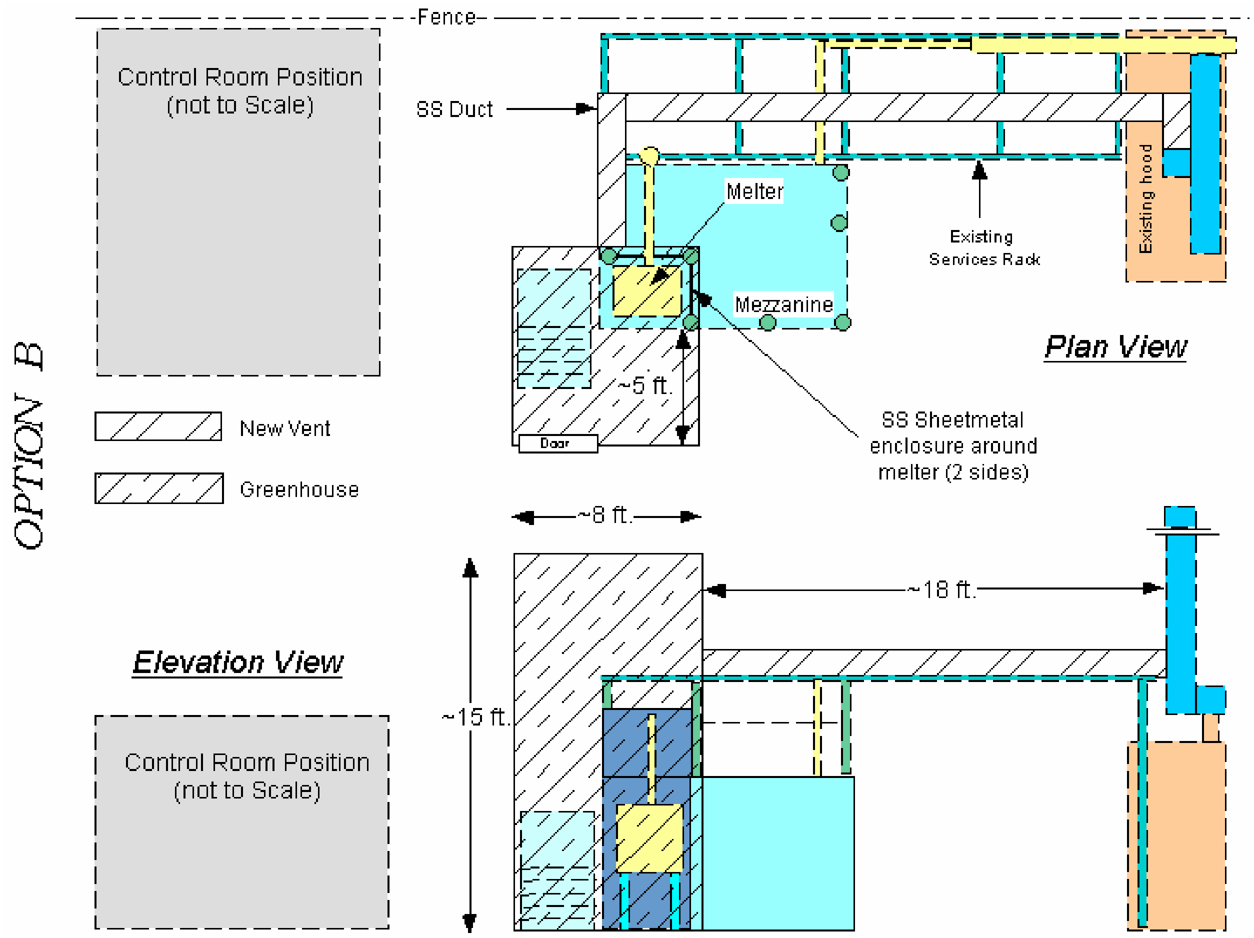

Figure 4.3. Plan and Elevation View of Temporary Melter Hood Enclosure

4.1.2 Feed System

The melter-feed system is located on the elevated steel platform adjacent to the melter (see Figure 4.1). Two agitated conical bottom tanks were staged on this platform during the current test. A master (55 gal) tank accommodated the baseline feed formulation that was periodically transferred to the melter's 15-gal feed tank where it was mixed with appropriate spike additives (Hg, NaCl, and/or sugar) to create the seven feed conditions that formed the basis of the experimental studies of the current test. The melter-feed tanks, the variable-speed agitators, the peristaltic-feed pump, and the valve-control station are attached to a steel pallet that allows the melter-feed-tank system, which includes a secondary containment vessel and load-cell platform scales, to be lifted from the platform with a forklift. The electronic record of time-dependent feed-tank weights, generated by the system's load-cell platform scales, provides for redundant feed-transfer measurements and a direct measure of the melter mass-feeding rate. Figure 4.7 provides a photographic perspective of this elevated tank and feed-delivery system.

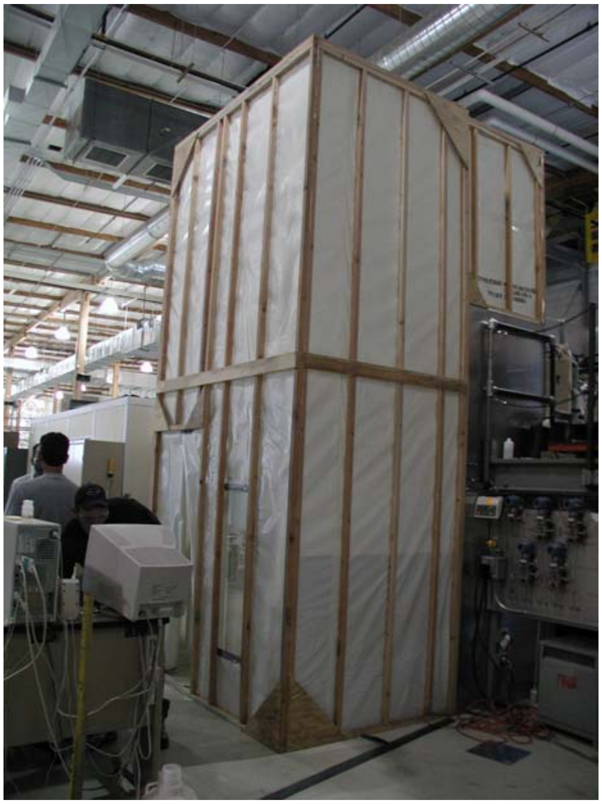

Figure 4.4. Exterior View of Melter Enclosure

Figure 4.5. Interior View of Enclosed Melter

Two peristaltic pumps were used to extract and deliver feed from the 15-gal tank to the melter. As schematically illustrated in Figure 4.8, a large pump was used to recirculate feed from the bottom to the top of the conical, bottom-drain tank, while a smaller pump was used to extract a slip stream from the larger recirculation line and deliver it to the melter. A valve-control station associated with the melter feed delivery system allowed feed to be either sampled or delivered to the water-cooled feed nozzle that extended through the melter lid into the melter's plenum. The valve station, illustrated in Figure 4.8, also permits feed lines to be flushed with air and/or water without resorting to disassembly. A computer/pump interface allowed the pump's feeding rate to be controlled remotely, thus facilitating necessary adjustments required to maintain a steady melting process.

4.1.3 Off-Gas Processing System

Melter off-gas is treated by an off-gas treatment system consisting of a film cooler, Ejector Venturi Scrubber (EVS), HEME, and high efficiency particulate air (HEPA) filter (see Figure 4.2). The film cooler, located at the melter's exhaust port, injects room-temperature building air into the off-gas pipe to

- cool and solidify entrained vitreous matter to minimize pipe-wall particle adhesion
- speed aerosol transport to the EVS quench scrubber to minimize aerosol-settling losses in horizontal off-gas line (2 in.) pipe runs.

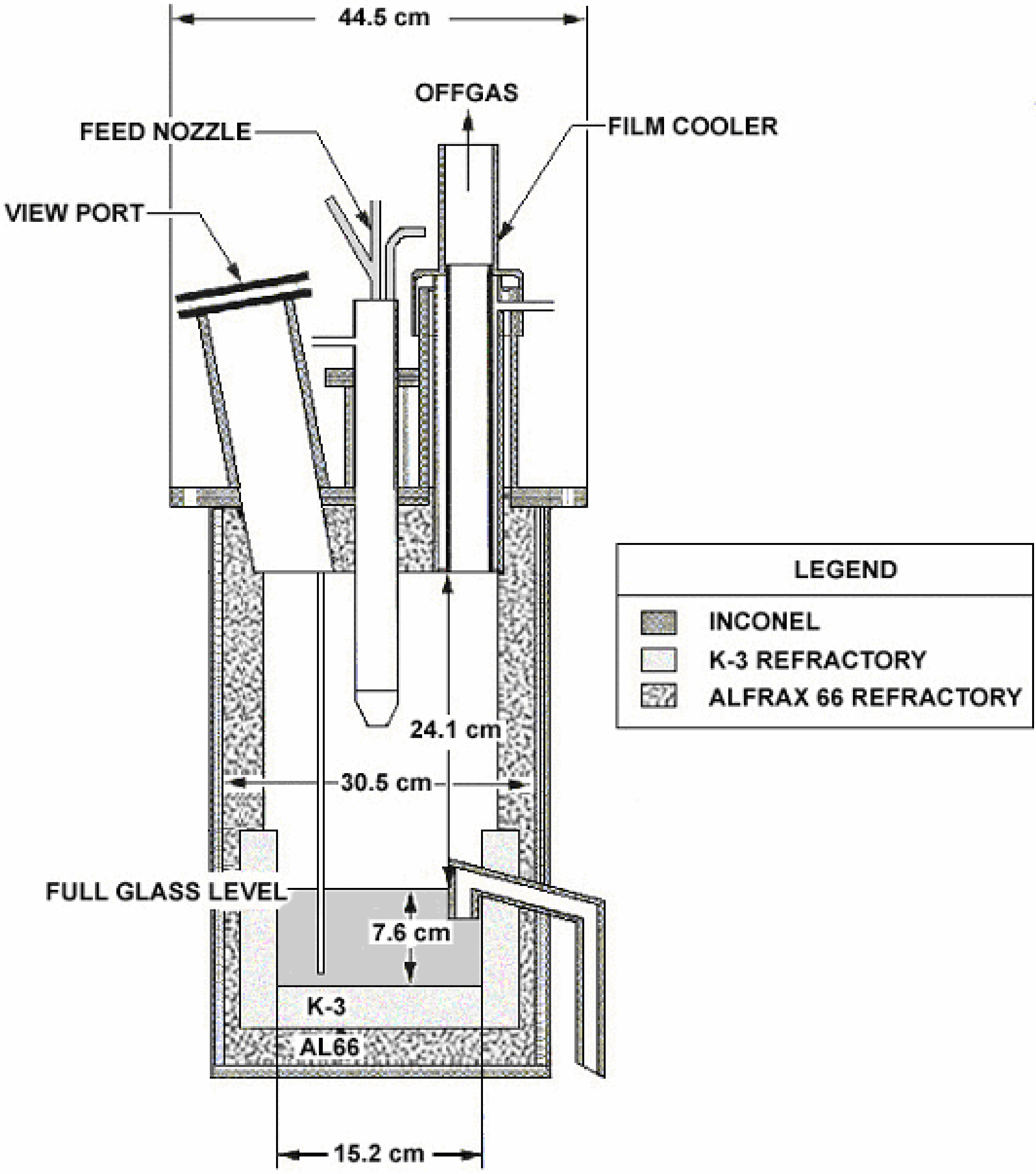

Figure 4.6. Cross Section View of the Research-Scale Melter (not drawn to scale)

The EVS used a high-pressure aqueous scrubbing liquor (condensate) spray to contact the process exhaust stream to quench it and to remove steam, large-diameter aerosols, and some condensable and/or acid gases. A 90-L (24-gal) charge of water was put in the scrubbing liquor/condensate collection tank at the start of the test. Off-gas condensate supernatant samples were collected at the conclusion of each discrete test segment while the UDS that accumulated within the condensate tank throughout the duration of the test were fully collected and sampled at the end of the test. A water-cooled heat exchanger located in the EVS's spray circuit was used to maintain nominal room-temperature scrubbing-liquor conditions.

Table 4.1. RSM Dimensions and Operational Specifications

Parameter	Value
Melter cavity diameter	15 cm
Melter cavity height	17 cm
Melter inside volume	4.5 L
Glass pool surface area	182 cm^2
Nominal glass depth	7.6 cm
Melter glass inventory volume	1.4 L
Nominal molten glass mass	3.6 kg
Glass turnover rate @ nominal feed rate of 1.5 L/h of feed with 0.6 kg/L oxides	4.5 h
Maximum operating temperature	1,200°C
Nominal operating temperature	1,150°C
Electrode Dimensions	7.6 cm × 7.6 cm
Electrode Material	Inconel® 690
Electrode melt-cavity bottom clearance	0 cm
Electrode current (average)	90 A
Electrode voltage (average)	25 V
Electrode current density (average/maximum)	1.6/2.0 A/cm^2

The HEME uses a deep, regenerable fibrous bed to remove both liquid aerosols generated by the high-pressure EVS spray and submicron condensed-phase aerosols that successfully penetrate the low-efficiency quench (EVS) scrubber. The demisted and relatively clean HEME exhaust is then heated before being treated with a certified HEPA filter to remove all significant remaining concentrations of aerosol matter before the process exhaust is released to the environment.

Since the RSM off-gas processing system provides unit off-gas treatment operations of quenching, wet scrubbing, and high-efficiency filtration similar/equivalent to that provided by the WTP's primary melter off-gas system, comprehensive effluent partitioning behavior can be directly assessed under representative conditions. It should be noted that the aqueous quench-scrubber employed in the current test (EVS) has been previously shown to be functionally equivalent to the SBS technology (Goles and Schmidt 1992) that will be used in the WTP.

4.1.4 Off-Gas Sampling System

Process off-gas sampling during the current test was limited to characterizing the melter source term and establishing the Hg-emission-abatement performance of the melter's aqueous quench scrubber and HEME as a function of processing conditions, i.e., mercury, chlorine, and reductant concentrations. These data were collected in support of engineering flowsheet design and are not intended to support

WTP regulatory or environmental-release modeling activities. Melter exhaust gases and effluents with significant room-temperature vapor pressures were monitored continuously with gas analyzers described in Table 4.2, while four limited discrete sampling campaigns were conducted to characterize condensed-phase effluents and condensable/scrubbable gases. These sampling data will also provide a cross check for contemporaneous mercury monitoring results.

(a) (b)

Figure 4.7. Elevated Melter Feed Tank, Secondary Containment, and Load Cell Platform Scale

4.1.4.1 Continuous Emissions Monitoring

Continuous-emission monitoring was conducted for flue gases (H_2, O_2, N_2, CO, CO_2, NO, NO_2 and total hydrocarbons [THCs]) and volatile forms of mercury. Although the continuous-emission monitors (CEMs) were configured as shown in Figure 4.9, flue-gas monitoring was exclusively conducted between the film-cooler and quench scrubber. Mercury monitoring was also selectively conducted between the EVS and the HEME and downstream of the HEME, independent of the flue-gas monitoring system.

Table 4.2. RSM's Effluent Gas Analyzers

Analyzer/EPA Method	Targeted Effluent Gases
Gas Chromatograph	H_2 & He
Oxygen/3A	O_2
Carbon Monoxide/10	CO
Carbon Dioxide/3A	CO_2
Nitrogen Oxide/7E	NO & NO_2
Sulfur Oxide/6C	SO_2
Total Hydrocarbon/25A	Volatile Hydrocarbons
Gas Phase Mercury Analyzer	Hg (oxidized and elemental)

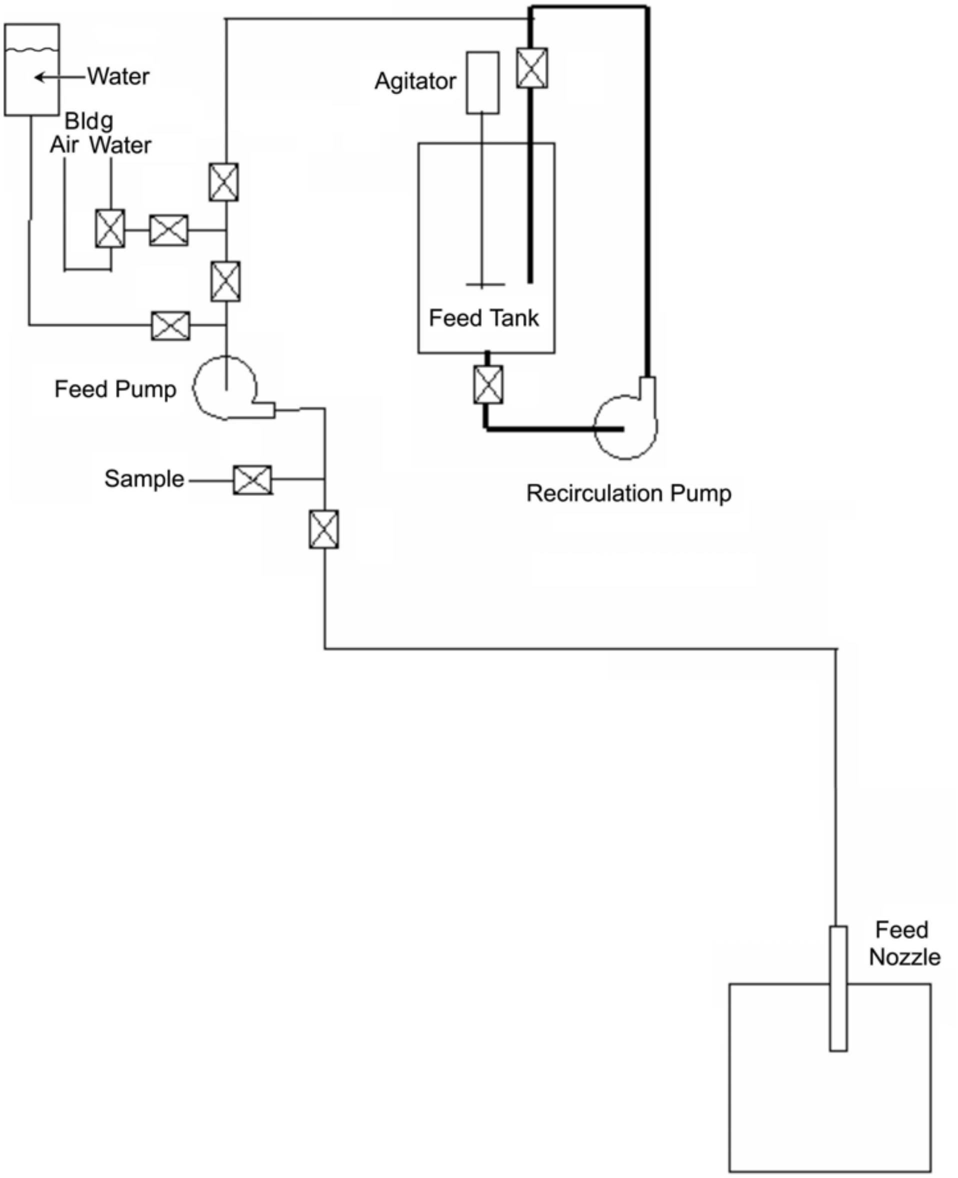

Figure 4.8. Melter-Valve-Station Configuration and Flow Logic

Testing and analysis guidelines used in the performance of this continuous monitoring activity are presented in the July 1, 2002, edition of the U.S. Environmental Protection Agency (EPA) document Title 40, Code of Federal Regulations, Part 60 (40 CFR 60), Appendix A. Details for the instrument-specific methods employed are described below.

Oxygen and Carbon Dioxide: Method 3A was performed to determine the concentrations of oxygen (O_2) and carbon dioxide (CO_2). O_2 was measured using a paramagnetic analyzer. CO_2 was measured using a non-dispersive infrared (NDIR) analyzer. Gas measurements were recorded once every 10 seconds on a continuous basis during each emission test period and were averaged into 1-min readings.

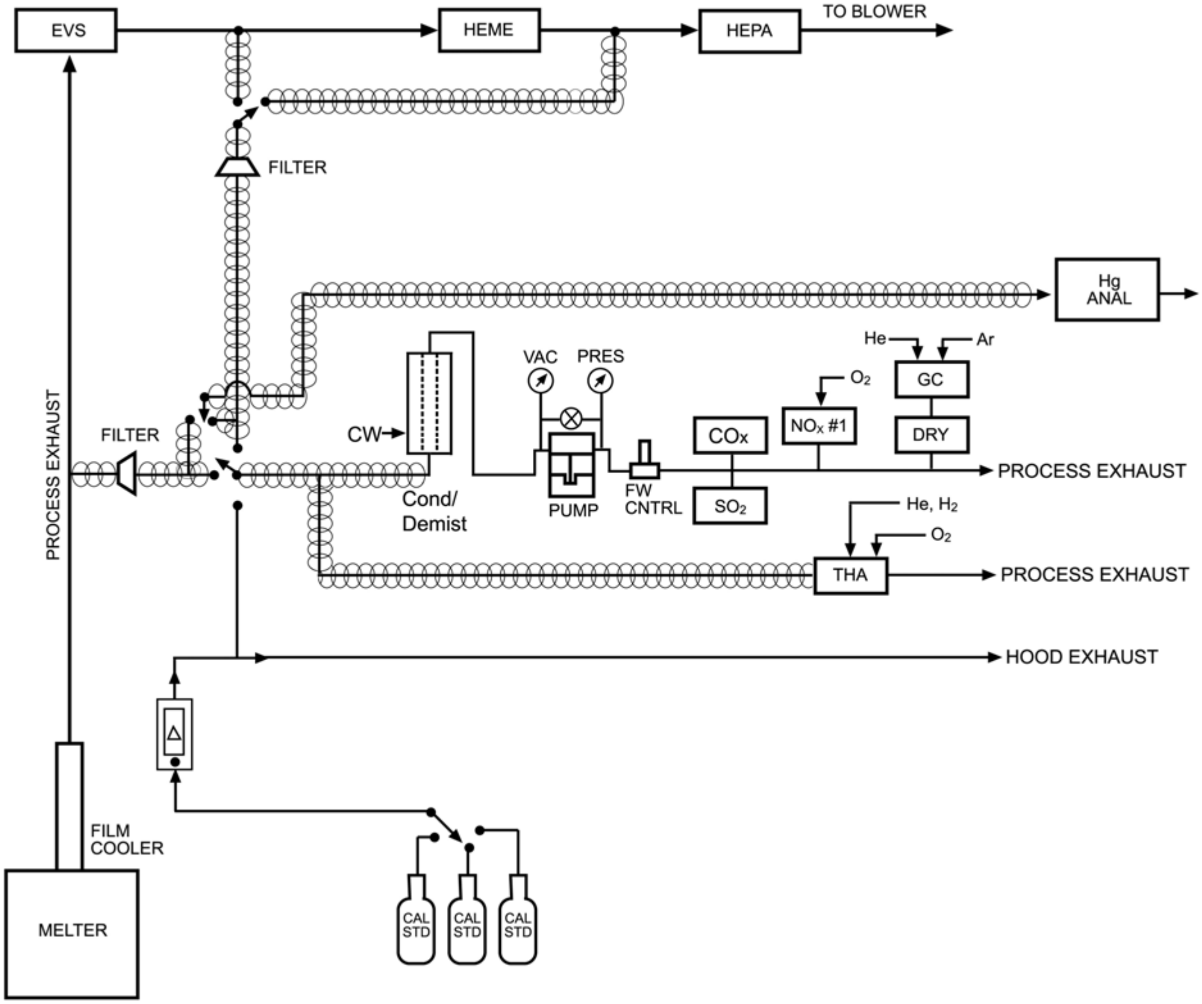

Figure 4.9. Gas-Distribution System Supplying Continuous-Emission Monitors

The instruments were calibrated daily using EPA Protocol One certified gas. A 3-point calibration error check of each analyzer was performed before commencing testing.

Nitrogen Oxides: Method 7E was performed to quantify emissions of speciated nitrogen oxides (NO and NO_2) using a chemiluminescent analyzer. The NO_x concentrations were recorded in dry ppm once per minute using a data-acquisition system. The analyzer was calibration bias and drift checked using EPA Protocol One certified gas daily, and a 3-point calibration error check was performed before commencing testing. The nitrogen dioxide (NO_2) to nitrogen oxide (NO) conversion-efficiency test discussed in Section 5.6 of Method 20 was performed onsite before beginning the test sequence.

Carbon Monoxide: EPA Method 10 was performed to quantify emissions of carbon monoxide (CO) using a gas-filter correlation NDIR analyzer. CO concentrations were recorded in dry parts per million (ppm) at least once per minute using a data-acquisition system, and averaged. EPA Method 10 testing was conducted with the same rigorous bias and drift requirements as found in EPA Method 6C. Before testing, an analyzer calibration error check was performed using zero-, mid-, and high-range EPA Protocol One calibration gases. A system calibration was performed daily.

Total Gaseous Organic Concentration: Method 25A was performed to quantify emissions of volatile organic compounds (VOC) measured as total gaseous organic concentrations, as propane, using a flame ionization analyzer (FIA). For the Method 25A, a heated sample line introduced gas to the FIA analyzer on a hot, wet basis. VOC concentrations were recorded in wet ppm at least once per minute, using a data-acquisition system, and averaged. Before testing, an analyzer calibration error test was performed using zero-, low-, mid-, and high-range EPA Protocol One calibration gases. The analyzer was calibrated daily.

Hydrogen and Helium: A gas chromatograph (GC) was used to quasi-continuously determine the concentration of hydrogen and helium in the off gas. This was accomplished by directly injecting the off gas into an onsite portable GC equipped with a thermal conductivity detector (TCD) and a set of micro columns designed to separate and analyze hydrogen and helium. Results were generated on a quasi-continuous basis at approximate 5-min intervals.

Continuous Mercury Monitoring: The mercury analyzer employed is a PS Analytical Sir Gallahad instrument designed to selectively measure elemental (Hg^o) and total vapor concentrations of mercury (Hg^T). The chemically combined fraction, referred to as oxidized mercury, is derived by difference. This unit operates semi-continuously in 5-min cycles, alternating between the Hg^T and the Hg^o modes. In each cycle, a 1-min-average data point for either Hg^T or Hg^o is determined.

In operation, sample gas is withdrawn continuously through a heated sample line by the CEM's heated vacuum pump. The sample gas is diluted, if appropriate, and split evenly into two streams. One stream is continuously passed through an impinger containing 2 w/v % $SnCl_2$/ 5 w/v % NaOH, where oxidized forms of mercury are reduced to Hg^o. The other stream flows continuously through an impinger containing 5 w/v % NaOH, where oxidized forms of Hg are scrubbed from the gas into the impinger solution.

In the first cycle, the sample gas from the $SnCl_2$/NaOH impinger is passed into a cold-wall condenser to remove water vapor and through a bed of gold-coated sand where the total mercury as Hg^o is sorbed. This is the collection cycle for the Hg^T measurement. The sorbent is then heated and purged with N_2 to release the total Hg into an atomic-fluorescence measurement cell. In this cycle, all chemically combined forms of Hg in the sample gas are reduced to Hg^o in the $SnCl_2$/NaOH impinger and detected and measured along with any elemental mercury that may have been originally present.

In the next cycle, the sample gas from the NaOH impinger is passed through the cold-wall condenser and into the gold-coated sand adsorber. Since the NaOH impinger removes oxidized Hg species from the sample gas, only Hg^o is collected in the gold sorbent. When thermally desorbed into the measurement cell, only Hg^o is detected.

The instrument alternates between measuring total and elemental mercury and displays the data in $\mu g/m^3$ in the form of a trend graph and stores the data in an Excel file. During every 10-min period, the instrument reports a single 1-min-average total Hg value, a single 1-min-average Hg^o value, and total oxidized Hg, determined by the difference between the two other values. The two 1-min-average values are measured 5 minutes apart, so the reported value for oxidized Hg is not a true difference of simultaneous Hg^T and Hg^o values. A diagram of the instrument's flow and measurement system is illustrated in Figure 4.10.

The mercury analyzer is calibrated using a mercury-vapor injection system supplied by the vendor. This system consisted of a vessel containing liquid mercury from which measured volumes of mercury-saturated air at a measured temperature are withdrawn by hypodermic syringe and injected into an N_2 carrier gas by means of a sample port. The analyzer software calculates the mass of mercury injected, which is converted to a mercury concentration by using both the measured carrier-gas flow rate and the time interval used for sampling.

Prior to sampling the melter off-gas, room air was sampled by the mercury analyzer to set sampling flow rates and establish a baseline. A manual data sheet was used for recording sampling flow rates, condenser temperatures, and observations and comments.

4.1.4.2 Manual Off-Gas Sampling and Analysis

Manual off-gas sampling and analysis were performed to provide off-gas emissions data in addition to that obtained from the CEMS. All manual off-gas sampling was performed at the film-cooler outlet location in order to best characterize the melter source using an EPA Method 29 (40 CFR 60, Appendix A) sampling protocol. The actual system used, illustrated in Figure 4.11, did not employ the standard pitot-tube-equipped stack probe. Rather, helium-dilution flow measurements (see below) were used in conjunction with process line and sampling-tube geometrical factors to establish isokinetic sampling flow rates. This off-gas sampling system was composed of an appropriately sized quartz sampling probe, a heated aerosol collection device, a condenser to remove condensable vapors, and a series arrangement of chemical gas scrubbers used to collect reactive non-condensable gases. Photographs of similar sample-train collection and flow-control equipment to that used during the current test are shown in Figure 4.12 and Figure 4.13, respectively. Since all gas scrubbers were usually immersed in an ice-bath container, the first (empty) scrubber vessel also served as the system's condenser.

Since species-specific mercury-vapor scrubbing was of primary interest in this test, the gas-scrubbing components used consisted of two impingers containing a mixture of 10% hydrogen peroxide (H_2O_2) and 5% nitric acid (HNO_3) and an empty impinger followed by two additional impingers containing 4% potassium permanganate ($KMnO_4$) and 10% sulfuric acid (H_2SO_4). In this arrangement, the first two impingers will selectively remove oxidized forms of mercury while the final two impingers are designed to oxidize and trap elemental vapors penetrating the first two non-oxidizing gas scrubbers. Operational

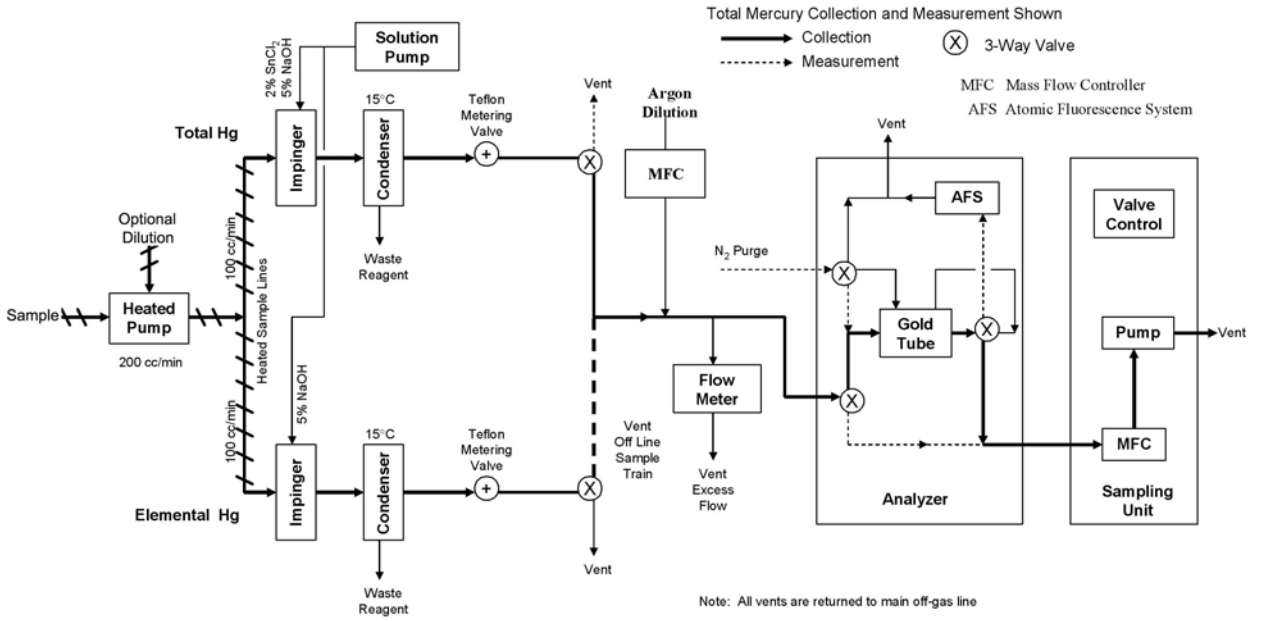

Figure 4.10. Mercury Monitor Flow and Analysis Schematic

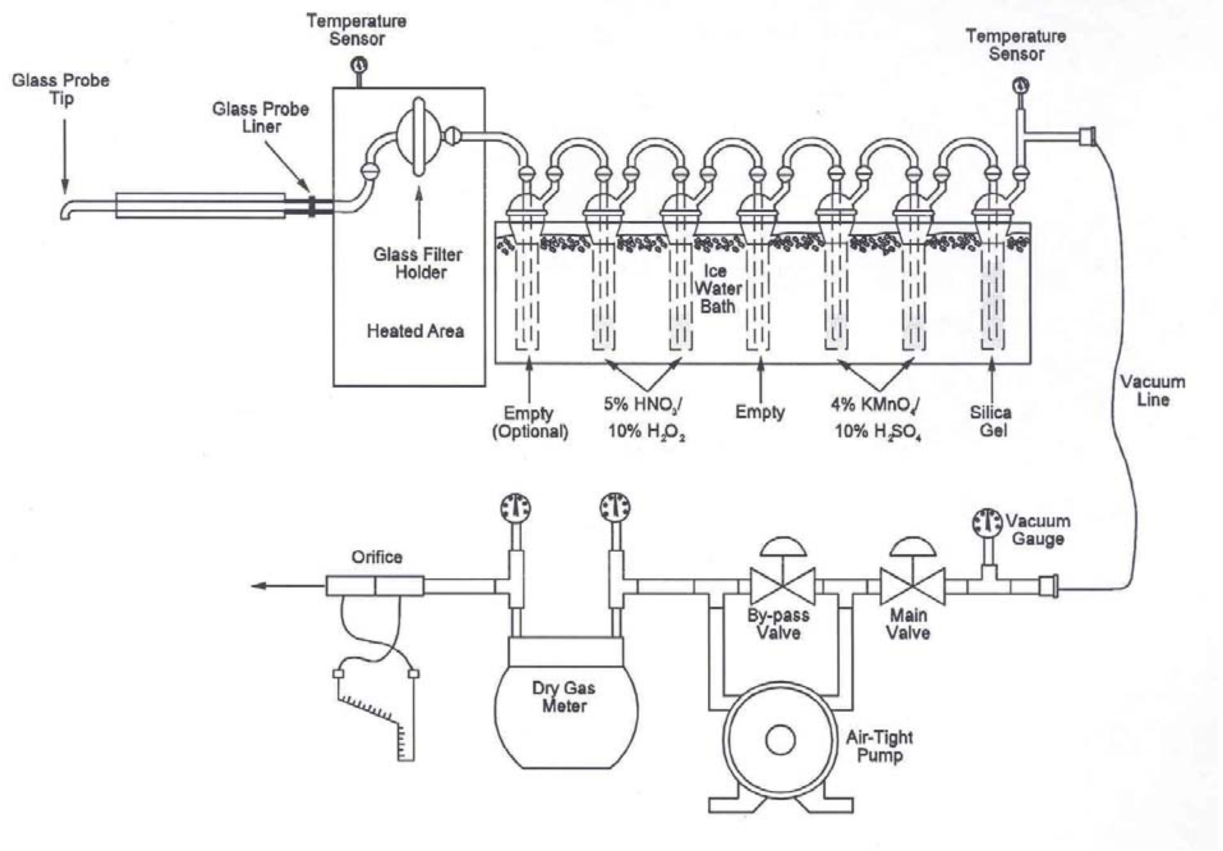

Figure 4.11. EPA Method 29, Total Mercury Sampling Train

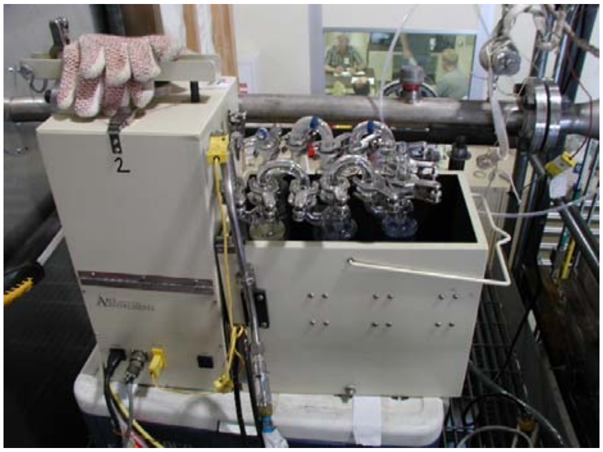

Figure 4.12. Sample Train Collection Module

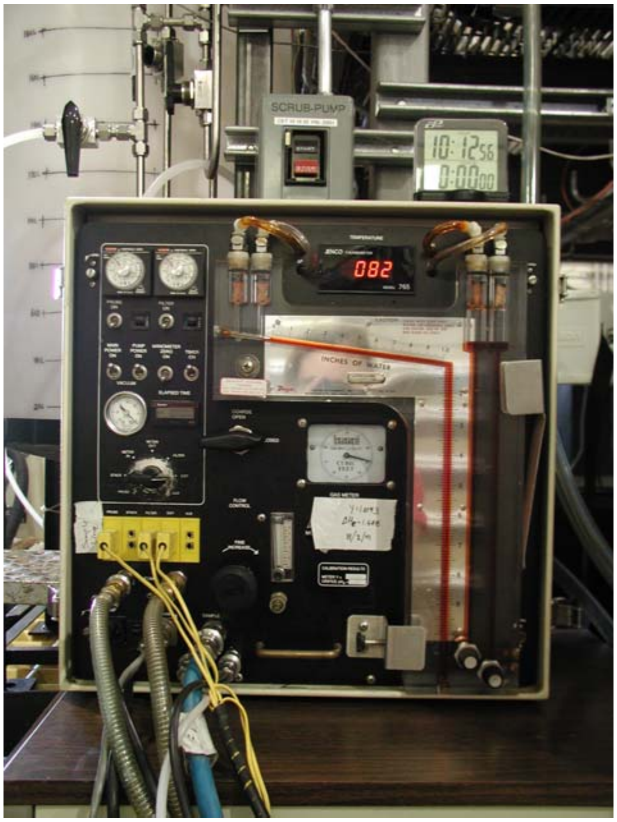

Figure 4.13. Sample-Train Flow-Control Module

conditions allowed an ~120-min Modified Method 29 (40 CFR 60, Appendix A) test to be conducted during four testing segments.

In operation, the Method 29 sampling probe, a straight quartz tube, was inserted coaxially along the centerline of the off-gas pipe into the process off-gas line at an elbow between the film cooler and the EVS (see Figure 4.14). The diameter of the beveled sampling-probe inlet was chosen to allow isokinetic sampling conditions to be achieved with reasonable sampling flow rates. The heated filter assembly employed a quartz-filter media to quantitatively collect particulate matter entrained in the unquenched (225°C), post film-cooler melter exhaust. The filtered gas stream was then subsequently quenched (0°C) and chemically washed to remove reactive gases (e.g., Hg) by a series arrangement of several gas-washing vessels.

To establish isokinetic sampling conditions, the total off-gas flow rate has to be measured. During RSM testing, this was accomplished by injecting a helium tracer into the film-cooler's air-injection stream at a fixed flow rate (1 L/min) and measuring its resultant off-gas concentration with the online gas chromatograph discussed above. The relationship between flow rate (Flw), He injection rate (IR), and resultant He concentration (He_{ppm}) can be expressed as follows: $Flw = IR \times 10^6 / He_{ppm}$. Since GC-derived process flow rates are on a dry basis (see Figure 4.9), average steady-state feeding rates and the water content of the feed had to be used to estimate flow rates on a wet basis. Having calculated a total off-gas flow rate, the fraction of the total flow required to establish isokinetic sampling conditions was determined by the ratio of the geometrical cross-sectional areas of the sampling probe to that of the off-gas line where the sampling was being conducted. These process off-gas (POG) flow-rate data were also of fundamental importance in establishing effluent concentrations and emission rates.

Figure 4.14. Melter Off-Gas Line Sampling Port

4.2 Data-Acquisition and Process-Control System

The RSM is controlled and monitored with a Square D, SY/MAX® 400 Programmable Logic Controller (PLC). Operators interface with the PLC using a PC running FIX DMACS® software on a Microsoft NT platform that is serially linked to the PLC. FIX32 provides user-control inputs as well as history logging of the RSM system-process variables.

This data-acquisition and control system monitors and controls the electrodes, the melter and discharge canister kilns, the heater for the discharge section, and the peristaltic pump for the feed system. Data collected include the voltage and current values for major electrical components, temperature at various locations in the system (e.g., molten glass, plenum space in melter, melter kiln, and off-gas treatment system), pressures in the melter and across all off-gas system components, and the weight of the feed tank. Data are typically archived every minute, but are displayed at more frequent intervals to assist the operators.

4.3 Condensate Evaporator

Under WTP operations, aqueous secondary waste from HLW processing will be transferred to the pretreatment facility where it will be concentrated. Since the species of mercury present in this waste stream may influence the manner in which mercury partitions to HLW, LAW, LERF/ETF, and off-gas streams, quench-scrubber condensate generated during RSM testing was concentrated using a lab-scale evaporator that was integrated with the gas-scrubber components of the Method 29 (40 CFR 60, Appendix A) sampler discussed in the previous section. The design criteria, mode of operation, lab-scale system description, and analytical objectives of this study are discussed below.

4.3.1 Evaporator Design Criteria

The operating parameters to be subsequently discussed were based on information from design specifications and current working-evaporator operations detailed in the following documents:

1. Engineering Specifications for the Forced Circulation Vacuum Evaporator System: DIM No. 24590-PTF-3PI-MEVV-00001, Rev A.[a]
2. Process Data for Waste Feed Evaporator, Feed Vessels, and Feed/Concentration Pumps: Calculation Sheet – Calc No. 24590-PTF-MEC-FEP-00001, Rev B.
3. 242-A Evaporator Documented Safety Analysis, Chapter 2 – Facility Description.[b]

In addition, previous WTP-sponsored small-scale evaporation tests documented in the reports listed below were examined to ensure consistency of the current test with previous studies.

1. Waste Feed Evaporation: Physical Properties and Solubility Determination (U), Savannah River Technology Center, SRT-RPP-2003-00094, Rev 0.[c]
2. AN-107 (C) Simulant Bench-Scale Law Evaporation with Organic Regulatory Analysis, SRT-RPP-2000-00047, Savannah River Technology Center.[d]

(a) Issued by the River Protection Project – Waste Treatment Plant Project, Richland, WA (June 4, 2002).
(b) Waste Management Project, Hanford Site, Rev. 0, Richland, WA (April 10, 2003).
(c) Westinghouse Savannah River Company, Savannah River Site, Aiken, SC (May 13, 2003).
(d) Westinghouse Savannah River Company, Savannah River Site, Aiken, SC.

4.3.2 Normal Evaporator Operation Parameters and Resulting Testing Parameters

The evaporators currently used on the Hanford Site and the ones planned for use with the WTP are continuous, forced-circulation vacuum systems with recycle. In operation, the feed enters a reboiler where the temperature is raised a few degrees and then pumped into the evaporator tank with a fixed liquid level. The evaporator's vacuum-induced vapor stream travels through de-entrainment pads equipped with countercurrent water sprays and then onto the primary condenser.

The primary condenser is a tube in-shell condenser that uses the raw process water as its cooling fluid. The inlet temperature of this fluid can vary from 2 to 24°C based on the time of year. To be conservative, the test condenser emulating the primary condenser was operated at 30°C. The normal temperature of the condensate collection tank is 38°C with a Hi alarm set for 49°C; a 30°C target value was adopted for this laboratory-scale test.

Since the current site evaporators operate best when maintaining approximately a 50% volumetric-waste-reduction target, this value was adopted for this small-scale test. Beyond the concentration factor, there is a range of acceptable evaporator operating conditions that are typified by the 242-A Evaporator conditions summarized in Table 4.3. Apart from temperatures and flow ranges, Hanford Site evaporators maintain feed pH between 7 and 10 and operate at a nominal pressure of 60 torr absolute. However, current WTP pretreatment evaporators are expected to operate at a much higher pH. As a result, duplicate evaporator tests were conducted at two pH conditions: 8.4 and 13.0. Since material and laboratory-scale equipment limitations made it infeasible to operate continuously, a single batch concentration campaign was conducted for each pH condition to satisfy the requirements of this evaluation.

4.3.3 Laboratory-Scale Evaporator Description

The laboratory-scale evaporator schematically illustrated in Figure 4.15 and pictorially depicted in Appendix A was used to concentrate a representative sample of the EVS condensate collected during the RSM testing phase of this BNI-sponsored task. The feed evaporator tank was a 4-L reaction vessel, set up in a heating mantle with an automatic temperature controller with a 49°C setpoint. That is within the normal operational range of the evaporator and representative of the daily operation temperature differential between feed and final condensate.

A standard reflux condenser that returns condensate back into the batch vessel was used to simulate the contact reflux that the de-entrainment pads induce in the vacuum-evaporator units. Its target temperature (47°C to 49°C) was nominally set at 49°C to match the boiler control temperature.

Table 4.3. Typical Range of Temperature and Volume Conditions Seen by the 242-A Evaporator

Stream	Temperature °C (°F)	Flow, L/min (gpm)		Specific Gravity
		Average	Range	
Feed	18 – 49 (65 – 120)	340 (90)	265 – 494 (70 – 130)	1.0 – 1.5
Slurry	18 – 66 (65 – 150)	170 (45)	~115-265 (~30-70)	1.0 – 1.6
Process condensate to LERF[(a)] (boil-off)	27 – 43 (80 – 110)	190 (50)	75 – 230 (20 – 60)	1.0
Raw water (cooling)	2 – 24 (35 – 75)	10,410 (2,750)	na	1.0
(a) LERF – Liquid Effluent Retention Facility				

The primary condenser temperature target was 30°C, ± 5°C, and the actual range achieved during testing was 30°C ± 1°C. A secondary condenser through which the gas stream passed between the collection vessel and the impinger train also was held at this temperature. These two columns successfully condensed the majority of evaporated water into the condensate collection vessel during both tests. The gas stream then entered a Method-29 mercury-vapor wet scrubbing system, which has been previously described in Section 4.1.4.2.

The scrubbed gas then passed though two Drierite water traps, the second of which also had an ~5-cm layer of "Mersorb" to trap any residual mercury vapor remaining before the gas stream passed through the pump and was vented to a hood.

A controlled air purge of approximately 8 to 9 mL/min was introduced into the evaporator vessel to simulate normal air in-leakage. This rate was based on previous Savannah River Technology Center (SRTC) laboratory evaporator design criteria,(a) scaled by the relative evaporator vessel volumes. The in-leakage source consisted of a metered flow of room air.

4.3.4 Analytical Objectives

The laboratory-scale evaporator system described above was designed to allow mercury partitioning to HLW/LAW, LERF/ETF, and vessel-vent off-gas streams to be projected from the mercury content in the various aqueous solutions generated by the batch operation of the previously described evaporator/sampler system. Specifically, analyses of soluble/insoluble mercury in the evaporator bottoms will establish the HLW/LAW distribution, while the mercury in the evaporator condensate will project

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(a) Waste Feed Evaporation: Physical Properties and Solubility Determination (U), Savannah River Technology Center, SRT-RPP-2003-00094, Rev 0. Westinghouse Savannah River Company, Savannah River Site, Aiken, SC (May 13, 2003).

AN-107 (C) Simulant Bench-Scale Law Evaporation with Organic Regulatory Analysis, SRT-RPP-2000-00047, Savannah River Technology Center. Westinghouse Savannah River Company, Savannah River Site, Aiken, SC.

partitioning to the LERF/ETF. The distribution of mercury across the chemical scrubbers, shown in Figure 4.15, will establish species-specific off-gas partitioning of mercury as previously described in Section 4.1.4.2.

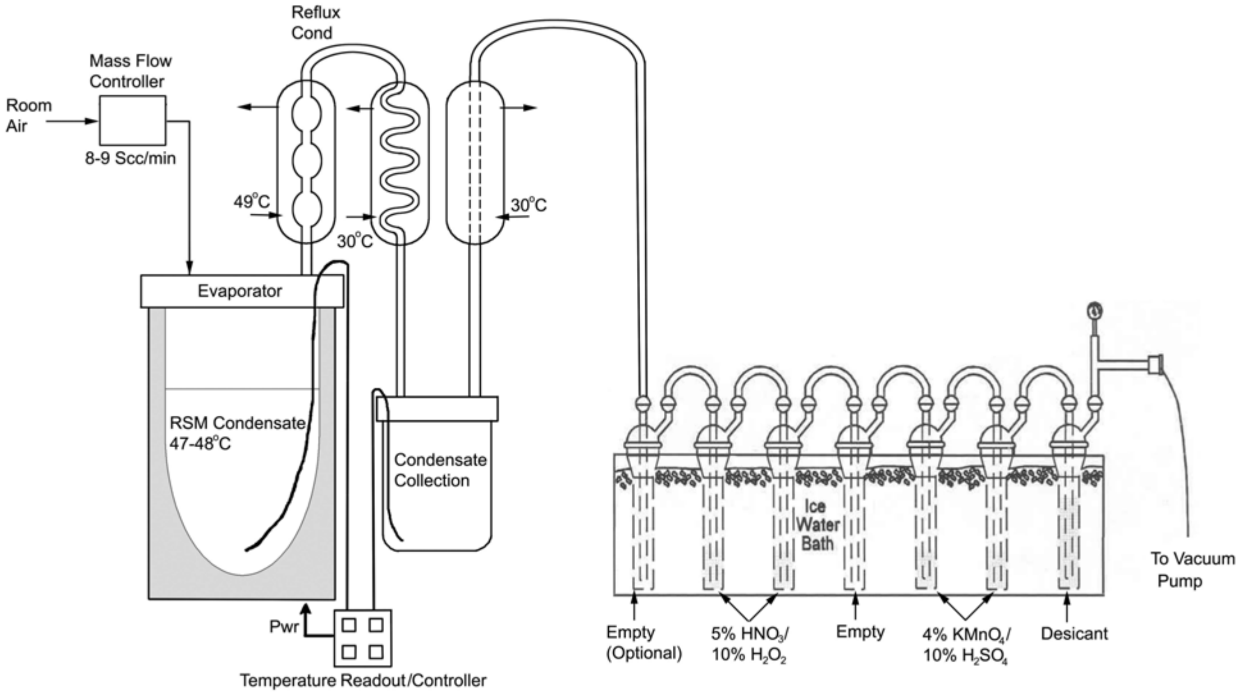


Figure 4.15. Vacuum-Evaporator and Mercury-Vapor Chemical Scrubbers

5.0 C-104/AY-101 Simulant, Melter Feed, and Product Glass

The primary objective of the Liquid Fed Ceramic Melter (LFCM) waste-vitrification process is to immobilize toxic and/or hazardous elements and/or radionuclides in a suitable matrix that will control environmental release rates to safe and acceptable levels. The vitrification technology achieves this by incorporating and thereby immobilizing these hazardous-waste constituents within a high quality, durable glass matrix. To create a vitreous waste product, glass-forming chemicals have to be added to the waste before it can be vitrified (calcined and melted) in a high-temperature melter. However, to meet stringent waste-form durability criteria, an appropriate glass composition has to be formulated, and its chemical properties (multi-valent oxidation states) have to be carefully controlled.

The BNI-supplied baseline melter-feed material used during RSM testing was commercially prepared by mixing C-104/AY-101 waste-simulant chemicals (~30wt%, oxide basis) with appropriate quantities of glass-forming chemicals. Portions of this baseline feed formulation were subsequently spiked with mercuric nitrate, sodium chloride, and/or sugar to create each of the seven discrete processing conditions of the test. The following discussion provides detailed information concerning the constituents of the feed-streams processed.

5.1 C-104/AY-101 Waste Surrogate and Feed Mixture

As mentioned above, the surrogate waste that was processed during the current RSM test is C-104/AY-101. The equivalent oxide feed formulation to be processed is composed of ~30% waste oxides and ~70% glass formers composed of B, Li, Na, Si, and Zn oxides. Table 5.1 summarizes the C-104/AY-101 equivalent waste-oxide composition, the relative proportions of the glass formers used, and the resultant target glass composition to be prepared during melter testing.

Although the equivalent oxide presentation in Table 5.1 provides a clear relationship between waste, glass former, and product glass, the actual feed to be processed is not composed of oxides as Table 5.2 clearly illustrates. As is clear from this table, the feed constituents of interest, Hg, Cl, and sucrose, for the current test are not represented in the baseline feed batch and must be added in the appropriate proportions to establish the various test conditions as will be discussed later in this section. Since chlorine is the only additive that was incorporated into the glass product, and its maximum concentration will not exceed 0.1 wt%, the target glass composition detailed in Table 5.1 will accurately represent the product glass composition throughout all phases of testing.

An as-delivered feed sample was collected and analyzed to validate the composition of the sponsor-supplied feed batch. The results of this analysis, which are summarized in Table 5.3, are compared to the target values previously described in Table 5.1.

Table 5.1. Compositional Summary (oxide basis) of the C-104/AY-101 HLW Simulant, Glass Additives, and the Glass for Melter Tests

Oxide	C-104/AY-101 HLW Simulant	Glass Former (as wt% of Glass)	Melter Glass
Al_2O_3	11.89%	—	3.58%
B_2O_3	0.34%	10.71%	10.81%
CaO	1.60%	—	0.48%
Cr_2O_3	0.21%	—	0.06%
Cs_2O	0.17%		0.05%
CuO	0.10%	—	0.03%
F	0.39%	—	0.12%
Fe_2O_3	31.67%	—	9.54%
I	0.33%	—	0.10%
La_2O_3	0.53%	—	0.15%
Li_2O	0.33%	3.21%	3.31%
MnO	5.04%	—	1.52%
Na_2O	5.26%	9.91%	11.49%
Nd_2O_3	0.36%	—	0.11%
NiO	1.55%	—	0.47%
PbO	0.41%	—	0.12%
P_2O_5	0.14%	—	0.04%
SiO_2	8.24%	43.90%	46.39%
TiO_2	0.07%	—	0.02%
ZnO	0.06%	2.14%	2.16%
ZrO_2	31.30%	—	9.43%
TOTAL	100.0%	69.87%	100.0%

Given that this feed evaluation was only generated to support a go/no-go decision, the results were found to be in reasonably good agreement with target-value expectation. Of the major feed constituents, only Al and Zr exhibited significant variances. As subsequent, more rigorous feed and glass analyses suggest, the high alumina value appears real, while the Table 5.3 Zr value appears to be biased high. It should be noted that the feed alumina aggregate size distribution was larger than normal and, as a result, created feed-nozzle blockages that were extremely difficult to clear during the melter testing. The low concentrations of the halides and other anionic constituents are due primarily to the fact that only soluble species were analyzed. The impurity levels of chloride present appear to be less than that indicated in Table 5.3, as suggested by subsequent feed analyses to be discussed in Section 5.3.

Table 5.2. Composition of Melter Feed to Produce 1 Metric Ton of Target Glass from C-104/AY-101 HLW Simulant (20 wt% suspended solids)

C-104/AY-101 HLW Simulant		Glass-Forming Additives	
Starting Materials	**Target Weight (kg)**	**Starting Materials**	**Target Weight (kg)**
$Al(OH)_3$	57.72		
H_3BO_3	1.86	$Na_2B_4O_7 \cdot 10H_2O$	296.24
$Ca(OH)_2$	6.50		
Cr_2O_3	0.64		
CsOH (50% solution)	1.06		
CuO	0.30		
NaF	2.65		
$Fe(OH)_3$ (13% slurry)	977.65		
NaI	1.19		
$La(OH)_3 \cdot 3H_2O$	2.41		
Li_2CO_3	2.54	Li_2CO_3	81.48
MnO_2	18.81		
NaOH	13.98	Na_2CO_3	88.76
Nd_2O_3	1.09		
$Ni(OH)_2$	6.01		
$FePO_4 \cdot xH_2O$ (80%)	1.08		
PbO	1.24		
SiO_2	25.08	SiO_2	443.45
TiO_2	0.22		
ZnO	0.19	ZnO	21.63
$Zr(OH)_4 \cdot xH_2O$ (50%)	243.75		
$NaNO_2$	1.64		
$NaNO_3$	6.77		
$H_2C_2O_4 \cdot 2H_2O$	2.12		
Water	496.50		
TOTAL	1873.00	TOTAL	931.56
		FEED TOTAL	2804.56

Table 5.3. As Received Simulant Feed Sample Composition

	C-104/AY-101 HLW Simulant					Conc. (mg/g-Fd)		
Oxide	**Anal**	**Nomalized**	**Target**	**%Dev**	**Anion**	**Analysis[(a)]**	**Target**	**%Dev**
Al_2O_3	3.770	4.590	3.580	28.3	Cl^-	0.099	----	----
B_2O_3	8.800	10.700	10.800	-0.8	F^-	0.410	0.461	-11.00
CaO	0.402	0.490	0.480	2.0	I^-	0.230	0.388	-41.00
Cr_2O_3	0.042	0.051	0.060	-16.0	NO_2^-	0.200	0.421	-52.00
Cs_2O	----	----	0.050	----	NO_3^-	1.900	1.900	-0.05
CuO	----	----	0.030	----	$C_2O_4^=$	0.560	0.570	-1.70
Fe_2O_3	8.250	10.100	9.540	5.4	(a) Soluble			
La_2O_3	0.090	0.110	0.150	-27.0				
Li_2O	2.300	2.800	3.310	-15.0				
MnO	1.420	1.730	1.520	13.5				
Na_2O	9.200	11.200	11.500	-2.5				
Nd_2O_3	----	----	0.110	----				
NiO	0.401	0.488	0.470	3.9				
PbO	0.102	0.125	0.120	3.9				
P_2O_5	----	----	0.040	----				
SiO_2	40.500	49.400	46.400	6.4				
SrO	0.003	0.003	----	----				
TiO_2	----	----	0.020	----				
ZnO	1.310	1.590	2.160	-26.0				
ZrO_2	5.480	6.680	9.430	-29.0				
Sum	82.100	100.000	100.000	----				

Beyond chemical composition, the physical properties of the C-104/AY-101 surrogate melter feed were also measured. Specifically, measurements were conducted on the baseline melter feed to establish density as well as solids, oxide, and water loadings. These values are summarized in Table 5.4.

Table 5.4. Physical Properties of Baseline, C-104/AY-101 Surrogate Melter Feed

		Weight Loss (%)		Slurry Feed Loading (g/L)		
Sample	**Sp. Grav.**	**Drying**	**Ignition**	**H_20**	**Solids**	**Oxides**
RSM-Hg-6	1.44	55.3	61.5	797	644	555
RSM-Hg-7	1.45	55.1	61.4	798	650	559
RSM-Hg-8	1.45	55.4	61.7	802	645	555
Average	1.45	55.3	61.5	799	646	556
StDev	0.26%	0.31%	0.23%	0.35%	0.51%	0.44%

5.2 Feed Mixture/Test Condition Description

As mentioned above, the surrogate C-104/AY-101 feed mixture that was processed during the current test is complete and inclusive of all constituents except for mercury, chlorine, and sucrose. To satisfy Test Plan objectives (see Section 2), separate feed batches were prepared to provide the seven different conditions for process-feed compositions previously referred to. The feed additives used and the quantities to be dispensed and processed, assuming maximum expected processing conditions, are summarized in Table 5.5.

Table 5.5. Target Test Condition, Feed Additives, Concentrations, and Processing Expectations

	TstCond		Wt%			g/L @ 0.56 kg-Ox/L			Mass Processed (g)		
Batch#	**Hg:Cl:Red**	**Duration**	**HgO**	**Cl**	**Sugar**	**$Hg(NO_3)_2 \cdot H_2O$**	**NaCl**	**Sugar**	**$Hg(NO_3)_2 \cdot H_2O$**	**NaCl**	**Sugar**
1	Lo:Lo:Lo	18	0.05	0.009	0	0.44	0.083	0	8.8	1.64	0
	Lo:Hi:Lo	18	0.05	0.06	0	0.44	0.550	0	8.8	10.95	0
	Lo:Hi:Hi	6	0.05	0.06	0.90	0.44	0.550	5	2.9	3.65	33
2	Hi:Lo:Lo	18	0.15	0.009	0	1.32	0.083	0	26.3	1.64	0
	Hi:Hi:Lo	18	0.15	0.06	0	1.32	0.550	0	26.3	10.95	0
3	Mx:Hi:Lo	18	0.95	0.06	0	8.37	0.550	0	166.6	10.95	0
	Mx:Hi:Hi	6	0.95	0.06	0.90	8.37	0.550	5	55.54	3.65	33
	Total	102	----	----	----	----	----	----	295	43.4	66

The actual processing conditions executed during RSM testing varied little from the above target values, as the assumed and achieved processing rates were essentially identical. Only processing durations varied somewhat from plan values, as shown in Table 5.6; these plan variations, although inconsequential, were prompted by sampling needs. The feed-preparation sheets used to prepare all melter-feed-tank batches throughout RSM testing are summarized in Appendix B.

5.3 Melter-Feed Characteristics

Melter-feed samples were collected from each feed batch prepared during the C-104/AY-101 melter test. These feed samples were subsequently analyzed to determine their physical properties and chemical composition. Table 5.7 presents the physical properties associated with all the feed batches prepared during RSM testing. Also presented in this table, for comparison purposes, are the pre-test evaluation results previously discussed. The reproducibility is remarkable as two separate laboratory groups evaluated the samples collected before and during the melter test. Furthermore, the consistency of the data validates the adequacy of the tank agitations and delivery systems employed during RSM testing.

Table 5.6. Actual RSM Testing Conditions

Test Condition		Test Period		Duration	Feed
#	Hg/Cl/Red	Start	Stop	(h)	Proc. kg
0	ShakeDwn	07/28/03 09:25	07/28/03 14:58	5.6	11.1
1	Lo/Lo/Lo	07/28/03 16:33	07/29/03 11:22	18.8	28.1
2	Lo/Hi/Lo	07/29/03 11:22	07/30/03 05:47	18.4	26.7
3	Lo/Hi/Hi	07/30/03 05:47	07/30/03 13:26	7.6	10.4
Idle	Transition	07/30/03 13:26	07/30/03 16:16	2.8	----
4	Hi/Lo/Lo	07/30/03 16:16	07/31/03 10:55	18.7	27.3
5	Hi/Hi/Lo	07/31/03 10:55	08/01/03 05:26	18.5	26.1
6	Mx/Hi/Lo	08/01/03 05:26	08/01/03 22:20	16.9	27.0
7	Mx/Hi/Hi	08/01/03 22:20	08/02/03 05:11	6.8	10.9
			Total	114.2	167.6

Table 5.7. Physical Properties of Surrogate C-104/AY-101 Melter Feeds

			Weight Loss (%)		Slurry Feed Loading (g/L)		
Sample	Hg/Cl/Red	Sp. Grav.	Drying	Ignition	H_20	Solids	Oxides
RSM-Hg-6	PreTest	1.44	55.3	61.5	797	644	555
RSM-Hg-7	PreTest	1.45	55.1	61.4	798	650	559
RSM-Hg-8	PreTest	1.45	55.4	61.7	802	645	555
RSM-Hg-13	Lo/Lo/Lo	1.46	56.0	61.8	816	642	556
RSM-Hg-34	Lo/Hi/Lo	1.46	55.4	61.9	809	651	557
RSM-Hg-42	Lo/Hi/Hi	1.45	55.5	61.8	806	645	554
RSM-Hg-51	Hi/Lo/Lo	1.45	55.9	62.0	809	638	549
RSM-Hg-65	Hi/Hi/Lo	1.46	55.9	61.9	813	643	556
RSM-Hg-80	Mx/Hi/Lo	1.45	55.7	62.0	805	641	549
RSM-Hg-87B	Mx/Hi/Hi	1.44	55.1	61.8	796	649	552
	Average	1.45	55.5	61.8	805	645	554
	StDev	0.44%	0.57%	0.34%	0.85%	0.65%	0.58%

The feed's total-oxide values derived from laboratory loss-on-drying (LOD, at 110°C) and loss-on-ignition (LOI of wet waste at 1050°C) tests are found to satisfactorily agree with the feed-formulation expectations of 550 g-Ox/L-Fd (JM Perez, private communication). The total average oxide loading of the feed calculated from all the feed processed and the glass produced throughout the duration of RSM testing, 505 g-oxide/L, also agrees reasonably well with the values derived from LOI measurements, given that significant bubbler-aggravated feed losses to the melter's walls and plenum could not be accounted for, as will be described later.

The oxide-equivalent compositions of cationic species for each of the unique feed batches prepared during RSM testing are summarized in Table 5.8 and compared to target baseline values based upon the previously defined waste- and glass-composition values. All of the major feed-component concentrations were reasonably consistent throughout the nominal 5 days of testing. With the exception of alumina, which appears to be biased high, and the Ba, K, and Sr chemical impurities, there were no trends or large variations of importance, and most components, except for P and Ti, were reasonably close to their target values. The large variances observed for P and Ti feed constituents may be due to analytical-detection-limit difficulties associated with these elements.

An analysis of soluble anionic species in the feed was also carried out for completeness, and the results obtained are summarized in Table 5.9. The most important of these anions are chloride and nitrate as these are constituents of the feed additives used, i.e., NaCl and $Hg(NO_3)_2{\cdot}H_2O$. The as-found concentrations of these anions are found to be reasonably close to target values when the feed additives used are taken into account. The slightly elevated chloride levels present under low-chlorine processing campaigns is most likely due to contributions from chemical impurities that are clearly responsible for the presence of sulfate. The feed nitrite content is shown to be consistently below expectation, as is the concentration of iodide, whose solubility properties may be responsible for the lower-than-expected condition. On the other hand, the soluble fluoride present is reasonably close to the target value as is the reductant oxalate. Being a test-matrix variable, the nitrate agreement in Table 5.9 circumstantially validates the appropriateness of the $Hg(NO_3)_2{\cdot}H_2O$ additions made throughout the test.

Apart from the problems associated with identifiable analytical biases, the contaminants and trace constituents just discussed, the overall melter-feed composition data agree quite well with feed-formulation expectation values. In general, it appears there was good control over feed composition throughout the entire test period, which will be corroborated when the glass data are subsequently discussed.

5.4 Product Glass Characteristics

Glass grab samples were collected from RSM pours throughout the C-104/AY-101 test period. When operated without glass-pool-bubbler agitation, melter glass discharges nominally occur every 2 hours, whenever the glass-pool head pressure overcomes the flow resistance presented by the slightly cooler overflow channel. However, the effect of bubbler-glass-pool agitation was to create quasi-continuous overflow conditions with very low glass flows. Nevertheless, sufficient glass was collected during each phase of testing to allow required analyses to be conducted. The Fe^{+2}:Fe^{Tot} ratio measurements were conducted to assess the impact of changing feed-reductant levels upon the oxidation state of the glass product. In addition, representative glass samples collected from each of the distinct feeds were compositionally analyzed, and some of these were subjected to the toxicity characteristic leach procedure (TCLP). The results of these measurements will now be discussed.

Table 5.8. Melter-Feed-Batch Composition

	Feed Sample Weight Percent Composition									
Oxide	**RSM-13**	**RSM-34**	**RSM-42**	**RSM–51**	**RSM–65**	**RSM-80**	**RSM-87B**	**Average**	**Target**	**%Dev**
Al_2O_3	4.350	4.290	4.340	4.280	4.500	4.370	4.460	4.370	3.580	22.100
B_2O_3	10.200	11.000	10.600	10.500	10.300	11.200	10.500	10.600	10.800	-1.900
BaO	0.013	0.014	0.014	0.015	0.014	0.015	0.017	0.015	----	----
CaO	0.514	0.462	0.445	0.451	0.458	0.404	0.461	0.456	0.480	-4.900
Cr_2O_3	0.069	0.061	0.068	0.064	0.065	0.067	0.059	0.065	0.060	8.140
Cs_2O	0.036	0.035	0.032	0.030	0.035	0.034	0.033	0.034	0.050	-33.000
CuO	0.076	0.030	0.037	0.035	0.049	0.032	0.024	0.040	0.030	34.400
Fe_2O_3	9.240	9.150	9.290	9.100	9.270	9.230	9.240	9.220	9.540	-3.400
HgO	0.052	0.053	0.043	0.160	0.109	1.020	0.895	0.334	----	----
K_2O	----	0.235	0.292	0.266	0.208	----	----	0.250	----	----
La_2O_3	0.121	0.103	0.119	0.119	0.116	0.132	0.126	0.119	0.150	-20.000
Li_2O	3.050	3.470	4.160	3.540	4.690	3.710	3.180	3.690	3.310	11.300
MnO	1.680	1.650	1.710	1.650	1.640	1.600	1.620	1.650	1.520	8.590
Na_2O	11.600	12.700	12.000	11.700	11.300	11.400	11.300	11.700	11.500	1.870
NiO	0.466	0.466	0.471	0.467	0.473	0.471	0.459	0.468	0.470	-0.510
P_2O_5	0.177	0.216	0.206	0.203	0.215	0.253	0.249	0.217	0.040	443.000
PbO	0.122	0.120	0.125	0.119	0.118	0.120	0.120	0.120	0.120	0.404
SiO_2	46.200	44.600	44.400	44.700	44.800	44.400	45.300	44.900	46.400	-3.200
SrO	0.007	0.005	0.023	0.007	0.005	0.006	0.004	0.008	----	----
TiO_2	0.110	0.109	0.113	0.113	0.116	0.107	0.117	0.112	0.020	461.000
ZnO	1.440	1.420	1.450	1.420	1.440	1.440	1.430	1.440	2.160	-34.000
ZrO_2	10.500	9.820	10.100	11.000	10.100	9.960	10.500	10.300	9.430	9.000
Sum	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	0.020

5.4.1 Oxidation State Results

As previously discussed (see Section 5.2), the feed sucrose concentration was an experimental parameter during RSM testing. Reductant additives can sometimes be beneficial in optimizing feed-processing rates and in nitrate destruction (NO_x abatement). The major concern regarding the use of reductant is producing an overly reduced glass that can affect glass durability and accelerate insoluble metal production, settling rates, and resultant melter electrode shorting. Based upon previous melter testing of a similar C-106/AY-102 waste simulant, a sugar loading (5g/L-Fd) was chosen to produce a measurable change in the fraction of iron in its +II oxidation state but without producing an overly reduced glass (Fe^{+2}:Fe^{tot} >0.3). The post-test analysis of glass samples collected during the test has been subsequently examined to determine the effects of this incremental change in feed reductant upon the glass-oxidation state.

Table 5.9. Soluble Anionic Feed Species

		Concentration (mg/g)								
Sample ID	**Hg/Cl/Red**	**Cl^{-1}**	**NO_2^{-1}**	**Br^{-1}**	**NO_3^{-1}**	**PO_4^{-3}**	**SO_4^{-2}**	**$C_2O_4^{-2}$**	**I^{-1}**	**F^{-1}**
RSM-Hg-13	Lo/Lo/Lo	0.049	0.237	< 0.012	1.97	< 0.1	0.110	0.496	< 0.1	0.372
RSM-Hg-34	Lo/Hi/Lo	0.182	0.244	< 0.016	2.03	< 0.1	0.115	0.507	0.150	0.389
RSM-Hg-42	Lo/Hi/Hi	0.172	0.246	< 0.015	2.03	< 0.1	0.110	0.504	< 0.1	0.373
RSM-Hg-51	Hi/Lo/Lo	0.053	0.238	< 0.014	2.16	< 0.1	0.107	0.494	< 0.1	0.371
RSM-Hg-65	Hi/Hi/Lo	0.210	0.256	< 0.011	2.38	< 0.1	0.115	0.576	< 0.1	0.385
RSM-Hg-80	Mx/Hi/Lo	0.211	0.261	< 0.010	3.68	< 0.1	0.110	0.589	< 0.1	0.352
RSM-Hg-87B	Mx/Hi/Hi	0.229	0.279	< 0.013	3.76	< 0.1	0.121	0.612	< 0.1	0.354
	Average		0.251	----		----	0.113	0.540	----	0.371
	Target		0.421	----		----	----	0.570	0.388	0.461
	Lo	0.035			2.010					
	Hi	0.231			2.230					
	Mx				4.000					

To accomplish this, a chemical method for measuring an Fe(II) complex colorimetrically at a wavelength of 515 ηm was used to establish the vitreous iron fraction in the +II valance state. This is accomplished by dissolving a powdered-glass sample in H_2SO_4 and HF, buffering the resultant solution with sodium acetate/boric acid solution containing an o-phenanthroline complexing agent, and conducting an Fe(II)-specific absorbance measurement at 515 ηm. Ascorbic acid is subsequently used to reduce all remaining iron in the dissolved sample to the Fe(II) state, which allows the total Fe to be measured by a subsequent absorption measurement. These results allow the fraction of iron in the +II valence state in the glass sample to be directly determined.

The oxidation-state results obtained from glass samples obtained during current RSM testing are summarized in Table 5.10 along with the corresponding sugar-loading values used. These data show that the oxalate present in the baseline feed was sufficient to measurably affect the multi-valent distribution of iron in the glass. At first glance, it appears that inconsistent results were obtained when adding sugar to the melter feed. However, grab-glass samples from the melter's overflow were not available during the Mx/Hi/Hi processing campaign. As a result, a post-test glass sample had to be collected from the surface of the glass-collection canister. Since this canister is contained in a clam-shell furnace controlled at an 800°C temperature, partial reoxidation of the collected glass resulted. Since duplicate redox determinations demonstrated relative standard errors of the order of 3%, and the two glasses produced with no sugar additive demonstrated good reproducibility, it is fairly safe to conclude that sugar, at a 5 g/L-Fd loading, produced a measurable (~3.5×) change in the oxidation state of the glass produced and that this change was within acceptable limits, i.e., $Fe^{+2}:Fe^{Tot} \leq 30\%$.

Table 5.10. C-104/AY-101 Sugar Loadings and Glass-Oxidation States

Sample	Hg/Cl/Red	Fe^{+2}:Fe^{Tot} (%)	Sugar (g/L-Fd)
RSM-Hg-38	Lo/Hi/Lo	1.49	0
RSM-Hg-43	Lo/Hi/Hi	5.46	5
RSM-Hg-58	Hi/Lo/Lo	1.60	0
RSM-Hg-90	Mx/Hi/Hi	1.95	5

5.4.2 Compositional Data

Glass-product compositional data associated with samples taken throughout all phases of melter processing are summarized in Table 5.11 along with the corresponding target value for the baseline C-104/AY-101 surrogate feed. Apart from the contaminant (e.g., Ba, Sr, S) and detection limit-driven variances that have been previously discussed (Section 5.3), all major oxide constituents compared favorably with their respective target values. However, like the feed data discussed earlier, the glass-compositional data also indicate a higher-than-expected alumina concentration. Although mercury was detected in essentially all C-104/AY-101 glasses produced, it was found to be present at vanishingly low concentrations.

Overall, the target/actual composition comparison for the glass samples analyzed mirror corresponding results obtained from feed data previously discussed. Based on a simple comparison of product-glass analytical and target-glass compositions, the classic volatiles/semi-volatiles feed components (e.g., B, alkalis) do not appear to have partitioned significantly to the process exhaust. Partitioning values or melter DFs will be discussed in a later section dealing with off-gas emission characterization.

5.4.3 TCLP Results

Representative glass samples generated under worst-case testing conditions (Mx/Hi/Lo and Mx/Hi/Hi) were subjected to EPA’s TCLP test (TCLP 1992). In that procedure, crushed glass is leached with a sodium acetate buffer solution for 18 hours at 22°C while under constant, end-over-end agitation. The leachate compositions were subsequently analyzed, and the results obtained are summarized in Table 5.12.

The concentrations of all hazardous analytes, except for Ba and Cr (for which estimates are provided), were found to be below their instrumental detection limits, and all were below their respective Universal Treatment Standard (UTS) limits. In the case of Ba and Cr, the estimates provided are at least an order of magnitude below their corresponding UTS limits. The extremely low mercury concentrations found in the glass clearly present no adverse leaching problems that would preclude the glass vitrification product from conforming with all existing Resource Conservation and Recovery Act (RCRA) land-disposal limits (40 CFR 268).

Table 5.11. Oxide-Composition of Melter C-104/AY-101 Glass Samples

	Normalized Glass Oxide Composition (Wt%)									
Oxide	**RSM-23**	**RSM-38**	**RSM-43**	**RSM-58**	**RSM-73**	**RSM-85B**	**RSM-90**	**Average**	**Target**	**% Dev.**
Al_2O_3	4.790	4.760	4.850	4.680	4.680	4.710	4.710	4.740	3.580	32.300
B_2O_3	10.100	10.500	10.800	10.300	10.400	10.500	10.500	10.400	10.800	-3.400
BaO	0.016	0.015	0.014	0.013	0.013	0.014	0.014	0.014	----	----
CaO	0.555	0.551	0.600	0.598	0.549	0.562	0.562	0.568	0.480	18.400
Cr_2O_3	0.167	0.102	0.103	0.086	0.092	0.086	0.086	0.103	0.060	71.800
Cs_2O	0.035	0.032	0.033	0.032	0.032	0.035	0.035	0.033	0.050	-33.000
CuO	----	----	0.043	0.028	0.020	0.034	0.034	0.032	0.030	5.850
Fe_2O_3	9.430	9.400	9.690	9.370	9.390	9.460	9.460	9.460	9.540	-0.880
HgO	1.90E-06	----	----	1.41E-06	1.49E-06	4.84E-06	4.91E-06	5.08E-06	----	----
La_2O_3	----	----	0.123	0.122	0.115	0.119	0.119	0.120	0.150	-20.000
Li_2O	3.020	3.060	3.350	3.340	3.090	3.160	3.160	3.170	3.310	-4.300
MnO	1.850	1.760	0.180	1.730	1.720	1.740	1.740	1.530	1.520	0.643
Na_2O	10.800	10.600	11.800	11.400	10.800	10.900	10.900	11.000	11.500	-4.000
Nd_2O_3	----	----	----	----	----	----	----	----	0.110	----
NiO	0.523	0.529	0.509	0.482	0.525	0.523	0.523	0.516	0.470	9.850
P_2O_5	----	----	0.243	0.218	0.246	0.279	0.279	0.253	0.040	533.000
PbO	----	----	0.129	0.127	0.132	0.129	0.129	0.129	0.120	7.680
SO_3	----	----	----	----	0.222	----	----	0.222	----	----
SiO_2	47.400	47.400	45.000	45.300	46.600	46.100	46.100	46.300	46.400	-0.290
SrO	0.128	0.043	0.055	0.042	0.025	0.022	0.022	0.048	----	----
TiO_2	0.118	0.133	0.131	0.127	0.124	0.128	0.128	0.127	0.020	535.000
ZnO	1.400	1.440	1.480	1.440	1.450	1.470	1.470	1.450	2.160	-33.000
ZrO_2	9.750	9.730	10.900	10.600	9.810	10.000	10.000	10.100	9.430	7.140
Sum	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	----	----

Table 5.12. TCLP Leachate Concentrations from C-104/AY-101 Glasses

	Leachate Concentration (mg/L): Estimate/Detection-Limit$^{(a)}$								Sugar
Item	**Ag**	**As**	**Ba**	**Cd**	**Cr**	**Hg**	**Pb**	**Se**	**(g/L-Fd)**
UTS Limit	0.14	5	21	0.11	0.60	0.025	0.75	5.7	N/A
Detect Limit	0.015	0.092	0.0023	0.0050	0.0050	0.00050	0.092	0.086	N/A
RSM-Hg-101	ND	ND	0.24	ND	0.038	ND	ND	ND	0
RSM-Hg-102	ND	ND	0.30	ND	0.022	ND	ND	ND	5

(a) ND = not detected; N/A = not applicable

6.0 Process Characterization

RSM evaluation of the simulated, mercury-containing C-104/AY-101 flowsheet was initiated on July 28, 2003, and concluded on August 2, 2003. During this ~120-h period, C-104/AY-101 melter feeds containing varying concentrations of mercury, chlorine, and reductant, but, at a fixed 30-wt% waste loading, were successfully processed. The observations and experimental test results derived from all phases of C-104/AY-101 melter testing will now be discussed. For the interested reader, low resolution, hourly data logs of the most important melter and off-gas process parameters are reproduced in Appendix B.

6.1 Processing Observations and Parameters

The melting characteristics of the C-104/AY-101 feed formulation under study were found to be independent of the range of mercury, chlorine, and sugar concentrations used during melter testing. Bubblers were employed throughout all phases of testing, and glass-pool characteristics remained invariant independent of feed-spike loading. When operated without bubblers, reductant additives are often required to control the oxidation states of multivalent glass constituents to preclude melter-glass foaming that can adversely affect processing rates. Although the feed oxalate concentration was sufficiently high to preclude foaming (see Section 5.4.1), no changes in cold-cap characteristics or processing behavior were observed when the sugar additive was used.

Beyond the influence of sugar upon the glass oxidation state (see Section 5.4.1), the sugar additive was also found to produce noticeable changes in the melter's NO_x source term. In both processing campaigns involving sugar, significant quantities of the nitrate present in the waste appeared to be efficiently reduced to N_2. During all processing campaigns containing no sugar additive, NO dominated the melter's nitrogen oxide emission source term. However, whenever sugar was present in the melter feed, off-gas concentrations of NO were significantly reduced. This subject will be discussed in greater detail in Section 7.1.

The processing characteristics documented for all feed batches prepared during RSM testing are summarized in Figure 6.1. Because of the manner in which the melter test conditions were staged (see Section 2), essentially all feed-batch changes were conducted without interrupting melter processing. The only exception to this statement occurred during the transition between processing conditions 3 and 4 (see Section 2) when a high reductant loading condition was being replaced with a low one. Since the high condition required sugar addition and the low condition contained no sugar, the melter's feed tank had to be emptied before the new batch could be prepared. Consequently, the feed-processing history is composed of two quasi-continuous curves with amazingly similar slopes. Figure 6.2 and Figure 6.3 summarize the processing characteristic during each of the two feeding campaigns.

The average feed-processing rates displayed in the latter two figures represent both active feed-processing periods and non-feeding time intervals, and as such are conservative estimates. The fact that noticeable gaps are not apparent in these processing-campaign curves indicate that down times associated primarily with feed-nozzle blockages were not very significant, although the large alumina aggregate responsible for these feed-nozzle blockages were extremely difficult to clear.

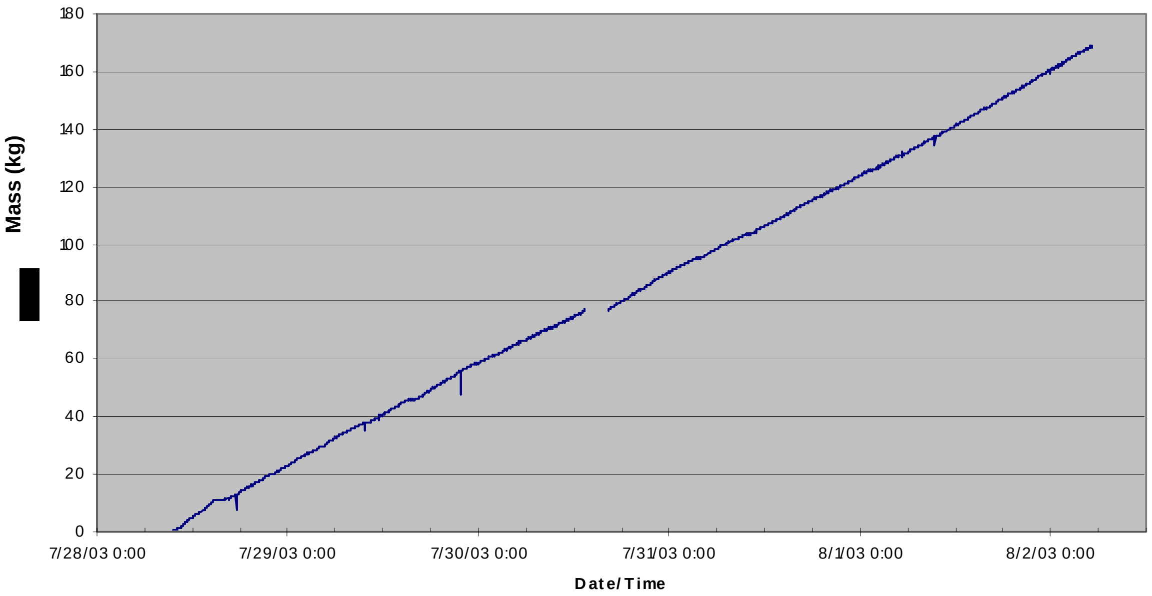


Figure 6.1. Process History of RSM Feed Batches and Average Overall Processing Rate

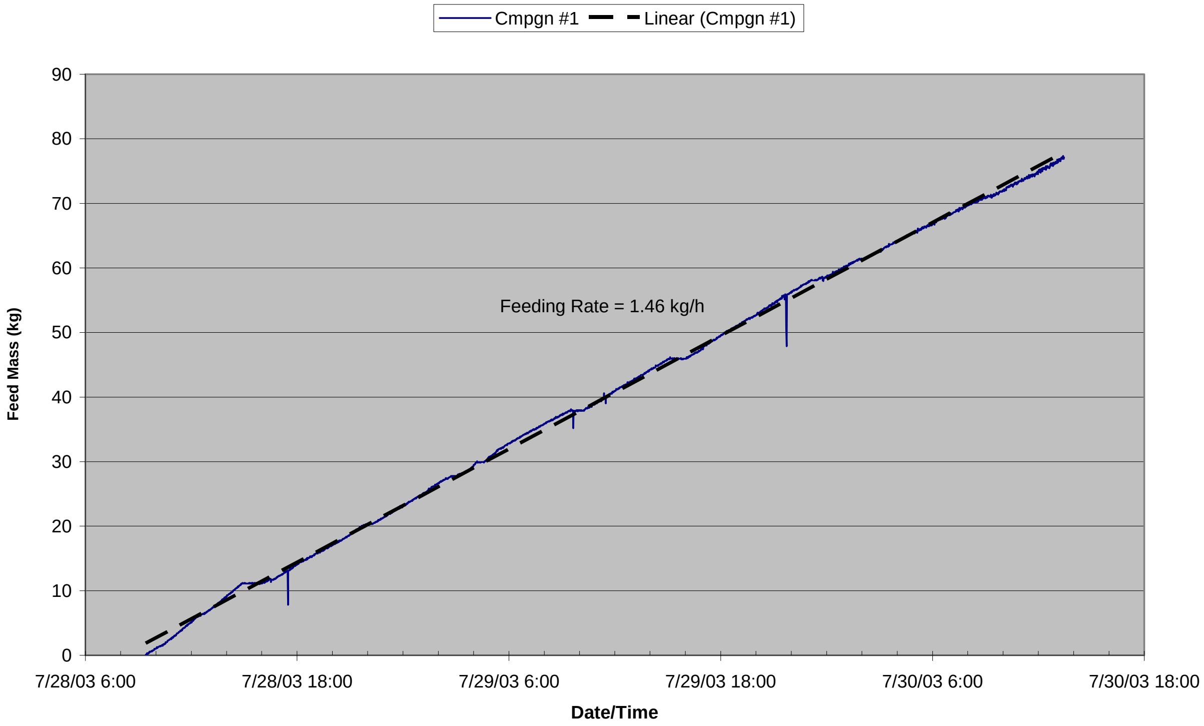


Figure 6.2. Processing History of the First Quasi-Continuous Processing Campaign

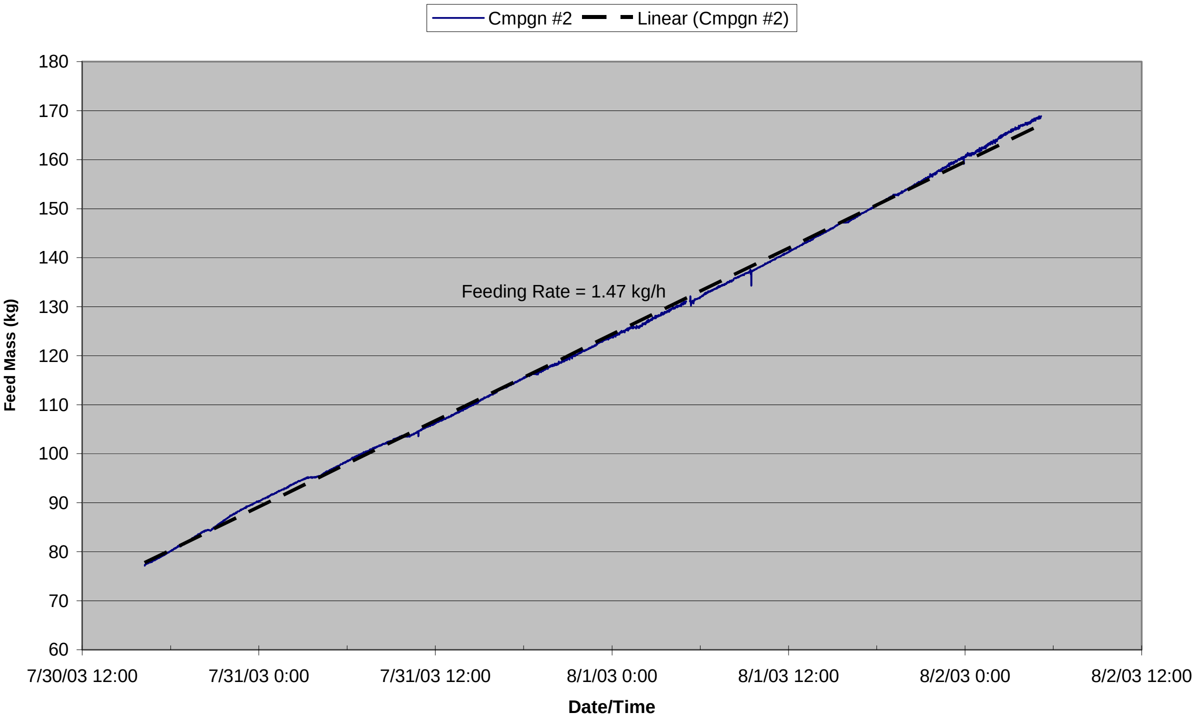


Figure 6.3. Processing History of the Second Quasi-Continuous Processing Campaign

As is apparent from Figure 6.2 and Figure 6.3, individual batch-processing rates varied somewhat from the composite average curve. Table 6.1 summarizes the processing rates and derived glass-production rates for all individual test conditions evaluated during RSM testing. The relationship between feed-processing and glass-production rates used in this table was derived from empirical feed-property data discussed in Table 5.7.

Referring to the Table 6.1 data, the highest processing rate achieved was when the melter-system operations were being aligned. In fact, this rate represents an over-feeding condition that ultimately produced a complete cold-cap-coverage condition when the feed pile surrounding the bubbler vents collapsed. Although, at first glance, Test Condition #3 results appear to suggest that processing the C-104/AY-101 feed formulation with a sugar additive is not advantageous; this conclusion is not, however, substantiated by Condition #7 results.

Also included in Table 6.1 are specific glass-production rates derived from the experimentally determined total oxide loading of the feed (see Section 5.3), the glass pool surface area (6-in. dia), and the corresponding melter feeding rates. These calculated values comfortably exceed the minimum acceptable rate of 0.4 MT/h/m^2 and closely approach the maximum expectation value (0.8 MT/h/m^2). The derived overall average-production-rate value, however, does not agree completely with the actual glass-accumulation information (0.54 vs 0.49 kg/h) that was derived from manually recorded data throughout the duration of the test. These glass-accumulation data are summarized in Figure 6.4 and in Table 6.2.

Table 6.1. C-104/AY-101 Feed Processing Rates and Derived Glass-Production Rates

Test Condition		Test Period		Duration	Feed		Glass[a]		
#	Hg/Cl/Red	Start	Stop	(h)	kg	kg/h[b]	kg	kg/h[b]	$MT/d/m^2$[b]
0	ShakeDwn	07/28/03 09:25	07/28/03 14:58	5.6	11.1	2.00	4.28	0.77	1.01
1	Lo/Lo/Lo	07/28/03 16:33	07/29/03 11:22	18.8	28.1	1.49	10.8	0.58	0.76
2	Lo/Hi/Lo	07/29/03 11:22	07/30/03 05:47	18.4	26.7	1.45	10.3	0.56	0.73
3	Lo/Hi/Hi	07/30/03 05:47	07/30/03 13:26	7.6	10.4	1.36	4.02	0.52	0.69
Idle	Transition	07/30/03 13:26	07/30/03 16:16	2.8	----	----	----	----	----
4	Hi/Lo/Lo	07/30/03 16:16	07/31/03 10:55	18.7	27.3	1.47	10.5	0.56	0.74
5	Hi/Hi/Lo	07/31/03 10:55	08/01/03 05:26	18.5	26.1	1.41	10.0	0.54	0.71
6	Mx/Hi/Lo	08/01/03 05:26	08/01/03 22:20	16.9	27.0	1.60	10.4	0.61	0.81
7	Mx/Hi/Hi	08/01/03 22:20	08/02/03 05:11	6.8	10.9	1.59	4.19	0.61	0.80
			Total/Average	114.2	168	1.48	64.5	0.57	0.75
			Sample/OG Corrections		160	1.40	61.5	0.54	0.71

(a) Calculated value.
(b) Average excludes Cond# 0.

Although the tabular and graphically derived average glass rates are nominally equivalent, the variability in test-segments glass rates appears to be due to the highly discrete nature of the manually collected data, as interpolation between recorded values was not conducted. Since data recording is not synchronized to process events, maximum glass-canister weights are generally not recorded, as it would require an unlikely coincidence of events. As a result, the total glass estimate derived from these data is lower than the value established from post-test measurements (54.6 vs 55.7 kg).

The larger glass-production estimate derived from feed-processing data (61.5 vs 55.7 kg) is believed to be predominantly due to unaccounted-for feed material encrusting the inside surfaces of the melter's plenum. The cold-cap turbulence created by the melter's bubblers in conjunction with low plenum temperatures (~400°C) created ideal conditions to accumulate unfused plenum deposits. However, there was no reasonable way to measure this internal residue at the conclusion of testing.

Although the ~10% difference between feed projections and glass could also have resulted from variations of the oxide loading of the batched baseline feed, no dilution of the master or melter-feed tank contents occurred during melter testing, and all batch-feed transfers were extracted from a tank bottom-to-top recirculation loop. Since measurements of the physical properties of feed-batch were, as described in Section 5.3, remarkably consistent; unaccounted for feed losses must be responsible for the variance between projected and measured glass results.

6.2 Operating Parameters

The primary functional indicators of the RSM processing system are temperatures (glass melt, melter plenum space, and post-film cooler off-gas stream), pressure (plenum, off-gas), and melter electrical values (electrode current and voltage). The process data relating to these operating parameters will now be discussed.

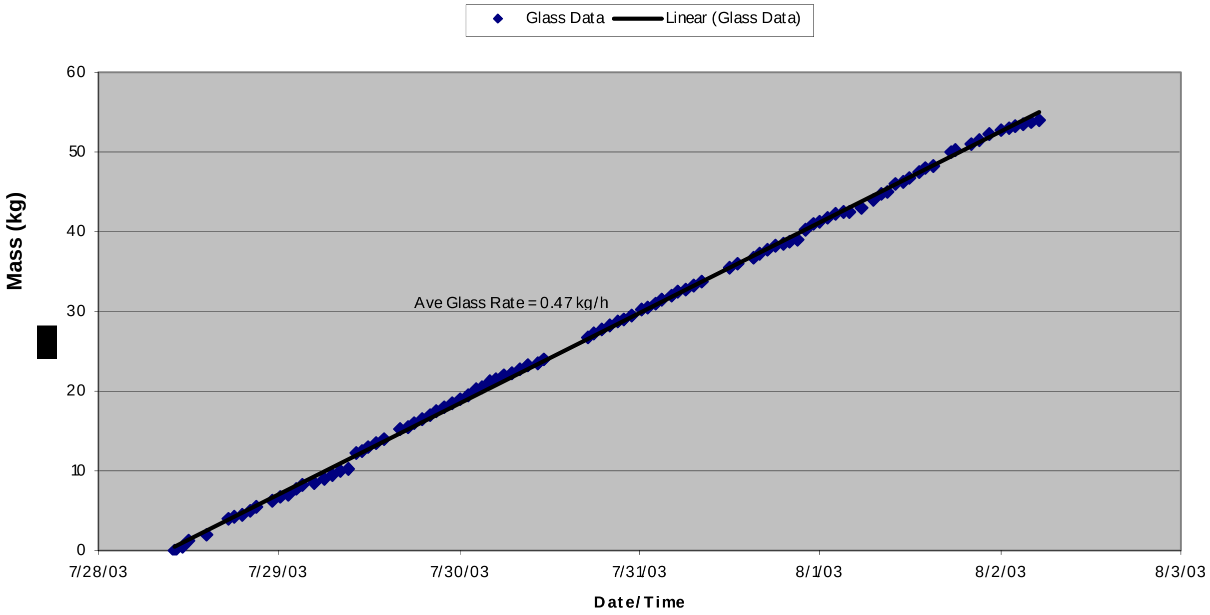


Figure 6.4. C-104/AY-101 Glass-Accumulation Data

Table 6.2. Experimental C-104/AY-101 Glass-Production-Rate Data

Test Condition		Test Period		Duration	Glass Produced		
#	Hg/Cl/Red	Start	Stop	(h)	kg	kg/h$^{(a)}$	MT/d/m^{2*}
0	ShakeDwn	7/28/03 9:25	7/28/03 14:58	5.6	1.99	0.36	0.47
1	Lo/Lo/Lo	7/28/03 16:33	7/29/03 11:22	18.8	10.5	0.56	0.74
2	Lo/Hi/Lo	7/29/03 11:22	7/30/03 5:47	18.4	9.21	0.50	0.66
3	Lo/Hi/Hi	7/30/03 5:47	7/30/03 13:26	7.6	2.50	0.33	0.43
Idle	Transition	7/30/03 13:26	7/30/03 16:16	2.8	----	----	----
4	Hi/Lo/Lo	7/30/03 16:16	7/31/03 10:55	18.7	9.85	0.53	0.69
5	Hi/Hi/Lo	7/31/03 10:55	8/1/03 5:26	18.5	8.95	0.48	0.64
6	Mx/Hi/Lo	8/1/03 5:26	8/1/03 22:20	16.9	9.11	0.54	0.71
7	Mx/Hi/Hi	8/1/03 22:20	8/2/03 5:11	6.8	2.50	0.36	0.48
			Total/Average	114.2	54.6	0.47	0.62
			Post-Test, Derived Values		55.7	0.49	0.64

(a) Average excludes Cond# 0

6.2.1 Process Temperatures

During RSM testing, the temperatures of the following process items were routinely logged:

- Glass Melt
- Melter Plenum
- Post Film-Cooler Off-Gas
- Melter Off-Gas (horizontal run)
- Post EVS Off-Gas
- Post HEME Off-Gas
- EVS Spray
- EVS Condensate.

Table 6.3 summarizes the maximum, minimum, and average temperatures of the melter's glass, plenum, and off-gas stream throughout the entire duration of C-104/AY-101 melter-flowsheet evaluation. Also presented in this table are the standard deviations associated with the temperatures listed. The magnitude of temperature variations (StDev) about the mean is indicative of overall process parameter stability. Table 6.4 provides similar daily tabular data for the melter's kiln, overflow spout, and canister oven.

Test compliance with process operational-temperature target values described in Section 2 of this report are clearly demonstrated by the summary data presented in Table 6.3, although the averaging also included the shakedown and idling phases of the test. Temporal melter and off-gas process-temperature data collected during the C-104/AY-101 flowsheet evaluations are also graphically presented in Appendix C on a daily basis. These graphical data clearly show the influence of the extremely high ambient temperatures accompanying the test (Mon 108°F, Tues 108°F, Wed 108°C, Th 106°F, Fri 104°F). The diurnal, cyclic-temperature variations of the HEME exhaust most clearly document the influence of ambient-temperature conditions upon the process parameters that were not actively controlled. Increased bubbler-induced melter-vessel heat losses obviated the need to use kiln power to achieve the melter tank's external temperature setpoint. More will be said about this condition in Section 6.2.3.

Table 6.3. RSM's Operating Temperature Characteristics

	Temperature (°C)								
Date/Item	**Glass 1(a)**	**Glass 2**	**Plenum**	**FCExh**	**MOGLine**	**PostEVS**	**PstHEME**	**EVSpray**	**EVSTnk**
7/28/2003									
Average	1150.0	1140.0	456.0	202.0	221.0	34.1	34.6	37.5	33.6
Std Dev	21.1	24.3	59.0	28.5	20.7	1.0	2.0	3.4	1.3
Min	1050.0	1020.0	307.0	149.0	159.0	30.0	28.5	31.0	29.0
Max	1160.0	1160.0	607.0	307.0	269.0	38.0	37.0	42.0	36.0
7/29/2003									
Average	1150.0	1150.0	421.0	223.0	232.0	33.7	33.7	34.6	33.3
Std Dev	2.2	5.6	36.8	16.0	13.4	1.1	2.3	6.0	1.0
Min	1140.0	1130.0	312.0	180.0	208.0	31.0	29.4	22.0	31.0
Max	1170.0	1170.0	551.0	276.0	263.0	40.5	38.0	43.6	36.0
7/30/2003									
Average	1150.0	1150.0	433.0	235.0	240.0	34.2	34.1	35.4	33.9
Std Dev	2.4	7.4	72.5	8.8	8.2	1.3	2.5	7.0	1.2
Min	1140.0	1130.0	343.0	216.0	215.0	31.6	30.0	24.0	31.0
Max	1160.0	1170.0	658.0	268.0	252.0	44.0	38.5	47.5	37.0
7/31/2003									
Average	1150.0	1140.0	409.0	219.0	220.0	34.1	34.0	36.0	33.8
Std Dev	2.4	6.3	23.1	14.3	8.2	0.6	1.7	5.4	0.4
Min	1140.0	1130.0	332.0	184.0	199.0	31.9	30.5	26.0	31.9
Max	1160.0	1160.0	500.0	256.0	244.0	41.1	37.0	44.5	35.0
8/1/2003									
Average	1150.0	1140.0	409.0	182.0	204.0	33.3	33.5	36.1	32.9
Std Dev	2.2	5.6	18.2	12.0	9.8	0.7	1.9	5.1	0.6
Min	1140.0	1110.0	343.0	153.0	182.0	31.6	30.0	25.5	31.6
Max	1160.0	1150.0	509.0	213.0	227.0	37.0	37.0	44.0	34.5
8/2/2003									
Average	1150.0	1130.0	407.0	165.0	198.0	32.3	32.1	32.1	32.1
Std Dev	2.5	4.0	24.8	7.5	3.6	0.4	0.9	1.6	0.4
Min	1140.0	1120.0	371.0	148.0	190.0	31.0	30.5	29.4	31.0
Max	1160.0	1150.0	476.0	178.0	204.0	33.5	34.1	36.0	33.0
7/28 – 8/2									
Average	1150.0	1140.0	422.0	211.0	222.0	33.8	33.9	35.6	33.4
Std Dev	7.9	12.4	47.5	26.4	17.9	1.1	2.1	5.6	1.0
Min	1050.0	1020.0	307.0	148.0	159.0	30.0	28.5	22.0	29.0
Max	1170.0	1170.0	658.0	307.0	269.0	44.0	38.5	47.5	37.0
Target									
Range/Value	1150	----	400-450	----	200-250	----	----	----	----

(a) Control Value.

Table 6.4. Melter Kiln, Pour Spout, and Canister Oven Temperatures

	Temperature (°C)				
	Kiln			Pour Spout	Can Oven
Date/Statistic	Bot	Mid	Top		
7/28/02					
Average	807.00	855.00	767.00	1060.00	685.00
Std Dev	26.60	12.30	30.90	21.50	160.00
Minimum	766.00	844.00	724.00	1030.00	125.00
Maximum	909.00	901.00	887.00	1110.00	775.00
7/29/02					
Average	845.00	878.00	805.00	1130.00	748.00
Std Dev	13.80	10.60	15.60	23.30	18.00
Minimum	820.00	861.00	779.00	1080.00	492.00
Maximum	872.00	893.00	835.00	1150.00	781.00
7/30/02					
Average	844.00	877.00	807.00	1090.00	749.00
Std Dev	32.50	24.80	32.90	111.00	13.40
Minimum	752.00	811.00	711.00	769.00	484.00
Maximum	874.00	898.00	837.00	1180.00	777.00
7/31/02					
Average	838.00	873.00	800.00	1090.00	822.00
Std Dev	20.00	14.50	20.50	80.30	41.90
Minimum	757.00	818.00	716.00	801.00	587.00
Maximum	857.00	886.00	820.00	1180.00	883.00
8/1/02					
Average	863.00	890.00	825.00	1100.00	869.00
Std Dev	27.20	21.10	27.90	81.60	11.20
Minimum	760.00	821.00	717.00	789.00	641.00
Maximum	884.00	910.00	847.00	1140.00	881.00
8/2/03					
Average	876.00	904.00	836.00	1070.00	870.00
Std Dev	23.50	10.60	24.70	96.70	1.34
Minimum	823.00	867.00	782.00	877.00	862.00
Maximum	903.00	910.00	863.00	1140.00	876.00
7/28 – 8/2					
Average	844.00	877.00	805.00	1100.00	786.00
Std Dev	30.20	21.00	31.50	79.20	87.10
Minimum	752.00	811.00	711.00	769.00	125.00
Maximum	909.00	910.00	887.00	1180.00	883.00

6.2.2 Process Pressures

Melter and differential off-gas system pressures were recorded throughout the duration of the RSM test. Specifically, the process pressures recorded were

- plenum gauge pressure
- film-cooler pressure drop
- EVS pressure drop
- HEME pressure drop.

A graphical summary of these operating parameters extracted from the electronic process log is presented in Figure 6.5. The pressure-drop data for the EVS is not displayed because it did not produce any. With the low off-gas flow rate (~5 scfm) used during the current test, the EVS, apart from all other off-gas system devices, assisted the blower in maintaining the melter-plenum vacuum. Specifically, the operation of this device created aspiration conditions that help pump gas from the melter's plenum. Indeed, the EVS was so effective in pumping gas that it was fully capable of maintaining an ~2 wc" vacuum without any assistance from the blower.

The low off-gas flow rate also made it impossible for the automated off-gas valve to control the melter vacuum. Recognizing that automatic off-gas control based on plenum pressure was inoperable throughout the entire duration of RSM testing, it is apparent that vacuum control of the melter and its off-gas system was easily maintained throughout all phases of testing. Buildup of debris within the film-cooler posed the only challenge to the manual control system. However, the debris was easily removed by inserting a rod through the off-gas sampling port (see Figure 4.14). As is clear from the stable and nominally invariant film-cooler pressure-drop data, no permanent off-gas obstructions formed within this device during C-104/AY-101 melter flowsheet testing.

6.2.3 Melter Electrical Data

The RSM's electrodes, kiln, discharge, and pour-spout heating loads are all controlled by phase angle, silicon-controlled rectifiers (SCRs). The SCRs control the voltage going to the load and are capable of adjustments anywhere from zero to the full line voltage (120 V and 208 V).

Figure 6.6 graphically summarizes the time-dependent behavior of the electrode electrical parameters. Due to the glass bubblers that provided an additional heat-loss mechanism and a required 400°C plenum temperature that required inleakage cooling, much greater electrode amperage and associated power was required to maintain the glass pool at 1150°C than is normally observed in the absence of bubbling and higher plenum temperatures. The spikes in amperage and power that occurred periodically throughout the test resulted from the need to compensate for decreased overflow heating power that was used to increase the glass level in the melter. Bubbler action eliminated the RSM's normal cyclic pouring behavior; by freezing the overflow channel and building up a glass head, high volumetric glass flows could be stimulated. Electrode parameter plots that provide much more time-resolved detail are displayed in Appendix C for the interested reader.

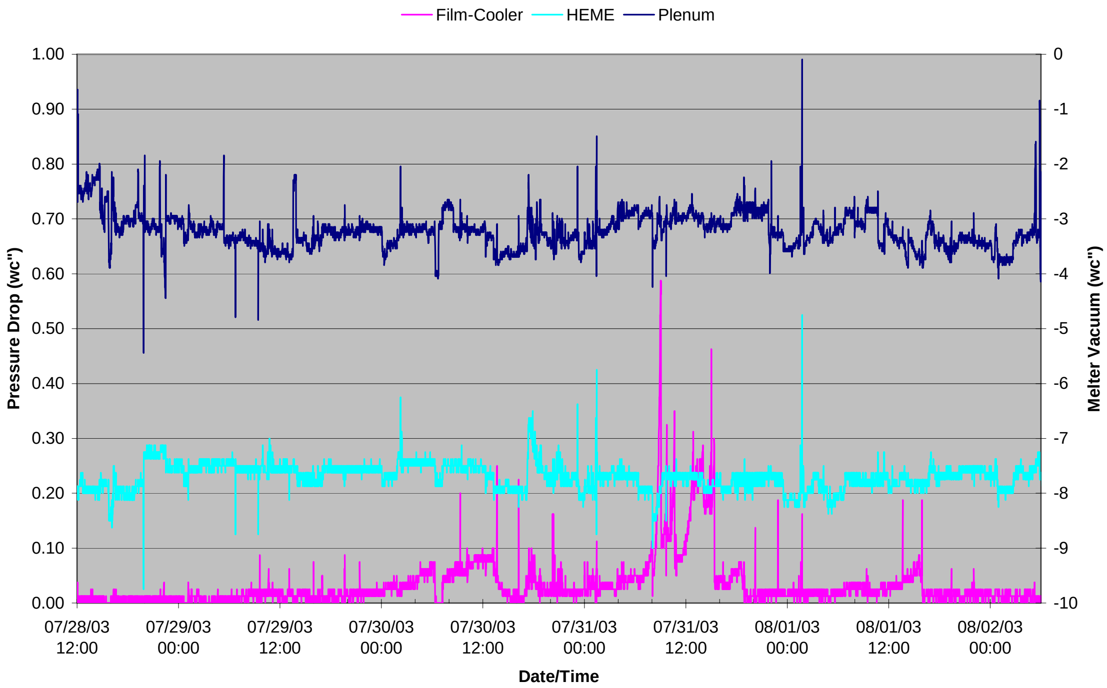


Figure 6.5. Melter Vacuum and Off-Gas Pressure Drop Data

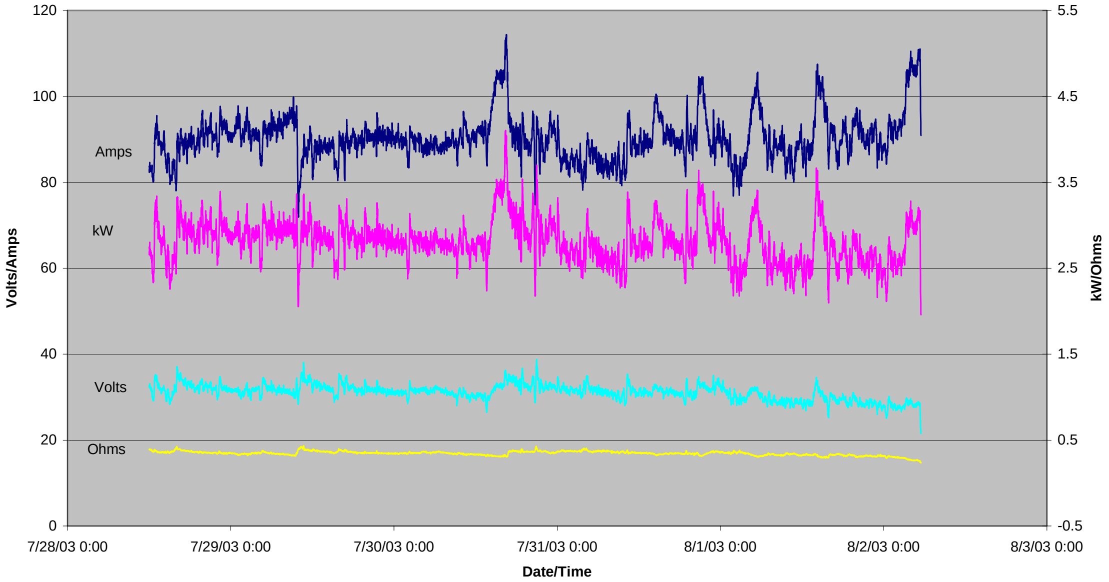


Figure 6.6. RSM Electrode Operating Characteristics

Table 6.5 summarizes the maximum, minimum, and average electrode operating parameters and their standard deviations during all processing periods (see Table 6.1). The average Joule-heating requirements of each batch in this table were used with corresponding average batch-feeding rates (see Table 6.1) to derive specific Joule-energy processing requirements for C-104/AY-101 feeds. These data are summarized in Table 6.6.

Typical specific energy requirements for unagitated slurry-fed Joule-heated ceramic melters range from 2 to 4 kW•h/kg of glass produced (Perez et al. 2001). The average energy requirements under all phases of RSM testing for vitrifying the nominally invariant C-104/AY-101 feed were found, without exception, to exceed this range. The use of bubblers is, of course, the reason for this result. Although increased glass-production rates result from the agitation created by the bubblers, there is also a very significant concomitant thermal energy loss rate to the melter plenum and off-gas system that has to be compensated for by increased Joule-heating requirements.

As mentioned earlier, the melter was significantly overfed during the initial shakedown testing phase, and since the glass rates are derived from feeding-rate data, the associated specific energy result is artificially low, totally misleading, and should be disregarded. Steady-state processing conditions were, however, achieved during all remaining testing phases as the similarity in their specific energy requirements attest. As a group, the first five test conditions are the most similar in energy requirements, exhibiting only a 2% variability. The final two test conditions, which involved maximum mercury concentration, exhibited consistently lower specific energy values due to uniformly higher glass-production rates. Despite the apparent clustering of specific energy results within two discrete test-condition groups, the overall variability amongst all seven test conditions is only ~8%.

It should also be noted that in addition to the electrical power delivered to the melt pool, combustion energy was also being provided by the reductant feed-stream component. Although sugar was the most significant source of combustion energy, at an ~ 1 L/h feeding rate and a 5 g/L concentration, the combustion contributions to the vitrification energy requirements are seen to be trivially small. Although the RSM construction and design is hardly representative of ceramic-lined production melters, the energy expended to vitrify the C-104/AY-101 feeds is, nevertheless, consistent with generalized LFCM operating expectations, if bubbler energy loss rates are considered.

Like the melter electrodes, the RSM’s kiln and overflow heater circuits were similarly characterized. Because of the relatively invariant nature of the electrical loads involved, these data do not contain much structure or embedded information and are therefore summarized on a daily basis in Table 6.7. As mentioned earlier, the bubblers delivered so much heat energy to the melter vessel that kiln power was not always required to maintain the melter canister’s external temperature setpoint. The minimum overflow heater condition summarized in Table 6.7, as discussed earlier, resulted from attempts to generate large volumetric pours by freezing the overflow port in order to build up a glass inventory (head) in the melter.

Table 6.5. RSM Electrode Circuit Operating Characteristics

	RSM Electrode Parameter			
Date/Item	**Volt**	**Amp**	**kVA**	**Ohm**
Shake Down				
Average	33.20	83.90	2.79	0.41
Std Dev	3.10	12.20	0.58	0.09
Min	29.00	49.90	1.68	0.35
Max	64.20	119.00	7.63	0.73
Lo/Lo/Lo				
Average	32.10	91.10	2.92	0.35
Std Dev	1.25	3.57	0.16	0.02
Min	28.30	71.90	2.05	0.32
Max	38.10	99.80	3.39	0.43
Lo/Hi/Lo				
Average	31.80	89.10	2.84	0.36
Std Dev	1.09	2.27	0.14	0.01
Min	28.40	80.40	2.37	0.34
Max	35.50	96.20	3.31	0.40
Lo/Hi/Hi				
Average	30.80	90.00	2.77	0.34
Std Dev	0.81	2.01	0.10	0.01
Min	28.00	83.80	2.38	0.32
Max	32.70	96.50	3.12	0.37
Hi/Lo/Lo				
Average	32.20	87.80	2.83	0.37
Std Dev	1.57	5.50	0.30	0.01
Min	28.00	74.80	2.18	0.31
Max	38.80	114.00	4.10	0.43
Hi/Hi/Lo				
Average	31.20	90.60	2.83	0.35
Std Dev	1.21	5.29	0.26	0.01
Min	28.10	76.80	2.18	0.31
Max	35.00	105.00	3.64	0.38
Mx/Hi/Lo				
Average	29.30	90.60	2.66	0.32
Std Dev	1.20	5.12	0.25	0.01
Min	25.20	80.00	2.09	0.29
Max	34.60	108.00	3.67	0.35
Mx/Hi/Hi				
Average	28.00	95.90	2.68	0.29
Std Dev	1.06	7.53	0.27	0.02
Min	21.50	83.30	1.96	0.24
Max	30.20	111.00	3.28	0.33
All Condition				
Average	31.20	90.10	2.81	0.35
Std Dev	1.93	5.98	0.28	0.03
Min	21.50	49.90	1.68	0.24
Max	64.20	119.00	7.63	0.73

Table 6.6. Specific Process Energy Requirements for C-104/AY-101 Feeds

Test Condition		**Glass Rate(a)**		**Sucrose**	**Power (kW)**		**Spec Engy (kW-h/kg)**	
#	**Hg/Cl/Red**	**(kg/h)**	**MT/d/m^2**	**(g/L)$_{Fd}$**	**Joule**	**Combust**	**Joule**	**Total**
0	ShakeDwn	0.67	1.01	0.00	2.79	0.00	4.20	4.20
1	Lo/Lo/Lo	0.50	0.76	0.00	2.92	0.00	5.88	5.88
2	Lo/Hi/Lo	0.48	0.73	0.00	2.84	0.00	5.90	5.90
3	Lo/Hi/Hi	0.45	0.69	5.00	2.77	0.02	6.11	6.16
4	Hi/Lo/Lo	0.49	0.74	0.00	2.83	0.00	5.81	5.81
5	Hi/Hi/Lo	0.47	0.71	0.00	2.83	0.00	6.05	6.05
6	Mx/Hi/Lo	0.53	0.81	0.00	2.66	0.00	5.01	5.01
7	Mx/Hi/Hi	0.53	0.80	5.00	2.68	0.02	5.08	5.12
(a) Feed projection scaled to glass produced.							Average(b) =	5.71
(b) Condition 0 excluded.							Std Dev(b) =	7.9%

6.2.4 Bubbler Glass Agitation

Two ¼-inch Inconel® tubes were inserted through the melter lid and into the glass pool and were used with a compressed air source to create forced convective mixing within the melter's glass crucible. The tubes, separated by 3 inches, are off centerline but collinear with the electrodes that are separated by ~6 inches. Because of the active-convective process created by this bubbler configuration, the minimum acceptable compressed-gas flow rate was used throughout all phases of testing. Figure 6.7 summarizes the operational characteristics of the bubbler system during RSM testing. The average rate achieved compares well with the minimum of the target flow range (1 to 2 scfm/m^2).

6.2.5 Melter Off-Gas Temperature and Residence Time Characteristics

In order to create off-gas chemistry conditions that are representative of the WTP, the unquenched off-gas temperature and melter-to-quencher residence time had to be controlled. Off-gas line insulation and external heating were the primary parameters used to provide temperature control. The film-cooler air-injection rate was used to establish the proper flow-rate/residence-time conditions. While active off-gas temperature measurements were used to make appropriate off-gas line-heating adjustments, helium-dilution techniques were employed to measure off-gas flow rate and associated off-gas residence time in the melter's off-gas jumper. To determine the RSM's off-gas flow rate, a helium tracer was injected at a fixed flow rate (1 SL/min) into the RSM's film-cooler injection stream, and the resultant helium concentration was continuously sampled and measured downstream of the film cooler, after complete mixing with melter exhaust had occurred, using an on-line gas chromatograph. Since the chromatograph provides concentration results on a dry basis, these data were used with melter feeding rates and the physical properties of the feed (see Table 5.4) to establish the total steam-laden flow-rate and resultant residence-time value. An operational summary of unquenched melter off-gas temperatures and residence times occurring during all phases of RSM testing is graphically portrayed in Figure 6.8. A statistical summary of these and related flow-rate parameters for each of the melter operating test conditions is also detailed in Table 6.8.

Table 6.7. Operational Characteristics of Melter Kiln and Overflow Heaters

	Kiln Electrical Parameter			OverFlow Heater Parameter		
Date/Item	**Volt**	**Amp**	**kVA**	**Volt**	**Amp**	**kVA**
7/28/2003						
Average	27.60	1.91	0.13	149.00	13.50	2.01
Std Dev	30.10	2.85	0.32	10.60	0.76	0.26
Min	2.50	0.00	0.00	129.00	11.90	1.54
Max	123.00	14.20	1.74	176.00	15.50	2.72
7/29/2003						
Average	2.84	0.00	0.00	170.00	14.80	2.52
Std Dev	0.31	0.00	0.00	11.50	0.73	0.29
Min	2.25	0.00	0.00	149.00	13.30	1.98
Max	3.50	0.00	0.00	181.00	15.60	2.84
7/30/2003						
Average	9.57	0.40	0.03	158.00	13.50	2.40
Std Dev	22.20	1.33	0.12	55.40	4.72	0.93
Min	2.25	0.00	0.00	3.00	0.00	0.00
Max	112.00	6.50	0.73	189.00	17.50	3.16
7/31/2003						
Average	3.14	0.01	0.00	158.00	13.60	2.35
Std Dev	1.85	0.12	0.00	48.60	4.21	0.76
Min	2.50	0.00	0.00	3.00	0.00	0.00
Max	23.30	1.34	0.03	181.00	17.80	3.22
8/1/2003						
Average	2.94	0.00	0.00	167.00	14.10	2.54
Std Dev	0.40	0.02	0.00	45.30	3.83	0.73
Min	2.25	0.00	0.00	2.75	0.00	0.00
Max	7.50	0.36	0.00	182.00	17.30	3.05
8/2/2003						
Average	31.30	1.90	0.22	154.00	13.20	2.22
Std Dev	48.50	3.35	0.45	49.30	3.84	0.94
Min	2.50	0.00	0.00	2.75	0.00	0.00
Max	161.00	11.70	1.88	181.00	16.90	3.06
7/28 – 8/02						
Average	8.77	0.42	0.03	161.00	13.90	2.39
Std Dev	20.40	1.55	0.17	41.90	3.53	0.71
Min	2.25	0.00	0.00	2.75	0.00	0.00
Max	161.00	14.20	1.88	189.00	17.80	3.22

Table 6.8. Off-Gas Flow Rate, Residence Time, and Temperature Test-Condition Statistics

Test Condition Hg/Cl/Red Conc	Melter Off-Gas Characteristics				
	Flow Rate			Transit Time (s)	Temp °C
	Dry, scfm	Wet, scfm	Wet, acfm		
Shake Down					
Average	5.27	5.86	10.90	0.966	235
Std. Dev.	1.28	1.28	2.21	0.196	7.9
Minimum	4.09	4.68	8.83	0.786	227
Maximum	6.45	7.04	12.90	1.150	243
Melter Idle #1					
Average	4.33	4.92	9.32	1.100	243
Std. Dev.	0.51	0.51	1.02	0.120	10.4
Minimum	3.50	4.09	7.81	0.890	232
Maximum	5.20	5.79	11.40	1.300	268
Low/Low/Low					
Average	5.50	6.09	11.00	0.927	221
Std. Dev.	0.48	0.48	0.84	0.077	10.8
Minimum	3.56	4.15	7.37	0.783	208
Maximum	6.58	7.17	13.00	1.380	269
Low/High/Low					
Average	5.48	6.07	11.50	0.884	244
Std. Dev.	0.17	0.17	0.36	0.027	5.9
Minimum	5.04	5.63	10.50	0.701	232
Maximum	6.97	7.56	14.50	0.967	263
Low/High/High					
Average	5.20	5.79	10.90	0.931	242
Std. Dev.	0.24	0.24	0.49	0.043	5.4
Minimum	4.45	5.05	9.33	0.852	231
Maximum	5.67	6.26	11.90	1.090	252
Melter Idle #2					
Average	4.72	4.74	8.79	1.150	234
Std. Dev.	0.06	0.09	0.19	0.023	3.0
Minimum	4.56	4.56	8.48	1.040	229
Maximum	4.86	5.23	9.74	1.200	243
High/Lo/Lo					
Average	5.09	5.68	10.40	0.981	228
Std. Dev.	0.50	0.50	1.04	0.099	10.8
Minimum	2.86	3.46	6.17	0.701	201
Maximum	7.02	7.62	14.50	1.650	251

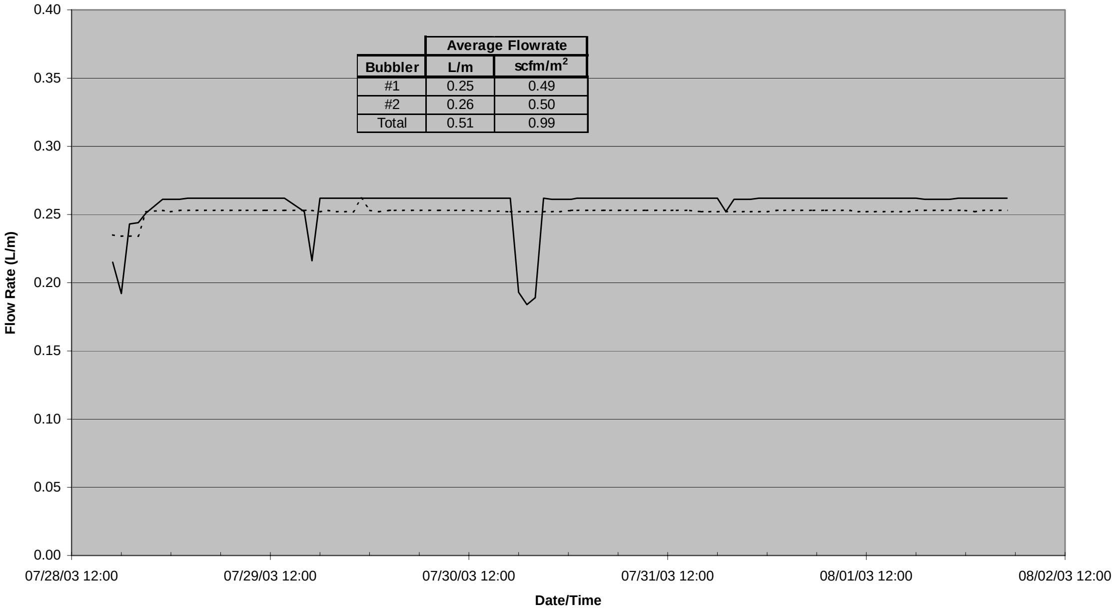
Table 6.8 (Contd)

	Melter Off-Gas Characteristics				
Test Condition	**Flow Rate**			**Transit**	**Temp**
Hg/Cl/Red Conc	**Dry, scfm**	**Wet, scfm**	**Wet, acfm**	**Time (s)**	**°C**
High/High/Lo					
Average	4.96	5.55	10.00	1.010	219
Std. Dev.	0.18	0.18	0.33	0.034	5.3
Minimum	4.17	4.77	8.70	0.910	205
Maximum	5.51	6.11	11.10	1.170	227
Max/High/Lo					
Average	5.02	5.61	9.72	1.040	200
Std. Dev.	0.12	0.12	0.26	0.028	7.0
Minimum	4.47	5.06	8.90	0.929	182
Maximum	5.84	6.43	10.90	1.140	213
Max/High/High					
Average	5.01	5.61	9.68	1.050	199
Std. Dev.	0.13	0.13	0.24	0.025	3.3
Minimum	4.76	5.35	9.12	0.954	192
Maximum	5.58	6.17	10.60	1.110	204
All Conditions					
Average	5.18	5.76	10.50	0.976	224
Std. Dev.	0.42	0.44	0.95	0.090	17.2
Minimum	2.86	3.46	6.17	0.701	182
Maximum	7.02	7.62	14.50	1.650	269

As the graphical data show, good control over both these experiment parameters was achieved throughout the melter testing campaign. Indeed, the target values for these parameters are well represented by the average values achieved.

6.2.6 EVS Condensate Tank, Film Cooler Injection Air

As described earlier, the EVS acts to both quench the melter exhaust stream and remove entrained debris generated by the melter source. As seen in Table 6.3, the EVS's scrubbing-liquor temperature appeared to remain fairly constant (~33°C), on the average, throughout RSM testing. However, as Figure 6.9 shows, the condensate temperature was measurably affected by diurnal ambient temperature variation throughout the test, despite the relatively constant temperature of the heat exchanger. Because of the relatively high temperature of this fluid, EVS steam-collection rates were quite low. Based on the average feeding rate of the melter and the feed properties described in Table 5.7, the 0.18 L/h represents 22% of the overall average rate to which water was fed to the melter.



	Average Flowrate	
Bubbler	L/m	scfm/m^2
#1	0.25	0.49
#2	0.26	0.50
Total	0.51	0.99

Figure 6.7. Flow Rate Behavior of Glass Agitation Bubblers

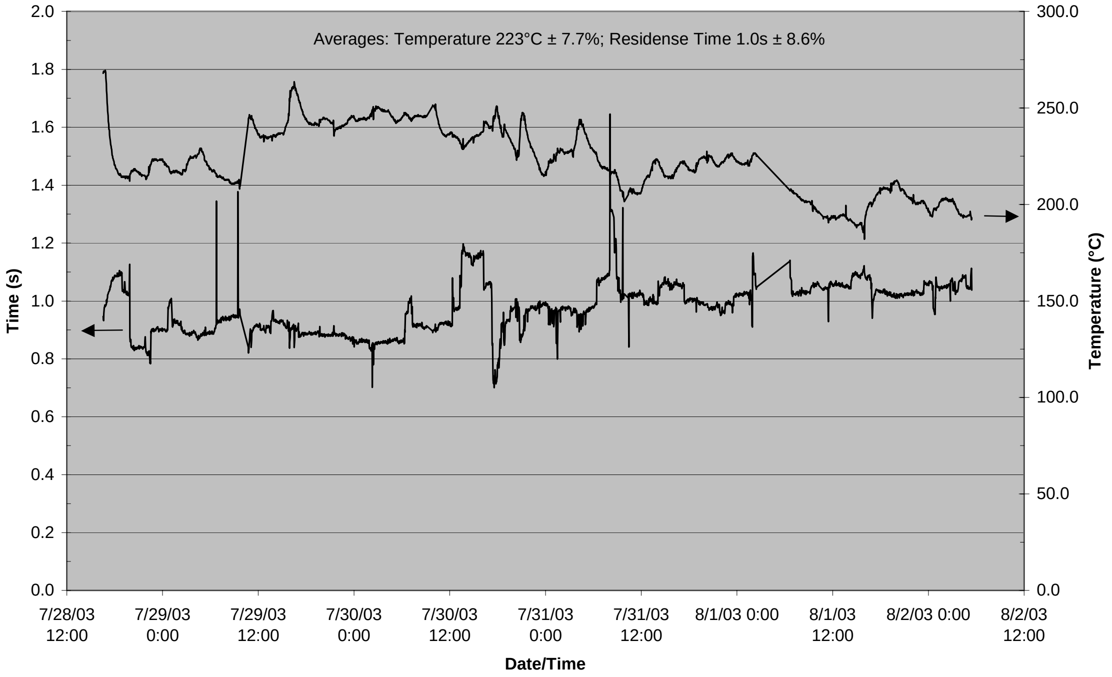


Figure 6.8. Unquenched Off-Gas Temperatures and Residence Times During RSM Testing

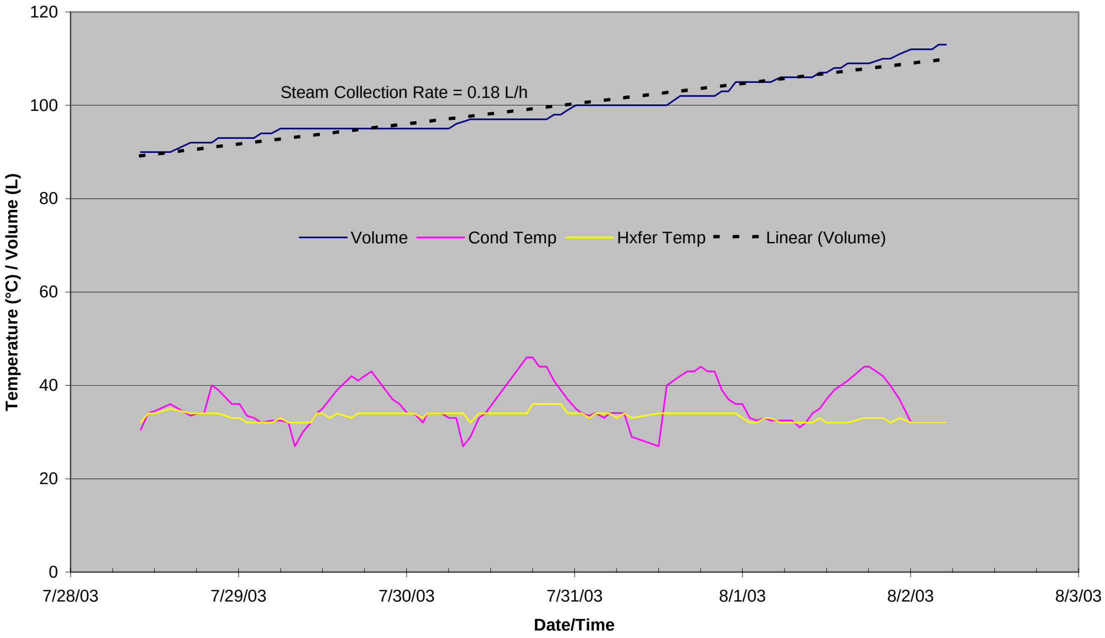


Figure 6.9. EVS Condensate Tank Temperature and Volume

7.0 Melter Off-Gas Emission Characterization

Off-gas effluent studies were conducted during C-104/AY-101 flowsheet testing to characterize the melter-effluent source. As described in Section 4.1.4, the off-gas sampling network assembled in support of this objective was designed to determine the composition of the melter exhaust with regard to non-condensable (25°C) as well as condensable effluents.

The composition of melter-generated, non-condensable effluent emissions was established using the gas analyzers described in Section 4 of this report. The instruments used were designed to continuously (or quasi-continuously) monitor and record process-exhaust concentrations of H_2, He, N_2, CO, CO_2, NO, NO_2, O_2, SO_2, and THC. In addition to these conventionally applied analytical instruments, a continuous-emission monitor for volatile forms of mercury was also integrated into the RSM's off-gas monitoring network. Discrete sampling for gaseous emissions, including semi-volatiles such as mercury as well as condensed-phase effluents, was also conducted as described below.

To characterize the melter source of gaseous and condensed-phase effluents, manual (40 CFR 60, Appendix A, Method 29) sampling trains composed of a high-efficiency (99.95% efficient for 0.3-µm aerosols) filter, condenser, and a series of chemically specific gas scrubbers were employed (see Section 4). The manner in which any given element is distributed across the various discrete sampling stages of this device allows the physical/chemical state or states assumed by this effluent species to be inferred. The Method 29 sampling train used in this study is designed specifically to quantify mercury emissions and to provide limited speciation information.

For reference, Table 7.1 summarizes the masses of test-parameter chemical additives processed during each of the seven test conditions evaluated using averaged test-segment operational conditions described in the previous Section of this report. Since mercury incorporation in glass has been shown to be negligibly small (Table 5.11), the test segment-dependent off-gas concentrations of mercury in all its forms (vapor and condensed) have been projected and are also included in Table 7.1.

The operational data and experimental results obtained from the melter off-gas studies conducted in support of the C-104/AY-101 flowsheet evaluations are discussed below.

Table 7.1. Test-Segment Trace-Additive Summary

Test Condition		Duration	Feed		Glass[a]			Wt% (oxide basis)			Mass Processed (g)			Melter Off-Gas	
#	Hg/Cl/Red	(h)	kg	kg/h	kg	kg/h	$MT/d/m^2$	HgO	Cl	Sugar	Hg	Cl	Sugar	scfm	$Hg(mg/m^3)$
1	Lo/Lo/Lo	18.8	27.3	1.45	10.5	0.56	0.73	0.05	0.009	0.00	4.9	0.9	0.0	6.09	25.0
2	Lo/Hi/Lo	18.4	26.0	1.41	10.0	0.54	0.72	0.05	0.06	0.00	4.6	6.0	0.0	6.07	24.4
3	Lo/Hi/Hi	7.6	10.1	1.32	3.90	0.51	0.67	0.05	0.06	0.90	1.8	2.3	35.0	5.79	24.0
4	Hi/Lo/Lo	18.7	26.6	1.42	10.2	0.55	0.72	0.15	0.01	0.00	14.2	0.9	0.0	5.68	78.9
5	Hi/Hi/Lo	18.5	25.5	1.38	9.8	0.53	0.70	0.15	0.06	0.00	13.6	5.9	0.0	5.55	78.1
6	Mx/Hi/Lo	16.9	26.3	1.55	10.1	0.60	0.79	0.95	0.06	0.00	89.1	6.1	0.0	5.61	553.0
7	Mx/Hi/Hi	6.8	10.5	1.53	4.02	0.59	0.77	0.95	0.06	0.90	35.5	2.4	36.2	5.61	543.0
	Total/Average	105.8	152.2	1.44	58.6	0.55	0.73	----	----	----	163.7	24.6	71.2	5.77	----

(a) Calculated values.

7.1 Flue-Gas Effluent

For the surrogate C-104/AY-101 melter feed used during the July/August 2003 test, CO_2 and NO_x (specifically NO) were the major non-condensable (~25°C) gases produced by the vitrification process. Table 7.2 summarizes the maximum, minimum, and average concentrations (by volume) of melter-generated gaseous effluents during the active processing periods for each discrete melter operating condition (see Table 6.1). Also presented in this table are the standard deviations associated with the concentrations listed.

For a non-condensable off-gas flow rate of ~5.5 scfm and a steady-state feeding rate of 1 L/h, the melter off-gas (MOG) concentrations of the major effluent gases (CO_2 and NO) were found to be, nominally, 0.27% and 0.01%, respectively. The combustible gas CO was barely detectable (<5 ppm), except when sugar was added to the feed, and H_2 was not detectable (<10 ppm) under any of the test processing conditions. Throughout all phases of processing, the CO concentration averaged only 2.7 ppm, and the highest sustained concentration recorded, 0.0023%, occurred during processing of feed containing 5 g of sugar/L of feed. These concentrations are well below the lower flammability limits of this combustible gas, 15.5% for CO.

Table 7.2. Unquenched Melter Off-Gas Composition

Test Condition	**Melter Exhaust Gas Concentration (ppm)(a)**							
Hg/Cl/Red Conc	**O_2**	**CO_2**	**CO**	**SO_2**	**NO**	**NO_2**	**THC**	**NO_x**
Pretest Idle								
Average	211,000	1.79	0.00	1.19	0.01	0.00	0.07	0.00
Std. Dev.	171	10.90	0.00	0.61	0.10	0.00	0.17	0.00
Minimum	211,000	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Maximum	211,000	79.40	0.00	2.56	2.04	0.00	0.97	0.00
Process Shake Down								
Average	209,000	3,860	1.00	0.03	164.0	9.0	0.12	172.0
Std. Dev.	888	1,520	1.41	0.18	42.9	7.8	0.08	45.1
Minimum	202,000	0.00	0.00	0.00	1.2	0.00	0.01	0.00
Maximum	211,000	11,800	3.54	1.48	270.0	30.2	0.86	293.0
Melter Idle #1								
Average	210,000	2,670	0.50	0.00	93.8	9.4	0.12	103.0
Std. Dev.	376	2,070	0.81	0.00	90.2	8.7	0.10	98.5
Minimum	209,000	273.00	0.00	0.00	5.6	0.00	0.00	5.6
Maximum	210,000	7,310	1.92	0.00	357.0	34.8	0.40	385.0
Low/Low/Low								
Average	210,000	2,420	0.59	0.38	102.0	10.1	0.09	112.0
Std. Dev.	255	1,060	1.28	0.69	35.7	3.8	0.17	38.5
Minimum	208,000	0.00	0.00	0.00	1.53	0.00	0.00	2.02
Maximum	210,000	5,230	5.27	3.41	215.0	48.3	1.38	239.0

(a) Dry concentration except for THC.

Table 7.2 (Contd)

Test Condition Hg/Cl/Red Conc	Melter Exhaust Gas Concentration (ppm)[a]							
	O_2	CO_2	CO	SO_2	NO	NO_2	THC	NO_x
Low/High/Low								
Average	210,000	3,850	1.32	0.14	111.0	9.6	0.19	121.0
Std. Dev.	574	1,310	1.80	0.38	35.5	3.3	0.25	38.0
Minimum	209,000	348.00	0.00	0.00	2.54	0.0	0.00	2.76
Maximum	211,000	6,040	7.61	2.06	278.0	19.7	1.55	293.0
Low/High/High								
Average	210,000	2,860	13.20	2.12	23.0	0.7	0.98	23.6
Std. Dev.	232	790	2.83	1.16	11.5	1.2	0.34	12.5
Minimum	209,000	0.00	1.41	0.00	1.25	0.00	0.01	1.25
Maximum	211,000	5,240	23.20	4.05	107.0	9.9	2.71	115.0
Melter Idle #2								
Average	210,000	979	0.88	0.00	3.4	0.1	0.08	3.4
Std. Dev.	747	815	3.42	0.00	6.8	0.2	0.37	6.7
Minimum	209,000	555.00	0.00	0.00	1.07	0.00	0.00	0.90
Maximum	211,000	5,200	20.10	0.00	48.1	1.2	2.38	47.4
High/Lo/Lo								
Average	210,000	2,980	2.26	2.27	125.0	9.7	0.02	134.0
Std. Dev.	680	1,750	2.30	1.88	43.2	3.9	0.10	45.6
Minimum	209,000	0.00	0.00	0.00	1.33	0.00	0.00	1.37
Maximum	211,000	6,590	8.39	5.21	257.0	29.6	3.18	276.0
High/High/Lo								
Average	206,000	2,500	3.37	0.99	124.0	10.7	0.04	135.0
Std. Dev.	3,040	940	2.30	1.12	34.9	3.5	0.46	37.0
Minimum	192,000	0	0.00	0.00	2.1	0.0	0.00	3.2
Maximum	212,000	4,880	23.30	3.60	275.0	27.0	14.40	291.0
Max/High/Lo								
Average	209,000	3,430	0.62	1.10	210.0	16.6	0.00	226.0
Std. Dev.	265	927	0.68	1.25	53.7	4.9	0.01	56.4
Minimum	209,000	0	0.00	0.00	7.76	0.00	0.00	10.8
Maximum	210,000	8,050	4.34	3.80	476.0	49.3	0.01	489.0
Max/High/High								
Average	209,000	3,440	10.10	1.09	67.4	1.5	0.25	68.4
Std. Dev.	233	940	3.30	0.37	26.2	2.9	0.19	28.3
Minimum	208,000	0	0.33	0.16	3.00	0.00	0.00	0.81
Maximum	210,000	5,700	14.90	1.88	228.0	30.4	1.17	239.0
All Conditions								
Average	209,000	2,800	2.70	1.00	110.0	8.8	0.14	119.0
Std. Dev.	1,820	1,540	4.07	1.31	68.8	6.3	0.33	74.1
Minimum	192,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	212,000	11,800	23.30	5.21	476.0	49.3	14.40	489.0

(a) Dry concentration except for THA.

The time-dependent behavior of gaseous process effluent emissions was recorded at nominally 1-min intervals throughout the melter-processing campaign. Because steady-state feeding conditions were maintained throughout most phases of testing, the average process exhaust concentrations of these off-gas effluents remained relatively invariant. They were, however, perturbed by scheduled feed-batch preparations and changes in film-cooler injection rates as well as during feed sampling and/or feed system repair. Figure 7.1 graphically presents the temporal behavior of melter off-gas effluents on a daily basis.

The only distinctive feature in this graphical gaseous-effluent data that has not already been discussed is the apparent effectiveness of even small amounts of sugar upon the melter's NO_x source term. Only during the processing of feeds containing no sugar is NO a significant byproduct of melter nitrate destruction. These data suggest that the sugar-feed additive is effectively reducing the nitrate feed component to N_2. Throughout RSM testing, NO_2 (~ 8 ppm) was found to be an unimportant contributor to the melter's overall nitrogen oxide source term. Appendix C provides higher time-resolved plots of these off-gas data.

Table 7.3 compares actual NO_x and CO_x off-gas concentrations with calculated values based upon nitrogen oxy-anion and reductant feed composition, respectively, and off-gas flow-rate data. The impact of sugar upon apparent NO_2^-/NO_3^- destruction is clearly shown by this NO_x comparative data. Nominally 21% destruction of the oxy-anions of nitrogen was observed in the absence of sugar while ~81% reduction to nitrogen is achieved when this reductant at a 5g/L loading is used.

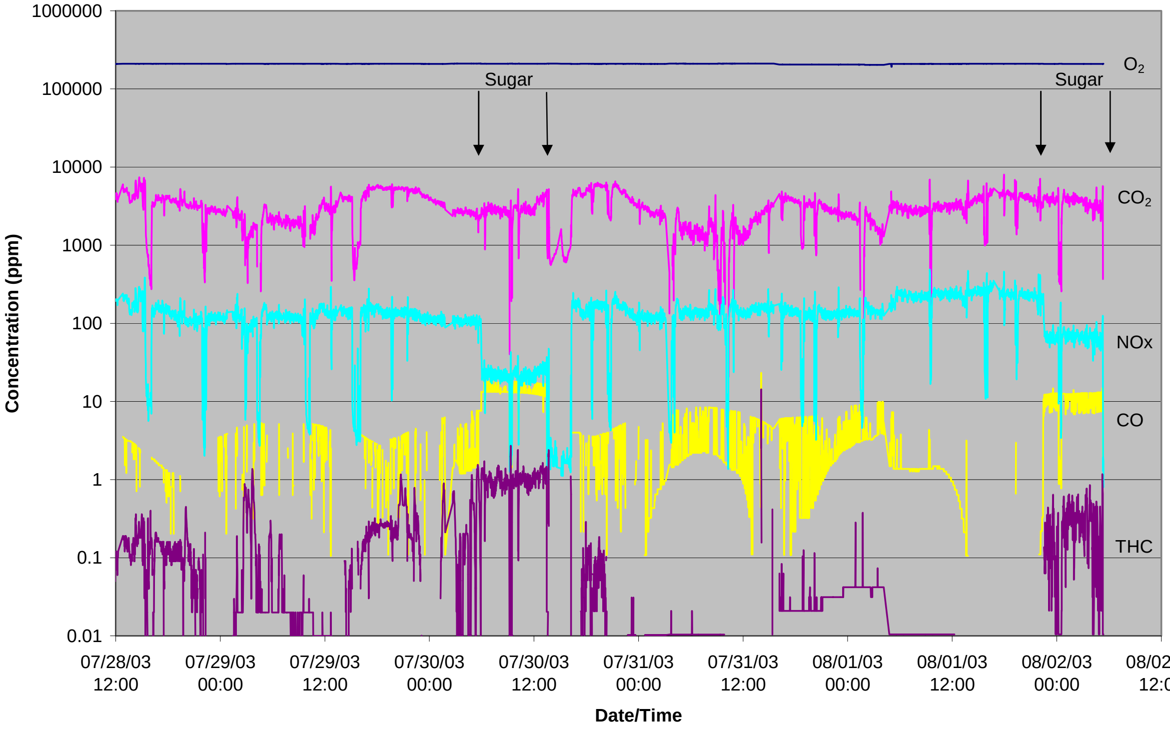


Figure 7.1. Temporal Behavior of Major Process Effluent Gases

Table 7.3. Actual Vs. Calculated CO_x and NO_x Process Off-Gas Concentration

Test	Feeding Rate		Off-Gas	NO_x Conc. (ppm)		Reduction	CO_x Conc. (ppm)	
Hg/Cl/Red	kg/h	L/h	Flw (scfm)	Calculated	Actual	To N_2 (%)	Calculated	Actual
ShakeDwn	2.00	1.39	5.27	199	172	14	64.9	3,860
Lo/Lo/Lo	1.49	1.03	5.50	149	112	25	46.4	2,420
Lo/Hi/Lo	1.45	1.00	5.48	145	121	16	45.1	3,850
Lo/Hi/Hi	1.36	0.94	5.20	144	24	84	464.0	2,880
Hi/Lo/Lo	1.47	1.01	5.09	171	134	22	49.1	2,980
Hi/Hi/Lo	1.41	0.98	4.96	169	135	20	48.5	2,510
Mx/Hi/Lo	1.60	1.11	5.02	309	226	27	54.3	3,430
Mx/Hi/Hi	1.59	1.10	5.01	308	68	78	561.0	3,450

The comparative CO_x data in Table 7.3 reveal an off-gas source of carbon oxides that is an order of magnitude greater than projections based upon both oxalate- and sugar-feed sources. The pretest monitoring data clearly show that an analyzer zero bias is not the source of this apparent anomaly. Although the two short RSM idling periods demonstrate a relationship between the unexpectedly high CO_x levels and processing, the impact of relatively low concentrations of sugar upon nitrogen oxy-anion destruction suggests a carbon source external to the feed stream. That is, the observed impact of sugar at 5 g/L-Fd upon both nitrogen-oxide reduction and glass-oxidation state is clearly inconsistent with a high extraneous source of carbon in the feed stream. New refractory material in the melter lid could be the source of carbonaceous material responsible for the abnormally high CO_x off-gas concentrations, but it would be difficult to explain how this source could create the processing/idling characteristics described in Table 7.3 unless a water-gas reaction is responsible for the excess CO_x production. Assuming that process steam and carbonaceous lid materials were producing water-gas reaction products, then it must also be assumed that highly efficient plenum combustion of these reaction products also occurred as no hydrogen (<10 ppm) and very low concentrations of CO were present in the melter's process off-gas stream.

7.2 Mercury-Vapor Emissions

As described in Section 4.1.1.4, quasi-continuous off-gas monitoring of vapor-state mercury compounds was conducted in the exhaust stream of the melter, EVS, and HEME. Since melter glass exhibits no appreciable capacity for mercury, it was expected that nominally all mercury fed to the melter will be lost to the melter's off-gas system. Although mercury compounds are unstable at melter-glass temperatures (~1150°C), reactions in the plenum (~400°C) and unquenched (225°C) off-gas line can convert the thermally decomposed elemental mercury source to a variety of (oxidized mercury) compounds. Since some of these oxidized forms (compounds) of mercury (e.g., $HgCl_2$) exhibit vapor pressures similar to that of elemental mercury, characterizing the melter's mercury effluent source requires measuring volatile (elemental and oxidized) as well as non-volatile (chemically combined) species in the process exhaust stream. Nonvolatile mercury partitioning results will be separately discussed with condensed-phase effluents.

7.2.1 Thermodynamic Model of Mercury Speciation

In a previous, but similar, melter study (Goles et al. 2002), efforts to shed light on the mercury speciation in a typical melter exhaust stream produced the thermodynamic equilibrium model predictions shown in Figure 7.2. These model predictions were found to be largely invariant over a rather large range of oxidizing and generic off-gas conditions. Since the model presumes an equilibrium condition, it serves only to indicate what mercury speciation is possible and which species are most probable, independent of kinetic considerations. Specifically, the model results indicate that at typical unquenched off-gas processing conditions, the predominant mercury species predicted, under favorable kinetic conditions, is $HgCl_2$. In support of earlier statements, elemental mercury is also found to be the predominate species predicted above ~500°C.

7.2.2 CEM Mercury Measurements

Two separate sample-stream conditioning systems were used to support process off-gas monitoring objectives. The primary system exclusively sampled the melter source while the secondary system was used to selectively monitor the EVS or HEME exhaust sampling sites (see Figure 4.9). Since both systems shared a common detection module, simultaneous results could not be obtained from the primary and secondary sampling sites. Table 7.4 summarizes the monitoring results obtained for each of the test conditions evaluated during the C-104/AY-101 vitrification flowsheet study.

This table presents the average total and elemental gaseous concentrations of mercury in the melter, EVS, and HEME exhausts as a function of test constituents. Also presented, for each testing condition, are the corresponding standard deviation and the minimum and maximum values of the concentrations recorded. The number of observations used to derive these numbers, which are also detailed, clearly show that an emphasis was placed on collecting mercury-species information from the primary melter-exhaust sampling site.

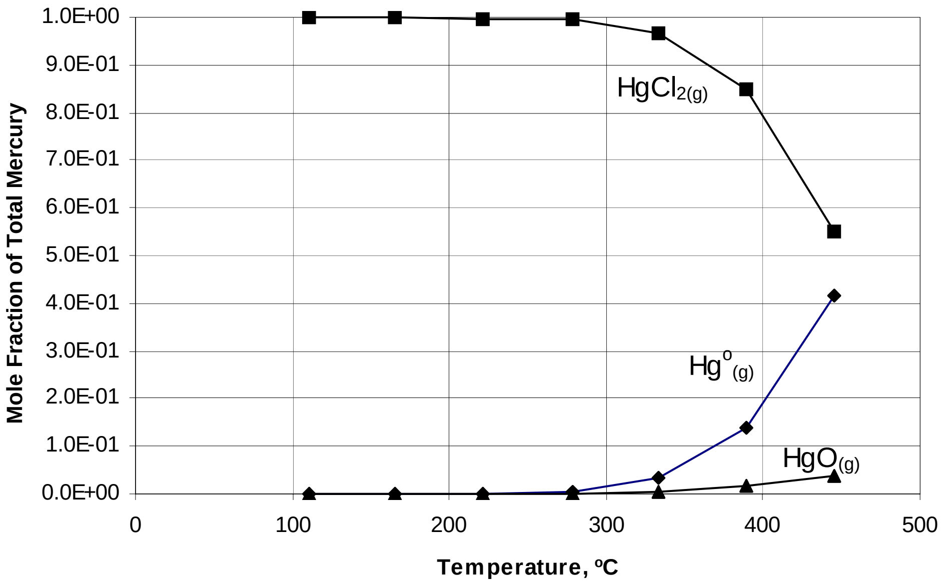


Figure 7.2. Thermodynamic Predictions of Speciation of Mercury Compounds

The standard deviations associated with these tabular data suggest a very large spread in recorded results, especially for the low-mercury-concentration conditions. The nature of these highly dispersed data is graphically summarized in Appendix C where all test-condition data are appropriately grouped and displayed. Subsequent discussions of these data will reveal that instrumental difficulties compromised the quantitative value of much of the mercury CEM data collected. As a result, average sample site concentration results are somewhat inconsistent and should not be directly compared. Indeed, comparison of Table 7.4 average concentration data with processing expectation detailed in Table 7.1 suggests a very significant quantitative problem, unless significant condensed-phase mercury effluent is being generated, which is not likely as will be shown in Section 7.3. In order to further clarify the functional dependence of the mercury off-gas source term upon test conditions, the average (relative) mercury concentration data for the melter, EVS, and HEME sampling sites have been graphically combined and summarized in Figure 7.3 through Figure 7.5, respectively.

The melter exhaust data in Figure 7.3 suggest that under low mercury feed-concentration conditions, chlorine-feed loading may significantly increase partitioning to oxidized forms of mercury (i.e., $HgCl_2$). When the high-feed concentration of mercury was employed, overall mercury-vapor concentrations increased in a manner consistent with the corresponding feed-concentration change (~3×). As in the low-mercury-feed case, an increase in feed halogen content was found to enhance the relative yield of the oxidized mercury, which was further increased when the mercury-feed content was maximized at fixed chlorine content. However, there are strong suggestions that this latter result may not be reliable, as no significant increase in total mercury-vapor concentrations accompanied the ~6-x change in feed composition. In addition, unreasonable elemental to total-mercury ratios ($Hg^\circ/Hg>1$) occurred with increasing frequency as is typified by the results of the seventh test condition.

Unlike the melter source term, the mercury vapor in the exhaust of the EVS was found, with the exception of the Hi/Lo/Lo condition, to be dominated by the unoxidized form of the element. Although the magnitude of mercury-vapor concentration increased significantly when the mercury-feed-stream concentration was maximized, meaningless elemental to total-mercury ratios (>1) were also consistently recorded.

Significantly fewer mercury-vapor measurements were made downstream of the HEME than occurred at the Melter and EVS sampling sites. No observations were, in fact, conducted at the HEME sampling site under the low-mercury-feed condition. However, like the EVS result, a systematic increase in mercury-vapor concentration accompanied the Hi to Mx mercury-feed-composition change, and absurd elemental-to-total-mercury ratios were also observed under maximum mercury-processing conditions. The greater than unity average elemental-to-total-mercury ratio observed under the Hi mercury-feed conditions is in part a consequence of the small number of observations averaged.

It should be pointed out that the concentrations in Table 7.4 and in Figure 7.3 through Figure 7.5 are average results of, in general, noncontemporaneous measurements. As a result, meaningful comparisons of averaged elemental and oxidized concentrations assume stable operating and concomitant off-gas processing conditions, which, for the current test, is a valid supposition. However, it also has to be assumed that the mercury off-gas behavior is functionally and reproducibly related to the controlled process parameters.

Table 7.4. Volatile Mercury Concentration During RSM Test Conditions

	Mercury Species Exhaust Concentration (mg/m^3)					
	Melter		EVS		HEME	
Date/Item	Element	Total	Element	Total	Element	Total
ShakeDwn						
Average	2.60	2.70	0.20	0.14	----	----
Std Dev	0.36	0.45	0.09	0.01	----	----
Min	2.40	2.40	0.13	0.13	----	----
Max	2.90	3.20	0.26	0.15	----	----
#Obs.	2	3	2	2	----	----
Idle #1						
Average	0.50	----	0.11	0.07	----	----
Std Dev	0.61	----	0.12	0.12	----	----
Min	----	----	----	----	----	----
Max	1.20	----	0.24	0.20	----	----
#Obs.	4	2	3	3	----	----
Lo/Lo/Lo						
Average	0.46	0.45	0.35	0.11	----	----
Std Dev	0.89	0.93	0.35	0.23	----	----
Min	----	----	----	----	----	----
Max	5.40	5.50	1.20	0.84	----	----
#Obs.	50	55	25	25	----	----
Lo/Hi/Lo						
Average	0.68	3.10	0.05	0.04	----	----
Std Dev	1.70	2.20	0.06	0.04	----	----
Min	----	----	0.00	----	----	----
Max	14.00	17.00	0.21	0.19	----	----
#Obs.	130	120	19	22	----	----
Lo/Hi/Hi						
Average	2.20	3.70	0.92	0.97	----	----
Std Dev	1.20	1.00	0.53	0.60	----	----
Min	----	1.30	----	0.03	----	----
Max	7.70	7.90	1.40	1.50	----	----
#Obs.	66	61	6	8	----	----
Idle #2						
Average	0.55	2.70	----	----	----	----
Std Dev	0.59	0.95	----	----	----	----
Min	0.23	2.00	----	----	----	----
Max	3.20	6.20	----	----	----	----
#Obs.	24	28	----	----	----	----
Hi/Lo/Lo						
Average	9.60	10.00	3.10	5.20	5.00	6.10
Std Dev	1.90	1.90	2.40	2.60	0.59	2.30
Min	3.00	5.70	0.51	0.48	4.60	1.60
Max	15.00	15.00	7.40	9.20	6.40	7.40
#Obs.	130	130	20	33	8	6

Table 7.4 (Contd)

	Mercury Species Exhaust Concentration (mg/m^3)					
	Melter		EVS		HEME	
Date/Item	Element	Total	Element	Total	Element	Total
Hi/Hi/Lo						
Average	8.10	8.90	4.70	4.70	7.80	4.00
Std Dev	1.70	1.10	2.10	2.30	0.80	3.30
Min	3.60	6.00	1.20	1.10	7.00	0.95
Max	15.00	12.00	10.00	7.10	8.60	8.70
#Obs.	140	140	24	10	3	13
Mx/Hi/Lo						
Average	6.60	9.60	21.00	15.00	14.00	14.00
Std Dev	2.70	2.80	----	2.10	4.40	1.90
Min	0.37	0.17	21.00	9.50	7.30	11.00
Max	22.00	16.00	21.00	18.00	20.00	18.00
#Obs.	110	110	1	54	15	10
Mx/Hi/Hi						
Average	8.20	5.70	14.00	8.00	12.00	10.00
Std Dev	4.00	2.00	2.50	4.10	0.48	1.30
Min	0.12	0.10	7.70	0.08	11.00	9.40
Max	16.00	8.70	19.00	15.00	13.00	12.00
#Obs.	29	29	23	14	8	3
All Cond.						
Average	5.30	6.60	4.30	6.70	11.00	8.20
Std Dev	4.20	4.00	5.40	6.50	4.60	5.20
Min	----	----	----	----	4.60	0.95
Max	22.00	17.00	21.00	18.00	20.00	18.00
#Obs.	680	670	120	170	34	32

In an attempt to further characterize the occurrence and frequency of incongruous instrument responses (e.g., Hg°/Hg>1), quasi-contemporaneous data pairs for each test condition at each sampling location were examined. The results of this evaluation are summarized in Table 7.5, assuming a 20% tolerance, because the measurements, although closely spaced, are nevertheless sequential. For the melter sampling site, the highest frequency of errant data generation occurred during the first (Lo/Lo/Lo) and seventh (Mx/Hi/Hi) test conditions, suggesting that unreliable information was being generated during these testing phases. The conclusion regarding the quality of EVS and HEME data based on this errant frequency criteria is less clear cut as the populations of these time-paired data are too small to be reliably used.

Nevertheless, these tabular results in combination with the high temporal variability of the recorded concentration values suggest that significant instrument-stability problems may be affecting the quality of the data generated. The time-dependent data collected from the melter sampling site shown in Figure 7.6 may help illustrate this point.

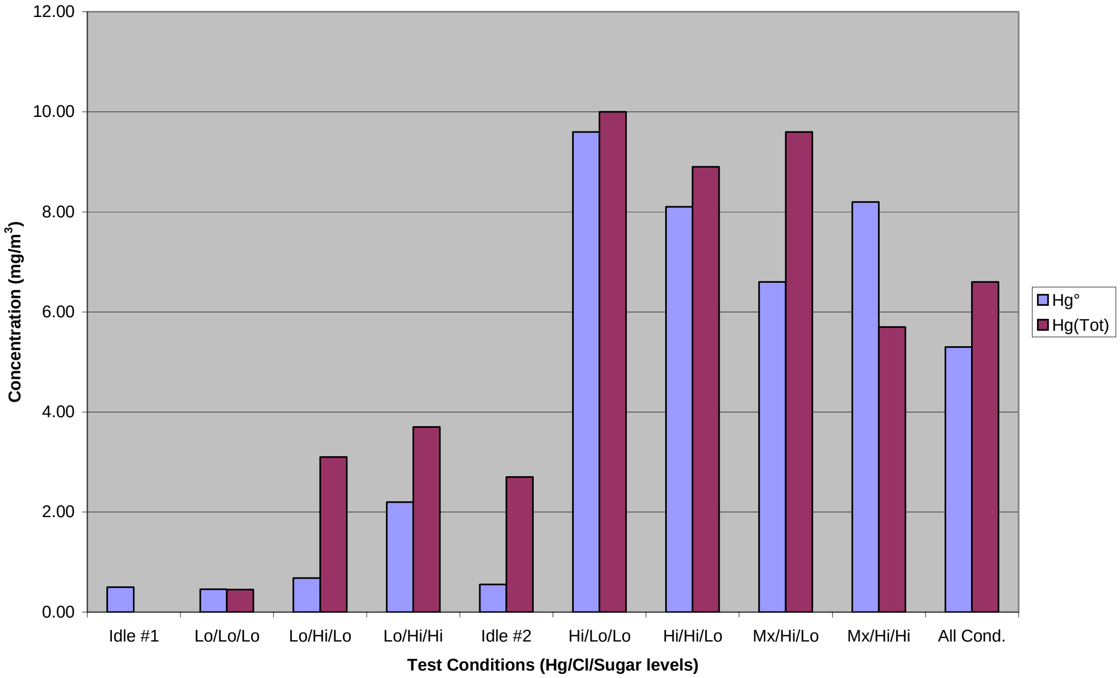


Figure 7.3. Mercury-Vapor Concentration in the Unquenched Melter Exhaust

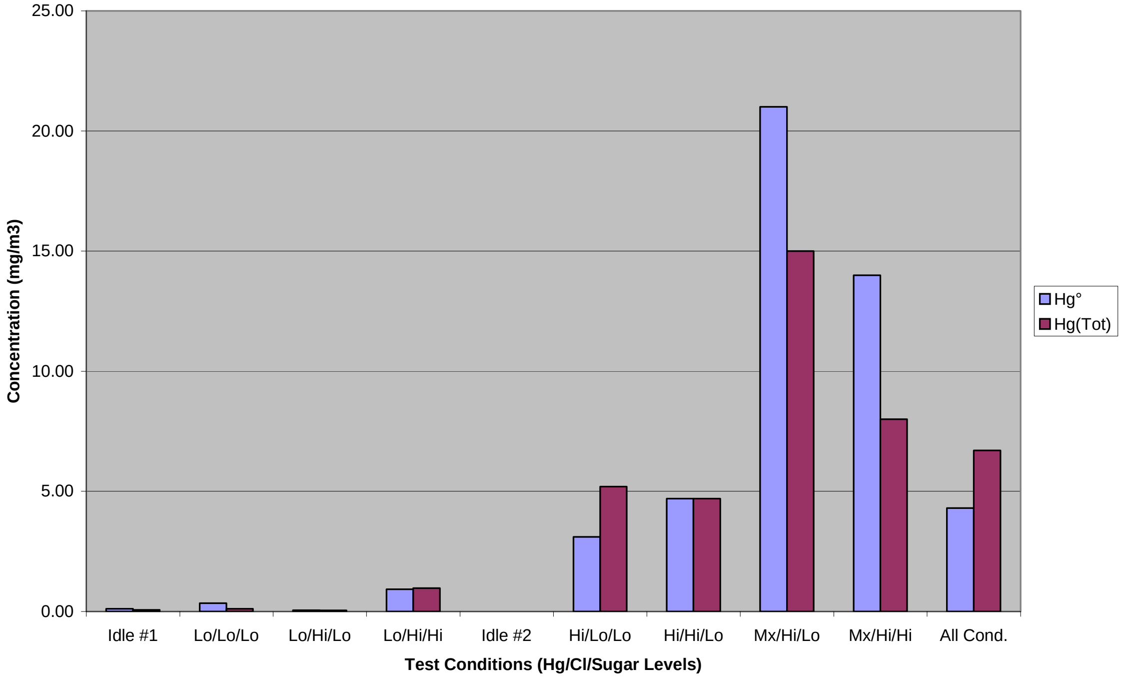


Figure 7.4. Mercury-Vapor Concentration in the EVS Exhaust

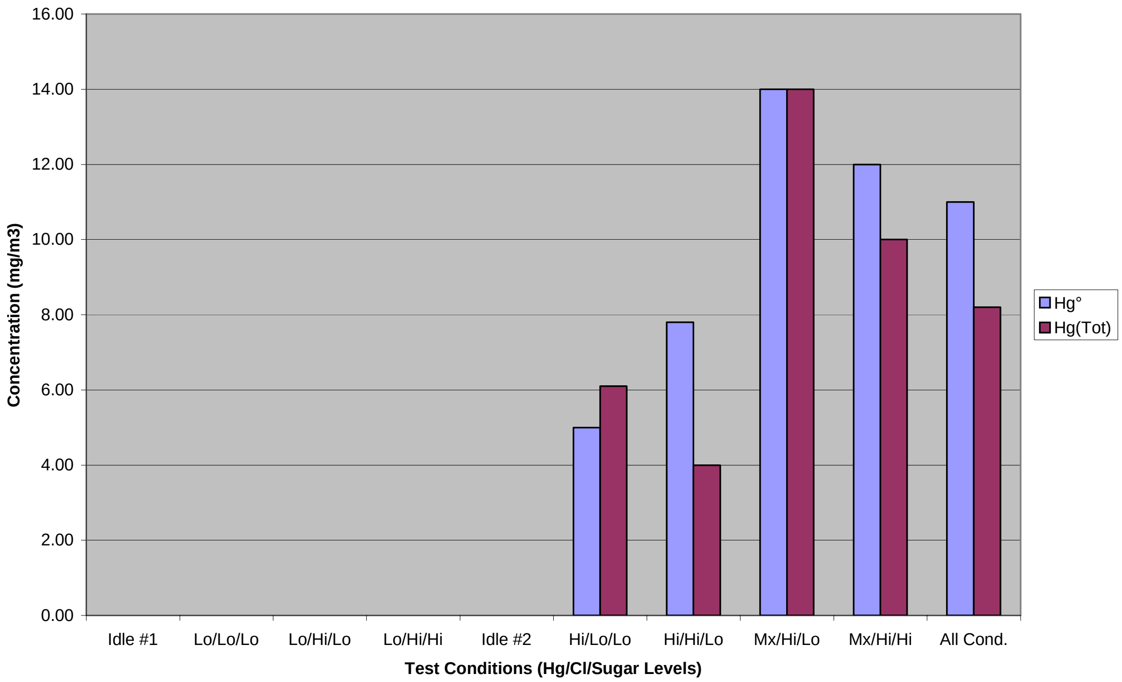


Figure 7.5. Mercury-Vapor Concentration in the HEME Exhaust

Specifically, the instrument response accompanying a step change in reductant feed concentration at ~06:00 on 7/30/03 appears to be a definite cause-and-affect correlation. Indeed, the instrument also appeared to respond appropriately to a feeding interruption at ~09:00. However, after feeding was resumed and steady-state conditions were re-established, the instrument responded differently than before the feed outage. On the basis of systematic arguments, this suggests nonreproducible results, although there could conceivably be unknown factors responsible for the observed changes in process chemistry.

Table 7.5. Paired Elemental and Total-Mercury-Vapor Measurements

	Melter: (Hg°/Hg)		EVS: (Hg°/Hg)		HEME: (Hg°/Hg)	
Condition	**Observ #**	**% >1.2**	**Observ #**	**% >1.2**	**Observ #**	**% >1.2**
Lo/Lo/Lo	23	65	14	64	0	----
Lo/Hi/Lo	42	2	3	33	0	----
Lo/Hi/Hi	20	0	0	----	0	----
Hi/Lo/Lo	43	2	1	100	1	100
Hi/Hi/Lo	45	4	2	50	0	----
Mx/Hi/Lo	62	13	1	100	8	0
Mx/Hi/Hi	28	71	1	100	1	0

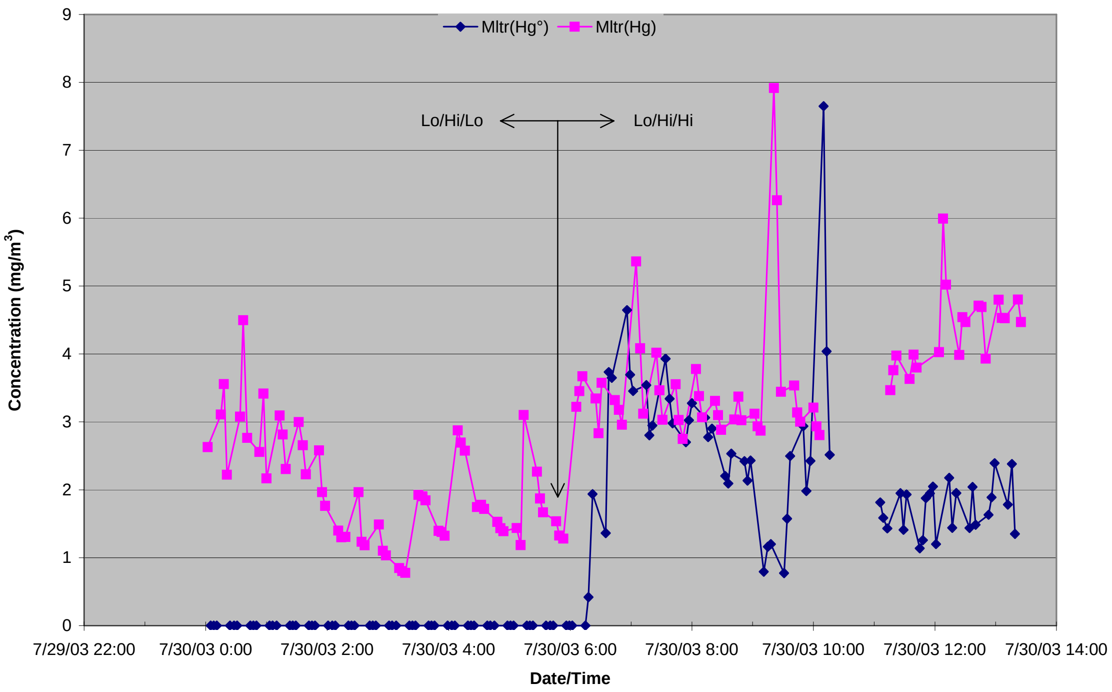


Figure 7.6. Mercury CEM Response to a Step Change in Feed Composition

The time-dependent variability (Std. Dev) in the data collected during each test condition summarized in Table 7.4 and graphically portrayed in Appendix C further erodes confidence in the quantitative validity of much of the CEM data collected since stable processing conditions existed throughout essentially all phases of testing. The only exceptions to the above characterization occurred during the Hi/Lo/Lo and Hi/Hi/Lo test segments where instrument responses were long-term stable and reproducible but were nevertheless significantly below engineering expectations (see Table 7.1). Although certain aspects of Hg CEM data compare favorably with off-gas sampling and secondary-waste-stream analytical results to be subsequently discussed, these latter results, as will be shown, undercut the overall quantitative validity of the quasi real-time mercury-monitoring data.

As will be further discussed in Section 8.5, inadequate sample-stream dilution is likely responsible for instrument condensation losses and resultant low concentration-related responses. This unfortunate circumstance, if true, should not, however, appreciably affect Hg:$HgCl_2$ ratio measurements, as these species exhibit very similar vapor-pressure characteristics.

7.3 Condensed-Phase Effluents

The effluents entering the MOG system that require long-term environmental isolation are primarily condensed-phase matter, i.e., aerosols. Many feed components are volatilized to some extent within the melter; however, rapid condensation in the melter plenum transforms most of these effluent vapors to airborne aerosols before they can be carried into the off-gas system. Feed and/or glass matter can also be physically ejected into the melter-plenum volume by cold-cap and/or glass-surface turbulence. Once in the plenum, this debris can become entrained in gas currents and exhausted from the melter as entrained particulate matter. Both of these loss mechanisms produce off-gas system aerosols; however, the physical characteristics and chemical composition of these two types of airborne matter are markedly different.

Entrained aerosols typically have a mass-median diameter of » 1 µm and are compositionally similar to the feed. Consequently, entrainment losses, to first approximation, will influence all feed components in the same way. Feed constituents that fume at melter vitrification temperatures, e.g., alkali halides, quickly form condensation aerosols, which are predominantly submicron and are chemically dissimilar to the bulk feed. The importance of the volatilization/condensation loss mechanism is totally dependent upon the physical and chemical properties of the feed components and the range of compounds they can form. Consequently, melter aerosol loss rates will be exacerbated by the presence of semi-volatile feed components, and effluent emission rates of elements capable of forming semi-volatile compounds will always be greater than those elements only capable of forming refractory compounds. Effluent loss rates are traditionally expressed in terms of equipment DFs. A device DF value for a particular feed component is derived by taking the ratio of the rate at which the component enters the device to the rate at which it exits. Aerosol DFs are partial DFs that relate to only one off-gas effluent form: aerosols.

7.3.1 Aerosol Mass DFs

The melter's aerosol mass DFs, as measured by the filter catches of the Method 29, differential sampler previously described, are tabulated in Table 7.6 for each distinct sample taken during RSM testing. Sampling data were taken during four of the seven test conditions previously discussed in Section 2 of this report. The four conditions sampled were considered to be most likely to reveal any differences in off-gas mercury chemistry related to the test's independent parameters.

These melter aerosol loss data summarized in Table 7.6 represent a 0.6% to 2.5% mass partitioning to the off-gas system, which is entirely consistent with previous small-scale melter flowsheet tests. Also listed in this table are related melter DFs and off-gas aerosol loading values. Since the processing data presented in Section 6.1 clearly demonstrated that uniform feeding and concomitant stable, steady-state cold-cap conditions were achieved throughout RSM testing, the variability of these condensed-phase melter loss data is indicative of the significant range over which stable melter processing conditions can be achieved.

It should be noted that quasi isokinetic sampling conditions were achieved during RSM particulate sampling campaigns. Consequently, a fairly representative sample of off-gas aerosols should have been collected by the sampling filters. With the caveat that sampling was conducted in a small 2-in.-OD pipe, 96% isokinetic conditions, on the average, were maintained throughout all sampling campaigns. The relative proportions of fuming to entrained effluents will be examined in the following section.

Table 7.6. Gross Melter Aerosol Emission Characteristics

Date/Time		Proc. Cond.		Sampling		MOG Flw	Aerosol Catch		Melter	
Start	Stop	#	Hg/Cl/Red	Time (m)	Flw (slpm)	(scfm)	Mass (g)	Con (mg/L)	DF	Loss%
07/30/03 00:04	07/30/03 01:59	2	Lo/Hi/Lo	115	15.7	6.2	1.020	0.562	100	1.00
07/30/03 23:19	07/31/03 01:19	4	Hi/Lo/Lo	120	17.4	5.8	1.480	0.710	87	1.15
07/31/03 23:32	08/01/03 01:32	5	Hi/Hi/Lo	120	15.9	5.5	2.760	1.450	40	2.51
08/02/03 00:42	08/02/03 02:42	7	Mx/Hi/Hi	120	15.8	5.6	0.808	0.427	161	0.62

7.3.2 Aerosol Elemental DFs

Individual melter-aerosol DFs have been calculated for all melter-feed components using the compositional data derived from off-gas filter samples. A comparison of these filter compositional data with the oxide-feed target values is shown in Table 7.7. It must be pointed out that the silica content of the Method 29 aerosol samples does not include likely sizable contributions from the filter material, as the quartz filter substrate was digested with the aerosol material it contained. As a result, the wt% values of all effluent constituents are artificially elevated relative to the corresponding feed data also appearing in Table 7.7. To establish a clearer basis for comparing the aerosol samples with the baseline feed composition, the sample data in Table 7.7 have been normalized to iron—a classic nonvolatile feed constituent. These results, detailed in Table 7.8, show that the concentration of the classic semivolatiles (e.g., B, Cs, Cr) are modestly enriched over their nominal feed-composition values. As expected, the non-fuming components, such as Ca, La, Mn, and Zn, are seen to be present at much lower to nominally equivalent feed concentrations. The high aluminum ratio in these samples, as discussed previously, is due to its higher than target concentration in the feed. The general compositional characteristics of the effluents listed in Table 7.8 are in total conformity with generalized LFCM effluent-emission expectations developed from past melter-source-term characterization studies.

Using target feed-composition and physical-property information provided in Section 5, melter DFs associated with aerosol loss for individual elements can be calculated for the constituents listed in Table 7.7. These derived DF values are tabulated in Table 7.9. These tabular results reinforce the previous discussion that predicted low DFs for feed constituents that are volatile or can form volatile or semivolatile compounds at melter-processing temperatures and higher DFs for those that cannot.

Although enhanced relative to refractory, non volatile components, the Cs losses recorded, as predicted earlier from glass-composition results, are significantly lower than nominal expectations (DF=10). On the other hand, the vanishingly low glass concentrations of mercury and its relatively high aerosol DF suggest high volatility losses for this element, especially for the Mx/Hi/Hi test condition.

The reproducibility of melter-feed component DFs is, overall, quite good. Furthermore, the magnitudes of the DF values listed in Table 7.9 are well within expectations and are quite representative of average melter-performance behavior.

7.3.3 Volatile Partitioning and Total Elemental DFs

Since only a very few feed components are lost to the off-gas processing system in the gaseous state, essentially all the aerosol performance values listed in Table 7.9 also represent total melter DFs for these elements. Notable exceptions to this statement include B, Cl, F, Hg, P, and S, whose volatility usually dominates melter off-gas system losses and determines their melter DFs. However, because the methodology and chemical solutions employed in Method 29 sampling precluded halide analyses in the various sample fractions, only B, Hg, P, and any volatilized metals (e.g., Cr) could be effectively tracked. Table 7.10 summarizes the overall cumulative elemental mass collected by the Method 29's impinger train for effluents penetrating the upstream aerosol filter of the differential sampling system previously described (see Section 4.1.4.2). With the exception of B, Hg, and possibly Cr, these data show little evidence of other gas-phase effluents. The other cations in these impinger solutions are an artifact of reagent blank correction uncertainties.

Table 7.7. Oxide Composition of Melter-Generated Aerosols and Melter Feed

	Hg/Cl/Red Test Condition Aerosol Compositions (Wt%)							
	Lo/Hi/Lo		Hi/Lo/Lo		Hi/Hi/Lo		Mx/Hi/Hi	
Oxide	**Aerosol**	**Feed**	**Aerosol**	**Feed**	**Aerosol**	**Feed**	**Aerosol**	**Feed**
Al_2O_3	8.140	3.580	7.840	3.580	8.100	3.570	7.800	3.540
B_2O_3	27.400	10.800	27.000	10.800	24.900	10.800	22.100	10.700
CaO	0.499	0.480	0.485	0.479	0.457	0.479	0.505	0.475
Cl	----	0.060	----	0.009	----	0.060	----	0.060
Cr_2O_3	0.145	0.060	0.155	0.060	0.138	0.060	0.127	0.059
Cs_2O	0.191	0.050	0.195	0.050	0.164	0.050	0.198	0.050
CuO	0.035	0.030	0.034	0.030	0.032	0.030	0.051	0.030
F	----	0.120	----	0.120	----	0.120	----	0.119
Fe_2O_3	13.900	9.530	13.500	9.530	16.000	9.520	13.900	9.450
HgO	0.257	0.050	0.331	0.150	0.170	0.150	1.300	0.950
I	----	0.100	----	0.100	----	0.100	----	0.099
La_2O_3	0.253	0.150	0.235	0.150	0.247	0.150	0.273	0.149
Li_2O	2.950	3.310	4.430	3.310	4.510	3.300	4.300	3.280
MnO	1.650	1.520	1.810	1.520	2.550	1.520	1.660	1.500
Na_2O	26.600	11.500	24.900	11.500	24.300	11.500	22.800	11.400
Nd_2O_3	----	0.110	----	0.110	----	0.110	----	0.109
NiO	0.657	0.470	0.762	0.469	0.757	0.469	0.702	0.465
P_2O_5	0.222	0.040	0.237	0.040	0.240	0.040	0.144	0.040
PbO	0.255	0.120	0.206	0.120	0.196	0.120	0.281	0.119
$SiO_2^{(a)}$	5.100	46.300	3.080	46.300	2.390	46.300	4.410	45.900
SrO	0.003	----	0.004	----	0.005	----	0.005	----
TiO_2	0.094	0.020	0.114	0.020	0.138	0.020	0.098	0.020
ZnO	3.720	2.160	3.440	2.160	3.460	2.160	3.350	2.140
ZrO_2	7.950	9.420	11.200	9.420	11.300	9.410	16.000	9.340

(a) Greater/equal value

Table 7.8. Normalized Oxide Composition of Melter-Generated Aerosols

	Aerosol Element Ratio For Hg/Cl/Red Fd Batches					Baseline Feed
Element	**Lo/Hi/Lo**	**Hi/Lo/Lo**	**Hi/Hi/Lo**	**Mx/Hi/Hi**	**Average**	
Al	0.443	0.439	0.384	0.424	0.422	0.284
B	0.873	0.888	0.693	0.704	0.789	0.503
Ca	0.037	0.037	0.029	0.037	0.035	0.051
Cl	----	----	----	----	----	----
Cr	0.010	0.011	0.008	0.009	0.010	0.006
Cs	0.019	0.020	0.014	0.019	0.018	0.007
Cu	0.003	0.003	0.002	0.004	0.003	0.004
F	----	----	----	----	----	0.018
Fe	1.000	1.000	1.000	1.000	1.000	1.000
Hg	0.025	0.032	0.014	0.124	0.049	----
I	----	----	----	----	----	0.015
La	0.022	0.021	0.019	0.024	0.022	0.019
Li	0.141	0.218	0.188	0.205	0.188	0.230
Mn	0.132	0.149	0.177	0.132	0.147	0.176
Na	2.030	1.960	1.610	1.740	1.830	1.280
Nd	----	----	----	----	----	0.014
Ni	0.053	0.063	0.053	0.057	0.057	0.055
Pb	0.021	0.023	0.020	0.014	0.020	0.017
P	0.012	0.010	0.008	0.013	0.010	0.003
Si	0.245	0.152	0.100	0.212	0.177	3.250
Sr	0.0002	0.0003	0.0004	0.0005	0.0004	----
Ti	0.006	0.007	0.007	0.006	0.007	0.002
Zn	0.307	0.292	0.249	0.277	0.281	0.260
Zr	0.605	0.876	0.749	1.220	0.861	1.050

As was done for particulate matter, volatile melter DFs, which are partial DFs relating to only volatile melter losses, can be derived by combining the meaningful condensate data with actual feed-compositional and physical-property information previously discussed in Section 5. These volatile DFs are summarized in Table 7.11.

As discussed above, the only constituents with any significant volatility in this list are Hg, B, and possibly Cr. The low volatile DFs determined for Hg were expected, and this behavior was quite reproducible, except possibly for the Lo/Hi/Lo sampling period during which time a significant proportion (11 wt%) of effluent mercury was associated with condensed phase (particulate) matter. The volatile DFs determined for boron were found to be consistent throughout all phases of testing, and their magnitudes were quite comparable with previous melter results.

By combining the aerosol-filter and corresponding impinger sampler fractions for condensed and condensable effluents, total melter DFs for all feed constituents detected in the process exhaust can be derived. Table 7.12 summarizes total elemental melter DFs measured during the processing of C-104/AY-101 waste-feed simulant. Comparison of these total values with corresponding particulate DFs previously discussed (Table 7.9) clearly illustrate the dominant role played by the aerosol loss mechanism. Volatility contributions to the melter-effluent source term were only significant for boron and mercury, although halogen behavior, as discussed earlier, could not be determined; all other total DFs are nominally equivalent to their particulate values.

Table 7.9. Elemental Melter DFs Associated With Aerosol Emissions

	Melter Aerosol DF For Hg/Cl/Red Feed Batch				
Element	**Lo/Hi/Lo**	**Hi/Lo/Lo**	**Hi/Hi/Lo**	**Mx/Hi/Hi**	**Ave(a)**
Al	70	70	31	139	59
B	63	61	31	149	56
Ca	153	150	74	289	132
Cl	----	----	----	----	----
Cr	66	59	31	143	56
Cs	42	39	21	77	37
Cu	137	133	65	179	112
F	----	----	----	----	----
Fe	109	107	42	208	85
Hg	31	69	62	224	59
I	----	----	----	----	----
La	94	97	43	167	80
Li	178	114	52	----	89
Mn	146	127	42	209	92
Na	69	70	33	----	51
Nd	----	----	----	2	----
Ni	114	94	44	203	85
Pb	86	77	35	254	70
P	25	30	14	43	24
Si	----	----	----	----	----
Sr	----	----	----	----	----
Ti	34	27	10	62	22
Zn	92	96	44	196	81
Zr	188	128	59	179	112

(a) From average partitioning values.

These element-specific, total DFs, like their corresponding particulate values, are reasonably close to general expectations and are with few exceptions consistent with previous RSM melter-testing results. Mercury, however, is an exception to this statement. Although fairly low DFs (<2) were recorded for all but the Lo/Hi/Lo test condition, the general expectation as validated by the glass data presented in Section 5.4.2, is that a DF of ~1 should have been obtained. At melter and off-gas operating temperatures, no significant loss mechanism between the melter and the EVS can be identified that might be responsible for the greater-than-unity DFs measured. Analytical losses, unrepresentative sampling, and/or analytical uncertainties are no doubt factors responsible for the higher-than-expected DF results obtained.

Table 7.10. Off-Gas Sampler Impinger Solution Composition

	Impinger Train Integral Catch (mg)				
Element	**Lo/Hi/Lo**	**Hi/Lo/Lo**	**Hi/Hi/Lo**	**Mx/Hi/Hi**	**Average**
Al	0.195	0.243	----	0.200	0.211
B	12.300	11.000	14.600	18.700	13.600
Ca	0.074	0.199	0.237	0.064	0.104
Cr	0.046	----	----	----	0.046
Cu	----	----	----	0.015	0.015
Fe	0.078	0.144	0.072	0.610	0.114
Hg	10.200	98.500	72.700	539.000	32.400
Li	----	----	----	16.600	16.600
Na	2.480	2.140	2.380	0.362	0.987
Si	----	0.095	0.020	0.160	0.046
Zn	----	0.069	----	0.025	0.037

Table 7.11. Volatile Melter DFs from Impinger Solution Data

	Melter Volatile DF For Hg/Cl/Red Fd Batch				
Element	**Lo/Hi/Lo**	**Hi/Lo/Lo**	**Hi/Hi/Lo**	**Mx/Hi/Hi**	**Average[(a)]**
Al	8,500	8,640	----	10,500	8,570
B	239	338	217	198	238
Ca	4,080	1,910	1,370	5,890	2,400
Cr	781	----	----	----	781
Fe	74,700	51,400	87,200	12,100	31,500
Hg	4	2	2	2	2
Na	3,010	4,420	3,390	26,000	4,480
Si	----	252,000	1,000,000	150,000	258,000
Zn	----	27,800	----	76,700	40,800
(a) From average partitioning values.					

Apart from generating volatility DF information, the Method 29 sampling train, as previously described (Section 4.1.4.2), is also capable of providing mercury-speciation information as well. Table 7.13 summarizes the distribution of mercury effluent across the filter and sequential H_2O_2 and $KMnO_4$ chemically selective gas-scrubber traps. These data show that the majority of the total Hg (94% on average) was captured by the initial H_2O_2/HNO_3 gas-scrubber impingers, suggesting, at first glance, that most of the total mercury existed as a chemically combined volatile (e.g., $HgCl_2$) at the film-cooler outlet. However, this is only a correct interpretation if the elemental mercury-vapor dew point of the influent stream is below the gas scrubber's bath temperature (0°C). For the current test, this condition was never satisfied. Table 7.14 projects the mercury distribution across the Method 29 sampling components if the mercury influent source was totally in its elemental state. Since the model used assumes equilibrated vapor-pressure conditions and neglects condensed phase-carryover effects, the $KMnO_4$ projections represent minimum expectation values.

Table 7.12. Total Individual Elemental Melter DF Values

	Total Melter DF				
Element	**Lo/Hi/Lo**	**Hi/Lo/Lo**	**Hi/Hi/Lo**	**Mx/Hi/Hi**	**Average[(a)]**
Al	69.3	68.9	31.1	138.0	58.5
B	49.7	51.6	26.8	85.0	45.1
Ca	147.0	139.0	70.1	275.0	125.0
Cl	----	----	----	----	----
Cr	60.6	58.9	30.6	143.0	54.7
Cs	41.6	38.9	21.4	76.6	36.5
Cu	137.0	133.0	65.4	163.0	110.0
F	----	----	----	----	----
Fe	109.0	107.0	42.0	205.0	84.7
Hg	3.5	1.5	1.8	1.8	1.9
I	----	----	----	----	----
La	94.3	97.1	42.8	167.0	79.6
Li	178.0	114.0	51.6	71.2	83.6
Mn	53.5	37.0	13.1	98.2	30.3
Na	67.0	68.9	32.9	152.0	60.3
Nd	----	----	----	----	----
Ni	114.0	93.8	43.6	203.0	84.6
Pb	85.8	76.8	35.2	254.0	70.2
P	24.9	29.5	14.3	43.2	24.0
Si	----	2,270.0	1,360.0	3,130.0	2,010.0
Sr	----	----	----	----	----
Ti	33.7	26.7	10.2	62.1	22.0
Zn	92.3	95.1	43.9	195.0	81.2
Zr	188.0	128.0	58.7	179.0	112.0

(a) From average partitioning values.

Comparing Table 7.13 results with the Table 7.14 projections, the absence of significant mercury in the $KMnO_4$ catch during the Lo/Hi/Lo test condition suggests a predominantly chemically-combined mercury effluent source, which is in total conformity with the mercury CEM results discussed earlier (see Section 7.2.2). For the Hi-Hg/Lo-Cl test condition, the results suggest a mercury-effluent source dominated by the elemental form, which, again, is in total conformity with the previously discussed CEM data. On the other hand, a mixed volatile mercury source is suggested during the Hi-Hg/Hi-Cl test condition, as the proportion of mercury trapped in the final $KMnO_4$ impinger solutions was below the minimum projected value for a pure Hg° source. The Hg CEM data taken during this test period suggests, on the average, that 90% of the volatile mercury was in its elemental state. The sample-train distribution of mercury under the Mx-Hg/Hi-Cl test condition appears to have been influenced by breakthrough and/or Hg-mist carryover effects and as a consequence provides no useful speciation insights.

Table 7.13. Distribution of Mercury Effluent Across Sampler Components

Test Cond	% Collected By Device		
	Filter	H_2O_2	$KMnO_4$
Lo/Hi/Lo	11.400	88.600	0.003
Hi/Lo/Lo	2.220	94.800	2.950
Hi/Hi/Lo	2.830	96.200	0.990
Mx/Hi/Hi	0.806	98.000	1.160

Table 7.14. Projected Elemental Mercury Distribution Across Sampler Components

	Hg° Temp Partitioning[(a)] (%)		
Test Cond	Filter	H_2O_2	$KMnO_4$
Lo/Hi/Lo	0.0	91.2	8.8
Hi/Lo/Lo	0.0	97.1	2.9
Hi/Hi/Lo	0.0	97.1	2.9
Mx/Hi/Hi	0.0	99.5	0.5

(a) Filter 150°C; Impingers 0°C

Additional effluent speciation insights can sometimes be inferred from the off-gas behavior and resultant distribution of effluents in successive off-gas emission abatement devices. Indeed, estimates of total melter, elemental DFs can also be extracted from the off-gas system and secondary-waste-stream-composition data, provided the volatiles are efficiently captured by emission-abatement equipment and that the resultant equipment effluent steams can be representatively sampled. These off-gas-related insights and source-emission estimates will be discussed in the following Section.

7.4 Process-Waste-Stream Composition

The RSM's off-gas system, which is composed of an EVS quench scrubber, a HEME (deep-bed regenerable filter), and a HEPA filter, acts like a multi-component sampler for process aerosols and condensable and/or reactive effluent gases (see Section 4.1.3). The EVS function is to quench and condition the hot melter-exhaust stream for subsequent cleanup stages. As such, it removes entrained (large-diameter) debris and condenses steam and other chemically reactive and/or condensable gases that are generated during LFCM processing. Boron, chlorine, fluorine, phosphorus, and sulfur feed components are all volatilized to some extent during LFCM processing, and some of the volatile species are efficiently removed (physically and/or chemically) by the aqueous off-gas system quencher—in this case, the EVS. The HEME serves to efficiently demist the EVS's exhaust stream and to remove small-diameter aerosols (<1 μm) that successfully penetrate the upstream EVS. However, because of its high surface area and the moisture content of the influent stream, it can also serve as a fairly efficient aqueous contactor for reactive/condensable gases. The HEPA is a polishing filter that removes any remaining off-gas aerosols before the off-gas is released to the environment.

An aqueous secondary waste stream is generated by both the EVS and HEME off-gas processing devices, although the extent of HEME runoff can be significantly influenced by temperature and dew-point considerations. In the case of the EVS, both soluble and insoluble matter that accumulates within this device's condensate tank is readily collectable. The waste stream generated by the HEME, on the other hand, is composed primarily of soluble-effluent species that dissolve in, usually, a highly acidic oxidizing aqueous media. Because of its extremely high surface area, the HEME provides efficient contacting between acid gasses (e.g., NO_x, SO_x, and halogens) and the mist-generated aqueous run-off. Insoluble solids collected on the HEME are not directly recoverable, as is the case with the HEPA filter, which is itself a secondary waste. Consequently, overall melter DFs can be approximated from the compositions and flow rates of the secondary waste streams generated by the EVS and HEME.

7.4.1 EVS Condensate Composition

Although UDS were not collected from the EVS's condensate tank until the RSM test was complete, EVS supernatant was sampled throughout the duration of melter flowsheet testing. The time-dependent cation composition of this EVS scrubbing liquor during RSM testing is summarized in Table 7.15 while condensate physical properties (pH and density) and anion composition are detailed in Table 7.16. The fact that only universally soluble species (e.g., halogens, nitrates, and alkali-earths boron) exhibit a strongly increasing concentration while insolubles (e.g., Fe, Mg, Mn, and Si) do not is a reflection of the presence of these latter constituents in the UDS. The time-dependent, monotonically increasing soluble anions concentrations are graphically shown in Figure 7.7 where the dramatic increases in time are amplified by a low-steam-condensing efficiency (22%) of the EVS due to high operating temperatures (~33°C) as discussed in Section 6.2.6.

Also presented in this graphical display is the time- and test-dependent behavior of soluble mercury. Clearly, the most dramatic aspect of the mercury data presented is the step change in soluble mercury concentration that was associated with the 6-h, high-reductant-processing campaign—the Lo/Hi/Hi test condition. Unfortunately, the magnitude of this accumulation is totally inconsistent with the quantity of mercury processed during this 7.5-h test period. The only possible, nontrivial explanation for such a short-term injection of the significant quantities of mercury required to produce the observed concentration change is to assume that a long-term mercury-accumulation source in the EVS inlet port suddenly collapsed and was transferred to the condensate tank by the EVS water jet.

Since the EVS' inlet port provides a 200ºC to 30ºC temperature transition region that can influence condensable gases, selective condensation and resultant accumulation of volatile, chemically-combined mercury compounds is a completely plausible circumstance. Indeed, the composition of pipe deposits to be subsequently discussed corroborates that vapor deposition at the EVS' inlet is an observable fact. Assuming that the mercury injection mechanism as described above is true, the EVS condensate result suggests that chemically combined mercury dominated the melter mercury source term during the initial three test conditions. Furthermore, the declining mercury concentrations for all subsequent samples suggest an EVS process chemistry that slowly converts soluble mercury into insoluble sludge, and a melter source that, under all but Lo-Hg test conditions, is generating predominantly insoluble forms of mercury effluent. Although the spike result could also be explained by analytical contamination and/or error, the systematic and dramatic change in the mercury content of condensate samples collected before and after the large injection cannot be adequately explained without the presence of such an event.

Table 7.15. EVS Condensate Soluble Effluent Composition

	EVS Condensate Concentration at Test-Condition Conclusion (mg/L)							
Element	**ShkDwn**	**Lo/Lo/Lo**	**Lo/Hi/Lo**	**Lo/Hi/Hi**	**Hi/Lo/Lo**	**Hi/Hi/Lo**	**Mx/Hi/Lo**	**Mx/Hi/Hi**
B	31.00	120.00	190.00	210.00	270.00	320.00	370.00	375.00
Ca	18.00	6.20	1.40	0.90	0.41	0.18	0.46	0.44
Cl	8.77	16.80	31.70	38.60	49.70	64.80	78.10	86.40
Cr	0.30	0.93	1.20	1.40	1.50	1.70	1.60	1.00
Cs	----	1.40	1.90	2.30	2.70	2.90	3.10	3.30
F	20.60	55.40	82.50	95.50	126.00	154.00	176.00	183.00
Fe	----	0.06	1.70	0.26	0.38	0.45	0.60	0.40
Hg	0.01	6.00	5.50	175.00	110.00	49.00	31.00	35.00
I	11.50	13.80	23.00	31.30	34.50	33.30	5.75	5.75
Li	6.40	26.00	40.00	45.00	56.00	73.00	79.00	80.00
Na	62.00	220.00	330.00	370.00	470.00	600.00	640.00	660.00
Ni	----	----	----	----	----	----	0.07	----
Si	5.10	6.20	6.40	6.80	7.00	6.90	7.50	6.70
Sr	0.80	0.18	0.03	0.03	----	----	----	----
Zn	0.07	0.06	0.09	0.12	0.15	0.19	0.30	0.26
Zr	----	0.06	----	----	0.16	0.20	0.28	0.27
Vol (L)	90	95	95	97	100	106	110	113

Table 7.16. EVS Condensate Soluble-Anion Concentrations

				Concentration (mg/L)								
Sample ID	**Hg/Cl/Red**	**pH**	**SpG**	**Cl^{-1}**	**NO_2^{-1}**	**Br^{-1}**	**NO_3^{-1}**	**PO_4^{-3}**	**SO_4^{-2}**	**$C_2O_4^{-2}$**	**I^{-1}**	**F^{-1}**
RSM-Hg-9	ShkDwn	7.9	1.00	8.77	3.91	< 1	26.4	< 7	19.7	< 2.4	< 7	20.5
RSM-Hg-25	Lo/Lo/Lo	8.1	1.00	16.80	16.20	< 0.5	23.6	< 3.5	36.8	0.783	< 3.5	55.3
RSM-Hg-39	Lo/Hi/Lo	8.3	1.00	31.70	25.00	< 0.5	24.8	< 3.5	47.4	0.602	< 3.5	82.2
RSM-Hg-44	Lo/Hi/Hi	8.3	1.00	38.60	24.00	< 0.5	24.6	< 3.5	56.1	0.783	< 3.5	95.2
RSM-Hg-59	Hi/Lo/Lo	8.4	1.00	49.70	33.60	< 1	26.6	< 7	68.6	1.200	< 7	126.0
RSM-Hg-74	Hi/Hi/Lo	8.4	1.00	64.80	39.80	< 1	27.2	< 7	75.5	1.810	< 7	154.0
RSM-Hg-86A	Mx/Hi/Lo	8.4	1.00	78.10	47.10	< 1	29.0	< 7	79.4	1.200	< 7	176.0
RSM-Hg-89	Mx/Hi/Hi	8.4	1.00	86.40	63.00	< 2	32.1	< 14	86.1	1.450	< 14	183.0
RSM-Hg-100	#N/A	8.4	1.00	41.00	29.40	< 1	20.6	< 7	43.1	< 2.5	< 7	75.7

EVS UDS, as mentioned above, were harvested from the condensate tank at the conclusion of testing. These solids were concentrated, sampled, dried, weighed, and homogenized before being sent to the analytical laboratory. The compositional results obtained from two independent UDS samples are summarized in Table 7.17. The results reveal a very significant inventory of accumulated mercury, as well as classically insoluble feed constituents, e.g., Fe, Si, and Zr. Table 7.18 summarizes the elemental distributions of all detected EVS effluent species between the soluble aqueous phase and the UDS. In agreement with the inferences of graphical data previously discussed, the EVS' soluble inventory of mercury at the conclusion of testing represents only ~9% of the total mercury collected by this device.

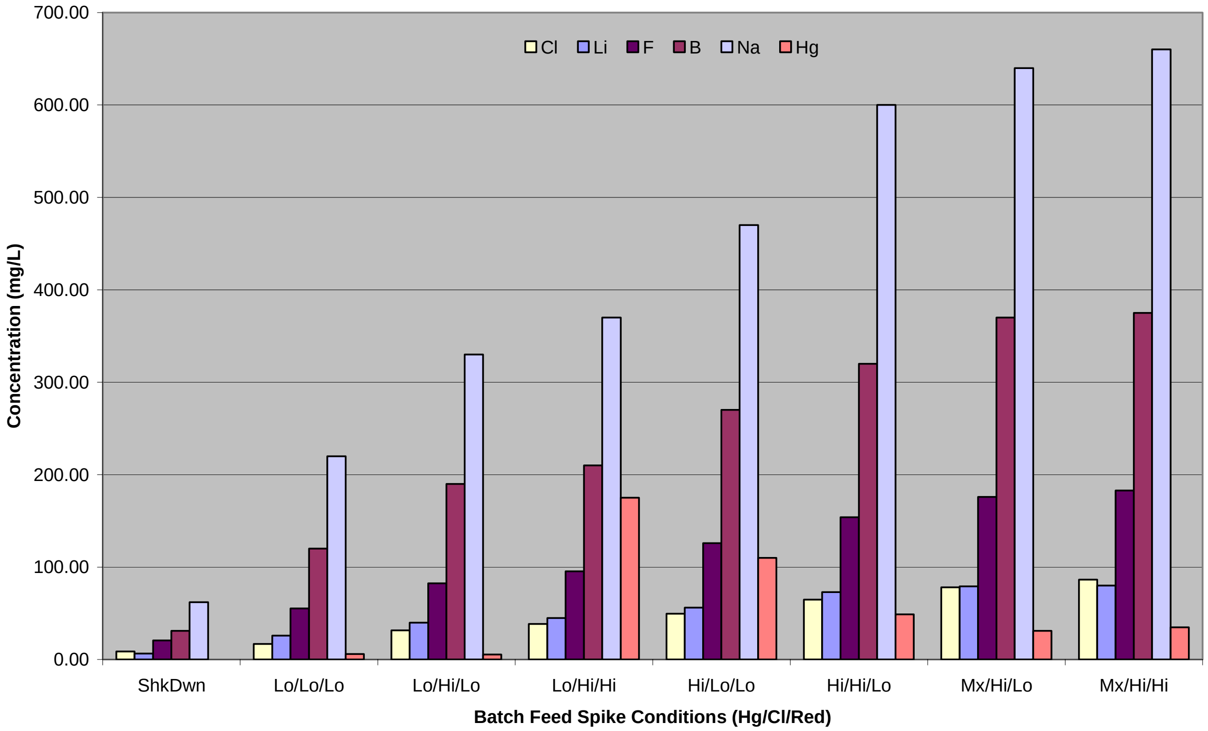


Figure 7.7. EVS Condensate Anion Concentrations at the Conclusion of Sequential Test Conditions

7.4.2 Overall Melter DF

As mentioned earlier, total melter, elemental DFs can also be estimated from the off-gas system and secondary-waste-stream-composition data, provided the volatiles are efficiently captured by emission-abatement equipment and that the resultant equipment effluent steams can be representatively sampled. Using the EVS waste-stream composition, volumes and/or masses with melter feed composition, and physical properties in combination with processing-history information, overall average melter DFs have been derived for the C-104/AY-101 flowsheet test. Table 7.19 presents these DF approximations and compares them to the reference average values derived from the off-gas sampling campaigns.

These data show that both off-gas sampling and secondary-waste-stream derived DF values exhibit the same relative trends for related groups of elements and are of remarkably comparable magnitudes for most corresponding waste constituents. Not surprisingly, the greatest differences between these data sets are associated with volatile constituents that present unique and significant EVS collection difficulties. In particular, the ~2× difference in sampling and EVS mercury DFs suggest a likely significant accumulation of mercury in the downstream HEME, which will be subsequently discussed. The general agreement between multiple off-gas sampling results, taken during ~2-h periods, and cumulative overall test DF results further corroborates that stable operating conditions prevailed throughout most phases of this melter-flowsheet-evaluation study. Furthermore, the overall element-specific DFs recorded using both approaches are all reasonably close to general expectations.

Table 7.17. Composition of EVS Undissolved Solids

	EVS UDS Wt%		Average	
Element	**RSM-96A**	**RSM-96B**	**(Wt%)**	**(g)**
Al	3.520	3.410	3.470	26.200
B	0.712	0.703	0.707	5.350
Ca	0.637	0.717	0.677	5.120
Cl	----	----	----	----
Cr	0.086	0.080	0.083	0.627
Cs	0.042	0.042	0.042	0.320
Cu	0.039	0.038	0.039	0.292
F	----	----	----	----
Fe	9.610	9.190	9.400	71.100
Hg	4.910	5.930	5.420	41.000
I	----	----	----	----
La	0.121	0.122	0.122	0.921
Li	0.177	0.530	0.353	2.670
Mn	0.918	0.917	0.917	6.940
Na	1.500	1.720	1.610	12.200
Nd	----	----	----	----
Ni	0.527	0.445	0.486	3.670
Pb	0.142	0.147	0.145	1.090
P	0.101	0.089	0.095	0.718
Si	15.000	14.900	15.000	113.000
Sr	0.063	0.109	0.086	0.648
Ti	0.095	0.095	0.095	0.717
Zn	1.540	1.530	1.530	11.600
Zr	9.620	10.600	10.100	76.300
Total EVS UDS Mass				756.000

7.4.3 HEME Effluent Catch

Although a HEME aqueous runoff stream is normally expected, ambient temperatures during the test period created atypical high operating temperatures that precluded aqueous accumulations in the HEME’s sump drain. However, the HEME filter element and its containment were soaked in a single 5 M nitric acid bath over a period of weeks in order to dissolve and subsequently account for any accumulations of mercury. Since the HEME had been exposed to a similar, nonmercury-containing effluent source previous to the current test, only mercury that is unique to the current test could be defensibly quantified. However, sampling of the HEME leachate solution was complex, as the filter media retained a significant mass of leachate (sponge) solution that was significantly higher in mercury concentration than the free-acid solution surrounding it. Assuming that a representative sample of the sponge leachate solution contained within the filter was successfully collected, the leachate solution analyses indicated that a very significant fraction of the mercury processed during RSM testing penetrated the EVS and accumulated within the HEME. Specifically, ~70% of the mercury fed to the melter was found to reside in the HEME. The overall distribution of mercury in the RSM’s secondary waste streams will be further discussed in Section 8.2.

Table 7.18. EVS Waste-Stream Effluent Distribution

	EVS Effluent Mass (g)			
Element	UDS	Soluble	Total	UDS %
Al	26.20	----	26.20	----
B	5.35	41.20	46.60	11.50
Ca	5.12	0.05	5.17	99.10
Cl	----	9.50	9.50	----
Cr	0.63	0.11	0.74	85.10
Cs	0.32	0.36	0.68	46.80
Cu	0.29	----	0.29	----
F	----	20.10	20.10	----
Fe	71.10	0.04	71.10	99.90
Hg	41.00	3.85	44.80	91.40
I	----	0.63	0.63	----
La	0.92	----	0.92	----
Li	2.67	8.80	11.50	23.30
Mn	6.94	----	6.94	----
Na	12.20	72.60	84.70	14.40
Nd	----	----	----	----
Ni	3.67	----	3.67	----
Pb	1.09	----	1.09	----
P	0.72	----	0.72	----
Si	113.00	0.74	114.00	99.40
Sr	0.65	----	0.65	----
Ti	0.72	----	0.72	----
Zn	11.60	0.03	11.60	99.80
Zr	76.30	0.03	76.40	100.00

Table 7.19. Off-Gas Sampler and Waste-Stream Total Melter DF Values

	Melter DF	
Element	EVS	Sampler
Al	46.5	58.5
B	46.4	45.1
Ca	42.7	125.0
Cl	2.7	----
Cr	35.8	54.7
Cs	44.5	36.5
Cu	52.8	110.0
F	3.8	----
Fe	60.4	84.7
Hg	3.8	2.0
I	102.0	----
La	89.3	79.6
Li	86.2	88.3
Mn	109.0	----
Na	64.7	63.9
Nd	----	2.2
Ni	64.7	84.6
Pb	65.5	70.2
P	15.6	24.0
Si	122.0	----
Sr	----	----
Ti	10.8	22.0
Zn	95.9	81.2
Zr	58.8	112.0

7.4.4 Off-Gas Line Effluent Accumulations

To complete the off-gas characterization, off-gas solid debris had to be accounted for. To accomplish this, the off-gas system was disassembled, and all pipe deposits were collected, ball-mill homogenized, sampled, and analyzed, as discussed in Section 7.4.1. Significant pipe deposits were only found in pipe sections between the melter and the EVS quench scrubber. The location and masses of these deposits are detailed in Section 8.1. The elemental compositions of the above-described UDS and pipe deposits are summarized in Table 7.20.

The mercury distribution in these samples demonstrates the effect of mercury-vapor deposition in pipe segments undergoing a significant temperature transition with the coolest location having the highest pipe-solids mercury concentration. Unlike mercury volatiles that remain gaseous at off-gas temperatures (~200ºC), fuming alkali salts like CsCl will condense and/accrete on all available surfaces. Not surprisingly then, the pipe segments closest to the melter source possess the highest concentration of these semivolatiles.

Comparing the average compositions of the EVS's UDS and the pipe deposits also summarized in Table 7.20, it is fairly clear that the off-gas deposits are representative of material ordinarily collected by the EVS. Since the pipe deposits possess higher concentrations of nominally soluble constituents, the overall wt% of insoluble constituents appears to be biased low as a result. For completeness, the soluble anionic constituents of the pipe deposits are summarized in Table 7.21. Comparison to similar feed data described in Table 5.9 clearly suggests a much higher oxide content in the pipe-deposit materials. Furthermore, a very low soluble F^-:Cl^- ratio in these solids when compared to the condensate (see Table 7.16) suggest that the melter's fluorine effluent source term may be predominantly gaseous, i.e., HF and/or F_2. The properties and magnitudes of the secondary waste stream discussed above are summarized in Table 7.22.

Table 7.20. RSM Off-Gas Pipe Deposit Composition

	Off-Gas Pipe Deposits (Wt%)					Average	
Element	**Flm-Cool**	**Elbow**	**Horizontal**	**Reducer**	**EVS**	**Pipe Dep**	**UDS**
Al	2.510	2.010	2.440	2.540	2.720	2.450	3.470
B	2.680	2.640	3.260	4.100	3.010	3.140	0.707
Ca	0.279	0.241	0.272	0.277	0.492	0.312	0.677
Cl	2.190	0.325	0.296	0.633	0.586	0.806	----
Cr	0.347	0.044	0.053	0.062	0.065	0.114	0.083
Cs	0.103	0.020	0.050	0.038	0.033	0.049	0.042
Cu	0.028	0.015	0.023	0.026	0.026	0.024	0.039
F	0.001	0.000	0.000	0.001	0.001	0.001	----
Fe	7.130	4.890	5.980	5.410	5.660	5.810	9.400
Hg	0.090	0.140	0.091	0.426	1.650	0.479	5.420
I	----	----	----	----	----	----	----
La	0.100	0.097	0.112	0.114	0.112	0.107	0.122
Li	0.851	0.710	0.808	0.826	0.920	0.823	0.353
Mn	1.330	1.510	1.610	1.160	1.230	1.370	0.917
Na	6.950	6.350	7.110	8.640	5.720	6.960	1.610
Nd	----	----	----	----	----	----	----
Ni	0.969	0.264	0.363	0.351	0.361	0.462	0.486
Pb	0.301	0.127	0.182	0.147	0.149	0.181	0.145
P	0.109	0.118	0.083	0.110	0.083	0.100	0.095
Si	17.600	17.700	19.900	15.300	15.600	17.200	15.000
Sr	0.013	0.019	0.010	0.050	0.047	0.028	0.086
Ti	0.076	0.059	0.073	0.073	0.082	0.073	0.095
Zn	1.100	0.971	1.180	1.120	1.170	1.110	1.530
Zr	8.570	7.950	8.950	9.570	10.100	9.030	10.100

Table 7.21. Pipe Solids Soluble Anion Composition

		Solids Anion Concentration (mg/g)								
Sample ID	**OG Location**	**Cl^{-1}**	**NO_2^{-1}**	**Br^{-1}**	**NO_3^{-1}**	**PO_4^{-3}**	**SO_4^{-2}**	**$C_2O_4^{-2}$**	**I^{-1}**	**F^{-1}**
RSM-Hg-94A	FC Inlet	21.90	0.221	< 0.04	0.710	< 0.3	28.60	0.120	< 0.3	0.0058
RSM-Hg-94B	90° Sweep	3.25	0.609	0.00	3.380	< 0.3	0.0	0.153	< 0.3	0.0040
RSM-Hg-94C	Horiz. Pipe	2.96	0.537	0.00	2.230	< 0.3	0.0	0.224	< 0.3	0.0039
RSM-Hg-94D	2-in. to 3-in. Trans.	6.33	1.620	0.00	2.540	< 0.3	0.0	0.314	< 0.3	0.0055
RSM-Hg-94E	EVS Inlet	5.86	2.370	0.00	1.890	< 0.3	0.0	0.199	< 0.3	0.0102

Table 7.22. Secondary Waste Stream Quantities

Waste Stream	**Unit**	**Quantity**
Condensate	L	110
UDS	g	756
Pipe Deposits	g	489

8.0 Byproducts, Residuals, Mass Balance, and Volume Reduction

Beyond the analytical characterization of feed, glass, off-gas effluents, and process-system waste streams previously discussed, a physical accounting of off-gas pipe deposits, process products, off-gas generated waste streams and mercury partitioning during condensate evaporation has also been conducted. The results of these evaluations as well as an overall process summary assessment are discussed below.

8.1 Off-Gas Line Deposits

At the conclusion of RSM testing, the off-gas line from the melter to the EVS was disassembled, inspected, and sampled. Figure 8.1 is a schematic of this segmented off-gas jumper that may be useful in providing perspective for understanding the interrelationship of these pipe segments and the samples obtained from them. Due to the low film-cooler injection rates during the current test, the cumulative accumulations within this off-gas jumper were found to be significantly (~25 x) higher than had been previously observed under similar feed-processing conditions (Goles et al. 2002). The manner in which the deposits were distributed within this jumper is summarized in Table 8.1.

Although these data suggest that film-cooler accumulations were minimal, in fact, the inlet section of this device had to be manually cleaned (rodded out) several times throughout testing. As a result, the reported mass of deposited material within this device actually represents only about 12 hours of accumulation. If one ignores film-cooler accretions, the greatest accumulations of deposited material occurred in the 90° elbow where physical impaction enhanced overall losses of entrained debris and in the 8-ft-long horizontal off-gas line segment where settling created the largest overall source of off-gas pipe deposits. All other pipe-accumulation sites accounted for the remaining 25% of collected deposits. Photographs of accumulated debris within the pipe segments identified in Figure 8.1 are displayed in Appendix D. As is clear from these photographs, the deposits that accumulated did not significantly influence the internal geometry of the pipe sections, except for the film-cooler, as discussed earlier. In total, about a half a kilogram of material accumulated within the entire run of this off-gas line jumper over the ~114-h processing period. This represents about 65% of the UDS collected in the EVS' condensate tank.

As mentioned earlier, all harvested pipe deposits were individually analyzed. The resultant analytical data were summarized and previously discussed in Section 7.4.4.

Table 8.1. Distribution of Melter Off-Gas Line Deposits

	Deposit Mass	
Pipe Segment	**(g)**	**(%)**
Film-Cooler	5.73	1.17
Elbow	157.00	32.10
Horizontal	201.00	41.20
Reducer	90.90	18.60
EVS Throat	33.50	6.86
Total	489.00	

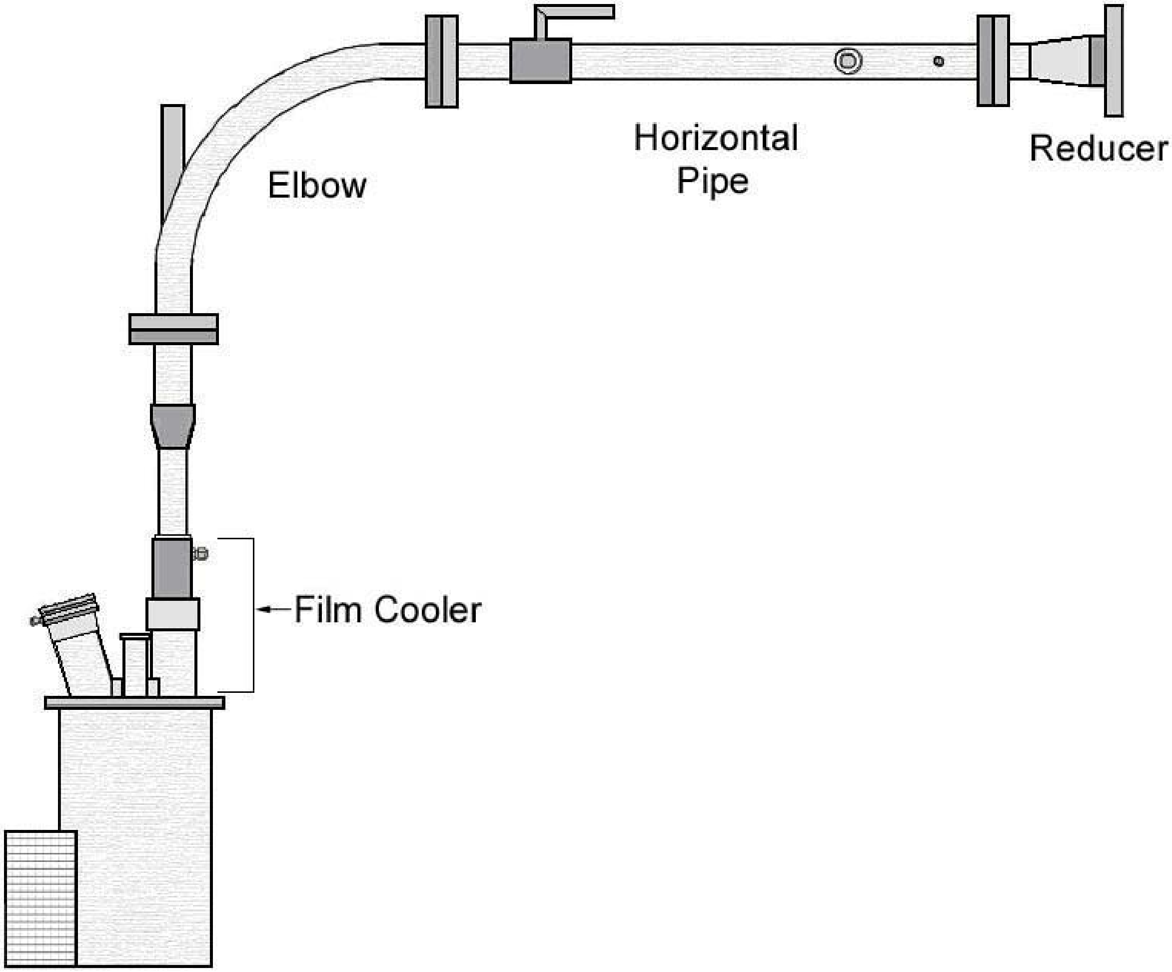


Figure 8.1. Melter Off-Gas Jumper Configuration and Sample Site Locations

8.2 Process Mass Balance

The compositional data of process streams previously discussed and summarized were combined in an attempt to fully characterize the C-104/AY-101 vitrification process flowsheet. Average analytical feed/ glass/off-gas compositional data were exclusively used for this purpose. The mass-balance results for the overall test are summarized in Table 8.2. Recognizing the limitations imposed by analytical uncertainties, very reasonable mass closures are demonstrated for most of the feed constituents for which complete analytical data exist. The partial data existing for the volatile halogen feed constituents suggests a low overall melter DF (~1.1) for F, as discussed in Section 7.4, and an apparent accounting problem for Cl. Since the feed compositional data for chlorine represent only the soluble fraction of this element, the apparent over recovery of this element suggested by Table 8.2 is a reflection of the lower bound feed-concentration value used in this evaluation.

Table 8.2. Stream-Dependent %-Partitioning of C-104/AY-101 Melter-Feed Constituents

		EVS Condensate				
Element	**Glass**	**Soluble**	**UDS**	**Pipe Dep.**	**HEME**	**Total**
Al	96.3	----	1.8	0.8	----	98.9
B	87.4	2.0	0.3	0.8	----	90.4
Ca	109.0	0.0	2.5	0.7	----	112.0
Cl	----	110.0	----	23.1	----	133.0
Cr	140.0	0.4	2.2	1.0	----	143.0
Cs	87.0	1.8	1.6	0.9	----	91.3
Cu	62.8	----	1.3	0.5	----	64.5
F	----	92.2	----	0.0	----	92.2
Fe	91.0	0.0	1.8	0.7	----	93.5
Hg	0.0	2.3	24.7	0.8	70.3	98.2
I	----	----	----	----	----	0.0
La	89.2	----	1.4	0.8	----	91.4
Li	77.3	0.8	0.3	0.4	----	78.7
Mn	82.2	----	0.9	0.9	----	84.0
Na	83.6	1.3	0.2	0.6	----	85.7
Nd	----	----	----	----	----	0.0
Ni	97.8	----	1.6	0.7	----	100.0
Pb	95.3	----	1.6	1.1	----	97.9
P	106.0	----	1.2	0.8	----	108.0
Si	91.1	0.0	0.9	0.7	----	92.6
Sr	612.0	----	17.5	3.0	----	633.0
Ti	101.0	----	1.7	0.8	----	104.0
Zn	89.6	0.0	1.6	0.7	----	92.0
Zr	87.0	0.0	1.6	0.9	----	89.5

The other elements exhibiting poor mass closure but possessing complete analytical results include Cr, Cu, Li, and Sr. Declared analytical difficulties are responsible for the poor Li mass-balance results, while the results associated with the trace constituents Cr, Cu, and Sr were limited by instrumental analytical-detection sensitivities. Recorded mass deficits, especially for the alkali elements, are, to some extent, a result of the fact that the HEME waste-stream contributions to the process mass balance, as discussed in Section 7.4.3, could only be characterized for mercury.

The mass-balance result recorded for mercury is essentially identical to that obtained during a previous melter flowsheet test involving another simulated U.S. Department of Energy (DOE) tank waste (Goles et al. 2002). Specifically, 70% of the mercury processed penetrated the off-gas system quench scrubber and accumulated within the HEME's deep-bed filter. Of the 27% that accumulated in the quench-scrubber's condensate tank, only about 9% of the quench-scrubber's inventory was soluble.

8.3 Vitrification Process Statistics

During the July 2003 melter-flowsheet evaluation studies, 116 L (31 gal) of 30 wt% C-104/AY-101 simulated melter feed, having a total mass of 168 kg, were processed by the RSM, producing 22 L (5.7 gal) of glass having a total mass of 56 kg. Although vitrification results in both mass and volume waste reductions, only the volume-reduction parameter is meaningful since a major mass contributor to the waste (H_2O) is a nonvitrifiable, volatile effluent. On the other hand, since most of the hazardous and rad-waste components can be incorporated and immobilized in the melter's vitreous product and tank-waste volumes are a physical reality, volume reduction has important waste-disposal implications. During the current RSM test, an overall C-104/AY-101 feed-volume reduction factor of 4.7 was achieved. If one assumes a ~15% waste-to-feed-volume expansion factor, a 4.1 waste-volume reduction factor is suggested.

8.4 Mercury Partitioning Under Vacuum-Evaporator Concentration of Melter-Generated Condensate

Under WTP operations, aqueous secondary waste from HLW processing will be transferred to the pretreatment facility where it will be concentrated. Since the species of mercury present in this waste stream may influence the manner in which mercury partitions to HLW, LAW, LERF/ETF, and off-gas streams, quench-scrubber condensate generated during RSM testing was concentrated using a laboratory-scale evaporator, described in Section 4.3.

Evaporator operating parameters were chosen conservatively from acceptable design ranges (Table 4.3) that apply to the Hanford Site's 242-A-Evaporator and by extension to the WTP evaporator design specifications. However, because the WTP's pretreatment evaporators are expected to operate at a higher pH range, duplicate evaporator tests were conducted at pH=8.4 and pH=13.0 that are consistent with current Site and projected WTP evaporator operating conditions, respectively. Beyond pH constraints, the target temperature, pressure, and flow parameters adopted for the current evaporator test are summarized in Table 8.3 along with the actual values achieved during both testing campaigns.

8.4.1 Experimental Observations and Results

The laboratory-scale evaporator, described in Section 4.3 and pictorially depicted in Appendix A, was used to concentrate a representative sample of the melter-generated, mercury-containing, quench-scrubber condensate at initial feed pH conditions of 8.4 and 13.

8.4.1.1 Testing at pH=8.4

During the initial evaporator test conducted at reference 242-A Evaporator conditions, a 1.7-L sample of melter-generated condensate containing UDS was concentrated by a factor of 1.67 (40.2% volume reduction) over an ~17-h period using a vacuum evaporator under nominally prototypic Table 8.3 conditions. Except for the concentration factor, all major operating test parameters were met and maintained throughout the evaporator experiment. Although a 2× concentration factor was sought, based upon optimum operation of site evaporators, a 40% boil down is well within the concentration design operation range of 20 to 80% for the evaporators.

The test overall was very successful. As mentioned above, 40.2% of the original feed volume was evaporated. Of this, 98.4% was collected in the condensate collection vessel, and 99.0% of the evaporated material was collected before the chemical scrubber solutions. Only ~1% of the material evaporated could not be accounted for in the condensate fractions collected at the conclusion of testing. A mass-balance of the pH=8.4 evaporator test is summarized in Table 8.4.

Table 8.3. Evaporator Design and Test Conditions

Stream	Basis Data	Testing		
		Target	Achieved	
Feed Temperature Slurry Temperature (242-A Evaporator)	18 – 49°C 18 – 66°C	49°C ± 10°C	**pH=8.4**	**pH=13.0**
			47–49°C	48–49°C
Reflux Condenser 1 Simulates de-entrainment pads (242-A Evaporator)	Same nominal temperature as evaporator pot – 49°C	49°C ± 10°C	47–49°C	49°C
Condensers #2 and #3 Simulates primary condenser (242-A Evaporator)	Raw Water – Skin Temp 2 – 24°C Material out usually 38°C	30°C	30°C	30°C
Purge Flow (Scc/min)	Air in leakage (scaled from SRTC small scale evaporation testing)	8–9	8.75	8.50
Vacuum (242-A Evaporator)	As close to 60 torr (current operation) as can be achieved with equipment available	60–100 Torr	71–90 Torr mid 70s to lower 80s typical	67–85 Torr mid 70s to lower 80s typical

By far the most significant potential mass loss was material adhering to the surface areas of the condensers and all the connecting glassware and tubing. There was visible moisture on some parts at breakdown, even though the condenser temperatures were adjusted for the last 30 minutes, as part of the shutdown procedure, to try and dry these out. None of this equipment was tared independently, and therefore this material cannot be accounted for in the overall mass balance.

Based on the material balance, it appears that most of the moisture collected in the Drierite columns came from the last chemical impinger.

Table 8.4. Mercury Partitioning Study, Mass Balance (pH=8.4)

Vessel	Tare	Material Added g	Starting Wts g	Final Wts g	Gained/Lost g
4-L Reaction	1401	1752.9	3153.9	2454	-699.88
Condensate Collection	299.7	0	299.7	988.5	688.80
Method 29 Train Vessel 1	523	0	523	526.8	3.80
Method 29 Train Vessel 2	545.3	215.8	761.1	760.2	-0.90
Method 29 Train Vessel 3	510.2	236.1	746.3	744.5	-1.80
Method 29 Train Vessel 4	507.6	0	507.6	507.7	0.10
Method 29 Train Vessel 5	438.1	230	668.1	666.3	-1.80
Method 29 Train Vessel 6	442.4	228.7	671.1	640.1	-31.00
Drierite Desiccant #1			913.7	936.4	22.70
Drierite Desiccant #2			1108.1	1117.9	9.80

Material evaporated (g)	699.88
% collected at 30°C	98.42
Material collected before chemical impingers (g)	692.60
% collected before chemical impingers	98.96
Impinger #2 - #6 accumulation (g)	-7.28
Water mass balance (g)	-10.18

8.4.1.2 Testing at pH=13

During the evaporator test conducted at projected WTP pre-treatment evaporation conditions, a 2.2-L sample of melter-generated condensate containing UDS was concentrated by a factor of 2.7 over an ~4-h period using a vacuum evaporator under the nominally prototypic conditions summarized in Table 8.3. All major operating test parameters were met and maintained throughout the evaporator experiment. The significantly reduced time required to perform the second evaporation campaign resulted from the much better vacuum conditions achieved during the second test. The operating pressure of the evaporator system during the second test was dominated by the partial pressure of water vapor, which apparently was not true during the first campaign.

The test overall was very successful. As mentioned above, 62% of the original feed volume was evaporated. Of this, 81% was collected in the condensate collection vessel, and 94% of the evaporated material was collected before the chemical scrubber solutions. Less than 0.1% of the system's solution mass could not be accounted for at the conclusion of testing. A mass-balance of the pH=13 evaporator test is summarized in Table 8.5.

The lower collection efficiency of the primary condensate collection vessel observed during the second evaporator test was a reflection of the much greater evaporation rates achieved during this test relative to the first campaign, as previously discussed. This higher evaporation rate led to significantly higher collected condensate temperatures that averaged 37°C, even though the condenser's heat exchange fluid was maintained at 30°C. Although higher than the 30°C temperatures observed during the initial pH=8.4 test, the average condensate temperature achieved during the second pH=13 test was quite prototypic of the reference 242-A Evaporator condensate condition (38°C) discussed in Section 4.3.2.

Table 8.5. Mercury Partitioning Study, Mass Balance (pH=13)

	Mass in Grams				
Vessel Description	**Tare Wt.**	**Material Added**	**Starting Wt.**	**Final Wt**	**Gained/Lost**
4-liter reaction	2953.9	2176.4	5130.3	3775	-1355.3
Condensate collection	603.0	0	603	1701.2	1098.2
method 29 Impinger 1	335.6	0	399.7	571.9	172.2
method 29 Impinger 2	341.7	107.8	513.5	568.8	55.3
method 29 Impinger 3	335.6	107.9	507.2	519.2	12
method 29 Impinger 4	333.4	0	397.9	401.1	3.2
method 29 Impinger 5	337.7	113.9	515.7	513.1	-2.6
method 29 Impinger 6	329.5	112.7	505.6	501.4	-4.2
Drierite Desiccant #1	----	----	944.7	964.6	19.9
Drierite Desiccant #2	----	----	1112.5	1114.8	2.3

Material evaporated (g)	1355.30
% collected at 30°C	81.03
Material collected before chemical impingers (g)	1270.40
% collected before chemical impingers	93.74
Impinger #2 - #6 accumulation (g)	84.90
Water mass balance (g)	1.00

8.4.2 Mercury Partitioning

All aqueous solutions making up the vacuum-evaporator/off-gas-sampler system described in Section 4.3 were analyzed to characterize the fate and behavior of the mercury in the melter's quench-scrubber aqueous waste under evaporator conditions that are representative of projected WTP pretreatment operations. As discussed above, two identical tests were conducted under different initial feed pH conditions. The mercury partitioning results obtained will now be discussed.

8.4.2.1 Melter Quench-Scrubber Evaporation At pH of 8.4

The initial evaporator test conducted on RSM quench scrubber aqueous waste did not require pH adjustment as its pH was within the 7 to 10 operating range of the reference 242-A Evaporator. The results obtained from the analyses of the condensate and off-gas sampling components summarized in Table 8.6 suggest that significant measurable mercury partitioning to both the condensate and vessel-vent off-gas streams does indeed occur. Specifically, up to 1.4% of the initial mercury inventory partitioned to the evaporator's condensate product. Moreover, the concentration of the condensate's nonvolatile constituents, e.g. Ca, Na, and Si, suggest little evidence for a gross entrainment transfer mechanism. The 3-fold increase in aqueous mercury concentration in the evaporator bottoms also suggests an increased suspension of insoluble mercury or a changing chemistry that is allowing mercury-sludge components to be solubilized. Ignoring off-gas system losses to be discussed next, the observed mercury in the evaporator's condensate fraction suggests that mercury partitioning to the evaporator's exhaust is over an order of magnitude greater than the current WTP design value for the contract maximum mercury-feed-rate condition.

Table 8.6. Evaporator Component Composition for pH 8.4 Test (mg/L)

	Boiler[a]		Evap.	Method 29 Gas Phase Hg Sampling Train Impinger						Reagent Blanks		
Element	Initial	Final	Cond.	#1	#2	#3	#4	#5	#6	H_2O_2/HNO_3	$HNO_3/KMnO_4$	Nitric Wash
Al	2.700	3.100	----	----	----	----	----	----	0.900	----	----	----
B	370.000	600.000	1.600	0.280	0.170	0.150	1.800	1.100	1.800	0.130	1.300	0.100
Ca	1.500	2.700	0.370	0.770	0.430	0.320	1.200	0.320	0.410	0.500	0.420	0.800
Cr	2.000	3.200	----	----	----	----	----	----	----	----	----	----
Cu	----	----	----	0.200	0.200	----	0.450	----	----	----	----	----
Fe	5.700	3.000	----	0.220	0.100	0.070	0.150	----	----	0.300	----	----
Hg	13.000	42.000	14.000	0.730	0.250	0.005	0.059	----	----	----	----	----
Li	84.000	140.000	----	----	----	----	0.380	----	----	----	----	----
Mn	0.200	0.090	----	----	0.100	----	0.460	570.000	370.000	----	170.000	----
Na	690.000	1200.000	2.500	3.100	1.200	1.100	7.700	----	----	0.730	27.000	4.400
Ni	0.200	0.200	----	----	----	----	----	----	----	----	----	----
Si	14.000	14.000	1.600	0.880	0.500	1.000	1.500	----	----	0.200	----	0.800
Sr	0.040	0.045	----	----	----	----	----	----	----	----	----	----
Zn	2.700	1.200	----	0.090	0.030	0.020	0.110	0.050	0.050	----	0.040	0.035
Zr	1.100	----	----	----	----	----	----	----	----	----	----	----
Hg (mg)[b]	677	668	9.64	0.0174	0.0506	0.0011	0.0007	----	----	----	----	----
% of Input	100	98.6	1.42	0.0026	0.0075	0.0002	0.0001	----	----	----	----	----

(a) Soluble concentrations
(b) Boiler value includes sludge contributions.

The presence of mercury in the gas-scrubber impingers, although small in comparison to the condensate fraction, further suggests a persistent, noncondensable mercury vapor source ($HgCl_2$) that is readily removed without the use of strong oxidizing agents, i.e., $KMnO_4$. The concentration of the evaporator's noncondensable mercury vapor source in the simulated inleakage flow that is projected to partition to the Pretreatment facility's vessel vent system is 8 mg/m^3. However, this off-gas concentration represents an upper-bound value, as unintended inleakage of undetermined magnitude was likely significant (see pressure comments in 8.4.1.2).

Beyond the LERF/ETF and vessel-vent partitioning projections discussed above, the composition of the condensate concentrate in the evaporator bottoms will establish the manner in which mercury is distributed to the HLW and LAW streams. The current results indicate that ~93% of the mercury in the condensate concentrate is associated with UDS and will, as a result, be recycled to the HLW melter, while the remaining soluble fraction (~7%) will flow into the LAW stream.

Since the target pH range of the evaporator feed used in the current test (7 to 10) apparently was not representative of that planned for use during WTP processing, a duplicate evaporator test was subsequently conducted at pH 13. The results of this subsequent test are discussed below.

8.4.2.2 Melter Quench-Scrubber Evaporation at pH of 13

As discussed in Section 8.4.1.2, the second evaporation campaign was, with the exception of pH, conducted identically to the first test. To adjust the melter's quench scrubber's slurry to pH=13, sodium hydroxide was added. Significant cation precipitation accompanied this pH adjustment operation, which directly affected the physical properties of the slurry by significantly increasing settling rates. The

Appendix A photographs of post-test evaporator vessels graphically illustrate the differences in UDS suspension concentrations present in these evaporator bottoms. As a result of the precipitation reactions discussed above, a 23% excess of NaOH had to be used to achieve the required slurry pH value of 13.

Although constructed and operated identically to that of the first test, the laboratory-scale evaporator used for the second test achieved a much higher no-load system vacuum than was achieved during the first test. As a result, significantly improved evaporation throughput rates were achieved that appreciably reduced the required testing period duration. However, the higher throughput rates also affected the average condensate temperature, even though condenser cooling fluid was maintained at the reference 30°C temperature. This affected condensate collection efficiency as discussed in Section 8.4.1.2, and also influenced mercury off-gas system losses as is discussed below.

The mercury partitioning results obtained from the analyses of laboratory-scale evaporator samples summarized in Table 8.7 suggest that, like the previous evaporator test, significant mercury partitioning to both the condensate and vessel-vent off-gas streams does occur. However, unlike the first test, mercury partitioning to the condensate is significantly less (~17×) than to the off-gas stream, and the overall evaporator mercury partitioning is appreciably greater (~3×).

Table 8.7. Evaporator Component Composition for pH 13 Test (mg)

	Boiler		**Evap.**	**Method 29 Gas Phase Hg Sampling Train Impinger(a)**					
Element	**Initial**	**Final(b)**	**Cond.(c)**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**
B	646.000	640.000	(0.110)	----	----	----	----	----	----
Ca	69.000	56.200	(0.270)	----	----	----	----	----	----
Li	142.000	146.000	(0.010)	----	----	----	----	----	----
Na	6920.000	6750.000	(2.200)	----	----	----	----	----	----
Hg	380.000	326.000	0.920	0.095	0.814	3.550	0.017	11.600	0.003
% of Input	100.000	85.700	0.242	0.025	0.214	0.933	0.005	3.060	0.001

(a) Not measured: ----
(b) Slurry results only; does not include evaporator vessel deposits.
(c) Values in parentheses are below analytical reportable limits.

Specifically during the current test, 0.24% of the mercury present in the evaporator feed partitioned to the condensate, and 4.2% partitioned to the off-gas stream. Of the uncondensable (30°C condenser) mercury partitioning to the off-gas stream, 0.7% was condensed at 0°C, and ~27% was collected by the nonoxidizing traps while the remaining ~72% was collected by the oxidizing $KMnO_4/H_2SO_4$ gas scrubber solutions. This suggests that the mixed mercury vapor source was dominated by the elemental form (~75%), but it contained a significant proportion (~25%) of one or more volatile oxidized mercury compounds.

If pure physical capture processes, e.g., condensation, were responsible for the mercury sample train collection, a distribution similar to that of moisture collection illustrated in Table 8.5 would be also expected for mercury. Since it is not, selective chemical processes are no doubt responsible for the distribution of collected mercury as explained above. Although the distribution of mercury across the sequential H_2O_2/HNO_3 gas-scrubbers appears unintuitive, chemical dilution affects resulting from significantly different moisture accumulations within these traps may be partly responsible for the differing mercury collection yields in these sequential traps (see Table 8.5).

As in the previous, pH=8.4 evaporator test, the estimates of nonvolatile cationic species in the evaporator condensate suggest little evidence for aqueous aerosol carryover during the evaporator feed concentration process. The concentration increase in soluble mercury in the evaporator's feed concentrate (3.6) was also found to be greater than the overall test concentration factor (2.7), and most of the mercury mass in the evaporator's concentrate (86%) was associated with UDS in total agreement with previous testing results.

It should be noted that only 90% of the mercury is accounted for in the mass balance data summarized in Table 8.7. Since mercury surface deposits on all components down-stream of the evaporator's reflux condenser were collected and accounted for, the unaccounted for mercury is presumed to be associated with unremoveable evaporator vessel residues.

8.4.2.3 Evaporator Test Discussion

In contrast to the results of the second test in which only 0.24% of evaporated mercury was found in the primary condensate vessel, the analytical data from the initial evaporator test indicated that 99% of the partitioned mercury was condensable and resided in the evaporator's condensate. Moreover, the distribution of mercury trapped by chemical gas scrubbers during this first test suggested that the remaining mercury carried into the off-gas stream was primarily associated with one or more volatile oxidized forms of mercury whereas a mixed, 1:3, oxide/elemental volatile source of mercury was observed during the second test. For the same reason that the higher partial pressure of atmospheric gases severely limited moisture evaporation rates during the first test, overall mercury loss was also found to be significantly lower (3×) than that observed during the second test. Moreover, the lower condensate and off-gas temperatures observed during the first evaporation test that resulted from the reduced heat load to the evaporator system's condenser are no doubt responsible for the higher mercury condensate accumulation and lower mercury off-gas concentration observed during that test.

Of the two tests performed, overall operational conditions of the second test (pH=13) appear to be most representative of projected WTP evaporator operations due to the unreasonably low evaporation throughput rates that characterized the first test. Consequently, apart from pH considerations, the mercury partitioning behavior recorded during the second test is also more likely to be characteristic of expected Plant operations than is the behavior observed during the first test.

Although test results differed, the mercury partitioning observed during the current laboratory evaporator tests are in stark contrast to previous work(a) that found no detectable mercury contamination in

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(a) Engineering Specifications for the Forced Circulation Vacuum Evaporator System: DIM No. 24590-PTF-3PI-MEVV-00001, Rev A. Issued by the River Protection Project – Waste Treatment Plant Project, Richland, WA (June 4, 2002).

242-A Evaporator Documented Safety Analysis, Chapter 2 – Facility Description. Waste Management Project, Hanford Site, Rev. 0, Richland, WA (April 10, 2003).

Waste Feed Evaporation: Physical Properties and Solubility Determination (U), Savannah River Technology Center, SRT-RPP-2003-00094, Rev 0. Westinghouse Savannah River Company, Savannah River Site, Aiken, evaporator condensate or in the vessel vent-exhaust stream. These contradictory results may be due to chemical differences in the evaporator feed materials used, but the factors responsible for these differences need to be identified as they apparently have a major impact upon the partitioning behavior of mercury.

8.5 Process Summary

The mercury CEM results obtained during C-104/AY-101 melter-flowsheet evaluations were to have definitively elucidated any correlations existing between the parameters of the test (Hg, Cl, and reductant concentrations) and the melter-effluent characteristics of mercury. However, the performance of this continuous monitor was less than ideal during the RSM testing campaign. Specifically, the mercury CEM did not provide reliable off-gas vapor concentration values, due, presumably, to inadequate sample stream dilution and resultant condensation losses. However, since the major volatile species expected (Hg° and $HgCl_2$) exhibit very similar temperature-dependent vapor pressures, sample condensation losses would be expected to affect both species in a similar way; consequently, CEM speciation results should remain valid if: 1) condensation losses were responsible for the observed nonquantitative instrumental behavior and 2) $HgCl_2$ is the primary oxidized form of mercury being sampled. However, meaningless elemental to total mercury ratios were nevertheless observed, especially for the melter-exhaust sampling site during the first and last testing segments.

Comparing the valid CEM data over the first three test conditions with soluble mercury collected in the quench-scrubber condensate, both independent sets of data suggest a melter mercury-effluent source dominated by oxidized species (presumably $HgCl_2$). Conducting a similar comparison for the last four test segments, these data suggest a melter mercury source that is mostly in the elemental form. Overall, the mercury CEM did not demonstrate a consistent dependence on the test-parameter variables.

Discrete sampling data were also used to characterize the melter's mercury source term by examining the distribution of mercury across sampler components. The results obtained during the 2nd test condition suggested a mercury effluent source primarily in the oxidized state, which is in total agreement with both CEM and EVS data previously discussed. Unlike the 2nd test condition, the Method-29 sampler results suggested a predominantly elemental melter-mercury effluent source during the 4th test condition in total conformity with both CEM and EVS data. On the other hand, sampler results obtained during the 5th test condition suggested a mixed melter mercury source with a strong elemental component, which is similar to corresponding CEM data that indicated a 90% elemental source. Like the CEM data, the massive mercury concentrations present during the last test condition created unsuitable sampling conditions for speciation determinations. However, because of the high Hg:Cl molar ratio (2.6) created by the Mx condition for mercury, there is little doubt that the melter's volatile mercury source term was dominated by the elemental species, which is corroborated by the decrease in soluble mercury content of the EVS condensate during this test segment.

SC (May 13, 2003).

AN-107 (C) Simulant Bench-Scale Law Evaporation with Organic Regulatory Analysis, SRT-RPP-2000-00047, Savannah River Technology Center. Westinghouse Savannah River Company, Savannah River Site, Aiken, SC.

Just as the melter's mercury source term for the last test condition can be deduced using the existing Hg:Cl molar ratio, so can the contrasting results for the two halves of the melter test previously described be explained. For the initial three test segments for which the oxidized form of effluent mercury predominated, the Hg:Cl molar ratio was less than 1. On the other hand, during the second half of testing when the melter's mercury source was predominantly elemental, the Hg:Cl molar ratio was, with a single exception, significantly greater than 1. The 5th test condition, being the 2nd half exception, used feed with a Hg:Cl molar ratio of 0.4 and exhibited a mixed melter-mercury source according to the sampling data discussed above.

Although not dramatically apparent from any single source of data, the CEM, off-gas sampling, and waste-stream data, when taken together, suggest that when significant chlorine is present in a mercury-containing feed stream that is vitrified under WTP processing conditions, the formation of $HgCl_2$ is both thermodynamically and kinetically favored. With a Hg:Cl molar ratio of 0.1 (test conditions #2 & #3), conversion to chemically combined mercury was essentially complete, whereas a 0.4 molar ratio (test condition #5) produced a mixed mercury effluent source with an appreciable elemental component. On the other hand, for test segments 4, 6, and 7, where the elemental form was the dominant melter mercury effluent species, Hg:Cl ratios were all in excess of 2.5. Thus, these results suggest that when mercury-containing melter feed with a very low Hg:Cl molar ratio is vitrified under WTP processing conditions, a chemically combined ($HgCl_2$) mercury effluent source results; otherwise, depending upon the magnitude of the Hg:Cl molar ratio, a mixed or elemental source will dominate the melter-mercury source term.

Because of the focused interest in characterizing the melter source term, most mercury CEM data associated with the exhausts of the EVS and HEME were conducted during the second half of testing, i.e., test conditions 4 through 7. Recognizing that these data were similarly influenced by the instrument-performance problems discussed above, the body of reasonable data collected indicate an off-gas mercury vapor source that is composed primarily of the elemental species. This is in agreement with the corresponding melter-source-term results previously discussed.

Post-test evaluation of the melter's secondary waste streams has shown that ~70% of the mercury fed to the melter penetrated the off-gas system's quench scrubber and accumulated in the HEME's deep-bed filter, suggesting a primarily elemental mercury-effluent source. Indeed, 76% of the total mercury processed during RSM testing occurred during test segments 6 and 7 (Mx conditions) when the melter's mercury-effluent source was predominantly in the elemental state. Of the 27% of the mercury collected in the quench-scrubber's condensate, only 9% of the quench-scrubber's mercury inventory was found to be soluble.

To project HLW/LAW, LERF/ETF, and VV Hg partitioning during pretreatment secondary-waste concentration, representative samples of the quench-scrubber's condensate/scrubbing liquor were vacuum evaporated and concentrated with and without initial pH adjustment. Of the two tests conducted, the results obtained from the pH-adjusted (pH = 13) evaluation are considered to be most representative of projected WTP evaporation conditions and as a result are discussed below. The analyses of evaporator condensate and off-gas sample solutions suggest that the mercury partitioning to the Pretreatment Plant's condensate collection and VV systems will be an order of magnitude greater than the current WTP design value for the contract maximum mercury feed rate (Cramer 2001). Specifically, the observed evaporator mercury DF (~22) for RSM condensate is significantly less than the reference feed concentrator DF of 997 for this element. Of the partitioned mercury, 5.4% was collected in the overhead condensate fraction with the remaining 94.6% being carried off by the gaseous exhaust (vessel vent system). The chemical nature of the evaporator's mercury off-gas source term was evaluated by observing the mercury distribution across the off-gas chemical scrubbers employed during the laboratory-scale tests. The results obtained suggest a mixed volatile oxide/elemental mercury source term dominated by the elemental form (3×). Post-test analyses of the mercury remaining in the evaporator concentrate after both pH=8.4 and pH=13 tests demonstrated that most (86% and 93%, respectively) of the mercury present was associated with UDS. If representative, this result suggests that 7% to 14% of the mercury present in WTP evaporator bottoms will be recycled to the HLW melter, with the remainder contributing to the LAW stream.

However, since the Pretreatment Plant's evaporator influent stream will be composed of more than just the secondary, aqueous waste generated by HLW melters, the mercury-partitioning results established by the above laboratory-scale evaporator tests may not be totally representative of actual plant operations. All factors that can affect the chemical composition of mercury in the evaporator's influent stream need to be considered before accurate Pretreatment Plant projections of mercury behavior can be established.

Melter partitioning of individual feed constituents, derived from both off-gas sampling and secondary waste-stream analysis, revealed that with the exception of boron, mercury, sulfur, and the halogens, essentially all feed constituents (excluding, for example, C, N, and H_2O) were found to be primarily in a condensed state downstream of the film cooler. Overall, the element-specific DFs recorded during RSM testing are reasonably close to general expectations and are generally consistent with previous RSM testing results. Indeed, the very reasonable mass closure demonstrated for most of the feed constituents for which complete analytical data exist suggests that the current melter test has successfully characterized the C-104/AY-101 vitrification flowsheet.

Representative glass samples generated under worst-case testing conditions (Mx/Hi/Lo and Mx/Hi/Hi) were subjected to EPA's TCLP test (TCLP 1992). The concentrations of all hazardous analytes, except for Ba and Cr (for which estimates are provided), were found to be below instrument detection limits, and all were below their respective UTS limits. The extremely low mercury concentrations found in the glass present no adverse leaching problems that would preclude the glass-vitrification product from conforming with all existing RCRA land-disposal limits (40 CFR 268).

9.0 QA Requirements

PNWD implements the RPP-WTP quality requirements by performing work in accordance with the PNWD Waste Treatment Plant Support Project quality assurance project plan (QAPjP) approved by the RPP-WTP Quality Assurance (QA) organization. This work was performed to the quality requirements of NQA-1-1989 Part I, Basic and Supplementary Requirements, and NQA-2a-1990, Part 2.7. These quality requirements are implemented through PNWD's *Waste Treatment Plant Support Project (WTPSP) Quality Assurance Requirements and Description Manual*. The analytical requirements are implemented through PNWD's *Conducting Analytical Work in Support of Regulatory Programs*.

PNWD addresses internal verification and validation activities by conducting an Independent Technical Review of the final data report in accordance with PNWD's procedure QA-RPP-WTP-604. This review verifies that the reported results are traceable, that inferences and conclusions are soundly based, and that the reported work satisfies the Test Plan objectives. This review procedure is part of PNWD's *WTPSP Quality Assurance Requirements and Description Manual*.

10.0 References

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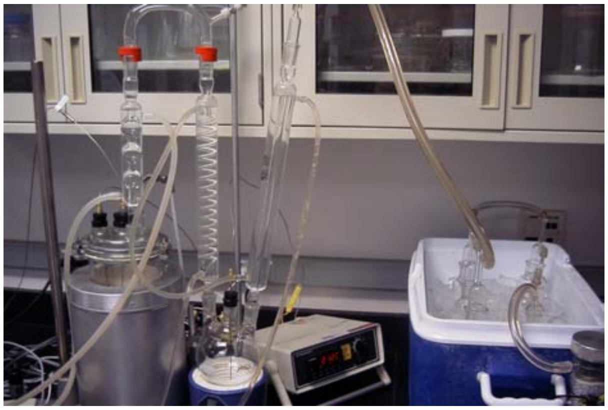
Appendix A

Evaporator Hardware Photographs

Appendix A: Evaporator Hardware Photographs

Laboratory Scale Evaporator Hardware



Boiler, Distillation Columns, Condensate Pot, and Gas Scrubbers

Insulated Evaporator System

Column Temperature Control Recirculators, Foreground; Boiler Temperature Controller, Inleakage Flow Controller, Background

Mercury Vapor Chemical Scrubbers

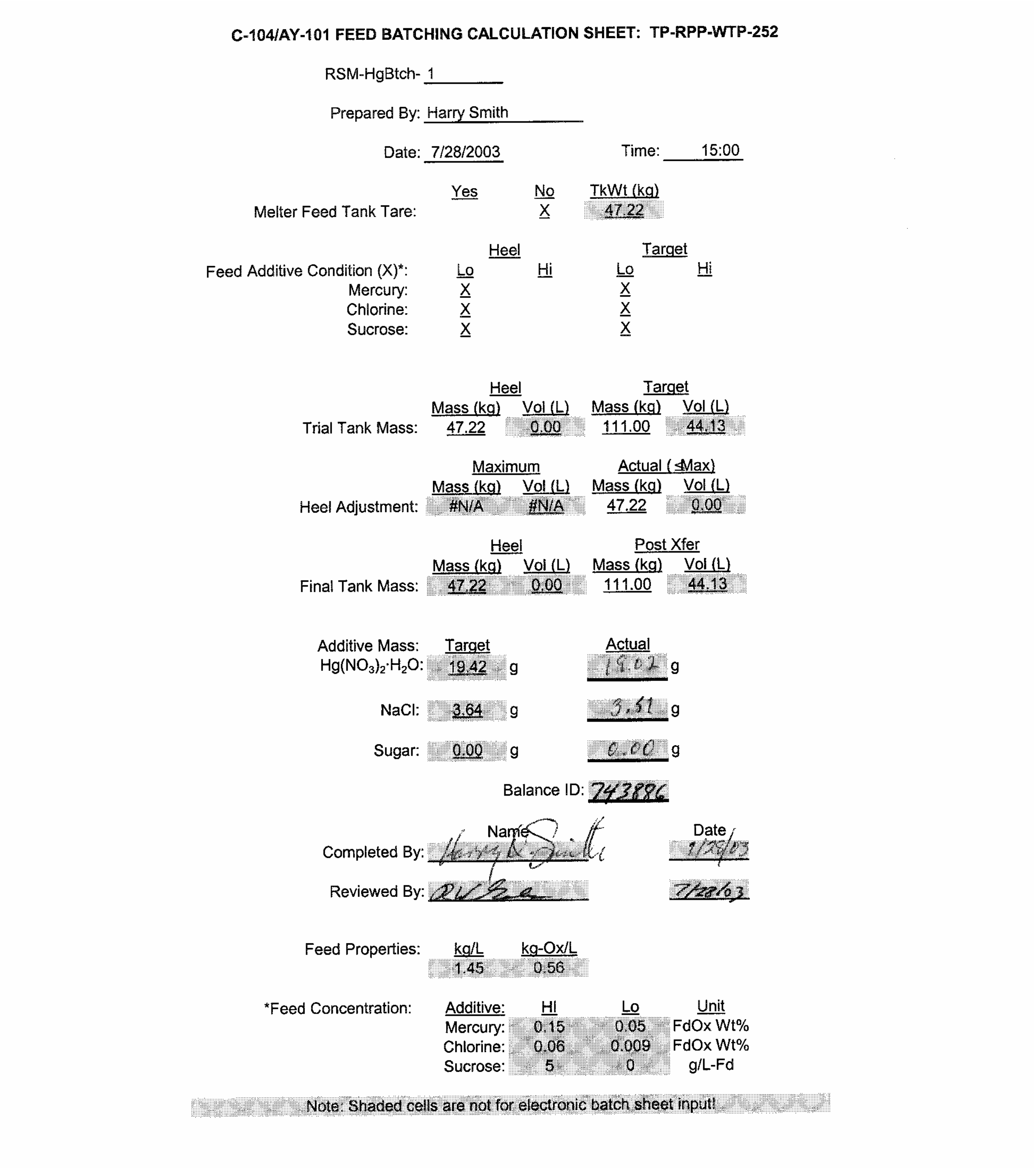
Evaporator Concentrate at the Conclusion
of the pH = 8.4 Test

Evaporator Concentrate at the Conclusion
of the pH = 13 Test

Appendix B

Feed Batching and Data Sheets

Appendix B: Feed Batching and Data Sheets



C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

RSM-HgBtch- 1

Prepared By: Harry Smith

Date: 7/28/2003 Time: 15:00

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		X	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:	X		X	
Chlorine:	X		X	
Sucrose:	X		X	

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	47.22	0.00	111.00	44.13

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	#N/A	#N/A	47.22	0.00

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	47.22	0.00	111.00	44.13

Additive Mass:	Target	Actual
$Hg(NO_3)_2 \cdot H_2O$:	19.42 g	19.02 g
NaCl:	3.64 g	3.51 g
Sugar:	0.00 g	0.00 g

Balance ID: 743886

	Name	Date
Completed By:		7/28/03
Reviewed By:		7/28/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.15	0.05	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

RSM-HgBtch- 2

Prepared By: Harry Smith

Date: 7/29/2003 Time: 10:29

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		X	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:	X		X	
Chlorine:	X			X
Sucrose:	X		X	

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	81.00	23.37	81.00	23.37

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	#N/A	#N/A	81.00	23.37

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	81.00	23.37	81.00	23.37

Additive Mass:	Target		Actual	
$Hg(NO_3)_2 \cdot H_2O$:	0.00	g	0.00	g
NaCl:	10.93	g	10.93	g
Sugar:	0.00	g	0.00	g

Balance ID: 743886

	Name	Date
Completed By:	Harry N Smith	7/29/03
Reviewed By:		7/29/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.15	0.05	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

RSM-HgBtch- 3

Prepared By: Ron Goles

Date: 7/29/2003 Time: 23:45

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		X	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:	X		X	
Chlorine:		X		X
Sucrose:	X		X	

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	62.60	10.64	83.66	25.21

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	#N/A	#N/A	62.60	10.64

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	62.60	10.64	83.66	25.21

Additive Mass:	Target	Actual
$Hg(NO_3)_2 \cdot H_2O$:	6.41 g	6.49 g
NaCl:	8.02 g	8.08 g
Sugar:	0.00 g	0.00 g HDS 8/7/03

Balance ID: 743886

	Name	Date
Completed By:	RW Goles	7/29/03
Reviewed By:	Harry D Smith	8/7/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.15	0.05	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

RSM-HgBtch- 4

Prepared By: John Tixier

Date: 7/30/2003 Time: 5:47 AM

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		x	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:	X		x	
Chlorine:		x		x
Sucrose:	x			x

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	75.00	19.22	75.00	19.22

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	#N/A	#N/A	75.00	19.22

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	75.00	19.22	75.00	19.22

Additive Mass:	Target	Actual
$Hg(NO_3)_2 \cdot H_2O$:	0.00 g	— g
NaCl:	0.00 g	— g
Sugar:	96.11 g	95.90 g

Balance ID: 743886

	Name	Date
Completed By:		7/30/03
Reviewed By:		7/30/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.15	0.05	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

RSM-HgBtch- 5

Prepared By: Harry Smith

Date: 7/30/2003 Time: 15:40

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		X	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:	X			X
Chlorine:		X	X	
Sucrose:		X	X	

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	49.15	1.34	115.28	47.09

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	47.22	0.00	49.15	1.34

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	49.15	1.34	115.28	47.09

Additive Mass:	Target		Actual	
$Hg(NO_3)_2 \cdot H_2O$:	61.57	g	62.24	g
NaCl:	3.15	g	3.15	g
Sugar:	-6.68	g	—	g

Balance ID: 743886

	Name	Date
Completed By:	Harry Smith	7/30/03
Reviewed By:		7/30/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.15	0.05	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

RSM-HgBtch- 6

Prepared By: Harry Smith

Date: 7/31/2003 Time: 8:35

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		X	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:		X		X
Chlorine:	X			X
Sucrose:	X		X	

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	88.00	28.22	88.00	28.22

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	#N/A	#N/A	88.00	28.22

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	88.00	28.22	88.00	28.22

Additive Mass:	Target	Actual
$Hg(NO_3)_2 \cdot H_2O$:	0.00 g	0.00 g
NaCl:	13.20 g	13.2 g
Sugar:	0.00 g	0.00 g

Balance ID: 743886

	Name	Date
Completed By:	Harry E. Smith	7/31/03
Reviewed By:		7/31/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.15	0.05	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

RSM-HgBtch- 7

Prepared By: Ron Goles

Date: 7/31/2003 Time: 21:40

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		X	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:		X		X
Chlorine:		X		X
Sucrose:	X		X	

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	72.30	17.35	79.30	22.20

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	#N/A	#N/A	72.30	17.35

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	72.30	17.35	79.30	22.20

Additive Mass:	Target	Actual	
$Hg(NO_3)_2 \cdot H_2O$:	6.39 g	6.43 g	
NaCl:	2.66 g	2.70 g	
Sugar:	0.00 g	0.00 g	HDS 8/7/03

Balance ID: 743886

	Name	Date
Completed By:		7/31/03
Reviewed By:	Harry D. Smith	7/31/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.15	0.05	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

(Test Condition 6 & 7 only! Maximum Mercury Concentration)

RSM-HgBtch-8

Prepared By: RW Goles

Date: 8/1/2003 Time: 4:45

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		X	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:	X			X
Chlorine:		X		X
Sucrose:	X		X	

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	68.50	14.72	100.00	36.52

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	#N/A	#N/A	68.50	14.72

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	68.50	14.72	100.00	36.52

Additive Mass:	Target		Actual	
$Hg(NO_3)_2{\cdot}H_2O$:	285.84	g	285.77	g
NaCl:	11.99	g	12.02	g
Sugar:	0.00	g	—	g

Balance ID: 743886

	Name	Date
Completed By:	RW Goles	7/1/03
Reviewed By:		8/1/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.95	0.15	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

C-104/AY-101 FEED BATCHING CALCULATION SHEET: TP-RPP-WTP-252

(Test Condition 6 & 7 only! Maximum Mercury Concentration)

RSM-HgBtch- 9

Prepared By: Harry Smith

Date: 8/1/2003 Time: 20:53

	Yes	No	TkWt (kg)
Melter Feed Tank Tare:		X	47.22

	Heel		Target	
Feed Additive Condition (X)*:	Lo	Hi	Lo	Hi
Mercury:		X		X
Chlorine:		X		X
Sucrose:	X			X

	Heel		Target	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Trial Tank Mass:	74.00	18.53	74.00	18.53

	Maximum		Actual (≤Max)	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Heel Adjustment:	#N/A	#N/A	74.00	18.53

	Heel		Post Xfer	
	Mass (kg)	Vol (L)	Mass (kg)	Vol (L)
Final Tank Mass:	74.00	18.53	74.00	18.53

Additive Mass:	Target		Actual	
$Hg(NO_3)_2 \cdot H_2O$:	0.00	g	0.00	g
NaCl:	0.00	g	0.00	g
Sugar:	92.65	g	92.4	g

Balance ID: 743886

	Name	Date
Completed By:	Harry D. Smith	8/1/03
Reviewed By:		8/1/03

Feed Properties:	kg/L	kg-Ox/L
	1.45	0.56

*Feed Concentration:	Additive:	HI	Lo	Unit
	Mercury:	0.95	0.15	FdOx Wt%
	Chlorine:	0.06	0.009	FdOx Wt%
	Sucrose:	5	0	g/L-Fd

Note: Shaded cells are not for electronic batch sheet input!

Data Sheet #1: Priority and Electrical Data

178°C

Data Sheet #1: Priority & Electrical Data

RSM, July 2003										
	By:		WXB	WCB	HDS	H.D.S	WCB	[illegible]	~~[illegible]~~	[illegible]
	Date:		7/28/03	7/28/03	7/28/03	7/28/03	7/28/03	7/28	~~7/28~~	7/28
	Time		1000	1002	11:30	12:12	14:04	1658	~~[illegible]~~ 1710	1805
DESCRIPTION	UNITS	Range								
Priority Data			1052							
Melt Temperature (T1, control)	° C	1125 - 1175	~~1053~~	1052	1148	1152	1147	1150		1150
Melt Temperature (T2)	° C	1125 - 1175	~~[illegible]~~	1047	1154	1138	1152	1160		1154
Plenum Temperature	° C	400 - 450	~~556~~	556	481	429	432	486		457
Post FC Off-gas Temperature	° C	200-250		247	193	176	242	201		191.
Cold Cap Coverage	%	> 85		50	50	90	—	85		90
Slurry Pool Coverage of Cap	%			50	50	80	—	40		50
Cold Cap Flexibility Visible	y or n			N	N	N	—	Y		N
Number of Vents	#			bubbler	bubbler	bubbler	bubbler	2 Bubblers		2 Bub.
Cold Cap Thickness	inch			NA	NA	NA	—	1/2"		1"
Phase Separation (Note in LRB)	y or n			N	N	N	—	N		N
Glass Pouring	y or n			N	Y	N	Y	N		dripping
OFF gas				232			242	256		219
Electrical Data										
Electrode Potential	Volts			43.0	34.7	32.3	32.0	34.1		32.6
Electrode Current	Amps			109.7	89.0	83.2	89.7	88.1		89.4
Electrode Power	kW			4.7	2.9	2.7	2.9	2.9		2.9
Melt Resistance	Ω			0.395			0.360	.377		.368
Melt (Electrode) Setpoint Temp	° C	1150		1150	1150	1150	1150	1150		1150
(Electrode Power) Output	%			54	44	42	44	44		45
(Electrode) Control Mode	A or M			A	A	A	A	A		A
Kiln Power	kW			1.1	0	0.2	0.6	0		0.1
Kiln Temp Setpoint	° C	850		900	850	850	850	850		850
Kiln Actual (Upper) Temp	° C			844	~~848~~ 760	747	741	766		758
Kiln Actual (Middle) Temp	° C			870	804	785	785	805		797
Kiln Actual (Lower) Temp	° C			900	848	846	849	850		861
Kiln Power Output	%			55	4	27	22	12		19
Kiln Control Mode	A or M			A	A	A	A	A		A
Kiln Variac Setting (or NA)	% / NA			50	50	50	25	25		25
Discharge Can Power	kW			0	0.3	0.5	0.6	0.6		0.6
Discharge Can Temp Setpoint	° C	750		100	688	705	750	750		750
Discharge Can Power Output	%			0	49	56	61	59		58
Overflow Heater Power	kW	WCB		2.6	1.8	1.9	1.8	1.9		1.8
Overflow Heater Setpoint	° C	~~1150~~ 1050		1050	1050	1051	1050	1050		1050
Overflow Heater Power Output	%	7/28/03		85	69	73	71	72		70
Time	hh:mm			1010	11:37		1415	1503		1811

Reviewed and Approved: RW Gale

Date: 8/6/03

Sheet 1 of 13

OG Temp 7/29/03

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:									
	Date:		7/28	7/28/03	7/28	7/28	7/29	7/29	7/29	7/29
	Time		1901	2007	2102	2257	0024	0103	0204	0320
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1149	1150	1149	1149	1150	1149	1149	1150
Melt Temperature (T2)	° C	1125 - 1175	1149	1150	1154	1157	1142	1157	1143	1650
Plenum Temperature	° C	400 - 450	442	420	405	413	399	383	399	450
Post FC Off-gas Temperature	° C	200-250	214	218	217	224	214	216	216	218
Cold Cap Coverage	%	> 85	90	85	80	85	90	90*	90	80
Slurry Pool Coverage of Cap	%		30	30	50	40	50	?	20	20
Cold Cap Flexibility Visible	y or n		N	Y	Y	N	N	N	N	N
Number of Vents	#		2 Bubbles	1+2	1+2	2 Bubbles	2	2	2	2
Cold Cap Thickness	inch		1"	3/4	3/4	3/4	3/4	1	3/4	3/4
Phase Separation (Note in LRB)	y or n		N	N	N	N	N	N	N	N
Glass Pouring	y or n		N	Drips	Drip	Drips	Drips	drizzle	Y	Y
Electrical Data										
Electrode Potential	Volts		32.6	32.5	33.4	32.5	31.5	31.7	31.5	31.9
Electrode Current	Amps		89.2	90.4	95.9	92.9	91.5	96.6	92.7	90.9
Electrode Power	kW		2.9	2.9	3.2	3.0	2.8	3.1	2.8	3.0
Melt Resistance	Ω		.363	.362	.348	.345	.347	.325	.341	0.347
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
(Electrode Power) Output	%		46	46	48	47	46	49	46	46
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825	825	825	825	825	825	825
Kiln Actual (Upper) Temp	° C		756	755	766	740	786	~~[illegible]~~ 780	780	789
Kiln Actual (Middle) Temp	° C		798	797	808	822	822	822	821	829
Kiln Actual (Lower) Temp	° C		846	846	854	862	863	863	863	863
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		0%	0	0	0	0	10	~~1140~~ NA	10
Discharge Can Power	kW		0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Discharge Can Temp Setpoint	° C	750	750	750	750	750	750	750	750	750
Discharge Can Power Output	%		58	58	54	54	64	54	51	59
Overflow Heater Power	kW		1.8	1.8	2.2	2.2	2.2	2.2	2.1	2.1
Overflow Heater Setpoint	° C	1150	1050	1050	1100	1100	1100	1100	1100	1100
Overflow Heater Power Output	%		70	69	78	78	79	79	77	76
Time	hh:mm		1905	2011	2106	2302	0027	0110	0211	0324

* covered except at 2 bubble vents

Reviewed and Approved: ____ Date: 3/6/03 Sheet 2 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		gl	JJ	[illegible]	WCB	WCB	WCB	WCB	WCB
	Date:		7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03
	Time		0447	0607	0703	0810	0906	1025	1103	1205
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1144	1152	1150	1150	1150	1150	1149	1150
Melt Temperature (T2)	° C	1125 - 1175	1143	1160	1157	1156	1160	1135	1157	1142
Plenum Temperature	° C	400 - 450	434	390	400	397	392	489	467	420
Post FC Off-gas Temperature	° C	200-250	218	218	214	201.5	199	234	243	238
Cold Cap Coverage	%	> 85	90	90	90	40	Lost feed WCB 7/29/03	Feed [illegible] WCB 7/29/03	50	60
Slurry Pool Coverage of Cap	%		30	30	30	80			80	80
Cold Cap Flexibility Visible	y or n		Y	Y	Y	Y			N	N
Number of Vents	#		2	2	2	2			bubbler	bubbler
Cold Cap Thickness	inch		3/4	3/4	3/4	3/4			1/2	1/2
Phase Separation (Note in LRB)	y or n		N	N	N	N		N	N	N
Glass Pouring	y or n		Y	Y	Y	Y		N	N	N
Electrical Data										
Electrode Potential	Volts		34.6	31.4	31.4	31.3	30.8	34.8	34.7	32.5
Electrode Current	Amps		92.1	92.4	93.6	93.8	95.0	85.1	87.3	82.9
Electrode Power	kW		3.1	2.9	2.9	2.9	2.9	2.9	2.9	2.7
Melt Resistance	Ω		0.370	0.342	0.338	0.333	0.324	0.408	0.387	0.391
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1160	1150	1150	1150	1150
(Electrode Power) Output	%		47	46	47	47	48	43	44	42
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825	825	825	825	826	825	825
Kiln Actual (Upper) Temp	° C		799	789	789	792	796	824	818	813
Kiln Actual (Middle) Temp	° C		834	830	827	834	837	861	854	851
Kiln Actual (Lower) Temp	° C		867	867	867	868	869	882	876	886
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	N/A	10	10	10	10	10	10
Discharge Can Power	kW		0.7	0.5	0.6	0.6	0.6	0.5	0.6	0.6
Discharge Can Temp Setpoint	° C	750	750	750	750	749	750	750	750	750
Discharge Can Power Output	%		64	52	56	59	58	54	59	56
Overflow Heater Power	kW		2.1	2.0	2.1	2.0	2.2	2.8	2.8	2.7
Overflow Heater Setpoint	° C	1150	1100	1100	1100	1100	1100	1150	1150	1150
Overflow Heater Power Output	%		76	75	76	78	79	90	90	90
Time	hh:mm		0457	0611	0705	0820		1031	1109	

Reviewed and Approved: ______ Date: 8/6/03

Sheet 3 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		WCB	WCB	JW	JW	JW	JW	JW	ORK
	Date:		7/29/03	7/29/03	7/29/03	7/29	7/29	7/29	7/29	7/29
	Time		1302	1402	1616	1710	1804	1906	2005	2109
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	°C	1125 - 1175	1148	1149	1151	1153	1150	1150	1150	~~1149~~ 1150 ORK
Melt Temperature (T2)	°C	1125 - 1175	1154	1147	1142	1142	1152	1151	1152	1149
Plenum Temperature	°C	400 - 450	424	417	500	434	415	411	415	396
Post FC Off-gas Temperature	°C	200-250	234	236	254.5	234	228	236.4	239.5	243
Cold Cap Coverage	%	> 85	60	50	70	80	85	80	85	85
Slurry Pool Coverage of Cap	%		80	80	80	50	50	50	50	50
Cold Cap Flexibility Visible	y or n		N	N	N	N	N	Y	Y	Y
Number of Vents	#		bubbler	bubbler	2Bubblers	2	2	2	2	2
Cold Cap Thickness	inch		1/2	1/2	1/2	1/2	3/4	3/4	3/4	3/4
Phase Separation (Note in LRB)	y or n		N	N	N	N	N	N	N	N
Glass Pouring	y or n		N	N	N	N Drip	Drips	Drips	Drips	Drips
Electrical Data										
Electrode Potential	Volts		32.7	32.2	33.4	32.6	32.4	31.7	31.8	31.7
Electrode Current	Amps		89.7	86.5	88.1	87.9	91.4	89.0	90.1	89.4
Electrode Power	kW		3.0	2.8	3.0	2.9	2.9	2.8	2.8	2.9
Melt Resistance	Ω		0.364	0.363	.377	.365	.354	.352	.351	0.357
Melt (Electrode) Setpoint Temp	°C	1150	1150	1150	1150	1150	1150	1150	1150	1150
(Electrode Power) Output	%		45	45	45	45	46	45	46	46
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	°C	850	825	825	825	825	825	825	825	825
Kiln Actual (Upper) Temp	°C		811	815	834	822	814	814	815	817
Kiln Actual (Middle) Temp	°C		851	863	870	857	852	852	853	855
Kiln Actual (Lower) Temp	°C		886	885	892	891	888	886	887	888
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	10	10	10	10	10	10	10
Discharge Can Power	kW		0.5	0.5	0.5	0.5	0.5	0.5	.05	0.5
Discharge Can Temp Setpoint	°C	750	750	750	750	750	750	750	750	750
Discharge Can Power Output	%		55	55	53	52	53	52	53	53
Overflow Heater Power	kW		2.7	2.8	2.7	2.7	2.8	2.7	2.8	2.8
Overflow Heater Setpoint	°C	1150	1150	1150	1150	1150	1150	1151	1150	1150
Overflow Heater Power Output	%		89	90	89	89	90	89	90	90
Time	hh:mm		1306	1405	1619	1712	1806	1908	2007	2114

Reviewed and Approved: R W

Date: 8/6/03

Sheet 4 of 12

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:					RW2				
	Date:		7/29/03	7/29	7/30	7/30	7/30	7/30	7/30	7/30
	Time		2207	2305	0004	01:00	0218	0305	0401	0505
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1152	1149	1149	1149	1145	1150	1151	1149
Melt Temperature (T2)	° C	1125 - 1175	1151	1150	1152	1154	1149	1156	1160	1155
Plenum Temperature	° C	400 - 450	384	392	393	389	441	417	404	394
Post FC Off-gas Temperature	° C	200-250	240	235	237.5	244	249	250	248	243
Cold Cap Coverage	%	> 85	85		80	80	50	70	80	80
Slurry Pool Coverage of Cap	%		50		50	50	60	30	25	20
Cold Cap Flexibility Visible	y or n		y		Y	Y	y	y	Y	Y
Number of Vents	#		1/2		1+2	2	2	2	3	2
Cold Cap Thickness	inch		3/4		3/4	3/4	1/2	3/4	1	1
Phase Separation (Note in LRB)	y or n		N		N	N	N	N	n	n
Glass Pouring	y or n		drips		Drips	DRIPS	Drips	Drips	y	drips
Electrical Data										
Electrode Potential	Volts		31.1	31.6	31.1	30.8	33.2	32.3	31.6	31.1
Electrode Current	Amps		89.4	90.7	90.3	90.1	90.3	89.4	88.1	89.2
Electrode Power	kW		2.8	2.9	2.8	2.9	3.0	2.8	2.8	2.8
Melt Resistance	Ω		0.348	.344	.347	0.344	0.365	0.354	.357	.351
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
(Electrode Power) Output	%		45	46	44	45	46	45	45	45
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825	825	825	825	825	825	825
Kiln Actual (Upper) Temp	° C		813	814	823	825	832	832	897	829
Kiln Actual (Middle) Temp	° C		853	855	861	863	869	869	867	865
Kiln Actual (Lower) Temp	° C		886	887	890	892	885	897	831	843
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	10	10	10	10	10	N/A	N/A
Discharge Can Power	kW		0.5	0.6	0.6	0.6	0.6	0.7	0.5	0.6
Discharge Can Temp Setpoint	° C	750	750	750	750	750	750	750	750	750
Discharge Can Power Output	%		52	58	60	60	60	61	56	59
Overflow Heater Power	kW		2.8	2.8	2.8	2.8	2.8	2.8	2.7	2.8
Overflow Heater Setpoint	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
Overflow Heater Power Output	%		90	90	90	90	90	90	89	90
Time	hh:mm		2212	2307	0006	01:09	0220	0308	0405	510

Reviewed and Approved:

Date: 8/6/03

Sheet 5 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		ADJ	ADJ	WCB	WCB	WCB	WCB	[illegible]	JW
	Date:		7/30/03	7/30	7/30/03	7/30/03	7/30/03	7/30/03	7/30/03	7/30
	Time		0603	0708	0800	0900	1025	1110	1701	1809
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1149	1149		1149	1150	1152	1154	1152
Melt Temperature (T2)	° C	1125 - 1175	1156	1148		1150	1162	1155	1157	1146
Plenum Temperature	° C	400 - 450	389	383	[illegible] Swapped Over to [illegible]	399	404	399	549	410
Post FC Off-gas Temperature	° C	200-250	246	244		246	244	231	235.5	247.5
Cold Cap Coverage	%	> 85	80	70		40	50	40	60	85
Slurry Pool Coverage of Cap	%		20	20		80	40	80	70	60
Cold Cap Flexibility Visible	y or n		Y	Y		Y	N.	N	Y	N
Number of Vents	#		3	3		bubbler	bubbler	bubbler	Bubbler	Bub
Cold Cap Thickness	inch		1	1/2		1/2	1/2	1/2	1/2	3/4
Phase Separation (Note in LRB)	y or n		n	n		N	N	N	N	N
Glass Pouring	y or n		drips	NO		N	N	N	YES	drip
Electrical Data										
Electrode Potential	Volts		32.2	31.6		30.2	30.6	29.4	33.6	32.4
Electrode Current	Amps		89.5	88.8		88.7	93.3	86.7	93.4	86.9
Electrode Power	kW		2.9	2.9		2.7	2.9	2.6	3.2	2.9
Melt Resistance	Ω		.359	~~.344~~ .356		0.342	0.331	0.331	.366	.370
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150		1150	1150	1150	1150	1150
(Electrode Power) Output	%		45	44		45	47	44	47	45
(Electrode) Control Mode	A or M		A	A		A	A	A	A	A
Kiln Power	kW		0	0		0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825		825	825	825	825	825
Kiln Actual (Upper) Temp	° C		829	832		832	833	833	798	797
Kiln Actual (Middle) Temp	° C		865	868		869	869	870	834	832
Kiln Actual (Lower) Temp	° C		893	895		895	895	897	853	865
Kiln Power Output	%		0	0		0	0	0	0	0
Kiln Control Mode	A or M		A	A		A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		N/A	N/A		10	10	10	10	10
Discharge Can Power	kW		0.6	0.6		0.6	0.5	0.6	0.6	0.5
Discharge Can Temp Setpoint	° C	750	750	750		750	750	750	750	750
Discharge Can Power Output	%		58	60		58	52	56	58	54
Overflow Heater Power	kW		2.8	2.8		2.8	2.8	2.8	2.8	2.8
Overflow Heater Setpoint	° C	1150	1150	1150		1150	1160	1150	1150	1125
Overflow Heater Power Output	%		90	90		90	90	90	90	90
Time	hh:mm		0610	0713		0905	0930	1113	1709	1811

Reviewed and Approved: 　　　　Date: 8/6/03 　　　　Sheet 6 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:								SP	SP
	Date:		7/30/03	7/30	7/30	7/30	7/30	7/31	07/31	7/31
	Time		1904	2007	2059	2204	2300	0016	0110	0206
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1152	1152	1139	1152	1144	1152	1149	1149
Melt Temperature (T2)	° C	1125 - 1175	1156	1147	1144	1138	1145	1147	1136	1131
Plenum Temperature	° C	400 - 450	411	393	448	401	366	405	404	399
Post FC Off-gas Temperature	° C	200-250	243	231.0	262.0	229.4	218.0	218	224	229
Cold Cap Coverage	%	> 85	90	90	75	95	95	85	85	85
Slurry Pool Coverage of Cap	%		40	50	60	50	50	25	25	25
Cold Cap Flexibility Visible	y or n		N	N	N	N	N	Y	Y	Y
Number of Vents	#		2+2Bub	2Bub	1Big	2Bub	2	2	2	2
Cold Cap Thickness	inch		1"	1"	3/4	1"	1"	1"	1"	1
Phase Separation (Note in LRB)	y or n		N	N	N	N	N	N	N	N
Glass Pouring	y or n		Drip	Drips	N	N	N	N	Drips	Drips
Electrical Data										
Electrode Potential	Volts		33.0	32.0	37.7	31.3	33.5	32.9	32.4	31.8
Electrode Current	Amps		91.6	86.6	93.4	84.2	96.4	90.5	86.5	86.5
Electrode Power	kW		3.0	2.7	3.5	2.7	3.3	3.0	2.8	2.8
Melt Resistance	Ω		.358	.366	.400	.366	.340	.363	0.370	0.365
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
(Electrode Power) Output	%		47	45	48	43	47	45	44	44
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825	825	825	825	825	825	825
Kiln Actual (Upper) Temp	° C		796	794	797	797	728	864	800	802
Kiln Actual (Middle) Temp	° C		833	832	834	835	768	827	838	841
Kiln Actual (Lower) Temp	° C		870	872	873	874	822	789	870	869
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	10	10	10	10	N/A	10	10
Discharge Can Power	kW		0.5	0.9	0.7	0.6	0.6	0.7	0.6	0.6
Discharge Can Temp Setpoint	° C	750	750	750	750	750	750	61	~~558~~ 750	750
Discharge Can Power Output	%		55	71	64	59	57	750	58	59
Overflow Heater Power	kW		2.7	2.7	2.8	2.6	2.9	2.8	2.8	2.8
Overflow Heater Setpoint	° C	1150	1125	1125	1125	1125	1125	1125	1150	1150
Overflow Heater Power Output	%		88	89	90	87	90	90	90	90
Time	hh:mm		1906	2010	2103	2207	2303	0021	0114	0209

Reviewed and Approved:

Date: 8/6/03

Sheet 7 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		Sl	JJD	Sl	Sl	Sl	WCB	WCB	WCB
	Date:		7/31/03	7/31/03	7/31	7/31	7/31	7/31/03	7/31/03	7/31/03
	Time		0306	0412	0506	0600	0706	0820	1214	1305
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1150	1152	1147	1150	1149	1149	1149	1150
Melt Temperature (T2)	° C	1125 - 1175	1133	1130	1145	1140	1140	1137	1143	1143
Plenum Temperature	° C	400 - 450	393	458*	420	383	395	418	431	403
Post FC Off-gas Temperature	° C	200-250	228	243	238	227	220	224	210	212
Cold Cap Coverage	%	> 85	80	60*	70	80	85	40	40	50
Slurry Pool Coverage of Cap	%		25	50*	25	25	25	60	50	50
Cold Cap Flexibility Visible	y or n		Y	Y	Y	Y	Y	N	N	N
Number of Vents	#		2	2	3	2	2	bubbler	bubbler	bubbler
Cold Cap Thickness	inch		3/4	1/4	3/4	3/4	3/4	3/4	3/4	1
Phase Separation (Note in LRB)	y or n		N	H	N	N	N	N	N	N
Glass Pouring	y or n		Drips	M	Drips	Drips	Drips	drip	drip	drip
Electrical Data										
Electrode Potential	Volts		31.6	32.6	32.6	31.3	31.7	31.1	31.9	31.1
Electrode Current	Amps		89.3	81.8	88.4	82.9	85.6	84.4	91.9	87.8
Electrode Power	kW		2.6	2.7	2.9	2.6	2.7	2.6	2.8	2.8
Melt Resistance	Ω		0.372	.401	0.360	0.379	0.373	0.362	0.348	0.351
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
(Electrode Power) Output	%		43	41	45	42	43	43	46	45
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825	825	825	825	825	825	825
Kiln Actual (Upper) Temp	° C		806	817	811	806	806	808	815	818
Kiln Actual (Middle) Temp	° C		844	853	848	844	844	847	853	856
Kiln Actual (Lower) Temp	° C		876	881	882	882	881	881	884	886
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	N/A	10	10	10	10	10	10
Discharge Can Power	kW		0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6
Discharge Can Temp Setpoint	° C	750	800	800	800	800	800	800	800	800
Discharge Can Power Output	%		67	67	62	63	62	61	60	58
Overflow Heater Power	kW		2.7	2.7	2.5	2.5	2.6	2.6	2.4	2.7
Overflow Heater Setpoint	° C	1150	1125	1125	1125	1125	1125	1125	1125	1125
Overflow Heater Power Output	%		89	89	85	86	86	87	84	88
Time	hh:mm		0309	0415	0509	0603	0709	0826	1217	1209

*just finished changing feed pump tube

Reviewed and Approved: RW Gooler Date: 8/6/03 Sheet 8 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		WCB						CK	
	Date:		7/31/03	7/31	7/31	7/31	7/31	7/31	7/31	7/31
	Time		1514	1614	1658	1758	1906	2008	2108	2208
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1149	1150	1149	1149	1142	1149	1147	1151
Melt Temperature (T2)	° C	1125 - 1175	1142	1140	1137	1137	1136	1133	1137	1150
Plenum Temperature	° C	400 - 450	427	403	406	399	428	418	387	394
Post FC Off-gas Temperature	° C	200-250	215	212.0	219.0	215.0	204.0	198.9	198.5	204.5
Cold Cap Coverage	%	> 85	60	75	90	90	85	[illegible] See Note LRB	90	85
Slurry Pool Coverage of Cap	%		70	50	40	40	50		40	50
Cold Cap Flexibility Visible	y or n		N	N	N	N	N		N	N
Number of Vents	#		bubbler	2 + 2B	2 Bubbler	2	2		2	2
Cold Cap Thickness	inch		1	3/4	1"	1"	3/4		3/4	3/4
Phase Separation (Note in LRB)	y or n		N	N	N	N	N		N	N
Glass Pouring	y or n		Y	N	Dripping	Dripping	Drip		N	N
Electrical Data										
Electrode Potential	Volts		32.2	31.3	31.9	30.4	33.7	30.5	32.3	32.2
Electrode Current	Amps		96	96.1	92.9	89.0	98.6	96.5	104.1	92.6
Electrode Power	kW		3.1	3.1	2.9	2.7	3.3	2.7	3.4	3.0
Melt Resistance	Ω		0.334	.334	.343	.346	.339	.335	0.318	.349
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150	1150	1150	1149	1150
(Electrode Power) Output	%		48	47	47	45	50	46	52	47
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0.0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	805	825	825	825	825	825	~~825~~ 825	825
Kiln Actual (Upper) Temp	° C		787	799	806	804	815	819	~~820~~ 797	802
Kiln Actual (Middle) Temp	° C		828	838	843	843	851	855	757	841
Kiln Actual (Lower) Temp	° C		858	869	874	879	883	884	818	867
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	10	10	10	10	10	10	~~10~~ 10Ω
Discharge Can Power	kW		0.7	0.7	1.0	0.9	0.9	0.9	1.0	0.9
Discharge Can Temp Setpoint	° C	750	870	870	870	870	870	870	870	870
Discharge Can Power Output	%		64	62	77	73	72	72	77	70
Overflow Heater Power	kW		2.6	2.4	2.4	2.3	2.3	2.0	2.3	2.8
Overflow Heater Setpoint	° C	1150	1100	1100	1100	1100	1100	860	1150	1150
Overflow Heater Power Output	%		86	83	83	81	82	0	90	90
Time	hh:mm		1519	1618		1800	1908	2010	2113	2211

Reviewed and Approved:

Date: 8/1/03

Sheet 9 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		[illegible]	SP	[illegible]	SP	SP	SP	[illegible]	SP
	Date:		7/31/03	8/1/03	8/1/03	8/1	8/1	8/1	8/1	8/1
	Time		2259	0001	0106	0207	0301	0405	0531	0700
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1142	1150	1151	1147	1154	1149	1153	1149
Melt Temperature (T2)	° C	1125 - 1175	1148	1141	1147	1135	1136	1135	1146	1130
Plenum Temperature	° C	400 - 450	345	392	400	420	399	381	411	416
Post FC Off-gas Temperature	° C	200-250	204.0	222	221	206	198	184	203	187
Cold Cap Coverage	%	> 85	80	85	85	85	85	85	80	85
Slurry Pool Coverage of Cap	%		50	40	20	25	25	25	25	25
Cold Cap Flexibility Visible	y or n		N	N	N	Y	Y	Y	Y	Y
Number of Vents	#		2	2	2	2	2	2	2	2
Cold Cap Thickness	inch		3/4	3/4	3/4	3/4	3/4	3/4	1/2	3/4
Phase Separation (Note in LRB)	y or n		N	N	N	N	N	N	N	N
Glass Pouring	y or n		N	N	drips	drips	N	N	N	N
Hg conc in Greenhouse	mg/m³								0.0	0
Electrical Data										
Electrode Potential	Volts		34.3	32.2	30.7	31.0	28.5	30.7	30.6	30.7
Electrode Current	Amps		96.2	90.2	88.8	83.7	80.5	89.4	94.8	89.4
Electrode Power	kW		3.3	2.9	2.7	2.6	2.4	2.8	3.1	2.6
Melt Resistance	Ω		.358	0.359	0.350	0.366	0.356	0.343	.307	0.348
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
(Electrode Power) Output	%		49	45	44	42	41	45	50	49
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825	825	825	825	825	825	825
Kiln Actual (Upper) Temp	° C		812	791	820	836	833	756	805	834
Kiln Actual (Middle) Temp	° C		846	829	857	872	869	794	845	872
Kiln Actual (Lower) Temp	° C		883	860	884	897	849	857	865	895
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	10	N/A	10	10	10	N/A	10
Discharge Can Power	kW		0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.7
Discharge Can Temp Setpoint	° C	750	870	870	870	870	870	870	870	870
Discharge Can Power Output	%		71	72	70	69	69	72	68	64
Overflow Heater Power	kW		0	2.8	2.7	2.8	2.8	0	2.8	2.8
Overflow Heater Setpoint	° C	1150	800	1150	1150	1150	1150	800	1150	1150
Overflow Heater Power Output	%		0	90	90	90	90	0	90	90
Time	hh:mm		2302	0003	0110	0209	0303	0407	0536	0704

Reviewed and Approved: Date: 7/6/03 Sheet 10 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		Jw	Jw	Jw	Jw	Jw	RWG	Jw	Jw
	Date:		8/1/03	8/1	8/1	8/1	8/1	8/1	8/1	8/1
	Time		0801	0859	1005	1110	1205	1254	1410	1507
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1150	1147	1147	1149	1154	1151	1148	1153
Melt Temperature (T2)	° C	1125 - 1175	1140	1137	1142	1135	1138	1135	1116	1142
Plenum Temperature	° C	400 - 450	404	413	415	406	408	406	391	413
Post FC Off-gas Temperature	° C	200-250	185.5	184.6	163.0	164.0	166.5	194	182.4	176.4
Cold Cap Coverage	%	> 85	90	90	90	95	90	90	80	85
Slurry Pool Coverage of Cap	%		40	40	30	40	40	40	50	50
Cold Cap Flexibility Visible	y or n		N	N	N	N	N	N	Y	N
Number of Vents	#		2	2	2	2	2	2	3	3
Cold Cap Thickness	inch		1"	1"	3/4	1"	3/4		1/2	3/4
Phase Separation (Note in LRB)	y or n		N	N	N	N	N	N	N	N
Glass Pouring	y or n		N	N	N	N	N	N	Y	N
Hg concentration in Greenhouse	mg/m³		000	000	0.00	000	0	000	000	000
Electrical Data										
Electrode Potential	Volts		29.2	29.9	29.5	28.7	27.5	29.0	32.9	30.3
Electrode Current	Amps		87.8	91.4	88.5	86.8	84.9	87.6	102.3	100.8
Electrode Power	kW		2.5	2.8	2.6	2.6	2.4	2.5	3.4	3.0
Melt Resistance	Ω		.326	.326	.334	.332	.326	0.329	.319	.298
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
(Electrode Power) Output	%		45	45	45	44	43	45	52	51
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825	825	825	825	825	825	825
Kiln Actual (Upper) Temp	° C		837	841	839	834	836	~~897~~ 836 RWG	743	817
Kiln Actual (Middle) Temp	° C		874	877	874	870	874	872	783	856
Kiln Actual (Lower) Temp	° C		898	900	900	895	897	897	823	872
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	10	10	10	10	10	10	10
Discharge Can Power	kW		0.7	0.7	0.7	0.7	0.6	0.6	1.0	0.9
Discharge Can Temp Setpoint	° C	750	870	870	870	870	870	870	870	870
Discharge Can Power Output	%		64	64	61	62	60	40	74	71
Overflow Heater Power	kW		2.8	2.7	2.8	2.8	2.7	2.7	2.9	2.7
Overflow Heater Setpoint	° C	1150	1150	1150	1150	1150	1150	1150	~~870~~ 1150	1150
Overflow Heater Power Output	%		90	90	90	90	90	90	90	90
Time	hh:mm		0809	0902	1007	1112	1208	1306	1412	1511

Reviewed and Approved: RW Gole

Date: 8/6/03

Sheet 11 of 13

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		WCB	WCB	WCB	WCB	WCB	WCB	SP	[illegible]
	Date:		8/1/03	8/1/03	8/1/03	8/1/03	8/1/03	8/1/03	8/2/03	8/2/03
	Time		1705	1808	1902	2010	2103	2230	0000	0103
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1150	1150	1147	1154	1150	1152	1149	1154
Melt Temperature (T2)	° C	1125 - 1175	1132	1139	1128	1143	1138	1137	1126	1131
Plenum Temperature	° C	400 - 450	423	410	401	411	406	390	405	408
Post FC Off-gas Temperature	° C	200-250	201*	208*	207*	185	180	175	166	199
Cold Cap Coverage	%	> 85	60	60	50	50	50	60	70	80
Slurry Pool Coverage of Cap	%		70	80	70	80	80	50	40	20
Cold Cap Flexibility Visible	y or n		N	N	N	N	N	N	n	y
Number of Vents	#		bubbler	bubbler	bubbler	bubbler	bubbler	bubbler	n	2
Cold Cap Thickness	inch		3/4	3/4	3/4	3/4	3/4	3/4	3/4	1
Phase Separation (Note in LRB)	y or n		N	N	N	N	N	N	N	n
Glass Pouring	y or n		N	N	N	N	N	N	N	n
H_2 concentration in Greenhouse	mg/m³		0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Electrical Data										
Electrode Potential	Volts		29.2	29.9	29.1	28.3	28.2	28.0	27.8	27.5
Electrode Current	Amps		86.3	93.5	89.9	93.2	90.6	89.8	88.6	90.0
Electrode Power	kW		2.5	2.8	2.7	2.7	2.6	2.6	2.5	2.6
Melt Resistance	Ω		0.337	0.321	0.329	0.304	0.310	0.312	0.316	.306
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
(Electrode Power) Output	%		44	46	46	47	46	46	45	46
(Electrode) Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Power	kW		0	0	0	0	0	0	0	0
Kiln Temp Setpoint	° C	850	825	825	825	825	825	825	825	825
Kiln Actual (Upper) Temp	° C		839	836	839	844	846	843	846	854
Kiln Actual (Middle) Temp	° C		876	874	877	882	884	881	884	892
Kiln Actual (Lower) Temp	° C		902	903	906	909	909	907	905	909
Kiln Power Output	%		0	0	0	0	0	0	0	0
Kiln Control Mode	A or M		A	A	A	A	A	A	A	A
Kiln Variac Setting (or NA)	% / NA		10	10	10	10	10	10	10	N/A
Discharge Can Power	kW		0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8
Discharge Can Temp Setpoint	° C	750	870	870	870	870	870	870	870	870
Discharge Can Power Output	%		71	70	70	70	70	68	69	68
Overflow Heater Power	kW		2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Overflow Heater Setpoint	° C	1150	1150	1150	1150	1150	1150	1150	1150	1150
Overflow Heater Power Output	%		90	90	90	90	90	90	90	90
Time	hh:mm		1710	1812	1908	2017	2106	2234	0005	0107

Reviewed and Approved: ________ Date: 8/1/03 Sheet 12 of 13

* accidently used offgas line temp

Data Sheet #1: Priority & Electrical Data

RSM, July 2003	By:		[illegible]	[illegible]	[illegible]	[illegible]				
	Date:		8/2/03	8/2/03	8/2/03	8/2/03				
	Time		0202	0304	0402	0504				
DESCRIPTION	UNITS	Range								
Priority Data										
Melt Temperature (T1, control)	° C	1125 - 1175	1149	1149	1150	1147				
Melt Temperature (T2)	° C	1125 - 1175	1124	1127	1127	1152				
Plenum Temperature	° C	400 - 450	396	381	398	448				
Post FC Off-gas Temperature	° C	200-250	203	202	194	195				
Cold Cap Coverage	%	> 85	90	95	85	70				
Slurry Pool Coverage of Cap	%		30	30	30	30				
Cold Cap Flexibility Visible	y or n		y	y	N	y				
Number of Vents	#		2	2	2	1 bigone				
Cold Cap Thickness	inch		3/4	1	1	1/2				
Phase Separation (Note in LRB)	y or n		n	n	n	n				
Glass Pouring	y or n		n	n	n	n				
H_2 concentration in Greenhouse	mg/m³		0.000	0.000	0.000	0.000				
Electrical Data			27.7							
Electrode Potential	Volts		91.9	28.0	28.8	28.4				
Electrode Current	Amps			95.9	107.2	108.6				
Electrode Power	kW		2.6	2.7	3.1	3.1				
Melt Resistance	Ω		.302	.287	0.268	.260				
Melt (Electrode) Setpoint Temp	° C	1150	1150	1150	1150	1150				
(Electrode Power) Output	%		46	48	54	55				
(Electrode) Control Mode	A or M		A	A	A	A				
Kiln Power	kW		0	0	0.9	0				
Kiln Temp Setpoint	° C	850	825	825	900	900				
Kiln Actual (Upper) Temp	° C		851	801	798	867				
Kiln Actual (Middle) Temp	° C		841	840	841	898				
Kiln Actual (Lower) Temp	° C		909	881	902	909				
Kiln Power Output	%		0	0	54	0				
Kiln Control Mode	A or M		A	A	A	A				
Kiln Variac Setting (or NA)	% / NA		N/A	N/A	50%	N/A				
Discharge Can Power	kW		0.8	0.9	0.9	0.7				
Discharge Can Temp Setpoint	° C	750	870	870	870	870				
Discharge Can Power Output	%		67	70	70	65				
Overflow Heater Power	kW		2.7	0.7	0.7	2.7				
Overflow Heater Setpoint	° C	1150	1150	900	900	1128				
Overflow Heater Power Output	%		90	42	41	90				
Time	hh:mm		0207	0307		0510				

Reviewed and Approved:

Date: 8/6/03

Sheet 13 of 13

Date Sheet #2: Routine Status Sheets

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	HDS	H.D.S.	H.D.S.	WCB	CRH	JD	JD	CRH
		Date:	7/28	7/28	7/28	7/28/03	7/28/03	7/28	7/28	7/28
		Time:	10:00	11:06	12:03	1413	1710	1811	1905	2010
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	0.22	0.75	0.8	0.8	0.8	0.8	0.8	0.8
Film Cooler Air Supply	scfm	1-4 (reg OGT)	3.9	2.1	3.1	3.1	2.9	2.9	2.9	2.9
Film Cooler Pressure	psig	20-50	3.5	2	2	2.5	2.5	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	1.6	3.4	2.5	2.4	3.1	3.1	3.0	3.1
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0.1	0	0	0	0	0	0	0
HEME ΔP	in. H2O		0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	2.8	1.9	2.0	2.0	2.1	2.1	2.0	1.9
EVS Scrub Tank Volume	liters	60-220	90	90	90	90	92	92	92	92
EVS Nozzle Pressure	psi	50 - 55	53	53	53	53	53	53	53	53
EVS Nozzle Flow	gpm		3.1	3.1	3.2	3.1	3.1	3.1	3.1	3.1
EVS Scrub Solution pH	pH		—	—	—	—	—	—	—	—
OG Control Valve position	%		80	0		0	0	0	0	0
OG Control Valve mode	A or M		A	A	A	A	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		—	—	—	OK	NA	OK	OK	OK
Recirc Pump Tubing (Master)	Chg/Pull		—	—	—	OK	NA	OK	OK	OK
Recirc Pump Tubing (DayTnk)	Chg/Pull		—	—	—	OK	OK	OK	OK	OK
1-10 Day Tnk Agitator Setting	%		DC	NC	NC	NC	NC	4	4	4
0-100 Master Tank Agitator Setting	%		70		70	70	70	70	70	70
Blower Cooling Flow	gpm	1 - 1.5	1.5	1.6	1.6	1.6	1.9	1.8	1.8	1.8
Feed Nozzle Temp (FNT)	° C	< 40	29	28	27	28	28	28	28	27
Melter Off-Gas Jumper Temp	° C	200 - 250	227	215	180	243	234	217	215	218
Post EVS Off-Gas Temp	° C	< 50	32	34	34	35	34	34	34	34
Post HEME Off-Gas Temp	° C	100	30	32	33	34	36	36	36	30
Hg-Bed Temperature (or NA)	° C / NA	100	NA	NA	NA	NA	NA	—	—	—
Scrub Liquid Temp (SLT)	° C	≤40	305	34.1	34.5	36	33.5	34	34	40.
EVS HX Cooling Temp	° C	≤30	32	34.0	34	35	34	34	34	34
Feed Pump Setting	%		12	13	13	13	10	9%	9%	9%
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	—	—	—	—		—	—	—
Day Tank Wt	Kg	<83 Net	119.3	117.5	115.5	110.98	107.92	106.17	105.07	103.33
Master Feed Tank Wt	lb ~~Kg~~ WCB 7/28/03	<300 Net	410	410	409	409	408	408	408	405
Overflow Temp	° C	1100 - 1150	1051	1048	1050	1051	1050	1050	1050	1050
Discharge Can Temp	° C	750 - 850	380	467	705	753	799	750	750	750
Glass Scale	Kg	< 10	0	0.58	1.15	1.99	4.05	4.26	4.51	5.00
Alarm Condition	On/Off	off	off	off	—	off	off	off	—	—
time	hh:mm		10:31			1440	1720	1823		2018

Reviewed and Approved: Date: 8/6/03 Sheet 1 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By: JW Date: 7/28 Time: 2106	JW 7/28 2106	JW 7/28 2302	JW 7/29 0009	SL 7/29 0112	MJ 7/29 0212	SL 7/29 0313	MJ 7/29 0442	SL 7/29 0559
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	.75	.8	.8	0.8	0.77	0.77	0.76	0.6
Film Cooler Air Supply	scfm	1-4 (reg OGT)	2.8	2.25	2.3	2.0	2.4	2.4	2.5	2.6
Film Cooler Pressure	psig	20-50	2	2	2	2	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.1	3.0	3.1	3.1	3.2	3.1	3.1	3.2
EVS ΔP	in. H2O		0	0	0	0		0	0	0
Film Cooler ΔP	in. H2O		0	0	0	0		0	0	0
HEME ΔP	in. H2O		0.3	0.2	0.3	0.2		0.3	0.3	0.3
System ΔP	in. H2O		0	0	0	0		0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	1.8	2.0	2.0	1.9	1.8	1.9	1.8	1.4
EVS Scrub Tank Volume	liters	60-220	93	93	93	93	93	94	94	95
EVS Nozzle Pressure	psi	50 - 55	53	53	53	53	53	53	53	53
EVS Nozzle Flow	gpm		3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
EVS Scrub Solution pH	pH		—	—	—	—	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		OK	OK	OK	OK	OK	OK	changed	OK
Recirc Pump Tubing (Master)	Chg/Pull		OK	OK	OK	OK	OK	OK	of	OK
Recirc Pump Tubing (DayTnk)	Chg/Pull		OK	OK	OK	OK	OK	OK	tubes	OK
Day Tnk Agitator Setting	%		NC	NC	NC	NC	NC	NC	NC	NC
Master Tank Agitator Setting	%		NC	NC	NC	NC	NC	NC	NC	NC
Blower Cooling Flow	gpm	1 - 1.5	1.7	1.8	1.8	1.8	1.8	1.8	1.4	1.9
Feed Nozzle Temp (FNT)	° C	< 40	27	28	27	27	27	27	27	28
Melter Off-Gas Jumper Temp	° C	200 - 250	217	223	222	216	218	223	228	218
Post EVS Off-Gas Temp	° C	< 50	34	34	33	34	34	32	34	33
Post HEME Off-Gas Temp	° C	100	36	35	34	34	32	32	30	30
Hg-Bed Temperature (or NA)	° C / NA	100	NA	NA	NA	N/A	NA	N/A	N/A	N/A
Scrub Liquid Temp (SLT)	° C	≤40	39	36	36	33.5	33	32	32.5	32.5
EVS HX Cooling Temp	° C	≤30	34	33	33	32	32	32	32	33
Feed Pump Setting	%		9.5	9.5	9.5	9.5	9.5	9.5	12.0	10
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.7	1.0	1.5	0.8	1.2	1.1	2.0	1.9
Day Tank Wt	Kg	<83 Net	101.87	99.14	97.23	93.61	93.34	92.75	90.05	87.97
Master Feed Tank Wt	Kg	<300 Net	409	408	409	408	408	408	408	408
Overflow Temp	° C	1100 - 1150	1100	1100	1101	1102	1100	1101	1100	1100
Discharge Can Temp	° C	750 - 850	749	750	750	750	750	750	750	750
Glass Scale	Kg	< 10	5.41	6.23	6.71	7.01	7.82	8.16	0.43	0.93
Alarm Condition	On/Off	off	off	off	off	off	off	ON	off	OFF
time	hh:mm					0120	0237	0319	501	0607

NC = No Change

Reviewed and Approved: RW Gole

Date: 8/6/03

Sheet 2 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	sl	WCB	WCB	WCB	WCB	WCB	JD	WCB
		Date:	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29	7/29/03
		Time:	0707	0803	0911	1015	1109	1159	1300	1405
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	0.7	0.7	0.8	0.8	0.8	0.8	.85	0.85
Film Cooler Air Supply	scfm	1-4 (reg OGT)	2.6	2.6	2.5	2.5	2.4	2.4	2.3	2.3
Film Cooler Pressure	psig	20-50	2	2	2	2	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.2	3.4	3.4	3.8	3.8	3.8	3.6	3.6
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0	0	0	0	0	0	0	0
HEME ΔP	in. H2O		0.2	0.3	0.3	0.2	0.3	0.3	0.3	0.2
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	1.8	1.8	1.8	1.9	2.0	2.0	2.0	2.0
EVS Scrub Tank Volume	liters	60-220	95	95	95	95	95	95	95	95
EVS Nozzle Pressure	psi	50 - 55	53	53	53	53	53	53	53	53
EVS Nozzle Flow	gpm		3.2	3.2	3.2	3.2	3.1	3.1	3.2	3.1
EVS Scrub Solution pH	pH		—	—	—	—	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	m	M
Feed Pump (tubing) Condition	Chg/Pull		OK	OK	OK	OK	OK	OK	OK	OK
Recirc Pump Tubing (Master)	Chg/Pull		OK	OK	OK	OK	OK	OK	OK	OK
Recirc Pump Tubing (DayTnk)	Chg/Pull		OK	OK	OK	OK	OK	OK	OK	OK
Day Tnk Agitator Setting	%		40	NC	NC	NC	NC	NC	NC	NC
Master Tank Agitator Setting	%		70	NC	NC	NC	NC	NC	NC	NC
Blower Cooling Flow	gpm	1 - 1.5	1.5	1.6	1.6	1.8	1.85	1.85	1.9	
Feed Nozzle Temp (FNT)	° C	< 40	27	26	27	27	27	27	27	27
Melter Off-Gas Jumper Temp	° C	200 - 250	214	213	211	229	246	238	234	235
Post EVS Off-Gas Temp	° C	< 50	32	32	32	32	34	34	34	34
Post HEME Off-Gas Temp	° C	100	30	30	30	32	32	32	34	35
Hg-Bed Temperature (or NA)	° C / NA	100	N/A	NA	NA	NA	NA	NA	N/A	NA
Scrub Liquid Temp (SLT)	° C	≤40	32	27	30	32	34	35	37	39
EVS HX Cooling Temp	° C	≤30	32	32	32	32	34	34	33	34
Feed Pump Setting	%		9.5	9.5	9.5	8.5	10	11	10.0	10.0
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.9	1.8	1.4	1.7	1.1	1.3	1.1	1.0
Day Tank Wt	Kg	<83 Net	86.1	84.8	83.2	82.6	81.4	79.7	78.01	76.4
Master Feed Tank Wt	Kg	<300 Net	409	409	409	408	408	408	408	408
Overflow Temp	° C	1100 - 1150	1100	1100	1100	1149	1133	1149	1151	1150
Discharge Can Temp	° C	750 - 850	756	749	750	750	750	750	750	750
Glass Scale	Kg	< 10	1.34	1.81	2.15	4.10	4.26	4.84	5.39	5.9
Alarm Condition	On/Off	off	off	OFF	off	off	on	on	clear	OFF
time	hh:mm		0714	0812	0911	1025	1114	1205	1308	1411

Reviewed and Approved: RW Gooler

Date: 8/6/03

Sheet 3 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	7/29/03					RWG		
		Date:	7/29/03	7/29/03	7/29	7/29	7/29	7/29	7/29	7/29
		Time:	1609	1704	1759	1900	1959	2100	2200	2300
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	.85	.85	.8	0.8	0.8	0.8	0.8	0.75
Film Cooler Air Supply	scfm	1-4 (reg OGT)	2.2	2.2	2.1	2.1	2.1	2.1	2.2	2.1
Film Cooler Pressure	psig	20-50	2	2	2	2	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.4	3.4	3.2	3.4	3.4	3.4	3.2	3.2
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0	0	0	0	0	0	0	0
HEME ΔP	in. H2O		0.2	0.3	0.2	0.2	0.3	0.3	0.3	0.3
System ΔP	in. H2O		0	0	0	0	0	0.	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	2.1	2.0	1.9	1.9	1.9	1.9	1.9	1.8
EVS Scrub Tank Volume	liters	60-220	95	95	95	95	95	95	95	95
EVS Nozzle Pressure	psi	50 - 55	53	53	53	53	53	53	53	53
EVS Nozzle Flow	gpm		3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.2
EVS Scrub Solution pH	pH		—	—	—	—	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		Chg	OK	OK	OK	OK	OK	OK	OK
Recirc Pump Tubing (Master)	Chg/Pull		OK	OK	OK	OK	OK	~~OK~~ OK	OK	OK
Recirc Pump Tubing (DayTnk)	Chg/Pull		OK	OK	OK	OK	OK	OK	OK	OK
Day Tnk Agitator Setting	%		N.Ch.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	NC
Master Tank Agitator Setting	%		No Ch.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
Blower Cooling Flow	gpm	1 - 1.5	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.8
Feed Nozzle Temp (FNT)	° C	< 40	28	27	28	27	27	27	27	27
Melter Off-Gas Jumper Temp	° C	200 - 250	260	254	244	241	244	242	240	241
Post EVS Off-Gas Temp	° C	< 50	34	36	36	35	34	35	35	34
Post HEME Off-Gas Temp	° C	100	36	36	37	37	37	36	35	35
Hg-Bed Temperature (or NA)	° C / NA	100	—	—	—	—	—	—	—	—
Scrub Liquid Temp (SLT)	° C	≤40	42	41	42	43	41	39	37	36
EVS HX Cooling Temp	° C	≤30	33	34	34	34	34	34	34	34
Feed Pump Setting	%		10	10.0	10.5	10	10.5	10.5	10.0	9.0
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.6	2.0	2.0	1.3	2.1	1.4	1.5	1.9
Day Tank Wt	Kg	<83 Net	74.53	72.87	71.25	69.47	68.0	65.7	64.28	62.82
Master Feed Tank Wt	Kg	<300 Net	407	407	406	406	406	406	406	406
Overflow Temp	° C	1100 - 1150	1151	1149	1156	1150	1149	1138	1142	1146
Discharge Can Temp	° C	750 - 850	751	750	750	751	750	750	749	758
Glass Scale	Kg	< 10	7.14	7.44	7.80	8.37	8.85	9.33	9.95	0.36
Alarm Condition	On/Off	off	on Alam	Clear	Clear	Clear	Clear	CLEAR	Clear	Clear
time	hh:mm									

Reviewed and Approved: Date: 3/6/03 Sheet 4 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	JW	SL	SG	MJ	MJ	SL	SL	SL
		Date:	7/30	7/30	7/30	7/30	7/30	7/30	7/30	7/30
		Time:	0007	0104	0220	0300	0406	0500	0602	0705
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	0.75	0.75	0.75	0.75	0.72	0.72	0.71	0.72
Film Cooler Air Supply	scfm	1-4 (reg OGT)	2.3	2.3	2.4	2.4	2.4	2.4	2.3	2.4
Film Cooler Pressure	psig	20-50	2	2	2	2	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.6	3.6	3.3	3.2	3.3	3.2	3.2	3.2
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0	0	0	0	0	0.1	0.1	0
HEME ΔP	in. H2O		0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.2
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	1.8	1.8	1.6	1.76	1.5	1.75	1.7	1.7
EVS Scrub Tank Volume	liters	60-220	95	95	95	95	95	95	95	96
EVS Nozzle Pressure	psi	50 - 55	53	53	53	53	53.5	53.5	53.6	53.6
EVS Nozzle Flow	gpm		3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
EVS Scrub Solution pH	pH		—	—	—	—	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		OK	ok	ok	ok	ok	OK	ok	OK
Recirc Pump Tubing (Master)	Chg/Pull		off	off	off	off	off	off	off	off
Recirc Pump Tubing (DayTnk)	Chg/Pull		OK	OK	ok	ok	?	ok	ok	ok
Day Tnk Agitator Setting	%		N.C.	70	N.C.	NC	NC	NC	NC	NC
Master Tank Agitator Setting	%		N.C.	40	N.C.	NC	NC	NC	NC	NC
Blower Cooling Flow	gpm	1 - 1.5		1.8	1.6	1.8	1.7	1.7	1.7	1.7
Feed Nozzle Temp (FNT)	° C	< 40	27	28	27	27	27	27	27	27
Melter Off-Gas Jumper Temp	° C	200 - 250	244	244	250	250	258	244	245	244
Post EVS Off-Gas Temp	° C	< 50	34	34	34	34	34	34	33	34
Post HEME Off-Gas Temp	° C	100	34	34	32	32	32	32	30	31
Hg-Bed Temperature (or NA)	° C / NA	100	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Scrub Liquid Temp (SLT)	° C	≤40	34	34	32	34	34	34	33	33
EVS HX Cooling Temp	° C	≤30	34	34	33	34	34	34	34	34
Feed Pump Setting	%		9.0%	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.9	1.8	1.6	1.0	1.7	1.9	1.8	1.7
Day Tank Wt	Kg	<83 Net	82.79	81.32	80.00	79.05	77.35	76.05	74.7	73.20
Master Feed Tank Wt	Kg	<300 Net	360	360	360	360	360	360	360	360
Overflow Temp	° C	1100 - 1150	1142	1152	1147	1144	1148	1145	1149	1146
Discharge Can Temp	° C	750 - 850	750	749	750	749	752	749	751	749
Glass Scale	Kg	< 10	0.96	1.49	2.17	2.43	3.17	3.40	3.86	4.21
Alarm Condition	On/Off	off	clear	off	on	off	off	off	off	off
time	hh:mm			0112	0224	0308	0414	0506	0608	0710

Reviewed and Approved:

Date: 8/6/03

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Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	WCB	WCB	WCB	WCB	JW	JW	JW	JW
		Date:	7/30/03	7/30/03	7/30/03	7/30/03	7/30/03	7/30	7/30	7/30
		Time:	0905	0907	1020	1114	1709	1801	1857	2000
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)		0.7	0.75	0.75	0.75	0.7	0.7	.65
Film Cooler Air Supply	scfm	1-4 (reg OGT)	*	2.4	2.3	2.3	2.3	1.6	1.4	1.3
Film Cooler Pressure	psig	20-50		2	2	2	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0		3.2	3.4	3.4	3.0	3.2	3.2	3.4
EVS ΔP	in. H2O		0.0	0.0	0.0	0.0	0.0	0	0.0	0.0
Film Cooler ΔP	in. H2O		0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0
HEME ΔP	in. H2O		0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.2
System ΔP	in. H2O		0.0	0.0	0.0	0.0	0.0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)		1.5	1.9	1.8	2.4	2.4	2.3	2.2
EVS Scrub Tank Volume	liters	60-220		97	97	97	97	97	97	97
EVS Nozzle Pressure	psi	50 - 55		53	53	53	53	53	53	53
EVS Nozzle Flow	gpm		*	3.1	3.1	3.1	3.1	3.1	3.1	3.1
EVS Scrub Solution pH	pH			—	—	—	—	—	—	—
OG Control Valve position	%			0	0	0	0	0	0	0
OG Control Valve mode	A or M			M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		OK	OK	OK	OK	OK	OK	OK	OK
Recirc Pump Tubing (Master)	Chg/Pull		OK	OK	OK	OK	OK	OK	off/OK	off/OK
Recirc Pump Tubing (DayTnk)	Chg/Pull		OK	OK	OK	OK	OK	OK	OK	OK
Day Tnk Agitator Setting	%		NC	NC	NC	NC	N.C.	N.C.	N.C.	N.C.
Master Tank Agitator Setting	%		NC	NC	NC	NC	N.C.	N.C.	N.C.	N.C.
Blower Cooling Flow	gpm	1 - 1.5		1.8	1.8	1.8	1.8	1.8	1.8	
Feed Nozzle Temp (FNT)	° C	< 40	27	26	27	27	29	28	29	28
Melter Off-Gas Jumper Temp	° C	200 - 250	246	246	246	238	240	246	239	229
Post EVS Off-Gas Temp	° C	< 50	33	33	34	34	35	36	36	36
Post HEME Off-Gas Temp	° C	100	30	32	32	34	37	39	38	37
Hg-Bed Temperature (or NA)	° C / NA	100	NA	NA	NA	NA	—	—	—	—
Scrub Liquid Temp (SLT)	° C	≤40	27	29	33	34	46	46	44	44
EVS HX Cooling Temp	° C	≤30	34	32	34	34	34	36	36	36
Feed Pump Setting	%		9	10	9	9	12	12.5	12.5	12.5
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.3	0.7	0.7	1.6	1.6	0.9	1.5	1.2
Day Tank Wt	Kg	<83 Net	71.7	70.4	69.9	67.7	114.07	112.59	111.03	109.03
Master Feed Tank Wt	lb ~~Kg~~	<300 Net	361	364	363	363	217	217	217	217
Overflow Temp	° C	1100 - 1150		1141	1143	1140	1124	1125	1126	1125
Discharge Can Temp	° C	750 - 850		749	754	749	755	750	751	1162
Glass Scale	Kg	< 10		5.15	5.42	5.89	8.65	9.05	9.61	0.42
Alarm Condition	On/Off	off	*	active	OFF	OFF	clear	clear	clear	clear
time	hh:mm			0937	1025	1119		1808	1900	2003

* incomplete due to process demands
7/30/03 WCB

Reviewed and Approved: R W Nalu Date: 8/6/03 Sheet 6 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:								
		Date:	2103	7/30	2302	0012	0101	7/31	7/31	7/31
		Time:	7/30	2200	7/30	7/31	7/31	0205	0301	0414
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Film Cooler Air Supply	scfm	1-4 (reg OGT)	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5
Film Cooler Pressure	psig	20-50	2	2	2	2	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.0
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0	0	0	0	0	0	0	0
HEME ΔP	in. H2O		0.3	0.2	0.2	0.2	0.2	.2	0.2	0.0
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
EVS Scrub Tank Volume	liters	60-220	98	98	99	100	100	100	100	100
EVS Nozzle Pressure	psi	50 - 55	53	53	53	53	53.1	53.1	53.1	53.2
EVS Nozzle Flow	gpm		3.1	3.1	3.1	3.2	3.2	3.2	3.2	3.2
EVS Scrub Solution pH	pH		—	—	—	—	—	—	—	
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		OK/chg	OK	OK	OK	OK	pulled	NC	OK
Recirc Pump Tubing (Master)	Chg/Pull		off/ok	off	off	off	off	off	off	off
Recirc Pump Tubing (DayTnk)	Chg/Pull		OK	OK	OK	OK	OK	NC	NC	OK
Day Tnk Agitator Setting	%		N.C	N.C	N.C	45	NC	NC	NC	NC
Master Tank Agitator Setting	%		N.C.	N.C.	N.C	100	NC	NC	NC	NC
Blower Cooling Flow	gpm	1 - 1.5	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Feed Nozzle Temp (FNT)	° C	< 40	29	29	28	29	29	29	29	29
Melter Off-Gas Jumper Temp	° C	200 - 250	248	232	220	218	224	228	228	244
Post EVS Off-Gas Temp	° C	< 50	36	35	35	34	34	34	54	34
Post HEME Off-Gas Temp	° C	100	37	36	36	35	34	33	33	32
Hg-Bed Temperature (or NA)	° C / NA	100	—	—	—	N/A	N/A	N/A	N/A	N/A
Scrub Liquid Temp (SLT)	° C	≤40	41	39	37	35	34	33.5	34.1	33.0
EVS HX Cooling Temp	° C	≤30	36	36	34	34	34	33	34	34
Feed Pump Setting	%		12.5	10.5	9.0	8.5	8.5	8.5	8.5	12.0
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.5	1.0	1.5	1.1	1.4	0.9	1.4	1.7
Day Tank Wt	Kg	<83 Net	107.57	105.63	103.57	102.10	100.70	99.23	97.99	97.00
Master Feed Tank Wt	Kg	<300 Net	217	217	217	217	217	217.5	217.5	217
Overflow Temp	° C	1100 - 1150	1113	1124	1088	1123	1123	1116	1126	1126
Discharge Can Temp	° C	750 - 850	750	752	749	749	750	750	800	801
Glass Scale	Kg	< 10	1.02	1.32	1.72	2.53	2.82	3.38	3.70	4.37
Alarm Condition	On/Off	off	clear	clear	clear	clear	clear	off	off	off
time	hh:mm		2107		2312	0019	0109	0215	0306	0418

Reviewed and Approved:

Date: 8/6/03

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Data Sheet #2: Routine Status Sheet

RSM, July 2003										
		By:	[illegible]	[illegible]	[illegible]	WCB	WCB	WCB	WCB	[illegible]
		Date:	7/31/03	7/31	7/31	7/31/03	7/31/03	7/31/03	7/31/03	7/31
		Time:	0501	0602	0704	0811	1200	1309	1504	1604
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	0.62	0.62	0.60	0.6	0.7	0.55	0.58	.6
Film Cooler Air Supply	scfm	1-4 (reg OGT)	1.5	1.6	1.8	1.5	2.75	2.6	2.8	2.6
Film Cooler Pressure	psig	20-50	2	2	2	2.5	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3	2.9	3.0	3.6	3.2	3.2	3.2	3.2
EVS ΔP	in. H2O		0	0	0	0	0.0	0	0.0	0
Film Cooler ΔP	in. H2O		0	0.1	0.1	0.1	0.1	0.2	0.2	0
HEME ΔP	in. H2O		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	2.0	2.0	2.0	2.1	2.2	3.0	3.2	3.2
EVS Scrub Tank Volume	liters	60-220	100	100	100	100	100	100	102	102
EVS Nozzle Pressure	psi	50 - 55	53.5	53.5	53.6	54	53	53	53	53
EVS Nozzle Flow	gpm		3.2	3.2	3.2	3.0	3.0	3.0	2.9	3.0
EVS Scrub Solution pH	pH		—	—	-	9	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		pulled	Pulled	ok	OK	OK	OK	OK	OK
Recirc Pump Tubing (Master)	Chg/Pull		NC	off	NC	OK	OK	OK	OK	off
Recirc Pump Tubing (DayTnk)	Chg/Pull		NC	ok	NC	OK	OK	OK	OK	OK
Day Tnk Agitator Setting	%		NC	NC	NC	NC	NC	NC	NC	44
Master Tank Agitator Setting	%		NC	NC	NC	NC	NC	NC	NC	95%
Blower Cooling Flow	gpm	1 - 1.5	1.6	1.6	1.5	1.6	1.75	1.7	1.8	1.8
Feed Nozzle Temp (FNT)	° C	< 40	29	29	29	29	29	29	27	29
Melter Off-Gas Jumper Temp	° C	200 - 250	236	227	220	217	208	217	215	215
Post EVS Off-Gas Temp	° C	< 50	34	34	34	34	34	34	34	34
Post HEME Off-Gas Temp	° C	100	32	32	32	32	34	34	36	36
Hg-Bed Temperature (or NA)	° C / NA	100	NA	N/A	N/A	NA	NA	NA	NA	-
Scrub Liquid Temp (SLT)	° C	≤40	34.1	34.1	34.1	29	27	40	42	43
EVS HX Cooling Temp	° C	≤30	34	33	34	33	34	34	34	34
Feed Pump Setting	%		9.0	9.0	9.0	9.0	9.0	10.0	10.0	9.5
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.2	1.5	1.4	1.6	1.6	1.4	1.0	1.6
Day Tank Wt	Kg	<83 Net	95.6	94.12	92.54	91.1	86.3	84.8	81.7	80.21
Master Feed Tank Wt	Kg	<300 Net	218	218	218	218	217	217	216	216
Overflow Temp	° C	1100 - 1150	1124	1124	1125	1126	1125	1126	1070	1101
Discharge Can Temp	° C	750 - 850	800	799	801	800	801	800	869	870
Glass Scale	Kg	< 10	4.68	5.15	5.61	6.04	7.77	8.21	9.01	9.62
Alarm Condition	On/Off	off	off	off	off	off	off	off	off	Clear
time	hh:mm		0510	0608	0710	0818	1213	1314	1512	1614

Reviewed and Approved: R W Goles Date: 8/6/03 Sheet 8 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	JW	JW	JW	JW	JW	JW	JW	JW
		Date:	7/31/03	7/31	7/31	7/31	7/31	7/31/03	7/31	7/31
		Time:	1705	1802	1902	2001	2102	2200	2302	2359
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Film Cooler Air Supply	scfm	1-4 (reg OGT)	2.6	3.0	3.0	3.0	3.0	3.1	2.9	2.9
Film Cooler Pressure	psig	20-50	2	2	2	2	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.2	2.8	3.2	2.8	3.0	3.2	3.4	3.6
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0	0.1	0	0	0	0	0	0
HEME ΔP	in. H2O		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0
EVS Scrub Tank Volume	liters	60-220	102	102	102	102	103	103	105	105
EVS Nozzle Pressure	psi	50 - 55	53	53	53	53	53	53	54	54
EVS Nozzle Flow	gpm		2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.8
EVS Scrub Solution pH	pH		—	—	—	—	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		ok	OK	OK	OK	OK	OK	OK	OK
Recirc Pump Tubing (Master)	Chg/Pull		off	off	off	off	off	off	off	off
Recirc Pump Tubing (DayTnk)	Chg/Pull		[illegible]	OK	OK	OK	OK	OK	OK	OK
Day Tnk Agitator Setting	%		~~30~~ ~~44~~ ~~54~~ 24	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
Master Tank Agitator Setting	%		95	N.C	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
Blower Cooling Flow	gpm	1 - 1.5	1.8	1.8	1.8	~~OK~~ 1.8	1.7	1.7	1.7	1.7
Feed Nozzle Temp (FNT)	° C	< 40	29	29	29	30	29	29	29	29
Melter Off-Gas Jumper Temp	° C	200 - 250	222	218	221	225	222	222	225	222
Post EVS Off-Gas Temp	° C	< 50	34	34	34	34	34	34	34	34
Post HEME Off-Gas Temp	° C	100	36	36	36	37	36	34	34	34
Hg-Bed Temperature (or NA)	° C / NA	100	—	—	—	—	—	—	—	—
Scrub Liquid Temp (SLT)	° C	≤40	43	44	43	43	39	37	36	36
EVS HX Cooling Temp	° C	≤30	34	34	34	34	34	34	34	33
Feed Pump Setting	%		9.5	9.5	9.0	9.0	9.0	9.0	9.0	9.0
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.4	1.7	1.3	1.5	1.3	1.5	1.2	0.8
Day Tank Wt	Kg	<83 Net	74.42	77.23	76.14	74.57	73.16	78.72	77.08	75.76
Master Feed Tank Wt	Kg	<300 Net	216	216	216	216	216	201	201	201
Overflow Temp	° C	1100 - 1150	1100	1100	1100	1100	800	1126	916	1112
Discharge Can Temp	° C	750 - 850	674	870	869	870	870	870	969	870
Glass Scale	Kg	< 10	0.37	0.81	1.18	1.53	1.65	2.97	3.73	4.02
Alarm Condition	On/Off	off	off	off	clear	clear	clear	clear	clear	clear
time	hh:mm		[illegible]	1807	1906	2008	2108	2208	2307	0005

Reviewed and Approved: RW [illegible] Date: 8/6/03 Sheet 9 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Date:	8/1/03	8/1	8/1	8/1	8/1	8/1	8/1	8/1
		Time:	0102	0202	0307	0400	0528	0703	0810	0902
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	0.57	0.6	0.56	0.56	0.54	0.55	0.55	055
Film Cooler Air Supply	scfm	1-4 (reg OGT)	3	1.8	2.8	2.8	2.9	3.4	3.3	3.3
Film Cooler Pressure	psig	20-50	2	2	2	2	2	2.5	2.5	2.5
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.5	3.6	3.1	3.2	3.3	2.9	3.2	3.2
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0	0	0	0	0	0	0	0
HEME ΔP	in. H2O		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	2.9	3.0	2.9	2.9	2.7	[illegible]	2.9	2.8
EVS Scrub Tank Volume	liters	60-220	105	105	105	105	106	106	106	106
EVS Nozzle Pressure	psi	50 - 55	54.5	54.5	54.9	55	55	55	55	55
EVS Nozzle Flow	gpm		2.8	2.7	2.6	2.6	2.5	2.5	2.6	2.6
EVS Scrub Solution pH	pH		—	9	—	—	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		Pull	ok		ok	ok	ok	OK	
Recirc Pump Tubing (Master)	Chg/Pull		N/A	off		off	off	off	off	off
Recirc Pump Tubing (DayTnk)	Chg/Pull		ok	ok		ok	ok	ok	OK	
Day Tnk Agitator Setting	%		40	NC	NC	NC	50	NC	<4	N.C.
Master Tank Agitator Setting	%		100	NC	NC	NC	NC	NC	95	N.C.
Blower Cooling Flow	gpm	1 - 1.5	1.7	1.7	1.6	1.6	1.6	1.6	1.6	
Feed Nozzle Temp (FNT)	° C	< 40	29	29	29	29	29	27	27	28
Melter Off-Gas Jumper Temp	° C	200 - 250	222	227	220	211	203	206	203	201
Post EVS Off-Gas Temp	° C	< 50	34	32	33	33	33	33	32	32
Post HEME Off-Gas Temp	° C	100	34	32	32	32	31	31	31	31
Hg-Bed Temperature (or NA)	° C / NA	100	N/A	N/A	N/A	N/A	N/A	N/A	—	—
Scrub Liquid Temp (SLT)	° C	≤40	33	32.5	33	32.5	32.5	32.5	31	32
EVS HX Cooling Temp	° C	≤30	32	32	33	33	32	32	32	32
Feed Pump Setting	%		9.0	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	0.9	1.7	1.5	1.8	1.8	1.5	1.3	1.0
Day Tank Wt	Kg	<83 Net	74.10	73.3	71.6	70.1	100.7	98.2	96.65	95.21
Master Feed Tank Wt	Kg	<300 Net	202	202	202	202	131	131	131	131
Overflow Temp	° C	1100 - 1150	1130	1130	1133	839	1122	1133	1128	1131
Discharge Can Temp	° C	750 - 850	869	869	870	870	876	870	869	869
Glass Scale	Kg	< 10	4.44	4.97	5.19	5.37	5.66	6.72	7.42	7.66
Alarm Condition	On/Off	off	off	off	off	off	off	off	off	off
time	hh:mm		0107	0206	0312	0406	0534	0710	0818	0909

Reviewed and Approved:

Date: 8/6/03

Sheet 10 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003										
		By:				CRH			WCB	WCB
		Date: 8/1	[illegible]	8/1	8/1	8/1	8/1	8/1	8/1/03	8/1/03
		Time:	0959	1101	1159	1307	1403	1502	1723	1804
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	0.6	0.6	0.6	0.6	0.6	0.65	0.65	0.65
Film Cooler Air Supply	scfm	1-4 (reg OGT)	3.3	3.2	3.2	3.2	3.1	3.1	2.6	2.6
Film Cooler Pressure	psig	20-50	2.5	2.5	2.5	2.5	3.5	2.5	0	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.0	3.4	3.4	3.5	3.8	3.8	2.8	3.6
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0	0	0	0	0	0.1	0	0
HEME ΔP	in. H2O		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	3.0	3.0	3.0	3.1	3.1	3.2	3.4	3.1
EVS Scrub Tank Volume	liters	60-220	106	107	107	108	108	109	109	109
EVS Nozzle Pressure	psi	50 - 55	54	54	53	53	53	53	52	52
EVS Nozzle Flow	gpm		2.8	2.9	2.9	3.0	3.1	3.1	3.1	3.1
EVS Scrub Solution pH	pH		—	9	—	—	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		OK	OK	OK	OK	OK	OK	OK	OK
Recirc Pump Tubing (Master)	Chg/Pull		off	off	off	off	off	off	off	off
Recirc Pump Tubing (DayTnk)	Chg/Pull		Chg	OK	OK	ok	OK	OK	OK	OK
Day Tnk Agitator Setting	%		N.C.	NC	NC	NC	NC	N.C.	NC	NC
Master Tank Agitator Setting	%		N.C.	NC	NC	NC	NC	N.C.	NC	NC
Blower Cooling Flow	gpm	1 - 1.5	1.6	1.7	1.75	1.8	1.8	1.8	1.75	1.8
Feed Nozzle Temp (FNT)	° C	< 40	28	29	28	29	28	29	29	29
Melter Off-Gas Jumper Temp	° C	200 - 250	197	194	194	194	192	189	204	208
Post EVS Off-Gas Temp	° C	< 50	33	34	33	34	34	33	34	34
Post HEME Off-Gas Temp	° C	100	32	32	33	34	34	34	36	36
Hg-Bed Temperature (or NA)	° C / NA	100	—	-	-	—	—	-	—	—
Scrub Liquid Temp (SLT)	° C	≤40	34	35	37	39	40	41	44	44
EVS HX Cooling Temp	° C	≤30	32	33	32	32	32	32	33	33
Feed Pump Setting	%		10	10	10	10	9	10	10	10
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	0.9	1.4	1.8	1.8	1.7	1.6	1.7	1.6
Day Tank Wt	Kg	<83 Net	93.92	92.29	90.78	88.81	87.34	85.78	82.2	80.9
Master Feed Tank Wt	Kg	<300 Net	131	130	130	130	130	129	129	129
Overflow Temp	° C	1100 - 1150	1131	1124	1135	1018	799	1110	1119	1126
Discharge Can Temp	° C	750 - 850	870	869	870	870	870	870	870	869
Glass Scale	Kg	< 10	8.60	8.95	9.48	10.12	.05	0.73	2.46	2.62
Alarm Condition	On/Off	off	off	off	off	off	off	off	off	OFF
time	hh:mm		1004	1109	1203	1313	1409	1506	1528	1808

Reviewed and Approved: Date: 8/4/03 Sheet 11 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	WCB	WCB	WCB	SD	[illegible]	[illegible]	[illegible]	[illegible]
		Date:	8/1/03	8/1/03	8/1/03	8/2/03	8/2	8/2	8/2	8/2
		Time:	2003	2106	2225	0006	0103	0201	0306	0400
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	.6	0.6	0.6	0.6	0.6	0.6	0.6	0.57
Film Cooler Air Supply	scfm	1-4 (reg OGT)	2.6	2.8	2.8	3.0	2.8	2.8	3.0	3.3
Film Cooler Pressure	psig	20-50	2	2	2	2	2	2	2	2
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.6	3.6	3.6	3.5	3.8	3.8	3.4	3.4
EVS ΔP	in. H2O		0	0	0	0	0	0	0	0
Film Cooler ΔP	in. H2O		0	0	0	0	0	0	0	0
HEME ΔP	in. H2O		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
System ΔP	in. H2O		0	0	0	0	0	0	0	0
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0
EVS Scrub Tank Volume	liters	60-220	110	110	111	112	112	112	112	113
EVS Nozzle Pressure	psi	50 - 55	52	52	52	52	52.1	52.1	52.1	52.1
EVS Nozzle Flow	gpm		3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
EVS Scrub Solution pH	pH		—	—	—	—	—	—	—	—
OG Control Valve position	%		0	0	0	0	0	0	0	0
OG Control Valve mode	A or M		M	M	M	M	M	M	M	M
Feed Pump (tubing) Condition	Chg/Pull		OK	OK	OK	Pull	ok	ok	ok	ok
Recirc Pump Tubing (Master)	Chg/Pull		off	OK/off	off	off	off	off	off	off
Recirc Pump Tubing (DayTnk)	Chg/Pull		OK	OK	OK	ok	ok	ok	ok	ok
Day Tnk Agitator Setting	%		NC	NC	NC	40	NC	NC	NC	NC
Master Tank Agitator Setting	%		NC	NC	NC	100	NC	NC	NC	NC
Blower Cooling Flow	gpm	1 - 1.5	1.8	1.75	1.75	1.75	1.7	1.7	1.7	1.7
Feed Nozzle Temp (FNT)	° C	< 40	29	29	27	29	29	29	29	28
Melter Off-Gas Jumper Temp	° C	200 - 250	211	206	201	196	199	203	201	199
Post EVS Off-Gas Temp	° C	< 50	34	34	34	32	32	32	32	32
Post HEME Off-Gas Temp	° C	100	36	36	35	34	33	32	32	31
Hg-Bed Temperature (or NA)	° C / NA	100	NA	NA	NA	N/A	N/A	N/A	N/A	N/A
Scrub Liquid Temp (SLT)	° C	≤40	42	40	37	32	32	32	32	32
EVS HX Cooling Temp	° C	≤30	33	32	33	32	32	32	32	32
Feed Pump Setting	%		10	10	10	12	10	10	9.0	9.0
Feed Pump Control Mode	A or M		A	A	A	A	A	A	A	A
Feed Pressure	psi	<1.0	1.5	1.6	0.8	0.8	1.7	1.1	1.5	1.0
Day Tank Wt	Kg	<83 Net	77.9	76.2	73.8	70.7	69.6	68.1	66.0	64.5
Master Feed Tank Wt	Kg	<300 Net	129	129	129	129	129	130	129	130
Overflow Temp	° C	1100 - 1150	1131	1134	1135	1132	1131	1128	900	900
Discharge Can Temp	° C	750 - 850	870	869	867	869	870	870	870	870
Glass Scale	Kg	< 10	3.56	4.06	4.68	5.27	5.55	5.85	6.14	6.19
Alarm Condition	On/Off	off	OFF	OFF	OFF	ON	off	off	on	off
time	hh:mm		2011	2112	2230	0037	0107	0205	0311	0404

Reviewed and Approved: RW Goles

Date: 8/6/03

Sheet 12 of 13

Data Sheet #2: Routine Status Sheet

RSM, July 2003		By:	GD							
		Date:	8/2/03							
		Time:	0505							
DESCRIPTION	**units**	**range**								
Feed Nozzle Cooling Flow	gpm	.5 - 1(reg FNT)	0.56							
Film Cooler Air Supply	scfm	1-4 (reg OGT)	3.5							
Film Cooler Pressure	psig	20-50	2							
Melter Vacuum-Magnehelic	in. H2O	0.1 - 2.0	3.4							
EVS ΔP	in. H2O		0							
Film Cooler ΔP	in. H2O		0							
HEME ΔP	in. H2O		0.2							
System ΔP	in. H2O		0							
EVS HX Cooling Flow	gpm	1-5 (reg SLT)	2.8							
EVS Scrub Tank Volume	liters	60-220	113							
EVS Nozzle Pressure	psi	50 - 55	52.2							
EVS Nozzle Flow	gpm		3.2							
EVS Scrub Solution pH	pH		—							
OG Control Valve position	%		0							
OG Control Valve mode	A or M		M							
Feed Pump (tubing) Condition	Chg/Pull		ok							
Recirc Pump Tubing (Master)	Chg/Pull		off							
Recirc Pump Tubing (DayTnk)	Chg/Pull		ok							
Day Tnk Agitator Setting	%		40							
Master Tank Agitator Setting	%		100							
Blower Cooling Flow	gpm	1 - 1.5	1.7							
Feed Nozzle Temp (FNT)	° C	< 40	29							
Melter Off-Gas Jumper Temp	° C	200 - 250	195							
Post EVS Off-Gas Temp	° C	< 50	32							
Post HEME Off-Gas Temp	° C	100	32							
Hg-Bed Temperature (or NA)	° C / NA	100	N/A							
Scrub Liquid Temp (SLT)	° C	≤40	32							
EVS HX Cooling Temp	° C	≤30	32							
Feed Pump Setting	%		9.0							
Feed Pump Control Mode	A or M		A							
Feed Pressure	psi	<1.0	1.0							
Day Tank Wt	Kg	<83 Net	63.1							
Master Feed Tank Wt	Kg	<300 Net	130							
Overflow Temp	° C	1100 - 1150	1128							
Discharge Can Temp	° C	750 - 850	869							
Glass Scale	Kg	< 10	6.52							
Alarm Condition	On/Off	off	ON							
time	hh:mm		0509							

Reviewed and Approved:

Date: 8/6/03

Sheet 13 of 13

Data Sheet #3: Off-Gas Monitoring Data

Data Sheet #3: Off-Gas Monitoring Data

Stopped 2300 due to feed nozzle plug

RSM, July 2003		By:	HDS	HDS	CAH	CAH	CAH	CAH	CAH	[illegible]
		Date:	7/28	7/28/03	7/28/03	7/28/03	7/28/03	7/28/03	7/28/03	7/28/03
		Time:	10:40	11:38	1654	1900	1900	2003	2100	2300
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	5.5	–	7.6	7.7	7.3	6.0	5.9	6.4
H_2	ppm	<1e4	0	–	–	–	–	–	–	–
Off-Gas Residence Time	s	0.8-1.2								
AmTest										
O_2	% ~~ppm~~			20.3	20.3	20.2	20.3	20.3	20.3	20.3
NO	ppm		2	200	135	150	92.9	96.3	98.01	116.6
NOx	ppm			200	157	165	107.1	102.4	112.1	118.5
CO	ppm	<3E4		4.9	2.4	2.1	–	–	–	–
CO_2	% ~~ppm~~			0.371	0.301	0.321	0.241	0.212	0.243	0.227
SO_2	ppm	<2E4		0	0	0	–	–	–	–
PS Analytical										
Elemental Hg Concentration	mg/m^3			–	0.6 / 3.0	0. / .07	–	–	–	–
Total Hg Concentration	mg/m^3			–	0.121 / 3.9	– / –	–	–	–	–
Sample Source*	M/E/H/C			–	E / M	E / M	–	–	–	–
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.0	1.0	1.0	1.0	1.0	1.0	1	1
Melter Bubbler #1, Chan-2	lpm	0-0.5	.129	0.129	0.235	0.234	0.234	0.234	0.252	0.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	.136	0.136	0.245	0.192	0.243	0.244	0.251	0.261
He/H_2 Sample Flow	lpm	0.1-1								
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	0	0	1.5	1.5	1.7	1.9	2.0	2.0
Filter Change?	Y/N		N	N	N	N	N	N	N	N
Filter Temperature	°C	>100	–	–	hot	hot	hot	hot	hot	hot
Pres Gauge	psig	<15	5.2	5.5	5.0	5.0	5.0	5.0	5.0	5.0
Dreirite OK?	Yes/Chg		Y	Y	Y	Y	Y	Y	Y	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	2.2	–	3.2	3.1	2.6	2.9	2.8	2.8
Post EVS	wc"		–	–	–	–	–	–	–	–
Post HEME	wc"		↓	–	1.0	1.2	1.3	1.8	1.9	1.5
Post Charcoal Trap	wc"		~~1.5~~ 4.58	–	1.0	1.1	1.1	1.5	1.7	1.3
~~Post HEME~~	~~wc"~~		–	–						
Post Cntrl Valve	wc"		1.5	–	28	30	28	30	29	29
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	680	680	680	680	670	670	670	670
He GC	psig	>200	1850	1840	1800	1800	1790	1730	1700	1650
He Tracer	psig	>200	–	–	–	–	–	–	–	
time	hh:mm					19:12	1904	20:09	2106	22:05

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)
Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved: RW Goles

Date: 8/6/03

Sheet 1 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003										
		By:								HDS
		Date:	7/28/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03
		Time:	23:57	0102	0204	0303	0405	0607	0711	
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	6.4	6.48	6.40	6.2	6.28	6.21	0	6.49
H_2	ppm	<1e4	—	✓	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2								
AmTest										
O_2	% ~~ppm~~		20.3	Calibration	20.3	20.3	20.2	20.3	20.2	20.2
NO	ppm		100.7		103.3	53.03	121.2	103.8	111.2	92.8
NOx	ppm		114.0		117.8	58.38	134.7	103.6	119.2	104.0
CO	ppm	<3E4	4.4		0	0	5.5	0	0	0
CO_2	% ~~ppm~~		0.188		0.15	0.18	0.09	0.12	0.13	0.10
SO_2	ppm	<2E4	—		0.31	1.47	0.68	0.92	0.55	0
PS Analytical Mg/m³										
Elemental Hg Concentration	mg/m³		—	—	—	—	—	—		0.5
Total Hg Concentration	mg/m³		—	—	—	—	—	—		0.5
Sample Source*	M/E/H/C		—	—	—	—	—	—		~~1.0~~ M
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Melter Bubbler #1, Chan-2	lpm	0-0.5	252	253	253	253	253	253	253	.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	261	261	262	262	262	262	262	.262
He/H_2 Sample Flow	lpm	0.1-1	—	—	—		—			
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	2.0	2.0	2.4	2.5	2.5	2.5	3.0	~~0~~ 3.0
Filter Change?	Y/N		N	N	N	N	N	N	N	N
Filter Temperature	°C	>100	hot	hot	hot		Hot	Hot	Hot	Warm
Pres Gauge	psig	<15	5.0	5.0	5.0	5.0	5.0	5.0	4.7	4.7
Dreirite OK?	Yes/Chg		Y	Yes	Yes	Yes	Yes	Yes	Yes	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	2.8	3.1	3.1	3.0	3.0	3.1	3.0	3.0
Post EVS	wc"		—	0.2	0.4	0.4	0.3	0.3	0	0
Post HEME	wc"		1.4	1.4	1.4	1.4	1.3	1.5	1.8	1.8
Post Charcoal Trap	wc"		1.5	1.5	1.5	1.5	1.5	1.5	1.7	1.6
~~Post HEME~~	wc"			—	—	—	—	—	—	—
Post Cntrl Valve	wc"		30	30	30	30	30	30	30	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	670	675	660	660	660	650	650	610
He GC	psig	>200	1600	1590	1680	1580	1550	1520	1510	1490
He Tracer	psig	>200	—	—	—	—	—			
time	hh:mm		0004	0108	0212	0313	0445	0611	0724	08:26

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)
Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved:

Date: 8/6/03

Sheet 2 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003										
		By:	H.D.S.	H.D.S.	HDS	HDS	CRH	CRH	CRH	CRH
		Date:	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03	7/29/03
		Time:	9:07	10:05	11:26	13:43	1607	1702	18:00	1900
DESCRIPTION	**units**	Range								
Gas Chromatograph										
He	kppm	5-7	6.74	HDS ~~6.17~~ 6.55	6.63	6.74	6.84	6.99	6.52	6.53
H_2	ppm	<1e4	0	HDS ~~51.8~~ 0	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2								
AmTest										
% O_2	~~ppm~~		20.28	20.29	20.23	20.21	20.3	20.3	20.28	20.36
NO	ppm		100.9	6.06	163	127	121.8	151	103	116
NOx	ppm		95.7	7.05	174 HDS	145	139	163	112	123
CO	ppm	<3E4	0	0	~~5.0~~ 0	0	1.9	1.5	0.	0
% CO_2	~~ppm~~		0.101	0	0.26	0.296	0.262	0.411	0.460	0.402
SO_2	ppm	<2E4	0	1.9	0	0	0	0	0	0
PS Analytical										
Elemental Hg Concentration	mg/m^3		—	—	0.6	0.04	0.5 ~~[illegible]~~	4.0	—	—
Total Hg Concentration	mg/m^3		—	—	2.9	0.04	2.4	16	—	—
Sample Source*	M/E/H/C						M	M	—	—
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	0.253	0.253	0.253	0.253	0.253	0.253	0.252	0.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	0.262	0.262	0.262	0.262	0.252	0.216	0.262	0.262
He/H_2 Sample Flow	lpm	0.1-1								
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	3.0	2.7	1.4	1.5	1.5	1.5	1.5	1.0
Filter Change?	Y/N		N	~~N~~ Y	N		N	N	N	N
Filter Temperature	°C	>100	~~cool~~ HDS					hot	hot	hot
Pres Gauge	psig	<15	4.5	4.9	5.5	5.6	5.4	5.4	5.5	5.5
Dreirite OK?	Yes/Chg		Y	Y	Y	Y	Y	Y	Y	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	HDS ~~7.0~~ 3.2	3.4	3.4	3.0	3.2	3.1	2.9	3.2
Post EVS	wc"		0	0	0	0.3	0	0	0	0
Post HEME	wc"		1.7	1.7	1.8	1.4	1.8	1.8	1.7	1.5
Post Charcoal Trap	wc"		1.8	1.7	1.8	1.5	1.5	1.4	1.4	1.4
Post HEME	wc"		–	–	–	–	–	–	–	–
Post Cntrl Valve	wc"		50 *	50 *	50 *	50 *	30	30	30	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	650	650	650	680	670	670	670	670
He GC	psig	>200	1480	1450	1440	1370	1300	1270	1260	1220
He Tracer	psig	>200								
time	hh:mm				11:34		16:15	17:07	18:09	1906

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

Multiple tanks for the He Tracer can be switched by manual valving if need be.

* These values appear to have been taken off of a nearby pressure ~~gage~~ gage (control valve actuator air) - At the 607 reading I logged the ~~value~~ value off of the magnahelic located down stream of control valve CH [illegible] 7/29/03

Reviewed and Approved: Zlu [illegible] Date: 8/6/03

Sheet 3 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	CRH	CRH	CRH	CRH	SH	DWR	RWR	SH
		Date:	7/29/03	7/29/03	7/29/03	7/29/03	7/30/03	7/30	7/30	7/30
		Time:	20:00	21:00	22:00	2259	0002	0109	0219	0300
DESCRIPTION	**units**	Range								
Gas Chromatograph										
He	kppm	5-7	6.49	6.45	6.43	6.36	6.19	6.36	6.34	0
H_2	ppm	<1e4	0	0	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2								
AmTest										
O_2	% ~~ppm~~		20.34	20.33	20.34	20.30	20.23	20.24	20.24	20.20
NO	ppm		130	103	97.4	116	109	86.25	110	94
NOx	ppm		135	111	108.6	123	108	93.60	120	98
CO	ppm	<3E4	1.7	0	0	~~311~~ 0	0	~~0.599~~ 02	0	0.2
CO_2	% ~~ppm~~		0.402	0.373	0.364	0.346	0.28	0.199	0.199	0.2
SO_2	ppm	<2E4	0	0	0	0	0	0	0	0
PS Analytical										
Elemental Hg Concentration	mg/m^3		—	—	0 | 0	—	—	—	—	—
Total Hg Concentration	mg/m^3		—	—	4.6 | 0	—	—	—	—	—
Sample Source*	M/E/H/C		—	—	M | E	—	—	—	—	—
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1	1	1	1	1.0	1.0	1.0	1.0
Melter Bubbler #1, Chan-2	lpm	0-0.5	.252	.252	.252	.252	253	252	253	253
Melter Bubbler #1, Chan-3	lpm	0-0.5	.262	.262	.262	.262	262	262	262	262
He/H_2 Sample Flow	lpm	0.1-1	—	—	—	—			—	—
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	1.7	1.5	1.8	1.6	2.0	2.0	2.0	2.5
Filter Change?	Y/N		N	N	N	N	N	N	N	N
Filter Temperature	°C	>100	hot	hot	hot	hot	hot	HOT	HOT	Hot
Pres Gauge	psig	<15	5.2	5.1	5.1	5.1	5.0	5	5	5
Dreirite OK?	Yes/Chg		Y	Y	Y	Y	Y	YES	Y	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	3.1	3.1	3.0	3.0	3.3	3.2	3.2	2.9
Post EVS	wc"		~~4.0~~ 0	0	0	0	0.5	0.5	0.5	0.3
Post HEME	wc"		1.5	1.5	1.5	1.5	1.6	1.6	1.4	1.3
Post Charcoal Trap	wc"		1.4	1.5	1.5	1.5	1.3	1.5	1.5	1.5
Post HEME	wc"		—	—	—	—	—		—	—
Post Cntrl Valve	wc"		30	30	29	30	30	30	30	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	660	660	660	650	650	650	625	650
He GC	psig	>200	1190	1150	1140	1120	1100	1100	1100	1090
He Tracer	psig	>200	—	—	—	—	—		—	—
time	hh:mm		20:06	2109	2206	2305	0005	0116	0225	0304

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved:

Date: 8/6/03

Sheet 4 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003										
		By:	SP	SP	SP	SP	HDS	HDS	HDS	[illegible]
		Date:	7/30/03	7/30/03	7/30/03	7/30/03	7/30/03	7/30/03	7/30/03	7/30/03
		Time:	0401	0506	0608	0710	0823	10:19	11:55	1700
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	0	0	0	0	~~6.9~~ 6.7	6.7	6.1	7.8
H_2	ppm	<1e4	0	0	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2	—	—	—	—				
AmTest										
O_2	% ~~ppm~~		20.22	20.22	20.21	20.17	—	20.24	20.21	19.8
NO	ppm		90.29	85.84	19.02	19.04	—	22.4	19.4	128
NOx	ppm		94.65	99.13	20.43	22.91	—	22.9	19.4	144
CO	ppm	<3E4	0	0	9.9	9.9	—	9.6	9.2	1.4
CO_2	% ~~ppm~~		0.18	0.16	0.18	0.23	—	0.19	0.169	0.522
SO_2	ppm	<2E4	0	0.85	2.75	2.63	—	1.99	0.17	0
PS Analytical										
Elemental Hg Concentration	mg/m^3		—	—	—	—	~100%			—
Total Hg Concentration	mg/m^3		—	—	—	—	3.3			—
Sample Source*	M/E/H/C		—	—	—	—	M			—
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.0	1.0	1.0	1.0	1.0	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	.253	.253	.253	.253	253	253	.253	.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	.262	.262	.262	.262	262	262	.262	.262
He/H_2 Sample Flow	lpm	0.1-1	—	—	—		1.01	—	—	
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	2.5	2.8	3.0	3.2	3.2	~~HP2.6~~ 1.3	1.4	1.5
Filter Change?	Y/N		N	N	No	No	NO	N	N	N
Filter Temperature	°C	>100	Hot	Hot	Hot	Hot	Hot	Hot	Hot	Hot
Pres Gauge	psig	<15	5	5	4.5	4.2	4.2	5.5	5.5	5.0
Dreirite OK?	Yes/Chg		Yes	Yes	Yes	Yes	Y	Y	Y	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	3.0	3.0	3.0	2.8	~~2.6~~ 3	3.0	3.0	3.3
Post EVS	wc"		0.2	0.2	0.2	0	0	0.5	0	0
Post HEME	wc"		1.2	1.2	1.2	0.6	1	1.0	1	1.4
Post Charcoal Trap	wc"		1.4	1.3	1.3	0.5	1	1.0	1	1.3
Post HEME	wc"		—	—	—	—	—	—	—	—
Post Cntrl Valve	wc"		30	30	30	30	30	30	30	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	650	650	650	650	625	—	—	650
He GC	psig	>200	1090	1080	1080	1080	1050	1030	1010	~~69~~ 800
He Tracer	psig	>200	—	—	—	—		—	—	
time	hh:mm		0406	0511	0612	0715	08:30			17:08

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

\# Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved: RW [illegible] Date: 7/6/03 Sheet 5 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	CRK	CRH	CRH	CRH	CRH	CRH	SL	JJJ
		Date:	7/30/03	7/30/03	7/30/03	7/30/03	7/30/03	7/30/03	7/31/03	7/31/03
		Time:	1800	1900	2000	2100	2200	2300	0019	0104
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	5.7	6.6	6.96	6.34	6.95	6.90	6.89	6.50
H_2	ppm	<1e4	2675	3082	3257	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2								
AmTest										
O_2	% ~~ppm~~		19.89	19.87	19.89	19.89	19.89	19.86	19.86	19.85
NO	ppm		104	169	136	179	140	137	104.65	~~99.69~~
NOx	ppm		118	193	142	195	151	149	113.91	112.97
CO	ppm	<3E4	0	1.0	0	1.8	0	0	0	-2.0
CO_2	% ~~ppm~~		0.511	0.611	0.569	0.566	0.465	0.387	0.317	0.268
SO_2	ppm	<2E4	0	0	0	0	0.60	1.58	1.58	1.77
PS Analytical										
Elemental Hg Concentration	mg/m^3		—	—	—	—	—	—	—	—
Total Hg Concentration	mg/m^3		—	—	—	—	—	—	—	—
Sample Source*	M/E/H/C		—	—	—	—	—	—	—	—
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	.252	.252	.252	.252	.252	.252	.253	.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	.193	.184	.189	.262	.261	.261	.261	.262
He/H_2 Sample Flow	lpm	0.1-1	—	—	—	—	—	—		
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	1.7	1.5	1.7	1.8	1.9	2.0	2.0	2.3
Filter Change?	Y/N		N	N	N	N	N	N	No	No
Filter Temperature	°C	>100	hot	hot	hot	hot	hot	hot	Hot	hot
Pres Gauge	psig	<15	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Dreirite OK?	Yes/Chg		Y	Y	Y	Y	Y	Y	Yes	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	3.5	3.1	3.3	3.3	3.3	3.2	~~2.0~~ 3.2	3.3
Post EVS	wc"		—	—	—	—	—	—	0.4	0.4
Post HEME	wc"		1.8	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Post Charcoal Trap	wc"		1.5	1.2	1.5	~~1.5~~ 1.2	1.5	1.5	1.3	1.4
Post HEME	wc"		—	—	—	—	—	—	—	
Post Cntrl Valve	wc"		29	28	29	30	30	30	30	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	650	650	670	660	670	670	670	670
He GC	psig	>200	750	740	720	700	690	670	650	620
He Tracer	psig	>200	—	—	—	—	—	—	—	
time	hh:mm		18:10	19:06	20:07	21:05	2206	2306	0025	0122

107.63 JJJ

← readings taken to [illegible]. fluctuating quite a bit

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

\# Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved:

Date: 8/6/03

Sheet 6 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	SD	al	JJB	al	JP	SD	HDS	HDS
		Date:	7/31/03	7/31	7/31	7/31	7/31	7/31	7/31	7/31
		Time:	0210	0301	0414	0501	0608	0701	8:00	9:25
DESCRIPTION	**units**	Range								
Gas Chromatograph										
He	kppm	5-7	6.91	6.99	6.54	0	0	0	0	7.1
H_2	ppm	<1e4	0	0	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2	—	—	—	—	—	—	—	—
AmTest										
O_2	% ~~ppm~~		19.83	19.81	19.82	19.86	19.81	19.83	19.75	19.83
NO	ppm		115.69	113.79	157.08	125.25	120.33	126.83	141	90
NOx	ppm		126.20	109.60	164.54	134.14	130.77	139.65	150	100
CO	ppm	<3E4	0	0	-1.5	0	0	4.7	4.6	0
CO_2	% ~~ppm~~		0.27	0.25	0.339	0.22	0.22	0.23	0.25	0.109
SO_2	ppm	<2E4	2.02	0	3.17	3.85	4.46	4.52	4.46	4.20
PS Analytical										
Elemental Hg Concentration	mg/m^3		9.5 / 1.5	—	8.0 / 1.5	~~9.24 / 3.6~~	~~9.87 / 3.64~~	—	—	-
Total Hg Concentration	mg/m^3		9.7 / 1.2	—	9.3 / 1.2	~~10.4 / 4.9~~	~~10.34 / 4.94~~	—	—	-
Sample Source*	M/E/H/C		M / E	—	M / ~~HEM~~	~~H / E~~	~~H / E~~	—	—	-
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	.253	.253	.253	.253	.253	.253	.253	.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	.262	.262	.262	.262	.262	.262	.262	.262
He/H_2 Sample Flow	lpm	0.1-1	—	—		—	—			
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	2.4	2.4	2.8	2.8	3.0	3.1	3.5	3.6
Filter Change?	Y/N		N	N	N	No	No	No	N	N
Filter Temperature	°C	>100	Hot	Hot	hot	Hot	Hot	Hot	Hot	
Pres Gauge	psig	<15	5	4.6	4.5	4.5	4.4	4.2	3.9	3.6
Dreirite OK?	Yes/Chg		Yes	Yes	Y	Yes	Yes	Yes	Chg Y?	on HS.
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	3.1	3.0	2.7	3.3	2.6	2.7	3.3	2.9
Post EVS	wc"		0.2	0.2	0.2	0.2	0.2	0	0	0
Post HEME	wc"		1.2	1.2	1.1	1.2	1.2	1.4	1.8	1.9
Post Charcoal Trap	wc"		1.2	1.2	1.1	1.2	1.3	1.5	1.8	1.9
Post HEME	wc"		—	—	—	—	—	—	—	—
Post Cntrl Valve	wc"		30	30	30	30	30	30	30	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	650	650	650	650	650	650	— ~~480~~ HDS	—
He GC	psig	>200	620	620	620	610	610	610	420	400
He Tracer	psig	>200	✓	—		✓	—	✓		
time	hh:mm		0217	0303	0422	0605	0612	0705	9:13	9:30

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved: Date: 8/6/03 Sheet 7 of 13

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Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	HDS	HDS	HDS	RW2	HDS	[illegible]	[illegible]	[illegible]
		Date:	7/31/03	7/31/03	7/31/03	7/31/03	7/31/03	7/31/03	7/31/03	7/31/03
		Time:	10:28	11:33	12:27	1305	14:41	1604	1700	1900
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	6.98	6.99	6.90	7.0	N Reading	7.3	7.43	7.03
H_2	ppm	<1e4	0	0	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2								
AmTest										
O_2	% ~~ppm~~		19.79	19.82	19.83	19.9	19.88	19.18	19.2	19.23
NO	ppm		148	136	108	131	133	130	146	125
NOx	ppm		158	145	112	141	140	148	157	138
CO	ppm	<3E4	3.9	0	0	2.6	1.7	2.9	3.2	0
CO_2	% ~~ppm~~		0.278	0.218	0.205	0.285	0.252	0.499	0.429	0.379
SO_2	ppm	<2E4	3.4	2.36	1.0	0	0	0	0	0
PS Analytical										
Elemental Hg Concentration	mg/m^3		9.9,	7.0		10	–	–	–	–
Total Hg Concentration	mg/m^3		10.6, 6.1	8.3		8	–	–	–	–
Sample Source*	M/E/H/C		M E	E		M	–	–	–	–
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	0.253	0.253	0.253	.253	0.253	0.252	0.252	0.252
Melter Bubbler #1, Chan-3	lpm	0-0.5	0.262	0.262	0.262	.262	0.262	0.262	~~0.756~~ 0.262	0.262
He/H_2 Sample Flow	lpm	0.1-1								
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Filter Change?	Y/N		N	N	N	N	N	N	N	N
Filter Temperature	°C	>100				Hot	Hot	hot	hot	hot
Pres Gauge	psig	<15	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.2
Dreirite OK?	Yes/Chg		Y	Y	Y	Y	Y	Y	Y	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	2.6	2.7	2.6	2.7	3.0	3.0	3.0	2.6
Post EVS	wc"		1.4	0.4	0	0	0	0	0	0
Post HEME	wc"		1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0
Post Charcoal Trap	wc"		–		–	–		–	–	–
Post HEME	wc"		1.9	2.0	1.9	2.0	2.0	2.0	2.0	2.0
Post Cntrl Valve	wc"		29	29	29	30	29	30	29	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	–	–	–	650		680	680	690
He GC	psig	>200	330	340	320	300	2060	2020	2010	2000
He Tracer	psig	>200								
time	hh:mm		10:39	11:38		13:20	14:49	1609	1705	18 04

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)
Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved: Date: 8/6/03 Sheet 8 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	CRH	CRH	CRH	CAH	CRH	SP	SP	JJJ
		Date:	7/31/03	7/31/03	7/31/03	7/31/03	7/31/03	8/1/03	8/1/03	8/1
		Time:	1902	2001	2102	2200	2300	0003	0107	0204
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	7.0	6.98	6.88	6.67	7.07	7.20	7.24	8.3
H_2	ppm	<1e4	0	0	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2								
AmTest										
O_2	ppm		19.22	19.26	19.21	19.27	19.22	19.19	19.20	19.2
NO	ppm		89	114	112	99	118	117.81	112.23	132
NOx	ppm		106	124	118	109	127	140.14	124.29	144
CO	ppm	<3E4	0	0	0	0	0	0	0.3	0.6
CO_2	ppm		0.330	0.350	0.342	0.281	0.275	0.278	0.23	0.23
SO_2	ppm	<2E4	0	0	0	0.59	0.60	1.46	1.83	1.71
PS Analytical										
Elemental Hg Concentration	mg/m^3		—	—	—	—	—	—	—	7.8
Total Hg Concentration	mg/m^3		—	—	—	—	—	—	—	9.6
Sample Source*	M/E/H/C		—	—	—	—	—	—	—	na
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	.252	.252	.252	.252	.252	.252	.253	.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	.252	.261	.261	.261	.262	.262	.262	.262
He/H_2 Sample Flow	lpm	0.1-1								
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	1.4	1.5	1.5	1.6	1.5	1.8	1.9	2.0
Filter Change?	Y/N		N	N	N	N	N	N	N	N
Filter Temperature	°C	>100	hot	hot	hot	hot	hot	Hot	Hot	hot
Pres Gauge	psig	<15	5.2	5.2	5.1	5.1	5.0	5.0	5.0	5.0
Dreirite OK?	Yes/Chg		Y	Y	Y	Y	Y	Y	Y	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	2.7	3.4	2.7	3.0	3.0	3.3	3.2	3.2
Post EVS	wc"		—	—	—	—	—	0.2	0.2	0.2
Post HEME	wc"		1.9	2.0	2.0	2.2	2.5	2.8	2.8	2.8
Post Charcoal Trap	wc"		2.0	2.0	2.0	2.4	2.5	2.6	2.7	2.8
Post HEME	wc"		—	—	—	—	—	—	—	—
Post Cntrl Valve	wc"		30	30	30	30	30	30	29	29
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	680	680	680	~~26~~ 680	680	680	680	680
He GC	psig	>200	1980	1950	1910	1890	1870	1820	1800	1770
He Tracer	psig	>200	—	—	—	—	—	—	—	—
time	hh:mm		1907	2007	2107	22:10	23:05	0008	0112	0216

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved: Date: 8/6/03 Sheet 9 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	SL	SP	SP	SP	CRH	CRH	CRH	CRH
		Date:	8/1/03	8/1	8/1	8/1	8/1	8/1	8/1	8/1
		Time:	0304	0407	0534	0705	0801	0900	1002	11:00
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	7.48	7.48	7.48	7.06	6.89	NA	7.05	6.92
H_2	ppm	<1e4	0	0	0	0	0	NA	0	0
Off-Gas Residence Time	s	0.8-1.2	—	—	—	—	—	—	—	—
AmTest										
O_2	% ~~ppm~~		19.23	19.11	19.83	19.83	19.81	19.79	19.80	20.91
NO	ppm		126.47	123.0	188.71	213.50	216	200	251	227
NOx	ppm		138.34	142.39	198.42	230.67	228	212	262	237
CO	ppm	<3E4	0.8	0.19	0	0	0	0	0	0
CO_2	% ~~ppm~~		0.22	0.20	0.29	0.37	0.339	0.369	0.347	0.349
SO_2	ppm	<2E4	2.09	3.30	4.21	3.42	3.48	2.93	3.44	2.44
PS Analytical										
Elemental Hg Concentration	mg/m^3		10.4	9.2	21.7	—	~~9.7~~ 6.7	~~12~~ 8.6	6.1	6.5
Total Hg Concentration	mg/m^3		8.6	8.2	9.2	—	~~8.2~~ 9.7	12.3	10.8	10.7
Sample Source*	M/E/H/C		M	M	M	—	M	M	M	M
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	.253	.253	.253	.253	.253	.253	.253	.252
Melter Bubbler #1, Chan-3	lpm	0-0.5	.262	.262	.262	.262	.262	.262	.262	.262
He/H_2 Sample Flow	lpm	0.1-1	—					—	—	—
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	2.0	2.0	2.1	2.1	2.4	2.4	2.5	1.1
Filter Change?	Y/N		No	No	No	No	No	No	No	Yes
Filter Temperature	°C	>100	Hot	Hot	Hot	Hot	Hot	Hot	Hot	Hot
Pres Gauge	psig	<15	5.0	5.0	5.0	4.9	4.9	4.8	4.6	5.4
Dreirite OK?	Yes/Chg		Yes	Yes	Yes	Yes	Y	Y	Y	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	2.9	3.0	3.0	2.7	3.0	3.0	2.7	3.2
Post EVS	wc"		0.2	0.2	0.1	0	0	0	0	0
Post HEME	wc"		2.3	2.6	2.7	2.6	2.8	3.0	2.5	2.8
Post Charcoal Trap	wc"		2.3	2.3	2.7	2.5	2.8	2.7	2.5	3.0
Post HEME	wc"		—	—	—	—	—	—	—	—
Post Cntrl Valve	wc"		30	30	30	30	30	30	30	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	660	650	650	650	660	660	660	670
He GC	psig	>200	1740	1710	1680	1620	1600	1595	1580	1560
He Tracer	psig	>200	—	—	—	—	—	—	—	—
time	hh:mm		0309	0412	0543	0709	0809	0906	10:11	11:09

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved:

Date: 8/6/03

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Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	CRH	CRH	CRH	CRH	HDS	HDS	H.D.S.	HDS
		Date:	8/1/03	8/1/03	8/1/03	8/1/03	8/1/03	8/1/03	8/1/03	8/1/03
		Time:	1200	1300	1402	1503	16:05	17:05	18:00	19:02
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	~~7.0~~ 7.01	6.98	6.90	7.17	7.2	6.7	7.1	7.0
H_2	ppm	<1e4	0	0	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2	–	–	–	–				
AmTest										
O_2	% ~~ppm~~		19.83	19.86	19.85	19.88	19.87	Calibrating	19.86	19.92
NO	ppm		211	211	224	224	228		222	59
NOx	ppm		226	227	236	238	249		240	72
CO	ppm	<3E4	0	0	0	0	0		0	0
CO_2	% ~~ppm~~		0.359	0.417	0.385	0.463	0.582		0.412	0.293
SO_2	ppm	<2E4	1.76	0.59	0	0	0		0	0
PS Analytical										
Elemental Hg Concentration	mg/m^3		8.5	–	~~16.0~~	5.7	5[illegible] HDS	4.2	~~17.1~~ 8.1 HDS	
Total Hg Concentration	mg/m^3		9.5	–	16.0	11.0	9[illegible] HDS	6.2	14.3 –	
Sample Source*	M/E/H/C		M	–	H	M	M		ME	
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	.252	.252	.252	.252	0.252	0.252	0.253	0.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	.262	.262	.262	.262	0.262	0.262	0.262	0.261
He/H_2 Sample Flow	lpm	0.1-1	–							
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.4
Filter Change?	Y/N		N	N	N	N	N	N	N	N
Filter Temperature	°C	>100	hot	hot	hot	hot	hot	hot	hot	hot
Pres Gauge	psig	<15	5.5	5.1	5.5	5.4	5.3	5.4	5.3	5.4
Dreirite OK?	Yes/Chg		Y	Y	Y	Y	X	Y	Y	Y
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	3.0	3.4	3.6	3.4	2.5	2.9	3.3	3.4
Post EVS	wc"		–	–	–	–	0	0	0.65	0.3
Post HEME	wc"		2.4	2.5	2.6	1.8	1.7	1.0	1.0	1.2
Post Charcoal Trap	wc"		2.5	2.5	2.5	2.0	1.7	1.0	1.0	1.2
Post HEME	wc"		–	–	–	–	–	–		
Post Cntrl Valve	wc"		30	30	30	30	29	29	29	2.9
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	670	680	680	680	–	–	–	–
He GC	psig	>200	1520	1505	1500	1500	1460	1420	1410	1380
He Tracer	psig	>200	–	–	–	–				
time	hh:mm		1207	1306	1409	1510	16:15		18:05	19:30

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved: R W Goles

Date: 8/6/03

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Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	H.D.S.	H.D.S	HDS	HDS	HDS	[illegible]	SP	SP
		Date:	8/1/03	8/1/03	8/1/03	8/1/03	8/1/03	8/2/03	8/2/03	8/2
		Time:	20:06	21:04	22:03	23:07	23:56	0107	0205	0301
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	7.1	7.0	7.0	6.9	7.2	7.0	7.16	7.31
H_2	ppm	<1e4	0	0	0	0	0	0	0	0
Off-Gas Residence Time	s	0.8-1.2								—
AmTest										
O_2	% ~~ppm~~		19.89	19.84	19.86	19.84	19.84	19.8	19.8	19.8
NO	ppm		204	204	461	63	61	64	77.26	60.38
NOx	ppm		221	226	485	63	61	62	80.14	59.17
CO	ppm	<3E4	0	0	0	9.0	4.1	9.0	9.1	4.1
CO_2	% ~~ppm~~		0.464	0.466	0.707	0.458	0.440	0.44	.89	0.39
SO_2	ppm	<2E4	0	0.29	1.46	0.92	0.74	1.22	1.22	1.16
PS Analytical										
Elemental Hg Concentration	mg/m^3		7.0, –	8.0, –	—				—	—
Total Hg Concentration	mg/m^3		10.2, 15.4	10.0, 13.2	11.9		9.5		—	—
Sample Source*	M/E/H/C		M E	M E	~~M~~ E		E		—	—
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	~~[illegible]~~ 1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Melter Bubbler #1, Chan-2	lpm	0-0.5	0.253	0.253	0.253	0.253	0.253	.252	.253	.253
Melter Bubbler #1, Chan-3	lpm	0-0.5	0.261	0.261	0.261	0.262	0.262	.262	.262	.262
He/H_2 Sample Flow	lpm	0.1-1								
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5
Filter Change?	Y/N		N	N	N	N	N	N	No	No
Filter Temperature	°C	>100	hot	hot	hot	hot	hot	hot	Hot	Hot
Pres Gauge	psig	<15	5.4	5.3	5.3	5.3	5.4	5.4	5.4	5.4
Dreirite OK?	Yes/Chg		Y	Y	Y	Y	Y	Y	Yes	Yes
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	3.3	3.2	3.0	3.2	3.2	3.5	3.5	3.2
Post EVS	wc"		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2
Post HEME	wc"		1.3	1.2	1.2	1.2	1.2	1.3	1.3	1.2
Post Charcoal Trap	wc"		—	—				—	1.3	1.2
Post HEME	wc"		1.3	1.2	1.2	1.2	1.2	—	—	—
Post Cntrl Valve	wc"		29	29	29	30	30	30	30	30
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	—	—	—	—	—	600	650	650
He GC	psig	>200	1360	1330	1300	1280	1260	1210	1200	1180
He Tracer	psig	>200							—	—
time	hh:mm		20:13	21:09	22:06	—	00:03		2210	0305

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

Multiple tanks for the He Tracer can be switched by manual valving if need be.

Reviewed and Approved: RW Gales Date: 8/6/03 Sheet 12 of 13

Data Sheet #3: Off-Gas Monitoring Data

RSM, July 2003		By:	Sd	Sd						
		Date:	8/2/03	8/2						
		Time:	0405	0500						
DESCRIPTION	**units**	**Range**								
Gas Chromatograph										
He	kppm	5-7	7.11	6.99						
H_2	ppm	<1e4	0	0						
Off-Gas Residence Time	s	0.8-1.2	—	—						
AmTest										
O_2	ppm		19.8	19.8						
NO	ppm		47.18	41.22						
NOx	ppm		45.66	42.66						
CO	ppm	<3E4	4.2	2.7						
CO_2	ppm		.038	0.30						
SO_2	ppm	<2E4	1.34	4.5						
PS Analytical										
Elemental Hg Concentration	mg/m^3		—							
Total Hg Concentration	mg/m^3		—							
Sample Source*	M/E/H/C		—							
MKS Mass Flow										
He Tracer, Chan-1	lpm	1	1.00	1.00						
Melter Bubbler #1, Chan-2	lpm	0-0.5	.253	.253						
Melter Bubbler #1, Chan-3	lpm	0-0.5	.262	.262						
He/H_2 Sample Flow	lpm	0.1-1	—							
He/H2 Sample Conditions										
Vac Gauge	"Hg	≤0	1.5	1.5						
Filter Change?	Y/N		No	No						
Filter Temperature	°C	>100	Hot	Hot						
Pres Gauge	psig	<15	5.4	5.4						
Dreirite OK?	Yes/Chg		Yes	Yes						
Off-Gas Gauge Pressures										
Plenum	wc"	0.5-4.0	3.2	3.1						
Post EVS	wc"		0.1	0.1						
Post HEME	wc"		1.1	1.0						
Post Charcoal Trap	wc"		1.1	1.0						
Post HEME	wc"		—	—						
Post Cntrl Valve	wc"		30	30						
Gas Cylinders Tank Pres#										
Ar GC	psig	>200	650	650						
He GC	psig	>200	1150	1120						
He Tracer	psig	>200	—	—						
time	hh:mm		0409	0504						

*Exhaust of Melter (M), EVS (E), HEME (H), or Carbon Bed (C)

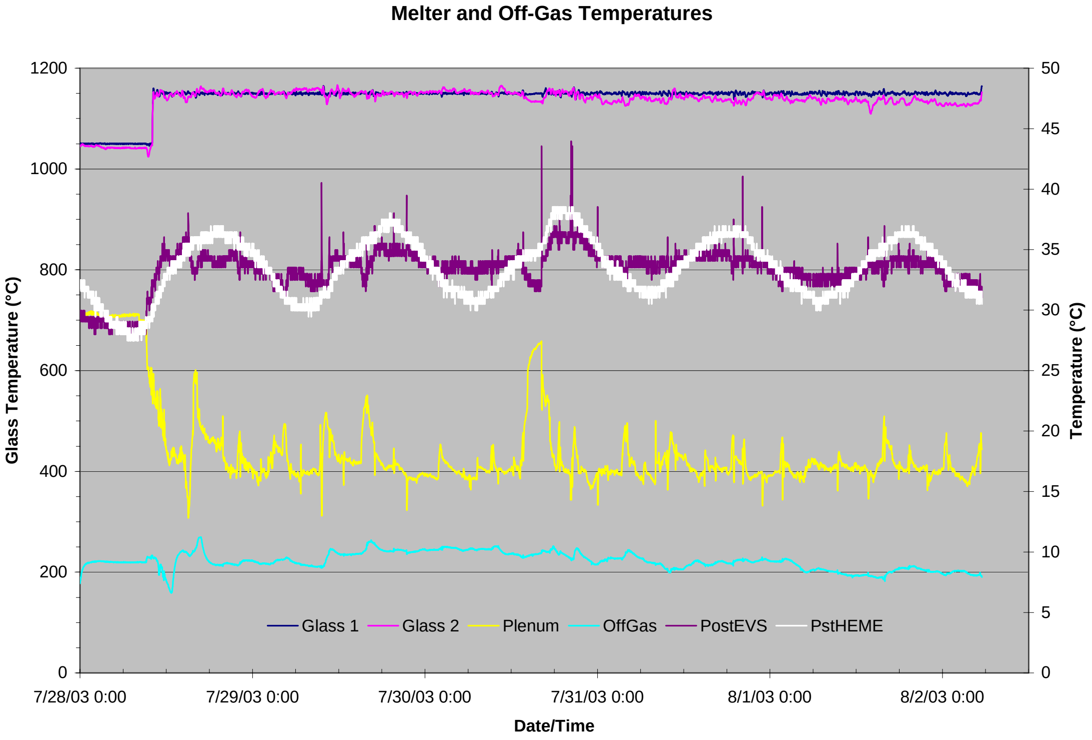
Multiple tanks for the He Tracer can be switched by manual valving if need be.

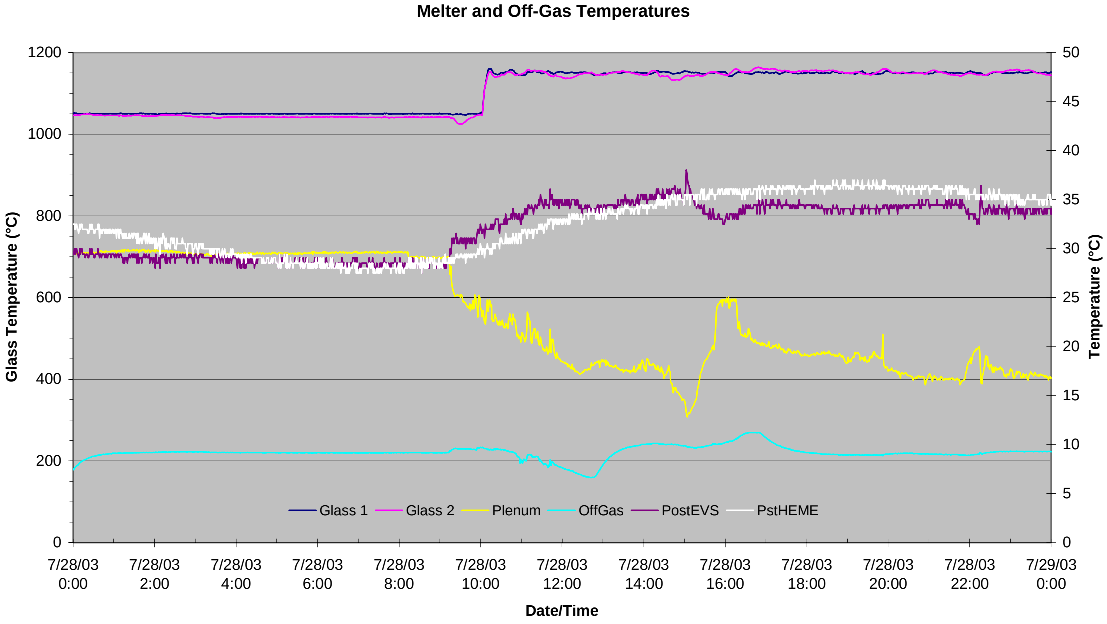
Reviewed and Approved: Date: 8/6/03 Sheet 13 of 13

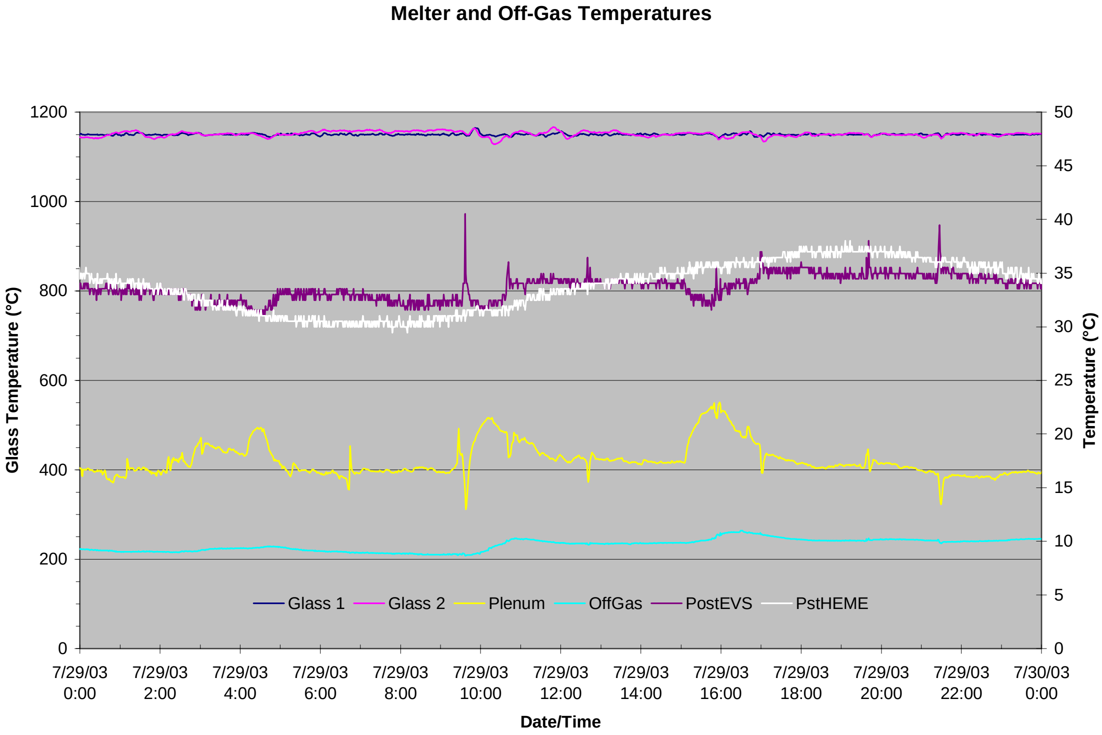
Appendix C

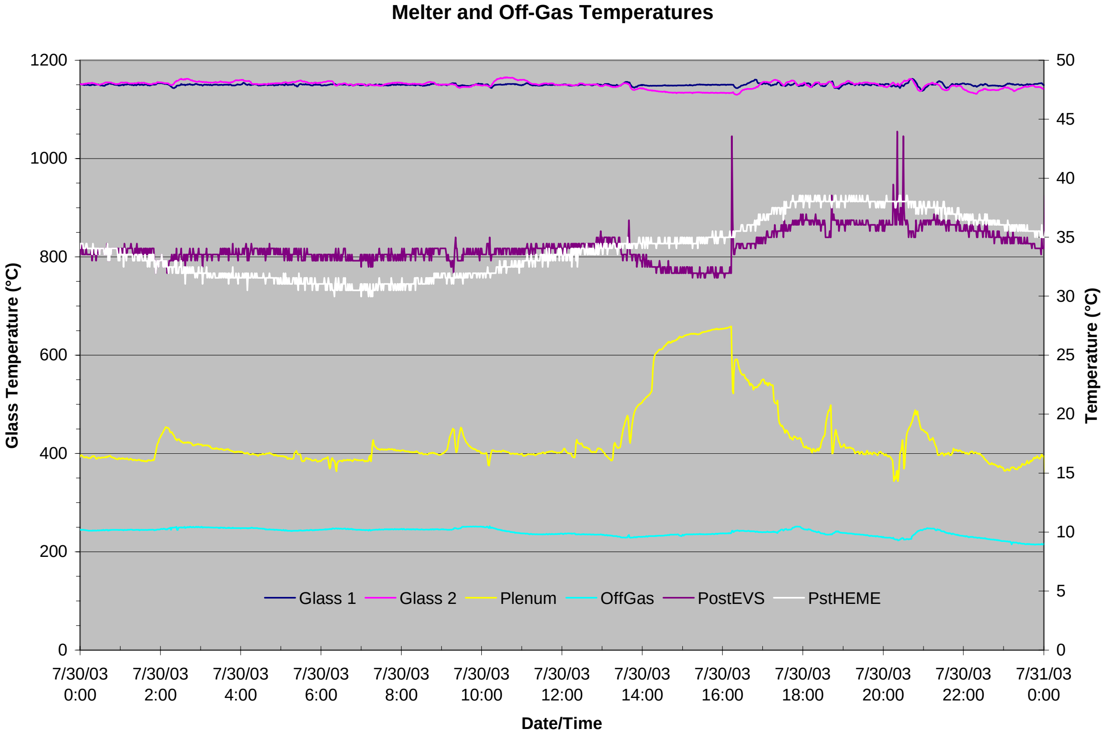
Graphical Temperature, Electrical Parameter, and Noncondensable Off-Gas Data

Graphical Temperature Data





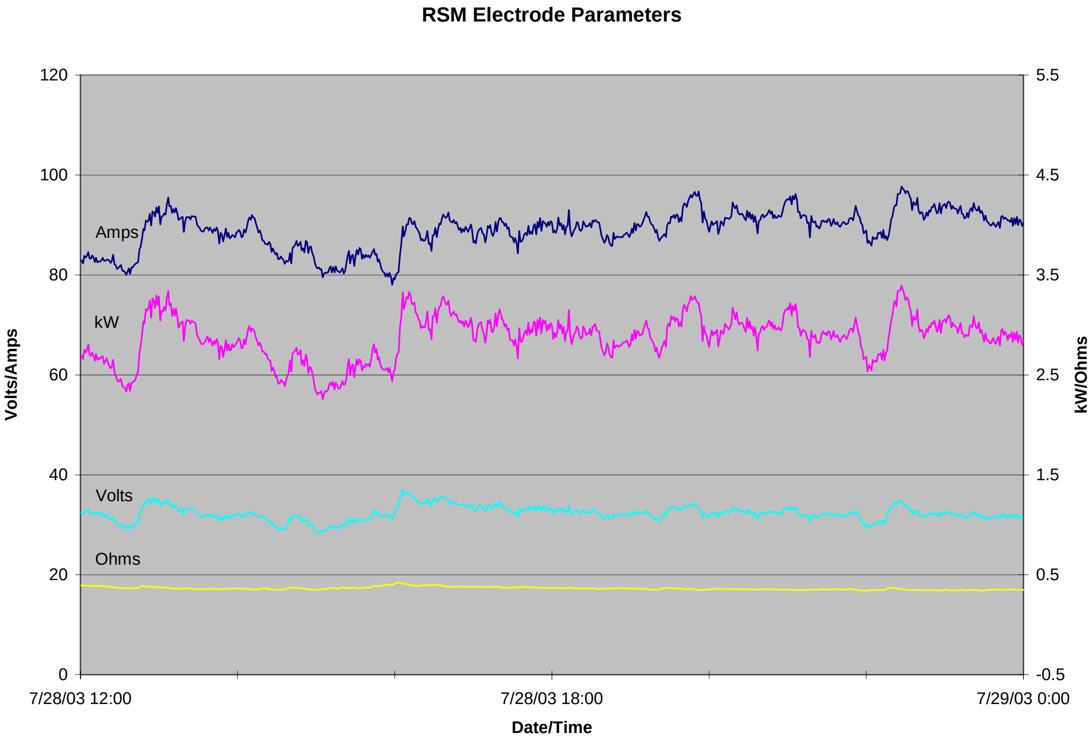

Melter and Off-Gas Temperatures
Glass Temperature (°C)
Temperature (°C)
1200
1000
800
600
400
200
0
50
45
40
35
30
25
20
15
10
5
0
Glass 1
Glass 2
Plenum
OffGas
PostEVS
PstHEME
7/29/03 0:00
7/29/03 2:00
7/29/03 4:00
7/29/03 6:00
7/29/03 8:00
7/29/03 10:00
7/29/03 12:00
7/29/03 14:00
7/29/03 16:00
7/29/03 18:00
7/29/03 20:00
7/29/03 22:00
7/30/03 0:00
Date/Time

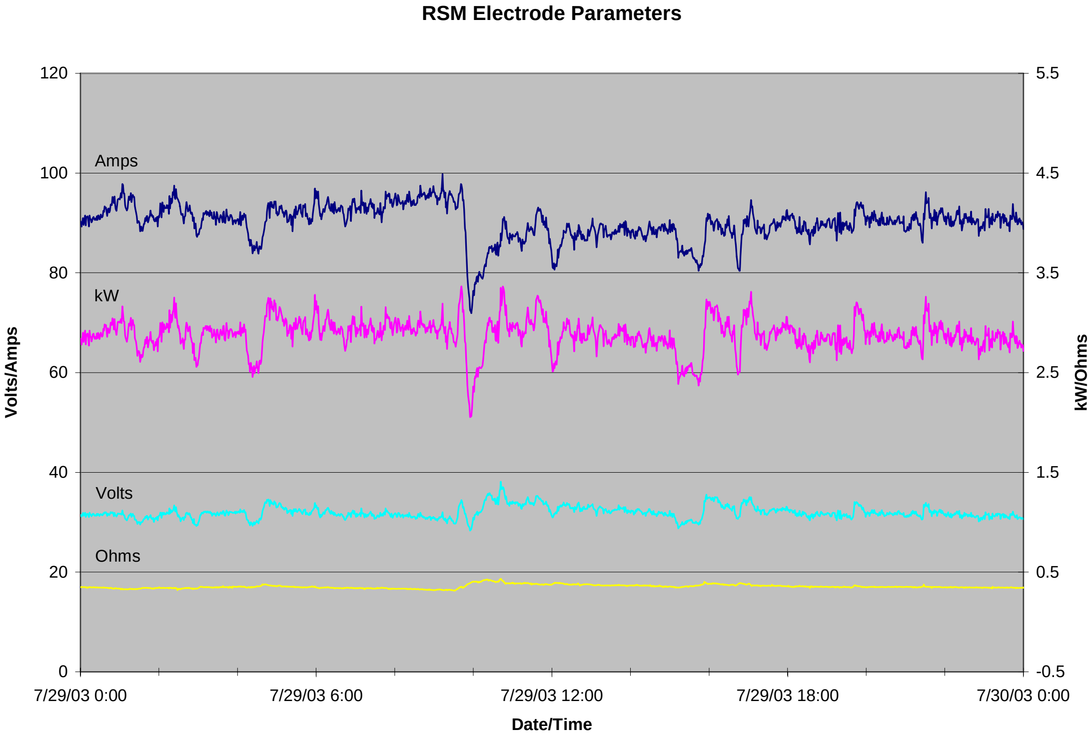

Melter and Off-Gas Temperatures
Glass Temperature (°C)
Temperature (°C)
1200
1000
800
600
400
200
0
50
45
40
35
30
25
20
15
10
5
0
Glass 1
Glass 2
Plenum
OffGas
PostEVS
PstHEME
7/30/03 0:00
7/30/03 2:00
7/30/03 4:00
7/30/03 6:00
7/30/03 8:00
7/30/03 10:00
7/30/03 12:00
7/30/03 14:00
7/30/03 16:00
7/30/03 18:00
7/30/03 20:00
7/30/03 22:00
7/31/03 0:00
Date/Time

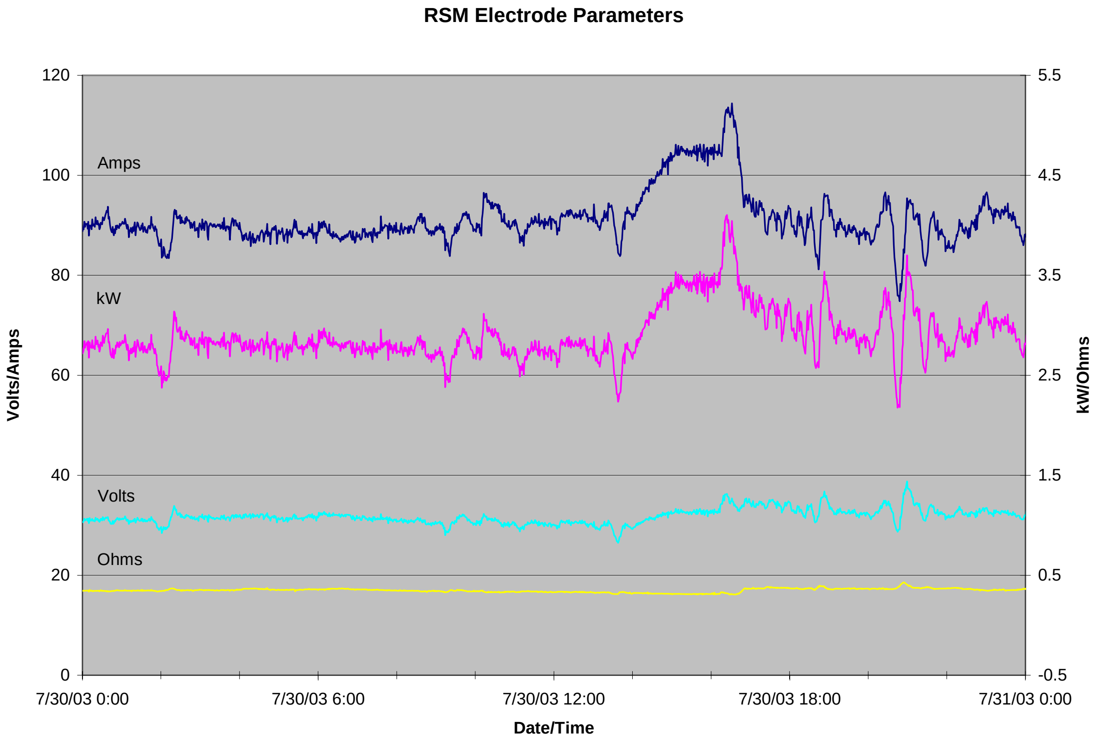
Melter and Off-Gas Temperatures

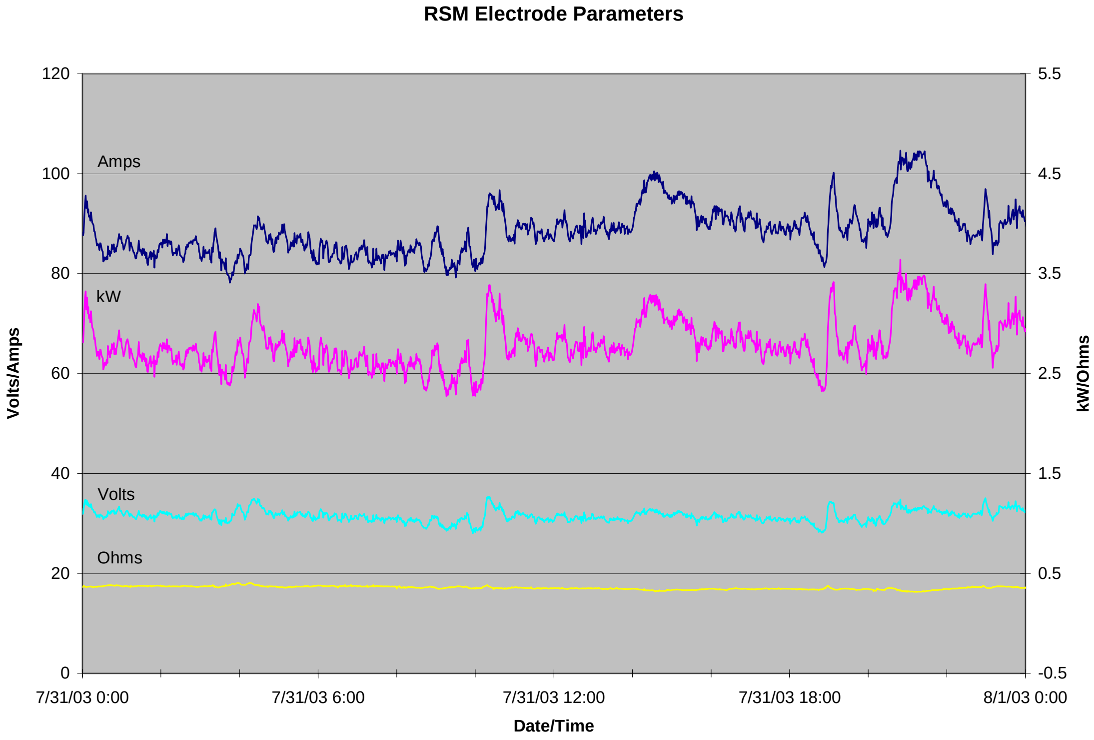
Melter and Off-Gas Temperatures

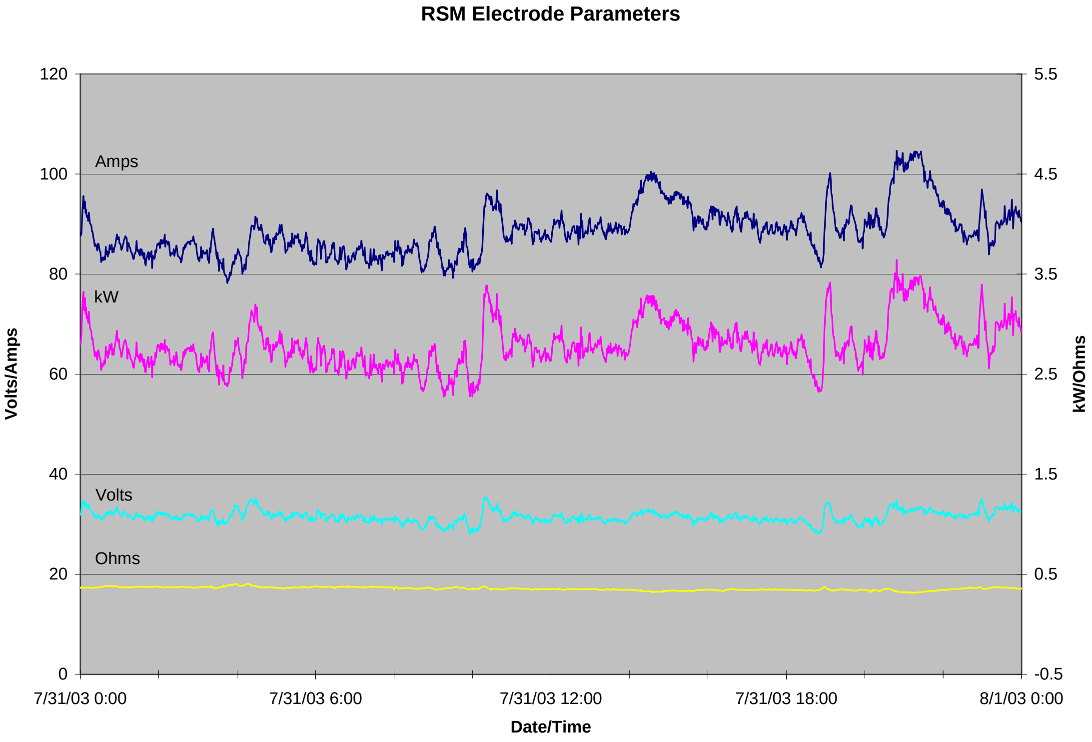
Graphical Electrode Parameter Data

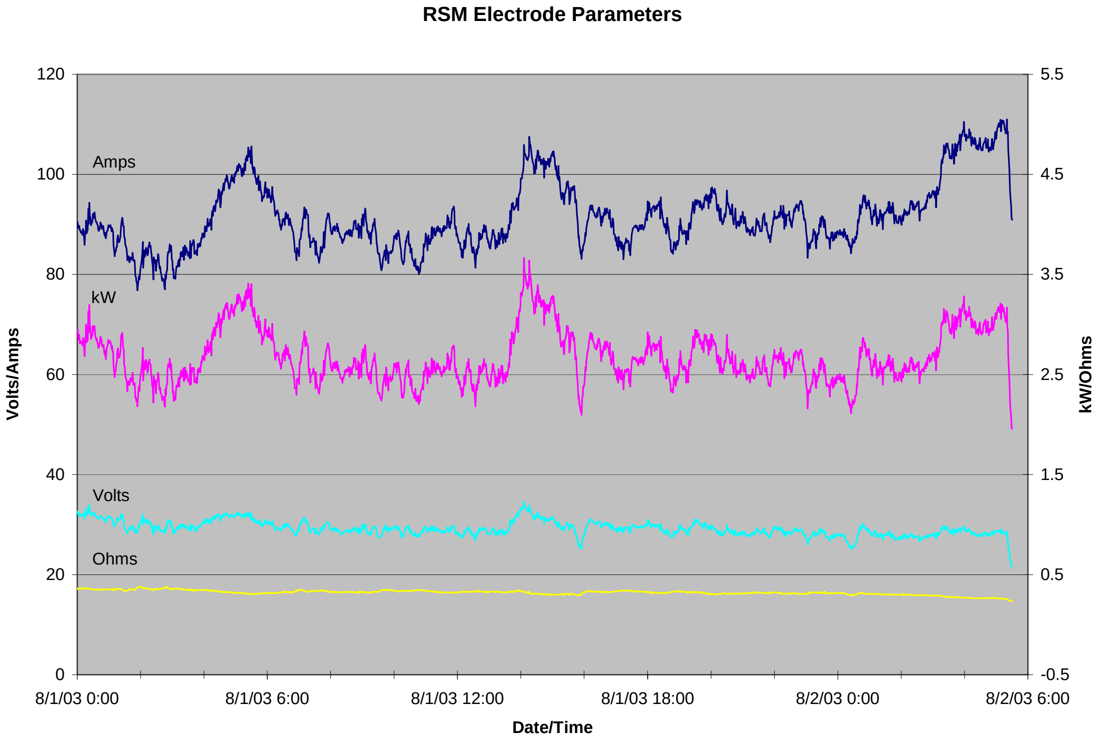




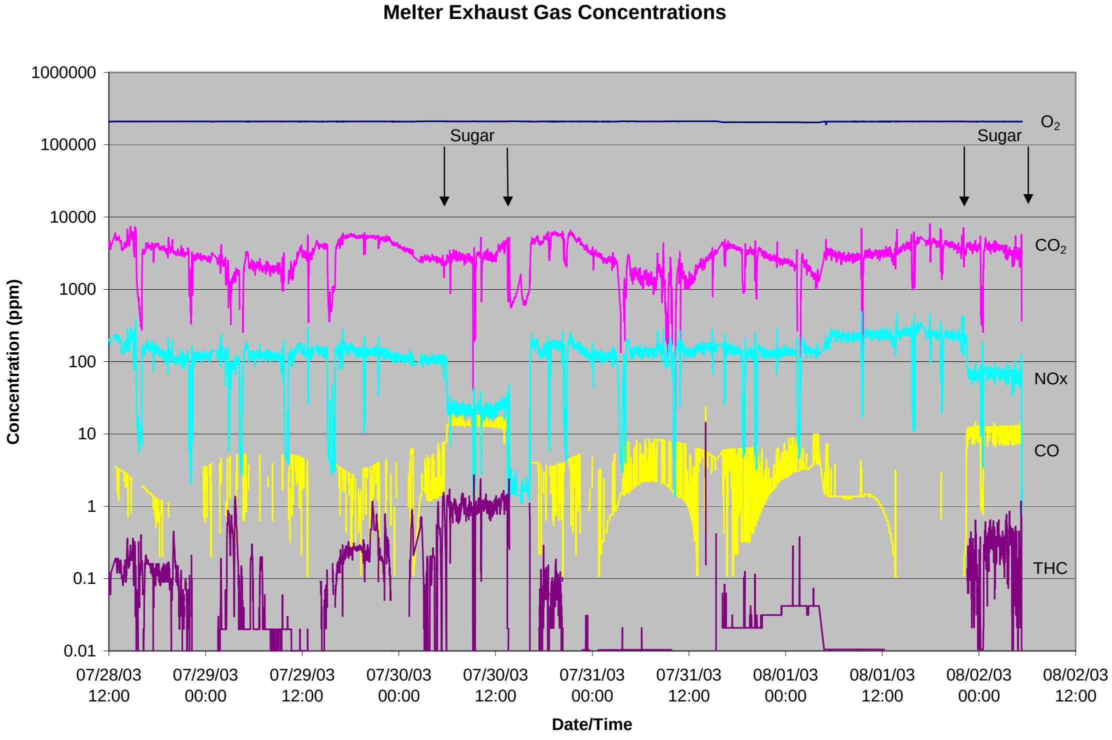

RSM Electrode Parameters
Amps
kW
Volts
Ohms
Volts/Amps
kW/Ohms
120
100
80
60
40
20
0
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
7/30/03 0:00
7/30/03 6:00
7/30/03 12:00
7/30/03 18:00
7/31/03 0:00
Date/Time

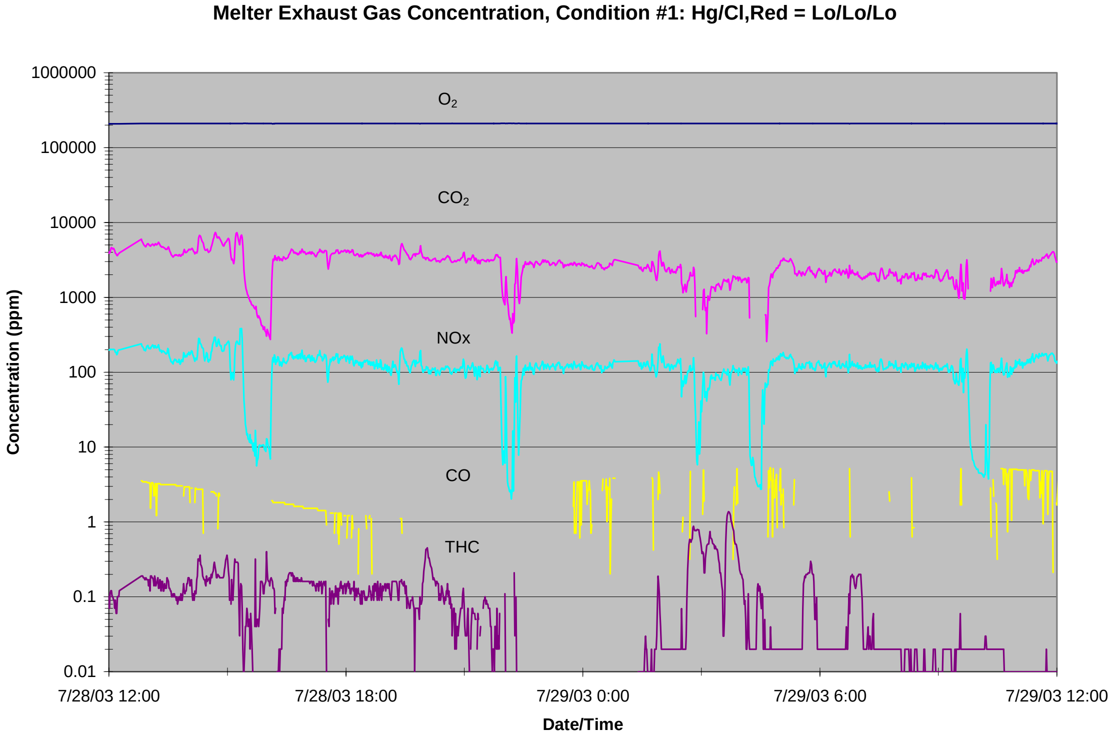

RSM Electrode Parameters
Amps
kW
Volts
Ohms
Volts/Amps
kW/Ohms
120
100
80
60
40
20
0
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
7/31/03 0:00
7/31/03 6:00
7/31/03 12:00
7/31/03 18:00
8/1/03 0:00
Date/Time


RSM Electrode Parameters
Volts/Amps
kW/Ohms
Amps
kW
Volts
Ohms
120
100
80
60
40
20
0
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
7/31/03 0:00
7/31/03 6:00
7/31/03 12:00
7/31/03 18:00
8/1/03 0:00
Date/Time

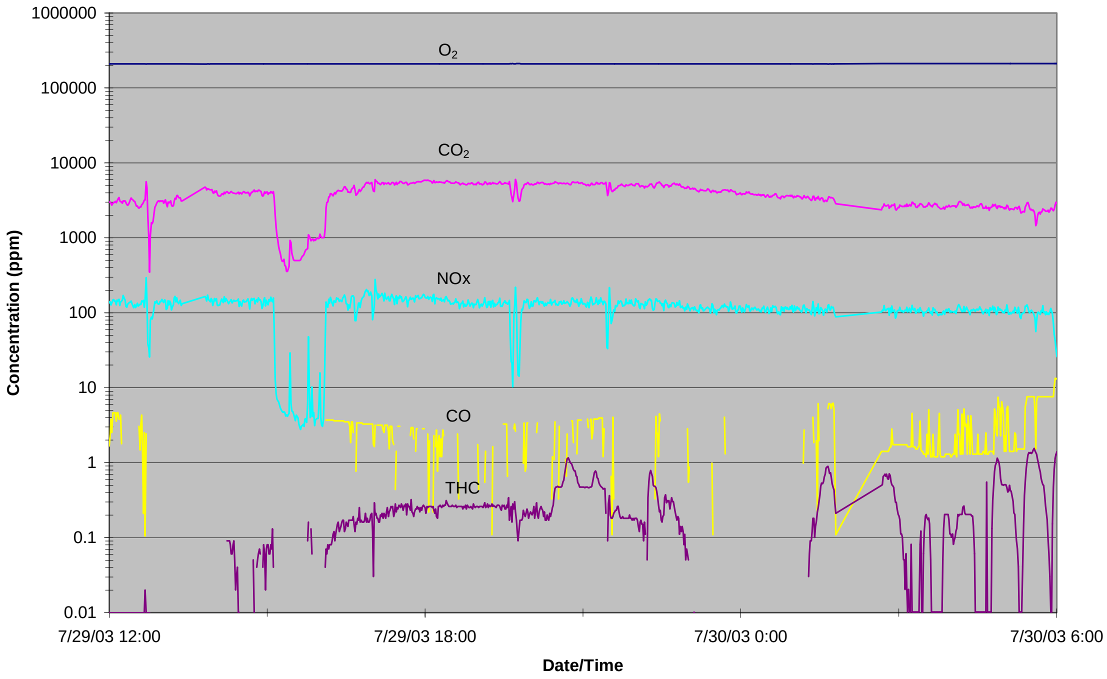

RSM Electrode Parameters
Volts/Amps
kW/Ohms
Amps
kW
Volts
Ohms
120
100
80
60
40
20
0
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
8/1/03 0:00
8/1/03 6:00
8/1/03 12:00
8/1/03 18:00
8/2/03 0:00
8/2/03 6:00
Date/Time

Graphical Noncondensible Off-Gas Data

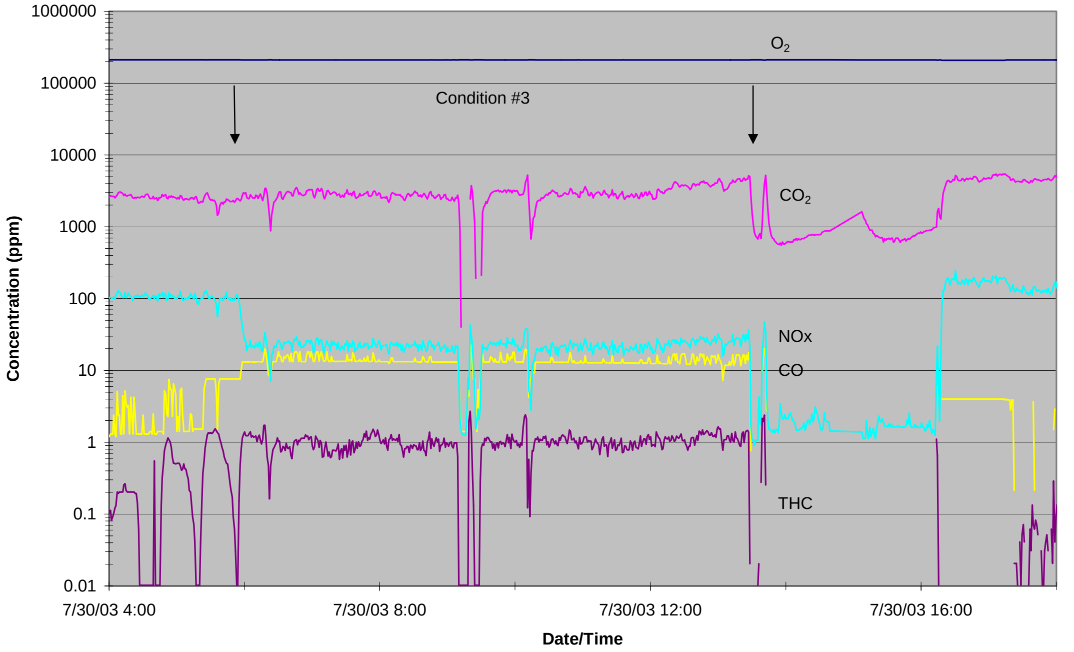




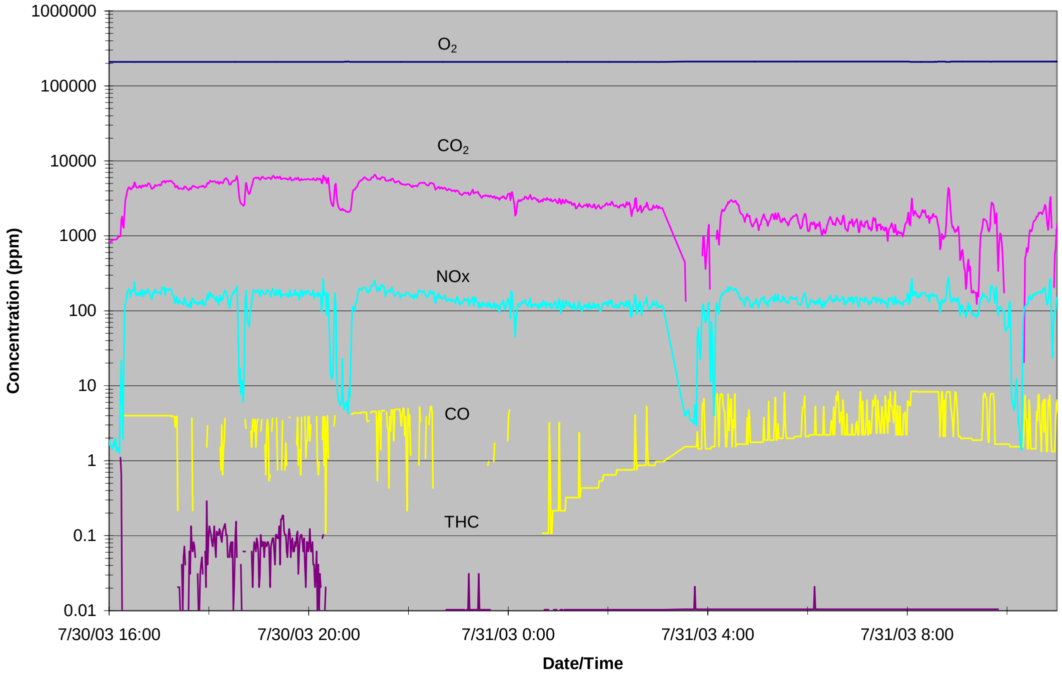
Melter Exhaust Gas Concentration, Condition #2: Hg/Cl,Red = Lo/Hi/Lo



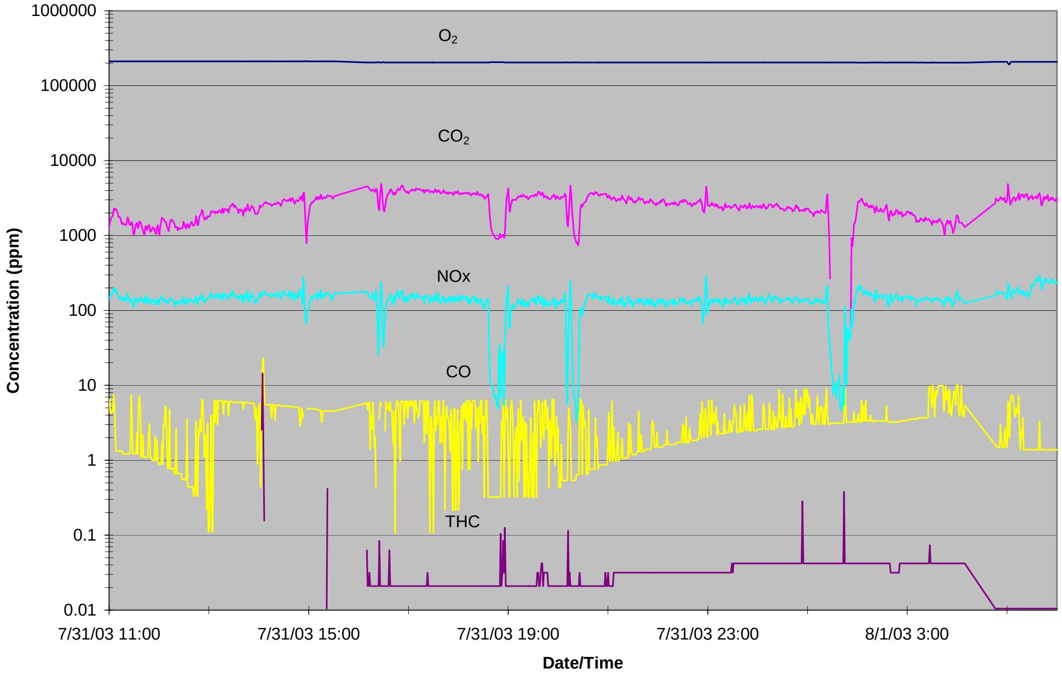
Melter Exhaust Gas Concentration, Condition #3: Hg/Cl,Red = Lo/Hi/Hi



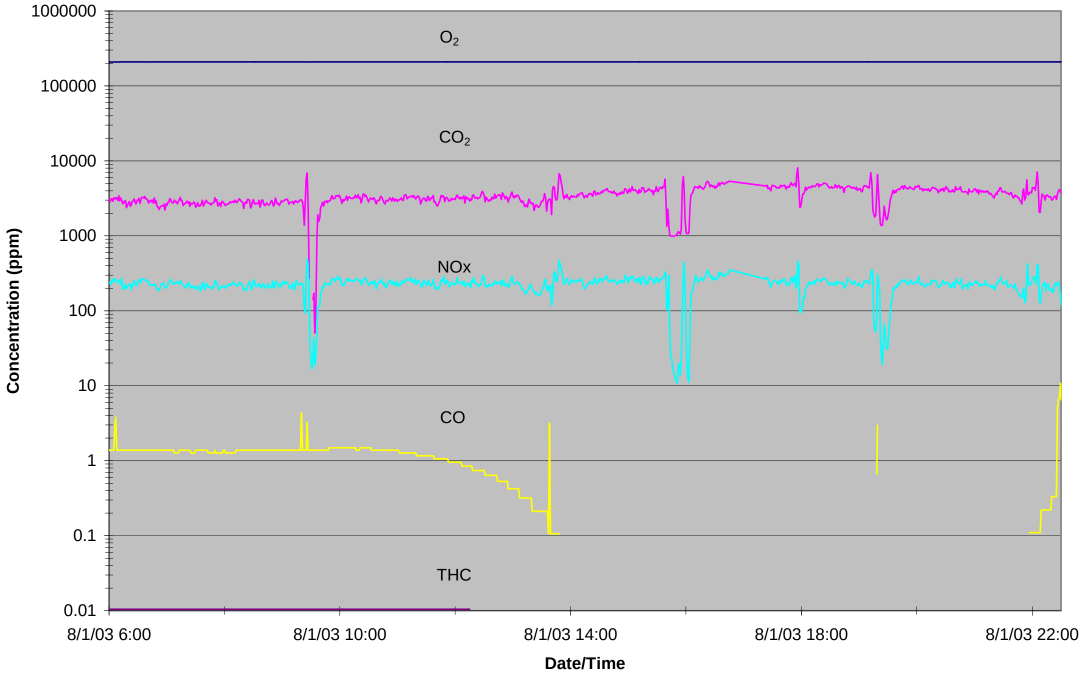
Melter Exhaust Gas Concentration, Condition #4: Hg/Cl,Red = Hi/Lo/Lo



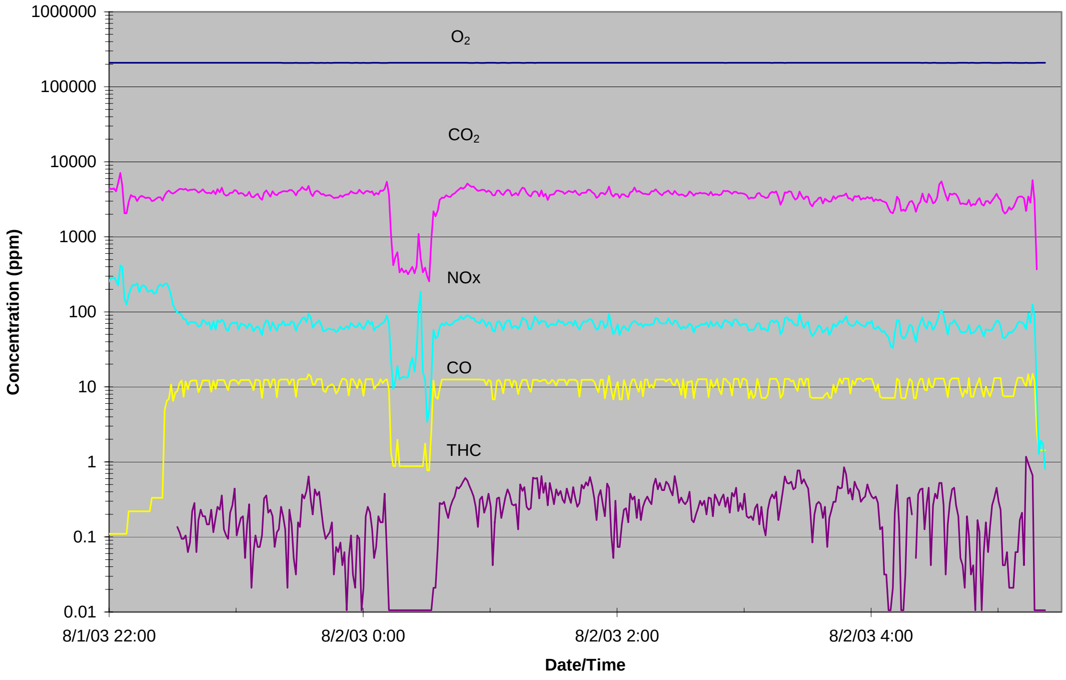
Melter Exhaust Gas Concentration, Condition #5: Hg/Cl,Red = Hi/Hi/Lo



Melter Exhaust Gas Concentration, Condition #6: Hg/Cl,Red = Mx/Hi/Lo

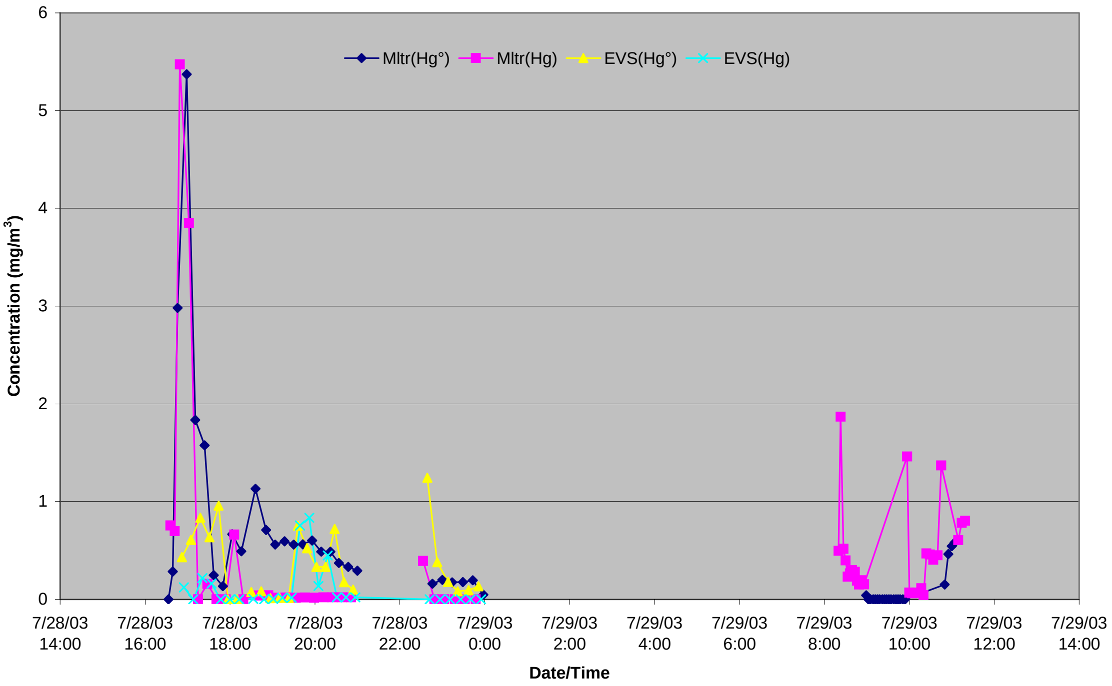


Melter Exhaust Gas Concentration, Condition #7: Hg/Cl,Red = Mx/Hi/Hi

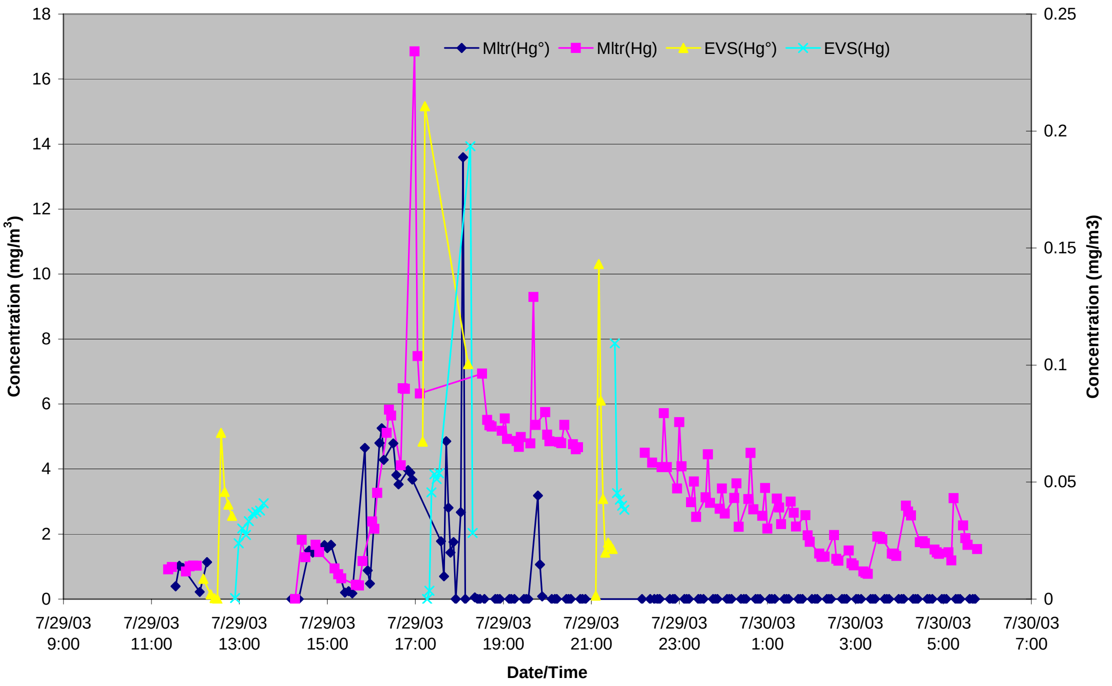


Graphical Mercury Off-Gas Data

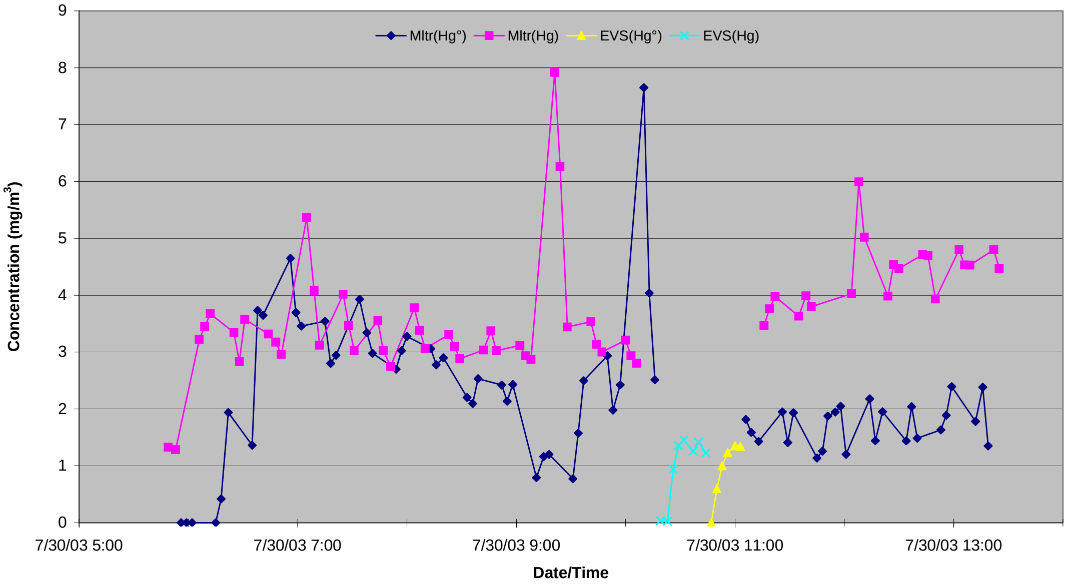
Melter Exhaust Concentration, Condition #1: Hg/Cl/Red = Lo/Lo/Lo



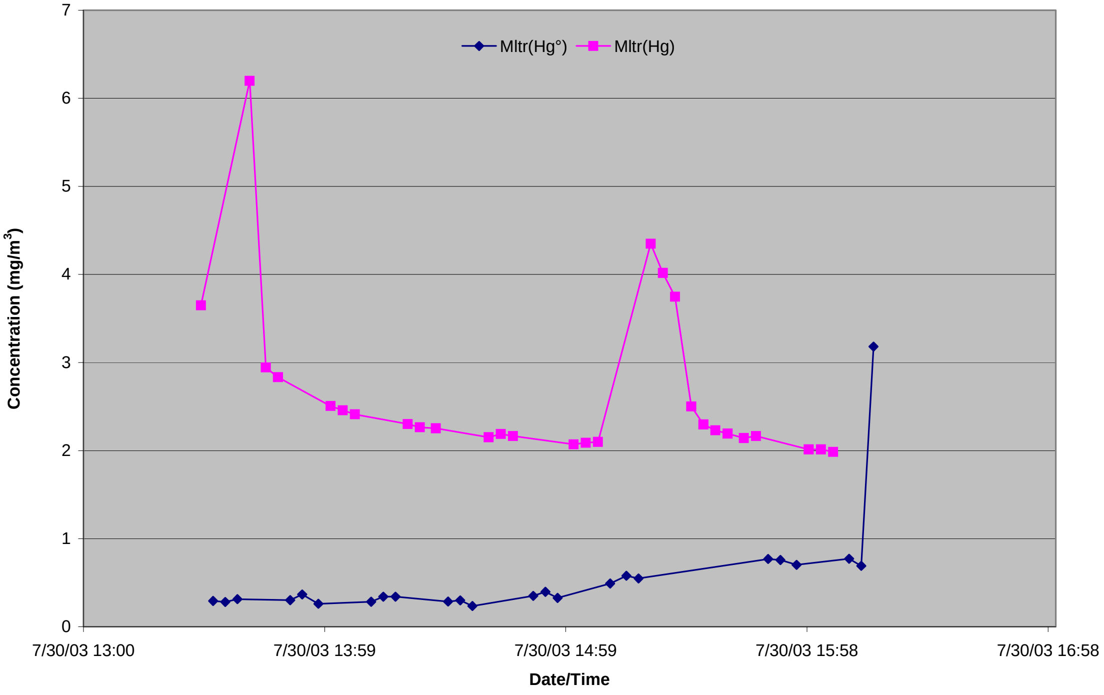
Mercury Vapor Off-Gas Concentration, Condition #2: Hg/Cl/Red = Lo/Hi/Lo

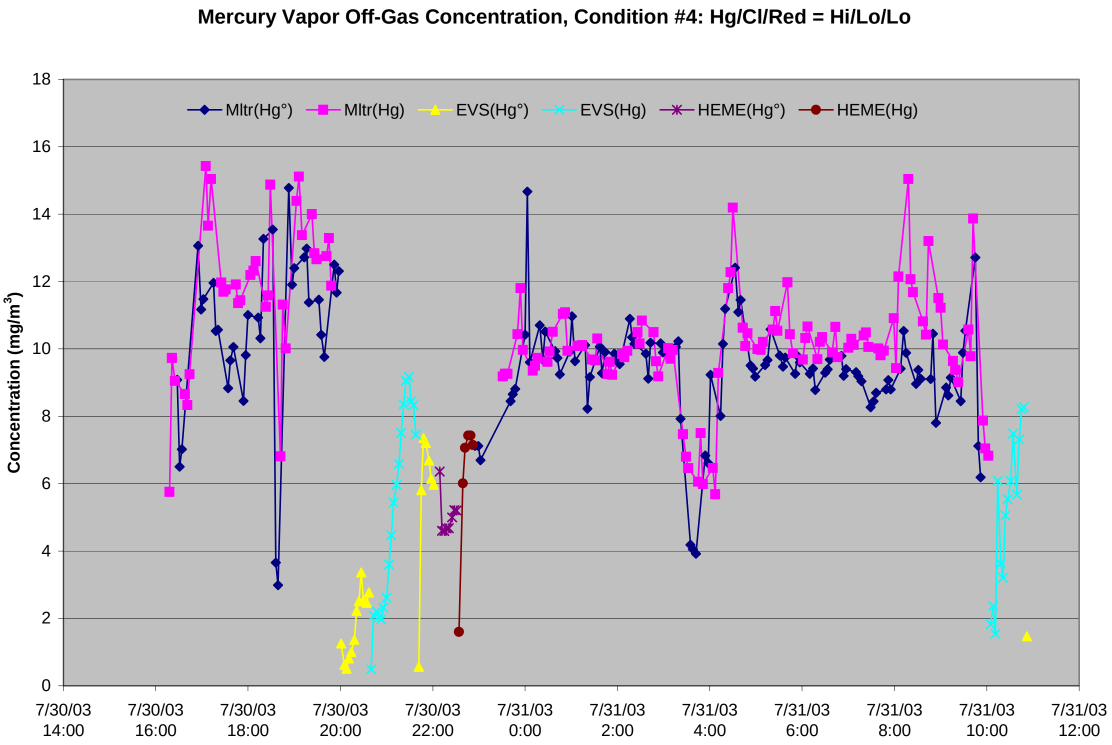


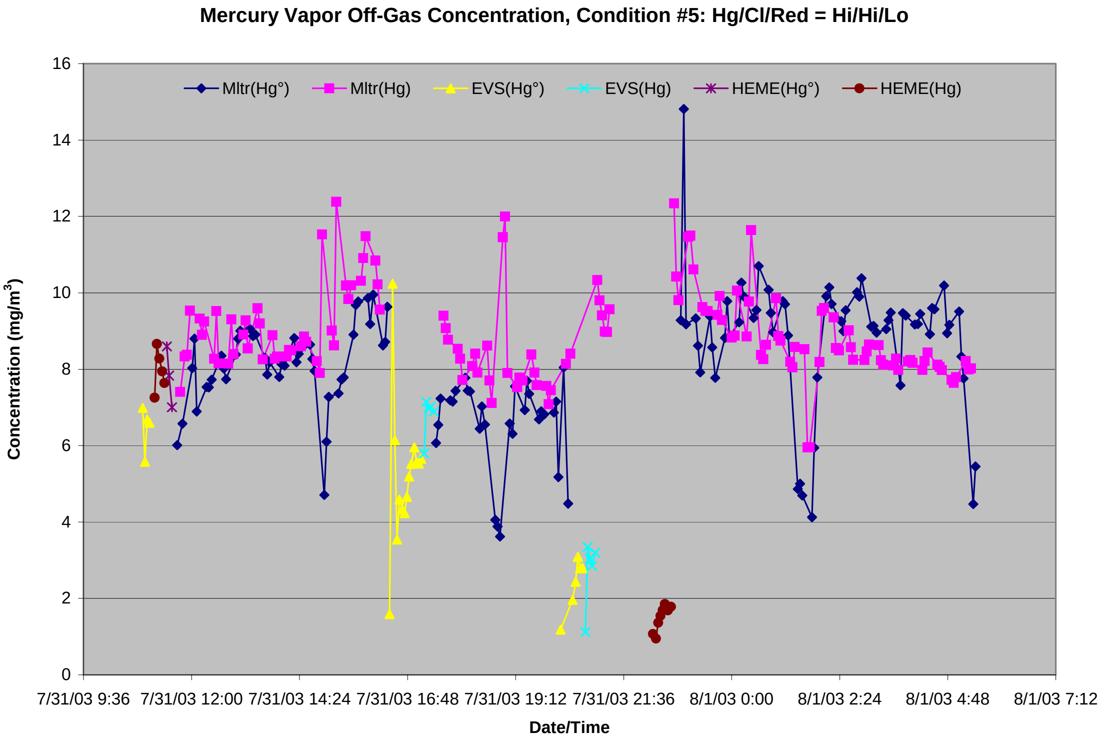
Mercury Vapor Off-Gas Concentration, Condition #3: Hg/Cl/Red = Lo/Hi/Hi



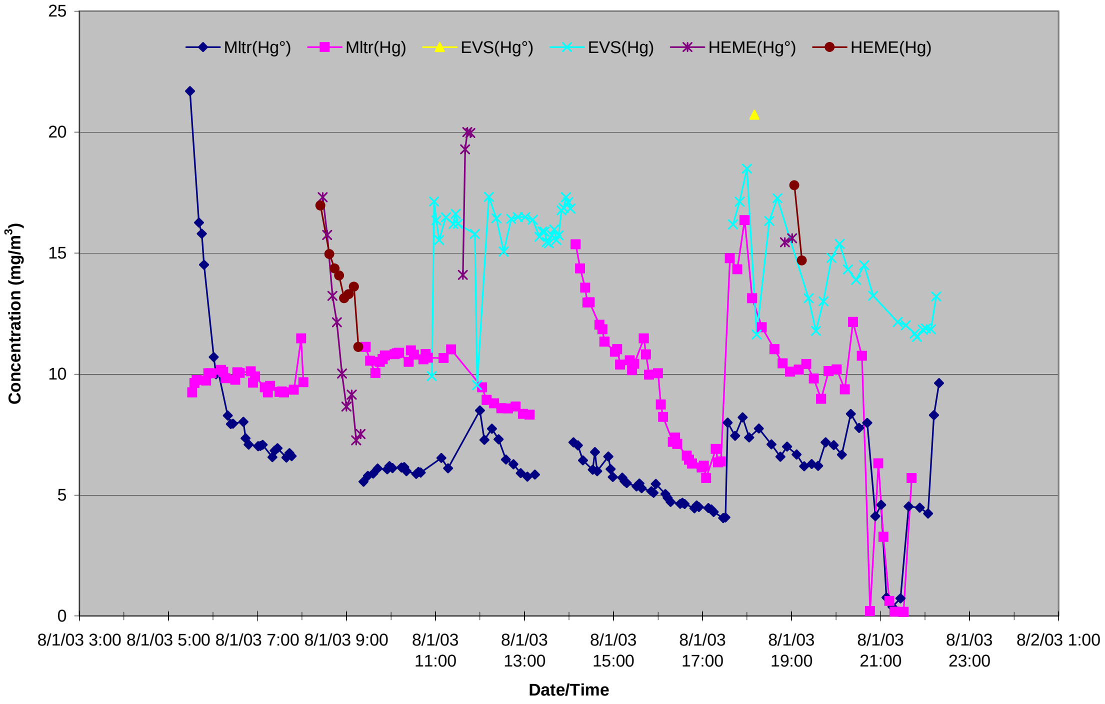
Melter Exhaust Concentration During Idling



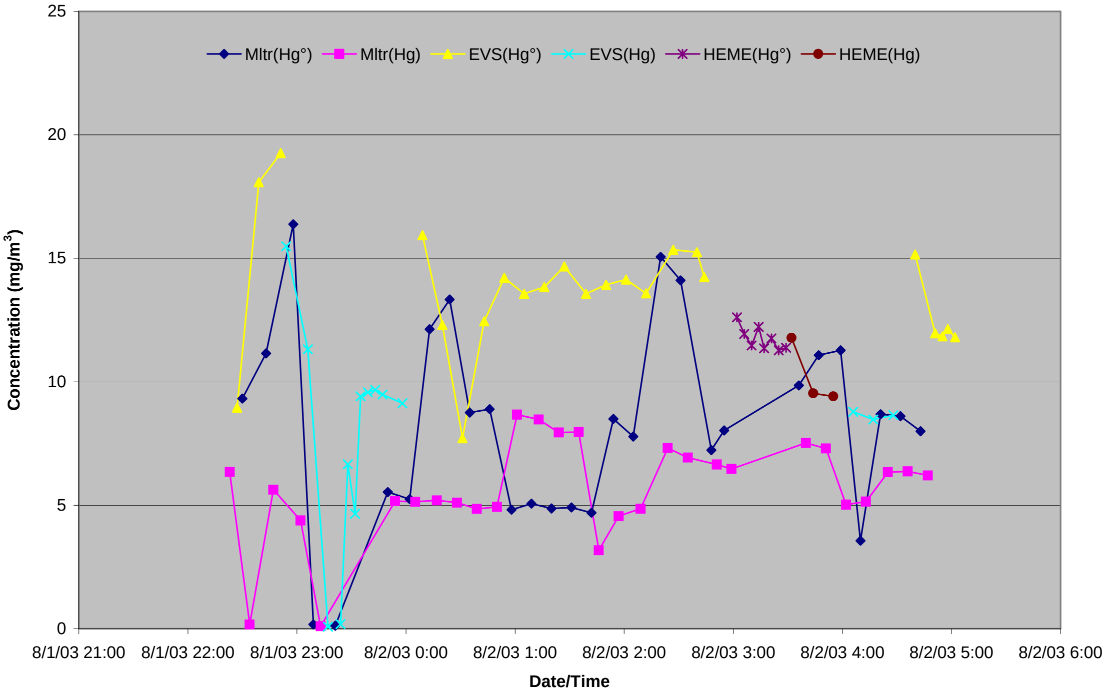

Mercury Vapor Off-Gas Concentration, Condition #4: Hg/Cl/Red = Hi/Lo/Lo


Mercury Vapor Off-Gas Concentration, Condition #5: Hg/Cl/Red = Hi/Hi/Lo

Mercury Vapor Off-Gas Concentration, Condition #6: Hg/Cl/Red = Mx/Hi/Lo



Mercury Vapor Off-Gas Concentration, Condition #7: Hg/Cl/Red = Mx/Hi/Hi

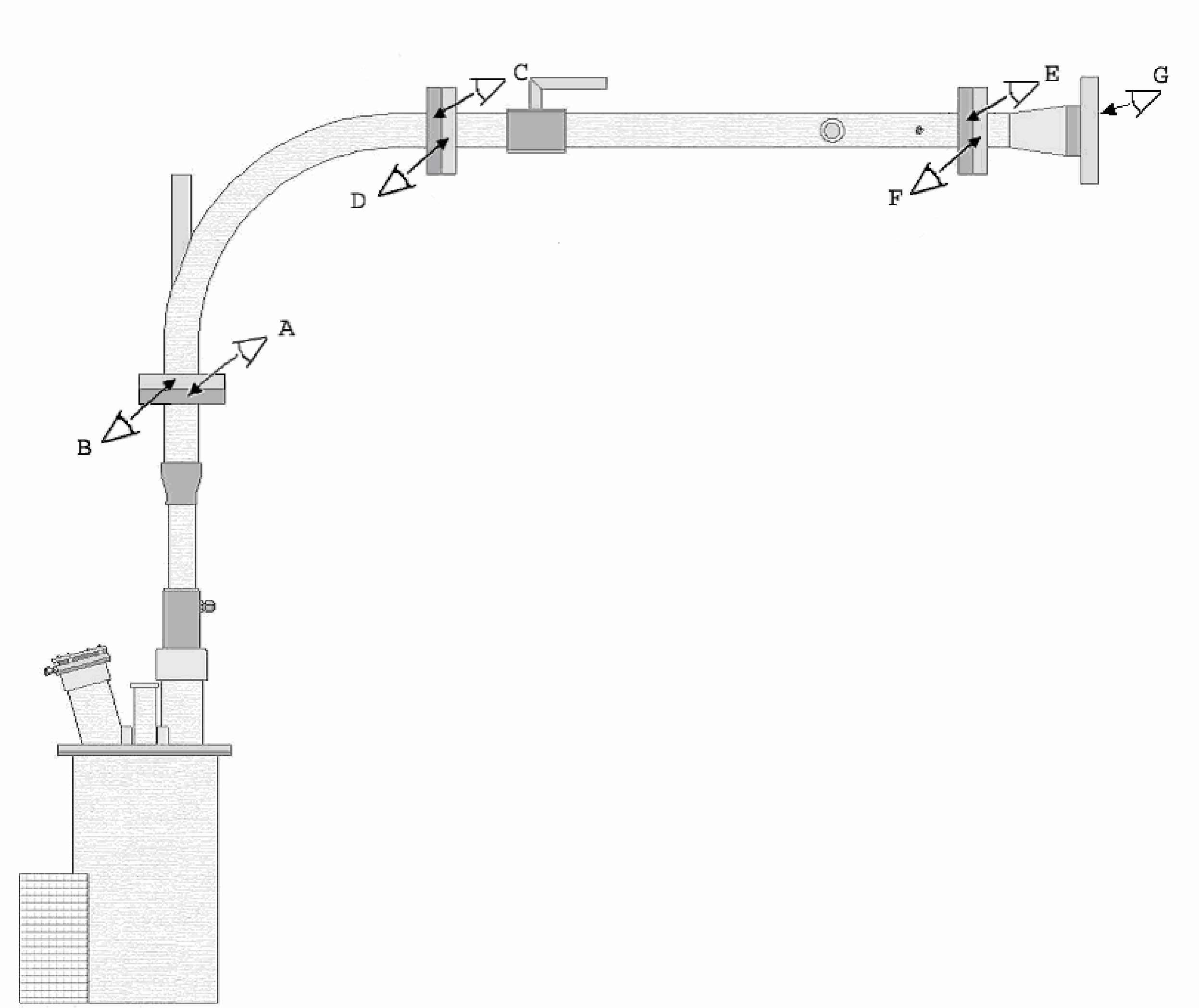


Appendix D

Piping Hardware Photographs

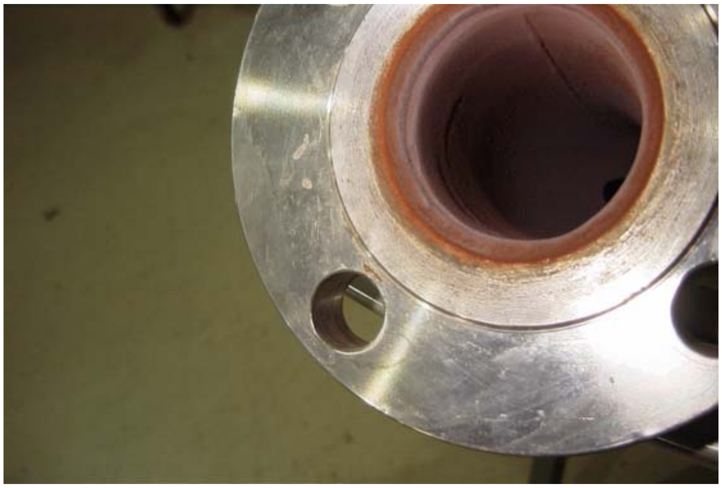
Appendix D: Piping Hardware Photographs

3-RSM Off-Gas Line Component Views

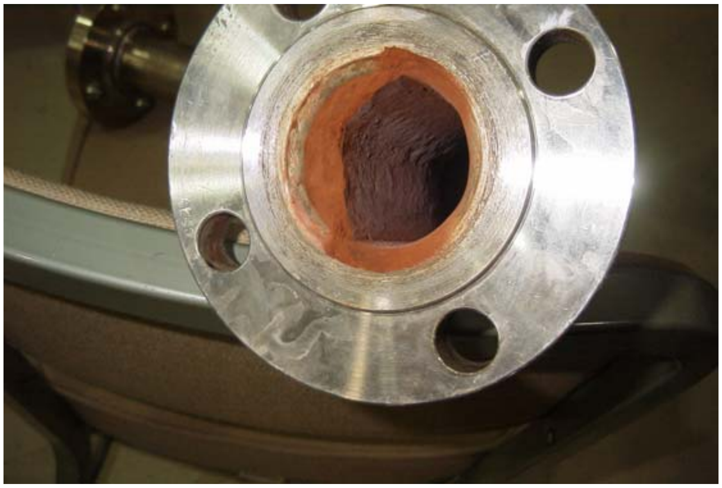


Film Cooler Inlet

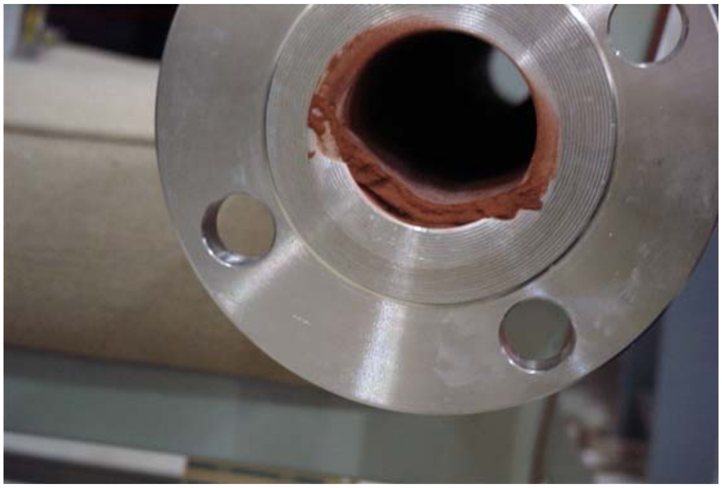
Film Cooler Exhaust Port, View A



Inlet of Curved Elbow, View B



Outlet of Curved Elbow, View C

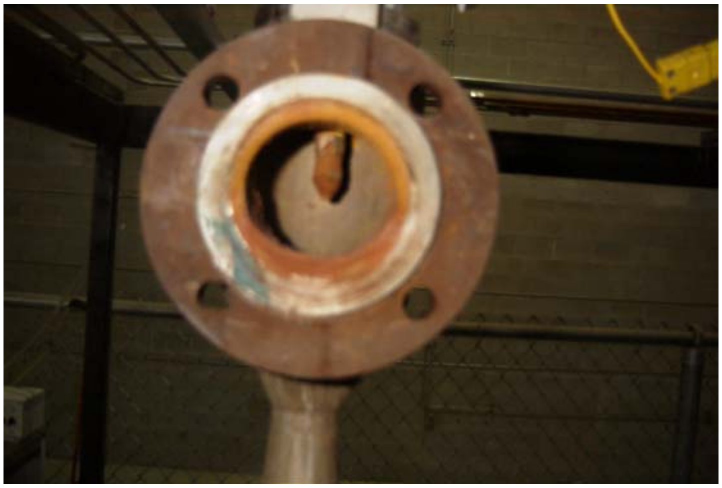


Inlet to Horizontal Pipe Segment, View D

Outlet of Horizontal Pipe Section, View E

Inlet to Pipe Reducer, View F

Outlet of Pipe Reducer, View G



Inlet to EVS

HEME Filter Bed Inlet

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