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DURABILITY OF GLASSES FROM THE HG-DOPED INTEGRATED DWPF MELTER SYSTEM (IDMS) CAMPAIGN (U)

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ABSTRACT

The Integrated DWPF Melter System (IDMS) is designed and constructed to be a 1/9th scale prototype of the full scale Defense Waste Processing Facility (DWPF) melter. The IDMS facility is the first engineering scale melter system capable of processing mercury, and flowsheet levels of halides and noble metals. In order to determine the effects of mercury on the feed preparation process, the off-gas chemistry, glass melting behavior, and glass durability, a three-run mercury (Hg) campaign was conducted. The glasses produced during the Hg campaign were composed of Batch 1 sludge, simulated precipitate hydrolysis aqueous product (PHA) from the Precipitate Hydrolysis Experimental Facility (PHEF), and Frit 202. The glasses were produced using the DWPF process/product models for glass durability, viscosity, and liquidus. The durability model indicated that the glasses would all be more durable than the glass qualified in the DWPF Environmental Assessment (EA). The glass quality was verified by performing the Product Consistency Test (PCT) which was designed for glass durability testing in the DWPF.

The durability of three glasses from each of the three runs was examined with the PCT. There was very little variation in the glass durability during run HG-1 until excess NaOH was added to adjust the glass viscosity to be in the correct processing range. The addition of the excess NaOH caused the glasses in runs HG- 2 and HG-3 to be less durable than the glasses in run HG-1. The nine IDMS Hg glasses were of comparable durability to previously examined sludge-only 165 glasses and to glasses fabricated from Frit 202 with excess alkali. All the IDMS Hg glasses were over 20 times more durable than the glass that was qualified in the DWPF Environmental Assessment (EA). The IDMS Hg campaign glasses would, therefore, meet current Waste Acceptance Preliminary Specification (WAPS) criteria for product consistency.

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DURABILITY OF GLASSES FROM THE HG-DOPED INTEGRATED DWPF MELTER SYSTEM (IDMS) CAMPAIGN (U)

INTRODUCTION

Liquid high-level nuclear waste will be immobilized at the Savannah River Site (SRS) by vitrification into borosilicate glass. The production process to be used in the Defense Waste Processing Facility (DWPF) is designed to reliably produce durable borosilicate nuclear waste glasses.

The Integrated DWPF Melter System (IDMS) was designed and constructed to be a 1/9th scale prototypic pilot plant of the full scale DWPF melter. The IDMS facility is the first engineering scale melter system operated at SRS that is capable of processing mercury, and flowsheet levels of halides and noble metals. The mercury, present in the waste due to the use of mercuric nitrate as a catalyst during nitric acid dissolution of spent fuel rods, decomposes at temperatures much less than the borosilicate glass melt temperature. Any mercury present in the waste at the time of vitrification will likely exit the melter in the off-gas. Therefore, the DWPF has planned to remove most of the mercury prior to vitrification by reduction and steam stripping.[1]

In order to determine the effects of mercury on the feed preparation process, the off-gas chemistry, glass melting behavior, and glass durability, a mercury (Hg) campaign was conducted in the IDMS. The IDMS was operated batch-style for three SRAT/SME (Slurry Receipt Adjustment Tank/Slurry Mix Evaporator) cycles. The facility was operated close to DWPF flowsheet conditions. The process/product models [2] developed for DWPF were used in spreadsheet format since the DWPF process control system, the Product Composition Control System (PCCS)[3] had not yet been fully implemented. Mercury containing Batch 1 sludge[4] without noble metals was blended with precipitate hydrolysis aqueous (PHA) product and Frit 202. This PHA glass was designed to have similar process and product characteristics to SRS sludge-only glasses which were formulated without PHA.[5]

A durability test, designated the Product Consistency Test (PCT), has been developed to measure the consistency of the glass product produced in the Defense Waste Processing Facility (DWPF) during routine production.[6-8] The test was designed to meet the requirements of the Waste Acceptance Preliminary Specifications (WAPS) 1.3.[9] Currently this specification states that based on comparative PCT analyses, a DWPF glass must have a release which is better than the glass that was qualified in the DWPF Environmental Assessment (EA).[10] The PCT measurement of glass durability will take a minimum of 7 days.[6-8] Therefore, a product quality model based on hydration free energy was developed.[11-17] The use of the hydration thermodynamic model allows the glass quality to be predicted from the composition of vitrified melter feed, and then verified after production.

This study documents the final glass chemistry and the measured glass durability of glasses produced during the IDMS-Hg campaign. Over 15,000 pounds of glass was poured during the entire campaign. This represented about 5000 pounds of glass for each of the three runs (Hg-1, Hg-2 and Hg-3). Three samples of IDMS glass were taken from the beginning of each of the three runs (Hg 1-1, Hg 2-1, Hg 3-1), at the middle of each run (Hg 1-2, Hg 2-2 and Hg 3-2), and at the end of each run (Hg 1-3, Hg 2-3, Hg 3-3). This represented glass pouring intervals of ~0, 2500, and 5000 pounds of glass. The process/product properties calculated from the vitrified slurry are compared to the properties calculated from the final glass product as a function of run sequence. The measured glass durability is reported and compared to the following:

- the predicted glass durability
- previously tested SRS sludge-only and PHA glasses
- the sludge-only glass qualified in the DWPF Environmental Assessment.

EXPERIMENTAL

Glass Homogeneity

X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) analyses coupled with Energy Dispersive Analysis by X-ray (EDAX) were performed on the nine IDMS-Hg campaign glasses in order to determine the crystallinity and/or homogeneity of the glass.

Glass Composition

The elemental composition of the nine glasses was originally measured by the TNX laboratory. The glasses were reanalyzed by the Analytic Development Section of the Savannah River Technology Center because the original analyses were inconsistent. The nine glasses were analyzed for whole element chemistry and redox. The glass samples were analyzed by the following techniques:

- Dissolution by Na_2O_2 with an HCl uptake
  - ICP for Al, Ca, Fe, Mg, Mn, Li, Si, Cr, B, Sr, Ti, P, Ba, Pb, Mo, Zn, Cu, Ni, La, Cd
- Dissolution by HCl/HF microwave
  - ICP for Na, Zr
  - AA for Na, K
- Dissolution by H_2SO_4/HF in the presence of NH_4VO_3[18]
  - Colorimetric for Fe^{2+} and $Fe_{(Total)}$

where ICP is Inductively Coupled Plasma Spectroscopy and AA is Atomic Absorption analysis.

Glass Durability

The durability of the nine glasses was studied using Version 3.0 of the PCT.[8] In the PCT, crushed glass of 100-200 mesh is immersed in ASTM Type I water for 7 days at 90°C. The volume of solution (V) used was the recommended 10 mL per gram of glass. Leachates were filtered to remove colloids and/or particulates. At the end of triplicate analyses, both the pH and the leachate concentrations were measured for the glass species of interest. A standard glass was used as a control to eliminate bias in the experimental analysis and in the analytical data. Triplicate analyses and triplicate glass standards were run simultaneously. A multielement solution standard was used to detect any significant biases in the analysis of the leachates.

The leachate concentrations are reported as normalized elemental losses, NC_i, released from the glass in grams of glass per L of leachant. This has the advantage that the release concentrations in parts per million are normalized by the weight fraction of that element present in the glass. The

normalized release, NC_i, is calculated as:

$$NC_i = \frac{C_i}{F_i} \quad (1)$$

where NC_i = normalized release ($g_{glass}/L_{leachant}$)

C_i = mass of element "i" in the solution (g_i/m^3)

F_i = fraction of element "i" in the glass (g_i/g_{glass})

QUALITY ASSURANCE

All the vitrification activities and glass analyses were performed in accordance with DWPT Task Plan-IDMS Mercury Studies, DWPTQA-89-0041. All tasks were controlled in accordance with the task QA Plan.

The PCT Version 3.0 is a Glass Technology Category 1 Procedure requiring experimenter data input and signoff at every step (GTOP-3-025 in The Glass Technology Procedures Manual, DPSTM-88-700-5, L 13-1). All the ovens, balances, and water purification systems used for the PCT are M&TE Category 1.

Analytical Development Section (ADS) procedures were followed for all chemical and x-ray diffraction data so that the data is readily retrievable.

All the PCT data for this study are recorded in DPSTN-4789 (E-56079) and WSRC-NB-90-271. The glass composition data is recorded in DPSTN-4771 (E-56053).

GLASS SAMPLE IDENTIFICATION

The glass nomenclature Hg 1-1, 1-2, 1-3 was used to facilitate the understanding of the chemical variation occurring in the first (Hg-1) run of the IDMS Hg campaign as a function of the sequence in which the glasses were sampled.[19] Glasses Hg 1-1, 1-2, and 1-3 appear in the IDMS production records as GLAS 2340, 2427, and 2518, respectively. Glasses Hg 2-1, 2-2, and 2-3 are GLAS 2630, 2838, and 2877, respectively. Glass Hg 3-1 is a combined sample of production run GLAS 2124 and 2125. Glass Hg 3-2 is a combined sample of production run GLAS 3236 and 3237. Glass Hg 3-3 is production run GLAS 3357.

RESULTS AND DISCUSSION

Glass Homogeneity

The x-ray diffraction analysis of the crushed and sieved glass indicated that there was no crystallization present in any of the IDMS-Hg glasses. During SEM/EDAX analysis of the crushed glass, small amounts of metallic Cu° were observed. The Cu° appeared to be on the glass surface, indicating that it may have been contamination from the brass sieves. No evidence of glass crystallization was observed during SEM/EDAX analysis.

Glass Composition

The chemical analyses indicated that there had been an excursion in Na_2O content in the glass vitrified in IDMS between runs Hg-1 and Hg-2. This excursion occurred when the vitrified slurry analyses indicated that the resulting melt would be too viscous to pour, e.g., over the viscosity process control limit of 100 poise.[19] NaOH was added to run Hg-2 to adjust the feed so that it would form a glass of < 100 poise viscosity. Additional PHA, which is Na_2O rich, was added to the run Hg-3 feed instead of NaOH, so that the Hg-3 run glass would conform to the viscosity process limit of <100 poise.

Analysis of the glass used in the durability studies indicated that the glasses run during run Hg-1 (Hg 1-1, Hg 1-2, and Hg 1-3) and the very first sample taken at the beginning of run Hg-2 (Hg 2-1) were consistent in composition while the sequence of glasses after the NaOH (Hg 2-2, Hg 2-3) and the PHA (Hg 3-1, Hg 3-2, Hg 3-3) additions were consistent. The glass compositions were measured in duplicate and were determined to be biased low compared to the original analyses of these glasses at the TNX laboratory. Therefore, the reanalyzed glass compositions were bias-corrected to the original IDMS Hg-1 glass data (Appendix I). The measured redox ratios ($Fe^{2+}/\Sigma Fe$) of the IDMS glasses were <0.05 during runs Hg-1 and Hg-2 and between 0.07 and 0.1 during run Hg-3 (Appendix I). The measured redox for Hg-1 and Hg-2 glasses were more oxidizing than those measured from the vitrified feed for Hg-1 and Hg-2. The measured redox for Hg-3 glasses was slightly more reduced than the redox measured from the vitrified feed for Hg-3.[19]

The effect of the glass composition variability calculated for each of the compositionally dependent process (viscosity and liquidus) and product (durability) constraints is shown in Figure 1a-c as a function of production run sequence. The process and product parameters calculated from the average glass compositions given in Appendix I followed the same trends as the parameters calculated[19] from the vitrified melter feed for all runs. The chemical analysis of vitrified feed from run Hg 2-1 indicated that the melt would have exceeded the upper viscosity limit of 100 poise (Figure 1a) and the upper liquidus temperature of 1050°C (Figure 1b) had the glass composition not been remediated to the value indicated by the Hg 2-2 glass analysis. Glass Hg 2-1 had been sampled early in run 2 before the melt volume had completely turned over after the addition of the NaOH. Moreover, Figure 1c indicates that the remediation of the glass composition within the process constraints did not adversely affect the glass durability, e.g. the calculated glass durability, expressed as the glass free energy of hydration, remained a more positive value than -7 kcal/mole.

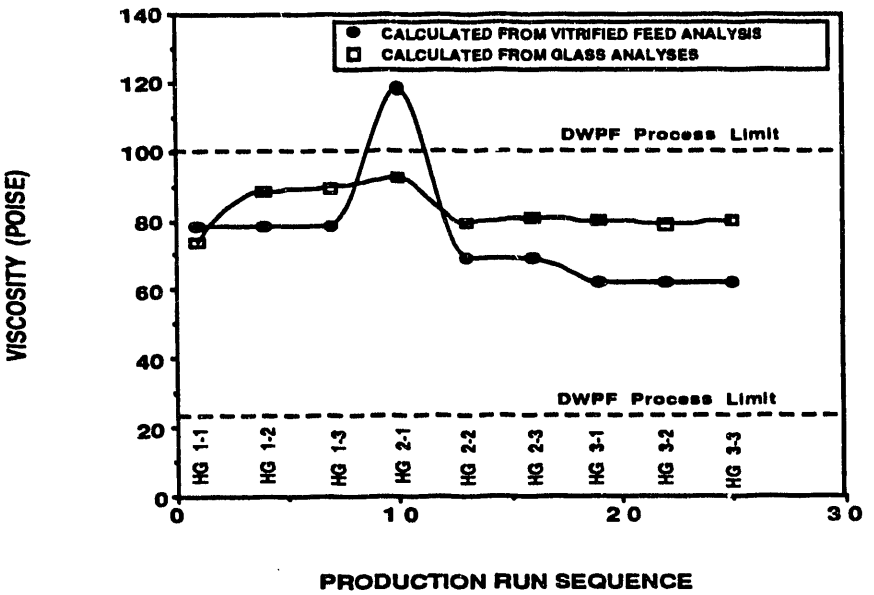

Figure 1a. Comparison of predicted glass viscosity based on vitrified feed analyses and final glass composition analysis.

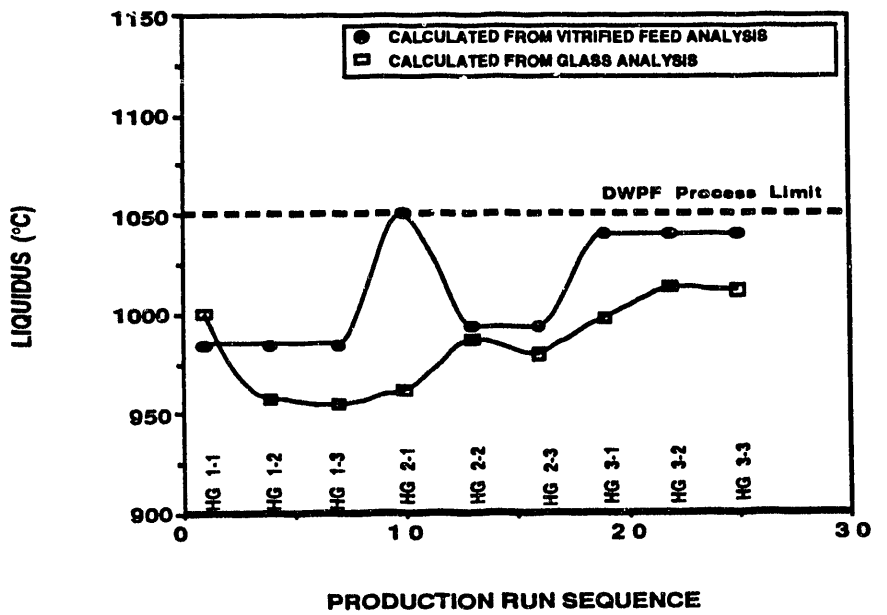

Figure 1b. Comparison of predicted glass liquidus based on vitrified feed analyses and final glass product analysis.

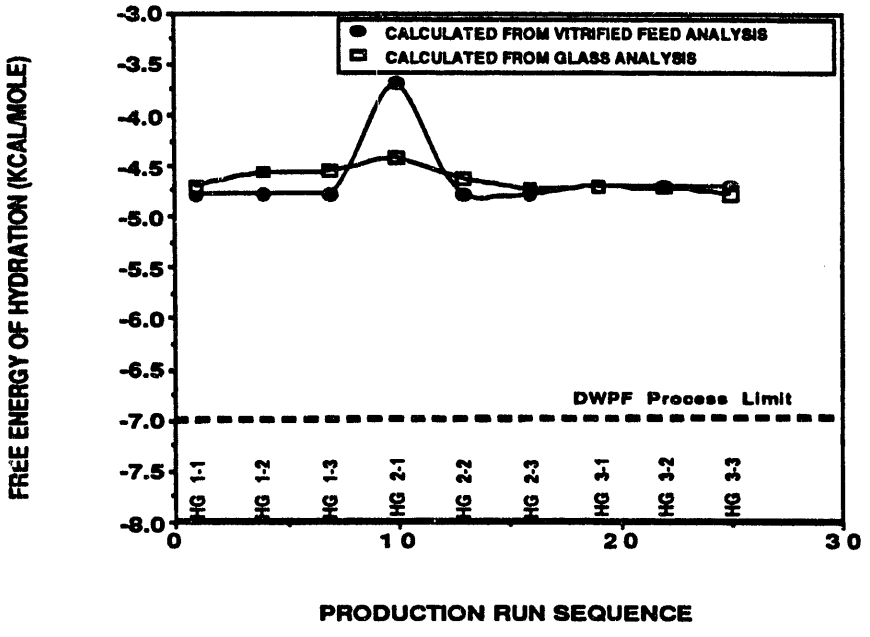

Figure 1c. Comparison of predicted glass liquidus based on vitrified feed analyses and final glass product analysis.

Glass Durability

The triplicate glass durability analysis pH values shown in Figure 2 also reflect the changing alkali content of the Hg campaign glass as a function of production run sequence. The leachate pH changed significantly between campaign Hg 2-1 and Hg 2-2 when the excess NaOH addition to the sludge became a significant contribution in the resulting glass. This is not surprising since excess Na_2O in the glass would cause excess OH^- in the leachate which causes the leachate pH to become more basic via the following reaction:

$$Na_2SiO_3 + 2H_2O \rightarrow 2Na^+ + H_2SiO_3 + 2OH^- \qquad (2)$$

The pH corrected free energy of hydration was calculated from the glass composition and the leachate pH (Appendix I).[12] The pH corrected free energy of hydration was plotted as a function of glass production run sequence for the IDMS-Hg glasses (Figure 3). A significant change in the free energy of hydration, ΔG_{hyd}, is noted between runs Hg 2-1 where the calculated value is about -7 kcal/mole and Hg 2-2 where the calculated value is about -8 kcal/mole. The change in the pH corrected ΔG_{hyd} coincided with the the point at which the excess Na_2O became a significant contribution to the glass.

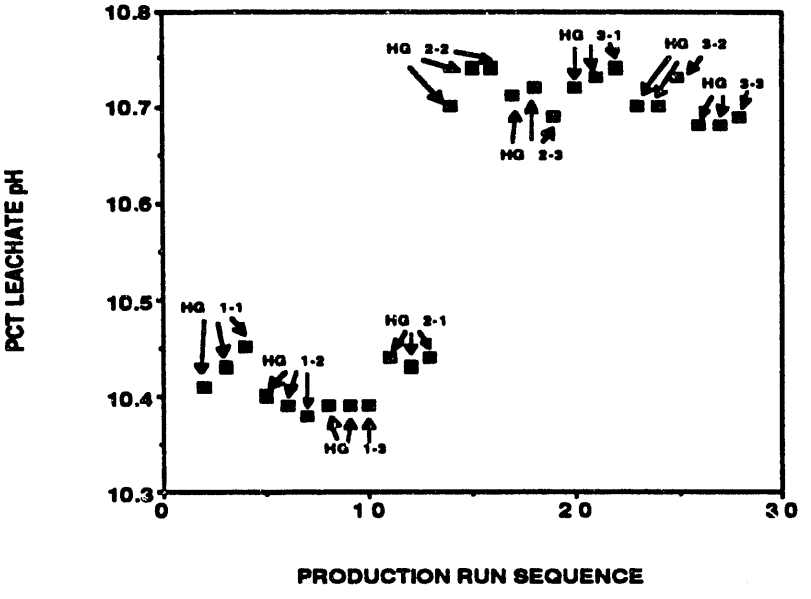

Figure 2. Variation of leachate pH with IDMS Hg glasses in the sequence in which the glasses were produced and poured.

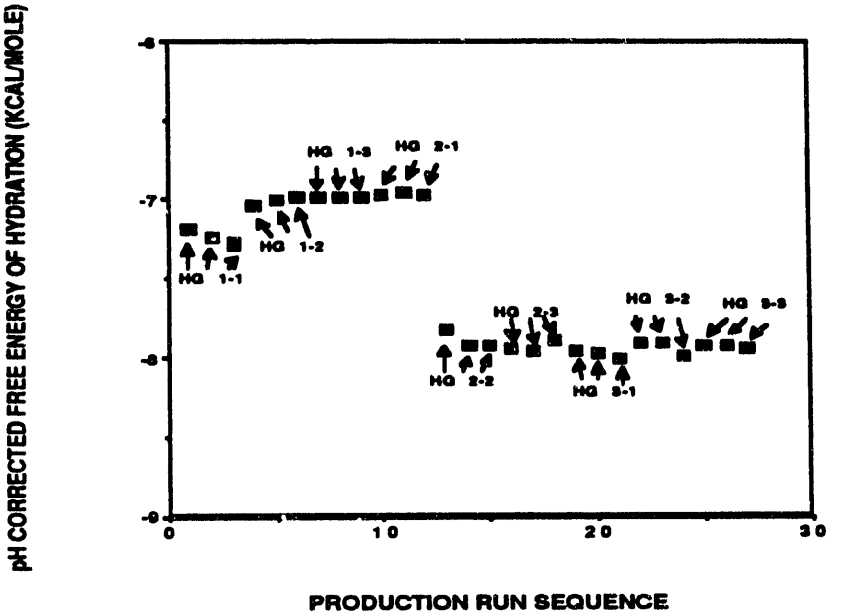

Figure 3. Variation of the calculated free energy of hydration (calculated from the glass composition and the solution pH) for IDMS Hg glasses shown in the sequence in which the glasses were produced and poured.

A multielement solution standard was run after every 5 leachate samples. Analysis of the solution standard data indicated that there was less than 0.5 ppm bias in the ICP analyses for Na, B, Li, Al, and Fe and in the Atomic Absorption (AA) analyses for K. The data also indicated that there was about a 1.4 ppm bias in the Na determinations made by AA and a -1.47 bias in the Si determinations by ICP analysis (Appendix II).

The raw data used to convert the leachate concentrations to NC_i is given in Appendix III. Boron and lithium releases from glass are considered to be the most accurate indicators of glass durability since these elements are leached from glass faster than any other elements. Boron is probably the best indicator of glass durability because it does not saturate in the leachate and does not participate in precipitation reactions caused by solution supersaturation. The elemental releases measured in the leachates were checked for internal consistency by plotting the normalized releases for Li, Si, Na, and K against the normalized releases of B (Figure 4). Normalized units are plotted since the glasses before run Hg 2-2 are considerably different in composition than those after run Hg 2-2. The plots of Li, Si, Na and K versus B were all consistent, e.g. if a given glass released a great deal of B it, likewise, released a great deal of Li and/or Si, Na, or K. Figure 4 also demonstrates a consistently high bias in the Na analyses by AA over the Na analyses by ICP.

The normalized elemental release of B was plotted against the pH corrected ΔG_{hyd}. The elemental release of B from the IDMS Hg glasses were compared with PCT results from previous experimentation (Table 1 and Figure 5). The previous experimental results had been collected prior to May 1989. Historical control charting of the ARM-1 standard glass indicated a shift in the elemental releases for all elements in May 1989. This shift correlated with a change from PCT 2.0 to PCT 3.0 when a glass powder washing procedure was introduced to remove adhering fine particles from the sieved glass. Since removal of the glass fines prior to conducting the durability test biases the PCT 3.0 leachate data lower than the historic data, the historic data was bias corrected to be consistent with the data derived from PCT 3.0.

The bias corrected normalized B release for the historic data and the PCT 3.0 leachate data for the Hg glasses was plotted against the ΔG_{hyd} calculated from the glass composition and the solution pH. This comparison indicated that the glasses from the IDMS Hg-1 campaign (Hg 1-1, Hg 1-2 and Hg 1-3) and the glass from the first sample of the Hg-2 campaign (Hg 2-1) were very similar in durability to DWPF startup glass, 165 sludge-only glasses, and Frit 202 glass with excess alkali (Figure 5). The remaining glasses in the Hg-2 campaign (Hg 2-2 and Hg 2-3) and in the Hg-3 campaign (Hg 3-1, Hg 3-2, and Hg 3-3) were higher in Na_2O content due to NaOH addition during run Hg-2 and the excess PHA addition during run Hg-3 in order to adjust the glass viscosity. These glasses were less durable than the Frit 202 glass with excess PHA but more durable than 131 sludge-only glasses. All the IDMS Hg glasses are more durable than the glass that was qualified in the DWPF Environmental Assessment (EA).[10] Comparisons of the data in Table 1 for the average EA glass leachate concentrations and the data in Appendix I for the Hg Campaign glasses indicates that the Hg Campaign glasses are over 20 times more durable than the EA glass. The IDMS Hg campaign glasses would, therefore, meet current Waste Acceptance Preliminary Specification (WAPS) criteria for product consistency.

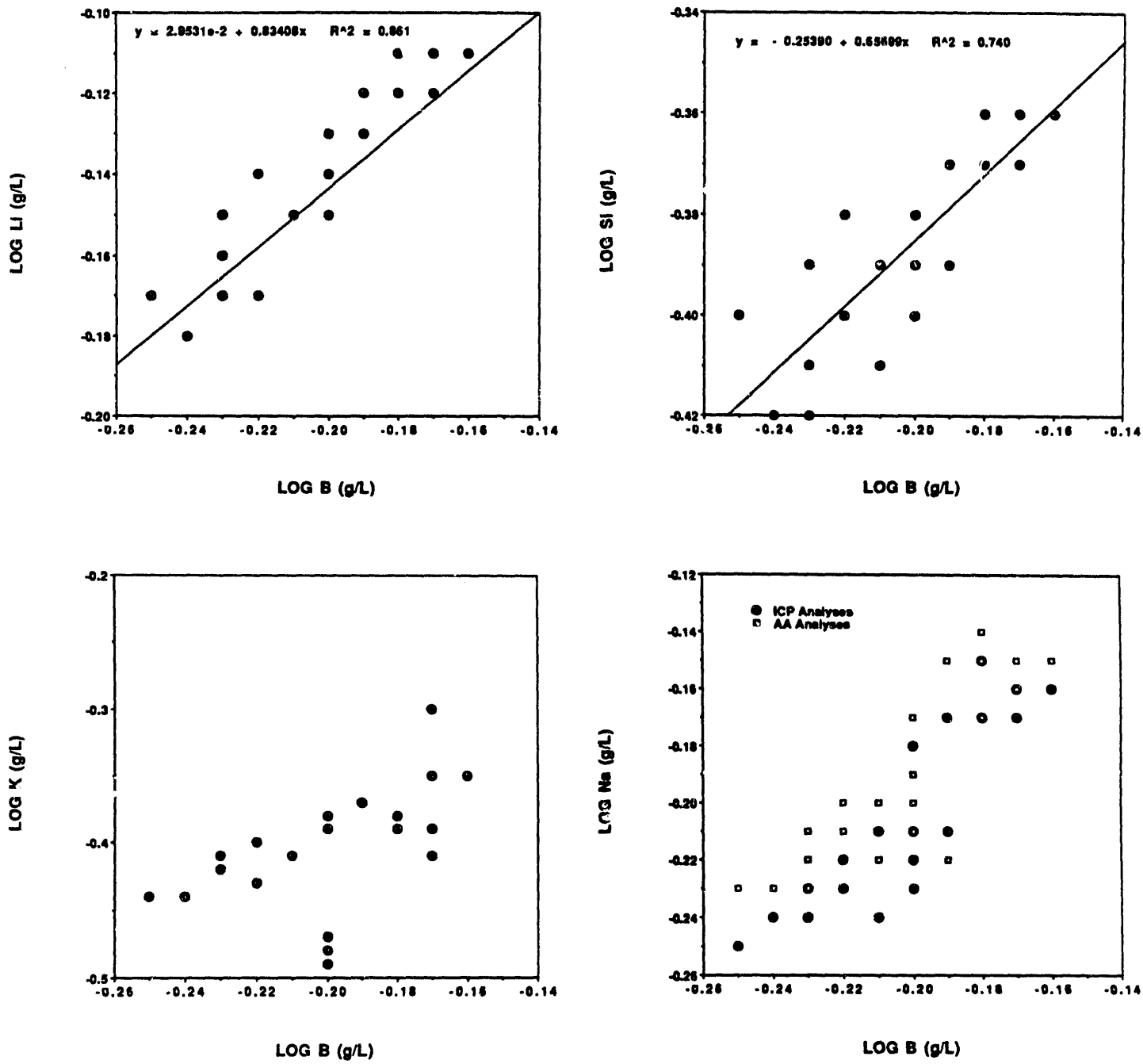

Figure 4. Internal consistency of IDMS leachate analyses. Note that the IDMS leachate analyses are significantly lower than the average values of Li, Na, B and Si for the EA glass which are 189±17, 1650±131, and 576±46, 882±105 ppm, respectively. See Table 1.

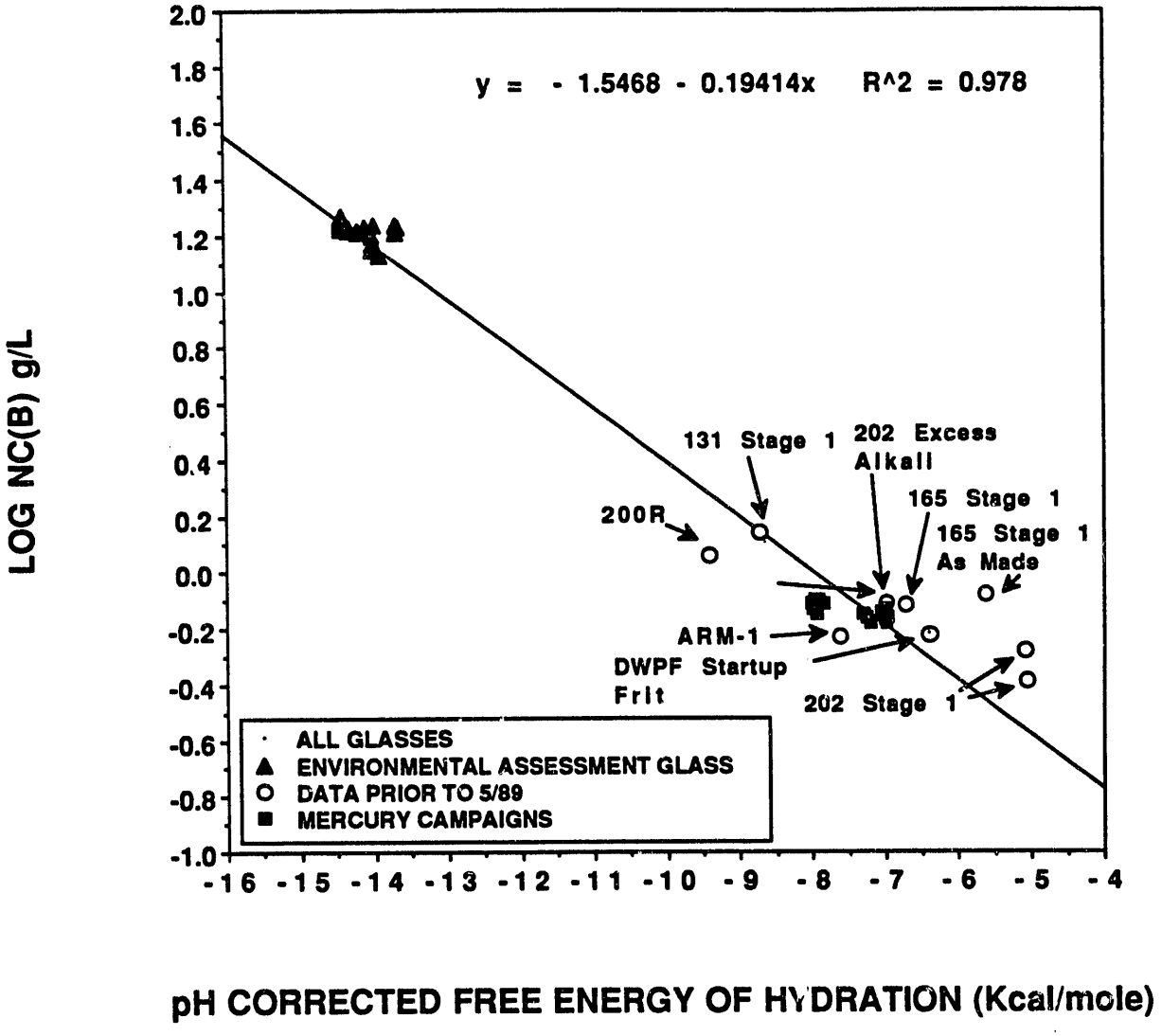

Figure 5. Correlation of the free energy of hydration, ΔG_{hyd}, calculated from the glass composition and the leachate pH, versus the logarithm of the normalized boron release from glasses investigated for the Defense Waste Processing Facility (DWPF). The measured durability values for the IDMS Hg-1, Hg-2, and Hg-3 campaigns with Batch 1 sludge, PHA, and 202 frit are overlain for reference.

CONCLUSIONS

Glasses produced during the three IDMS Hg run campaigns were produced using the DWPF process/product models. The durability model indicated that the glasses would all be more durable than the glass qualified in the DWPF Environmental Assessment (EA). The measured glass durability demonstrated that the Hg campaign glasses were as durable as previously examined Frit 202 PHA glasses and sludge-only 165 glasses and more durable than the EA glass. The IDMS Hg glasses, therefore, meet the current Waste Acceptance Preliminary Specification (WAPS) 1.3 criteria for control of product consistency.

Table 1. Calculated Free Energies of Hydration and PCT Durability of DWPF Borosilicate Waste Glasses

Glass/Reference	pH Corrected Free Energy of Hydration (Kcal/mole)	Log NC(Si)	Log NC(B)	Log NC(Na)	Log NC(Li)	pH	PCT
		($g_{glass}/L_{leachate}$)					
EA Glass-Average of 24 PCT Tests[20]	-14.05	0.58	1.21	1.12	0.98	11.92	3.0
202 Stage 1 (AH-10) DPSTN-4724	-5.050	-0.53*	-0.39*	-0.51*	-0.35	9.59	2.1
165 Stage 1 (AH-165) DPSTN-4630	-5.62	-0.32	-0.08	-0.14	-0.061	9.73	2.1W
165 Standard (Corning) DPSTN-4575	-6.72	-0.29*	-0.12*	-0.07*	-0.14*	10.31	2.0
DWPF Startup Frit-Remelted DPSTN-4630	-6.39	-0.90*	-0.22*	-0.23*	-0.33*	10.24	2.1
202-Stage 1 Excess Alkali (Corning 202P) DPSTN-4630	-6.99	-0.41*	-0.11*	-0.08*	-0.16*	10.18	2.1
200 Average Radioactive DPSTN-4570	-9.41	-0.33	0.06	0.00	-0.01	10.55	2.1W
131 Stage 1 (AH 131) DPSTN-4630	-8.71	-0.51	0.14	0.10	0.02	10.43	2.1W
202-Stage 1 (Corning 202G) DPSTN-4631	-5.08	-0.46*	-0.28*	-0.20	-0.24	9.79	2.1

* Solution data corrected for Si bias of -13.31 ppm, B bias of -4.10 ppm, Na bias of -8.4 ppm, and an Li bias of -3.34 ppm; higher solution values were noted when glass fines were not removed from the meshed glass prior to durability testing (PCT 2.0 and 2.1). PCT 2.1W indicates PCT procedure 2.1 with fines washing and these data are directly comparable to data from PCT 3.0 without bias correction.

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GLASS ID= HG1-1A (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.3410	1.8895	4.4233	1.21	5.35	5.2009	101.9600	0.0524	3.3227	3.0400	0.1010	-0.0665	1.5943
CaO	0.7770	1.3992	1.0872	1.11	1.21	1.1748	56.0794	0.0215	1.3646	-16.1160	-0.2199	0.0273	-3.4711
Fe2O3	8.1820	1.4297	11.6512	1.04	12.09	11.7573	159.6922	0.0757	4.7959	15.5000	0.7434	-0.0959	11.7326
FeO	N/A	1.2865	0.0419	1.00	0.04	0.0408	71.8464	0.0006	0.0370	-14.6090	-0.0054	0.0007	-0.0853
MgO	0.7980	1.6583	1.3233	1.12	1.49	1.4474	40.3114	0.0369	2.3388	-13.8880	-0.3248	0.0468	-5.1266
MnO	1.4320	1.2912	1.8490	1.31	2.42	2.3541	70.9374	0.0341	2.1617	-14.8710	-0.3215	0.0432	-5.0737
Na2O	6.5850	1.3480	8.8766	1.03	9.14	8.8857	61.9790	0.1474	9.3388	-28.8150	-2.6910	0.1868	-42.4721
Li2O	1.9660	2.1525	4.2318	1.06	4.48	4.3589	29.8774	0.1500	9.5034	-22.7400	-2.1611	0.1901	-34.1084
NiO	0.5720	1.2726	0.7279	1.18	0.86	0.8375	74.7094	0.0115	0.7302	-14.3470	-0.1048	0.0146	-1.6534
SiO2	23.0310	2.1393	49.2702	1.10	54.17	52.6910	60.0848	0.9016	57.1238	5.5900	1.6396	0.0000	25.8783
Cr2O3	0.1620	1.4616	0.2368	1.59	0.38	0.3668	151.9974	0.0025	0.1571	37.3600	0.0587	-0.0031	0.9264
B2O3	2.1240	3.2201	6.8395	1.02	6.96	6.7673	69.6204	0.0999	6.3317	-9.9300	-0.6287	0.0000	-9.9235
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0398	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0220	1.1826	0.0260	1.00	0.03	0.0253	103.6194	0.0003	0.0159	-24.4000	-0.0039	0.0003	-0.0613
ZrO2	0.1180	1.3508	0.1594	1.00	0.16	0.1547	123.2188	0.0013	0.0818	45.1000	0.0369	0.0033	0.5820
TiO2	0.2170	1.6680	0.3620	0.98	0.35	0.3436	79.8988	0.0044	0.2801	15.9900	0.0448	0.0112	0.7069
K2O	2.4100	1.2046	2.9031	0.92	2.67	2.5961	94.2034	0.0283	1.7952	-41.7350	-0.7492	0.0359	-11.8250
Cs2O	0.0650	1.0602	0.0689	1.00	0.07	0.0670	281.8094	0.0002	0.0155	-46.8200	-0.0073	0.0003	-0.1145
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0120	2.2910	0.0275	1.00	0.03	0.0267	141.9370	0.0002	0.0123	-53.6200	-0.0066	0.0000	-0.1039
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0620	1.1165	0.0692	1.14	0.08	0.0766	153.3394	0.0005	0.0326	-30.5700	-0.0100	0.0007	-0.1571
PbO	0.0940	1.0772	0.1013	2.11	0.21	0.2078	223.1900	0.0010	0.0606	-8.8100	-0.0053	0.0012	-0.0843
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1630	1.2447	0.2029	2.00	0.41	0.3955	81.3800	0.0050	0.3166	-2.4000	-0.0076	0.0063	-0.1199
CuO	0.1560	1.2518	0.1953	1.18	0.23	0.2244	79.5454	0.0029	0.1838	1.7900	0.0033	0.0037	0.0519
Fe2+/Fe3+	0.0040												
SUMS	51.2890		94.6743		102.8107	100.0000		1.5783	100.0000		-4.6193	0.4069	-72.9076
										SUM + pH SI	-5.4066		
										SUM + pH B	-7.1494		
ALK/SiO2 =		0.362								pH =	10.43		
ALK+ B2O3/SiO2 =		0.472				TIME=							
B2O3/SiO2 =		0.111											
VISCOSITY @TEMP(°C)		85.319				SA/V=							
LIQUIDUS RATIO =		0.084											
LIQUIDUS (°C) =		967											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG1-1B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.4220	1.8895	4.5764	1.21	5.5321	5.4931	101.9600	0.0543	3.5547	3.0400	0.1081	-0.0711	1.6494
CaO	0.9160	1.3992	1.2817	1.11	1.4239	1.4139	56.0794	0.0254	1.6635	-16.1160	-0.2681	0.0333	-4.0920
Fe2O3	9.3400	1.4297	13.3002	1.04	13.7986	13.7013	159.6922	0.0864	5.6611	15.5000	0.8775	-0.1132	13.3931
FeO	N/A	1.2865	0.0479	1.00	0.0479	0.0475	71.8464	0.0007	0.0437	-14.6090	-0.0064	0.0009	-0.0973
MgO	0.8500	1.6583	1.4096	1.12	1.5850	1.5738	40.3114	0.0393	2.5760	-13.8880	-0.3578	0.0515	-5.4607
MnO	1.1310	1.2912	1.4603	1.31	1.9115	1.8980	70.9374	0.0269	1.7654	-14.8710	-0.2625	0.0353	-4.0072
Na2O	6.6510	1.3480	8.9655	1.03	9.2270	9.1619	61.9790	0.1489	9.7536	-28.8150	-2.8105	0.1951	-42.8978
Li2O	1.9120	2.1525	4.1156	1.06	4.3593	4.3276	29.8774	0.1459	9.5570	-22.7400	-2.1733	0.1911	-33.1716
NiO	0.5720	1.2726	0.7279	1.18	0.8610	0.8549	74.7094	0.0115	0.7550	-14.3470	-0.1083	0.0151	-1.6534
SiO2	21.3870	2.1393	45.7532	1.10	50.3051	49.9503	60.0848	0.8372	54.8522	5.5900	1.4837	0.0000	22.6470
Cr2O3	0.1360	1.4616	0.1988	1.59	0.3164	0.3142	151.9974	0.0021	0.1384	37.3600	0.0510	-0.0027	0.7777
B2O3	2.1650	3.2201	6.9715	1.02	7.0918	7.0418	69.6204	0.1019	6.6737	-9.9300	-0.6627	0.0000	-10.1151
UO2		1.1344	0.0000	1.00	0.0000	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.0000	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0030	1.1826	0.0035	1.00	0.0035	0.0035	103.6194	0.0000	0.0022	-24.4000	-0.0005	0.0000	-0.0084
ZrO2	0.1180	1.3508	0.1594	1.00	0.1590	0.1579	123.2188	0.0013	0.0845	45.1000	0.0381	0.0034	0.5820
TiO2	0.3540	1.6680	0.5905	0.98	0.5763	0.5722	79.8988	0.0072	0.4725	15.9900	0.0756	0.0188	1.1533
K2O	2.4080	1.2046	2.9007	0.92	2.6669	2.6481	94.2034	0.0283	1.8548	-41.7350	-0.7741	0.0371	-11.8152
Cs2O	0.0650	1.0602	0.0689	1.00	0.0689	0.0684	281.8094	0.0002	0.0160	-46.8200	-0.0075	0.0003	-0.1145
Sb2O3		1.1970	0.0000	1.00	0.0000	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5		2.2910	0.0000	1.00	0.0000	0.0000	141.9370	0.0000	0.0000	-53.6200	0.0000	0.0000	0.0000
Nd2O3		1.1660	0.0000	1.00	0.0000	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.0000	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.0000	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.1160	1.1165	0.1295	1.14	0.1474	0.1464	153.3394	0.0010	0.0630	-30.5700	-0.0193	0.0013	-0.2939
PbO		1.0772	0.0000	2.11	0.0000	0.0000	223.1900	0.0000	0.0000	-8.8100	0.0000	0.0000	0.0000
CeO2		1.2264	0.0000	1.00	0.0000	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.0000	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.0870	1.2447	0.1083	2.00	0.2170	0.2155	81.3800	0.0027	0.1747	-2.4000	-0.0042	0.0035	-0.0640
CuO	0.2790	1.2518	0.3493	1.18	0.4127	0.4098	79.5454	0.0052	0.3399	1.7900	0.0061	0.0068	0.0929
Fe2+/Fe3+	0.0040												
SUMS	50.9120		93.1186		100.7103	100.0000		1.5263	100.0000		-4.8151	0.4065	-73.4957
										SUM + pH SI	-5.6024		
ALK/SIO2 =		0.386				TEST=				SUM + pH B	-7.3452		
ALK+ B2O3/SIO2 =		0.508				TIME=				pH =	10.43		
B2O3/SIO2 =		0.122											
VISCOSITY @TEMP(°C)		61.798				SA/V=							
LIQUIDUS RATIO =		0.105											
LIQUIDUS (°C) =		1034											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG1-2A (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.2690	1.8895	4.2873	1.21	5.18	4.9863	101.9600	0.0508	3.1800	3.0400	0.0967	-0.0636	1.5452
CaO	0.6940	1.3992	0.9710	1.11	1.08	1.0379	56.0794	0.0192	1.2035	-16.1160	-0.1940	0.0241	-3.1003
Fe2O3	8.1340	1.4297	11.5713	1.04	12.00	11.5502	159.6922	0.0752	4.7032	15.5000	0.7290	-0.0941	11.6522
FeO	N/A	1.2865	0.0521	1.00	0.05	0.0501	71.8464	0.0007	0.0453	-14.6090	-0.0066	0.0009	-0.1059
MgO	0.8120	1.6583	1.3465	1.12	1.51	1.4568	40.3114	0.0376	2.3499	-13.8880	-0.3264	0.0470	-5.2165
MnO	1.3560	1.2912	1.7509	1.31	2.29	2.2050	70.9374	0.0323	2.0212	-14.8710	-0.3006	0.0404	-4.8044
Na2O	6.4160	1.3480	8.6488	1.03	8.90	8.5638	61.9790	0.1436	8.9848	-28.8150	-2.5890	0.1797	-41.3821
Li2O	2.0290	2.1525	4.3674	1.06	4.63	4.4498	29.8774	0.1548	9.6846	-22.7400	-2.2023	0.1937	-35.2014
NiO	0.5310	1.2726	0.6758	1.18	0.80	0.7690	74.7094	0.0107	0.6693	-14.3470	-0.0960	0.0134	-1.5349
SiO2	23.5070	2.1393	50.2885	1.10	55.29	53.1972	60.0848	0.9202	57.5715	5.5900	1.6677	0.0000	26.6569
Cr2O3	0.1550	1.4616	0.2265	1.59	0.36	0.3469	151.9974	0.0024	0.1484	37.3600	0.0555	-0.0030	0.8863
B2O3	2.1170	3.2201	6.8170	1.02	6.93	6.6719	69.6204	0.0996	6.2315	-9.9300	-0.6188	0.0000	-9.8908
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0220	1.1826	0.0260	1.00	0.03	0.0250	103.6194	0.0003	0.0157	-24.4000	-0.0038	0.0003	-0.0613
ZrO2	0.0840	1.3508	0.0865	1.00	0.09	0.0830	123.2188	0.0007	0.0438	45.1000	0.0197	0.0018	0.3156
TiO2	0.1730	1.6680	0.2886	0.98	0.28	0.2710	79.8988	0.0035	0.2205	15.9900	0.0353	0.0088	0.5636
K2O	3.1660	1.2046	3.8138	0.92	3.51	3.3736	94.2034	0.0372	2.3287	-41.7350	-0.9719	0.0466	-15.5344
Cs2O	0.0650	1.0602	0.0689	1.00	0.07	0.0663	281.8094	0.0002	0.0153	-46.8200	-0.0072	0.0003	-0.1145
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0290	2.2910	0.0664	1.00	0.07	0.0639	141.9370	0.0005	0.0293	-53.6200	-0.0157	0.0000	-0.2510
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0610	1.1165	0.0681	1.14	0.08	0.0746	153.3394	0.0005	0.0316	-30.5700	-0.0097	0.0006	-0.1546
RbO	0.0790	1.0772	0.0851	2.11	0.18	0.1727	223.1900	0.0008	0.0503	-8.8100	-0.0044	0.0010	-0.0709
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1530	1.2447	0.1904	2.00	0.38	0.3672	81.3800	0.0047	0.2934	-2.4000	-0.0070	0.0059	-0.1126
CuO	0.1530	1.2518	0.1915	1.18	0.23	0.2177	79.5454	0.0028	0.1780	1.7900	0.0032	0.0036	0.0509
Fe2+/Fe3+	0.0050												
SUMS	51.9850		95.8884		103.9371	100.0000		1.5984	100.0000		-4.7463	0.4074	-75.8646
										SUM + pH SI	-5.4929		
						TEST=				SUM + pH B	-7.1839		
						TIME=				pH =	10.39		

ALK/SIO2 =	0.365
ALK+ B2O3/SIO2 =	0.473
B2O3/SIO2 =	0.108
VISCOSITY @TEMP(°C)	83.488
LIQUIDUS RATIO =	0.081
LIQUIDUS (°C) =	958

SA/V=

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG1-2B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.2480	1.8895	4.2476	1.21	5.13	4.9933	101.9600	0.0504	3.1749	3.0400	0.0965	-0.0635	1.5309
CaO	0.7010	1.3992	0.9808	1.11	1.09	1.0597	56.0794	0.0194	1.2250	-16.1160	-0.1974	0.0245	-3.1315
Fe2O3	8.1240	1.4297	11.5571	1.04	11.99	11.6602	159.6922	0.0751	4.7335	15.5000	0.7337	-0.0947	11.6379
FeO	N/A	1.2865	0.0520	1.00	0.05	0.0506	71.8464	0.0007	0.0456	-14.6090	-0.0067	0.0009	-0.1057
MgO	0.8160	1.6583	1.3532	1.12	1.52	1.4797	40.3114	0.0377	2.3797	-13.8880	-0.3305	0.0476	-5.2422
MnO	1.3580	1.2912	1.7534	1.31	2.30	2.2320	70.9374	0.0324	2.0398	-14.8710	-0.3033	0.0408	-4.8115
Na2O	6.2400	1.3480	8.4115	1.03	8.66	8.4186	61.9790	0.1397	8.8056	-28.8150	-2.5373	0.1761	-40.2469
Li2O	2.0300	2.1525	4.3696	1.06	4.63	4.4999	29.8774	0.1549	9.7640	-22.7400	-2.2203	0.1953	-35.2188
NiO	0.5200	1.2726	0.6618	1.18	0.78	0.7812	74.7094	0.0105	0.6605	-14.3470	-0.0948	0.0132	-1.5031
SiO2	23.5330	2.1393	50.3441	1.10	55.35	53.8294	60.0848	0.9212	58.0789	5.5900	1.7285	0.0000	27.4171
Cr2O3	0.1420	1.4616	0.2075	1.59	0.33	0.3213	151.9974	0.0022	0.1370	37.3600	0.0512	-0.0027	0.8120
B2O3	2.1270	3.2201	6.8492	1.02	6.97	6.7756	69.6204	0.1001	6.3092	-9.9300	-0.6265	0.0000	-9.9375
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0210	1.1826	0.0248	1.00	0.02	0.0242	103.6194	0.0002	0.0151	-24.4000	-0.0037	0.0003	-0.0585
ZrO2	0.0640	1.3508	0.0865	1.00	0.09	0.0839	123.2188	0.0007	0.0441	45.1000	0.0199	0.0018	0.3156
TiO2	0.1710	1.6680	0.2852	0.98	0.28	0.2707	79.8988	0.0035	0.2196	15.9900	0.0351	0.0088	0.5571
K2O	2.3720	1.2046	2.8573	0.92	2.63	2.5547	94.2034	0.0279	1.7581	-41.7350	-0.7337	0.0352	-11.6385
Cs2O	0.0650	1.0602	0.0689	1.00	0.07	0.0670	281.8094	0.0002	0.0154	-46.8200	-0.0072	0.0003	-0.1145
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0140	2.2910	0.0321	1.00	0.03	0.0312	141.9370	0.0002	0.0142	-53.6200	-0.0076	0.0000	-0.1212
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0580	1.1165	0.0648	1.14	0.07	0.0717	153.3394	0.0005	0.0303	-30.5700	-0.0093	0.0006	-0.1470
PbO	0.0930	1.0772	0.1002	2.11	0.21	0.2055	223.1900	0.0009	0.0597	-8.8100	-0.0053	0.0012	-0.0834
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1630	1.2447	0.2029	2.00	0.41	0.3954	81.3800	0.0050	0.3150	-2.4000	-0.0076	0.0063	-0.1199
CuO	0.1490	1.2518	0.1865	1.18	0.22	0.2143	79.5454	0.0028	0.1747	1.7900	0.0031	0.0035	0.0496
Fe2+/Fe3+	0.0050												
SUMS	51.0090		94.6970		102.8301	100.0000		1.5862	100.0000		-4.4232	0.3954	-70.1601
										SUM + pH SI	-5.1698		
ALK/SiO2 =		0.350				TEST=				SUM + pH B	-6.8608		
ALK+ B2O3/SiO2 =		0.459				TIME=				pH =	10.39		
B2O3/SiO2 =		0.109											
VISCOSITY @TEMP(°C)		92.898				SA/V=							
LIQUIDUS RATIO =		0.080											
LIQUIDUS (°C) =		957											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG1-3A (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY hYDRATION	NBO	KCAL/KG
Al2O3	2.2160	1.8895	4.1871	1.21	5.06	4.9279	101.9600	0.0496	3.1249	3.0400	0.0950	-0.0625	1.5091
CaO	0.6950	1.3992	0.9724	1.11	1.08	1.0518	56.0794	0.0193	1.2127	-16.1160	-0.1954	0.0243	-3.1047
Fe2O3	8.0630	1.4297	11.3573	1.04	11.78	11.4717	159.6922	0.0738	4.6446	15.5000	0.7199	-0.0929	11.4367
FeO	N/A	1.2865	0.1533	1.00	0.15	0.1492	71.8464	0.0021	0.1343	-14.6090	-0.0196	0.0027	-0.3117
MgO	0.8150	1.6583	1.3515	1.12	1.52	1.4796	40.3114	0.0377	2.3731	-13.8880	-0.3296	0.0475	-5.2358
MnO	1.3370	1.2912	1.7263	1.31	2.26	2.2000	70.9374	0.0319	2.0052	-14.8710	-0.2982	0.0401	-4.7371
Na2O	6.3980	1.3480	8.6245	1.03	8.88	8.6416	61.9790	0.1432	9.0147	-28.8150	-2.5976	0.1803	-41.2660
Li2O	2.0430	2.1525	4.3976	1.06	4.66	4.5339	29.8774	0.1559	9.8115	-22.7400	-2.2311	0.1962	-35.4443
NiO	0.4940	1.2726	0.6287	1.18	0.74	0.7240	74.7094	0.0100	0.6265	-14.3470	-0.0899	0.0125	-1.4280
SiO2	23.5590	2.1393	50.3998	1.10	55.41	53.9506	60.0848	0.9223	58.0543	5.5900	1.7183	0.0000	27.2976
Cr2O3	0.1230	1.4616	0.1798	1.59	0.29	0.2786	151.9974	0.0019	0.1185	37.3600	0.0443	-0.0024	0.7033
B2O3	2.1390	3.2201	6.8878	1.02	7.01	6.8216	69.6204	0.1006	6.3351	-9.9300	-0.6291	0.0000	-9.9936
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0220	1.1826	0.0260	1.00	0.03	0.0253	103.6194	0.0003	0.0158	-24.4000	-0.0039	0.0003	-0.0613
ZrO2	0.0020	1.3508	0.0027	1.00	0.00	0.0026	123.2188	0.0000	0.0014	45.1000	0.0006	0.0001	0.0099
TiO2	0.1620	1.6680	0.2702	0.98	0.26	0.2587	79.8988	0.0033	0.2078	15.9900	0.0332	0.0083	0.5278
K2O	2.3390	1.2046	2.8176	0.92	2.59	2.5221	94.2034	0.0275	1.7310	-41.7350	-0.7224	0.0346	-11.4766
Cs2O	0.0650	1.0602	0.0689	1.00	0.07	0.0671	281.8094	0.0002	0.0154	-46.8200	-0.0072	0.0003	-0.1145
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0250	2.2910	0.0573	1.00	0.06	0.0558	141.9370	0.0004	0.0254	-53.6200	-0.0136	0.0000	-0.2164
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0590	1.1165	0.0659	1.14	0.07	0.0730	153.3394	0.0005	0.0308	-30.5700	-0.0094	0.0006	-0.1495
PbO	0.0860	1.0772	0.0926	2.11	0.20	0.1903	223.1900	0.0009	0.0551	-8.8100	-0.0049	0.0011	-0.0771
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1490	1.2447	0.1855	2.00	0.37	0.3619	81.3800	0.0046	0.2875	-2.4000	-0.0069	0.0058	-0.1096
CuO	0.1490	1.2518	0.1865	1.18	0.22	0.2146	79.5454	0.0028	0.1744	1.7900	0.0031	0.0035	0.0496
Fe2+/Fe3+	0.0150												
SUMS	50.9400		94.6393		102.7124	100.0000		1.5886	100.0000		-4.5443	0.4004	-72.1921
										SUM + pH SI	-5.2909		
										SUM + pH B	-6.9819		

ALK/SiO2 =	0.354	TEST=	pH = 10.39
ALK+ B2O3/SiO2 =	0.463	TIME=	
B2O3/SiO2 =	0.109		
VISCOSITY @TEMP(°C)	89.825	SA/V=	
LIQUIDUS RATIO =	0.079		
LIQUIDUS (°C) =	954		

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG1-3B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.1670	1.8895	4.0945	1.21	4.95	4.8536	101.9600	0.0485	3.0766	3.0400	0.0935	-0.0615	1.4758
CaO	0.7380	1.3992	1.0326	1.11	1.15	1.1249	56.0794	0.0205	1.2965	-16.1160	-0.2089	0.0259	-3.2968
Fe2O3	8.0190	1.4297	11.2953	1.04	11.72	11.4912	159.6922	0.0734	4.6507	15.5000	0.7209	-0.0930	11.3743
FeO	N/A	1.2865	0.1525	1.00	0.15	0.1495	71.8464	0.0021	0.1345	-14.6090	-0.0196	0.0027	-0.3100
MgO	0.8050	1.6583	1.3349	1.12	1.50	1.4720	40.3114	0.0372	2.3600	-13.8880	-0.3278	0.0472	-5.1716
MnO	1.3290	1.2912	1.7160	1.31	2.25	2.2028	70.9374	0.0317	2.0067	-14.8710	-0.2984	0.0401	-4.7087
Na2O	6.3710	1.3480	8.5881	1.03	8.84	8.6671	61.9790	0.1426	9.0377	-28.8150	-2.6042	0.1808	-41.0918
Li2O	2.0290	2.1525	4.3674	1.06	4.63	4.5353	29.8774	0.1548	9.8105	-22.7400	-2.2309	0.1962	-35.2014
NiO	0.5080	1.2726	0.6465	1.18	0.76	0.7498	74.7094	0.0102	0.6487	-14.3470	-0.0931	0.0130	-1.4684
SiO2	23.3800	2.1393	50.0168	1.10	54.99	53.9258	60.0848	0.9153	58.0048	5.5900	1.7080	0.0000	26.9502
Cr2O3	0.1220	1.4616	0.1783	1.59	0.28	0.2783	151.9974	0.0019	0.1183	37.3600	0.0442	-0.0024	0.6976
B2O3	2.1140	3.2201	6.8073	1.02	6.92	6.7904	69.6204	0.0995	6.3036	-9.9300	-0.6259	0.0000	-9.8768
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0240	1.1826	0.0284	1.00	0.03	0.0278	103.6194	0.0003	0.0174	-24.4000	-0.0042	0.0003	-0.0668
ZrO2	0.0020	1.3508	0.0027	1.00	0.00	0.0026	123.2188	0.0000	0.0014	45.1000	0.0006	0.0001	0.0099
TiO2	0.1580	1.6680	0.2635	0.98	0.26	0.2522	79.8988	0.0032	0.2040	15.9900	0.0326	0.0082	0.5147
K2O	2.3540	1.2046	2.8356	0.92	2.61	2.5565	94.2034	0.0277	1.7539	-41.7350	-0.7320	0.0351	-11.5502
Cs2O	0.0650	1.0602	0.0689	1.00	0.07	0.0678	281.8094	0.0002	0.0155	-46.8200	-0.0073	0.0003	-0.1145
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0190	2.2910	0.0435	1.00	0.04	0.0427	141.9370	0.0003	0.0194	-53.6200	-0.0104	0.0000	-0.1644
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0570	1.1165	0.0636	1.14	0.07	0.0710	153.3394	0.0005	0.0299	-30.5700	-0.0092	0.0006	-0.1444
PbO	0.0720	1.0772	0.0776	2.11	0.16	0.1605	223.1900	0.0007	0.0465	-8.8100	-0.0041	0.0009	-0.0646
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1500	1.2447	0.1867	2.00	0.37	0.3669	81.3800	0.0046	0.2914	-2.4000	-0.0070	0.0058	-0.1104
CuO	0.1460	1.2518	0.1828	1.18	0.22	0.2118	79.5454	0.0027	0.1721	1.7900	0.0031	0.0034	0.0486
Fe2+/Fe3+	0.0150												
SUMS	50.6290		93.9837		101.9789	100.0000		1.5779	100.0000		-4.5891	0.4037	-72.2699
										SUM + pH SI	-5.3268		
ALK/SiO2 =		0.355				TEST=				SUM + pH B	-7.0177		
ALK+ B2O3/SiO2 =		0.464				TIME=				pH =	10.39		
B2O3/SiO2 =		0.109											
VISCOSITY @TEMP(°C)		88.602				SA/V=							
LIQUIDUS RATIO =		0.079											
LIQUIDUS (°C) =		954											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG2-1A (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.2590	1.8895	4.2684	1.21	5.16	5.0169	101.9600	0.0506	3.1887	3.0400	0.0969	-0.0638	1.5384
CaO	0.8980	1.3992	0.9766	1.11	1.09	1.0550	56.0794	0.0193	1.2191	-16.1160	-0.1965	0.0244	-3.1181
Fe2O3	8.2610	1.4297	11.7287	1.04	12.17	11.8312	159.6922	0.0762	4.8012	15.5000	0.7442	-0.0960	11.8106
FeO	N/A	1.2865	0.0739	1.00	0.07	0.0718	71.8464	0.0010	0.0648	-14.6090	-0.0095	0.0013	-0.1502
MgO	0.8110	1.6583	1.3449	1.12	1.51	1.4704	40.3114	0.0375	2.3638	-13.8880	-0.3283	0.0473	-5.2101
MnO	1.3640	1.2912	1.7612	1.31	2.31	2.2415	70.9374	0.0325	2.0477	-14.8710	-0.3045	0.0410	-4.8327
Na2O	6.3580	1.3480	8.5706	1.03	8.82	8.5763	61.9790	0.1423	8.9672	-28.8150	-2.5839	0.1793	-41.0080
Li2O	2.0300	2.1525	4.3696	1.06	4.63	4.4992	29.8774	0.1549	9.7587	-22.7400	-2.2191	0.1952	-35.2188
NiO	0.5150	1.2726	0.6554	1.18	0.78	0.7537	74.7094	0.0104	0.6538	-14.3470	-0.0938	0.0131	-1.4887
SiO2	23.5830	2.1393	50.4511	1.10	55.47	53.9344	60.0848	0.9232	58.1709	5.5900	1.7364	0.0000	27.5573
Cr2O3	0.1480	1.4616	0.2163	1.59	0.34	0.3348	151.9974	0.0023	0.1427	37.3600	0.0533	-0.0029	0.8463
B2O3	2.0880	3.2201	6.7236	1.02	6.84	6.6502	69.6204	0.0962	6.1902	-9.9300	-0.6147	0.0000	-9.7553
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0220	1.1826	0.0260	1.00	0.03	0.0253	103.6194	0.0003	0.0158	-24.4000	-0.0039	0.0003	-0.0613
ZrO2	0.0020	1.3508	0.0027	1.00	0.00	0.0026	123.2188	0.0000	0.0014	45.1000	0.0006	0.0001	0.0099
TiO2	0.1580	1.6680	0.2635	0.98	0.26	0.2501	79.8988	0.0032	0.2028	15.9900	0.0324	0.0081	0.5147
K2O	2.2070	1.2046	2.6586	0.92	2.44	2.3766	94.2034	0.0259	1.6349	-41.7350	-0.6823	0.0327	-10.6269
Cs2O	0.0450	1.0602	0.0477	1.00	0.05	0.0464	281.8094	0.0002	0.0107	-46.8200	-0.0050	0.0002	-0.0793
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0200	2.2910	0.0458	1.00	0.05	0.0446	141.9370	0.0003	0.0203	-53.6200	-0.0109	0.0000	-0.1731
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0590	1.1165	0.0659	1.14	0.07	0.0729	153.3394	0.0005	0.0308	-30.5700	-0.0094	0.0006	-0.1495
RbO	0.0750	1.0772	0.0808	2.11	0.17	0.1657	223.1900	0.0008	0.0481	-8.8100	-0.0042	0.0010	-0.0673
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1510	1.2447	0.1879	2.00	0.38	0.3662	81.3800	0.0046	0.2916	-2.4000	-0.0070	0.0058	-0.1111
CuO	0.1490	1.2518	0.1865	1.18	0.22	0.2143	79.5454	0.0028	0.1746	1.7900	0.0031	0.0035	0.0496
Fe2+/Fe3+	0.0070												
SUMS	51.0030		94.7056		102.8479	100.0000		1.5871	100.0000		-4.4868	0.3912	-69.9255
										SUM + pH SI	-5.2036		
										SUM + pH B	-6.9594		

ALK/SiO2 =	0.350	TEST=	pH = 10.44
ALK+ B2O3/SiO2 =	0.457	TIME=	
B2O3/SiO2 =	0.106		
VISCOSITY @TEMP(°C)	92.986	SA/V=	
LIQUIDUS RATIO =	0.031		
LIQUIDUS (°C) =	961		

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG2-1B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.2490	1.8895	4.2495	1.21	5.14	5.0035	101.9600	0.0504	3.1810	3.0400	0.0967	-0.0636	1.5316
CaO	0.7010	1.3992	0.9808	1.11	1.09	1.0614	56.0794	0.0194	1.2268	-16.1160	-0.1977	0.0245	-3.1315
Fe2O3	8.2420	1.4297	11.7017	1.04	12.14	11.8247	159.6922	0.0760	4.7998	15.5000	0.7440	-0.0960	11.7835
FeO	N/A	1.2865	0.0737	1.00	0.07	0.0718	71.8464	0.0010	0.0648	-14.6090	-0.0095	0.0013	-0.1499
MgO	0.8110	1.6583	1.3449	1.12	1.51	1.4730	40.3114	0.0375	2.3686	-13.8880	-0.3290	0.0474	-5.2101
MnO	1.3620	1.2912	1.7586	1.31	2.30	2.2421	70.9374	0.0325	2.0488	-14.8710	-0.3047	0.0410	-4.8257
Na2O	6.4000	1.3480	8.6272	1.03	8.88	8.6481	61.9790	0.1433	9.0447	-28.8150	-2.6062	0.1809	-41.2789
Li2O	2.0250	2.1525	4.3588	1.06	4.62	4.4960	29.8774	0.1545	9.7544	-22.7400	-2.2181	0.1951	-35.1320
NiO	0.5260	1.2726	0.6694	1.16	0.79	0.7712	74.7094	0.0106	0.6691	-14.3470	-0.0960	0.0134	-1.5205
SiO2	23.4820	2.1393	50.2350	1.10	55.23	53.7977	60.0848	0.9192	58.0388	5.5900	1.7202	0.0000	27.2452
Cr2O3	0.1460	1.4616	0.2134	1.59	0.34	0.3308	151.9974	0.0022	0.1411	37.3600	0.0527	-0.0028	0.8349
B2O3	2.0850	3.2201	6.7139	1.02	6.83	6.6523	69.6204	0.0961	6.1937	-9.9300	-0.6150	0.0000	-9.7413
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0210	1.1826	0.0248	1.00	0.02	0.0242	103.6194	0.0002	0.0151	-24.4000	-0.0037	0.0003	-0.0585
ZrO2	0.0020	1.3508	0.0027	1.00	0.00	0.0026	123.2188	0.0000	0.0014	45.1000	0.0006	0.0001	0.0099
TiO2	0.1560	1.6680	0.2602	0.98	0.25	0.2473	79.8988	0.0032	0.2007	15.9900	0.0321	0.0080	0.5082
K2O	2.2330	1.2046	2.6899	0.92	2.47	2.4088	94.2034	0.0263	1.6575	-41.7350	-0.6918	0.0332	-10.9565
Cs2O	0.0450	1.0602	0.0477	1.00	0.05	0.0465	281.8094	0.0002	0.0107	-46.8200	-0.0050	0.0002	-0.0793
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0140	2.2910	0.0321	1.00	0.03	0.0312	141.9370	0.0002	0.0143	-53.6200	-0.0077	0.0000	-0.1212
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0580	1.1165	0.0648	1.14	0.07	0.0718	153.3394	0.0005	0.0304	-30.5700	-0.0093	0.0008	-0.1470
PbO	0.0880	1.0772	0.0948	2.11	0.20	0.1948	223.1900	0.0009	0.0566	-8.8100	-0.0050	0.0011	-0.0789
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1640	1.2447	0.2041	2.00	0.41	0.3985	81.3800	0.0050	0.3174	-2.4000	-0.0076	0.0063	-0.1206
CuO	0.1400	1.2518	0.1753	1.18	0.21	0.2017	79.5454	0.0026	0.1644	1.7900	0.0029	0.0033	0.0466
Fe2+/Fe3+	0.0070												
SUMS	50.9500		94.5233		102.6676	100.0000		1.5839	100.0000		-4.4570	0.3942	-70.5920
										SUM + pH SI	-5.2546		
ALK/SiO2 =		0.353				TEST=				SUM + pH B	-7.0103		
ALK+ B2O3/SiO2 =		0.459				TIME=				pH =	10.44		
B2O3/SiO2 =		0.107											
VISCOSITY @TEMP(°C)		91.060				SA/V=							
LIQUIDUS RATIO =		0.882											
LIQUIDUS (°C) =		961											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG2-2A (SPREADSHEET REVISION 5.6, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.4620	1.8895	4.6519	1.21	5.62	5.3862	101.9600	0.0552	3.4490	3.0400	0.1048	-0.0690	1.6767
CaO	0.7420	1.3992	1.0382	1.11	1.15	1.1048	56.0794	0.0206	1.2862	-16.1160	-0.2073	0.0257	-3.3147
Fe2O3	8.8710	1.4297	12.6072	1.04	13.08	12.5278	159.6922	0.0819	5.1219	15.5000	0.7939	-0.1024	12.6953
FeO	N/A	1.2865	0.0681	1.00	0.07	0.0652	71.8464	0.0009	0.0592	-14.6090	-0.0087	0.0012	-0.1384
MgO	0.7510	1.6583	1.2454	1.12	1.40	1.3413	40.3114	0.0347	2.1724	-13.8680	-0.3017	0.0434	-4.8246
MnO	1.4610	1.2912	1.8864	1.31	2.47	2.3651	70.9374	0.0348	2.1767	-14.8710	-0.3237	0.0435	-5.1764
Na2O	7.5770	1.3480	10.2138	1.03	10.51	10.0682	61.9790	0.1696	10.6058	-28.8150	-3.0561	0.2121	-48.8703
Li2O	1.9790	2.1525	4.2598	1.06	4.51	4.3207	29.8774	0.1510	9.4417	-22.7400	-2.1470	0.1888	-34.3340
NiO	0.5210	1.2726	0.6630	1.18	0.78	0.7511	74.7094	0.0105	0.6564	-14.3470	-0.0942	0.0131	-1.5060
SiO2	23.3810	2.1393	50.0190	1.10	55.00	52.6749	60.0848	0.9153	57.2369	5.5900	1.6235	0.0000	25.9626
Cr2O3	0.1330	1.4616	0.1944	1.59	0.31	0.2964	151.9974	0.0020	0.1273	37.3600	0.0476	-0.0025	0.7605
B2O3	1.8840	3.2201	6.0667	1.02	6.17	5.9110	69.6204	0.0886	5.5432	-9.9300	-0.5504	0.0000	-8.8022
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0240	1.1826	0.0284	1.00	0.03	0.0272	103.6194	0.0003	0.0171	-24.4000	-0.0042	0.0003	-0.0668
ZrO2	0.1550	1.3508	0.2094	1.00	0.21	0.2000	123.2188	0.0017	0.1060	45.1000	0.0478	0.0042	0.7644
TiO2	0.1420	1.6680	0.2369	0.98	0.23	0.2214	79.8988	0.0029	0.1809	15.9900	0.0289	0.0072	0.4626
K2O	1.6970	1.2046	2.0442	0.92	1.88	1.8002	94.2034	0.0200	1.2476	-41.7350	-0.5207	0.0250	-8.3265
Cs2O	0.0350	1.0602	0.0371	1.00	0.04	0.0355	281.8094	0.0001	0.0082	-46.8200	-0.0039	0.0002	-0.0616
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0230	2.2910	0.0527	1.00	0.05	0.0505	141.9370	0.0004	0.0232	-53.6200	-0.0124	0.0000	-0.1991
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0680	1.1165	0.0759	1.14	0.09	0.0826	153.3394	0.0006	0.0352	-30.5700	-0.0108	0.0007	-0.1723
PbO	0.1040	1.0772	0.1120	2.11	0.24	0.2264	223.1900	0.0011	0.0662	-8.8100	-0.0058	0.0013	-0.0933
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1640	1.2447	0.2041	2.00	0.41	0.3918	81.3800	0.0050	0.3144	-2.4000	-0.0075	0.0063	-0.1208
CuO	0.1070	1.2518	0.1339	1.18	0.16	0.1516	79.5454	0.0020	0.1244	1.7900	0.0022	0.0025	0.0356
Fe2+/Fe3+	0.0060												
SUMS	52.2810		96.0486		104.4050	100.0000		1.5991	100.0000		-4.6956	0.4017	-73.6492
										SUM + pH SI	-5.6949		
ALK/SiO2 =		0.372				TEST=				SUM + pH B	-7.7940		
ALK+ B2O3/SiO2 =		0.469				TIME=				pH =	10.7		
B2O3/SiO2 =		0.097											
VISCOSITY @TEMP(°C)		80.753				SA/V=							
LIQUIDUS RATIO =		0.098											
LIQUIDUS (°C) =		986											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG2-2B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.4350	1.8895	4.6009	1.21	5.56	5.3403	101.9600	0.0545	3.4203	3.0400	0.1040	-0.0684	1.6583
CaO	0.7080	1.3992	0.9906	1.11	1.10	1.0568	56.0794	0.0196	1.2306	-16.1160	-0.1983	0.0246	-3.1628
Fe2O3	8.8690	1.4297	12.6044	1.04	13.08	12.5561	159.6922	0.0819	5.1345	15.5000	0.7958	-0.1027	12.6925
FeO	N/A	1.2865	0.0681	1.00	0.07	0.0653	71.8464	0.0009	0.0594	-14.6090	-0.0087	0.0012	-0.1384
MgO	0.7540	1.6583	1.2504	1.12	1.41	1.3500	40.3114	0.0349	2.1870	-13.8880	-0.3037	0.0437	-4.8439
MnO	1.4800	1.2912	1.9110	1.31	2.50	2.4018	70.9374	0.0353	2.2110	-14.8710	-0.3288	0.0442	-5.2437
Na2O	7.6970	1.3480	10.3756	1.03	10.68	10.2530	61.9790	0.1723	10.8028	-28.8150	-3.1128	0.2161	-49.6443
Li2O	1.9740	2.1525	4.2490	1.06	4.50	4.3205	29.8774	0.1506	9.4432	-22.7400	-2.1474	0.1889	-34.2472
NiO	0.5280	1.2726	0.6719	1.18	0.79	0.7631	74.7094	0.0106	0.6670	-14.3470	-0.0957	0.0133	-1.5263
SiO2	23.2310	2.1393	49.6981	1.10	54.64	52.4669	60.0848	0.9094	57.0230	5.5900	1.6009	0.0000	25.5310
Cr2O3	0.1270	1.4616	0.1856	1.59	0.30	0.2837	151.9974	0.0019	0.1219	37.3600	0.0455	-0.0024	0.7262
B2O3	1.8930	3.2201	6.0956	1.02	6.20	5.9539	69.6204	0.0891	5.5847	-9.9300	-0.5546	0.0000	-8.8443
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0230	1.1826	0.0272	1.00	0.03	0.0261	103.6194	0.0003	0.0165	-24.4000	-0.0040	0.0003	-0.0640
ZrO2	0.1550	1.3508	0.2094	1.00	0.21	0.2005	123.2188	0.0017	0.1063	45.1000	0.0479	0.0043	0.7644
TiO2	0.1410	1.6680	0.2352	0.98	0.23	0.2204	79.8988	0.0029	0.1801	15.9900	0.0288	0.0072	0.4594
K2O	1.6500	1.2046	1.9876	0.92	1.83	1.7546	94.2034	0.0194	1.2163	-41.7350	-0.5076	0.0243	-8.0959
Cs2O	0.0350	1.0602	0.0371	1.00	0.04	0.0356	281.8094	0.0001	0.0083	-46.8200	-0.0039	0.0002	-0.0616
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0310	2.2910	0.0710	1.00	0.07	0.0682	141.9370	0.0005	0.0314	-53.6200	-0.0168	0.0000	-0.2683
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0870	1.1165	0.0748	1.14	0.09	0.0818	153.3394	0.0006	0.0348	-30.5700	-0.0106	0.0007	-0.1698
PbO	0.1120	1.0772	0.1206	2.11	0.25	0.2444	223.1900	0.0011	0.0715	-8.8100	-0.0063	0.0014	-0.1005
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1720	1.2447	0.2141	2.00	0.43	0.4120	81.3800	0.0053	0.3306	-2.4000	-0.0079	0.0066	-0.1265
CuO	0.1020	1.2518	0.1277	1.18	0.15	0.1449	79.5454	0.0019	0.1189	1.7900	0.0021	0.0024	0.0340
Fe2+/Fe3+	0.0060												
SUMS	52.1840		95.8059		104.1484	100.0000		1.5948	100.0000		-6.6821	0.4059	-74.6719
										SUM + pH SI	-5.8078		
ALK/SIO2 =		0.377				TEST=				SUM + pH B	-7.9471		
ALK+ B2O3/SIO2 =		0.474				TIME=				pH =	10.73		
B2O3/SIO2 =		0.098											
VISCOSITY @TEMP(°C)		77.343				SA/V=							
LIQUIDUS RATIO =		0.000											
LIQUIDUS (°C) =		988											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG2-3A (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.3760	1.6895	4.4895	1.21	5.43	5.2730	101.9600	0.0532	3.3642	3.0400	0.1023	-0.0873	1.6181
CaO	0.7160	1.3992	1.0018	1.11	1.11	1.0814	56.0794	0.0198	1.2544	-16.1160	-0.2022	0.0251	-3.1985
Fe2O3	8.6220	1.4297	12.2534	1.04	12.71	12.3518	159.6922	0.0796	5.0315	15.5000	0.7799	-0.1006	12.3390
FeO	N/A	1.2865	0.0662	1.00	0.07	0.0643	71.8464	0.0009	0.0582	-14.6090	-0.0085	0.0012	-0.1345
MgO	0.7470	1.6583	1.2388	1.12	1.39	1.3534	40.3114	0.0346	2.1840	-13.8680	-0.3033	0.0437	-4.7989
MnO	1.4390	1.2912	1.8580	1.31	2.43	2.3631	70.9374	0.0343	2.1670	-14.8710	-0.3223	0.0433	-5.0985
Na2O	7.5090	1.3480	10.1221	1.03	10.42	10.1217	61.9790	0.1681	10.6234	-28.8150	-3.0611	0.2125	-48.4318
Li2O	1.9700	2.1525	4.2404	1.06	4.49	4.3631	29.8774	0.1503	9.4996	-22.7400	-2.1602	0.1900	-34.1778
NiO	0.5050	1.2726	0.6427	1.18	0.76	0.7386	74.7094	0.0102	0.6431	-14.3470	-0.0923	0.0129	-1.4598
SiO2	23.2600	2.1393	49.7601	1.10	54.71	53.1583	60.0848	0.9106	57.5520	5.5900	1.6455	0.0000	26.0335
Cr2O3	0.1260	1.4616	0.1842	1.59	0.29	0.2848	151.9974	0.0019	0.1219	37.3600	0.0455	-0.0024	0.7205
B2O3	1.8590	3.2201	5.9862	1.02	6.09	5.9167	69.6204	0.0875	5.5283	-9.9300	-0.5490	0.0000	-8.6854
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0230	1.1826	0.0272	1.00	0.03	0.0264	103.6194	0.0003	0.0166	-24.4000	-0.0040	0.0003	-0.0640
ZrO2	0.0510	1.3508	0.0689	1.00	0.07	0.0668	123.2188	0.0006	0.0353	45.1000	0.0159	0.0014	0.2515
TiO2	0.1370	1.6680	0.2285	0.98	0.22	0.2167	79.8988	0.0028	0.1764	15.9900	0.0282	0.0071	0.4463
K2O	1.6450	1.2046	1.9816	0.92	1.82	1.7702	94.2034	0.0193	1.2224	-41.7350	-0.5102	0.0244	-8.0714
Cs2O	0.0650	1.0602	0.0689	1.00	0.07	0.0670	281.8094	0.0002	0.0155	-46.8200	-0.0072	0.0003	-0.1145
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5		2.2910	0.0000	1.00	0.00	0.0000	141.9370	0.0000	0.0000	-53.6200	0.0000	0.0000	0.0000
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0650	1.1165	0.0726	1.14	0.08	0.0803	153.3394	0.0005	0.0341	-30.5700	-0.0104	0.0007	-0.1647
PbO	0.0820	1.0772	0.0883	2.11	0.19	0.1811	223.1900	0.0008	0.0528	-8.8100	-0.0046	0.0011	-0.0736
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1600	1.2447	0.1992	2.00	0.40	0.3878	81.3800	0.0049	0.3100	-2.4000	-0.0074	0.0062	-0.1177
CuO	0.0930	1.2518	0.1164	1.18	0.14	0.1337	79.5454	0.0017	0.1093	1.7900	0.0020	0.0022	0.0310
Fe2+/Fe3+	0.0060												
SUMS	51.4500		94.6948		102.9203	100.0000		1.5821	100.0000		-4.6235	0.4019	-73.1512
										SUM + pH SI	-5.7250		
ALK/SiO2 =		0.371				TEST=				SUM + pH B	-7.8374		
ALK+ B2O3/SiO2 =		0.467				TIME=				pH =	10.71		
B2O3/SiO2 =		0.096											
VISCOSITY @TEMP(°C)		81.796				SA/V=							
LIQUIDUS RATIO =		0.087											
LIQUIDUS (°C) =		978											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG2-3B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.3690	1.8895	4.4762	1.21	5.41	5.1391	101.9600	0.0531	3.3167	3.0400	0.1008	-0.0663	1.6133
CaO	0.7060	1.3992	0.9878	1.11	1.10	1.0423	56.0794	0.0196	1.2231	-16.1160	-0.1971	0.0245	-3.1539
Fe2O3	8.6450	1.4297	12.2860	1.04	12.75	12.1060	159.6922	0.0798	4.9884	15.5000	0.7732	-0.0998	12.3719
FeO	N/A	1.2865	0.0663	1.00	0.07	0.0630	71.8464	0.0009	0.0577	-14.6090	-0.0084	0.0012	-0.1349
MgO	0.7450	1.6583	1.2354	1.12	1.39	1.3194	40.3114	0.0345	2.1538	-13.8880	-0.2991	0.0431	-4.7861
MnO	1.4340	1.2912	1.8516	1.31	2.42	2.3018	70.9374	0.0342	2.1352	-14.8710	-0.3175	0.0427	-5.0808
Na2O	7.6570	1.3480	10.3216	1.03	10.62	10.0889	61.9790	0.1714	10.7114	-28.8150	-3.0865	0.2142	-49.3863
Li2O	1.9720	2.1525	4.2447	1.06	4.50	4.2692	29.8774	0.1505	9.4027	-22.7400	-2.1382	0.1881	-34.2125
NiO	0.5230	1.2726	0.6656	1.18	0.79	0.7477	74.7094	0.0105	0.6586	-14.3470	-0.0945	0.0132	-1.5118
SiO2	23.2420	2.1393	49.7216	1.10	54.67	51.9214	60.0848	0.9099	56.8629	5.5900	1.6135	0.0000	25.8177
Cr2O3	0.1390	1.4616	0.2032	1.59	0.32	0.3071	151.9974	0.0021	0.1330	37.3600	0.0497	-0.0027	0.7948
B2O3	1.8650	3.2201	6.0055	1.02	6.11	5.8021	69.6204	0.0877	5.4840	-9.9300	-0.5446	0.0000	-8.7134
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0220	1.1826	0.0260	1.00	0.03	0.0247	103.6194	0.0003	0.0157	-24.4000	-0.0038	0.0003	-0.0613
ZrO2	0.0510	1.3508	0.0689	1.00	0.07	0.0653	123.2188	0.0006	0.0349	45.1000	0.0157	0.0014	0.2515
TiO2	0.1360	1.6680	0.2268	0.98	0.22	0.2103	79.8988	0.0026	0.1732	15.9900	0.0277	0.0069	0.4431
K2O	1.6440	1.2046	1.9804	0.92	1.82	1.7293	94.2034	0.0193	1.2079	-41.7350	-0.5041	0.0242	-8.0665
Cs2O	0.0650	1.0602	0.0689	1.00	0.07	0.0655	281.8094	0.0002	0.0153	-46.8200	-0.0072	0.0003	-0.1145
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5		2.2910	0.0000	1.00	0.00	0.0000	141.9370	0.0000	0.0000	-53.6200	0.0000	0.0000	0.0000
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0640	1.1165	0.0715	1.14	0.08	0.0773	153.3394	0.0005	0.0332	-30.5700	-0.0101	0.0007	-0.1622
PbO	0.0820	1.0772	0.0883	2.11	0.19	0.1770	223.1900	0.0008	0.0522	-8.8100	-0.0046	0.0010	-0.0736
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3	1.4340	1.5003	2.1514	1.00	2.15	2.0433	143.9382	0.0149	0.9341	-21.7500	-0.2032	0.0000	-3.2510
ZnO	0.1550	1.2447	0.1929	2.00	0.39	0.3672	81.3800	0.0048	0.2969	-2.4000	-0.0071	0.0059	-0.1140
CuO	0.0940	1.2518	0.1177	1.18	0.14	0.1321	79.5454	0.0017	0.1092	1.7900	0.0020	0.0022	0.0313
Fe2+/Fe3+	0.0060												
SUMS	53.0440		97.0585		105.2904	100.0000		1.6001	100.0000		-4.8434	0.4010	-77.4990
										SUM + pH SI	-5.9449		
										SUM + pH B	-8.0573		

ALK/SIO2 =	0.375	TEST=	pH = 10.71
ALK+ B2O3/SIO2 =	0.472	TIME=	
B2O3/SIO2 =	0.096		
VISCOSITY @TEMP(°C)	78.940	SA/V=	
LIQUIDUS RATIO =	0.087		
LIQUIDUS (°C) =	979		

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG3-1A (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.4560	1.8895	4.6406	1.21	5.61	5.4887	101.9600	0.0550	3.5181	3.0400	0.1070	-0.0704	1.6726
CaO	0.7340	1.3992	1.0270	1.11	1.14	1.1164	56.0794	0.0203	1.3010	-16.1160	-0.2097	0.0260	-3.2790
Fe2O3	8.6660	1.4297	12.0952	1.04	12.55	12.2776	159.6922	0.0786	5.0246	15.5000	0.7788	-0.1005	12.1797
FeO	N/A	1.2865	0.5224	1.00	0.52	0.5111	71.8464	0.0073	0.4650	-14.6090	-0.0679	0.0093	-1.0623
MgO	0.7350	1.6583	1.2189	1.12	1.37	1.3410	40.3114	0.0340	2.1741	-13.8880	-0.3019	0.0435	-4.7219
MnO	1.4720	1.2912	1.9006	1.31	2.49	2.4342	70.9374	0.0351	2.2426	-14.8710	-0.3335	0.0449	-5.2154
Na2O	7.2720	1.3480	9.8027	1.03	10.09	9.8708	61.9790	0.1628	10.4083	-28.8150	-2.9992	0.2082	-46.9031
Li2O	1.9160	2.1525	4.1242	1.06	4.37	4.2732	29.8774	0.1462	9.3472	-22.7400	-2.1255	0.1869	-33.2410
NiO	0.5310	1.2726	0.6758	1.18	0.80	0.7820	74.7094	0.0107	0.6841	-14.3470	-0.0981	0.0137	-1.5349
SiO2	22.7000	2.1393	48.5621	1.10	53.39	52.2413	60.0848	0.8686	56.8226	5.5900	1.5815	0.0000	24.7327
Cr2O3	0.1400	1.4616	0.2046	1.58	0.33	0.3187	151.9974	0.0021	0.1370	37.3600	0.0512	-0.0027	0.8006
B2O3	1.8700	3.2201	6.0216	1.02	6.13	5.9933	69.6204	0.0880	5.6260	-9.9300	-0.5587	0.0000	-8.7368
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0230	1.1826	0.0272	1.00	0.03	0.0266	103.6194	0.0003	0.0168	-24.4000	-0.0041	0.0003	-0.0640
ZrO2	0.1300	1.3508	0.1756	1.00	0.18	0.1714	123.2188	0.0014	0.0909	45.1000	0.0410	0.0036	0.6411
TiO2	0.1410	1.6680	0.2352	0.98	0.23	0.2246	79.8988	0.0029	0.1837	15.9900	0.0294	0.0073	0.4594
K2O	1.8160	1.2046	2.1876	0.92	2.01	1.9678	94.2034	0.0214	1.3652	-41.7350	-0.5698	0.0273	-8.9104
Cs2O	0.0300	1.0602	0.0318	1.00	0.03	0.0311	281.8094	0.0001	0.0072	-46.8200	-0.0034	0.0001	-0.0528
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0230	2.2910	0.0527	1.00	0.05	0.0516	141.9370	0.0004	0.0237	-53.6200	-0.0127	0.0000	-0.1991
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0660	1.1165	0.0737	1.14	0.08	0.0821	153.3394	0.0005	0.0350	-30.5700	-0.0107	0.0007	-0.1672
PbO	0.1020	1.0772	0.1099	2.11	0.23	0.2268	223.1900	0.0010	0.0664	-8.8100	-0.0059	0.0013	-0.0915
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1670	1.2447	0.2079	2.00	0.42	0.4076	81.3800	0.0051	0.3273	-2.4000	-0.0079	0.0065	-0.1229
CuO	0.1120	1.2518	0.1402	1.18	0.17	0.1621	79.5454	0.0021	0.1332	1.7900	0.0024	0.0027	0.0373
Fe2+/Fe3+	0.0480												
SUMS	51.3020		94.0373		102.2054	100.0000		1.5639	100.0000		-4.7177	0.4089	-73.7790
										SUM + pH SI	-5.8434		
ALK/SIO2 =		0.372				TEST=				SUM + pH B	-7.9827		
ALK+ B2O3/SIO2 =		0.471				TIME=				pH =	10.73		
B2O3/SIO2 =		0.099											
VISCOSITY @TEMP(°C)		79.802				SA/V=							
LIQUIDUS RATIO =		0.089											
LIQUIDUS (°C) =		997											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG3-1B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.4690	1.8895	4.6652	1.21	5.64	5.5129	101.9600	0.0553	3.5345	3.0400	0.1074	-0.0707	1.6814
CaO	0.7290	1.3992	1.0200	1.11	1.13	1.1078	56.0794	0.0202	1.2913	-16.1160	-0.2081	0.0258	-3.2566
Fe2O3	8.8510	1.4297	12.0747	1.04	12.53	12.2460	159.6922	0.0784	5.0129	15.5000	0.7770	-0.1003	12.1591
FeO	N/A	1.2865	0.5215	1.00	0.52	0.5098	71.8464	0.0073	0.4639	-14.6090	-0.0678	0.0093	-1.0605
MgO	0.7350	1.6583	1.2189	1.12	1.37	1.3398	40.3114	0.0340	2.1727	-13.8880	-0.3017	0.0435	-4.7219
MnO	1.4610	1.2912	1.8864	1.31	2.47	2.4138	70.9374	0.0348	2.2244	-14.8710	-0.3308	0.0445	-5.1764
Na2O	7.2930	1.3480	9.8310	1.03	10.12	9.8906	61.9790	0.1632	10.4318	-28.8150	-3.0059	0.2086	-47.0386
Li2O	1.9110	2.1525	4.1134	1.06	4.36	4.2583	29.8774	0.1458	9.3169	-22.7400	-2.1187	0.1863	-33.1542
NiO	0.5350	1.2726	0.6808	1.18	0.81	0.7872	74.7094	0.0108	0.6888	-14.3470	-0.0988	0.0138	-1.5465
SiO2	22.6930	2.1393	48.5471	1.10	53.38	52.1790	60.0848	0.8884	56.7691	5.5900	1.5777	0.0000	24.6889
Cr2O3	0.1430	1.4616	0.2090	1.59	0.33	0.3252	151.9974	0.0022	0.1399	37.3600	0.0523	-0.0028	0.8177
B2O3	1.8820	3.2201	6.0602	1.02	6.16	6.0264	69.6204	0.0865	5.5585	-9.9300	-0.5619	0.0000	-8.7929
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0230	1.1826	0.0272	1.00	0.03	0.0266	103.6194	0.0003	0.0168	-24.4000	-0.0041	0.0003	-0.0640
ZrO2	0.1300	1.3508	0.1756	1.00	0.18	0.1712	123.2188	0.0014	0.0908	45.1000	0.0410	0.0036	0.8411
TiO2	0.1440	1.6680	0.2402	0.98	0.23	0.2292	79.8988	0.0029	0.1875	15.9900	0.0300	0.0075	0.4691
K2O	1.8350	1.2046	2.2104	0.92	2.03	1.9867	94.2034	0.0216	1.3786	-41.7350	-0.5754	0.0276	-9.0037
Cs2O	0.0300	1.0602	0.0318	1.00	0.03	0.0311	281.8094	0.0001	0.0072	-46.8200	-0.0034	0.0001	-0.0528
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0150	2.2910	0.0344	1.00	0.03	0.0336	141.9370	0.0002	0.0155	-53.6200	-0.0083	0.0000	-0.1298
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0670	1.1165	0.0748	1.14	0.09	0.0832	153.3394	0.0006	0.0355	-30.5700	-0.0108	0.0007	-0.1698
PbO	0.1020	1.0772	0.1099	2.11	0.23	0.2266	223.1900	0.0010	0.0664	-8.8100	-0.0058	0.0013	-0.0915
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1840	1.2447	0.2290	2.00	0.46	0.4487	81.3800	0.0056	0.3604	-2.4000	-0.0087	0.0072	-0.1354
CuO	0.1150	1.2518	0.1440	1.18	0.17	0.1663	79.5454	0.0021	0.1367	1.7900	0.0024	0.0027	0.0383
Fe2+/Fe3+	0.0480												
SUMS	51.3470		94.1056		102.2959	100.0000		1.5649	100.0000		-4.7224	0.4092	-73.8988
										SUM + pH SI	-5.8481		
ALK/SIO2 =		0.372				TEST=				SUM + pH B	-7.9874		
ALK+ B2O3/SIO2 =		0.472				TIME=				pH =	10.73		
B2O3/SIO2 =		0.100											
VISCOSITY @TEMP(°C)		79.607				SA/V=							
LIQUIDUS RATIO =		0.089											
LIQUIDUS (°C) =		997											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG3-2A (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.5110	1.8895	4.7445	1.21	5.74	5.5807	101.9600	0.0563	3.5914	3.0400	0.1092	-0.0718	1.7100
CaO	0.7570	1.3992	1.0592	1.11	1.18	1.1450	56.0794	0.0210	1.3397	-16.1160	-0.2159	0.0268	-3.3817
Fe2O3	9.2210	1.4297	12.3323	1.04	12.79	12.4494	159.6922	0.0801	5.1153	15.5000	0.7929	-0.1023	12.4185
FeO	N/A	1.2865	0.7657	1.00	0.77	0.7450	71.8464	0.0107	0.6804	-14.6090	-0.0994	0.0136	-1.5570
MgO	0.7280	1.6583	1.2072	1.12	1.36	1.3209	40.3114	0.0337	2.1501	-13.8880	-0.2986	0.0430	-4.6769
MnO	1.5260	1.2912	1.9704	1.31	2.58	2.5095	70.9374	0.0364	2.3213	-14.8710	-0.3452	0.0464	-5.4067
Na2O	7.1490	1.3480	9.6369	1.03	9.92	9.6504	61.9790	0.1600	10.2166	-28.8150	-2.9439	0.2043	-46.1098
Li2O	1.8800	2.1525	4.0467	1.06	4.29	4.1698	29.8774	0.1434	9.1575	-22.7400	-2.0824	0.1832	-32.6164
NiO	0.5240	1.2726	0.6668	1.18	0.79	0.7675	74.7094	0.0106	0.6741	-14.3470	-0.0967	0.0135	-1.5147
SiO2	22.5960	2.1393	48.3396	1.10	53.15	51.7154	60.0848	0.8846	56.4757	5.5900	1.5579	0.0000	24.4004
Cr2O3	0.1270	1.4616	0.1856	1.59	0.30	0.2875	151.9974	0.0019	0.1241	37.3600	0.0464	-0.0025	0.7262
B2O3	1.9070	3.2201	6.1407	1.02	6.25	6.0782	69.6204	0.0897	5.7285	-9.9300	-0.5688	0.0000	-8.9097
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-8.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0250	1.1826	0.0296	1.00	0.03	0.0288	103.6194	0.0003	0.0182	-24.4000	-0.0044	0.0004	-0.0696
ZrO2	0.1290	1.3508	0.1743	1.00	0.17	0.1691	123.2188	0.0014	0.0901	45.1000	0.0406	0.0036	0.6362
TiO2	0.1500	1.6680	0.2502	0.98	0.24	0.2376	79.8988	0.0031	0.1951	15.9900	0.0312	0.0078	0.4887
K2O	2.0500	1.2046	2.4694	0.92	2.27	2.2092	94.2034	0.0241	1.5388	-41.7350	-0.6422	0.0308	-10.0586
Cs2O	0.0400	1.0602	0.0424	1.00	0.04	0.0413	281.8094	0.0002	0.0096	-46.8200	-0.0045	0.0002	-0.0705
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0100	2.2910	0.0229	1.00	0.02	0.0223	141.9370	0.0002	0.0103	-53.6200	-0.0055	0.0000	-0.0865
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3	0.0030	1.1728	0.0035	1.00	0.00	0.0034	325.8100	0.0000	0.0007	-31.1400	-0.0002	0.0000	-0.0034
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0700	1.1165	0.0782	1.14	0.09	0.0866	153.3394	0.0006	0.0370	-30.5700	-0.0113	0.0007	-0.1774
PbO	0.0960	1.0772	0.1034	2.11	0.22	0.2123	223.1900	0.0010	0.0624	-8.8100	-0.0055	0.0012	-0.0861
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1590	1.2447	0.1979	2.00	0.40	0.3859	81.3800	0.0049	0.3112	-2.4000	-0.0075	0.0062	-0.1170
CuO	0.1280	1.2518	0.1602	1.18	0.19	0.1842	79.5454	0.0024	0.1520	1.7900	0.0027	0.0030	0.0426
Fe2+/Fe3+	0.0690												
SUMS	51.7860		94.6277		102.7718	100.0000		1.5663	100.0000		-4.7514	0.4082	-74.4192
										SUM + pH SI	-5.8528		
										SUM + pH B	-7.9653		

ALK/SiO2 =	0.370	TEST=	pH = 10.71
ALK+ B2O3/SiO2 =	0.472	TIME=	
B2O3/SiO2 =	0.101		
VISCOSITY @TEMP(°C)	78.450	SA/V=	
LIQUIDUS RATIO =	0.091		
LIQUIDUS (°C) =	1012		

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG3-2B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.5080	1.8895	4.7389	1.21	5.73	5.5665	101.9600	0.0562	3.5824	3.0400	0.1089	-0.0716	1.7080
CaO	0.7620	1.3992	1.0662	1.11	1.18	1.1510	56.0784	0.0211	1.3468	-16.1160	-0.2171	0.0269	-3.4040
Fe2O3	9.3050	1.4297	12.4447	1.04	12.91	12.5459	159.6922	0.0808	5.1552	15.5000	0.7991	-0.1031	12.5316
FeO	N/A	1.2865	0.7727	1.00	0.77	0.7508	71.8464	0.0108	0.6857	-14.6090	-0.1002	0.0137	-1.5711
MgO	0.7360	1.6583	1.2205	1.12	1.37	1.3336	40.3114	0.0340	2.1709	-13.8880	-0.3015	0.0434	-4.7283
MnO	1.5400	1.2912	1.9884	1.31	2.60	2.5292	70.9374	0.0367	2.3395	-14.8710	-0.3479	0.0468	-5.4563
Na2O	7.0610	1.3480	9.5182	1.03	9.80	9.5188	61.9790	0.1581	10.0777	-26.8150	-2.9039	0.2016	-45.5422
Li2O	1.8950	2.1525	4.0790	1.06	4.32	4.1974	29.8774	0.1446	9.2186	-22.7400	-2.0963	0.1844	-32.8766
NiO	0.5230	1.2726	0.6656	1.18	0.79	0.7650	74.7094	0.0105	0.6719	-14.3470	-0.0964	0.0134	-1.5118
SiO2	22.6250	2.1393	48.4017	1.10	53.22	51.7121	60.0848	0.8857	56.4745	5.5900	1.5615	0.0000	24.4896
Cr2O3	0.1210	1.4616	0.1769	1.59	0.28	0.2735	151.9974	0.0019	0.1161	37.3600	0.0441	-0.0024	0.6919
B2O3	1.9250	3.2201	6.1987	1.02	6.31	6.1273	69.6204	0.0906	5.7751	-9.9300	-0.5735	0.0000	-8.9938
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0250	1.1826	0.0296	1.00	0.03	0.0287	103.6194	0.0003	0.0182	-24.4000	-0.0044	0.0004	-0.0696
ZrO2	0.1290	1.3508	0.1743	1.00	0.17	0.1689	123.2188	0.0014	0.0899	45.1000	0.0406	0.0036	0.6362
TiO2	0.1500	1.6680	0.2502	0.98	0.24	0.2373	79.8988	0.0031	0.1949	15.9900	0.0312	0.0078	0.4887
K2O	1.9940	1.2046	2.4020	0.92	2.21	2.1459	94.2034	0.0234	1.4948	-41.7350	-0.6238	0.0299	-9.7638
Cs2O	0.0400	1.0602	0.0424	1.00	0.04	0.0412	281.8094	0.0002	0.0096	-46.8200	-0.0045	0.0002	-0.0705
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0110	2.2910	0.0252	1.00	0.03	0.0245	141.9370	0.0002	0.0113	-53.6200	-0.0061	0.0000	-0.0952
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0690	1.1165	0.0770	1.14	0.09	0.0852	153.3394	0.0006	0.0365	-30.5700	-0.0111	0.0007	-0.1748
RbO	0.1040	1.0772	0.1120	2.11	0.24	0.2297	223.1900	0.0011	0.0675	-8.8100	-0.0059	0.0014	-0.0933
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1600	1.2447	0.1992	2.00	0.40	0.3878	81.3800	0.0049	0.3127	-2.4000	-0.0075	0.0063	-0.1177
O,O	0.1250	1.2518	0.1565	1.18	0.18	0.1797	79.5454	0.0023	0.1462	1.7900	0.0027	0.0030	0.0416
Fe2+/Fe3+	0.0690												
SUMS	51.8080		94.7397		102.9103	100.0000		1.5683	100.0000		-4.7122	0.4062	-73.9015
										SUM + pH SI	-5.8136		
ALK/SiO2 =		0.368				TEST=				SUM + pH B	-7.9261		
ALK+ B2O3/SiO2 =		0.471				TIME=				pH =	10.71		
B2O3/SiO2 =		0.102											
VISCOSITY @TEMP(°C)		78.840				SA/V=							
LIQUIDUS RATIO =		0.092											
LIQUIDUS (°C) =		1014											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG3-3A (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.5300	1.8895	4.7804	1.21	5.78	5.5930	101.9600	0.0567	3.5927	3.0400	0.1092	-0.0719	1.7230
CaO	0.7950	1.3992	1.1124	1.11	1.24	1.1961	56.0794	0.0220	1.3969	-16.1160	-0.2251	0.0279	-3.5515
Fe2O3	9.3100	1.4297	12.1336	1.04	12.59	12.1837	159.6922	0.0788	4.9969	15.5000	0.7745	-0.0999	12.2184
FeO	N/A	1.2865	1.0591	1.00	1.06	1.0250	71.8464	0.0147	0.9344	-14.6090	-0.1365	0.0187	-2.1535
MgO	0.7420	1.6583	1.2305	1.12	1.38	1.3392	40.3114	0.0343	2.1758	-13.8880	-0.3022	0.0435	-4.7668
MnO	1.5560	1.2912	2.0091	1.31	2.63	2.5453	70.9374	0.0371	2.3500	-14.8710	-0.3495	0.0470	-5.5130
Na2O	6.9670	1.3480	9.3915	1.03	9.67	9.3548	61.9790	0.1559	9.8854	-26.8150	-2.8485	0.1977	-44.9359
Li2O	1.9070	2.1525	4.1048	1.06	4.35	4.2072	29.8774	0.1455	9.2227	-22.7400	-2.0972	0.1845	-33.0848
NiO	0.5250	1.2726	0.6681	1.16	0.79	0.7649	74.7094	0.0106	0.6705	-14.3470	-0.0962	0.0134	-1.5176
SiO2	22.6950	2.1393	48.5514	1.10	53.38	51.6661	60.0848	0.8884	56.3160	5.5900	1.5407	0.0000	24.3048
Cr2O3	0.1050	1.4616	0.1535	1.59	0.24	0.2364	151.9974	0.0016	0.1019	37.3600	0.0381	-0.0020	0.6004
B2O3	1.9660	3.2201	6.3307	1.02	6.44	6.2330	69.6204	0.0925	5.8636	-9.9300	-0.5823	0.0000	-9.1853
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0250	1.1826	0.0296	1.00	0.03	0.0286	103.6194	0.0003	0.0181	-24.4000	-0.0044	0.0004	-0.0696
ZrO2	0.1170	1.3508	0.1580	1.00	0.16	0.1526	123.2188	0.0013	0.0811	45.1000	0.0366	0.0032	0.5770
TiO2	0.1550	1.6680	0.2585	0.98	0.25	0.2442	79.8988	0.0032	0.2002	15.9900	0.0320	0.0080	0.5050
K2O	2.1270	1.2046	2.5622	0.92	2.36	2.2800	94.2034	0.0250	1.5851	-41.7350	-0.6616	0.0317	-10.4364
Cs2O	0.0100	1.0602	0.0106	1.00	0.01	0.0103	281.8094	0.0000	0.0024	-46.8200	-0.0011	0.0000	-0.0176
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5	0.0150	2.2910	0.0344	1.00	0.03	0.0333	141.9370	0.0002	0.0153	-53.6200	-0.0082	0.0000	-0.1298
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0680	1.1165	0.0759	1.14	0.09	0.0836	153.3394	0.0006	0.0357	-30.5700	-0.0109	0.0007	-0.1723
PbO	0.1000	1.0772	0.1077	2.11	0.23	0.2200	223.1900	0.0010	0.0645	-8.8100	-0.0057	0.0013	-0.0897
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1720	1.2447	0.2141	2.00	0.43	0.4153	81.3800	0.0053	0.3342	-2.4000	-0.0080	0.0067	-0.1265
CuO	0.1310	1.2518	0.1640	1.18	0.19	0.1875	79.5454	0.0024	0.1544	1.7900	0.0028	0.0031	0.0436
Fe2+/Fe3+	0.0970												
SUMS	52.0180		95.1400		103.3205	100.0000		1.5775	100.0000		-4.8836	0.4140	-75.7785
										SUM + pH SI	-5.8726		
ALK/SIO2 =		0.367						1.4988		SUM + pH B	-7.9490		
ALK+ B2O3/SIO2 =		0.472				TIME=				pH =	10.683		
B2O3/SIO2 =		0.104											
VISCOSITY @TEMP(°C)		79.301				SA/V=							
LIQUIDUS RATIO =		0.000											
LIQUIDUS (°C) =		1014											

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

GLASS ID= HG3-3B (SPREADSHEET REVISION 5.0, OCTOBER 23, 1990)

	ELEMENT WT%	GRAV FACTOR	OXIDE WT%	FACTORS FOR BIAS CORRECT	BIAS CORRECT OXIDE WT%	NORM OXIDE WT%	M.W.	MOLE FRACTION	NORM OXIDE MOLE %	COMPONENT FREE ENERGY	FREE ENERGY HYDRATION	NBO	KCAL/KG
Al2O3	2.5360	1.8895	4.7918	1.21	5.79	5.6259	101.9600	0.0568	3.6070	3.0400	0.1097	-0.0721	1.7271
CaO	0.7970	1.3992	1.1152	1.11	1.24	1.2033	56.0794	0.0221	1.4027	-16.1160	-0.2261	0.0261	-3.5604
Fe2O3	9.1530	1.4297	11.9289	1.04	12.38	12.0201	159.6922	0.0775	4.9205	15.5000	0.7627	-0.0984	12.0123
FeO	N/A	1.2865	1.0412	1.00	1.04	1.0113	71.8464	0.0145	0.9201	-14.6090	-0.1344	0.0184	-2.1172
MgO	0.7420	1.6583	1.2305	1.12	1.38	1.3438	40.3114	0.0343	2.1792	-13.8880	-0.3026	0.0436	-4.7668
MnO	1.4000	1.2912	1.8077	1.31	2.37	2.2981	70.9374	0.0334	2.1178	-14.8710	-0.3149	0.0424	-4.9603
Na2O	7.0210	1.3480	9.4643	1.03	9.74	9.4602	61.9790	0.1572	9.9779	-28.8150	-2.8751	0.1998	-45.2842
Li2O	1.9090	2.1525	4.1091	1.06	4.35	4.2283	29.8774	0.1456	9.2471	-22.7400	-2.1028	0.1849	-33.1195
NiO	0.5210	1.2726	0.6630	1.18	0.78	0.7617	74.7094	0.0105	0.8665	-14.3470	-0.0956	0.0133	-1.5060
SiO2	22.7500	2.1393	48.6691	1.10	53.51	51.9724	60.0848	0.8906	56.5444	5.5900	1.5611	0.0000	24.5883
Cr2O3	0.1060	1.4616	0.1549	1.59	0.25	0.2395	151.9974	0.0018	0.1030	37.3600	0.0385	-0.0021	0.6061
B2O3	1.9610	3.2201	6.3148	1.02	6.42	6.2389	69.6204	0.0923	5.8580	-9.9300	-0.5817	0.0000	-9.1620
UO2		1.1344	0.0000	1.00	0.00	0.0000	270.0388	0.0000	0.0000	-6.8000	0.0000	0.0000	0.0000
ThO2		1.1379	0.0000	1.00	0.00	0.0000	264.0400	0.0000	0.0000	-2.5330	0.0000	0.0000	0.0000
SrO	0.0250	1.1826	0.0296	1.00	0.03	0.0287	103.6194	0.0003	0.0181	-24.4000	-0.0044	0.0004	-0.0696
ZrO2	0.1170	1.3508	0.1580	1.00	0.16	0.1531	123.2188	0.0013	0.0812	45.1000	0.0366	0.0032	0.5770
TiO2	0.1500	1.6680	0.2502	0.98	0.24	0.2372	79.8988	0.0031	0.1940	15.9900	0.0310	0.0078	0.4887
K2O	2.1120	1.2046	2.5441	0.92	2.34	2.2718	94.2034	0.0248	1.5765	-41.7350	-0.6579	0.0315	-10.3628
Cs2O	0.0100	1.0602	0.0106	1.00	0.01	0.0103	281.8094	0.0000	0.0024	-46.8200	-0.0011	0.0000	-0.0176
Sb2O3		1.1970	0.0000	1.00	0.00	0.0000	291.4982	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P2O5		2.2910	0.0000	1.00	0.00	0.0000	141.9370	0.0000	0.0000	-53.6200	0.0000	0.0000	0.0000
Nd2O3		1.1660	0.0000	1.00	0.00	0.0000	336.4782	0.0000	0.0000	-28.3200	0.0000	0.0000	0.0000
La2O3		1.1728	0.0000	1.00	0.00	0.0000	325.8100	0.0000	0.0000	-31.1400	0.0000	0.0000	0.0000
Y2O3		1.2699	0.0000	1.00	0.00	0.0000	225.8082	0.0000	0.0000	-12.9500	0.0000	0.0000	0.0000
BaO	0.0700	1.1165	0.0782	1.14	0.09	0.0864	153.3394	0.0006	0.0368	-30.5700	-0.0113	0.0007	-0.1774
PbO	0.0960	1.0772	0.1034	2.11	0.22	0.2119	223.1900	0.0010	0.0621	-8.8100	-0.0055	0.0012	-0.0861
CeO2		1.2284	0.0000	1.00	0.00	0.0000	172.1200	0.0000	0.0000	11.3450	0.0000	0.0000	0.0000
MoO3		1.5003	0.0000	1.00	0.00	0.0000	143.9382	0.0000	0.0000	-21.7500	0.0000	0.0000	0.0000
ZnO	0.1690	1.2447	0.2104	2.00	0.42	0.4095	81.3800	0.0052	0.3289	-2.4000	-0.0079	0.0066	-0.1243
CuO	0.1320	1.2518	0.1652	1.18	0.20	0.1896	79.5454	0.0025	0.1558	1.7900	0.0028	0.0031	0.0439
Fe2+/Fe3+	0.0970												
SUMS	51.7770		94.8400		102.9606	100.0000		1.5750	100.0000		-4.7798	0.4122	-75.2708

ALK/SiO2 =	0.368	TEST=		SUM + pH Si	-5.8480
ALK+ B2O3/SiO2 =	0.472	TIME=		SUM + pH B	-7.9244
B2O3/SiO2 =	0.104			pH =	10.683
VISCOSITY @TEMP(°C)	80.313	SA/V=			
LIQUIDUS RATIO =	0.088				
LIQUIDUS (°C) =	1008				

NOTE LIQUIDUS AND VISCOSITY FORMULAS CHANGED TO CALCULATE ALL FE AS FE2O3 (OCTOBER 23, 1990)

APPENDIX II Leachate Multielement Standard Analyses

Element	Concentration of Multielement Standard ug/mL)	Run before Samples-1 ug/mL	Run before Samples-2 ug/mL	Run after 5 Samples-1 ug/mL	Run after 5 Samples-2 ug/mL	Run after 10 Samples-1 ug/mL	Run after 10 Samples-2 ug/mL	Run after 15 Samples-1 ug/mL	Run after 15 Samples-2 ug/mL
Na (ICP)	50.00	49.72	49.86	50.48	50.14	49.59	49.62	48.97	49.40
Na (AA)		51.82	52.32	52.16	52.82	51.49	51.49	49.51	51.00
SI	50.10	48.41	48.67	49.79	49.06	48.78	48.54	48.25	48.42
B	20.10	20.23	20.29	20.57	20.38	20.17	20.17	19.82	19.97
K	10.00	9.99	9.92	9.74	10.00	9.85	9.66	9.24	9.77
LI	10.00	10.01	10.03	10.16	10.08	9.97	9.98	9.79	9.88
AI	4.00	3.64	3.66	3.72	3.72	3.64	3.65	3.62	3.63
Fe	4.00	3.92	3.94	3.99	4.00	3.92	3.92	3.91	3.93

Element	Concentration of Multielement Standard ug/mL	Average Bias before Leachate Analysis ug/mL	Average Bias after 5 Leachate Analyses ug/mL	Average Bias after 10 Leachate Analyses ug/mL	Average Bias after 15 Leachate Analyses ug/mL
Na (ICP)	50.00	-0.21	0.31	-0.40	-0.82
Na (AA)		2.07	2.49	1.49	0.26
SI	50.10	-1.56	-0.68	-1.44	-1.77
B	20.10	0.16	0.38	0.07	-0.21
K	10.00	-0.05	-0.13	-0.25	-0.50
LI	10.00	0.02	0.12	-0.02	-0.17
AI	4.00	-0.35	-0.28	-0.36	-0.38
Fe	4.00	-0.07	0.00	-0.08	-0.08

Element	Concentration of Multielement Standard ug/mL)	Run after 20 Samples-1 ug/mL	Run after 20 Samples-2 ug/mL	Run after 25 Samples-1 ug/mL	Run after 25 Samples-2 ug/mL
Na (ICP)	50.00	49.43	49.31	49.69	49.48
Na (AA)		51.33	51.00	51.82	50.00
SI	50.10	48.79	48.41	48.34	48.14
B	20.10	19.90	19.84	19.93	19.85
K	10.00	9.87	10.35	9.9	10.03
LI	10.00	9.88	9.85	9.94	9.89
AI	4.00	3.58	3.60	3.55	3.56
Fe	4.00	3.91	3.96	3.9	3.9

ELEMENT	TOTAL AVERAGE BIAS ug/mL
Na (ICP)	-0.36
Na (AA)	1.40
SI	-1.47
B	-0.01
K	-0.14
LI	-0.05
AI	-0.37
Fe	-0.07

Element	Concentration of Multielement Standard ug/mL	Average Bias after 20 Leachate Analyses ug/mL	Average Bias after 25 Leachate Analyses ug/mL
Na (ICP)	50.00	-0.63	-0.42
Na (AA)		1.16	0.91
SI	50.10	1.50	-1.86
B	20.10	-0.23	-0.21
K	10.00	0.11	-0.04
LI	10.00	-0.14	-0.09
AI	4.00	-0.41	-0.45
Fe	4.00	-0.07	-0.10

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APPENDIX III Leachate Data for the IDMS Hg Campaigns 1, 2, 3

GLASS ANALYSIS ID'S	ADS #	NOTEBOOK/REF #	CALCULATED FREE ENERGY HYDRATION w/o pH	AVG. CALC. FREE ENERGY HYDRATION w/o pH	CALCULATED FREE ENERGY HYDRATION Si DISS. pH	CALCULATED FREE ENERGY HYDRATION Si + B DISS. pH	AVG. CALC. FREE ENERGY HYDRATION WITH pH
HG-1-1A	200057660	DPSTN-4771	-4.62		-5.48	-7.20	
HG-1-1B	200057661	DPSTN-4771	-4.82		-5.50	-7.25	
					-5.52	-7.29	
HG-1-1-AVG				-4.72			-7.25
HG-1-2A	200057663	DPSTN-4771	-4.75		-5.34	-7.05	
HG-1-2B	200057664	DPSTN-4771	-4.42		-5.33	-7.02	
					-5.32	-7.00	
HG-1-2-AVG				-4.58			-7.02
HG-1-3-7-1	200057665	DPSTN-4771	-4.54		-5.31	-7.00	
HG-1-3-7-2	200057666	DPSTN-4771	-4.58		-5.31	-7.00	
					-5.31	-7.00	
HG-1-3-AVG				-4.56			-7.00
HG-2-1-7-1	200057668	DPSTN-4771	-4.41		-5.23	-6.98	
HG-2-1-7-2	200057669	DPSTN-4771	-4.46		-5.22	-6.96	
					-5.23	-6.98	
HG-2-1-AVG				-4.43			-6.98
HG-2-2-7-1	200057671	DPSTN-4771	-4.61		-5.73	-7.83	
HG-2-2-7-2	200057673	DPSTN-4771	-4.66		-5.78	-7.93	
					-5.78	-7.93	
HG-2-2-AVG				-4.64			-7.90
HG-2-3-7-1	200057675	DPSTN-4771	-4.62		-5.83	-7.95	
HG-2-3-7-2	200057676	DPSTN-4771	-4.84		-5.85	-7.97	
					-5.81	-7.90	
HG-2-3-AVG				-4.73			-7.94
HG-3-1-7-1	200057677	DPSTN-4771	-4.72		-5.83	-7.96	
HG-3-1-7-2	200057678	DPSTN-4771	-4.72		-5.85	-7.98	
					-5.86	-8.01	
HG-3-1-AVG				-4.72			-7.98
HG-3-2-7-1	200057679	DPSTN-4771	-4.75		-5.82	-7.92	
HG-3-2-7-2	200057680	DPSTN-4771	-4.71		-5.82	-7.92	
					-5.86	-8.00	
HG-3-2-AVG				-4.73			-7.95
HG-3-3-7-1	200057791	DPSTN-4771	-4.80		-5.86	-7.93	
HG-3-3-7-2	200057682	DPSTN-4771	-4.78		-5.86	-7.93	
HG-3-3-AVG					-5.87	-7.95	
				-4.79			-7.94

GLASS ANALYSIS ID'S	B WT. % IN GLASS	LI WT.% IN GLASS	Na WT. % IN GLASS	SI WT. % IN GLASS	K WT.% IN GLASS
HG-1-1A	2.17	2.08	6.78	25.33	2.22
HG-1-1B	2.21	2.03	6.85	23.53	2.22
HG-1-1-AVG	2.19	2.05	6.82	24.43	2.22
HG-1-2A	2.16	2.15	6.61	25.86	2.91
HG-1-2B	2.17	2.15	6.43	25.89	2.18
HG-1-2-AVG	2.17	2.15	6.52	25.87	2.55
HG-1-3-7-1	2.18	2.17	6.59	25.92	2.15
HG-1-3-7-2	2.16	2.34	6.56	25.71	2.17
HG-1-3-AVG	2.17	2.26	6.57	25.81	2.16
HG-2-1-7-1	2.13	2.15	6.55	25.94	2.03
HG-2-1-7-2	2.13	2.15	6.59	25.83	2.05
HG-2-1-AVG	2.13	2.15	6.57	25.89	2.04
HG-2-2-7-1	1.92	2.10	7.80	25.72	1.56
HG-2-2-7-2	1.93	2.09	7.93	25.55	1.52
HG-2-2-AVG	1.93	2.10	7.87	25.63	1.54
HG-2-3-7-1	1.90	2.09	7.73	25.59	1.51
HG-2-3-7-2	1.90	2.09	7.89	25.56	1.51
HG-2-3-AVG	1.90	2.09	7.81	25.58	1.51
HG-3-1-7-1	1.91	2.03	7.49	24.97	1.67
HG-3-1-7-2	1.92	2.03	7.51	24.96	1.69
HG-3-1-AVG	1.92	2.03	7.50	24.96	1.68
HG-3-2-7-1	1.95	1.99	7.36	24.86	1.89
HG-3-2-7-2	1.96	2.01	7.27	24.89	1.83
HG-3-2-AVG	1.95	2.00	7.32	24.87	1.86
HG-3-3-7-1	2.01	2.02	7.18	24.96	1.96
HG-3-3-7-2	2.00	2.02	7.23	25.03	1.94
HG-3-3-AVG	2.00	2.02	7.20	24.99	1.95

PCT LEACHATE IDS	ADS #	RESEARCHER	NOTEBOOK/REF #	PCT VERSION	MEASURED pH	MEASURED B (ICP) (ppm)	NORMALIZED B (ICP) (g/L)	LOG NORM. B (ICP) (g/L)
HG-1-1-7-1	200052676	B.J. Waters	DPSTN-4789	3.0	10.41	14.37	0.66	-0.18
HG-1-1-7-2	200052677	B.J. Waters	DPSTN-4789	3.0	10.43	14.99	0.69	-0.16
HG-1-1-7-3	200052678	B.J. Waters	DPSTN-4789	3.0	10.45	15.32	0.70	-0.15
HG-1-1-AVG					10.43	14.89	0.68	-0.17
HG-1-2-7-1	200052679	B.J. Waters	DPSTN-4789	3.0	10.40	15.65	0.72	-0.14
HG-1-2-7-2	200052680	B.J. Waters	DPSTN-4789	3.0	10.39	15.71	0.73	-0.14
HG-1-2-7-3	200052681	B.J. Waters	DPSTN-4789	3.0	10.38	15.91	0.73	-0.13
HG-1-2-AVG					10.39	15.76	0.73	-0.14
HG-1-3-7-1	200052684	B.J. Waters	DPSTN-4789	3.0	10.39	14.81	0.68	-0.17
HG-1-3-7-2	200052685	B.J. Waters	DPSTN-4789	3.0	10.39	14.74	0.68	-0.17
HG-1-3-7-3	200052686	B.J. Waters	DPSTN-4789	3.0	10.39	14.93	0.69	-0.16
HG-1-3-AVG					10.39	14.83	0.68	-0.17
HG-2-1-7-1	200052687	B.J. Waters	WSRC-NB-90-271	3.0	10.44	14.15	0.66	-0.18
HG-2-1-7-2	200052688	B.J. Waters	WSRC-NB-90-271	3.0	10.43	14.75	0.69	-0.16
HG-2-1-7-3	200052689	B.J. Waters	WSRC-NB-90-271	3.0	10.44	15.20	0.71	-0.15
HG-2-1-AVG					10.44	14.70	0.69	-0.16
HG-2-2-7-1	200052692	B.J. Waters	WSRC-NB-90-271	3.0	10.70	14.85	0.77	-0.11
HG-2-2-7-2	200052693	B.J. Waters	WSRC-NB-90-271	3.0	10.74	14.87	0.77	-0.11
HG-2-2-7-3	200052694	B.J. Waters	WSRC-NB-90-271	3.0	10.74	14.86	0.77	-0.11
HG-2-2-AVG					10.73	14.86	0.77	-0.11
HG-2-3-7-1	200052695	B.J. Waters	WSRC-NB-90-271	3.0	10.71	15.02	0.79	-0.10
HG-2-3-7-2	200052696	B.J. Waters	WSRC-NB-90-271	3.0	10.72	14.94	0.79	-0.10
HG-2-3-7-3	200052697	B.J. Waters	WSRC-NB-90-271	3.0	10.69	14.96	0.79	-0.10
HG-2-3-AVG					10.71	14.97	0.79	-0.10
HG-3-1-7-1	200052700	B.J. Waters	WSRC-NB-90-271	3.0	10.72	14.08	0.74	-0.13
HG-3-1-7-2	200052701	B.J. Waters	WSRC-NB-90-271	3.0	10.73	14.36	0.75	-0.13
HG-3-1-7-3	200052702	B.J. Waters	WSRC-NB-90-271	3.0	10.74	14.86	0.78	-0.11
HG-3-1-AVG					10.73	14.43	0.75	-0.12
HG-3-2-7-1	200052703	B.J. Waters	WSRC-NB-90-271	3.0	10.70	15.36	0.79	-0.10
HG-3-2-7-2	200052704	B.J. Waters	WSRC-NB-90-271	3.0	10.70	15.04	0.77	-0.11
HG-3-2-7-3	200052705	B.J. Waters	WSRC-NB-90-271	3.0	10.73	15.19	0.78	-0.11
HG-3-2-AVG					10.71	15.20	0.78	-0.11
HG-3-3-7-1	200052709	B.J. Waters	WSRC-NB-90-271	3.0	10.68	14.24	0.71	-0.15
HG-3-3-7-2	200052710	B.J. Waters	WSRC-NB-90-271	3.0	10.68	14.60	0.73	-0.14
HG-3-3-7-3	200052712	B.J. Waters	WSRC-NB-90-271	3.0	10.69	15.09	0.75	-0.12
HG-3-3-AVG					10.68	14.64	0.73	-0.14

PCT LEACHATE IDS	MEASURED LI (ICP) (ppm)	NORMALIZED LI (ICP) (g/L)	LOG NORM. LI (ICP) (g/L)	MEASURED K (AA) (ppm)	NORMALIZED K (AA) (g/L)	LOG NORM. K (AA) (g/L)
HG-1-1-7-1	13.14	0.64	-0.19	8.80	0.40	-0.40
HG-1-1-7-2	13.64	0.66	-0.18	9.43	0.42	-0.37
HG-1-1-7-3	13.89	0.68	-0.17	9.65	0.43	-0.36
HG-1-1-AVG	13.56	0.66	-0.18	9.29	0.42	-0.38
HG-1-2-7-1	14.44	0.67	-0.17	9.29	0.36	-0.44
HG-1-2-7-2	14.46	0.67	-0.17	9.25	0.36	-0.44
HG-1-2-7-3	14.63	0.68	-0.17	8.95	0.35	-0.45
HG-1-2-AVG	14.51	0.67	-0.17	9.16	0.36	-0.44
HG-1-3-7-1	14.00	0.62	-0.21	8.94	0.41	-0.38
HG-1-3-7-2	13.90	0.62	-0.21	8.90	0.41	-0.38
HG-1-3-7-3	14.07	0.62	-0.20	8.95	0.41	-0.38
HG-1-3-AVG	13.99	0.62	-0.21	8.93	0.41	-0.38
HG-2-1-7-1	13.39	0.62	-0.21	8.08	0.40	-0.40
HG-2-1-7-2	13.88	0.65	-0.19	8.30	0.41	-0.39
HG-2-1-7-3	14.28	0.66	-0.18	8.72	0.43	-0.37
HG-2-1-AVG	13.85	0.64	-0.19	8.37	0.41	-0.39
HG-2-2-7-1	15.20	0.73	-0.14	7.03	0.46	-0.34
HG-2-2-7-2	15.25	0.73	-0.14	7.01	0.46	-0.34
HG-2-2-7-3	15.21	0.73	-0.14	6.90	0.45	-0.35
HG-2-2-AVG	15.22	0.73	-0.14	6.98	0.45	-0.34
HG-2-3-7-1	15.12	0.72	-0.14	7.38	0.49	-0.31
HG-2-3-7-2	14.92	0.71	-0.15	6.41	0.42	-0.37
HG-2-3-7-3	14.90	0.71	-0.15	6.65	0.44	-0.36
HG-2-3-AVG	14.98	0.72	-0.14	6.81	0.45	-0.35
HG-3-1-7-1	14.22	0.70	-0.15	7.38	0.44	-0.36
HG-3-1-7-2	14.51	0.71	-0.15	7.71	0.46	-0.34
HG-3-1-7-3	14.90	0.73	-0.13	8.16	0.49	-0.31
HG-3-1-AVG	14.54	0.72	-0.14	7.75	0.46	-0.34
HG-3-2-7-1	14.57	0.73	-0.14	10.16	0.55	-0.26
HG-3-2-7-2	14.46	0.72	-0.14	8.24	0.44	-0.35
HG-3-2-7-3	14.63	0.73	-0.14	8.28	0.45	-0.35
HG-3-2-AVG	14.55	0.73	-0.14	8.89	0.48	-0.32
HG-3-3-7-1	13.45	0.67	-0.18	8.30	0.43	-0.37
HG-3-3-7-2	13.78	0.68	-0.17	8.79	0.45	-0.35
HG-3-3-7-3	14.12	0.70	-0.16	8.98	0.46	-0.34
HG-3-3-AVG	13.78	0.68	-0.17	8.69	0.45	-0.35

PCT LEACHATE IDS	MEASURED Na (ICP) (ppm)	NORMALIZED Na (ICP) (g/L)	LOG NORM. Na (ICP) (g/L)	MEASURED Na (AA) (ppm)	NORMALIZED Na (AA) (g/L)	LOG NORM. Na (AA) (g/L)	MEASURED Si (ICP) (ppm)	NORMALIZED Si (ICP) (g/L)	LOG NORM. Si (ICP) (g/L)
HG-1-1-7-1	43.81	0.64	-0.19	45.70	0.67	-0.17	91.22	0.37	-0.43
HG-1-1-7-2	45.60	0.67	-0.17	47.68	0.70	-0.16	94.34	0.39	-0.41
HG-1-1-7-3	46.76	0.69	-0.16	49.18	0.72	-0.14	95.70	0.39	-0.41
HG-1-1-AVG	45.39	0.67	-0.18	47.52	0.70	-0.16	93.75	0.38	-0.42
HG-1-2-7-1	45.29	0.69	-0.16	46.36	0.71	-0.15	100.06	0.39	-0.41
HG-1-2-7-2	45.11	0.69	-0.16	47.85	0.73	-0.13	99.67	0.39	-0.41
HG-1-2-7-3	45.51	0.70	-0.16	48.02	0.74	-0.13	100.58	0.39	-0.41
HG-1-2-AVG	45.30	0.69	-0.16	47.41	0.73	-0.14	100.10	0.39	-0.41
HG-1-3-7-1	42.99	0.65	-0.18	44.04	0.67	-0.17	96.23	0.37	-0.43
HG-1-3-7-2	42.62	0.65	-0.19	44.70	0.68	-0.17	94.12	0.36	-0.44
HG-1-3-7-3	43.17	0.66	-0.18	44.54	0.68	-0.17	95.19	0.37	-0.43
HG-1-3-AVG	42.93	0.65	-0.19	44.43	0.68	-0.17	95.18	0.37	-0.43
HG-2-1-7-1	42.61	0.65	-0.19	44.37	0.68	-0.17	93.23	0.36	-0.44
HG-2-1-7-2	44.45	0.68	-0.17	46.53	0.71	-0.15	96.86	0.37	-0.43
HG-2-1-7-3	45.76	0.70	-0.16	46.69	0.71	-0.15	99.66	0.39	-0.41
HG-2-1-AVG	44.27	0.67	-0.17	45.86	0.70	-0.16	96.65	0.37	-0.43
HG-2-2-7-1	62.82	0.80	-0.10	64.90	0.83	-0.08	105.23	0.41	-0.39
HG-2-2-7-2	62.84	0.80	-0.10	65.07	0.83	-0.08	105.36	0.41	-0.39
HG-2-2-7-3	62.57	0.80	-0.10	63.41	0.81	-0.09	104.75	0.41	-0.39
HG-2-2-AVG	62.74	0.80	-0.10	64.46	0.82	-0.09	105.11	0.41	-0.39
HG-2-3-7-1	61.76	0.79	-0.10	62.59	0.80	-0.10	105.40	0.41	-0.38
HG-2-3-7-2	61.31	0.79	-0.11	62.09	0.80	-0.10	106.75	0.42	-0.38
HG-2-3-7-3	61.29	0.78	-0.11	61.76	0.79	-0.10	106.34	0.42	-0.38
HG-2-3-AVG	61.45	0.79	-0.10	62.15	0.80	-0.10	106.16	0.42	-0.38
HG-3-1-7-1	56.49	0.75	-0.12	57.95	0.77	-0.11	98.54	0.39	-0.40
HG-3-1-7-2	57.79	0.77	-0.11	60.10	0.80	-0.10	100.20	0.40	-0.40
HG-3-1-7-3	59.48	0.79	-0.10	60.76	0.81	-0.09	102.09	0.41	-0.39
HG-3-1-AVG	57.92	0.77	-0.11	59.60	0.79	-0.10	100.28	0.40	-0.40
HG-3-2-7-1	56.73	0.76	-0.11	58.45	0.80	-0.10	100.08	0.40	-0.40
HG-3-2-7-2	56.18	0.77	-0.11	56.79	0.76	-0.11	99.61	0.40	-0.40
HG-3-2-7-3	56.78	0.76	-0.11	58.12	0.79	-0.10	99.89	0.40	-0.40
HG-3-2-AVG	56.56	0.77	-0.11	57.79	0.79	-0.10	99.86	0.40	-0.40
HG-3-3-7-1	51.57	0.72	-0.15	53.31	0.74	-0.13	92.48	0.37	-0.43
HG-3-3-7-2	53.00	0.74	-0.13	54.97	0.76	-0.12	95.15	0.38	-0.42
HG-3-3-7-3	54.66	0.76	-0.12	54.14	0.75	-0.12	97.49	0.39	-0.41
HG-3-3-AVG	53.08	0.74	-0.13	54.14	0.75	-0.12	95.04	0.38	-0.42

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