

RMIS View/Print Document Cover Sheet

This document was retrieved from the Documentation and Records Management (DRM) ISEARCH System. It is intended for Information only and may not be the most recent or updated version. Contact a Document Service Center (see Hanford Info for locations) if you need additional retrieval information.

Accession #: D196030799

Document #: SD-WM-VI-031

Title/Desc:

VECTRA GSI INC LLW MELTER TESTING PHASE 1 TEST
REPORT

Pages: 291

FEB 21 1996 (21)

ENGINEERING DATA TRANSMITTAL

Page 1 of 1
1. EDT No 611890

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Waste Product Technology	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: TWRS LLW Program	6. Cog. Engr.: G. E. Stegen (509) 376-5548	7. Purchase Order No.: MMI-SVV-384211
8. Originator Remarks: VECTRA GSI, Inc. LLW melter testing Phase 1 test report for issuance.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks: N/A		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-WM-VI-031		0	VECTRA GSI, Inc. Low-Level Waste Melter Testing Phase 1 Test Report	Q	1,2	1	

16. KEY			
Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)										(G)	(H)
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	Reason	Disp.
1	1	Cog.Eng. G.E. Stegen	<i>[Signature]</i>	2/9/96	H5-27	K.C. Burgard	<i>[Signature]</i>	2/7/96	H5-83	1	
1	1	Cog. Mgr. D.W. Washenfelder	<i>[Signature]</i>	2/9/96	H5-27	C.N. Wilson	<i>[Signature]</i>	2/7/96	H5-27	1	
1	1	QA: D.W. Duncan	<i>[Signature]</i>	2/9/96	H4-55						
		Safety									
		Env.									

18. G.E. Stegen <i>[Signature]</i> 2/9/96 Signature of EDT Originator Date	19. D.W. Washenfelder <i>[Signature]</i> 2/9/96 Authorized Representative Date for Receiving Organization	20. C.N. Wilson <i>[Signature]</i> 2/9/96 Cognizant Manager Date	21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
---	--	---	---

Vectra GSI, Inc. Low-Level Waste Melter Testing Phase 1 Test Report

G. E. Stegen, C. N. Wilson
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 611890 UC: 2020
Org Code: 73510 Charge Code: D4NCO
B&R Code: EW3130010 Total Pages: 287

Key Words: Low-level waste, vitrification, melter, Hanford Site tank waste, fluid bed calcination, rotary dryer, slurry feed

Abstract: A multiphase program was initiated in 1994 to test commercially available melter technologies for the vitrification of the low-level waste (LLW) stream from defense wastes stored in underground tanks at the Hanford Site in southeastern Washington State. Vectra GSI, Inc. was one of seven vendors selected for Phase 1 of the melter demonstration tests using simulated LLW that were completed during fiscal year 1995. The attached report prepared by Vectra GSI, Inc. describes results of melter testing using slurry feed and dried feeds. Results of feed drying and prereaction tests using a fluid bed calciner and rotary dryer also are described.

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Printed in the United States of America. To obtain copies of this document, contact: WHC/BCS Document Control Services, P.O. Box 1970, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

Karen H. Noland 2/21/96
Release Approval Date



Approved for Public Release

PART 1 - FLUID BED CALCINER TEST REPORT

FLUID BED CALCINER TEST REPORT - FINAL

For

WHC Contract No. MMI-SVV-384211

EVALUATION OF MELTER SYSTEM TECHNOLOGIES FOR
VITRIFICATION OF HIGH SODIUM CONTENT LLRW

VECTRA GSI Report No. WHC-VIT-03

August 1995

by

VECTRA Government Services, Inc.
2939 Richardson Road
Richland, WA 99352

Prepared by:

John J. Koehr 
Brent Spurgeon 

Approved by:

Brad Mason 

CONTENTS

1.0	INTRODUCTION	1-1
2.0	PURPOSE	1-1
3.0	CHRONOLOGY OF EVENTS	1-2
4.0	EQUIPMENT OPERATING BEHAVIOR	1-2
4.1	CALIBRATION	1-2
4.1.1	Waste Feed Pump	1-2
4.1.2	Pressure Indicator (PI) Calibration	1-2
4.1.3	Temperature Indicator (TI) Calibration	1-2
4.1.4	CEMS Calibration	1-6
4.2	FLOW DIAGRAM	1-6
4.3	CHEMICAL MIXING AND BATCHING	1-7
4.3.1	Bench and Pilot Simulant Feed System	1-7
4.3.2	Bench and Pilot Calciner Filter Blowback Gas	1-7
4.3.3	Bench Scale Calciner Start-up and Shutdown Sequence	1-8
4.3.4	Sampling	1-8
4.3.5	Bench Scale Scrubber Solution	1-9
4.3.6	Bench Scale Dry Glass Former Feed System	1-9
5.0	BENCH SCALE TESTS AND OBSERVATIONS	1-9
5.1	GLASS FORMER FLUIDIZATION TESTS	1-9
5.2	FBC-S0: GLASS FORMERS W/ WATER/SIMULANT, NO REDUCTANTS	1-10
5.3	FBC-S1: GLASS FORMERS AND SIMULANT W/ 600% SUCROSE AT 700 °C	1-12
5.4	FBC-S2: GLASS FORMERS AND SIMULANT W/ 200% AMMONIA AT 700 °C	1-13
5.5	FBC-S3: GLASS FORMERS AND SIMULANT W/ 100% SUCROSE AT 700 °C	1-14
5.6	FBC-S4: GLASS FORMERS AND SIMULANT W/ 125% SUCROSE AT 500 °C	1-15
5.7	FBC-S5: GLASS FORMERS AND SIMULANT W/ 100% SUCROSE AT 500 °C	1-15
5.8	FBC-S6: GLASS FORMERS AND SIMULANT W/ 200% AMMONIA AT 500 °C	1-15
5.9	FBC-S7: GLASS FORMERS AND SIMULANT W/ 200% HYDROGEN AT 300 °C	1-16
5.10	FBC-S8: GLASS FORMERS AND SIMULANT W/ 200% METHANE AT 500 °C	1-16
5.11	FBC-S9: GLASS FORMERS AND SIMULANT W/ 75% SUCROSE AT 500 °C	1-16
5.12	FBC-S10: GLASS FORMERS W/ 100% BORIC ACID FEED AT 500 °C	1-17
5.13	FBC-S11: GLASS FORMERS (INCLUDING 9% BORIC ACID) AND 16% BORIC ACID FEED AT 500 °C	1-17
5.14	FBC-S12: GLASS FORMERS W/ BORIC OXIDE FEED AND SIMULANT W/ 100% SUCROSE AT 400 °C	1-18
5.15	FBC-S13: GLASS FORMERS W/ BORIC OXIDE FEED AND SIMULANT W/ 100% SUCROSE AT 425 °C	1-19
5.16	BENCH SCALE TEST EVALUATION SUMMARY	1-19

CONTENTS (cont)

6.0	PILOT SCALE TESTS AND OBSERVATIONS	1-21
6.1	FBC-PO: GLASS FORMERS WITH WATER	1-21
6.2	PRODUCTION RUN: GLASS FORMERS AND SIMULANT WITH 100% SUCROSE	1-22
7.0	CONCLUSIONS	1-23
8.0	RECOMMENDATIONS FOR FUTURE TESTING	1-24

APPENDIXES

1A	LAB ANALYSES	1-25
1B	MASS BALANCE CALCULATIONS	1-71
1C	DATA SHEETS	1-91

LIST OF TABLES

1-1	Fluid Bed Calciner Test Log Summary	1-3
1-2	Fluid Bed Composition, Glass Former Mix A	1-11
1-3	Fluid Bed Composition, Glass Former Mix B	1-12
1-4	Fluid Bed Composition, Glass Former Mix C	1-14
1-5	Fluid Bed Composition, Glass Former Mix D	1-18
1-6	Fluid Bed Composition, Glass Former Mix E	1-19
1-7	Bench Scale Fluid Bed Calciner Test Run Summary	1-20
1-8	Pilot Scale Glass Former Mix C	1-21

ACRONYMS

GSI	VECTRA Government Services, Inc.
LLRW	low-level radioactive waste
MCW	melter cooling water
RBEA	Roger B. Ek Associates
RVR	radwaste volume reduction
TPD	tons per day
WHC	Westinghouse Hanford Company

This page intentionally left blank.

PART 1 - FLUID BED CALCINER TEST REPORT

1.0 INTRODUCTION

The Westinghouse Hanford Company (WHC) is conducting an evaluation of glass melter system technologies for vitrification of liquid low-level radioactive waste (LLRW) streams consisting mostly of sodium nitrate and nitrite salts in alkaline liquid slurry form. As part of this technology evaluation, VECTRA will demonstrate the performance of the EnviroGlass™ Vitrification System feed and VE-SKULL™ melter subsystems. The Fluid Bed Calciner system is part of the melter feed system and is intended to dry and react the liquid waste simulant and mix the simulant with glass formers prior to vitrification.

2.0 PURPOSE

This test report documents accomplishment of the Fluid Bed Calciner test objectives. Test objectives included the following:

- 2.1 Demonstrate that a fluidized bed can be operated successfully to produce a dry, prereacted material that is suitable as a melter feed using at least one reductant.
- 2.2 Demonstrate ability of fluid bed calciner to do the following:
 - Evaporate water
 - Volatize CO_3 , NO_3 , and NO_2
 - Reduce NO_3 and NO_2 with good yield of N_2 gas
 - Calcine inorganics (Na, K, Al, Ca, etc.)
 - Pyrolyze/Oxidize organics.
- 2.3 Determine throughput of calciner when operating within parameters for achieving objectives 2.1 and 2.2.
- 2.4 Determine efficiency of NO_3/NO_2 reductions to N_2 using the following additives: methane (CH_4) gas, hydrogen (H_2) gas, solid sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$), and ammonia (NH_3) gas. Investigate affects of reductant to nitrate ratio over a wide temperature range.

™VE-SKULL and EnviroGlass are trademarks of VECTRA Technologies, Inc.

3.0 CHRONOLOGY OF EVENTS

A detailed chronology of fluid bed calciner bench scale testing has been recorded in the Test Log. A brief summary is provided in Table 1-1. Numbers shown in parentheses following the VECTRA GSI test number are corresponding Procedyne test numbers.

4.0 EQUIPMENT OPERATING BEHAVIOR

4.1 CALIBRATION

Generally, equipment calibration was performed and documented as required by the Test Procedure. Any deviations from the test procedure or otherwise noteworthy equipment calibration related events are summarized below.

4.1.1 Waste Feed Pump

1. Initial Waste feed pump (pump no. 1) was a laboratory, positive displacement, piston type, simplex pump. Pump calibration was performed at various piston stroke settings (0-10 range) to develop a curve of pump setting vs. flowrate. Pump no.1 flowrates became inconsistent during FBC-S0 (I-2) testing and the pump was unable to overcome vessel pressure, indicating pump failure.
2. A back-up feed pump (pump no. 2) was calibrated and installed. Pump no. 2 was a 20 GPD peristaltic tubing pump with variable speed and a discharge pressure rating of 25 psig. The pump was calibrated using water and various pump speeds. A curve of pump speed (rpm) vs. flow rate (ml/min) was generated over the range of the pump. Calibrated settings were verified at multiple discharge pressure settings and with simulant and sucrose mixtures. Calibration data are included in Reference 3.2. Pump no. 2 tubing kit was replaced on 2/15/95 prior to FBC-S3 (I-7) testing. A single point calibration check was performed and found to be consistent with the original calibration.

4.1.2 Pressure Indicator (PI) Calibration

Original pressure gauge PI-FG, for the fluidizing gas supply pressure to the vessel, had a low range (0-100" water). Over the course of testing, this gauge was replaced with a 0-10 psig gauge. Gauges were calibrated.

4.1.3 Temperature Indicator (TI) Calibration

Thermocouples T1 through T6 were calibrated using a manufacturer's calibrated thermocouple (TC) with 2-point temperature check.

Table 1-1. Fluid Bed Calciner Test Log Summary. (4 sheets)

Date	Activities/events
2/8/95 FBC-S0 (I-1)	- Glass formers mix A, water injection only, no reductants, at 750 °C. Mix A included boric acid at approximately 9.2 %wt - Good dry bed fluidization - Obtained/confirmed fluid bed heat transfer data (20 ml/min max feed flow) - Feed pump no. 1 calibration point verification failed/ recalibrated pump
2/9/95 FBC-S0 (I-2)	- Glass formers mix A with simulant, no reductants, at 750 °C - Feed pump no. 1 failed, test terminated early
2/10/95 FBC-S0 (I-3)	- Glass formers mix A with simulant only, no reductants, at 700 °C. - Feed pump no.2 calibrated and installed - High NOx, rapid bed caking
2/13/95 FBC-S1 (I-4)	- Glass formers mix B, at 700 °C. Mix B included boric acid at 16.2%wt - Modified glass former bed proportions based on revised calculations. - Lost fluidization prior to simulant injection due to melting Boric Acid at higher relative weight percent.
FBC-S1 (I-5)	- Glass former mix C, w/simulant and 600% sucrose, at 700 °C. Mix C had no boric acid. - Good initial fluidization, no NOx - Lost fluidization at 3 hours, continued for full run (4 hours). - Vessel completely caked with carbon
2/14/95 FBC-S2 (I-6)	- Glass former mix C, w/ simulant and 200% NH₃ injection, at 700 °C. - Feed injection nozzle plugged from previous sucrose test, repaired - Low NOx - Lost fluidization rapidly, but continued full run (4 hours) - Severe caking in bed

Table 1-1. Fluid Bed Calciner Test Log Summary. (4 sheets)

Date	Activities/events
2/15/95 FBC-S3 (I-7)	- Glass formers mix C, w/ simulant and 100% sucrose, at 700 °C. - Shifted to open testing with modified sucrose percentages - Replaced pump no. 2 hose. Performed single point calibration check with simulant. - Added water flush funnel to feed suction line. - Lost fluidization quickly. Terminated test early - Bed inspection revealed caking
FBC-S4 (I-8)	- Glass formers mix C, w/ simulant and 125% sucrose, at 500 °C - Full 4-hour run - Low NOx - Post test bed inspection revealed successful run with minimal caking
2/16/95 FBC-S5 (I-9)	- Glass formers mix C, w/ simulant and 100% sucrose, at 500 °C - Full 4-hour run - Low NOx - Inspection revealed successful run
FBC-S6 (I-10)	- Glass formers mix C, w/ simulant and 200% NH₃ addition, at 500 °C - Rapid loss of fluidization - Low NOx - Terminated test early - Inspection revealed bed caking
2/17/95 FBC-S7 (I-11)	- Glass formers mix C, w/ simulant and 200% H₂ addition, at 300 °C - Rapid loss of fluidization - Low NOx - Inspection showed bed caking
FBC-S8 (I-12)	- Glass formers mix C, w/ simulant and 200% CH₄, at 500 °C - Rapid loss of fluidization - High NOx - Terminated test early - Inspection showed caking
FBC-S9 (I-13)	- Glass formers mix C, w/ simulant and 75% sucrose at 500 °C - Full 4-hour test run - Low NOx - Post test inspection revealed successful test with minimal caking

Table 1-1. Fluid Bed Calciner Test Log Summary. (4 sheets)

Date	Activities/events
2/22/95 FBC-S10 (I-14)	- Glass formers mix C, w/ 100% solid boric acid injected at 500 °C. No simulant injected. - 75 minute test run - Feed line plugged with melted boric acid - Post test inspection revealed bed agglomerations
FBC-S11 (I-15)	- Glass former mix D, w/ 16 wt% solid boric acid injected at 500 °C. Mix D included boric acid at 9.2 wt% - Good fluidization of initial bed - Feed line plugged rapidly with melted boric acid - Post test inspection revealed large hard lump at top of bed
2/28/95 FBC-S12 (I-16)	- Glass formers mix E, w/ simulant and 100% sucrose at 400 °C. Mix E included boric oxide at 8 %wt which was fed separately into fluidizing bed. - Glass former mix fluidized well throughout most of test - 3-3/4 hour test run - Fluctuating NOx levels - Post test inspection revealed a free flowing reddish bed below a soft black cake (from unreacted sucrose).
3/6/95 FBC-S13 (I-17)	- Glass formers mix E, w/ simulant and 100% sucrose at 425 °C. Mix E included boric oxide at 8 %wt which was fed separately into fluidizing bed. - Glass former mix fluidized well throughout most of test - Fluctuating NOx levels - Post test inspection revealed a free flowing reddish bed below a soft black cake (from unreacted sucrose).
3/8/95 FBC-P0 (I-1)	- Initial bed loading of 205 lb of glass former mix C. Mix C included no boric acid - Fluidization with N₂ at 30 fpm and bed temperature at 500 °C. - No simulant/glass former feed or product discharge - Water injected at various flowrates to establish thermodynamic performance. Bed fluidized well at all flowrates. Bed temperatures were steady and the wall temperatures stayed below 540 °C.
FBC-P1 (I-1)	- Bed fluidization continued at 500 °C. - Simulant with 100% stoichiometric sucrose injected to establish initial simulant solid loading in bed. - Batch fluidization with simulant injection continued for 4 hours at 500 °C. - Calciner cooled down and shutdown overnight

Table 1-1. Fluid Bed Calciner Test Log Summary. (4 sheets)

Date	Activities/events
3/9/95 FBC-P1 (I-1)	- Batch fluidization resumed at 500 °C - Simulant w/ 100% stoichiometric sucrose injected to achieve initial dry simulant bed loading. - Balanced simulant injection, dry glass former feed, and product discharge initiated. - Steady state production continued for 7 hours - 181 Kg (400 lb) dry product processed - Calciner cooled down and shutdown overnight
3/9/95 FBC-P1	- Bed fluidization resumed at 500 °C. - Balanced simulant/100% sucrose injection, dry glass formers, and product discharge resumed. - Feed pump leak forced shutdown and cooldown. Reinitiation of feed at 464 °C resulted in bed cakes, loss of fluidization, and product discharge plugging. - Steady state fluidization at 500 °C with balanced feed and discharge was reinitiated after repairs. - 4 hour mass balance performed - Production complete after 5 hours continuous operation, 272 Kg (600 lb) product generated for total of 454Kg (1,000 lb). - Calciner cooled down and shutdown. - Inspection revealed free flowing product, some caking on simulant injection line, and light freeboard caking.

4.1.4 CEMS Calibration

A continuous emissions monitoring system (CEMS) combustion gas and pollution gas monitor was installed and calibrated by an EPA qualified vendor for NO, NO₂, and NO_x only.

4.2 FLOW DIAGRAM

The following changes to the Bench Scale Calciner Flow Diagram were incorporated during testing.

- Pressure gauge (PI-FEED) was added downstream of the feed pump. Although positive displacement peristaltic pump flowrates are independent of discharge pressure within the rating of the pump, PI-FEED was necessary to quickly give an indication of feed system problems (such as plugged injection line).
- A branch line with a funnel and isolation valve was added at the feed pump suction to allow water flush following tests. The injection line was found to plug rapidly on tests immediately following sucrose injection.

- PI-OUT was not part of the existing equipment, was considered unnecessary for operations or testing, and was deleted from the drawing. Filter differential pressure (DP-FF) taps into the calciner top freeboard and the off-gas line, downstream of the filters. In many cases during testing, a high vessel pressure (>3 psig) required isolation of DP-FF to prevent over-ranging.
- TI-WALL, inside wall temperature, was deleted since installation was not practical. This temperature indication was not critical to bench scale fluid bed calciner operation or test results. A wall temperature indication was available on the pilot scale test bed.
- TI-Annulus (T6), external electric heater temperature, was added and recorded. Although not critical for testing results, this temperature readout is useful in verifying proper fluid bed calciner operation.

4.3 CHEMICAL MIXING AND BATCHING

4.3.1 Bench and Pilot Simulant Feed System

Two (2) DOT 17H 55-gallon drums were provided with DSSF simulant for Fluid Bed Calciner testing. These drums were lined with plastic bags prior to simulant fill and shipment to Procedyne. To avoid damaging the plastic bags which could result in plastic contamination of feed, these drums were allowed to settle. Liquid simulant was pumped from the simulant shipping drum to an intermediate 55-gallon poly mix drum. Residual solids within the plastic shipping bags were manually transferred into the intermediate mix drum.

The intermediate mix drum was equipped with an electric mixer, drum pump, and splash lid. DSSF simulant was thoroughly mixed within the intermediate mix drums and transferred via the installed drum pump into a portable container for manual filling of the 26 L (7 gal) stainless steel waste hold-up tank (feed tank). Sucrose ($C_{12}H_{22}O_{11}$) was manually added to the waste hold-up tank in a batch quantity necessary for the original sugar test (FBC-S1). Open sucrose testing (FBC-S3/4/5/9) utilized the original concentrated 600% stoichiometric simulant/sugar solution remaining from FBC-S1 which was mixed with new simulant in the waste hold-up tank in the proportions necessary to achieve the proper stoichiometric ratios and test volumes.

The waste hold-up tank mixer was continuously operated during simulant feeding into the fluid bed calciner. The feed suction flush funnel allowed water flush through the feed line into the fluid bed prior to cooldown for all test after FBC-S3.

4.3.2 Bench and Pilot Calciner Filter Blowback Gas

Separate N_2 bottles were not utilized for filter blowback gas. Filter blowback operated continuously with a 5 second blowback every 40 seconds during bed fluidization. Although filter blowback operation introduced N_2 gas into the bed and ultimately in the off-gas, N_2 mass balance accountability was

not required for bench scale testing. Additionally, only NO, NO₂, and NO₃ were monitored in the off-gas. Filter blowback N₂ bottles were weighted during Pilot scale mass balance run (FBC-P1).

4.3.3 Bench Scale Calciner Start-up and Shutdown Sequence

The bench scale calciner start-up procedure varied slightly from that outlined in the Test Procedure (Reference 3.2). The fluidized alumina bath external heating furnace was preheated to expected operating temperature prior to each test.

Before insertion into the alumina bath furnace, the bench scale test vessel was loaded with a 5.5 kg (12 lb) premixed glass former bed. The test vessel was then mounted to the top assembly (freeboard) suspended from overhead rigging equipment. Fluidizing gas, N₂ filter blowback, and off-gas hoses were attached. Fluidizing N₂ gas flow and the N₂ blowback auto sequence were then initiated. While continuously monitoring temperatures, the bench scale fluid bed test vessel was then lowered into the preheated fluidized external heating furnace bath to commence test bed heat-up. The feed line was then connected.

Once steady state temperatures were established in the test fluid bed, gaseous reductant flow was initiated for applicable tests. Feed injection was then initiated to start the test. Instead of varying feed flow up to the heat transfer limits of the bed, a nominal 20 ml/min flowrate was maintained throughout all testing, based on the conservative heat transfer results with water injection.

The feed metering quantity was calculated using calibrated pump flowrates and resulting time to achieve the quantity of simulant necessary for proper glass ratios. Feed injection was stopped after the appropriate amount of simulant had been injected. For FBC-S3 and later tests, a water flush funnel was available at the feed pump suction. Potable water was added to the funnel, the waste hold-up tank was isolated, and water was injected to clear the feed line of any residual simulant. This was particularly important for tests with sucrose.

Following test completion, the feedline was isolated and disconnected from the test vessel. External cooling water flow and fluidizing gas flow were then initiated to the alumina cooldown bath, located next to the heating furnace. The test vessel was then lifted from the furnace and inserted in the alumina cooldown bath using overhead rigging equipment. Test bed fluidization continued until the bed was cooled down to a point where it could be safely handled.

4.3.4 Sampling

During testing, small test fluid bed samples were drawn from the lower bed region using N₂ motive gas and a sample line venturi eductor. In many cases, the inability to draw a large volume sample with the eductor indicated that the bed had lost fluidization.

4.3.5 Bench Scale Scrubber Solution

Soda ash (Na_2CO_3) was added to the scrubber solution to maintain pH. Scrubber solution replacement was required when temperature reached 120 °F due to PVC components in the solution piping.

4.3.6 Bench Scale Dry Glass Former Feed System

For bench scale test FBC-S10 (I-14) through FBC-S13 (I-17), dry glass formers were fed into the fluidizing bed during testing in order to gradually add boric acid and boric oxide. The feed line utilized an existing un-used 3/4" penetration with a "feedlock" spool attached. The feedlock spool consisted of two ball valves with a pipe spool between equipped with a connection for N_2 pressurization. One end of the spool was connected to the top of the calciner freeboard. The other end was open for addition of dry feed material.

During dry feeding the bottom ball valve was closed and the top valve open to load the feed material. After loading, the top valve was closed and the feedlock spool between the valves was pressurized with N_2 to approximately 80 Kpag (12 psig). With the fluid bed operating at approximately 20 Kpag (3 psig), the bottom ball valve was opened and the feedlock contents were injected into the fluid bed.

5.0 BENCH SCALE TESTS AND OBSERVATIONS

5.1 GLASS FORMER FLUIDIZATION TESTS

Although not specifically required by the Test Procedure, fluidization tests were performed with bulk glass former materials and the premixed glass former bed in order to qualitatively evaluate the adequate fluidization of the glass formers and determine the optimum fluidization gas velocity for subsequent testing.

Fluidization tests were performed in transparent fluid bed test tubes 14 and 7.6 cm (5.5" and 3" diameter). Compressed air was used as the fluidization gas. An initial 15 cm (6") bed height was loaded. Fluidization gas flow was slowly initiated. The "incipient" velocity was recorded when the bed started to fluidize. The "operating" velocity was recorded when the bed stabilized at approximately 1.5 times the initial bed height. The "maximum" fluidizing velocity was noted when the fluidizing action became unstable and excessive dusting started to occur.

A nominal glass former bed flowrate was determined to be 6 m/min (20 fpm) for glass former mix A and 12 m/min (40 fpm) for mix B. Mixed glass former fluid bed performance was determined to be acceptable. Fluidization velocity was maintained fairly high (12 m/min) for most tests to minimize the potential loss of fluidization due to liquid feed injection.

The original Alumina tested was hydrated and exhibited poor fluidizing performance during bulk testing. A larger particle size, calcined alumina was also tested and exhibited superior fluidizing characteristics. The larger particle size alumina was used in bench and pilot scale testing.

The bulk magnesium carbonate exhibited adequate fluidization characteristics but excessive dusting, which can cause elutriated fines in the off-gas. Since some of the magnesium carbonate required for the glass formulation was to be derived from the dolomite, the weight of bulk magnesium carbonate necessary in the fluid bed was relatively small. However, since magnesium carbonate has a small bulk density compared to other glass formers (See Table 6.1-1) the volume percent of magnesium carbonate was relatively large (approx. 30%) for glass former mix A. The mixed bed dusting was attributed to the bulk magnesium carbonate. It is anticipated that a bulk magnesium carbonate with less water content will fluidize more efficiently.

Glass former mix B was generated based on revised calculations which accounted for impurities in various bulk glass formers. Mix B had considerable lower weight percentage of magnesium carbonate which resulted in a larger weight percentage of boric acid. Mix B was tested in the fluidization test tube and found to be a superior fluidizing mixture. This is largely attributed to the lower magnesium carbonate percentage.

Glass former mix C differed from mix B only by the removal of boric acid. Glass former mix C was not tested in the fluidizing test tube since the removal of boric acid was not expected to significantly affect fluidization characteristics. Actual testing showed that mix C fluidized easily at 6-12 m/min (20-40 fpm).

Glass former Mix D differed from Mix C due to the addition of 9%wt H_2BO_3 . Glass former mix E differed from Mix C due to the addition of 9%wt Boric Oxide. Neither Mix D nor Mix E was tested for fluidization but both performed well in the bench scale calciner at 9 m/min (30 fpm) fluidization velocity.

5.2 FBC-SO: GLASS FORMERS W/ WATER/SIMULANT, NO REDUCTANTS

The purpose of this test was to determine the fluidization performance of the mixed glass former bed, determine limiting feed flowrate based on heat transfer relationships with water, prove that a high temperature fluid bed could volatilize NO_x , and to verify that feed line caking would not result due to simulant melting. Portions of this test were performed between 2/8/95 and 2/10/95. Test data corresponds to Procedyne test numbers I-1 through I-3.

The glass former fluid bed composition used for this test is given in Table 1-2.

Table 1-2. Fluid Bed Composition, Glass Former Mix A.

Glass former	Weight percent	Weight, kg (lb) [rounded to nearest .05 lb]
Silica sand	60.0	2.45 (5.40)
Boric acid	9.2	0.39 (0.85)
Dolomite	10.9	0.45 (1.00)
Alumina	11.4	0.48 (1.05)
Iron oxide	1.0	0.05 (0.10)
Magnesium carbonate	7.5	0.29 (0.65)
Total	100.0	4.10 (9.05)

Initial concerns with bed fluidization at 700 °C included possibility that boric acid would decompose to boric oxide and melt (450 °C) causing the bed to agglomerate and lose fluidization. Results of Procedyne test I-1 through I-3 revealed that in the above concentrations (mix A), the mixed glass former bed could be successfully fluidized at temperatures up to 750 °C without agglomeration.

An initial concern with injection of liquid slurry into the fluidizing bed was that excess liquid/moisture would result in bed caking causing a loss of fluidization. For conservatism, water was injected into the fluid bed to establish a maximum feed rate. Since the DSSF Simulant is approximately 60% by weight water, the heat transfer performance of the fluid bed is bounded by maximum feed rates of 100% water. Procedyne test I-1 demonstrated that a feed flowrate of up to 20 ml/min of water could be processed effectively within the heat transfer capacity of the bench scale fluid bed without loss of fluidization.

Initial concerns with the injection of DSSF Simulant without reductants was that non-reacted salts would melt and/or decompose, resulting in bed caking, agglomeration, and loss of fluidization. Additionally, processing the simulant without reductants in the fluid bed was expected to release large volumes of NO_x off-gas which is an atmospheric pollutant and should be minimized.

Procedyne test no. I-2 attempted the injection of simulant into a fluidizing bed of glass formers (mix A) at 750 °C. Mechanical failure of feed pump no. 1 forced termination of test I-2. Feed pump no. 2, a peristaltic tubing pump, was installed and utilized for injecting simulant at 20 ml/min during Procedyne test no. I-3 and later tests. As expected, simulant injection without reductants resulted in rapidly diverging upper and lower fluid bed temperatures, indicating a loss of fluidization caused from caking. Additionally, NO_x levels in the off-gas increased rapidly to over 12,000 ppm, indicating that the fluid bed was effectively volatilizing NO_x.

Although loss of fluidization was evident within 15 minutes of starting the test, the test was continued for a total of 1 hour to evaluate bed and feed line conditions. Inspection of the bed following testing revealed a very hard cake; however, the simulant feed line inside was not obstructed. Additionally, liberation of water from the bulk glass formers caused bed shrinkage. In order to guarantee that both the upper and lower thermocouples were covered during fluidization, 5.5 kg (12 lb) of glass former mixture was used on subsequent testing instead of 4.1 kg (9 lb) for FBC-S0.

5.3 FBC-S1: GLASS FORMERS AND SIMULANT W/ 600% SUCROSE AT 700 °C

Glass former mix B was generated based on slightly revised calculations which accounted for impurities in various bulk glass formers. Mix B had considerably lower weight percentage of magnesium carbonate which resulted in a larger weight percentage of boric acid. Glass former mix B composition is given in Table 1-3 and was used for FBC-S1 (I-4) conducted on 2/13/95.

The bulk sucrose reductant was added directly to the feed tank. Calculation of the initial weight of sucrose additive was based on the 100% stoichiometric reaction with NaNO_3 in the simulant. This same concentration of sucrose was utilized for both Procedyne tests I-4 and I-5.

As the fluidizing bed was heating up to 700 °C prior to injection of the simulant/sucrose feed for test FBC-S1 (I-4), the upper and lower bed temperatures diverged rapidly, indicating loss of fluidization and caking. The test was terminated prior to feed injection. Inspection of the bed showed severe caking. This caking was attributed to the larger weight percent (16%) of boric acid which melts at 169 °C and decomposes to B_2O_3 which melts at 450 °C. Note that in test FBC-S0 glass former mix A boric acid weight percent was 9% and bed fluidization was acceptable.

Table 1-3. Fluid Bed Composition, Glass Former Mix B.

Glass former	Weight percent	Weight, kg (lb) [rounded to nearest .05 lb]
Silica sand	59.69	3.24 (7.15)
Boric acid	16.19	0.88 (1.95)
Dolomite	10.89	0.59 (1.30)
Alumina	11.48	0.63 (1.40)
Iron oxide	1.04	0.05 (0.10)
Magnesium carbonate	0.71	0.05 (0.10)
Total	100.0	5.44 (12.00)

The glass former mixture was reformulated to remove the boric acid and readjust remaining constituent weight percentages. The resulting mixture was glass former mix C, which was used for test FBC-S1 (I-5) also conducted on 2/13/94. Glass former mix C composition is given in Table 1-4.

Test FBC-S1 (I-5) was reinitiated with glass former mix C. Adequate fluidization was observed during bed heat-up to 700 °C indicating that the boric acid had indeed been the cause of previous caking in glass former mix B.

Simulant with sucrose additive was injected at 20 ml/min. Good fluidization characteristics were observed for the first 3 hours of the test. NOx levels in the off-gas were negligible, indicating a successful reaction between the sucrose and the simulant. NOx levels peaked at approximately 30 ppm and dropped to 0 ppm after the first half hour.

Fluid bed upper and lower temperatures began to diverge after 3 hours indicating bed agglomeration or caking. Efforts to bring the temperatures back together by adjusting fluidizing gas flowrate were unsuccessful. Additionally, NOx levels were detectable after the bed lost fluidization. The test was terminated approximately 45 minutes early.

Inspection of the fluid bed test vessel revealed a significant excess of carbon material and severe bed caking. The entire bed and freeboard region were packed with carbon material which resembled a soft black powder in the upper freeboard, a soft black cake in the lower freeboard, and a hard black cake in the bed region. Results of the inspection indicated that greater than 100% stoichiometric sucrose proportions had been added to the simulant in the feed tank.

Sucrose calculational assumptions were revised to account for actual concentrations of sodium nitrate (NaNO_3), and sodium nitrite (NaNO_2) and EDTA in the simulant. The results of the revised calculations required significantly less sucrose to achieve 100% stoichiometric concentrations. These results indicated that test FBC-S1 (I-5) had been performed with approximately 600% stoichiometric sucrose. This number seemed reasonable compared to observations of bed caking.

5.4 FBC-S2: GLASS FORMERS AND SIMULANT W/ 200% AMMONIA AT 700 °C

Test FBC-S2 (I-6) was conducted on 2/14/95. Glass former mix C was loaded into the bench scale fluid bed calciner and preheated to 500 °C. Ammonia (NH_3) reductant gas was added to the fluidization gas (N_2) and simulant was injected at 20 ml/min. Ammonia addition was calculated based on 200% stoichiometric necessary to convert sodium nitrites/nitrates ($\text{NaNO}_2/\text{NaNO}_3$) to sodium oxide (Na_2O).

Initial testing was delayed due to feed injection tube plugging, believed to be caused by the previous sucrose testing. The feed line was cleared and testing resumed.

Table 1-4. Fluid Bed Composition, Glass Former Mix C.

Glass former	Weight percent	Weight, kg (lb) [rounded to nearest .05 lb]
Silica sand	71.3	3.88 (8.55)
Boric acid	0.0	0.00
Dolomite	13.0	0.70 (1.55)
Alumina	13.6	0.75 (1.65)
Iron oxide	1.3	0.07 (0.15)
Magnesium carbonate	0.8	0.05 (0.10)
Total	100.0	5.44 (12.00)

Fluid bed upper and lower temperatures began to diverge rapidly within the first 15 minutes of the test indicating loss of fluidization, caking, or agglomeration. NO_x levels were negligible for the first hour of testing, but then increased to approximately 350 ppm. Although loss of fluidization was evident by the divergent temperatures, the test was continued for the full duration since NO_x levels were low, indicating that the desired reaction was continuing.

Inspection of the bed following test completion showed severe hard caking which was difficult to clean from the inside surfaces of the fluid bed vessel.

5.5 FBC-S3: GLASS FORMERS AND SIMULANT W/ 100% SUCROSE AT 700 °C

Test FBC-S3 (I-7) was performed on 2/15/95. Although the Test Procedure (Reference 3.2) called for scoping tests with methane (CH₄) and hydrogen (H₂) first, previous successful sucrose results and limited schedule called for open testing of sucrose as a priority over continuing with the scoping tests with other reductants.

A 100% stoichiometric sucrose and simulant solution was mixed in the feed tank. The fluid bed vessel was preheated to 700 °C and injection began. NO_x levels in the off-gas rose rapidly and stabilized at approximately 600 ppm. After approximately 20 minutes, fluid bed upper and lower temperatures began to diverge indicating loss of fluidization. After 30 minutes, NO_x levels began to increase to approximately 1800 ppm. On line sampling yielded only small amounts of product from the bed. Since loss of fluidization was obvious, the test was terminated early after 50 minutes total run time.

Bed inspection revealed a soft cake with agglomerated chunks. It appeared that the reaction at 700 °C resulted in some melting salts.

5.6 FBC-S4: GLASS FORMERS AND SIMULANT W/ 125% SUCROSE AT 500 °C

Based on the results of test FBC-S3, sucrose concentration in the simulant feed was increased to 125% stoichiometric and fluid bed temperature was lowered to 500 °C. Test FBC-S4 was conducted on 2/15/95.

The feed line became blocked upon initiation of feed. Following on-line removal, the lower 15 cm (6") of the feed line was discovered to be blocked with carbon cake and required cutting off that section of tubing. Following repairs, simulant and 125% sucrose were injected at 20 ml/min. The fluid bed (mix C) exhibited good fluidization characteristics. NO_x levels initially rose to approximately 1200 ppm and then gradually lowered to approximately 200 ppm after 2 hours where levels remained reasonably stable for the duration of the test. The test was continued to completion with a total duration of 4 hours.

Post test inspection of the bed revealed a free flowing dry product with a thin, soft cake on the filters and vessels walls. This product could easily be handled for melter feed. Final bed weight of 7.6 Kg (16.75 lb) resulted from the addition of simulant. Solids from simulant made up 28% of final bed weight.

5.7 FBC-S5: GLASS FORMERS AND SIMULANT W/ 100% SUCROSE AT 500 °C

Following the success and experience of test FBC-S4, 100% stoichiometric sucrose was again attempted, but FBC-S4 (I-9) was conducted with the fluid bed at 500 °C, on 2/16/95.

The 100% stoichiometric sucrose and simulant was injected at 20 ml/min. NO_x levels in the off-gas rose rapidly to over 2500 ppm and gradually lowered over the 4-hour test period to approximately 1500 ppm. The bed exhibited excellent fluidizing characteristics. The test was continued until completion.

Post test inspection of the fluid bed revealed a dry free flowing product with minor lumps/agglomeration. This product could also be easily handled for melter feed. Final bed weight of 7.0 Kg (15.5 lb) resulted from the addition of simulant. Solids from simulant accounted for 23% of final bed weight.

5.8 FBC-S6: GLASS FORMERS AND SIMULANT W/ 200% AMMONIA AT 500 °C

Based on success with sucrose at a lower temperature and previous success converting nitrites/nitrates with NH₃ addition, open testing with ammonia as the reductant at 500 °C was performed during test FBC-S6 (I-10) on 2/16/95.

The glass former bed (mix C) was preheated with nitrogen fluidization to 500 °C. Ammonia was added to the fluidizing gas flow based on 200% stoichiometric necessary to convert sodium nitrites/nitrates (NaNO₂/NaNO₃) to sodium oxide (Na₂O). NO_x levels in the off-gas rose initially to over 5,600 ppm but dropped rapidly over a 2 hour period to approximately 300 ppm indicating that nitrite/nitrate conversion was taking place.

The bed upper and lower temperatures began to diverge after approximately 30 minutes indicating loss of fluidization. The test was continued for a total of 2 hours and 15 minutes.

Bed inspection revealed caking and channeling with some free flowing dry product within.

5.9 FBC-S7: GLASS FORMERS AND SIMULANT W/ 200% HYDROGEN AT 300 °C

Scoping tests were resumed to evaluate the affect of hydrogen as a reductant. The calculation for hydrogen addition was based on 200% stoichiometric hydrogen necessary for conversion of sodium nitrite (NaNO_2) and nitrate (NaNO_3) to sodium oxide (Na_2O). Test FBC-S7 (I-11) was performed 2/17/95. Since ammonia was unsuccessful at 500 °C and the hydrogen reaction was expected to be similar, a lower temperature (300 °C) was investigated.

The glass former bed (mix C) was preheated to 300 °C. Hydrogen reactant gas was added to the fluidizing gas flow to achieve expected 200% stoichiometry. Simulant was then injected at 20 ml/min. NO_x levels in the off-gas stream remained less than approximately 300 ppm throughout the test. After approximately 20 minutes, upper and lower fluid bed temperatures began to diverge. The test was terminated early after 30 minutes due to loss of fluidization.

Post test inspection of the fluid bed revealed bed caking.

5.10 FBC-S8: GLASS FORMERS AND SIMULANT W/ 200% METHANE AT 500 °C

Scoping tests continued with investigation of the affects of methane (CH_4) as a reductant. The calculation for methane addition was based on 200% stoichiometric methane necessary for conversion of sodium nitrite (NaNO_2) and nitrate (NaNO_3) to sodium carbonate (Na_2CO_3). Test FBC-S8 (I-12) was performed 2/17/95.

The glass former bed (mix C) was preheated to 500 °C. Methane reductant gas was added to the fluidizing gas flow to achieve expected 200% stoichiometry. Simulant was then injected at 20 ml/min. NO_x levels in the off-gas stream rose rapidly to over 6,000 ppm and then lowered to less than 1200 ppm over a 30 minute period. After approximately 15 minutes, upper and lower fluid bed temperatures began to diverge. The test was terminated early (after 45 minutes) due to loss of fluidization.

Post test inspection of the fluid bed revealed hard caking on top of the bed with lumps in the lower bed region.

5.11 FBC-S9: GLASS FORMERS AND SIMULANT W/ 75% SUCROSE AT 500 °C

Since testing has already proven that a fluid bed without reductants would agglomerate and lose fluidization, and that a bed with 100% stoichiometric sucrose could process simulant at 500 °C and maintain

fluidization, the affects of a smaller stoichiometric sucrose concentration (75%) were investigated. Test FBC-S9 was performed on 2/17/95.

The glass former bed (mix C) was preheated to 500 °C. 75% stoichiometric sucrose and simulant were added to the fluid bed at 20 ml/min. NO_x levels in the off-gas rapidly stabilized at approximately 7,000 ppm and remained relatively stable for the duration of the run. Excellent fluidization characteristics were exhibited for the full duration of the test, 4 hours.

Post test inspection revealed a reddish colored free-flowing bed with some agglomerates. Freeboard region was coated with fines. Final bed product weight of 6.8 Kg (15 lb) resulted from addition of simulant. Solids added to bed from simulant accounted for 20% of final weight.

5.12 FBC-S10: GLASS FORMERS W/ 100% BORIC ACID FEED AT 500 °C

Since the presence of boric acid (oxide) in the final product bed is desirable and premixed boric acid attempts at 700 °C had failed, the possibility of slowly added boric acid to a fluidizing bed was investigated.

The bench scale calciner was modified to allow addition of a second feed stream through the feed lock in the freeboard region. Solid 100% boric acid was selected as the second feed stream. Test FBC-S10 was performed on 2/22/95.

Glass former Mix C was preheated to 500 °C. Once stable at temperature, solid 100% boric acid feed was slowly initiated through the feedlock. Feed rate was limited to very small amounts. No simulant or reductants were injected. After 75 minutes approximately 0.45 pounds of boric acid had been fed into the fluid bed. The bed still exhibited excellent fluidization characteristics; however, the test was terminated due to feed line plugging.

Post test inspection revealed that the boric acid had melted in the feed pipe which was completely plugged at the 45 ° elbow closest to the freeboard. The product bed was free-flowing with some hard agglomerates mixed throughout. The bed agglomerates were believed to be melted boric acid.

5.13 FBC-S11: GLASS FORMERS (INCLUDING 9% BORIC ACID) AND 16% BORIC ACID FEED AT 500 °C

Since test FBC-S10 proved that 100% boric acid would melt in and plug the feed line, it was decided to test the use of a 16 wt% boric acid/glass former mix as a feed material.

Additionally, since test FBC-S0 (1-1,2,3) demonstrated that a boric acid hydrate weight percent of 9% would fluidize well at 700 °C, a new bed of premixed glass formers was prepared with 9 % wt boric acid and loaded into the reactor. The 16% wt boric acid/glass former mix was to be fed into the 9% bed while some of the bed material would be extracted through the eductor. This would slowly raise the boric acid level in the reactor to the desired 16% wt. The initial glass former mixture (Mix D) is shown in Table 1-5.

Table 1-5. Fluid Bed Composition, Glass Former Mix D.

Glass former	Weight percent	Weight, kg (lb) [rounded to nearest .05 lb]
Silica sand	64.88	3.54 (7.80)
Boric acid	9.0	0.50 (1.10) [initial load, 16 wt% added during test]
Dolomite	11.83	0.63 (1.40)
Alumina	12.38	0.68 (1.50)
Iron oxide	1.18	0.68 (0.15)
Magnesium carbonate	.73	0.05 (0.10)
Total	100.0	5.46 (12.05)

Glass former mix D was preheated to 500 °C. Good fluidization characteristics were observed as the bed reached steady state. The 16% solid boric acid mixture feed was then initiated. After approximately 10 minutes, 2 lb of mixture had been injected, and the feed line plugged.

Post test inspection revealed a completely plugged feed line and a large hard lump at the top of the bed. Once again, this caking was attributed to melting boric acid.

5.14 FBC-S12: GLASS FORMERS W/ BORIC OXIDE FEED AND SIMULANT W/ 100% SUCROSE AT 400 °C

Previous tests proved that boric acid mixed with the other glass formers in the proper proportions (Mix B) caused bed agglomeration at temperatures above 500 °C. Since the melting point of boric oxide (B_2O_3) is 450 °C, it was hoped that operation of the fluid bed calciner at temperatures below 450 °C could successfully process the complete glass former mixture, simulant, and sucrose reductant.

Addition of boric oxide (B_2O_3) to the glass former mixture instead of boric acid (H_2BO_3) was investigated in order to minimize boric acid melting and transition to boric oxide, which occurs at 169 °C. Additionally, the boric oxide was not mixed in with the initial fluidizing bed but was added throughout test period. The revised glass former mixture (Mix E) is shown in Table 1-6. Test FBC-S12 was performed on 2/28/95.

Glass former mix E was preheated to 400 °C. 100% stoichiometric sucrose ($C_{12}H_{22}O_{11}$) was added to the fluidizing bed at 20 ml/min. Boric oxide was slowly added to the fluidizing bed over a 15 minute period, within the first 35 minutes of testing. NOx levels fluctuated between 400 and 7,000 ppm throughout the test. Good glass former bed fluidizing characteristics were initially observed. The test was terminated early (after 3-3/4 hours) when bed temperatures began to diverge, and a sample could not be drawn via the sample eductor.

Table 1-6. Fluid Bed Composition, Glass Former Mix E.

Glass former	Weight percent	Weight, kg (lb) [rounded to nearest 0.05 lb]
Silica sand	64.8	3.54 (7.80)
Boric oxide	9.1	0.50 (1.10) [added during test]
Dolomite	11.8	0.63 (1.40)
Alumina	12.4	0.68 (1.50)
Iron oxide	1.2	0.07 (0.15)
Magnesium carbonate	0.7	0.05 (0.10)
Total	100.0	5.46 (12.05)

Post test inspection revealed a reddish colored, free-flowing bed of glass formers. A soft, black, airy cake filled the freeboard region above the glass former bed. Final bed product weight of 6.01 Kg (13.25 lb) resulted from addition of simulant. Solids added to bed from simulant accounted for 9% of final weight.

5.15 FBC-S13: GLASS FORMERS W/ BORIC OXIDE FEED AND SIMULANT W/ 100% SUCROSE AT 425 °C

Results of previous testing indicated that sucrose would completely react with the simulant above 500 °C (FBC-S3,4,9) but not at temperatures below 400 °C (FBC-S12). Since the melting point of boric oxide (B_2O_3) is 450 °C, a temperature of 425 °C was selected in order to determine the minimum temperature for the sucrose/simulant reaction, and prevent bed agglomeration resulting from boric oxide melting. FBC-S12 (I-16) was repeated with the temperature at 425 °C. Test FBC-S13 was performed on 3/6/95.

Glass former mix E was preheated to 425 °C. 100% stoichiometric sucrose ($C_{12}H_{22}O_{11}$) was added to the fluidizing bed at 20 ml/min. Boric oxide was slowly added to the fluidizing bed over a 15 minute period. As observed in test FBC-S12, NOx levels fluctuated throughout the test. Good initial glass former bed fluidizing characteristics were observed. The test was terminated early when bed temperatures began to diverge, and a sample could not be drawn via the sample eductor.

Post test inspection revealed a reddish colored free-flowing bed of glass formers. A soft, black, airy cake filled the freeboard region above the glass former bed.

5.16 BENCH SCALE TEST EVALUATION SUMMARY

A summary of test data and conditions for the bench scale fluid bed calciner test runs is given in Table 1-7.

Table 1-7. Bench Scale Fluid Bed Calciner Test Run Summary.

VECTRA test	FBC-S0	FBC-S1	FBC-S2	FBC-S3	FBC-S4	FBC-S5	FBC-S6	FBC-S7	FBC-S8	FBC-S9	FBC-S10	FBC-S11	FBC-S12	FBC-S13
Procedyne Test	I-1,2,3	I-4,5	I-6	I-7	I-8	I-9	I-10	I-11	I-12	I-13	I-14	I-15	I-16	I-17
Reductant	none	sucrose	NH ₃	sucrose	sucrose	sucrose	NH ₃	H ₂	CH ₄	sucrose	none	none	sucrose	sucrose
Stoichiometry (%)	N/A	600	200	100	125	100	200	200	200	75	N/A	N/A	100	100
Temp (°C)	700	700	700	700	500	500	500	300	500	500	500	500	400	425
Glass Former Mix	A	B,C	C	C	C	C	C	C	C	C	C	D	E	E
Simulant Feed Rate (ml/min)	20	20	20	20	20	20	20	20	20	20	0.45lb/ H ₂ BO ₃	2lb/ 16% H ₂ BO ₃	20	20
Fluidizing Velocity m/min (fpm)	9-12 (30-40)	9-14 (30-45)	12 (40)	12 (40)	12 (40)	12 (40)	12 (40)	11 (35)	11 (35)	11 (35)	9 (30)	9 (30)	9 (30)	9 (30)
Gaseous Reductant Flow Nm ³ /hr (SCFM)	N/A	N/A	0.406 (0.239)	N/A	N/A	N/A	0.406 (0.239)	0.612 (0.360)	0.153 (0.090)	N/A	N/A	N/A	N/A	N/A
Test Date('95)	2/8-10	2/13	2/14	2/15	2/15	2/16	2/16	2/17	2/17	2/17	2/22	2/22	2/28	3/6
Test Duration (min.)	60	195	240 end	50	240 end	240 end	135	30	45	240 end	75	78	225	240
WHC-VIT-02A section	4.3.2	4.3.3	4.3.4	4.3.9	4.3.9	4.3.9	4.3.9	4.3.6	4.3.5	4.3.9	4.3.9	4.3.9	4.3.9	4.3.9
Final Bed Characteristics	-hard cake -red	-excess carbon -bed egglom. -black	-hard cake -red	-hard cake -red	-free flowing -black	-free flowing -grey	-hard cake -channels -red	-hard cake -red	-hard cake -red	-free flowing -red	-feed plug -free flow -hard egglom.	-feed plug -hard cake @ top -bed free flow	-not uniform -upper: black cake -bed: red/ free flowing	-not uniform -upper: black cake -bed: red/ free flowing
NOx: high (ppm)-low -avg	12000 1380 3700	75 0 3	390 0 144	1815 150 795	1275 120 424	2760 660 1821	6750 300 1732	300 120 190	6990 195 2863	9750 465 6422	N/A	N/A	30720 15 3415	30720 15 3415
Melt Characteristics	N/A	-no foam -crystals	N/A	N/A	-no foam -crystals	-no foam -crystals	N/A	N/A	N/A	-no foam -crystals	N/A	N/A	N/A	N/A
Overall Evaluation	Poor	Poor	Poor	Poor	Good	Good	Poor	Poor	Poor	Good	Poor	Poor	Poor	Poor

6.0 PILOT SCALE TESTS AND OBSERVATIONS

Based on the results of the bench scale testing, the optimum process was determined to be 100% stoichiometric sucrose at 500 °C with initial Mix C bed composition. The glass former mix C fluid bed composition used for the pilot scale production run is given in Table 1-8.

Nitrogen was utilized as the fluidizing gas. No other gasses were added.

Based on observations of the bench scale tests, the following process parameters were initially selected for pilot scale testing:

Reductant:	Sucrose, Powdered
Reductant to NO ₃ /NO ₂ Ratio:	100% stoichiometric
Waste Feed Injection Rate:	100 ml/min
Glass Former Charge:	93 kg (205 lb) (Mix C)
Fluidizing Gas Velocity:	9.1 m/min (30 feet/min)
Gas Preheat Temperature:	240 °C
Calciner Bed Operating Temperature:	500 °C
Freeboard Temperature:	500 °C

6.1 FBC-P0: GLASS FORMERS WITH WATER

The initial bed was charge with 92.97kg (205 lb) of mix C glass formers. On the morning of March 8, 1995, bed fluidization was initiated with N₂ only and the bed was preheated to 500 °C. Fluidizing gas was initially preheated to 240 °C and the calciner freeboard was preheated to 520 °C. The off-gas scrubber was started up with pH of 12.

Table 1-8. Pilot Scale Glass Former Mix C.

Glass former	Weight percent	Weight, kg (lb) [rounded to nearest 0.05 lb)
Silica sand	74.66	69.42 (153.05)
Boric acid	0.00	0.00
Dolomite	13.62	12.66 (27.90)
Alumina	9.54	8.87 (19.55)
Iron oxide	1.30	1.21 (2.65)
Magnesium carbonate	0.88	0.82 (1.80)
Total	100.0	92.98 (205.00)

Once the bed was fluidizing at steady state, potable water feed injection was initiated at 100 ml/min in order to establish thermodynamic performance characteristics. The pilot scale calciner was operated for approximately 4 hours at steady state in the batch mode with water injection into the fluidizing bed of glass formers. The pump speed was gradually increased throughout the batch test in order to evaluate thermodynamic performance. Pump speed was adjusted between 100ml/min and 400 ml/min. Good bed fluidization characteristics were observed for all feed rates. The critical data point was the inside wall temperature of the calciner. If temperatures were too high, caking could start on the walls. A feed rate of about 350 ml/min showed good performance.

6.2 PRODUCTION RUN: GLASS FORMERS AND SIMULANT WITH 100% SUCROSE

The bed remained fluidizing at 500 °C while simulant with 100% sucrose reductant was mixed in the feed tank. Simulant injection began at 225 ml/min. Fluidization gas preheated temperature was 250 °C and freeboard temperature was 550 °C. After approximately 50 minutes with simulant injection at 225 ml/min and stable fluidization, feed rate was raised to 275 ml/min. After another 50 minutes of stable fluidization, feed pump speed was raised to 350 ml/min. High off-gas flow was observed 1-1/2 hours into the test. Injection of simulant and batch fluidization at 500 °C were continued for a total duration of 4 hours. The pilot scale calciner was then cooled down and shutdown on the evening of March 8, 1995. The initial simulant loading (20 wt% Na₂O equivalent) had not yet been reached so the fluid bed was not changed out.

On the morning of March 9, 1995, the pilot scale calciner fluidization was reinitiated at 9.1 M/min (30 fpm) and the bed was preheated to 500 °C with the fluidization gas and freeboard at 270 °C and 570 °C, respectively. After the fluid bed stabilized, simulant injection with 100% stoichiometric sucrose was initiated at 110 ml/min. Feed injection was gradually increased from 110 ml/min to 350 ml/min over a 10 minute period to maintain good fluidization and minimize wall temperature transients. Batch operation was continued for 1 hour until the calculated bed simulant loading had been achieved. Fluidization gas preheated temperature was stabilized at approximately 337 °C, and freeboard temperature was stabilized at approximately 550 °C. Continuous glass former feed was initiated at 20.4 Kg/hr (45 lb/hr), and continuous product discharge was initiated at 25.4 Kg (56 lb/hr). Simulant feed was continued at 350 ml/min. Continuous processing with balanced feed and discharge rates was continued for over 7 hours. The pilot scale calciner was cooled down and shutdown on the evening of March 9, 1995. Up to this point a cumulative product total weight of 181 Kg (400 lb) had been generated. The observed throughputs exceeded expected levels by a factor of 3.

On the morning of March 10, 1995, pilot scale fluidization was again initiated and stabilized at 9.1 m/min fluidization gas velocity, 500 °C bed temperature, 300 °C fluidization gas preheat temperature, and 500 °C freeboard temperature. After the fluid bed was preheated and stable, simulant feed with 100% stoichiometric sucrose was initiated. Additionally, continuous dry glass former feed and product discharge were initiated to balance feed and discharge.

A feed pump leak developed early in the test run and required securing all feed and discharge. Additionally, calciner heaters were turned off during feed pump repair. When repairs were complete, the fluidizing bed temperature had cooled to 464 °C. Heaters were turned on to begin heat-up to 500 °C. Balanced simulant injection, dry glass former feed, and product discharge were all reinitiated while the bed was heating up from 464 °C. Initial feed pump setting was 350 ml/min. Within 45 minutes, fluid bed temperatures were above 480 °C and began to diverge. Additionally, product discharge flow was restricted and ultimately became plugged with small chunks. All feed and discharges were secured and the discharge line was cleared. Some bed material was removed during discharge line corrective maintenance.

After repairs were complete, the fluid bed was allowed to preheat and stabilize at 500 °C. Balanced simulant injection, dry glass former feed, and product discharge were initiated and gradually increased to match a feed rate of 350 ml/min. Good bed fluidization characteristics were observed. Steady state operations were continued for over 5 hours. The corresponding calculations are presented in Appendix 1B. A 4 hour mass balance was performed during this period. In the afternoon of March 10, 1995 the required quantity of dry product had been produced, feed and discharge were secured, the pilot scale calciner was cooled down, the bed was unloaded through the screw cooler discharge line, and then the calciner was opened and inspected. A total of 454 Kg (1,000 lb) of dry product was generated by pilot scale testing.

Post test inspection revealed free flowing product, minor caking in the freeboard region, and a large lump at the product exit nozzle. Loss of fluidization at 464 °C was attributed to incomplete reaction of sucrose and melting of unreacted salts. This is believed to also be the source of lumps in the bed.

7.0 CONCLUSIONS

- Mixed glass formers fluidized well at ambient temperature in the proportions of mix A, B, C, D and E.
- Operation of bed at less than 460 °C or greater than 700 °C results in bed caking and agglomeration.
- Sucrose ($C_{12}H_{22}O_{11}$) proved to be the optimal reductant by efficiently converting nitrates and nitrites while maintaining stable bed operating conditions.
- Addition of less than 100% stoichiometric sucrose in the simulant resulted in lower conversion of nitrites/nitrates to N_2 and resulted in higher NOx off-gas levels. Higher levels of sucrose (up to 125%) resulted in lower NOx levels.
- Operation of fluidized bed with addition of simulant and hydrogen, methane or ammonia reductants was unsuccessful, even at operating

temperatures as low as 300 °C as bed caking and loss of fluidization resulted.

- Operation of bed at 480-525 °C produced well fluidized, uniform bed with reasonable conversion efficiencies when sucrose is used as reductant.
- Boric acid addition of greater than 9 wt% in glass former mix causes early bed agglomeration and loss of fluidization, even at temperatures as low as 500 °C.
- Boric oxide in the glass former bed fluidizes well at temperatures below 425 °C.
- Sucrose does not completely react with simulant in the fluid bed at temperatures below 480 °C. Incomplete reaction results in caking and loss of bed fluidization.
- Feed addition of glass formers with boric acid (at greater than 16 wt%) into a fluidizing bed at 500 °C causes feed line plugging and bed agglomeration.

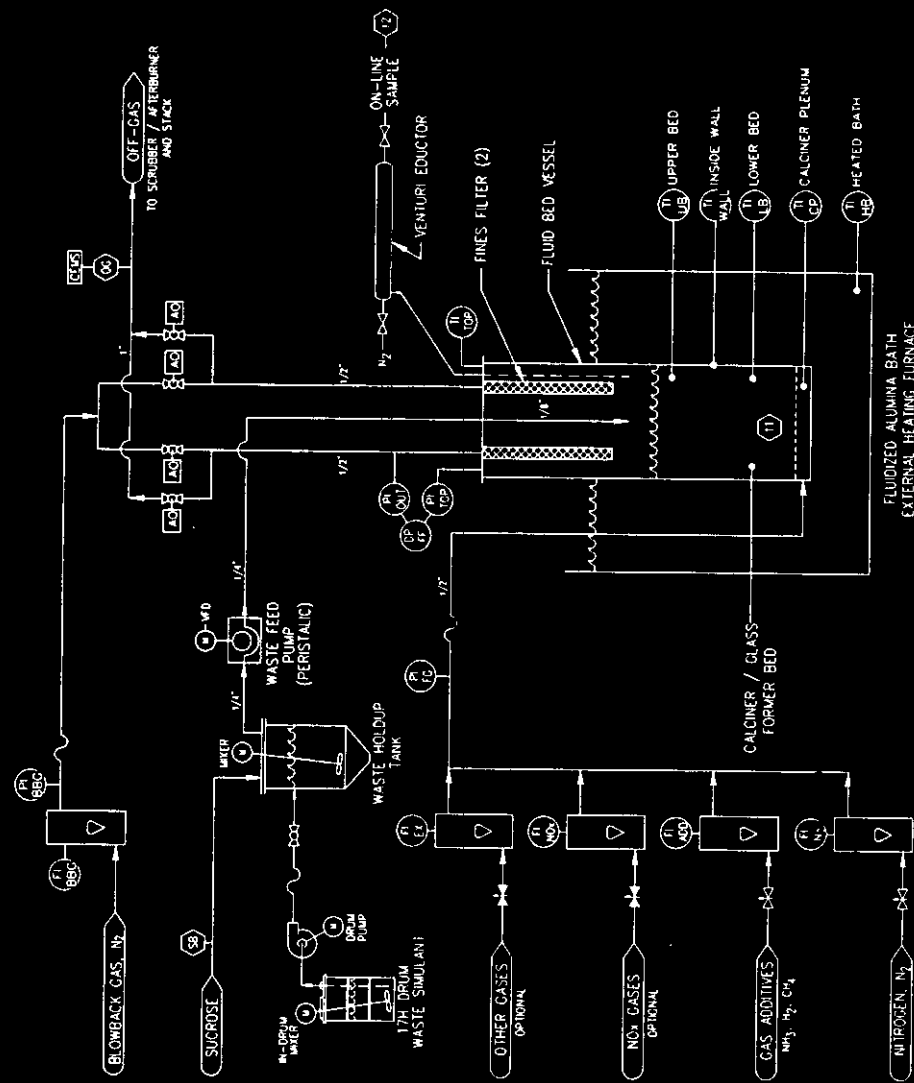
8.0 RECOMMENDATIONS FOR FUTURE TESTING

Additional testing is recommended to bound fluidized bed calciner operating temperature range. Suggested test range would be 480 °C to 650 °C, with 60% stoichiometric sucrose addition.

Testing is also recommended to investigate glass former constituents that can be used to incorporate boron into initial bed mix by use of high melting point minerals, such as use of calcium borate, in lieu of boric acid.

APPENDIX 1A

LAB ANALYSES

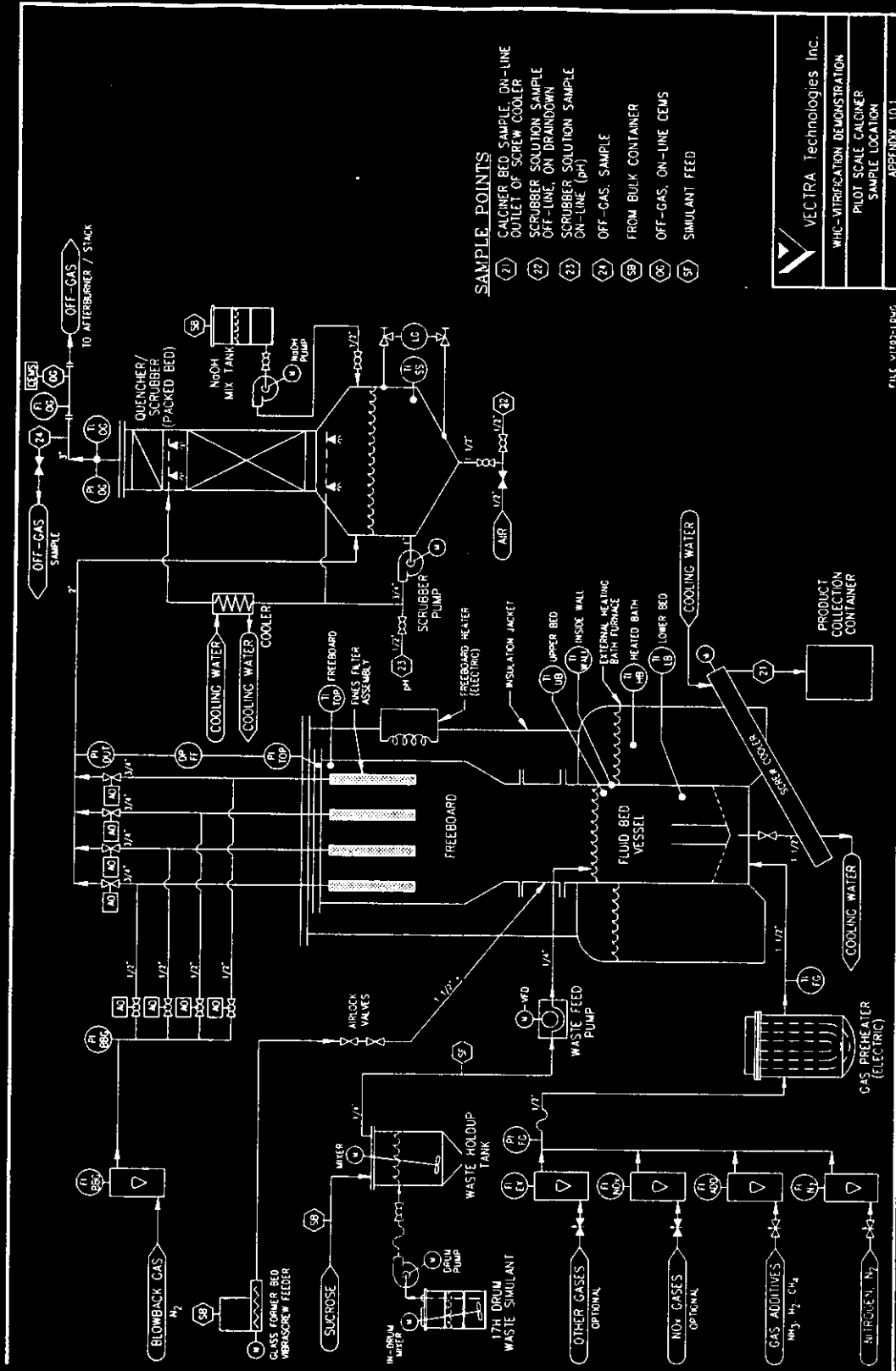


SAMPLE POINT

- (11) CALCINER BED SAMPLE OFF-LINE
- (12) ON-LINE SAMPLE, FROM VENTURI EDUCTOR
- (58) FROM DRY SOLID BULK CONTAINER
- (60) OFF-GAS, ON-LINE CEMS TOTAL NO_x ($NO + NO_2$)

VECTRA Technologies Inc.
WHC-VIRIFICATION DEMONSTRATION
BENCH SCALE CALCINER
SAMPLE LOCATION
APPENDIX 10.1

P/LC-VI-031-2



SAMPLE LOG

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V1 FS0 / F SB -001	8/2	1155	Initial Bedmix (F)			
V1 FS0 / I12 -002	8/2	1210	Bed sample during (I)			
V1 FS0 / I12 -003	8/2	1315	Bed sample during (I)			
V1 FS0 / I11 -004	8/2	1630	Clump sample (I)			
V1 FS0 / I12 -005	8/2	1203	Bed sample (I)			
V1 FS0 / I12 -006	9/2	1330	Bed sample (I)			
V1 FS0 / I12 -007	10/2	1725	Bed sample (I)			
V1 FS0 / I11 -008	13/2	900	Bed sample			
V1 FS0 / I11 -009	13/2	900	Bed sample			
V1 FS0 / I11 -010	13/2	900	Bed sample			
V1 FS0 / I11 -011	13/2	900	Clump sample			
V1 FS0 / I11 -012	13/2	900	Bed sample			
V1 FS1 / I12 -013	13/2	1630	Bed sample (I)			
V1 FS1 / I11 -014	14/2	0840	Upper freeboard			
V1 FS1 / I11 -015 H	14/2	0840	Lower freeboard			
V1 FS1 / I11 -016 H	14/2	0845	Bed			
V1 FS1 / I11 -017 H	14/2	0845	Bed			
V1 FS1 / I11 -018 H	14/2	0845	Bed			
V1 FS1 / I11 -019 H	14/2	0845	Bed			

SAMPLE LOG

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V1FS1/I11-020H	14/2	0845	Bed Cake			
V1FS1/I11-021H	14/2	0845	Bed	Melt Test		
V1FS2/I12-022	14/2	1305	Bed			
V1FS2/I11-023H	15/2	0800	Bed Cake			
V1FS2/I11-024H	15/2	0800	Bed			
V1FS2/I11-025H	15/2	0800	Bed			
V1FS2/I11-026H	15/2	0800	Bed			
V1FS2/I11-027H	15/2	0800	Bed			
V1FS3/I11-028H	15/2	1400	Bed Cake			
V1FS3/I11-029H	15/2	1400	Bed			
V1FS3/I11-030H	15/2	1400	Bed			
V1FS3/I11-031	15/2	1400	Bed			
V1FS3/I11-032	15/2	1400	Bed			
V1FS4/I11-033	16/2	1030	Bed	WHC Archive	3/1/95	
V1FS4/I11-034	16/2	1030	Bed	PED	2/24/95	
V1FS4/I11-035	16/2	1030	Bed			
V1FS4/I11-036	16/2	1030	Bed			
V1FS4/I11-037	16/2	1030	Freeboard			
V1FS4/I11-038	16/2	1030	Crust/Cake			
V1FS5/I12-039	16/2	1200	Bed			
V1FS5/I11-040	16/2	1800	Bed			
V1FS5/I11-041	16/2	1800	Bed	WHC Archive	3/1/95	

SAMPLE LOG

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V1FS5/I11-042	16/2	1800	Bed	PED	2/24/95	
V1FS5/I11-043	16/2	1800	Bed			
V1FS6/I11-044	17/2	0810	Cake			
V1FS6/I11-045	17/2	0810	Bed			
V1FS6/I11-046	17/2	0810	Bed			
V1FS7/I11-047	17/2	1400				
V1FS7/I11-048	17/2	1400				
V1FS7/I11-049	17/2	1400				
V1FS8/I11-050	17/2	1405				
V1FS8/I11-051	17/2	1405				
V1FS8/I11-052	17/2	1405				
V1FS9/I12-053	17/2	1545				
V1FS9/I11-054 V	24/2	1340	Bed	PED	2/24/95	
V1FP1/W23-001 1	10/3	1200	Scrubber			
V1FP1/W23-002 1	10/3	1200	Scrubber			
V1FP1/I21-003 1	10/3	1200	Bed			
V1FP1/S SF-004 1	10/3	1400	Simulant & Sugar			
V1FP1/W23-005 2	10/3	1600	Scrubber			
V1FP1/W23-006 2	10/3	1600	Scrubber			
V1FP1/I21-007 2	10/3	1600	Product			
V1FP1/W23-008 1-2	10/3	1200-1600	Scrubber			
V1FP1/W23-009 1-2	10/3	1200-1600	Scrubber			

SAMPLE LOG

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V 1 FP1 / F SB -010 -	10/3	1700	Feed Sample			
V 1 FP1 / I 21 -011 V 1	30/3	1545	Taken from 003	PED	3/30/95	
V 1 FP1 / I 21 -012 V 2	30/3	1545	Taken from 007	PED	3/30/95	
V 1 FP1 / F SB -013 V	30/3	1545	Taken from 010	PED	3/30/95	
V 1 FP1 / I 21 -014 P 2	31/3	1200	Taken from 007	PNL	3/31/95	1317, 95-05284
V 1 FP1 / I 21 -015 U 2	31/3	1200	Taken from 007	USGS	3/31/95	D - 583636 & D - 583637
V 1 FP1 / I 21 -016 U 1	31/3	1200	Taken from 003	USGS	3/31/95	D - 583638 & D - 583639
V 1 FP1 / I 21 -017 P 1	31/3	1200	Taken from 003	PNL	3/31/95	1318, 95-05285
V 1 FP1 / W 23 -018 P 1-2	31/3	1300	Taken from 008	PNL	3/31/95	1319, 95-4-256
V 1 FP1 / W 23 -019 P 2	31/3	1300	Taken from 006	PNL	3/31/95	1320, 95-4-257
V 1 FP1 / W 23 -020 P 1	31/3	1300	Taken from 001	PNL	3/31/95	1321, 95-4-258
V 1 FP1 / F SB -021 V	10/3	1700	Taken from 010	Lockheed	5/5/95	VIFP1/FSSB-021V
V 1 FP1 / I 21 -022 V 1	10/3	1200	Taken from 003	Lockheed	5/5/95	VIFP1/I21-022V1
V 1 FP1 / I 21 -023 V 2	10/3	1600	Taken from 007	Lockheed	5/5/95	VIFP1/I21-023V2

SAMPLE LOG



Lockheed Analytical Services

METALS RESULTS

METALS RESULTS

Client Sample ID: V1FP1/FSB-021V	Date Collected: 03-10-95	Matrix: solid waste
LAL Batch ID(s): 509 vc	Date Received: 05-09-95	

Constituents	Method	Concentration (mg/kg)	Reporting Detection Limit (mg/kg)	Data Qualifier(s)	Date Analyzed	LAL Sample ID
Aluminum	6010	3000	40		05-26-95	L4472-1
Boron	6010	2000	40		05-26-95	L4472-1
Calcium	6010	31,000	1000		05-26-95	L4472-1
Chromium	6010	4.2	2	C	05-26-95	L4472-1
Cesium	3500	<800	800		05-18-95	L4472-1
Iron	6010	6,400	20		05-26-95	L4472-1
Magnesium	6010	20,000	1000		05-26-95	L4472-1
Manganese	6010	36	3		05-26-95	L4472-1
Molybdenum	6010	40	40		05-26-95	L4472-1
Nickel	6010	<8	8		05-26-95	L4472-1
Potassium	6010	<1000	1000	C	05-26-95	L4472-1
Silicon	6010	85,000	400	D(1:5)	05-17-95	L4472-1
Sodium	6010	<1000	1000		05-26-95	L4472-1
Strontium	6010	<20	20		05-26-95	L4472-1
Zinc	6010	6.9	4		05-26-95	L4472-1

Comments:

METALS RESULTS

Client Sample ID: V1FP1/IZ1-022V1	Date Collected: 03-10-95	Matrix: solid waste
LAL Batch ID(s): 509 vc	Date Received: 05-09-95	

Constituents	Method	Concentration (mg/kg)	Reporting Detection Limit (mg/kg)	Data Qualifier(s)	Date Analyzed	LAL Sample ID
Aluminum	6010	12000	40		05-26-95	L4472-2
Boron	6010	960	40	-	05-26-95	L4472-2
Calcium	6010	21,000	1000		05-26-95	L4472-2
Chromium	6010	180	2	C	05-26-95	L4472-2
Cesium	3500	<800	800		05-18-95	L4472-2
Iron	6010	400	20		05-26-95	L4472-2
Magnesium	6010	13,000	1000		05-26-95	L4472-2
Manganese	6010	35	3		05-26-95	L4472-2
Molybdenum	6010	610	40		05-26-95	L4472-2
Nickel	6010	15	8		05-26-95	L4472-2
Potassium	6010	7,500	1000	C	05-26-95	L4472-2
Silicon	6010	69,000	400	D(1:5)	05-17-95	L4472-2
Sodium	6010	91,000	1000		05-26-95	L4472-2
Strontium	6010	570	20		05-26-95	L4472-2
Zinc	6010	16	4		05-26-95	L4472-2

Comments:

METALS RESULTS

Client Sample ID: V1FP1/I21-023V2	Date Collected: 03-10-95	Matrix: solid waste
LAL Batch ID(s): 509 vc	Date Received: 05-09-95	

Constituents	Method	Concentration (mg/kg)	Reporting Detection Limit (mg/kg)	Data Qualifier(s)	Date Analyzed	LAL Sample ID
Aluminum	6010	12,000	40		05-26-95	L4472-3
Boron	6010	970	40		05-26-95	L4472-3
Calcium	6010	24,000	1000		05-26-95	L4472-3
Chromium	6010	190	2	C	05-26-95	L4472-3
Cesium	3500	<800	800		05-18-95	L4472-3
Iron	6010	4100	20		05-26-95	L4472-3
Magnesium	6010	15,000	1000		05-26-95	L4472-3
Manganese	6010	38	3		05-26-95	L4472-3
Molybdenum	6010	580	40		05-26-95	L4472-3
Nickel	6010	<8	8		05-26-95	L4472-3
Potassium	6010	7,000	1000	C	05-26-95	L4472-3
Silicon	6010	67,000	400	D(1:5)	05-26-95	L4472-3
Sodium	6010	92,000	1000		05-26-95	L4472-3
Strontium	6010	570	20		05-26-95	L4472-3
Zinc	6010	15	4		05-26-95	L4472-3

Comments:

METALS QC DATA SUMMARY

LAL Batch ID(s): 509 vc

Constituent	Client Sample ID	LAL Sample ID	Date Analyzed	QC Sample Analyses		
				Reagent Blank (mg/kg)	Duplicate Precision (% RPD)	Matrix Spike Recovery (%)
Aluminum	V1FP1/FSB-021V	L4472-1	05-26-95	<40	1.8	a
Boron	V1FP1/FSB-021V	L4472-1	05-26-95	<40	0.1	a
Calcium	V1FP1/FSB-021V	L4472-1	05-26-95	<1000	0.3	102
Chromium	V1FP1/FSB-021V	L4472-1	05-26-95	8	2.9	104
Cesium	V1FP1/FSB-021V	L4472-1	05-18-95	<800	b	78
Iron	V1FP1/FSB-021V	L4472-1	05-26-95	<20	0.4	a
Magnesium	V1FP1/FSB-021V	L4472-1	05-26-95	<1000	0.6	100
Manganese	V1FP1/FSB-021V	L4472-1	05-26-95	<3	0.7	99
Molybdenum	V1FP1/FSB-021V	L4472-1	05-26-95	<40	b	101
Nickel	V1FP1/FSB-021V	L4472-1	05-26-95	<8	b	102
Potassium	V1FP1/FSB-021V	L4472-1	05-26-95	2100	b	99
Silicon	V1FP1/FSB-021V	L4472-1	05-17-95	<400	0.1	a
Sodium	V1FP1/FSB-021V	L4472-1	05-26-95	<1000	3.7	100
Strontium	V1FP1/FSB-021V	L4472-1	05-26-95	<20	1.0	103
Zinc	V1FP1/FSB-021V	L4472-1	05-26-95	<4	14	105

"b" - The RPD cannot be computed, because the sample or the duplicate concentration was below the Reporting Detection Limit.

Comments:



Lockheed Analytical Services

NON-METALS RESULTS

LOCKHEED ANALYTICAL SERVICES

COMMON IONS AND ADDITIONAL ANALYTES

Sample Results

Client Sample ID: VI-FP1/FSB-021V	Date Collected: 10-MAR-95
Matrix: SolidWaste	Date Received: 09-MAY-95

Constituent	Units	Method	Result	Reporting Det Limit	Data Qualifier(s)	Date Analyzed	LAS Batch ID	LAS Sample ID
Chloride	mg/kg	300.0	14.	0.2	H	11-MAY-95	22723	L4472-1
Nitrate-N	mg/kg	300.0	0.28	0.2	H	11-MAY-95	22724	L4472-1
Nitrite-N	mg/kg	300.0	< 0.1	0.1	H	11-MAY-95	22725	L4472-1
Sulfate	mg/kg	300.0	700	1	H	11-MAY-95	22726	L4472-1
Fluoride	mg/kg	340.2	19.	4.1665	HD(1:8.333)	11-MAY-95	22727	L4472-1
Total Phosphorus	mg/kg	365.2	0.58	0.3	H	13-MAY-95	22799	L4472-1
Total Inorganic Carbon	mg/kg	415.2	46000	1000	H	17-MAY-95	22728	L4472-1
Total Organic Carbon	mg/kg	415.2	< 1000	1000	H	17-MAY-95	22729	L4472-1
Iodine	mg/kg	100IN	< 30	30	H	13-MAY-95	22730	L4472-1

LOCKHEED ANALYTICAL SERVICES

COMMON IONS AND ADDITIONAL ANALYTES

Sample Results:

Client Sample ID: V1FP1/IZ1-022V1	Date Collected: 10-MAR-95
Matrix: SolidWaste	Date Received: 09-MAY-95

Constituent	Units	Method	Result	Reporting Det Limit	Data Qualifier(s)	Date Analyzed	LAS Batch ID	LAS Sample ID
Chloride	mg/kg	300.0	2200	2	HD(1:10)	11-MAY-95	22723	L4472-2
Nitrate-N	mg/kg	300.0	71.	2	HD(1:10)	11-MAY-95	22724	L4472-2
Nitrite-N	mg/kg	300.0	19.	1	HD(1:10)	11-MAY-95	22725	L4472-2
Sulfate	mg/kg	300.0	1900	10	HD(1:10)	11-MAY-95	22726	L4472-2
Fluoride	mg/kg	340.2	49.	4.1665	HD(1:8.333)	11-MAY-95	22727	L4472-2
Total Phosphorus	mg/kg	365.2	< 0.3	0.3	H	13-MAY-95	22799	L4472-2
Total Inorganic Carbon	mg/kg	415.2	22000	1000	H	17-MAY-95	22728	L4472-2
Total Organic Carbon	mg/kg	415.2	12000	1000	H	17-MAY-95	22729	L4472-2
Iodine	mg/kg	100IN	590	30	H	13-MAY-95	22730	L4472-2

Revision 0
LOCKHEED ANALYTICAL SERVICES

COMMON IONS AND ADDITIONAL ANALYTES

Sample Results

Client Sample ID: V1FP1/IZ1-023V2	Date Collected: 10-MAR-95
Matrix: SolidWaste	Date Received: 09-MAY-95

Constituent	Units	Method	Result	Reporting Det Limit	Data Qualifier(s)	Date Analyzed	LAS Batch ID	LAS Sample ID
Chloride	mg/kg	300.0	1600	2	HD(1:10)	11-MAY-95	22723	L4472-3
Nitrate-N	mg/kg	300.0	< 2	2	HD(1:10)	11-MAY-95	22724	L4472-3
Nitrite-N	mg/kg	300.0	20.	1	HD(1:10)	11-MAY-95	22725	L4472-3
Sulfate	mg/kg	300.0	1700	10	HD(1:10)	11-MAY-95	22726	L4472-3
Fluoride	mg/kg	340.2	400	2.5	HD(1:5)	11-MAY-95	22727	L4472-3
Total Phosphorus	mg/kg	365.2	< 0.3	0.3	H	13-MAY-95	22799	L4472-3
Total Inorganic Carbon	mg/kg	415.2	32000	1000	H	17-MAY-95	22728	L4472-3
Total Organic Carbon	mg/kg	415.2	11000	1000	H	17-MAY-95	22729	L4472-3
Iodine	mg/kg	100IN	710	30	H	13-MAY-95	22730	L4472-3

USGS Results

Message Contents

Text item 1: Text Item

Received: by ccmil from fepl.rl.gov
From: plamothe@helios.cr.usgs.gov@fep0
X-Envelope-From: plamothe@helios.cr.usgs.gov@fep0
Received: by fepl.rl.gov (5.51/5.17.rl-1)
id AA14587; Tue, 16 May 95 09:53:20 PDT
Received: from helios.cr.usgs.gov (helios.cr.usgs.gov [136.177.21.1]) by isdsun.c
r.usgs.gov (8.6.9/8.6.9) with SMTP id KAA11185; Tue, 16 May 1995 10:48:01 -0600
Received: by helios.cr.usgs.gov (4.1/SMI-4.1)
id AA04202; Tue, 16 May 95 10:48:56 MDT
Date: Tue, 16 May 1995 10:48:56 -0600 (MDT)
From: Paul Lamothe <plamothe@helios.cr.usgs.gov@fep0>
To: Joy Smith <Joy_Y_Smith@rl.gov>
Cc: Eric Mast <Eric_S_Mast@rl.gov>
Subject: VECTRA feeds
Message-Id: <Pine.SUN.3.91.950516104444.4151A-100000@helios>
Mime-Version: 1.0
Content-Type: TEXT/PLAIN; charset=US-ASCII

Joy,

Here is all the data for the VECTRA feed samples. The previous email transmission contained only the VECTRA glass samples. The only thing pending on these feeds is the total nitrogen analysis. We'll have to send the samples to our Virginia lab because we don't have the necessary equipment here in Denver. We should have the total nitrogen data in about 2 weeks. Hope you can read this file. Let me know if you need me to look at this data. Thanks.

VECTRA Feed Samples

FieldNo	Lab No	SiO2 % XRF	Al2O3 % XRF	Fe2O3 % XRF	MgO % XRF	CaO % XRF	Na2O % XRF
VIFP1121-015U	D-583636	58.0	8.48	0.65	2.44	3.16	13.2
VIFP1121-015U	D-583637	57.9	8.51	0.65	2.41	3.16	13.2
VIFP1121-016U	D-583638	57.9	9.08	0.65	2.32	3.01	13.3
VIFP1121-016U	D-583639	57.9	8.94	0.66	2.30	3.01	13.4

VECTRA Feed Samples

FieldNo	Lab No	K2O % XRF	TiO2 % XRF	P2O5 % XRF	MnO % XRF	LOI 925C XRF	Cl % ISE
VIFP1121-015U	D-583636	0.93	0.02	0.17	< 0.01	11.8	0.24
VIFP1121-015U	D-583637	0.94	0.02	0.19	< 0.01	11.8	0.18
VIFP1121-016U	D-583638	0.97	0.02	0.16	< 0.01	11.2	0.26
VIFP1121-016U	D-583639	0.97	0.02	0.17	< 0.01	11.2	0.27

VECTRA Feed Samples

FieldNo	Lab No	F % ISE	FeO % TITRN	TOTAL S % S-ANALZR	B PPM ICP	Ba PPM ICP	Cr PPM ICP
VIFP1121-015U	D-583636	0.14	---	0.06	1300	8	210
VIFP1121-015U	D-583637	0.15	---	0.06	1300	8	210
VIFP1121-016U	D-583638	0.13	---	0.06	1300	9	250
VIFP1121-016U	D-583639	0.14	---	0.06	1300	9	230

Field No	Lab No	Cs PPM INAA	Mo PPM ICP	Ni PPM ICP	Sr PPM ICP	Zr PPM ICP	TOTAL C C-ANALYZ	Revision 0
VIFP1121-015U	D-583636	750	660	15	620	160	3.10	
VIFP1121-015U	D-583637	763	670	< 8	630	210	3.09	
VIFP1121-016U	D-583638	806	700	44	620	220	2.93	
VIFP1121-016U	D-583639	806	700	29	620	190	2.95	

VECTRA Feed Samples

FieldNo	Lab No	ORGNC C% Calc	CRBNT C% CO3-anal	I ppm INAA	Nitrite % Ion Chrom	Nitrate % Ion Chrom	Total N % CHN-Analz
VIFP1121-015U	D-583636	0.02	3.08	797	< 0.001	< 0.001	
VIFP1121-015U	D-583637	0.07	3.02	---	< 0.001	< 0.001	
VIFP1121-016U	D-583638	< 0.01	2.94	866	< 0.001	< 0.001	
VIFP1121-016U	D-583639	0.03	2.92	---	< 0.001	< 0.001	

Paul J. Lamothe
U.S. Geological Survey
plamothe@helios.cr.usgs.gov
(303) 236-1923

PNL Results

CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST

SAF NUMBER: 94-108

Page 1 of 1

Company Contact: Gary Stegen
Telephone No. (509) 376-5548
Sample Type: Incinerator
Shipped To: PNL

VENDOR: Vestra
Protocol:
Date Turnaround
Priority
Date Required:

Possible Hazards:

Container Type	Plastic	Plastic
Weight	100 grams	100 grams
# of Containers	1	1
Sample Analysis	Specific Gravity	Evaporable Water
	AL, B, Ba, Ca, Cd, Cr, Fe, K, Mg, Mn, Mo, Na, Ni, P, S, Sr, Ti, Zn	AL, B, Ba, Ca, Cd, Cr, Fe, K, Mg, Mn, Mo, Na, Ni, P, S, Sr, Ti, Zn
	Antions: F, Cl, SO ₄ , I, NO ₂ , NO ₃ , PO ₄	Antions: F, Cl, SO ₄ , I, NO ₂ , NO ₃ , PO ₄
	TIC	TIC
	Volume Percent	Volume Percent
	SEM-EDX	SEM-EDX
	XRD	XRD
	Optical Microscopy	Optical Microscopy
	Chemical Analysis	Chemical Analysis
	AL, B, Ba, Ca, Cd, Cr, Fe, K, Mg, Mn, Mo, Na, Ni, P, S, Sr, Ti, Zn	AL, B, Ba, Ca, Cd, Cr, Fe, K, Mg, Mn, Mo, Na, Ni, P, S, Sr, Ti, Zn
	Toxicity	Toxicity
	Product Consistency	Product Consistency

Time

12:00

3/10/95

21

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

SPECIAL INSTRUCTIONS / REMARKS: Also provide weight loss on firing.

It possible, also provide total nitrogen analysis

VIIP Sample split off from VIIP1/221-003-1 3/31/95

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

VIIP1/221-003-1

3/31/95

BEST COPY AVAILABLE

CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST

Collector: <i>Project Corporation</i>		Company Contact: <i>Gary Stegen</i>		SAF NUMBER: 94-408	
Project: <i>Melior Systems Technology</i>		Telephone No. (509) 376-5548		Page <i>1</i> of <i>1</i>	
Evaluation: <i>Phase I</i>		Sample Type: <i>I - Calibrated</i>		Data Turnaround	
Sample Point: <i>Calibrated # 2-1</i>		Sample Type: <i>I - Calibrated</i>		Priority	
Possible Hazards:		Shipped To: <i>PNL</i>		Manual	
				Date Required:	

SAMPLE IDENTIFICATION				ANALYSIS													
Sample Number	Sample Point	Date Sampled	Time	Specific Gravity	Evaporable Water	Chemical Analysis	Antions: F, Cl, SO ₄	TOC	TIC	Volume Percent	SEM-EDX	XRD	Optical Microscopy	Chemical Analysis	Fe (ID)	Product Consistency	Method A
<i>VIFF/I-21-018P2</i>	<i>2-1</i>	<i>3/16/95</i>	<i>16:00</i>	<i>X</i>		<i>Al, B, Fe, K, Mn, Si, Ti, Zn</i>	<i>L NO₂, NO₃, PO₄</i>	<i>X</i>	<i>X</i>	<i>X</i>				<i>Al, B, Fe, K, Mn, Si, Ti, Zn</i>	<i>Fe (ID)</i>	<i>Product Consistency</i>	<i>Method A</i>

SPECIAL INSTRUCTIONS / REMARKS: *Also provide weight loss on firing. If possible, also provide total nitrogen analysis. VIFF Sample Split off from VIFF1/I-21-007P2*

RECEIVED BY		Date/Time	RELINQUISHED BY		Date/Time	RECEIVED BY		Date/Time
<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>	<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>	<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>
<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>	<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>	<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>
<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>	<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>	<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>
<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>	<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>	<i>David Stegen</i>	<i>3/21/95</i>	<i>1400</i>

BEST COPY AVAILABLE

CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST

SAF NUMBER: 94-111

Page 1 of 1

Collector: <i>Brett S. Peterson</i>	Company Contact: Gary Stegen	VENDOR: Vectra
Project: Mettler System Technology Evaluation: Phase I	Telephone No. (509) 376-5518	Protocol:
Sample Point: <i>Gravel Sub 104 (23)</i>	Sample Type: <i>W-Sample</i>	Shipped To: PNL
Possible Hazards: <i>None</i>		

Container Type		Plastic																					
Volume		1000 ml																					
# of Containers		1																					
Sample Number	Sample Point	Date Sampled	Time	Sample Analysis	Unfilled Metal: Al, Fe, Zn Cu, Pb, Ni, Cd Mn, Mo, V, Ni, Se Sr, Zr	6010	Anions: F, Cl, SO ₄	Lab Specific	NO ₂ , NO ₃	Lab Specific	TOC	Lab Specific	TIC	Lab Specific	pH	Lab Specific	Visual Color	Lab Specific	Total Phosphorus	Lab Specific	Density	Lab Specific	
94-111-023-02301	23	3/10/95	12:00																				

SPECIAL INSTRUCTIONS / REMARKS: *Spl. off from VIFPI/023-001-1 3/31/95*

Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
<i>Gary Stegen</i>	<i>3/31/95 1400</i>	<i>Gary Stegen</i>	<i>3/31/95 16:00</i>				
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
<i>Gary Stegen</i>	<i>3/31/95 1500</i>	<i>Gary Stegen</i>	<i>3/31/95 16:00</i>				
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time
Relinquished By	Date/Time	Received By	Date/Time	Relinquished By	Date/Time	Received By	Date/Time

SAMPLE TYPE:
S= Simulant G= Glass
A= Additives O= Offgas
F= Fecal, Mixed W= Waste
I= Intermediate

CHAIN OF CUSTODY / SAMPLE ANALYSIS REQUEST

P3

SAF NUMBER: 94-411

Page 1 of 1

Collector: *David S. W. F. G. P. G. A.*Project: Meher System Technology
Evaluation: Phase 1

Company Contact: Gary Stegen

Telephone No. (509) 376-5548

VENDOR: Vecira

Protocol:

Data Turnaround

Priority Normal

Sample Point: *Scrub Solution (Drum)* 23 Sample Type: *W - Scrubber*

Shipped To: PNL

Possible Hazards:

Container Type

Plastic

Volume

1000 ml

of Containers

1

SAMPLE IDENTIFICATION

1-48

Sample Analysis

Unfiltered
Metals: AL, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z
Sr, Zr
Mo, Ni, Nb, Ta, Ti, V, W, Zn6010
Anions: F, Cl, SO₄
I, NO₂, NO₃, PO₄

Lab Specific

TOC

Lab Specific

TIC

Lab Specific

Visual Color

Lab Specific

Total Phosphorus

Lab Specific

Density

Lab Specific

Lat Specific

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

Sample Number

Sample Point

Date Sampled

Time

VIEP1/W23-08P17

23

3/10/95

16:00

SPECIAL INSTRUCTIONS/REMARKS: *Split 3 (2 from VIEP1/W23-08-1-2 3/31/95)*SAMPLE TYPE
S= Simulant G= Glass
A= Additives O= Offgas
F= Feed, Mixed W= Waste
I= Intermediate

Relinquished By

Date/Time

Received By

Date/Time

Relinquished By

Date/Time

Received By

Date/Time

Relinquished By

Date/Time

Received By

Date/Time

Relinquished By

Date/Time

Received By

Date/Time

Relinquished By

Date/Time

Received By

Date/Time

Relinquished By

Date/Time

Received By

Date/Time

Relinquished By

Date/Time

Received By

Date/Time

Relinquished By

Date/Time

Received By

Date/Time

DENSITY ANALYSES

ANALYTICAL AND PROCESS SUPPORT LABORATORY

SUPERNATANT ☐ SLURRY ☐

1.0 Laboratory Number(s)	1317	1318	
2.0 Customer	C.Freeman		
3.0 Customer's Sample Identification(s)	P2-014	P1-017	
4.0 Sample Preparation			
Sample + Centrifuge Tube Weight	129.5363 gram	122.2125 gram	gram
Centrifuge Tube Weight	92.1049 gram	92.1049 gram	gram
Sample Weight	37.4314 gram	30.1076 gram	0.0000 gram
Sample Volume	26.00 mL	21.0 mL	mL
5.0 Density Calculation	1.44 g/mL	1.43 g/mL	#DIV/0! g/mL

6.0 Balance Used 364-06-01-28

7.0 Analyst's Signature and Date

8.0 Approved by and Date M. Garg 4/13/95

9.0 Comments

ICP ANALYSIS ON FUSED SAMPLES

Analytical and Process Support Laboratory

1.0 ICP Analysis

The solutions from the fused samples were analyzed on the ICP at 324 Building

2.0 Lab No 1318
3.0 Customer C. Freeman
4.0 Customer's ID P2-014
5.0 Data File ID 269
6.0 Fusion Method KOH/Ni Na2O2/Zr
7.0 Sample Wt 0.2658 g 0.2667 g
8.0 Dilution 2500 mL 2500 mL

1318
C. Freeman
P2-014
269
KOH/Ni Na2O2/Zr
0.2658 g 0.2667 g
2500 mL 2500 mL

9.0 Analysis

Element	Wt % Element	Wt % Element
Ag	-0.005%	-0.005%
Al	1.959%	3.758%
B	0.162%	0.166%
Be	-0.003%	-0.003%
Ba	-0.003%	-0.003%
Bi	-0.056%	-0.056%
Ca	2.734%	2.825%
Cd	-0.006%	-0.006%
Ce	-0.038%	-0.037%
Co	-0.009%	-0.009%
Cr	0.030%	0.028%
Cu	-0.006%	-0.006%
Dv	-0.006%	-0.006%
Eu	-0.004%	-0.004%
Fe	0.547%	0.553%
K	-0.009%	0.418%
La	-0.009%	-0.009%
Li	-0.005%	-0.005%
Mg	1.558%	1.612%
Mn	0.005%	0.005%
Mo	0.091%	0.087%
Na	13.905%	
Nd	-0.019%	0.023%
Ni	-0.019%	-0.019%
P	0.290%	0.216%
Pb	-0.075%	-0.075%
S	0.161%	0.126%
Si	5.826%	20.501%
Sn	-0.075%	-0.075%
Sr	0.083%	0.090%
Te	-0.056%	-0.056%
Ti	0.006%	0.005%
V	-0.009%	-0.009%
Y	-0.003%	-0.003%
Zn	0.186%	0.184%
Zr	-0.009%	

Oxide	Wt % Oxide	Wt % Oxide	Average Wt % Oxide	Percent Deviation Oxide
Ag2O	-0.005%	-0.005%	-0.01%	0%
Al2O3	3.701%	7.101%	5.40%	-63%
B2O3	0.522%	0.536%	0.53%	-3%
BaO	-0.003%	-0.003%	0.00%	0%
BeO	-0.008%	-0.008%	-0.01%	0%
Bi2O3	-0.063%	-0.063%	-0.06%	0%
CaO	3.826%	3.952%	3.83%	
CdO	-0.006%	-0.006%	-0.01%	0%
CeO2	-0.046%	-0.046%	-0.05%	0%
Co2O3	-0.013%	-0.013%	-0.01%	0%
Cr2O3	0.044%	0.040%	0.04%	9%
CuO	-0.007%	-0.007%	-0.01%	0%
Dv2O3	-0.006%	-0.006%	-0.01%	0%
Eu2O3	-0.004%	-0.004%	0.00%	0%
Fe2O3	0.782%	0.791%	0.79%	-1%
K2O		0.503%	0.50%	
La2O3	-0.011%	-0.011%	-0.01%	0%
Li2O	-0.010%	-0.010%	-0.01%	0%
MgO	2.750%	2.674%	2.71%	3%
MnO	0.008%	0.008%	0.01%	3%
MoO3	0.136%	0.131%	0.13%	4%
Na2O	18.744%		18.74%	
Nd2O3	-0.022%	0.027%	0.00%	-1952%
NiO		-0.024%	-0.02%	
P2O5	0.664%	0.495%	0.58%	29%
PbO	-0.081%	-0.081%	-0.08%	0%
SO3	0.402%	0.315%	0.36%	24%
SiO2	12.462%	43.854%	28.16%	-111%
SnO2	-0.096%	-0.095%	-0.10%	0%
SrO	0.098%	0.107%	0.10%	-8%
TeO2	-0.071%	-0.070%	-0.07%	0%
TiO2	0.010%	0.008%	0.01%	21%
VO2	-0.015%	-0.015%	-0.02%	0%
Y2O3	-0.004%	-0.004%	0.00%	0%
ZnO	0.231%	0.229%	0.23%	1%
ZrO2	-0.013%		-0.01%	

Sub-total =	27.64%	30.60%
K =	0.418%	Na = 13.905%
Ni =	0.000%	Zr = 0.000%
Total =	28.06%	44.50%

Sub-total =	44.382%	60.772%
K2O =	0.503%	Na2O = 18.744%
NiO =	0.000%	ZrO2 = 0.000%
Total =	44.9%	79.5%

12.0 Note: The KOH fusion is performed in a nickel metal crucible. Thus potassium and nickel reported are values obtained from the Na2O2/Zr fusion. The Na2O2 fusion is performed in zirconium metal crucible. Thus the Zr and Fe reported are values obtained from the KOH/Ni fusion.

13.0 Comment: At low concentration of Ca, the Na2O2 fusion is not included in the average value. Negative values reported in this procedure are at or below the estimated detection limit for the ICP/AES procedure.

14.0 Calculated by and date

15.0 Approved by and date

please use the results as core in. Goni

ICP ANALYSIS ON FUSED SAMPLES
Analytical and Process Support Laboratory

1.0 ICP Analysis

The solutions from the fused samples were analyzed on the ICP at 324 Building

2.0 Lab No 1317
3.0 Customer C. Freeman
4.0 Customer's ID P1-017
5.0 Data File ID 269
6.0 Fusion Method KOH/Ni Na2O2/Zr
7.0 Sample Wt 0.2647 g 0.2724 g
8.0 Dilution 2500 mL 2500 mL

1317
C. Freeman
P1-017
269
KOH/Ni Na2O2/Zr
0.2647 g 0.2724 g
2500 mL 2500 mL

9.0 Analysis

Element	Wt % Element	Wt % Element
Ag	-0.005%	-0.005%
Al	3.083%	3.565%
B	0.215%	0.240%
Ba	-0.003%	0.003%
Be	0.007%	-0.003%
Bi	-0.057%	-0.055%
Ca	4.197%	4.374%
Cd	0.009%	-0.006%
Ce	-0.038%	-0.037%
Co	-0.009%	-0.009%
Cr	0.058%	0.040%
Cu	-0.006%	-0.006%
Dy	-0.006%	-0.006%
Eu	-0.004%	-0.004%
Fe	0.546%	0.603%
K		0.659%
La	-0.009%	-0.009%
Li	0.012%	0.005%
Mg	2.421%	2.439%
Mn	0.009%	0.008%
Mo	0.099%	0.101%
Na	19.108%	
Nd	-0.019%	0.045%
Ni		-0.018%
P	0.325%	0.519%
Pb	-0.076%	-0.073%
S	0.195%	0.193%
Si	10.994%	11.742%
Sn	-0.076%	-0.073%
Sr	0.116%	0.127%
Ta	-0.057%	-0.055%
Ti	0.005%	0.006%
V	-0.009%	-0.009%
Y	0.008%	-0.003%
Zn	0.162%	0.263%
Zr	0.019%	

Oxide	Wt % Oxide	Wt % Oxide	Average Wt % Oxide	Percent Deviation Oxide
Ag2O	-0.005%	-0.005%	-0.01%	3%
Al2O3	5.826%	6.737%	6.28%	-15%
B2O3	0.692%	0.773%	0.73%	-11%
BaO	-0.003%	0.003%	0.00%	-12221%
BeO	0.020%	-0.008%	0.01%	438%
Bi2O3	-0.063%	-0.061%	-0.06%	3%
CaO	5.872%	6.119%	5.87%	
CdO	0.010%	-0.006%	0.00%	929%
CeO2	-0.046%	-0.045%	-0.05%	3%
Co2O3	-0.013%	-0.013%	-0.01%	3%
Cr2O3	0.085%	0.059%	0.07%	37%
CuO	-0.007%	-0.007%	-0.01%	3%
Dy2O3	-0.007%	-0.006%	-0.01%	3%
Eu2O3	-0.004%	-0.004%	0.00%	3%
Fe2O3	0.780%	0.863%	0.82%	-10%
K2O		0.793%	0.79%	
La2O3	-0.011%	-0.011%	-0.01%	3%
Li2O	0.025%	0.010%	0.02%	85%
MgO	4.016%	4.045%	4.03%	-1%
MnO	0.015%	0.013%	0.01%	12%
MoO3	0.148%	0.152%	0.15%	-3%
Na2O	25.758%		25.76%	
Nd2O3	-0.022%	0.052%	0.02%	-492%
NiO		-0.023%	-0.02%	
P2O5	0.745%	1.189%	0.97%	-46%
PbO	-0.081%	-0.079%	-0.08%	3%
SO3	0.486%	0.481%	0.48%	1%
SiO2	23.518%	25.117%	24.32%	-7%
SnO2	-0.096%	-0.093%	-0.09%	3%
SrO	0.136%	0.150%	0.14%	-9%
TaO2	-0.071%	-0.069%	-0.07%	3%
TiO2	0.009%	0.010%	0.01%	-8%
VO2	-0.015%	-0.015%	-0.02%	3%
Y2O3	0.010%	-0.003%	0.00%	432%
ZnO	0.202%	0.328%	0.26%	-43%
ZrO2	0.025%		0.03%	

Sub-total =	41.59%	24.93%
K =	0.659%	Na = 19.108%
Ni =	0.000%	Zr = 0.019%
Total =	42.25%	44.06%

Sub-total =	68.375%	46.896%
K2O =	0.793%	Na2O = 25.758%
NiO =	0.000%	ZrO2 = 0.025%
Total =	69.2%	72.7%

12.0 Note: The KOH fusion is performed in a nickel-metal crucible. Thus potassium and nickel reported are values obtained from the Na2O2/Zr fusion. The Na2O2 fusion is performed in zirconium metal crucible. Thus the Zr and Na reported are values obtained from the KOH/Ni fusion.

13.0 Comment: At low concentration of Ca, the Na2O2 fusion is not included in the average value.
Negative values reported in this procedure are at or below the estimated detection limits for the ICP/AES procedure.

14.0 Calculated by and date

15.0 Approved by and date

PLEASE USE THE RESULTS AS
CORRECTED
11/15/01

ICP ANALYSIS ON ACIDIFIED SAMPLES
Element Concentration in the Sample

1.0 The ICP/AES analysis are performed by the Analytical Process and Support Laboratory (APSL) using the method APSL-14.
The instrument used is a Thermo Jarrell-Ash Model 61E Spectrometer located in room 146 in 324 Building.

2.0 Customer	C. Freeman			Data File No 269		
3.0 Laboratory Log No.	1319	1320	1321	0	0	0
4.0 Customer's Sample ID	W23-VIFP1-018	VIFP1-W23	UFP1-W23	0	0	0
	0	019P2	020P1	0	0	0
5.0 Acid used	HNO3	HNO3	HNO3	0	0	0
6.0 Dilution Factor	10	10	10	0	0	0

7.0 ICP Analysis

Since the ICP have detection limit values which are different for each element, concentrations below the estimated detection limits are tabulated as negative values. Sample dilution's performed by this laboratory have been corrected in the tabulated "Element Concentration in the Samples".

Element	Detection Limit	Element Conc in Sample ug/mL	Element Conc in Sample ug/mL	Element Conc in Sample ug/mL	Element Conc in Sample ug/mL	Element Conc in Sample ug/mL	Element Conc in Sample ug/mL
Ag	0.01	-0.05	-0.05	-0.05	0.00	0.00	0.00
Al	0.03	-0.30	-0.30	-0.30	0.00	0.00	0.00
B	0.01	23.19	28.77	38.18	0.00	0.00	0.00
Ba	0.00	-0.03	-0.03	-0.03	0.00	0.00	0.00
Be	0.00	-0.03	-0.03	-0.03	0.00	0.00	0.00
Bi	0.06	-0.60	-0.60	-0.60	0.00	0.00	0.00
Ca	0.01	1.08	1.94	1.07	0.00	0.00	0.00
Cd	0.01	-0.06	-0.06	-0.06	0.00	0.00	0.00
Ce	0.04	-0.40	-0.40	-0.40	0.00	0.00	0.00
Co	0.01	-0.10	-0.10	-0.10	0.00	0.00	0.00
Cr	0.02	-0.20	-0.20	-0.20	0.00	0.00	0.00
Cu	0.01	1.09	0.88	0.86	0.00	0.00	0.00
Dy	0.01	-0.06	-0.06	-0.06	0.00	0.00	0.00
Eu	0.00	-0.04	-0.04	-0.04	0.00	0.00	0.00
Fe	0.01	2.24	2.03	1.75	0.00	0.00	0.00
K	0.30	-3.00	-3.00	-3.00	0.00	0.00	0.00
La	0.01	-0.10	-0.10	-0.10	0.00	0.00	0.00
Li	0.01	-0.05	-0.05	-0.05	0.00	0.00	0.00
Mg	0.06	1.68	1.88	2.35	0.00	0.00	0.00
Mn	0.00	0.17	0.14	0.13	0.00	0.00	0.00
Mo	0.01	0.23	0.22	0.22	0.00	0.00	0.00
Na	0.05	2077.14	2635.25	3575.61	0.00	0.00	0.00
Nd	0.02	-0.20	-0.20	-0.20	0.00	0.00	0.00
Ni	0.02	2.19	2.14	2.28	0.00	0.00	0.00
P	0.08	10.49	10.29	11.94	0.00	0.00	0.00
Pb	0.08	-0.80	-0.80	-0.80	0.00	0.00	0.00
S	0.08	18.00	19.63	23.07	0.00	0.00	0.00
Si	0.01	1.26	1.12	1.36	0.00	0.00	0.00
Sn	0.08	2.38	2.57	2.51	0.00	0.00	0.00
Sr	0.00	-0.03	-0.03	-0.03	0.00	0.00	0.00
Te	0.06	-0.60	-0.60	-0.60	0.00	0.00	0.00
Ti	0.00	-0.03	-0.03	-0.03	0.00	0.00	0.00
V	0.01	-0.10	-0.10	-0.10	0.00	0.00	0.00
Y	0.00	-0.03	-0.03	-0.03	0.00	0.00	0.00
Zn	0.01	40.49	50.62	29.60	0.00	0.00	0.00
Zr	0.01	-0.10	-0.10	-0.10	0.00	0.00	0.00
Total =		2181.62	2757.48	3690.94	0.00	0.00	0.00

8.0 Comment

9.0 Calculated by and date

10.0 Approved by and date

5/6/17 Guy's

X-RAY FLUORESCENCE ANALYSIS

REPORT: KEILING CONC
DATE OF WORK: 4/25/95
ORDER NUMBER: PROJECT: #20193
OF MATERIAL: SOLUTIONS
ASR# 1980

TESTS RUNS ASSOCIATED WITH THIS SAMPLE SET:
C02401

DESCRIPTION OF XRF TECHNIQUES USED
USUAL PROCEDURE FOR SOLUTION SAMPLES.
EOD LAMPS ON SPOT.

[Handwritten signature]
4/25/95

REVIEW:

RON SANDERS
376-3877

ANALYST:
PHONE:

USGS AGV-1	ATM LW-205	1317-95	1318
PPH	506.	< 8.4	< 12.
PPH	77.4	175.5	< 11.
PPH	14.5	< 6.7	< 9.5
PPH	< 11.	< 6.0	< 9.6
PPH	< 9.0	< 6.0	< 8.2
PPH	< 9.2	< 6.7	< 9.5
PPH	< 12.	< 9.8	< 12.
PPH	< 13.	< 9.9	< 14.
PPH	< 17.	< 13.	< 17.
PPH	< 24.	959.	1007.
PPH	650.	44.	53.
PPH	456.	844.	965.
PPH	166.	< 34.	< 49.
PPH	2320.	< 29.	< 42.
PPH	130.	< 49.	< 69.

(w23-VFPI-018)

Parameter	Unit	Value	95% CI
Intercept		0.21	(0.21, 0.21)
CD		0.21	(0.21, 0.21)
SH		0.50	(0.50, 0.50)
SB		0.63	(0.63, 0.63)
TE		195.8	(195.8, 195.8)
I		0.83	(0.83, 0.83)
CS		2.8	(2.8, 2.8)
PO		3.7	(3.7, 3.7)
LO		2.7	(2.7, 2.7)
CE		2.9	(2.9, 2.9)

(UFL-W23)

+/-

+/-

AG < 0.24
CD < 0.22
SH < 0.30
SB < 0.35
TE < 0.67
I < 1.0
CS 228.
BA < 1.5
LA < 3.0
CE < 5.4

AG < 0.24
CD < 0.22
SH < 0.50
SB < 0.65
TE 189.4
I < 1.0
CS 9.3
BA < 2.3
LA < 2.6
CE < 2.9

AG < 0.32
CD < 0.30
SH < 0.43
SB < 0.50
TE < 0.59
I 2.39
CS < 1.3
BA < 1.3
LA < 2.5
CE < 1.8

0.43

12.

ADVANCED INORGANIC ANALYSIS GROUP
 ATOMIC AND MOLECULAR CHEMISTRY SECTION, CHEMICAL SCIENCES DEPARTMENT
 BATTELLE, PACIFIC NORTHWEST LABORATORIES, RICHLAND, WA

pH, Conductivity, Titration, Ion Chromatograph, and Carbon Analyzer
 RESULTS

Name: Giving for Charlie FreemanReviewed By: S. O. Slater (date) 4-14-95Work Package # K10209Analysis Performed By: Karen SchelkeReport Date: 4-14-95Concentration in mg/L or as specified

Sample Log-In #	95-4-256	95-4-257	95-4-258		Date of Analysis	Reference
Sample ID	P018	P019	P020			
pH						
Conductivity ($\mu\text{mhos/cm}$)						
F ⁻ (electrode)						
NH ₃ (electrode)						
F ⁻ (IC)						
HCO ₃ ⁻ (IC)						
Cl ⁻ (IC)						
NO ₂ ⁻ (IC)						
NO ₃ ⁻ (IC)						
PO ₄ ⁻³ (IC)						
SO ₄ ⁻² (IC)						
(IC)						
(IC)						
(IC)						
CO ₃ ⁻² (Titration)						
HCO ₃ ⁻ (Titration)						
OH ⁻ (Titration)						
O ₂ (Titration)						
Total Carbon	4500	4500	4100		4-13-95 KPS	LPB55439
Total Organic Carbon	~~4500~~ 1200	1100	900			p. 15
Inorganic Carbon	~~4500~~					

Analytical Equipment:

- ☐ pH Meter, Orion Model 501 (S/N 51137)
☐ Conductivity Bridge, Yellow Spring, Inc. Model 32 (S/N 2404)
☐ Ion Chromatograph (IC), Dionex Series 4000i (WB37427)
☐ Autotitrator, Mettler (WA27596, WA27998)
☒ Carbon Analyzer, Xetex-Dohrmann Model DC-60 (WA72402, WA72403)
☐ Balance, Mettler electronic (WA27667), calibration expires _____

Procedures:

- ☐ PNL-ALO-212 Rev. 1 (IC); ☒ PNL-ALO-392.1 Rev. 0 (TOC); ☐ PNL-ALO-501 Rev. 0 (pH); ☐ Instruction Manual (conductivity, ion specific electrode); ☐ PNL-ALO-226 Rev. 0 (NH₃ by electrode); ☐ PNL-ALO-228 (alkalinity by titration)

ION CHROMATOGRAPHY

Analytical and Process Support Laboratory

Lab No	1317-95	1318-95	1319-95
Customer	Freeman	Freeman	Freeman
Customers's ID	I21-017P1	I21-014P2	W23-018P-1-2
Water Leach DF	109.09	108.33	1
Sample DF	2	2	5
	Slurry	Slurry	Supernatant
Analysis	Reported	Reported	Reported
IC values	values	IC values	values
(ug/mL)	ug/g	(ug/mL)	ug/mL
Fluoride	IND	F	IND
Chloride	9.347	Cl	IND
Nitrite	-218.18	NO2	-2.50
Nitrate	-218.18	NO3	-5.00
Phosphate	2.435	PO4	-5.00
Sulfate	8.663	SO4	-5.00
Oxalate	-218.18	(COOH)2	45.85
Formate	-109.09	(HCOO)	-5.00

Lab No	1320-95	1321-95	
Customer	Freeman	Freeman	
Customers's ID	W23-019P2	W23-020P1	
Water Leach dilution	1	1	
Second dilution	5	5	
	Supernatant	Supernatant	Slurry
Analysis	Reported	Reported	Reported
IC values	values	IC values	values
(ug/mL)	ug/mL	(ug/mL)	ug/mL
Fluoride	IND	F	IND
Chloride	-2.50	Cl	-2.50
Nitrite	-5.00	NO2	-5.00
Nitrate	-5.00	NO3	-5.00
Phosphate	1.568	PO4	10.51
Sulfate	10.056	SO4	56.24
Oxalate	-5.00	(COOH)2	-5.00
Formate	-2.50	(HCOO)	-2.50

Dionex Model 300DX M&TE Number WD00284

Analyst Signature and Date

Reviewed by and Date

Comments Estimated detection limit of the anions analysed in the diluted solution.

Fluoride = 0.5 ug/mL Phosphate = 1.0 ug/mL

Chloride = 0.5 ug/mL Sulfate = 1.0 ug/mL

Formate = 0.5 ug/mL Oxalate = 1.0 ug/mL

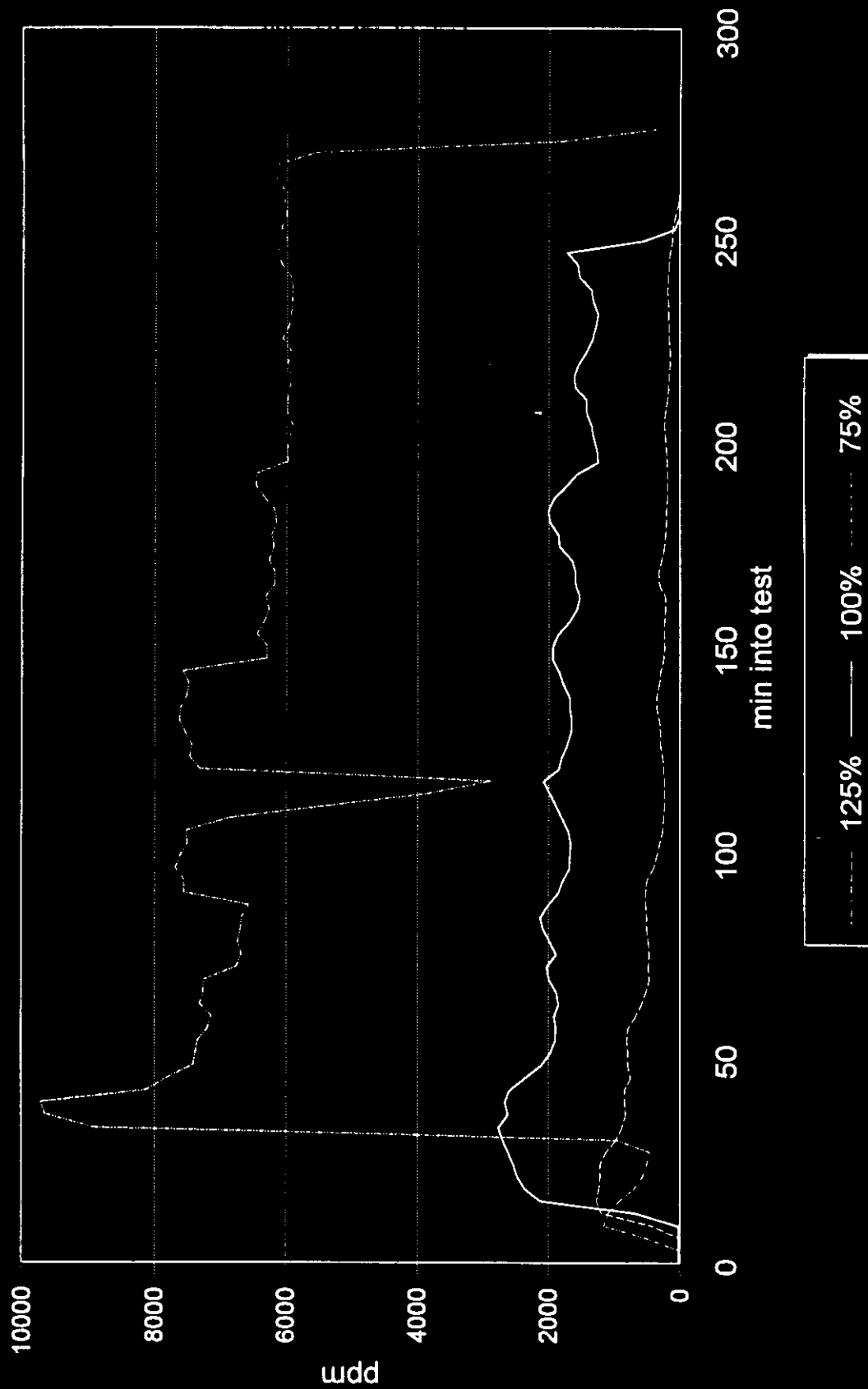
Nitrite = 1.0 ug/mL

Nitrate = 1.0 ug/mL

Negative values are the estimated detection limit of the anions in the sample.

Off Gas Results

Comparison of NOx Three different carbon stoichiometries





Gas Analysis Report

First Environment
90 Riverdale Road
Riverdale, NJ 07457
201-616-9700 (Fax 201-616-1930)

Attn: Mr. Larry Brunt

Sample ID 1: Chemical Process Gas
Sample ID 2: Project # VEG001, Procedyne
Comments: 5, 15L Tedlar bags containing brownish gas.

AAL Number: 4607
Received On: 03/10/95
Report Date: 03/14/95
PO Number: VEG001

Sampled On: 3/8 - 3/10/95
Sample Point: see COC

Date Taken/Sample Identification

	Nitrogen ¹ <u>% v/v</u>	Nitrous Oxide ² <u>ppm v/v</u>
3/8/95, 1500h, Bag #1	94.6	890
3/9/95, 1135h, Bag #2	93.8	750
3/9/95, 1600h, Bag #3	92.2	1,680
3/10/95, 1305h, Bag #4	96.1	1,980
3/10/95, 1600h, Bag #5	95.5	2,170

Note 1: Nitrogen (N₂) Detection Limit = 0.001%

Note 2: Nitrous Oxide (N₂O) Detection Limit = 5 ppm v/v

nd = indicates the concentration is less than the report detection limit. - = test not performed. % = parts per hundred (percent). ppm = parts per million. w/w = weight analyte/weight sample format. v/v = volume analyte/volume sample format (equivalent to mole fraction for normalized, ideal gas mixtures).

Comments:

Reviewed By,

Don Pachuta, Ph.D.

Attachments:

-Chain of Custody

Addendum:

-Chromatograms on-file

-Notebook data on-file

**FIRST
ENVIRONMENT**

90 Riverdale Road
Riverdale, New Jersey 07457
(201) 616-9700 • FAX (201) 616-1930

May 8, 1995

Mr. Jim Care
Vectra Government Services, Inc.
2939 Richardson Road
Richland, Washington 99352

Re: Emission Tests - Particulate Sampling Results
Procedyne Facility

Dear Jim,

The particulate analyses have been completed for the samples collected at the Procedyne facility.
The results are summarized below:

<u>Run No.</u>	<u>Sample I.D.</u>	<u>Particulate Concentration, mg/l</u>
1	P-1	0.146
2	P-2	0.141
3	P-3	0.143
4	P-4	0.125
5	P-5	0.113

These results should be the final data required from the emission testing completed at the Procedyne facility. Please check your records to ensure that you have received all the necessary data.

If you have any questions, please do not hesitate to call.

Very truly yours,

FIRST ENVIRONMENT, INC.

Lawrence G. Brunt
(mm)
Lawrence G. Brunt, P.E.
Manager - Riverdale Office

cc: R. Biasca

ZENON 5555 North Service Road Tel 905 332 8788
Environmental Burlington Ontario Fax 905 332 9169
Laboratories Canada L7L 5H7



Certificate of Analysis

CLIENT INFORMATION

Attention: L.Brunt
Client Name: First Environment Inc.
Project: VEG001
Project Desc: Vectra Government Corp.

Address: 90 Riverdale Road
Riverdale, New Jersey
NJ 07457

Fax Number: 201-616-1930

Phone Number: 201-616-9700

LABORATORY INFORMATION

Contact: Yvonne Bond/Ron McLeod
Project: AN950257
Date Received: 95/03/15
Date Reported: 95/04/24

Submission No.: 5C0317
Sample No.: 008169-008174

Regional

Laboratories:

British Columbia

Ontario

Quebec

NOTES:

'-' = not analysed 'C' = less than Method Detection Limit (MDL) 'NA' = no data available

LOQ can be determined for all analytes by multiplying the appropriate MDL X 3.33

All organic data is blank corrected except for PCDD/F, Hi-Res MS and CLP volatile analyses

Solids data is based on dry weight except for biota analyses.

Organic analyses are not corrected for extraction recovery standards except for isotope dilution methods, (i.e. CARB 429 PAH, all PCDD/F and DDD/DBF analyses)

Methods used by Zenon are based upon those found in 'Standard Methods for the Examination of Water and Wastewater', Seventeenth Edition. Other methods are based on the principles of MISA or EPA methodologies.

All work recorded herein has been done in accordance with normal professional standards using accepted testing methodologies, quality assurance and quality control procedures except where otherwise agreed to by the client and testing company in writing. Any and all use of these test results shall be limited to the actual cost of the pertinent analysis done. There is no other warranty expressed or implied. Your samples will be retained at Zenon for a period of three weeks from receipt of data or as per contract.

COMMENTS:

Certified by:

95/04/24

Zenon Environmental Laboratories - Certificate of Analysis

Page 02

End of
mass Balance
P5 H2O

TO 12015151930

Client ID:
Zenon ID:
Date Sampled:
MDL

Component

Units

Impinger volume measured

0

ml

Ammonia (as N)

3.0

ug

Fluoride

3.0

ug

Chloride

0.005

mg

ortho-Phosphate (as P)

0.010

"

Boron

1.0

ug

Cont#2

Imp.H2O P3

008170 95

95/03/09

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

95/03/10

Recovery

008171 95

95/03/09

950474

Zenon Environmental Laboratories - Certificate of Analysis

Beginning of
Mass Balance

Client ID:

Zenon ID:

Date Sampled:

MDL

Units

Component

Impinger volume measured

Ammonia (as N)

Fluoride

Chloride
ortho-Phosphate (as P)

Boron

P2 Cont#2
Imp.H2O
008174 95
95/03/09

P1 Cont#2
Imp.H2O
008173 95
95/03/08

P4 H2O
Recovery
008172 95
95/03/10

P5 H2O
Recovery
008171 95
95/03/10
% Recovery

P5 H2O
Recovery
008171 95
95/03/10
M. Spike

P5 H2O
Recovery
008171 95
95/03/10
Duplicate

ml

ug

ug

mg

"

ug

870

5700000

4800

0.69

<0.087

4100

990

1800000

4900

540

0.19

<0.049

5600

82

11000000

4900

2.0

<0.099

860

WHC-SD-WM-VI-031
Revision 0

95/04/24

ZEL Summary of Analysis & Prep. Dates

Page MS-1

Batch Code: 0410FSA1*Impinger volume measured etc.* 008169

008170

008171

008172

008173

008174

Analysis Date: 95/04/10**Preparation Date:** 95/04/10**Batch Code:** 0407FSA1 0407FSA2*Ammonia (as N) etc.* 008169 008171

008170

008171

008172

008173

008174

Analysis Date: 95/04/07 95/04/07**Preparation Date:** 95/04/07 95/04/07**Batch Code:** 0412MNA1*Fluoride etc.* 008169

008170

008171

008172

008173

008174

Analysis Date: 95/04/12**Preparation Date:** 95/04/12**Batch Code:** 0412MNA1*Chloride etc.* 008169

008170

008171

008172

008173

008174

Analysis Date: 95/04/12**Preparation Date:** 95/04/12**Batch Code:** 0412MNA1*ortho-Phosphate (as P) etc.* 008169

008170

008171

008172

008173

95/04/24

ZEL Summary of Analysis & Prep. Dates

Page MS-2

008174
Analysis Date: 95/04/12
Preparation Date: 95/04/12

Batch Code: 0421BMB1
Boron etc. 008169

008170

008171

008172

008173

008174

Analysis Date: 95/04/21
Preparation Date: 95/04/21

This page intentionally left blank.

APPENDIX 1B

MASS BALANCE CALCULATIONS

Revision 0

WHC High Sodium LLR Waste Simulant

WHCox

Rev

10/1/95

Formulas changed 2020

Component	10 M Na Moles/L	Weight		Mol Wt Oxide	Dryed Product g/L
		Elemental	Simulant		
Al	1.01667	26.98	27.42967	Al ₂ O ₃ (3)	51.82967
Ca	0.00106	40.08	0.04208	CaO	0.00888
Cr	0.00867	52.00	0.45363	Cr ₂ O ₃ (3)	0.86863
Fe	0.00077	55.85	0.04282	Fe ₂ O ₃ (3)	0.08122
K	0.50000	39.10	19.55000	K ₂ O	23.55000
Mg	0.00103	24.31	0.02512	MgO	0.04166
Mn	0.00042	54.93	0.02286	MnO(2)	0.03622
Mo	0.01667	95.94	1.59300	MoO(3)	2.39900
Na	10.00000	23.00	230.00000	Na ₂ O	310.00000
Sr	0.01667	87.62	1.48033	SrO	1.72700
Ca	0.01667	132.91	2.21509	Ca ₂ O	2.34843
PO ₄ (4)	0.04333	94.97	4.11543	P ₂ O ₅ (5)	3.07589
IO ₃ (3)	0.01667	174.90	2.91500	I	2.11508
CO ₃ (3)	0.26667	60.01	16.00267	—	0.00000
Cl	0.18000	35.45	5.67200	—	0.00000
F	0.25000	19.00	4.75000	—	0.00000
SO ₄ (4)	0.04333	96.06	4.16259	SO ₃ (3)	3.48948
NO ₃ (3)	3.16667	62.01	196.36500	—	0.00000
NO ₂ (2)	1.66667	46.01	76.68333	—	0.00000
OH	6.99667	17.00	113.33333	—	0.00000
TOC	0.13500	416.20	56.18700	—	0.00000
Total			763.02		411.79 g/L

WHC Glass Formula and Waste Loading RVR Unit

Na ₂ O from simulant 310 g/L simulant	Oxide	Weight Percent	Glass Substituent per liter of simulant		Glass Additive Needed per liter of simulant	
	SiO ₂ (2)	52.8%	818.40		818.40	
	B ₂ O ₃ (3)	8.0%	124.00		124.00	
Total weight of Glass 1550 g/L simulant	Na ₂ O	20.0%	310.00		0.00	
	CaO	2.9%	44.95		44.95	
	MgO	2.1%	32.55		32.51	
Waste Loading 26.6%	Al ₂ O ₃ (3)	10.0%	155.00		103.17	
	Fe ₂ O ₃ (3)	1.0%	15.50		15.44	
	Other	3.2%	49.60		0.00	
	Total	100.00%	1550.00		1138.41	

Formulas changed 2020

	g / l simulant	g water / l simulant	g volatile / l simulant	g other / l simulant
Silica Sand	811.95	0.00	0.00	0.284
Boric Acid	220.25	96.25	0.00	0.000
Dolomite	148.13	0.00	0.00	-0.000
Alumina	158.09	54.54	0.00	0.783
Iron Oxide	14.11	0.00	0.00	0.282
Magnesium Oxide	9.58	1.85	3.53	0.132
Total	1362.12	152.64	3.53	1.48

WHC Glass Formula and Waste Loading Calciner Fluid Bed

Na ₂ O from simulant 310 g/L simulant	Oxide	Weight Percent	Glass Substituent per liter of simulant		Glass Additive Needed per liter of simulant	
	SiO ₂ (2)	52.8%	818.40		818.40	
	B ₂ O ₃ (3)	8.0%	124.00		124.00	
Total weight of Glass 1550 g/L simulant	Na ₂ O	20.0%	310.00		0.00	
	CaO	2.9%	44.95		44.88	
	MgO	2.1%	32.55		32.51	
Waste Loading 26.6%	Al ₂ O ₃ (3)	10.0%	155.00		103.17	
	Fe ₂ O ₃ (3)	1.0%	15.50		15.44	
	Other	3.2%	49.60		0.00	
	Total	100.00%	1550.00		1138.41	

Formulas changed 2020

	g / l simulant	g water / l simulant	g volatile / l simulant	g other / l simulant
Silica Sand	811.95	0.00	0.00	0.284
Boric Acid	220.25	0.00	0.00	0.248
Dolomite	148.13	0.00	0.00	-0.000
Alumina	103.80	0.00	0.00	1.036
Iron Oxide	14.12	0.00	0.00	0.282
Magnesium Oxide	9.58	1.85	3.53	0.132
Total	1211.83	1.85	3.53	1.99

RVR Glass Formers

Product	Composition (wt%)										
	SiO ₂ (2)	B ₂ O ₃ (3)	Na ₂ O	CaO	CaCO ₃ (3)	MgCO ₃ (3)	MgO	Al ₂ O ₃ (3)	Fe ₂ O ₃ (3)	Water	Volatile
Dolomite	5.000%				54.000%	40.000%			1.000%		-0.00%
Silica Sand	99.850%		0.007%	0.010%			0.003%	0.050%	0.015%		0.03%
Alumina	0.001%							85.000%	0.004%	34.500%	0.50%
Boric Acid		56.300%								43.700%	0.00%
Iron Oxide								98.000%			2.00%
Magnesium Oxide	0.130%			0.150%			42.200%	0.030%	0.010%	19.300%	1.38%

Calciner Glass Formers

Product	Composition (wt%)										
	SiO ₂ (2)	B ₂ O ₃ (3)	Na ₂ O	CaO	CaCO ₃ (3)	MgCO ₃ (3)	MgO	Al ₂ O ₃ (3)	Fe ₂ O ₃ (3)	Water	Volatile
Dolomite	5.000%				54.000%	40.000%			1.000%		-0.00%
Silica Sand	99.850%		0.007%	0.010%			0.003%	0.050%	0.015%		0.03%
Alumina								99.000%			1.00%
Boric Acid		99.800%									0.20%
Iron Oxide								96.000%			2.00%
Magnesium Oxide	0.130%			0.150%			42.200%	0.030%	0.010%	19.300%	1.38%

Mass Balance, Procedyne Pilot ScalePrepared by: Brent Spurgeon BS Date: 08/17/95Checked by: John Koehr JK Date: 08/17/95**Total Simulant Injection**

	High	Low	Difference
Total Inches	12.625	5.250	7.375
	17.125	6.125	11.000
	17.375	5.000	12.375
	17.000	5.750	11.250
	18.500	5.500	13.000
	16.500	7.000	9.500
			<u>64.500</u>

Density of Simulant 1.49 kg/liter

Assume 0.61 (cm³/g Sugar) volume increase measured during test

15.1 lb Sugar = 6849.244 g Sugar

 180 lb Simulant = 81.64662 kg Simulant
 = 54.79639 liters of Simulant

Sugar concentration 125 g sugar / l simulant

$$125 \text{ g sugar / l simulant} \times \frac{1 \text{ l simulant}}{1.08 \text{ sugar simulant}} = 116.14 \frac{\text{g sugar}}{\text{l sim w/ sugar}}$$

@100% Stoich C

64.5 in. x 1.25 liter/in. = 80.625 liters with sugar per Procedyne Cal pg. 36

$$80.625 \text{ liters w/sugar} \times \frac{116.14 \text{ g sugar}}{\text{l w/ sugar}} \times \frac{0.61 \text{ ml}}{\text{g sugar}} = 5712 \text{ ml sugar}$$

80.625 liters w/sugar - 5.712 liter sugar = 74.91 liter simulant

Total Glass Formers In: 170.00 lb = 77.11 kg

Glass Former Composition:

Silica Sand	74.66%
Dolomite	13.62%
Alumina	9.54%
Iron Oxide	1.30%
Magnesium Carbonate	0.88%

Total Product Out:

223.85 lb = 101.54 kg

Off-Gas:

Average Reading =	2.6 in H ₂ O	per Data
Flow Rate	15.57 CFM (V1)	per calibration

Assume Gas Temp:	40 °C
	313.15 K (T1)

$$V2 = T2/T1 * V1$$

Standard Flow (V2) @ 298.15 K (T2):

-	14.82 SCFM
or	25.19 N m ³ /hr

Scrubber:

Start Volume:	22.00 gal	=	83.30 liter
End Volume:	36.02 gal	=	136.37 liter

Water Balance

Water in:

Total Simulant In: 74.91 liters

Water In Simulant:

Density of Simulant:	1490.00 g/l	
Other chemicals in simulant:	763.02 g/l	from f)WHCox.
Weight of Water in simulant:	726.98 g/l	

This equals: 0.727 l water / l simulant

Total water in: 54.46 liters

Water Out:

117 lb = 53.0703 liters of water plus contaminant

Nitrogen Balance**NITROGEN IN:**

$$\begin{array}{rcl} \text{NO(3)} & & 196.37 \text{ g/liter of simulant} \\ & \times & \frac{74.91 \text{ liter of simulant}}{14710 \text{ g NO(3)}} \end{array} \quad \text{per WHCox.wb1}$$

$$\%N = \frac{14.01 \text{ g N}}{62.01 \text{ g NO(3)}} = 22.59\% \text{ N}$$

$$\text{N in NO(3)} = 3323.52 \text{ g N}$$

$$\begin{array}{rcl} \text{NO(2)} & & 76.68 \text{ g/liter of simulant} \\ & \times & \frac{74.91 \text{ liter of simulant}}{5745 \text{ g NO(2)}} \end{array} \quad \text{per WHCox.wb1}$$

$$\%N = \frac{14.01 \text{ g N}}{46.01 \text{ g NO(2)}} = 30.45\% \text{ N}$$

$$\text{N in NO(2)} = 1749.22 \text{ g N}$$

EDTA:

$$\begin{array}{rcl} \text{concentration:} & & 0.135 \text{ mol EDTA/liter Simulant} \\ \text{Simulant Used:} & & 74.91 \text{ liter} \end{array}$$

$$\begin{array}{rcl} \text{EDTA:} & & 10.11 \text{ mol EDTA} \\ \times 416.20 \text{ g/mol} = & & 4209 \text{ g EDTA} \end{array}$$

$$\frac{28 \text{ g N}}{416.2 \text{ g Na(4)EDTA}} = 6.73\%$$

$$\text{N in Na(4)EDTA} = 283.17 \text{ g N}$$

Fluidizing Gas:

$$\begin{array}{rcl} \% \text{flow of flow meter} & & 30.00\% \\ \text{Actual Flow} = & & 12.00 \text{ SCFM N(2)} \\ \text{or} & & 20.39 \text{ N m}^3/\text{hr} \end{array}$$

$$n = PV/RT$$

$$\frac{101.0 \text{ kPa} \cdot 20.39 \text{ N m}^3/\text{hr}}{8.314 \text{ kPa} \cdot \text{m}^3/\text{kmol} \cdot \text{K} \cdot 298.15 \text{ K}} = 0.831 \text{ kmol/hr}$$

$$\begin{array}{rcl} \text{Total Time} = & & 4.0 \text{ hr} \\ \text{Total kmol} = & & 3.32 \text{ kmol} \\ \text{mw of N(2)} & & 28.01 \text{ kg/kmol} \end{array}$$

$$\text{Nitrogen from fluidizing gas: } 93.07 \text{ kg N}$$

Filter Blowback Nitrogen:

$$\text{flow rate} = \frac{14.7 \text{ lb}}{1.75 \text{ hr}} = 8.4 \text{ lb/hr}$$

$$\begin{array}{l} \text{test time:} \quad 4 \text{ hr} \\ \text{Total N(2):} \quad 33.6 \text{ lb} = 15.24 \text{ kg N} \end{array}$$

$$\text{Total Nitrogen In:} \quad 113.67 \text{ kg N}$$

NITROGEN OUT:

Product: Total Product = 101.54 kg

Nitrogen in Product is Negligible

Off-Gas:

Flow Rate: 25.19 N m³/hr

Elemental Nitrogen:

Average N(2) level in off-gas: 95.80% per analysis
Nitrogen flow: 24.13 N m³/hr

$$n = PV/RT$$

$$\frac{101.0 \text{ kPa} \cdot 24.13 \text{ N m}^3/\text{hr}}{8.314 \text{ kPa} \cdot \text{m}^3/\text{kmol} \cdot \text{K} \cdot 298.15 \text{ K}} = 0.983 \text{ kmol/hr}$$

$$= 27.54 \text{ kg/hr}$$

Test Time: 4.00 hr total 110.15 kg N

N(2)O:

Average N(2)O Reading: 2075 ppm per analysis
N(2)O flow: 0.0523 N m³/hr

$$n = PV/RT$$

$$\frac{101.0 \text{ kPa} \cdot 0.0523 \text{ N m}^3/\text{hr}}{8.314 \text{ kPa} \cdot \text{m}^3/\text{kmol} \cdot \text{K} \cdot 298.15 \text{ K}} = 0.00213 \text{ kmol/hr}$$

total kmol for 4 hr: 0.008518 kmol

$$\frac{28.01 \text{ kg N/kmol N(2)O}}{44.01 \text{ kg N(2)O/kmol N(2)O}} = 0.636 \text{ kg N/kg N(2)O}$$

Total N(2)O: 0.375 kg

Total Nitrogen from N(2)O: 0.239 kg

NO:

Average NO Reading: 3062 ppm per off-gas data

NO flow: 0.0771 N m³/hr

$$n = PV/RT$$

$$\frac{101.0 \text{ kPa} \cdot 0.0771 \text{ N m}^3/\text{hr}}{8.314 \text{ kPa} \cdot \text{m}^3/\text{kmol} \cdot \text{K} \cdot 298.15 \text{ K}} = 0.00314 \text{ kmol/hr}$$

total kmol for 4 hr: 0.012569 kmol

$$\frac{14.00 \text{ kg N/kmol NO}}{30.00 \text{ kg NO/kmol NO}} = 0.467 \text{ kg N/kg NO}$$

Total NO: 0.377 kg

Total Nitrogen from NO: 0.176 kg

NO(2):

Average NO(2) Reading: 133.5 ppm per off-gas data

NO(2) flow: 3.36E-03 N m³/hr

$$n = PV/RT$$

$$\frac{101.0 \text{ kPa} \cdot 3.36\text{E-}03 \text{ N m}^3/\text{hr}}{8.314 \text{ kPa} \cdot \text{m}^3/\text{kmol} \cdot \text{K} \cdot 298.15 \text{ K}} = 1.37\text{E-}04 \text{ kmol/hr}$$

total kmol for 4 hr: 0.000548 kmol

$$\frac{14.00 \text{ kg N/kmol N(2)O}}{46.00 \text{ kg N(2)O/kmol N(2)O}} = 0.304 \text{ kg N/kg N(2)O}$$

Total NO(2): 0.025 kg

Total Nitrogen from NO(2): 7.67E-03 kg N

NH(3):

Average NH(3) Reading: 6.00 g/hr per Zenon Analysis runs #4 and #

total kmol for 4 hr: 24.00 g

$$\frac{14.00 \text{ kg N}}{17.00 \text{ kg NH(3)}} = 0.824 \text{ kg N/kg NH(3)}$$

Total Nitrogen from NH(3): 19.765 g N

Total Nitrogen Out: ERR kg N

Total Nitrogen In: 113.67 kg N

Difference ERR kg

% Missing ERR

Carbon Balance**Carbon In:**

sucrose:

for 100% Stoichiometry 116.14 g sucrose/l sim with sucrose

Simulant/sucrose Solution used: 80.625 liter

Total sucrose in: 9364 g sucrose

$$\frac{144 \text{ g C}}{342 \text{ g sucrose}} = 42.11\%$$

Total C from sucrose: 3.94 kg C

EDTA:

concentration: 0.135 mol EDTA/liter Simulant

Simulant Used: 74.91 liter

 EDTA: 10.11 mol EDTA
 x 416.20 g/mol = 4209 g EDTA

$$\frac{120 \text{ g C}}{416.2 \text{ g Na(4)EDTA}} = 28.83\%$$

Total C from EDTA: 1.21 kg C

glass formers:

Dolomite In: 10.50 kg

CaCO(3) from Dolomite 5.67 kg

MgCO(3) from Dolomit 4.20 kg

$$\frac{12.00 \text{ g C}}{100.00 \text{ g CaCO(3)}} = 12.00\%$$

$$\frac{12.00 \text{ g C}}{84.31 \text{ g MgCO(3)}} = 14.23\%$$

Total C from Dolomite: 1.28 kg C

Mag. Carb. In: 0.68 kg

%C in MagCarb: 10.09%

per mat. cut sheet

Total C from Mag Carb: 0.0685 kg C**Total C in: 6.503 kg C**

Carbon Out:

Product: Total Product Out: 101.54 kg

Average TIC in Product: 2.78%
2.82 kg avg. of analysisAverage TOC in Product: 0.18%
0.18 kg

Total C in Product: 3.01 kg

Off-Gas:Flow Rate: 25.19 N m³/hrTotal Volume out: 100.75 m³**CO:**

Avg Reading: 3485 ppm

Volume of CO: 0.351 m³

$$n = PV/RT$$

$$\frac{101.0 \text{ kPa} *}{8.314 \text{ kPa} \cdot \text{m}^3 / \text{kmol} \cdot \text{K}} \frac{0.35 \text{ N m}^3}{298.15 \text{ K}} = 0.014 \text{ kmol}$$

Total C from CO: 0.172 kg C

CO(2):

Avg Reading: 3.31%

Volume of CO(2): 3.33 m³

$$n = PV/RT$$

$$\frac{101.0 \text{ kPa} *}{8.314 \text{ kPa} \cdot \text{m}^3 / \text{kmol} \cdot \text{K}} \frac{3.33 \text{ N m}^3}{298.15 \text{ K}} = 0.136 \text{ kmol}$$

Total C from CO(2): 1.63 kg C

TOC:Assume CH₄

Avg Reading: 8.87 ppm

Volume of TOC: 0.000894 m³

$$n = PV/RT$$

$$\frac{101.0 \text{ kPa} *}{8.314 \text{ kPa} \cdot \text{m}^3 / \text{kmol} \cdot \text{K}} \frac{8.94\text{E-}04 \text{ N m}^3}{298.15 \text{ K}} = 3.64\text{E-}05 \text{ kmol}$$

Total C from TOC: 4.37E-04 kg C

Scrubber Solution:

Start C concentration: 4100 mg/L

Total C at Start: 0.342 kg

End C concentration: 4500 mg/L

Total C at End: 0.614 kg

carbon accumulation: 0.272 kg C

Total Carbon Out: 5.080 kg C

Total Carbon In: 6.503 kg C

percent missing: 21.88%

Sodium Balance

Na(2)O In Simulant: 310.00 g/liter
23.22 kg

Silica Sand contains: 0.0040 kg

Total Na(2)O in: 23.227 kg

Na(2)O in product: 16.27%
16.52 kg

Na in Scrubber @ start: 3576 mg/liter
0.298 kg

Na in Scrubber @ end: 2356 mg/liter
0.321 kg

Na accumulation: 0.023 kg
corresponding Na(2)O weight: 0.031 kg

Total Na(2)O out: 16.547 kg

% missing: 28.76%

Halide Balances

Total Simulant In:	74.91 liter
Total Off-Gas out:	100.75 N m ³ /hr
Total Product Out:	101.54 kg

Fluoride Balance:

F in Simulant:	4.75 g/liter	per WHCox.wb1
Total F in:	0.356 kg	
Avg F in Product:	0.473 g/kg	per PNL
Total F in product:	48.03 g	
Avg F in Off-Gas:	0.0045 g/hr	per ZENON
Total F in Off-Gas:	0.018 g	
Fluoride in scrubber @ Start:	5.00 mg/liter	per PNL
Total F at Start:	0.416 g	
Fluoride in scrubber @ End:	6.00 mg/liter	
Total F at End:	0.818 g	
Accumulation of F:	0.402 g	
Total F out:	0.0484 kg	
% missing:	86.39%	

Chloride Balance:

Cl in Simulant:	5.672 g/liter	per WHCox.wb1
Total Cl in:	0.425 kg	
Avg Cl in Product:	0.24%	per USGS
Total Cl in product:	0.24 kg	
Avg Cl in Off-Gas:	2.00 mg/hr	per ZENON
Total Cl in Off-Gas:	8.00E-06 kg	
Chloride in scrubber:	ND-	per PNL
Total Cl out:	0.244 kg	
% missing:	42.65%	

Iodide Balance:

I in Simulant:	2.12 g/liter	per WHCox.wb1
Total I in:	0.158 kg	
Avg I in product:	832 ppm	per USGS
Total I out:	0.084 kg	
% missing	46.68%	

Cesium Balance:

Cesium In:

$$74.91 \text{ liter} * 2.21509 \text{ g Cesium / liter simulant} = 165.94 \text{ g}$$

Cesium Out:

$$101.54 \text{ kg product} * 781 \text{ ppm} = 79.30 \text{ g} \quad \text{per USGS}$$

Strontium Balance:

Strontium In:

$$74.91 \text{ liter} * 1.46 \text{ g Strontium / liter Simulant} = 109.40 \text{ g}$$

Strontium Out:

$$101.5366 \text{ kg product} * 0.11\% \text{ ppm} = 111.69 \text{ g} \quad \text{per PNL}$$

Chromium Balance:

Chromium In:

$$74.91 \text{ liter} * 0.45 \text{ g Chrom / liter Simulant} = 33.76 \text{ g}$$

Chromium Out:

$$101.5366 \text{ kg product} * 0.03\% = 34.52 \text{ g} \quad \text{per PNL}$$

Potassium Balance:

Potassium In:

$$74.91 \text{ liter} * 19.55 \text{ g potassium / liter Simulant} = 1464.552 \text{ g}$$

Potassium Out:

$$101.5366 \text{ kg product} * 0.54\% = 546.77 \text{ g} \quad \text{per PNL}$$

Manganese Balance:

Manganese In:

$$74.91 \text{ liter} * 0.02289 \text{ g Manganese / liter simulant} = 1.71 \text{ g}$$

Manganese Out:

$$101.5366 \text{ kg product} * 0.01\% = 6.60 \text{ g} \quad \text{per PNL}$$

$$\text{Mn in Scrubber @ Start: } 0.130 \text{ mg/liter} \quad \text{per PNL}$$

$$0.011 \text{ g}$$

$$\text{Mn in Scrubber @ End: } 0.155 \text{ mg/liter} \quad \text{per PNL}$$

$$0.021 \text{ g}$$

$$\text{Mn Accumulation: } 0.010 \text{ g}$$

$$\text{Total Manganese Out: } 6.61$$

Molybdenum Balance:

Moly In:

$$74.91 \text{ liter} * 1.599 \text{ g moly / liter simulant} = 119.79 \text{ g}$$

Moly Out:

$$101.5366 \text{ kg product} * 0.09\% = 95.44 \text{ g} \quad \text{per PNL}$$

$$\text{Mo in Scrubber @ Start: } 0.220 \text{ mg/liter} \quad \text{per PNL}$$

$$0.018 \text{ g}$$

$$\text{Mo in Scrubber @ End: } 0.225 \text{ mg/liter} \quad \text{per PNL}$$

$$0.031 \text{ g}$$

$$\text{Mo Accumulation: } 0.012 \text{ g}$$

$$\text{Total Moly Out: } 95.46$$

Phosphorous Balance:

Phosphorous in:

$$74.91 \text{ liter} * 1.343333 \text{ g Phosphorus / liter simulant} = 100.63 \text{ g}$$

Phosphorous out:

$$101.5366 \text{ kg product} * 0.37\% = 373.15 \text{ g} \quad \text{per PNL}$$

$$\text{P in Scrubber @ Start: } 11.940 \text{ mg/liter} \quad \text{per PNL}$$

$$0.995 \text{ g}$$

$$\text{P in Scrubber @ End: } 10.390 \text{ mg/liter} \quad \text{per PNL}$$

$$1.417 \text{ g}$$

$$\text{P Accumulation: } 0.422 \text{ g}$$

$$\text{Total Phosphorous Out: } 373.57$$

Glass Former Balances

Total Glass Formers In: 170 lb = 77.11069 kg

Glass Former Composition:

Silica Sand	74.66%
Dolomite	13.62%
Alumina	9.54%
Iron Oxide	1.30%
Magnesium Carbonate	0.88%

SiO(2):

Silica Sand	57.50 kg
Dolomite	0.53 kg
Alumina	0.00 kg
Iron Oxide	0.00 kg
Magnesium Carbonate	0.00 kg
SiO(2) from G.F.:	58.03 kg

Silica in product:	55.00%	Avg USGS & PNL
	55.85 kg	

% Missing:	3.76%
------------	-------

CaO:

Silica Sand	0.006 kg
Dolomite	2.949 kg
Alumina	0.000 kg
Iron Oxide	0.000 kg
Magnesium Carbonate	0.001 kg
CaO from G.F.	2.956 kg

CaO in Simulant:	0.059 g/liter
	0.004 kg

Total CaO In:	2.960 kg
----------------------	-----------------

CaO in Product:	3.09%	Avg USGS & PNL
	3.13 kg	

% Missing:	-5.81%
------------	--------

Al(2)O(3):

Silica Sand	0.029 kg
Dolomite	0.000 kg
Alumina	7.286 kg
Iron Oxide	0.000 kg
Magnesium Carbonate	0.000 kg
Al(2)O(3) from G.F.	7.315 kg

Al(2)O(3) in Simulant: 51.830 g/liter
3.883 kg

Total Al(2)O(3) In: 11.198 kg

Al(2)O(3) in product: 8.14% Avg USGS & PNL
8.27 kg

% Missing: 26.18%

Fe(2)O(3):

Silica Sand	0.009 kg
Dolomite	0.105 kg
Alumina	0.000 kg
Iron Oxide	0.981 kg
Magnesium Carbonate	6.8E-05 kg
Fe(2)O(3) from G.F.:	1.095 kg

Fe(2)O(3) in Simulant: 0.061 g/liter
0.005 kg

Total Fe(2)O(3) In: 1.099 kg

Fe(2)O(3) in Product: 0.71% Avg USGS & PNL
0.72 kg

% Missing: 34.51%

MgO:

Silica Sand	0.002 kg
Dolomite	2.008 kg
Alumina	0.000 kg
Iron Oxide	0.000 kg
Magnesium Carbonate	0.287 kg
MgO from G.F.:	2.296 kg

MgO in Simulant: 0.042 g/liter
0.0031 kg

Total MgO In: 2.300 kg

MgO in Product: 2.37% Avg USGS & PNL
2.40 kg

% Missing: -4.54%

This page intentionally left blank.

APPENDIX 1C

DATA SHEETS

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 100% sucrose			Sht / of 17		
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C		107	240	244	245	247
TI-Lower Bed	°C		299	504	502	502	502
TI-Upper Bed	°C		302	504	502	502	502
TI-Freeboard	°C		337	521	515	513	514
TI- off-gas	°C		56	86	92	97	102
TI-	°C						
PI-Blowback Gas	kPag		138	138	138	138	138
PI-Fluidizing Gas	kPag		17	14	15	15	15
PI-Calcliner Freeboard	kPag						
PI-Off-gas line (AD)	kPag		0.8	0.4	0.4	0.4	0.3
PI-Fines Filter Δ	kPag		1.5	1.2	1.5	1.7	2.0
PI	kPag						
Simulant Injection Rate	ml/min	H ₂ O →			50	77	77
Total Simulant Injected		0					
Scrubber Level	cm						
Blowback Gas	kPag	~~138~~ <10	~~138~~ <10	~~138~~ <10	~~138~~ <10	~~138~~ <10	~~138~~ <10
Off-Gas in H ₂ O	~~mm/hr~~	~~3.2~~	~~3.7~~	~~1.6~~	~~1.6~~	~~1.6~~	~~1.2~~
Fluidizing N ₂	N m ³ /hr	50.52	26.93	20.14	20.14	20.14	20.14
3-8-95		0800	0845	0945	1000	1015	1030
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 100% SUCROSE				Sht 2 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	249	254	254	256	258	256
TI-Lower Bed	°C	502	502	502	502	501	502
TI-Upper Bed	°C	501	502	502	502	502	502
TI-Freeboard	°C	519	518	522	522	526	532
TI- off-gas	°C	105	108	110	116	116	117
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	13
PI-Fluidizing Gas	kPag	14	15	16	16	17	19
PI-Calciner Freeboard	kPag						
PI-Off-gas line (ΔP)	kPag	0.25	.37	.47	0.40	0.55	0.65
PI-Fines Filter (ΔP)	kPag	1.5	2.0	2.5	2.5	3.2	4.0
PI	kPag						
Simulant Injection Rate	ml/min	110	165	223	223	275	340
Total Simulant Injected		0					
Scrubber Level	cm						
Blowback Gas	kPag	138 ≤10	138 ≤10	138 ≤10	138 ≤10	138 ≤10	138 ≤10
Off-Gas "wc	Nm ³ /hr	1.0	1.5	1.9	1.6	2.2	2.6
N ₂ fluidizing gas	Nm ³ /hr	19.52	19.52	19.52	19.52	19.84	20.19
3-8-95 - TIME		1050	1100	1115	1130	1240	1245
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S_____		ADDITIVE 100% <u>Sucrose</u>				Sht <u>3</u> of <u>17</u>	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	258	259	254	253	253	253
TI-Lower Bed	°C	499	500	503	502	502	503
TI-Upper Bed	°C	499	500	502	502	502	503
TI-Freeboard	°C	531	532	554	540	540	541
TI- <u>off gas</u>	°C	off					
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	138
PI-Fluidizing Gas	kPag	19	20	17	17	17	17
PI-Calciner Freeboard	kPag						
PI-Off-gas line <u>(ΔP)</u>	kPag	1.29	1.29	1.42	1.42	1.42	1.47
PI-Fines Filter <u>(ΔP)</u>	kPag	5.0	<u>5.55</u>	5.0	3.5	3.7	3.7
PI	kPag						
			Simulant				
Simulant Injection Rate	ml/min	395	395	223	223	223	223
Total Simulant Injected	l	0	0	0			12.19
Scrubber Level	cm						
Blowback Gas	kPag	<u>138</u> <10	<u>138</u> <10	<u>138</u> <10	<u>138</u> <10	<u>138</u> <10	<u>138</u> <10
Off-Gas <u>*wc</u>	~~mm/hr~~	5.2	5.2	5.7	5.7	5.7	5.9
<u>N₂ Fluidizing</u>	Nm ³ /hr	20.19	19.52	20.19	20.19	20.19	20.19
<u>3-8-95</u> <u>Time</u>		1300	1315	1330	1345	1400	1405
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 100 % <u>Seam</u>				Sht <u>4</u> of <u>17</u>	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	251	250	251	251	+	247
TI-Lower Bed	°C	502	503	503	502		503
TI-Upper Bed	°C	502	502	502	502		502
TI-Freeboard	°C	538	539	540	540		543
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138		138
PI-Fluidizing Gas	kPag	-	-	19	19		21
PI-Calcliner Freeboard	kPag						
PI-Off-gas line (ΔP)	kPag	1.39	1.39	2.04	2.07		2.49
PI-Fines Filter (ΔP)	kPag	5.5	4.0	4.5	4.5		4.5
PI	kPag						
Simulant Injection Rate	ml/min	275	275	275	340		340
Total Simulant Injected				26.09			
Scrubber Level	cm						
Blowback Gas	kPag	$\frac{138}{<10}$	$\frac{138}{<10}$	$\frac{138}{<10}$	$\frac{138}{<10}$		$\frac{138}{<10}$
Off-Gas "WC"	$\frac{NM^3}{hr}$	5.6	5.6	8.2	8.3		10.0
<u>N₂ Fluidizing</u>	$\frac{NM^3}{hr}$	20.19	20.19	20.19	20.19		20.19
3-8-45 Time		1430	1445	1500	1515	1530	1545
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S_____		ADDITIVE <u>100% Sucrose</u>				Sht <u>5</u> of <u>17</u>	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	247	246	246	250	250	251
TI-Lower Bed	°C	~~142~~ 502	502	502	503	503	502
TI-Upper Bed	°C	502	502	502	503	502	502
TI-Freeboard	°C	544	547	546	545	545	547
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	138
PI-Fluidizing Gas	kPag	23	21	21	20	20	20
PI-Calciner Freeboard	kPag						
PI-Off-gas line <i>AP</i>	kPag	2.54	2.42	2.39	2.27	2.49	2.47
PI-Fines Filter <i>AP</i>	kPag	5.7	4.2	4.2	4.0	4.2	4.0
PI	kPag						
Simulant Injection Rate	ml/min	340	340	340	340	340	340
Total Simulant Injected		40.31	—	53.56	—	—	66.06
Scrubber Level	cm						
Blowback Gas	kPag	~~138~~ <10	~~138~~ <10	~~138~~ <10	~~138~~ <10	~~138~~ <10	~~138~~ <10
Off-Gas <i>"WC"</i>	~~Nm³/hr~~	10.2	9.7	9.6	9.1	10	9.9
N ₂ fluidizing	Nm ³ /hr	20.19	20.19	20.19	20.19	20.19	20.19
<i>3895 - TIME</i>		1600	1615	1630	1650	1700	1715
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S_____		ADDITIVE 100 % SULFOX				Sht 6 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	252	268	294	303	310	316
TI-Lower Bed	°C	502	502	502	502	501	502
TI-Upper Bed	°C	501	502	502	502	501	503
TI-Freeboard	°C	546	570	572	529	536	546
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	138
PI-Fluidizing Gas	kPag	20	17	17	20	—	21
PI-Calciner Freeboard	kPag						
PI-Off-gas line ✓	kPag	2.44	0.50	—	0.57	—	0.57
PI-Fines Filter AP	kPag	4.0	2.0	2.5	6.2	—	5.0
PI	kPag						
Simulant Injection Rate	ml/min	340	—	—	340	—	340
Total Simulant Injected		—	—	—	79.5	—	—
Scrubber Level	cm						
Blowback Gas	kPag	138 <10	138 <10	138 <10	138 <10	138 <10	138 <10
Off-Gas WE	Nm ³ /hr	9.8	2.0		2.3		2.3
N ₂ fluidizing	Nm ³ /hr	20.19	20.19	20.19	20.19		20.19
3-8-95 / 3-9-95 Time		1730	3/9/95 0900	0945	1000	1015	1035
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S_____		ADDITIVE 100 %sucrose				Sht 7 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	314	325	332	335	336	336
TI-Lower Bed	°C	502	502	502	502	499	501
TI-Upper Bed	°C	501	503	502	502	500	502
TI-Freeboard	°C	548	559	546	547	551	551
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	138
PI-Fluidizing Gas	kPag	21	21	21	21	24	23
PI-Calcliner Freeboard	kPag						
PI-Off-gas line ΔP	kPag	0.55	0.57	0.62	0.65	0.77	0.67
PI-Fines Filter ΔP	kPag	4.5	4.7	4.7	4.7	5.0	5.5
PI	kPag						
Simulant Injection Rate	ml/min	340	340	340	340	340	340
Total Simulant Injected		94.81	—	—	—	111.39	—
Scrubber Level	cm						
Blowback Gas	kPag	138 ≤10	138 ≤10	138 ≤10	138 ≤10	138 ≤10	138 ≤10
Off-Gas *WC	MM³/hr	2.2	2.3	2.5	2.6	3.1	2.7
N2 fluidizing	Nm³/hr	20.14	19.52	20.19	20.19	20.86	20.19
3-9-95		1045	1100	1115	1130	1145	1200
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 160 % Sucron				Sht 8 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	336	337	336	337	336	338
TI-Lower Bed	°C	502	502	502	502	503	502
TI-Upper Bed	°C	502	502	503	502	501	503
TI-Freeboard	°C	552	553	549	553	554	553
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	138
PI-Fluidizing Gas	kPag	22	25	23	23	23	23
PI-Calciner Freeboard	kPag						
PI-Off-gas line <i>OP</i>	kPag	0.55	0.45	0.02			
PI-Fines Filter <i>N</i>	kPag	5.2	5.2	5.7	5.5	6.0	5.5
PI	kPag						
Simulant Injection Rate	ml/min	340	340	340	340	340	340
Total Simulant Injected		128.88	~	~	~	141.39	~
Scrubber Level	cm						
Blowback Gas	kPag	138 <10	138 <10	138 <10	138 <10	138 <10	138 <10
Off-Gas <i>"wc"</i>	Nm ³ /hr	2.2	1.8	0.1	—	—	—
N ₂ Fluidizing	Nm ³ /hr	20.86	20.14	20.86	20.14	20.14	20.56
3-9-95 TIME		1215	1230	1245	1300	1315	1330
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S_____		ADDITIVE/100 % Sacrosol				Sht 9 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	337	336	337	335	337	337
TI-Lower Bed	°C	502	502	502	502	500	503
TI-Upper Bed	°C	502	503	502	502	501	502
TI-Freeboard	°C	552	550	552	549	547	550
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	138
PI-Fluidizing Gas	kPag	23	23	23	24	23	23
PI-Calciner Freeboard	kPag						
PI-Off-gas line DP	kPag						
PI-Fines Filter DP	kPag	5.5	5.5	5.5	6.0	6.5	6.0
PI	kPag						
Simulant Injection Rate	ml/min	340	340	340	340	340	340
Total Simulant Injected	l	—	157.34	—	—	172.03	—
Scrubber Level	cm						
Blowback Gas	kPag	138 ≤10	138 ≤10	138 ≤10	138 ≤10	138 ≤10	138 ≤10
Off-Gas "WC"	Nm ³ /hr	—	—	—	—	—	—
N ₂ Fluidizing	Nm ³ /hr	20.86	20.86	20.86	20.86	20.14	20.86
3-9-95 - Time		1345	1400	1415	1430	1445	1500
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S_____		ADDITIVE 100% Sucrose				Sht/0 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	336	337	337	337	325	338
TI-Lower Bed	°C	502	502	502	503	502	502
TI-Upper Bed	°C	502	503	501	502	501	503
TI-Freeboard	°C	548	547	545	546	547	548
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	138
PI-Fluidizing Gas	kPag	23	23	23	23	23	23
PI-Calcliner Freeboard	kPag						
PI-Off-gas line	kPag						
PI-Fines Filter	kPag	6.2	6.2	6.2	6.7	7.0	7.2
PI	kPag						
Simulant Injection Rate	ml/min	340	340	340	340	340	340
Total Simulant Injected	l						182.97
Scrubber Level	cm						
Blowback Gas	kPag	138 <10	138 <10	138 <10	138 <10	138 <10	138 <10
Off-Gas "WC	Nm³/hr	—	—	—	—	—	—
N₂ Fluidizing	Nm³/hr	20.86	20.86	20.86	20.86	20.86	20.86
3-9-95 Time		1515	1530	1545	1600	1615	1630
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S_____		ADDITIVE 100% Sucrose				Sht 11 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	337	337	337	337	337	337
TI-Lower Bed	°C	501	502	502	501	500	501
TI-Upper Bed	°C	502	501	502	501	502	502
TI-Freeboard	°C	547	551	543	543	544	544
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	138
PI-Fluidizing Gas	kPag	23	23	24	25	25	25
PI-Calcliner Freeboard	kPag						
PI-Off-gas line	kPag						
PI-Fines Filter ΔP	kPag	7.0	6.7	6.7	8.2	8.5	8.0
PI	kPag						
Simulant Injection Rate	ml/min	340	340	340	340	340	340
Total Simulant Injected	l	194.84	~~~~~	~~~~~	~~~~~	~~~~~	~~~~~
Scrubber Level	cm						
Blowback Gas	kPag	138 <10	138 28	138 28	138 <10	138 <10	138 <10
Off-Gas °Wc	mm/hr	—	—	—	—	—	—
N ₂ Fluidizing	Nm ³ /hr	20.19	20.19	20.19	20.19	20.19	20.19
3-9-95		1645	1700	1715	1730	1745	1800
Initials						-	

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 100% Sucrose				Sht 12 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	259	281	304	304	297	314
TI-Lower Bed	°C	501	504	496	504	464	480
TI-Upper Bed	°C	501	504	502	503	464	479
TI-Freeboard	°C	492	512	514	547	511	513
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	138	138	138	138	138	159
PI-Fluidizing Gas	kPag	20	17	19	18	23	23
PI-Calcliner Freeboard	kPag						
PI-Off-gas line ΔP	kPag	0.75	0.85	0.75	0.67	0.70	0.82
PI-Fines Filter ΔP	kPag	3.0	4.7	3.5	3.2	9.5	8.0
PI	kPag						
Simulant Injection Rate	ml/min	223	223	—	—	350	350
Total Simulant Injected	l						
Scrubber Level	cm						
Blowback Gas	kPag	$\frac{138}{<10}$	$\frac{138}{<10}$	$\frac{138}{<10}$	$\frac{138}{<10}$	$\frac{138}{<10}$	$\frac{159}{14}$
Off-Gas "wc	~~Nm³/hr~~	3	3.4	3	2.7	2.8	3.3
N ₂ Fluidizing	Nm ³ /hr	20.14	18.84	18.84	18.17	18.17	20.19
3-10-95 Time		0745	0800	0820	0845	0925	0945
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 100% Sucrose				Sht 13 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	327	334	345	347	348	348
TI-Lower Bed	°C	489	485	510	494	504	503
TI-Upper Bed	°C	489	477	501	497	503	501
TI-Freeboard	°C	516	512	535	526	520	520
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	165	159	159	—	172	172
PI-Fluidizing Gas	kPag	23	21	21	22	25	24
PI-Calciner Freeboard	kPag						
PI-Off-gas line ΔP	kPag	0.82	0.37	0.27	0.37	0.85	0.90
PI-Fines Filter ΔP	kPag	9.2	9.5	10.0	8.5	8.5	7.5
PI	kPag						
Simulant Injection Rate	ml/min	350	—	360	320	350	350
Total Simulant Injected	l	—	206.22	—	—	221.22	—
Scrubber Level	cm						
Blowback Gas	kPag	165 14	159 14	159 14	~~X~~	172 21	172 21
Off-Gas "WC	mm/hg	3.3	1.5	1.1	1.5	3.4	3.6
N ₂ Fluidizing	Nm ³ /hr	20.14	20.14		18.84	20.14	20.14
3-10-95		1000	1015	1030	1130	1145	1215
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 100% Sucrose			Sht 14 of 17		
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	347	348	349	349	350	354
TI-Lower Bed	°C	503	503	503	502	504	502
TI-Upper Bed	°C	502	501	502	501	501	501
TI-Freeboard	°C	522	521	524	521	524	511
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	172	172	172	172	172	172
PI-Fluidizing Gas	kPag	25	26	23	23	23	24
PI-Calciner Freeboard	kPag						
PI-Off-gas line ΔP	kPag	0.82	0.80	0.62	0.70	0.60	0.27
PI-Fines Filter ΔP	kPag	10.0	9.5	9.5	10.0	9.7	9.7
PI	kPag						
Simulant Injection Rate	ml/min	350	350	350	350	350	350
Total Simulant Injected	l	236.06					251.06
Scrubber Level	cm						
Blowback Gas	kPag	$\frac{172}{21}$	$\frac{172}{210}$	$\frac{172}{14}$	$\frac{172}{14}$	$\frac{172}{14}$	$\frac{172}{14}$
Off-Gas ΔWC	~~mm~~ /hr	3.3	3.2	2.5	2.8	2.4	1.1
N ₂ Fluidizing	Nm ³ /hr	20.19	20.19	20.19	20.19	20.19	20.19
3-10-95 Time		1230	1245	1300	1315	1330	1345
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S_____		ADDITIVE 100 % Sucrose				Sht 15 of 17	
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	353	353	352	349	349	348
TI-Lower Bed	°C	503	502	503	503	503	503
TI-Upper Bed	°C	501	501	502	503	501	~~MS 500~~ ~~502~~
TI-Freeboard	°C	525	525	527	527	526	~~MS 524~~ ~~500~~
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	172	172	172	172	172	172
PI-Fluidizing Gas	kPag	24	23	20	22	23	24
PI-Calciner Freeboard	kPag						
PI-Off-gas line <i>OP</i>	kPag	0.47	0.70	0.67	0.70	0.57	0.60
PI-Fines Filter <i>OP</i>	kPag	10.2	8.0	7.5	8.0	8.5	8.7
PI	kPag						
Simulant Injection Rate	ml/min	350	350	350	350	350	350
Total Simulant Injected	<i>l</i>					267.00	
Scrubber Level	cm						
Blowback Gas	kPag	~~172~~ 21	~~172~~ 21	~~172~~ 21	~~172~~ 21	~~172~~ 21	~~172~~ 21
Off-Gas <i>"wc"</i>	~~Nm³/hr~~	1.9	2.8	2.7	2.8	2.3	2.4
N ₂ fluidizing	Nm³/hr	20.19	20.19	20.19	20.19	20.19	20.19
		1400	1415	1430	1445	1500	1515
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 100 % Sucrose			Sht 16 of 17		
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	330	351	353	349	354	353
TI-Lower Bed	°C	502	503	503	502	503	502
TI-Upper Bed	°C	501	501	501	499	502	502
TI-Freeboard	°C	522	521	521	518	519	518
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	172	172	172	172	172	172
PI-Fluidizing Gas	kPag	23	23	23	23	23	23
PI-Calciner Freeboard	kPag						
PI-Off-gas line <i>AP</i>	kPag	0.62	0.60	0.65	0.62	0.60	0.60
PI-Fines Filter <i>AV</i>	kPag	8.7	8.5	9.5	10.0	9.5	8.7
PI	kPag						
Simulant Injection Rate	ml/min	350	350	350	350	350	350
Total Simulant Injected	l	280.75	~~~~~		244.97	~~~~~	296.375
Scrubber Level	cm						
Blowback Gas	kPag	172 21	172 21	172 21	172 21	172 21	172 21
Off-Gas <i>Wc</i>	Nm ³ /hr	2.5	2.4	2.6	2.5	2.4	2.4
N ₂ fluidizing	Nm ³ /hr	20.19	20.19	19.52	20.19	20.19	20.19
3-10-95		1530	1545	1600	1615	1630	1645
Initials							

Pilot-Scale Test - Datasheet

Pg 2 of 2

Test No. FBC-S		ADDITIVE 100% Sucrose		Sht 17 of 17			
Parameter	Units	Readings					
TI-Heated Bath	°C						
TI-Fluidizing Gas	°C	553					
TI-Lower Bed	°C	502					
TI-Upper Bed	°C	501					
TI-Freeboard	°C	519					
TI-	°C						
TI-	°C						
PI-Blowback Gas	kPag	172					
PI-Fluidizing Gas	kPag	23					
PI-Calciner Freeboard	kPag						
PI-Off-gas line ΔP	kPag	0.57					
PI-Fines Filter	kPag	9.7					
PI	kPag						
Simulant Injection Rate	ml/min	350					
Total Simulant Injected							
Scrubber Level	cm						
Blowback Gas	kPag	172	2.1				
Off-Gas $W C$	~~Nm³/hr~~	2.3					
N_2 Fluidizing	Nm³/hr	20.14					
3-10-95		1700					
Initials							

PART 2 - RVR DRYER/CALCINER TEST REPORT

RVR DRYER/CALCINER - TEST REPORT - FINAL

FOR

**EVALUATION OF MELTER SYSTEM TECHNOLOGIES FOR
VITRIFICATION OF HIGH SODIUM CONTENT LLRW**

VECTRA GSI Report No. WHC-VIT-04

August 1995

for

WHC Contract No. MMI-SVV-384211

by

VECTRA Government Services, Inc.
2939 Richardson Road
Richland, WA 99352
(509) 375-3535

Prepared by:

John J. Koehr

Brent Spurgeon




Approved by:

Brad Mason



CONTENTS

1.0	INTRODUCTION	2-1
2.0	PURPOSE	2-1
3.0	CHRONOLOGY OF EVENTS	2-1
4.0	EQUIPMENT OPERATING BEHAVIOR	2-5
4.1	CHEMICAL AND GLASS FORMER MIXING, BATCHING, AND FEEDING	2-5
4.1.1	Simulant Feed System	2-5
4.1.2	Glass Former Feed System	2-6
4.2	OFF-GAS SYSTEM	2-6
4.3	HEAT TRANSFER SYSTEM	2-7
4.4	RVR DRYER MECHANICAL	2-7
5.0	SCOPING TESTS AND OBSERVATIONS	2-8
5.1	TESTING WITH GLASS FORMERS AND WASTE FEED	2-8
5.2	INITIAL RVR TESTING WITH LLRW SIMULANT AND GLASS FORMERS	2-10
5.2.1	RVR-S1: Glass Former Mix C, Liquid Simulant, 100% Stoichiometric Sucrose Reductant	2-10
5.2.2	Glass Former Mix C, Liquid Simulant, 60% Stoichiometric Sucrose	2-11
5.2.3	RVR-S3: Glass Former Mix C, Liquid Simulant, No Additives	2-12
5.3	RVR LABORATORY SCALE OVEN TESTS W/ SUCROSE AND FORMIC ACID REDUCTANTS	2-12
5.3.1	Oven Reaction Tests: Dried Glass Formers and Simulant with 60% and 100% Dry Sucrose Reductant	2-13
5.3.2	Oven Reaction Tests: Glass Formers and Liquid Simulant with 60% sucrose and 100% Formic Acid Reductants	2-13
5.4	RVR SIMULANT VACUUM DRYING PCP TESTS	2-14
5.5	RVR TWO STAGE DRYING/REACTING	2-15
5.5.1	RVR-S4: Pre-Dried Glass Formers and Simulant W/ 60% Stoichiometric Sucrose	2-16
5.5.2	RVR-S5: Pre-Dried Glass Formers and Simulant W/ 80% Stoichiometric Sucrose	2-17
5.5.3	RVR-S6: Pre-Dried Glass Formers and Simulant W/ 100% Stoichiometric Sucrose	2-17
5.5.4	RVR-S7: Pre-Dried Glass Formers and Simulant W/ 125% Stoichiometric Sucrose	2-18
5.6	SCOPING TEST EVALUATION SUMMARY	2-19
6.0	CONCLUSIONS	2-19
7.0	RECOMMENDATION FOR FUTURE TESTS	2-19

CONTENTS (cont)

APPENDIXES

2A	DATA SHEETS	2-21
2B	RVR TESTING SAMPLE LOG	2-51

LIST OF TABLES

2-1	RVR Dryer Testing Chronology Summary	2-2
2-2	Glass Former Mix B	2-8
2-3	Glass Former Mix C	2-9
2-4	Oven Reaction Tests with Sugar and Formic Acid Reductants	2-13
2-5	Product Generated During Two Stage RVR Drying Tests	2-15
2-6	Average Steady State Bed Temperature Profiles Observed During Second Stage RVR Drying Tests	2-16
2-7	RVR Test Evaluation Summary	2-20

PART 2 - REV DRYER/CALCINER TEST REPORT

1.0 INTRODUCTION

The Westinghouse Hanford Company (WHC) is conducting an evaluation of glass melter system technologies for vitrification of liquid low-level radioactive waste (LLRW) streams consisting mostly of sodium nitrate and nitrite salts in alkaline liquid slurry form. As part of this technology evaluation, VECTRA will demonstrate the performance of the EnviroGlass™ Vitrification System feed and VE-SKULL™ melter subsystems. The RVR Dryer System is a potential EnviroGlass™ feed subsystem and is intended to dry, mix, and react the liquid waste simulant together with glass formers and reductant additives prior to vitrification.

2.0 PURPOSE

This test report documents accomplishment of the RVR Dryer/Calciner test objectives. Test objectives include the following:

- 2.1 Generate dry LLRW simulant for use in VE-SKULL™ melter testing.
- 2.2 Demonstrate the ability of the VECTRA RVR Dryer to do the following:
 - Evaporate water to produce a dry, free flowing solid
 - Volatize NO_2 and NO_3
 - Convert NaNO_3 and NaNO_2 salts to Na_2CO_3 salts
 - Reduce NO_3 and NO_2 to N_2 gas
 - Mix dry simulant with glass formers and reductant additive
- 2.3 Determine throughput of RVR Dryer/Calciner when operating within parameters for achieving objectives number one and two.
- 2.4 Determine efficiency of NO_2/NO_3 reductions using the following additives to dryer: sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$), formic acid (HCO_2H).

3.0 CHRONOLOGY OF EVENTS

A detailed chronology of RVR dryer scoping testing has been recorded in the Test Log and data sheets. A brief summary is provided in Table 2-1.

Table 2-1. RVR Dryer Testing Chronology Summary. (4 sheets)

Dates	Activities/events
3/14/95 (Water Feed)	- Dry glass formers w/ boric acid (Mix B) - Water feed, no simulant, no reductants - Hot oil temp 570 °F. - Slurry leaks at rotor shaft packing seals - Bed caking developed after approx. 1 hour - Following cooldown, bed solidified due to presence of H_2BO_3 in bed
3/16/95 (Water Feed)	- Discharge weir removed to lower bed level for future tests. - Dry glass formers w/o boric acid (Mix C) - Water feed, no simulant, no reductants - Initial hot oil temp 570 °F. Hot oil temp could not be maintained above 483 °F. - Hard crust developed on wetted heat transfer surfaces - Bed free-flowing, no solidification on cooldown.
3/20/95 (Water Feed)	- RVR dryer barrel external jacket insulated - Dry glass formers w/o boric acid (Mix C) - Water feed, no simulant, no reductants - Hot oil temp maintained near 570 °F - Minor caking observed, bed free flowing
3/21/95 (RVR-S1)	- Dry glass formers w/o boric acid (Mix C) - Liquid LLW simulant injection w/ 100% sucrose reductant - Hot oil temp 570 °F - Test duration approx. 6 hours - Average NOx 1353 ppm, average CO 446 ppm - Off-gas carryover and leaks noted - Periodic exothermic reactions raised bed temperatures, hot oil system tripped on high temperature. - Peak NOx and CO observed during exothermic reaction periods - 161.9 kg (357 lbs) black product generated
3/24/95 (60% sucrose)	- Off-gas system modified - More insulation and jacketing added to RVR dryer and hot oil system piping - dry glass formers w/o boric acid (Mix C) - Liquid LLW simulant injection - 60% sucrose reductant - Hot oil temp 570 °F - Bag filter in new off-gas drum became plugged - Bed developed cake, required clean-out - No usable product generated

Table 2-1. RVR Dryer Testing Chronology Summary. (4 sheets)

Dates	Activities/events
3/25/95 (60% sucrose)	- Dry glass formers w/o boric acid (Mix C) Repeat of test from 3/24/95. - Liquid LLW simulant injection - 60% sucrose reductant - Hot oil temp 570 °F - Bed developed hard cake which required clean-out. - No usable product generated - Unable to duplicate results of RVR-S1.
3/26/95-3/27/95 (RVR-S3)	- Dry glass formers w/o boric acid (Mix C) - Liquid LLW simulant injection only, no reductants - Hot oil temperature 225-325 °F - Slow drying, wet zone migrated toward discharge end. - Operated in drying mode for approx. 5 hours - Severe bed caking resulted >240 °F - 81 kg (179 lbs) dry glass formers and simulant product generated
3/27/95 (Oven Reaction Testing)	- Oven test: 200g dry glass formers and simulant (RVR-S1 product) - Dry 100% stoich. sucrose reductant - Oven temp 530 °F - Dark black free-flowing product generated - Oven test: 200g dry glass formers and simulant (RVR-S1 product) - Dry 60% stoich. sucrose reductant - Oven temperature 530 °F - Lighter black free-flowing product generated
3/29/95 (Oven Drying/ Reaction Testing)	- Oven test: dry glass formers - Liquid LLRW simulant w/ 60% stoich. sucrose reductant - Oven temperature 530 °F - Dark black, hard cake formed - Oven test: dry glass formers - Liquid LLRW simulant - Dry 100% stoich. formic acid reductant - Formic reacted w/ NaNO_2 at room temperature, volatized some NO_x - Oven temperature 530 °F - Formic volatized prior to reacting with NaNO_3 - Hard red cake formed upon cooling indicating no reaction and resulting melted salts

Table 2-1. RVR Dryer Testing Chronology Summary. (4 sheets)

Dates	Activities/events
3/29/95-3/31/95 (RVR Vacuum Dryer PCP)	- RVR Process Control Program (PCP): liquid simulant and glass formers - 300 ml simulant - Vacuum 22" Hg, temp 120 °F - After 4 hours 0.29 kg (0.63 lbs) glass formers added - Yellowish waxy, oily product, significant particulate carryover indicated - Hydrated salts present - Not suitable for RVR batch vacuum drying - RVR PCP: liquid simulant only - Vacuum 25-27" Hg, temp 120 °F - Yellowish hard crystalline cake - Not suitable for RVR batch vacuum drying - RVR PCP: liquid simulant bubbled w/ CO₂ - 150 ml simulant bubbles w/ CO₂ at 1 SCFH and 80 °F for over 1 hour - Yellowish/white foam, precipitation, no pH change - Vacuum dried at 28"Hg - Yellowish, waxy, oily agglomeration - Not suitable for RVR batch vacuum drying
3/29/95-4/2/95 (RVR Drying)	- RVR stage 1 drying: dry glass formers (Mix C), liquid simulant, no reductants - Hot oil 230 °F - 195 kg (430 lbs) additional dry reddish product generated for use in stage 2 RVR reactions (RVR-S4 through S7). Total of 276 kg (609 lbs) dry RVR product available.
4/5/95 (RVR-S4) (RVR-S5)	- RVR stage 2 reaction test: dry glass formers and simulant (RVR 1st stage product) - 60% stoich. sucrose - Hot oil 570 °F - Exothermic reactions (574 °F peak) - Average NOx 45.8 ppm, average CO 18.4 ppm. - Minor caking - Free flowing black product generated - RVR stage 2 reaction test: dry glass formers and simulant (RVR 1st stage product) - 80% stoich. sucrose - Hot oil 570 °F - Exothermic reactions (653 °F peak) - Average NOx 68.2 ppm, average CO 36.1 ppm - Free flowing black product generated

Table 2-1. RVR Dryer Testing Chronology Summary. (4 sheets)

Dates	Activities/events
4/11/95 RVR-S6	- RVR stage 2 reaction test: dry glass formers and simulant (RVR 1st stage product) - 100% stoich. sucrose - Hot oil 570 °F - Exothermic reactions (573 °F peak) - Average NOx 185.4 ppm, average CO 52.0 ppm - Free flowing black product generated
RVR-S7	- RVR stage 2 reaction test: dry glass formers and simulant (RVR 1st stage product) - 125% stoich. sucrose - Hot oil 570 °F - Exothermic reactions (587 °F peak) - Average NOx 220.0 ppm, average CO 60.5 ppm - Free flowing black product generated

4.0 EQUIPMENT OPERATING BEHAVIOR

4.1 CHEMICAL AND GLASS FORMER MIXING, BATCHING, AND FEEDING

4.1.1 Simulant Feed System

DSSF simulant was provided in DOT 17H 55-gallon drums. Drums were staged adjacent to the RVR feed tank (Waste Hold-up Tank). The drum was opened and fitted with an electric mixer, drum pump, and splash lid. DSSF simulant was thoroughly mixed within the drum and transferred via the installed drum pump and hose directly into the RVR feed tank.

A 378 liter (100 gal) stainless steel RVR feed tank was equipped with a top mounted electric tank mixer. The tank was calibrated for liquid level by means of visual level indication in the sight glass. As needed, calculated simulant quantities were pumped from the simulant drums until the desired RVR feed tank level was achieved. For testing requiring addition of sucrose ($C_{12}H_{22}O_{11}$) reductant, dry sucrose was manually added to the RVR feed tank in weighed quantities necessary to achieve desired stoichiometric concentration. The RVR feed tank mixer was continuously operated during batching and subsequent simulant feeding to assure a homogeneous slurry.

Liquid slurry was pumped from the RVR mix tank into the RVR dryer via a stainless steel tubing feed line using a variable speed, positive displacement, peristaltic tubing pump. The simulant feed pump stainless steel suction tubing was provided with a connection for water. This connection was utilized for water injection testing and to flush the feed line following simulant injection. A separate stainless steel tubing feed line was also installed for liquid formic acid injection but never used.

4.1.2 Glass Former Feed System

A variable speed dry product feeder/mixer was utilized for dry glass former feed. The feeder hopper could hold over 45 kg (100 lbs) of dry material. During RVR dryer operation, the feeder was kept full above the top of the discharge pipe in order to prevent dryer off-gas from escaping through the dry feed line.

Dry glass formers were premixed by the supplier and shipped in 34 kg (75 lb) bags to VECTRA's Richland, Washington facility. Prior to each test, calculated dry glass former quantities were weighed and added to the dry feeder hopper. During stage two reaction scoping tests (RVR-S4, S5, S6, and S7) dry sucrose reductant was calculated for desired stoichiometric ratio, weighed, premixed with glass formers, and added to the feeder hopper.

In order to achieve proper weight percentages of constituents in the RVR discharge, the dry glass former feed rate and liquid slurry feed rate were carefully balanced based on calculated ratios.

4.2 OFF-GAS SYSTEM

The off-gas system for RVR Dryer testing up to and including RVR-S1 (3/21/95) consisted of a spray scrubber/condenser (T-SCB), a scrubber discharge vent blower (P-VS), a vent separator tank (T-VS), site vent stack and dilution ventilation blower (P-SB). Accumulated condensate and liquid carryover in the spray scrubber was pumped to a drain tank using an air driven diaphragm drain pump. Scrubber spray flow was provided by a centrifugal pump which took a suction on the drain tank and discharged into the scrubber spray header. The drain pump and spray pump were operated continuously to recirculate the scrubber. The small scrubber discharge blower took a suction on the scrubber and discharged off-gas into the vent separator tank. The spray scrubber and scrubber discharge blower were physically located within the test building, in close proximity to the RVR dryer. A short run of hose (less than 10') ran directly from the top of the RVR dryer to the spray scrubber.

During test RVR-S1 (100% sucrose) significant carryover was observed in the off-gas system as evidenced by the accumulation of glass former material in the scrubber tank. Additionally, off-gas fumes were observed leaking out of the ductwork at the scrubber discharge blower into the test area atmosphere.

Following RVR-S1 testing, the off-gas system was modified. The scrubber and small vent fan were retired in place. Vent flow was directed from the RVR dryer lid into a modified 55 gallon drum which served as a dry product/liquid carryover collection reservoir. The drum outlet was fitted with a bag filter. Off-gas flow traveled through the filter, off-gas hoses, and off-gas instrumentation to the suction side of a vent blower (located outside the test building) which discharged into the vent separator. The vent separator interfaced with centrifugal pumps for continuous vent separator draindown to a large poly tank and continuous vent separator return spray flow from the poly tank. The vent separator was vented into the stack and joined dilution air flow at the discharge of a large vent blower.

During subsequent testing, the off-gas system was further modified by removal of the bag filter mounted within the 55-gallon collection reservoir.

4.3 HEAT TRANSFER SYSTEM

During initial testing with dry glass former feed and water injection (3/16/95), hot oil inlet temperature setpoint could not be maintained by heater H-H0 (40 kw). In order to avoid limiting liquid feed rates to below acceptable levels, additional thermal insulation was added to the RVR dryer barrel. The addition of insulation significantly reduced thermal losses to ambient and a more stable hot oil inlet temperature was maintained during subsequent testing with water injection.

Additional insulation and jacketing was added to the RVR barrel, top, and hot oil system piping following test RVR-S1 (3/21/95). No further difficulty was experienced in maintaining hot oil inlet temperature.

4.4 RVR DRYER MECHANICAL

During initial testing with dry glass former and water feed, liquid slurry was observed leaking from the RVR paddle shaft packing seals when bed level was raised above the paddles. In order to minimize leakage of slurry from the paddle shaft seals, the RVR bed discharge weir was removed to allow earlier discharge of dry product and limit the bed height. This effectively limited the total bed quantity to approximately 23 kg (50 lbs) of material, which is approximately half the maximum bed capacity.

Hot oil leaks were observed at the rotary joints connecting hot oil system hoses to the counter-rotating RVR dryer shafts. Repair required parts for rebuilding the rotary joint seals. Parts were not available, and the maintenance was not performed. Since leakage was minor, testing continued.

During the initial testing with glass formers (boric acid) and water injection (3/14/95), severe bed hardening restricted movement of the rotary paddles and caused the RVR dryer drive motor to trip on over-torque (over-current). No equipment damage was observed.

During test RVR-S3 (3/27/95), the RVR drive motor chain had become loose and required tightening. No subsequent problems were experienced with the drive unit.

During many RVR dryer tests, hard caking developed within the dryer bed, on barrel wall surfaces, and on the paddles. Due to the configuration of the equipment and the composition of the dried material, this hard, water soluble cake was difficult to remove.

5.0 SCOPING TESTS AND OBSERVATIONS

The continuous RVR dryer, hot oil system, off-gas system, simulant and glass former feed systems, and CEMS were installed at VECTRA's Richland, Washington facility. All RVR scoping tests were performed in Richland.

5.1 TESTING WITH GLASS FORMERS AND WASTE FEED

Following RVR Dryer initial check-out and calibration of equipment and instrumentation, initial testing was required to determine acceptability of the glass former mix, envelope heat transfer performance of the RVR dryer, and observe drying characteristics with injection of water only. This testing was performed from 3/14/95 to 3/20/95 and was in addition to the testing detailed in the Test Plan. Following initial testing, Scoping Test Procedure RVR-S1 was performed on 3/21/95.

Glass formers were premixed to the composition of Mix B shown in Table 2-2. Note that this is the same weight percent as Mix B used in the Fluid Bed Calcliner testing (WHC-VIT-03).

On 3/14/95, the RVR dryer was preheated to 570 °F with the hot oil system operating. The RVR counter-rotating mixing paddles were energized at 30 rpm. The dry glass former feeder was filled with pre-mixed glass formers and energized for an initial dry feed rate of 68 kg/hr (150 lb/hr). Once the initial RVR bed was established, water injection began at 800 ml/min.

Liquid slurry was observed leaking from the RVR paddle shaft seals when bed level was raised above the paddles. Additionally, rapid bed caking and coating of wetted heat transfer surfaces (paddles and barrel) were experienced. After approximately 1 hour, the RVR paddle motor tripped on over-torque resulting from excessive bed caking. The hot oil system was shutdown and the bed allowed to cooldown. Following cooldown, the bed solidified to an extremely hard cake throughout.

Table 2-2. Glass Former Mix B.

Glass former	Weight percent
Silica sand	59.69
Boric acid	16.19
Dolomite	10.89
Alumina	11.48
Iron oxide	1.04
Magnesium carbonate	0.71
Total	100.0

It is believed that the initial caking developed due to melting boric acid which solidified upon cooling, forming an extremely hard cake.

Adjustments were made to minimize problems observed during the initial test run. The glass former mixture was reformulated to remove boric acid. The resulting RVR dryer test glass former Mix C is shown in Table 2-3. In order to minimize leakage of slurry from the paddle shaft seals, the RVR bed discharge weir was removed to allow earlier discharge of dry product and limit the bed height. The RVR bed and heat transfer surfaces were cleaned out. The hard dry cake was discovered to be water soluble.

On 3/16/95 the RVR dryer was preheated to 570 °F with the hot oil system. After heat-up, the paddles were energized and dry glass formers were fed into the bed. The dry glass former feeder was filled above the feed nozzle in order to seal off the potential vent path. The scrubber water spray flow was initiated and the vent fan was energized. Water injection was initiated at 500 ml/min. After about 1 hour, hot oil system inlet temperature dropped to 483 °F with outlet at 477 °F (6 °F differential temperature). The steady state bed temperature profile started with boiling (212 °F) in the first 25% of the bed, heat-up in the second 25% of the bed (300 °F), bed temperature peak in the bed center (453 °F), and gradual cooldown toward the discharge end of the bed (416 °F). Dry product was produced. Minor caking developed on wetted heat transfer surfaces, but the bed was free-flowing. No additional caking or hardening was observed following bed cooldown, confirming the previously observed results attributed to boric acid.

The heat transfer capability of the hot oil system appeared to be limiting feed rates and temperatures. It was hoped that subsequent tests with simulant (lower percentage of water) would allow higher feed rates. Additionally, insulation was added to the RVR dryer barrel to reduce heat losses to ambient.

Table 2-3. Glass Former Mix C.

Glass former	Weight percent
Silica sand	71.3
Boric acid	0.0
Dolomite	13.0
Alumina	13.6
Iron oxide	1.3
Magnesium carbonate	0.8
Total	100.0

On 3/20/95, the RVR dryer was again tested with glass former mix C and water injection to evaluate the effectiveness of the added insulation. Hot oil temperature dropped slowly to 566 °F with a 9 °F differential temperature. Similar to previous testing, the resulting steady state bed temperature profile started with boiling (210 °F) in the first 25% of the bed, heat-up in the second 25% of the bed (423 °F), temperature peak in the bed center (533 °F), and gradual cooldown toward the discharge end of the bed (514 °F). Dry product was produced. Similar to previous test results, minor caking was observed on wetted heat transfer surfaces, but the bed was free-flowing. A dry product generation rate of 100lb/hr was projected.

5.2 INITIAL RVR TESTING WITH LLRW SIMULANT AND GLASS FORMERS

Initial RVR drying runs were made feeding liquid LLRW simulant with different reductant additives and dry glass former mix C. A planned test (RVR-S2) using formic acid reductant was deleted based on oven reaction crucible test results.

5.2.1 RVR-S1: Glass Former Mix C, Liquid Simulant, 100% Stoichiometric Sucrose Reductant

On 3/21/95 the RVR dryer was preheated to 570 °F in preparation for test RVR-S1. Sucrose and liquid simulant were mixed in the feed tank to achieve 100% stoichiometric sucrose concentration (110 grams sucrose/liter simulant). Dry glass former feed and liquid simulant/sugar feed were initiated into the RVR. Dry feed and liquid simulant/sugar feed were balanced to achieve a target 20% Na₂O concentration in the final glass form.

The RVR dryer was operated continuously for over 5 hours. During this time period, simulant injection rate was maintained at 425 ml/min and balanced dry glass former feed rate was maintained at 45.4 kg/hr (100 lb/hr). Plugging in the liquid simulant feed line temporarily forced feed shutdown and replacement of a feed line valve.

Throughout testing, hot oil system supply temperature averaged 566 °F with a 5.5 °F differential temperature. "Steady state" was achieved after approximately 1 hour of operation. Average temperature profile was near boiling (222 °F) in the first 25% of the bed, heating up (385 °F) in the second 25% of the bed, peak temperature (558 °F) in the center of the bed, and gradual cooldown (507 °F) through the last half of the bed. Average NO_x and CO levels of 1353 ppm and 446 ppm, respectively, were observed in the off-gas.

Sucrose reaction with the simulant was noted on several occasions due to exothermic reaction, as evidenced by NO_x and CO spikes in the off-gas, and black colored product. The reaction initially began in the center of the bed. Temperatures in excess of 600 °F were observed. As the reaction progressed, the temperature peak moved toward the bed inlet until slurry was encountered and temperature dropped. The temperature peak would then move back toward the center of the bed. The cycle repeated several times. At one point the exotherm was so extreme that the hot oil outlet temperature increased above the inlet temperature to the high temperature trip setpoint. NO_x and CO spikes in the off-gas were observed simultaneously.

A total of 161.9 kg (357 lbs) of dried product was produced. Samples were drawn. Significant carryover was observed in the off-gas system as evident by the accumulation of glass former material in the scrubber tank. Additionally, off-gas fumes were observed leaking out of the ductwork at the vent fan connection into the test area atmosphere. Modification to the off-gas system was necessary.

5.2.2 Glass Former Mix C, Liquid Simulant, 60% Stoichiometric Sucrose

Following the results of the RVR-S1 testing, the off-gas system was modified. The scrubber and small vent fan were retired in place. Vent flow was directed from the RVR dryer lid into a modified 55 gallon drum which served as a dry product/liquid carryover collection reservoir. The drum outlet was fitted with a bag filter. Off-gas flow traveled through the filter, off-gas hoses, and off-gas instrumentation to the suction side of a vent fan (located outside the test building) which discharged into the vent separator. The vent separator flow loop contained centrifugal pumps for continuous vent separator draindown to a large poly tank and continuous vent separator return spray flow from the poly tank. The vent separator was vented into the stack and joined dilution air flow at the discharge of a large vent blower.

In addition to the off-gas system modification, additional insulation and jacketing material was added to the RVR dryer barrel and hot oil system piping.

On 3/24/95, the impact of reducing the sucrose stoichiometric ratio to 60% was investigated. The RVR dryer was once again pre-heated to 570 °F. 60% stoichiometric sucrose was mixed in with the liquid LLRW simulant in the feed tank to achieve 51 grams sucrose per liter of simulant. Balanced dry glass former (mix C) feed and simulant/sucrose feed were initiated at 120 lb/hr and 825 ml/min, respectively.

Excessive glass former carryover was again observed and resulted in rapid plugging of the off-gas system bag filter. Additionally, the RVR bed developed severe caking on wetted heat transfer surfaces. Testing was terminated early to clean-out the bed and remove the off-gas system bag filter. No usable dry product was generated.

On 3/25/95, following bed clean-out and removal of the off-gas filter, the 60% stoichiometric sucrose testing continued. The RVR dryer was once again heated to 570 °F. Balanced dry glass former feed and liquid simulant feed were initiated at 60 lb/hr and 400 ml/min respectively.

Rapid bed caking resulted and required shutdown after less than 1 hour operation. A hard cake had developed on wetted heat transfer surfaces requiring dryer clean-out. No usable product was generated. The reasonably steady state operating conditions and periodic sucrose reactions experience during the RVR-S1 testing could not be duplicated.

5.2.3 RVR-S3: Glass Former Mix C, Liquid Simulant, No Additives

Due to the limited success with 100% stoichiometric sucrose and no success with 60% stoichiometric sucrose, investigation of the impact of drying simulant with no reductants was necessary. Since high temperatures were causing bed caking, dryer performance was investigated at lower temperatures.

On 3/26/95 the RVR dryer was heated up to 225 °F. Balanced dry glass former (mix C) feed and liquid simulant feed were initiated at 60 lb/hr and 400 ml/min, respectively. A reasonable flat temperature profile was observed across the bed with gradual heat-up averaging from 140 °F at the beginning of the bed to 188 °F at the discharge end of the bed. Extremely slow drying rates were observed. The bed became wet throughout with moist product discharging. Dry and liquid feeds were secured to allow the bed to dry out. When paddle caking began to develop, testing was secured. The bed required clean-out prior to resumption of testing.

On the morning of 3/27/95 the RVR dryer was preheated to 235 °F. Dry glass former feed was initiated at 60 lb/hr. After 1-1/2 hours continuous operation with dry feed only a dry product discharge rate of 54 lb/hr was observed. Balanced liquid simulant/sucrose injection was initiated at 300 ml/min. As drying continued, the wet portion of the bed was observed steadily extending toward the discharge end of the bed. Hot oil inlet temperature was gradually increased to 340 °F over a 1 hour period before the wet zone was observed to travel back toward the front half of the bed.

Bed caking was observed after hot oil temperature was raised above 240 °F. Reasonably flat temperature profiles were observed across the bed with gradual heating throughout with an average heat-up of 53 °F across the bed. After about 3-1/2 hours of continuous operation at 340 °F a hard cake developed on the wetted heat transfer surfaces and the RVR dryer was secured. A total of 81 kg (179 lb) of dry product was produced.

In order to generate dry product for subsequent RVR scoping tests RVR-S4 through S7 (described later), additional RVR drying with glass formers (mix C), liquid simulant, and no reductants was performed from 3/29/95 to 4/2/95. Hot oil temperature was limited to 230 °F. A total of 195 kg (430 lb) of additional dried glass former/simulant (no additives) was produced.

5.3 RVR LABORATORY SCALE OVEN TESTS W/ SUCROSE AND FORMIC ACID REDUCTANTS

Based on the limited success with drying and reacting glass formers and simulant with one pass through the continuous RVR dryer, and the resulting excessive dryer clean-up requirements, laboratory scale tests were initiated to investigate drying and reacting options.

5.3.1 Oven Reaction Tests: Dried Glass Formers and Simulant with 60% and 100% Dry Sucrose Reductant

Oven reaction tests were performed to determine if a dried RVR product of glass formers and simulant (no reductants) would react at high temperatures in the presence of dry sucrose reductant at 60% and 100% stoichiometric ratios.

On 3/27/95, two separate crucibles were prepared with approximately 200 g of dry glass formers and simulant (no reductants) produced with the RVR dryer during test RVR-S3 (3/27/95). This material was reddish in color. Dry sucrose was added to the two crucibles one with 100% and the other with 60% stoichiometric ratio. The dry sucrose was white in color.

Both crucibles were placed in a laboratory oven and slowly heated to 530 °F. After approximately 1 hour, both crucibles were observed to have reacted. The product in the 100% crucible was a homogeneous, dark black, free flowing, dry powder. The 60% crucible was similar in appearance, but a lighter color.

5.3.2 Oven Reaction Tests: Glass Formers and Liquid Simulant with 60% sucrose and 100% Formic Acid Reductants

Oven reaction tests were performed to determine if dry glass formers, liquid simulant, and liquid formic acid reductant could be successfully dried and reacted to produce a desired product in a single step. Additionally, ability to process dry glass formers and liquid simulant with 60% sucrose reductant was also investigated in an effort to compare laboratory results with previous (poor) RVR dryer test results. On 3/29/95, two crucibles were prepared as described in Table 2-4.

Brownish fumes (NO_x) were observed when the formic acid was added to crucible 1.

Both crucibles were placed in a laboratory oven, slowly heated to 330 °F and held for 90 minutes. The crucibles were then heated to 530 °F and held for 1 hour.

Table 2-4. Oven Reaction Tests with Sugar and Formic Acid Reductants.

Constituent	Crucible 1	Crucible 2
Dry glass formers, mix C (grams)	153.2	98
Liquid simulant (ml)	134	
Liquid simulant with 60% sucrose (ml)		88
Liquid formic acid (ml)	60	

Bubbles were observed in crucible 1 (formic). The reddish product appeared slightly molten and not completely dried. A film formed in crucible 2 (sucrose). The crucible 2 product was black, not completely dry, and slightly molten with evidence of foaming. The product in both crucibles solidified to a hard material following removal from the oven and cooldown.

The fumes observed after initial addition of formic acid to crucible 1 were believed to be from volatilization of NO_2 from formic acid reaction with the NaNO_2 in the simulant at room temperature. It was believed that residual formic acid then volatilized at higher temperatures prior to reacting with the NaNO_3 in the simulant and the resulting hard product in crucible 1 was due to melting of salts in the simulant. Based on the results of the formic acid laboratory scale testing, test RVR-S2 (100% stoichiometric formic acid) was not performed.

5.4 RVR SIMULANT VACUUM DRYING PCP TESTS

As discovered in test RVR-S3, a hard cake develops on the RVR dryer heat transfer surfaces when dry glass formers and liquid simulant are mixed with hot oil temperature greater than 240 °F. High temperatures (>570 °F) are required to produce the desired reaction between sucrose and simulant. Based on results of previous oven tests, pre-dried glass formers and simulant will react with dry sucrose reductant at high temperatures. In order to produce dry product at a low temperature and react at a high temperature, investigation of a two stage drying/reacting alternative was necessary.

Drying of simulant using the atmospheric RVR continuous dryer was observed to be extremely slow with hot oil temperatures limited to 240 °F. Since liquid saturation temperatures are lower and evaporation rates are higher within a vacuum, VECTRA RVR vacuum dryer Process Control Program (PCP) tests were performed to determine if liquid simulant could be successfully dried by the batch in VECTRA's RVR Vacuum Dryer.

On 3/29/95, a PCP test was performed to dry liquid simulant and glass formers. Liquid simulant (300 ml) and a magnetic stirring bar were added to a flask. The flask was placed on a magnetic stirring/hot plate and connected to the PCP vacuum and condensate system. A vacuum of 22" Hg was drawn on the flask, stirring was initiated, and heat-up to 120 °F commenced. Significant particulate carryover was noted. After 4 hours of boiling, 0.29 kg (0.63 lbs) of dry glass former mix (mix C) was added to the flask. The final dried product was a yellowish, oily, waxy agglomeration. The dried product was water soluble.

On 3/30/95, a PCP was performed to dry liquid simulant at lower temperatures (higher vacuum). Liquid simulant (150 ml) were added to a flask and 27" Hg vacuum was drawn in the flask. Stirring and heat-up were initiated. After 30 minutes, the flask was boiling at 93 °F. Forty minutes later, the flask was boiling at 97 °F and a vacuum of 25" Hg. Solution internal temperature was measured at 119.2 °F. The final dried product was a hard crystalline substance caked to the bottom of the flask with a soft, oily material around the flask bottom radius. The dried product was water soluble. This product was determined to be unsuitable for RVR vacuum dryer processing.

Inability to vacuum dry liquid simulant was in part attributed to the presence of hydrated salts, which held on to unliberated water at low temperatures. Conversion of hydrated salts within the simulant to carbonates by exposure to CO_2 was investigated.

On 3/31/95 150 ml of liquid simulant was added to a flask. Initial pH was measured at greater than 10.6. CO_2 was bubbled through the solution in the flask at 1 SCFH while the flask was stirred and heated to 80 °F. After 30 minutes of CO_2 exposure, a yellowish/white film formed on the top of the solution and precipitates began to form in the bottom of the flask. The pH was still greater than 10.6. After over 1 hour of CO_2 exposure, the CO_2 bubbling was stopped.

The flask with simulant was connected to the laboratory vacuum and condensate systems, 28" Hg vacuum was drawn and stirring and heat-up initiated. After 2-1/2 hours, vacuum drying was complete. The final dried product formed a waxy agglomeration on the bottom of the flask. This product was determined to be unsuitable for RVR vacuum dryer processing.

5.5 RVR TWO STAGE DRYING/REACTING

Since laboratory scale oven tests had shown that dry glass formers and simulant (RVR product) and dry sucrose would react at high temperatures (530 °F), this process was performed using the RVR continuous dryer. First stage RVR drying had produced 276 kg (609 lb) of dried glass formers and simulant (no reductants). This first stage dried product was combined with various stoichiometric ratios of sucrose reductant for the high temperature second stage reaction tests, RVR-S4 through RVR-S7. The quantities of product generated in these second stage RVR tests are given in Table 2-5. The RVR temperature profiles measured during these tests are given in Table 2-6.

Table 2-5. Product Generated During Two Stage RVR Drying Tests.

Date	Test	Product generated, kg (lb)
03/27/95	RVR-S4	81.2 (179)
03/29/95	RVR-S5	70.3 (155)
03/31/95	RVR-S6	51.2 (113)
04/02/95	RVR-S7	73.5 (162)
Total		276.2 (609)

Table 2-6. Average Steady State Bed Temperature Profiles Observed During Second Stage RVR Drying Tests.

Test	Temperature, °C (°F)				
	Inlet	25% point	50% point	75% point	Discharge
RVR-S4 60% sucrose	183.7 (362.6)	284.9 (544.8)	272.6 (522.6)	275.4 (527.8)	201.8 (395.2)
RVR-S5 80% sucrose	197.6 (387.7)	274.2 (525.6)	272.2 (521.9)	277.7 (531.9)	200.1 (392.1)
RVR-S6 100% sucrose	173.9 (345.0)	265.1 (509.2)	272.2 (522.0)	284.6 (544.2)	255.8 (492.4)
RVR-S7 125% sucrose	166.0 (330.8)	266.4 (511.5)	291.0 (555.8)	286.0 (546.8)	248.8 (479.8)

5.5.1 RVR-S4: Pre-Dried Glass Formers and Simulant W/ 60% Stoichiometric Sucrose

On 4/5/95, the impact of combining dried glass formers and simulant with 60% stoichiometric sucrose in the RVR dryer at high temperature (570 °F) was investigated. 56.7 kg (125 lbs) of dried glass formers/simulant was premixed with 1.57 kg (3.46 lbs) of dry sucrose reductant to achieve 60% stoichiometric ratio. The RVR dryer was preheated with a hot oil supply temperature of 566 °F. The off-gas system was started up. RVR dryer rotors were energized and set at 34 rpm. Dry feed was initiated at 54 kg (120 lb/hr).

After approximately 15 minutes a reasonable steady bed temperature profile was observed. Lower temperatures were observed at the inlet and discharge ends of the bed. Peak temperatures were observed in the first half of the bed. The average temperature profile for run RVR-S4 is given in Table 2-6.

Reaction between the sucrose and dried simulant was observed. Average NO_x and CO levels throughout the test were 45.8 ppm and 27.3 ppm, respectively. A dry black product was generated. Additionally, exothermic reactions within the bed occasionally resulted in local bed temperatures slightly higher than hot oil supply temperature. Exothermic temperature peaks [301 °C (574 °F)] did not necessarily correspond to NO_x peaks (130 ppm) in the off-gas. CO peaks (43 ppm) did not occur with NO_x peaks, as was observed in test RVR-S1. Average hot oil differential temperature was only 4 °F.

When all the premixed dry material had been fed into the RVR dryer, sand was added to the glass former feeder to help clear out the bed for the next test. Representative samples were drawn at the RVR discharge during the middle of each scoping test. The dry product was a black, free flowing granular powder. Minor caking was observed on the dryer heat transfer surfaces.

5.5.2 RVR-S5: Pre-Dried Glass Formers and Simulant W/ 80% Stoichiometric Sucrose

RVR scoping tests continued on 4/5/95 by investigating the impact of combining dried glass formers and simulant with 80% stoichiometric sucrose in the RVR dryer at high temperature (570 °F). 56.7 kg (125 lbs) of dried glass formers/simulant was premixed with 2.49 kg (5.50 lbs) of dry sucrose reductant to achieve 80% stoichiometric ratio. The RVR dryer was preheated with a hot oil supply temperature of 565 °F. The off-gas system was started up. RVR dryer rotors were energized and set at 34 rpm. Dry feed was initiated at 54 kg (120 lb/hr).

As in the 60% sucrose run (RVR-S4) a reasonable steady bed temperature profile was observed. Lower temperatures were again observed at the inlet and discharge ends of the bed. Peak temperatures were observed in the first half of the bed. The average temperature profile is given in Table 2-6.

Reaction between the sucrose and dried simulant was observed. Average NO_x and CO levels throughout the test were 180 ppm and 60 ppm, respectively. The average NO_x and CO off-gas levels were higher than the 60% sucrose run. Dry black product was generated. Additionally, exothermic reactions within the bed resulted in local bed temperatures slightly higher than hot oil supply temperature. Exothermic temperature peaks appeared to correspond with NO_x and CO peaks in the off-gas. Exothermic temperature peaks [345 °C (653 °F)] and NO_x peaks (215 ppm) were higher than the 60% run. Average hot oil differential temperature was only 2.3 °F.

When all the premixed dry material had been fed into the RVR dryer, sand was added to the glass former feeder to help clear out the bed for the next test. Representative samples were drawn at the RVR discharge during the middle of the scoping test. The dry product was a black, free flowing granular powder slightly lighter than the RVR-S4 (60%) product.

5.5.3 RVR-S6: Pre-Dried Glass Formers and Simulant W/ 100% Stoichiometric Sucrose

RVR scoping tests continued on 4/11/95 by investigating the impact of combining dried glass formers and simulant with 100% stoichiometric sucrose in the RVR dryer at high temperature (570 °F). 56.7 kg (125 lbs) of dried glass formers/simulant was premixed with 3.39 kg (7.47 lbs) of dry sucrose reductant to achieve 100% stoichiometric ratio. The RVR dryer was preheated with a hot oil supply temperature of 571 °F. The off-gas system was started up. RVR dryer rotors were energized and set at 34 rpm. Dry feed was initiated at 24 kg/hr (60 lb/hr) but later increased to approximately 40.8 kg/hr (90 lb/hr).

Similar to the previous two second stage scoping runs (RVR-S4, S5) a reasonable steady bed temperature profile was observed. Lower temperatures were observed at the inlet ends of the bed. Peak temperatures were observed toward the second half of the bed. The average temperature profile is given in Table 2-6.

Reaction between the sucrose and dried simulant was observed. Average NO_x and CO levels throughout the test were 220 ppm and 70 ppm, respectively. The average NO_x and CO off-gas levels were higher than the 80% sucrose run. Dry black product was generated. Additionally, exothermic reactions within the bed resulted in local bed temperatures slightly higher than hot oil supply temperature. Exothermic temperature peaks [301 °C (573 °F)] and NO_x peaks (280 ppm) were higher than the 80% run. Average hot oil differential temperature was only 3.6 °F.

When all the premixed dry material had been fed into the RVR dryer, sand was added to the glass former feeder to help clear out the bed for the next test. Representative samples were drawn at the RVR discharge during the middle of scoping test. The dry product was a dark gray, free flowing granular powder slightly lighter in color than the RVR-S5 (80%) product.

The results of RVR-S1 (liquid simulant w/ 100% sucrose) can be compared to the results of RVR-S6 (dry simulant w/ 100% sucrose). A much more stable and even temperature profile was observed during RVR-S6. Additionally, RVR-S6 reactions appeared less violent and more controlled. Bed caking was experienced during RVR-S1 and not during RVR-S6. Average NO_x and CO levels in the RVR-S1 off-gas were nearly an order of magnitude higher, at 1352.8 and 445.6 ppm respectively. However, this may be attributable to exhaust gas flow rates that are such lower in the S1 testing.

5.5.4 RVR-S7: Pre-Dried Glass Formers and Simulant W/ 125% Stoichiometric Sucrose

RVR scoping tests continued on 4/11/95 by investigating the impact of combining dried glass formers and simulant with 125% stoichiometric sucrose in the RVR dryer at high temperature (570 °F). 56.7 kg (125 lbs) of dried glass formers/simulant was premixed with 4.56 kg (10.05 lbs) of dry sucrose reductant to achieve 100% stoichiometric ratio. The RVR dryer was preheated with a hot oil supply temperature of 568 °F. The off-gas system was started up. RVR dryer rotors were energized and set at 34 rpm. Dry feed was initiated at approximately 40.8 kg/hr (90 lb/hr).

Similar to the previous scoping run (RVR-S6) a reasonable steady bed temperature profile was observed. Lower temperatures were observed at the inlet ends of the bed. Peak temperatures were observed in the center of the bed. The average temperature profile is given in Table 2-6.

Reaction between the sucrose and dried simulant was observed. Average NO_x and CO levels throughout the test were 220 ppm and 85 ppm, respectively. The average NO_x and CO off-gas levels, were about the same as the 100% run. Dry black product was generated. Additionally, exothermic reactions within the bed resulted in local bed temperatures slightly higher than hot oil supply temperature. Exothermic temperature peaks [308 °C (587 °F)] and NO_x peaks (335 ppm) were higher than all previous second state scoping runs. NO_x and CO peaks in the off-gas were observed to correspond with exothermic temperature peaks. Average hot oil differential temperature was only 1.8 °F.

When all the premixed dry material had been fed into the RVR dryer, representative samples were drawn at the RVR discharge. The dry product was a dark gray, free flowing granular powder very similar to the RVR-S6 (100%) product.

5.6 SCOPING TEST EVALUATION SUMMARY

A summary of the RVR drying/reacting tests is given in Table 2-7.

6.0 CONCLUSIONS

The following conclusions are drawn from the results of the RVR drying tests.

- Boric acid in the glass former mixture melts in the RVR dryer at 570 °F hot oil inlet temperatures causing hard caking.
- Bed caking results when glass formers and liquid simulant are dried by the RVR continuous dryer. Principal caking occurs in the transition zone where the final free water is evaporated and the product bed temperature begins to exceed the boiling point of water. Liquid simulant drying at <115 °C (<240 °F) and reacting at 300 °C (570 °F) cannot be performed consistently with a single pass through the RVR dryer.
- Laboratory scale vacuum drying of liquid simulant results in a waxy product which is undesirable for RVR rotary vacuum dryer processing.
- Under laboratory conditions, Formic Acid volatilizes before it can completely react with liquid simulant at 530 °F and is therefore, not suitable as a reductant for RVR dryer processing.
- Glass formers and predried simulant will react with Sucrose ($C_{12}H_{22}O_{11}$) at stoichiometric ratios of 60%, 80%, 100%, and 125% in the RVR dryer with 570 °F hot oil inlet temperature. The reaction is exothermic and non-uniform. NO_x and CO off-gas concentrations increase as stoichiometric sucrose ratio increases. Two stage RVR drying/reacting can be successfully performed with the continuous RVR dryer. The first stage drying could be a pulse or spray dryer with the second stage high temperature reacting process performed in an RVR dryer.

7.0 RECOMMENDATION FOR FUTURE TESTS

VECTRA does not recommend any additional testing be considered for any rotary dryer process. VECTRA recommends that future tests target non-mechanical dryers such as pulse or spray dryers.

Table 2-7. RVR Test Evaluation Summary.

Parameter	Test Run						
	RVR-S1	RVR-S2*	RVR-S3	RVR-S4	RVR-S5	RVR-S6	RVR-S7
Stoichiometric Reductant Ratio	Sucrose 100%	Formic Acid 100%	None	Sucrose - 60%	Sucrose - 80%	Sucrose - 100%	Sucrose - 125%
Off-gas - NO _x Range (PPM) - NO _x Ave (PPM) - CO Range (PPM) - CO Ave (PPM)	472-2600 1352.8 160-660 445.8	N/A	N/A	0-130 45.8 0-43 18.4	0-215 68.2 0-72 36.1	0-280 185.4 0-82 52.0	0-335 222.0 0-88 80.5
Appearance - Free Flowing - Color	-free flowing -black -hard cake formation	Lab: -molten salts -hard red cake formation	-free flowing -red -moderate caking	-free flowing -black -minor caking	-free flowing -black/brown	-free flowing -dark gray	-free flowing -black -dark gray
Melt Characteristics	N/A	N/A	N/A	No foaming Good degassing Needs some refining agents	No foaming Good degassing Needs some refining agents	N/A	N/A
Evaluation	Not acceptable Sporadic degassing. Cannot maintain steady state	Not acceptable (caking)	Not acceptable (caking)	Good as 2nd stage NO ₂ / NO ₃ Reactor	Good as 2nd stage NO ₂ / NO ₃ Reactor	Good as 2nd stage NO ₂ / NO ₃ Reactor	Good as 2nd stage NO ₂ / NO ₃ Reactor

*Information from crucible drying test with formic acid reductant. Based on these results, the actual RVR-S2 test was not conducted.

APPENDIX 2A

DATA SHEETS

Scoping Test - Datasheet

Test No. RVR-	Additive:	SUCROSE (110g/2)					Sht	of 3
Parameter	Unit	Readings						
Date:								
Time:		1130	1200	1230	1300	1330		
Hot Oil System								
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0		
Pump Outlet pressure PI-OUT	kPag	124	124	124	124	124		
Hot Oil Supply, temperature	°C	299	299	298	298	298		
Hot Oil Return, temperature	°C	297	296	295	297	295		
Expansion Tank level	cm		20	20	20	20		
RVR Dryer Bed Temperatures								
TI-1	°C	248	145	99	103	106		
TI-2	°C	266	236	206	273	202		
TI-3	°C	284	280	281	292	290		
TI-4	°C	260	253	258	262	265		
TI-5	°C	243	251	242	248	253		
Rotor Speed Setting	RPM	30	30	30	30	30		
Glass Former Feed Rate	kg/hr Dial #	45/10	45/10	45/10	45/10	45/10		
Total glass formers fed (this period)	kg	0	46	45				
Total dried product this period	kg	0	21	13				6.3
Total dried mixture output (accumulated)	kg	0						
Tank level reading	L	120	116	114	108	98		
Simulant/Additive Injection Rate	mL/min	425	425	425	425	425		
Total Simulant/Additive Input	L	0						
Off-Gas System								
Off-gas flow anemometer	m/s	0.44	0	0				
NO Reading	ppm	0	0	300				500
NO _x Reading	ppm	0	0	172				
Total NO _x Reading	ppm	0	0	472				
CO Reading	ppm	0		160				500
Recirc Line Temp - TI-SCB	°C	17	18	19	19	19		
Scrubber Level - LG-SCB	cm	0						
Off-gas Pressure - PI-OFG	kPag	0	0	0	0	0		
Vent Separator Level - LG-VENT	cm							
Vent Separator Temp - TI-VENT	°C							

① INST. NOT READING.

Scoping Test - Datasheet

Test No. RVR-		Additive: <i>Glucose</i>			Sht 2 of 3	
Parameter	Unit	Readings				
Date: <i>3/21/95</i>						
Time:		<i>1400</i>	<i>1430</i>	<i>1445</i>	<i>1455</i>	<i>1500</i>
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	<i>12</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>
Pump Outlet pressure PI-OUT	kPag	<i>124</i>	<i>124</i>			<i>124</i>
Hot Oil Supply, temperature	°C	<i>299</i>	<i>299</i>			<i>299</i>
Hot Oil Return, temperature	°C	<i>295</i>	<i>295</i>			<i>295</i>
Expansion Tank level	cm	<i>20</i>				
RVR Driver Bed Temperatures						
TI-1	°C	<i>104</i>	<i>104</i>	<i>115</i>	<i>129</i>	<i>114</i>
TI-2	°C	<i>166</i>	<i>219</i>	<i>145</i>	<i>309</i>	<i>251</i>
TI-3	°C	<i>303</i>	<i>293</i>	<i>320</i>	<i>338</i>	<i>291</i>
TI-4	°C	<i>279</i>	<i>276</i>	<i>278</i>	<i>286</i>	<i>277</i>
TI-5	°C	<i>264</i>	<i>266</i>	<i>266</i>	<i>267</i>	<i>267</i>
Rotor Speed Setting	RPM	<i>30</i>	<i>30</i>	<i>30</i>	<i>30</i>	<i>30</i>
Glass Former Feed Rate	kg/hr Dial #	<i>45/10</i>	<i>45/10</i>			
Total glass formers fed (this period)	kg					
Total dried product this period	kg	<i>7.3</i>	<i>7.1</i>			<i>8.5</i>
Total dried mixture output (accumulated)	kg					
Tank level reading	L	<i>92</i>	<i>82</i>			<i>68</i>
Simulant/Additive Injection Rate	mL/min	<i>425</i>				<i>425</i>
Total Simulant/Additive Input	L					
Off-Gas System						
Off-gas flow anemometer	m/s - Nm ³ /hr					
NO Reading	ppm	<i>500</i>	<i>500</i>			<i>500</i>
NO _x Reading	ppm	<i>400</i>	<i>300</i>			<i>500</i>
Total NO _x Reading	ppm	<i>900</i>	<i>800</i>			<i>1000</i>
CO Reading	ppm	<i>350</i>	<i>600</i>			<i>300</i>
Recirc Line Temp - TI-SCB	°C	<i>20</i>	<i>21</i>			<i>24</i>
Scrubber Level - LG-SCB	cm					
Off-gas Pressure - PI-OPG	kPag	<i>0</i>				
Vent Separator Level - LG-VENT	cm					
Vent Separator Temp - TI-VENT	°C					

WHC-SD-WM-VI-031
Revision 0
Scoping Test - Datasheet

Page 1 of 1

Test No. RVR-	Additive: SUCROSE	Sht 30: 3				
Parameter	Unit	Readings				
Date: 3/21/95					SPRINKLER FEED	
Time:		1530	1600	1630	1700	1730
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	124	124	124	124	139
Hot Oil Supply temperature	°C	298	278	293	298	218
Hot Oil Return temperature	°C	296	274	292	293	213
Expansion Tank level	cm	20	20			
RVR Dryer Bed Temperatures						
TI-1	°C	107	107	108	100	102
TI-2	°C	193	161	176	112	102
TI-3	°C	338	253	269	313	229
TI-4	°C	291	278	276	305	215
TI-5	°C	272	263	279	282	198
Rotor Speed Setting	RPM	30	30	30	30	60
Glass Former Feed Rate	kg/hr Dial #	45	45			
Total glass formers fed (this period)	kg	0	23.2	20.5	22.6	
Total dried product this period	kg	7.6	21.0	21.9	24.0	24.7
Total dried mixture output (accumulated)	kg					
Tank level reading	L	60	53	42		
Simulant/Additive Injection Rate	mL/min					
Total Simulant/Additive Input	L					
Off-Gas System						
Off-gas flow anemometer	m/s					
NO Reading	ppm	800	800	1000	650	
NO _x Reading	ppm	800	950	1600	1050	
Total NO _x Reading	ppm	1600	1750	2600	1700	
CO Reading	ppm	500	450	650	500	
Recirc Line Temp - TI-SCB	°C	26	27	28	29	
Scrubber Level - LG-SCB	cm					
Off-gas Pressure - PI-OFG	kPag	0	0			
Vent Separator Level - LG-VENT	cm					
Vent Separator Temp - TI-VENT	°C					

WHC-SD-WM-VI-031
Revision 0
Scoping Test - Datasheet

Page 1 of 1

Test No. RVR-		Additive:		Sht. / of /	
Parameter	Unit	Readings			
Date:		3/24/95			
Time:		1400			
Hot Oil System					
Pump Inlet pressure PI-IN	kPag	7			
Pump Outlet pressure PI-OUT	kPag	124			
Hot Oil Supply, temperature	°C	291			
Hot Oil Return, temperature	°C	286			
Expansion Tank level	cm				
RVR Dryer Bed Temperatures					
TI-1	°C	115			
TI-2	°C	121			
TI-3	°C	139			
TI-4	°C	277			
TI-5	°C	253			
Rotor Speed Setting	RPM	30			
Glass Former Feed Rate	kg/hr gal #	54.4			
Total glass formers fed (this period)	kg				
Total dried product this period	kg				
Total dried mixture output (accumulated)	kg				
Tank level reading	L	92			
Simulant/Additive Injection Rate	mL/min	0			
Total Simulant/Additive Input	L	16			
Off-Gas System					
Off-gas flow anemometer	m/s - m/hr	1000			
NO Reading	ppm	0			
NO _x Reading	ppm	0			
Total NO _x Reading	ppm	0			
CO Reading	ppm	0			
Recirc Line Temp - TI-SCB	°C				
Scrubber Level - LG-SCB	cm				
Off-gas Pressure - PI-OFG	kPag				
Vent Separator Level - LG-VENT	cm				
Vent Separator Temp - TI-VENT	°C				

Scoping Test - Datasheet

Test No. RVR-_____	Additive:_____	Sht 1 of 1			
Parameter	Unit	Readings			
Date: 3/25/95					
Time:		0900	0945		
Hot Oil System					
Pump Inlet pressure PI-IN	kPag				
Pump Outlet pressure PI-OUT	kPag				
Hot Oil Supply, temperature	°C	299			
Hot Oil Return, temperature	°C	297	289		
Expansion Tank level	cm				
RVR Driver Bed Temperatures					
TI-1	°C	244	83		
TI-2	°C	263	131		
TI-3	°C	252	175		
TI-4	°C	272	262		
TI-5	°C	202	224		
Rotor Speed Setting	RPM	36	36		
Glass Former Feed Rate	kg/hr Dial #	26.3	22.7		
Total glass formers fed (this period)	kg	13.9			
Total dried product this period	kg				
Total dried mixture output (accumulated)	kg				
Tank level reading	L	92	84		
Simulant/Additive Injection Rate	mL/min	0	350		
Total Simulant/Additive Input	L	16	22		
Off-Gas System					
Off-gas flow anemometer	m/s mL/hr	1200	0		
NO Reading	ppm	0	0		
NO _x Reading	ppm	0	0		
Total NO _x Reading	ppm	0	0		
CO Reading	ppm	0	0		
Recirc Line Temp - TI-SCB	°C				
Scrubber Level - LG-SCB	cm				
Off-gas Pressure - PI-OPG	kPag	0			
Vent Separator Level - LG-VENT	cm				
Vent Separator Temp - TI-VENT	°C				

Scoping Test - Datasheet

Test No. RVR-	Additive:	Sht 1 of 1				
Parameter	Unit	Readings				
Date: 3/26/95						
Time:		1850	1855	2030		
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0		
Pump Outlet pressure PI-OUT	kPag	152	152	152		
Hot Oil Supply, temperature	°C	107	108	111		
Hot Oil Return, temperature	°C	104	106	109		
Expansion Tank level	cm	10	10			
RVR Dryer Bed Temperatures						
TI-1	°C	67	57	57		
TI-2	°C	49	90	74		
TI-3	°C	44	49	86		
TI-4	°C	87	86	60		
TI-5	°C	83	84	93		
Rotor Speed Setting	RPM					
Glass Former Feed Rate	Kg/hr Dial #	27.2 11	27.2 11	27.2 11		
Total glass formers fed (this period)	kg		47.5	35.7		
Total dried product this period	kg		~~5.9~~			
Total dried mixture output (accumulated)	kg		5.9			
Tank level reading	L	240	230	222		
Simulant/Additive Injection Rate	mL/min	400				
Total Simulant/Additive Input	L		10	18		
Off-Gas System						
Off-gas flow anemometer	m ³ NmL/hr	6.7	6.5			
NO Reading	ppm					
NO ₂ Reading	ppm					
Total NO _x Reading	ppm					
CO Reading	ppm					
Recirc Line Temp - TI-SCB	°C					
Scrubber Level - LG-SCB	cm	33				
Off-gas Pressure - PI-OFG	kPag	0				
Vent Separator Level - LG-VENT	cm					
Vent Separator Temp - TI-VENT	°C					

Scoping Test - Datasheet

Test No. RVR-	Additive: NONE	Sht. 1 of 2				
Parameter	Unit	Readings				
Date: 3/27/95						
Time:		0330	0400	0430	0500	0530
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	152	152	152	152	152
Hot Oil Supply, temperature	°C	112	129	161	163	165
Hot Oil Return, temperature	°C	110	127	157	161	161
Expansion Tank level	cm	10	10	10	10	10
RVR Dryer Bed Temperatures						
TI-1	°C	74	69	83	111	116
TI-2	°C	62	57	68	72	125
TI-3	°C	80	87	115	124	128
TI-4	°C	77	69	109	118	116
TI-5	°C	97	99	109	132	132
Rotor Speed Setting	RPM	34	34	34	34	34
Glass Former Feed Rate	kg/hr Dial #	27.2	27.2	27.2	27.2	27.2
Total glass formers fed (this period)	kg					35.5
Total dried product this period	kg		8.7	7.6	8.5	7.4
Total dried mixture output (accumulated)	kg		8.7	16.3	24.8	32.4
Tank level reading	L	220	210	201	192	184
Simulant/Additive Injection Rate	mL/min	300	300	300	300	300
Total Simulant/Additive Input	L		10	19	28	36
Off-Gas System						
Off-gas flow anemometer	m/s ~~min/max~~	7.0	—	—	6.1	5.5
NO Reading	ppm	0	0	0	0	0
NO _x Reading	ppm	0	0	0	0	0
Total NO _x Reading	ppm	0	0	0	0	0
CO Reading	ppm	0	0	0	0	0
Recirc Line Temp - TI-SCB	°C	13	13	13	14	15
Scrubber Level - LG-SCB	cm	16	33	33	66	22
Off-gas Pressure - PI-OFG	kPag	0	0	0	0	0
Vent Separator Level - LG-VENT	cm					
Vent Separator Temp - TI-VENT	°C					

Scoping Test - Datasheet

Test No. RVR-	Additive:	Sht 2 of 2			
Parameter	Unit	Readings			
Date: 3/27/95					
Time:		0600	0630	0700	0800
Hot Oil System					
Pump Inlet pressure PI-IN	kPag	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	152	145	145	152
Hot Oil Supply, temperature	°C	162	167	166	114
Hot Oil Return, temperature	°C	161	163	165	113
Expansion Tank level	cm	10	10	10	10
RVR Dryer Bed Temperatures					
TI-1	°C	114	86	123	66
TI-2	°C	123	131	127	77
TI-3	°C	132	133	134	88
TI-4	°C	114	121	139	106
TI-5	°C	144	133	151	110
Rotor Speed Setting	RPM	34	34	34	38
Glass Former Feed Rate	kg/hr Dial #	27.2/9	27.2/9	27.2/9	27.2/9
Total glass formers fed (this period)	kg				35.4
Total dried product this period	kg	11.7	12.6	16.2	14.4
Total dried mixture output (accumulated)	kg	44.1	56.7	66.9	
Tank level reading	L	174	168	161	154
Simulant/Additive Injection Rate	mL/min	300	300	300	300
Total Simulant/Additive Input	L	46	52	59	66
Off-Gas System					
Off-gas flow anemometer	m/s ~~nm/hr~~	5.3	5.6	5.4	4.3
NO Reading	ppm	0	0	0	0
NO _x Reading	ppm	0	0	0	0
Total NO _x Reading	ppm	0	0	0	0
CO Reading	ppm	0	0	0	0
Recirc Line Temp - TI-SCB	°C	16	16	17	19
Scrubber Level - LG-SCB	cm	22	33	33	33
Off-gas Pressure - PI-OFG	kPag	0	0	0	0
Vent Separator Level - LG-VENT	cm				
Vent Separator Temp - TI-VENT	°C				

Scoping Test - Datasheet

Test No. RVR-	Additive:	Sht/ of 4				
Parameter	Unit	Readings				
Date:	3-29-95					
Time:		0930	1000	1030	1100	1130
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	165	165	165	165	165
Hot Oil Supply, temperature	°C	110	112	109	109	112
Hot Oil Return, temperature	°C	109	109	108	109	111
Expansion Tank level	cm	10	10	10	10	10
RVR Dryer Bed Temperatures						
TI-1	°C	59	68	66	64	71
TI-2	°C	32	46	50	76	53
TI-3	°C	78	64	86	85	84
TI-4	°C	52	66	67	62	65
TI-5	°C	53	72	83	76	90
Rotor Speed Setting	RPM	30	30	34	34	34
Glass Former Feed Rate	Kg/hr Dial #	27.2 9				→
Total glass formers fed (this period)	kg	START N/11 Hoggar 11	—	—	—	—
Total dried product this period	kg	—	—	0.76	2.29	3.19
Total dried mixture output (accumulated)	kg				3.10	6.29
Tank level reading	L	150	144	140	136	134
Simulant/Additive Injection Rate	mL/min	400				→
Total Simulant/Additive Input	L		6	10	14	16
Off-Gas System						
Off-gas flow annemometer	M/S Nm ³ /hr	6.3	0.36	1.33	6.35	6.12
NO Reading	ppm					
NO ₂ Reading	ppm					
Total NO _x Reading	ppm					
CO Reading	ppm					
Recirc Line Temp - TI-SCB	°C	13	15	16	17	18
Scrubber Level - LG-SCB	cm	33	33	33	22	22
Off-gas Pressure - PI-OFG	kPag					
Vent Separator Level - LG-VENT	cm/in					
Vent Separator Temp - TI-VENT	°C					

Scoping Test - Datasheet

Test No. RVR-	Additive:	NONE					shc 2 of 4
Parameter	Unit	Readings					
Date:							
Time:		1200	1230	1300	1330	1400	
Hot Oil System							
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0	
Pump Outlet pressure PI-OUT	kPag	165	159	159	159	159	
Hot Oil Supply, temperature	°C	112	112	112	109	110	
Hot Oil Return, temperature	°C	109	109	112	109	108	
Expansion Tank level	cm	10	10	10	10	10	
RVR Dryer Bed Temperatures							
TI-1	°C	69	95	102	79	78	
TI-2	°C	87	87	52	88	78	
TI-3	°C	83	91	99	88	91	
TI-4	°C	74	81	89	68	72	
TI-5	°C	94	102	108	107	86	
Rotor Speed Setting	RPM	34	34	34	34	34	
Glass Former Feed Rate	Kg/hr Dial #	27.21 9					
Total glass formers fed (this period)	kg	—	—	—	35.15		
Total dried product this period	kg	1.36	0.93	1.18	2.88	2.70	
Total dried mixture output (accumulated)	kg	7.66	8.58	9.76	12.64	15.35	
Tank level reading	L	186	186	186	178	175	
Simulant/Additive Injection Rate	mL/min	400					
Total Simulant/Additive Input	L				24	27	
Off-Gas System							
Off-gas flow anemometer	m/s ~~m/s~~	6.22	4.61	4	4	5.5	
NO Reading	ppm						
NO _x Reading	ppm						
Total NO _x Reading	ppm						
CO Reading	ppm						
Recirc Line Temp - TI-SCB	°C	19	19	19	20	20	
Scrubber Level - LG-SCB	cm						
Off-gas Pressure - PI-OFG	kPag						
Vent Separator Level - LG-VENT	cm/in	17	17	17	17	22	
Vent Separator Temp - TI-VENT	°C						

Scoping Test - Datasheet

Page 1 of 4

Test No. RVR-		Additive: NONE		Sht 3 of 4		
Parameter	Unit	Readings				
Date:	3-29-95					
Time:		1430	1500	1530	1600	1630
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	165	165	165	165	165
Hot Oil Supply, temperature	°C	110	110	109	111	112
Hot Oil Return, temperature	°C	109	108	109	110	112
Expansion Tank level	cm	10	10	10	10	10
RVR Dryer Bed Temperatures						
TI-1	°C	68	77	66	74	91
TI-2	°C	84	68	68	67	72
TI-3	°C	91	91	92	89	90
TI-4	°C	83	79	84	86	88
TI-5	°C	107	106	106	95	110
Rotor Speed Setting	RPM	34	34	34	34	34
Glass Former Feed Rate	kg/hr Dial #	27.21 9	27.21 9	27.21 9	27.21 9	27.21 9
Total glass formers fed (this period)	kg	—	—	—	3560	—
Total dried product this period	kg	6.67	13.89	9.05	7.78	3.01
Total dried mixture output (accumulated)	kg	22.01	35.90	44.95	52.83	55.85
Tank level reading	L	171	166	162	160	156
Simulant/Additive Injection Rate	mL/min	400				→
Total Simulant/Additive Input	L	31	36	40	42	46
Off-Gas System						
Off-gas flow anemometer	m/s ~~mm³/hr~~	4.8	5.6	5.22	5.05	
NO Reading	ppm					
NO ₂ Reading	ppm					
Total NO _x Reading	ppm					
CO Reading	ppm					
Recirc Line Temp - TI-SCB	°C	21	21	22	22	22
Scrubber Level - LG-SCB	cm					
Off-gas Pressure - PI-OFG	kPag	0	0	0	0	0
Vent Separator Level - LG-VENT	cm/in	22	33	33	33	33
Vent Separator Temp - TI-VENT	°C					

Scoping Test - Datasheet

Test No. RVR-	Additive: <i>NONE</i>	Sht 4 of 4			
Parameter	Unit	Readings			
Date: <i>3-29-95</i>					
Time:		<i>1700</i>	<i>1800</i>		
Hot Oil System					
Pump Inlet pressure PI-IN	kPag	<i>0</i>			
Pump Outlet pressure PI-OUT	kPag	<i>165</i>			
Hot Oil Supply, temperature	°C	<i>112</i>			
Hot Oil Return, temperature	°C	<i>110</i>			
Expansion Tank level	cm	<i>10</i>			
RVR Dryer Bed Temperatures					
TI-1	°C	<i>102</i>	<i>88</i>		
TI-2	°C	<i>61</i>	<i>41</i>		
TI-3	°C	<i>96</i>	<i>98</i>		
TI-4	°C	<i>96</i>	<i>93</i>		
TI-5	°C	<i>112</i>	<i>108</i>		
Rotor Speed Setting	RPM	<i>34</i>	<i>34</i>	<i>S/D</i>	
Glass Former Feed Rate	kg/hr Dial #				
Total glass formers fed (this period)	kg				
Total dried product this period	kg	<i>3.94</i>	<i>10.66</i>		
Total dried mixture output (accumulated)	kg	<i>59.78</i>	<i>70.41</i>		
Tank level reading	L	<i>156</i>	<i>156</i>		
Simulant/Additive Injection Rate	mL/min				
Total Simulant/Additive Input	L	<i>46</i>	<i>46</i>		
Off-Gas System					
Off-gas flow anemometer	m/s mm²/hr	<i>3.10</i>			
NO Reading	ppm				
NO _x Reading	ppm				
Total NO _x Reading	ppm				
CO Reading	ppm				
Recirc Line Temp - TI-SCB	°C	<i>23</i>			
Scrubber Level - LG-SCB	cm	<i>33</i>	<i>MS</i>		
Off-gas Pressure - PI-OFG	kPag				
Vent Separator Level - LG-VENT	cm/in	<i>33</i>			
Vent Separator Temp - TI-VENT	°C				

WHC-SD-WM-VI-031
Revision 0

Scoping Test - Datasheet

Page 1 of 3

Test No. RVR-		Additive: <i>NONE</i>			Sht 1 of 3	
Parameter	Unit	Readings				
Date:						
Time:		1030	1100	1130	1200	1230
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	165	165	165	165	165
Hot Oil Supply, temperature	°C	112	112	109	109	111
Hot Oil Return, temperature	°C	109	110	111	109	109
Expansion Tank level	cm	10	10	10	10	10
RVR Dryer Bed Temperatures						
TI-1	°C	47	64	68	63	57
TI-2	°C	48	47	54	61	50
TI-3	°C	82	69	87	91	92
TI-4	°C	78	72	75	92	86
TI-5	°C	94	87	93	77	106
Rotor Speed Setting	RPM	34	34	34	34	34
Glass Former Feed Rate	Kg/hr Dial #	27.4 9				
Total glass formers fed (this period)	kg	-	-	-	-	-
Total dried product this period	kg	-	5.21	1.02	2.01	3.69
Total dried mixture output (accumulated)	kg		5.21	6.23	8.24	11.94
Tank level reading	L	206	200	194	192	186
Simulant/Additive Injection Rate	mL/min	400				
Total Simulant/Additive Input	L		6	12	14	20
Off-Gas System						
Off-gas flow annemometer	M ³ /hr					
NO Reading	ppm					
NO ₂ Reading	ppm					
Total NO _x Reading	ppm					
CO Reading	ppm					
Recirc Line Temp - TI-SCB	°C	18	18	19	20	21
Scrubber Level - LG-SCB	cm					
Off-gas Pressure - PI-OFG	kPag					
Vent Separator Level - LG-VENT	cm/in	22/9	22/9	33/13	22/9	17/7
Vent Separator Temp - TI-VENT	°C					

Scoping Test - Datasheet

Page 1 of 3

Test No. RVR-		Additive: NONE		Shc 2 of 3		
Parameter	Unit	Readings				
Date:	3-30-95					
Time:		1300	1330	1400	1430	1500
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	165	165	165	165	165
Hot Oil Supply, temperature	°C	109	109	110	109	111
Hot Oil Return, temperature	°C	109	109	108	109	109
Expansion Tank level	cm	10	10	10	10	10
RVR Dryer Bed Temperatures						
TI-1	°C	67	72	48	74	79
TI-2	°C	56	53	63	62	63
TI-3	°C	92	92	84	69	92
TI-4	°C	72	69	79	91	86
TI-5	°C	86	80	89	79	98
Rotor Speed Setting	RPM	34	34	34	34	34
Glass Former Feed Rate	kg/hr Dial #	27.2 9				
Total glass formers fed (this period)	kg					
Total dried product this period	kg	3.41	1.46	0.74	1.71	3.57
Total dried mixture output (accumulated)	kg	15.05	16.51	17.25	18.96	22.53
Tank level reading	L	184	181	179	174	168
Simulant/Additive Injection Rate	mL/min	400				
Total Simulant/Additive Input	L	22	25	27	32	38
Off-Gas System						
Off-gas flow anemometer	M ₁ , M ₂ /hr			3.88		
NO Reading	ppm					
NO ₂ Reading	ppm					
Total NO ₂ Reading	ppm					
CO Reading	ppm					
Recirc Line Temp - TI-SCB	°C	21	21	22	22	22
Scrubber Level - LG-SCB	cm					
Off-gas Pressure - PI-OFG	kPag					
Vent Separator Level - LG-VENT	cm/in	8 3/25	33/13	33/13	33/13	22/9
Vent Separator Temp - TI-VENT	°C					

Scoping Test - Datasheet

Test No. RVR-		Additive: NONE		Sht 3 of 3	
Parameter	Unit	Readings			
Date:	3-30-95				
Time:		1530	1600	---	END (1830)
Hot Oil System					
Pump Inlet pressure PI-IN	kPag	0	0		
Pump Outlet pressure PI-OUT	kPag	165	165		
Hot Oil Supply, temperature	°C	107	112		
Hot Oil Return, temperature	°C	109	109		
Expansion Tank level	cm	10	10		
RVR Dryer Bed Temperatures					
TI-1	°C	77	75		
TI-2	°C	58	60		
TI-3	°C	84	94		
TI-4	°C	81	81		
TI-5	°C	79	103		
Rotor Speed Setting	RPM	34	34		
Glass Former Feed Rate	kg/hr Dial #				
Total glass formers fed (this period)	kg				
Total dried product this period	kg	1.55		16.59	19.37
Total dried mixture output (accumulated)	kg	~~54.20~~ 55.75	24.18	40.77	60.13
Tank level reading	L	168	166	163	
Simulant/Additive Injection Rate	mL/min				
Total Simulant/Additive Input	L	38	40	43	
Off-Gas System					
Off-gas flow anemometer	mL, Nm³/hr	1.0	3.76		
NO Reading	ppm				
NO _x Reading	ppm				
Total NO _x Reading	ppm				
CO Reading	ppm				
Recirc Line Temp - TI-SCB	°C	22	22		
Scrubber Level - LG-SCB	cm				
Off-gas Pressure - PI-OFG	kPag				
Vent Separator Level - LG-VENT	cm/in	33/13	33/13		
Vent Separator Temp - TI-VENT	°C				

Scoping Test - Datasheet

Page 1 of 4

Test No. RVR-	Additive:	NCNE					Sht 1 of 4
Parameter	Unit	Readings					
Date:		3-31-95					
Time:		0800	0830	0900	0930	1000	
Hot Oil System							
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0	
Pump Outlet pressure PI-OUT	kPag	159	165	165	165	165	
Hot Oil Supply, temperature	°C	111	110	111	110	111	
Hot Oil Return, temperature	°C	109	109	110	109	109	
Expansion Tank level	cm	10	10	10	10	10	
RVR Dryer Bed Temperatures							
TI-1	°C	76	69	64	72	67	
TI-2	°C	57	63	61	71	62	
TI-3	°C	72	63	76	83	93	
TI-4	°C	71	83	73	78	77	
TI-5	°C	76	79	83	82	87	
Rotor Speed Setting	RFM	34	34	34	34	34	
Glass Former Feed Rate	Kg/hr Dial #	27.21 9					
Total glass formers fed (this period)	kg				3.65		
Total dried product this period	kg				1.40	1.90	
Total dried mixture output (accumulated)	kg				1.40	3.29	
Tank level reading	L	162	159	154	151	148	
Simulant/Additive Injection Rate	mL/min						
Total Simulant/Additive Input	L		3	8	11	14	
Off-Gas System							
Off-gas flow anemometer	m ³ /hr						
NO Reading	ppm						
NO ₂ Reading	ppm						
Total NO ₂ Reading	ppm						
CO Reading	ppm						
Recirc Line Temp - TI-SCB	°C	19	20	21	22	23	
Scrubber Level - LG-SCB	cm	50	33	33	22	66	
Off-gas Pressure - PI-OPG	kPag						
Vent Separator Level - LG-VENT	cm/in						
Vent Separator Temp - TI-VENT	°C						

Scoping Test - Datasheet

Test No. RVR-	Additive:	NONE					Sht 2 of 4
Parameter	Unit	Readings					
Date:							
Time:		1030	1100	1130	1200	1230	
Hot Oil System							
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0	
Pump Outlet pressure PI-OUT	kPag	165	165	165	165	165	
Hot Oil Supply, temperature	°C	112	111	112	112	110	
Hot Oil Return, temperature	°C	110	111	111	111	108	
Expansion Tank level	cm	-10	10	10	10	10	
RVR Dryer Bed Temperatures							
TI-1	°C	77	78	68	71	64	
TI-2	°C	69	74	66	67	66	
TI-3	°C	78	86	88	92	96	
TI-4	°C	86	85	89	68	78	
TI-5	°C	72	99	99	76	97	
Rotor Speed Setting	RPM	34	34	34	34	34	
Glass Former Feed Rate	kg/hr Dial #	27.21 9					
Total glass formers fed (this period)	kg						
Total dried product this period	kg	1.55	1.32	5.75	3.19	1.88	
Total dried mixture output (accumulated)	kg	4.84	11.91	11.91	15.10	16.98	
Tank level reading	L	141	142	140	136	130	
Simulant/Additive Injection Rate	m L/min						
Total Simulant/Additive Input	L	18	20	22	26	32	
Off-Gas System							
Off-gas flow annemometer	m/s $\Delta m^2/hr$						
NO Reading	ppm						
NO ₂ Reading	ppm						
Total NO _x Reading	ppm						
CO Reading	ppm						
Recirc Line Temp - TI-SCB	°C	24	26	27	27	29	
Scrubber Level - LG-SCB	cm	33	33	33	33	33	
Off-gas Pressure - PI-OFG	kPag						
Vent Separator Level - LG-VENT	cm/in						
Vent Separator Temp - TI-VENT	°C						

Scoping Test - Datasheet

Test No. RVR-	Additive:	NONE					Sht 3 of 4
Parameter	Unit	Readings					
Date: 3-31-95							
Time:		1300	1330	1400	1430	1500	
Hot Oil System							
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0	
Pump Outlet pressure PI-OUT	kPag	165	165	165	165	165	
Hot Oil Supply, temperature	°C	110	110	109	110	111	
Hot Oil Return, temperature	°C	110	110	111	111	112	
Expansion Tank level	cm	10	10	10	10	10	
RVR Dryer Bed Temperatures							
TI-1	°C	~~78~~ 81	81	79	84	79	
TI-2	°C	78	66	70	76	79	
TI-3	°C	93	93	—	—	—	
TI-4	°C	89	95	96	83	84	
TI-5	°C	102	108	113	100	106	
Rotor Speed Setting	RPM	341	34	34	34	34	
Glass Former Feed Rate	Kg/hr Dial #						
Total glass formers fed (this period)	kg						35.83
Total dried product this period	kg	1.05	2.17	6.73	447	1.41	
Total dried mixture output (accumulated)	kg	18.03	20.20	26.93	31.40	32.82	
Tank level reading add simulant - from 13010211L —→		211	209	208	204	202	
Simulant/Additive Injection Rate	mL/min						
Total Simulant/Additive Input	L	32	34	35	39	41	
Off-Gas System							
Off-gas flow annemometer	m ³ /hr						
NO Reading	ppm						
NO ₂ Reading	ppm						
Total NO _x Reading	ppm						
CO Reading	ppm						
Recirc Line Temp - TI-SCB	°C	31	33	33	36	37	
Scrubber Level - LG-SCB	cm	33	33	33	33	33	
Off-gas Pressure - PI-OFG	kPag						
Vent Separator Level - LG-VENT	cm/in						
Vent Separator Temp - TI-VENT	°C						

Scoping Test - Datasheet

Page 1 of

Test No. RVR-	Additive:	NONE			Sht 4 of 4
Parameter	Unit	Readings			
Date: 3-31-95					
Time:		1530	1600	1630	
Hot Oil System					
Pump Inlet pressure PI-IN	kPag	0	0	0	
Pump Outlet pressure PI-OUT	kPag	165	165	165	
Hot Oil Supply, temperature	°C	111	112	112	
Hot Oil Return, temperature	°C	112	110	109	
Expansion Tank level	cm	10	10	10	
RVR Dryer Bed Temperatures					
TI-1	°C	85	81	85	
TI-2	°C	75	71	75	
TI-3	°C	98	83	86	
TI-4	°C	92	83	86	
TI-5	°C	105	97	81	
Rotor Speed Setting	RPM	34	34	34	
Glass Former Feed Rate	kg/hr Dial #				
Total glass formers fed (this period)	kg				
Total dried product this period	kg	2.11	1.06	0.84	
Total dried mixture output (accumulated)	kg	34.93	35.98	36.83	51.42 - Total
Tank level reading	L	200	196	194	
Simulant/Additive Injection Rate	mL/min				
Total Simulant/Additive Input	L	43	47	49	
Off-Gas System					
Off-gas flow annemometer	m ³ /hr				
NO Reading	ppm				
NO ₂ Reading	ppm				
Total NO _x Reading	ppm				
CO Reading	ppm				
Recirc Line Temp - TI-SCB	°C	38	39	41	
Scrubber Level - LG-SCB	cm				
Off-gas Pressure - PI-OFG	kPag				
Vent Separator Level - LG-VENT	cm/in	33/13	22/9	22/9	
Vent Separator Temp - TI-VENT	°C				

Scoping Test - Datasheet

Test No. RVR-		Additive: NONE			Page 1 of 1		
Sht/ of 4							
Parameter		Unit	Readings				
Date: 4-2-95							
Time:			0800	0830	0900	0930 1000	
Hot Oil System							
Pump Inlet pressure PI-IN		kPag	0	0	0	0	
Pump Outlet pressure PI-OUT		kPag	159	165	165	165 165	
Hot Oil Supply, temperature		°C	111	111	112	111 110	
Hot Oil Return, temperature		°C	109	111	110	111 111	
Expansion Tank level		cm	10	10	10	10 10	
RVR Dryer Bed Temperatures							
TI-1		°C	61	76	77	78 75	
TI-2		°C	63	77	76	73 76	
TI-3		°C	81	88	66	83 76	
TI-4		°C	87	80	83	87 70	
TI-5		°C	102	92	87	89 78	
Rotor Speed Setting		RPM	34	34	34	34 34	
Glass Former Feed Rate		kg/hr Dial #	27.21 9	→			
Total glass formers fed (this period)		kg					
Total dried product this period		kg	6.0	3.07	0.80	1.54 4.34	
Total dried mixture output (accumulated)		kg	6.0	9.06	9.86	11.40 15.74	
Tank level reading		L	194	188	185	182 180	
Simulant/Additive Injection Rate		m L/min	400	→			
Total Simulant/Additive Input		L		6	9	12 14	
Off-Gas System							
Off-gas flow anemometer		m ³ /hr					
NO Reading		ppm					
NO ₂ Reading		ppm					
Total NO _x Reading		ppm					
CO Reading		ppm					
Recirc Line Temp - TI-SCB		°C	21	21	21	22 22	
Scrubber Level - LG-SCB		cm	33	44	33	33 22	
Off-gas Pressure - PI-OFG		kPag					
Vent Separator Level - LG-VENT		cm/in					
Vent Separator Temp - TI-VENT		°C					

Scoping Test - Datasheet

Page 1 of 4

Test No. RVR-		Additive: NONE			Sht 2 of 4		
Parameter		Unit	Readings				
Date: 4-2-95							
Time:			1030	1100	1130	1200	1230
Hot Oil System							
Pump Inlet pressure PI-IN		kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT		kPag	165	165	165	165	165
Hot Oil Supply, temperature		°C	111	112	112	109	111
Hot Oil Return, temperature		°C	109	109	111	111	109
Expansion Tank level		cm	10	10	10	10	10
RVR Dryer Bed Temperatures							
TI-1		°C	77	76	73	78	75
TI-2		°C	76	76	76	74	78
TI-3		°C	81	88	85	87	97
TI-4		°C	78	89	64	83	82
TI-5		°C	86	103	87	93	89
Rotor Speed Setting		RPM	34	34	34	34	34
Glass Former Feed Rate		kg/hr Dial #					
Total glass formers fed (this period)		kg					
Total dried product this period		kg	1.28	2.93	2.91	2.48	1.98
Total dried mixture output (accumulated)		kg	17.02	19.95	22.86	25.33	27.31
Tank level reading		L	176	174	172	168	167
Simulant/Additive Injection Rate		mL/min					
Total Simulant/Additive Input		L	18	20	22	26	27
Off-Gas System							
Off-gas flow anemometer		m ³ /h - Nm ³ /hr					
NO Reading		ppm					
NO ₂ Reading		ppm					
Total NO _x Reading		ppm					
CO Reading		ppm					
Recirc Line Temp - TI-SCB		°C	23	23	24	24	25
Scrubber Level - LG-SCB		cm	17	44	22	22	22
Off-gas Pressure - PI-OFG		kPag					
Vent Separator Level - LG-VENT		cm/in					
Vent Separator Temp - TI-VENT		°C					

Scoping Test - Datasheet

Test No. RVR-	Additive:	NONE					Shc 3 of 4
Parameter	Unit	Readings					
Date: 4-2-95							
Time:		1300	1330	1400	1430	1500	
Hot Oil System							
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0	
Pump Outlet pressure PI-OUT	kPag	165	165	165	165	165	
Hot Oil Supply, temperature	°C	111	111	110	112	110	
Hot Oil Return, temperature	°C	111	109	111	112	111	
Expansion Tank level	cm						
RVR Dryer Bed Temperatures							
TI-1	°C	74	75	83	72	72	
TI-2	°C	77	76	72	74	69	
TI-3	°C	87	92	94	86	88	
TI-4	°C	96	82	85	89	83	
TI-5	°C	103	91	91	98	96	
Rotor Speed Setting	RPM	34	34	34	34	34	
Glass Former Feed Rate	kg/hr Dial #						
Total glass formers fed (this period)	kg						35.24
Total dried product this period	kg	4.44	268	2.10	2.21	3.06	
Total dried mixture output (accumulated)	kg	31.76	3443	36.54	38.75	41.80	
Tank level reading	L	164	161	157	156	152	
Simulant/Additive Injection Rate	mL/min	400					
Total Simulant/Additive Input	L	30	33	37	38	42	
Off-Gas System							
Off-gas flow annemometer	m ³ /hr						
NO Reading	ppm						
NO ₂ Reading	ppm						
Total NO _x Reading	ppm						
CO Reading	ppm						
Recirc Line Temp - TI-SCB	°C	26	26	26	26	26	
Scrubber Level - LG-SCB	cm	22	33	-0-	33	22	
Off-gas Pressure - PI-OFG	kPag						
Vent Separator Level - LG-VENT	cm/in						
Vent Separator Temp - TI-VENT	°C						

Scoping Test - Datasheet

Test No. RVR-		Additive: <i>NONE</i>		Page 1 of 1		
Sht 4 of 4						
Parameter		Unit	Readings			
Date: <i>4-2-95</i>						
Time:			1530	1600	1630	1700
Hot Oil System						
Pump Inlet pressure PI-IN		kPag	0	0	0	0
Pump Outlet pressure PI-OUT		kPag	165	165	165	165
Hot Oil Supply, temperature		°C	111	112	111	112
Hot Oil Return, temperature		°C	111	111	112	111
Expansion Tank level		cm	10	10	10	10
RVR Dryer Bed Temperatures						
TI-1		°C	84	84	88	82
TI-2		°C	70	77	71	101
TI-3		°C	77	96	96	92
TI-4		°C	84	93	96	101
TI-5		°C	68	90	105	112
Rotor Speed Setting		RPM	34	34	34	34
Glass Former Feed Rate		kg/hr Dial #				
Total glass formers fed (this period)		kg	0			
Total dried product this period		kg	0.44	0.99	4.15	5.96
Total dried mixture output (accumulated)		kg	42.24	43.23	47.37	53.33
Tank level reading		L	152	151	150	148
Simulant/Additive Injection Rate		mL/min				
Total Simulant/Additive Input		L	42	43	44	46
Off-Gas System						
Off-gas flow anemometer		m ³ /hr				
NO Reading		ppm				
NO ₂ Reading		ppm				
Total NO _x Reading		ppm				
CO Reading		ppm				
Recirc Line Temp - TI-SCB		°C	26	26	26	27
Scrubber Level - LG-SCB		cm	33	33	33	33
Off-gas Pressure - PI-ORG		kPag				
Vent Separator Level - LG-VENT		cm/in				
Vent Separator Temp - TI-VENT		°C				

Scoping Test - Datasheet

Test No. RVR- 4		Additive: SUCROSE (60%)			Sht / of 3		
Parameter		Unit	Readings				
Date: 4-5-95							
Time:			1230	1245	1300	1330	1345
Hot Oil System							
Pump Inlet pressure PI-IN		kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT		kPag	124	124	124	124	124
Hot Oil Supply, temperature		°C	297	297	296	297	296
Hot Oil Return, temperature		°C	—	294	294	295	294
Expansion Tank level		cm	20	20	20	20	20
RVR Dryer Bed Temperatures							
TI-1		°C	249	166	175	171	158
TI-2		°C	266	277	296	293	292
TI-3		°C	212	266	287	301	297
TI-4		°C	263	266	278	287	284
TI-5		°C	179	189	202	215	224
Rotor Speed Setting		RPM	34	34	34	34	34
Glass Former Feed Rate		Kg/hr pial #		54	54	54	
Total glass formers fed (this period)		56.7 kg glass/pil + 11.57 SUCROSE/kg					
Total dried product this period		kg				12.24	12.87
Total dried mixture output (accumulated)		kg				12.24	25.12
Tank level reading		L					
Simulant/Additive Injection Rate		mL/min					
Total Simulant/Additive Input		L					
Off-Gas System							
Off-gas flow annemometer		m/s Nm ³ /hr	1.78	1.13	1.16	0.5	1.45
NO Reading		ppm	0	71	111	10	5
NO ₂ Reading		ppm	0	9	19	2	2
Total NO ₂ Reading		ppm	0	80	130	12	7
CO Reading		ppm	0	10	20	43	19
Recirc Line Temp - TI-SCB		°C	18	18	19	19	20
Scrubber Level - LG-SCB		cm	33	50	33	33	33
Off-gas Pressure - PI-OFG		kPag					
Vent Separator Level - LG-VENT		cm/in					
Vent Separator Temp - TI-VENT		°C					

Scoping Test - Datasheet

Test No. RVR-		Additive: SUCROSE (80%)		Sht 2 of 3		
Parameter	Unit	Readings				
Date:	4-5-95					
Time:		1530	1545	1600	1615	1630
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	124	124	124	124	124
Hot Oil Supply, temperature	°C	296	296	297	296	298
Hot Oil Return, temperature	°C	294	294	295	295	294
Expansion Tank level	cm	20	20	20	20	20
RVR Dryer Bed Temperatures						
TI-1	°C	255	163	272	263	146
TI-2	°C	267	293	345	242	243
TI-3	°C	224	282	274	231	280
TI-4	°C	272	275	280	272	275
TI-5	°C	191	193	198	191	187
Rotor Speed Setting	RPM	34	34	34	34	34
Glass Former Feed Rate	kg/hr Dial #	54.42				
Total glass formers fed (this period)	kg		59.18			
Total dried product this period	kg	15.25 11.05		12.89		
Total dried mixture output (accumulated)	kg	26.29		39.18		
Tank level reading	L					
Simulant/Additive Injection Rate	mL/min					
Total Simulant/Additive Input	L					
Off-Gas System						
Off-gas flow annemometer	W5 Nm ³ /hr	1.00	0.44	1.70	0.70	0.44
NO Reading	ppm	0	182	142	1.9	21
NO _x Reading	ppm	0	33	22	0.6	4
Total NO _x Reading	ppm	0	215	164	2.5	25
CO Reading	ppm	0	53	32	0	36
Recirc Line Temp - TI-SCB	°C	21	21	21	21	22
Scrubber Level - LG-SCB	cm	33	33	44	44	44
Off-gas Pressure - PI-OEG	kPag					
Vent Separator Level - LG-VENT	cm/in					
Vent Separator Temp - TI-VENT	°C					

Scoping Test - Datasheet

Test No. RVR-		Additive: <i>GLUCOSE (80%)</i>		Sht 3 of 3	
Parameter	Unit	Readings			
Date:					
Time:		1700	1715		
Hot Oil System					
Pump Inlet pressure PI-IN	kPag	0	0		
Pump Outlet pressure PI-OUT	kPag	124	124		
Hot Oil Supply, temperature	°C	297	288		
Hot Oil Return, temperature	°C	295	289		
Expansion Tank level	cm	20	20		
RVR Dryer Bed Temperatures					
TI-1	°C	146	139		
TI-2	°C	267	261		
TI-3	°C	303	311		
TI-4	°C	283	287		
TI-5	°C	192	249		
Rotor Speed Setting	RPM	34	34		
Glass Former Feed Rate	Kg/hr Dial #	54.42	→		
Total glass formers fed (this period)	kg				
Total dried product this period	kg	12.91	~~13.80~~ 10.45		
Total dried mixture output (accumulated)	kg		53.46		
Tank level reading	L				
Simulant/Additive Injection Rate	mL/min				
Total Simulant/Additive Input	L				
Off-Gas System					
Off-gas flow anemometer	m/s ~~mm/hr~~	1.85	—		
NO Reading	ppm	28	30		
NO _x Reading	ppm	6	7		
Total NO _x Reading	ppm	34	37		
CO Reading	ppm	60	72		
Recirc Line Temp - TI-SCB	°C	22	22		
Scrubber Level - LG-SCB	cm	33	33		
Off-gas Pressure - PI-OFG	kPag				
Vent Separator Level - LG-VENT	cm/in				
Vent Separator Temp - TI-VENT	°C				

Scoping Test - Datasheet

Page 1 of 1

Test No. RVR-56	Additive: Sucrose -100% STCIC	Sht 1 of 1				
Parameter	Unit	Readings				
Date: 4-11-95						
Time:		1200	1230	1300	1330	1340
Hot Oil System						
Pump Inlet pressure PI-IN	kPag	0	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	124	124	124	124	124
Hot Oil Supply, temperature	°C	299	298	299	299	299
Hot Oil Return, temperature	°C	298	297	298	298	298
Expansion Tank level	cm	10	10	10	10	10
RVR Dryer Bed Temperatures						
TI-1	°C	253	156	164	147	148
TI-2	°C	257	258	264	286	281
TI-3	°C	212	274	279	296	301
TI-4	°C	282	282	285	287	287
TI-5	°C	244	263	252	257	263
Rotor Speed Setting	RPM	34	34	34	34	34
Glass Former Feed Rate	Kg/hr Dial #	(54.42)				
Total glass formers fed (this period)	kg	—	—	15.66	—	—
Total dried product this period	kg			15.66	18.03	10.93
Total dried mixture output (accumulated)	kg			15.66	33.70	44.63
Tank level reading	L					
Simulant/Additive Injection Rate	mL/min					
Total Simulant/Additive Input	L					
Off-Gas System						
Off-gas flow anemometer	M/S ~~km³/hr~~	1.55	1.73	1.70	1.20	1.30
NO Reading	ppm	0	200	140	183	182
NO _x Reading	ppm	0	58	27	39	98
Total NO _x Reading	ppm	0	258	167	222	280
CO Reading	ppm	0	82	43	72	63
Recirc Line Temp - TI-SCB	°C	17	17	18	19	20
Scrubber Level - LG-SCB	cm	22	22	33	33	50
Off-gas Pressure - PI-OFG	kPag					
Vent Separator Level - LG-VENT	cm/in					
Vent Separator Temp - TI-VENT	°C					

Scoping Test - Datasheet

Page 1 of 1

Test No. RVR-87	Additive: SUCROSE 125% STOLC	shc / of 1			
Parameter	Unit	Readings			
Date: 4-11-95					
Time:		1405	1435	1505	1525
Hot Oil System					
Pump Inlet pressure PI-IN	kPag	0	0	0	0
Pump Outlet pressure PI-OUT	kPag	124	124	124	124
Hot Oil Supply, temperature	°C	298	298	298	299
Hot Oil Return, temperature	°C	297	298	298	298
Expansion Tank level	cm	10	10	10	10
RVR Dryer Bed Temperatures					
TI-1	°C	195	190	137	143
TI-2	°C	241	259	280	285
TI-3	°C	264	291	301	308
TI-4	°C	284	287	286	287
TI-5	°C	258	256	235	246
Rotor Speed Setting	RPM	34	34	34	34
Glass Former Feed Rate	kg/hr Dial #				
Total glass formers fed (this period)	kg	-	19.4	17.69	16.18
Total dried product this period	kg	-	19.4	37.09	53.27
Total dried mixture output (accumulated)	kg				
Tank level reading	L				
Simulant/Additive Injection Rate	mL/min				
Total Simulant/Additive Input	L				
Off-Gas System					
Off-gas flow anemometer	M/min/hr	1.58	1.15	0.42	1.26
NO Reading	ppm	0	180	180	192
NO ₂ Reading	ppm	0	70	115	143
Total NO ₂ Reading	ppm	0	250	295	335
CO Reading	ppm	0	70	84	88
Recirc Line Temp - TI-SCB	°C	20	20	22	22
Scrubber Level - LG-SCB	cm	33	66	66	33
Off-gas Pressure - PI-OPG	kPag				
Vent Separator Level - LG-VENT	cm/in				
Vent Separator Temp - TI-VENT	°C				

This page intentionally left blank.

APPENDIX 2B

RVR TESTING SAMPLE LOG

SAMPLE LOG

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V 1 RS1 / I 21 -001	21/3	1625	Product			
V 1 RS1 / I 21 -002	21/3	1745	Product			
V 1 RS3 / I 21 -003	5/4	1245	Dry SIM			
V 1 RS1 / I 21 -004	5/4	1345	Reacted Product			
V 1 RS4 / I 21 -005	5/4	1740	Reacted Product			
V 1 RS5 / I 21 -006	11/4	1350	Reacted Product			
V 1 RS6 / I 21 -007	11/4	1525	Reacted Product			
V 1 RS1-7 / W 22 -008	11/5	0910	Scrubber Solution Final			

**PART 3 - VE-SKULL MELTER PHASE 1
FINAL TEST REPORT**

VE-SKULL™ MELTER PHASE 1 FINAL TEST REPORT

For

WHC Contract No. MMI-SVV-384211

EVALUATION OF MELTER SYSTEM TECHNOLOGIES FOR
VITRIFICATION OF HIGH SODIUM CONTENT LLRW

VECTRA GSI Report No. WHC-VIT-05

August 1995

by

VECTRA Government Services, Inc.
2939 Richardson Road
Richland, WA 99352

Prepared by:

John J. Koehr 
Brent Spurgeon 

Approved by:

Brad Mason 

CONTENTS

1.0	INTRODUCTION	3-1
2.0	PURPOSE	3-1
3.0	CHRONOLOGY OF EVENTS	3-1
4.0	EQUIPMENT OPERATING BEHAVIOR	3-4
4.1	START-UP	3-4
4.2	BOTTOM DRAIN ASSEMBLY	3-5
4.3	GLASS FRIT SYSTEM	3-6
4.4	SLURRY FEED SYSTEM	3-6
4.5	ELECTRODES	3-7
4.6	MELTER OPERATING BEHAVIOR	3-8
4.7	MELTER SAMPLING	3-8
4.8	OFF-GAS SYSTEM	3-9
4.9	REFRACTORY	3-9
4.10	SERVICE LOADS	3-10
5.0	MELTER TESTS AND OBSERVATIONS	3-10
5.1	MT-1: MELTER TEST PREPARATIONS	3-10
5.1.1	Melter Start-up	3-10
5.1.2	VECTRA Glass Dry Feed Operations	3-12
5.1.3	LLRW Slurry Feed Operations	3-14
5.2	MT-2: REACT/VITRIFY GLASS FORMER, LLRW SIMULANT, AND REDUCTANT SLURRY FEED	3-15
5.3	MT-3: VITRIFY SIMULATED DRY CALCINED PRODUCT	3-17
5.4	MT-4: VITRIFY DRY CALCINED PRODUCT	3-17
5.5	V-SIM HIGH THROUGHPUT TEST	3-19
5.6	SLURRY HIGH THROUGHPUT TEST	3-19
5.7	HIGH SODIUM TESTING	3-19
5.8	MELTER DRAINDOWN, SHUTDOWN, AND INSPECTION	3-21
5.9	MELTER THROUGHPUT	3-22
5.10	MELTER MASS BALANCE	3-22
5.11	MELTER SCALE-UP	3-36
6.0	CONCLUSIONS	3-36
APPENDIXES		
3A	LAB ANALYSES	3-39
3B	THROUGHPUT LOG	3-55
3C	MASS BALANCE CALCULATIONS	3-75

LIST OF FIGURES

3-1	MT-1 VECTRA Glass Throughput	3-24
3-2	MT-1 VECTRA Glass Peak Throughput	3-25
3-3	VECTRA Glass Idle Throughput	3-26
3-4	MT-1 Slurry Throughput	3-27
3-5	MT-1 Slurry Peak Throughput	3-28
3-6	MT-2 Slurry Throughput	3-29
3-7	MT-3 V-SIM Throughput	3-30
3-8	MT-4 Calcined Throughput	3-31
3-9	V-SIM High Throughput (HT) Run	3-32
3-10	V-SIM High Throughput (HT) Run Peak Throughput	3-33
3-11	Slurry High Throughput (HT) Run	3-34
3-12	High Sodium (Na) Run Throughput	3-35

LIST OF TABLES

3-1	VE-SKULL Melter Testing Chronology Summary	3-2
3-2	Electrode Weight Losses	3-7
3-3	Melter System Phase 1 Testing Service Loads	3-11
3-4	VECTRA Glass Feed Composition	3-13
3-5	RVR Glass Formers (Mix B) Composition	3-14
3-6	Slurry Feed Batch Recipes	3-15
3-7	Target Glass Composition	3-16
3-8	MT-2 Slurry Feed Composition	3-16
3-9	V-SIM Feed Composition	3-18
3-10	Boric Acid Addition to Dry Calcined Feed Product	3-19
3-11	V-SIM High Throughput Summary	3-20
3-12	LLRW Slurry Feed High Throughput Summary	3-20
3-13	High Sodium Run Batch Makeup	3-20
3-14	High Sodium Run Throughput Summary	3-21
3-15	Phase 1 Throughput Summary	3-23
3-16	VE-SKULL™ Melter Sizing Specifications	3-37

This page intentionally left blank.

PART 3 - VE-SKULL MELTER PHASE 1 FINAL TEST REPORT

1.0 INTRODUCTION

The Westinghouse Hanford Company (WHC) is conducting an evaluation of glass melter system technologies for vitrification of liquid low-level radioactive waste (LLRW) streams consisting mostly of sodium nitrate and nitrite salts in alkaline liquid slurry form. As part of this technology evaluation, VECTRA has demonstrated performance of the EnviroGlass™ Vitrification System feed and VE-SKULL™ melter subsystems. The VE-SKULL™ melter is the heart of the EnviroGlass™ Vitrification System. Performance testing for EnviroGlass™ feed system components has been completed and documented in Part 1 (Fluid Bed Calciner Test) and Part 2 (RVR Dryer/Calciner Test) of this report.

2.0 PURPOSE

This final test report (Part 3) documents accomplishment of the VE-SKULL™ melter test objectives. Test objectives include the following:

- 2.1 Demonstrate ability of VE-SKULL™ melter to melt dry/calced LLRW (from fluid bed Calciner and RVR dryer tests), simulated calcined LLRW, and simulant slurry feed combined with glass formers and reductants to create a product glass formulation which exceeds performance criteria including PCT tests.
- 2.2 Verify operating parameters while processing with high-sodium LLRW for test basis glass compositions, *i.e.*, power supply voltage and amperage, throughput capability, cold-cap (batch blanket) depth, degree of phase separation, glass foaming, melt characteristics of dry/calced feed materials, glass pour nozzle operation, and off-gas rates and compositions.
- 2.3 Investigate throughput capability of melter.

3.0 CHRONOLOGY OF EVENTS

A detailed chronology of VE-SKULL™ melter Phase 1 testing has been recorded in the Test Log. Detailed times for specific tests are recorded in the Throughput Log (Appendix 3C). A brief test chronology summary is provided in Table 3-1.

Table 3-1. VE-SKULL Melter Testing Chronology Summary. (3 sheets)

Date	Activities/events
3/28/95 (MT-1, start-up, boring bar)	- 976 kg (2152 lb) glass cullet in melter - Attempted start-up with boring bars - Poor success due to boring bar high iron/low magnesium content - 11 boring bars consumed, unable to establish molten glass pool between electrodes - Boring Bar start-up terminated due to melter head MCW jacket erosion
3/30/95-4/1/95 (MT-1, start-up, gas burner)	- Melter head MCW jacket repaired - Performed start-up with gas burners - Melter in auto temperature control - 408 kg (900 lb) cullet added as make-up.
4/2/95-4/6/95 (MT-1, transition batch)	- 179 kg (395 lb) of various transition batches periodically added to melter - Establish joule heat through drain ring and pin to melt bottom glass - On-line replacement of drain ring
4/7/95-4/17/95 (MT-1, VECTRA batch)	- VECTRA batch - Performed initial drain of 233 kg (513 lb) glass - 5401 kg (11,909 lb) VECTRA glass dry batch added - >3886 kg (8569 lb) VECTRA glass drained - Idled melter over Easter Weekend (4/14-4/16); 135 kg (297 lb) dry VECTRA glass batch feed; 136 kg (300 lb) glass drained - Average feed throughput 30.2 kg/hr (66.6 lb/hr) - Peak feed throughput 88.5 kg/hr (195.2 lb/hr), 156 kg/hr-m² (32.0 lb/hr-ft²)
4/17/95-4/21/95 (MT-1, slurry feed)	- Initial slurry feed system arrangement resulted in line plugging - Additional slurry feed tank, mixer, and recirc hoses added on melter test stand. Injection pump moved to test stand. - Commenced slurry feeding - 3563 kg (7857 lb) slurry feed added - >1437 kg (3169 lb) glass drained - Average feed throughput: 36.2 kg/hr (79.8 lb/hr) - Peak feed throughput: 77.3 kg/hr (170.5 lb/hr), 136.4 kg/hr-m² (28.0 lb/hr-ft²)
4/21/95-4/22/95 (MT-2, slurry feed mass balance)	- Started slurry feed mass balance at 2300 on 4/21/95. - CEMS monitoring - 14 hour steady state mass balance run ended at 1300 on 4/22/95. - 865 kg (1907 lb) slurry feed added - >406 kg (896 lb) glass drained - Average feed throughput: 59.9 kg/hr (132.0 lb/hr), 105.6 kg/hr-m² (21.6 lb/hr-ft²)

Table 3-1. VE-SKULL Melter Testing Chronology Summary. (3 sheets)

Date	Activities/events
4/22/95 (MT-3, simulated dry calcined feed)	- Prebatched dry "V-SIM" feed to simulate dry calcined fluid bed product. Started a mass balance at 1900 on 4/22/95. - CEMS monitoring - 3 hour steady state mass balance run ended at 2200 on 4/22/95. - 100 kg (220 lb) V-SIM added - >69 kg (151 lb) glass drained - Average feed throughput: 43.2 kg/hr (95.2 lb/hr), 76.2 kg/hr-m² (15.6 lb/hr-ft²)
4/23/95 (MT-4, dry calcined feed)	- Started calcined feed mass balance at 1000 on 4/23/95. Steady state mass balance run ended at 1400 on 4/23/95. - 4 hour test duration - 162 kg (357 lb) dry/calcined feed (Procedyne product) added - >136 kg (300 lb) glass drained - Average feed throughput: 25.7 kg/hr (56.6 lb/hr), 45.3 kg/hr-m² (9.3 lb/hr-ft²)
4/24/95-4/26/95 (V-SIM high throughput)	- Performed high throughput run with simulated dry/calcined feed (V-SIM) - 2809 kg (6193 lb) V-SIM feed added - >2101 kg (4632 lb) glass drained - Average feed throughput: 47.4 kg/hr (104.6 lb/hr) - Peak feed throughput: 71.0 kg/hr (156.5 lb/hr), 125.2 kg/hr-m² (25.7 lb/hr-ft²) - Average Power: 119.4 kw
4/26/95 (Slurry high throughput)	- Performed high throughput run with liquid LLW simulant, dry glass formers, and dry reductant slurry feed - 375 kg (826 lb) slurry feed added - >310 kg (684 lb) glass drained - Average feed throughput: 67.5 kg/hr (148.9 lb/hr), 119.1 kg/hr-m² (24.4 lb/hr-ft²) - Average Power: 121.3 kw
4/26/95-4/27/95 (High Na high throughput) 4/27/95 (draindown)	- Performed batch transition to high Na content dry feed (>26% Na₂O in feed on oxide basis). - 408 kg (900 lb) high Na feed added - >239 kg (528 lb) glass drained - Average feed throughput: 40.0 kg/hr (88.2 lb/hr), 70.6 kg/hr-m² (14.5 lb/hr-ft²) - Average Power: 106.4 kw - VE-SKULL™ Melter shutdown, complete draindown, and cooldown - 917 kg (2022 lb) glass drained into two (2) 55-gallon drums

Table 3-1. VE-SKULL Melter Testing Chronology Summary. (3 sheets)

Date	Activities/events
4/28/95 (inspection)	- Performed VE-SKULL™ melter post test inspection

4.0 EQUIPMENT OPERATING BEHAVIOR

The Phase I Melter test equipment was installed within VECTRA's maintenance building in Richland, Washington. The Melter and dry feeder were mounted on a large structural steel test stand which contained space for the SCADA control system, CCTV, and melter watch standers. The Melter Cooling Water (MCW) tank, pump, heat exchanger, and ion exchanger were staged under the Melter Test Stand.

The slurry feed system was mounted on a test stand staged at ground level across from the melter test stand and consisted of a mix tank, glass former feeder, and two diaphragm recirculation pumps. Slurry feed recirculation hoses ran from the diaphragm recirculation pumps to the melter test stand batch drum and peristaltic feed pump. The glass quench trough and tank were staged at ground level between the slurry feed and melter stands.

The off-gas skid was mounted outside the maintenance building and contained the scrubber, vent fans and stack. The scrubber drain tank, drain pump, and spray pump were staged outside with hoses run to the scrubber. The quench water recirculation tanks, quench water supply pump, quench water return pump were staged outside the maintenance building with hoses run to the quench trough and tank inside the building. The cooling tower was staged outside the maintenance building with hoses run to the MCW heat exchanger under the melter test stand.

Other equipment stage outside included the diesel generator, service air compressor, nitrogen tanks, and propane tanks.

4.1 START-UP

Initial start-up was attempted using magnesium boring bars. Tempered glass cullet was loaded into the melter. A boring bar was attached to an oxygen supply hose, ignited, and manually inserted into the melter through an open 6" port between electrodes. The operator attempted to melt glass cullet between electrodes so that molten glass continuity could allow melter electrode operation for continued heat-up. Reddish smoke and a significant quantity of "slag" generated by the boring bars indicated a high iron content. A total of eleven (11) boring bars were expended attempting to start the melter. A flaw in the side of bar number 11 resulted in the erosion of the melter head MCW jacket. An MCW leak was created which required terminating boring bar start-up, isolating MCW, weld repair to the melter head jacket within the 6" nozzle, hydrostatic test to 45 psig, and inspection by an ASME certified inspector.

Following unsuccessful boring bar start-up, gas burners were positioned in two of the melter head 6" nozzles between electrode phases. The burners were ignited and glass cullet start-up was successfully accomplished.

4.2 BOTTOM DRAIN ASSEMBLY

The bottom drain assembly consisted of a drain ring inserted inside melter refractory liner. The ring provided a small diameter orifice to control glass drain rate. The drain ring was held in place with four (4) lugs attached to a water cooled bottom support ring which was mounted to the melter bottom plate. The ring support lugs were electrically isolated from the ring by insulated pads. High drain ring temperatures melted the original isolation pads which required replacement with a material rated for higher temperature.

Sparge lines penetrated the bottom support ring through refractory into the melter to allow glass pool sparging with nitrogen. Nitrogen sparging was performed throughout Phase 1 testing.

An air cylinder operated, water cooled, stopper plug was utilized to plug the drain ring orifice when glass draining was not desired. The stopper plug performed very well as long as glass buildup broke away from the plug. Air and water tubes were directed at the bottom of the ring and could be utilized as a back-up method to cool the ring and help reduce ring temperature. Air cooling was periodically utilized to stop any leakage around ring perimeter following glass drain operations.

In order to allow glass draining following melter start-up, the glass on the bottom of the melter above the drain ring had to be fully melted. Heat generated by the three main electrodes was insufficient to melt the glass at the bottom of the melter. For the Test Program, the electrodes could not be fully extended due to fixed electrode holder design. A moveable electrode design will correct this limitation. A welding machine provided a single phase joule heating loop between one electrode phase (A) and the drain ring. Initially, a pin was inserted through the drain ring into the hot glass pool. The joule heating loop was established through this pin which was slowly withdrawn out the drain ring orifice as heat-up progressed. When the pin was fully withdrawn, the bottom joule heating loop was shifted back to the drain ring. Throughout the test program, drain ring temperature was maintained by the welding machine. Glass draining was initiated by opening the drain stopper plug and raising the drain ring to $>871^{\circ}\text{C}$ (1600°F). Drain ring temperature was maintained below 1093°C (2000°F).

No drain ring damage or erosion was observed throughout phase 1 melter testing except minor damage resulting from metal deposits restricting orifice on the final day of testing.

The metal deposits originated from the boring bars used during the first attempted start up and also the erosion of the electrodes and the electrode holders. To remove this metal and restore the drain ring to an acceptable operating condition, the ring would have to be remachined to open the orifice back to its original diameter.

4.3 GLASS FRIT SYSTEM

The glass frit system functioned to cool the molten glass draining from the melter, and allow the glass to cool and shatter into granular pieces under controlled conditions. The glass product was collected in the glass frit tank. Quench water recirculated from two (2) 10,000 L poly tanks with a centrifugal supply pump, through the glass frit chute and into the glass frit tank. Molten glass was dumped from the melter into the quench water stream within the glass frit chute. Quench water was pumped from the frit tank by a variable speed centrifugal pump back into the poly tanks. The quench water was cooled by tank ambient losses.

The glass frit system produced a fine to medium granular product at moderate glass drain rates [>4.5 kg/min (10 lb/min)]. At drain rates less than approximately 2.3 kg/min (5 lb/min), or with excessive chute water flow, spaghetti-like glass strands were produced.

4.4 SLURRY FEED SYSTEM

The original slurry feed system consisted of a slurry mix tank with internal mixer, diaphragm recirculation pump, 25 ft³ dry feeder, LLRW simulant drum mixer, and LLRW simulant drum transfer pump. The slurry mix tank was mounted on a scale which provided constant readout of mix tank weight. LLRW Simulant bulk drums were continuously mixed with installed drum mixers. LLRW simulant was transferred in calculated quantities from the drums to the slurry mix tank with a drum transfer pump. Calculated quantities of dry glass formers and sucrose were added to the slurry mix tank directly or with the dry feeder. The slurry mix tank was continuously agitated with the tank mixer and recirculated with the diaphragm pump. The melter feed line ran from the diaphragm pump discharge to the melter off-gas/feed plenum. The slurry mix tank weight was monitored to observe quantities of feed transferred from the recirculating slurry tank into the melter. During initial slurry feed operations feed line plugging resulted, and steady feed flow could not be maintained.

The slurry feed system was modified. A batch drum with mixer was placed on the melter test stand near the top of the Melter to serve as a slurry feed day tank. Larger diaphragm pumps were installed as recirculation pumps, and recirculation lines were run up to the melter stand. Intermediate quantities of slurry feed were transferred from the recirculation line to the batch drum as necessary. A positive displacement peristaltic tubing pump took a suction on the batch drum and injected slurry through tubing into the melter via the 16" off-gas/feed plenum. The feed tube extended down to about 15 cm. (6 in) above the glass pool. The batch drum was calibrated for level which was periodically monitored. Weight of simulant transferred from the slurry mix tank to the salvage drum was monitored on the slurry mix tank scale. This modified slurry feed system was utilized for melter test preparation slurry operations (MT-1), the slurry feed mass balance testing (MT-2), and the slurry feed high throughput testing.

4.5 ELECTRODES

The Phase 1 VE-SKULL™ melter utilized three (3) 2-1/2" diameter vertical molybdenum electrodes. The electrodes were powered from a diesel generator through a 120V transformer and SCR. Electrode power levels ranged from 0-145 kw. Idle power level was approximately 85 kw.

The electrodes penetrated the melter head and were held in position by stainless steel holders and water cooled stainless steel castings and stainless steel pipe sleeves. The castings were designed for water cooling to control electrode temperature and form a cold glass seal at the holder/electrode interface, thus preventing corrosion from the molten glass. The cooling water was not initiated to the electrode holders throughout the test program due to presence of casting defects that caused minor water leakage into melter. The electrode thermocouples and electrode holder cooling water tubes failed as a result of no cooling water. Severe erosion of the stainless steel holders occurred below the upper glass melt line levels.

The electrodes were adjustable in height only during this test. The electrodes required very little adjustment during testing other than to extend two electrodes as they eroded. During testing, electrode phase B developed a phase imbalance due to electrode erosion. Electrode B was lowered further into the melter and the phase imbalance was corrected. Just prior to final melter drain down, electrode A was also extended.

Inspection of the electrodes following final melter drain down indicated severe erosion of all three electrodes. Electrodes A and B actually eroded to such an extent that a "bubble" erosion pocket in each electrode developed and a 12"-16" section of each electrode separated from the main electrode after 28 days of high temperature operation.

Erosion of electrodes was most severe in glass/gas interface zone as indicated by "necking down" of electrode just below electrode holder area. Pre- and post-testing electrode weight given in Table 3-2 indicate the extent of electrode wear.

Table 3-2. Electrode Weight Losses.

Electrode	Weight		
	Before	After	Loss
A*	195.47 kg	150.22 kg	45.25 kg
B*	195.47 kg	109.07 kg	86.4 kg
C	195.47 kg	186.90 kg	8.57 kg

*Loss includes pieces that physically separated and fell to the melter floor.

The electrodes were operated under high power operation for 28 days with glass melt temperature $>1400^{\circ}\text{C}$ (2600°F). It is estimated that the melter was operated for at least 14 days at extreme high glass temperatures $>1480^{\circ}\text{C}$ (2700°F) with operation at $>1540^{\circ}\text{C}$ (2800°F) for more than 7 days. The glass composition was at approximately 20 wt% Na_2O for 26 of the 28 days of operation. Electrode erosion is attributed primarily to lack of cooling water, glass pool level excursions below holder, and lack of sufficient inert gas purge during draindown.

4.6 MELTER OPERATING BEHAVIOR

The goal during dry feeding was to maintain glass pool level above the electrode holders, provide make-up for melter losses through volatilization or draining, and maintain a stable "batch blanket" on top of the molten glass pool. Optimization of batch blanket thickness allowed control of off-gas particulate carry-over, minimized melter plenum temperature, and allowed operator observation of melter pool refinement via the CCTV system.

Glass pool "freeboard" level and batch blanket thickness were periodically checked by the operators by removing a 6" insulated plug from the melter head and inserting a calibrated dip stick into the molten glass pool. Glass draining was periodically performed throughout all phases of testing to control glass pool level. When operator inspection revealed sufficient glass pool level, glass draining was initiated by opening the remote drain stopper plug. Melter weight was transmitted from load cells and monitored by the operator at the control system. Drain rate was dependent upon glass and drain ring temperature. Draining was stopped by closing the drain plug when the desired weight of glass had been removed or when the desired freeboard level was achieved.

The melter electrodes were operated in automatic power control after start-up throughout all phases of testing. Glass temperature and refining rate were controlled by limiting electrode power level. One electrode phase supplied power to a welding machine connected to the drain ring lug. Power to the welding machine was manually adjusted to maintain drain ring temperature less than 1093°C (2000°F) and to keep the melter bottom glass molten. Following start-up, melter internal thermocouples failed and glass pool temperature indication was not available. Glass pool temperature was controlled by operator observation via the CCTV system, removal of insulated plugs for direct inspection through 6" melter head nozzles, and operator experience. Periodic dip thermocouple readings indicated glass temperature to be 1093 – 1560°C (2000 – 2850°F) following start-up throughout all phases of testing.

The nitrogen sparge system was operated continuously to facilitate molten glass pool mixing and refinement. Nitrogen sparge was maintained at a low level (5–20 scfh) throughout all testing.

4.7 MELTER SAMPLING

Product glass sampling was performed by inserting circular graphite forms into the molten glass drain stream. Alternatively, stainless steel ladles

were filled with molten glass and poured into forms. Resultant glass disks would shatter upon cooling unless annealed in an oven. Glass frit samples were withdrawn directly from the glass frit tank.

Product glass was originally green with glass cullet, transition batch, and VECTRA Glass feed. When LLRW simulant slurry feed testing was initiated the glass gradually turned darker with each pour. Final glass product was black.

4.8 OFF-GAS SYSTEM

The melter off gas was drawn out through the 16" combined off-gas/ feed plenum. Off-gas piping, metal hoses, and off-gas instrumentation were installed between the melter plenum and the suction side of a vent blower (located outside the test building) which discharged into the vent separator. The vent separator interfaced with centrifugal pumps for continuous vent separator draindown to a large poly tank and continuous vent separator return spray flow from the poly tank. The vent separator was vented into the stack and joined dilution air flow into stack at the discharge of a large vent blower.

The scrubber solution was not treated to control pH. Original scrubber solution remained from previous RVR Dryer testing and contained noticeable amounts of particulates and glass formers from carryover. The vent separator tank and drain levels were monitored, during melter testing.

4.9 REFRACTORY

The melter is provided with a thin refractory liner inside the inner vessel shell. Following 26 days of high temperature operation with high (20 wt%) Na_2O glass the refractory appeared to be in original condition with no visible erosion except for:

- Several minor (<1 cm) concave indentations in refractory block in the glass/gas interface area. It is unknown if the concave indentations were initially present in refractory blocks.
- Mortar between blocks was partially eroded at interior surface leaving minor gaps 0-4 mm (0-0.16 inches) wide by 0-25 mm (0-1 inches deep) between blocks.

Refractory life is estimated to match 10 year design life of melter, if refractory seams-gaps are reduced to <1 mm during initial refractory installations.

Mass balance calculations indicated an excess amount of chromium in the product glass. This excess chromium may be the result of minor refractory erosion. Approximately 1 kg of excess Cr_2O_3 resulted from MT-2 testing, and approximately 180 g of excess Cr_2O_3 resulted from MT-3 testing. These values are consistent with observed refractory erosion.

4.10 SERVICE LOADS

The VE-SKULL™ Melter was operated from 3/26/95 to 4/27/95 for the performance of Phase 1 testing. During this time period, various services were provided to sustain melter operation. These services include the following:

- Electrical power for melter electrodes, cooling tower, MCW pump, quench water recirculation pumps, off-gas blowers, scrubber drain and spray pumps, and slurry tank mixers (provided by diesel generator)
- Nitrogen gas for melter sparging and electrode holder cooling
- Propane gas for melter start-up burners
- Service water for cooling tower system, glass quench system, and off-gas system
- Service air for operation of slurry feed recirculation pumps and the melter drain plug valve.

A summary of service loads during the Phase 1 melter test period is given in Table 3-3.

5.0 MELTER TESTS AND OBSERVATIONS

5.1 MT-1: MELTER TEST PREPARATIONS

VE-SKULL™ melter start-up and test preparations were performed from 3/28/95 through 4/21/95. During this period melter start-up was performed and the VE-SKULL™ melter was operated continuously with glass cullet, dry VECTRA glass (20 wt % Na₂O), and LLW simulant slurry feed.

5.1.1 Melter Start-up

VE-SKULL™ melter initial start-up was performed from 3/28/95 through 4/2/95. The cold melter was initially loaded with 976 kg (2152 lb) of tempered glass cullet. The off-gas, cooling water, and MCW systems were started up. "Magnesium" boring bars were initially utilized to attempt melter start-up. Eleven (11) boring bars were consumed attempting to start the melter, but generation of a molten glass pool between the electrodes was unsuccessful. Additionally, a boring bar flaw caused erosion of the melter head MCW jacket and resulted in an MCW leak which required weld repair. No further boring bar start-ups were attempted.

Table 3-3. Melter System Phase 1 Testing Service Loads.

Service	Quantity	Average daily operating cost (over 32-day test period)
Electrical Power (Electrodes Only)	55,736 KW-HR	
Average Electrode Power Level	96.9 KW	
Diesel Fuel (for generator)	26,047 liters (6,881 US Gallons); \$.819/gallon	\$ 176.08
Cumulative Diesel Run Hours	647.79 hours	
Average Diesel Fuel Consumption	40.2 liters/hr (10.62 gallons/hr)	
Nitrogen	5148 kg (11,352 lb); 43 bottles, 120 kg (264 lb) N ₂ /bottle, \$117/bottle	\$ 164.00
Propane	1022 liters (270 gallons); \$1.25/gallon	
Service Water (initial fill: cooling water, glass quench, scrubber)	approx. 26,500 liters (7000 US Gallons)	
Service Water (cooling tower make-up)	approx. 3785 liters (1000 US Gallons)	
Service Air (during feed recirc pump operations only)	approx. 120 SCFM	
Consumable Molybdenum Electrodes	121.3 cm (47.75 inches); 6.35 cm (2.5 in) OD, 0.323 kg/cm (1.81 lb/in), \$25/lb	\$ 67.53
TOTAL DAILY OPERATING COST		\$ 408.53

Following weld repair to the melter head MCW jacket, melter start-up strategy was shifted to gas burners instead of the boring bars which had proven ineffective. Melter start-up with burners was performed from 3/30/95 through 4/1/95. Gas burners were ignited and manually inserted into the melter through the two 6" openings in the top. The glass cullet was slowly melted to establish a conductive molten glass pool between the electrodes. Glass cullet temperature was monitored by thermocouples inserted into the melter through the head. Electrodes were periodically energized to monitor melt progress. After over 20 hours of slow burner heat-up, the glass cullet was molten between electrodes with glass pool temperature 760-982°C (1400-1800°F). The melter electrodes were shifted to automatic current control, and the burners were turned off. Glass pool heat-up to approximately 1540° C

(2800°F) with the electrodes continued for approximately 2 days. During this period a total of 408 kg (900 lb) additional glass cullet were added to the melter.

In order to gradually adjust the melter glass pool chemistry toward the test chemistry expected for LLRW testing, transition batch high sodium feed was added to the melter. Transition batch consisted of various mixtures of soda ash, boric acid, and alumina. A total of 179 kg (395 lb) of transition batch feed was added to the melter over a 4-1/2 day period (4/2/95 - 4/6/95).

During the transition batch period, operation of the melter electrodes alone would not melt the glass at the bottom of the melter above the bottom drain assembly due to the fixed electrode angle. Heating of the bottom glass was initiated by establishment of an additional single phase joule heating loop through the drain ring orifice and one electrode phase. A metal pin was inserted through the drain ring into the glass pool. The joule heating loop was established through this pin, the glass, and one electrode phase. As heat-up progressed, the pin was slowly withdrawn. At one point the pin could not be withdrawn due to deformation caused by excessive temperatures. This required on-line replacement of the drain ring and insertion of a new pin. When the pin was fully withdrawn, the bottom joule heating loop was shifted back to the drain ring.

To initiate glass draining, cooling water to the bottom drain assembly was stopped, and joule heating was again initiated to the drain ring. On 4/6/95, the first VE-SKULL™ melter glass drain was performed when >233 kg (513 lb) of glass was drained from the melter. The glass product was green upon cooling.

5.1.2 VECTRA Glass Dry Feed Operations

From 4/7/95 through 4/17/95, the VE-SKULL™ phase I melter was operated continuously with VECTRA Glass dry feed. The VECTRA Glass feed composition is presented in Table 3-4.

With the melter in steady state operation following start-up with the cullet and transition batch, the VECTRA Glass feed was initiated. Pre-mixed VECTRA Glass feed was supplied in pre-weighed bulk bags [approximately 36 kg (80 lb) each]. The premixed bags were loaded into the 0.425 m³ (15 ft³) melter dry feeder hopper which was mounted on the melter test stand and connected directly to the 16" off-gas/feed plenum. Since the feeder was constant speed only, the motor was periodically operated for discrete time periods (usually 20 seconds) to establish an average feed rate. The goal during dry feeding was to maintain glass pool level above the electrode holders, provide make-up for melter losses through volatilization or draining, and maintain a stable "batch blanket" on top of the molten glass pool. Optimization of batch blanket thickness provided reduced particulate carry-over off-gas, reduced melter plenum temperature, and allowed operator observation of melter pool refinement via the CCTV system.

Table 3-4. VECTRA Glass Feed Composition.

Component	Glass weight %	
	As batched	Oxide basis
Silica	41.17	54.40
Boric Acid	11.17	8.32
Dolomite	7.52	4.91
Magnesium Carbonate	0.49	0.27
Alumina	12.10	10.40
Iron Oxide	0.72	0.92
Soda Ash	26.87	20.78
TOTAL	100.0	100.00

Glass pool "freeboard" level and batch blanket thickness were periodically checked by the operators by removing a 6" insulated plug from the melter head and inserting a calibrated dip stick into the molten glass pool. During VECTRA Glass feed operation, draining was periodically performed to control glass pool level. When operator inspection revealed sufficient glass pool refinement and adequate freeboard level, glass draining was initiated by opening the remote drain stopper plug. Melter weight was transmitted from load cells and monitored by the operator at the control system. Drain rate was dependent upon glass and drain ring temperature. Draining was stopped by closing the drain stopper plug when the desired weight of glass had been removed or when the desired freeboard level was achieved.

The melter electrodes were operated in automatic power control. Glass temperature and refining rate were controlled by limiting electrode power level. One electrode phase supplied power to a welding machine connected to the drain ring lug. Power to the welding machine was manually adjusted to maintain drain ring temperature less than 1093°C (2000°F) and keep the melter bottom glass molten.

During a three day period over the Easter Holiday Weekend (4/14/95 through 4/16/95) the melter was operated at idle operations with an average power level of approximately 85 kw. During this time period 135 kg (297 lb) of VECTRA Glass batch feed was added to the melter, and >136 kg (300 lb) of glass product were drained.

Over the eleven (11) day period of VECTRA Glass feed operations, 5401 kg (11,909 lb) of VECTRA Glass dry feed was added to the melter. A total of >3886 kg (8569 lb) of glass product was drained from the melter. This glass was green upon cooling. The average feed throughput was 30.2 kg/hr (66.6 lb/hr) with a peak throughput of 88.5 kg/hr (195.2 lb/hr). Since the Phase 1 VE-SKULL™ Melter has a 0.56 m² (6.1 ft²) active glass surface area, the peak feed throughput corresponds to 156.2 kg/hr-m² (32.0 lb/hr-ft²). The active glass surface area is defined as the glass pool cross sectional area

(8.1 ft³) adjusted for a 2.5" radial cold zone along the melter wall. Since the VECTRA batch feed was approximately 25% water and other volatiles (75% glass by weight), the calculated glass throughput is 117.1 kg/hr-m² (24.0 lb/hr-ft²). Up to this point, a cumulative total of 7059 kg (15,565 lb) of feed had been added to the VE-SKULL melter and >3886 kg (8,569 lb) of glass product had been drained.

5.1.3 LLRW Slurry Feed Operations

Operation of the VE-SKULL™ melter with LLRW simulant slurry feed was performed from 4/18/95 through 4/21/95. Liquid LLRW simulant, dry glass formers, and dry sucrose reductant were premixed and injected into the melter as a slurry. The dry glass formers were identical to the glass former Mix B utilized for initial RVR dryer testing and are shown in Table 3-5.

Sucrose was added to the LLRW simulant and RVR glass formers (Mix B) for reaction with NaNO₂ and NaNO₃ to form Na₂CO₃ and nitrogen in the off-gas. The various slurry compositions utilized during slurry testing are given in Table 3-6.

The original slurry feed system consisted of a slurry mix tank with internal mixer, diaphragm recirculation pump, 0.71 m³ (25 ft³) dry feeder, LLRW simulant drum mixer, and LLRW simulant drum transfer pump. During initial slurry feed operations on 4/18/95, the feed line plugged, and steady feed flow could not be maintained.

The slurry feed system was modified to add a 341 liter (90 gal) batch drum (slurry feed day tank), larger diaphragm recirculation pumps, recirculation lines to the melter stand, and a positive displacement peristaltic tubing pump. The peristaltic pump took a suction on the batch drum and injected slurry through tubing into the melter via the 16" off-gas/feed plenum. The slurry batch drum was calibrated for level which was periodically monitored. Weight of simulant transferred from the slurry mix tank to the batch drum was monitored on the slurry mix tank scale.

Table 3-5. RVR Glass Formers (Mix B) Composition.

Glass former	Weight percent	
	As batched	Weight oxide
Silica Sand	59.61	62.40
Boric Acid	16.17	14.67
Dolomite	10.87	8.65
Magnesium Carbonate	0.70	0.48
Alumina	11.61	12.16
Iron Oxide	1.04	1.64
Total	100.00	100.00

Table 3-6. Slurry Feed Batch Recipes.

Slurry batch	Weight %			
	LLRW simulant	RVR glass formers	Sucrose reductant	Total
Batches 1,2	48.04	49.96	2.00	100.0
Batches 3,4,5,6	47.06	48.94	4.00	100.0

An average feed throughput of 36.2 kg/hr (79.8 lb/hr) and peak feed throughput of 77.3 kg/hr (170.5 lb/hr) slurry feed were processed by the melter. This translates to a peak throughput of 136.4 kg/hr-m² (28.0 lb feed/hr-ft²) of active glass surface area. Note that evaporation of water adds an additional heat load to the melter electrodes. Since the slurry feed was approximately 57% glass by weight, an equivalent calculated peak glass throughput of 77.8 kg/hr-m² (15.9 lb glass/hr-ft²) was observed.

There were a few variations of the slurry batch. These variations did not change the formulation and the oxide composition of the slurry by more than ± 2% by weight.

During slurry feed operations, a total of 3563 kg (7857 lb) of LLRW simulant slurry was added, and a total of >1437 kg (3169 lb) of glass was drained. This glass product became a darker green with each pour. At this point a cumulative total of 10,622 kg (23,422 lb) of feed had been added to the melter and a total of >5323 kg (11,738 lb) of glass product had been drained.

With the completion of Melter Test Preparations (MT-1) the VE-SKULL™ melter had processed dry and slurry feed. Homogeneous glass had been produced. All melter systems had been tested and were operational. Additionally, the melter chemistry had been adjusted to approximate levels expected for the remaining tests. Since a LLRW melter glass volume is approximately 1224 kg (2700 lb), over one melter glass volume had been processed with slurry feed prior to commencement of the remaining tests (MT-2 through MT-4).

5.2 MT-2: REACT/VITRIFY GLASS FORMER, LLRW SIMULANT, AND REDUCTANT SLURRY FEED

For Melter tests MT-2 (Slurry Feed), MT-3 (V-SIM), and MT-4 (Calcined feed), the target glass composition was the same and is given in Table 3-7.

Once the melter was operating at nearly steady state with slurry feed, melter test sequence MT-2 was initiated. Testing with LLRW simulant, glass formers, and sucrose reductant slurry was performed from 4/21/95 to 4/22/95. Three (3) separate batches were mixed during test MT-2. The batch slurry feed makeup fractions are shown in Table 3-8.

Table 3-7. Target Glass Composition.

Component	Target composition
SiO ₂	52.80
B ₂ O ₃	8.00
Na ₂ O	20.00
CaO	2.90
MgO	2.10
CsCl	0.14
Al ₂ O ₃	10.00
Fe ₂ O ₃	1.00
Other	23.95
Total	100.00

Table 3-8. MT-2 Slurry Feed Composition.

Slurry batch	Weight %			
	LLRW simulant	RVR glass formers	Sucrose reductant	Total
Batch 1a	49.72	46.38	3.90	100.0
Batches 2a, 3a	46.38	49.72	3.90	100.0

The slurry feed system was operated identical to slurry feed operations in MT-1. A total of 141 kg (310 lb) of batch 1 and 724 kg (1596 lb) of batches 2a and 3a was added during MT-2. A fourteen (14) hour steady state mass balance run was performed. Mass balance data including off-gas samples were taken at the beginning and end of the run. Mass balance off-gas, glass, feed, and liquid sample results are given in Appendix 3C.

During the MT-2 mass balance run, an electrode phase imbalance was observed indicating possible erosion on the Phase B electrode. The Phase B electrode was lowered into the melter and the three electrode phases were again balanced. Post run inspection indicated that a piece of the electrode broke off due to corrosion at the glass/gas interface.

The slurry feed had favorable melting characteristics. Its melt rate was the fastest of the three different feeds. The batch blanket was well formed on top of the glass pool and the tendency to foam was minimal.

During the MT-2 mass balance run, a total of 865 kg (1907 lb) of slurry feed was added to the melter. A total of >406 kg (896 lb) of glass product

was drained from the melter. The average feed throughput was 59.9 kg/hr (132.0 lb feed/hr). This corresponds to an average feed throughput of 105.6 kg/hr-m² (21.6 lb feed/hr-ft²) of active glass surface area. Since the slurry feed was approximately 57% glass by weight, an equivalent calculated average glass throughput of 60.2 kg/hr-m² (12.3 lb glass/hr-ft²) was observed.

5.3 MT-3: VITRIFY SIMULATED DRY CALCINED PRODUCT

Following slurry feed testing (MT-2) the slurry feed system was shut down and the melter was prepared for dry feed operations. Pre-batched simulated dry calcined feed (V-SIM) was supplied in pre-weighed bags [approximately 36 kg (80 lb) each]. The composition of the V-SIM feed is shown in Table 3-9.

MT-3 was performed on 4/22/95. The V-SIM feed was added to the melter dry feeder as was done with the VECTRA Glass batch (section 6.1.2). V-SIM feed was processed for approximately 15 hours. During this time period a three (3) hour steady state mass balance run was performed. Mass balance data and samples were taken at the beginning and end of the run. Mass balance off-gas, glass, feed, and liquid sample results are included in Appendix 3B.

During the MT-3 mass balance run, a total of 100 kg (220 lb) of V-SIM dry feed was added to the melter. A total of >69 kg (151 lb) of glass product was drained from the melter. The glass product was dark green/black. An average feed throughput of 43.2 kg/hr (95.2 lb/hr) was observed. This corresponds to an average feed throughput of 76.2 kg/hr-m² (15.6 lb feed/hr-ft²) of active glass surface area. Since the V-SIM was approximately 75% glass by weight, an equivalent calculated average glass throughput of 57.1 kg/hr-m² (11.7 lb glass/hr-ft²) was observed.

The V-SIM batch melt characterization was less desirable than that of the slurry feed. It was more difficult to get a uniform batch blanket on top of the glass pool because of the dry feed. The V-SIM also had a slower melt rate than the slurry feed. It did have less of a tendency to foam and was easier to handle in that respect.

5.4 MT-4: VITRIFY DRY CALCINED PRODUCT

Test MT-4 was performed on 4/23/95 to determine the melter performance with actual dry calcined product that was generated during the fluid bed calciner pilot scale testing (See WHC-VIT-03). The dry calcined fluid bed product was provided in 208 liter (55 gallon) drums. Since boric acid could not be processed with the glass formers at fluid bed temperatures (500°C) the boric acid was mixed with the dry calcined product just prior to feed to melter. The ratio of dry calcined product to boric acid is shown in Table 3-10.

Calcined feed was processed for approximately eight (8) hours. During this time period a four (4) hour steady state mass balance run was performed. Mass balance data and samples were taken at the beginning and end of the run. Mass balance off-gas, glass, feed, and liquid sample results are attached in Appendix 3B.

Table 3-9. V-SIM Feed Composition.

Target Oxide Composition		Actual V-SIM Batch	
Component	Target Wt%	Component	As Batched (wt%)
SiO(2)	52.80	Silica	39.18
B(2)O(3)	8.00	Boric Acid	10.52
CaO	2.90	Dolomite	7.27
MgO	2.10	Magnesium Carbonate	0.04
Na(2)O	20.00	Na ₂ CO ₃	23.95
Al(2)O(3)	10.00	Alumina	11.53
Fe(2)O(3)	1.00	Iron Oxide	0.68
MoO(3)	0.15	NaMoO ₄	0.01
Cr(2)O(3)	0.04	K ₂ Cr ₂ O ₇	0.03
K(2)O	1.52	K ₂ CO ₃	0.83
MnO(2)	0.0023	KMnO ₄	0.00
SrO	0.11	SrCO ₃	0.12
Cs(2)O	0.15	CsCl	0.14
P(2)O(5)	0.20	Tri-Sodium Phosphate	0.79
I	0.07	NaIO ₃	0.09
Cl	0.29	NaCl	0.29
F	0.28	NaF	0.46
SOx	0.22	Na ₂ SO ₄	0.21
		KOH	0.67
		NaNO ₃	0.68
		NaNO ₂	0.28
		Carbon	2.23
		Total	100.0

Table 3-10. Boric Acid Addition to Dry Calcined Feed Product.

Component	Weight %
Dry Calcined Product	86.36
Boric Acid	13.64
Total	100.0

During the MT-4 mass balance run, a total of 162 kg (357 lb) of dry calcined feed was added to the melter. A total of >136 kg (300 lb) of glass product was drained from the melter on two separate drain operations. The glass product was dark black. Only a short run was performed due to the limited quantity of calcine product available.

An average throughput of 25.7 kg/hr (56.6 lb feed/hr) was observed. This corresponds to an average feed throughput of 45.3 kg/hr-m² (9.3 lb feed/hr-ft²) of active glass surface area. Since the Calcined feed was approximately 95% glass by weight, an equivalent calculated average glass throughput of 43.0 kg/hr-m² (8.8 lb glass/hr-ft²) was observed.

The dry calcined feed was significantly more difficult to melt due to low NO₃/NO₂ levels in the calcined product; however, NO_x levels in the off-gas were negligible. The batch blanket that formed with this product was thick and cold with respect to the other two feed streams. Because of this batch blanket, foaming was non-existent.

5.5 V-SIM HIGH THROUGHPUT TEST

A high throughput run was performed using the V-SIM feed from 4/24/95 through 4/26/95. Off-gas data was not obtained during this test. The test results are summarized in Table 3-11.

5.6 SLURRY HIGH THROUGHPUT TEST

As with the V-SIM, a high throughput run was also performed using slurry feed mixed to the composition of batch 1a (Table 3-8). The testing was performed on 4/26/95. Off-gas data was not obtained. A summary of test results is presented in Table 3-12.

5.7 HIGH SODIUM TESTING

In order to investigate the impact of higher Na₂O feed levels on melter performance, a run was performed with a separate transition feed batch prepared to the composition summarized in Table 3-13.

Table 3-11. V-SIM High Throughput Summary.

Parameter	Value
Average Electrode Power (kw)	119.4
Average Electrode Power during Peak Throughput period (kw)	129.2
Total feed, kg (lb)	2809 (6193)
Total glass poured, kg (lb)	2101 (4632)
Duration of high throughput run (hrs)	58.5
Average throughput, kg/hr (lb/hr)	47.4 (104.6)
Peak throughput, kg/hr (lb/hr)	71.0 (156.5)
Peak throughput, kg/hr-m ² (lb/hr-ft ²)	125.2 (25.7)
Calculated Peak Glass throughput, kg/hr-m ² (lb/hr-ft ²), 75% glass	93.9 (19.2)

Table 3-12. LLRW Slurry Feed High Throughput Summary.

Parameter	Value
Average Electrode Power (kw)	121.3
Total feed, kg (lb)	375 (826)
Total glass poured, kg (lb)	310 (684)
Duration of high throughput run (hrs)	5.8
Average throughput, kg/hr (lb/hr)	67.5 (148.9)
Average throughput, kg/hr-m ² (lb/hr-ft ²)	119.1 (24.4)
Calculated Average Glass throughput, kg/hr-m ² (lb/hr-ft ²), 57% glass	67.9 (13.9)

Table 3-13. High Sodium Run Batch Makeup.

Component	Weight %
V-SIM Pre-batched Dry Feed	60.00
Soda Ash (Na ₂ CO ₃)	40.00
Total	100.0

The goal of the High Sodium Test was to achieve 26-28 wt% Na₂O in glass. Lab analyses of the high sodium glass is attached in Appendix 3A. A summary of high sodium test results is presented in Table 3-14.

5.8 MELTER DRAINDOWN, SHUTDOWN, AND INSPECTION

The VE-SKULL™ Melter was completely drained into two stainless steel 208 liter (55 gallon) drums on 4/27/95. The 208 liter (55 gallon) drums were placed within 341 liter (90 gal) carbon steel salvage drums. The annulus between the outside of the stainless steel drum and the inside of the salvage drum was filled with silica sand. Molten glass was drained directly into the stainless steel drum via a short graphite trough which ran from the melter bottom drain assembly to the stainless steel 208 liter (55-gallon) drum. A total of approximately 917 kg (2022 lb) of glass product was drained into the two drums. It took approximately 5 hours to drain the entire melter.

When draindown was complete, electrode power was shut off and the melter allowed to cooldown.

On 4/28/95, following melter cooldown, the melter was disassembled and inspected. The following was observed:

- All three electrode holders were severely eroded.
- All three electrodes were severely eroded. Short sections of electrodes A and B had separated and fallen to the bottom of melter.
- Refractory appeared undamaged.
- Glass film on refractory was very thin (<1/8").

Table 3-14. High Sodium Run Throughput Summary.

Parameter	Value
Average Electrode Power (kw)	106.4
Total feed, kg (lb)	408 (900)
Total glass poured, kg (lb)	239 (528)
Duration of high throughput run (hrs)	8.2
Average throughput, kg/hr (lb/hr)	40.0 (88.2)
Average throughput, kg/hr-m ² (lb/hr-ft ²)	70.6 (14.5)
Calculated Average Glass throughput, kg/hr-m ² (lb/hr-ft ²), 75% glass	52.9 (10.8)

The two drums of glass, together with outer salvage drum and sand, were allowed to air cool. The partially full [approximately 408 kg (900 lb)] drum was allowed to air cool to ambient and the full drum [approximately 500 kg (1100 lb)] was wrapped in 2.5 cm (1") of kaowool insulation and allowed to air cool to ambient. The uninsulated drum took approximately 36 hrs to cool to less than 71°C (160°F) and the insulated drum took approximately 168 hrs to cool to less than 71°C (160°F) on outer surface of salvage drum. The glass in the center and top surface of the insulated drum was sampled and analyzed. Lab results are attached in Appendix 3A.

5.9 MELTER THROUGHPUT

VECTRA's VE-SKULL™ Melter was operated continuously following start-up from 4/7/95 to 4/27/95. During this time period, a variety of different feed material was processed to accomplish melter test objectives. Generally, emphasis was placed on testing melter performance rather than maximizing melter throughput. Cumulative feed (kg) vs. Time (hrs) was plotted for each Phase 1 test period, and a linear fit of the resulting data scatter was performed. The slope of the resulting trend line is the average feed throughput (kg/hr). For some short duration tests (MT-2 slurry, MT-3 V-SIM, and MT-4 Calcined), data from periods before and after the test were utilized in order to generate representative throughput results. For tests with sufficient recorded data (MT-1 VECTRA glass, MT-1 slurry, and V-SIM high throughput), extended high throughput periods (>6 hours) were identified and expanded to reveal the peak steady state feed throughput. Graphs of the Phase 1 feed throughput data are included in Figures 3-1 through 3-12.

The feed throughput results [kg/hr (lb/hr)] were divided by the VE-SKULL™ Melter active glass surface area [0.57 m² (6.1 ft²)] to reveal standard units of kg/hr-m² (lb/hr-ft²). The active glass surface area is defined as the glass pool cross sectional area (8.1 ft²) adjusted for a 2.5" radial cold zone along the melter wall. Since each Phase 1 feed material contained water and other volatiles, the melter glass throughput was calculated by adjusting the graphical feed throughput results by the corresponding glass weight percent for each type of feed.

A detailed accounting of quantities of melter feed processed and glass produced over the entire Phase 1 melter test period is presented in Appendix 3B, Throughput Log. A throughput summary is presented in Table 3-15.

5.10 MELTER MASS BALANCE

Mass balance calculations were performed on melt tests MT-2 and MT-3. A mass balance calculation was not performed on test MT-4 due to the small amount of feed that was used during this test. The amount of material would not have allowed any amount of change in glass chemistry that could be detected above the normal laboratory error present in the chemical analyses.

The mass balance calculations are presented in Appendix 3C.

Table 3-15. Phase 1 Throughput Summary.

Test Phase	Test Duration (hrs)	Total Feed		Total Glass Product		Graphical Avg. Feed Throughput		Graphical Peak Feed Throughput		Peak Feed Throughput [Based on Active Area (note 2)]		wt% Glass in Feed	Calculated Peak Glass Throughput		Average Power (kw)
		(kg)	(lb)	(kg)	(lb)	(kg/hr)	(lb/hr)	(kg/hr)	(lb/hr)	(kg/hr-m ²)	(lb/hr-ft ²)		(kg/hr-m ²)	(lb/hr-ft ²)	
Start-up	217.2	1858.0	3656.0	0.0	0.0					156.2	32.0		117.1	24.0	82.3
MT-1 Vectra-Glass	253.2	5400.9	11909.0	3686.2	8569.0	30.2	66.6	88.5	195.2	3.9	0.8		2.9	0.6	91.0
MT-1 Idle	73.0	134.7	297.0	136.1	300.0	2.2	4.8	2.2	4.8	136.4	28.0		77.8	15.9	82.7
MT-1 Slurry	102.2	3563.1	7856.7	1437.2	3169.0	36.2	79.8	77.3	170.5	105.6	21.6		60.2	12.3	114.0
MT-2 Slurry	14.0	864.6	1906.5	406.3	896.0	59.9	132.0	59.9	132.0	76.2	15.6		57.1	11.7	115.6
MT-3 V-SIM	3.0	99.8	220.0	68.5	151.0	43.2	95.2	43.2	95.2	45.3	9.3		43.0	8.8	84.4
MT-4 Calcined	4.0	161.7	356.6	136.1	300.0	25.7	56.6	25.7	56.6	125.2	25.7		93.9	19.2	119.4
High Throughput V-SIM	58.5	2808.6	6193.0	2100.7	4632.0	47.4	104.6	71.0	156.5	119.1	24.4		67.9	13.9	121.3
High Throughput Slurry	5.8	374.4	825.6	310.2	684.0	67.5	148.9	67.5	148.9	70.6	14.5		52.9	10.8	106.4
High Sodium (Na)	8.2	408.2	900.0	239.5	528.0	40.0	88.2	40.0	88.2						
Final Drain Down				917.0	2022.0										
TOTAL PHASE 1 (1)	766.7	16434.1	36237.3	10173.7	22433.0										96.9
Notes:															
(1) Totals include feed and drain during transition periods between tests.															
(2) Active Area = Gross Glass Pool Area (6.1 ft ²) minus assumed 2.5" radial cold zone along wall = 6.1 ft ²															

Figure 3-1. MT-1 VECTRA Glass Throughput.

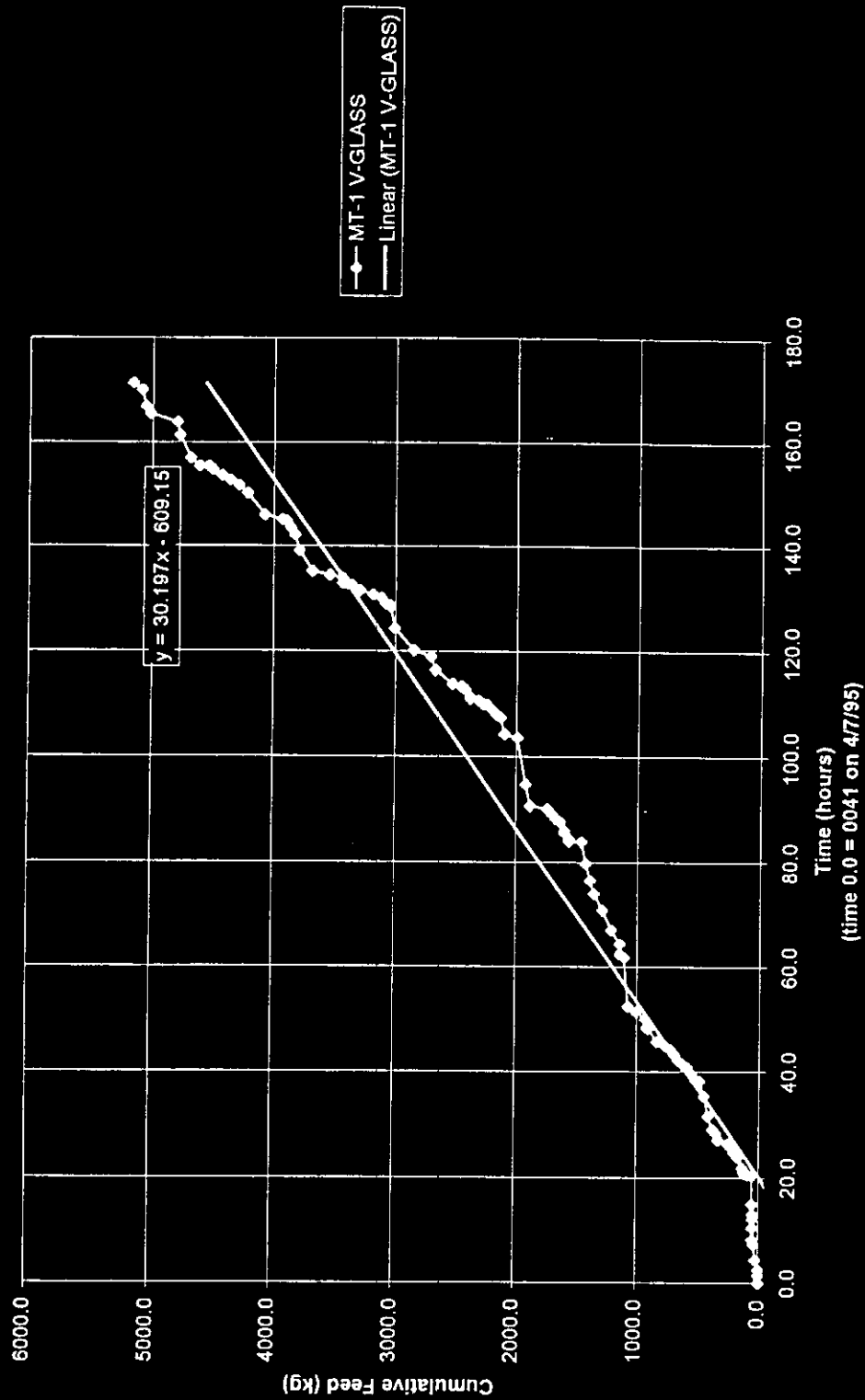


Figure 3-2. MT-1 VECTRA Glass Peak Throughput.

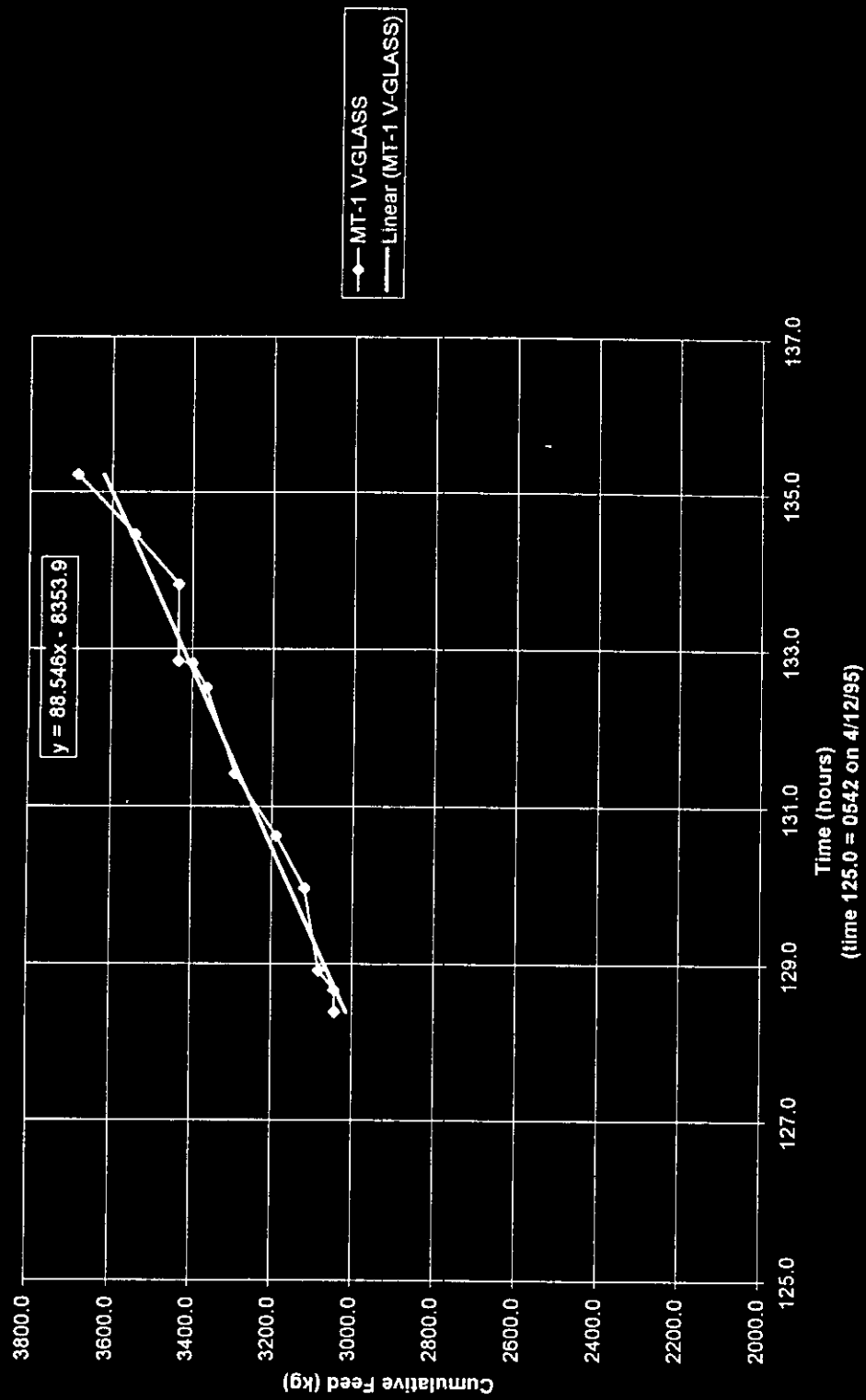


Figure 3-3. VECTRA Glass Idle Throughput.

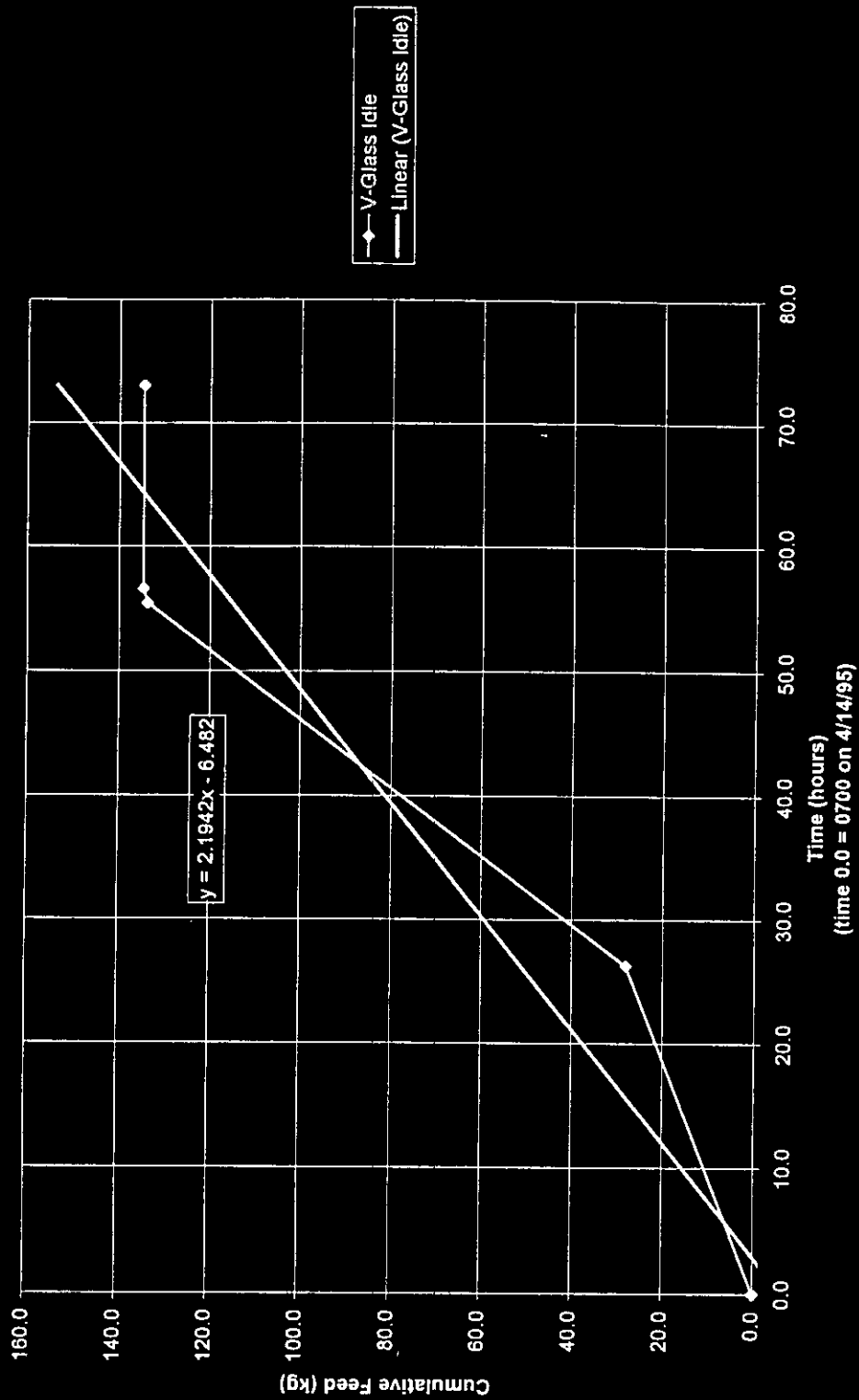


Figure 3-4. MT-1 Slurry Throughput.

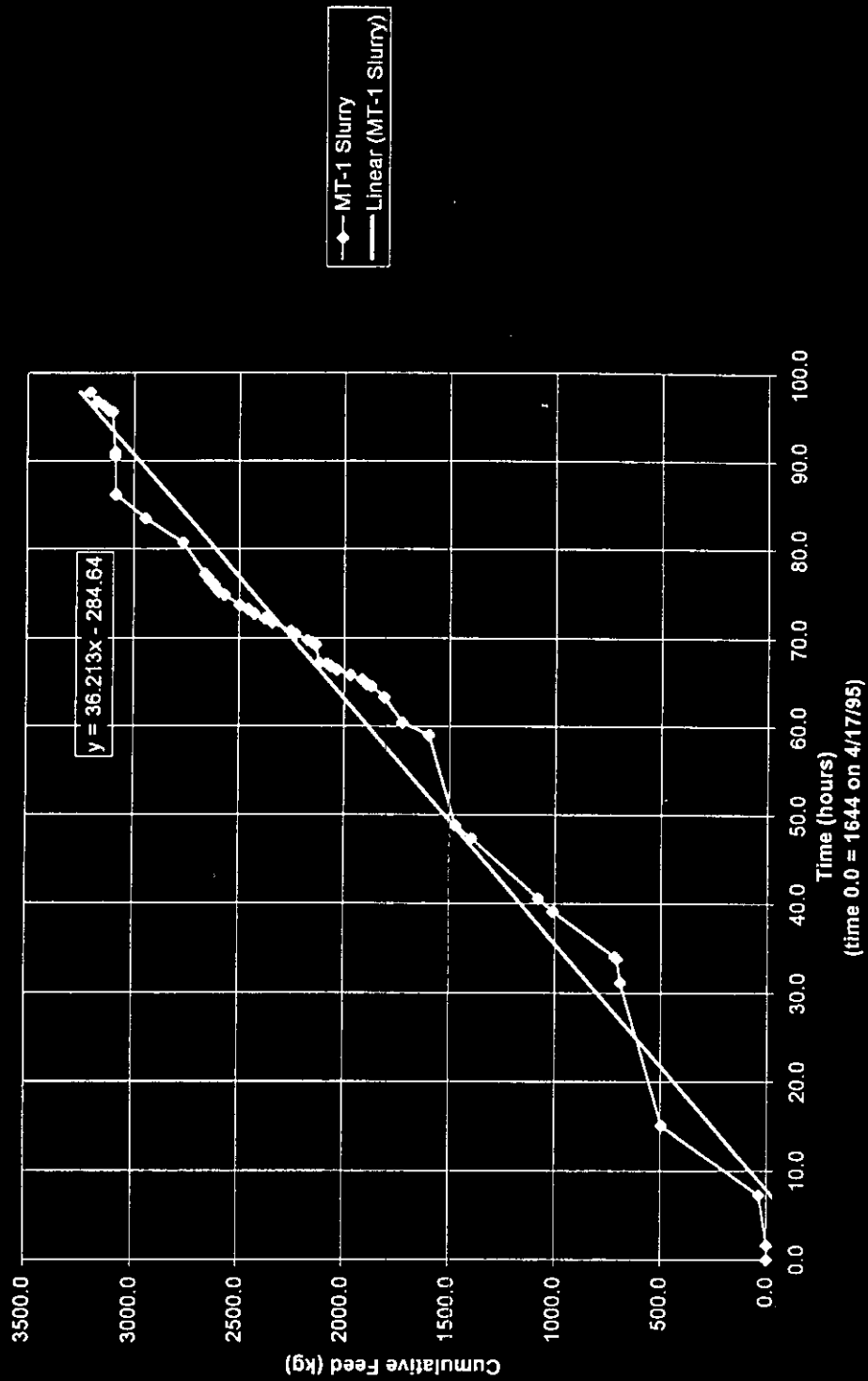


Figure 3-5. MT-1 Slurry Peak Throughput.

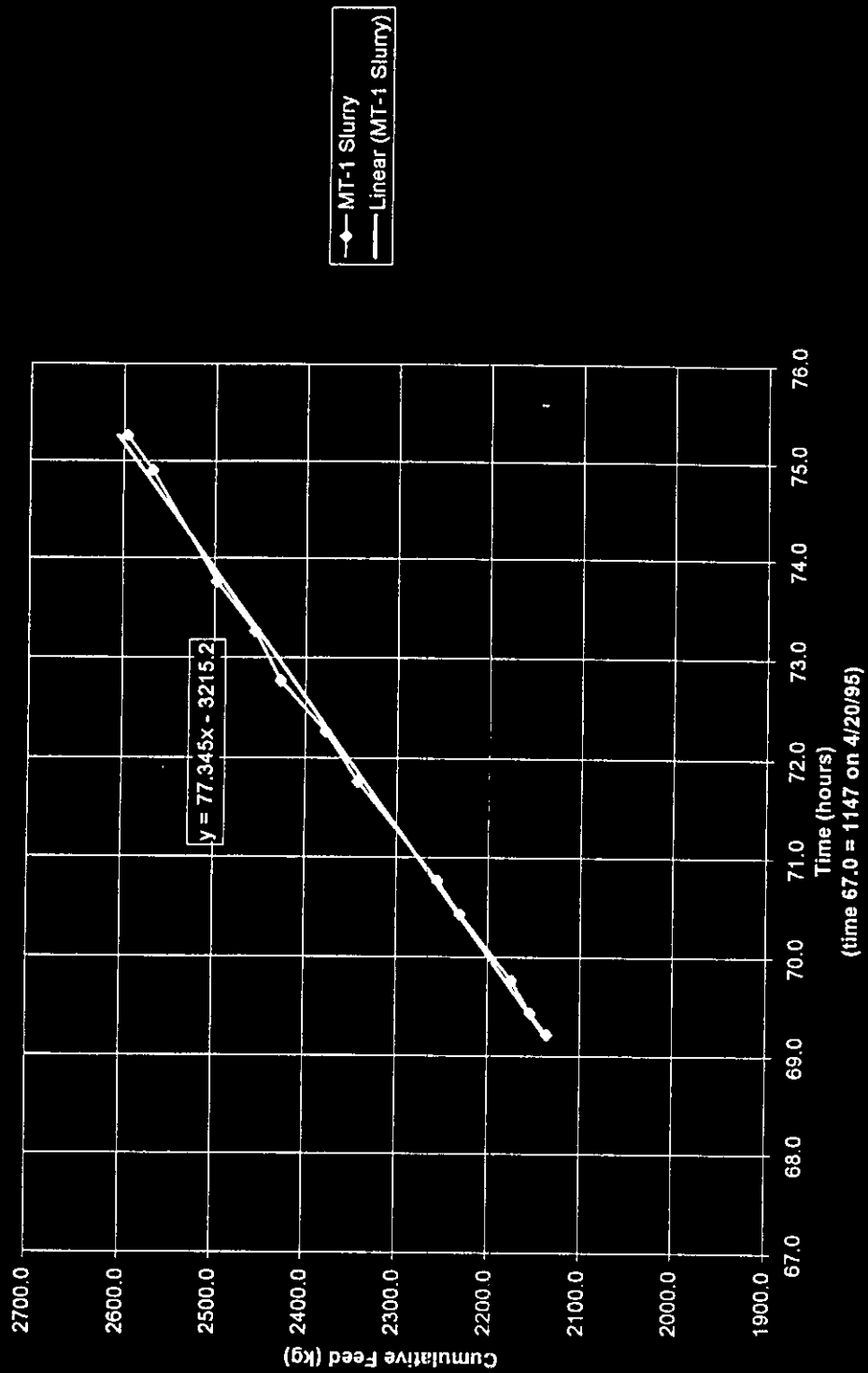


Figure 3-6. MT-2 Slurry Throughput.

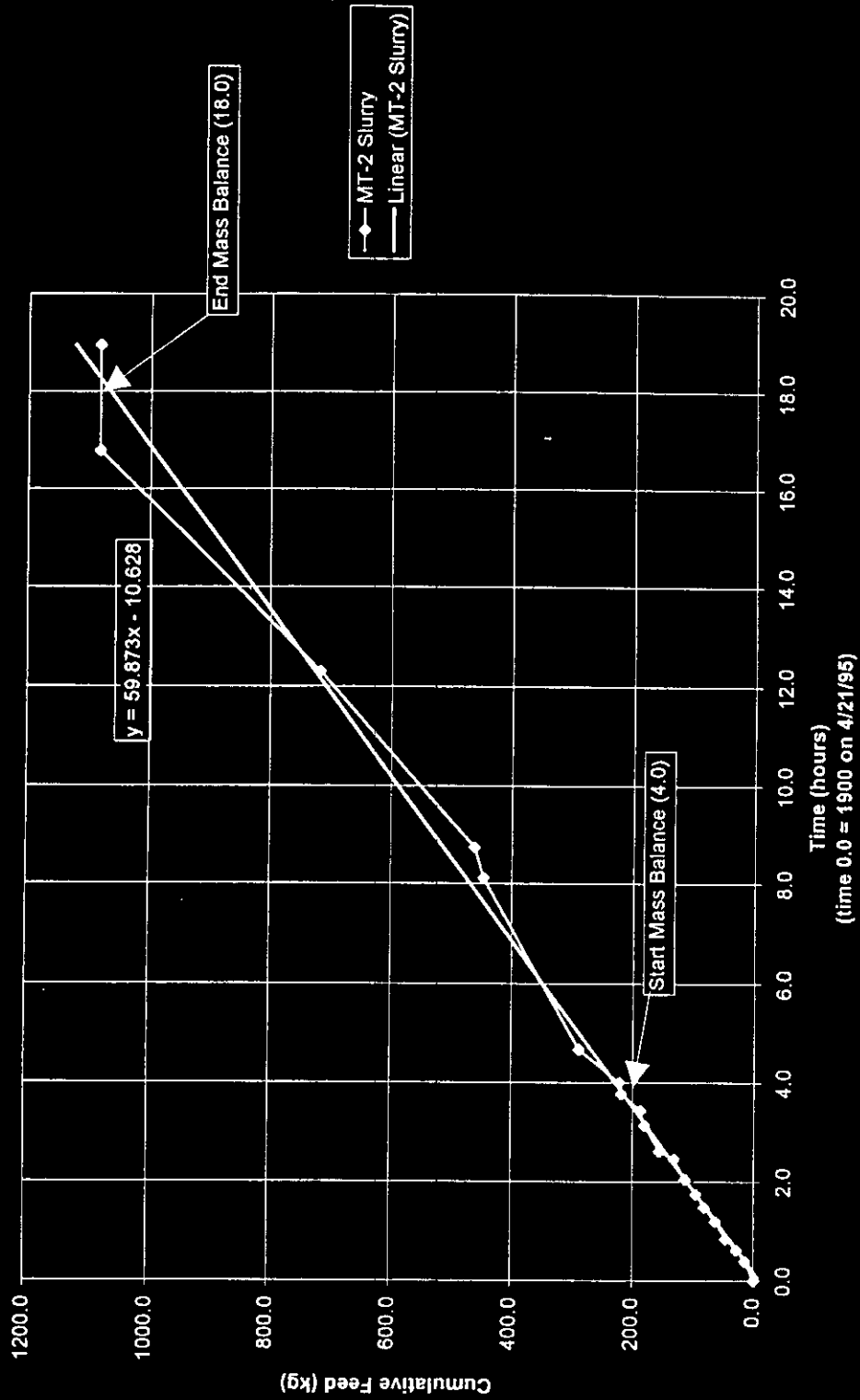


Figure 3-7. MT-3 V-SIM Throughput.

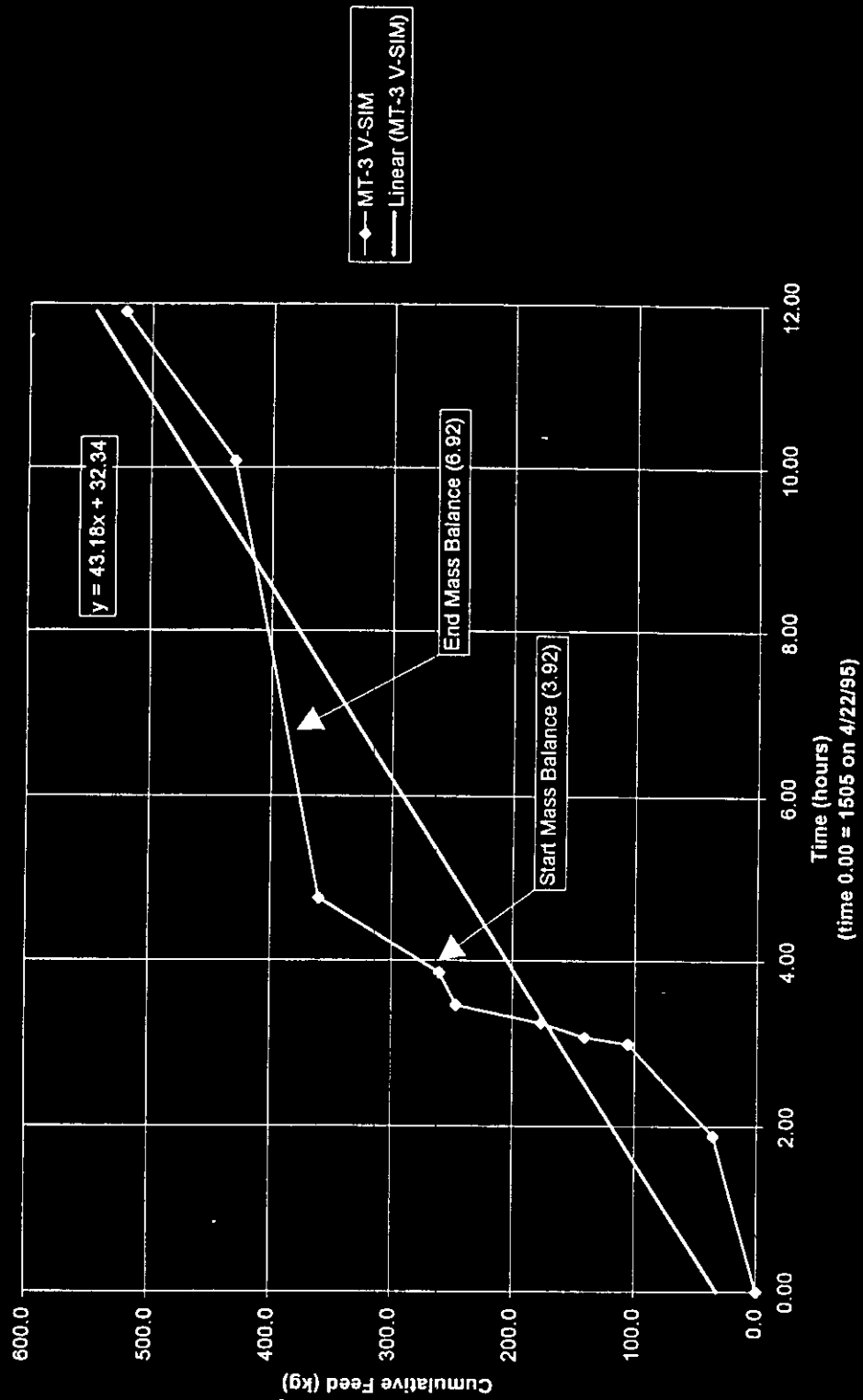


Figure 3-8. MT-4 Calcined Throughput.

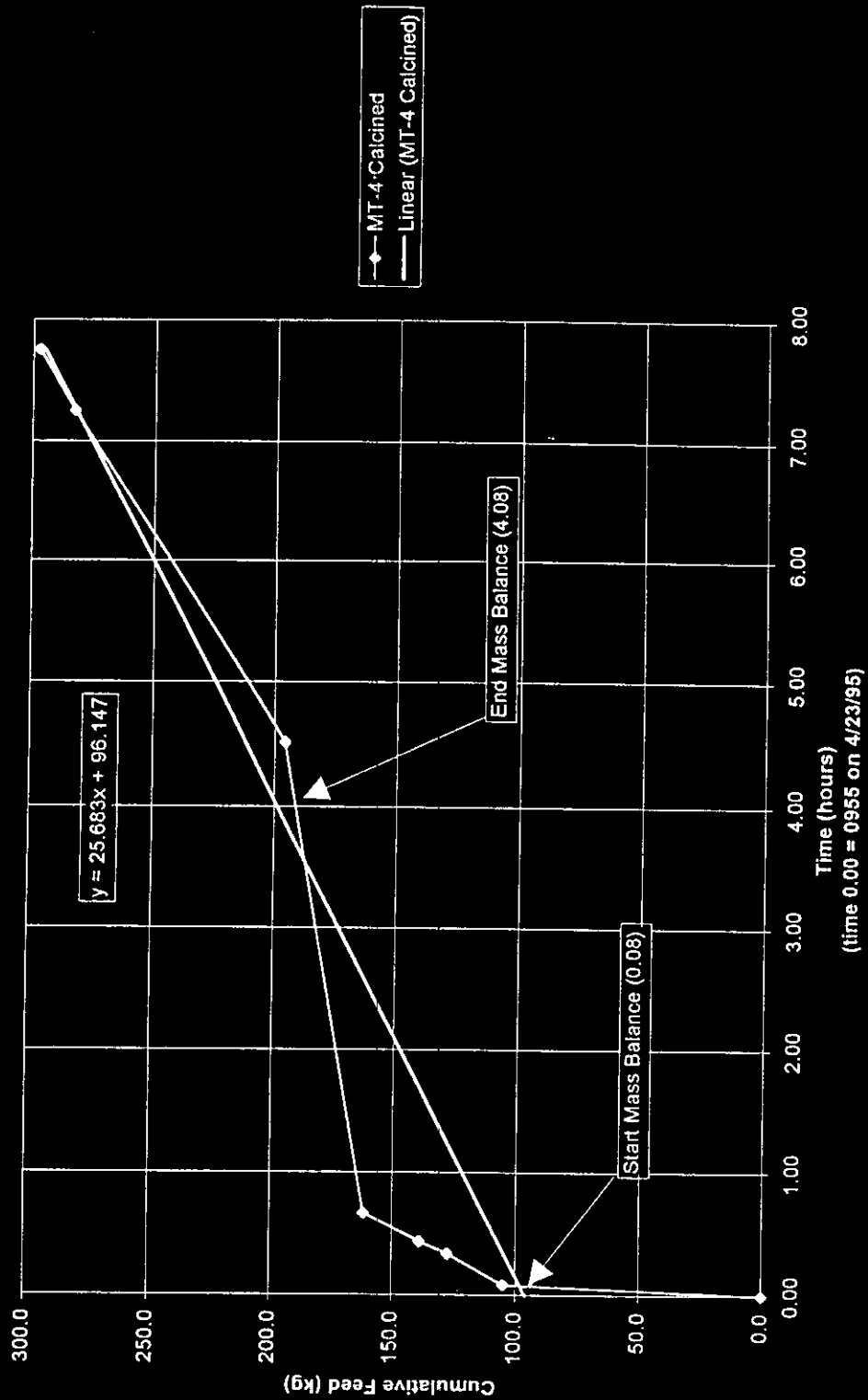


Figure 3-9. V-SIM High Throughput (HT) Run.

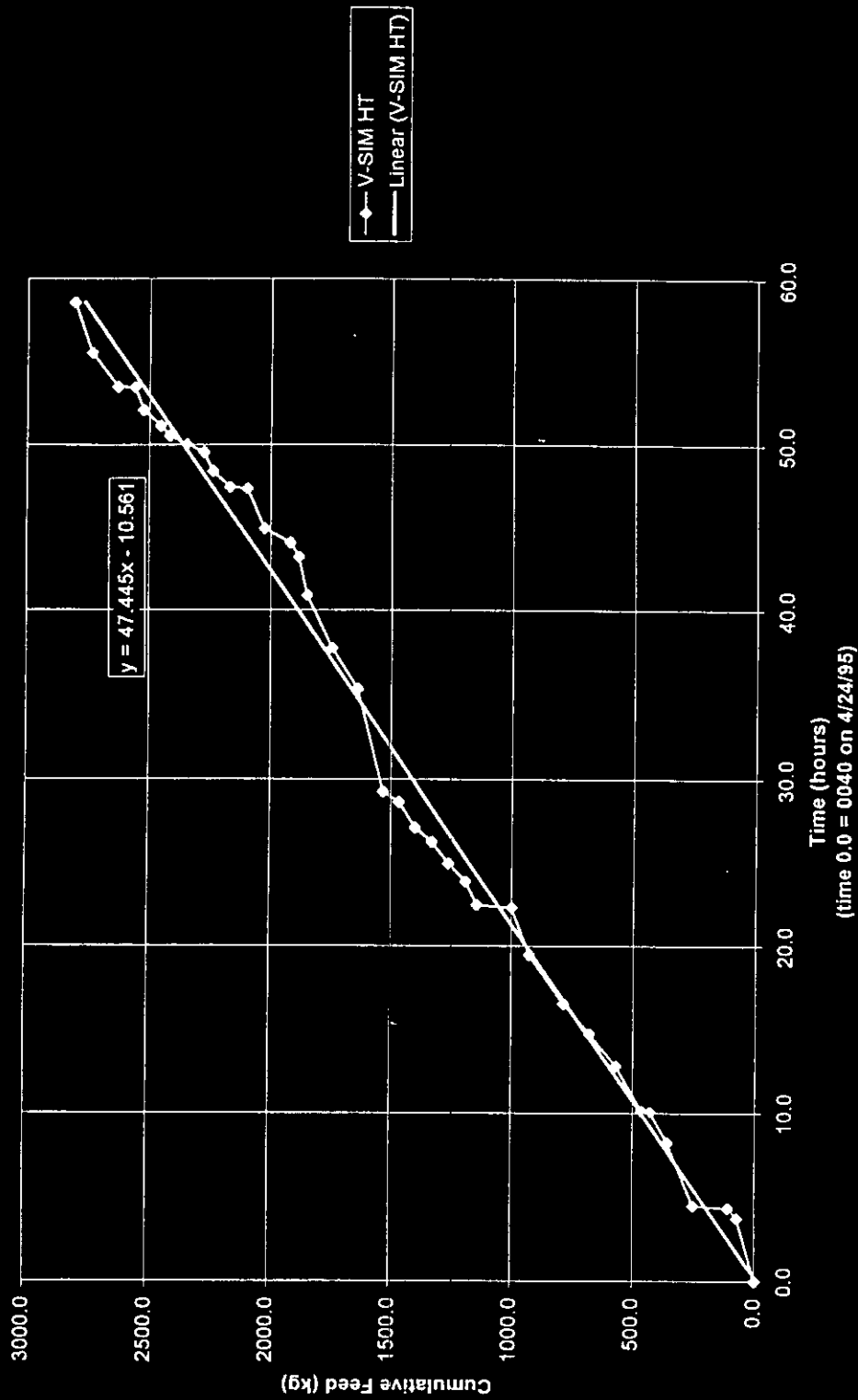


Figure 3-10. V-SIM High Throughput (HT) Run Peak Throughput.

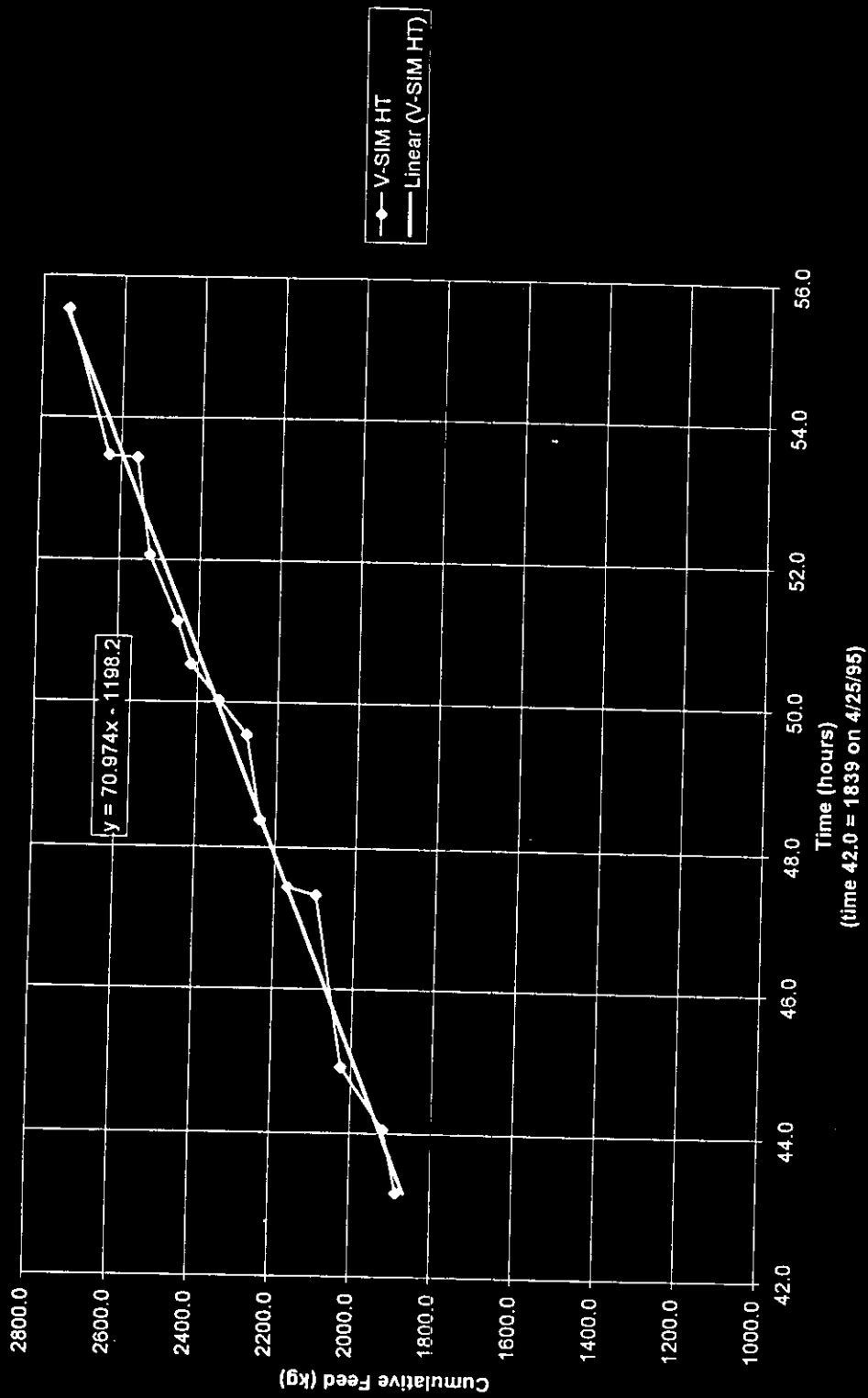


Figure 3-11. Slurry High Throughput (HT) Run.

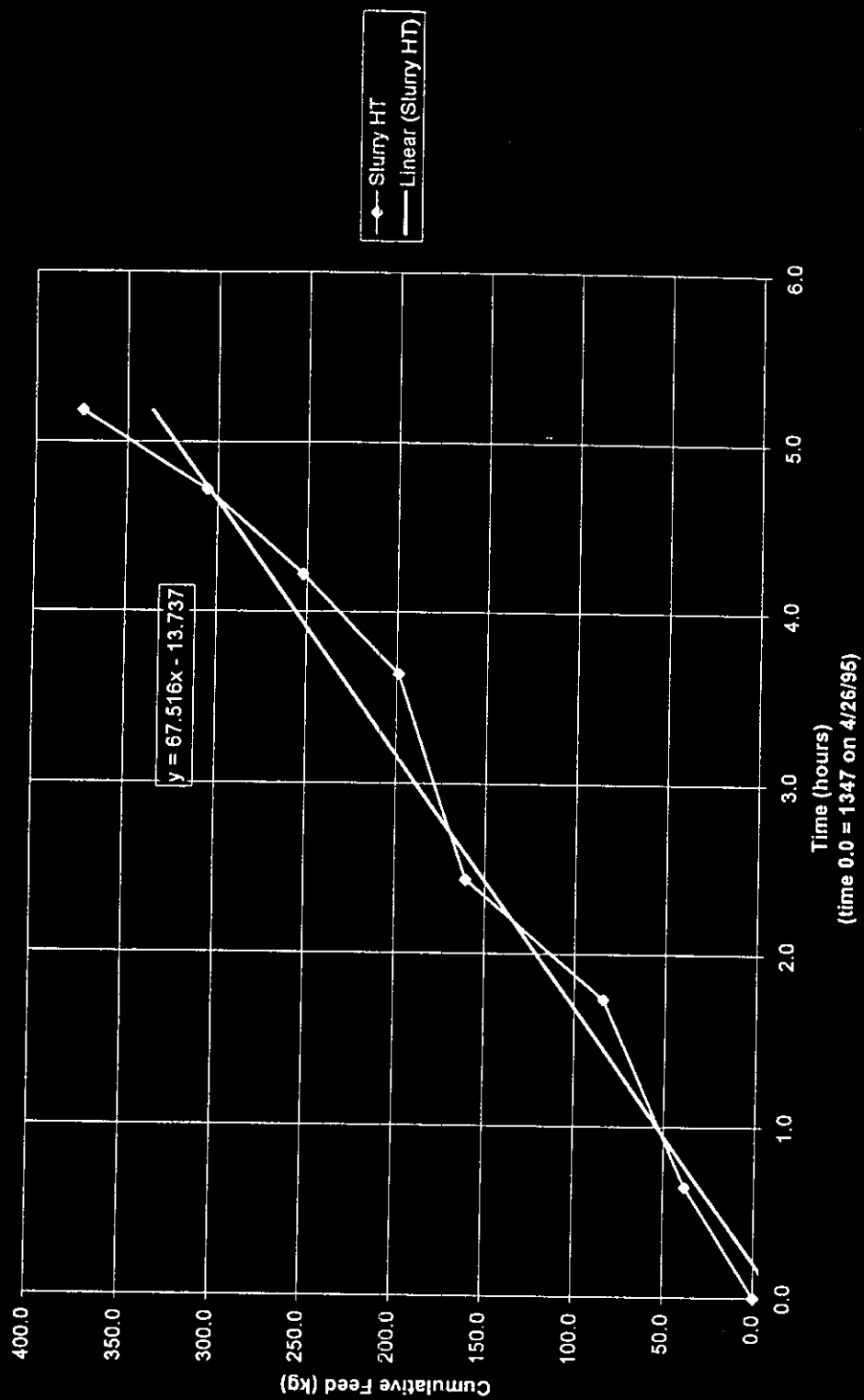
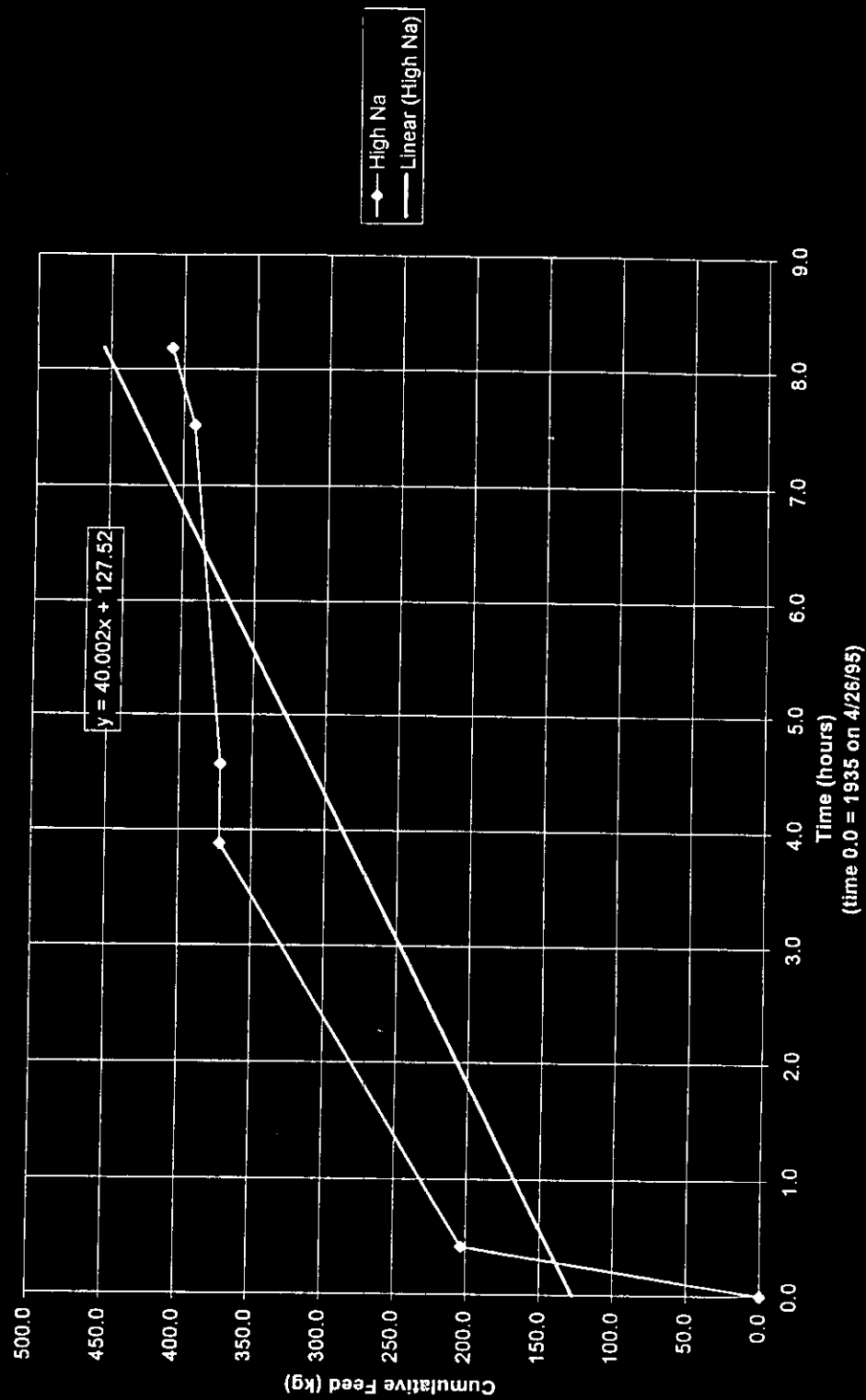


Figure 3-12. High Sodium (Na) Run Throughput.



5.11 MELTER SCALE-UP

Phase 1 testing provided throughput basis for various types of melter feed. With corresponding increases in number and size of electrodes, electrode power supplies, glass surface area, glass pool depth, and feed components, the melter glass throughput (kg/hr) per active glass cross-sectional area (m^2) is expected to remain relatively constant as the melter is scaled up. Since improved throughput is expected due to increased glass mixing in larger melters, the Phase 1 throughput basis has been adjusted by a scale-up factor. Melter scale-up will be further verified during Phase 2 testing.

For basis of scale-up, the active glass area equals melter refractory inside diameter cross section area (8.1 ft^2) less a 2.5" radial cool zone around inside perimeter of melter. For the Phase 1 melter, the active glass area was 0.57 m^2 (6.1 ft^2).

Estimated VE-SKULL™ Melter sizing specifications are presented in Table 3-16.

6.0 CONCLUSIONS

The following conclusions are drawn from the Phase 1 VE-SKULL™ melter testing.

- Single point dry or slurry feed into VE-SKULL™ melter results in a uniform batch blanket covering the molten glass pool with no mechanical spreading required. However, it is expected that multiple point or feed spreading will allow use of thicker, more efficient batch blanket with resultant increased throughput.
- VE-SKULL™ Melter start-up with high iron content "magnesium" boring bars is not recommended. Start-up with gas burners can be performed in a controlled manner.
- The joule heated bottom pour assembly, air operated drain plug, and water cooled bottom support ring functioned properly to control glass draining. Occasional minor glass flow around drain ring block necessitates future addition of water cooled seal under drain ring.
- Simulated, dry batched calcine feed throughputs were significantly higher than actual dry calcined product throughputs. The presence of very low nitrate levels in calcined product hinders melting rate. Moderate nitrate levels increase melting rates.
- Feed with blended slurry made up of liquid LLRW simulant, dry glass formers, and dry sucrose reductant results in a uniform batch blanket, excellent glass refinement, and significantly higher feed throughputs than dry calcined feed. Slurry feed is recommended feed method.

Table 3-16. VE-SKULL™ Melter Sizing Specifications.

Item	Phase 1 Dry Feed	Phase 1 Slurry Feed	10 TPD Dry Feed	50 TPD Dry Feed	50 TPD Slurry Feed	100 TPD Dry Feed
Outside Diameter (ft)	4.3	4.3	7.5	14.5	17.0	19.5
Net Inside Diameter (ft)	3.2	3.2	6.5	13.4	15.8	18.3
Melter Overall Height (ft)	5.5	5.5	8.5	10.0	10.0	11.0
Melter Cross Sectional Area	8.1	8.1	33.2	140	195	265
Throughput Basis:						
- Dry Feed (lb/hr-ft ²)	30	22	30	30	22	30
- Melter Size Factor [3]	1.0	1.0	1.1	1.15	1.15	1.2
- Design Basis Glass	30	22	33	35	25	36
- Active Glass Surface	6.1	6.1	28	130	185	255
Total Design Throughput	2	2	10	50	50	100
Scale-Up Factor	Basis	Basis	5.0	5.0	5.0	10.0
Power Rating, KW [4]	140	160	350	1050	1200	1600
No. Electrodes	3	3	3	6	6	12
Electrode Diameter (in)	2.5	2.5	4.0	4.0	4.0	4.0
Electrode Material	moly	moly	moly	moly	moly	moly
Glass Depth (in)	20-30	20-30	42-48	48-60	48-60	48-60
Glass Volume (ft ³)	20	20	150	600	880	1200
Electrode Current Density	9.1	9.1	5.3	8.0	9.1	6.0
Waste Feed Ports						
- Number	one	one	one	three	three	four
- Size, ID (in)	16 [5]	16 [5]	6 [6]	6	6	6
Off-Gas Ports						
- Number	one	one	one	one	one	one
- Size, ID (in)	16 [5]	16 [5]	18 [6]	20	20	24
Weight [2]						
- Empty (lb)	18,300	18,300	55,000	155,000	195,000	285,000
- Operating (lb)	21,500	21,500	80,000	250,000	335,000	480,000
Glass Drain	one	one	one	one	one	one
- Glass Drain Type	joule heated	joule heated	Induction	Induction	Induction	Induction
- Materials of Construction	proprietary	proprietary	proprietary	proprietary	proprietary	proprietary

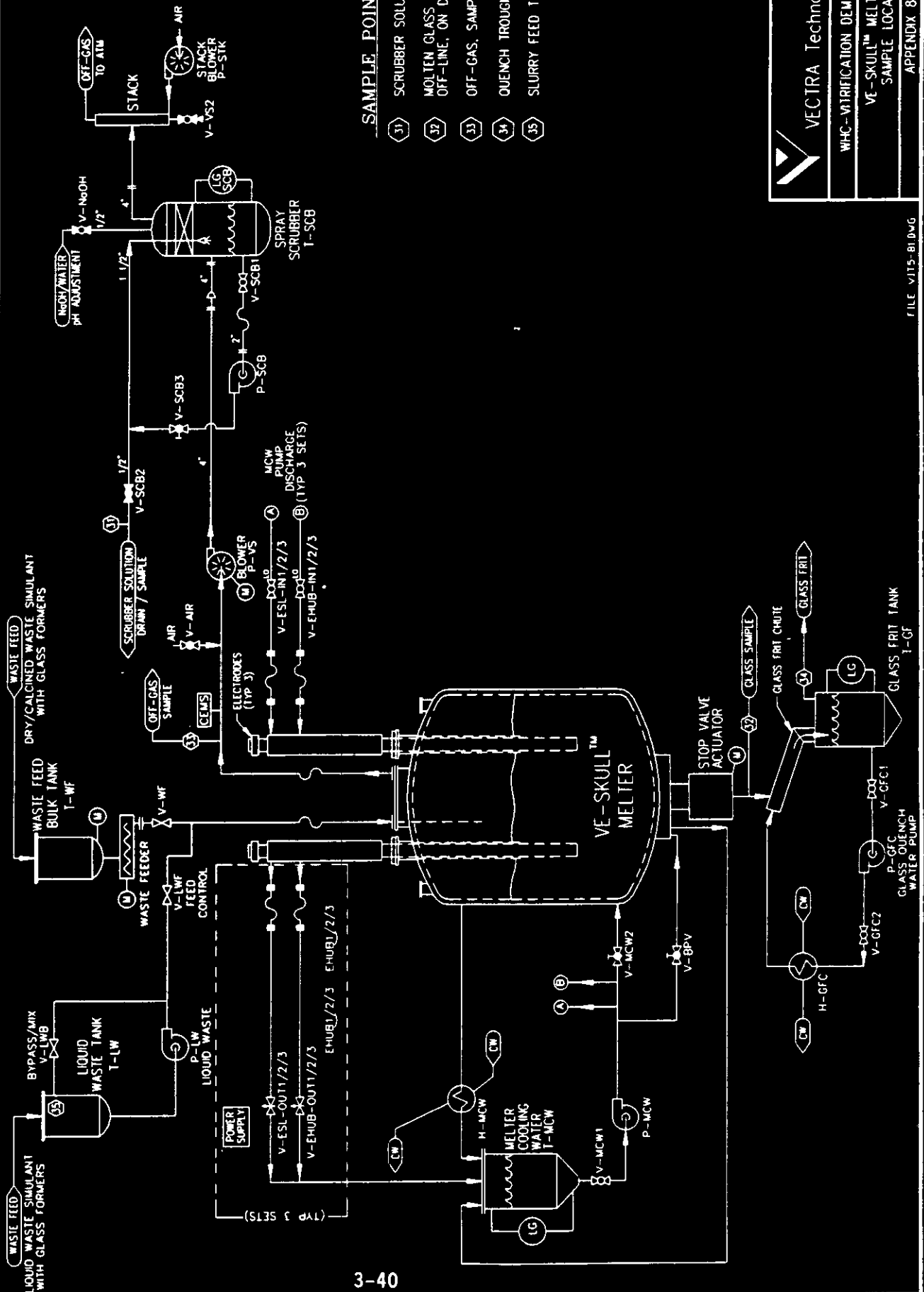
- The VECTRA Glass composition is a suitable feed mixture for idle melter operations. Short term idle melter operation can continue with a minimum amount of feeding or glass draining.
- Lower melter NOx and off-gas emissions resulted with dry, reacted, calcined feed than with VECTRA Glass, simulated calcined feed, or LLRW simulant slurry feed.
- Severe corrosion and failure of stainless steel electrode holders was experienced. New electrode holder design is required to allow angle and height adjustment on electrodes while in service. Holders must be water cooled to eliminate electrode corrosion at glass/gas interface. Glass pool level should be maintained above the holder/electrode interface.
- Drain ring extension should be placed into melter to allow simple melting of startup cullet in bottom zone of melter to drain ring.
- Partial dissolution of mortar between refractory blocks indicates that refractory blocks seams should be minimized and gaps eliminated to the maximum extent possible.
- The nitrogen purge system should be improved to prevent molybdenum oxidation when draining glass from melter.

APPENDIX 3A

LAB ANALYSES

SAMPLE POINTS

- ① SCRUBBER SOLUTION SAMPLE
- ② MOLTEN GLASS SAMPLE, OFF-LINE, ON DRAINDOWN
- ③ OFF-GAS, SAMPLE
- ④ QUENCH TROUGH
- ⑤ SLURRY FEED TANK



VECTRA Technologies Inc.

WHC-VITRIFICATION DEMONSTRATION

VE-SKULL™ MELTER TEST
SAMPLE LOCATIONS

APPENDIX 8.1

FILE VIT5-BIDWG

SAMPLE LOG

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V I M2 / F 35 -001	21/4	1700	Slurry Feed 1A	Slurry Mixed Sample		
V I M2 / W 31 -002 I	21/4	2000	Scrubber Solution			
V I M2 / W 31 -003 U I	21/4	2000	Scrubber Solution	USGS		
V I M2 / W 31 -004 P I	21/4	2000	Scrubber Solution	PNL	4/24/95	1489-95
V I M2 / W 31 -005 A I	21/4	2000	Scrubber Solution	Geotechnical		
V I M2 / W 34 -006 I	21/4	2000	Quench Trough			
V I M2 / W 34 -007 U I	21/4	2000	Quench Trough	USGS		
V I M2 / W 34 -008 A I	21/4	2000	Quench Trough	Geotechnical		
V I M2 / W 34 -009 P I	21/4	2000	Quench Trough	PNL	4/24/95	1500-95
V I M2 / F 35 -010	21/4	2300	Slurry Feed 2			
V I M2 / G 32 -011 P I	21/4	2230	Glass (Pour 1)	PNL	4/24/95	1501
V I M2 / G 32 -012 U I	21/4	2230	Glass (Pour 1)	USGS	4/24/95	D - 583957 & D - 583958
V I M2 / G 32 -013 C I	21/4	2230	Glass (Pour 1)	Corning	4/24/95	1, 2
V I M2 / G 32 -014 A I	21/4	2230	Glass (1)		5/9/95	
V I M2 / G 32 -015 P	22/4	0500	Glass Frit (2)	PNL	4/24/95	1507
V I M2 / G 34 -016 U	22/4	0500	Glass Frit (2)	USGS	4/24/95	D - 583959 & D - 583960
V I M2 / G 34 -017 C	22/4	0500	Glass Frit (2)	Corning		
V I M2 / G 34 -018 A	22/4	0500	Glass Frit (2)	Archive		
V I M2 / G 32 -019 P	22/4	0545	Glass (Pour 2)	PNL		

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V1 M2 / G 32 -020 U	22/4	0545	Glass (2)	USGS		
V1 M2 / G 32 -021 C	22/4	0545	Glass (2)	Corning		
V1 M2 / G 32 -022 A	22/4	0545	Glass (2)	Archive		
V1 M2 / F 35 -023	22/4	0550	Slurry Feed			
V1 M2 / G 32 -024 P	22/4	0800	Glass (3)	PNL		
V1 M2 / G 32 -025 U	22/4	0800	Glass (3)	USGS	4/26/95	D - 583977 & D - 583978
V1 M2 / G 32 -026 C	22/4	0800	Glass (3)	Corning		
V1 M2 / G 32 -027 A	22/4	0800	Glass (3)	Archive		
V1 M2 / W 34 -028 P 2	22/4	1100	Quench Trough	PNL	4/24/95	1495-95
V1 M2 / W 34 -029 U 2	22/4	1100	Quench Trough	USGS		
V1 M2 / W 34 -030 A 2	22/4	1100	Quench Trough	Geotechnical		
V1 M2 / W 34 -031 2	22/4	1100	Quench Trough			
V1 M2 / W 31 -032 P 2	22/4	1145	Scrubber Solution	PNL	4/24/95	1490-95
V1 M2 / W 31 -033 U 2	22/4	1145	Scrubber Solution	USGS		
V1 M2 / W 31 -034 A 2	22/4	1145	Scrubber Solution	Geotechnical		
V1 M2 / W 31 -035 2	22/4	1145	Scrubber Solution			
V1 M2 / G 32 -036 P	22/4	1100	Glass (4)	PNL		
V1 M2 / G 32 -037 C	22/4	1100	Glass (4)	Corning		
V1 M2 / G 32 -038 U	22/4	1100	Glass (4)	USGS	4/26/95	D - 583975 & D - 583976
V1 M2 / G 32 -039 A	22/4	1100	Glass (4)	Geotechnical		
V1 M2 / G 32 -040 P 2	22/4	1400	Glass (5)	PNL	4/24/95	1502
V1 M2 / G 32 -041 C 2	22/4	1400	Glass (5)	Corning	4/24/95	3, 4

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V I M2 / G 32 -042 U 2	22/4	1400	Glass (5)	USGS	4/24/95	D - 583961 & D - 583962
V I M2 / G 32 -043 A 2	22/4	1400	Glass (5)	Geotechnical	5/9/95	
V I M3 / W 34 -044 P 1	22/4	1935	Quench Trough	PNL	4/24/95	1496-95
V I M3 / W 34 -045 U 1	22/4	1935	Quench Trough	USGS		
V I M3 / W 34 -046 A 1	22/4	1935	Quench Trough	Geotechnical		
V I M3 / W 34 -047 I	22/4	1935	Quench Trough			
V I M3 / W 31 -048 P 1	22/4	1940	Scrubber Solution	PNL	4/24/95	1491-95
V I M3 / W 31 -049 U 1	22/4	1940	Scrubber Solution	USGS		
V I M3 / W 31 -050 A 1	22/4	1940	Scrubber Solution	Geotechnical		
V I M3 / W 31 -051 I	22/4	1940	Scrubber Solution			
V I M3 / F SB -052	22/4	1833	V-SIM BAG 1			
V I M3 / F SB -053	22/4	1833	V-SIM (2) Feed			
V I M3 / F SB -054	22/4	1856	V-SIM Feed (3)			
V I M3 / F SB -055	22/4	1950	V-SIM Feed (4)			
V I M3 / F SB -056	22/4	1950	V-SIM Feed (5)			
V I M3 / F SB -057	22/4	1950	V-SIM Feed (6)			
V I M3 / F SB -058	22/4	2045	RVR Feed (7)			
V I M3 / G 32 -059 P 1	22/4	2035	Glass (6)	PNL	4/24/95	1503
V I M3 / G 32 -060 U 1	22/4	2035	Glass (6)	USGS	4/24/95	D - 583971 & D - 583972
V I M3 / G 32 -061 C 1	22/4	2035	Glass (6)	Corning	4/24/95	5, 6
V I M3 / G 32 -062 A 1	22/4	2035	Glass (6)	Geotechnical		
V I M3 / W 34 -063 P 2	22/4	2150	Quench Trough	PNL	4/24/95	1497-95

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V I M3 / W 34 -064 U 2	22/4	2150	Quench Trough	USGS		
V I M3 / W 34 -065 A 2	22/4	2150	Quench Trough	Geotechnical		
V I M3 / W 34 -066 2	22/4	2150	Quench Trough			
V I M3 / W 31-067 P 2	22/4	2155	Scribber Solution	PNL	4/24/95	1492-95
V I M3 / W 31-068 U 2	22/4	2155	Scribber Solution	USGS		
V I M3 / W 31 -069 A 2	22/4	2155	Scribber Solution	Geotechnical		
V I M3 / W 31 -070 2	22/4	2155	Scribber Solution			
V I M3 / G 34 -071 P	22/4	2200	Glass Frit (6)	PNL	4/24/95	1508
V I M3 / G 34 -072 U	22/4	2200	Glass Frit (6)	USGS	4/24/95	D - 583963 & D - 583964
V I M3 / G 34 -073 C	22/4	2200	Glass Frit (6)	Corning		
V I M3 / G 34 -074 A	22/4	2200	Glass Frit (6)	Geotechnical		
V I M3 / G 32 -075 P 2	22/4	2240	Glass (7)	PNL	4/24/95	1504
V I M3 / G 32 -076 U 2	22/4	2240	Glass (7)	USGS	4/24/95	D - 583965 & D - 583966
V I M3 / G 32 -077 C 2	22/4	2240	Glass (7)	Corning	4/24/95	7, 8
V I M3 / G 32 -078 A 2	22/4	2240	Glass (7)	Geotechnical		
V I M4 / F SB-079	23/4	0312	Mixed Calcined Feed			
V I M3 / G 32 -080 P	23/4	0530	Glass (8)	PNL		
V I M3 / G 32 -081 U	23/4	0530	Glass (8)	USGS		
V I M3 / G 32 -082 C	23/4	0530	Glass (8)	Corning		
V I M3 / G 32 -083 A	23/4	0530	Glass (8)	Geotechnical		
V I M4 / W 31 -084 P 1	23/4	1045	Scribber	PNL	4/24/95	1493-95
V I M4 / W 31 -085 U 1	23/4	1045	Scribber	USGS		

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V1 M4 / W 31 -086 A 1	23/4	1045	Scribber	Geotechnical		
V1 M4 / W 31 -087 I	23/4	1045	Scribber			
V1 M4 / G 32 -088 P 1	23/4	1015	Glass (9)	PNL	4/24/95	1505
V1 M4 / G 32 -089 C 1	23/4	1015	Glass (9)	Corning	4/24/95	9, 10
V1 M4 / G 32 -090 U 1	23/4	1015	Glass (9)	USGS	4/24/95	D - 583967 & D - 583968
V1 M4 / G 32 -091 A 1	23/4	1015	Glass (9)	Geotechnical		
V1 M4 / W 34 -092 P 1	23/4	1300	Quench Trough	PNL	4/24/95	1498-95
V1 M4 / W 34 -093 U 1	23/4	1300	Quench Trough	USGS		
V1 M4 / W 34 -094 A 1	23/4	1300	Quench Trough	Geotechnical		
V1 M4 / W 34 -095 I	23/4	1300	Quench Trough			
V1 M4 / G 32 -096 P 2	23/4	1315	Glass (10)	PNL	4/24/95	1506
V1 M4 / G 32 -097 C 2	23/4	1315	Glass (10)	Corning	4/24/95	11,12
V1 M4 / G 32 -098 U 2	23/4	1315	Glass (10)	USGS	4/24/95	D - 583969 & D - 583970
V1 M4 / G 32 -099 A 2	23/4	1315	Glass (10)			
V1 M4 / W 34 -100 P 2	23/4	1600	Quench Trough	PNL	4/24/95	1499-95
V1 M4 / W 34 -101 U 2	23/4	1600	Quench Trough			
V1 M4 / W 34 -102 A 2	23/4	1600	Quench Trough			
V1 M4 / W 34 -103 2	23/4	1600	Quench Trough			
V1 M4 / W 31 -104 P 2	23/4	1600	Scribber	PNL	4/24/95	1494-95
V1 M4 / W 31 -105 U 2	23/4	1600	Scribber			
V1 M4 / W 31 -106 A 2	23/4	1600	Scribber			
V1 M4 / W 31 -107 2	23/4	1600	Scribber			

SAMPLE NUMBER	DATE	TIME	SAMPLE TYPE	DESTINATION LAB	SHIPMENT DATE	LAB SAMPLE #
V I M2 / F 35 - 108 P	22/4	0550	Slurry	PNL	5/1/95	
V I M2 / F 35 - 109 U	22/4	0550	Slurry			
V I M2 / F 35 - 110	22/4	0550	Slurry			
V I M2/F 35 - 111 A	22/4	0550	Slurry	Geotech		
V I M5/F 35 - 112	26/4	1300	Slurry			
V I M5/O 33 - 113	28/4	1400	Pipe Scale Build Up (Horizontal Pipe)			
V I M5/O 33 - 114	28/4	1400	Pipe Scale Build Up (Plenum Cross)			
V I M5/O 33 - 115	28/4	1400	Pipe Scale Build Up (Lower Elbow)			
V I M5/G IB - 116 C	18/5	1430	Inside Barrel	Corning	5/18/95	Sample 1
V I M5/G OB - 117 C	18/5	1430	Outside Barrel	Corning	5/18/95	Sample 2
V I M5/G 32 - 118 C	26/4	1035	Glass from V-Sim	Corning	5/18/95	Sample 3

SUPPLEMENTARY GLASS ANALYSES

Three glass samples were directly submitted to Corning by Vectra and analyzed under a separate subcontract. Sample description and results of analyses are as follows.

Sample Description

Sample VIM5/GIB-116C was taken from a drum of glass poured during final melter draining. This drum was wrapped with an insulating fiber mat during cooldown and the sample was taken near the center of the drum. This glass sample therefore was cooled at a relatively slow rate.

Sample VIM5/GOB-117C was taken from the same drum but from near the outside. This glass therefore was cooled at a significantly faster rate than the first sample.

Sample VIM5/G32-118C was taken during a normal glass pour at the end of the V-Sim high-throughput test (see Section 5.5).

Quantitative Chemical Analysis Results

CELS Client No.: 15334-001
Lab I.D. No.: 12120-95

Sample	Results (wt%)			Test method
	VIM5/GIB-116C	VIM5/GOB-117C	VIM5/G32-118C	
K ₂ O	1.15	1.15	1.24	FES
Na ₂ O	26.8	27.0	20.3	FES
Al ₂ O ₃	8.94	8.87	9.91	PLS
B ₂ O ₃	7.45	7.46	8.08	PLS
CaO	2.52	2.50	2.73	PLS
Cr ₂ O ₃	0.27	0.27	0.29	PLS
Fe ₂ O ₃	0.87	0.87	0.92	PLS
MgO	1.83	1.81	1.97	PLS
MnO ₂	0.010	0.010	0.013	PLS
P ₂ O ₅	0.18	0.15	0.17	PLS
SiO ₂	48.0	47.6	52.5	PLS
TiO ₂	0.012	0.012	0.012	PLS
ZrO ₂	0.094	0.085	0.077	PLS
C	0.01	0.02	0.01	LECO

WHC-SD-WM-VI-031
Revision 0

Results (wt%)				Test method
Sample	VIM5/GIB-116C	VIM5/GOB-117C	VIM5/G32-118C	
SO ₃	0.11	0.12	0.12	LECO
O ₂	39.6	39.1	41.3	LECO
F ⁻	0.20	0.20	0.22	PRYO
FeO	0.69	0.67	0.65	COLOR
Cl ⁻	0.14	0.14	0.17	TITR

FES = Flame Emission Spectroscopy
 PLS = Plasma/Emission Spectroscopy
 LECO = LECO Instrumentation
 COLOR = Colorimetry
 TITR = Titrimetry

Product Consistency Test (PCT) Results

Lab I.D. No.: 12040-95

Sample I.D.	Results (ppm)				
	Cs	Na	Al	Si	Sr
VIM5/GIB-116C					
Dissolution 1	0.55	217	31	168	0.021
Dissolution 2	0.55	217	31	168	0.023
VIM5/GIB-116C					
Dissolution 1	0.56	219	31	169	0.021
Dissolution 2	0.56	220	31	168	0.023
VIM5/GOB-117C					
Dissolution 1	0.53	215	31	165	0.025
Dissolution 2	0.53	212	31	164	0.027
VIM5/GOB-117C					
Dissolution 1	0.57	208	30	161	0.026
Dissolution 2	0.57	211	30	161	0.025
VIM5/G32-118C					
Dissolution 1	0.13	51	12	71	0.012
Dissolution 2	0.13	50	12	71	0.011
VIM5/G32-118C					
Dissolution 1	0.13	50	12	71	0.012
Dissolution 2	0.13	51	12	72	0.013

Sample I.D.	Results				
pH					
VIM5/GIB-116C Dissolution 1 Dissolution 2	12 12				
VIM5/GOB-117C Dissolution 1 Dissolution 2	12.1 12.2				
VIM5/G32-118C Dissolution 1 Dissolution 2	11.3 11.3				
Test methods: Cs by Flame Emission Spectroscopy. Na, Al, Si, Sr by Plasma/Emission Spectroscopy.					

MT2BALAN CHECK

MT-2	SiO ₂		B ₂ O ₃		Na ₂ O		CaO		MgO		Al ₂ O ₃		Fe ₂ O ₃	
	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS
	59.40	58.90	7.26	6.80	16.20	15.50	2.93	2.89	2.24	2.21	9.49	9.55	1.01	1.05
	58.90	58.80	7.32	6.96	16.20	15.50	2.91	2.89	2.23	2.22	9.44	9.55	1.00	1.02
	58.40	58.70	7.26	7.35	16.20	14.90	2.87	2.97	2.21	2.31	9.39	9.63	1.00	1.02
	58.20	58.70	7.29	7.28	16.20	15.00	2.86	2.99	2.20	2.28	9.44	9.62	1.00	1.04
	58.70		7.59		15.40		2.98		2.29		9.54		1.01	
	58.60		7.66		15.40		2.99		2.29		9.53		1.01	
	58.70		7.62		15.40		2.99		2.29		9.61		1.00	
	57.80		7.63		15.40		2.93		2.33		9.55		0.99	
AVERAGE	58.65		7.34		15.61		2.93		2.26		9.53		1.01	

MT3BALAN CHECK

MT-3	Na(2)O		Cl		F		I		Ca(2)O		SrO		Cr(2)O(3)	
	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS
	16.20	15.80	0.09	0.10	0.16	0.15		197.00	0.054	0.062	0.065	0.070	0.25	0.26
	16.20	15.80	0.09	0.10	0.16	0.17		202.00	0.054	0.062	0.066	0.070	0.26	0.28
	16.20	15.60	0.09	0.11	0.16	0.15			0.053	0.060	0.065	0.070	0.25	0.25
	16.30	15.70	0.09	0.11	0.16	0.16			0.054	0.059	0.065	0.070	0.25	0.24
	16.40			0.12	0.16				0.056		0.067		0.27	
	16.40			0.12	0.16				0.056		0.067		0.26	
	16.30				0.16				0.055		0.068		0.27	
	16.30				0.16				0.056		0.066		0.26	
AVERAGE	16.10		0.10		0.16		199.50		0.057		0.067		0.26	
	P(2)O(5)		B(2)O(3)		Al(2)O(3)		SiO(2)		CaO		MgO		Fe2O3	
	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS
	0.17	0.19	7.63	7.38	9.62	9.71	57.00	57.70	2.91	2.96	2.21	2.24	0.89	1.00
	0.12	0.18	7.67	7.44	9.56	9.72	57.40	57.80	2.93	2.95	2.23	2.24	0.99	1.03
	0.11	0.18	7.69	7.28	9.62	9.68	57.50	57.90	2.94	2.96	2.24	2.25	0.98	1.02
	0.10	0.18	7.72		9.55	9.70	57.20	58.00	2.92	2.97	2.22	2.24	0.98	1.05
	0.13		7.63		9.52		56.80		2.90		2.21		0.97	
	0.19		7.71		9.51		57.20		2.92		2.22		0.97	
	0.14		7.67		9.53		57.90		2.97		2.25		0.98	
	0.13		7.73		9.48		56.90		2.90		2.21		0.97	
AVERAGE	0.15		7.60		9.60		57.44		2.94		2.23		0.99	
	MnO		MnO(2)		MnO(3)		K2O		C					
	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS	Corning	USGS
		0.01	0.009		0.160	0.165	0.810	0.81	0.0030					
		0.01	0.008		0.160	0.165	0.810	0.81	0.0030					
		0.01	0.009		0.160	0.165	0.810	0.79	0.0030					
		0.01	0.009		0.160	0.165	0.810	0.79	0.0030					
			0.010		0.150		0.840		0.0030					
			0.009		0.160		0.840		0.0030					
			0.009		0.150		0.830		0.0030					
			0.009		0.160		0.830		0.0050					
AVERAGE	0.010		0.009		0.160		0.815		0.0033					



May 16, 1995

Mike Hill
Vectra Technologies, Inc.
One Harbison Way, Suite 209
Columbia, South Carolina 29212-3408

Dear Mr. Hill:

This letter serves to transmit OMNI Environmental Services, Inc. (OMNI) data report for testing services conducted on the vitrification process "melter" at the Vectra Technologies, Inc. Richland, Washington facilities during the period from April 21 to April 23, 1995. OMNI conducted isokinetic sampling and gaseous emissions analysis procedures on the exhaust stack which vents the process melter. The sampled exhaust gases consisted of a mixture of fumes generated by the heating of feedstock materials in the melter and ambient air which is drawn through the melter vent system to carry melter fumes to the emissions control/treatment system before being discharged to the atmosphere. OMNI sampled all emissions at a point in the exhaust-duct system which is more than 8 diameters downstream and 2 diameters upstream from disturbances and located between the melter and the emission control/treatment equipment.

Mr. Mike Hill was the project manager and technical liaison for Vectra Technologies and Mr. Paul Tiegs was the on-site project manager for OMNI.

Six one-hour test runs were performed on the following schedule:

Run Number 1 from 2305, April 21, 1995 to 0005, April 22, 1995
Run Number 2 from 1156, April 22, 1995 to 1256, April 22, 1995
Run Number 3 from 1910, April 22, 1995 to 2010, April 22, 1995
Run Number 4 from 2105, April 22, 1995 to 2205, April 22, 1995
Run Number 5 from 1041, April 23, 1995 to 1141, April 23, 1995
Run Number 6 from 1202, April 23, 1995 to 1302, April 23, 1995

Two runs were conducted for each of three different melter feedstock materials:

Run Numbers 1 and 2 were conducted while slurry #1 was used, Run Numbers 3 and 4 were conducted while slurry #2 was used, and Run Numbers 5 and 6 were conducted while a dry calcined feedstock was used.

Isokinetically (U.S. EPA Method 5 Type) sampled particulate material was analyzed for total mass and for the elemental and cation/anion constituents presented in Table 1. Except for methane and nitrous oxide (N_2O), the exhaust-gas gaseous constituents were measured on-site with

OMNI Environmental Services, Inc.

Consulting ♦ Engineering ♦ Testing

Vectra Technologies, Inc.
Richland, Washington

Table 2 (Page 1 of 2):
RESULTS of Melter Exhaust-Gas Sampling and Analysis (Standard International Reporting Units)
Testing Conducted April 21, 22, and 23, 1995

Measured Parameters	Reporting Units	Run Number 1	Run Number 2	Run Number 3	Run Number 4	Run Number 5	Run Number 6
Exhaust Gas:							
Flow Rate	(dscm/m)	2.95	2.81	7.11	11.38	14.85	9.14
Temperature	(Degrees Celsius)	150.1	138	73	60	50	47
Moisture (H ₂ O)	(% of exhaust gas)	28.0	24.0	4.0	4.4	2.3	1.7
Carbon Dioxide (CO ₂)	(% of exhaust gas)	1.10	0.68	0.49	0.63	0.33	0.32
Carbon Monoxide (CO)	(% of exhaust gas)	0.040	0.002	0.160	0.110	ND(0.005)	ND(0.005)
Oxygen (O ₂)	(% of exhaust gas)	19.8	20.2	20.3	20.2	20.6	20.6
Nitrogen (N ₂)	(% of exhaust gas)	79.1	79.1	79.1	79.1	79.1	79.1
Particulate Constituents:							
"Filter/Frontair" Catch: Total							
Nitrite (NO ₂)	(mg/dscm)	5666	4236	577	294	81	145
Nitrate (NO ₃)	(% of total particulate)	0.700	0.718	0.042	0.003	ND(0.001)	ND(0.001)
Sulfate (SO ₄)	(% of total particulate)	0.012	0.027	0.046	0.107	0.022	0.015
Ammonium (NH ₄)	(% of total particulate)	5.350	5.210	2.580	2.870	26.900	8.120
Carbonate (as CaCO ₃)	(% of total particulate)	0.001	0.001	0.004	0.003	ND(0.0002)	ND(0.0002)
Fluoride (F)	(% of total particulate)	25.54	23.15	28.63	24.86	15.80	14.80
Chloride (Cl)	(% of total particulate)	1.500	1.850	0.890	0.791	0.404	0.612
Iodide (I)	(% of total particulate)	4.780	6.240	9.200	8.930	14.600	14.600
pH (from 1:100 distilled H ₂ O extract)	(-log of H ⁺ concentration)	1.705	1.330	1.350	2.256	0.053	0.442
Elemental Analyses		8.94	8.99	9.46	9.18	9.18	9.16
Silicon (Si)	(% of total particulate)	0.890	0.160	0.890	0.851	ND(0.0005)	ND(0.0005)
Aluminum (Al)	(% of total particulate)	0.854	0.258	1.011	1.047	ND(0.0005)	ND(0.0005)
Cadmium (Cd)	(% of total particulate)	0.002	ND(0.0005)	ND(0.0005)	ND(0.0005)	ND(0.0005)	ND(0.0005)
Magnesium (Mg)	(% of total particulate)	0.013	0.005	0.026	0.006	ND(0.0005)	ND(0.0005)
Manganese (Mn)	(% of total particulate)	0.530	0.278	1.382	0.498	0.013	0.001
Iron (Fe)	(% of total particulate)	0.407	9.400	0.395	0.749	0.455	0.216
Molybdenum (Mo)	(% of total particulate)	0.078	0.042	0.049	0.024	0.771	0.152
Chromium (Cr)	(% of total particulate)	0.006	0.002	0.031	0.021	0.001	ND(0.0005)
Strontium (Sr)	(% of total particulate)	ND(0.0002)	ND(0.0002)	ND(0.0002)	ND(0.0002)	0.129	0.141
Cesium (Cs)	(% of total particulate)	0.028	0.081	0.050	ND(0.0005)	ND(0.0005)	ND(0.0005)
Phosphorus (P)	(% of total particulate)	4.109	3.765	3.548	3.329	3.666	3.114
Potassium (K)	(% of total particulate)	22.000	20.900	18.600	19.900	32.200	21.500
Sodium (Na)	(% of total particulate)	8.000	6.620	12.000	11.700	9.170	8.820
Boron (B)	(mg/dscm)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Ammonium (NH ₄)	(ppm)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)
Fluoride (F)	(ppm)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Chloride (Cl)	(ppm)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Phosphorus (P)	(ppm)	ND(100)	ND(100)	ND(100)	ND(100)	ND(100)	ND(100)
Boron (B)	(ppm)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)
"Backhalf" Catch: Total							
Gaseous Parameters:							
Total Nitrogen Oxides (NO_x)							
Nitric Oxide (NO)	(ppm)	360	235	105	80	ND(1.0)	ND(1.0)
Nitrogen Dioxide (NO ₂)	(ppm)	349	224	103	80	ND(1.0)	ND(1.0)
Nitrogen Oxide (N ₂ O)	(ppm)	11	11	2	ND(1.0)	ND(1.0)	ND(1.0)
Sulfur Dioxide (SO ₂)	(ppm)	0.8	ND(1.0)	ND(1.0)	ND(1.0)	10.1	12.4
Carbon Monoxide (CO)	(ppm)	397	23	1600	1100	ND(5.0)	ND(5.0)
Methane (CH ₄)	(ppm)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
Total Hydrocarbon (as propane, C ₃ H ₈)	(ppm)	18.3	20.7	3.0	0.9	ND(1.0)	ND(1.0)

Notes: ND = Not Detected at the level indicated in parentheses.
NAP = Not Applicable
STP = 21.1 degrees Celsius and 1.00 atmosphere barometric pressure.
One gram-mole = 24.1 liters gaseous
All gaseous constituents are reported as dry basis.

ON CAMPUS
DATE 7/27/95

Vectra Technologies, Inc
Richland, Washington

Table 2 (Page 2 of 2): RESULTS of Melter Exhaust-Gas Sampling and Analysis (Standard International Reporting Units)
Testing Conducted April 21, 22, and 23, 1995

Measured Parameters	Reporting Units	Run Number 1	Run Number 2	Run Number 3	Run Number 4	Run Number 5	Run Number 6
Exhaust Gas:							
Flow Rate	(kg/hour)	212.7	202.6	512.9	820.3	1070.8	658.9
Temperature	(Degrees Kelvin)	423	411	346	333	323	320
Moisture (H2O)	(kg/hour)	37.0	30.2	12.7	22.2	15.3	6.8
Carbon Dioxide (CO2)	(kg/hour)	3.6	2.1	3.8	7.9	5.4	3.2
Carbon Monoxide (CO)	(kg/hour)	0.0617	0.0044	0.7935	0.7925	0.0000	0.0000
Oxygen (O2)	(kg/hour)	46.5	45.2	115.1	183.1	243.8	150.0
Nitrogen (N2)	(kg/hour)	162.7	155.0	392.5	627.5	616.8	503.9
Particulate Constituents:							
"Filter/Frontal" Catch:							
Total	(kg/hour)	1.00	0.71	0.25	0.20	0.07	0.08
Nitrate (NO3)	(kg/hour)	0.00702	0.00513	0.00010	0.00001	ND(0.001)	ND(0.001)
Sulfate (SO4)	(kg/hour)	0.00072	0.00019	0.00011	0.00021	0.00002	0.00001
Ammonium (NH4)	(kg/hour)	0.05368	0.03721	0.00635	0.00535	0.01933	0.00645
Carbonate (as CaCO3)	(kg/hour)	0.00001	0.00001	0.00001	0.00001	ND(0.0002)	ND(0.0002)
Fluoride (F)	(kg/hour)	0.25623	0.16532	0.00558	0.00001	0.01135	0.01159
Chloride (Cl)	(kg/hour)	0.01505	0.01321	0.00217	0.00159	0.00049	0.00049
Iodide (I)	(kg/hour)	0.04776	0.04457	0.02265	0.01790	0.01049	0.01159
pH (from 1:100 distilled H2O extract)	N/A	0.01711	0.00950	0.00332	0.00452	0.00004	0.00035
Elemental Analyses							
Silicon (Si)	(kg/hour)	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum (Al)	(kg/hour)	0.00692	0.00129	0.00219	0.00191	ND(0.0005)	ND(0.0005)
Cadmium (Cd)	(kg/hour)	0.00657	0.00213	0.00249	0.00210	ND(0.0005)	ND(0.0005)
Magnesium (Mg)	(kg/hour)	0.00002	ND(0.0005)	ND(0.0005)	ND(0.0005)	ND(0.0005)	ND(0.0005)
Manganese (Mn)	(kg/hour)	0.00013	0.00004	0.00006	0.00001	ND(0.0005)	ND(0.0005)
Iron (Fe)	(kg/hour)	0.00531	0.00199	0.00340	0.00069	0.00001	0.00000
Molybdenum (Mo)	(kg/hour)	0.00408	0.00714	0.00097	0.00150	0.00033	0.00017
Chromium (Cr)	(kg/hour)	0.00078	0.00030	0.00012	0.00005	0.00055	0.00012
Strontium (Sr)	(kg/hour)	0.00062	0.00011	0.00077	0.00042	0.00001	ND(0.0005)
Cesium (Cs)	(kg/hour)	ND(0.0002)	ND(0.0002)	ND(0.0002)	ND(0.0002)	0.00009	0.00011
Phosphorus (P)	(kg/hour)	0.00028	0.00058	0.00012	ND(0.0005)	0.00009	ND(0.0005)
Potassium (K)	(kg/hour)	0.04123	0.02889	0.00873	0.00467	0.00263	0.00247
Sodium (Na)	(kg/hour)	0.22073	0.14928	0.46626	0.03989	0.02314	0.01707
Boron (B)	(kg/hour)	0.06026	0.04728	0.02954	0.02345	0.00659	0.00700
"Backhalf" Catch:							
Ammonium (NH4)	(kg/hour)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Fluoride (F)	(kg/hour)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)
Chloride (Cl)	(kg/hour)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Phosphorus (P)	(kg/hour)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Boron (B)	(kg/hour)	ND(100)	ND(100)	ND(100)	ND(100)	ND(100)	ND(100)
Gasous Parameters:							
Total Nitrogen Oxides (NOx)	(kg/hour)	0.12168	0.07562	0.06555	0.10425	ND(1.0)	ND(1.0)
Nitric Oxide (NO)	(kg/hour)	0.07179	0.04388	0.05108	0.06345	ND(1.0)	ND(1.0)
Nitrogen Dioxide (NO2)	(kg/hour)	0.00356	0.00339	0.00156	ND(1.0)	ND(1.0)	ND(1.0)
Nitrous Oxide (N2O)	(kg/hour)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
Sulfur Dioxide (SO2)	(kg/hour)	0.00038	ND(1.0)	ND(1.0)	ND(1.0)	0.02390	0.01906
Carbon Monoxide (CO)	(kg/hour)	0.09167	0.00441	0.79354	0.67250	ND(5.0)	ND(5.0)
Methane (CH4)	(kg/hour)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
Total Hydrocarbon (as propane, C3H8)	(kg/hour)	0.00753	0.00811	0.00238	0.00146	ND(1.0)	ND(1.0)

Notes: ND = Not Detected at the level indicated in parentheses.

N/A = Not Applicable

STP = 21.1 degrees Celsius and 1.00 atmosphere barometric pressure.

One gram-mole at STP = 24.1 liters gasous

All gaseous constituents are reported as dry basis

OK Complete
Defect

APPENDIX 3B

THROUGHPUT LOG

THROUGHPUT LOG

Feed/Drain Log		Test Phase		Feed											
Date & Time	Cum. hours	Cullet (lbs)	Soda Ash	Refiner	Trans Batch (lbs)	VECTRA Glass (lbs)	Slurry Batched (lbs)	Transfer to drum (lbs)	Drum Level (in)	Drum delta level (in)	Slurry (lbs)	V-SIM (lbs)	Calclined (lbs)	High Na (lbs)	Cum. Feed (lbs)
3/28/95 17:00	0.0	2152.0													2152.0
3/28/95 11:41	42.7		25.0												2177.0
3/28/95 11:54	42.9		25.0												2202.0
3/28/95 12:05	43.1	50.0													2252.0
3/31/95 14:10	117.2														2254.0
3/31/95 16:19	119.3		5.0												2259.0
3/31/95 20:30	123.5	75.0													2334.0
3/31/95 21:40	124.7	75.0													2409.0
3/31/95 22:47	125.8	75.0													2484.0
4/1/95 0:35	127.6	75.0													2559.0
4/1/95 1:30	128.5		120.0												2679.0
4/1/95 4:00	131.0	50.0													2729.0
4/1/95 5:20	132.3	100.0													2829.0
4/1/95 11:12	138.2			1.0											2830.0
4/1/95 11:24	138.4		1.0												2831.0
4/1/95 12:00	139.0		3.0	1.0											2835.0
4/1/95 13:56	141.0														2835.0
4/1/95 16:00	143.0	100.0													3085.0
4/1/95 18:30	145.5	150.0													3235.0
4/2/95 0:07	151.1	150.0		2.0											3235.0
4/2/95 9:00	160.0			2.0											3237.0
4/2/95 16:47	167.8				25.0 batch 1										3239.0
4/2/95 17:20	168.3				20.0										3264.0
4/2/95 18:20	169.3				25.0 batch 2										3264.0
4/2/95 19:25	170.4				25.0										3309.0
4/2/95 21:15	172.2				25.0										3334.0
4/2/95 22:05	173.1			1.0											3359.0
4/2/95 22:35	173.6			4.0											3360.0
4/3/95 0:35	175.6			2.0											3364.0
4/3/95 2:10	177.2				25.0 batch 3										3391.0
4/3/95 6:45	181.7				25.0										3398.0
4/3/95 7:30	182.5		2.0												3416.0
4/3/95 9:20	184.3		1.0	1.0											3418.0
4/3/95 9:35	184.6		2.0	1.0											3420.0
4/3/95 9:45	184.7		1.0	1.0											3423.0
4/3/95 10:37	185.6		2.0												3425.0
4/3/95 11:19	186.3		1.0												3427.0
4/3/95 12:13	187.2		1.0												3428.0
4/3/95 12:40	187.7				25.0										3428.0
4/3/95 14:20	188.3				25.0										3454.0
4/3/95 18:17	193.3				25.0										3479.0
4/3/95 21:15	196.2				25.0 batch 4										3504.0
4/3/95 22:15	197.3				25.0										3529.0
4/3/95 23:15	198.2				25.0										3554.0
4/4/95 0:35	199.6				25.0										3579.0
4/4/95 1:15	200.3				25.0										3604.0
4/4/95 2:15	201.2				25.0										3629.0
4/4/95 8:44	207.7		1.0												3654.0
4/4/95 18:15	217.2		1.0												3655.0
															3656.0

THROUGHPUT LOG

Feed/Drain Log		Cum. hours	Test Phase	Cullet (lbs)	Soda Ash	Refiner	Trans Batch (lbs)	VECTRA Glass (lbs)	Slurry Batched (lbs)	Transfer to drum (lbs)	Drum Level (in)	Drum delta level (in)	Slurry (lbs)	V-SIM (lbs)	Calclined (lbs)	High Ne (lbs)	Cum. Feed (lbs)
Date & Time																	
4/7/95 0:41	271.7	MT-1, V-glass START						70.0									3726.0
4/7/95 2:07	273.1	MT-1, V-glass		2.0													3726.0
4/7/95 2:13	273.2	MT-1, V-glass															3726.0
4/7/95 3:10	274.2	MT-1, V-glass		2.0													3730.0
4/7/95 5:06	276.1	MT-1, V-glass						50.0									3780.0
4/7/95 6:00	278.0	MT-1, V-glass						25.0									3805.0
4/7/95 9:00	280.0	MT-1, V-glass						25.0									3830.0
4/7/95 11:06	282.1	MT-1, V-glass		2.0													3832.0
4/7/95 12:49	283.8	MT-1, V-glass		2.0													3834.0
4/7/95 13:47	284.8	MT-1, V-glass															3836.0
4/7/95 15:42	286.7	MT-1, V-glass		4.0													3840.0
4/7/95 21:04	292.1	MT-1, V-glass															3840.0
4/7/95 21:15	292.2	MT-1, V-glass						80.0									3920.0
4/7/95 21:40	292.7	MT-1, V-glass						77.0									3997.0
4/7/95 22:30	293.5	MT-1, V-glass						25.0									4022.0
4/8/95 0:30	295.5	MT-1, V-glass						77.0									4099.0
4/8/95 1:30	298.5	MT-1, V-glass						78.0									4177.0
4/8/95 2:15	297.2	MT-1, V-glass						25.0									4202.0
4/8/95 3:00	298.0	MT-1, V-glass						90.0									4282.0
4/8/95 3:50	298.8	MT-1, V-glass						178.0									4460.0
4/8/95 5:00	300.0	MT-1, V-glass						40.0									4500.0
4/8/95 5:45	300.8	MT-1, V-glass						60.0									4560.0
4/8/95 8:15	303.2	MT-1, V-glass						80.0									4640.0
4/8/95 12:00	307.0	MT-1, V-glass						75.0									4715.0
4/8/95 14:52	309.9	MT-1, V-glass						75.0									4780.0
4/8/95 14:56	309.9	MT-1, V-glass															4865.0
4/8/95 15:04	310.1	MT-1, V-glass						75.0									4865.0
4/8/95 16:20	311.3	MT-1, V-glass						80.0									4945.0
4/8/95 17:30	312.5	MT-1, V-glass						77.0									5022.0
4/8/95 18:00	313.0	MT-1, V-glass						77.0									5099.0
4/8/95 18:47	313.8	MT-1, V-glass						80.0									5179.0
4/8/95 20:00	315.0	MT-1, V-glass						77.0									5256.0
4/8/95 21:00	316.0	MT-1, V-glass						76.0									5332.0
4/8/95 21:34	316.6	MT-1, V-glass						78.0									5410.0
4/8/95 22:27	317.4	MT-1, V-glass						156.0									5566.0
4/9/95 1:00	320.0	MT-1, V-glass						156.0									5724.0
4/9/95 1:10	320.2	MT-1, V-glass						30.0									5754.0
4/9/95 2:40	321.7	MT-1, V-glass						30.0									5784.0
4/9/95 4:10	323.2	MT-1, V-glass						157.0									5941.0
4/9/95 5:10	324.2	MT-1, V-glass						156.0									6097.0
4/9/95 14:20	333.3	MT-1, V-glass															6097.0
4/9/95 14:22	333.4	MT-1, V-glass						70.0									6167.0
4/9/95 15:07	334.1	MT-1, V-glass						78.0									6245.0
4/9/95 17:00	336.0	MT-1, V-glass		2.0													6245.0
4/9/95 18:40	338.7	MT-1, V-glass															6247.0
4/9/95 23:30	342.5	MT-1, V-glass						158.0									6405.0
4/10/95 2:35	345.6	MT-1, V-glass						155.0									6560.0
4/10/95 5:10	348.2	MT-1, V-glass						155.0									6715.0
4/10/95 6:21	351.3	MT-1, V-glass						81.0									6790.0
																	6871.0

[illegible]

Feed/Drain Log		Cum. hours	Test Phase	Feed											
Date & Time	Cullet (lbs)			Soda Ash	Refiner	Trans Batch (lbs)	VECTRA Class (lbs)	Slurry Batched (lbs)	Transfer to drum (lbs)	Drum Level (in)	Drum delta level (in)	Slurry (lbs)	V-SIM (lbs)	Catched (lbs)	High Na (lbs)
4/13/95 0:15		415.2	MT-1, V-glass												12242.0
4/13/95 1:30		416.5	MT-1, V-glass												12318.0
4/13/95 1:45		416.7	MT-1, V-glass												12395.0
4/13/95 2:40		417.7	MT-1, V-glass												12712.0
4/13/95 6:55		421.9	MT-1, V-glass												13028.0
4/13/95 8:26		423.4	MT-1, V-glass												13178.0
4/13/95 9:09		424.1	MT-1, V-glass												13337.0
4/13/95 9:30		424.5	MT-1, V-glass												13780.0
4/13/95 10:19		425.3	MT-1, V-glass												13337.0
4/13/95 11:29		426.5	MT-1, V-glass												13465.0
4/13/95 12:10		427.2	MT-1, V-glass				2.0								13635.0
4/13/95 12:12		427.2	MT-1, V-glass												13735.0
4/13/95 13:40		428.7	MT-1, V-glass												13896.0
4/13/95 18:00		433.0	MT-1, V-glass				2.0								14053.0
4/13/95 19:30		434.6	MT-1, V-glass												14257.0
4/13/95 20:30		435.5	MT-1, V-glass												14257.0
4/13/95 22:10		437.2	MT-1, V-glass												14307.0
4/13/95 23:30		438.5	MT-1, V-glass												14791.0
4/14/95 2:40		441.7	MT-1, V-glass												14871.0
4/14/95 4:00		443.0	MT-1, V-glass												14948.0
4/14/95 7:00		446.0	Idle												15106.0
4/15/95 9:18		472.3	Idle												15106.0
4/16/95 14:22		501.4	Idle												15170.0
4/16/95 14:27		501.4	Idle												15170.0
4/16/95 15:35		502.6	Idle												15403.0
4/17/95 8:00		519.0	Idle												15405.0
4/17/95 8:45		519.6	MT-1, V-glass												15405.0
4/17/95 11:06		522.1	MT-1, V-glass												15405.0
4/17/95 11:10		522.2	MT-1, V-glass												15405.0
4/17/95 13:52		524.9	MT-1, V-glass STOP												15406.0
4/17/95 16:44		527.7	MT-1:slurry START												15565.0
4/17/95 18:17		529.3	MT-1:slurry												15603.0
4/18/95 0:00		535.0	MT-1:slurry												15603.0
4/18/95 3:21		538.3	MT-1:slurry												15603.0
4/18/95 7:46		542.6	MT-1:slurry												15681.0
4/18/95 8:45		543.6	MT-1:slurry												16898.0
4/18/95 9:20		544.3	MT-1:slurry												16898.0
4/18/95 13:11		548.2													

THROUGHPUT LOG

Feed/Drain Log		Cum. hours	Test Phase	Cullet (lbs)	Soda Ash Refiner	Trans Batch (lbs)	VECTRA Glass (lbs)	Slurry Batched (lbs)	Transfer to drum (lbs)	Drum Level (in)	Drum delta level (in)	Slurry (lbs)	V-SIM (lbs)	Calched (lbs)	High Na (lbs)	Cum. Feed (lbs)
Date & Time																
4/19/95 17:30		576.5	MT-1 slurry				166.0									19049.0
4/19/95 21:10		580.2	MT-1 slurry													19049.0
4/20/95 1:40		584.7	MT-1 slurry							28.0						19049.0
4/20/95 2:00		585.0	MT-1 slurry					1064.0	batch 4							19049.0
4/20/95 3:45		586.7	MT-1 slurry							17.0	9.0	278.0				19049.0
4/20/95 3:45		586.7	MT-1 slurry							32.0						19328.0
4/20/95 5:06		588.1	MT-1 slurry							23.0	9.0	278.0				19328.0
4/20/95 5:30		588.5	MT-1 slurry					1064.0	batch 5							19607.0
4/20/95 5:49		588.8	MT-1 slurry													19607.0
4/20/95 6:10		589.2	MT-1 slurry													19607.0
4/20/95 6:00		591.0	MT-1 slurry						372.0	35.0						19607.0
4/20/95 9:15		592.2	MT-1 slurry							28.0	6.0	186.0				19793.0
4/20/95 9:30		592.5	MT-1 slurry							24.5	4.5	139.5				19932.5
4/20/95 10:00		593.0	MT-1 slurry							23.0	1.5	46.5				19979.0
4/20/95 10:31		593.5	MT-1 slurry							21.5	1.5	46.5				20026.5
4/20/95 11:05		594.1	MT-1 slurry							17.5	4.0	124.0				20149.5
4/20/95 11:30		594.5	MT-1 slurry							13.0	4.5	139.5				20289.0
4/20/95 11:47		594.8	MT-1 slurry							11.0	2.0	62.0				20351.0
4/20/95 11:53		594.9	MT-1 slurry				80.0					42.3	approx			20393.2
4/20/95 12:02		595.0	MT-1 slurry													20473.2
4/20/95 12:30		595.5	MT-1 slurry						440.0							20473.2
4/20/95 13:00		596.0	MT-1 slurry					849.0	batch 6							20473.2
4/20/95 13:47		596.8	MT-1 slurry							28.5						20473.2
4/20/95 14:10		597.2	MT-1 slurry							25.3	1.3	36.8				20511.9
4/20/95 14:30		597.5	MT-1 slurry							24.0	1.3	36.8				20550.7
4/20/95 15:10		598.2	MT-1 slurry							22.5	1.5	46.5				20597.2
4/20/95 15:15		598.2	MT-1 slurry							18.5	4.0	124.0				20721.2
4/20/95 15:30		598.5	MT-1 slurry					354.0		28.0						20721.2
4/20/95 16:26		599.4	MT-1 slurry							27.3	1.8	54.3				20775.4
4/20/95 16:30		599.5	MT-1 slurry													20775.4
4/20/95 17:00		600.0	MT-1 slurry							21.0	6.3	183.8				20869.2
4/20/95 17:30		600.5	MT-1 slurry							18.5	2.5	77.5				21046.7
4/20/95 17:39		600.7	MT-1 slurry							15.0	3.5	108.5				21155.2
4/20/95 18:00		601.0	MT-1 slurry					444.0		31.0						21155.2
4/20/95 18:30		601.5	MT-1 slurry							29.0	2.0	62.0				21217.2
4/20/95 19:36		602.6	MT-1 slurry							26.0	3.0	93.0				21310.2
4/20/95 20:00		603.0	MT-1 slurry							21.0	5.0	155.0				21465.2
4/20/95 20:22		603.4	MT-1 slurry							19.0	2.0	62.0				21527.2
4/20/95 20:44		603.7	MT-1 slurry							18.0	1.0	31.0				21568.2
4/20/95 20:56		603.9	MT-1 slurry							17.5	0.5	15.5				21573.7
4/20/95 21:16		604.3	MT-1 slurry						364.3	29.3						21573.7
4/20/95 21:38		604.6	MT-1 slurry							27.5	1.8	54.3				21627.9
4/20/95 21:57		604.9	MT-1 slurry							27.0	0.5	15.5				21643.4
4/20/95 23:15		606.2	MT-1 slurry							26.0	1.0	31.0				21674.4
4/21/95 1:26		608.4	MT-1 slurry													21674.4
4/21/95 4:10		611.2	MT-1 slurry							18.5	7.5	232.5				21906.9
4/21/95 6:55		613.9	MT-1 slurry				315.0			6.0	12.5	387.5				22294.4
4/21/95 10:35		617.6	MT-1 slurry													22609.4
																22609.4

THROUGHPUT LOG

Feed/Drain Log	Date & Time	Cum. hours	Test Phase	Cullet (lbs)	Soda Ash Refiner	Trans Batch (lbs)	VECTRA Glass (lbs)	Slurry Batched (lbs)	Transfer to drum (lbs)	Drum Level (in)	Drum delta level (in)	Slurry (lbs)	V-SIM (lbs)	Calculated (lbs)	High Na (lbs)	Cum. Feed (lbs)
	4/21/95 11:17		618.3 MT-1-slurry													22613.4
	4/21/95 11:45		618.8 MT-1-slurry		4.0											22614.4
	4/21/95 12:15		619.2 MT-1-slurry		1.0			1078.0 batch 1a								22614.4
	4/21/95 12:54		619.9 MT-1-slurry													22614.4
	4/21/95 16:20		623.3 MT-1-slurry													22614.4
	4/21/95 16:29		623.5 MT-1-slurry													22614.4
	4/21/95 17:00		624.0 MT-1-slurry													22614.4
	4/21/95 17:28		624.5 MT-1-slurry													22614.4
	4/21/95 18:30		625.5 MT-1-slurry													22614.4
	4/21/95 19:00		626.0 MT-1-slurry													22614.4
	4/21/95 19:23		626.4 MT-1-slurry													22614.4
	4/21/95 19:37		626.6 MT-1-slurry													22614.4
	4/21/95 19:50		626.8 MT-1-slurry													22614.4
	4/21/95 20:12		627.2 MT-1-slurry													22614.4
	4/21/95 20:29		627.5 MT-1-slurry													22614.4
	4/21/95 20:29		627.5 MT-1-slurry													22614.4
	4/21/95 20:45		627.8 MT-1-slurry													22614.4
	4/21/95 21:03		628.0 MT-1-slurry													22614.4
	4/21/95 21:27		628.5 MT-1-slurry													22614.4
	4/21/95 21:37		628.6 MT-1-slurry													22614.4
	4/21/95 22:08		629.1 MT-1-slurry													22614.4
	4/21/95 22:28		629.4 MT-1-slurry													22614.4
	4/21/95 22:46		629.8 MT-1-slurry													22614.4
	4/21/95 22:55		629.9 MT-1-slurry STOP													22614.4
	4/21/95 23:00		630.0 MT-2-slurry MB START													22614.4
	4/21/95 23:40		630.7 MT-2-slurry													22614.4
	4/21/95 23:45		630.8 MT-2-slurry													22614.4
	4/22/95 1:54		632.9 MT-2-slurry													22614.4
	4/22/95 3:07		634.1 MT-2-slurry													22614.4
	4/22/95 3:07		634.1 MT-2-slurry													22614.4
	4/22/95 3:45		634.7 MT-2-slurry													22614.4
	4/22/95 4:05		635.1 MT-2-slurry													22614.4
	4/22/95 4:13		635.2 MT-2-slurry													22614.4
	4/22/95 7:10		638.2 MT-2-slurry													22614.4
	4/22/95 7:18		638.3 MT-2-slurry													22614.4
	4/22/95 7:18		638.3 MT-2-slurry													22614.4
	4/22/95 10:45		641.7 MT-2-slurry													22614.4
	4/22/95 11:48		642.8 MT-2-slurry													22614.4
	4/22/95 13:00		644.0 MT-2-slurry MB STOP													22614.4
	4/22/95 13:57		645.0													22614.4
	4/22/95 14:58		646.0													22614.4
	4/22/95 15:05		646.1													22614.4
	4/22/95 16:58		648.0													22614.4
	4/22/95 17:36		648.6													22614.4
	4/22/95 18:05		649.1													22614.4
	4/22/95 18:10		649.2													22614.4
	4/22/95 18:20		649.3													22614.4
	4/22/95 18:33		649.5													22614.4

THROUGHPUT LOG

Feed/Drain Log		Cum. hours	Test Phase	Cullet (lbs)	Soda Ash	Refiner	Trans Batch (lbs)	VECTRA Glass (lbs)	Slurry Batched (lbs)	Transfer to drum (lbs)	Drum Level (in)	Drum delta level (in)	Slurry (lbs)	V-SIM (lbs)	Calchred (lbs)	High Na (lbs)	Cum. Feed (lbs)
Date & Time																	
4/22/95 18:56		649.9												30.0			26140.2
4/22/95 19:00		650.0	MT-3: V-SIM MB START														26140.2
4/22/95 19:50		650.6	MT-3: V-SIM											220.0			26360.2
4/22/95 20:36		651.6	MT-3: V-SIM														26360.2
4/22/95 22:00		653.0	MT-3: V-SIM MB STOP														26360.2
4/22/95 22:53		653.9															26360.2
4/23/95 1:10		656.2															26516.2
4/23/95 2:59		656.0												156.0			26516.2
4/23/95 5:37		660.6												200.0			26716.2
4/23/95 6:20		661.3															26716.2
4/23/95 6:25		661.4												76.0			26794.2
4/23/95 8:55		664.9												77.0			26871.2
4/23/95 10:00		665.0	MT-4: Calchred MB START														26871.2
4/23/95 10:15		665.3	MT-4: Calchred												231.6		27102.8
4/23/95 10:21		665.3	MT-4: Calchred												50.0		27152.8
4/23/95 10:30		665.5	MT-4: Calchred												25.0		27177.8
4/23/95 10:35		665.6	MT-4: Calchred														27177.8
4/23/95 13:30		668.5	MT-4: Calchred												50.0		27227.8
4/23/95 13:48		668.8	MT-4: Calchred														27227.8
4/23/95 14:00		669.0	MT-4: Calchred MB STOP														27227.8
4/23/95 14:26		669.4															27227.8
4/23/95 17:10		672.2													75.0		27302.8
4/23/95 17:40		672.7													192.0		27494.8
4/23/95 19:30		674.5													32.0		27526.8
4/23/95 23:57		678.9												156.0			27682.8
4/24/95 0:40		679.7	HT: V-SIM START														27682.8
4/24/95 2:25		681.4	HT: V-SIM											541.0			28223.8
4/24/95 4:24		683.4	HT: V-SIM														28223.8
4/24/95 4:39		683.6	HT: V-SIM											159.0			28382.8
4/24/95 5:00		684.0	HT: V-SIM														28382.8
4/24/95 5:10		684.2	HT: V-SIM											79.0			28461.8
4/24/95 8:02		687.0	HT: V-SIM											316.0			28777.8
4/24/95 8:55		687.9	HT: V-SIM														28777.8
4/24/95 10:01		689.0	HT: V-SIM											232.0			29009.8
4/24/95 10:44		689.7	HT: V-SIM														29009.8
4/24/95 10:47		689.8	HT: V-SIM											157.0			29166.8
4/24/95 13:31		692.5	HT: V-SIM											77.0			29243.8
4/24/95 14:13		693.2	HT: V-SIM											234.0			29477.8
4/24/95 15:27		694.5	HT: V-SIM														29477.8
4/24/95 17:03		696.0	HT: V-SIM											245.0			29722.8
4/24/95 17:14		696.2	HT: V-SIM														29722.8
4/24/95 18:43		697.7	HT: V-SIM											235.0			29957.8
4/24/95 20:10		699.2	HT: V-SIM														29957.8
4/24/95 22:53		701.9	HT: V-SIM											311.0			30268.8
4/24/95 23:00		702.0	HT: V-SIM														30268.8
4/24/95 23:10		702.2	HT: V-SIM											160.0			30428.8
4/25/95 0:35		703.6	HT: V-SIM											317.0			30745.8
4/25/95 1:40		704.7	HT: V-SIM											100.0			30845.8
4/25/95 2:58		706.0	HT: V-SIM											155.0			31002.8
																	31157.8

THROUGHPUT LOG

Feed/Drain Log	Cum. hours	Test Phase	Cullet (lbs)	Soda Ash Refiner	Trans Batch (lbs)	VECTRA Glass (lbs)	Slurry Batched (lbs)	Transfer to drum (lbs)	Drum Level (in)	Drum delta level (in)	Slurry (lbs)	V-SIM (lbs)	Calched (lbs)	High Na (lbs)	Cum. Feed (lbs)
4/25/95 3:35	706.6	HT: V-SIM													31157.8
4/25/95 3:49	708.9	HT: V-SIM													31311.8
4/25/95 5:20	708.3	HT: V-SIM										154.0			31457.8
4/25/95 5:55	708.9	HT: V-SIM										146.0			31603.8
4/25/95 8:53	711.9	HT: V-SIM										146.0			31603.8
4/25/95 11:51	714.8	HT: V-SIM													31603.8
4/25/95 12:00	715.0	HT: V-SIM													31603.8
4/25/95 13:30	716.5	HT: V-SIM										232.0			31835.8
4/25/95 14:23	717.4	HT: V-SIM													31835.8
4/25/95 15:36	718.6	HT: V-SIM										234.0			32069.8
4/25/95 17:31	720.5	HT: V-SIM													32069.8
4/25/95 19:51	722.8	HT: V-SIM										232.0			32301.8
4/25/95 20:43	723.7	HT: V-SIM										77.0			32378.8
4/25/95 21:20	724.3	HT: V-SIM										77.0			32455.8
4/25/95 21:35	724.6	HT: V-SIM													32455.8
4/25/95 0:00	727.0	HT: V-SIM										233.0			32688.8
4/25/95 0:06	727.1	HT: V-SIM										157.0			32845.8
4/25/95 1:03	728.0	HT: V-SIM										156.0			33001.8
4/25/95 2:13	728.2	HT: V-SIM										159.0			33160.8
4/25/95 2:18	728.3	HT: V-SIM										80.0			33240.8
4/25/95 2:42	728.7	HT: V-SIM													33240.8
4/25/95 3:12	730.2	HT: V-SIM										157.0			33397.8
4/25/95 3:48	730.8	HT: V-SIM										156.0			33553.8
4/25/95 4:38	731.6	HT: V-SIM										78.0			33631.8
4/25/95 4:44	731.7	HT: V-SIM													33631.8
4/25/95 6:07	733.1	HT: V-SIM										158.0			33789.8
4/25/95 6:09	733.1	HT: V-SIM										78.0			33868.8
4/25/95 8:12	735.2	HT: V-SIM										156.0			34024.8
4/25/95 10:45	737.7	HT: V-SIM										234.0			34258.8
4/25/95 11:13	738.2	HT: V-SIM STOP													34258.8
4/25/95 13:35	740.6											158.0			34416.8
4/25/95 13:47	740.8	HT: Slurry START						665.0	31.0			V-SIM to FDR			34416.8
4/25/95 14:26	741.4	HT: Slurry							30.5	0.5	16.9				34433.6
4/25/95 15:31	742.5	HT: Slurry							28.0	2.5	84.3				34517.9
4/25/95 16:06	743.1	HT: Slurry							25.0	3.0	101.1				34619.0
4/25/95 16:13	743.2	HT: Slurry													34619.0
4/25/95 17:11	744.2	HT: Slurry							20.0	5.0	168.5				34787.5
4/25/95 17:28	744.4	HT: Slurry						295.0	30.0						34787.5
4/25/95 18:00	745.0	HT: Slurry							27.5	2.5	84.3				34871.7
4/25/95 18:30	745.5	HT: Slurry							24.0	3.5	118.0				34989.7
4/25/95 18:58	746.0	HT: Slurry STOP							20.5	3.5	118.0				35107.6
4/25/95 19:35	746.6	High Na START							16.0	4.5	151.7				35259.3
4/25/95 20:00	747.0	High Na													35259.3
4/25/95 23:28	750.5	High Na										78.0		371.0	35708.3
4/27/95 0:09	751.1	High Na												371.0	36078.3
4/27/95 3:06	754.1	High Na													36078.3
4/27/95 3:46	754.8	High Na STOP										45.0			36124.3
4/27/95 7:40	758.7											35.0			36159.3
4/27/95 9:47	760.8											78	off-gas seal		36237.3

THROUGHPUT LOG

Feed/Drain Log		Feed															
Date & Time	Cum. hours	Test Phase	Cullet (lbs)	Soda Ash	Refiner	Trans Batch (lbs)	VECTRA Glass (lbs)	Slurry Batched (lbs)	Transfer to drum (lbs)	Drum Level (in)	Drum delta level (in)	Slurry (lbs)	V-SIM (lbs)	Calculated (lbs)	High Na (lbs)	Cum. Feed (lbs)	
4/27/95 17:43	768.7																36237.3
TOTALS	768.7		3052.0	213.0	31.0	395.0	12711.0	10336.0	7539.9			9728.7	8709.0	855.6	742.0		36237.3

THROUGHPUT LOG

Feed/Drain Log Date & Time	Cum. hours	Test Phase	Graphical Data		Drain			Throughput	
			Test Cum Hours	Test Cum Feed (kg)	Drain #	Drain (lbs)	AVG Drain Rate (lb/min)	Cum. Drain (lbs)	Feed This Period (lb/hr) Gross This Period (lb/hr)
3/28/95 17:00	0.0	Start-up						0.0	
3/28/95 11:41	42.7	Start-up						0.0	0.6
3/28/95 11:54	42.9	Start-up						0.0	115.4
3/28/95 12:05	43.1	Start-up						0.0	272.7
3/31/95 14:10	117.2	Start-up						0.0	0.0
3/31/95 16:19	119.3	Start-up						0.0	2.3
3/31/95 20:30	123.5	Start-up						0.0	17.9
3/31/95 21:40	124.7	Start-up						0.0	64.3
3/31/95 22:47	125.8	Start-up						0.0	67.2
4/1/95 0:35	127.6	Start-up						0.0	41.7
4/1/95 1:30	128.5	Start-up						0.0	130.9
4/1/95 4:00	131.0	Start-up						0.0	20.0
4/1/95 5:20	132.3	Start-up						0.0	75.0
4/1/95 11:12	136.2	Start-up						0.0	0.2
4/1/95 11:24	138.4	Start-up						0.0	5.0
4/1/95 12:00	139.0	Start-up						0.0	6.7
4/1/95 13:50	141.0	Start-up						0.0	50.8
4/1/95 16:00	143.0	Start-up						0.0	73.8
4/1/95 18:30	145.5	Start-up						0.0	60.0
4/2/95 0:07	151.1	Start-up						0.0	0.4
4/2/95 8:00	160.0	Start-up						0.0	0.2
4/2/95 16:47	167.8	Start-up						0.0	36.4
4/2/95 17:20	168.3	Start-up						0.0	23.1
4/2/95 18:20	169.3	Start-up						0.0	13.6
4/2/95 19:25	170.4	Start-up						0.0	1.2
4/2/95 21:15	172.2	Start-up						0.0	8.0
4/2/95 22:05	173.1	Start-up						0.0	1.0
4/2/95 22:35	173.6	Start-up						0.0	15.8
4/3/95 0:35	175.6	Start-up						0.0	5.5
4/3/95 2:10	177.2	Start-up						0.0	2.7
4/3/95 6:45	181.7	Start-up						0.0	1.1
4/3/95 7:30	182.5	Start-up						0.0	12.0
4/3/95 9:20	184.3	Start-up						0.0	2.3
4/3/95 9:35	184.6	Start-up						0.0	1.4
4/3/95 9:45	184.7	Start-up						0.0	1.1
4/3/95 10:37	185.6	Start-up						0.0	15.0
4/3/95 11:19	186.3	Start-up						0.0	6.3
4/3/95 12:13	187.2	Start-up						0.0	8.4
4/3/95 12:40	187.7	Start-up						0.0	25.0
4/3/95 14:20	189.3	Start-up						0.0	25.0
4/3/95 18:17	193.3	Start-up						0.0	18.8
4/3/95 21:15	196.2	Start-up						0.0	37.5
4/3/95 22:15	197.3	Start-up						0.0	25.0
4/3/95 23:15	198.2	Start-up						0.0	0.0
4/4/95 0:35	199.6	Start-up						0.0	0.0
4/4/95 1:15	200.3	Start-up						0.0	0.0
4/4/95 2:15	201.2	Start-up						0.0	0.0
4/4/95 8:44	207.7	Start-up						0.0	0.0
4/4/95 18:15	217.2	Start-up						0.0	0.1

THROUGHPUT LOG

Feed/Drain Log Date & Time	Cum. hours	Test Phase	Graphical Data		Drain			Throughput	
			Test Cum Hours	Test Cum Feed (kg)	Drain #	Drain (lbs)	AVG Drain Rate (lbs/min)	Cum. Drain (lbs)	Feed This Period (lb/hr) Glass This Period (lb/hr)
4/7/95 0:41	271.7	MT-1, V-glass START	0.0	0.0					
4/7/95 2:07	273.1	MT-1, V-glass	1.4	0.9				0.0	1.3
4/7/95 2:13	273.2	MT-1, V-glass						0.0	1.4
4/7/95 3:10	274.2	MT-1, V-glass			1	513.0	2.6	513.0	
4/7/95 5:08	276.1	MT-1, V-glass	2.5	1.8				513.0	1.9
4/7/95 8:00	279.0	MT-1, V-glass	4.5	24.5				513.0	25.4
4/7/95 9:00	280.0	MT-1, V-glass	7.3	33.8				513.0	8.7
4/7/95 11:08	282.1	MT-1, V-glass	8.3	47.2				513.0	25.0
4/7/95 12:49	283.6	MT-1, V-glass	10.5	48.1				513.0	0.9
4/7/95 13:47	284.8	MT-1, V-glass	12.1	49.0				513.0	1.2
4/7/95 15:42	286.7	MT-1, V-glass	13.1	49.9				513.0	2.1
4/7/95 21:04	292.1	MT-1, V-glass	15.0	51.7				513.0	2.1
4/7/95 21:15	292.2	MT-1, V-glass	20.4	51.7	2	827.0	4.3	1340.0	43.9
4/7/95 21:40	292.7	MT-1, V-glass	20.6	88.0				1340.0	14.4
4/7/95 22:30	293.5	MT-1, V-glass	21.0	122.9				1340.0	184.6
4/7/95 0:30	295.5	MT-1, V-glass	21.8	134.2				1340.0	30.0
4/7/95 1:30	296.5	MT-1, V-glass	23.8	169.2				1340.0	38.5
4/7/95 2:15	297.2	MT-1, V-glass	24.8	204.5				1340.0	78.0
4/7/95 3:00	297.2	MT-1, V-glass	25.6	215.9				1340.0	33.3
4/7/95 3:50	298.0	MT-1, V-glass	26.3	282.2				1340.0	108.7
4/7/95 5:00	300.0	MT-1, V-glass	27.1	332.9				1340.0	213.6
4/7/95 5:45	300.8	MT-1, V-glass	28.3	351.0				1340.0	34.3
4/7/95 6:15	303.2	MT-1, V-glass	29.1	378.2				1340.0	80.0
4/7/95 12:00	307.0	MT-1, V-glass	31.6	414.5				1340.0	32.0
4/7/95 14:32	309.9	MT-1, V-glass	35.3	448.5				1340.0	20.0
4/7/95 14:36	309.9	MT-1, V-glass	38.2	462.5				1340.0	28.2
4/7/95 15:04	310.1	MT-1, V-glass			3	903.0	17.5	2143.0	44.9
4/7/95 16:20	311.3	MT-1, V-glass	38.4	516.6				2143.0	375.0
4/7/95 17:30	312.5	MT-1, V-glass	39.7	552.8				2143.0	63.2
4/7/95 18:00	313.0	MT-1, V-glass	40.8	597.6				2143.0	66.0
4/7/95 18:47	313.6	MT-1, V-glass	41.3	622.7				2143.0	154.0
4/7/95 20:00	315.0	MT-1, V-glass	42.1	659.0				2143.0	102.1
4/7/95 21:34	316.0	MT-1, V-glass	43.3	683.9				2143.0	63.3
4/7/95 22:27	316.6	MT-1, V-glass	44.3	728.3				2143.0	76.0
4/7/95 1:00	317.4	MT-1, V-glass	44.9	763.7				2143.0	137.6
4/7/95 1:10	320.0	MT-1, V-glass	45.8	834.5				2143.0	176.6
4/7/95 2:40	320.2	MT-1, V-glass	46.3	906.1				2143.0	62.0
4/7/95 4:10	321.7	MT-1, V-glass	48.5	919.7				2143.0	180.0
4/7/95 5:10	323.2	MT-1, V-glass	50.0	933.3				2143.0	20.0
4/7/95 14:20	324.2	MT-1, V-glass	51.5	1004.5				2143.0	104.7
4/7/95 15:07	333.3	MT-1, V-glass	52.5	1075.3				2143.0	156.0
4/7/95 17:00	333.4	MT-1, V-glass			4	407.0	5.3	2550.0	17.4
4/7/95 18:40	334.1	MT-1, V-glass	61.7	1107.0				2550.0	7.6
4/7/95 23:30	336.7	MT-1, V-glass	62.4	1142.4				2550.0	104.0
4/7/95 2:35	338.0	MT-1, V-glass	64.3	1143.3				2550.0	1.1
4/7/95 5:10	342.5	MT-1, V-glass	67.0	1215.0				2550.0	59.3
4/7/95 5:21	345.6	MT-1, V-glass	70.8	1285.3				2550.0	40.4
4/7/95 5:21	348.2	MT-1, V-glass	73.9	1355.6				2550.0	50.3
4/7/95 5:21	351.3	MT-1, V-glass	76.5	1388.6				2550.0	28.0
4/7/95 5:21	351.3	MT-1, V-glass	79.7	1426.3				2550.0	25.4

THROUGHPUT LOG

Feed/Drain Log Date & Time	Cum. hours	Test Phase	Graphical Data		Drain			Throughput	
			Test Cum Hours	Test Cum Feed (kg)	Drain #	Drain (lbs)	AVG Drain Rate (lbs/min)	Cum. Drain (lbs)	Feed This Period (lb/hr) Glass This Period (lb/hr)
4/10/95 12:31	355.5	MT-1, V-glass			5	564.0	5.2	3114.0	25.4
4/10/95 12:39	355.6	MT-1, V-glass	84.0	1463.0				3114.0	
4/10/95 12:42	355.7	MT-1, V-glass	84.0	1564.2				3114.0	69.9
4/10/95 13:04	356.1	MT-1, V-glass	84.4	1664.6				3114.0	2.7
4/10/95 14:19	357.3	MT-1, V-glass	85.6	1600.5				3114.0	63.2
4/10/95 14:40	357.7	MT-1, V-glass	86.0	1600.9				3114.0	2.9
4/10/95 16:24	359.4	MT-1, V-glass	87.7	1635.6				3114.0	44.4
4/10/95 17:02	360.0	MT-1, V-glass	88.4	1671.2				3114.0	128.2
4/10/95 17:54	360.9	MT-1, V-glass	89.2	1707.5				3114.0	92.3
4/10/95 18:50	361.6	MT-1, V-glass	90.1	1742.9				3114.0	63.6
4/10/95 19:26	362.4	MT-1, V-glass	90.8	1865.3				3114.0	523.3
4/10/95 23:30	365.5	MT-1, V-glass	94.8	1920.2				3114.0	18.9
4/11/95 6:13	375.2	MT-1, V-glass	103.5	1990.5				3114.0	17.8
4/11/95 8:52	375.9	MT-1, V-glass			6	307.0	7.1	3421.0	15.1
4/11/95 8:54	375.9	MT-1, V-glass	104.2	2094.3				3421.0	335.1
4/11/95 11:00	378.0	MT-1, V-glass			7	810.0	19.2	4231.0	379.7
4/11/95 12:08	379.1	MT-1, V-glass	107.5	2130.2				4231.0	24.4
4/11/95 12:39	379.6	MT-1, V-glass	108.0	2168.4				4231.0	154.8
4/11/95 13:40	380.7	MT-1, V-glass	109.0	2203.2				4231.0	79.7
4/11/95 14:30	381.5	MT-1, V-glass	109.8	2238.1				4231.0	92.4
4/11/95 14:43	381.7	MT-1, V-glass	110.0	2275.7				4231.0	383.1
4/11/95 15:20	382.3	MT-1, V-glass	110.7	2311.6				4231.0	128.1
4/11/95 15:47	382.8	MT-1, V-glass	111.1	2331.9				4231.0	344.4
4/11/95 16:00	383.0	MT-1, V-glass	111.3	2362.8				4231.0	9.2
4/11/95 17:28	384.5	MT-1, V-glass	112.8	2420.0				4231.0	55.9
4/11/95 18:04	385.1	MT-1, V-glass	113.4	2466.2				4231.0	133.3
4/11/95 18:27	385.5	MT-1, V-glass			8	554.0	34.0	4785.0	74.4
4/11/95 18:33	385.5	MT-1, V-glass	113.9	2528.3				4785.0	329.0
4/11/95 21:10	388.2	MT-1, V-glass	116.5	2672.1				4785.0	121.1
4/11/95 23:35	390.6	MT-1, V-glass	118.9	2707.9				4785.0	32.7
4/12/95 0:55	391.9	MT-1, V-glass	120.2	2849.9				4785.0	234.8
4/12/95 5:00	396.0	MT-1, V-glass	124.3	3007.7				4785.0	65.2
4/12/95 6:03	399.0	MT-1, V-glass			9	593.0	23.0	5378.0	43.6
4/12/95 9:04	400.1	MT-1, V-glass	128.4	3042.2				5378.0	16.7
4/12/95 9:21	400.3	MT-1, V-glass	128.7	3043.1				5378.0	7.4
4/12/95 9:36	400.6	MT-1, V-glass	128.9	3083.0				5378.0	352.0
4/12/95 10:35	401.6	MT-1, V-glass			10	759.0	33.0	6137.0	299.6
4/12/95 10:39	401.6	MT-1, V-glass	130.0	3117.9				6137.0	73.3
4/12/95 11:19	402.3	MT-1, V-glass	130.6	3188.7				6137.0	234.0
4/12/95 12:06	403.1	MT-1, V-glass	131.4	3283.4				6137.0	284.9
4/12/95 13:11	404.2	MT-1, V-glass	132.5	3363.7				6137.0	143.1
4/12/95 13:30	404.5	MT-1, V-glass	132.6	3398.6				6137.0	
4/12/95 13:32	404.5	MT-1, V-glass	132.8	3434.0				6137.0	442.9
4/12/95 14:30	405.5	MT-1, V-glass	133.6	3434.5				6137.0	1.0
4/12/95 15:08	406.1	MT-1, V-glass	134.5	3542.9				6137.0	377.4
4/12/95 15:55	408.9	MT-1, V-glass	135.2	3683.9				6137.0	397.0
4/12/95 18:25	409.4	MT-1, V-glass			11	626.0	35.0	6763.0	79.9
4/12/95 19:47	410.5	MT-1, V-glass	139.1	3788.6				6763.0	60.3
4/12/95 22:47	413.8	MT-1, V-glass	142.1	3826.3				6763.0	27.0

THROUGHPUT LOG

Feed/Drain Log Date & Time	Cum. hours	Test Phase	Graphical Data		Drain		Throughput	
			Test Cum Hours	Test Cum Feed (kg)	Drain & Drain (lbs)	AVG Drain Rate (lbs/min)	Cum. Drain (lbs)	Feed This Period (lb/hr) Glass This Period (lb/hr)
4/13/95 0:15	415.2	MT-1, V-glass	143.6	3662.1			6763.0	53.9
4/13/95 1:30	416.5	MT-1, V-glass	144.8	3696.6			6763.0	60.8
4/13/95 1:45	416.7	MT-1, V-glass	145.1	3831.5			6763.0	306.0
4/13/95 2:40	417.7	MT-1, V-glass	146.0	4075.3			6763.0	345.8
4/13/95 6:55	421.9	MT-1, V-glass	150.2	4218.6			6763.0	74.4
4/13/95 8:28	423.4	MT-1, V-glass	151.8	4286.6			6763.0	98.9
4/13/95 9:09	424.1	MT-1, V-glass			12	855.0	7619.0	58.1
4/13/95 9:30	424.5	MT-1, V-glass	152.8	4356.7			7619.0	148.1
4/13/95 10:19	425.3	MT-1, V-glass	153.6	4430.4			7619.0	193.5
4/13/95 11:28	426.5	MT-1, V-glass	154.8	4502.9			7619.0	137.1
4/13/95 12:10	427.2	MT-1, V-glass	155.5	4539.2			7619.0	
4/13/95 12:12	427.2	MT-1, V-glass	155.5	4612.2			7619.0	336.3
4/13/95 13:40	428.7	MT-1, V-glass	157.0	4684.4			7619.0	108.4
4/13/95 18:00	433.0	MT-1, V-glass	161.3	4776.0			7619.0	46.6
4/13/95 19:38	434.6	MT-1, V-glass			13	548.0	8167.0	52.3
4/13/95 20:30	435.5	MT-1, V-glass	163.8	4798.6			8167.0	20.0
4/13/95 22:10	437.2	MT-1, V-glass	165.5	5018.1			8167.0	290.4
4/13/95 23:30	438.5	MT-1, V-glass	166.8	5054.4			8167.0	60.0
4/14/95 2:40	441.7	MT-1, V-glass	170.0	5089.3			8167.0	24.3
4/14/95 4:00	443.0	MT-1, V-glass	171.3	5161.9			8167.0	120.0
4/14/95 7:00	446.0	Idle	0.0	0.0			8167.0	
4/15/95 8:18	472.3	Idle	26.3	28.1			8167.0	2.1
4/16/95 14:22	501.4	Idle			14	300.0	8467.0	4.5
4/16/95 14:27	501.4	Idle	55.5	133.8			8467.0	8.0
4/16/95 15:35	502.6	Idle	56.6	134.7			8467.0	1.8
4/17/95 8:00	519.0	Idle	73.0	134.7			8467.0	
4/17/95 8:45	519.8	MT-1, V-glass					8467.0	
4/17/95 11:06	522.1	MT-1, V-glass			15	102.0	8569.0	4.9
4/17/95 11:10	522.2	MT-1, V-glass					8569.0	4.1
4/17/95 13:52	524.9	MT-1, V-glass STOP					8569.0	29.3
4/17/95 16:44	527.7	MT-1-slurry START	0.0	0.0			8569.0	83.0
4/17/95 18:17	529.3	MT-1-slurry	1.5	0.0	16	90.0	8659.0	12.5
4/18/95 0:00	535.0	MT-1-slurry	7.3	35.4			8659.0	10.7
4/18/95 3:21	538.3	MT-1-slurry			17	504.0	9163.0	55.6
4/18/95 7:46	542.8	MT-1-slurry	15.0	496.6			9163.0	130.9
4/18/95 8:45	543.8	MT-1-slurry					9163.0	
4/18/95 9:20	544.3	MT-1-slurry					9163.0	
4/18/95 13:11	548.2	MT-1-slurry			18	104.0	9267.0	10.6
4/18/95 23:55	558.9	MT-1-slurry	31.2	691.1			9267.0	26.6
4/19/95 2:35	561.6	MT-1-slurry	33.8	709.2	19	285.0	9562.0	22.0
4/19/95 2:50	561.8	MT-1-slurry	34.1	710.3			9562.0	80.0
4/19/95 4:27	563.4	MT-1-slurry			20	197.0	9759.0	105.5
4/19/95 7:51	566.8	MT-1-slurry	39.1	1010.0	21	156.0	9915.0	128.2
4/19/95 9:20	568.3	MT-1-slurry	40.6	1079.4			9915.0	103.1
4/19/95 10:30	569.5	MT-1-slurry					9915.0	
4/19/95 12:40	571.7	MT-1-slurry					9915.0	
4/19/95 15:45	574.7	MT-1-slurry					9915.0	
4/19/95 16:04	575.1	MT-1-slurry	47.3	1396.8			9915.0	104.0

THROUGHPUT LOG

Feed/Drain Log		Cum. hours	Test Phase	Graphical Data		Drain			Throughput	
Date & Time	Test Cum Hours			Test Cum Feed (kg)	Drain #	Drain (lbs)	AVG Drain Rate (lbs/min)	Cum. Drain (lbs)	Feed This Period (lb/hr)	Glass This Period (lb/hr)
4/19/95 17:30		576.5	MT-1-slurry	48.8	1472.1				9915.0	115.8
4/19/95 21:10		580.2	MT-1-slurry			22	264.0	17.0	10179.0	19.8
4/20/95 1:40		584.7	MT-1-slurry						10179.0	
4/20/95 2:00		585.0	MT-1-slurry						10179.0	
4/20/95 3:45		586.7	MT-1-slurry	59.0	1598.6				10179.0	27.2
4/20/95 3:45		586.7	MT-1-slurry						10179.0	
4/20/95 5:06		588.1	MT-1-slurry	60.4	1725.2				10179.0	206.7
4/20/95 5:30		588.5	MT-1-slurry						10179.0	
4/20/95 5:49		588.8	MT-1-slurry			23	502.0	22.0	10681.0	55.8
4/20/95 6:10		589.2	MT-1-slurry						10681.0	
4/20/95 8:00		591.0	MT-1-slurry	63.3	1809.5				10681.0	64.1
4/20/95 8:15		592.2	MT-1-slurry	64.5	1872.8				10681.0	111.8
4/20/95 9:30		592.5	MT-1-slurry	64.8	1893.9				10681.0	186.0
4/20/95 10:00		593.0	MT-1-slurry	65.3	1915.0				10681.0	93.0
4/20/95 10:31		593.5	MT-1-slurry	65.8	1971.2				10681.0	240.0
4/20/95 11:05		594.1	MT-1-slurry	66.3	2034.5				10681.0	246.2
4/20/95 11:30		594.5	MT-1-slurry	66.8	2062.6				10681.0	148.8
4/20/95 11:47		594.8	MT-1-slurry	67.0	2081.7				10681.0	148.8
4/20/95 11:53		594.9	MT-1-slurry	67.1	2118.0				10681.0	800.0
4/20/95 12:02		595.0	MT-1-slurry			24	81.0	11.5	10762.0	13.8
4/20/95 12:30		595.5	MT-1-slurry						10762.0	
4/20/95 13:00		596.0	MT-1-slurry						10762.0	
4/20/95 13:47		596.8	MT-1-slurry						10762.0	
4/20/95 13:57		597.0	MT-1-slurry	69.2	2135.6				10762.0	18.7
4/20/95 14:10		597.2	MT-1-slurry	69.4	2153.1				10762.0	178.8
4/20/95 14:30		597.5	MT-1-slurry	69.6	2174.2				10762.0	139.5
4/20/95 15:10		598.2	MT-1-slurry	70.4	2230.5				10762.0	186.0
4/20/95 15:15		598.2	MT-1-slurry						10762.0	
4/20/95 15:30		598.5	MT-1-slurry	70.6	2255.1				10762.0	162.7
4/20/95 16:26		599.4	MT-1-slurry			25	239.0	10.9	11001.0	54.3
4/20/95 16:30		599.5	MT-1-slurry	71.8	2342.9				11001.0	193.8
4/20/95 17:00		600.0	MT-1-slurry	72.3	2378.1				11001.0	155.0
4/20/95 17:30		600.5	MT-1-slurry	72.8	2427.3				11001.0	217.0
4/20/95 17:39		600.7	MT-1-slurry						11001.0	
4/20/95 18:00		601.0	MT-1-slurry	73.3	2455.4				11001.0	124.0
4/20/95 18:30		601.5	MT-1-slurry	73.8	2497.6				11001.0	186.0
4/20/95 19:38		602.6	MT-1-slurry	74.9	2567.9				11001.0	136.8
4/20/95 20:00		603.0	MT-1-slurry	75.3	2596.0				11001.0	169.1
4/20/95 20:22		603.4	MT-1-slurry	75.6	2610.0				11001.0	84.5
4/20/95 20:44		603.7	MT-1-slurry	76.0	2617.1				11001.0	42.3
4/20/95 20:56		603.9	MT-1-slurry						11001.0	
4/20/95 21:18		604.3	MT-1-slurry	76.6	2641.7				11001.0	95.7
4/20/95 21:39		604.6	MT-1-slurry	76.9	2648.7				11001.0	46.5
4/20/95 21:57		604.9	MT-1-slurry	77.2	2662.8				11001.0	97.9
4/20/95 23:15		606.2	MT-1-slurry			26	231.0	5.8	11232.0	33.9
4/21/95 1:26		608.4	MT-1-slurry	80.7	2766.2				11232.0	66.7
4/21/95 4:10		611.2	MT-1-slurry	83.4	2944.0				11232.0	141.6
4/21/95 6:55		613.9	MT-1-slurry	86.2	3086.8				11232.0	114.5
4/21/95 10:35		617.6	MT-1-slurry			27	383.0	5.5	11615.0	33.8

THROUGHPUT LOG

Feed/Drain Log Date & Time		Cum. hours	Test Phase	Graphical Data		Drain			Throughput		
				Test Cum Hours	Test Cum Feed (kg)	Drain #	Drain (lbs)	AVG Drain Rate (lb/min)	Cum. Drain (lbs)	Feed This Period (lb/hr)	Glass This Period (lb/hr)
4/21/95 11:17		618.3	MT-1-slurry	90.5	3088.6				11615.0		0.9
4/21/95 11:45		618.6	MT-1-slurry	91.0	3089.1				11615.0		2.1
4/21/95 12:15		619.2	MT-1-slurry						11615.0		
4/21/95 12:54		619.9	MT-1-slurry						11615.0		
4/21/95 16:20		623.3	MT-1-slurry	95.6	3103.1				11615.0		6.8
4/21/95 16:29		623.5	MT-1-slurry	95.7	3120.7				11615.0		288.3
4/21/95 17:00		624.0	MT-1-slurry	96.3	3145.3				11615.0		105.0
4/21/95 17:28		624.5	MT-1-slurry	96.7	3173.4				11615.0		132.9
4/21/95 18:30		625.5	MT-1-slurry	97.6	3208.6				11615.0		75.0
4/21/95 19:00		626.0	MT-1-slurry	0.0	0.0				11615.0		124.0
4/21/95 19:23		626.4	MT-1-slurry	0.4	14.1				11615.0		80.9
4/21/95 19:37		626.6	MT-1-slurry	0.6	28.1				11615.0		132.9
4/21/95 19:50		626.8	MT-1-slurry	0.8	45.7				11615.0		178.8
4/21/95 20:12		627.2	MT-1-slurry	1.2	63.3				11615.0		105.7
4/21/95 20:29		627.5	MT-1-slurry	1.5	80.8				11615.0		136.8
4/21/95 20:29		627.5	MT-1-slurry						11615.0		
4/21/95 20:45		627.8	MT-1-slurry	1.8	94.9				11615.0		116.3
4/21/95 21:03		628.0	MT-1-slurry	2.1	112.6				11615.0		130.2
4/21/95 21:27		628.5	MT-1-slurry	2.5	130.8				11615.0		100.0
4/21/95 21:37		628.6	MT-1-slurry	2.6	155.2				11615.0		323.6
4/21/95 22:06		629.1	MT-1-slurry	3.1	179.8				11615.0		105.0
4/21/95 22:26		629.4	MT-1-slurry	3.4	186.8				11615.0		51.7
4/21/95 22:46		629.8	MT-1-slurry	3.8	218.5				11615.0		209.2
4/21/95 22:55		629.9	MT-1-slurry STOP			28	123.0	6.2	11738.0		10.0
4/21/95 23:00		630.0	MT-2-slurry MB START	4.0	222.0				11738.0		33.2
4/21/95 23:40		630.7	MT-2-slurry	4.7	288.8				11738.0		220.9
4/21/95 23:45		630.8	MT-2-slurry						11738.0		
4/22/95 1:34		632.9	MT-2-slurry			29	197.0	4.9	11935.0		68.0
4/22/95 3:07		634.1	MT-2-slurry	8.1	446.9				11935.0		101.1
4/22/95 3:07		634.1	MT-2-slurry						11935.0		
4/22/95 3:45		634.7	MT-2-slurry	8.8	461.0				11935.0		48.9
4/22/95 4:05		635.1	MT-2-slurry						11935.0		
4/22/95 4:13		635.2	MT-2-slurry			30	193.0	6.4	12128.0		83.3
4/22/95 7:10		638.2	MT-2-slurry			31	189.0	5.4	12317.0		64.1
4/22/95 7:18		638.3	MT-2-slurry	12.3	717.6				12317.0		159.4
4/22/95 7:18		638.3	MT-2-slurry						12317.0		
4/22/95 10:45		641.7	MT-2-slurry			32	317.0	5.3	12634.0		88.5
4/22/95 11:48		642.8	MT-2-slurry	16.8	1063.1				12634.0		
4/22/95 11:48		642.8	MT-2-slurry						12634.0		178.1
4/22/95 13:00		644.0	MT-2-slurry MB STOP						12634.0		
4/22/95 13:57		645.0							12634.0		
4/22/95 14:58		646.0		19.0	1083.1	33	74.0	7.4	12708.0		23.1
4/22/95 15:05		646.1		0.00	0.0	34	150.0	17.0	12856.0		147.5
4/22/95 16:58		648.0		1.88	35.4				12856.0		72.5
4/22/95 17:36		648.6							12856.0		41.4
4/22/95 18:05		649.1		3.00	105.7	35	204.0	20.4	13062.0		77.5
4/22/95 18:10		649.2		3.08	141.0				13062.0		
4/22/95 18:20		649.3		3.25	176.4				13062.0		184.2
4/22/95 18:33		649.5		3.47	246.7				13062.0		468.0
									13062.0		715.4

THROUGHPUT LOG

Feed/Drain Log Date & Time	Cum. hours	Test Phase	Graphical Data		Drain			Throughput	
			Test Cum Hours	Test Cum Feed (kg)	Drain #	Drain (lbs)	AVG Drain Rate (lbs/min)	Cum. Drain (lbs)	Feed This Period (lb/hr) Glass This Period (lb/hr)
4/22/95 18:56	649.9		3.65	260.3				13062.0	76.3
4/22/95 19:00	650.0	MT-3: V-SIM MB START						13062.0	
4/22/95 19:50	650.8	MT-3: V-SIM	4.75	350.1				13062.0	244.4
4/22/95 20:36	651.6	MT-3: V-SIM			36	151.0	21.6	13213.0	49.8
4/22/95 22:00	653.0	MT-3: V-SIM MB STOP						13213.0	
4/22/95 22:53	653.9				37	162.0	5.2	13375.0	72.0
4/23/95 1:10	656.2		10.00	430.8				13375.0	29.3
4/23/95 2:59	658.0		11.90	521.5				13375.0	110.1
4/23/95 5:37	660.8				38	308.0	11.4	13683.0	45.7
4/23/95 6:20	661.3							13683.0	
4/23/95 6:25	661.4							13683.0	45.1
4/23/95 9:55	664.9		0.00	0.0	38	184.0	6.6	13683.0	42.8
4/23/95 10:00	665.0	MT-4: Calched MB START						13683.0	
4/23/95 10:15	665.3	MT-4: Calched	0.33	127.7				13687.0	64.6
4/23/95 10:21	665.3	MT-4: Calched	0.43	139.0				13687.0	200.0
4/23/95 10:30	665.5	MT-4: Calched						13687.0	250.0
4/23/95 10:35	665.6	MT-4: Calched	0.67	161.7				13687.0	214.3
4/23/95 13:30	668.5	MT-4: Calched						13687.0	
4/23/95 13:48	668.8	MT-4: Calched			40	300.0	7.9	14167.0	77.3
4/23/95 14:00	669.0	MT-4: Calched MB STOP						14167.0	
4/23/95 14:26	669.4		4.52	195.7				14167.0	19.5
4/23/95 17:10	672.2		7.25	282.8				14167.0	70.2
4/23/95 17:40	672.7		7.75	287.3				14167.0	64.0
4/23/95 19:30	674.5							14167.0	85.1
4/23/95 23:57	678.9				41	220.0	13.8	14367.0	21.7
4/24/95 0:40	679.7	HT: V-SIM START	0.0	0.0				14367.0	
4/24/95 2:25	681.4	HT: V-SIM			42	197.0	7.8	14564.0	79.9
4/24/95 4:24	683.4	HT: V-SIM	3.7	72.1				14564.0	42.6
4/24/95 4:39	683.6	HT: V-SIM			43	344.0	24.5	14928.0	154.0
4/24/95 5:00	684.0	HT: V-SIM	4.3	107.9				14928.0	
4/24/95 5:10	684.2	HT: V-SIM	4.5	251.2				14928.0	515.2
4/24/95 8:02	687.0	HT: V-SIM			44	188.0	19.0	15086.0	49.7
4/24/95 8:55	687.9	HT: V-SIM	8.3	356.5				15086.0	61.9
4/24/95 10:01	689.0	HT: V-SIM			45	254.0	18.0	15350.0	128.1
4/24/95 10:44	689.7	HT: V-SIM	10.1	427.7				15350.0	
4/24/95 10:47	689.8	HT: V-SIM	10.1	462.6				15350.0	128.4
4/24/95 13:31	692.5	HT: V-SIM	12.8	568.7				15350.0	85.6
4/24/95 14:13	693.2	HT: V-SIM			46	234.0	18.0	15584.0	55.7
4/24/95 15:27	694.5	HT: V-SIM	14.8	679.8				15584.0	126.7
4/24/95 17:03	696.0	HT: V-SIM			47	312.0	24.0	15896.0	110.1
4/24/95 17:14	696.2	HT: V-SIM	16.6	786.4				15896.0	131.8
4/24/95 18:43	697.7	HT: V-SIM			48	79.0	13.0	15975.0	47.4
4/24/95 20:10	699.2	HT: V-SIM	19.5	927.4				15975.0	106.0
4/24/95 22:53	701.9	HT: V-SIM			49	254.0	5.6	16229.0	61.0
4/24/95 23:00	702.0	HT: V-SIM	22.3	1000.0				16229.0	
4/24/95 23:10	702.2	HT: V-SIM	22.5	1143.8				16229.0	159.0
4/25/95 0:35	703.6	HT: V-SIM	23.9	1189.1				16229.0	70.6
4/25/95 1:40	704.7	HT: V-SIM	25.0	1260.3				16229.0	144.9
4/25/95 2:58	706.0	HT: V-SIM	26.3	1330.6				16229.0	119.2

THROUGHPUT LOG

Feed/Drain Log Date & Time	Cum. hours	Test Phase	Graphical Data		Drain			Throughput	
			Test Cum Hours	Test Cum Feed (kg)	Drain #	Drain (lbs)	AVG Drain Rate (lbs/mtr)	Cum. Drain (lbs)	Feed This Period (lbs/hr) Glass This Period (lbs/hr)
4/25/95 3:35	706.6	HT: V-SIM			50	489.0	5.3	16718.0	104.0
4/25/95 3:49	706.8	HT: V-SIM	27.1	1400.5				16718.0	161.2
4/25/95 5:20	708.3	HT: V-SIM	28.7	1466.7				16718.0	96.3
4/25/95 5:55	708.9	HT: V-SIM	29.3	1532.9				16718.0	250.3
4/25/95 8:53	711.9	HT: V-SIM			51	176.0	7.0	16894.0	33.2
4/25/95 11:51	714.5	HT: V-SIM			52	190.0	5.8	17084.0	64.0
4/25/95 12:00	715.0	HT: V-SIM	35.3	1638.1				17084.0	36.1
4/25/95 13:30	716.5	HT: V-SIM						17084.0	
4/25/95 14:23	717.4	HT: V-SIM	37.7	1744.2				17084.0	98.2
4/25/95 15:38	718.6	HT: V-SIM			53	204.0	7.0	17288.0	54.4
4/25/95 17:31	720.5	HT: V-SIM	40.6	1849.4				17288.0	74.0
4/25/95 19:51	722.8	HT: V-SIM	43.2	1884.4				17288.0	33.0
4/25/95 20:45	723.7	HT: V-SIM	44.0	1919.3				17288.0	88.8
4/25/95 21:20	724.3	HT: V-SIM			54	538.0	17.3	17826.0	83.8
4/25/95 21:35	724.6	HT: V-SIM	44.9	2024.9				17826.0	268.8
4/26/95 0:00	727.0	HT: V-SIM	47.3	2098.1				17826.0	
4/26/95 0:06	727.1	HT: V-SIM	47.4	2166.9				17826.0	124.4
4/26/95 1:03	728.0	HT: V-SIM	48.4	2239.0				17826.0	167.4
4/26/95 2:13	728.2	HT: V-SIM	49.5	2275.3				17826.0	68.6
4/26/95 2:18	728.3	HT: V-SIM			55	455.0	21.7	18281.0	91.8
4/26/95 2:42	728.7	HT: V-SIM	50.0	2346.5				18281.0	324.8
4/26/95 3:12	730.2	HT: V-SIM	50.5	2417.2				18281.0	312.0
4/26/95 3:48	730.8	HT: V-SIM	51.1	2462.6				18281.0	130.0
4/26/95 4:36	731.6	HT: V-SIM			56	501.0	11.1	18782.0	214.7
4/26/95 4:44	731.7	HT: V-SIM	52.1	2524.3				18782.0	169.3
4/26/95 5:07	733.1	HT: V-SIM	53.4	2560.1				18782.0	
4/26/95 6:09	733.1	HT: V-SIM	53.5	2630.6				18782.0	165.9
4/26/95 8:12	735.2	HT: V-SIM	55.5	2737.0				18782.0	114.1
4/26/95 10:45	737.7	HT: V-SIM			57	237.0	4.5	19019.0	38.7
4/26/95 11:13	738.2	HT: V-SIM STOP	58.5	2806.6				19019.0	52.4
4/26/95 13:35	740.6							19019.0	
4/26/95 13:47	740.8	HT: Slurry START	0.0	0.0				19019.0	6.6
4/26/95 14:26	741.4	HT: Slurry	0.7	35.2				19019.0	129.6
4/26/95 15:31	742.5	HT: Slurry	1.7	84.1				19019.0	83.3
4/26/95 16:06	743.1	HT: Slurry			58	463.0	5.0	19502.0	90.3
4/26/95 16:13	743.2	HT: Slurry	2.4	160.5				19502.0	240.7
4/26/95 17:11	744.2	HT: Slurry						19502.0	
4/26/95 17:25	744.4	HT: Slurry	3.6	186.7				19502.0	70.2
4/26/95 18:00	745.0	HT: Slurry	4.2	252.2				19502.0	202.2
4/26/95 18:30	745.5	HT: Slurry	4.7	305.7				19502.0	235.9
4/26/95 18:55	746.0	HT: Slurry STOP	5.2	374.4				19502.0	328.0
4/26/95 19:35	746.6	High Na START	0.0	0.0	59	201.0	5.7	19703.0	57.7
4/26/95 20:00	747.0	High Na	0.4	203.6				19703.0	434.5
4/26/95 23:28	750.5	High Na	3.9	371.9				19703.0	107.0
4/27/95 0:09	751.1	High Na	4.6	371.9	60	327.0	2.3	20030.0	71.6
4/27/95 3:06	754.1	High Na	7.5	392.3				20030.0	12.4
4/27/95 3:46	754.6	High Na STOP	8.2	406.2				20030.0	52.5
4/27/95 7:40	758.7				61	381.0	8.7	20411.0	50.7
4/27/95 9:47	760.8							20411.0	

THROUGHPUT LOG

Feed/Drain Log				Graphical Data		Drain			Throughput	
Date & Time	Cum. hours	Test Phase	Test Cum Hours	Test Cum Feed (kg)	Drain #	Drain (lbs)	AVG Drain Rate (lbs/min)	Cum. Drain (lbs)	Feed This Period (lb/hr)	Glass This Period (lb/hr)
4/27/95 17:43	768.7				62	2022.0	6.6	22433.0		201.2
TOTALS	768.7				62.0	22433.0	11.7	22433.0	109.4	60.8

This page intentionally left blank.

APPENDIX 3C

MASS BALANCE CALCULATIONS

Revision 0 WHC High Sodium LLR Waste Simulant

1) WHCox

Rev.

10/1/95

Formulas Chemical 3/2/94

Component	10 M Na Moles/L	Weight		Mol Wt Oxide	Dried Product g/L
		Mol Wt Elemental	Simulant Wt g/L		
Al	1.01667	26.98	27.42967	Al ₂ O ₃ (3)	51.82967
Ca	0.00105	40.08	0.04208	CaO	0.05888
Cr	0.00867	52.00	0.45063	Cr ₂ O ₃ (3)	0.65863
Fe	0.00077	55.85	0.04282	Fe ₂ O ₃ (3)	0.06122
K	0.50000	39.10	19.55000	K ₂ O	23.55000
Mg	0.00103	24.31	0.02512	MgO	0.04185
Mn	0.00042	54.93	0.02289	MnO(2)	0.03622
Mo	0.01867	95.94	1.58900	MoO ₃ (3)	2.39900
Na	10.00000	23.00	230.00000	Na ₂ O	310.00000
Si	0.01667	28.09	0.46933	SiO ₂	1.72700
Sr	0.01667	137.33	2.21509	SrO	2.34843
PO ₄ (4)	0.04333	94.97	4.11543	P ₂ O ₅ (5)	3.07569
IO ₃ (3)	0.01667	174.90	2.91500	I ₂ O ₅	2.11506
CO ₃ (3)	0.26667	60.01	16.00267	—	0.00000
Cl	0.18000	35.45	6.37200	—	0.00000
F	0.25000	19.00	4.75000	—	0.00000
SO ₄ (4)	0.04333	96.06	4.16259	SO ₃ (3)	3.48948
NO ₃ (3)	3.16667	62.01	196.36500	—	0.00000
NO ₂ (2)	1.66667	46.01	76.68333	—	0.00000
OH	6.66667	17.00	113.33333	—	0.00000
TOC	0.13500	416.20	56.18700	—	0.00000
Total			763.02		411.79 g/L

WHC Glass Formula and Waste Loading RVR Unit

Na ₂ O from simulant 310 gl simulant	Oxide	Weight Percent	Grams Substituent per liter of simulant		Grams Additive Needed per liter of simulant	
			g/l simulant		g/l simulant	
	SiO ₂	52.8%	811.96	811.40	811.40	0.284
	B ₂ O ₃ (3)	8.0%	124.00	124.00	124.00	0.000
Total weight of Glass 1550 gl simulant	Na ₂ O	20.0%	310.00	310.00	310.00	0.000
	CaO	2.9%	44.95	44.89	44.89	0.000
	MgO	2.1%	32.55	32.51	32.51	0.000
Waste Loading 26.6%	Al ₂ O ₃ (3)	10.0%	155.00	103.17	103.17	0.000
	Fe ₂ O ₃ (3)	1.0%	15.50	15.44	15.44	0.000
	Other	3.2%	49.60	49.60	49.60	0.000
	Total	100.00%	1550.00	1138.41	1138.41	

Formulas Chemical 3/2/94

	g/l simulant	g water/l simulant	g volatile/l simulant	g other/l simulant
Silica Sand	811.96	0.00	0.00	0.284
Boric Acid	220.25	96.25	0.00	0.000
Dolomite	148.13	0.00	0.00	-0.000
Alumina	158.00	54.54	0.00	0.783
Iron Oxide	14.11	0.00	0.00	0.282
Magnesium Oxide	9.58	1.85	3.53	0.132
Total	1362.12	152.84	3.53	1.48

WHC Glass Formula and Waste Loading Calciner Fluid Bed

Na ₂ O from simulant 310 gl simulant	Oxide	Weight Percent	Grams Substituent per liter of simulant		Grams Additive Needed per liter of simulant	
			g/l simulant		g/l simulant	
	SiO ₂	52.8%	811.96	811.40	811.40	0.284
	B ₂ O ₃ (3)	8.0%	124.00	124.00	124.00	0.000
Total weight of Glass 1550 gl simulant	Na ₂ O	20.0%	310.00	310.00	310.00	0.000
	CaO	2.9%	44.95	44.89	44.89	0.000
	MgO	2.1%	32.55	32.51	32.51	0.000
Waste Loading 26.6%	Al ₂ O ₃ (3)	10.0%	155.00	103.17	103.17	0.000
	Fe ₂ O ₃ (3)	1.0%	15.50	15.44	15.44	0.000
	Other	3.2%	49.60	49.60	49.60	0.000
	Total	100.00%	1550.00	1138.41	1138.41	

Formulas Chemical 3/2/94

	g/l simulant	g water/l simulant	g volatile/l simulant	g other/l simulant
Silica Sand	811.96	0.00	0.00	0.284
Boric Acid	124.25	0.00	0.00	0.248
Dolomite	148.13	0.00	0.00	-0.000
Alumina	103.80	0.00	0.00	1.038
Iron Oxide	14.12	0.00	0.00	0.282
Magnesium Oxide	9.58	1.85	3.53	0.132
Total	1211.83	1.85	3.53	1.99

RVR Glass Formers

Product	Composition (wt%)										
	SiO ₂	B ₂ O ₃ (3)	Na ₂ O	CaO	CaCO ₃	MgCO ₃	MgO	Al ₂ O ₃ (3)	Fe ₂ O ₃ (3)	Water	Volatile
Dolomite	5.000%				54.000%	40.000%			1.000%		-0.00%
Silica Sand	99.880%		0.007%	0.010%			0.003%	0.050%	0.015%		0.03%
Alumina	0.001%							65.000%	0.004%	34.500%	0.50%
Boric Acid		56.300%								43.700%	0.00%
Iron Oxide									98.000%		2.00%
Magnesium Oxide	0.130%			0.150%			42.200%	0.030%	0.010%	19.300%	1.38%

Calciner Glass Formers

Product	Composition (wt%)										
	SiO ₂	B ₂ O ₃ (3)	Na ₂ O	CaO	CaCO ₃	MgCO ₃	MgO	Al ₂ O ₃ (3)	Fe ₂ O ₃ (3)	Water	Volatile
Dolomite	5.000%				54.000%	40.000%			1.000%		-0.00%
Silica Sand	99.880%		0.007%	0.010%			0.003%	0.050%	0.015%		0.03%
Alumina								99.000%			1.00%
Boric Acid		56.300%									0.20%
Iron Oxide									98.000%		2.00%
Magnesium Oxide	0.130%			0.150%			42.200%	0.030%	0.010%	19.300%	1.38%

Expected Na(2)O Levels and Glass Production for Slurry Feed GlassPrepared by: Brent Spurgeon *Brent Spurgeon* Date: 08/17/95Checked by: John Koehr *JKoehr* Date: 08/17/95

Assume:	Density of simulant =	1.49 g/ml	Na(2)O level
	Molarity of Simulant =	10 Molar	17.71% per end of calc

Feed Ratio, lb of RVR mix/lb Simulant = 1.07

For Batch 2A & 3A	Simulant =	500 lb	Per Feed Log
	RVR Mix =	536 lb	Per Feed Log

Total Batch Weight 1036 lb = 469.92 kg

Total Oxides from RVR Mix:

3 lb or 1362 g of RVR Mix Yields...

SiO(2)	818.40 g	} per f)WHCox.wb1
B(2)O(3)	124.00 g	
Na(2)O	0.00 g	
CaO	44.89 g	
MgO	32.51 g	
Al(2)O(3)	103.17 g	
Fe(2)O(3)	15.44 g	
Other	1.48 g	
Total	1138.41 g	

RVR mix lb	<u>536</u>	=	178.6667
Above yields for	<u>3</u>		

Total Oxides From RVR Mix

SiO(2)	146.22 kg
B(2)O(3)	22.15 kg
Na(2)O	0.00 kg
CaO	8.02 kg
MgO	5.81 kg
Al(2)O(3)	18.43 kg
Fe(2)O(3)	2.76 kg
Other	0.26 kg
Total	203.66 kg

Oxides from Simulant

Density of Simulant = 1.49 g/ml = 3.28 lb/l

Total liters of simulant = 152.21 l simulant

Oxides from Simulant

Oxide	g/l simulant	kg total
Al(2)O(3)	51.83	7.89
CaO	0.06	0.01
Fe(2)O(3)	0.06	0.01
MgO	0.04	0.01
Na(2)O	310.00	47.19
Total	361.99	55.10

NOTE: g/l simulant from WHCox.wb1

Others

Oxide	g/l simulant	kg total
Cr(2)O(3)	0.65863	0.10
K(2)O	23.55000	3.58
MnO(2)	0.03622	0.01
MoO(3)	2.39900	0.37
SrO	1.72700	0.26
Cs(2)O	2.34843	0.36
P(2)O(5)	3.07569	0.47
I	2.11508	0.32
Cl	5.67200	0.86
F	4.75000	0.72
SO(3)	3.46948	0.53
Total	49.80	7.58

Total Oxides

Oxide	kg	
SiO(2)	146.22	54.89%
B(2)O(3)	22.15	8.32%
Na(2)O	47.19	17.71%
CaO	8.03	3.01%
MgO	5.85	2.20%
Al(2)O(3)	26.32	9.88%
Fe(2)O(3)	2.77	1.04%
Other	7.85	2.95%
Total	266.38	100.00%

Glass to Slurry Ratio:

56.69%

Simulated Simulant Mix Composition and Glass Yield

- 1) 20% Na₂O in Glass
- 2) 4 melder volumes = $(4 \times 20 \text{ ft}^3 \text{ vol} \times 160 \text{ lb/ft}^3) = 12,800 \text{ lbs (5,818 kg)}$ glass

wt%	g Oxide/L 10 M slm	wt equivalent acid per kg glass	wt GF oxide per kg glass	TOTAL OXIDES per kg glass	TOTAL OXIDES for MT-2 Test	gmoles required	Still Needed	Alumina	Silica Sand	Dolomite	Iron Oxide	NaNO ₂	NaCl	NaF
52.6%	0.000	0.000	528.000	528.000	3071.904 SiO ₂	51126.14	-0.000	101.95	80.09	27.80	159.69	64.99	58.44	41.99
8.0%	0.000	0.000	80.000	80.000	465.440 B ₂ O ₃ (3)	6685.61	0.000	0.01	3044.35					
20.0%	310.000	200.000	0.000	200.000	1163.600 Na	37547.60	-483.278							
2.9%	0.059	0.036	28.962	29.000	166.722 Ca	3008.59	0.000		0.43			7.19	7.49	19.45
2.1%	0.042	0.027	20.873	21.000	122.178 Mg	3030.96	-0.019		0.30	120.27				
10.0%	51.830	33.438	66.562	100.000	581.400 Al ₂ O ₃ (3)	5705.16	0.000	580.27	1.52	72.06				
1.0%	0.061	0.039	9.961	10.000	58.160 Fe ₂ O ₃ (3)	354.33	-0.000	0.04	0.46	5.56	52.13			
3.2%	47.135	30.409		1.591	9.254 Other		0.000	4.46	0.81	1.06				
	2.369	1.548		1.548	9.005 Mo	62.56	0.000							
	0.659	0.425		0.425	2.472 Cr	32.53	0.000							
	23.550	15.184		15.184	88.366 K	1676.77	0.001							
	0.036	0.023		0.023	0.136 Mn	1.59	0.000							
	1.727	1.114		1.114	6.482 Sr	62.56	0.000							
	2.348	1.515		1.515	8.615 Cs	62.56	-0.000							
	3.076	1.964		1.964	11.545 PO ₄	162.72	-0.000							
	1.058	0.682		0.682	3.970 IO ₃	31.28	-0.000							
	4.538	2.827		2.827	17.032 Cl	480.45	-0.000							
	4.275	2.758		2.758	16.046 F	844.55	-0.000							
	3.469	2.238		2.238	13.023 SO ₄	135.57	-0.000							
	408.128	263.853		1000.000	5816.000 NO ₃	594.40	0.000							
					NO ₂	312.9	-0.000	307.99				14.40	14.82	16.05
					H ₂ O		0.000							
					Carbon		-174.000			339.19				
					CO ₂		-1426.022							
					OH		-15.779							
					Total Kg	7785.10		892.77	3048.07	564.89	53.19	21.59	22.31	35.50

Notes: 1. To simplify material pricing, assume 16 N/L
1400 Cl₂ and 1000 F₂ available for
calculation.

Class Yield:	74.70%
--------------	--------

Na ₂ (SO ₄)	Na ₂ O(3)	CsCl	K ₂ MnO ₄ (4)	Na ₂ MnO ₄ (4) 2H ₂ O	NaNO ₃ (3)	K ₂ CO ₃ (3)	KOH	SrCO ₃ (3)	K ₂ Cr ₂ O ₇ (7)	Na ₂ CO ₃ (3)	Boric Acid	Na ₃ PO ₄ (4) 12 H ₂ O	C	MgCO ₃ (3)
119.05	187.88	166.36	158.04	241.85	84.88	138.21	56.10	147.83	184.20	105.99	68.62			84.32
3.12	0.81			2.88	16.24					808.46	482.58	11.23		0.01
				6.00					1.89					0.01
			0.06			36.34	36.34		0.84					1.53
			0.06					5.46						0.00
		8.31												0.00
	6.19	2.22										15.45		
13.02														
				2.26	36.86									
						27.89	15.80	3.75		1055.19	359.05	35.11	174.00	1.16
				11.13	53.06	64.23	52.14	9.24	2.33	1863.67	821.63	61.79	174.00	2.71
16.14	7.00	10.53	0.15											

Mass Balance for MT-2, slurry feed

Prepared by: Brent Spurgeon JB

Date: 08/17/95

Checked by: John Koehr JK

Date: 08/17/95

General Information

whcvt05.xls = Throughput Summary

Test Duration:	14.0 hr	per whcvt05.xls
Total Slurry Feed:	864.60 kg	
Batch Ratio: wt. of RVR mix / wt. Simulant	1.07	
wt. of Sugar / wt. simulant	0.084	
Density of Simulant:	1.49 kg/liter	per WHC inform
Molarity of Simulant:	10.00 M	per whcvt05.xls
Total Simulant:	401.39 kg 269.39 liters	
Total RVR Mix:	429.49 kg	
Total Sugar:	33.72 kg	
Total Glass Product:	406.42 kg = 896.0 lb	per whcvt05.xls
Average Off-Gas flow rate:	204.70 kg/hr	
Total Off-Gas:	2865.80 kg	
Average Particulate in Off-Gas:	0.855 kg/hr = 4951 mg/dscm	per Omni report
Total Particulate in Off-Gas:	11.97 kg	

Glass Composition:

Component	Target Composition	Actual Average Composition		
SiO(2)	52.8%	58.65%	11.08%	high
B(2)O(3)	8.0%	7.34%	8.25%	low
Na(2)O	20.0%	15.61%	21.95%	low
CaO	2.9%	2.93%	1.15%	high
MgO	2.1%	2.26%	7.62%	high
Al(2)O(3)	10.0%	9.53%	4.70%	low
Fe(2)O(3)	1.0%	1.01%	1.00%	high
Other	3.2%	2.67%	16.56%	low
Total	100.00%	100.00%		

JS

JS

RVR Mix Composition:

Silica Sand	59.61%
Boric Acid	16.17%
Dolomite	10.87%
Alumina	11.61%
Iron Oxide	1.04%
Mag. Carb.	0.70%

Sodium Balance

Sodium In:

Sodium In Simulant:	230.00 g/liter	per whcox.wb1
Total Simulant In:	269.39 liter	
Total Sodium from Simulant:	61.96 kg Na	

Sodium Out:

Sodium in Glass:	15.61% Na(2)O	Average of all analysis
	x 74.19% Na in Na(2)O	
	11.58% Elemental Na in Glass	
	47.07 kg Na	

Sodium in Off-Gas particulate:	21.45% Na in Off-gas	Per Omni Repor
Total Particulate during MT-2:	11.97 kg	
Total Na in the Particulate:	2.57 kg Na	

Percent loss to Off-gas on an Oxide Basis:

Oxide equivalent in Slurry:	83.52 kg Na(2)O
Oxide equivalent in Off-Gas:	3.46 kg Na(2)O
Percent Na(2)O to Off-Gas:	4.14% of Feed

Error Analysis:	Total Sodium In:	61.96 kg
	Total Sodium Out:	49.64 kg
	Difference	12.32 kg
	Percent Error:	19.89% not accounted for

Chloride Balance

Chloride In:

Chloride in Simulant:	5.672 g/l	per WHCoxLwb1
Total Simulant In:	269.39 liter	
Total Chloride from Simulant	1.53 kg	

Chloride Out:

% Cl in Off-Gas Particulate:	5.50%
Total Particulate Out:	11.97 kg
Total Chloride Out in Off-Gas:	0.66 kg

Percent Chloride lost to Off-Ga 43.09%

Chloride in Glass:	0.06%
Total Glass Out:	406.42 kg
Total Chloride in glass:	0.248 kg

Total Cl Out: 0.906 kg

% Cl not accounted for: 40.69%

Fluoride Balance

Fluoride In:

Fluoride in Simulant:	4.75 g/l	per WHCoxLwb1
Total Simulant In:	269.39 liter	
Total Fluoride from Simulant:	1.28 kg	

Fluoride Out:

% F in Off-Gas Particulate:	1.68%
Total Particulate Out:	11.97 kg
Total Fluoride Out in Off-Gas:	0.20 kg

Percent Fluoride lost to Off-Ga 15.67%

Fluoride in Glass:	0.13%
Total Glass Out:	406.42 kg
Total Fluoride in glass:	0.539 kg

Total F Out: 0.739 kg

% F not accounted for: 42.25%

Iodide Balance

Iodide In:

Iodide in Simulant:	2.115 g/l	per WHCox.wb1
Total Simulant In:	269.39 liter	
Total Iodide from Simulant:	0.57 kg	

Iodide Out:

% Iodide in Off-Gas Particulate	1.52%
Total Particulate Out:	11.97 kg
Total Iodide Out in Off-Gas:	0.18 kg
Percent Iodide lost to Off-Gas:	31.88%
Iodide in Glass:	203.00 ppm
Total Glass Out:	406.42 kg
Total Iodide in glass:	0.083 kg

Total I Out:	0.264 kg
--------------	----------

% I not accounted for:	53.64%
------------------------	--------

Cesium Balance

Cesium In:

Cesium in Simulant:	2.22 g/l	per WHCox.wb1
Total Simulant In:	269.39 liter	
Total Cesium from Simulant:	0.60 kg	

Cesium Out:

Cesium in Off-Gas:	Non Detectable	
Cesium in Glass:	366.00 ppm	
Total Glass Out:	406.42 kg	
Total Cesium in glass:	0.149 kg	
Total Cs Out:	0.149 kg	
% Cs not accounted for:	75.07%	

Strontium Balance

Strontium In:

Strontium in Simulant:	1.46 g/liter	per WHCox.wb1
Total Simulant In:	269.39 liter	
Total Strontium In:	393.40 g	

Strontium Out:

Strontium in Off-Gas:	0.0040%	
Total Particulate Out:	11.97 kg	
Total Strontium in Off-Gas:	0.4788 g	
Percent Strontium lost to Off-Gas:	0.12%	
Strontium in Glass:	505.00 ppm	
Total Glass Out:	406.42 kg	
Strontium out in glass:	205.24 g	
Total Strontium Out:	205.72 g	
% Strontium not accounted for:	47.71%	

Chromium Balance

Chromium in:

Cr(2)O(3) in Simulant:	0.659 g/liter
Total Simulant in:	269.39 liter
total Cr(2)O(3):	0.177 kg

Chromium out:

Cr(2)O(3) in glass:	2060.00 ppm
Total Glass out:	406.42 kg
Cr(2)O(3) out in glass:	0.84 kg

Cr out with particulate:	0.06%
total Particulate Out:	11.97 kg
Total Cr Out:	0.0072 kg
% Cr in Cr(2)O(3):	68.42%
Cr(2)O(3) equivalent:	0.0105 kg

Total Cr(2)O(3) out:	0.85 kg
----------------------	---------

% Excess:	477.78%
-----------	---------

Potassium Balance

Potassium in:

K(2)O in Simulant:	23.55 g/liter
Total Simulant In:	269.39 liter
Total K(2)O from Simulant:	6.34 kg

Potassium Out:

K(2)O in glass:	0.63%
Total Glass Out:	406.42 kg
Total K(2)O in Glass:	2.56 kg

Potassium in Particulate:	3.94%
Total Particulate Out:	11.97 kg
Total Potassium in Particulate:	0.471 kg
% K in K(2)O:	83.02%
K(2)O equivalent:	0.568 kg

total K(2)O out:	3.13 kg
------------------	---------

% K(2)O not accounted for:	50.69%
----------------------------	--------

Manganese Balance

Manganese In:

MnO(2) in Simulant: 0.0362 g/liter
Simulant In: 269.39 liter
Total MnO(2) in from Simulant: 0.0098 kg

Manganese Out:

MnO(2) in Glass: 0.0096%
Total Glass Out: 406.42 kg
Total MnO(2) in Glass: 0.0388 kg

Mn in Particulate: 0.0090%
total Particulate Out: 11.97 kg
Total Mn in Particulate: 0.0011 kg
% Mn in MnO(2): 63.22%
MnO(2) equivalent: 0.0017 kg

total MnO(2) out: 0.0405 kg

% excess MnO(2): 415.23%

Phosphorus Balance

Phosphorus in:

P(2)O(5) equivalent in Simulant: 3.08 g/liter
Total amount of Simulant in: 269.39 liter
Total P(2)O(5) equivalent in: 0.829 kg

Phosphorus Out:

Phosphorus in Off-Gas Particulate: 0.055%
Total Particulate Out: 11.97 kg
Total Phosphorus out: 0.006524 kg

P(2)O(5) equivalent out: 0.014949 kg
percent P(2)O(5) in Off-Gas: 1.80%

P(2)O(5) in Glass: 0.11%
0.466 kg

Total P(2)O(5) Out: 0.481 kg

% P(2)O(5) not accounted for: 41.91%

Silicon Balance

Silicon In:

%Silica Sand in RVR MIX:	59.61%
SiO ₂ in Silica Sand:	99.88%
total SiO ₂ in RVR mix:	255.71 kg

Silicon Out:

SiO ₂ in product:	58.65%
Total Product Out:	406.42
SiO ₂ out:	238.36 kg
% SiO ₂ not accounted for:	6.78%

Boron Balance

Boron In:

Boric Acid in RVR Mix:	16.17%	per WHCox.wb1
Total RVR Mix:	429.49 kg	
Total Boric Acid In:	69.45 kg	

Boric Acid ->	56.30% B ₂ O ₃	per WHCox.wb1
Total Boron on Oxide Basis:	39.10 kg B ₂ O ₃	

Boron Out:

Boron in Off-Gas Particulate:	7.31%	per Omni Report
Total Particulate:	11.97 kg	
Total Boron in Particulate:	0.88 kg	

B in B ₂ O ₃ :	31.03%
Total Boron on Oxide Basis:	2.82 kg B ₂ O ₃
Percent Lost to Off-Gas:	7.21%
B ₂ O ₃ in glass:	7.45%
	30.28 kg
Total B ₂ O ₃ out:	33.10 kg
% not accounted for	15.35%

Calcium Balance

CaCO(3) in RVR Mix:

Silica Sand	0.03 kg
Boric Acid	0.00 kg
Dolomite	14.12 kg
Alumina	0.00 kg
Iron Oxide	0.00 kg
Magnesium Carbonate	0.005 kg

CaO in Simulant: 0.016 kg

Total CaO In: 14.16 kg

CaO in Glass: 2.93%
11.92 kg

% Missing: 15.83%

Magnesium Balance

MgO in RVR Mix:

Silica Sand	0.008 kg
Boric Acid	0.000 kg
Dolomite	8.929 kg
Alumina	0.000 kg
Iron Oxide	0.000 kg
Magnesium Carbonate	1.269 kg

MgO in Simulant: 0.011 kg

Total MgO In: 10.216 kg

MgO in Glass: 2.26%
9.19 kg

% Missing: 10.09%

Alumina Balance

Al(2)O(3) in RVR Mix:

Silica Sand	0.128 kg
Boric Acid	0.000 kg
Dolomite	0.000 kg
Alumina	32.411 kg
Iron Oxide	0.000 kg
Magnesium Carbonate	0.001 kg

Al(2)O(3) in Simulant: 13.962 kg

Total Al(2)O(3) In: 46.503 kg

- Al(2)O(3) in Glass: 9.53%
38.73 kg

% Missing: 16.71%

Iron Balance

Fe(2)O(3) in RVR Mix:

Silica Sand	0.038 kg
Boric Acid	0.000 kg
Dolomite	0.467 kg
Alumina	0.002 kg
Iron Oxide	4.377 kg
Magnesium Carbonate	0.000 kg

Fe(2)O(3) in Simulant: 0.016 kg

Total Fe(2)O(3) In: 4.901 kg

Fe(2)O(3) in Glass: 1.01%
4.10 kg

% Missing: 16.25%

Nitrogen Balance

Nitrogen In Simulant:

NO(3) in Simulant:	196.365 g/liter	per WHCox.wb1
Total NO(3):	52.90 kg	
%N in NO(3):	22.58%	
N from NO(3):	11.94 kg	

NO(2) in Simulant:	76.683 g/liter	per WHCox.wb1
Total NO(2):	20.66 kg	
% N in NO(2):	30.44%	
N from NO(2):	6.29 kg	

Na(4)EDTA in Simulant:	56.187 g/liter	
Total Na(4)EDTA:	15.14 kg	
% N in Na(4)EDTA:	6.73%	
N from Na(4)EDTA:	1.02 kg	

Total Nitrogen from Simulant: 19.25 kg

Nitrogen compound out of melter:

Total Particulate Out:	11.97 kg	per OMNI
------------------------	----------	----------

NO(3) in particulate:	0.020%	per OMNI
	0.0023 kg	
N from NO(3):	0.0005 kg	

NO(2) in particulate:	0.709%	per OMNI
	0.0849 kg	
N from NO(2):	0.0258 kg	

NH(3) in Particulate:	0.001%	per OMNI
	0.00012 kg	
N in NH(3):	82.35%	
N from NH(3):	9.9E-05 kg	

NOx in Off-Gas:	0.09864 kg/hr	per OMNI
Total NOx in Off-Gas:	1.38096 kg	
N in NOx:	30.44%	
Total N from NOx:	0.420295 kg	

% NO(2)/NO(3) lost of particulate: 0.12%

NO(2)/NO(3) conversion to N: 97.55%

Sulfur Balance

Sulfur in:

SO(4) in Simulant:	4.16 g/liter
Total Simulant In:	269.39 liter
Total SO(4) in:	1.12 kg
%S in SO(4):	33.33%

Total S in:	0.37 kg
-------------	---------

Sulfur out:

SO(3) in Glass:	0.017%
Total Glass Out:	406.42 kg
Total SO(3) out:	0.070 kg
% S in SO(3):	40.00%
Total S in Glass:	0.028 kg

SO(2) in Off-Gas:	ND
-------------------	----

SO(4) in Off-Gas Particulate:	5.28%
Total SO(4) out:	0.632 kg
% S in SO(4):	33.33%
Total S in Particulate:	0.211 kg

Total S out:	0.239
--------------	-------

% missing:	36.19%
------------	--------

Mass Balance for MT-3, V-SIM

Prepared by: Brent Spurgeon ib

Date: 08/17/95

Checked by: John Koehr JK

Date: 08/17/95

General Information

whcvt05.xls = Throughput Summary

V-SIM composition:

Component	Wt%
Alumina	11.500%
Silica Sand	39.100%
Dolomite	7.250%
Iron Oxide	0.683%
NaNO(2)	0.277%
NaCl	0.286%
NaF	0.456%
Na(2)SO(4)	0.207%
NaI O(3)	0.090%
CsCl	0.135%
KMnO(4)	0.002%
NaMoO(4)	0.014%
NaNO(3)	0.681%
K(2)CO(3)	0.825%
KOH	0.669%
SrCO(3)	0.119%
K(2)Cr(2)O(7)	0.030%
Na(2)CO(3)	23.900%
Boric Acid	10.500%
Na(3)PO(4) * 12H(2)O	0.793%
Carbon	2.230%
Mag Carb.	0.035%
	100%

Test Duration: 3 hr

Total Feed During Test: per whcvt05.xls

220.0 lb = 99.79 kg

Average Off-Gas flow rate: 657.05 kg/hr

Total Off-Gas: 1971.15 kg

Per OMNI Runs
3&4

Average Particulate in Off-Gas: 0.225 kg/hr

Total Particulate in Off-Gas: 0.675 kg

Total Glass Out: per whcvt05.xls

151.0 lb = 68.49 kg

Sodium Balance

Sodium In:

Sodium In V-Sim

Components with Sodium

Component	wt% in V-Sim	wt% Na in Component	wt% Na in V-SIM
NaNO(2)	0.277%	33.33%	0.09%
NaCl	0.286%	39.35%	0.11%
NaF	0.456%	54.76%	0.25%
Na(2)SO(4)	0.207%	32.39%	0.07%
NaIO(3)	0.090%	11.62%	0.01%
NaMoO(4)	0.01%	12.57%	0.00%
NaNO(3)	0.68%	27.06%	0.18%
Na(2)CO(3)	23.90%	43.40%	10.37%
Na(3)PO(4) * 12H(2)O	0.79%	18.16%	0.14%
Total percentage of Na in V-SIM			11.23%

Total V-Sim Feed: 99.79 kg
Total Sodium Feed: 11.21 kg

Equivalent Na(2)O: 15.11 kg

Sodium Out:

Sodium in Off-Gas Particulate: 19.35%
Total Particulate in Off-Gas: 0.675 kg
Total Sodium Out: 0.131 kg
Na(2)O equivalent: 0.176 kg

Percent Na lost to Off-Gas: 1.17%

Na(2)O in Glass: 16.10%
Total glass Out: 68.49 kg
Total Na(2)O out of glass: 11.03 kg

Total Na(2)O Out: 11.20

% not accounted for 25.85%

Chloride Balance

Chloride In:

Chloride in V-Sim:

Component	wt% in V-SIM	wt% Cl in Component	wt% Cl in V-SIM
NaCl	0.286%	60.68%	0.17%
CsCl	0.135%	21.08%	0.03%
Total Cl percentage in V-SIM			0.20%

Total V-Sim Feed: 99.79 kg
Total Chloride Feed: 0.20 kg

Chloride Out:

Chloride in Particulate: 9.07%
Total Particulate in Off-Gas: 0.675 kg
Total Chloride in Particulate: 0.06 kg

Percent loss to Off-Gas: 30.35%

Chloride in Glass: 0.10%
Total Glass Out: 68.49 kg
Total Chloride in Glass: 0.068 kg

% not accounted for: 66.02%

Fluoride Balance

Fluoride In:

Fluoride in V-Sim:

Component	wt% In V-SIM	wt% F in Component	wt% in V-SIM
NaF	0.00456	45.24%	0.21%

Total V-Sim Feed: 99.79 kg

Total Fluoride Feed: 0.21 kg

Fluoride Out:

Fluoride in Particulate: 0.84%

Total Particulate in Off-Gas: 0.675 kg

Total Fluoride in Particulate: 0.01 kg

Percent loss to Off-Gas: 2.74%

Fluoride in Glass: 0.16%

Total Glass Out: 68.49 kg

Total F in Glass: 0.109 kg

Total F out: 0.115 kg

% not accounted for: 44.30%

Iodide Balance

Iodide In:

Iodide in V-Sim:

Component	wt% in V-SIM	wt% I in Component	wt% I in V-SIM
NaIO(3)	0.090%	64.14%	0.06%

Total V-Sim Feed: 99.79 kg
Total Iodide Feed: 0.06 kg

Iodide Out:

Iodide in Particulate: 1.80%
Total Particulate in Off-Gas: 0.675 kg
Total Iodide in Particulate: 0.01 kg

Percent loss to Off-Gas: 21.13%

I in Glass: 199.5 PPM
Total glass Out: 68.49 kg
total I in Glass: 0.014 kg

Total I out: 0.026 kg

% not accounted for: 55.15%

Cesium Balance

Cesium In:

Iodide in V-Sim:

Component	wt% In V-SIM	wt% Cs in Component	wt% Cs in V-SIM
CsCl	0.135%	78.93%	0.11%

Total V-Sim Feed: 99.79 kg
Total Cesium in Feed: 0.11 kg

Cesium Out:

Cesium in Off-Gas: Non Detectable

Cs(2)O in Glass 0.057%
Total Glass Out: 68.49 kg
Total Cs(2)O in Glass: 0.039 kg
Total Cs in glass: 0.037 kg

% not accounted for 65.38%

Strontium Balance

Strontium In:

Strontium in V-Sim:

	wt%	wt% Sr	wt% Sr
Component	In V-SIM	in Component	in V-SIM
SrCO(3)	0.119%	58.96%	0.07%

Total V-Sim Feed: 99.79 kg

Total Strontium Feed: 0.07 kg

SrO equivalent out: 0.083 kg

Strontium Out:

Strontium in Particulate: 0.03%

Total Particulate in Off-Gas: 0.675 kg

Total Strontium in Particulate: 0.00018 kg

SrO Equivalent: 0.00021 kg

Percent loss to Off-Gas: 0.25%

SrO in Glass: 0.067%

Total Glass Out: 68.49

Total SrO in Glass: 0.046 kg

Total SrO Out: 0.046

% not accounted for: 44.33%

Phosphorus Balance

Phosphorus In:

Phosphorus in V-Sim:

Component	wt% in V-SIM	wt% P in Component	wt% P in V-SIM
Na(3)PO(4) * 12H(2)O	0.793%	8.16%	0.06%

Total V-Sim Feed: 99.79 kg

Total Phosphorus Feed: 0.06 kg

P(2)O(5) equivalent: 0.148 kg

Phosphorus Out:

Phosphorus in Particulate: 0.03%

Total Particulate in Off-Gas: 0.675 kg

Total Phosphorus in Particulate: 0.0002 kg

P(2)O(5) equivalent: 0.0004 kg

Percent loss to Off-Gas: 0.26%

P(2)O(5) in Glass: 0.15%

Total Glass Out: 68.49 kg

Total P(2)O(5) in Glass: 0.103 kg

Total P(2)O(5) Out: 0.103

% not accounted for: 30.25%

Boron Balance

Boron In:

Boron in V-Sim:

	wt%	wt% B	wt% B
Component	In V-SIM	in Component	in V-SIM
Boric Acid	10.500%	17.47%	1.83%

Total V-Sim Feed: 99.79 kg

Total Boron Feed: 1.83 kg

B(2)O(3) equivalent: 5.90 kg

Boron Out:

Boron in Particulate: 11.85%

Total Particulate in Off-Gas: 0.675 kg

Total Boron in Particulate: 0.080 kg

B(2)O(3) equivalent: 0.258 kg

Percent loss to Off-Gas: 4.37%

B(2)O(3) in Glass: 7.60%

Total Glass Out: 68.49 kg

Total B(2)O(3) in glass: 5.21 kg

Total B(2)O(5) OUT: 5.46 kg

% not accounted for: 7.94%

Alumina Balance

Alumina In:

Component	Wt% in V-Sim	Wt% Al(2)O(3) in Alumina	Wt% Al(2)O(3) Total
Alumina	11.500%	65.00%	7.48%

Total V-Sim Feed: 99.79 kg
Total Al(2)O(3) in: 7.46 kg

Alumina Out:

Al in Particulate out: 1.029%
Total Particulate Out: 0.675
Total Al Out: 0.0069 kg
Al(2)O(3) equivalent: 0.0131 kg

Al(2)O(3) in Glass: 9.60%
Total Glass Out: 68.49 kg
Total Al(2)O(3): 6.58 kg

Total Al(2)O(3) out: 6.59

% not accounted for: 11.68%

Silica Balance

Silica In:

Component	Wt% in V-Sim	Wt% SiO(2) in Component	Wt% SiO(2) Total
Silica Sand	39.100%	99.80%	39.02%
Dolomite	7.250%	5.00%	0.36%
			39.38%

Total V-Sim Feed: 99.79 kg
Total SiO(2) in: 39.30 kg

Silica Out:

Si in Particulate: 0.92%
Total Particulate: 0.675 kg
Total Si in Particulate: 0.0062 kg
SiO(2) equivalent: 0.0133 kg

SiO(2) in Glass: 57.44%
Total Glass Out: 68.49 kg
Total SiO(2) in Glass: 39.34 kg

Total SiO(2) Out: 39.36 kg

% excess: 0.14%

Calcium Balance

Calcium In:

Component	Wt% in V-Sim	Wt% CaO in Component	Wt% CaO Total
Dolomite	7.250%	30.24%	2.19%

Total V-Sim Feed: 99.79 kg
Total CaO in: 2.19 kg

Calcium Out:

CaO in Glass: 2.94%
Total Glass Out: 68.49 kg
Total CaO in Glass: 2.01 kg

% not accounted for: 8.09%

Magnesium Balance

MgO In:

Component	Wt% in V-Sim	Wt% MgO in Component	Wt% MgO Total
Dolomite	7.250%	19.13%	1.39%
Mag Carb.	0.035%	42.20%	0.01%
			1.40%

Total V-Sim Feed: 99.79 kg
Total MgO: 1.40 kg

MgO Out:

MgO in Glass: 2.23%
Total Glass Out: 68.49 kg
Total MgO in Glass: 1.53 kg

% excess: 9.22%

Iron Balance

Iron In:

Component	Wt% in V-Sim	Wt% Fe(2)O(3) in Component	Wt% Fe(2)O Total
Iron Oxide	0.683%	98.00%	0.67%

Total V-Sim Feed: 99.79 kg
Total Fe(2)O(3) in: 0.67 kg

Iron Out:

Fe(2)O(3) in Glass: 0.99%
Total Glass Out: 68.49 kg
Total Fe(2)O(3) in Glass: 0.68 kg

% excess: 1.86%

Chromium Balance

Chromium In:

Component	Wt% in V-Sim	Wt% Cr(2)O(3) in Component	Wt% Cr(2)O Total
K(2)Cr(2)O(7)	0.030%	51.70%	0.02%

Total V-Sim Feed: 99.79 kg
Total Cr(2)O(3) in: 0.0155 kg

Chromium Out:

Chromium in Particulate: 0.037%
Total Particulate Out: 0.675 kg
Total Chromium in Particulate: 0.00025 kg
Cr(2)O(3) equivalent: 0.00036 kg

Cr(2)O(3) in Glass: 0.26%
Total Glass Out: 68.49 kg
Total Cr(2)O(3) in Glass: 0.1781 kg

Total Cr(2)O(3) Out: 0.1784 kg

% excess: 1052.89%

Manganese Balance

Manganese In:

Component	Wt% in V-Sim	Wt% MnO(2) in Component	Wt% MnO(2) Total
KMnO(4)	0.002%	55.03%	0.0011%

Total V-Sim Feed: 99.79 kg
Total MnO(2) in: 0.0011 kg

Manganese Out:

MnO(2) in Glass: 0.009%
Total Glass Out: 68.49 kg
Total MnO(2) in Glass: 0.006 kg

% Excess: 479.99%

Molybdenum Balance

Molybdenum In:

Component	Wt% in V-Sim	Wt% MoO(3) in Component	Wt% MoO(3) Total
NaMoO(4)	0.014%	78.63%	0.0110%

Total V-Sim Feed: 99.79 kg
Total MoO(3) in: 0.0110 kg

Molybdenum Out:

MoO(3) in Glass: 0.16%
Total Glass Out: 68.49 kg
Total MoO(3) in Glass: 0.11 kg

% Excess: 885.13%

Potassium Balance

Potassium In:

Component	Wt% in V-Sim	Wt% K(2)O in Component	Wt% K(2)O Total
KMnO(4)	0.002%	59.46%	0.0012%
K(2)CO(3)	0.825%	68.12%	0.5620%
KOH	0.669%	167.86%	1.1230%
K(2)Cr(2)O(7)	0.030%	31.97%	0.0096%
			1.70%

Total V-Sim In: 99.79 kg

Total K(2)O in V-Sim: 1.69 kg

Potassium Out:

Potassium in Particulate: 3.44%
Total Particulate out: 0.675 kg
Total Potassium in Particulate: 0.023 kg
K(2)O equivalent: 0.028 kg

K(2)O in Glass: 0.82%
Total Glass Out: 68.49 kg
Total K(2)O in Glass: 0.558 kg

Total K(2)O Out: 0.586 kg

% not accounted for: 65.36%

Carbon Balance

Carbon In:

Component	Wt% in V-Sim	Wt% C in Component	Wt% C Total
Dolomite	7.250%	12.17%	0.8825%
K(2)CO(3)	0.825%	8.68%	0.0716%
SrCO(3)	0.119%	8.13%	0.0097%
Na(2)CO(3)	23.900%	11.32%	2.7057%
Carbon	2.230%	100.00%	2.2300%
Mag Carb.	0.035%	10.09%	0.0035%
			5.9031%

Total V-Sim In: 99.79 kg
total C in V-Sim: 5.89 kg

Carbon Out:

C in Off-Gass:

Carbon Dioxide Out: 5.75 kg/hr
17.25 kg
Carbon Equivalent: 4.71 kg

Carbon Monoxide Out: 0.82 kg/hr
2.46 kg
Carbon equivalent: 1.06 kg

Total C in Off-Gas: 5.76 kg

C in Glass:

Total Carbon in Glass 0.0033%
Total Glass Out: 68.49 kg
Total C in Glass: 0.0023 kg

Total C Out: 5.77 kg

% not accounted for: 2.10%

Nitrate/Nitrite Conversion

Nitrate/Nitrite in:

Component	Wt% in V-Sim	Wt% in Component	Wt% Total
Nitrate:			
NaNO(3)	0.681%	54.19%	0.37%
Nitrite:			
NaNO(2)	0.277%	66.67%	0.18%
		Total	0.55%

Total V-Sim in: 99.79 kg
Total Nitrate/Nitrite: 0.55 kg

NOx Out:

NOx in Off-Gas, (as NO(2)) 0.0949 kg/hr
0.2847 kg

Nitrate/Nitrite in Particulate: Negligible
Total Particulate Out: 0.675 kg
Total Out: 0.0000 kg

Conversion to N(2): 48.47%

This page intentionally left blank.

DISTRIBUTION SHEET

To Distribution	From Waste Product Technology	Page 1 of 2
		Date 02/7/96
Project Title/Work Order VECTRA GSI, Inc. Low-Level Waste Melter Testing Phase 1 Test Report		EDT No. 611890 [WHC-SD-WM-VI-031, Rev. 0]
		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./Appendix Only	EDT/ECN Only
------	------	-----------------------	-----------	-----------------------	--------------

OFFSITE

VECTRA GSI, Inc.
500 Executive Parkway, Suite 500
San Ramon, CA 94583

G. Klein (2) X

VECTRA Technologies
2939 Richardson Road
Richland, WA 99352

M. Hall (2) X
B. Spurgeon (2) X

VECTRA Technologies
107 Carpenter Drive, Suite 110
Sterling, VA 20164

K. Allen (2) X

VECTRA Waste Services
One Harbison Way, Suite 209
Columbia, SC 29212-3408

P. Denault (2) X

Roger B. EK & Associates, Inc
2711 226th Ave SE
Issaquah, WA 98027

R. B. Ek X

Washington State Department
of Ecology

Nuclear Waste Program
P.O. Box 47600
Olympia, WA 98504-7600

J. Granthum (2) X

DISTRIBUTION SHEET

To Distribution	From Waste Product Technology	Page 2 of 2			
Project Title/Work Order VECTRA GSI, Inc. Low-Level Waste Melter Testing Phase 1 Test Report		Date 02/7/96			
		EDT No. 611890 [MHC-SD-WM-VI-031, Rev. 0]			
		ECN No.			
Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only

ONSITE

U.S. Department of Energy, Richland Operations Office

N. R. Brown	K6-51	X			
L. A. Huffman	K6-51	X			
J. C. Peschong	K6-51				X
G. H. Sanders	S7-53	X			
C. L. Sohn	K6-51	X			

Pacific Northwest National Laboratory

C. J. Freeman	P7-41	X			
D. Vela	K6-51	X			
J. H. Westsik	K9-80				X
G. A. Whyatt	P7-19	X			

Westinghouse Hanford Company

M. J. Bowman	G1-25	X			
K. C. Burgard	H5-03	X			
R. P. Colburn	H5-27	X			
D. W. Duncan	B4-55				X
W. C. Eaton	H5-27	X			
P. Felise	B4-55	X			
J. S. Garfield	H5-49	X			
R. L. Gibby	H5-27				X
D. W. Hendrickson	L5-31				X
B. A. Higley	H5-27				X
S. L. Lambert	H5-27	X			
E. S. Mast	S3-90	X			
R. J. Murkowski	H5-03				X
S. R. Nelson	B4-55	X			
R. M. Orme	H5-27	X			
C. A. Petersen	H5-27				X
E. H. Randklev	H5-27	X			
J. W. Shade	H5-27	X			
G. E. Stegen	H5-27	X			
D. J. Washenfelder	H5-61	X			
C. N. Wilson (5)	H5-27	X			
Central Files (orig. +1)	A3-88	X			