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Final Report - High Level Waste Vitrification System Improvements, VSL-07R1010-1, Rev 0, dated 04/16/07

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Office of River Protection

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Richland, Washington 99352

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Final Report

High Level Waste Vitrification System Improvements

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This report describes the results of testing specified by the above Test Plan. The work was performed in compliance with the quality assurance requirements specified in the Test Plan. Results required by the Test Plan are reported. The test results and this report have been reviewed for correctness, technical adequacy, completeness, and accuracy.

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List of Abbreviations

AA	Atomic Absorption Spectroscopy
ADS	Air Displacement Slurry
CCC	Canister Center Line Cooling
DCP-AES	Direct Current Plasma Atomic Emission Spectroscopy
DF	Decontamination Factor
DM	DuraMelter®
DOE	Department of Energy
DRE	Destruction & Removal Efficiency
DWPF	Defense Waste Processing Facility
EPA	Environmental Protection Agency
EDS	Energy Dispersive X-Ray Spectroscopy
FTIR	Fourier Transform Infrared Spectroscopy
GC	Gas Chromatography
HEPA	High-Efficiency Particulate Air Filter
HLW	High Level Waste
IHLW	Immobilized High Level Waste
LAW	Low Activity Waste
M	Molarity
N	Normality
NIST	National Institute of Standards and Technology
PCT	Product Consistency Test
QA	Quality Assurance
QAPjP	Quality Assurance Project Plan for Testing Programs Generating Environmental Regulatory Data
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPP	River Protection Project
SEM	Scanning Electron Microscopy
SIPP	Semi Integrated Pilot Plant
SRM	Standard Reference Material
SRNL	Savannah River National Laboratory
TCLP	Toxicity Characteristic Leaching Procedure
VSL	Vitreous State Laboratory
WTP	Hanford Tank Waste Treatment and Immobilization Plant
WVDP	West Valley Demonstration Project
XRD	X-ray Diffraction
XRF	X-Ray Fluorescence

SECTION 1.0
INTRODUCTION

This report describes work conducted to support the development and testing of new glass formulations that extend beyond those that have been previously investigated for the Hanford Waste Treatment and Immobilization Plant (WTP). The principal objective was to investigate maximization of the incorporation of several waste components that are expected to limit waste loading and, consequently, high level waste (HLW) processing rates and canister count. The work was performed with four waste compositions specified by the Office of River Protection (ORP); these wastes contain high concentrations of bismuth, chromium, aluminum, and aluminum plus sodium. The tests were designed to identify glass formulations that maximize waste loading while meeting all processing and product quality requirements. The work included preparation and characterization of crucible melts in support of subsequent DuraMelter 100 (DM100) tests designed to examine the effects of enhanced glass formulations, increased glass processing temperature, increased crystallinity, and feed solids content on waste processing rate and product quality. This work builds on previous work performed at VSL for DOE to increase waste loading and processing rates for high-iron HLW waste streams [1]. The scope of this study was outlined in a Test Plan [2] that was prepared in response to an ORP-supplied statement of work [3].

DOE HLW treatment programs have featured joule heated ceramic melter technology for the vitrification of high level tank waste. The melter technology used at the West Valley Demonstration Project (WVDP) in New York and at the Defense Waste Processing Facility (DWPF) at the Savannah River Site (SRS) process(ed) HLW in ceramic melters at an operating temperature of 1150°C. Historically, HLW melters are operated at temperatures of 1150°C to allow for sufficient temperature control for normal as well as upset conditions in an operating melter, while still protecting the electrodes from potential damage due to unanticipated high temperature swings. Since the HLW melters deployed in the United States at West Valley and DWPF do not actively mix the glass pool, temperature variations within the glass pool can be relatively large (~±75°C) with respect to the nominal operating temperature since natural convection within the glass pool is limited in the viscous molten glass. In advancing the technology, Duratek/VSL have demonstrated on very large scale melters (Duratek M-Area facility, Duratek RPP-WTP HLW pilot melter, and the Duratek RPP-WTP LAW pilot melter) that active mixing of the glass pool using Duratek's patented bubbler technology significantly reduces the temperature gradient within the glass pool and allows the melter to be controlled in a tighter operating band. As a result, the operating temperature of the melter can be modestly increased by some 25 to 50°C with the current materials of construction, (and yet higher with changes of electrode and bubbler materials) while maintaining the operating integrity of the melter at the higher temperature. For HLW waste streams, increases in operating temperature have the advantage of increased processing rate as well as increased waste loading, both of which translate into significant cost savings.

The waste loading of high-level nuclear waste streams is typically limited by crystal formation because of the relatively high concentrations of elements such as Fe, Cr, Ni, Mn, Zr, Al, Th, Bi, etc. in the waste and their tendency to form crystalline phases. While the presence of crystalline phases rarely affects the quality of the glass product, it can present a significant processing concern since such phases can settle and accumulate in the melter, ultimately reducing the life of the melter. For this reason, HLW glasses (e.g., DWPF and WVDP) have traditionally been designed to have a liquidus temperature that is lower than the nominal processing temperature by some target value. Since the basic practical issue is crystal settling and accumulation, depending upon the crystal size and density, non-zero amounts of near-liquidus phases can often be maintained in suspension and, therefore, tolerated in bubbled melters. These considerations have led Duratek/VSL to develop and implement an "operational liquidus" constraint in which a non-zero fraction of crystals is tolerated at a given temperature. Glasses designed for DuraMelter vitrification systems have employed a limit of <1 vol. % crystals at a reference temperature (typically 950°C) below the operating temperature. Based on this experience and recommendation, this constraint has now been formally adopted for use at the Hanford WTP in place of the traditional, much more conservative, liquidus-temperature constraint. Additional increases in the amount of crystals allowable in the glass would further increase waste loadings and therefore further reduce waste treatment costs. However, at present, although it is expected that the actively mixed DuraMelter systems should be able to tolerate a larger amount of crystals than is the case for conventional melters, the maximum concentration of crystals such melter systems can tolerate is not yet known. For the current work, glass formulations with modestly higher amounts of crystals (i.e., closer to the 1 vol% limit than is typical of the current WTP baseline glasses) were considered for melter testing, if it resulted in higher waste loading. The maximum amount of crystals in the glass formulations selected for melter testing was decided on a case-by-case basis, in consultation with ORP, and was based on the specific glass formulation and the composition and characteristics of the crystal phase. Previous DM10 work demonstrated successful processing of high-iron wastes with glasses formulated with up to ~3 vol% crystals at 950°C [1].

Under a separate contract to support the WTP, the VSL is developing and testing glass formulations for WTP HLW waste compositions to provide data to meet the WTP contract requirements and to support system design activities [4-6]. That work is based upon small-scale batch melts ("crucible melts") using waste simulants. Selected formulations have also been tested in small-scale, continuously fed, joule-heated melters (DM100) [7-10] and, ultimately, in the HLW DM1200 Pilot Melter [9-17]. Such melter tests provide information on key process factors such as feed processing behavior, dynamic effects during processing, secondary phase formation, processing rates, off-gas amounts and compositions, foaming control, etc., that cannot be reliably obtained from crucible melts. This sequential scale-up approach in the vitrification testing program ensures that maximum benefit is obtained from the more costly melter tests and that the most effective use is made of those resources.

The glass formulation and melter testing work described in this report is aimed at identifying glass compositions that maximize waste loadings for the four waste streams specified by ORP. This information provides ORP with a basis for projection of the amount of Immobilized High Level Waste (IHLW) to be produced at Hanford, and evaluation of the likely potential for future enhancements of the WTP over and above the present well-developed baseline. It should be noted that the compositions of the four specified waste streams differ significantly from those of the feed tanks (AZ-101, AZ-102, C-16/AY-102, and C-104/AY-101) that have been the focus of the extensive technology development and design work performed for the WTP baseline. In this regard, the work described in this report is complementary to and necessarily of a more exploratory nature than the work in support of the current WTP baseline. It should be noted, therefore, that to the extent that the present effort is successful, considerable further work would be required to bring the level of confidence in the new glass composition regions to a similar level of maturity to that of the current WTP baseline. Additional testing in larger melters such as the DM1200 will be needed to confirm feed processing characteristics at larger scales. Additional testing at the crucible and melter scales will be needed to determine the robustness of the new compositions with respect to variations in the feed compositions that may results from process variations. Off-gas characteristics will have to be determined and data to support engineering and permitting requirements will need to be collected using a WTP prototypic off-gas system. In addition, since the high waste loading glass compositions are likely to be in a new composition space as compared to the current WTP compositions, additional effort will be required to develop and extend the current qualified glass composition region and supporting models to include these new compositions.

Literature information on glass formulations containing the components of interest in the present work (Cr, Bi, Al, and Na) is summarized and discussed in the Appendix. The concentrations of these components in the formulations developed in the present work are also compared to expectations based on literature information.

1.1 Test Objectives

The principal objectives of this work were [2, 3] to test and evaluate HLW glass compositions to determine the maximum waste loading that can be achieved and still produce a simulated glass composition that has acceptable durability and processing characteristics. Glass composition development was based on four HLW waste compositions specified by ORP that have high concentrations of bismuth, chromium, aluminum, and aluminum in combination with sodium. These objectives were addressed through a combination of crucible-scale tests and confirmation tests on the DM100 melter system. The DM100-BL unit was selected for these tests. The DM100-BL was used for previous tests on HLW glass compositions [7-10] that were used to support subsequent tests on the HLW Pilot Melter [9-17]. The volatility of cesium and rhenium (as a surrogate for technetium) during the vitrification of an HLW AZ-102 composition was also studied on the DM100-BL [18]. The same melter was selected for the present tests in order to maintain comparisons between the previously collected data. The tests provided information on melter processing characteristics and off-gas data, including formation of secondary phases and partitioning. In addition, the work evaluated the effect on production rate of modest increases in melter operating temperature and changes in feed solids content. Once glass formulation development was completed for each of the four waste compositions, the data were reviewed with ORP prior to making a decision on whether to proceed directly to DM100-BL tests or to first conduct screening tests on the DM10.

Per the Statement of Work [3], a parametric “crucible scale” study of the effects of waste loading was conducted for each waste composition. Waste loadings were increased until the maximum expected waste loading was achieved, or the limits of a glass property were exceeded.

Glass properties for evaluation included: viscosity, electrical conductivity, crystallinity, salt phase separation, and durability per the 7-day Product Consistency Test (PCT, ASTM-1285). Glass property limits were based upon the reference properties for the WTP HLW melter. However, the WTP crystallinity limit (< 1 vol% at 950°C) was not used as a waste loading constraint for the crucible melts. Instead, in the present work, a less conservative approach was employed such that crucible melt tests evaluated glasses that exhibit up to about 5 – 10 vol% crystallization [2].

1.2 Quality Assurance

This work was conducted under a quality assurance program that is based on NQA-1 (1989) and NQA-2a (1990) Part 2.7 that is in place at the VSL. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work [19] that is conducted at VSL. Test and procedure requirements by which the testing activities are planned and controlled are also defined in this plan. The program is supported by VSL standard operating procedures that were used for this work [20]. In addition, the requirements of DOE/RW-0333P were applicable to the following specific aspects of this work:

- Crucible melt preparation
- Analysis of crucible melt glasses
- PCT

1.3 DM10 Melter System

The DM10 unit is a ceramic refractory-lined melter fitted with two Inconel 690 plate electrodes that are used for joule-heating of the glass pool and a bubbler for stirring the melt. The glass product is removed from the melter by means of an air-lift discharge system. The DM10 unit has a melt surface area of 0.021 m^2 and a glass inventory of about 8 kg, less than a tenth of that of the DM100. As with the DM100, the melter feed is introduced in batches into a stirred feed container that is mounted on a load cell for weight monitoring. The feed is constantly recirculated except for periodic, momentary interruptions during which the weight is recorded. The feed can be introduced into the melter by means of a simulated air-displacement slurry (ADS) pump system or through a peristaltic pump; the latter was used for the present tests. The recirculation loop extends to the top of the melter where feed is diverted from the recirculation loop into the melter through a Teflon-lined feed line and water-cooled, vertical feed tube. The off-gas system is similar to that for the DM100, which is described below. Samples for analysis are taken from the discharged glass and by dip-sampling of the glass pool using a threaded rod.

1.4 DM100 Melter Systems

1.4.1 D100 Feed System

A schematic diagram of the DM100 vitrification system is shown in Figure 1.1. The melter feed is introduced in batches into a feed container that is mounted on a load cell for weight monitoring. The feed is stirred with a variable speed mixer and constantly recirculated except for periodic, momentary interruptions during which the weight is recorded. Feed is normally introduced into the melter via a system designed to mimic the operation of an ADS pump, which is the present WTP baseline; however, a peristaltic pump was used in these tests to facilitate observations of any differences in processing rates and feed behavior. In this system, a recirculation loop extends to the top of the melter where feed is diverted from the recirculation loop to the peristaltic pump and subsequently into the melter through a Teflon-lined feed line and water-cooled, vertical feed tube.

1.4.2 Melter System

Cross-sectional diagrams of the DM100-BL melter are shown in Figures 1.2.a-c. The DM100-BL unit is a ceramic refractory-lined melter fitted with five electrodes: two pairs of opposing Inconel 690 plate electrodes and a bottom electrode. Power can be supplied in either three-phase or single-phase configurations. All of the tests in the present work were performed with the upper and lower electrodes on each side connected together and powered by a single-phase supply; the bottom electrode was not powered. Melt pool agitation is achieved by either a removable lance entering from the top of the melter or a permanent bubbler installed through the bottom electrode. In these tests the lance bubbler was used. The glass product is removed from the melter by means of an airlift discharge system. The melter has a melt surface area of 0.108 m^2 and a variable glass inventory of between 110 kg, when only the bottom pair of electrodes is used, and about 170 kg when both pairs of electrodes are used, which was the case in the present tests.

1.4.3 Off-Gas System

For operational simplicity, the DM100-BL is equipped with a dry off-gas treatment system involving gas filtration operations only. Exhaust gases leave the melter plenum through a film cooler device that minimizes the formation of solid deposits. The film-cooler air has constant flow rate and its temperature is thermostatically controlled. Consequently, under steady-state operating conditions, the exhaust gases passing through the transition line (between the melter and the first filtration device) can be sampled at constant temperature and airflow rate. The geometry of the transition line conforms to the requirements of the 40-CFR-60 air sampling techniques. Immediately downstream of the transition line are cyclonic filters followed by conventional pre-filters and HEPA filters. The temperature of the cyclonic filters is maintained above 150°C while the temperatures in the HEPAs are kept sufficiently high to prevent moisture condensation. The entire train of gas filtration operations is duplicated and each train is used alternately. An induced draft fan completes the system.

1.5 Feed Sample Analysis

Feed samples were taken directly from the feed recirculation line during each test. Feed samples were poured into a platinum/gold crucible that was placed into a programmed furnace for drying and fusion to form a glass. The glass produced from this fusion was ground to less than 200 mesh and sealed in 20-ml vials for subsequent analysis by x-ray fluorescence spectroscopy (XRF), or by acid digestion followed by direct current plasma - atomic emission spectroscopy (DCP-AES) on the resulting solution. The feed samples were also characterized for their rheological properties, density, pH, water content, and glass yield.

1.6 Glass Product Analysis

The glass product is discharged from the melter into 5-gallon steel pails periodically using an air-lift system. The discharged product glass was sampled at the end of each test by removing sufficient glass from the top of the cans for compositional analysis and secondary phase determinations. In addition, the Product Consistency Test (7 days at 90^{o}C) and Toxicity Characteristic Leaching Procedure (TCLP) were performed on samples of the glass product from the DM100 melter tests. Prior to those tests, the PCT and TCLP were also performed on the crucible melt compositions that were selected for the melter tests to ensure their compliance with the present WTP contract requirements. All of these procedures are routinely conducted at VSL and, therefore, standard operating procedures (SOPs) are in place.

Sample preparation for chemical analysis typically involves size reduction and sieving. All samples were subjected to XRF to determine the concentration of all elements except boron and lithium. A series of National Institute of Standards and Technology (NIST) reference materials were used for confirmation of the XRF data. Boron and lithium were determined by total acid dissolution of ground glass samples in HF/HNO_3 and subjecting the resulting solutions to DCP-AES analysis.

1.6.1 Viscosity

The melt viscosity, η, is measured using a Brookfield viscometer. Measurements are performed in the temperature range of 950-1250ºC and the data are interpolated to standard temperatures using the Vogel-Fulcher equation: $\ln \eta = [A/(T-T_o)]+B$, where A, B, and T_o are fitting parameters. The equipment is calibrated at room temperature using standard oils of known viscosity and then checked at 950-1250ºC using a NIST standard reference glass (SRM 711). Both precision and accuracy of the viscosity measurements are estimated to be within ±15 relative%.

1.6.2 Electrical Conductivity

The electrical conductivity, σ, of each glass melt is determined by measuring the resistance of the glass melt as a function of frequency using a calibrated platinum/rhodium electrode probe attached to a Hewlett-Packard model 4194A impedance analyzer. Measurements are performed over similar temperature ranges to those employed for the melt viscosity measurements. The results are analyzed and modeled to obtain the DC electrical conductivity.

The electrical conductivity data are then interpolated to standard temperatures using the Vogel-Fulcher equation: $\ln \sigma = [A/(T-T_o)] + B$, where A, B and T_o are fitting parameters. Estimated uncertainties in the electrical conductivity measurements are ± 20 relative%.

1.6.3 Product Consistency Test (PCT)

The product consistency test (PCT; ASTM C 1285) is used to evaluate the relative chemical durability of glasses by measuring the concentrations of the chemical species released from 100-200 mesh crushed glass (75-149 μm) to the test solution (de-ionized water in this case). PCT tests on the HLW glasses are performed at 90ºC, in accordance with the current WTP contract requirement. The ratio of the glass surface area to the solution volume for this test is about 2000 m^{-1} (typically, 10 g of 100-200 mesh glass is immersed in 100 ml deionized water). All tests are conducted in triplicate, in 304L stainless steel vessels, and in parallel with a standard glass included in each test set. The internal standard is the ANL-LRM reference glass [21] and/or the DWPF-EA glass, both of which have undergone round-robin testing. The leachates are sampled at predetermined times, the first of which is seven days. One milliliter of sampled leachate is mixed with 20 ml of 1M HNO_3 and the resulting solution is analyzed by DCP-AES; another 3 ml of sampled leachate is used for pH measurement.

1.6.4 Toxicity Characteristic Leaching Procedure (TCLP)

The TCLP was performed at VSL using SW-846 Method 1311, which employs leaching of crushed glass (< 3/8”) in a sodium acetate buffer solution for 18 hours at 22°C with constant end-over-end agitation. A mass of about 100 grams of glass is leached in 2 liters of TCLP extract, according to the extraction method for non-volatiles. The surface area to volume ratio for this test is about 20 m^{-1}, which is about two orders of magnitude lower than that in the PCT. The leachates are analyzed by DCP-AES according to VSL standard operating procedures.

1.6.5 Secondary Phases

Secondary phases in the glass samples were determined by optical microscopy and scanning electron microscopy coupled with energy dispersive x-ray spectroscopy (SEM-EDS). Secondary phases due to crystallization and phase separation can be identified using these methods. Quantitative determination of the amount of crystals in glass samples were made by SEM in conjunction with image analysis.

SECTION 2.0
WASTE SIMULANT

The waste stream compositions provided by DOE are given in Table 2.1 on an oxide basis [3] under the heading “Actual”. Omission of radioactive components and renormalization of the simulated waste yields the compositions shown in Table 2.1 as “Non-Rad”; these compositions were used for the majority of the crucible formulations and all of the melter testing. However, once the final formulations were selected, additional crucible melts were performed using the appropriate radioactive components (i.e., thorium and uranium).

Actual HLW Hanford tank wastes are aqueous solutions with suspended solids and dissolved salts including hydroxides, nitrates, nitrites, halides, and carbonates. For the purpose of the present work, the concentrations of the volatile components (i.e., carbonate, nitrite, nitrate, and organic carbon) are assumed to be similar to those found for the AZ-102 HLW waste [14]. With the waste compositions defined, formulation of the HLW waste simulant proceeds in a straightforward fashion from the oxide compositions listed in Table 2.1. In general, oxides and hydroxides were used as the starting materials, including a slurry of iron (III) hydroxide (13% by weight). Volatile inorganic components were added as the sodium salts, whereas organic carbon was added as oxalic acid. Finally, the water content was adjusted to target a glass yield of 500 g of glass per liter of feed. Feeds were diluted by the addition of water for the last DM100-BL test segments, targeting a glass yield of 250 g per liter. The compositions of the resulting four HLW waste simulants that were used for melter testing are given in Tables 2.2 - 2.5.

SECTION 3.0
GLASS FORMULATION

3.1 Enhanced Glass Formulation for Bi-Limited Waste

Crucible melts spanning a range of waste loadings were prepared and tested to determine the maximum viable waste loading for the bismuth-limited waste composition supplied by ORP [3]. Table 3.1 presents the compositions of the one radioactive and 16 non-radioactive glasses investigated in this work, along with the radioactive and non-radioactive versions of the Bi-limited waste. The non-radioactive version of the waste was obtained by renormalizing the waste composition to 100% after removing radioactive components U and Th. Besides the high concentration of Bi_2O_3, the Bi-limited waste contains several other ingredients that often limit waste loading in borosilicate glasses, notably, P_2O_5 (~10 wt%), NiO (~4 wt%), Cr_2O_3 (~1 wt%), SO_3 (~1 wt%) and F (~1.6 wt%). Phosphates can cause crystallization and liquid-liquid phase separation in borosilicate glass melts at levels of a few percent. Nickel and chromium oxides are major constituents of spinel, which is the most common near-liquidus phase in HLW glasses. The solubility of sulfate is rather low in silicate systems and can be further reduced by addition of halides (F, Cl).

The formulation work for the Bi-limited waste started with crucible melts targeting 30 wt% waste loading, which is double the contract-specified minimum of 15 wt%. HLW-E-Bi-11 (Table 3.1), one of the glasses with 30 wt% waste loading, is a typical high-sodium borosilicate waste glass, with around 44 wt% silica and moderate amounts of aluminum and iron oxides. The presence of about 4 wt% of Bi_2O_3 and 3 wt% of P_2O_5 from the Bi-limited waste did not adversely affect the glass properties. As reported in Table 3.2, the as-melted glass from the crucible melt and the sample after heat treat treatment for 70 hours at 950^{o}C were crystal-free, as determined by X-ray diffraction (XRD) and SEM analysis. Glasses with 40 wt% waste loading were formulated with lower SiO_2 concentrations (see HLW-E-Bi-1, -2, -3, and -4, in Table 3.1). The ZrO_2 concentration in these glasses was varied from nearly zero (HLW-E-Bi-1) to more than 2 percent (HLW-E-Bi-4) to investigate its effect on PCT response because the normalized PCT leach rates, although well within the acceptable range, were higher than those for the baseline WTP HLW glasses (Table 3.2). However, even though the 7-day PCT results from three glasses with 40 wt% waste loading and increasing levels of ZrO_2 showed improvement, the magnitude of the improvement was not large enough to justify the introduction of another glass former.

Overall, at 40 wt% waste loading, as-melted glasses and samples heat treated for 70 hours at 950^{o}C showed minimal amounts of crystallization (about 0.1 vol% of spinel), moderate viscosity and electrical conductivity, and acceptable leaching performance (see Table 3.2). Further increase of the waste loading, by 5 wt% to 45 wt%, did not result in significant changes to the glass properties. Four glasses with waste loadings of 45% were prepared with varying concentrations of ZrO_2 (HLW-E-Bi-5), B_2O_3 (HLW-E-Bi-8), Na_2O (HLW-E-Bi-9), and K_2O (HLW-E-Bi-10). All four glasses showed similar melting behavior and heat treatment results (~0.5 vol % of spinel after 70 hours at 950^{o}C, see Table 3.2). Crystallization of spinel increased considerably when the waste loading was increased by another 5 wt% to 50 wt%. HLW-E-Bi-6, with 50 wt% waste loading, showed good melting behavior, slightly higher viscosity (96 poise at 1150^{o}C), and acceptable leaching rate (Table 3.2), but a considerably higher vol% of crystalline phase in the heat treated glass. As shown in Table 3.2, and Figure 3.1 (vol % crystals vs. temperature for four Bi glasses), 1.8 vol% of crystalline phases consisting largely of spinel was present in HLW-E-Bi-6 after heat treatment for 70 hours at 950^{o}C. The percentage of the crystalline phases increases roughly linearly with decreasing heat treatment temperature to about 4 vol% at 800^{o}C. As shown in Figure 3.1, the amount of crystals increases further with increasing waste loading. The crystal content in the glasses heat treated for 70 hours at 950^{o}C increases from 1.8 vol% at 50 wt% loading to 2.7 vol% at 55 wt% loading (HLW-E-Bi-7, -13, and -15), and further to 4.2 vol% at 60 wt% waste loading. Moreover, as-melted glasses with more than 50 wt% waste loading displayed a heterogeneous texture that is indicative of the presence of crystalline phases even at the glass melting temperature of 1200^{o}C. Thus, although the glasses with 55 wt%, 60 wt% and 65 wt% waste loading are reasonably leach resistant and show acceptable viscosity and electrical conductivity, the presence of crystallization at the melting temperature was considered undesirable. Therefore, HLW-E-Bi-6 with 50 wt% waste loading was selected as a reasonable high waste loading glass formulation with acceptable glass properties.

Heat treatment of this glass according to the WTP HLW canister center line cooling (CCC) profile resulted in around 5.6 vol% of crystallization, with roughly half spinel and half phosphate phases. It should also be noted that the glass after CCC treatment showed clear signs of foaming, especially near the top surface in contact with air (see Figure 3.2). Foaming was not observed in the glass sample after isothermal heat treatment at 950, 900, 850 or 800^{o}C. Consequently, the foaming behavior appears to be associated with the particular CCC temperature profile. This observation is of concern in that during waste processing, the glass poured into the canister may foam sufficiently to spill out of the canister and it, therefore, deserves further study. The normalized 7-day PCT results for HLW-E-Bi-6 after CCC heat treatment are quite comparable to those of the quenched crucible melt (Table 3.2). HLW-E-Bi-6UThR1, the radioactive version of HLW-E-Bi-6, showed properties that are virtually identical to those of HLW-E-Bi-6 (see Table 3.2, Table 3.3, and Figure 3.3).

HLW-E-Bi-6 has a relatively high melt viscosity at the typical melter operating temperature of 1150^{o}C. Substitution of 2 wt% of K_2O for Na_2O and SiO_2 in HLW-E-Bi-6 produced HLW-E-Bi-16 (Tables 3.1 and 3.2), which showed a lower melt viscosity of 70 poise at 1150^{o}C. However, the volume % of crystals after heat treatment at 950^{o}C for 75 hours increased from 1.8 % for HLW-E-Bi-6 to 2.7 % for HLW-E-Bi-16. Although the measured viscosity of HLW-E-Bi-6 of 96 poise at 1150^{o}C is within the range acceptable for melter operation, minor modifications would be advisable for the production glass in order to bring the viscosity closer to the center of the operating range.

The composition and properties of the high-Bi glass selected for melter testing are given in Table 3.4. The selected glass formulation, HLW-E-Bi-6, meets all of the processing and product quality requirements imposed for these tests and has a waste oxide loading of 50 wt%. This exceeds both the minimum and maximum expected waste loadings provided in the scope of work [3] of 15 wt% and 40 wt%, respectively. The glass contains 6.7 wt% Bi_2O_3 and close to

5 wt% P_2O_5. The Bi_2O_3 content is more than three times the WTP contract minimum for Bi_2O_3 (2 wt%). The PCT leach rates are over an order of magnitude lower than those of the DWPF-EA glass and the TCLP leachate concentrations are all below the WTP Delisting Limits. The measured processing parameters are within acceptable ranges. As noted above, the viscosity is towards the high end of the acceptable range, which is appropriate in view of the fact that a portion of the testing was performed at elevated temperature. One concern that remains is the potential risk of foaming during cooling of the poured glass in the canister. The potential foaming observed after CCC heat treatment and its mitigation requires further investigation. The phenomenon is likely associated with the redox behavior of Bi and other glass components with variable valence states.

3.2 Enhanced Glass Formulation for Cr-Limited Waste

Crucible melts spanning a range of waste loadings were prepared and tested to determine the maximum viable waste loading for the chromium-limited waste composition. Table 3.5 presents the compositions of one radioactive and 19 non-radioactive glasses investigated in this work, along with the Cr-limited waste composition specified by ORP [3]. The non-radioactive version of the Cr-limited waste composition, obtained by removing the radioactive components U and Th and renormalizing, is also given in Table 3.5. Beside its relatively high Cr_2O_3 concentration, the Cr-limited waste contains considerable amount of SO_3 and F (~1.5 wt% and 2 wt%, respectively). Chromium interacts with sulfates in borosilicate melts through the formation of chromates, which are isomorphous with sulfates. High concentrations of Cr_2O_3 and SO_3 can promote the formation of a separate chromium-containing sulfate or sulfur-containing chromate phase during glass melting or subsequent heat treatment. Fluorine can also increase the tendency towards the formation of molten sulfate phases. Thus, in view of the typically low solubility of sulfate and chromium oxide in borosilicate glasses, it is possible that waste loading of this waste would be limited by salt formation rather than chromium crystallization, which would be the case if the sulfate content was lower.

Formulation work for Cr-limited waste was started with glasses at 30 wt% waste loading, which is 50% over the contract-specified minimum of 20 wt%. HLW-E-Cr-14 (Table 3.6) is a typical sodium borosilicate waste glass except for its high K_2O content of 6 wt%. Potassium oxide was used as a glass former because previous work [1] indicated its potential advantage in suppressing the formation of Fe-rich spinel from iron-rich borosilicate glasses. Other work at VSL suggested that potassium and lead oxides would help enhance the solubility of chromium oxide in borosilicate glasses. The heat treated sample of HLW-E-Cr-14 showed minimal crystallization (~0.1% spinel after 70 hours at 950°C). For this borosilicate waste glass, which contains 1 wt% Cr_2O_3, a few percent of Fe_2O_3, and some NiO, this amount of crystallization is atypically low, probably due to the presence of potassium oxide. However, as the waste loading was increased further, sulfate/chromate phase separation, rather than Cr-rich spinel crystallization, became the limiting factor in identifying an acceptable glass formulation. Among eleven glasses formulated with 40 wt% waste loading (1.33 wt% Cr_2O_3, 0.46 wt% NiO, and 0.66 wt% SO_3, see Table 3.6), five developed a yellow colored salt phase (HLW-E-Cr-1, -2, -3, -8, -9 in Table 3.5), and three appeared partially crystallized (HLW-E-Cr-4, -5, -6 in Table 3.6). Analysis of the collected salt phase indicated a mixture of chromate-sulfate salt that had segregated from the glass melt during the melting process (Table 3.7). The crystalline phases were mostly spinel, with lesser amounts of escolaite and perhaps phosphate (Table 3.6). A close examination of the properties and composition of these eleven glasses at 40 wt% waste loading revealed a subtle balance between the segregation of sulfate salt phase and precipitation of spinel crystals. As shown in Table 3.7, potassium is a major component in the segregated chromate-sulfate salt phase. It is then logical that salt formation would decrease with decreasing K_2O concentration in the glass. Indeed, as K_2O was decreased from 11.16 wt% (HLW-E-Cr-1), 10.16 wt% (HLW-E-Cr-2), 7.66 wt% (HLW-E-Cr-3) to below ~5 wt% (HLW-E-Cr-4, -5, -6), the yellow salt phase disappeared. However, reduced K_2O in the glasses also reduced the solubility of Cr-rich spinel, as manifested by the crystals in the glass samples HLW-E-Cr-4, -5, -6. Fine-tuning of the concentrations of Li_2O (HLW-E-Cr-8) and B_2O_3 (HLW-E-Cr-9) resulted in an acceptable glass, HLW-E-Cr-7, with only trace amounts of crystalline phases and no apparent separation of chromate/sulfate phase. The role of PbO in suppressing crystallization of Cr containing spinel was also investigated in this group of glasses but with inconclusive results. For glasses that showed spinel crystallization (HLW-E-Cr-4, -5 and -6), PbO concentrations from 1.21 wt% (HLW-E-Cr-4, -5) to 2.21 wt% (HLW-E-Cr-6) did not appear to be effective in suppressing spinel crystallization. Nevertheless, HLW-E-Cr-10, which is a variation of HLW-E-Cr-7 without PbO did show a moderate increase in the total volume of crystals after heat treatment in the temperature range of 800 to 950^{o}C. Another variation of HLW-E-Cr-7 with increased ZrO_2 concentration and no PbO, HLW-E-Cr-11, did not show any improvement in the PCT response, as shown in Table 3.6. All formulations with higher waste loadings (42.5 wt%, 45 wt%, and 50 wt%) resulted in, to various extents, formation of yellow chromate/sulfate salt during glass melting. No beneficial effect on salt formation was observed with the addition of V_2O_5 (HLW-E-Cr-15, and Cr-16), CaO (HLW-E-Cr-18), reduced SiO_2 (HLW-E-Cr-17), or simply renormalization from Cr-10 (HLW-E-Cr-12 and HLW-E-Cr-13).

In conclusion, three Cr-rich borosilicate glasses with 40 wt% waste loading that meet all processing and product quality requirements were identified. The three glasses differ only in that HLW-E-Cr-7 contains 3 wt% of PbO, HLW-E-Cr-11 contains 1 wt% ZrO_2, whereas HLW-E-Cr-10 contains neither of these additives. Considering their rather similar properties and performance, the simplest version of the three glass formulations, HLW-E-Cr-10, was chosen as the candidate for melter testing. However, in view of the importance of salt phase formation, screening tests on the DM10 melter were recommended, and approved by ORP, prior to performing the DM100 tests.

The composition and properties of HLW-E-Cr-10 are given in Table 3.8. The selected glass formulation meets all of the processing and product quality requirements imposed for these tests and has a waste oxide loading of 40 wt%. This exceeds the minimum and equals the maximum expected waste loadings provided in the scope of work [3] of 20 wt% and 40 wt%, respectively. The target glass composition contains 1.33 wt% Cr_2O_3, 0.66 wt% SO_3, and over 3 wt% Bi_2O_3. The Cr_2O_3, SO_3, Bi_2O_3, and Al_2O_3 contents all equal or exceed their WTP contract minimum values of 0.5, 0.5, 2, and 11 wt%, respectively. This glass formulation has the highest waste loading tested that did not result in a separate salt layer on the crucible melt surface. The PCT leach rates are about five times lower than those of the DWPF-EA glass and the TCLP leachate concentrations are all below the WTP Delisting Limits. The measured processing parameters are within acceptable ranges.

The screening tests performed on the DM10 melter tests with HLW-E-Cr-10 at 40 wt% waste loading resulted in separate salt phase formation on the melt surface. This is not inconsistent with the batch crucible melt results because salt phase formation is influenced by both thermodynamic and kinetic factors, and due to kinetic factors, in a continuously fed melter, salt phase formation can occur even before the solubility limits for the respective components are reached in the melt. Indeed, this was exactly why the screening tests were performed. To address salt phase formation, the waste loading in the melter glass formulation was progressively reduced to determine the maximum loading at which no salt phase was seen (See Section 4.0). Based on the results of the DM10 melter tests, the glass formulation with 32.5 wt% waste loading was selected for further tests on the larger DM100 melter. Both radioactive (HLW-E-CrMUTh) and non-radioactive (HLW-E-Cr-M) versions of the glass at 32.5 wt% were prepared at the crucible scale and characterized. The results are discussed below.

The compositions and the characterization results for HLW-E-Cr-M and HLW-E-CrMUTh are listed together with results for HLW-E-Cr-10 in Tables 3.3, 3.5, and 3.6. The radioactive and non-radioactive versions of the selected Cr-limited glass yield similar PCT and TCLP results. The volume percent of crystalline phases after isothermal and CCC heat treatments are generally lower in HLW-E-CrMUTh (see Figure 3.4). Nevertheless, the same crystalline phases were observed in both glasses, including the submicron sized bubble-like feature in glass samples subjected to CCC heat treatment. Both HLW-E-Cr-M and HLW-E-CrMUTh meet all product quality (PCT and TCLP) and processing requirements (crystallinity, viscosity, and electrical conductivity). The waste loading achieved (32.5 wt%) significantly exceeded the minimum (20 wt%), specified in the contract [3].

In summary, although this waste stream is designated a "chromium-limited" waste, there are several components, including sulfur, phosphorus, and bismuth, that are present at high enough levels to potentially challenge borosilicate glass formulations. Indeed, the results of the present tests showed that the factor that limited waste loading was not the Cr content alone, but a combination of Cr and S concentrations and the interaction between these two components. As a result, the limiting factor was not Cr-rich spinel crystallization, rather the formation of a separate chromate-sulfate salt phase.

3.3 Enhanced Glass Formulation for Al-Limited Waste

Crucible melts spanning a range of waste loadings were prepared and tested to determine the maximum viable waste loading for the aluminum-limited waste composition [3]. Table 3.9 presents the compositions of one radioactive and 29 non-radioactive glasses investigated in this work, along with the Al-limited waste composition supplied by OPR [3] and the non-radioactive version of the Al-limited waste composition obtained by removing the radioactive components U and Th and renormalizing. Beside its high Al_2O_3 concentration (~50 wt%), the Al-limited waste contains considerable amounts of Fe_2O_3 and Cr_2O_3 (~13 wt% and 1.2 wt%, respectively). All three oxides are major constituents of a typical spinel phase. More importantly, high concentrations of Al_2O_3, with SiO_2 and alkali oxides in the glass matrix promote the formation of alkali-aluminosilicates; such phases can often form in very large amounts. Amongst these phases, nepheline ($NaAlSiO_4$) forms fairly readily and can significantly degrade PCT performance. A "nepheline index" has been proposed as a guideline for glass formulation in order to prevent nepheline formation [22, 23]. From the perspective of a simple chemical reaction, formation of nepheline should be influenced most significantly by the concentrations of its major constituents, Na_2O, Al_2O_3, and SiO_2. Since Al_2O_3 is the most abundant component from the Al-limited waste, it is thus prudent to avoid addition of Na_2O and to limit the SiO_2 concentration to the minimum level necessary to meet other glass property requirements. A principal aspect of the strategy employed in the formulation of Al-limited waste glasses was, therefore, the evaluation of flux chemicals other than Na_2O.

The formulation work for the Al-limited waste was started at 35 wt% waste loading, which is 40% over the contract-specified minimum of 25 wt% waste loading. HLW-E-Al-24 (Table 3.9) has an Al_2O_3 content of more than 18 wt%. Moderate amounts of Na_2O and Li_2O were added along with B_2O_3 as fluxes while SiO_2 was maintained at a relatively low ~35 wt%. Heat treatment of this glass at 800^oC and under CCC conditions showed around 0.1-0.2 vol% of spinel crystallization (Table 3.10), which is well within acceptable processing limits.

Seven glasses with 45 wt% waste loading were tested with various combinations of alkaline and alkaline earth oxide (Na_2O, Li_2O, and CaO) contents and at different concentrations of SiO_2. However, at 45% waste loading, a considerable amount of spinel was observed in two of the as-melted glasses (HLW-E-Al-23 and Al-26) at similar Na_2O and Li_2O concentrations as in HLW-E-Al-24. Two other glasses with higher CaO contents resulted in melt viscosities that were lower than desirable (HLW-E-Al-12 and Al-18, Table 3.10). Addition of P_2O_5 also resulted in considerable crystallization in the as-melted glass (HLW-E-Al-16). Glasses HLW-E-Al-25 and Al-27 with moderate CaO, Li_2O, and Na_2O were largely crystal free on melting, with acceptable viscosity and crystallization on heat treatment (isothermal and CCC, see Table 3.10). Addition of one more percent B_2O_3 in HLW-E-Al-27 as compared to HLW-E-Al-25 was effective in reducing the melt viscosity from 60 poise to 46 poise at 1150^oC while suppressing crystallization of calcium phosphate in samples subjected to CCC treatment.

Fourteen glasses with waste loading equal to or greater than 50 wt%, the maximum value specified in the contract [3], were prepared and characterized. All glasses with moderate to high contents of CaO displayed significant crystallization either in the as-melted glass (HLW-E-Al-2, 3, -5 and -10 with CaO from 14.2 wt% to 11.2 wt%) or after heat treatment at 950^oC (HLW-E-Al-7, -8, -9, -11 with CaO at 20.2 wt%, 18.2 wt%, 16.2 wt% and 14.2 wt%, respectively). Most remarkably, about 30 vol% of alkali aluminosilicate, apatite, and spinel was observed in HLW-E-Al-4 and Al-6 after 70 hours at 950^oC. Substitution of MgO for CaO in HLW-E-Al-1 also resulted in heavy crystallization in the as-melted glass in addition to its unacceptable viscosity. The higher Li_2O concentration in HLW-E-Al-14 at 50 wt% waste loading and HLW-E-Al-17 at 55 wt% waste loading were not effective in suppressing crystallization in the as-melted glass. Addition of Na_2O with Li_2O in HLW-E-Al-19 also was not effective in suppressing crystallization. Since none of the 50 wt% waste loading glasses had acceptable properties, a slightly lower waste loading of 47.5% was chosen for further tests.

Seven glasses at 47.5 wt% waste loading were tested. All seven glasses showed signs of crystallization in the as-melted samples. The majority of them also displayed rather low viscosity, as judged visually on pouring. Among them are two glasses with moderate Na_2O and CaO concentrations (HLW-E-Al-28 and Al-29), one with moderate Na_2O and added K_2O (HLW-E-Al-22), two with high Na_2O concentrations (HLW-E-Al-20 and Al-21) and two with low Na_2O and higher Li_2O and CaO concentrations (HLW-E-Al-15 and Al-13).

Based on these results, 45 wt% was selected as the optimum waste loading for this waste stream and the glass HLW-E-Al-27 was selected for melter testing. This waste loading is slightly lower than the maximum expected waste loading of 50 wt% [3]. After heat treatment at 950^{o}C HLW-E-Al-27 shows about 1 vol% crystalline phases, which is the current operational crystallization limit for WTP. The amount of crystallization increased with decreasing temperature up to about 7 vol% at 800^{o}C. The glass sample after CCC treatment showed less than 2 vol% spinel crystals.

The compositions and the characterization results of the non-radioactive and radioactive versions of the selected glass (HLW-E-Al-27 and HLW-E-Al-27UTh) are given in Tables 3.3, 3.9, and 3.10. Both of the glasses show similar PCT and TCLP responses. The volume percent of the crystalline phases after isothermal and CCC heat treatments are generally lower in HLW-E-Al-27UTh than in HLW-E-Al-27 (Figure 3.5). Both glass samples, however, showed the same types of crystals. Table 3.11 presents the composition of the glass selected for processing on the DM100 and the measured properties of the crucible glass. The selected glass formulation, HLW-E-Al-27, meets all of the processing and product quality requirements imposed for these tests and has a waste oxide loading of 45 wt%. This exceeds both the minimum waste loading of 25 wt% and approaches the maximum expected waste loading of 50 wt% provided in the Scope of Work [3]. The glass contains 23.97 wt% Al_2O_3, which is more than two times the WTP contract minimum for Al_2O_3 (11 wt %). All of the measured processing parameters are within acceptable ranges. The PCT leach rates are over an order of magnitude lower than those of the DWPF-EA glass and the TCLP leachate concentrations are all below the WTP Delisting Limits. Sodium aluminosilicate formation (e.g., nepheline) on heat treatment (especially canister centerline cooling (CCC) heat treatment) is a known concern with high-aluminum formulations and was the waste-loading-limiting factor in the present work. The selected glass produced very little crystallization (~1.9 vol%) after CCC heat treatment and the heat treated glass also meet the PCT requirements by a wide margin. It is worth noting that the frequently-employed “nepheline discriminator” [22, 23] would have erroneously rejected this glass in favor of lower-waste-loading alternatives.

3.4 Enhanced Glass Formulation for Al-Na-Limited Waste

A total of one radioactive and 26 non-radioactive glasses were tested to identify a suitable glass formulation for the Al-Na-limited waste stream. As shown in Table 3.12, in addition to 43 wt% of Al_2O_3, which is close to that in the Al-limited waste, the Al-Na limited waste also contains ~26 wt% Na_2O and more than 4 wt% P_2O_5. The Al-Na-rich waste was the most challenging among the four waste streams because a melt rich in Al_2O_3, Na_2O, and SiO_2 tends to crystallize aluminosilicate phases such as nepheline, sodalite, and other silicates. To further complicate the formulation, the relatively high content of P_2O_5 in the Al-Na limited waste (almost double that of the Al-limited waste) tends to increase the propensity for precipitation of alkaline or alkaline earth phosphates (e.g., lithium phosphate, calcium phosphate, etc.). Consequently, the formulation selected for the Al-limited waste may not be suitable for this waste stream. In addition, the high Na_2O concentration in the waste stream allows even less flexibility in glass formulation. Similar to the Al-limited formulation, the formation of crystalline silicate or phosphate phases could be detrimental because of the potential for extensive crystallization of silicates or the formation of phases that degrade PCT response such as nepheline and lithium phosphate. The formulation work on Al-Na limited wastes was, therefore, focused on optimizing the balance between maximizing waste loading and the inhibition of the aforementioned crystallization.

Crucible melts spanning a range of waste loadings were prepared and tested to determine the maximum viable waste loading for the aluminum-sodium limited waste composition. Table 3.12 presents the compositions of the 26 glasses investigated in this work, along with the Al-Na-limited waste and non-radioactive version of the Al-Na-limited waste obtained by removing the radioactive components U and Th and renormalizing. The strategy employed in the formulation of Al-Na-limited waste was focused on identifying the appropriate amounts of flux chemicals other than Na_2O (in particular, CaO and Li_2O, the two components used successfully for the Al-limited waste formulation).

The formulation work for Al-Na-limited waste was started at 42 wt% waste loading, which is more than double the specified minimum of 20 wt% [3]. HLW-E-ANa-1 (Table 3.12) is similar to the glass HLW-E-Al-24 (Table 3.9, 35 wt% loading), with similar Al_2O_3, higher Na_2O (from the waste), and higher P_2O_5. Although the as-melted glass appeared normal and only 0.3 vol% of Cr-Fe oxide crystallized after 70 hours at 950°C, the melt viscosity judged visually by glass pouring seemed rather high. No further characterization was conducted on this glass in order to concentrate on the development of Al-Na-limited glasses with higher waste loading.

The formulation using Li and Ca as the major fluxes (in addition to Na from the waste and added B) resulted in extensive crystallization, in particular, of calcium phosphate and spinel. As evident from Table 3.13, at waste loadings of 43 wt%, 45 wt%, and 47 wt%, as-melted glass samples with both Li and Ca as fluxes showed minor or trace amounts of crystals. However, considerable amounts of calcium phosphate formed on CCC heat treatment in glasses HLW-E-ANa-19 (43 wt% waste loading with 5.7% CaO), HLW-E-ANa-17, -18 (45 wt% waste loading with 5.69% CaO), and HLW-E-ANa-13, -20, and -21 (47 wt% waste loading with 5.72% CaO for ANa-13 and 3.72% CaO for the other two). The amounts of phosphate and sodium aluminosilicate crystallization became massive at higher waste loadings for glasses with both Li and Ca, as demonstrated by HLW-E-ANa-14, -15 and -16 at 52 wt% loading. The volume percent of crystalline phases after CCC heat treatment ranged from 20 to 60 vol%. These results suggest that CaO is not a suitable fluxing additive for the Al-Na-limited waste due to its high P_2O_5 content. Therefore lithium oxide was preferred, particularly considering that Li^+ is too small to be incorporated into the nepheline structure.

The formulation using Li as the main flux (in addition to Na from waste and added B) started with HLW-E-ANa-2 at 47 wt% waste loading (Tables 3.12 and 3.13). The as-melted glass was crystal free with acceptable PCT responses. Heat treatment at 950°C resulted in only 0.3 vol% spinel crystallization. However, the glass melt seemed rather viscous, as judged visually on pouring. The viscosity was still relatively high for HLW-E-ANa-4, which had 1 wt% Li_2O added (89 poise, Table 3.13). Although this glass with additional Li had very similar PCT response and isothermal heat treatment result as HLW-E-ANa-2, up to 5 vol% of spinel and nepheline-like phases were identified in the sample after CCC heat treatment. Addition of another 4 wt% B_2O_3 (HLW-E-ANa-22 and HLW-E-ANa-23) significantly suppressed the crystallization and, in particular, that of the nepheline-like crystalline phases. HLW-E-ANa-23 with an additional 3% ZrO_2 replacing SiO_2 resulted in about 1.3 vol% of spinel and Fe-Cr oxide after CCC heat treatment; HLW-E-ANa-22 with increased B_2O_3 showed only 0.5% of spinel and Fe-Cr oxide after CCC treatment. Two glasses of similar composition but with higher waste loadings (50%) resulted in more crystallization after CCC treatment: 2-3 vol% of spinel and nepheline crystals were present in HLW-E-ANa-24 and 1.5-2 vol% crystals were present in HLW-E-ANa-25 (which contains 1 wt% additional B_2O_3). The majority of the glasses made using Li as the flux with waste loadings greater than 50 wt% encountered problems associated with crystallization of either nepheline-like phases after CCC heat treatment (HLW-E-ANa-5, ANa-26, ANa-9, ANa-11) or in as-melted glass samples (HLW-E-ANa-8, ANa-10, ANa-7 and ANa-12). Two glasses (HLW-E-ANa-3 and ANa-6) displayed melt viscosities that appeared too high for processing and, therefore, were not further characterized.

The test results suggest that an optimum waste loading for the Al-Na-limited waste is around 47 to 50 wt%, as exemplified by HLW-E-ANa-22 and ANa-25. With the Al_2O_3 content around 22 wt% and the Na_2O content around 13 wt%, the addition of B_2O_3 seemed most effective at suppressing crystallization of nepheline-like crystalline phases. From HLW-E-ANa-22 to ANa-25, the 3 wt% gain in waste loading comes with an increased level of crystallization under CCC conditions and, in particular, crystallization of nepheline. The other test data suggest that the amount of nepheline can rise quickly above about 50 wt% waste loading, potentially leaving little room for process variations. Therefore, although the two glasses have very similar PCT responses, viscosity, and electrical conductivity, the slightly lower waste loading HLW-E-ANa-22, which showed no sodium aluminosilicate crystallization, was selected as the best candidate for the DM100 tests.

The compositions and properties of the non-radioactive and radioactive versions of the selected glass (HLW-E-ANa-22 and HLW-E-ANa22UTh) are listed together in Tables 3.3, 3.12, and 3.13. Both glasses show similar PCT and TCLP responses. The volume percent of the crystalline phases after isothermal and CCC heat treatments are generally lower in HLW-E-CrMUTh (Figure 3.6). The same crystal phases were, however, observed in both glasses. Table 3.14 presents the composition of the glass selected for testing on the DM100 and the measured properties of the crucible glass. The selected glass formulation, HLW-E-ANa-22, meets all of the processing and product quality requirements imposed for these tests and has a waste oxide loading of 47 wt%. This is more than twice the minimum waste loading of 20 wt% and approaches the maximum expected waste loading of 60 wt% provided in the Scope of Work [3]. The glass contains 21.34 wt% Al_2O_3, which is nearly twice the WTP contract minimum for Al_2O_3 (11 wt%). The glass also contains 12.71 wt% Na_2O; this is below the WTP contract minimum for Na_2O+ K_2O (15 wt%) because of the high aluminum concentration. The measured processing parameters are within acceptable ranges. The PCT leach rates are more than a factor of four lower than those of the DWPF-EA glass and the TCLP leachate concentrations are all below the WTP Delisting Limits. Sodium aluminosilicate formation (e.g., nepheline) on heat treatment (especially canister centerline cooling heat treatment) is a known concern with high-aluminum formulations and was the waste-loading-limiting factor in the present work. The selected glass produced very little crystallization (~0.5 vol%) after CCC heat treatment and the heat treated glass also meets the PCT requirements by a wide margin. It is worth noting that the frequently-employed "nepheline discriminator" [22, 23] would have erroneously rejected this glass in favor of lower-waste-loading alternatives.

SECTION 4.0
DM10 MELTER OPERATIONS

Results from crucible scale testing with chromium limited waste showed that in spite of the high chromium content, the waste loading was not limited by crystallization but by sulfate-chromate salt formation due to the relatively high sulfate concentration in this waste, compounded by the chemical similarity and known interactions between sulfate and chromate. For this reason, screening tests were performed on the DM10 melter system to determine the maximum waste loading possible without forming secondary sulfate phases on the melt surface. A summary of the twelve tests conducted on the DM10, including feed composition, melter operating conditions, and sulfate layer identification, is provided in Table 4.1. The variation in the concentration of several oxides in the glass discharges over the course of the tests is shown in Figures 4.1 and 4.2.

Based on results from the crucible tests, the first test employed the 40% waste loading glass. A secondary sulfate layer was observed at the end of this test and, therefore, tests were conducted at successively lower waste loadings until a separated sulfate phase was not observed on the melt pool surface. No separated sulfate phase was observed at 30% waste loading and initial tests at 32.5% waste loading were not definitive due to the incompleteness of turnover in Test 5 and the minute trace of a sulfate phase on a single dip sample from Test 6. At the end of a repeated test at 32.5% waste loading conducted at the lower melt temperature of 1150°C, no secondary sulfate phase was observed on dip samples and therefore the glass composition with this waste loading was advanced for testing on the DM100. The composition of this glass and select measured properties are provided in Table 4.2.

Tests conducted using vanadium and sugar as additives were unsuccessful in increasing the waste loading attainable without the formation of a secondary sulfate phase or had other undesirable effects. In Test 2, 10 g sugar per liter was added to the feed, which reduced some of the sulfur thereby increasing sulfur emissions while decreasing the amount of sulfur in the glass product. As a result, no separate sulfate layer was observed at 40% waste loading. However this level of sugar addition resulted in the reduction of 28% of the iron to the divalent state and caused the measured concentration of bismuth in the product glass to drop by more than a factor of two, presumably due to reduction of bismuth to the metallic state causing it to settle out of the glass melt. The redox sensitivity of bismuth is an issue that deserves further investigation for bismuth-containing wastes since metal deposition could seriously affect melter lifetime and operations. The decreases in sulfur and bismuth concentrations are readily observed at about 40 kg glass production in Figures 4.1 and 4.2. Based on results from high-sulfur LAW melter tests, vanadium was added to the feed to achieve one percent vanadium oxide in the glass product in several tests to determine if it decreased the tendency to form a separate salt phase. However, the results of these tests are indistinguishable from comparable tests without vanadium, even when small amounts of sugar were added to the feed. Therefore, since no increase in waste loading was observed with vanadium, the 1 wt% V_2O_5 addition was not tested on the DM100. Instead, the 32.5 wt% waste loading formulation was selected as the best option.

SECTION 5.0
DM100 MELTER OPERATIONS

Melter tests were conducted on the DM100-BL between 7/17/06 and 11/20/06. These tests produced over three metric tons of glass from almost nine and a half metric tons of feed. Prior to feeding a new glass composition, the glass inventory was reduced from about 180 kg to about 100 kg in order to decrease the feeding time required to change over the composition of the glass pool. The series of sixteen nominally 50-hour tests were divided as follows:

- Bismuth-Limited Waste – 794 kg of Glass Produced
    - 1175°C glass temperature, optimized bubbling, 500 g glass per liter feed.
    - 1175°C glass temperature, 9 lpm bubbling, 500 g glass per liter feed.
    - 1150°C glass temperature, 9 lpm bubbling, 500 g glass per liter feed.
    - 1150°C glass temperature, 9 lpm bubbling, 250 g glass per liter feed.

- Chromium-Limited Waste – 540 kg of Glass Produced
    - 1175°C glass temperature, 9 lpm bubbling, 500 g glass per liter feed.
    - 1150°C glass temperature, 9 lpm bubbling, 500 g glass per liter feed.

- Aluminum-Limited Waste – 793 kg of Glass Produced
    - 1175°C glass temperature, optimized bubbling, 500 g glass per liter feed.
    - 1175°C glass temperature, 9 lpm bubbling, 500 g glass per liter feed.
    - 1150°C glass temperature, 9 lpm bubbling, 500 g glass per liter feed.
    - 1150°C glass temperature, 9 lpm bubbling, 250 g glass per liter feed.
    - 1150°C glass temperature, optimized bubbling, 500 g glass per liter feed.

- Aluminum-Plus-Sodium-Limited Waste – 934 kg of Glass Produced
    - 1175°C glass temperature, optimized bubbling, 500 g glass per liter feed.
    - 1175°C glass temperature, 9 lpm bubbling, 500 g glass per liter feed.
    - 1150°C glass temperature, 9 lpm bubbling, 500 g glass per liter feed.
    - 1150°C glass temperature, 9 lpm bubbling, 250 g glass per liter feed.
    - 1150°C glass temperature, optimized bubbling, 500 g glass per liter feed.

Fewer tests were performed on the DM100 with the chromium-limited waste because of the need to perform the screening tests on the DM10 for this waste stream.

Summaries of the tests are provided in Tables 5.1-5.4. Attempts were made to replicate the melter configuration and operating conditions used for previous tests with HLW simulants [7-10, 17, 18, 24]. These conditions include a near-complete cold cap, which is between 80-95% melt surface coverage for the DM100 since a 100% cold cap tends to lead to "bridging" in smaller melters. The bubbling rate was either fixed at 9 lpm and the feed rate was adjusted to maintain a complete cold cap or the bubbling rate was optimized to achieve the maximum production rate. This use of bubbling is in contrast to some previous tests where the production rate was fixed between 1000 to 1050 kg/m^2/day and the bubbling rate was adjusted to maintain the complete cold cap [7-10, 18]. The approach used in the present tests permits the evaluation of the effects of waste composition, glass temperature, glass pool bubbling, and feed solids content on production rate. Figures 5.1.a – 5.1.i illustrate the glass production rates as moving hourly averages throughout the tests. Steady-state production rates for current and previous tests [7, 17, 24] are tabulated in Table 5.5 and depicted in Figures 5.2 – 5.4. All parameters tested, including waste/feed composition, glass temperature, glass pool bubbling, and feed solids content, had an effect on glass production rate. As expected, glass production rates increased with increased bubbling rate, glass pool temperature, and feed solids content; however, the effect of waste composition was greater than any other tested variable. Notice in Figure 5.2 at constant bubbling rate and feed solids content, as well as in Figure 5.3 at constant glass temperature and feed solids content, that glass production rate ranged between 400 and 1400 kg/m^2/day over the waste compositions tested. WTP waste compositions previously tested, the vast majority of which were high in iron (as also has been the case at WVDP and DWPF), processed at the highest rates, whereas waste compositions high in aluminum processed at the slowest rates. The higher processing rates are not only attributable to the differences in waste composition but also the lower waste loadings (24-28 vs. 45-47 wt. % oxide) used in many of the previous tests [7, 17]. It is also noteworthy that of the four glass compositions tested, the highest production rates at constant bubbling were obtained for the chromium-limited waste, which had the lowest waste loading (32.5 wt%). The observed increases in production rate in response to increases in melt pool bubbling, glass temperature, and feed solids content also showed large variations with waste composition. Glass production rates increased 40-300% with optimized glass pool bubbling, 0-125% with a 25°C increase in glass pool temperature, and 40-60% with a doubling of the feed solids content.

Overall, there were no significant difficulties in processing these feed and glass compositions during these tests. Cold cap conditions were similar to the range of conditions observed in previous tests with HLW feeds [7-10, 17, 18, 24]. The chromium-limited waste formed a more fluid cold cap, which spread more evenly across the melt surface and was less likely to adhere to melter walls to form “shelves” and “bridges”. In contrast, the aluminum-limited waste streams showed a greater tendency to form shelves and bridges that limited the steady-state production rates. On occasions during Tests 1a, 5b, 6b, 7b and 8c, feeding was intentionally paused to allow deposits in the plenum space to be assimilated into the glass in order to better determine the actual steady-state, cold-cap-limited feed rate. Other, shorter interruptions were required during testing in order to energize the top pair of electrodes, transfer feed to the feed tank, adjust the feed line in the peristaltic pump as a result of wear from the pump rollers, and to perform other maintenance activities. Spikes in feed rate often occurred immediately after feed transfers due to adjustments in tank mixer speeds and pump settings. During steady-state feeding periods, production rates typically vary by about ten percent from the mean rate. No foamy glass was observed in the glass discharge and no foam was observed on the melt pool surface or cold cap.

The results of various operational measurements that were made during these tests are given in Tables 5.5 – 5.9. Glass bubbling rates are shown in Figures 5.5.a – 5.5.e, glass temperatures are shown in Figures 5.6.a – 5.6.i, plenum temperatures in Figures 5.7.a – 5.7.i, electrode temperatures in Figures 5.8.a – 5.8.i, and glass resistance in Figures 5.9.a – 5.9.i;

electrode power is included in the figures with electrode temperatures and glass resistance. The target bubbling rate of 9 lpm was maintained throughout the designated tests. Conversely, in other tests, the cold cap was constantly monitored and the bubbling rate was frequently adjusted to achieve the maximum cold-cap-limited feed rate. The test-average optimized bubbling rates were one-and-a-half to two times higher than the nominal bubbling rate of 9 lpm. Bulk glass temperatures (measured at 5 and 10 inches from the bottom of the melt pool) were largely within 10°C of the target glass temperatures of 1175°C and 1150°C throughout the vast majority of the tests. The test-segment-average bulk glass temperatures were 1166 - 1178°C and 1148 - 1161°C for tests targeting glass temperatures of 1175°C and 1150°C, respectively. Glass temperatures closer to the top of the melt pool (measured at 16 and 27 inches from the bottom) are not reliable indicators of bulk glass temperatures as a result of their sensitivity to variations in the level of glass in the melter and gradients near the melt surface. Glass temperatures measured at these locations were even lower at the beginning of tests with each new waste composition, prior to the glass level in the melter being increased to above the upper pair of electrodes. Plenum temperatures typically ranged from 250 to 450°C, which is lower than the 550 to 650°C target. These lower temperatures were the consequence of maintaining a more complete cold cap. The lower pair of electrodes was hotter than the upper pair of electrodes at the beginning of tests with each composition due to the lower glass levels at the beginning and end of the tests with each composition. The top pair of electrodes was also colder than the bottom pair in tests with production rates below 500 $kg/m^2/day$. Once the melter was filled with glass above the top electrodes, the two electrode pairs typically averaged 50 to 100 degrees lower than the glass pool. The bottom electrode, which was not powered, ranged between 630 and 830ºC. Power supplied to the electrodes typically varied between 9 and 26 kW. As expected, more power was required as the bubbling rate and, therefore, production rate increased. The opposite trend is observed when power usage is normalized to glass production due to the amount of energy required to maintain the glass pool at the target melting temperature. The calculated glass pool resistance decreased dramatically as the melter was filled with glass, as would be expected. Relative increases in resistance were observed with glass pool temperature decreases, feed water content increases, and with the aluminum-limited waste composition.

The gas temperature at the film cooler averaged between 254-282ºC and depended on the plenum temperature, the amount of added film cooler air, and the temperature of the added film cooler air. Drops of less than twelve degrees in gas temperature were observed across the (insulated) transition line; the high temperature is maintained in order to prevent condensation in the downstream filtration units.

SECTION 6.0
FEED SAMPLE AND GLASS PRODUCT ANALYSIS

6.1 Analysis of Feed Samples

6.1.1 General Properties

Feed samples from each test were analyzed to confirm physical properties and chemical composition. Samples were taken during melter testing from an inline sampling port. Sample names, sampling dates, and measured properties are given in Table 6.1. All samples were measured for both density and pH; at least one sample per unique waste composition and water content was analyzed for water content, glass conversion ratio, rheological properties, and oxide composition by XRF. The measured glass conversion ratio for all feed samples from tests targeting 500 g glass per liter were all within five percent of the target (see Tables 5.1-5.4 for target values) on a weight per weight basis, validating the use of the target conversion ratio for calculating glass production rates. Samples from tests targeting 250 g glass per liter had measured glass conversion ratios of 2 to 15% below the target values due to the difficulty in obtaining representative sub-samples for analysis. The low bias in measured glass conversion ratios can partially be attributed to water added to flush feed lines during feed transfers. The water content, density, glass yield, and pH varied within a narrow range for each feed type and water content. As intended, values for these parameters are lower for comparable samples at the lower target solids content of 250 g glass per liter.

6.1.2 Rheology

Samples of the melter feeds that were used for these tests were also subjected to rheological characterization. The results from rheological characterization of a variety of other melter feeds and waste simulants, as well as the effects of a range of test variables, are described in detail in a separate report [25]. Melter feeds were characterized using a Haake RS75 rheometer, which was equipped with either a Z40DIN or a FL22-SZ40 sensor. A typical set of measurements consists of identifying the flow characteristics of the slurry by measuring the shear stress on the slurry at controlled shear rates and temperatures. In these measurements, the shear rate values are preset and are increased stepwise from 0.01 s^{-1} to 200 s^{-1} (70 s^{-1} for FL22-SZ40) with a sufficient delay (typically 15 to 30 seconds) between steps to ensure that the shear stress is allowed to fully relax and therefore is measured at equilibrium. This approach is somewhat different from the "flow curve" approach in which the shear rate is ramped up to some maximum value and then ramped back down to produce a hysteresis curve that is dependent on the selected ramp rate. The viscosity of the sample as a function of the shear rate is then calculated as the ratio of the shear stress to the shear rate. The yield stress data for the melter feeds were measured using a controlled-stress mode in which the torque on the rotor was slowly increased while the resulting deformation of the fluid was monitored. The discontinuity in the measured deformation-torque curve was identified as the yield stress. It should be noted that this direct measurement of the yield stress can be quite different from the value that is often reported as the yield stress, which is obtained by extrapolation of the shear stress-shear rate curve to zero shear rate. All of the measurements in this work were made at 25°C; previous work [25], which examined a range of temperatures, showed a relatively weak effect of temperature.

Rheograms for the melter feeds, which show the feed viscosity versus shear rate, are presented in Figure 6.1; measured values for viscosity at selected shear rates and the yield stress are shown in Table 6.1. The aluminum-limited waste stream resulted in the most viscous feed, even when diluted to 250 g glass per liter. The least viscous feeds were those for the bismuth- and aluminum-plus-sodium-limited waste streams. As expected, each feed became significantly less viscous when diluted to 250 g glass per liter. The yield stress values exhibited the same trends as those described for the viscosity at low shear rates. All feeds were processed by the feed system without significant difficulties.

6.1.3 Chemical Composition

The methods used for analysis of feed sample chemical compositions are described in Section 1.5. The boron and lithium oxide target values were used for normalizing the XRF data since their concentrations were not determined by XRF. These results, compared to the target composition in Table 6.2, generally corroborate the consistency of the feed compositions and show good agreement with the target compositions for the major elements. All oxides with target concentrations greater than one percent deviated less than 10% from target for feed samples with bismuth- and aluminum-limited waste. The feed samples for the chromium-limited waste were within 10% of the target except for chromium and phosphorus oxides, which averaged 0.12 and 0.16 wt % absolute deviation above the target values. Deviations from target in the analysis of the feed sample for the aluminum-plus-sodium-limited waste are partially attributable to segregation during sub-sampling. This is discerned from the low glass recovery (Table 6.1) and the oxide deviations for sample BLN-F-107A. Samples with low solids content are difficult to sub-sample due to rapid settling of particulate matter. Once a biased sub-sample is taken, the remaining parent sample is also biased with respect to solids and, therefore, is no longer representative of the original feed, thus preventing further sub-sampling and analysis. Measurements from other feed samples with the aluminum-plus-sodium-limited waste are much closer to target values, supporting this contention. The composition of this feed is further corroborated by comparison to the product glasses (see Section 6.2.1), which shows all oxides with concentrations greater than 1 wt% in the target composition to be within 10% of the target except for iron, which had a absolute deviation of only 0.32 wt % in the non-segregated feed samples (BLN-F-9A and BLN-F-152A).

Low concentrations of manganese in all feeds, as well as titanium, neodymium, and chlorine in some feed compositions, were measured, even though they are not included in the target composition. Also, common elements such as magnesium, titanium, zirconium, potassium, barium, and calcium, when targeted at low concentrations, were typically above these targets. These positive deviations are often observed in melter feeds due to their ubiquity in the raw materials used to make up the simulants and in the glass forming additives. Cadmium was not detected in feed samples by XRF even though it is included at very low concentrations in two of the simulated waste streams. Analysis of the product glass using a method other than XRF (see Section 6.2.1) indicates the cadmium is present at the low target concentrations; however, these concentrations are below the sensitivity of the XRF for these glass matrices. Analyzed sulfur concentrations are below target concentrations due to volatilization during sample preparation.

6.2 Analysis of Glass Samples

Over three metric tons of glass was produced in these tests. The glass was discharged from the melter periodically into 5-gallon carbon steel pails using an airlift system. The discharged product glass was sampled at the end of each test by removing sufficient glass from the top of the cans for total inorganic analysis. Product glass masses, discharge date, and analysis performed are given in Tables 6.3-6.6. Glass samples were also obtained by dipping a rod into the glass pool at the beginning and end of each test. These "dip samples" underwent visual examinations to detect the presence of separate sulfate or crystalline phases on the glass surface as well as examination by SEM-EDS to determine the extent of crystallization in the melt pool.

6.2.1 Compositional Analysis of Discharge Glasses

All discharge glass samples were crushed and analyzed directly by XRF. The target values for boron and lithium oxides, which are not determined by XRF, were used for normalizing the XRF data to 100 wt%. The XRF analyzed compositions of discharged glass samples are provided in Tables 6.7-6.10. The majority of the XRF analysis results compared very favorably to their corresponding target values and feed sample analyses (see Section 6.1.3). Oxides with a target concentration greater than 1 weight percent showed less than 10% deviation from the target values. Exceptions are a deficit of nickel in the glasses from the bismuth-limited composition; surpluses of bismuth and chromium in the glasses from the chromium-limited composition due to insufficient glass production during the test to reduce the high concentrations of these elements present from the previous test; and a surplus of iron in the glasses from the aluminum-plus-sodium-limited composition, also observed in the feed samples. The origin of the nickel deficit in the bismuth-limited glasses is unclear since it was not observed in the feed samples. Also, nickel-bearing crystalline phases, although detected in dip samples, were lower in concentration in the bismuth-limited dip sample glasses than the in the dip sample glasses from the aluminum-plus-sodium composition, which did not have an analyzed nickel deficit. Similar to feed sample analysis, manganese in all glasses, as well as chlorine, neodymium, and titanium in some glasses (which are not in the target compositions), were measured at low concentrations in the product glasses. Also similar to feed sample analysis, common elements such as magnesium, titanium, zirconium, potassium, barium, and calcium, when targeted at low concentrations, were typically above their respective targets. Sulfur is below target for almost all glasses due to volatilization from the glass pool and cold cap.

Corroborative analysis using DCP on solutions of acid-dissolved glass was performed on select glasses produced from each test; the results are compared to the XRF analysis in Table 6.11. Values for all the major oxides compare favorably with the XRF analysis and target composition except for sodium, which often exhibits a low bias using this procedure [13] and chromium. The closeness of the DCP boron and lithium analysis to the target (deviations less than 10%) validates the use of the target boron and lithium concentrations for normalizing the XRF data. Relative deviations for lithium are larger for glass generated from the bismuth-limited waste due to the low lithium concentrations (lithium was not used as an additive in this test); however, the absolute deviations are less than 0.14 wt%. Cadmium concentrations measured by DCP are very close to target values, whereas the XRF method was not able to detect these low levels of cadmium.

Compositional trends for selected oxides shown in Figures 6.2-6.5 illustrate the closeness to targets at the end of tests with each composition. Exceptions include volatile species such as sulfur and fluorine, which remain significantly below target concentrations as a result of significant release to the melter exhaust. During tests with bismuth-limited wastes, bismuth, nickel, phosphorus, potassium, sulfur, sodium, fluorine, and chromium increase in concentration at the expense of iron, manganese, zinc, and silicon as the steady-state composition is approached. Subsequently, silicon, potassium, sulfur, fluorine, and chromium increase in concentration at the expense of sodium, bismuth, nickel, phosphorus, and iron as the glass pool transitioned from the bismuth- to the chromium-limited composition. The subsequent transition to the aluminum-limited waste composition resulted in increases in the concentrations of aluminum, calcium, sodium, fluorine, and lead at the expense of bismuth, potassium, and silicon. Testing ended with sodium, phosphorus, silicon, and sulfur increasing in concentration in the product glass at the expense of aluminum, calcium, iron, and lead as the glass pool transitioned to the aluminum-plus-sodium-limited composition. Common elements that are present in the target composition at low concentrations, such as potassium and magnesium, are observed at above target concentrations in the discharged glass, presumably due to contaminants in the glass forming chemicals. Chromium and nickel are observed at above target concentrations in some of the discharged glasses, presumably due to corrosion of the high-chromium melter bricks and Inconel components.

6.2.2 Chemical Durability of Discharge Glasses

Glass discharge samples from the end of at least two test segments for each waste composition were evaluated for chemical durability using the PCT and TCLP methods. The PCT results are compared to those for the benchmark DWPF-EA glass in Table 6.12 and the TCLP results are compared to the WTP delisting limits [29, 30] and Universal Treatment Standard (UTS) limits in Table 6.13. The chemical durability determined by both of these methods is excellent for the melter glasses. All measured PCT concentrations and normalized leach rates on discharge glass samples are at least ninety times lower than the corresponding values for the DWPF-EA glass. All regulated TCLP leachate concentrations are less than 1 mg/l and more than an order of magnitude less than WTP delisting limits. All measured concentrations are also well below the UTS limits. The highest TCLP leachate concentrations were for bismuth, which were less than or equal to 1 mg/l. The chemical durability of these glasses produced from wastes limited by bismuth, chromium, aluminum, and aluminum plus sodium is similar to that for glasses formulated with iron-limited waste [1]. The measured durability is also similar to durability for corresponding radioactive glasses produced in crucible melts (see Table 3.3).

These results confirm that glasses can be formulated from a variety of waste loading limiting constituents without compromising the quality of the vitrified product.

6.3 Glass Pool Samples

Glass pool samples were obtained to provide a conservative estimate of the extent of secondary phases in the glass melt in each test. However, even though the small dip samples cool much more quickly that the discharge samples, there is still the potential for crystallization during cooling of the dip sample. As a result, the crystal contents found in the dip samples will always overestimate the amount actually present in the melt pool at the time of sampling. A list of all dip samples including sample names, sampling dates, target glass pool temperature, visual observations of secondary phases, and SEM analysis are given in Table 6.14. These samples were also useful in detecting secondary phases on the melt pool surface, particularly sulfate in the tests with the chromium-limited waste. There was no visual evidence of secondary phases in the samples at the time of sampling as either material adhering to the sampling rod indicative of a surface layer or macroscopic features indicative of crystalline phases in the glass. However, SEM observations indicated that the glasses contained between 0.2 to 1.1 volume percent crystals. These crystal phases in glass samples were primarily spinels rich in iron, chromium, nickel and aluminum in all tests except tests conducted with chromium-limited waste. The amount of aluminum in the crystal phases observed varied with the concentration of aluminum in the product glass. No bismuth was observed in any of the secondary phases. The secondary phases observed in glasses produced from the chromium-limited waste were fine grained chromium oxide aggregates accounting for only 0.3 volume percent of the glass. The amount of crystalline phases observed in these glasses is consistent with observations on the same glass compositions from crucible scale testing (see Section 3.0). The ease of discharging these glasses during testing coupled with the low crystal content of these glass samples indicate that secondary phase formation should not be a concern in processing these compositions. The lack of secondary sulfate adhering to sampling rods used during the tests with the chromium-limited waste confirms the results obtained in the DM10 screening tests.

SECTION 7.0
MONITORED OFF-GAS EMISSIONS

7.1 Particulate Sampling

The melter exhaust was sampled for metals/particles according to 40-CFR-60 Methods 3, 5, and 29 at steady-state operating conditions during each test segment. The concentrations of off-gas species that are present as particulates and gaseous species that are collected in impinger solutions were derived from laboratory data on solutions extracted from air samples (filters and various solutions) together with measurements of the volume of air sampled. Particulate collection required isokinetic sampling, which entails removing gas from the exhaust at the same velocity that the air is flowing in the duct (40-CFR-60, Methods 1-5). Typically, a sample size of 30 dscf was taken at a rate of between 0.5 and 0.75 dscfm. Total particulate loading was determined by combining gravimetric analysis of the standard particle filter and chemical analysis of probe rinse solutions. An additional impinger containing 2 N NaOH was added to the sampling train to ensure complete scrubbing of all acid gases and, particularly, iodine. The collected materials were analyzed using direct current plasma atomic emission spectroscopy for the majority of the constituents and ion chromatography (IC) for anions. Melter emission fluxes are compared to feed fluxes in Table 7.1. Notice the distinction that is made between constituents sampled as particles and as "gas". The "gaseous" constituents are operationally defined as those species that are scrubbed in the impinger solutions after the air stream has passed through a 0.3 μm heated filter. All samples are well within the 90 – 110% limits for isokinetic sampling.

Particulate emissions from the melter constituted 0.06 to 0.57 percent of feed solids. This level of carry-over is less than that measured for HLW AZ-102 (0.57 - 1.47 percent) and HLW C-106/AY-102 SIPP (0.61 to 0.81 percent) simulants processed on the same melter [8, 18]. The higher carry-over in many of the previous tests is due to higher proportions of volatile species in the feed such as rhenium, cesium, and halogens. The carry-over is comparable to previous tests conducted with HLW AZ-101 simulants while bubbling the melt pool [7]. The effects of melt pool bubbling, glass pool temperature, and feed solids content on solids carry-over from the melter is depicted in Figures 7.1 – 7.3. Notice that no clear emissions trends can be seen as a function of the tested variables. Increases in particulate carry-over with melt pool bubbling have been extensively documented on the DM1200 with HLW waste streams [11-13, 16, 17]. The lack of an increase in emissions with bubbling in these DM100 tests maybe due to the proximity of the bubbling outlet to exhaust outlet of the melter as well as the height of the plenum. Tests with the DM1200 have demonstrated that the bubbler configuration as well as the bubbling rate has an effect on melter emissions [16, 17]. The results from previous tests have also shown that particulate melter emissions tend to increase with increasing glass processing temperature [13, 31-34]; however, the effect of only a 25°C increase is thought to be within the variability of the measurements [1, 34]. Tests on the DM10 and DM1200 with HLW wastes have also demonstrated that carry-over increases with increasing water content due presumably to the entrainment of solids with volatilized water [1, 11]. This same trend was not observed in these tests due perhaps to the differences in plenum geometry and blockage by plenum deposits formed during these tests.

As expected, the feed elements emitted at the lowest melter DF were clearly fluorine and sulfur. Other elements exhibiting volatile behavior in some of the tests include chromium, lead, boron, and alkali metals. The relative volatility of barium, cadmium, and titanium is difficult to evaluate due to the low target concentrations in the feed. Bismuth emissions range from <0.03 to 0.87 percent of bismuth fed to the melter. Emissions of chlorine were measured during all tests even though they were not included in simulant recipes or in analyzed compositions. Chlorine has frequently been observed in melter emissions when not present in feed recipe or at levels exceeding the amount in the feed recipe due to its ubiquity in raw materials, presence in tap water, and high volatility at glass melting temperatures. Boron, sulfur, and the halides were the only elements detected in the impinger solutions collected downstream of the heated particle filter in the sampling train, which constitutes the "gas" fraction of the melter emissions. The proportion of these elements present in the gas phase increases while processing feeds with higher water content due to the volatilization of acid species.

7.2 Gases Monitored by FTIR

Melter emissions were monitored in each test for a variety of gaseous components, most notably CO and nitrogen species, by Fourier Transform Infra-Red Spectroscopy (FTIR). The off-gas system temperature is maintained well above 100°C beyond the sampling port downstream of the HEPA filter to prevent analyte loss due to condensation prior to monitoring. A summary of average concentrations monitored during each test is provided in Table 7.2. The concentrations of two of the monitored species are plotted in Figures 7.4 - 7.12. The analytes listed in Table 7.2 are those that were thought likely to be observed during the test based on previous work; no other species were detected in the off-gas stream by FTIR. Generally, emissions were low as a result of the low concentrations of nitrogen, organic carbon, ammonia, and chlorine in the feed. The most abundant nitrogen species monitored was NO, which is in keeping with previous melter tests with both HLW and LAW feeds. Little or no nitrogen was detected as other species, except as NO_2, which was 10 to 20 times lower in concentration than NO in all but the test with chromium-limited wastes where no NO_2 was detected. The variability in the NO concentrations shown in Figures 7.4 – 7.12 is attributable to the dynamic conditions in the cold cap and in keeping with previous melter tests. The concentration of water in the exhaust increased with increasing feed rate for each waste type. Water emissions were elevated with respect to feed rate when processing feed with low solids content. Consistent with the gaseous chlorine and fluorine concentrations observed using the Method 5-type sampling discussed earlier, HF or HCl were observed by FTIR. The variations in emissions over the course of each test segment are due in part to changes in the melt pool cold cap. Hydrogen fluoride concentrations were lower at the beginning of testing due to the lack of fluorine in the glass pool and the processing time required for the glass to reach steady-state concentration with respect to fluorine. Sulfur dioxide emissions were higher in tests with higher feed sulfur concentrations (chromium- and bismuth-limited wastes) and increase with increasing feed rate for each waste composition. However, gaseous sulfur emissions can also be present in forms other than sulfur dioxide that are not monitored by the FTIR, such as sulfuric acid.

SECTION 8.0
SUMMARY AND CONCLUSIONS

A series of tests was conducted on the DM100-BL vitrification system installed at VSL to evaluate enhanced HLW glass formulations for WTP waste streams that are compositionally very different from those extensively studied to date, which are predominantly limited by iron. The waste streams employed for this work were provided by ORP; their loadings in glass are expected to be limited by bismuth, chromium, aluminum, and aluminum plus sodium. The melter tests evaluated the effects of modest increases in glass processing temperature, optimized glass pool bubbling, and feed solids content on glass productions rates. New glass formulations were developed with the objectives of achieving high waste loadings and determining the waste loading-limiting factors for each waste type. The formulations used for melter testing were selected based on the test results from a series of crucible melt glasses that were prepared and characterized for each waste type. Each of the selected formulations meets all of the product quality, processability, and waste loading requirements. The results of this work provide new information on waste loadings and glass production rates that are needed to underpin overall WTP waste treatment rate projections. The work also identifies new risks associated with these previously unstudied waste types. This information provides ORP with a basis for projection of the amount of Immobilized High Level Waste (IHLW) to be produced at Hanford, potential waste treatment rates, and evaluation of the prospects for future enhancements of the WTP over and above the present well-developed baseline.

Glass formulations that meet all processing and product quality requirements for each of the four waste streams were developed with waste loadings ranging from 40 to 50 wt% on a waste oxide basis. The 40 wt% loading selected for the chromium-limited waste was decreased to 32.5 wt% based on DM10 screening tests in order to mitigate sulfate/chromate salt formation. However, all of the final waste loadings far exceed the minimum and approach or meet the maximum levels specified by ORP.

Melter testing on the DM100 was performed with each of the four selected glass formulations in 50-hour test segments. These test segments employed glass pool temperatures of 1150°C and 1175°C, bubbling rates of 9 lpm and optimized flow, and 250 and 500 g glass per liter feed solids concentration. Almost nine and a half metric tons of feed was processed to produce over three metric tons of glass. Analysis was performed on discharge and glass pool samples throughout the tests for total composition and secondary phases. All of the melter tests were successfully completed with no evidence of processing issues. Glass production rates above the WTP requirement of 800 kg/m^2/day were obtained for each waste composition. However, only the bismuth- and chromium-limited wastes achieved this rate without increased bubbling and/or increased melt temperature. All compositions with low solids content processed at production rates well below 800 kg/m^2/day, in keeping with previous HLW tests with iron-limited waste streams.

Figure 8.1 shows the variation in glass production rates obtained in the present work as compared to results obtained previously on the DM100 melter with high-iron feeds. If the rates for the high-iron feeds are used as the baseline, these results show that there is a significant potential for production rate short-falls as the waste type is varied. In view of the large variations in glass production rates and waste loadings across the waste types studied in the present work and for the WTP baseline, it is instructive to consider the *waste oxide* processing rate, which is the product of these two factors. The waste oxide processing rate ties most directly to the overall question of the rate at which waste can be treated. Accordingly, Figure 8.2 shows the waste oxide processing rates for the results from the present work and other results obtained on the DM100 for WTP high-iron wastes. A strong dependence on waste type is evident. The chromium and bismuth limited wastes processed more rapidly than three of the four iron-limited wastes, whereas the two aluminum-limited wastes processed at considerably slower rates.

During each test, melter exhaust was sampled for particulate and gaseous species to determine the effect of the variations in feed composition, bubbling rate, and glass temperature on emissions. Total particulate carry-over from the melter into the off-gas stream was only 0.06 to 0.57 percent, which is below the range measured previously on the DM10 and DM100 when processing HLW simulants. Melter DFs were determined for most elements in the feed for all eight test segments performed. The most volatile species were sulfur and fluorine, which is typical. Particulate emissions from the melter were not significantly affected by glass pool temperature, bubbling rate, or water content but did change with waste type. Gaseous emissions of nitrogen oxides and byproducts of incomplete combustion, such as carbon monoxide and ammonia, were very low due to the lack of nitrates and organic carbon in the feed.

Glass samples from the crucible and melter tests were subjected to leach testing using the PCT and TCLP methods in order to evaluate product quality. The crucible melt results, with and without the addition of radioactive components (U and Th), were confirmed by tests performed on glass samples from the melter runs. Despite the higher waste loadings and range of waste loading limiting components, the glass products significantly out-performed the DWPF-EA benchmark glass on the PCT leaching procedure by factors of at least 90 and exhibited TCLP leachate concentrations that were well below the WTP delisting limits. Overall, the results from the melter tests and the associated processing and product quality data support the viability of the proposed HLW enhancement approaches.

Waste loadings, waste-loading-limiting factors, and key observations are summarized for each waste type below:

- Bismuth-Limited Waste
    - 50 wt% waste loading
    - Limited by crystallization (spinel + phosphate)
    - Bi_2O_3 content = 6.71 wt% vs. WTP contract minimum of 2 wt%, giving a 70% reduction in the volume of glass produced from this waste
    - Melt foaming on CCC heat treatment
    - Bismuth redox sensitivity (facile reduction to metal)
    - Low intrinsic melt rate

- Chromium-Limited Waste
    - 32.5 wt% waste loading
    - Limited by sulfate/chromate salt formation (not crystallization)
    - Cr_2O_3 content = 1.08 wt% vs. WTP contract minimum of 0.5 wt%, giving a 54% reduction in the volume of glass produced from this waste
    - Importance of sulfate-chromate interaction
    - Importance of salt formation mitigation for HLW (previously treated as a uniquely LAW issue)
    - High bismuth content

- Aluminum-Limited Waste
    - 45 wt% waste loading
    - Limited by crystallization on CCC and impact on PCT
    - Al_2O_3 content = 23.97 wt% vs. WTP contract minimum of 11 wt%, giving a 54% reduction in the volume of glass produced from this waste
    - Low intrinsic melt rate

- Aluminum-Plus-Sodium-Limited Waste
    - 47 wt% waste loading
    - Limited by crystallization on CCC and impact on PCT
    - Al_2O_3 content = 21.34 wt% vs. WTP contract minimum of 11 wt%, giving a 48% reduction in the volume of glass produced from this waste
    - Low intrinsic melt rate

As indicated above, compared to the current WTP HLW contract minima, the glass formulations developed in the present work achieve significantly higher waste loadings, which translate into reductions in the volume of glass produced from these streams of between 48 and 70%. Clearly, the extent of the increase in waste loading, and decrease in glass volume, will vary from tank to tank as a result of the differences in tank waste compositions. However, if even a fraction of this benefit can be realized across the entire Hanford HLW inventory, the potential cost savings are enormous. Taking an overall glass volume reduction of 30% for illustration, which appears conservative based on the present results, and further assuming a baseline canister count of about 15,000, this would reduce that number by about 4500 canisters to about 10500. Assuming a disposal cost of ~$1M per canister and a production cost of ~$1M per canister, this amounts to a cost saving of about $9B. Furthermore, there would likely be additional cost savings through the potential for schedule acceleration. Consequently, the potential return on the investment made in the development of these enhancements is extremely favorable.

8.1 Recommendations for Future Work

The results of the testing presented herein clearly demonstrate the viability of the enhancement and optimization strategies for the four HLW waste streams tested. Furthermore, simple estimates of the impacts of these enhancements show the potential for enormous savings in cost and schedule. As a result, it is recommended that testing and evaluation of these strategies be continued in order to provide a solid basis for their broad implementation in order to maximize the cost and schedule benefits while minimizing technical risk. Some of the elements of such a program are summarized below. While the discussion is centered around Hanford HLW streams, many of these enhancement strategies would also be applicable to other HLW streams, such as those being treated at the DWPF, with the potential for similarly large benefits.

- *Other WTP HLW Waste Types*: The present testing was based on four HLW compositions from the Hanford tanks. While these results are also relevant to waste from several other tanks, the diversity of the Hanford tank wastes means that there are several such waste-loading-limiting constituents, each of which needs to be addressed in order to maximize the benefit from these enhancements. As a starting point, a similar test program to the one performed in the present work should be performed for each of the principal waste-loading-limiting constituents. Particular attention should be paid to waste streams containing sulfur due to the potential of forming secondary phases on the melt pool surface. Key issues identified in the present work include:

    - Interaction between chromium and sulfate can lead to molten chromate-sulfate salt formation during HLW vitrification.

    - Redox sensitivity of bismuth and the potential for molten metal formation in the HLW melter. Appropriate redox operating ranges and process controls need to be developed and tested.

    - Potential for foaming of high-bismuth glasses in the HLW canister during cooling. The underlying cause and appropriate mitigation strategies need to be developed and tested.

- *Throughput*: A key risk area identified in the present work relates to the strong dependence of glass production rates on waste composition. The extent of this variation across the full spectrum of HLW waste types needs to be quantified in order to accurately project waste treatment rates. The vast majority of the previous testing for the WTP has been performed on iron-limited wastes and those results have formed the basis for vitrification system capacity projections. The results of the present work suggest that this basis may not be appropriate for other waste types. Testing also needs to be performed to develop approaches to mitigate the potential short-fall in glass production rates.

- *Formulating Glasses with higher crystal contents:* Previous tests with HLW iron-limited wastes showed that allowing a higher crystal content product can allow significantly increased waste loadings. Evaluation of this enhanced "operational liquidus temperature" approach for other waste streams would result in further waste loading increases.

- *Scale-Up Testing*: Testing should be extended to larger-scale melter systems in order to address potential risks associated with scale-up, particularly with respect to processing rates. Testing should be conducted at the DM1200 WTP HLW Pilot Melter scale (1.2 m^2). Optimization of bubbling rate was critical in achieving the required production rate in the DM100 tests and therefore testing with bubblers in the prototypical orientation at larger scale is required to confirm these findings.

- *Integrated System Testing*: Testing on the DM1200 WTP HLW Pilot Melter system would provide data from a one-third scale system with a prototypical feed delivery system and off-gas treatment train. Such testing is necessary to evaluate potential interactive effects on system operation arising from implementation of the enhancement strategies and to provide data on the performance of each unit operation, input for flow-sheet models and regulatory requirements, and information of recycle streams.

- *Longer-Duration Testing*: Once the results of this work are validated at larger scale, the duration of testing should be extended in order to address and quantify any chronic issues, such as the slow accumulation of crystals in the melter cavity, any degradation in the ability to discharge glass, and effects on off-gas line plugging.

SECTION 9.0
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Table 2.1. Oxide Compositions of Limiting Waste Streams.

Waste Oxides	Bi Limited		Cr Limited		Al Limited		Al and Na Limited	
	Actual	Non-Rad.	Actual	Non-Rad.	Actual	Non-Rad.	Actual	Non-Rad.
Al_2O_3	22.45%	23.32%	25.53%	27.64%	49.21%	53.27%	43.30%	45.40%
B_2O_3	0.58%	0.60%	0.53%	0.57%	0.39%	0.42%	0.74%	0.78%
CaO	1.61%	1.67%	2.47%	2.67%	2.21%	2.39%	1.47%	1.54%
Fe_2O_3	13.40%	13.92%	13.13%	14.21%	12.11%	13.11%	5.71%	5.99%
Li_2O	0.31%	0.32%	0.36%	0.39%	0.35%	0.38%	0.15%	0.16%
MgO	0.82%	0.85%	0.16%	0.17%	0.24%	0.26%	0.44%	0.46%
Na_2O	12.97%	13.47%	20.09%	21.75%	7.35%	7.96%	25.79%	27.04%
SiO_2	12.04%	12.51%	10.56%	11.43%	10.05%	10.88%	6.22%	6.52%
TiO_2	0.30%	0.31%	0.01%	0.01%	0.02%	0.02%	0.35%	0.37%
ZnO	0.31%	0.32%	0.25%	0.27%	0.17%	0.18%	0.36%	0.38%
ZrO_2	0.40%	0.42%	0.11%	0.12%	0.81%	0.88%	0.25%	0.26%
SO_3	0.91%	0.95%	1.52%	1.65%	0.41%	0.44%	0.44%	0.46%
Bi_2O_3	12.91%	13.41%	7.29%	7.89%	2.35%	2.54%	2.35%	2.46%
ThO_2	0.25%	Omitted	0.04%	Omitted	0.37%	Omitted	0.04%	Omitted
Cr_2O_3	1.00%	1.04%	3.07%	3.32%	1.07%	1.16%	1.44%	1.51%
K_2O	0.89%	0.92%	0.37%	0.40%	0.29%	0.31%	1.34%	1.40%
U_3O_8	3.48%	Omitted	7.59%	Omitted	7.25%	Omitted	4.58%	Omitted
BaO	0.02%	0.02%	0.03%	0.03%	0.11%	0.12%	0.06%	0.06%
CdO	0.00%	0.00%	0.01%	0.01%	0.05%	0.05%	0.02%	0.02%
NiO	3.71%	3.85%	1.06%	1.15%	0.82%	0.89%	0.20%	0.21%
PbO	0.48%	0.50%	0.48%	0.52%	0.84%	0.91%	0.18%	0.19%
P_2O_5	9.60%	9.97%	3.34%	3.62%	2.16%	2.34%	4.10%	4.30%
F-	1.58%	1.64%	2.00%	2.17%	1.37%	1.48%	0.46%	0.48%
Total	100.00%	100.0%	100.00%	100.0%	100.00%	100.0%	100.00%	100.0%

Table 2.2. Compositions of the Bi-Limited Waste (Oxide Basis) and the HLW Waste Simulant to Produce 100 kg of Waste Oxides (20 wt% suspended solids).

Bi-Limited Waste Composition		Bi-Limited HLW Waste Simulant	
Waste Oxide	**Wt%**	**Starting Materials**	**Target Weight (kg)** [1]
Al_2O_3	22.45%	Al_2O_3	22.677
B_2O_3	0.58%	H_3BO_3	1.041
CaO	1.61%	CaO	1.643
Fe_2O_3	13.40%	$Fe(OH)_3$ (13% Slurry)	26.752
Li_2O	0.31%	Li_2CO_3	0.786
MgO	0.82%	MgO	0.863
Na_2O	12.97%	NaOH	11.108
SiO_2	12.04%	SiO_2	12.162
TiO_2	0.30%	TiO_2	0.303
ZnO	0.31%	ZnO	0.313
ZrO_2	0.40%	$Zr(OH)_4 \cdot xH_2O$	1.034
SO_3	0.91%	Na_2SO_4	1.632
Bi_2O_3	12.91%	Bi_2O_3	13.040
ThO_2	0.25%	Omitted	
Cr_2O_3	1.00%	$Cr_2O_3 \cdot 1.5H_2O$	1.190
K_2O	0.89%	KNO_3	1.940
U_3O_8	3.48%	Omitted	
BaO	0.02%	$BaCO_3$	0.026
CdO	0.00%	CdO	0.000
NiO	3.71%	$Ni(OH)_2$	4.771
PbO	0.48%	PbO	0.485
P_2O_5	9.60%	$FePO_4 \cdot xH_2O$	25.501
F	1.58%	NaF	3.510
Carbonate	1.20[2]	Na_2CO_3	1.011
Nitrite	0.50	$NaNO_2$	0.769
Nitrate	2.00	$NaNO_3$	1.141
Organic Carbon	0.05	$H_2C_2O_4 \cdot 2H_2O$	0.264
—	—	Water	353.500
TOTAL	100.0%	TOTAL	487.463

[1]Target weights adjusted for assay information of starting materials
[2]—Unit for volatile components is g/100 g of waste oxide
— Empty data field

Table 2.3. Compositions of the Cr-Limited Waste (Oxide Basis) and the HLW Waste Simulant to Produce 100 kg of Waste Oxides (20 wt% suspended solids).

Cr-Limited Waste Composition		Cr-Limited HLW Waste Simulant	
Waste Oxide	**Wt%**	**Starting Materials**	**Target Weight (kg)** [1]
Al_2O_3	25.53%	Al_2O_3	25.788
B_2O_3	0.53%	H_3BO_3	0.951
CaO	2.47%	CaO	2.520
Fe_2O_3	13.13%	$Fe(OH)_3$ (13% Slurry)	96.476
Li_2O	0.36%	Li_2CO_3	0.913
MgO	0.16%	MgO	0.168
Na_2O	20.09%	NaOH	18.730
SiO_2	10.56%	SiO_2	10.667
TiO_2	0.01%	TiO_2	0.010
ZnO	0.25%	ZnO	0.253
ZrO_2	0.11%	$Zr(OH)_4 \cdot xH_2O$	0.284
SO_3	1.52%	Na_2SO_4	2.726
Bi_2O_3	7.29%	Bi_2O_3	7.364
ThO_2	0.04%	Omitted	
Cr_2O_3	3.07%	$Cr_2O_3 \cdot 1.5H_2O$	3.652
K_2O	0.37%	KNO_3	0.806
U_3O_8	7.59%	Omitted	
BaO	0.03%	$BaCO_3$	0.039
CdO	0.01%	CdO	0.010
NiO	1.06%	$Ni(OH)_2$	1.363
PbO	0.48%	PbO	0.485
P_2O_5	3.34%	$FePO_4 \cdot xH_2O$	8.872
F	2.00%	NaF	4.443
Carbonate	1.20[2]	Na_2CO_3	0.826
Nitrite	0.50	$NaNO_2$	0.769
Nitrate	2.00	$NaNO_3$	2.085
Organic Carbon	0.05	$H_2C_2O_4 \cdot 2H_2O$	0.264
—	—	Water	293.300
—	—	—	—
TOTAL	100.0%	TOTAL	483.765

[1]Target weights adjusted for assay information of starting materials
[2]—Unit for volatile components is g/100 g of waste oxide
— Empty data field

Table 2.4. Compositions of the Al-Limited Waste (Oxide Basis) and the HLW Waste Simulant to Produce 100 kg of Waste Oxides (20 wt% suspended solids).

Al-Limited Waste Composition		Al-Limited HLW Waste Simulant	
Waste Oxide	**Wt%**	**Starting Materials**	**Target Weight (kg)** [1]
Al_2O_3	49.21%	Al_2O_3	49.707
B_2O_3	0.39%	H_3BO_3	0.700
CaO	2.21%	CaO	2.255
Fe_2O_3	12.11%	$Fe(OH)_3$ (13% Slurry)	99.643
Li_2O	0.35%	Li_2CO_3	0.888
MgO	0.24%	MgO	0.253
Na_2O	7.35%	NaOH	4.235
SiO_2	10.05%	SiO_2	10.152
TiO_2	0.02%	TiO_2	0.020
ZnO	0.17%	ZnO	0.172
ZrO_2	0.81%	$Zr(OH)_4{\cdot}xH_2O$	2.093
SO_3	0.41%	Na_2SO_4	0.735
Bi_2O_3	2.35%	Bi_2O_3	2.374
ThO_2	0.37%	Omitted	
Cr_2O_3	1.07%	$Cr_2O_3{\cdot}1.5H_2O$	1.273
K_2O	0.29%	KNO_3	0.632
U_3O_8	7.25%	Omitted	
BaO	0.11%	$BaCO_3$	0.143
CdO	0.05%	CdO	0.051
NiO	0.82%	$Ni(OH)_2$	1.055
PbO	0.84%	PbO	0.848
P_2O_5	2.16%	$FePO_4{\cdot}xH_2O$	5.738
F	1.37%	NaF	3.044
Carbonate	1.20[2]	Na_2CO_3	0.806
Nitrite	0.50	$NaNO_2$	0.769
Nitrate	2.00	$NaNO_3$	2.230
Organic Carbon	0.05	$H_2C_2O_4{\cdot}2H_2O$	0.264
—	—	Water	279.400
TOTAL	100.0%	TOTAL	469.478

[1]Target weights adjusted for assay information of starting materials
[2]—Unit for volatile components is g/100 g of waste oxide
— Empty data field

Table 2.5. Compositions of the Al- and Na-Limited Waste (Oxide Basis) and the HLW Waste Simulant to Produce 100 kg of Waste Oxides (20 wt% suspended solids).

Al- and Na-Limited Waste Composition		Al- and Na-Limited HLW Waste Simulant	
Waste Oxide	**Wt%**	**Starting Materials**	**Target Weight (kg)** [1]
Al_2O_3	43.30%	Al_2O_3	43.737
B_2O_3	0.74%	H_3BO_3	1.328
CaO	1.47%	CaO	1.500
Fe_2O_3	5.71%	$Fe(OH)_3$ (13% Slurry)	11.292
Li_2O	0.15%	Li_2CO_3	0.380
MgO	0.44%	MgO	0.463
Na_2O	25.79%	NaOH	31.057
SiO_2	6.22%	SiO_2	6.283
TiO_2	0.35%	TiO_2	0.354
ZnO	0.36%	ZnO	0.364
ZrO_2	0.25%	$Zr(OH)_4 \cdot xH_2O$	0.646
SO_3	0.44%	Na_2SO_4	0.789
Bi_2O_3	2.35%	Bi_2O_3	2.374
ThO_2	0.04%	Omitted	
Cr_2O_3	1.44%	$Cr_2O_3 \cdot 1.5H_2O$	1.713
K_2O	1.34%	KNO_3	2.921
U_3O_8	4.58%	Omitted	
BaO	0.06%	$BaCO_3$	0.078
CdO	0.02%	CdO	0.020
NiO	0.20%	$Ni(OH)_2$	0.257
PbO	0.18%	PbO	0.182
P_2O_5	4.10%	$FePO_4 \cdot xH_2O$	10.891
F	0.46%	NaF	1.022
Carbonate	1.20[2]	Na_2CO_3	1.554
Nitrite	0.50	$NaNO_2$	0.769
Nitrate	2.00	$NaNO_3$	0.325
Organic Carbon	0.05	$H_2C_2O_4 \cdot 2H_2O$	0.264
—	—	Water	381.400
TOTAL	100.0%	TOTAL	501.964

[1]Target weights adjusted for assay information of starting materials
[2]—Unit for volatile components is g/100 g of waste oxide
— Empty data field

Table 3.1. Target Composition and XRF Analysis of Glasses Formulated for Bi-Limited Waste.

-	Bi Limited Waste	Bi Limited Waste (Non Rad)#	HLW-E-Bi-1		HLW-E-Bi-2		HLW-E-Bi-3		HLW-E-Bi-4		HLW-E-Bi-5		HLW-E-Bi-6		HLW-E-Bi-7		HLW-E-Bi-8	
			Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	22.45	23.31	9.32	9.60	9.32	9.14	9.32	9.68	9.32	9.49	10.49	10.54	11.66	11.85	12.82	12.89	10.49	10.50
B_2O_3	0.58	0.60	13.74	13.74	12.74	12.74	13.74	13.74	12.74	12.74	12.27	12.27	11.30	11.30	10.33	10.33	14.27	14.27
BaO	0.02	0.02	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Bi_2O_3*	12.91	13.41	5.36	5.60	5.36	5.78	5.36	5.41	5.36	5.63	6.03	6.12	6.71	6.83	7.38	7.61	6.03	6.39
CaO	1.61	1.67	0.67	0.70	0.67	0.72	0.67	0.71	0.67	0.72	0.75	0.80	0.84	0.57	0.92	0.94	0.75	0.80
Cr_2O_3	1.00	1.04	0.42	0.51	0.42	0.53	0.42	0.51	0.42	0.52	0.47	0.59	0.52	0.61	0.57	0.68	0.47	0.58
F*	1.58	1.64	0.66	-	0.66	-	0.66	-	0.66	-	0.74	-	0.82	-	0.90	-	0.74	-
Fe_2O_3	13.40	13.92	5.57	5.50	5.57	5.57	5.57	5.30	5.57	5.50	6.26	6.02	6.96	6.69	7.66	7.40	6.26	6.20
K_2O	0.89	0.92	0.37	0.45	0.37	0.43	0.37	0.43	0.37	0.44	0.41	0.48	0.46	0.50	0.51	0.56	0.41	0.47
Li_2O*	0.31	0.32	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.16	0.16	0.18	0.18	0.14	0.14
MgO	0.82	0.85	0.34	0.28	0.34	0.28	0.34	0.34	0.34	0.32	0.38	0.34	0.43	0.38	0.47	0.44	0.38	0.37
Na_2O	12.97	13.47	17.39	17.79	16.39	15.78	17.39	17.86	16.39	16.78	16.06	16.63	15.74	16.44	15.41	15.72	16.06	15.90
NiO	3.71	3.85	1.54	1.51	1.54	1.57	1.54	1.47	1.54	1.51	1.73	1.65	1.93	1.83	2.12	1.96	1.73	1.70
P_2O_5	9.60	9.97	3.99	4.26	3.99	4.86	3.99	4.67	3.99	4.34	4.49	4.95	4.99	5.48	5.48	6.10	4.49	5.08
PbO	0.48	0.50	0.20	0.19	0.20	0.20	0.20	0.18	0.20	0.19	0.23	0.20	0.25	0.24	0.28	0.26	0.23	0.22
SiO_2	12.04	12.51	39.50	38.87	39.50	39.40	38.00	37.37	39.00	38.46	37.63	37.42	36.26	35.84	33.88	33.75	36.63	36.46
ThO_2	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.30	0.31	0.12	0.16	0.12	0.15	0.12	0.15	0.12	0.16	0.14	0.17	0.16	0.18	0.17	0.21	0.14	0.17
SO_3	0.91	0.95	0.38	0.35	0.38	0.30	0.38	0.30	0.38	0.29	0.43	0.33	0.48	0.32	0.52	0.43	0.43	0.30
ZnO	0.31	0.32	0.13	0.15	1.13	1.18	1.13	1.11	0.63	0.65	0.14	0.16	0.16	0.18	0.18	0.20	0.14	0.17
ZrO_2	0.40	0.42	0.17	0.15	1.17	1.14	0.67	0.60	2.17	2.02	1.19	1.08	0.21	0.20	0.23	0.21	0.19	0.19
U_3O_8	3.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
#The non-radioactive version of the waste is calculated by renormalization of the waste constituents after removing U_3O_8 and ThO_2.
- Empty data field

Table 3.1. Target Composition and XRF Analysis of Glasses Formulated for Bi-Limited Waste (continued).

-	HLW-E-Bi-9		HLW-E-Bi-10		HLW-E-Bi-11		HLW-E-Bi-12		HLW-E-Bi-13		HLW-E-Bi-14		HLW-E-Bi-15		HLW-E-Bi-16		HLW-E-Bi6UTh	
	Comp	XRF	Comp	XRF	Comp	XRF	Comp	XRF	Comp	XRF	Comp	XRF	Comp	XRF	Comp	XRF	Comp	XRF
Al_2O_3	10.49	10.70	10.49	10.62	6.99	7.68	13.99	13.83	12.82	12.80	15.15	15.31	12.82	12.87	11.66	11.81	11.22	11.35
B_2O_3*	12.27	12.27	12.27	12.27	12.68	12.68	11.36	11.36	10.33	10.33	10.39	10.39	10.33	0.00	11.30	11.30	11.29	11.29
BaO	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.02
Bi_2O_3	6.03	6.01	6.03	6.17	4.02	4.34	8.05	8.17	7.38	7.41	8.72	9.18	7.38	7.92	6.71	7.35	6.45	7.03
CaO	0.75	0.78	0.75	0.80	0.50	0.66	1.00	1.05	0.92	0.95	1.09	1.12	0.92	0.97	0.84	0.89	0.80	0.85
Cr_2O_3	0.47	0.56	0.47	0.57	0.31	0.40	0.62	0.71	0.57	0.67	0.68	0.57	0.57	0.75	0.52	0.67	0.50	0.63
F*	0.74	-	0.74	-	0.49	-	0.98	-	0.90	-	1.07	-	0.90	-	0.82	-	0.79	-
Fe_2O_3	6.26	5.93	6.26	6.03	4.18	4.21	8.35	7.89	7.66	7.27	9.05	7.90	7.66	7.81	6.96	7.09	6.70	6.78
K_2O	0.41	0.46	2.41	2.45	0.28	0.35	0.55	0.64	2.51	2.54	0.60	0.64	2.51	2.50	2.46	2.50	0.44	0.50
Li_2O*	0.14	0.14	0.14	0.00	0.10	0.10	0.19	0.19	0.18	0.18	0.21	0.21	2.18	2.18	0.16	0.16	0.15	0.15
MgO	0.38	0.38	0.38	0.34	0.26	0.24	0.51	0.46	0.47	0.43	0.55	0.52	0.47	0.42	0.43	0.36	0.41	0.38
Na_2O	18.06	18.66	16.06	16.00	18.04	18.15	15.08	15.38	14.91	14.49	15.76	16.73	12.91	13.18	14.74	14.87	15.48	15.13
NiO	1.73	1.62	1.73	1.66	1.16	1.16	2.31	2.05	2.12	1.94	2.50	1.78	2.12	2.04	1.93	1.94	1.85	1.86
P_2O_5	4.49	5.05	4.49	5.61	2.99	3.28	5.98	7.45	5.48	6.89	6.48	7.38	5.48	5.98	4.99	5.41	4.80	5.28
PbO	0.23	0.21	0.23	0.21	0.15	0.14	0.30	0.29	0.28	0.24	0.33	0.32	0.28	0.26	0.25	0.25	0.24	0.23
SiO_2	36.63	36.26	36.63	36.15	44.25	43.10	29.51	29.32	32.38	32.65	26.13	26.57	32.38	31.59	35.26	34.27	36.02	35.40
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.13
TiO_2	0.14	0.17	0.14	0.17	0.09	0.12	0.19	0.21	0.17	0.21	0.20	0.24	0.17	0.22	0.16	0.20	0.15	0.18
SO_3	0.43	0.37	0.43	0.38	0.29	0.24	0.57	0.46	0.52	0.49	0.62	0.51	0.52	0.44	0.48	0.40	0.45	0.38
ZnO	0.14	0.16	0.14	0.16	1.10	1.13	0.19	0.22	0.18	0.20	0.21	0.23	0.18	0.21	0.16	0.19	0.15	0.18
ZrO_2	0.19	0.17	0.19	0.17	2.13	1.89	0.25	0.24	0.23	0.21	0.27	0.25	0.23	0.21	0.21	0.21	0.20	0.18
U_3O_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.74	1.99

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
- Empty data field

Table 3.2. Characterization of Glasses Formulated for Bi-Limited Waste.

	Glass Name	HLW-E-Bi-11	HLW-E-Bi-1	HLW-E-Bi-2	HLW-E-Bi-3	HLW-E-Bi-4	HLW-E-Bi-5	HLW-E-Bi-9	HLW-E-Bi-10
	Waste loading (wt%)	30%	40%	40%	40%	40%	45%	45%	45%
Crystal content	Glass as melted	Free	Trace	Trace	Trace	Trace	Trace	Trace	Trace
	Xl at 950C	-	Sp	Sp	Sp	-	Sp	Sp	Sp
	Glass after HT at 950ºC (vol%)	<0.1	0.125	0.1	0.1	-	0.4	0.5	0.4
	Glass after HT at 900ºC (vol%)	-	-	0.1	-	-	-	-	-
	Glass after HT at 850ºC (vol%)	-	-	1.0	-	-	-	-	-
	Glass after HT at 800ºC (vol%)	-	-	0.5	-	-	-	-	-
	Glass after HT of CCC (vol%)	-	-	-	-	-	-	-	-
Processing properties	Highly viscous during pouring (Y/N)	N	N	N	N	N	N	N	N
	Viscosity at 1250ºC (poise)	-	-	34.6	-	-	-	-	-
	Viscosity at 1150ºC (poise)	-	-	76.5	-	-	-	-	-
	Viscosity at 1050ºC (poise)	-	-	211.1	-	-	-	-	-
	Viscosity at 950ºC (poise)	-	-	813.1	-	-	-	-	-
	Electric conductivity at 1250ºC (S/cm)	-	-	0.45	-	-	-	-	-
	Electric conductivity at 1150ºC (S/cm)	-	-	0.34	-	-	-	-	-
	Electric conductivity at 1050ºC (S/cm)	-	-	0.24	-	-	-	-	-
	Electric conductivity at 950ºC (S/cm)	-	-	0.15	-	-	-	-	-
	Glass transition temperature (ºC)	-	-	-	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-	-	-	-
	B (ppm)	-	158.8	61.4	-	52.7	31.1	-	-
	Li (ppm)	-	1.6	0.6	-	0.4	0.3	-	-
	Na (ppm)	-	243.6	111.9	-	89.4	73.8	-	-
	Si (ppm)	-	49.1	51.5	-	43.6	46.1	-	-
	B (g/L)	-	3.72	1.55	-	1.33	0.82	-	-
	Li (g/L)	-	2.67	0.97	-	0.67	0.50	-	-
	Na (g/L)	-	1.89	0.92	-	0.74	0.62	-	-
	Si (g/L)	-	0.27	0.28	-	0.24	0.26	-	-
	PCT (for CCC sample)	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-	-
	Li (ppm)	-	-	-	-	-	-	-	-
	Na (ppm)	-	-	-	-	-	-	-	-
	Si (ppm)	-	-	-	-	-	-	-	-
	B (g/L)	-	-	-	-	-	-	-	-
	Li (g/L)	-	-	-	-	-	-	-	-
	Na (g/L)	-	-	-	-	-	-	-	-
	Si (g/L)	-	-	-	-	-	-	-	-
	TCLP (Pass/Fail)	-	-	Pass	-	-	-	-	-

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.2. Characterization of Glasses Formulated for Bi-Limited Waste (continued).

	Glass Name	HLW-E-Bi-8	HLW-E-Bi-6	HLW-E-Bi6UThR1	HLW-E-Bi-16	HLW-E-Bi-7	HLW-E-Bi-13	HLW-E-Bi-15	HLW-E-Bi-12	HLW-E-Bi-14
	Waste loading (wt%)	45%	50%	50%	50%	55%	55%	55%	60%	65%
Crystal content	Glass as melted	Trace	Trace	Not analyzed	Trace	Xtals	xtals	Xtals	Xtals	Xtals
	Xl at 950C	Sp	Sp + Pho	Sp + Pho	Sp + Pho	Sp +Pho	Sp + Pho	Sp	Sp + Pho	Sp + Pho
	Glass after HT at 950ºC (vol%)	0.5	1.8	1.4	2.7	2.7	3.2	2.1	4.2	3.3
	Glass after HT at 900ºC (vol%)	-	2.3	1.9	-	3.5	3.4	-	5.0	-
	Glass after HT at 850ºC (vol%)	-	3.3	2.8	-	4.9	4.5	-	5.6	-
	Glass after HT at 800ºC (vol%)	-	4.0	3.5	-	5.5	5.3	-	5.0	-
	Glass after HT of CCC (vol%)	-	5.6 (Pho + Sp + †)	5.0 (Pho + Sp + †)	-	-	-	-	-	-
Processing properties	Highly viscous during pouring (Y/N)	N	N	N	N	N	N	N	N	N
	Viscosity at 1250ºC (poise)	-	42.3	36.1	34.3	38.2	32.2	-	-	-
	Viscosity at 1150ºC (poise)	-	96.0	81.8	74.8	96.6	76.4	-	-	-
	Viscosity at 1050ºC (poise)	-	266.6	242.8	193.9	286.8	210.6	-	-	-
	Viscosity at 950ºC (poise)	-	987.2	1114.6	637.9	1048.5	704.1	-	-	-
	Electric conductivity at 1250ºC (S/cm)	-	0.61	0.47	0.51	0.57	0.53	-	-	-
	Electric conductivity at 1150ºC (S/cm)	-	0.47	0.36	0.41	0.43	0.38	-	-	-
	Electric conductivity at 1050ºC (S/cm)	-	0.35	0.26	0.30	0.31	0.24	-	-	-
	Electric conductivity at 950ºC (S/cm)	-	0.24	0.16	0.19	0.20	0.11	-	-	-
	Glass transition temperature (ºC)	-	484	-	-	-	-	-	-	-
Leaching performance	PCT	-		-	-	-	-	-	-	-
	B (ppm)	-	17.2	17.2	-	15.8	21.4	-	27.8	-
	Li (ppm)	-	0.1	0.4	-	0.1	0.4	-	0.6	-
	Na (ppm)	-	61.9	54.8	-	58.6	72.0	-	83.5	-
	Si (ppm)	-	45.7	39.5	-	40.3	39.3	-	39.8	-
	B (g/L)	-	0.49	0.49	-	0.49	0.67	-	0.79	-
	Li (g/L)	-	0.18	0.55	-	0.18	0.52	-	0.66	-
	Na (g/L)	-	0.53	0.48	-	0.51	0.65	-	0.75	-
	Si (g/L)	-	0.27	0.23	-	0.25	0.26	-	0.29	-
	PCT (for CCC sample)	-		-	-	-	-	-	-	-
	B (ppm)	-	16.9	-	-	-	-	-	-	-
	Li (ppm)	-	0.5	-	-	-	-	-	-	-
	Na (ppm)	-	69.4	-	-	-	-	-	-	-
	Si (ppm)	-	42.5	-	-	-	-	-	-	-
	B (g/L)	-	0.48	-	-	-	-	-	-	-
	Li (g/L)	-	0.67	-	-	-	-	-	-	-
	Na (g/L)	-	0.59	-	-	-	-	-	-	-
	Si (g/L)	-	0.25	-	-	-	-	-	-	-
	TCLP (Pass/Fail)	-	Pass	Pass	-	Pass	Pass	-	-	-

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate; †bubbles submicron size
- Empty data field

Table 3.3. TCLP Results (ppm) for Glasses Selected for Melter Tests and Their Corresponding Radioactive Glasses.

Element	Ba	Bi	Cd	Cr	Ni	Pb	Zn
UTS Limits	21	N/A	0.11	0.6	11	0.75	4.3
Delisting Limits	100	N/A	0.48	4.95	22.6	5	225
HLW-E-Al27R1	0.12	0.91	NA	0.21	0.20	0.37	0.13
HLW-E-Al27UThR2	0.12	0.55	0.04	0.31	0.39	0.58	0.13
HLW-E-ANa22R1	0.09	0.46	NA	0.21	<0.04	<0.1	0.11
HLW-E-ANa22UTh	0.05	0.26	<0.03	0.19	0.04	<0.1	0.07
HLW-E-Bi6	0.10	NA	NA	0.06	0.48	<0.1	0.08
HLW-E-Bi6UThR1	0.04	0.80	<0.03	0.06	0.48	<0.1	0.05
HLW-E-Cr-MR1	0.08	0.44	NA	0.07	<0.04	<0.1	0.06
HLW-E-Cr-MUTh	0.06	0.50	<0.03	0.20	0.11	<0.1	0.05
HLW-E-Cr-10	0.13	NA	NA	0.31	0.15	<0.1	0.08

N/A- Not Applicable
NA-Not analyzed

Table 3.4. Composition and Properties of Bismuth Limited Waste and Glass Formulation at 50% Waste Loading Used in Melter Tests (wt%).

-	Bi-Limited Waste*	Waste in Glass	Glass Forming Additives	Target Glass HLW-E-Bi-6
Al_2O_3	23.31	11.66	-	11.66
B_2O_3	0.60	0.30	11.00	11.30
BaO	0.02	0.01	-	0.01
Bi_2O_3	13.41	6.71	-	6.71
CaO	1.67	0.84	-	0.84
Cr_2O_3	1.04	0.52	-	0.52
F	1.64	0.82	-	0.82
Fe_2O_3	13.92	6.96	-	6.96
K_2O	0.92	0.46	-	0.46
Li_2O	0.32	0.16	-	0.16
MgO	0.85	0.43	-	0.43
Na_2O	13.47	6.74	9.00	15.74
NiO	3.85	1.93	-	1.93
P_2O_5	9.97	4.99	-	4.99
PbO	0.50	0.25	-	0.25
SiO_2	12.51	6.26	30.00	36.26
TiO_2	0.31	0.16	-	0.16
SO_3	0.95	0.48	-	0.48
ZnO	0.32	0.16	-	0.16
ZrO_2	0.42	0.21	-	0.21
Sum	100	50	50	100

* Renormalized from Ref. [3] after removal of radioactive components

Viscosity @1150ºC, P			96
Conductivity @1150ºC, S/cm			0.47
Crystal Content, As Melted			Trace
Crystal Content, 72 hr at 950^{o}C			~1.8vol%
TCLP			Pass
PCT, g/L	-	DWPF-EA	HLW-E-Bi-6
	B	16.7	0.49
	Li	9.6	0.18
	Na	13.3	0.53

- Empty data field

Table 3.5. Target Composition and XRF Analysis of Glasses Formulated for Cr-Limited Waste.

-	Cr-Limited Waste	Cr-limited waste (non-rad)#	HLW-E-Cr-1		HLW-E-Cr-2		HLW-E-Cr-3		HLW-E-Cr-4		HLW-E-Cr-5		HLW-E-Cr-6	
			Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	25.53	27.64	11.06	11.18	11.06	11.42	11.06	11.68	11.06	11.64	11.06	11.37	11.06	11.47
B_2O_3*	0.53	0.57	14.23	14.23	13.73	13.73	13.73	13.73	13.73	13.73	13.73	13.73	13.73	13.73
BaO	0.03	0.03	0.01	0.019	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.03
Bi_2O_3	7.29	7.89	3.16	3.34	3.16	3.25	3.16	3.24	3.16	3.29	3.16	3.33	3.16	3.36
CaO	2.47	2.67	1.07	1.13	1.07	1.10	1.07	1.12	1.07	1.14	1.07	1.11	1.07	1.15
CdO	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Cr_2O_3	3.07	3.32	1.33	1.28	1.33	1.38	1.33	1.39	1.33	0.57	1.33	1.58	1.33	1.51
F*	2.00	2.17	0.87	0.00	0.87	-	0.87	-	0.87	-	0.87	-	0.87	-
Fe_2O_3	13.13	14.22	5.69	5.77	5.69	5.58	5.69	5.58	5.69	5.59	5.69	5.63	5.69	5.73
K_2O	0.37	0.40	11.16	11.56	10.16	10.12	7.66	7.65	2.66	2.75	5.16	5.17	3.66	3.79
Li_2O*	0.36	0.39	0.16	0.16	1.16	1.16	2.66	2.66	3.16	3.16	2.16	3.16	3.16	3.16
MgO	0.16	0.17	0.07	0.072	0.07	0.06	0.07	0.05	0.07	0.10	0.07	0.06	0.07	0.08
Na_2O	20.09	21.75	8.70	8.32	8.70	8.74	8.70	8.70	8.70	9.18	8.70	8.82	8.70	8.60
NiO	1.06	1.15	0.46	0.44	0.46	0.45	0.46	0.45	0.46	0.44	0.46	0.45	0.46	0.45
P_2O_5	3.34	3.62	1.45	1.71	1.45	1.60	1.45	1.58	1.45	1.56	1.45	1.55	1.45	1.59
PbO	0.48	0.52	0.71	0.654	1.21	1.12	2.21	2.04	1.21	1.12	1.21	1.16	2.21	2.09
SiO_2	10.56	11.43	39.07	39.57	39.07	39.65	39.07	39.37	44.57	44.00	40.57	39.67	42.57	42.50
SrO	0.00	0.00	0.00	0.015	0.00	0.02	0.00	0.02	0.00	0.02	2.50	2.43	0.00	0.02
ThO_2	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.01	0.01	0.00	0.05	0.00	0.03	0.00	0.05	0.00	0.06	0.00	0.06	0.00	0.04
SO_3	1.52	1.65	0.66	0.315	0.66	0.32	0.66	0.41	0.66	0.39	0.66	0.40	0.66	0.44
V_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	0.25	0.27	0.11	0.108	0.11	0.14	0.11	0.13	0.11	0.14	0.11	0.13	0.11	0.12
ZrO_2	0.11	0.12	0.05	0.052	0.05	0.07	0.05	0.04	0.05	0.06	0.05	0.05	0.05	0.05
U_3O_8	7.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
#The non-radioactive version of the waste is calculated by renormalization of the waste constituents after removing U_3O_8 and ThO_2.
-Empty data field

Table 3.5. Target Composition and XRF Analysis of Glasses Formulated for Cr-Limited Waste (continued).

-	HLW-E-Cr-7		HLW-E-Cr-8		HLW-E-Cr-9		HLW-E-Cr-10		HLW-E-Cr-11		HLW-E-Cr-12		HLW-E-Cr-13		HLW-E-Cr-14	
	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	11.06	11.75	11.06	11.28	11.06	11.05	11.06	11.24	11.06	11.37	12.44	12.56	13.82	14.07	8.29	8.92
B_2O_3*	13.73	13.73	13.73	13.73	15.73	15.73	14.44	14.44	14.44	14.44	14.47	14.27	14.00	14.27	14.38	14.38
BaO	0.01	0.03	0.01	0.02	0.01	0.02	0.01	0.03	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01
Bi_2O_3	3.16	3.16	3.16	3.18	3.16	3.28	3.16	3.36	3.16	3.25	3.55	3.70	3.95	4.02	2.37	2.49
CaO	1.07	1.06	1.07	1.07	1.07	1.14	1.07	1.11	1.07	1.09	1.20	1.24	1.34	1.31	1.59	1.67
CdO	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Cr_2O_3	1.33	1.42	1.33	1.39	1.33	1.47	1.33	1.49	1.33	1.46	1.50	1.73	1.66	1.73	1.00	1.19
F*	0.87	-	0.87	-	0.87	-	0.87	-	0.87	-	0.97	-	1.08	-	0.65	-
Fe_2O_3	5.69	5.39	5.69	5.41	5.69	5.57	5.69	5.65	5.69	5.51	6.40	6.27	7.11	6.86	4.26	4.22
K_2O	5.16	5.06	7.66	7.41	5.16	5.15	5.42	5.62	5.42	5.47	5.44	5.27	5.20	4.90	6.12	6.14
Li_2O*	3.16	3.16	2.66	2.66	3.16	3.16	3.31	3.31	3.31	3.31	3.33	2.68	2.20	2.20	4.12	4.12
MgO	0.07	0.07	0.07	0.00	0.07	0.06	0.07	0.05	0.07	0.00	0.08	0.07	0.09	0.06	0.05	0.08
Na_2O	8.70	9.39	8.70	9.07	8.70	9.13	8.70	8.67	8.70	8.93	9.79	10.32	10.87	11.16	6.52	6.58
NiO	0.46	0.43	0.46	0.45	0.46	0.45	0.46	0.46	0.46	0.44	0.52	0.50	0.57	0.54	0.34	0.34
P_2O_5	1.45	1.58	1.45	1.77	1.45	1.77	1.45	1.61	1.45	1.63	1.63	1.89	1.81	1.99	1.08	1.23
PbO	3.21	2.91	3.21	2.90	3.21	2.95	0.21	0.20	0.21	0.20	0.23	0.22	0.26	0.23	0.16	0.15
SiO_2	40.07	40.15	38.07	38.79	38.07	38.26	41.94	41.99	40.94	41.22	37.51	38.51	35.00	35.83	45.43	45.04
SrO	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.02	0.00	0.01	0.00	0.02
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.00	0.05	0.00	0.04	0.00	0.05	0.00	0.06	0.00	0.05	0.00	0.04	0.01	0.04	0.00	0.04
SO_3	0.66	0.39	0.66	0.49	0.66	0.45	0.66	0.46	0.66	0.38	0.74	0.47	0.82	0.48	0.49	0.36
V_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	0.11	0.13	0.11	0.13	0.11	0.13	0.11	0.13	0.11	0.13	0.12	0.14	0.14	0.15	0.08	0.10
ZrO_2	0.05	0.03	0.05	0.04	0.05	0.05	0.05	0.04	1.05	0.98	0.05	0.05	0.06	0.06	3.04	2.80
U_3O_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
- Empty data field

Table 3.5. Target Composition and XRF Analysis of Glasses Formulated for Cr-Limited Waste (continued).

-	HLW-E-Cr-15		HLW-E-Cr-16		HLW-E-Cr-17		HLW-E-Cr-18		HLW-E-Cr-MrI		HLW-E-Cr-MUTh	
	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	12.44	12.49	13.82	13.95	11.75	12.13	11.75	12.03	8.98	9.77	8.30	8.88
B_2O_3*	14.47	14.47	14.09	14.09	14.45	14.45	14.45	14.45	16.17	16.17	16.16	16.16
BaO	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.03
Bi_2O_3	3.55	3.67	3.95	4.15	3.35	3.52	3.35	3.45	2.57	2.76	2.37	2.31
CaO	1.20	1.24	1.34	1.36	1.14	1.16	3.17	3.11	0.87	0.92	0.80	0.81
CdO	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr_2O_3	1.50	1.63	1.66	1.84	1.41	1.52	1.41	1.56	1.08	1.24	1.00	1.14
F*	0.97	-	1.08	-	0.92	-	0.92	-	0.70	-	0.65	-
Fe_2O_3	6.40	6.26	7.11	6.99	6.04	5.96	6.04	5.92	4.62	4.65	4.27	3.93
K_2O	5.44	5.39	5.20	5.28	5.43	5.37	5.43	5.42	6.05	5.73	6.04	5.82
Li_2O*	3.33	3.33	2.21	2.21	3.31	3.31	3.17	3.17	3.68	3.68	3.67	3.67
MgO	0.08	0.07	0.09	0.00	0.07	0.08	0.07	0.06	0.06	0.00	0.05	0.00
Na_2O	9.79	10.30	10.87	11.11	9.24	9.23	9.24	9.22	7.07	6.36	6.53	6.86
NiO	0.52	0.49	0.57	0.54	0.49	0.47	0.49	0.48	0.37	0.36	0.34	0.30
P_2O_5	1.63	2.05	1.81	2.03	1.54	1.70	1.54	1.69	1.18	1.34	1.09	1.25
PbO	0.23	0.22	0.26	0.25	0.22	0.20	0.22	0.21	0.17	0.17	0.16	0.13
SiO_2	36.01	35.97	33.41	33.81	39.75	40.14	37.86	38.42	45.76	45.92	45.47	45.58
SrO	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.02	0.00	0.02	0.00	0.02
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
TiO_2	0.00	0.05	0.01	0.04	0.00	0.08	0.00	0.05	0.00	0.05	0.00	0.04
SO_3	0.74	0.51	0.82	0.49	0.70	0.43	0.70	0.48	0.54	0.60	0.49	0.38
V_2O_5	1.50	1.57	1.50	1.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	0.12	0.15	0.14	0.15	0.12	0.14	0.12	0.13	0.09	0.12	0.08	0.13
ZrO_2	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.07	0.04	0.04	0.04	0.03
U_3O_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.47	2.43

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
- Empty data field

Table 3.6. Characterization of Glasses Formulated for Cr-Limited Waste.

	Glass Name	HLW-E-Cr-14	HLW-E-Cr-1	HLW-E-Cr-2	HLW-E-Cr-3	HLW-E-Cr-4	HLW-E-Cr-5	HLW-E-Cr-6	HLW-E-Cr-7	HLW-E-Cr-8	HLW-E-Cr-9
	Waste Loading (wt%)	30%	40%	40%	40%	40%	40%	40%	40%	40%	40%
Crystal content	Glass as melted	No salt	Cr/S salt	Cr/S salt	Cr/S salt	Xl+Trace salt	Xl+Trace salt	Xl+Trace salt	No salt	Cr/S salt	Cr/S salt
	Xl at 950ºC	Sp	Sp + Pho	Sp + Cr-Fe	Sp	Sp	Sp + Pho	Sp + Cr-Fe	Sp	Sp	Sp
	Glass after HT at 950ºC	0.1	0.5	0.3	0.3	0.8	0.9	0.9	0.5	0.2	0.7
	Glass after HT at 900ºC	-	0.9	-	-	-	-	-	0.6	-	-
	Glass after HT at 850ºC	-	-	-	-	-	-	-	0.6	-	-
	Glass after HT at 800ºC	-	-	-	-	-	-	-	1.2	-	-
	Glass after HT of CCC	-	-	-	-	-	-	-		-	-
	Viscosity at 1250ºC	-	-	-	-	-	-	-	23.0	-	-
	Viscosity at 1150ºC	-	-	-	-	-	-	-	46.8	-	-
	Viscosity at 1050ºC	-	-	-	-	-	-	-	120.3	-	-
	Viscosity at 950ºC	-	-	-	-	-	-	-	451.7	-	-
	Electric conductivity at 1250ºC	-	-	-	-	-	-	-	0.34	-	-
	Electric conductivity at 1150ºC	-	-	-	-	-	-	-	0.26	-	-
	Electric conductivity at 1050ºC	-	-	-	-	-	-	-	0.18	-	-
	Electric conductivity at 950ºC	-	-	-	-	-	-	-	0.11	-	-
	Glass transition temperature (ºC)	-	-	-	-	-	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-	-	-	312.2
	Li (ppm)	-	-	-	-	-	-	-	-	-	62.2
	Na (ppm)	-	-	-	-	-	-	-	-	-	225.1
	Si (ppm)	-	-	-	-	-	-	-	-	-	34.4
	B (g/L)	-	-	-	-	-	-	-	-	-	6.39
	Li (g/L)	-	-	-	-	-	-	-	-	-	4.25
	Na (g/L)	-	-	-	-	-	-	-	-	-	3.49
	Si (g/L)	-	-	-	-	-	-	-	-	-	0.19
	PCT (for CCC sample)	-	-	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-	-	-	-
	Li (ppm)	-	-	-	-	-	-	-	-	-	-
	Na (ppm)	-	-	-	-	-	-	-	-	-	-
	Si (ppm)	-	-	-	-	-	-	-	-	-	-
	B (g/L)	-	-	-	-	-	-	-	-	-	-
	Li (g/L)	-	-	-	-	-	-	-	-	-	-
	Na (g/L)	-	-	-	-	-	-	-	-	-	-
	Si (g/L)	-	-	-	-	-	-	-	-	-	-
	TCLP (Pass/Fail)	-	-	-	-	-	-	-	Pass	-	-

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate; Cr-Fe = Cr-Fe-oxide
- Empty data field

Table 3.6. Characterization of Glasses Formulated for Cr-Limited Waste (continued).

	Glass Name	HLW-E-Cr-10	HLW-E-Cr-11	HLW-E-Cr-17	HLW-E-Cr-18	HLW-E-Cr-12	HLW-E-Cr-15	HLW-E-Cr-13	HLW-E-Cr-16	HLW-E-Cr-M	HLW-E-Cr-MUTh
	Waste Loading (wt%)	40%	40%	42.5%	42.5%	45%	45%	50%	50%	32.50%	32.50%
Crystal content	Glass as melted	No salt	No salt	Cr/S salt	Cr/S salt	Trace salt	Cr/S salt	Cr/S salt	Cr/S salt	No salt	No salt
	Xl at 950ºCSP	-	Sp	Sp +Pho	Sp	Sp	Sp	Sp + Cr-Fe	Sp + Cr-Fe	Ni-rich oxide	Sp + Cr-Fe
	Glass after HT at 950ºC	0.6	-	1.1	0.6	0.7	0.7	1.2	2.0	0.8	0.2
	Glass after HT at 900ºC	0.8	-	-	-	-	-	-	-	0.9	0.2
	Glass after HT at 850ºC	0.8	-	-	-	-	-	-	-	NA	0.4
	Glass after HT at 800ºC	2.0	-	-	-	-	-	-	-	2.9	0.1
	Glass after HT of CCC	0.7 (Sp + Cr-Fe)	-	-	-	-	-	-	-	1.3 (Sp + Pho + †)	0.3 (CrFe + Sp +†)
	Viscosity at 1250ºC	29.8	-	-	-	-	-	-	-	36.2	26.1
	Viscosity at 1150ºC	59.5	-	-	-	-	-	-	-	77.9	54.6
	Viscosity at 1050ºC	144.0	-	-	-	-	-	-	-	201.0	143.2
	Viscosity at 950ºC	466.1	-	-	-	-	-	-	-	664.7	529.5
	Electric conductivity at 1250ºC	0.49	-	-	-	-	-	-	-	0.28	0.31
	Electric conductivity at 1150ºC	0.37	-	-	-	-	-	-	-	0.20	0.24
	Electric conductivity at 1050ºC	0.25	-	-	-	-	-	-	-	0.14	0.16
	Electric conductivity at 950ºC	0.14	-	-	-	-	-	-	-	0.09	0.09
	Glass transition temperature (ºC)	-	-	-	-	-	-	-	-	455	-
Leaching performance	PCT	-	-	-	-	-	-	-	-	-	-
	B (ppm)	130.1	138.3	133.1	-	98.5	-	174.3	-	229.7	238.5
	Li (ppm)	30.6	31.2	31.2	-	17.1	-	24.9	-	57.5	62.4
	Na (ppm)	96.7	104.2	102.3	-	89.1	-	153.0	-	112.0	132.8
	Si (ppm)	45.5	42.3	46.6	-	38.6	-	34.8	-	47.7	42.4
	B (g/L)	2.90	3.08	2.97	-	2.19	-	4.01	-	4.57	4.75
	Li (g/L)	1.99	2.02	2.03	-	1.10	-	2.44	-	3.36	3.66
	Na (g/L)	1.50	1.61	1.49	-	1.23	-	1.90	-	2.14	2.74
	Si (g/L)	0.23	0.22	0.25	-	0.22	-	0.21	-	0.22	0.20
	PCT (for CCC sample)	-	-	-	-	-	-	-	-	-	-
	B (ppm)	113.0	-	-	-	-	-	-	-	-	-
	Li (ppm)	42.2	-	-	-	-	-	-	-	-	-
	Na (ppm)	99.1	-	-	-	-	-	-	-	-	-
	Si (ppm)	51.1	-	-	-	-	-	-	-	-	-
	B (g/L)	2.52	-	-	-	-	-	-	-	-	-
	Li (g/L)	2.74	-	-	-	-	-	-	-	-	-
	Na (g/L)	1.54	-	-	-	-	-	-	-	-	-
	Si (g/L)	0.26	-	-	-	-	-	-	-	-	-
	TCLP (Pass/Fail)	Pass	-	-	-	-	-	-	-	Pass	Pass

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate; †bubbles submicron size
- Empty data field

Table 3.7. XRF Analysis of Yellow Salt Phase Collected from Glass Surface of a Crucible Melt. B_2O_3 and Li_2O were not analyzed by XRF.

Component	wt %
Al_2O_3	4.1
Bi_2O_3	1.1
CaO	2.6
Cr_2O_3	16.1
Fe_2O_3	1.0
K_2O	22.8
Na_2O	20.1
NiO	0.2
P_2O_5	6.2
PbO	0.5
SO_3	21.2
SiO_2	4.2
Sum	100

Table 3.8. Composition and Properties of Chromium Limited Waste and Glass Formulation at 40% Waste Loading Initially Used in DM10 Melter Tests (wt%).

-	Cr-Limited Waste*	Waste in Glass	Glass Forming Additives	Target Glass HLW-E-Cr-10
Al_2O_3	27.64	11.06	-	11.06
B_2O_3	0.57	0.23	14.21	14.44
BaO	0.03	0.01	-	0.01
Bi_2O_3	7.89	3.16	-	3.16
CaO	2.67	1.07	-	1.07
CdO	0.01	0.00	-	< 0.01
Cr_2O_3	3.32	1.33	-	1.33
F	2.17	0.87	-	0.87
Fe_2O_3	14.22	5.69	-	5.69
K_2O	0.40	0.16	5.26	5.42
Li_2O	0.39	0.16	3.16	3.31
MgO	0.17	0.07	-	0.07
Na_2O	21.75	8.70	-	8.70
NiO	1.15	0.46	-	0.46
P_2O_5	3.62	1.45	-	1.45
PbO	0.52	0.21	-	0.21
SiO_2	11.43	4.57	37.37	41.94
TiO_2	0.01	< 0.01	-	< 0.01
SO_3	1.65	0.66	-	0.66
ZnO	0.27	0.11	-	0.11
ZrO_2	0.12	0.05	-	0.05
Sum	100	40	60	100

Viscosity @1150^{o}C, P			59
Conductivity @1150^{o}C, S/cm			0.37
Crystal Content, As Melted			None
Crystal Content, 72 hr at 950^{o}C			~0.6 vol%
TCLP			Pass
PCT, g/L	-	DWPF-EA	HLW-E-Cr-10
	B	16.7	2.9
	Li	9.6	2
	Na	13.3	1.5

* Renormalized from Ref. [3] after removal of radioactive components
- Empty data field

Table 3.9. Target Composition and XRF Analysis of Glasses Formulated for Al-Limited Waste.

-	Al-Limited Waste	Al-Limited Waste (non rad)#	HLW-E-Al-1		HLW-E-Al-2		HLW-E-Al-3		HLW-E-Al-4		HLW-E-Al-5		HLW-E-Al-6	
			Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	49.21	53.27	26.63	24.82	26.63	25.91	26.63	26.02	26.63	25.74	26.63	25.97	26.63	25.87
B_2O_3*	0.39	0.42	10.21	10.21	3.21	3.21	8.21	8.21	10.21	10.21	8.21	8.21	12.21	12.21
BaO	0.11	0.12	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.05	0.06	0.05
Bi_2O_3	2.35	2.54	1.27	1.31	1.27	1.37	1.27	1.30	1.27	1.37	1.27	1.41	1.27	1.33
CaO	2.21	2.39	1.20	1.33	14.20	14.72	14.20	14.32	16.20	16.53	11.20	11.61	18.20	18.31
CdO	0.05	0.05	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00
Cr_2O_3	1.07	1.16	0.58	0.78	0.58	0.70	0.58	0.67	0.58	0.62	0.58	0.68	0.58	0.65
F*	1.37	1.48	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-
Fe_2O_3	12.11	13.11	6.55	6.99	6.55	6.56	6.55	6.38	6.55	6.59	6.55	6.69	6.55	6.46
K_2O	0.29	0.31	0.16	0.23	1.56	1.72	0.16	0.26	0.16	0.25	0.16	0.26	0.16	0.25
Li_2O*	0.35	0.38	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
MgO	0.24	0.26	9.13	7.77	0.13	0.10	0.13	0.13	0.13	0.11	0.13	0.08	0.13	0.11
Na_2O	7.35	7.96	10.98	11.73	9.58	9.51	8.98	9.94	6.98	7.32	11.98	12.32	4.98	5.35
NiO	0.82	0.89	0.44	0.44	0.44	0.41	0.44	0.40	0.44	0.40	0.44	0.41	0.44	0.41
P_2O_5	2.16	2.34	1.17	1.31	1.17	1.51	1.17	1.35	1.17	1.19	1.17	1.29	1.17	1.16
PbO	0.84	0.91	0.45	0.42	0.45	0.43	0.45	0.40	0.45	0.44	0.45	0.46	0.45	0.42
SiO_2	10.05	10.88	29.44	31.66	32.44	32.92	29.44	29.80	27.44	28.05	29.44	29.55	25.44	26.40
ThO_2	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.02	0.02	0.01	0.05	0.01	0.04	0.01	0.04	0.01	0.07	0.01	0.06	0.01	0.06
SO_3	0.41	0.44	0.22	0.17	0.22	0.29	0.22	0.24	0.22	0.28	0.22	0.21	0.22	0.22
ZnO	0.17	0.18	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.10	0.09	0.10	0.09	0.10
ZrO_2	0.81	0.88	0.44	0.39	0.44	0.18	0.44	0.17	0.44	0.40	0.44	0.40	0.44	0.39
U_3O_8	7.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
#The non-radioactive version of the waste is calculated by renormalization of the waste constituents after removing U_3O_8 and ThO_2.
- Empty data field

Table 3.9. Target Composition and XRF Analysis of Glasses Formulated for Al-Limited Waste (continued).

-	HLW-E-Al-7		HLW-E-Al-8		HLW-E-Al-9		HLW-E-Al-10		HLW-E-A1-11		HLW-E-Al-12		HLW-E-Al-13		HLW-E-Al-14		HLW-E-Al-15	
	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	26.63	26.02	26.63	26.32	26.63	26.25	26.63	26.16	26.63	25.89	23.97	23.34	25.30	24.78	26.63	26.76	25.30	25.00
B_2O_3*	15.21	15.21	18.21	18.21	18.21	18.21	20.21	20.21	16.21	16.21	20.19	20.19	19.29	19.29	18.21	18.21	20.20	20.20
BaO	0.06	0.07	0.06	0.07	0.06	0.07	0.06	0.00	0.06	0.06	0.05	0.06	0.06	0.05	0.06	0.05	0.06	0.06
Bi_2O_3	1.27	1.33	1.27	1.26	1.27	1.33	1.27	1.34	1.27	1.35	1.14	1.20	1.21	1.27	1.27	1.37	1.21	1.36
CaO	20.20	20.28	18.20	17.99	16.20	16.49	14.20	14.46	14.20	14.20	14.08	14.36	13.55	14.00	1.20	1.25	1.14	1.28
CdO	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.02	0.00	0.03	0.00	0.03	0.00	0.03	0.00
Cr_2O_3	0.58	0.67	0.58	0.62	0.58	0.68	0.58	0.64	0.58	0.68	0.52	0.62	0.55	0.66	0.58	0.67	0.55	0.62
F*	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	0.67	-	0.70	-	0.74	-	0.70	-
Fe_2O_3	6.55	6.25	6.55	6.10	6.55	6.43	6.55	6.41	6.55	6.39	5.90	5.77	6.23	6.14	6.55	6.42	6.23	6.43
K_2O	0.16	0.20	0.16	0.20	0.16	0.21	0.16	0.24	0.16	0.21	0.14	0.20	0.15	0.24	0.16	0.25	0.15	0.23
Li_2O*	1.19	1.19	1.19	1.19	3.19	3.09	5.19	5.19	5.19	5.19	5.17	5.17	4.95	4.95	7.19	7.19	7.68	7.68
MgO	0.13	0.11	0.13	0.07	0.13	0.10	0.13	0.12	0.13	0.10	0.12	0.11	0.12	0.11	0.13	0.07	0.12	0.00
Na_2O	3.98	4.14	3.98	4.19	3.98	4.09	3.98	4.05	3.98	4.67	3.58	3.65	3.78	3.94	3.98	4.03	3.78	3.93
NiO	0.44	0.42	0.44	0.41	0.44	0.41	0.44	0.43	0.44	0.42	0.40	0.40	0.42	0.41	0.44	0.42	0.42	0.42
P_2O_5	1.17	1.39	1.17	1.41	1.17	1.27	1.17	1.26	1.17	1.48	1.05	1.24	1.11	1.25	1.17	1.29	1.11	1.24
PbO	0.45	0.43	0.45	0.42	0.45	0.43	0.45	0.43	0.45	0.44	0.41	0.39	0.43	0.40	0.45	0.43	0.43	0.44
SiO_2	20.44	21.37	19.44	20.68	19.44	19.99	17.44	18.20	21.44	21.95	21.90	22.63	21.39	21.78	30.44	30.71	30.17	30.26
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.01	0.03	0.01	0.03	0.01	0.05	0.01	0.06	0.01	0.03	0.01	0.03	0.01	0.03	0.01	0.07	0.01	0.04
SO_3	0.22	0.26	0.22	0.24	0.22	0.19	0.22	0.19	0.22	0.15	0.20	0.13	0.21	0.21	0.22	0.26	0.21	0.22
ZnO	0.09	0.12	0.09	0.11	0.09	0.11	0.09	0.12	0.09	0.11	0.08	0.10	0.09	0.11	0.09	0.11	0.09	0.12
ZrO_2	0.44	0.43	0.44	0.40	0.44	0.41	0.44	0.41	0.44	0.41	0.39	0.37	0.42	0.30	0.44	0.40	0.42	0.39
U_3O_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
- Empty data field

Table 3.9. Target Composition and XRF Analysis of Glasses Formulated for Al-Limited Waste (continued).

-	HLW-E-Al-16		HLW-E-A1-17		HLW-E-A1-18		HLW-E-Al-19		HLW-E-Al-20		HLW-E-Al-21		HLW-E-Al-22		HLW-E-Al-23		HLW-E-Al-24	
	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	23.97	24.05	29.30	29.05	23.97	23.32	26.63	26.47	25.30	25.34	25.30	25.42	25.30	25.39	23.97	23.81	18.64	18.54
B_2O_3*	20.19	20.19	18.23	18.23	19.19	19.19	14.41	14.41	14.40	14.40	14.00	14.00	14.00	14.00	14.19	14.19	15.15	15.15
BaO	0.05	0.05	0.07	0.08	0.05	0.08	0.06	0.07	0.06	0.06	0.06	0.08	0.06	0.06	0.05	0.05	0.04	0.05
Bi_2O_3	1.14	1.20	1.40	1.46	1.14	1.26	1.27	1.32	1.21	1.24	1.21	1.23	1.21	1.15	1.14	1.19	0.89	1.00
CaO	1.08	1.12	1.32	1.39	13.08	13.71	1.20	1.27	1.14	1.19	1.14	1.18	1.14	1.12	1.08	1.12	0.84	0.91
CdO	0.02	0.00	0.03	0.00	0.02	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.02	0.00	0.02	0.00
Cr_2O_3	0.52	0.60	0.64	0.74	0.52	0.64	0.58	0.67	0.55	0.64	0.55	0.66	0.55	0.52	0.52	0.64	0.41	0.51
F*	0.67	-	0.82	-	0.67	-	0.74	-	0.70	-	0.70	-	0.70	-	0.67	-	0.52	-
Fe_2O_3	5.90	5.78	7.21	0.70	5.90	5.99	6.55	6.30	6.23	5.93	6.23	5.94	6.23	5.61	5.90	5.66	4.59	4.69
K_2O	0.14	0.23	0.17	0.25	0.14	0.21	0.16	0.21	0.15	0.22	0.15	0.22	5.15	4.91	0.14	0.18	0.11	0.19
Li_2O*	7.67	7.67	7.71	7.71	5.17	5.17	3.49	3.49	4.18	4.18	5.03	5.03	5.03	5.03	3.57	3.57	3.53	3.53
MgO	0.12	0.08	0.14	0.11	0.12	0.08	0.13	0.10	0.12	0.10	0.12	0.07	0.12	0.10	0.12	0.08	0.09	0.14
Na_2O	3.58	3.66	4.38	4.62	3.58	3.62	13.98	14.82	13.78	14.32	14.78	14.90	9.78	10.68	14.08	14.78	14.78	14.61
NiO	0.40	0.38	0.49	0.45	0.40	0.40	0.44	0.40	0.42	0.38	0.42	0.40	0.42	0.37	0.40	0.38	0.31	0.32
P_2O_5	3.55	3.82	1.29	1.42	1.05	1.14	1.17	1.30	1.11	1.25	1.11	1.26	1.11	1.28	1.05	1.23	0.82	0.94
PbO	0.41	0.38	0.50	0.48	0.41	0.41	0.45	0.41	0.43	0.39	0.43	0.39	0.43	0.36	0.41	0.37	0.32	0.34
SiO_2	29.90	29.97	25.48	26.04	21.90	22.00	27.94	27.89	29.47	29.54	28.02	28.35	28.02	28.58	32.00	31.95	35.81	35.72
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.01	0.05	0.01	0.05	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.05	0.01	0.04	0.01	0.07	0.01	0.05
SO_3	0.20	0.23	0.24	0.25	0.20	0.19	0.22	0.26	0.21	0.23	0.21	0.27	0.21	0.26	0.20	0.26	0.16	0.20
ZnO	0.08	0.10	0.10	0.13	0.08	0.11	0.09	0.12	0.09	0.10	0.09	0.12	0.09	0.10	0.08	0.10	0.06	0.09
ZrO_2	0.39	0.36	0.48	0.45	2.39	2.32	0.44	0.40	0.42	0.38	0.42	0.39	0.42	0.37	0.39	0.32	2.91	2.90
U_3O_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
- Empty data field

Table 3.9. Target Composition and XRF Analysis of Glasses Formulated for Al-Limited Waste (continued).

-	HLW-E-Al-25		HLW-E-Al-26		HLW-E-Al-27			HLW-E-Al-28		HLW-E-Al-29		HLW-E-Al27UTh	
	Target	XRF	Target	XRF	Target	XRF-27	XRF-27R1	Target	XRF-28	Target	XRF-29	Target	XRF
Al_2O_3	23.97	23.63	23.97	22.37	23.97	23.68	23.58	25.30	25.03	25.30	24.86	22.14	22.03
B_2O_3*	14.19	14.19	16.19	16.19	15.19	15.19	15.19	14.40	14.40	14.40	14.40	15.18	15.18
BaO	0.05	0.05	0.05	0.05	0.05	0.07	0.07	0.06	0.06	0.06	0.06	0.05	0.03
Bi_2O_3	1.14	1.24	1.14	1.31	1.14	1.31	1.26	1.21	1.35	1.21	1.34	1.06	1.14
CaO	6.08	6.42	1.08	1.19	6.08	6.41	6.17	6.14	6.46	9.14	9.31	5.99	6.29
CdO	0.02	0.00	0.02	0.00	0.02	0.00	0.00	0.03	0.00	0.03	0.00	0.02	0.00
Cr_2O_3	0.52	0.63	0.52	0.66	0.52	0.54	0.62	0.55	0.67	0.55	0.66	0.48	0.58
F*	0.67	-	0.67	-	0.67	-	-	0.70	-	0.70	-	0.62	-
Fe_2O_3	5.90	6.00	5.90	6.21	5.90	6.18	5.89	6.23	6.39	6.23	6.27	5.45	5.43
K_2O	0.14	0.19	0.14	0.24	0.14	0.19	0.22	0.15	0.21	0.15	0.23	0.13	0.20
Li_2O*	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.68	3.68	2.68	2.68	3.56	3.56
MgO	0.12	0.07	0.12	0.11	0.12	0.00	0.10	0.12	0.07	0.12	0.08	0.11	0.11
Na_2O	9.58	10.04	13.08	13.42	9.58	9.78	10.13	9.78	10.26	9.78	10.36	9.31	9.08
NiO	0.40	0.40	0.40	0.41	0.40	0.42	0.38	0.42	0.42	0.42	0.41	0.37	0.37
P_2O_5	1.05	1.19	1.05	1.27	1.05	1.20	1.16	1.11	1.26	1.11	1.21	0.97	1.11
PbO	0.41	0.40	0.41	0.42	0.41	0.42	0.39	0.43	0.44	0.43	0.43	0.38	0.37
SiO_2	31.50	31.18	31.00	31.66	30.50	30.13	30.46	28.97	28.44	26.97	26.81	30.12	30.19
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.02
TiO_2	0.01	0.03	0.01	0.04	0.01	0.04	0.05	0.01	0.05	0.01	0.06	0.01	0.06
SO_3	0.20	0.23	0.20	0.26	0.20	0.22	0.22	0.21	0.25	0.21	0.23	0.18	0.24
ZnO	0.08	0.10	0.08	0.11	0.08	0.11	0.11	0.09	0.11	0.09	0.11	0.08	0.11
ZrO_2	0.39	0.37	0.39	0.40	0.39	0.41	0.36	0.42	0.39	0.42	0.41	0.36	0.30
U_3O_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.26	3.44

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
- Empty data field

Table 3.10. Characterization of Glasses Formulated for Al-Limited Waste.

	Glass Name	HLW-E-Al-24	HLW-E-Al-16	HLW-E-Al-12	HLW-E-Al-18	HLW-E-Al-23	HLW-E-Al-26	HLW-E-Al-25
	Waste loading (wt%)	35	45	45	45	45	45	45
	Glass former type	Na+Li	Li	Ca+Li	Ca+Li	Na+Li	Na+Li	Na+Li+Ca
Crystal content	Glass as melted	Free	Xtls	Trace	Trace	Xtls	Xtls	Trace
	Xl at 950ºC	-	-	Sp	Sp + ZrO2	-	-	Sp + Pho
	Glass after HT at 950ºC (vol%)	-	-	1.6	~1.8	-	-	2.0
	Glass after HT at 900ºC (vol%)	-	-	-	-	-	-	3.7
	Glass after HT at 850ºC (vol%)	-	-	3.5	-	-	-	5.1
	Glass after HT at 800ºC (vol%)	0.2	-	4.1	-	12.3	-	5.5
	Glass after HT of CCC (vol%)	0.1 (Spinel)	-	-	-	-	-	1.9 (Sp + Pho)
Processing properties	Highly viscous during pouring (Y/N)	N	N	N	N	N	N	N
	Viscosity at 1250ºC (poise)	-	-	5.5	4.6	-	-	25.1
	Viscosity at 1150ºC (poise)	-	-	10.9	10.2	-	-	59.4
	Viscosity at 1050ºC (poise)	-	-	27.0	27.2	-	-	172.6
	Viscosity at 950ºC (poise)	-	-	96.7	92.5	-	-	669.1
	Electric conductivity at 1250ºC (S/cm)	-	-	0.37	0.29	-	-	0.35
	Electric conductivity at 1150ºC (S/cm)	-	-	0.25	0.20	-	-	0.26
	Electric conductivity at 1050ºC (S/cm)	-	-	0.16	0.12	-	-	0.17
	Electric conductivity at 950ºC (S/cm)	-	-	0.09	0.07	-	-	0.10
	Glass transition temperature (ºC)	-	-			-	-	-
Leaching performance	PCT	-	-			-	-	-
	B (ppm)	-	-	32.7	42.2	-	-	-
	Li (ppm)	-	-	12.2	15.2	-	-	-
	Na (ppm)	-	-	14.2	18.4	-	-	-
	Si (ppm)	-	-	4.4	4.4	-	-	-
	B (g/L)	-	-	0.52	0.71	-	-	-
	Li (g/L)	-	-	0.51	0.63	-	-	-
	Na (g/L)	-	-	0.54	0.69	-	-	-
	Si (g/L)	-	-	0.04	0.04	-	-	-
	PCT (for CCC sample)	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-
	Li (ppm)	-	-	-	-	-	-	-
	Na (ppm)	-	-	-	-	-	-	-
	Si (ppm)	-	-	-	-	-	-	-
	B (g/L)	-	-	-	-	-	-	-
	Li (g/L)	-	-	-	-	-	-	-
	Na (g/L)	-	-	-	-	-	-	-
	Si (g/L)	-	-	-	-	-	-	-
	TCLP (Pass/Fail)	-	-	Pass	Pass	-	-	-

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.10. Characterization of Glasses Formulated for Al-Limited Waste (continued).

	Glass Name	HLW-E-Al-27	HLW-E-Al-27UThR2	HLW-E-Al-15	HLW-E-Al-13	HLW-E-Al-20	HLW-E-Al-21	HLW-E-Al-22
	Waste loading (wt%)	45	45	47.5	47.5	47.5	47.5	47.5
	Glass former type	Na+Li+Ca	Na+Li+Ca	Li	Ca+Li	Na+Li	Na+Li	Na+Li
Crystal content	Glass as melted	Trace	-	Xtls	Trace	Xtls	Xtls	Xtls
	Xl at 950ºC	Sp	Sp	-	Sp + Apatite	Sp	Sp	Sp
	Glass after HT at 950ºC (vol%)	1.0	1.0	-	1.5	1.1	0.5	2.2
	Glass after HT at 900ºC (vol%)	3.8	Not analyzed	-	-	-	-	-
	Glass after HT at 850ºC (vol%)	3.4	3.0	-	-	-	-	-
	Glass after HT at 800ºC (vol%)	7.2	3.1	-	-	-	-	-
	Glass after HT of CCC (vol%)	1.9 (spinel)	1.7 (spinel)	-	-	-	-	-
Processing properties	Highly viscous during pouring (Y/N)	N	N	N	N	N	N	N
	Viscosity at 1250ºC (poise)	19.5	17.5	-	-	-	-	-
	Viscosity at 1150ºC (poise)	45.6	38.7	-	-	-	-	-
	Viscosity at 1050ºC (poise)	129.8	107.0	-	-	-	-	-
	Viscosity at 950ºC (poise)	488.8	407.8	-	-	-	-	-
	Electric conductivity at 1250ºC (S/cm)	0.35	0.41	-	-	-	-	-
	Electric conductivity at 1150ºC (S/cm)	0.26	0.29	-	-	-	-	-
	Electric conductivity at 1050ºC (S/cm)	0.18	0.19	-	-	-	-	-
	Electric conductivity at 950ºC (S/cm)	0.10	0.12	-	-	-	-	-
	Glass transition temperature (ºC)	483	-	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-	-	-
	B (ppm)	12.7	12.6	-	-	-	-	81.8
	Li (ppm)	7.3	6.4	-	-	-	-	35.0
	Na (ppm)	21.5	18.9	-	-	-	-	93.2
	Si (ppm)	20.1	16.3	-	-	-	-	36.1
	B (g/L)	0.27	0.27	-	-	-	-	1.88
	Li (g/L)	0.44	0.38	-	-	-	-	1.50
	Na (g/L)	0.30	0.27	-	-	-	-	1.28
	Si (g/L)	0.14	0.12	-	-	-	-	0.28
	PCT (for CCC sample)	-	-	-	-	-	-	-
	B (ppm)	14.72	-	-	-	-	-	-
	Li (ppm)	7.303	-	-	-	-	-	-
	Na (ppm)	23.1	-	-	-	-	-	-
	Si (ppm)	23.25	-	-	-	-	-	-
	B (g/L)	0.3121	-	-	-	-	-	-
	Li (g/L)	0.4403	-	-	-	-	-	-
	Na (g/L)	0.3250	-	-	-	-	-	-
	Si (g/L)	0.1631	-	-	-	-	-	-
	TCLP (Pass/Fail)	Pass	Pass	-	-	-	-	Pass

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.10. Characterization of Glasses Formulated for Al-Limited Waste (continued).

	Glass Name	HLW-E-Al-28	HLW-E-Al-29	HLW-E-Al-14	HLW-E-Al-7	HLW-E-Al-8	HLW-E-Al-9	HLW-E-Al-10	HLW-E-Al-11
	Waste loading (wt%)	47.5	47.5	50	50	50	50	50	50
	Glass former type	Na+Li+Ca	Na+Li+Ca	Li	Ca+Li	Ca+Li	Ca+Li	Ca+Li	Ca+Li
Crystal content	Glass as melted	Xtls	Xtls	Xtls	Trace	Trace	Trace	Xtls	Trace
	Xl at 950ºC	Sp + Pho	-	-	Pho + Nas + Sp	Sp + Nas	Sp + Pho	Sp + Pho	Sp + Pho
	Glass after HT at 950ºC (vol%)	2.8	-	-	6.7	6.8	4.0	2.1	2.9
	Glass after HT at 900ºC (vol%)	-	-	-	-	-	-	-	4.2
	Glass after HT at 850ºC (vol%)	-	-	-	-	-	-	-	5.3
	Glass after HT at 800ºC (vol%)	-	-	-	-	-	-	-	7.8
	Glass after HT of CCC (vol%)	-	-	-	-	-	-	-	
Processing properties	Highly viscous during pouring (Y/N)	N	N	N	N	N	N	N	N
	Viscosity at 1250ºC (poise)	-	-	-	-	9.9	-	-	6.3
	Viscosity at 1150ºC (poise)	-	-	-	-	27.1	-	-	14.0
	Viscosity at 1050ºC (poise)	-	-	-	-	103.6	-	-	35.7
	Viscosity at 950ºC (poise)	-	-	-	-	677.7	-	-	108.3
	Electric conductivity at 1250ºC (S/cm)	-	-	-	-	0.13	-	-	0.49
	Electric conductivity at 1150ºC (S/cm)	-	-	-	-	0.07	-	-	0.31
	Electric conductivity at 1050ºC (S/cm)	-	-	-	-	0.03	-	-	0.18
	Electric conductivity at 950ºC (S/cm)	-	-	-	-	0.01	-	-	0.10
	Glass transition temperature (ºC)	-	-	-	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	111.9	22.8
	Li (ppm)	-	-	-	-	-	-	44.3	13.1
	Na (ppm)	-	-	-	-	-	-	55.5	15.5
	Si (ppm)	-	-	-	-	-	-	2.2	7.4
	B (g/L)	-	-	-	-	-	-	1.78	0.45
	Li (g/L)	-	-	-	-	-	-	1.84	0.55
	Na (g/L)	-	-	-	-	-	-	1.88	0.52
	Si (g/L)	-	-	-	-	-	-	0.03	0.07
	PCT (for CCC sample)	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-	-
	Li (ppm)	-	-	-	-	-	-	-	-
	Na (ppm)	-	-	-	-	-	-	-	-
	Si (ppm)	-	-	-	-	-	-	-	-
	B (g/L)	-	-	-	-	-	-	-	-
	Li (g/L)	-	-	-	-	-	-	-	-
	Na (g/L)	-	-	-	-	-	-	-	-
	Si (g/L)	-	-	-	-	-	-	-	-
	TCLP (Pass/Fail)	-	-	-	-	-	-	-	Pass

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.10. Characterization of Glasses Formulated for Al-Limited Waste (continued).

	Glass Name	HLW-E-Al-19	HLW-E-Al-2	HLW-E-Al-3	HLW-E-Al-4	HLW-E-Al-5	HLW-E-Al-6	HLW-E-Al-1	HLW-E-Al-17
	Waste loading (wt%)	50	50	50	50	50	50	50	55
	Glass former type	Na+Li	Ca+Na	Ca+Na	Ca+Na	Ca+Na	Ca+Na	Mg+Na	Li
Crystal content	Glass as melted	Xtls	Xtls	Xtls	Trace	Xtls	Xtls	Xtls	Xtls
	Xl at 950ºC	Sp + Nas	-	-	Nas + Pho + Sp	-	Nas + Pho + Sp	-	-
	Glass after HT at 950ºC (vol%)	4.1	-	-	34.0	-	31.9	-	-
	Glass after HT at 900ºC (vol%)	3.2	-	-	-	-	-	-	-
	Glass after HT at 850ºC (vol%)	5.2	-	-	-	-	-	-	-
	Glass after HT at 800ºC (vol%)	2.7	-	-	-	-	-	-	-
	Glass after HT of CCC (vol%)	-	-	-	-	-	-	-	-
Processing properties	Highly viscous during pouring (Y/N)	N	Y	N	N	N	N	Y	N
	Viscosity at 1250ºC (poise)	-	-	-	-	-	28.9	-	-
	Viscosity at 1150ºC (poise)	-	-	-	-	-	101.5	-	-
	Viscosity at 1050ºC (poise)	-	-	-	-	-	568.1	-	-
	Viscosity at 950ºC (poise)	-	-	-	-	-	6961.8	-	-
	Electric conductivity at 1250ºC (S/cm)	-	-	-	-	-	0.06	-	-
	Electric conductivity at 1150ºC (S/cm)	-	-	-	-	-	0.03	-	-
	Electric conductivity at 1050ºC (S/cm)	-	-	-	-	-	0.01	-	-
	Electric conductivity at 950ºC (S/cm)	-	-	-	-	-	0.00	-	-
	Glass transition temperature (ºC)	-	-	-	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-	-
	Li (ppm)	-	-	-	-	-	-	-	-
	Na (ppm)	-	-	-	-	-	-	-	-
	Si (ppm)	-	-	-	-	-	-	-	-
	B (g/L)	-	-	-	-	-	-	-	-
	Li (g/L)	-	-	-	-	-	-	-	-
	Na (g/L)	-	-	-	-	-	-	-	-
	Si (g/L)	-	-	-	-	-	-	-	-
	PCT (for CCC sample)	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-	-
	Li (ppm)	-	-	-	-	-	-	-	-
	Na (ppm)	-	-	-	-	-	-	-	-
	Si (ppm)	-	-	-	-	-	-	-	-
	B (g/L)	-	-	-	-	-	-	-	-
	Li (g/L)	-	-	-	-	-	-	-	-
	Na (g/L)	-	-	-	-	-	-	-	-
	Si (g/L)	-	-	-	-	-	-	-	-
	TCLP (Pass/Fail)	-	-	-	-	-	-	-	-

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.11. Composition and Properties of Aluminum Limited Waste and Glass Formulation at 45% Waste Loading Used in Melter Tests (wt%).

-	Al-Limited Waste*	Waste in Glass	Glass Forming Additives	Target Glass HLW-E-Al-27
Al_2O_3	53.27	23.97	-	23.97
B_2O_3	0.42	0.19	15.00	15.19
BaO	0.12	0.05	-	0.05
Bi_2O_3	2.54	1.14	-	1.14
CaO	2.39	1.08	5.00	6.08
CdO	0.05	0.02	-	0.02
Cr_2O_3	1.16	0.52		0.52
F	1.48	0.67	-	0.67
Fe_2O_3	13.11	5.90	-	5.90
K_2O	0.31	0.14	-	0.14
Li_2O	0.38	0.17	3.40	3.57
MgO	0.26	0.12	-	0.12
Na_2O	7.96	3.58	6.00	9.58
NiO	0.89	0.40	-	0.40
P_2O_5	2.34	1.05	-	1.05
PbO	0.91	0.41	-	0.41
SiO_2	10.88	4.90	25.60	30.50
TiO_2	0.02	0.01	-	0.01
SO_3	0.44	0.20	-	0.20
ZnO	0.18	0.08	-	0.08
ZrO_2	0.88	0.39	-	0.39
Sum	100.00	45.00	55.00	100.00

* Renormalized from Ref. [3] after removal of radioactive components

Viscosity @1150ºC, P			46
Conductivity @1150ºC, S/cm			0.26
Crystal Content, As Melted			Trace
Crystal Content, 72 hr at 950^{o}C			~1.0 vol%
Crystal Content, CCC			~1.9 vol%
TCLP			Pass
PCT, g/L	-	DWPF-EA	HLW-E-Al-27
	B	16.7	0.27
	Li	9.6	0.44
	Na	13.3	0.30

- Empty data field

Table 3.12. Target Composition and XRF Analysis of Glasses Formulated for Al-Na-Limited Waste.

-	Al-Na-limited waste	Al-Na-limited waste (non rad)#	HLW-E-ANa-1		HLW-E-ANa-2		HLWE-ANa-3		HLWE-ANa-4		HLWE-ANa-5		HLWE-ANa-6		HLWE-ANa-7		HLWE-ANa-8	
			Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	43.30	45.40	19.07	18.99	21.34	21.10	23.61	23.32	21.34	21.03	23.61	23.39	25.88	25.37	27.24	26.89	25.88	25.41
B_2O_3*	0.74	0.78	14.33	14.33	14.37	14.37	13.41	13.41	14.37	14.37	14.41	14.41	14.44	14.44	14.47	14.47	14.44	14.44
BaO	0.06	0.06	0.03	0.02	0.03	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04
Bi_2O_3	2.35	2.46	1.03	1.09	1.16	1.21	1.28	1.26	1.16	1.15	1.28	1.35	1.40	1.61	1.48	1.53	1.40	1.50
CaO	1.47	1.54	0.65	0.67	0.72	0.78	0.80	0.88	0.72	0.76	0.80	0.85	0.88	1.00	0.92	1.00	0.88	0.95
CdO	0.02	0.02	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Cr_2O_3	1.44	1.51	0.63	0.77	0.71	0.83	0.79	0.96	0.71	0.85	0.79	1.02	0.86	1.12	0.91	1.08	0.86	1.07
F*	0.46	0.48	0.20	-	0.23	-	0.25	-	0.23	-	0.25	-	0.27	-	0.29	-	0.27	-
Fe_2O_3	5.71	5.99	2.52	2.51	2.82	2.76	3.11	3.12	2.82	2.75	3.11	3.19	3.41	3.73	3.59	3.56	3.41	3.42
K_2O	1.34	1.41	0.59	0.69	0.66	0.73	0.73	0.08	0.66	0.75	0.73	0.80	0.80	0.90	0.85	0.88	0.80	0.86
Li_2O*	0.15	0.16	4.07	4.07	3.08	3.08	2.58	2.58	4.08	4.08	3.58	3.58	2.81	2.81	2.82	2.82	3.59	3.59
MgO	0.44	0.46	0.19	0.17	0.22	0.20	0.24	0.19	0.22	0.19	0.24	0.20	0.26	0.22	0.28	0.23	0.26	0.24
Na_2O	25.79	27.04	11.36	11.40	12.71	12.96	14.06	14.09	12.71	12.65	14.06	14.56	15.41	15.16	16.22	15.88	15.41	15.65
NiO	0.20	0.21	0.09	0.08	0.10	0.10	0.11	0.10	0.10	0.10	0.11	0.11	0.12	0.14	0.13	0.12	0.12	0.13
P_2O_5	4.10	4.30	3.81	4.10	2.02	2.51	2.24	2.51	2.02	2.55	2.24	2.44	2.45	2.68	2.58	2.90	2.45	2.70
PbO	0.18	0.19	0.08	0.09	0.09	0.08	0.10	0.09	0.09	0.09	0.10	0.09	0.11	0.11	0.11	0.11	0.11	0.11
SiO_2	6.22	6.52	39.74	39.39	39.06	38.47	35.89	35.83	38.06	37.87	33.89	33.10	30.00	29.67	27.19	27.53	29.22	28.96
ThO_2	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.35	0.37	0.16	0.20	0.17	0.21	0.19	0.23	0.17	0.21	0.19	0.23	0.21	0.27	0.22	0.26	0.21	0.25
SO_3	0.44	0.46	0.19	0.18	0.22	0.22	0.24	0.23	0.22	0.24	0.24	0.23	0.26	0.26	0.28	0.28	0.26	0.27
ZnO	0.36	0.38	0.16	0.17	0.18	0.19	0.20	0.21	0.18	0.19	0.20	0.21	0.22	0.26	0.23	0.24	0.22	0.23
ZrO_2	0.25	0.26	1.11	1.01	0.12	0.12	0.14	0.10	0.12	0.11	0.14	0.14	0.15	0.16	0.16	0.15	0.15	0.15
U_3O_8	4.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
#The non-radioactive version of the waste is calculated by renormalization of the waste constituents after removing U_3O_8 and ThO_2.
- Empty data field

Table 3.12. Target Composition and XRF Analysis of Glasses Formulated for Al-Na-Limited Waste (continued).

-	HLWE-ANa-9		HLWE-ANa-10		HLWE-ANa-11		HLWE-ANa-12		HLWE-ANa-13		HLWE-ANa-14		HLWE-ANa-15		HLWE-ANa-16		HLWE-ANa-17		HLWE-ANa-18		HLWE-ANa-19	
	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF	Target	XRF
Al_2O_3	25.88	25.29	25.88	25.28	25.88	25.45	29.51	28.96	21.34	20.02	23.61	23.28	23.61	23.23	23.61	23.17	20.43	20.41	20.43	20.23	19.52	19.45
B_2O_3*	14.44	14.44	15.94	15.94	13.44	13.44	13.51	13.51	14.37	14.37	14.41	14.41	15.41	15.41	14.41	14.41	15.35	15.35	15.35	15.35	15.34	15.34
BaO	0.03	0.03	0.03	0.05	0.03	0.05	0.04	0.06	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.02	0.03	0.02	0.03	0.03
Bi_2O_3	1.40	1.66	1.40	1.53	1.40	1.49	1.60	1.65	1.16	1.29	1.28	1.35	1.28	1.38	1.28	1.45	1.11	1.02	1.11	1.11	1.06	1.04
CaO	0.88	0.90	0.88	0.94	0.88	0.94	1.00	1.03	5.72	5.95	5.80	5.82	5.80	5.91	5.80	6.03	5.69	5.37	5.69	5.52	5.66	5.52
CdO	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Cr_2O_3	0.86	1.01	0.86	1.07	0.86	1.05	0.98	1.13	0.71	0.90	0.79	0.93	0.79	0.97	0.79	1.00	0.68	0.73	0.68	0.77	0.65	0.74
F*	0.27	-	0.27	-	0.27	-	0.31	-	0.23	-	0.25	-	0.25	-	0.25	-	0.22	-	0.22	-	0.21	-
Fe_2O_3	3.41	3.23	3.41	3.47	3.41	3.41	3.89	3.73	2.82	2.89	3.11	3.08	3.11	3.16	3.11	3.24	2.70	2.37	2.70	2.54	2.58	2.38
K_2O	0.80	0.82	0.80	0.85	0.80	0.86	0.92	0.93	0.66	0.72	0.73	0.76	0.73	0.76	0.73	0.75	0.63	0.63	0.63	0.68	0.61	0.61
Li_2O*	5.09	5.09	3.59	3.59	5.09	5.09	2.10	2.10	3.08	3.08	2.58	2.58	2.58	2.58	3.58	3.58	3.07	3.07	3.07	3.07	3.57	3.57
MgO	0.26	0.21	0.26	0.21	0.26	0.23	0.30	0.25	0.22	0.20	0.24	0.17	0.24	0.18	0.24	0.19	0.21	0.17	0.21	0.19	0.20	0.19
Na_2O	15.41	16.11	15.41	15.88	15.41	15.17	17.58	18.85	12.71	13.12	14.06	14.59	14.06	14.46	14.06	14.03	12.17	12.95	12.17	12.41	11.63	12.08
NiO	0.12	0.12	0.12	0.12	0.12	0.12	0.14	0.12	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.09	0.09	0.09	0.08	0.09	0.08
P_2O_5	2.45	2.70	2.45	2.69	2.45	2.74	2.80	2.97	2.02	2.32	2.24	2.40	2.24	2.50	2.24	2.48	1.94	2.23	1.94	2.21	1.85	2.08
PbO	0.11	0.10	0.11	0.11	0.11	0.11	0.12	0.10	0.09	0.09	0.10	0.09	0.10	0.10	0.10	0.10	0.09	0.06	0.09	0.07	0.08	0.07
SiO_2	27.72	27.40	27.72	27.31	28.72	28.87	24.24	23.60	34.06	34.11	29.89	29.50	28.89	28.37	28.89	28.48	34.93	34.81	32.93	33.29	34.30	34.18
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.21	0.22	0.21	0.24	0.21	0.25	0.24	0.26	0.17	0.22	0.19	0.22	0.19	0.23	0.19	0.23	0.17	0.18	0.17	0.19	0.16	0.38
SO_3	0.26	0.28	0.26	0.27	0.26	0.32	0.30	0.28	0.22	0.22	0.24	0.26	0.24	0.25	0.24	0.26	0.21	0.24	0.21	0.19	0.20	0.19
ZnO	0.22	0.22	0.22	0.24	0.22	0.24	0.25	0.24	0.18	0.20	0.20	0.21	0.20	0.21	0.20	0.22	0.17	0.16	0.17	0.16	0.16	0.16
ZrO_2	0.15	0.13	0.15	0.15	0.15	0.15	0.17	0.16	0.12	0.13	0.14	0.14	0.14	0.13	0.14	0.14	0.12	0.09	2.12	1.82	2.11	1.83
U_3O_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
- Empty data field

Table 3.12. Target Composition and XRF Analysis of Glasses Formulated for Al-Na-Limited Waste (continued).

-	HLWE-ANa-20		HLWE-ANa-21		HLWE-ANa-22			HLWE-ANa-23		HLWE-ANa-24		HLWE-ANa-25			HLWE-ANa-26		HLW-E-ANa22UTh	
	Target	XRF	Target	XRF	Target	XRF	XRF-22R1	Target	XRF	Target	XRF	Target	XRF	XRF-25R1	Target	XRF	Target	XRF
Al_2O_3	21.34	21.00	21.34	20.81	21.34	21.21	21.15	21.34	21.29	22.70	22.51	22.70	25.52	22.47	23.61	23.32	20.35	20.17
B_2O_3*	14.37	14.37	15.37	15.37	18.37	18.37	18.37	18.37	18.37	18.39	18.39	19.39	19.39	19.39	19.41	19.41	18.35	18.35
BaO	0.03	0.03	0.03	0.03	0.03	0.04	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.03	0.03
Bi_2O_3	1.16	1.31	1.16	1.28	1.16	1.21	1.35	1.16	1.11	1.23	1.32	1.23	1.34	1.41	1.28	1.38	1.10	1.13
CaO	3.72	3.97	3.72	3.78	0.72	0.77	0.83	0.72	0.73	0.77	0.81	0.77	0.82	0.87	0.80	0.85	0.69	0.70
CdO	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00
Cr_2O_3	0.71	0.93	0.71	0.91	0.71	0.86	0.95	0.71	0.79	0.76	0.92	0.76	0.94	0.96	0.79	0.98	0.68	0.79
F*	0.23	-	0.23	-	0.23	-	-	0.23	-	0.24	-	0.24	-	-	0.25	-	0.22	-
Fe_2O_3	2.82	2.97	2.82	2.89	2.82	2.78	3.03	2.82	2.57	3.00	3.01	3.00	3.02	3.16	3.11	3.16	2.68	2.56
K_2O	0.66	0.72	0.66	1.13	0.66	0.69	0.72	0.66	0.67	0.71	0.72	0.71	0.75	0.74	0.73	0.76	0.63	0.69
Li_2O*	3.08	3.08	3.08	3.08	3.58	3.58	3.58	3.58	3.58	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.57	3.57
MgO	0.22	0.19	0.22	0.17	0.22	0.20	0.21	0.22	0.16	0.23	0.18	0.23	0.18	0.17	0.24	0.21	0.21	0.21
Na_2O	12.71	12.73	12.71	12.81	12.71	12.75	12.34	12.71	13.45	13.52	13.70	13.52	13.24	13.73	14.06	14.32	12.12	12.25
NiO	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.08	0.11	0.12	0.11	0.11	0.12	0.11	0.11	0.09	0.09
P_2O_5	2.02	2.27	2.02	2.24	2.02	2.28	2.29	2.02	2.36	2.15	2.38	2.15	2.41	2.43	2.24	2.45	1.93	2.17
PbO	0.09	0.10	0.09	0.09	0.09	0.09	0.10	0.09	0.00	0.10	0.09	0.10	0.09	0.11	0.10	0.11	0.08	0.09
SiO_2	32.06	31.55	30.06	29.43	34.56	34.25	34.09	31.56	31.47	32.26	31.91	31.26	31.25	30.49	29.39	28.93	34.42	34.29
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
TiO_2	0.17	0.22	2.17	2.34	0.17	0.22	0.23	0.17	0.19	0.19	0.22	0.19	0.23	0.23	0.19	0.25	0.16	0.20
SO_3	0.22	0.21	0.22	0.23	0.22	0.24	0.21	0.22	0.23	0.23	0.22	0.23	0.24	0.22	0.24	0.23	0.21	0.20
ZnO	0.18	0.21	0.18	0.19	0.18	0.20	0.21	0.18	0.17	0.19	0.21	0.19	0.21	0.21	0.20	0.22	0.17	0.18
ZrO_2	4.12	3.90	3.12	2.99	0.12	0.13	0.14	3.12	2.62	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.12	0.09
U_3O_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.15	2.21

*In XRF analysis target concentrations are used for B_2O_3 and Li_2O; F was not analyzed.
- Empty data field

Table 3.13. Characterization of Glasses Formulated for Al-Na-Limited Waste.

	Glass Name	HLW-E-ANa-1	HLW-E-ANa-19	HLW-E-ANa-17	HLW-E-ANa-18	HLW-E-ANa-13	HLW-E-ANa-20	HLW-E-ANa-21	HLW-E-ANa-23	HLW-E-ANa-2
	Waste loading (wt%)	42	43	45	45	47	47	47	47	47
	Glass former type	Li, Zr, P	Li,Ca, Zr	Li,Ca	LI,Ca, Zr	Li,Ca	Li,Ca, Zr	Li,Ca, Zr, Ti	Li, Zr	Li
Crystal content	Glass as melted	Trace (Spinel/Cr_2O_3)	Trace (Ca phosphate)	Minor (Ca phosphate)	Trace (Ca phosphate)	Minor (Ca phosphate+Nephline)	Minor (silicate)	Free	Free	Free
	Xl at 950ºC	Cr-Fe oxide	-	-	-	-	-	ZrO_2 + Sp	ZrO_2 + Sp	Sp
	Glass after HT at 950ºC (vol%)	0.3	-	-	-	-	1.9	0.4	1.0	0.3
	Glass after HT at 900ºC (vol%)	0.3	-	-	-	-	3.3	1.6	1.0	-
	Glass after HT at 850ºC (vol%)	1.2	-	-	-	-	4.6	2.6	1.2	-
	Glass after HT at 800ºC (vol%)	3.9	4.1 (Sp + Pho)	5.4 (Sp + Pho)	8.2 (Pho + Sp)	-	~12.5	~20	1.8	-
	Glass after HT of CCC (vol%)	-	Considerate amount	5.6 (Pho +Sp + Nas)	3.6 (Pho + Sp + Nas)	~12 (Apatite, Na-Al-Silicate, Spinel)	~31 (Nas + Pho + ZrO_2)	Phase separated	1.3 (spinel)	-
Processing properties	Highly viscous during pouring (Y/N)	Y	N	N	N	N	N	N	N	Y
	Viscosity at 1250ºC (poise)	-	-	-	-	22.1	-	-	-	-
	Viscosity at 1150ºC (poise)	-	-	-	-	46.9	-	-	-	-
	Viscosity at 1050ºC (poise)	-	-	-	-	119.0	-	-	-	-
	Viscosity at 950ºC (poise)	-	-	-	-	385.5	-	-	-	-
	Electric conductivity at 1250ºC (S/cm)	-	-	-	-	0.42	-	-	-	-
	Electric conductivity at 1150ºC (S/cm)	-	-	-	-	0.31	-	-	-	-
	Electric conductivity at 1050ºC (S/cm)	-	-	-	-	0.22	-	-	-	-
	Electric conductivity at 950ºC (S/cm)	-	-	-	-	0.14	-	-	-	-
	Glass transition temperature (ºC)	-	-	-	-	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-	-	15.5
	Li (ppm)	-	-	-	-	-	-	-	-	9.4
	Na (ppm)	-	-	-	-	-	-	-	-	27.0
	Si (ppm)	-	-	-	-	-	-	-	-	57.4
	B (g/L)	-	-	-	-	-	-	-	-	0.35
	Li (g/L)	-	-	-	-	-	-	-	-	0.66
	Na (g/L)	-	-	-	-	-	-	-	-	0.29
	Si (g/L)	-	-	-	-	-	-	-	-	0.31
	PCT (for CCC sample)	-	-	-	-	-	-	-	-	-
	B (ppm)	-	-	-	-	-	-	-	-	-
	Li (ppm)	-	-	-	-	-	-	-	-	-
	Na (ppm)	-	-	-	-	-	-	-	-	-
	Si (ppm)	-	-	-	-	-	-	-	-	-
	B (g/L)	-	-	-	-	-	-	-	-	-
	Li (g/L)	-	-	-	-	-	-	-	-	-
	Na (g/L)	-	-	-	-	-	-	-	-	-
	Si (g/L)	-	-	-	-	-	-	-	-	-
	TCLP (Pass/Fail)	-	-	-	-	-	-	-	-	-

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.13. Characterization of Glasses Formulated for Al-Na-Limited Waste (continued).

	Glass Name	HLW-E-ANa-4	HLW-E-ANa-22	HLW-E-ANa-22UTh	HLW-E-ANa-24	HLW-E-ANa-25	HLW-E-ANa-14	HLW-E-ANa-15
	Waste loading (wt%)	47	47	47	50	50	52	52
	Glass former type	Li	Li	Li	Li	Li	Li,Ca	Li,Ca
Crystal content	Glass as melted	Free	Free	NA	Free	Free	Minor (Ca-phosphate+Nephline)	Minor (Ca-phosphate+Nephline)
	Xl at 950ºC	Sp	Sp	Sp	Sp	Sp	Pho + Sp	Nas + Sp + Pho
	Glass after HT at 950ºC (vol%)	0.2	0.3	0.3	0.5	0.5	1.7	5.4
	Glass after HT at 900ºC (vol%)	0.2	0.5	0.2	0.7	0.7	-	-
	Glass after HT at 850ºC (vol%)	0.2	0.5	0.4	0.7	0.7	-	-
	Glass after HT at 800ºC (vol%)	2.1	0.5	0.3	1.0	0.9	-	-
	Glass after HT of CCC (vol%)	2-5 (Sp + Nas)	0.5 (Sp)	0.3 (Sp)	3 (Sp + Nas)	2 (Sp + Nas)	50-60 (Nas + Apatite + Sp)	20-50 (Nas + Apatite + Sp)
Processing properties	Highly viscous during pouring (Y/N)	N	N	N	N	N	N	Y
	Viscosity at 1250ºC (poise)	42.5	28.7	29.3	-	25.6	-	-
	Viscosity at 1150ºC (poise)	89.4	59.8	63.4	-	55.4	-	-
	Viscosity at 1050ºC (poise)	226.4	144.7	174.2	-	143.8	-	-
	Viscosity at 950ºC (poise)	747.5	428.4	690.5	-	481.6	-	-
	Electric conductivity at 1250ºC (S/cm)	0.17	0.48	0.57	-	0.48	-	-
	Electric conductivity at 1150ºC (S/cm)	0.25	0.38	0.43	-	0.36	-	-
	Electric conductivity at 1050ºC (S/cm)	0.34	0.28	0.30	-	0.25	-	-
	Electric conductivity at 950ºC (S/cm)	0.44	0.18	0.19	-	0.16	-	-
	Glass transition temperature (ºC)	-	469	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-	-	-
	B (ppm)	18.7	145.2	102.3	-	229.3	-	-
	Li (ppm)	11.4	34.8	25.7	-	42.8	-	-
	Na (ppm)	31.9	111.4	76.2	-	183.5	-	-
	Si (ppm)	61.2	49.8	46.3	-	43.2	-	-
	B (g/L)	0.42	2.55	1.80	-	3.81	-	-
	Li (g/L)	0.60	2.09	1.55	-	2.99	-	-
	Na (g/L)	0.34	1.18	0.85	-	1.83	-	-
	Si (g/L)	0.34	0.31	0.29	-	0.30	-	-
	PCT (for CCC sample)	-	-	-	-		-	-
	B (ppm)	32.1*	144.4	-	-	523.2	-	-
	Li (ppm)	22.2*	34.2	-	-	100.5	-	-
	Na (ppm)	44.1*	109.6	-	-	356.2	-	-
	Si (ppm)	62.4*	51.0	-	-	36.6	-	-
	B (g/L)	0.72*	2.53	-	-	8.69	-	-
	Li (g/L)	1.18*	2.06	-	-	7.02	-	-
	Na (g/L)	0.47*	1.16	-	-	3.55	-	-
	Si (g/L)	0.35*	0.32	-	-	0.25	-	-
	TCLP (Pass/Fail)	PASS	PASS	PASS	-	PASS	-	-

*Single sample analysis
Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.13. Characterization of Glasses Formulated for Al-Na-Limited Waste (continued).

	Glass Name	HLW-E-ANa-16	HLW-E-ANa-3	HLW-E-ANa-5	HLW-E-ANa26	HLW-E-ANa6
	Waste loading (wt%)	52	52	52	52	57
	Glass former type	Li,Ca	Li	Li	Li	Li
Crystal content	Glass as melted	Trace (Ca-phosphate+Nephline)	Trace (Sp)	Trace (Sp)	Free	Trace (Sp)
	Xl at 950ºC	Sp + Pho + Nas	Sp	Sp	Sp	Sp
	Glass after HT at 950ºC (vol%)	8.8	0.5	0.3	0.6	0.8
	Glass after HT at 900ºC (vol%)	-	-	0.5	0.7	5.6
	Glass after HT at 850ºC (vol%)	-	-	~5.4	0.9	~16
	Glass after HT at 800ºC (vol%)	~36	-	~5.7	0.6	~11
	Glass after HT of CCC (vol%)	30-50 (Pho+Na-Al-Silicate+Spinel)	-	~ 50 (Na-Al-Silicate)	5.6 (P-rich Na-Al-Silicate+spinel)	-
Processing properties	Highly viscous during pouring (Y/N)	N	Y	N	Y	N
	Viscosity at 1250ºC (poise)	-	-	35.6	-	48.5
	Viscosity at 1150ºC (poise)	-	-	81.9	-	115.0
	Viscosity at 1050ºC (poise)	-	-	213.7	-	342.1
	Viscosity at 950ºC (poise)	-	-	652.3	-	1416.1
	Electric conductivity at 1250ºC (S/cm)	-	-	0.17	-	0.65
	Electric conductivity at 1150ºC (S/cm)	-	-	0.25	-	0.49
	Electric conductivity at 1050ºC (S/cm)	-	-	0.35	-	0.35
	Electric conductivity at 950ºC (S/cm)	-	-	0.47	-	0.24
	Glass transition temperature (ºC)	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-
	B (ppm)	-	13.7	28.7	-	58.0
	Li (ppm)	-	8.0	13.5	-	15.6
	Na (ppm)	-	40.5	62.5	-	106.8
	Si (ppm)	-	54.3	61.0	-	52.1
	B (g/L)	-	0.33	0.64	-	1.29
	Li (g/L)	-	0.67	0.81	-	1.20
	Na (g/L)	-	0.39	0.60	-	0.93
	Si (g/L)	-	0.32	0.39	-	0.37
	PCT (for CCC sample)	-	-	-	-	-
	B (ppm)	-	-	-	-	-
	Li (ppm)	-	-	-	-	-
	Na (ppm)	-	-	-	-	-
	Si (ppm)	-	-	-	-	-
	B (g/L)	-	-	-	-	-
	Li (g/L)	-	-	-	-	-
	Na (g/L)	-	-	-	-	-
	Si (g/L)	-	-	-	-	-
	TCLP (Pass/Fail)	-	-	PASS	-	PASS

Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.13. Characterization of Glasses Formulated for Al-Na-Limited Waste (continued).

	Glass Name	HLW-E-ANa8	HLW-E-ANa9	HLW-E-ANa10	HLW-E-ANa11	HLW-E-ANa7	HLW-E-ANa12
	Waste loading (wt%)	57	57	57	57	60	65
	Glass former type	Li	Li	Li	Li	Li	Li
Crystal content	Glass as melted	Heterogeneous	Free	Heterogeneous	Free	Heterogeneous	Heterogeneous
	Xl at 950ºC	-	Spinel	Sp + Nas	-	-	Nas + Sp
	Glass after HT at 950ºC (vol%)	-	0.4	1.6	-	-	~10
	Glass after HT at 900ºC (vol%)	5.4	2.5	5.7	-	-	-
	Glass after HT at 850ºC (vol%)	-	6.6	~10	-	-	-
	Glass after HT at 800ºC (vol%)	-	~35	~16	-	-	-
	Glass after HT of CCC (vol%)	-	> 50 (Nephline+Sodalite)		>50 (Nephline+Sodalite)	-	-
Processing properties	Highly viscous during pouring (Y/N)	N	N	N	N	N	Y
	Viscosity at 1250ºC (poise)	-	22.4	-	21.6	-	-
	Viscosity at 1150ºC (poise)	-	38.9	-	43.7	-	-
	Viscosity at 1050ºC (poise)	-	83.0	-	102.3	-	-
	Viscosity at 950ºC (poise)	-	239.5	-	293.1	-	-
	Electric conductivity at 1250ºC (S/cm)	-	0.61	-	0.65	-	-
	Electric conductivity at 1150ºC (S/cm)	-	0.48	-	0.50	-	-
	Electric conductivity at 1050ºC (S/cm)	-	0.37	-	0.37	-	-
	Electric conductivity at 950ºC (S/cm)	-	0.27	-	0.26	-	-
	Glass transition temperature (ºC)	-	-	-	-	-	-
Leaching performance	PCT	-	-	-	-	-	-
	B (ppm)	83.5	121.8	111.8	97.1	-	-
	Li (ppm)	25.2	47.4	28.3	37.4	-	-
	Na (ppm)	140.9	201.8	162.3	172.1	-	-
	Si (ppm)	47.4	45.9	37.5	52.7	-	-
	B (g/L)	1.86	2.72	2.26	2.33	-	-
	Li (g/L)	1.51	2.00	1.69	1.58	-	-
	Na (g/L)	1.23	1.76	1.42	1.51	-	-
	Si (g/L)	0.35	0.35	0.29	0.39	-	-
	PCT (for CCC sample)	-	-	-	-	-	-
	B (ppm)	-	3630**	-	-	-	-
	Li (ppm)	-	1155.3**	-	-	-	-
	Na (ppm)	-	2107.5**	-	-	-	-
	Si (ppm)	-	<0.84**	-	-	-	-
	B (g/L)	-	81.07**	-	-	-	-
	Li (g/L)	-	49.33**	-	-	-	-
	Na (g/L)	-	18.43**	-	-	-	-
	Si (g/L)	-	-	-	-	-	-
	TCLP (Pass/Fail)	PASS	PASS	PASS	PASS	-	-

**Not standard test; single sample result; experiment terminated after 6 days.
Sp = spinel; Pho = phosphate; Nas = sodium aluminosilicate
- Empty data field

Table 3.14. Composition and Properties of Aluminum-Plus-Sodium-Limited Waste and Glass Formulation at 47% Waste Loading Used in Melter Tests (wt%).

-	Al-Na Limited Waste*	Waste in Glass	Glass Forming Additives	Target Glass HLW-E-ANa-22
Al_2O_3	45.40	21.34	0.00	21.34
B_2O_3	0.78	0.37	18.00	18.37
BaO	0.06	0.03	0.00	0.03
Bi_2O_3	2.46	1.16	0.00	1.16
CaO	1.54	0.72	0.00	0.72
CdO	0.02	0.01	0.00	0.01
Cr_2O_3	1.51	0.71	0.00	0.71
F	0.48	0.23	0.00	0.23
Fe_2O_3	5.99	2.82	0.00	2.82
K_2O	1.41	0.66	0.00	0.66
Li_2O	0.16	0.08	3.50	3.58
MgO	0.46	0.22	0.00	0.22
Na_2O	27.04	12.71	0.00	12.71
NiO	0.21	0.10	0.00	0.10
P_2O_5	4.30	2.02	0.00	2.02
PbO	0.19	0.09	0.00	0.09
SiO_2	6.52	3.06	31.50	34.56
TiO_2	0.37	0.17	0.00	0.17
SO_3	0.46	0.22	0.00	0.22
ZnO	0.38	0.18	0.00	0.18
ZrO_2	0.26	0.12	0.00	0.12
Sum	100.00	47.00	53.00	100.00

* Renormalized from Ref. [3] after removal of radioactive components

Viscosity @1150ºC, P			60
Conductivity @1150ºC, S/cm			0.38
Crystal Content, As Melted			Trace
Crystal Content, 72 hr at 950^{o}C			~0.3 vol %
Crystal Content, CCC			~0.5 vol %
TCLP			Pass
PCT, g/L	-	DWPF-EA	HLW-E-ANa-22
	B	16.7	2.55
	Li	9.6	2.09
	Na	13.3	1.18

- Empty data field

Table 4.1. Summary of Chromium-Limited Waste DM10 Test Conditions and Results.

Test		1	2	3	4	5	6
Time	Feed Start	7/31/06 10:00	8/1/06 11:35	8/2/06 13:11	8/3/06 14:11	8/4/06 14:09	8/7/06 7:20
	Feed End	8/1/06 9:30	8/2/06 12:30	8/3/06 12:45	8/4/06 12:20	8/5/06 4:00	8/7/06 19:45
	Net Slurry Feeding (hr)	23.5	24.9	23.6	22.2	13.9	12.4
Glass Temperature (°C)		1150	1150	1150	1150	1150	1175
Feed	Waste Loading	40%	40%	37.5%	35%	32.5%	32.5%
	wt% Cr_2O_3 as glass	1.33	1.33	1.25	1.16	1.08	1.08
	wt% SO_3 as glass	0.66	0.66	0.62	0.58	0.53	0.53
	Extra Additives	None	10 g/l sugar	None	None	None	None
	Feed Used (kg)	65.1	68.2	67.8	67.5	47.0	62.1
Average Production Rate (kg/m^2/day)		1154	1139	1192	1271	1413	2095
Average Bubbling Rate (lpm)		0.79	1.08	0.47	0.53	0.54	1.17
Product	Secondary Phases on Melt Surface at Test End	Yes	No	Yes	Yes	Yes	Trace
	Measured wt% Cr_2O_3	1.23	1.51	1.17	1.12	1.05	1.17
	Measured wt% SO_3	0.49	0.31	0.55	0.53	0.46	0.43

Table 4.1. Summary of Chromium-Limited-Waste DM10 Test Conditions and Results (continued).

Test		7A	8B	9	10A	10C	12
Time	Feed Start	8/8/06 7:00	8/9/06 7:00	8/14/06 8:50	8/15/06 3:00	8/15/06 21:30	8/16/06 17:00
	Feed End	8/8/06 19:30	8/9/06 20:30	8/14/06 23:04	8/15/06 19:45	8/16/06 16:00	8/17/06 11:32
	Net Slurry Feeding (hr)	12.5	13.5	14.2	16.75	18.5	18.5
Glass Temperature (°C)		1175	1150	1175	1175	1150	1150
Feed	Waste Loading	30%	30%	34.7%	34.7%	32.2%	32.5%
	wt% Cr_2O_3 as glass	1.0	1.0	1.15	1.15	1.07	1.08
	wt% SO_3 as glass	0.49	0.49	0.57	0.57	0.52	0.53
	Extra Additives	None	None	Vanadium	Vanadium + 2 g/l sugar	Vanadium	None
	Feed Used (kg)	67.0	65.1	66.1	67.2	66.7	66.5
Average Production Rate (kg/m^2/day)		2179	2023	1947	1678	1508	1504
Average Bubbling Rate (lpm)		1.31	1.31	1.32	1.54	1.55	1.42
Product	Secondary Phases on Melt Surface at Test End	No	No	Yes	Yes	No	No
	Measured wt% Cr_2O_3	1.12	1.13	1.21	1.23	1.16	1.17
	Measured wt% SO_3	0.38	0.42	0.64	0.41	0.39	0.45

Table 4.2. Composition and Properties of Chromium-Limited Waste and Glass Formulation at 32.5% Waste Loading Used in DM100 Melter Tests (wt%).

-	Cr-Limited Waste*	Waste in Glass	Glass Forming Additives	Target Glass HLW-E-Cr-M
Al_2O_3	27.64	8.98	-	8.98
B_2O_3	0.57	0.19	15.99	16.17
BaO	0.03	0.01	-	0.01
Bi_2O_3	7.89	2.56	-	2.56
CaO	2.67	0.87	-	0.87
CdO	0.01	0.00	-	< 0.01
Cr_2O_3	3.32	1.08	-	1.08
F	2.17	0.70	-	0.70
Fe_2O_3	14.22	4.62	-	4.62
K_2O	0.40	0.13	5.92	6.05
Li_2O	0.39	0.13	3.55	3.68
MgO	0.17	0.06	-	0.06
Na_2O	21.75	7.07	-	7.07
NiO	1.15	0.37	-	0.37
P_2O_5	3.62	1.18	-	1.18
PbO	0.52	0.17	-	0.17
SiO_2	11.43	3.72	42.04	45.76
TiO_2	0.01	0.00	-	< 0.01
SO_3	1.65	0.53	-	0.53
ZnO	0.27	0.09	-	0.09
ZrO_2	0.12	0.04	-	0.04
Sum	100	32.5	67.5	100

* Renormalized from Ref. [3] after removal of radioactive components

Viscosity @1150ºC, P			77.9
Conductivity @1150ºC, S/cm			0.20
Crystal Content, As Melted			None
Crystal Content, 72 hr at 950°C			0.8 vol %
Crystal Content, CCC			1.3 vol %
TCLP			Pass
PCT, g/L	-	DWPF-EA	HLW-E-Cr-M
	B	16.7	4.57
	Li	9.6	3.36
	Na	13.3	2.14

- Empty data field

Table 5.1. Summary of Results from DM100 Bismuth-Limited Waste Tests.

Test		1A	1B	2A	2B
Time	Feed Start	7/17/06 8:50	7/19/06 15:00	7/24/06 8:30	7/26/06 12:30
	Feed End	7/19/06 13:00	7/21/06 17:00	7/26/06 11:00	7/28/06 14:30
	Interval	52.2 hr	50.0 hr	50.5 hr	50.0 hr
Water Feeding for Cold Cap		0.5 hr	NA	0.5 hr	NA
Slurry Feeding		51.7 hr	50.0 hr	50.0 hr	50.0 hr
Feeding Interruptions		131 min	12 min	6 min	25 min
Cold cap burn		NA	4.3 hr	NA	5.5 hr
Target Glass Temperature		1175 °C	1175 °C	1150 °C	1150 °C
Average Bubbling Rate		14.1 lpm	9 lpm	9 lpm	9 lpm
Feed	Used	812 kg	642 kg	523 kg	549 kg
	Target Glass yield	500 g/l	500 g/l	500 g/l	250 g/l
		0.358 kg/kg	0.358 kg/kg	0.358 kg/kg	0.209 kg/kg
	Average Feed Rate	15.7 kg/hr	12.8 kg/hr	10.5 kg/hr	11.0 kg/hr
Glass Produced	Poured	193 kg	233 kg	168 kg	200 kg
	Average Rate$	NC	1036 $kg/m^2/day$	747 $kg/m^2/day$	NC
	Average Rate*	1249 $kg/m^2/day$	1021 $kg/m^2/day$	832 $kg/m^2/day$	510 $kg/m^2/day$
	Steady State Rate*	1200 $kg/m^2/day$	1000 $kg/m^2/day$	830 $kg/m^2/day$	510 $kg/m^2/day$
	Average Power Use	4.1 kW hr/kg glass	4.3 kW hr/kg glass	4.6 kW hr/kg glass	7.7 kW hr/ kg glass

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
NC- Not calculated during Tests 1a and 2b due to the changing of the level of glass in the melter.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.

Table 5.2. Summary of Results from DM100 Chromium-Limited Waste Tests.

Test		3B	4A
Time	Feed Start	8/21/06 8:33	8/23/06 16:06
	Feed End	8/23/06 15:30	8/25/06 19:43
	Interval	55.0 hr	51.6 hr
Water Feeding for Cold Cap		0.5 hr	NA
Slurry Feeding		54.5 hr	51.6 hr
Feeding Interruptions		56 min	4 min
Cold cap burn		NA	0.5 hr
Target Glass Temperature		1175 °C	1150 °C
Average Bubbling Rate		9 lpm	9 lpm
Feed	Waste Loading	32.5%	32.5%
	Used	866.5 kg	720.4 kg
	Target Glass yield	500 g/l	500 g/l
		0.366 kg/kg	0.366 kg/kg
	Average Feed Rate	15.9 kg/hr	14.0 kg/hr
Glass Produced	Poured	248.5 kg	291.8 kg
	Average Rate*	1293 $kg/m^2/day$	1136 $kg/m^2/day$
	Steady State Rate*	1300 $kg/m^2/day$	1150 $kg/m^2/day$
	Average Power Use	4.0 kW hr/kg glass	4.0 kW hr/kg glass
Secondary sulfates phases observed on melt pool samples		None	None

*- Rates calculated from feed data.
NA – Not applicable
Notes: Rates do not take into account the time for water feeding and cold cap burn-off. Production rates not calculated from amounts of poured glass due to the changing of the level of glass in the melter.

Table 5.3. Summary of Results from DM100 Aluminum-Limited Waste Tests.

Test		5A	5B	6A	6B	6C
Time	Feed Start	9/11/06 9:00	9/13/06 14:00	9/18/06 9:00	9/20/06 12:30	9/26/06 10:00
	Feed End	9/13/06 11:32	9/15/06 18:00	9/20/06 11:30	9/22/06 19:00	9/28/06 08:30
	Interval	50.5 hr	52.0 hr	50.5 hr	54.5	46.5 hr
Water Feeding for Cold Cap		0.5 hr	NA	0.5 hr	NA	0.5 hr
Slurry Feeding		50.0 hr	52.0 hr	50.0 hr	54.5 hr	46.0 hr
Feeding Interruptions		32 min	99 min	0 min	93 min	20 min
Cold cap burn		NA	6 hr	NA	5.5 hr	6 hr
Target Glass Temperature		1175 °C	1175 °C	1150 °C	1150 °C	1150 °C
Average Bubbling Rate		18 lpm	9 lpm	9 lpm	9 lpm	16.6 lpm
Feed	Used	667 kg	394 kg	361 kg	449 kg	594 kg
	Target Glass yield	500 g/l	500 g/l	500 g/l	250 g/l	500 g/l
		0.365 kg/kg	0.365 kg/kg	0.365 kg/kg	0.211 kg/kg	0.365 kg/kg
	Average Feed Rate	13.3 kg/hr	7.6 kg/hr	7.2 kg/hr	8.2 kg/hr	12.9 kg/hr
Glass Produced	Poured	171 kg	134 kg	137 kg	93 kg	259 kg
	Average Rate$	NC	567 kg/m^2/day	608 kg/m^2/day	379 kg/m^2/day	NC
	Average Rate*	1082 kg/m^2/day	615 kg/m^2/day	587 kg/m^2/day	386 kg/m^2/day	1047 kg/m^2/day
	Steady State Rate*	1000 kg/m^2/day	550 kg/m^2/day	550 kg/m^2/day	400 kg/m^2/day	1000 kg/m^2/day
	Average Power Use	4.4 kW hr/kg glass	5.8 kW hr/kg glass	6.4 kW hr/kg glass	9.2 kW hr/kg glass	4.5 kW hr/kg glass

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
NC- Not calculated during Tests 5a and 6c due to the changing of the level of glass in the melter.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.

Table 5.4. Summary of Results from DM100 Aluminum-Plus-Sodium-Limited Waste Tests.

Test		7A	7B	8A	8B	8C
Time	Feed Start	10/2/06 11:45	10/4/06 14:15	10/16/06 8:30	10/18/06 20:40	11/18/06 00:00
	Feed End	10/4/06 13:45	10/6/06 17:35	10/18/06 16:00	10/20/06 22:40	11/20/06 09:00
	Interval	50.0 hr	51.3 hr	55.5 hr	50.0	57.5 hr
Water Feeding for Cold Cap		0.5 hr	NA	0.5 hr	NA	0.5 hr
Slurry Feeding		49.5 hr	51.3 hr	55.0 hr	50.0 hr	57.0 hr
Feeding Interruptions		22 min	98 min	176 min	28 min	680 min
Cold cap burn		NA	3.5 hr	NA	6 hr	3.5 hr
Target Glass Temperature		1175 °C	1175 °C	1150 °C	1150 °C	1150 °C
Average Bubbling Rate		16 lpm	9 lpm	9 lpm	9 lpm	15 lpm
Feed	Used	872 kg	604 kg	385 kg	252 kg	717 kg
	Target Glass yield	500 g/l	500 g/l	500 g/l	250 g/l	500 g/l
		0.358 kg/kg	0.358 kg/kg	0.358 kg/kg	0.209 kg/kg	0.358 kg/kg
	Average Feed Rate	17.6 kg/hr	11.8 kg/hr	7.0 kg/hr	5.0 kg/hr	12.6 kg/hr
Glass Produced	Poured	259 kg	217 kg	154 kg	47 kg	256 kg
	Average Rate$	NC	940 kg/m^2/day	621 kg/m^2/day	209 kg/m^2/day	NC
	Average Rate*	1401 kg/m^2/day	936 kg/m^2/day	557 kg/m^2/day	234 kg/m^2/day	1002 kg/m^2/day
	Steady State Rate*	1400 kg/m^2/day	900 kg/m^2/day	400 kg/m^2/day	200 kg/m^2/day	1250 kg/m^2/day
	Average Power Use	4.1 kW hr/kg glass	4.8 kW hr/kg glass	6.6 kW hr/kg glass	13.4 kW hr/kg glass	4.7 kW hr/kg glass

$ - Rates calculates from glass poured.
*- Rates calculated from feed data.
NC- Not calculated during Tests 7A and 8C due to the changing of the level of glass in the melter.
Note: Rates do not take into account the time for water feeding and cold cap burn-off but do include feeding interruptions required to stabilize the cold during, transfer feed, and perform maintenance during testing,

Table 5.5. Steady-State Production Rates Achieved on the DM100 with HLW Compositions and Comparison to Previous Results with High-Iron Feeds.

HLW Waste	Bubbling Rate (lpm)	Glass Yield (g/L)	Glass Temperature (°C)	Production Rate $kg/m^2/day$
Bismuth Limited	Optimized	500	1175	1200
	9	500	1175	1000
	9	500	1150	830
	9	250	1150	510
Chromium Limited	9	500	1175	1300
	9	500	1150	1150
Aluminum Limited	Optimized	500	1175	1000
	9	500	1175	550
	9	500	1150	550
	9	250	1150	400
	Optimized	500	1150	1000
Aluminum and Sodium Limited	Optimized	500	1175	1400
	9	500	1175	900
	9	500	1150	400
	9	250	1150	200
	Optimized	500	1150	1250
AZ-101 [7]	9	530	1150	1300
AZ-102, Nominal Rheology [17]	9	550	1150	1200
AZ-102, Adjusted Rheology [17]	9	550	1150	1400
C-106/AY-102, High Waste Loading [17]	Optimized	420	1150	1350
C-106/AY-102, Nominal Rheology [24]	9	435	1150	1100
C-106/AY-102, Adjusted Rheology [24]	9	435	1150	1150
C-106/AY-102, SIPP [24]	9	470	1150	1180

Table 5.6. Summary of Measured DM100 Parameters for Bismuth-Limited Waste Tests.

Test			1A			1B			2A			2B		
			AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
TEMPERATURE (C)	Electrode	East Upper	915	601	1077	1053	1031	1090	1012	981	1038	982	704	1033
		West Upper	1056	675	1123	1097	1085	1110	1057	1031	1073	1032	903	1069
		West Lower	1093	1057	1118	1080	1069	1090	1037	1005	1049	1038	1026	1050
		Bottom	747	736	763	722	715	732	676	635	686	684	682	688
	Glass	27” from bottom	912	159	1169	1126	1059	1165	1090	999	1143	974	431	1133
		16” from bottom	1056	638	1177	1157	1127	1176	1131	1078	1150	1118	976	1146
		10” from bottom	1176	1112	1198	1178	1153	1193	1153	1124	1164	1152	1121	1166
		5” from bottom	1176	1145	1201	1176	1157	1190	1151	1129	1163	1152	1129	1169
	Plenum	Exposed	467	147	669	465	358	542	408	308	584	372	293	467
		Thermowell	411	216	645	380	301	504	363	296	556	327	254	435
	Discharge	Chamber	1030	973	1055	1046	1029	1060	1019	989	1036	1029	1010	1044
		Air Lift	998	927	1105	1016	998	1107	983	926	1070	993	970	1084
	Film Cooler Outlet		281	200	322	273	215	286	265	244	302	260	242	276
	Transition Line Outlet		279	222	326	267	239	283	261	242	300	254	239	270
Lance Bubbling (lpm)			14.1	2.5	20.5	9.0	8.8	9.1	9.0	8.7	9.6	9.0	8.8	9.2
Melter Pressure (inches water)			-1.81	-3.13	0.25	-1.76	-2.64	0.39	-1.84	-4.58	0.27	-1.61	-2.96	0.26
Total Electrode Voltage (V)			45.5	1.7	55.3	39.1	37.0	40.8	38.5	36.0	41.9	39.6	36.4	45.2
Total Power (kW)			22.9	0.3	28.0	19.7	17.9	21.5	17.3	15.4	20.0	17.6	15.0	19.5
Glass Resistance (ohms)			0.091	0.011	0.153	0.077	0.074	0.083	0.086	0.081	0.093	0.089	0.081	0.110

Table 5.7. Summary of Measured DM100 Parameters for Chromium-Limited Waste Tests.

Test			3B			4A		
			AVG	MIN	MAX	AVG	MIN	MAX
TEMPERATURE (C)	Electrode	East Upper	926	452	1062	1040	1022	1066
		West Upper	1032	476	1104	1075	1061	1101
		West Lower	1069	1010	1084	1060	1050	1081
		Bottom	704	625	730	722	719	729
	Glass	27” from bottom	884	113	1135	1085	1009	1143
		16” from bottom	981	112	1160	1121	1086	1161
		10” from bottom	1166	1115	1188	1151	1126	1184
		5” from bottom	1175	1151	1210	1151	1132	1181
	Plenum	Exposed	435	234	549	427	275	560
		Thermowell	411	356	511	405	311	505
	Discharge	Chamber	1013	865	1074	1050	1001	1071
		Air Lift	990	867	1125	991	907	1095
	Film Cooler Outlet		279	270	298	279	256	298
	Transition Line Outlet		276	233	294	273	256	291
Lance Bubbling (lpm)			9.0	9.0	9.1	9.0	9.0	9.1
Melter Pressure (inches water)			-1.66	-3.60	0.28	-1.60	-4.15	1.85
Total Electrode Voltage (V)			48.3	1.7	56.1	47.0	44.7	49.2
Total Power (kW)			23.4	0.3	25.0	20.6	19.5	21.5
Glass Resistance (ohms)			0.100	0.010	0.157	0.107	0.096	0.118

Table 5.8. Summary of Measured DM100 Parameters for Aluminum-Limited Waste Tests.

Test			5A			5B			6A			6B			6C		
			AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
TEMPERATURE (C)	Electrode	East Upper	970	652	1087	1054	1013	1084	1050	1011	1070	980	869	1082	1080	1031	1112
		West Upper	1087	694	1128	1102	1083	1117	1066	1037	1092	1011	902	1095	1068	1002	1103
		West Lower	1093	1075	1107	1081	1071	1093	1055	1034	1074	1053	1021	1076	1061	1031	1085
		Bottom	788	782	801	770	762	785	751	721	830	719	706	729	716	701	724
	Glass	27” from bottom	932	217	1151	1104	961	1166	1121	1059	1143	954	680	1148	1130	1016	1177
		16” from bottom	1037	540	1169	1152	1120	1179	1133	1104	1155	1106	1056	1155	1129	1070	1170
		10” from bottom	1172	1129	1197	1178	1153	1197	1153	1118	1179	1157	1103	1186	1154	1087	1197
		5” from bottom	1173	1131	1196	1174	1150	1194	1148	1108	1174	1152	1093	1179	1151	1095	1190
	Plenum	Exposed	445	348	663	398	273	527	448	361	523	366	189	526	432	259	536
		Thermowell	408	327	637	356	246	467	425	376	503	332	210	495	448	171	615
	Discharge	Chamber	1024	924	1064	1056	978	1112	1058	1011	1077	1067	1045	1080	1066	975	1089
		Air Lift	946	870	1051	1008	930	1147	1015	936	1112	1016	1000	1117	1040	1000	1130
	Film Cooler Outlet		277	260	304	261	233	279	274	265	293	260	233	290	282	247	294
	Transition Line Outlet		278	258	316	258	229	276	270	259	288	253	231	287	275	238	281
Lance Bubbling (lpm)			18.0	-2.3	22.9	9.0	8.7	17.9	9.1	9.0	9.3	9.0	8.9	9.3	16.6	9.5	23.6
Melter Pressure (inches water)			-1.80	-4.56	1.50	-1.93	-4.26	0.19	-1.93	-2.95	0.23	-1.94	-3.22	2.89	-1.87	-2.99	0.23
Total Electrode Voltage (V)			48.7	2.3	60.0	39.9	36.5	44.7	43.3	39.3	48.8	44.2	39.0	50.9	50.0	44.1	58.2
Total Power (kW)			21.3	0.3	24.4	16.2	13.9	19.4	16.9	13.4	21.5	16.0	11.4	21.5	21.0	14.9	26.4
Glass Resistance (ohms)			0.112	0.019	0.155	0.098	0.091	0.108	0.111	0.100	0.123	0.125	0.099	0.169	0.121	0.101	0.174

Table 5.9. Summary of Measured DM100 Parameters for Al + Na-Limited Waste Tests.

Test			7A			7B			8A			8B			8C		
			AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
TEMPERATURE (C)	Electrode	East Upper	1021	722	1139	1109	1048	1134	1019	854	1089	1048	1009	1085	1088	981	1116
		West Upper	1094	738	1143	1118	1072	1140	994	805	1097	1026	991	1056	1073	1044	1114
		West Lower	1105	1067	1126	1102	1080	1118	1062	1029	1099	1045	1020	1061	1070	1045	1099
		Bottom	746	716	752	740	736	744	773	747	825	747	741	754	755	724	768
	Glass	27” from bottom	1026	324	1180	1144	1012	1184	1012	430	1176	1123	994	1175	1148	1037	1195
		16” from bottom	1120	812	1167	1148	1110	1178	1118	1027	1170	1134	1091	1170	1132	1088	1162
		10” from bottom	1170	1126	1193	1175	1129	1200	1161	1117	1190	1160	1119	1185	1155	1124	1184
		5” from bottom	1171	1135	1203	1174	1135	1202	1149	1118	1180	1142	1109	1160	1148	1111	1178
	Plenum	Exposed	401	307	464	356	289	398	353	245	574	328	248	391	518	306	865
		Thermowell	439	341	516	402	324	470	373	219	649	346	225	488	414	109	666
	Discharge	Chamber	1069	1000	1106	1081	1050	1103	1063	991	1091	1066	1049	1090	996	966	1028
		Air Lift	1009	847	1186	930	748	1100	857	756	1015	891	827	982	860	832	879
	Film Cooler Outlet		282	274	290	276	142	289	275	257	302	271	257	284	288	245	393
	Transition Line Outlet		279	271	285	272	159	280	268	246	309	263	251	270	276	241	367
Lance Bubbling (lpm)			15.7	5.0	30.3	9.1	9.0	9.2	9.1	3.5	9.2	9.1	8.9	9.2	15.0	0.6	23.0
Melter Pressure (inches water)			-1.77	-5.06	0.26	-1.68	-4.41	0.66	-1.45	-3.08	0.28	-1.35	-2.63	0.32	-1.64	-3.74	0.88
Total Electrode Voltage (V)			48.3	1.9	58.2	38.3	34.3	42.0	38.9	30.7	49.3	38.5	1.8	52.3	44.9	28.4	52.4
Total Power (kW)			26.0	0.3	28.5	20.2	16.9	23.0	15.2	10.5	23.0	14.0	0.3	20.8	21.2	9.5	28.0
Glass Resistance (ohms)			0.091	0.012	0.189	0.073	0.067	0.088	0.101	0.075	0.127	0.106	0.012	0.132	0.096	0.075	0.120

Table 6.1. Characteristics of Melter Feed Samples from DM100 Tests.

Test	Date	Name	% Water	Density (g/ml)	Glass Yield (kg/kg)	Glass Yield (g/l)	pH	Yield Stress (Pa)	Viscosity (Poise) 1/s	Viscosity (Poise) 10/s	Viscosity (Poise) 100/s
1A	7/17/06	BLK-F-71A	61.88	1.39	0.353	491	10.51	0.04	1.03	0.21	0.05
	7/18/06	BLK-F-84A	NA	1.36	NA	NA	10.58	NA	NA	NA	NA
	7/19/06	BLK-F-100A	NA	1.32	NA	NA	10.41	NA	NA	NA	NA
1B	7/20/06	BLK-F-112A	61.65	1.38	0.353	487	10.72	NA	NA	NA	NA
2A	7/24/06	BLK-F-146A	NA	1.37	NA	NA	10.48	NA	NA	NA	NA
	7/25/06	BLK-F-152A	60.94	1.39	0.354	492	10.72	NA	NA	NA	NA
2B	7/26/06	BLL-F-20A	78.48	1.18	0.192	227	10.25	NA	NA	NA	NA
	7/27/06	BLL-F-30A	79.62	1.19	0.188	223	10.25	0.03	0.12	0.03	0.02
3B	8/21/06	BLL-F-65A	NA	1.36	NA	NA	9.56	NA	NA	NA	NA
	8/22/06	BLL-F-73A	59.52	1.37	0.355	487	9.58	0.1	2.65	0.65	0.19
	8/23/06	BLL-F-86A	NA	1.37	NA	NA	9.65	NA	NA	NA	NA
4A	8/24/05	BLL-F-100A	59.65	1.37	0.359	492	9.58	0.2	2.40	0.67	0.20
5A	9/11/06	BLL-F-132A	60.78	1.36	0.362	492	10.18	9.5	35.89	4.63	1.16
	9/11/06	BLL-F-135A	NA	1.34	NA	NA	10.21	NA	NA	NA	NA
	9/12/06	BLL-F-147A	NA	1.37	NA	NA	10.24	NA	NA	NA	NA
5B	9/13/06	BLM-F-14A	59.42	1.36	0.351	478	10.24	NA	NA	NA	NA
6A	9/18/06	BLM-F-53A	59.60	1.37	0.361	494	10.34	NA	NA	NA	NA
6B	9/20/06	BLM-F-75A	77.51	1.16	0.206	239	10.10	1.9	4.83	0.54	0.27
	9/21/06	BLM-F-91A	NA	1.18	NA	NA	10.12	NA	NA	NA	NA
6C	9/26/06	BLM-F-123A	60.14	1.38	0.356	492	10.28	NA	NA	NA	NA
	9/27/06	BLM-F-133A	NA	1.38	NA	NA	10.30	NA	NA	NA	NA
7A	10/2/06	BLN-F-9A	61.23	1.37	0.344	471	10.90	0.1	1.39	0.27	0.06
	10/3/06	BLN-F-21A	NA	1.38	NA	NA	10.92	NA	NA	NA	NA
	10/3/06	BLN-F-29A	NA	1.38	NA	NA	10.95	NA	NA	NA	NA
	10/4/06	BLN-F-35A	NA	1.38	NA	NA	10.8	NA	NA	NA	NA
7B	10/5/06	BLN-F-48A	NA	1.38	NA	NA	10.97	NA	NA	NA	NA
	10/6/06	BLN-F-62A	NA	1.39	NA	NA	10.97	NA	NA	NA	NA
8A	10/16/06	BLN-F-88A	NA	1.37	NA	NA	10.99	NA	NA	NA	NA
8B	10/18/06	BLN-F-107A	79.84	1.16	0.177	205	10.39	0.1	0.04	0.02	0.01
8C	11/18/06	BLN-F-146A	NA	1.36	NA	NA	10.75	NA	NA	NA	NA
	11/18/06	BLN-F-152A	61.16	1.38	0.345	476	10.78	NA	NA	NA	NA
	11/19/06	BLO-F-15A	NA	1.36	NA	NA	10.77	NA	NA	NA	NA

NA – Not analyzed.

Table 6.2. XRF Analyzed Compositions of Vitrified Melter Feed Samples (wt%).

Sample	Bi Limited								Cr Limited				
	Target	BLK-F-71A	BLK-F-112A	BLK-F-152A	BLL-F-G-20A	BLL-F-30A	Avg.	%Dev.	Target	BLL-F-73A	BLL-F-100A	Avg.	%Dev.
Al_2O_3	11.66	11.67	12.49	11.91	12.54	12.58	12.24	4.96	8.98	9.34	9.75	9.55	6.31
B_2O_3*	11.30	11.30	11.30	11.30	11.30	11.30	11.30	NC	16.17	16.17	16.17	16.17	NC
BaO	0.01	0.02	0.02	0.03	0.03	0.02	0.02	NC	0.01	0.01	0.02	0.02	NC
Bi_2O_3	6.71	6.31	6.64	6.15	6.67	6.11	6.38	-4.96	2.56	2.32	2.78	2.55	-0.59
CaO	0.84	0.86	0.81	0.82	0.83	0.83	0.83	NC	0.87	0.78	0.87	0.83	NC
CdO	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC	§	<0.01	<0.01	<0.01	NC
Cl	§	0.02	0.03	0.04	0.03	0.03	0.03	NC	§	<0.01	<0.01	<0.01	NC
Cr_2O_3	0.52	0.61	0.68	0.61	0.66	0.63	0.64	NC	1.08	1.12	1.27	1.20	10.80
F*	0.82	0.82	0.82	0.82	0.82	0.82	0.82	NC	0.70	0.70	0.70	0.70	NC
Fe_2O_3	6.96	7.15	7.56	7.05	7.53	7.11	7.28	4.61	4.62	4.28	4.91	4.60	-0.53
K_2O	0.46	0.50	0.54	0.51	0.52	0.51	0.52	NC	6.05	5.49	5.68	5.59	-7.60
La_2O_3	§	0.01	0.02	0.02	0.03	0.02	0.02	NC	§	<0.01	0.01	<0.01	NC
Li_2O*	0.16	0.16	0.16	0.16	0.16	0.16	0.16	NC	3.68	3.68	3.68	3.68	NC
MgO	0.43	0.48	0.50	0.41	0.42	0.46	0.45	NC	0.06	0.25	0.23	0.24	NC
MnO	§	0.12	0.09	0.10	0.09	0.11	0.10	NC	§	0.01	0.02	0.02	NC
Na_2O	15.74	15.16	15.80	16.31	15.78	14.83	15.57	-1.05	7.07	7.23	6.67	6.95	-1.65
Nd_2O_3	§	0.05	0.05	0.05	0.05	0.05	0.05	NC	§	<0.01	0.01	<0.01	NC
NiO	1.93	1.78	1.90	1.76	1.85	1.72	1.80	-6.69	0.37	0.34	0.40	0.37	NC
P_2O_5	4.99	5.10	5.43	5.24	5.59	5.42	5.36	7.32	1.18	1.36	1.33	1.34	14.40
PbO	0.25	0.29	0.30	0.28	0.28	0.27	0.28	NC	0.17	0.14	0.16	0.15	NC
SiO_2	36.26	36.53	33.67	35.30	33.62	35.86	35.00	-3.49	45.76	46.31	44.74	45.52	-0.51
SO_3	0.48	0.32	0.44	0.43	0.40	0.43	0.40	NC	0.53	0.32	0.37	0.34	NC
TiO_2	0.16	0.19	0.19	0.19	0.20	0.19	0.19	NC	§	0.02	0.04	0.03	NC
ZnO	0.16	0.18	0.19	0.18	0.20	0.18	0.18	NC	0.09	0.08	0.09	0.09	NC
ZrO_2	0.21	0.38	0.38	0.36	0.39	0.36	0.37	NC	0.04	0.05	0.06	0.05	NC
Sum	100	100	100	100	100	100	100	100	100	100	100	100	NC

§ - Not a target constituent
* Target values
NC –Not calculated

Table 6.2. XRF Analyzed Compositions of Vitrified Melter Feed Samples (wt%) (continued).

Sample	Al Limited							
	Target	BLL-F-132A	BLM-F-14A	BLM-F-53A	BLM-F-75A	BLM-F-123A	Avg.	%Dev.
Al_2O_3	23.97	22.89	22.67	22.62	23.90	22.63	22.94	-4.29
B_2O_3*	15.19	15.19	15.19	15.19	15.19	15.19	15.19	NC
BaO	0.05	0.38	0.40	0.34	0.34	0.33	0.36	NC
Bi_2O_3	1.14	1.24	1.19	1.15	1.16	1.14	1.17	2.47
CaO	6.08	5.78	5.73	5.70	5.67	5.74	5.73	-5.76
CdO	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Cl	§	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	NC
Cr_2O_3	0.52	0.58	0.56	0.54	0.57	0.54	0.56	NC
F*	0.67	0.67	0.67	0.67	0.67	0.67	0.67	NC
Fe_2O_3	5.90	6.24	6.08	5.95	6.02	5.92	6.04	2.40
K_2O	0.14	0.35	0.34	0.31	0.34	0.33	0.34	NC
La_2O_3	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Li_2O*	3.57	3.57	3.57	3.57	3.57	3.57	3.57	NC
MgO	0.12	0.38	0.39	0.44	0.40	0.39	0.40	NC
MnO	§	0.02	0.02	0.02	0.02	0.02	0.02	NC
Na_2O	9.58	8.63	9.39	9.95	8.18	9.91	9.21	-3.85
Nd_2O_3	§	0.01	0.01	0.01	<0.01	<0.01	0.01	NC
NiO	0.40	0.38	0.38	0.36	0.37	0.37	0.37	NC
P_2O_5	1.05	1.10	1.13	1.13	1.13	1.11	1.12	6.05
PbO	0.41	0.37	0.36	0.35	0.35	0.34	0.35	NC
SiO_2	30.50	31.42	31.15	30.98	31.38	31.09	31.21	2.33
SO_3	0.20	0.16	0.18	0.16	0.18	0.16	0.17	NC
TiO_2	0.01	0.04	0.04	0.04	0.04	0.04	0.04	NC
ZnO	0.08	0.09	0.09	0.08	0.08	0.08	0.08	NC
ZrO_2	0.39	0.50	0.49	0.45	0.45	0.45	0.47	NC
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

§ - Not a target constituent
* Target values
NC –Not calculated

Table 6.2. XRF Analyzed Compositions of Vitrified Melter Feed Samples (wt%) (continued).

Sample	Al + Na Limited						
	Target	BLN-F-107A	%Dev	BLN-F-9A	BLN-F-152A	Avg.	%Dev.
Al_2O_3	21.34	23.43	9.83	21.73	21.55	21.64	1.41
B_2O_3*	18.37	18.37	NC	18.37	18.37	18.37	NC
BaO	0.03	0.04	NC	0.05	0.04	0.04	NC
Bi_2O_3	1.16	1.38	19.08	1.27	1.21	1.24	7.00
CaO	0.72	1.03	NC	1.13	1.00	1.06	NC
CdO	0.01	<0.01	NC	<0.01	<0.01	<0.01	NC
Cl	§	<0.01	NC	0.01	0.01	0.01	NC
Cr_2O_3	0.71	0.93	NC	0.85	0.86	0.85	NC
F*	0.23	0.23	NC	0.23	0.23	0.23	NC
Fe_2O_3	2.82	3.39	20.48	3.19	3.14	3.17	12.51
K_2O	0.66	0.81	NC	0.71	0.71	0.71	NC
La_2O_3	§	<0.01	NC	<0.01	<0.01	<0.01	NC
Li_2O*	3.58	3.58	NC	3.58	3.58	3.58	NC
MgO	0.22	0.25	NC	0.25	0.20	0.23	NC
MnO	§	0.01	NC	0.02	0.02	0.02	NC
Na_2O	12.71	11.93	-6.11	11.77	12.25	12.01	-5.48
Nd_2O_3	§	0.01	NC	0.01	<0.01	0.01	NC
NiO	0.10	0.13	NC	0.13	0.12	0.12	NC
P_2O_5	2.02	2.39	18.47	2.07	2.12	2.10	3.67
PbO	0.09	0.11	NC	0.11	0.09	0.10	NC
SiO_2	34.56	31.25	-9.60	33.80	33.71	33.76	-2.34
SO_3	0.17	0.15	NC	0.18	0.19	0.19	NC
TiO_2	0.22	0.20	NC	0.18	0.20	0.19	NC
ZnO	0.18	0.20	NC	0.18	0.21	0.20	NC
ZrO_2	0.12	0.19	NC	0.19	0.20	0.20	NC
Sum	100.00	100.00	NC	100.00	100.00	100.00	NC

§ - Not a target constituent
* Target values
NC –Not calculated

Table 6.3. Listing of Glass Discharged, Masses, and Analysis Performed During Bismuth-Limited DM100 Tests.

Test	T (°C)	Date	Sample Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1A	1175	7/18/06	BLK-G-78A	-	-	-
			BLK-G-79A	-	-	-
			BLK-G-79B	XRF, DCP, F	13.60	13.60
			BLK-G-81A	-	-	-
			BLK-G-81B	-	-	-
			BLK-G-83A	-	-	-
			BLK-G-83B	XRF, DCP	26.50	40.10
			BLK-G-83C	-	-	-
			BLK-G-84A	XRF, DCP	14.46	54.56
			BLK-G-84B	-	-	-
			BLK-G-84C	XRF, DCP, F	19.74	74.30
			BLK-G-88A	-	-	-
			BLK-G-89A	XRF, DCP	33.64	107.94
			BLK-G-91A	-	-	-
		7/19/06	BLK-G-95A	XRF, DCP	22.82	130.76
			BLK-G-96A	-	-	-
			BLK-G-96B	XRF, F	24.24	155.00
			BLK-G-97A	-	-	-
			BLK-G-99A	XRF, DCP	17.60	172.60
			BLK-G-100A	-	-	-
			BLK-G-100B	XRF	20.24	192.84
1B			BLK-G-103A	-	-	-
			BLK-G-105A	XRF, DCP, F	23.88	216.72
			BLK-G-105B	-	-	-
		7/20/06	BLK-G-108A	XRF, DCP	26.46	243.18
			BLK-G-110A	-	-	-
			BLK-G-110B	XRF	26.02	269.20
			BLK-G-111A	-	-	-
			BLK-G-111B	XRF, F	21.40	290.60
			BLK-G-112A	-	-	-
			BLK-G-112B	XRF	26.36	316.96
			BLK-G-117A	-	-	-
			BLK-G-119A	XRF, DCP	26.22	343.18
			BLK-G-119B	-	-	-
			BLK-G-122A	XRF, F	26.76	369.94
			BLK-G-124A	-	-	-
			BLK-G-124B	XRF	22.64	392.58
			BLK-G-124C	-	-	-
			BLK-G-129A	XRF, DCP, PCT, TCLP	33.46	426.04
2A	1150	7/24/06	BLK-G-146A	-	-	-
			BLK-G-146B	XRF	18.16	444.20
			BLK-G-147A	-	-	-
			BLK-G-149A	XRF	19.68	463.88

- Empty data field

Table 6.3. List of Glass Discharged, Masses, and Analysis Performed During Bismuth-Limited DM100 Tests (continued).

Test	T (°C)	Date	Sample Name	Analysis	Mass (kg)	Cumulative Mass (kg)
2A	1150	7/24/05	BLK-G-150A	-	-	-
		7/25/06	BLK-G-150B	XRF, DCP, F	25.54	489.42
			BLK-G-151A	-	-	-
			BLK-G-151B	XRF, DCP	16.98	506.40
			BLL-G-9A	-	-	-
			BLL-G-9B	XRF	17.64	524.04
			BLL-G-9C	-	-	-
			BLL-G-10A	XRF, DCP	24.42	548.46
			BLL-G-11A	-	-	-
		7/26/06	BLL-G-11B	XRF, DCP	23.82	572.28
			BLL-G-15A	-	-	-
			BLL-G-15B	XRF, F	21.96	594.24
2B			BLL-G-20A	-	-	-
			BLL-G-23A	XRF	19.76	614.00
			BLL-G-27A	-	-	-
		7/27/06	BLL-G-27B	XRF, DCP	21.12	635.12
			BLL-G-28A	-	-	-
			BLL-G-30A	XRF, F	15.02	650.14
			BLL-G-31A	-	-	-
			BLL-G-35A	XRF, DCP	22.82	672.96
			BLL-G-38A	-	-	-
		7/28/06	BLL-G-40A	XRF, DCP	30.32	703.28
			BLL-G-41A	XRF	29.80	733.08
			BLL-G-46A	XRF	28.12	761.20
			BLL-G-46B	XRF, DCP, PCT, TCLP, F	33.14	794.34

-Empty data field

Table 6.4. List of Glass Discharged, Masses, and Analysis Performed During Chromium-Limited DM100 Tests.

Test	T (°C)	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
3B	1175	8/21/06	BLL-G-70A	-	-	-
		8/22/06	BLL-G-70B	XRF, F	24.94	24.94
			BLL-G-71A	-	-	-
			BLL-G-71B	XRF	32.34	57.28
			BLL-G-73A	-	-	-
			BLL-G-73B	XRF	24.38	81.66
			BLL-G-76A	-	-	-
			BLL-G-76B	XRF, F	25.42	107.08
			BLL-G-77A	-	-	-
			BLL-G-77B	XRF	28.10	135.18
			BLL-G-79A	-	-	-
		8/23/06	BLL-G-83A	XRF	35.60	170.78
			BLL-G-83B	-	-	-
			BLL-G-83C	XRF, F	32.02	202.80
			BLL-G-86A	-	-	-
			BLL-G-86B	XRF	17.32	220.12
			BLL-G-86C	-	-	-
			BLL-G-88A	XRF, DCP, TCLP, PCT	28.44	248.56
4A	1150		BLL-G-89A	-	-	-
			BLL-G-91A	XRF, F	27.56	276.12
		8/24/06	BLL-G-91B	-	-	-
			BLL-G-94A	XRF	30.18	306.30
			BLL-G-96A	-	-	-
			BLL-G-96B	XRF	22.86	329.16
			BLL-G-100A	-	-	-
			BLL-G-100B	XRF, F	21.00	350.16
			BLL-G-100C	-	-	-
			BLL-G-101A	XRF	25.40	375.56
			BLL-G-101B	-	-	-
			BLL-G-105A	XRF	28.56	404.12
		8/25/06	BLL-G-105B	-	-	-
			BLL-G-107A	XRF, DCP, F	29.88	434.00
			BLL-G-107B	-	-	-
			BLL-G-107C	XRF	19.34	453.34
			BLL-G-111A	-	-	-
			BLL-G-111B	XRF, DCP	27.76	481.10
			BLL-G-111C	-	-	-
			BLL-G-113A	XRF, DCP, TCLP	26.44	507.54
			BLL-G-113B	-	-	-
			BLL-G-121A	XRF, DCP, TCLP, PCT, F	32.86	540.40

- Empty data field

Table 6.5. List of Glass Discharged, Masses, and Analysis Performed During Aluminum-Limited DM100 Tests.

Test	T (°C)	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
5A	1175C	9/11/06	BLL-G-137A	-	-	-
		9/12/06	BLL-G-137B	XRF, F	26.9	26.90
			BLL-G-140A	-	-	-
			BLL-G-142A	XRF	21.56	48.46
			BLL-G-143A	-	-	-
			BLL-G-143B	XRF	20.88	69.34
			BLL-G-147A	-	-	-
			BLL-G-148A	XRF	25.62	94.96
			BLL-G-149A	-	-	-
			BLL-G-149B	XRF, F	22.56	117.52
			BLL-G-153A	-	-	-
		9/13/06	BLL-G-154A	XRF	27.56	145.08
			BLL-G-155A	-	-	-
			BLM-G-9A	XRF	25.84	170.92
5B			BLM-G-11A	-	-	-
			BLM-G-13A	XRF	23.82	194.74
		9/14/06	BLM-G-14A	-	-	-
			BLM-G-17A	XRF, F	18.57	213.31
			BLM-G-18A	-	-	-
			BLM-G-20A	XRF	15.84	229.15
			BLM-G-24A	-	-	-
			BLM-G-24B	XRF	21.5	250.65
			BLM-G-27A	-	-	-
		9/15/06	BLM-G-31A	XRF	29.56	280.21
			BLM-G-32A	-	-	-
			BLM-G-36A	XRF, F, DCP, TCLP, PCT	25	305.21
6A	1150C	9/18/06	BLM-G-53A	-	-	-
			BLM-G-54A	XRF	20.92	326.13
			BLM-G-55A	-	-	-
			BLM-G-57A	XRF	24.56	350.69
		9/19/06	BLM-G-60A	-	-	-
			BLM-G-62A	XRF	20	370.69
			BLM-G-62B	-	-	-
			BLM-G-65A	XRF, F	20.6	391.29
			BLM-G-67A	-	-	-
			BLM-G-71A	XRF	22.04	413.33
		9/20/06	BLM-G-72A	-	-	-
			BLM-G-73A	XRF	18.84	432.17
			BLM-G-73B	XRF	9.86	442.03
6B			BLM-G-79A	-	-	-
			BLM-G-80A	XRF, F	21.1	463.13
		9/21/06	BLM-G-83A	-	-	-
			BLM-G-85A	XRF	14.89	478.02

- Empty data field

Table 6.5. List of Glass Discharged, Masses, and Analysis Performed During Aluminum-Limited DM100 Tests (continued).

Test	T (°C)	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
6B	1150	9/21/06	BLM-G-88A	-	-	-
			BLM-G-90A	XRF	26.26	504.28
		9/22/06	BLM-G-91A	-	-	-
			BLM-G-100A	XRF	11.5	515.78
		9/23/06	BLM-G-110A	XRF, F, DCP, TCLP, PCT	12.92	528.70
		9/25/06	BLM-G-111A	XRF	6.18	534.88
		9/26/06	BLM-G-112A	-	-	-
6C			BLM-G-123A	-	-	-
			BLM-G-123B	XRF	23.3	558.18
			BLM-G-123C	-	-	-
			BLM-G-124A	XRF	11.98	570.16
			BLM-G-125A	-	-	-
			BLM-G-127A	XRF	17.32	587.48
		9/27/06	BLM-G-128A	-	-	-
			BLM-G-131A	XRF, F, DCP	28.58	616.06
			BLM-G-133A	-	-	-
			BLM-G-133B	XRF	18.38	634.44
			BLM-G-134A	-	-	-
			BLM-G-134B	XRF	19.68	654.12
			BLM-G-134C	-	-	
			BLM-G-138A	XRF	18.48	672.60
			BLM-G-138B	-	-	-
			BLM-G-139A	XRF, F, DCP	26.32	698.92
		9/28/06	BLM-G-143A	-	-	-
			BLM-G-144A	XRF	19.56	718.48
			BLM-G-144B	-	-	
			BLM-G-145A	XRF, F, DCP	17.68	736.16
			BLM-G-145B	-	-	
			BLM-G-146A	-	-	-
			BLM-G-146B	XRF, DCP, PCT, TCLP	19.52	755.68
			BLM-G-146C	-	-	-
			BLM-G-152A	-	-	-
			BLM-G-152B	XRF, F	27.08	782.76
			BLM-G-152C	-	-	-
			BLM-G-152D	XRF	10.62	793.38

- Empty data field

Table 6.6. List of Glass Discharged, Masses, and Analysis Performed During Aluminum-Plus-Sodium-Limited DM100 Tests.

Test	T (°C)	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
7A	1175	10/2/06	BLN-G-15A	-	-	-
		10/3/06	BLN-G-17A	XRF, F	19.46	19.46
			BLN-G-18A	-	-	-
			BLN-G-21A	XRF	21.7	41.16
			BLN-G-22A	-	-	-
			BLN-G-22B	XRF	26.36	67.52
			BLN-G-22C	-	-	-
			BLN-G-24A	XRF	28	95.52
			BLN-G-24B	-	-	-
			BLN-G-24C	XRF	23.02	118.54
			BLN-G-27A	-	-	-
			BLN-G-27B	XRF, F	25.24	143.78
			BLN-G-29A	-	-	-
		10/4/06	BLN-G-32A	XRF	23.1	166.88
			BLN-G-32B	-	-	-
			BLN-G-32C	XRF	27.86	194.74
			BLN-G-34A	-	-	-
			BLN-G-35A	XRF	24.42	219.16
			BLN-G-35B	-	-	-
			BLN-G-36A	XRF, DCP	26.46	245.62
			BLN-G-40A	XRF	13.86	259.48
7B			BLN-G-40B	-	-	-
			BLN-G-41A	XRF, F	21.88	281.36
			BLN-G-41B	-	-	-
		10/5/06	BLN-G-43A	XRF	21.64	303.00
			BLN-G-43B	-	-	-
			BLN-G-46A	XRF	22.18	325.18
			BLN-G-49A	-	-	-
			BLN-G-52A	XRF	17.94	343.12
			BLN-G-52B	-	-	-
			BLN-G-52C	XRF	30.66	373.78
			BLN-G-55A	-	-	-
		10/6/06	BLN-G-55B	XRF	25.24	399.02
			BLN-G-56A	-	-	-
			BLN-G-60A	XRF	26.66	425.68
			BLN-G-62A	-	-	-
			BLN-G-62B	XRF, F	23.56	449.24
			BLN-G-65A	-	-	-
			BLN-G-66A	XRF, DCP, TCLP, PCT	27.4	476.64
8A	1150	10/16/06	BLN-G-81A	-	-	-
			BLN-G-81B	XRF	19.3	495.94
			BLN-G-82A	-	-	-
			BLN-G-82B	XRF, F	17.18	513.12

- Empty data field

Table 6.6. List of Glass Discharged, Masses, and Analysis Performed During Aluminum-Plus-Sodium-Limited DM100 Tests (continued).

Test	T(°C)	Date	Name	Analysis	Mass(kg)	Cumulative Mass (kg)
8A	1150	10/16/06	BLN-G-82C	-	-	-
			BLN-G-83A	XRF	16.58	529.70
			BLN-G-83B	-	-	-
			BLN-G-85A	XRF	14.58	544.28
		10/17/06	BLN-G-88A	XRF	30.12	574.40
			BLN-G-94A	XRF, F	18.34	592.74
		10/18/06	BLN-G-101A	-	-	-
			BLN-G-101B	XRF	16.42	609.16
			BLN-G-102A	-	-	-
			BLN-G-106A	-	-	-
			BLN-G-106B	XRF, DCP, TCLP, PCT	21.28	630.44
8B		10/19/06	BLN-G-113A	-	-	-
			BLN-G-119A	XRF	15.64	646.08
		10/20/06	BLN-G-119B	-	-	-
			BLN-G-122A	XRF, F	11.78	657.86
			BLN-G-124A	-	-	-
			BLN-G-124B	-	-	-
		10/21/06	BLN-G-129A	XRF, DCP, TCLP, PCT	19.80	677.66
8C		11/18/06	BLN-G-147A	-	-	-
			BLN-G-147B	XRF	22.62	700.28
			BLN-G-149A	-	-	-
			BLN-G-150A	XRF, F	14.00	714.28
			BLN-G-150B	-	-	-
			BLN-G-152A	XRF	19.66	733.94
			BLN-G-153A	-	-	-
			BLN-G-153B	XRF	18.52	752.46
			BLN-G-154A	-	-	-
			BLN-G-154B	XRF	25.12	777.58
			BLN-G-154C	-	-	-
			BLN-G-155A	XRF	21.62	799.20
		11/19/06	BLO-G-5A	-	-	-
			BLO-G-5B	XRF, F	20.14	819.34
			BLO-G-5C	-	-	-
			BLO-G-10A	XRF	16.84	836.18
			BLO-G-10B	-	-	-
			BLO-G-15A	XRF	17.52	853.70
			BLO-G-16A	-	-	-
			BLO-G-16B	XRF	18.28	871.98
			BLO-G-18A	-	-	-
			BLO-G-18B	XRF	13.46	885.44
		11/20/06	BLO-G-19A	-	-	-
			BLO-G-22A	-	-	-
			BLO-G-22B	XRF, F	24.82	910.26
			BLO-G-22C	-	-	-
			BLO-G-24A	XRF, DCP	23.26	933.52

- Empty data field

Table 6.7. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Bismuth-Limited Composition (wt%).

Test		1A									
Glass (kg)		0.00	13.60	40.10	54.56	74.30	107.94	130.76	155.00	172.60	192.84
Constituent	Target	BLK-G-58A	BLK-G-79B	BLK-G-83B	BLK-G-84A	BLK-G-84C	BLK-G-89A	BLK-G-95A	BLK-G-96B	BLK-G-99A	BLK-G-100B
Ag_2O	§	0.08	0.06	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
Al_2O_3	11.66	7.06	8.59	9.19	9.27	9.80	10.34	10.10	10.32	10.26	10.74
B_2O_3*	11.30	9.97	10.42	10.54	10.60	10.67	10.78	10.84	10.90	10.94	10.97
BaO	0.01	0.07	0.07	0.05	0.04	0.06	0.05	0.05	0.04	0.03	0.03
Bi_2O_3	6.71	<0.01	2.28	3.18	3.42	3.41	3.79	4.21	4.57	4.71	4.85
CaO	0.84	0.60	0.66	0.70	0.71	0.73	0.74	0.78	0.77	0.78	0.78
CeO_2	§	0.10	0.07	0.04	0.04	0.04	0.03	0.03	0.01	0.02	0.01
Cl	§	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.03	0.03
Cr_2O_3	0.52	0.21	0.36	0.41	0.43	0.41	0.43	0.45	0.48	0.49	0.48
F	0.82	<0.1#	0.17	0.23	0.26	0.30#	0.32	0.33	0.35#	0.36	0.38
Fe_2O_3	6.96	12.79	10.63	9.29	9.40	8.86	8.60	8.90	8.29	8.32	7.97
K_2O	0.46	0.26	0.36	0.40	0.40	0.40	0.43	0.44	0.45	0.47	0.46
Li_2O*	0.16	2.62	1.95	1.70	1.59	1.44	1.22	1.09	0.98	0.90	0.82
MgO	0.43	0.30	0.37	0.40	0.41	0.40	0.47	0.45	0.44	0.48	0.41
MnO	§	2.39	1.57	1.12	1.11	1.01	0.89	0.86	0.69	0.66	0.57
Na_2O	15.74	12.21	13.50	14.47	14.66	14.69	14.33	14.98	15.16	14.90	15.51
Nd_2O_3	§	0.15	0.12	0.09	0.09	0.09	0.08	0.07	0.07	0.07	0.06
NiO	1.93	0.34	0.79	1.02	1.04	1.02	1.09	1.23	1.30	1.38	1.34
P_2O_5	4.99	0.43	2.15	3.05	3.10	3.24	3.52	3.55	3.98	4.15	4.22
PbO	0.25	0.42	0.37	0.32	0.34	0.31	0.31	0.33	0.30	0.31	0.29
SiO_2	36.26	47.90	43.75	42.19	41.49	41.57	41.07	39.73	39.46	39.34	38.70
SnO_2	§	0.04	0.03	0.02	0.01	0.02	0.01	0.01	0.01	<0.01	0.01
SO_3	0.48	0.07	0.21	0.31	0.30	0.30	0.32	0.32	0.35	0.37	0.36
SrO	§	0.14	0.09	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.04
TiO_2	0.16	0.05	0.10	0.12	0.11	0.13	0.14	0.15	0.14	0.15	0.16
ZnO	0.16	0.93	0.65	0.49	0.49	0.46	0.41	0.42	0.36	0.35	0.32
ZrO_2	0.21	0.87	0.68	0.55	0.56	0.52	0.50	0.52	0.47	0.47	0.45
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.7. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Bismuth-Limited Composition (wt%) (continued).

Test		1B									2A
Glass (kg)		216.72	243.18	269.20	290.60	316.96	343.18	369.94	392.58	426.04	444.20
Constituent	Target	BLK-G-105A	BLK-G-108A	BLK-G-110B	BLK-G-111B	BLK-G-112B	BLK-G-119A	BLK-G-122A	BLK-G-124B	BLK-G-129A	BLK-G-146B
Ag_2O	§	0.01	0.01	0.01	<0.01	<0.01	<0.01	0.00	0.01	0.01	<0.01
Al_2O_3	11.66	10.56	10.82	10.95	11.31	11.30	11.34	11.43	11.33	11.26	11.67
B_2O_3*	11.30	11.02	11.05	11.09	11.11	11.14	11.16	11.18	11.19	11.21	11.22
BaO	0.01	0.03	0.02	0.04	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Bi_2O_3	6.71	4.94	5.06	5.19	5.57	5.42	5.56	5.19	6.32	5.75	5.70
CaO	0.84	0.78	0.81	0.81	0.84	0.80	0.80	0.77	0.88	0.82	0.82
CeO_2	§	0.01	0.02	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cl	§	0.04	0.04	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.04
Cr_2O_3	0.52	0.48	0.47	0.48	0.50	0.47	0.48	0.45	0.52	0.49	0.45
F	0.82	0.40#	0.40	0.40	0.40#	0.42	0.43	0.45#	0.45	0.45	0.44
Fe_2O_3	6.96	7.87	7.60	7.47	7.73	7.41	7.23	6.80	7.79	7.13	6.88
K_2O	0.46	0.45	0.48	0.48	0.51	0.49	0.48	0.49	0.52	0.51	0.51
Li_2O*	0.16	0.74	0.66	0.59	0.54	0.49	0.45	0.41	0.38	0.34	0.32
MgO	0.43	0.49	0.52	0.52	0.48	0.50	0.52	0.53	0.50	0.51	0.53
MnO	§	0.53	0.45	0.40	0.39	0.37	0.31	0.27	0.28	0.26	0.22
Na_2O	15.74	15.90	15.60	15.74	14.39	15.42	15.81	16.04	14.40	16.00	16.38
Nd_2O_3	§	0.07	0.06	0.05	0.06	0.06	0.05	0.06	0.06	0.06	0.05
NiO	1.93	1.31	1.39	1.43	1.48	1.42	1.44	1.34	1.64	1.49	1.42
P_2O_5	4.99	4.30	4.58	4.61	4.74	4.71	4.76	4.96	4.92	4.92	4.97
PbO	0.25	0.29	0.29	0.28	0.29	0.29	0.28	0.26	0.31	0.28	0.27
SiO_2	36.26	38.47	38.41	38.15	38.27	37.96	37.57	38.11	37.08	37.24	36.84
SnO_2	§	<0.01	0.01	<0.01	0.01	0.01	<0.01	<0.01	0.01	0.01	0.01
SO_3	0.48	0.37	0.39	0.39	0.41	0.40	0.41	0.42	0.43	0.41	0.44
SrO	§	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
TiO_2	0.16	0.16	0.16	0.16	0.18	0.17	0.18	0.16	0.19	0.18	0.18
ZnO	0.16	0.31	0.28	0.26	0.27	0.25	0.24	0.22	0.25	0.22	0.21
ZrO_2	0.21	0.44	0.40	0.41	0.42	0.41	0.39	0.36	0.44	0.39	0.37
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.7. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Bismuth-Limited Composition (wt%) (continued).

Test		2A							2B		
Glass (kg)		463.88	489.42	506.40	524.04	548.46	572.28	594.24	614.00	635.12	650.14
Constituent	Target	BLK-G-149A	BLK-G-150B	BLK-G-151B	BLL-G-9B	BLL-G-10A	BLL-G-11B	BLL-G-15B	BLL-G-23A	BLL-G-27B	BLL-G-30A
Ag_2O	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al_2O_3	11.66	11.52	11.53	11.47	11.81	11.76	11.63	11.59	11.96	11.69	11.75
B_2O_3*	11.30	11.23	11.24	11.24	11.25	11.25	11.26	11.27	11.27	11.27	11.27
BaO	0.01	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.02
Bi_2O_3	6.71	6.12	6.08	6.15	5.97	6.06	6.20	6.43	5.81	6.15	6.15
CaO	0.84	0.84	0.82	0.84	0.83	0.82	0.84	0.86	0.82	0.85	0.83
CeO_2	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cl	§	0.04	0.04	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.05
Cr_2O_3	0.52	0.47	0.46	0.47	0.47	0.47	0.46	0.48	0.44	0.47	0.45
F	0.82	0.44	0.44#	0.44	0.43	0.43	0.42	0.42#	0.43	0.45	0.46#
Fe_2O_3	6.96	7.18	7.09	7.19	6.92	6.90	7.04	7.22	6.58	6.86	6.91
K_2O	0.46	0.52	0.51	0.51	0.52	0.50	0.51	0.52	0.50	0.52	0.52
Li_2O*	0.16	0.31	0.29	0.28	0.27	0.25	0.24	0.23	0.22	0.22	0.21
MgO	0.43	0.49	0.50	0.46	0.51	0.46	0.45	0.47	0.46	0.46	0.41
MnO	§	0.22	0.21	0.21	0.18	0.17	0.17	0.16	0.15	0.15	0.15
Na_2O	15.74	15.40	16.10	16.10	16.02	16.38	16.21	15.35	16.52	16.38	16.42
Nd_2O_3	§	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
NiO	1.93	1.50	1.45	1.51	1.47	1.47	1.54	1.59	1.43	1.51	1.53
P_2O_5	4.99	5.04	4.96	4.94	5.00	4.99	5.04	5.14	5.11	5.14	5.03
PbO	0.25	0.29	0.28	0.30	0.27	0.28	0.29	0.30	0.27	0.29	0.28
SiO_2	36.26	37.01	36.60	36.40	36.76	36.45	36.32	36.57	36.71	36.27	36.33
SnO_2	§	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SO_3	0.48	0.45	0.49	0.53	0.42	0.44	0.45	0.45	0.45	0.44	0.42
SrO	§	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.02
TiO_2	0.16	0.19	0.18	0.19	0.19	0.19	0.18	0.19	0.18	0.18	0.18
ZnO	0.16	0.21	0.21	0.21	0.20	0.19	0.20	0.20	0.18	0.18	0.19
ZrO_2	0.21	0.40	0.40	0.41	0.38	0.38	0.39	0.41	0.36	0.38	0.38
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.7. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Bismuth-Limited Composition (wt%) (continued).

Test		2B					Post Turnover	
Glass (kg)		672.96	703.28	733.08	761.20	794.34	572-795	
Constituent	Target	BLL-G-35A	BLL-G-40A	BLL-G-41A	BLL-G-46A	BLL-G-46B	Average	%Dev.
Ag_2O	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Al_2O_3	11.66	11.63	11.69	11.73	11.83	11.48	11.70	0.33
B_2O_3*	11.30	11.28	11.28	11.28	11.29	11.29	11.28	NC
BaO	0.01	0.02	0.02	0.03	0.02	0.03	0.03	NC
Bi_2O_3	6.71	6.31	6.25	6.30	5.93	6.67	6.22	-7.31
CaO	0.84	0.87	0.86	0.86	0.83	0.87	0.85	0.93
CeO_2	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Cl	§	0.04	0.04	0.04	0.05	0.05	0.04	NC
Cr_2O_3	0.52	0.46	0.46	0.47	0.45	0.51	0.47	NC
F	0.82	0.46	0.47	0.48	0.48	0.49#	0.46	NC
Fe_2O_3	6.96	7.05	6.90	7.04	6.65	7.38	6.96	0.04
K_2O	0.46	0.52	0.52	0.53	0.49	0.54	0.52	NC
Li_2O*	0.16	0.21	0.20	0.19	0.19	0.18	0.21	NC
MgO	0.43	0.46	0.44	0.41	0.47	0.50	0.45	NC
MnO	§	0.15	0.14	0.14	0.14	0.15	0.15	NC
Na_2O	15.74	15.21	15.89	15.62	16.15	15.23	15.90	0.99
Nd_2O_3	§	0.05	0.06	0.06	0.05	0.05	0.05	NC
NiO	1.93	1.54	1.55	1.56	1.46	1.67	1.54	-20.45
P_2O_5	4.99	5.19	5.12	5.14	5.23	5.06	5.12	2.63
PbO	0.25	0.29	0.28	0.29	0.27	0.30	0.29	NC
SiO_2	36.26	37.04	36.65	36.62	36.85	36.27	36.56	0.83
SnO_2	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
SO_3	0.48	0.44	0.41	0.41	0.44	0.43	0.43	NC
SrO	§	0.02	0.02	0.02	0.02	0.03	0.03	NC
TiO_2	0.16	0.19	0.19	0.19	0.17	0.19	0.19	NC
ZnO	0.16	0.19	0.18	0.19	0.18	0.20	0.19	NC
ZrO_2	0.21	0.39	0.38	0.39	0.36	0.42	0.39	NC
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.8. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Chromium-Limited Composition (wt%).

Test		3B									4A		
Glass (kg)		24.94	57.28	81.66	107.08	135.18	170.78	202.8	220.12	248.56	276.12	306.30	329.16
Constituent	Target	BLL-G-70B	BLL-G-71B	BLL-G-73B	BLL-G-76B	BLL-G-77B	BLL-G-83A	BLL-G-83C	BLL-G-86B	BLL-G-88A	BLL-G-91A	BLL-G-94A	BLL-G-96B
Al_2O_3	8.98	11.18	10.32	10.37	10.50	10.30	9.95	9.81	9.75	9.43	9.81	9.89	9.66
B_2O_3*	16.17	11.92	12.62	13.07	13.48	13.87	14.28	14.59	14.73	14.95	15.12	15.28	15.39
BaO	0.01	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
Bi_2O_3	2.56	4.42	4.64	4.05	3.48	3.51	3.52	3.32	3.23	3.36	3.00	2.87	2.88
CaO	0.87	0.84	0.88	0.83	0.80	0.82	0.85	0.82	0.81	0.84	0.81	0.80	0.81
Cr_2O_3	1.08	0.81	0.94	0.90	0.92	1.00	1.07	1.07	1.11	1.16	1.12	1.12	1.15
F	0.70	0.35#	0.39	0.41	0.44#	0.43	0.43	0.42#	0.42	0.43	0.44#	0.45	0.45
Fe_2O_3	4.62	5.80	6.13	5.57	5.14	5.27	5.43	5.29	5.21	5.43	5.02	4.90	4.98
K_2O	6.05	2.91	3.48	3.62	3.86	4.18	4.51	4.64	4.72	4.94	4.89	4.93	4.99
Li_2O*	3.68	0.64	1.14	1.46	1.75	2.03	2.33	2.55	2.65	2.80	2.93	3.04	3.12
MgO	0.06	0.36	0.32	0.33	0.33	0.30	0.28	0.29	0.27	0.28	0.24	0.29	0.31
MnO	§	0.09	0.08	0.07	0.05	0.05	0.06	0.05	0.04	0.05	0.04	0.04	0.04
Na_2O	7.07	12.94	12.17	11.64	10.91	10.02	9.13	9.31	9.47	8.90	8.73	8.65	8.67
Nd_2O_3	§	0.03	0.03	0.03	0.02	0.02	0.02	<0.01	0.01	0.01	0.01	0.01	0.01
NiO	0.37	1.00	1.02	0.89	0.79	0.79	0.78	0.76	0.72	0.74	0.66	0.63	0.61
P_2O_5	1.18	3.56	3.13	2.97	2.67	2.49	2.27	2.13	1.98	1.91	1.82	1.75	1.71
PbO	0.17	0.22	0.23	0.21	0.18	0.18	0.19	0.18	0.18	0.19	0.17	0.16	0.18
SiO_2	45.76	42.08	41.63	42.78	43.93	44.02	44.18	44.10	44.03	43.93	44.51	44.54	44.39
SO_3	0.53	0.33	0.33	0.35	0.36	0.35	0.36	0.36	0.36	0.37	0.37	0.37	0.39
SrO	§	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01
TiO_2	§	0.12	0.10	0.10	0.09	0.08	0.07	0.06	0.06	0.05	0.05	0.05	0.05
ZnO	0.09	0.14	0.15	0.13	0.11	0.11	0.12	0.12	0.11	0.12	0.11	0.10	0.10
ZrO_2	0.04	0.23	0.23	0.19	0.15	0.15	0.14	0.13	0.11	0.12	0.10	0.09	0.09
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.8. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Chromium-Limited Composition (wt%) (continued).

Test		4A								%Dev. from target for last sample
Glass (kg)		350.16	375.56	404.12	434.00	453.34	481.10	507.54	540.40	
Constituent	Target	BLL-G-100B	BLL-G-101A	BLL-G-105A	BLL-G-107A	BLL-G-107C	BLL-G-111B	BLL-G-113A	BLL-G-121A	
Al_2O_3	8.98	9.76	9.66	9.74	9.36	9.36	9.72	9.07	9.37	4.35
B_2O_3*	16.17	15.47	15.57	15.66	15.73	15.78	15.84	15.88	15.93	NC
BaO	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.01	NC
Bi_2O_3	2.56	2.82	2.88	2.58	2.93	2.87	2.69	2.90	2.88	12.42
CaO	0.87	0.81	0.82	0.76	0.84	0.82	0.80	0.83	0.81	NC
Cr_2O_3	1.08	1.15	1.14	1.06	1.19	1.19	1.14	1.19	1.19	9.74
F	0.70	0.46#	0.46	0.46	0.46#	0.47	0.48	0.49	0.51#	NC
Fe_2O_3	4.62	4.89	5.02	4.56	5.13	5.02	4.77	5.06	5.06	9.60
K_2O	6.05	5.02	5.18	4.98	5.41	5.43	5.36	5.53	5.51	-8.97
Li_2O*	3.68	3.18	3.25	3.31	3.37	3.40	3.44	3.47	3.51	NC
MgO	0.06	0.28	0.28	0.28	0.25	0.24	0.25	0.22	0.23	NC
MnO	§	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.04	NC
Na_2O	7.07	8.46	8.31	8.84	7.75	7.75	7.44	7.68	7.62	7.74
Nd_2O_3	0.00	0.01	0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	NC
NiO	0.37	0.59	0.60	0.52	0.58	0.55	0.50	0.53	0.54	NC
P_2O_5	1.18	1.66	1.62	1.57	1.57	1.52	1.51	1.48	1.46	23.96
PbO	0.17	0.16	0.16	0.15	0.17	0.17	0.15	0.17	0.16	NC
SiO_2	45.76	44.58	44.36	44.87	44.58	44.74	45.22	44.82	44.51	-2.74
SO_3	0.53	0.39	0.39	0.39	0.40	0.40	0.41	0.41	0.41	NC
SrO	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
TiO_2	§	0.05	0.04	0.04	0.04	0.04	0.05	0.03	0.04	NC
ZnO	0.09	0.10	0.11	0.09	0.10	0.10	0.10	0.11	0.11	NC
ZrO_2	0.04	0.09	0.09	0.07	0.08	0.08	0.07	0.07	0.08	NC
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
\# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.9. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Aluminum-Limited Composition (wt%).

Test		**5A**							**5B**						**6A**	
Glass (kg)		26.9	48.46	69.34	94.96	117.52	145.08	170.92	194.74	213.31	229.15	250.65	280.21	305.21	326.13	350.69
Constituent	Target	BLL-G-137B	BLL-G-142A	BLL-G-143B	BLL-G-148A	BLL-G-149B	BLL-G-154A	BLM-G-9A	BLM-G-13A	BLM-G-17A	BLM-G-20A	BLM-G-24B	BLM-G-31A	BLM-G-36A	BLM-G-54A	BLM-G-57A
Al_2O_3	23.97	14.43	15.58	16.38	17.44	18.11	18.70	18.98	19.90	20.20	20.42	20.79	21.13	20.95	21.34	21.50
B_2O_3*	15.19	15.83	15.76	15.69	15.63	15.58	15.52	15.48	15.44	15.42	15.40	15.37	15.35	15.33	15.31	15.30
BaO	0.05	0.12	0.19	0.22	0.24	0.28	0.27	0.24	0.30	0.30	0.31	0.30	0.30	0.32	0.36	0.36
Bi_2O_3	1.14	2.19	1.97	1.92	1.80	1.76	1.65	1.66	1.52	1.46	1.41	1.37	1.37	1.41	1.40	1.38
CaO	6.08	2.71	2.98	3.35	3.75	4.03	4.24	4.39	4.65	4.64	4.67	4.79	5.02	5.25	5.30	5.32
CdO	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr_2O_3	0.52	0.90	0.83	0.79	0.74	0.72	0.68	0.66	0.63	0.59	0.58	0.56	0.57	0.56	0.55	0.55
F	0.67	0.30#	0.32	0.33	0.35	0.37#	0.39	0.41	0.43	0.44#	0.43	0.43	0.42	0.41#	0.42	0.43
Fe_2O_3	5.90	5.78	5.62	5.71	5.73	5.88	5.82	5.94	5.81	5.67	5.60	5.54	5.77	5.97	5.97	5.91
K_2O	0.14	3.36	2.94	2.67	2.25	2.03	1.79	1.69	1.41	1.29	1.28	1.12	0.99	0.96	0.91	0.82
Li_2O*	3.57	3.52	3.52	3.53	3.53	3.54	3.54	3.55	3.55	3.55	3.55	3.55	3.56	3.56	3.56	3.56
MgO	0.12	0.30	0.31	0.30	0.33	0.33	0.33	0.33	0.35	0.35	0.35	0.36	0.38	0.35	0.34	0.38
MnO	§	0.12	0.11	0.10	0.09	0.08	0.07	0.08	0.06	0.06	0.06	0.05	0.05	0.05	0.06	0.06
Na_2O	9.58	8.53	8.59	8.51	9.20	8.81	9.27	9.36	9.18	9.64	9.22	9.76	9.32	9.64	9.23	9.44
Nd_2O_3	§	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01
NiO	0.40	0.55	0.51	0.48	0.47	0.47	0.43	0.42	0.41	0.38	0.37	0.36	0.35	0.37	0.35	0.33
P_2O_5	1.05	1.32	1.31	1.30	1.25	1.23	1.24	1.21	1.18	1.17	1.16	1.16	1.17	1.17	1.19	1.15
PbO	0.41	0.24	0.25	0.28	0.29	0.30	0.31	0.32	0.33	0.32	0.31	0.31	0.33	0.35	0.36	0.36
SiO_2	30.50	39.15	38.57	37.74	36.23	35.76	35.06	34.60	34.15	33.83	34.17	33.47	33.19	32.62	32.62	32.39
SO_3	0.20	0.22	0.20	0.20	0.18	0.20	0.16	0.16	0.16	0.15	0.15	0.16	0.16	0.15	0.16	0.15
TiO_2	0.01	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.03	0.04	0.04
ZnO	0.08	0.12	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.08	0.09	0.09	0.09	0.09
ZrO_2	0.39	0.26	0.27	0.31	0.33	0.36	0.37	0.38	0.40	0.39	0.39	0.39	0.42	0.44	0.46	0.46
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.9. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Aluminum-Limited Composition (wt%) (continued).

Test		**6A**					**6B**						**6C**	
Glass (kg)		370.69	391.29	413.33	432.17	442.03	463.13	478.02	504.28	515.78	528.70	534.88	558.18	570.16
Constituent	Target	BLM-G-62A	BLM-G-65A	BLM-G-71A	BLM-G-73A	BLM-G-73B	BLM-G-80A	BLM-G-85A	BLM-G-90A	BLM-G-100A	BLM-G-110A-2	BLM-G-111A	BLM-G-123B	BLM-G-124A
Al_2O_3	23.97	21.46	21.95	21.71	21.92	21.98	21.96	21.93	22.16	22.27	22.54	22.46	22.56	22.37
B_2O_3*	15.19	15.28	15.27	15.26	15.26	15.25	15.25	15.24	15.23	15.23	15.23	15.23	15.22	15.22
BaO	0.05	0.35	0.35	0.35	0.32	0.29	0.41	0.33	0.39	0.33	0.29	0.32	0.30	0.30
Bi_2O_3	1.14	1.43	1.25	1.38	1.31	1.30	1.35	1.26	1.25	1.24	1.19	1.25	1.18	1.24
CaO	6.08	5.54	5.31	5.54	5.53	5.59	5.71	5.52	5.46	5.48	5.44	5.62	5.31	5.57
CdO	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr_2O_3	0.52	0.58	0.53	0.53	0.54	0.52	0.54	0.53	0.48	0.50	0.49	0.48	0.48	0.49
F	0.67	0.43	0.44#	0.44	0.43	0.43	0.43#	0.42	0.40	0.40	0.39#	0.39	0.39	0.39
Fe_2O_3	5.90	6.26	5.78	6.09	6.05	5.97	6.17	5.92	5.75	5.75	5.58	5.80	5.49	5.80
K_2O	0.14	0.83	0.72	0.72	0.67	0.63	0.62	0.58	0.59	0.56	0.54	0.54	0.52	0.53
Li_2O*	3.57	3.56	3.56	3.56	3.56	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57
MgO	0.12	0.36	0.38	0.38	0.40	0.36	0.37	0.42	0.40	0.36	0.43	0.43	0.44	0.40
MnO	§	0.05	0.05	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
Na_2O	9.58	8.69	9.34	9.37	9.42	9.58	9.00	10.15	9.60	9.20	9.29	9.21	10.21	9.68
Nd_2O_3	§	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	<0.01
NiO	0.40	0.36	0.34	0.33	0.35	0.34	0.35	0.33	0.32	0.31	0.30	0.31	0.30	0.31
P_2O_5	1.05	1.18	1.16	1.16	1.15	1.15	1.15	1.13	1.16	1.15	1.15	1.14	1.13	1.15
PbO	0.41	0.38	0.34	0.37	0.35	0.35	0.38	0.35	0.35	0.35	0.35	0.36	0.34	0.34
SiO_2	30.50	32.46	32.50	31.99	31.95	31.93	31.91	31.54	32.11	32.53	32.48	32.09	31.83	31.88
SO_3	0.20	0.15	0.15	0.13	0.16	0.16	0.14	0.15	0.15	0.15	0.15	0.13	0.12	0.12
TiO_2	0.01	0.04	0.05	0.04	0.04	0.04	0.05	0.03	0.04	0.05	0.05	0.05	0.04	0.04
ZnO	0.08	0.10	0.09	0.10	0.09	0.09	0.09	0.09	0.08	0.09	0.08	0.10	0.09	0.09
ZrO_2	0.39	0.49	0.44	0.50	0.46	0.45	0.50	0.47	0.47	0.45	0.44	0.47	0.44	0.45
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.9. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Aluminum-Limited Composition (wt%) (continued).

Test		6C											Steady State	
Glass (kg)		587.48	616.06	634.44	654.12	672.6	698.92	718.48	736.16	755.68	782.76	793.38	558-794	
Constituent	Target	BLM-G-127A	BLM-G-131A	BLM-G-133B	BLM-G-134B	BLM-G-138A	BLM-G-139A	BLM-G-144A	BLM-G-145A	BLM-G-146B	BLM-G-152B	BLM-G-152D	Avg.	%Dev.
Al_2O_3	23.97	22.23	22.28	22.08	22.68	22.53	22.40	22.37	22.29	22.43	22.44	22.14	22.37	-6.68
B_2O_3*	15.19	15.22	15.21	15.21	15.21	15.21	15.21	15.20	15.20	15.20	15.20	15.20	15.21	NC
BaO	0.05	0.28	0.31	0.32	0.25	0.30	0.36	0.36	0.32	0.27	0.33	0.35	0.31	NC
Bi_2O_3	1.14	1.32	1.30	1.32	1.17	1.25	1.22	1.23	1.30	1.21	1.21	1.18	1.24	8.18
CaO	6.08	5.82	5.80	5.90	5.62	5.76	5.74	5.80	5.87	5.86	5.61	5.43	5.70	-6.21
CdO	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Cr_2O_3	0.52	0.53	0.52	0.53	0.49	0.51	0.51	0.52	0.52	0.52	0.49	0.45	0.50	NC
F	0.67	0.40	0.40#	0.40	0.40	0.40	0.40#	0.41	0.41	0.42	0.43#	0.43	0.41	NC
Fe_2O_3	5.90	6.19	6.13	6.22	5.72	5.95	5.94	5.97	6.16	6.00	5.79	5.54	5.92	0.28
K_2O	0.14	0.51	0.47	0.48	0.46	0.44	0.43	0.42	0.42	0.42	0.45	0.49	0.46	NC
Li_2O*	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	NC
MgO	0.12	0.38	0.38	0.42	0.40	0.41	0.36	0.35	0.43	0.38	0.39	0.41	0.40	NC
MnO	§	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.05	0.04	NC
Na_2O	9.58	9.24	9.29	9.44	9.73	9.47	9.69	9.85	9.80	9.83	9.98	10.19	9.72	1.48
Nd_2O_3	§	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NC
NiO	0.40	0.35	0.34	0.34	0.31	0.33	0.32	0.32	0.33	0.32	0.30	0.28	0.32	NC
P_2O_5	1.05	1.16	1.14	1.12	1.14	1.14	1.12	1.10	1.09	1.12	1.13	1.16	1.13	7.34
PbO	0.41	0.38	0.37	0.37	0.33	0.36	0.37	0.36	0.37	0.35	0.35	0.33	0.35	NC
SiO_2	30.50	31.64	31.60	31.48	31.81	31.59	31.56	31.36	31.09	31.34	31.54	32.05	31.60	3.62
SO_3	0.20	0.13	0.13	0.12	0.13	0.14	0.15	0.15	0.15	0.15	0.16	0.17	0.14	NC
TiO_2	0.01	0.04	0.13	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.03	0.05	NC
ZnO	0.08	0.09	0.09	0.09	0.08	0.08	0.09	0.08	0.09	0.08	0.09	0.09	0.09	NC
ZrO_2	0.39	0.47	0.48	0.49	0.43	0.47	0.48	0.48	0.49	0.45	0.47	0.48	0.47	NC
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.10. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Aluminum-Plus-Sodium-Limited Composition (wt%).

Test		**7A**											**7B**			
Glass (kg)		19.46	41.16	67.52	95.52	118.54	143.78	166.88	194.74	219.16	245.62	259.48	281.36	303.00	325.18	343.12
Constituent	Target	BLN-G-17A	BLN-G-21A	BLN-G-22B	BLN-G-24A	BLN-G-24C	BLN-G-27B	BLN-G-32A	BLN-G-32C	BLN-G-35A	BLN-G-36A	BLN-G-40A	BLN-G-41A	BLN-G-43A	BLN-G-46A	BLN-G-52A
Al_2O_3	21.34	22.37	21.98	21.87	21.71	21.66	21.43	21.42	21.19	21.24	21.13	21.34	21.27	21.11	21.05	21.11
B_2O_3*	18.37	15.52	15.85	16.19	16.50	16.73	16.94	17.11	17.29	17.43	17.56	17.62	17.70	17.78	17.85	17.90
BaO	0.03	0.22	0.22	0.17	0.14	0.16	0.11	0.12	0.11	0.12	0.11	0.09	0.10	0.09	0.08	0.08
Bi_2O_3	1.16	1.14	1.23	1.15	1.19	1.16	1.15	1.15	1.20	1.17	1.21	1.17	1.20	1.15	1.25	1.14
CaO	0.72	3.95	3.61	3.25	2.81	2.61	2.31	2.07	2.00	1.90	1.70	1.64	1.59	1.49	1.46	1.34
CdO	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr_2O_3	0.71	0.57	0.64	0.64	0.70	0.70	0.74	0.74	0.78	0.76	0.78	0.78	0.80	0.77	0.83	0.79
F	0.23	0.28#	0.27	0.25	0.24	0.22	0.21#	0.21	0.21	0.21	0.21	0.21	0.21#	0.21	0.21	0.21
Fe_2O_3	2.82	4.67	4.64	4.28	4.13	4.03	3.79	3.66	3.74	3.59	3.52	3.41	3.46	3.30	3.48	3.24
K_2O	0.66	0.51	0.55	0.55	0.58	0.60	0.60	0.62	0.64	0.63	0.66	0.64	0.66	0.65	0.68	0.67
Li_2O*	3.58	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57
MgO	0.22	0.37	0.39	0.34	0.35	0.33	0.36	0.32	0.30	0.29	0.32	0.31	0.27	0.28	0.27	0.32
MnO	§	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.04
Na_2O	12.71	11.10	10.86	11.84	11.51	11.67	12.07	12.31	12.36	12.34	12.05	12.22	11.98	12.66	12.11	12.26
Nd_2O_3	§	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NiO	0.10	0.26	0.24	0.22	0.23	0.22	0.21	0.20	0.20	0.20	0.19	0.18	0.19	0.18	0.18	0.17
P_2O_5	2.02	1.51	1.63	1.59	1.76	1.76	1.86	1.85	1.89	1.87	1.92	1.93	1.96	1.97	1.98	2.00
PbO	0.09	0.26	0.24	0.22	0.19	0.18	0.17	0.15	0.16	0.15	0.14	0.13	0.13	0.13	0.13	0.11
SiO_2	34.56	32.99	33.33	33.13	33.65	33.69	33.76	33.76	33.61	33.77	34.18	34.02	34.17	33.93	34.10	34.34
SO_3	0.22	0.11	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.14	0.16	0.16	0.15	0.16	0.17	0.18
TiO_2	0.17	0.09	0.11	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.16	0.16	0.17	0.16	0.17	0.17
ZnO	0.18	0.11	0.13	0.12	0.14	0.14	0.14	0.15	0.16	0.15	0.16	0.15	0.16	0.16	0.17	0.16
ZrO_2	0.12	0.35	0.35	0.31	0.28	0.27	0.25	0.24	0.24	0.24	0.23	0.21	0.22	0.21	0.22	0.19
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.10. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Aluminum-Plus-Sodium-Limited Composition (wt%) (continued).

Test		7B					8A								8B	
Glass (kg)		373.78	399.02	425.68	449.24	476.64	495.94	513.12	529.70	544.28	574.40	592.74	609.16	630.44	646.08	657.86
Constituent	Target	BLN-G-52C	BLN-G-55B	BLN-G-60A	BLN-G-62B	BLN-G-66A	BLN-G-81B	BLN-G-82B	BLN-G-83A	BLN-G-85A	BLN-G-88A	BLN-G-94A	BLN-G-101B	BLN-G-106B	BLN-G-119A	BLN-G-122A
Al_2O_3	21.34	21.20	21.02	20.94	21.29	20.92	20.84	20.92	20.88	20.81	20.76	21.05	20.61	20.81	20.69	20.74
B_2O_3*	18.37	17.97	18.02	18.07	18.11	18.14	18.17	18.18	18.20	18.21	18.24	18.25	18.26	18.27	18.28	18.28
BaO	0.03	0.06	0.06	0.07	0.05	0.06	0.07	0.06	0.07	0.07	0.04	0.07	0.06	0.07	0.06	0.05
Bi_2O_3	1.16	1.17	1.23	1.18	1.05	1.18	1.17	1.15	1.17	1.19	1.18	1.15	1.22	1.20	1.18	1.19
CaO	0.72	1.30	1.27	1.22	1.10	1.14	1.35	1.32	1.33	1.32	1.30	1.19	1.20	1.16	1.12	1.12
CdO	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr_2O_3	0.71	0.79	0.83	0.79	0.74	0.79	0.78	0.77	0.79	0.79	0.80	0.76	0.80	0.77	0.79	0.79
F	0.23	0.21	0.21	0.21	0.21#	0.20	0.19	0.18#	0.18	0.19	0.20	0.20#	0.21	0.22	0.22	0.23#
Fe_2O_3	2.82	3.27	3.30	3.14	2.92	3.14	3.38	3.30	3.38	3.38	3.37	3.16	3.33	3.20	3.14	3.16
K_2O	0.66	0.68	0.69	0.68	0.64	0.66	0.69	0.67	0.69	0.69	0.71	0.68	0.73	0.69	0.69	0.68
Li_2O*	3.58	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.58	3.58	3.58	3.58
MgO	0.22	0.31	0.27	0.32	0.29	0.28	0.30	0.28	0.29	0.27	0.33	0.30	0.31	0.26	0.28	0.31
MnO	§	0.03	0.04	0.03	0.03	0.03	0.07	0.06	0.07	0.07	0.06	0.05	0.05	0.05	0.05	0.05
Na_2O	12.71	12.07	12.31	12.40	12.52	12.79	11.94	12.47	12.27	12.19	12.16	12.42	12.24	12.74	12.64	12.71
Nd_2O_3	§	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NiO	0.10	0.17	0.18	0.17	0.15	0.16	0.21	0.21	0.21	0.21	0.20	0.18	0.19	0.17	0.16	0.17
P_2O_5	2.02	2.02	2.05	2.08	2.03	2.05	1.98	1.96	1.98	1.98	2.00	1.99	2.02	2.03	2.00	2.00
PbO	0.09	0.11	0.11	0.11	0.09	0.11	0.12	0.11	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.11
SiO_2	34.56	34.38	34.12	34.35	34.54	34.07	34.43	34.08	34.09	34.22	34.24	34.13	34.35	33.95	34.28	34.11
SO_3	0.22	0.16	0.17	0.16	0.15	0.17	0.18	0.18	0.18	0.18	0.18	0.19	0.18	0.17	0.17	0.17
TiO_2	0.17	0.17	0.18	0.16	0.17	0.16	0.17	0.17	0.16	0.16	0.17	0.17	0.17	0.16	0.17	0.17
ZnO	0.18	0.16	0.17	0.17	0.15	0.17	0.17	0.16	0.16	0.17	0.17	0.16	0.17	0.16	0.17	0.17
ZrO_2	0.12	0.19	0.20	0.19	0.16	0.19	0.21	0.20	0.20	0.20	0.19	0.20	0.20	0.20	0.20	0.20
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.10. XRF-Analyzed Compositions of Discharged Glass Samples from the DM100 Tests with the Aluminum-Plus-Sodium-Limited Composition (wt%) (continued).

Test		**8B**	**8C**													Steady State	
Glass (kg)		677.66	700.28	714.28	733.94	752.46	777.58	799.20	819.34	836.18	853.70	871.98	885.44	910.26	933.52	544-934	
Constituent	Target	BLN-G-129A	BLN-G-147B	BLN-G-150A	BLN-G-152A	BLN-G-153B	BLN-G-154B	BLN-G-155A	BLO-G-5B	BLO-G-10A	BLO-G-15A	BLO-G-16B	BLO-G-18B	BLO-G-22B	BLO-G-24A	Avg.	%Dev.
Al_2O_3	21.34	20.74	20.53	20.62	20.59	20.50	20.54	20.73	20.72	20.74	20.81	20.86	20.94	21.06	20.98	20.75	-2.74
B_2O_3*	18.37	18.29	18.30	18.31	18.31	18.32	18.32	18.33	18.33	18.34	18.34	18.34	18.34	18.35	18.35	18.30	NC
BaO	0.03	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.08	0.07	0.05	0.06	0.06	0.06	0.06	0.06	NC
Bi_2O_3	1.16	1.17	1.22	1.23	1.17	1.22	1.22	1.18	1.21	1.22	1.22	1.19	1.18	1.19	1.20	1.20	3.47
CaO	0.72	1.10	1.17	1.18	1.11	1.17	1.11	1.06	1.08	1.08	1.07	1.04	1.04	1.03	1.03	1.13	NC
CdO	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Cr_2O_3	0.71	0.78	0.70	0.75	0.74	0.75	0.78	0.77	0.78	0.79	0.79	0.78	0.79	0.77	0.78	0.77	NC
F	0.23	0.18	0.13	0.10#	0.11	0.13	0.14	0.16	0.17#	0.17	0.17	0.17	0.17	0.17#	0.17	0.17	NC
Fe_2O_3	2.82	3.12	3.35	3.43	3.22	3.36	3.30	3.18	3.23	3.23	3.26	3.17	3.15	3.14	3.15	3.24	14.97
K_2O	0.66	0.70	0.69	0.68	0.67	0.70	0.69	0.67	0.69	0.69	0.68	0.67	0.68	0.69	0.68	0.69	NC
Li_2O*	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	NC
MgO	0.22	0.26	0.28	0.31	0.26	0.26	0.27	0.28	0.21	0.24	0.25	0.22	0.20	0.25	0.22	0.26	NC
MnO	§	0.05	0.10	0.10	0.08	0.09	0.07	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.06	NC
Na_2O	12.71	12.82	12.78	12.27	13.27	12.39	12.49	13.03	12.42	12.40	12.57	12.70	12.59	12.35	12.48	12.56	-1.20
Nd_2O_3	§	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NC
NiO	0.10	0.16	0.21	0.21	0.19	0.21	0.19	0.18	0.18	0.17	0.17	0.17	0.16	0.15	0.15	0.18	NC
P_2O_5	2.02	1.99	2.05	2.08	2.01	2.04	2.07	2.00	2.07	2.08	2.03	2.05	2.06	2.05	2.09	2.03	0.55
PbO	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.11	0.10	0.10	0.10	0.10	0.11	NC
SiO_2	34.56	34.17	33.98	34.24	33.75	34.32	34.28	33.89	34.32	34.27	34.07	34.11	34.15	34.26	34.17	34.16	-1.18
SO_3	0.22	0.16	0.14	0.15	0.18	0.16	0.16	0.15	0.16	0.17	0.15	0.15	0.16	0.17	0.17	0.17	NC
TiO_2	0.17	0.16	0.16	0.17	0.16	0.17	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17	NC
ZnO	0.18	0.17	0.17	0.18	0.18	0.19	0.19	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.18	NC
ZrO_2	0.12	0.20	0.24	0.24	0.24	0.26	0.24	0.23	0.23	0.24	0.24	0.23	0.23	0.22	0.22	0.22	NC
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

§ - Not a target constituent
* - Target values calculated using simple well-stirred tank model
# - Fluorine was measured by XRF on polished samples, values for other samples calculated by interpolation

Table 6.11. XRF and DCP Analysis of Selected Glass Samples (wt%).

Limiting Element	**Bi**										
Constituent	Target	BLL-G-11B		BLL-G-27B		BLL-G-35A		BLL-G-40A		BLL-G-46B	
		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al_2O_3	11.66	11.63	10.69	11.69	10.86	11.63	11.08	11.68	11.15	11.48	10.64
B_2O_3	11.30	11.26*	11.69	11.27*	11.70	11.28*	11.91	11.28*	11.86	11.29*	11.18
BaO	0.01	0.03	0.03	0.03	0.03	0.02	<0.01	0.02	0.02	0.03	0.02
Bi_2O_3	6.71	6.20	6.17	6.15	6.12	6.31	6.09	6.25	6.16	6.67	5.72
CaO	0.84	0.84	0.91	0.85	0.92	0.87	0.94	0.86	0.93	0.87	0.93
CdO	§	<0.01	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01	NA
Cl	§	0.05	NA	0.04	NA	0.04	NA	0.04	NA	0.05	NA
Cr_2O_3	0.52	0.46	0.17	0.47	0.15	0.46	0.15	0.46	0.17	0.51	0.20
F	0.82	0.42$	NA	0.45$	NA	0.46$	NA	0.47$	NA	0.49#	NA
Fe_2O_3	6.96	7.04	6.75	6.86	6.75	7.05	6.69	6.90	6.79	7.38	6.38
K_2O	0.46	0.51	0.55	0.52	0.55	0.52	0.56	0.52	0.56	0.54	0.55
Li_2O	0.16	0.24*	0.33	0.22*	0.33	0.21*	0.30	0.20*	0.29	0.18*	0.32
MgO	0.43	0.45	0.48	0.46	0.48	0.46	0.49	0.44	0.48	0.50	0.48
MnO	§	0.17	0.18	0.15	0.18	0.15	0.16	0.14	0.15	0.15	0.16
Na_2O	15.74	16.21	14.47	16.38	14.47	15.21	14.91	15.88	14.67	15.23	14.12
Nd_2O_3	§	0.05	NA	0.05	NA	0.05	NA	0.06	NA	0.05	NA
NiO	1.93	1.54	1.29	1.51	1.29	1.54	1.26	1.55	1.34	1.67	1.39
P_2O_5	4.99	5.04	4.81	5.14	4.81	5.19	4.92	5.12	4.9	5.06	4.73
PbO	0.25	0.29	0.34	0.29	0.34	0.29	0.34	0.28	0.32	0.30	0.33
SiO_2	36.26	36.32	35.11	36.27	35.11	37.04	36.36	36.65	35.99	36.27	36.43
SO_3	0.48	0.45	NA	0.44	NA	0.44	NA	0.41	NA	0.43	NA
SrO	§	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.03
TiO_2	0.16	0.18	0.19	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19
ZnO	0.16	0.20	0.19	0.18	0.19	0.19	0.19	0.18	0.18	0.20	0.19
ZrO_2	0.21	0.39	0.47	0.38	0.47	0.39	0.47	0.38	0.46	0.42	0.43
Sum	100.00	100.00	94.85	100.00	94.97	100.00	97.04	100.00	96.64	100.00	94.42

§ - Not a target constituent;
NA - Not analyzed
* - for XRF-analyzed compositions, values for B_2O_3 and Li_2O were calculated based on simple well-stirred tank model and target values.
# - Fluorine measured by XRF on polished samples
$ - Fluorine values calculated by interpolation

Table 6.11. XRF and DCP Analysis of Selected Glass Samples (wt%) (continued).

Limiting Element	Cr									Al		
Constituent	Target	BLL-G-88A		BLL-G-107A		BLL-G-111B		BLL-G-121A		Target	BLM-G-36A	
		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP		XRF	DCP
Al_2O_3	8.98	9.43	8.38	9.36	8.22	9.72	8.33	9.37	8.06	23.97	20.95	19.94
B_2O_3	16.17	14.95*	15.51	15.73*	15.92	15.84*	16.15	15.93*	16.43	15.19	15.33*	15.74
BaO	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.05	0.32	0.28
Bi_2O_3	2.56	3.36	2.91	2.93	2.55	2.69	2.72	2.88	2.71	1.14	1.41	1.31
CaO	0.87	0.84	0.94	0.84	0.93	0.80	0.94	0.81	0.94	6.08	5.25	4.69
CdO	§	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	0.02	<0.01	0.02
Cl	§	<0.01	NA	<0.01	NA	<0.01	NA	<0.01	NA	§	<0.01	NA
Cr_2O_3	1.08	1.16	0.61	1.19	0.51	1.14	0.58	1.19	0.56	0.52	0.56	0.21
F	0.70	0.43$	NA	0.46#	NA	0.48$	NA	0.51#	NA	0.67	0.41#	NA
Fe_2O_3	4.62	5.43	5.41	5.13	5.11	4.77	5.19	5.06	5.01	5.90	5.97	5.25
K2O	6.05	4.94	4.20	5.41	4.54	5.36	4.71	5.51	4.69	0.14	0.96	1.03
Li_2O	3.68	2.80*	3.09	3.37*	3.33	3.44*	3.43	3.51*	3.47	3.57	3.56*	3.53
MgO	0.06	0.28	0.31	0.25	0.29	0.25	0.29	0.23	0.29	0.12	0.35	0.42
MnO	§	0.05	0.05	0.04	0.04	0.03	0.05	0.04	0.04	§	0.05	0.05
Na_2O	7.07	8.90	7.63	7.75	6.95	7.44	6.85	7.62	6.82	9.58	9.64	8.70
Nd_2O_3	§	0.01	NA	0.01	NA	0.01	NA	0.01	NA	§	<0.01	NA
NiO	0.37	0.74	0.72	0.58	0.57	0.50	0.53	0.54	0.52	0.40	0.37	0.27
P_2O_5	1.18	1.91	1.87	1.57	1.52	1.51	1.46	1.46	1.46	1.05	1.17	1.01
PbO	0.17	0.19	0.20	0.17	0.19	0.15	0.19	0.16	0.19	0.41	0.35	0.38
SiO_2	45.76	43.93	42.59	44.58	44.200	45.22	45.51	44.51	44.83	30.50	32.62	32.75
SO_3	0.53	0.37	NA	0.40	NA	0.41	NA	0.41	NA	0.20	0.15	NA
SrO	§	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	§	<0.01	<0.01
TiO_2	§	0.05	0.05	0.04	0.04	0.05	0.04	0.04	0.03	0.01	0.03	0.04
ZnO	0.09	0.12	0.11	0.10	0.10	0.10	0.11	0.11	0.11	0.08	0.09	0.08
ZrO_2	0.04	0.12	0.13	0.08	0.10	0.07	0.10	0.08	0.09	0.39	0.44	0.49
Sum	100.00	100.00	94.74	100.00	95.14	100.00	97.21	100.00	96.28	100.00	100.00	96.19

§ - Not a target constituent;
NA - Not analyzed
* - for XRF-analyzed compositions, values for B_2O_3 and Li_2O were calculated based on simple well-stirred tank model and target values.
# - Fluorine measured by XRF on polished samples
$ - Fluorine values calculated by interpolation

Table 6.11. XRF and DCP Analysis of Selected Glass Samples (wt%) (continued).

Limiting Element	Al										
Constituent	Target	BLM-G-110A		BLM-G-131A		BLM-G-139A		BLM-G-145A		BLM-G-146B	
		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al_2O_3	23.97	22.54	20.29	22.28	21.23	22.40	21.43	22.29	21.51	22.43	21.74
B_2O_3	15.19	15.23*	15.50	15.21*	16.07	15.21*	15.97	15.20*	16.27	15.20*	16.49
BaO	0.05	0.29	0.30	0.31	0.31	0.36	0.32	0.32	0.31	0.27	0.32
Bi_2O_3	1.14	1.19	1.19	1.30	1.25	1.22	1.20	1.30	1.16	1.21	1.24
CaO	6.08	5.44	5.32	5.80	5.14	5.74	5.22	5.87	5.28	5.86	5.28
CdO	0.02	<0.01	0.03	<0.01	0.02	<0.01	0.03	<0.01	0.02	<0.01	0.02
Cr_2O_3	0.52	0.49	0.24	0.52	0.23	0.51	0.20	0.52	0.21	0.52	0.21
F	0.67	0.39#	NA	0.40#	NA	0.40#	NA	0.41$	NA	0.42$	NA
Fe_2O_3	5.90	5.58	5.62	6.13	5.37	5.94	5.31	6.16	5.36	6.00	5.38
K_2O	0.14	0.54	0.58	0.47	0.48	0.43	0.43	0.42	0.42	0.42	0.42
Li_2O	3.57	3.57*	3.63	3.57*	3.52	3.57#	3.53	3.57*	3.53	3.57*	3.52
MgO	0.12	0.43	0.44	0.38	0.45	0.36	0.44	0.43	0.44	0.38	0.44
MnO	§	0.04	0.04	0.04	0.05	0.03	0.04	0.03	0.04	0.04	0.04
Na_2O	9.58	9.29	8.64	9.29	9.03	9.69	8.98	9.80	9.02	9.83	9.08
Nd_2O_3	§	0.01	NA	0.01	NA	0.01	NA	0.01	NA	0.01	NA
NiO	0.40	0.30	0.24	0.34	0.29	0.32	0.26	0.33	0.26	0.32	0.24
P_2O_5	1.05	1.15	1.04	1.14	0.97	1.12	0.98	1.09	0.83	1.12	1.05
PbO	0.41	0.35	0.41	0.37	0.41	0.37	0.41	0.37	0.41	0.35	0.41
SiO_2	30.50	32.48	31.03	31.60	31.49	31.56	30.97	31.09	30.98	31.34	31.59
SO_3	0.20	0.15	NA	0.13	NA	0.15	NA	0.15	NA	0.15	NA
SrO	§	<0.01	NA	<0.01	NA	<0.01	0.01	<0.01	0.01	<0.01	0.01
TiO_2	0.01	0.05	0.05	0.13	0.04	0.05	0.04	0.05	0.05	0.04	0.04
ZnO	0.08	0.08	0.08	0.09	0.08	0.09	0.08	0.09	0.08	0.08	0.08
ZrO_2	0.39	0.44	0.54	0.48	0.55	0.48	0.55	0.49	0.54	0.45	0.55
Sum	100.00	100.00	95.21	100.00	96.98	100.00	96.40	100.00	96.73	100.00	98.15

§ - Not a target constituent;
NA - Not analyzed
* - for XRF-analyzed compositions, values for B_2O_3 and Li_2O were calculated based on simple well-stirred tank model and target values.
# - Fluorine measured by XRF on polished samples
$ - Fluorine values calculated by interpolation

Table 6.11. XRF and DCP Analysis of Selected Glass Samples (wt%) (continued).

Limiting Elements	**Al+Na**										
Constituent	Target	BLN-G-36A		BLN-G-66A		BLN-G-106B		BLN-G-129A		BLO-G-24A	
		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al_2O_3	21.34	21.13	19.84	20.92	20.06	20.81	20.12	20.74	19.83	20.98	19.95
B_2O_3	18.37	17.56*	17.24	18.14*	17.58	18.27*	17.68	18.29*	17.80	18.35*	17.26
BaO	0.03	0.11	0.08	0.06	0.05	0.07	0.05	0.07	0.05	0.06	0.04
Bi_2O_3	1.16	1.21	1.2	1.18	1.18	1.20	1.18	1.17	1.16	1.20	1.22
CaO	0.72	1.70	1.71	1.14	1.22	1.16	1.24	1.10	1.16	1.03	1.10
CdO	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01
Cr_2O_3	0.71	0.78	0.39	0.79	0.47	0.77	0.43	0.78	0.45	0.78	0.45
F	0.23	0.21$	NA	0.20$	NA	0.22$	NA	0.18$	NA	0.17$	NA
Fe_2O_3	2.82	3.52	3.01	3.14	3.05	3.20	2.96	3.12	2.82	3.15	2.84
K_2O	0.66	0.66	0.69	0.66	0.72	0.69	0.75	0.70	0.77	0.68	0.76
Li_2O	3.58	3.57*	3.58	3.57*	3.61	3.58*	3.62	3.58*	3.64	3.58*	3.47
MgO	0.22	0.32	0.34	0.28	0.32	0.26	0.30	0.26	0.30	0.22	0.27
MnO	§	0.03	0.04	0.03	0.04	0.05	0.05	0.05	0.05	0.04	0.05
Na2O	12.71	12.05	11.19	12.79	11.65	12.74	11.63	12.82	11.67	12.48	11.66
Nd_2O_3	§	0.01	NA	0.01	NA	0.01	NA	0.01	NA	0.01	NA
NiO	0.10	0.19	0.16	0.16	0.15	0.17	0.15	0.16	0.14	0.15	0.13
P_2O_5	2.02	1.92	1.72	2.05	1.71	2.03	1.85	1.99	1.87	2.09	2.02
PbO	0.09	0.14	0.15	0.11	0.12	0.11	0.12	0.10	0.12	0.10	0.11
SiO_2	34.56	34.18	33.92	34.07	33.74	33.95	33.90	34.17	33.41	34.17	34.6
SO_3	0.22	0.16	NA	0.17	NA	0.17	NA	0.16	NA	0.17	NA
TiO_2	0.17	0.16	0.17	0.16	0.18	0.16	0.18	0.16	0.18	0.18	0.20
ZnO	0.18	0.16	0.14	0.17	0.16	0.16	0.14	0.17	0.14	0.19	0.19
ZrO_2	0.12	0.23	0.22	0.19	0.17	0.20	0.18	0.20	0.18	0.22	0.25
Sum	100.00	100.00	95.80	100.00	96.19	100.00	96.54	100.00	95.75	100.00	96.58

§ - Not a target constituent;
NA - Not analyzed
* - for XRF-analyzed compositions, values for B_2O_3 and Li_2O were calculated based on simple well-stirred tank model and target values.
# - Fluorine measured by XRF on polished samples
$ - Fluorine values calculated by interpolation

Table 6.12. PCT Results for Melter Glasses.

Limiting Element		Chromium		Bismuth		Aluminum		Aluminum + Sodium			DWPF-EA
Glass Samples		BLK-G-129A	BLL-G-46B	BLL-G-88A	BLL-G-121A	BLM-G-36A	BLM-G-110A	BLN-G-66A	BLN-G-106B	BLN-G-129A	
7-Day PCT Concentration in mg/L	B	9.71	8.04	183.10	164.80	1.57	10.72	88.32	83.69	90.61	-
	Li	0.91	0.74	43.40	40.46	5.99	5.84	21.76	21.27	22.57	-
	Na	56.27	53.82	135.00	118.50	16.95	17.22	74.54	72.21	75.49	-
	Si	39.92	35.32	50.25	49.03	21.76	16.22	44.21	46.26	47.03	3920
7-Day PCT Normalized Concentrations, g/L	B	0.28	0.23	3.71	3.33	0.03	0.23	1.57	1.48	1.60	16.7
	Li	0.57	0.87	2.69	2.48	0.36	0.35	1.31	1.28	1.36	9.6
	Na	0.47	0.48	2.37	2.10	0.24	0.25	0.78	0.76	0.79	13.3
	Si	0.23	0.21	0.24	0.24	0.14	0.11	0.28	0.29	0.29	-
	pH	9.70	9.65	9.72	9.71	9.53	9.75	9.53	9.53	9.54	-
7-Day PCT Normalized Mass Loss (g/m^2)	B	0.14	0.11	1.86	1.67	0.02	0.11	0.78	0.74	0.80	-
	Li	0.29	0.43	1.35	1.24	0.18	0.18	0.66	0.64	0.68	-
	Na	0.24	0.24	1.18	1.05	0.12	0.12	0.39	0.38	0.40	-
	Si	0.11	0.10	0.12	0.12	0.07	0.05	0.14	0.15	0.15	-
7-Day PCT Normalized Loss Rate, $g/d/m^2$	B	0.02	0.02	0.27	0.24	<0.01	0.02	0.11	0.11	0.11	-
	Li	0.04	0.06	0.19	0.18	0.03	0.03	0.09	0.09	0.10	-
	Na	0.03	0.03	0.17	0.15	0.02	0.02	0.06	0.05	0.06	-
	Si	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	-

- Empty data field

Table 6.13. TCLP Results for Melter Glasses (mg/L).

Limiting Element	Sample I.D.	Ba	Bi	Cd	Cr	Ni	Pb	Zn
	UTS Limits	21	N/A	0.11	0.60	11.00	0.75	4.3
	Delisting Limits	100	N/A	0.48	4.95	22.6	5.00	225
Bi	BLK-G-129A	0.22	0.56	NA	<0.01	0.41	<0.1	0.13
	BLK-G-46B	0.13	0.72	NA	<0.01	0.68	<0.1	0.10
Cr	BLL-G-88A	0.09	0.51	NA	0.05	0.12	<0.1	0.05
	BLL-G-113A	0.14	0.58	NA	0.06	0.10	<0.1	0.08
	BLL-G-121A	0.13	0.53	NA	0.07	0.10	<0.1	0.09
Al	BLM-G-36A	0.35	1.00	0.04	0.05	0.10	0.35	0.10
	BLM-G-110A	0.42	0.74	0.04	0.06	0.13	0.46	0.09
Al + Na	BLN-G-66A	0.11	0.47	<0.03	0.11	0.07	0.11	0.09
	BLN-G-106B	0.11	0.46	<0.03	0.11	0.07	0.11	0.08
	BLN-G-129A	0.11	0.62	<0.03	0.11	0.06	0.13	0.07

N/A – Not available
NA – Not analyzed, Cd is a target constituent only in aluminum- and aluminum-plus-sodium-limited formulations.

Table 6.14. Glass Pool Samples and Secondary Phase Observations.

Test		T (°C)	Date	Sample I.D.	Visual Observations During Sampling	SEM Observations	Volume Percent Crystals Determined by SEM
Bi	End of Test 1A	1175	7/19/06	BLK-D-100A	No secondary phases	Fe-Cr-Ni Spinel	0.3
	End of Test 1B		7/20/06	BLK-D-125A	No secondary phases	Fe-Cr-Ni Spinel, some with Cr oxide cores	0.3
				BLK-D-129A	No secondary phases	NA	NA
	End of Test 2A	1150	7/26/06	BLL-D-16A	No secondary phases	Fe-Cr-Ni Spinel	0.5
	End of Test 2B		7/28/06	BLL-D-45A	No secondary phases	NA	NA
				BLL-D-46A	No secondary phases	Fe-Cr-Ni Spinel, some with Cr oxide cores	0.4
Cr	End of Test 3B	1175	8/23/06	BLL-D-88A	No secondary phases	Finely grained chromium oxide aggregate	0.3
				BLL-D-88B	No secondary phases	NA	NA
				BLL-D-88C	No secondary phases	NA	NA
				BLL-D-88D	No secondary phases	NA	NA
	End of Test 4A	1150	8/25/06	BLL-D-113A	No secondary phases	Finely grained chromium oxide aggregate	0.3
				BLL-D-113B	No secondary phases	NA	NA
				BLL-D-113C	No secondary phases	NA	NA
				BLL-D-113D	No secondary phases	NA	NA
Al	End of Test 5A	1175	9/13/06	BLM-D-9A	No secondary phases	Fe-Ni-Cr spinel with trace of Zn, Mg, Al	0.9
	End of Test 5B		9/15/06	BLM-D-37A	No secondary phases	Fe-Ni-Cr spinel with trace of Al, Mg, Zn	0.7
	End of Test 6A	1150	9/20/06	BLM-D-73A	No secondary phases	Fe-Ni-Cr-Al spinel with trace of Mg, Zn	0.4
	End of Test 6B		9/23/06	BLM-D-110A	No secondary phases	Fe-Ni-Cr-Al spinel with trace of Mg, Zn	0.6
	End of Test 6C		9/28/06	BLM-D-146A	No secondary phases	Fe-Ni-Cr-Al spinel with trace of Mg	0.6
Al+Na	End of Test 7A	1175	10/04/06	BLN-D-40A	No secondary phases	Fe-Al-Cr spinel with trace of Ni Zn, Mg; Fe-Cr-Ni spinel with trace of Zn	1.1
	End of Test 7B		10/06/06	BLN-D-66A	No secondary phases	Fe-Al-Cr spinel with trace of Zn, Mg; Cr oxide platelets with Fe and Al	0.2
	End of Test 8A	1150	10/18/06	BLN-D-107B	No secondary phases	Fe-Cr spinel with trace of Ni, Zn, Al, Mg	0.2
	End of Test 8B		10/21/06	BLN-D-129A	No secondary phases	Fe-Cr spinel with trace of Zn, Ni, Al, Mg	0.2
	End of Test 8C		11/20/06	BLO-D-24A	No secondary phases	Fe-Cr spinel with trace of Mg	0.2

NA – Not Analyzed

Table 7.1. Results from Melter Off-Gas Emission Samples.

		Test 1A				Test 1B			
		07/19/06 11:26 – 12:26 98.6% Isokinetic, 9.8% Moisture				07/21/06 14:25 – 15:25 90.47% Isokinetic, 12.3 % Moisture			
		Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF	Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF
Particulate	Total[$]	97710	183	0.19	535	81420	392	0.48	208
	Al	5603	0.66	0.01	8479	4669	3.66	0.08	1277
	B	3185	0.57	0.02	5598	2655	18.50	0.70	144
	Ba	8	< 0.10	< 1.3	> 80	7	< 0.10	< 1.43	> 70
	Bi	5467	4.49	0.08	1219	4556	24.70	0.54	185
	Ca	545	0.13	0.02	4357	454	0.49	0.11	922
	Cd	0	< 0.10	NC	NC	0	< 0.10	NC	NC
	Cl*	0	1.59	NC	NC	0	8.52	NC	NC
	Cr	323	1.31	0.40	248	269	3.43	1.27	78.5
	F*	745	3.85	0.52	194	621	30.2	4.86	20.6
	Fe	4421	1.31	0.03	3374	3684	9.47	0.26	389
	K	347	3.43	0.99	101	289	6.83	2.36	42.3
	Li	68	0.79	1.16	86.0	56	0.66	1.17	85.1
	Mg	236	< 0.10	< 0.10	> 2360	196	0.52	0.27	376
	Na	10608	41.32	0.39	257	8840	75.21	0.85	118
	Ni	1378	0.34	0.02	4103	1148	2.71	0.24	424
	P	1979	0.56	0.03	3507	1649	5.40	0.33	305
	Pb	211	1.00	0.47	211	176	1.54	0.88	114
	S*	175	34.2	19.54	5.1	146	27.8	19.0	5.25
	Si	15397	1.25	0.01	12287	12830	11.06	0.09	1160
	Ti	87	< 0.10	< 0.11	> 870	73	0.35	0.48	207
	Zn	117	< 0.10	< 0.10	> 1170	97	0.28	0.29	342
	Zr	141	< 0.10	< 0.10	> 1410	118	0.19	0.16	612
Gaseous	B	3185	16.64	0.52	192	2655	46.29	1.74	57.3
	Cl	0	24.46	NC	NC	0	20.17	NC	NC
	F	745	125.82	16.89	5.9	621	156.36	25.19	4.0
	S	175	39.07	22.36	4.5	146	49.89	34.26	2.9

[$] - From gravimetric analysis of filters and particulate nitric acid rinses.
* Based on analysis of front-half rinse and water dissolution of filter particulate.
[#] - Feed rate calculated from target composition and production rate.
NC – Not Calculated

Table 7.1. Results from Melter Off-Gas Emission Samples (continued).

		Test 2A 07/25/06 19:42 – 20:45 97.8% Isokinetic, 8.3% Moisture				Test 2B 07/28/06 9:45 – 10:45 102% Isokinetic, 12.1 % Moisture			
		Feed Rate# (mg/min)	Emissions Rate (mg/min)	% Feed	DF	Feed Rate# (mg/min)	Emissions Rate (mg/min)	% Feed	DF
Particulate	Total$	67580	215	0.32	314	37640	118	0.31	319
	Al	3875	2.53	0.07	1534	2381	0.72	0.03	3295
	B	2203	7.95	0.36	277.3	1354	3.41	0.25	398
	Ba	6	< 0.10	< 1.67	> 60	3	< 0.10	< 3.33	> 30
	Bi	3781	10.81	0.29	349.8	2324	5.26	0.23	442
	Ca	377	0.29	0.08	1319	232	0.18	0.08	1303
	Cd	0	< 0.10	NC	NC	0	< 0.10	NC	NC
	Cl*	0	3.61	NC	NC	0	1.97	NC	NC
	Cr	224	1.40	0.63	160	137	0.94	0.69	145
	F*	515	10.56	2.05	48.77	317	12.4	3.91	25.6
	Fe	3058	5.30	0.17	577	1879	2.14	0.11	878
	K	240	3.21	1.34	74.8	147	2.33	1.58	63.4
	Li	47	0.31	0.66	152	29	0.16	0.54	185
	Mg	163	0.28	0.17	584	100	0.12	0.12	835
	Na	7337	39.90	0.54	184	4508	24.43	0.54	185
	Ni	953	1.55	0.16	616	585	0.59	0.10	988
	P	1369	1.67	0.12	819	841	0.74	0.09	1139
	Pb	146	0.70	0.48	209	90	0.56	0.62	161
	S*	121	22.06	18.23	5.5	74	14.4	19.5	5.1
	Si	10649	6.57	0.06	1622	6544	2.71	0.04	2417
	Ti	60	0.11	0.17	572	37	< 0.10	< 0.27	> 370
	Zn	81	0.11	0.14	710	50	< 0.10	< 0.20	> 500
	Zr	98	< 0.10	< 0.10	> 980	60	< 0.10	< 0.17	> 600
Gaseous	B	2203	25.74	1.17	85.6	1354	25.63	1.89	52.8
	Cl	0	13.81	NC	NC	0	17.30	NC	NC
	F	515	132.71	25.76	3.9	317	148.60	46.94	2.1
	S	121	24.36	20.16	5.0	74	25.41	34.21	2.9

$ - From gravimetric analysis of filters and particulate nitric acid rinses.
* Based on analysis of front-half rinse and water dissolution of filter particulate.
# - Feed rate calculated from target composition and production rate.
NC – Not Calculated

Table 7.1. Results from Melter Off-Gas Emission Samples (continued).

		Test 3B				Test 4A			
		08/23/06 13:42 – 14:42 108.5% Isokinetic, 12.2% Moisture				08/25/06 14:20 – 15:20 103.0% Isokinetic, 11.3 % Moisture			
		Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF	Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF
Particulate	Total[$]	108660	441	0.41	246	96120	264	0.27	364
	Al	5758	2.13	0.04	2701	5093	0.96	0.02	5317
	B	4410	27.24	0.62	162	3901	17.10	0.44	228
	Ba	9	0.16	1.81	55.3	8	< 0.10	< 1.25	> 80
	Bi	2789	11.17	0.40	250	2467	5.80	0.24	425
	Ca	753	1.23	0.16	610	666	0.56	0.08	1186
	Cd	0	< 0.10	NC	NC	0	< 0.10	NC	NC
	Cl	0	1.83	NC	NC	0	1.11	NC	NC
	Cr	895	9.00	1.00	99.5	792	7.40	0.93	107
	F	856	79.27	9.26	10.8	757	50.48	6.67	15.0
	Fe	3915	7.41	0.19	528	3463	4.00	0.12	865
	K	4428	48.42	1.09	91.4	3917	35.62	0.91	110
	Li	1513	5.59	0.37	271	1338	4.32	0.32	310
	Mg	42	0.37	0.90	112	37	0.20	0.55	181
	Na	6352	31.96	0.50	199	5619	18.73	0.33	300
	Ni	356	0.52	0.15	689	315	0.31	0.10	103
	P	623	0.85	0.14	736	551	0.42	0.08	1306
	Pb	192	0.88	0.46	217	170	0.51	0.30	333
	S	260	30.3	11.65	8.58	230	20.78	9.03	11.1
	Si	19292	11.31	0.06	1705	17066	4.67	0.03	3657
	Ti	0	< 0.10	NC	NC	0	< 0.10	NC	NC
	Zn	87	0.18	0.20	489	77	< 0.10	< 0.13	> 770
	Zr	36	< 0.10	< 0.28	> 360	32	< 0.10	< 0.31	> 320
Gaseous	B	4410	59.71	1.35	73.9	3901	44.87	1.15	86.9
	Cl	0	7.96	NC	NC	0	6.91	NC	NC
	F	856	141.62	16.54	6.0	757	140.66	18.57	5.4
	S	260	69.18	26.58	3.8	230	56.32	24.46	4.1

[$] - From gravimetric analysis of filters and particulate nitric acid rinses.
* Based on analysis of front-half rinse and water dissolution of filter particulate.
[#] - Feed rate calculated from target composition and production rate.
NC – Not Calculated

Table 7.1. Results from Melter Off-Gas Emission Samples (continued).

		Test 5A 09/13/06 10:04 – 11:04 100.8% Isokinetic, 10.2% Moisture				Test 5B 09/15/06 13:58 – 14:58 98.4% Isokinetic, 6.3 % Moisture			
		Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF	Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF
Particulate	Total[$]	82980	105	0.13	787	45640	41.0	0.09	1112
Particulate	Al	9599	2.18	0.02	4394	5279	0.64	0.01	8239
Particulate	B	3568	4.31	0.12	827	1963	0.94	0.05	2084
Particulate	Ba	34	0.24	0.70	142	19	0.13	0.71	141
Particulate	Bi	774	1.30	0.17	597	426	0.58	0.14	731
Particulate	Ca	3290	1.45	0.04	2266	1809	0.60	0.03	3017
Particulate	Cd	14	< 0.10	< 0.71	> 140	7	< 0.10	< 1.43	> 70
Particulate	Cl	0	0.40*	NC	NC	0	< 0.10[&]	NC	NC
Particulate	Cr	269	2.50	0.93	108	148	1.01	0.68	147
Particulate	F	507	10.69*	2.11	47.4	279	5.09[&]	1.82	54.8
Particulate	Fe	3123	3.12	0.10	1000	1718	1.13	0.07	1515
Particulate	K	88	5.44	6.18	16.2	48	1.49	3.08	32.5
Particulate	Li	1255	2.46	0.20	511	690	0.98	0.14	701
Particulate	Mg	55	0.16	0.29	341	30	< 0.10	< 0.33	> 300
Particulate	Na	5380	12.85	0.24	419	2959	5.99	0.20	494
Particulate	Ni	238	< 0.10	< 0.04	> 2380	131	< 0.10	< 0.08	> 1310
Particulate	P	347	< 0.10	< 0.03	> 3470	191	< 0.10	< 0.05	> 1910
Particulate	Pb	288	0.74	0.26	390	158	0.36	0.23	439
Particulate	S	61	9.96*	16.33	6.12	33	1.89[&]	< 5.73	> 17.5
Particulate	Si	10792	3.55	0.03	3042	5936	1.88	0.03	3151
Particulate	Ti	5	< 0.10	< 2.00	> 50	2	< 0.10	< 5.00	> 20
Particulate	Zn	49	< 0.10	< 0.82	> 123	27	< 0.10	< 0.37	> 270
Particulate	Zr	219	< 0.10	< 0.05	> 2190	120	< 0.10	< 0.08	> 1200
Gaseous	B	3568	36.54	1.02	97.7	1963	15.34	0.78	128
Gaseous	Cl	0	5.89	NC	NC	0	3.54	NC	NC
Gaseous	F	507	139.59	27.52	3.6	279	96.88	34.73	2.9
Gaseous	S	61	28.42	46.84	2.1	33	17.13	51.34	1.9

[$] - From gravimetric analysis of filters and particulate nitric acid rinses.
* Based on analysis of front-half rinse and water dissolution of filter particulate.
[&] Based on direct analysis of front-half rinse.
[#] - Feed rate calculated from target composition and production rate.
NC – Not Calculated

Table 7.1. Results from Melter Off-Gas Emission Samples (continued).

		Test 6A 09/20/06 08:59 – 09:59 97.1% Isokinetic, 6.4% Moisture				Test 6B 09/22/06 11:55 – 12:55 99.1% Isokinetic, 8.3% Moisture			
		Feed Rate# (mg/min)	Emissions Rate (mg/min)	% Feed	DF	Feed Rate# (mg/min)	Emissions Rate (mg/min)	% Feed	DF
Particulate	Total$	45640	259	0.57	176	32270	46.5	0.14	694
	Al	5279	5.56	0.11	950	3839	0.67	0.02	5757
	B	1963	16.34	0.83	120	1427	1.87	0.13	762
	Ba	19	1.05	5.63	17.8	14	0.13	0.99	101
	Bi	426	3.72	0.87	114	310	0.58	0.19	538
	Ca	1809	7.23	0.40	250	1316	0.73	0.06	1813
	Cd	7	0.11	1.45	69.1	5	< 0.10	< 2.00	> 50
	Cl	0	0.41*	NC	NC	0	< 0.10&	NC	NC
	Cr	148	1.93	1.30	76.9	108	0.86	0.80	125
	F	279	15.23*	5.46	18.3	203	5.71&	2.81	35.6
	Fe	1718	14.32	0.83	120	1249	1.43	0.11	872
	K	48	2.76	5.71	17.5	35	0.95	2.69	37.1
	Li	690	4.95	0.72	140	502	1.35	0.27	372
	Mg	30	0.82	2.74	36.6	22	< 0.10	< 0.45	> 220
	Na	2959	26.74	0.90	111	2152	7.08	0.33	304
	Ni	131	0.92	0.70	142	95	< 0.10	< 0.11	> 950
	P	191	0.78	0.41	246	139	< 0.10	< 0.07	> 1390
	Pb	158	1.66	1.05	95.6	115	0.41	0.35	282
	S	33	2.05*	6.21	16.1	24	1.52&	6.33	15.8
	Si	5936	16.65	0.28	357	4317	1.39	0.03	3110
	Ti	2	< 0.10	< 5.00	> 20	2	< 0.10	< 5.00	> 20
	Zn	27	0.25	0.94	107	19	0.10	0.54	186
	Zr	120	0.64	0.54	187	87	< 0.10	< 0.11	> 870
Gaseous	B	1963	22.39	1.14	87.6	1427	21.16	1.48	67.5
	Cl	0	3.14	NC	NC	0	2.79	NC	NC
	F	279	82.79	29.68	3.4	203	81.42	40.14	2.5
	S	33	11.78	35.31	2.8	24	14.80	61.00	1.6

$ - From gravimetric analysis of filters and particulate nitric acid rinses.
* Based on analysis of front-half rinse and water dissolution of filter particulate.
& Based on direct analysis of front-half rinse.
# - Feed rate calculated from target composition and production rate.
NC – Not Calculated

Table 7.1. Results from Melter Off-Gas Emission Samples (continued).

		Test 6C				Test 7A			
		09/27/06 21:45 – 22:45 100.7% Isokinetic, 9.3% Moisture				10/04/06 10:04 – 10:44 102.9% Isokinetic, 13.5% Moisture			
		Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF	Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF
Particulate	Total[$]	82980	438	0.53	189	114970	480	0.42	240
	Al	9599	14.36	0.15	668	11963	12.66	0.11	945
	B	3568	24.49	0.69	146	6042	39.63	0.66	152
	Ba	34	1.75	5.16	19.4	28	0.42	1.49	67.0
	Bi	774	5.94	0.77	130	1103	5.84	0.53	189
	Ca	3290	12.84	0.39	256	545	2.98	0.55	183
	Cd	14	0.18	1.33	75.1	9	0.17	1.77	56.4
	Cl*	0	0.52	NC	NC	0	0.59	NC	NC
	Cr	269	2.63	0.98	102	515	7.48	1.45	68.8
	F*	507	30.97	6.11	16.37	244	19.34	7.93	12.6
	Fe	3123	23.41	0.75	133	2090	7.75	0.37	270
	K	88	3.68	4.18	23.9	581	8.29	1.43	70.0
	Li	1255	7.72	0.61	163	1762	9.17	0.52	192
	Mg	55	1.36	2.49	40.2	141	0.59	0.42	239
	Na	5380	42.29	0.79	127	9993	72.03	0.72	139
	Ni	238	1.58	0.66	151	83	0.40	0.48	208
	P	347	1.36	0.39	256	935	4.89	0.52	191
	Pb	288	2.80	0.97	103	89	0.88	1.00	100
	S*	61	5.62	9.21	10.9	93	14.83	15.95	6.3
	Si	10792	30.94	0.29	349	17120	23.90	0.14	717
	Ti	5	< 0.10	< 2.00	> 50	108	0.54	0.50	198
	Zn	49	0.46	0.95	105	153	0.82	0.53	188
	Zr	219	1.30	0.59	168	94	0.32	0.34	292
Gaseous	B	3568	37.87	1.06	94.2	6042	49.29	0.82	123
	Cl	0	4.33	NC	NC	0	3.17	NC	NC
	F	507	118.72	23.41	4.3	244	62.01	25.44	3.9
	S	61	15.52	25.58	3.9	93	22.65	24.24	4.1

[$] - From gravimetric analysis of filters and particulate nitric acid rinses.
* Based on analysis of front-half rinse and water dissolution of filter particulate.
[#] - Feed rate calculated from target composition and production rate.
NC – Not Calculated

Table 7.1. Results from Melter Off-Gas Emission Samples (continued).

		Test 7B				Test 8A			
		10/06/06 12:32 – 13:32 101.9% Isokinetic, 10.0% Moisture				10/18/06 11:59 – 12:59 100.3% Isokinetic, 6.1% Moisture			
		Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF	Feed Rate[#] (mg/min)	Emissions Rate (mg/min)	% Feed	DF
Particulate	Total[$]	73910	69.4	0.09	1066	32850	19.7	0.06	1670
	Al	7691	0.59	0.01	13075	3418	0.27	0.01	12731
	B	3884	1.11	0.03	3484	1726	0.33	0.02	5242
	Ba	18	< 0.10	< 0.56	> 180	8	< 0.10	< 1.25	> 80
	Bi	709	0.71	0.10	993	315	< 0.10	< 0.03	> 3150
	Ca	351	0.24	0.07	1463	156	0.63	0.40	248
	Cd	6	< 0.10	< 1.67	> 60	3	< 0.10	< 3.33	> 30
	Cl[&]	0	< 0.10	NC	NC	0	< 0.10	NC	NC
	Cr	331	3.00	0.91	110	147	0.82	0.56	180
	F[&]	157	8.50	5.41	18.5	70	0.63	0.90	111
	Fe	1343	0.26	0.02	5189	597	0.23	0.04	2542
	K	373	2.15	5.76	173	166	0.65	0.39	255
	Li	1133	1.89	0.17	600	504	0.35	0.07	1429
	Mg	90	< 0.10	< 0.11	> 900	40	< 0.10	< 0.25	> 400
	Na	6424	12.82	0.20	501	2855	3.66	0.13	779
	Ni	54	< 0.10	< 0.19	> 540	24	< 0.10	< 0.42	> 240
	P	601	< 0.10	< 0.02	> 6010	267	< 0.10	< 0.04	> 2670
	Pb	57	0.21	0.37	274	25	< 0.10	< 0.40	> 250
	S[&]	60	7.83	13.05	7.66	27	0.79	2.93	34.2
	Si	11006	1.33	0.01	8252	4892	1.11	0.02	4424
	Ti	69	< 0.10	< 0.14	> 690	31	< 0.10	< 0.32	> 310
	Zn	99	< 0.10	< 0.10	> 990	44	< 0.10	< 0.23	> 440
	Zr	61	< 0.10	< 0.16	> 610	27	< 0.10	< 0.37	> 270
Gaseous	B	3884	24.25	0.62	160	1726	4.77	0.28	362
	Cl	0	3.02	NC	NC	0	0.41	NC	NC
	F	157	65.46	41.78	2.4	70	4.39	6.31	15.9
	S	60	19.64	32.70	3.1	27	8.30	31.09	3.2

[$] - From gravimetric analysis of filters and particulate nitric acid rinses.
[&] Based on direct analysis of front-half rinse.
[#] - Feed rate calculated from target composition and production rate.
NC – Not Calculated

Table 7.1. Results from Melter Off-Gas Emission Samples (continued).

		Test 8B 10/20/06 14:55 – 15:55 101.2% Isokinetic, 6.3% Moisture				Test 8C 11/19/06 22:15 – 23:15 98.9% Isokinetic, 8.6% Moisture			
		Feed Rate# (mg/min)	Emissions Rate (mg/min)	% Feed	DF	Feed Rate# (mg/min)	Emissions Rate (mg/min)	% Feed	DF
Particulate	Total$	14600	24.6	0.17	594	102653	122	0.12	840
	Al	1709	0.40	0.02	4310	10682	2.09	0.02	5104
	B	863	1.22	0.14	709	5394	8.30	0.15	650
	Ba	4	< 0.10	< 2.50	> 40	25	0.11	0.42	238
	Bi	158	< 0.10	< 0.06	> 1580	985	1.04	0.11	948
	Ca	78	0.59	0.76	132	487	0.67	0.14	732
	Cd	1	< 0.10	< 10.00	> 10	8	< 0.10	< 1.25	> 80
	Cl	0	< 0.10&	NC	NC	0	0.59*	NC	NC
	Cr	74	0.94	1.28	78.2	460	3.73	0.81	123
	F	35	0.55&	1.57	63.6	218	4.66*	2.14	46.8
	Fe	299	0.51	0.17	580	1866	1.66	0.09	1121
	K	83	0.68	0.82	122	518	3.08	0.59	168
	Li	252	0.39	0.15	648	1573	2.33	0.15	676
	Mg	20	< 0.10	< 0.50	> 200	126	< 0.10	< 0.08	> 1260
	Na	1428	4.45	0.31	321	8922	19.56	0.22	456
	Ni	12	< 0.10	< 0.83	> 120	74	< 0.10	< 0.14	> 740
	P	134	< 0.10	< 0.07	> 1340	835	0.63	0.08	1333
	Pb	13	< 0.10	< 0.77	> 130	79	0.25	0.31	322
	S	13	0.57&	4.38	22.8	83	6.87*	8.28	12.1
	Si	2446	1.00	0.04	2445	15286	5.37	0.04	2849
	Ti	15	< 0.10	< 0.67	> 150	96	< 0.10	< 0.01	> 960
	Zn	22	< 0.10	< 0.45	> 220	137	0.26	0.19	535
	Zr	13	< 0.10	< 0.77	> 130	84	< 0.10	< 0.12	> 840
Gaseous	B	863	7.15	0.83	121	5394	20.21	0.37	267
	Cl	0	0.42	NC	NC	0	0.53	NC	NC
	F	35	8.79	25.25	4.0	218	20.16	9.27	10.8
	S	13	8.20	61.43	1.6	83	13.74	16.47	6.1

$ - From gravimetric analysis of filters and particulate nitric acid rinses.
* Based on direct analysis of front-half rinse and water dissolution of filter particulate.
& Based on direct analysis of front-half rinse.
# - Feed rate calculated from target composition and production rate.
NC – Not Calculated

Table 7.2. Average Concentration (ppmv) of Selected Species in Off-Gas Measured by FTIR Spectroscopy.

Test	Bi-Limited								Cr-Limited			
	1A		1B		2A		2B		3B		4A	
	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
N_2O	1.6	<1.0 - 14.2	1.2	<1.0 - 8.3	1.2	<1.0 - 12.4	<1.0	<1.0 - 4.0	<1.0	<1.0 – 3.1	<1.0	<1.0 – 2.1
NO	193	<1.0 -1361	152	31.6 - 486	117	21.5 - 774	72.9	<1.0 - 396	59.2	8.8 - 193	51.2	9.4 - 136
NO_2	20.4	<1.0 - 221	13.8	<1.0 - 79.7	11.2	<1.0 - 114	5.0	<1.0 - 53.2	<1.0	<1.0 – 3.6	<1.0	<1.0 – 4.5
NH_3	<1.0	<1.0 - 4.5	<1.0	<1.0 - 1.4	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA
H_2O [%]	7.6	<1.0 - 13.1	6.1	3.7 - 13.6	5.3	2.3 - 23.1	6.9	1.7 - 20.4	7.5	2.8 – 19.2	6.9	2.4 – 19.2
CO_2	1204	8 - 4975	1022	361 - 2843	906	302 - 3924	898	494 - 2452	1878	934 - 5794	1709	924 - 3770
Nitrous Acid	<1.0	<1.0 - 2.8	<1.0	NA	<1.0	<1.0 - 2.2	<1.0	NA	<1.0	NA	<1.0	NA
Nitric Acid	<1.0	NA	<1.0	NA	<1.0	<1.0 - 5.5	<1.0	NA	<1.0	NA	<1.0	NA
HCN	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA
SO_2	3.7	<1.0 - 8.8	4.5	<1.0 - 9.0	3.2	<1.0 - 7.8	4.1	<1.0 - 9.2	8.0	<1.0 – 12.7	5.5	<1.0 – 9.0
CO	1.6	<1.0 - 12.6	1.1	<1.0 - 6.3	1.0	<1.0 - 7.7	<1.0	<1.0 - 6.1	1.1	<1.0 – 3.0	<1.0	<1.0 – 2.0
HCl	<1.0	<1.0 - 1.6	1.7	<1.0 - 7.1	3.1	<1.0 - 8.3	1.8	<1.0 - 4.4	2.3	<1.0 – 5.4	1.7	<1.0 – 3.1
HF	1.3	<1.0 - 4.9	5.7	1.2 - 20.3	15.2	4.0 - 29.4	19.4	10.7 - 33.1	17.6	1.1 – 35.9	22.4	13.8 – 27.1

NA - Not applicable.

Table 7.2. Average Concentration (ppmv) of Selected Species in Off-Gas Measured by FTIR Spectroscopy (continued).

Test	Al-Limited									
	5A		5B		6A		6B		6C	
	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
N_2O	<1.0	<1.0 - 1.2	<1.0	<1.0 - 1.0	<1.0	<1.0 - 1.3	<1.0	NA	<1.0	<1.0 - 1.3
NO	74.0	<1.0 - 460	40.3	0 - 273	34.9	<1.0 – 368	19.6	<1.0 - 152	64.8	<1.0 - 449
NO_2	4.0	<1.0 – 71.3	3.4	<1.0 – 61.8	3.4	<1.0 - 70.9	2.2	<1.0 - 32.4	5.8	<1.0 - 86.5
NH_3	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	<1.0 – 4.9	<1.0	NA
H_2O [%]	6.4	3.1 – 19.6	4.6	1.7 – 16.3	4.1	2.0 - 19.2	4.9	1.3 -18.5	5.8	2.7 - 22.5
CO_2	1263	380 - 5233	978	498 - 3971	935	476 – 5359	862	468 - 2958	1087	245 - 5319
Nitrous Acid	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	<1.0 – 1.4
Nitric Acid	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA
HCN	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA
SO_2	4.1	<1.0 – 15.1	<1.0	<1.0 – 3.7	1.2	<1.0 - 4.2	<1.0	<1.0 - 13.9	<1.0	<1.0 -16.4
CO	<1.0	<1.0 – 1.7	<1.0	<1.0 – 1.0	<1.0	NA	<1.0	<1.0 – 1.9	<1.0	<1.0 – 29.1
HCl	1.7	<1.0 – 3.4	<1.0	<1.0 – 1.8	<1.0	<1.0 -1.5	<1.0	<1.0 - 2.8	1.4	<1.0 - 2.9
HF	21.9	12.4 – 37.1	15.4	7.3 – 25.3	16.1	9.2 - 25.7	11.2	3.9 - 24.6	25.0	10.5 – 38.6

NA - Not applicable.

Table 7.2. Average Concentration (ppmv) of Selected Species in Off-Gas Measured by FTIR Spectroscopy (continued).

Test	Al+Na-Limited									
	7A		7B		8A		8B		8C	
	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
N_2O	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	2.7	<1.0 - 2.7
NO	99.4	<1.0 - 566	72.0	11.7 - 304	35.9	<1.0 – 249	13.5	<1.0 - 166	93.4	<1.0 - 636
NO_2	6.1	<1.0 - 79.4	4.3	<1.0 - 47.9	8.0	<1.0 - 53.2	<1.0	<1.0 - 24.4	3.4	<1.0 - 78.1
NH_3	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	<1.0 - 6.7
H_2O [%]	7.7	2.9 - 22.4	6.2	1.6 - 16.2	4.3	1.1 - 16.7	4.2	2.4 - 15.1	7.5	0.6 - 30.0
CO_2	1432	478 - 7255	1159	545 - 3968	941	425 – 4626	754	296 - 3211	1333	421 - 7823
Nitrous Acid	<1.0	<1.0 - 1.0	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	<1.0 - 1.6
Nitric Acid	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	<1.0 - 1.5
HCN	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	NA
SO_2	1.7	<1.0 - 5.2	1.9	<1.0 - 5.8	<1.0	<1.0 - 3.4	<1.0	<1.0 - 2.2	1.6	<1.0 - 5.4
CO	<1.0	<1.0 - 1.4	<1.0	NA	<1.0	NA	<1.0	NA	<1.0	<1.0 - 22.8
HCl	1.1	<1.0 - 4.2	<1.0	NA	<1.0	<1.0 - 2.5	<1.0	NA	1.4	<1.0 - 2.9
HF	20.5	12.1 - 25.7	10.5	2.9 - 14.5	3.2	<1.0 - 8.4	2.2	1.0 - 3.7	3.8	1.0 - 6.9

NA - Not applicable.

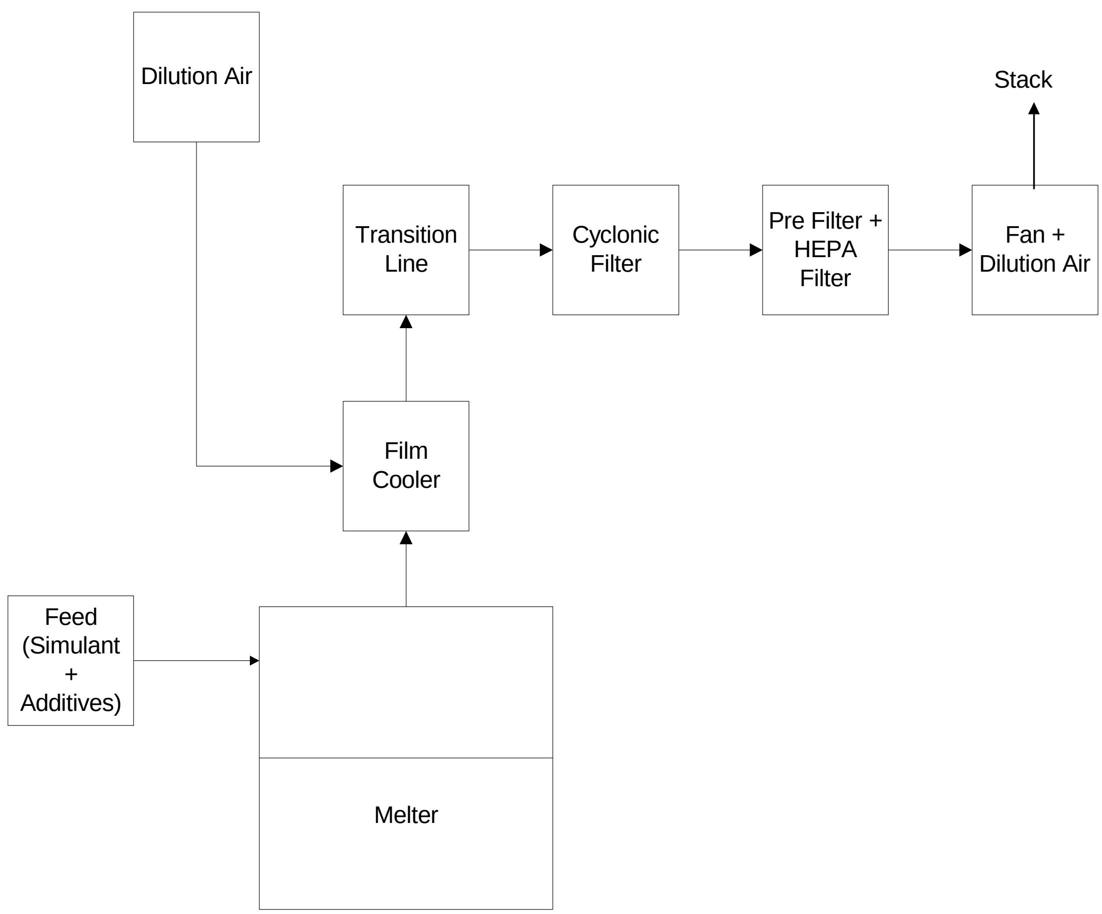


Figure 1.1. Schematic diagram of DuraMelter 100-BL vitrification system.

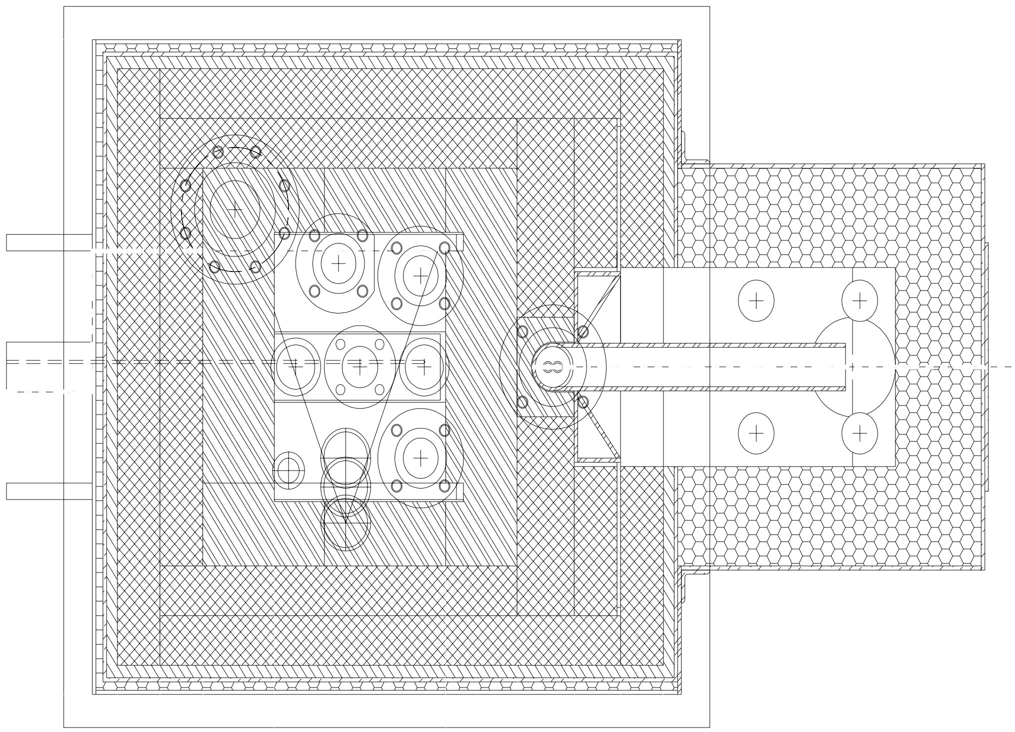


Figure 1.2.a. Schematic diagram showing cross-section through the DM100-BL-melter. Plan view showing locations of lid ports.

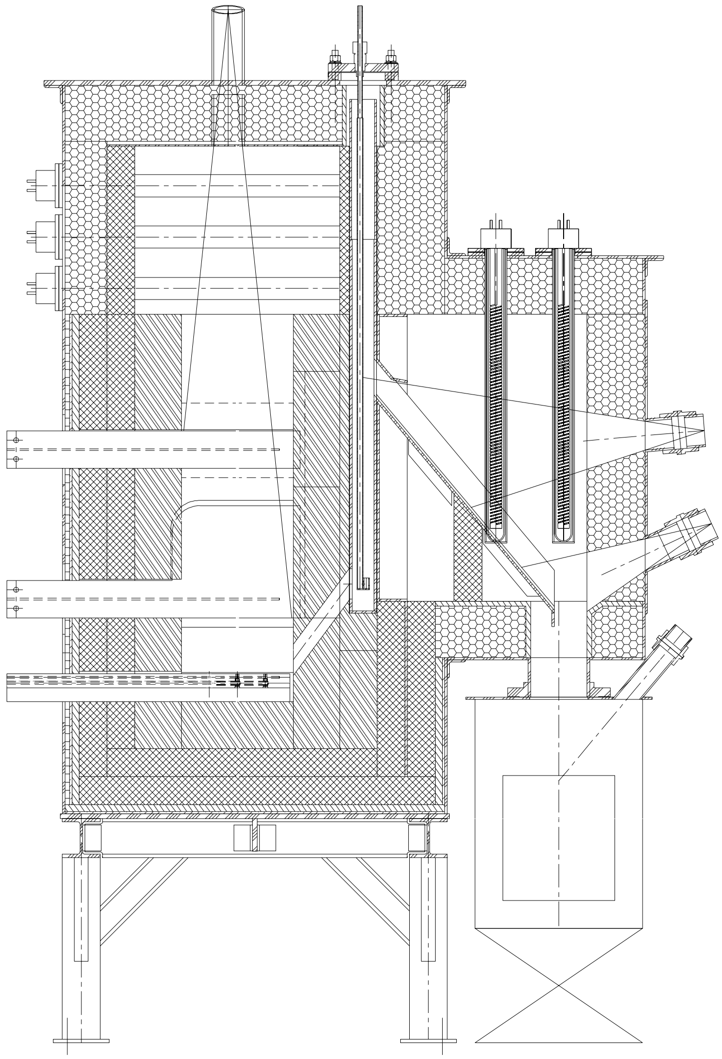


Figure 1.2.b. Schematic diagram showing cross-section through the DM100-BL melter.

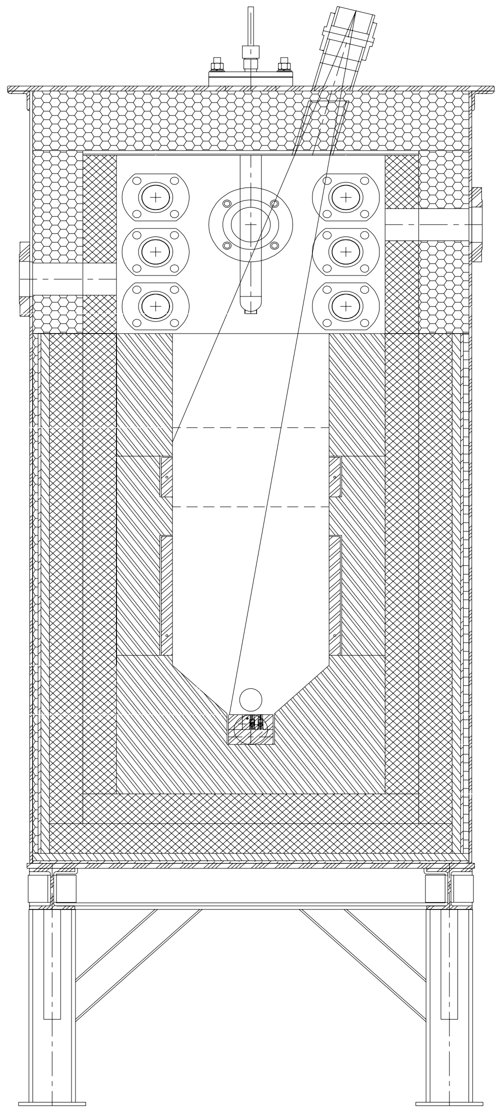


Figure 1.2.c. Schematic diagram showing cross-section through the DM100-BL melter.

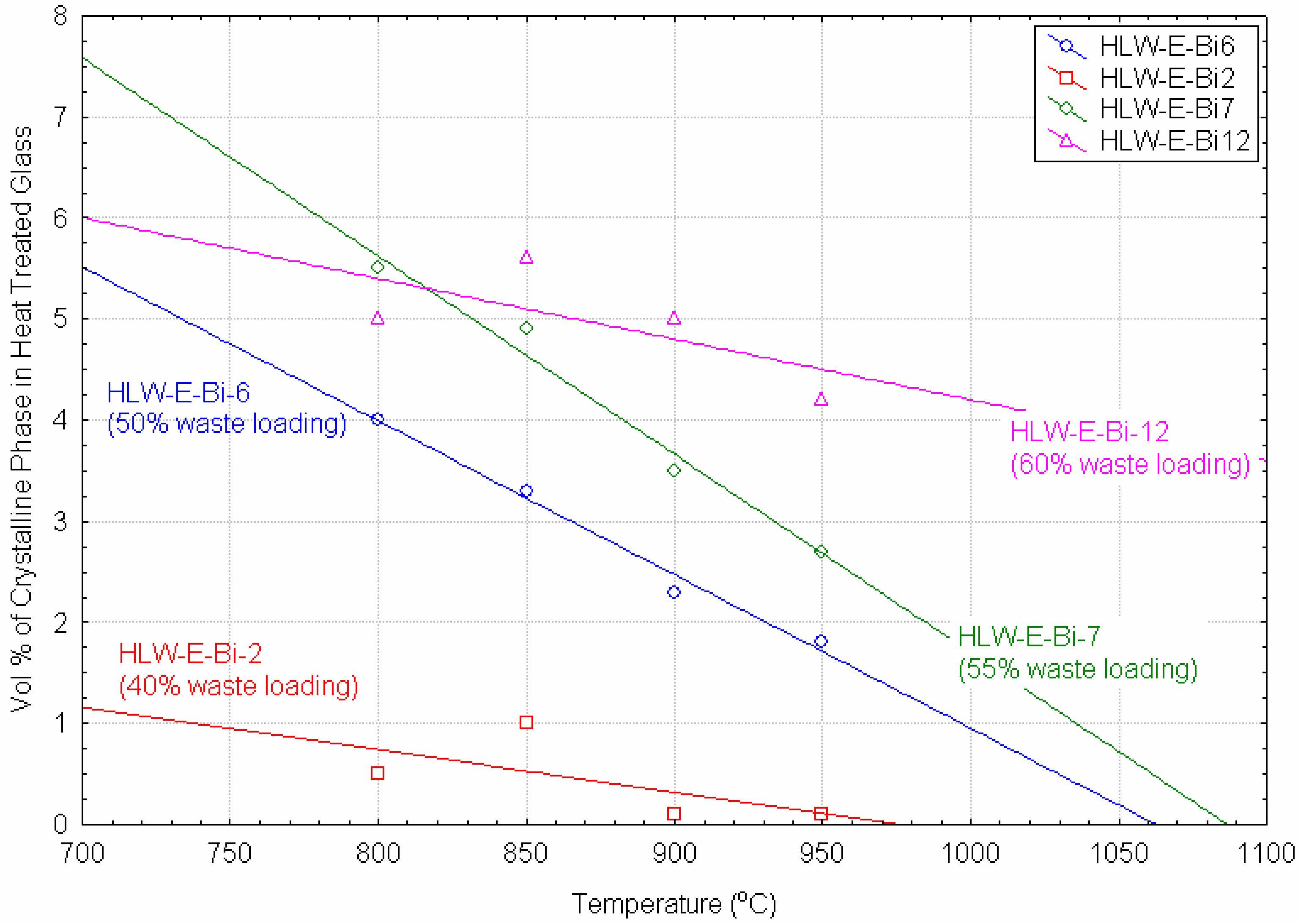


Figure 3.1. Volume % of crystalline phase in the heat treated glasses vs. heat treatment temperature. Lines are from linear regression of the available data points of each glass.

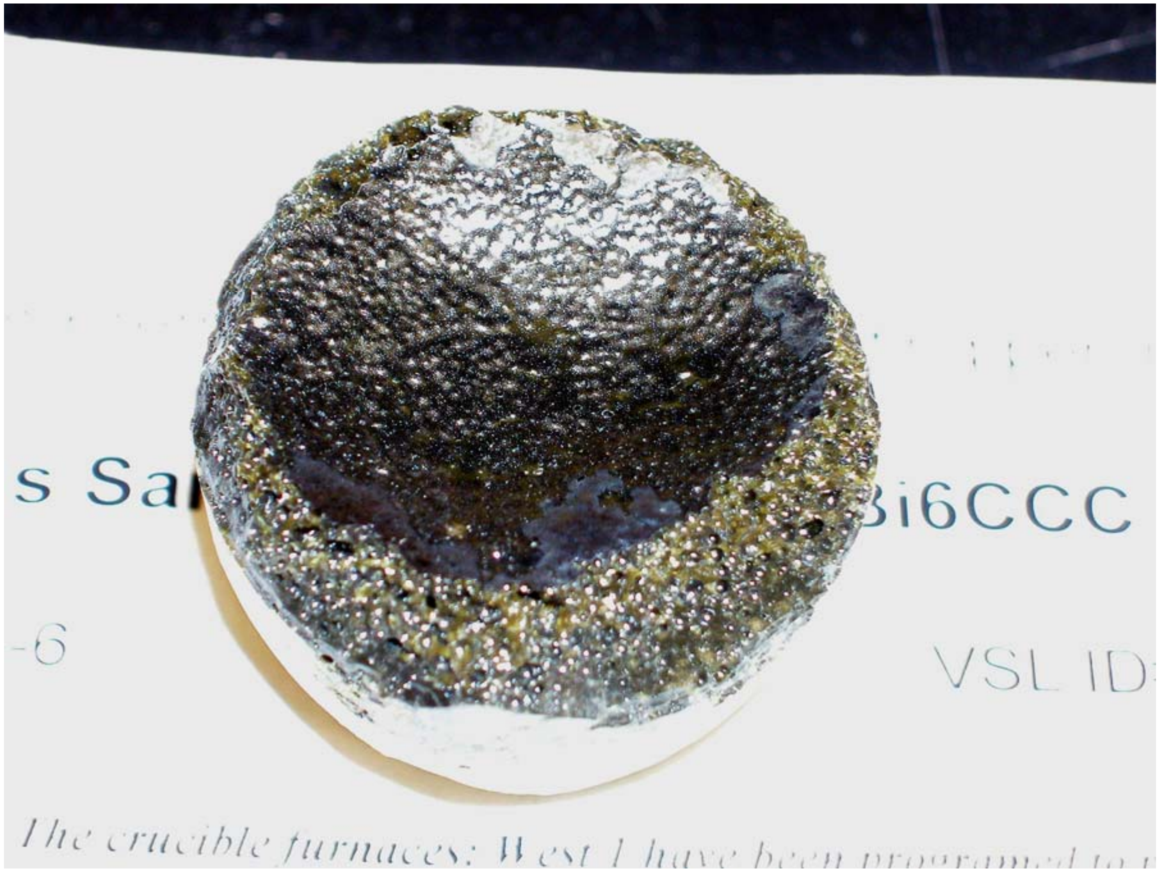


Figure 3.2. Top view of CCC sample of HLW-E-Bi6. Foaming observed is concentrated near the top of the sample.

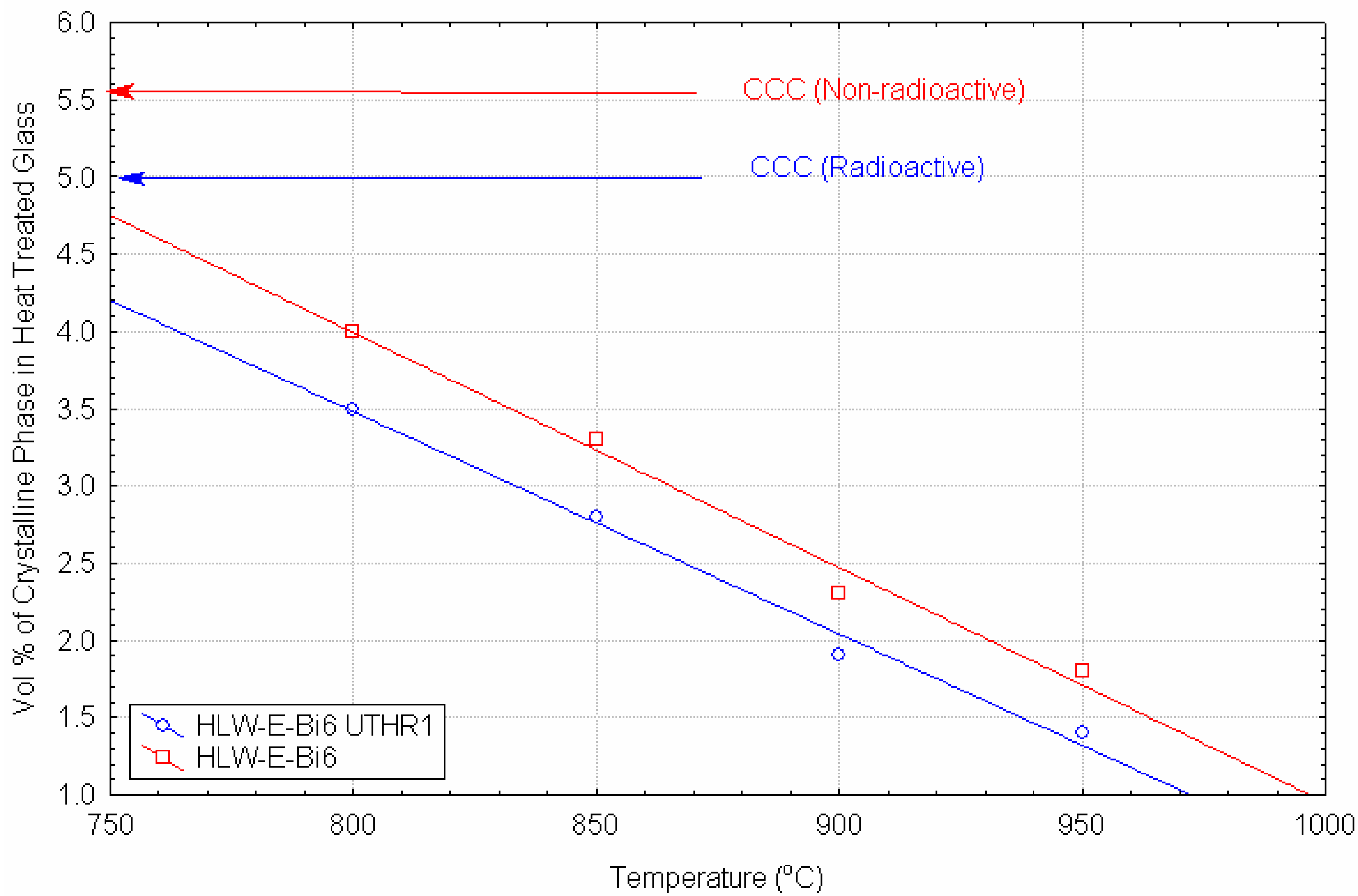


Figure 3.3. Volume% of crystalline phase in the heat treated glasses vs. heat treatment temperature for HLW-E-Bi-6 and HLW-E-BiUThR1. Two arrows indicate the volume% of crystals in the corresponding samples after CCC treatment.

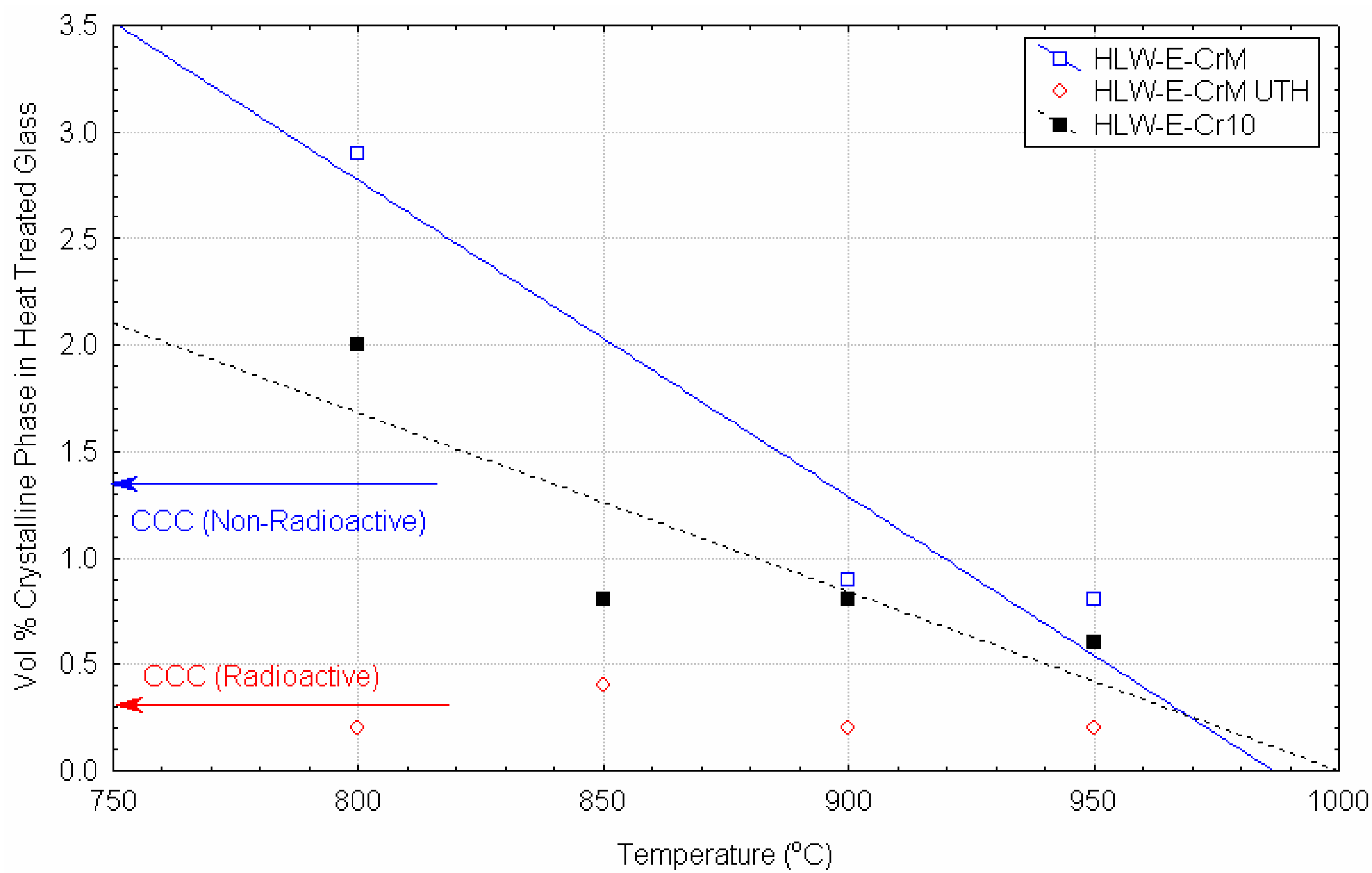


Figure 3.4. Volume% of crystalline phase in the heat treated glasses vs. heat treatment temperature for HLW-E-Cr-M and HLW-E-CrMUTh. Two arrows indicate the volume% of crystals in the corresponding samples after CCC treatment. The result from HLW-E-Cr-10 is also plotted for comparison.

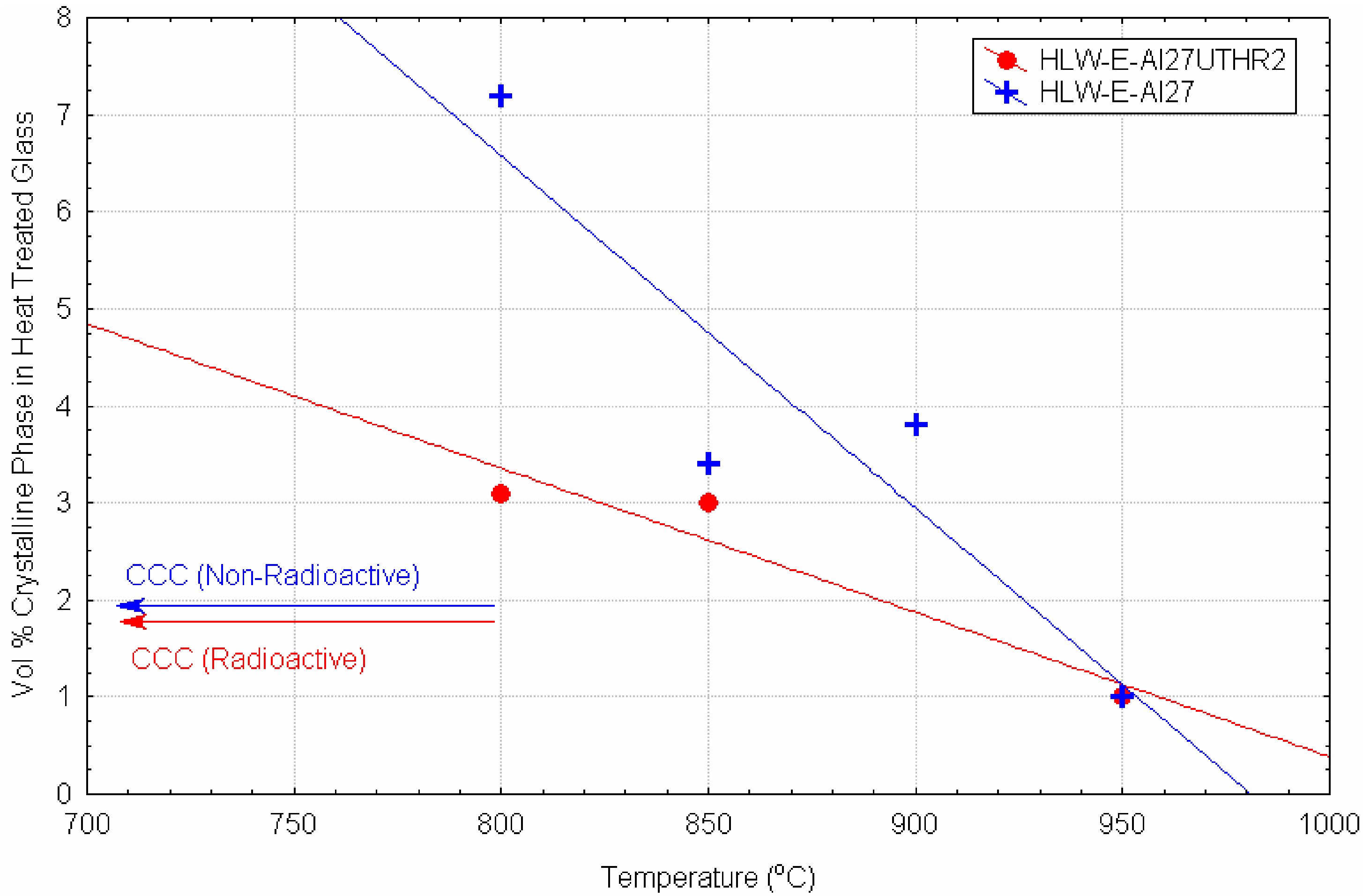


Figure 3.5. Volume% of crystalline phase in the heat treated glasses vs. heat treatment temperature for HLW-E-Al-27 and HLW-E-Al-27iUThR2. Two arrows indicate the volume% of crystals in the corresponding samples after CCC treatment.

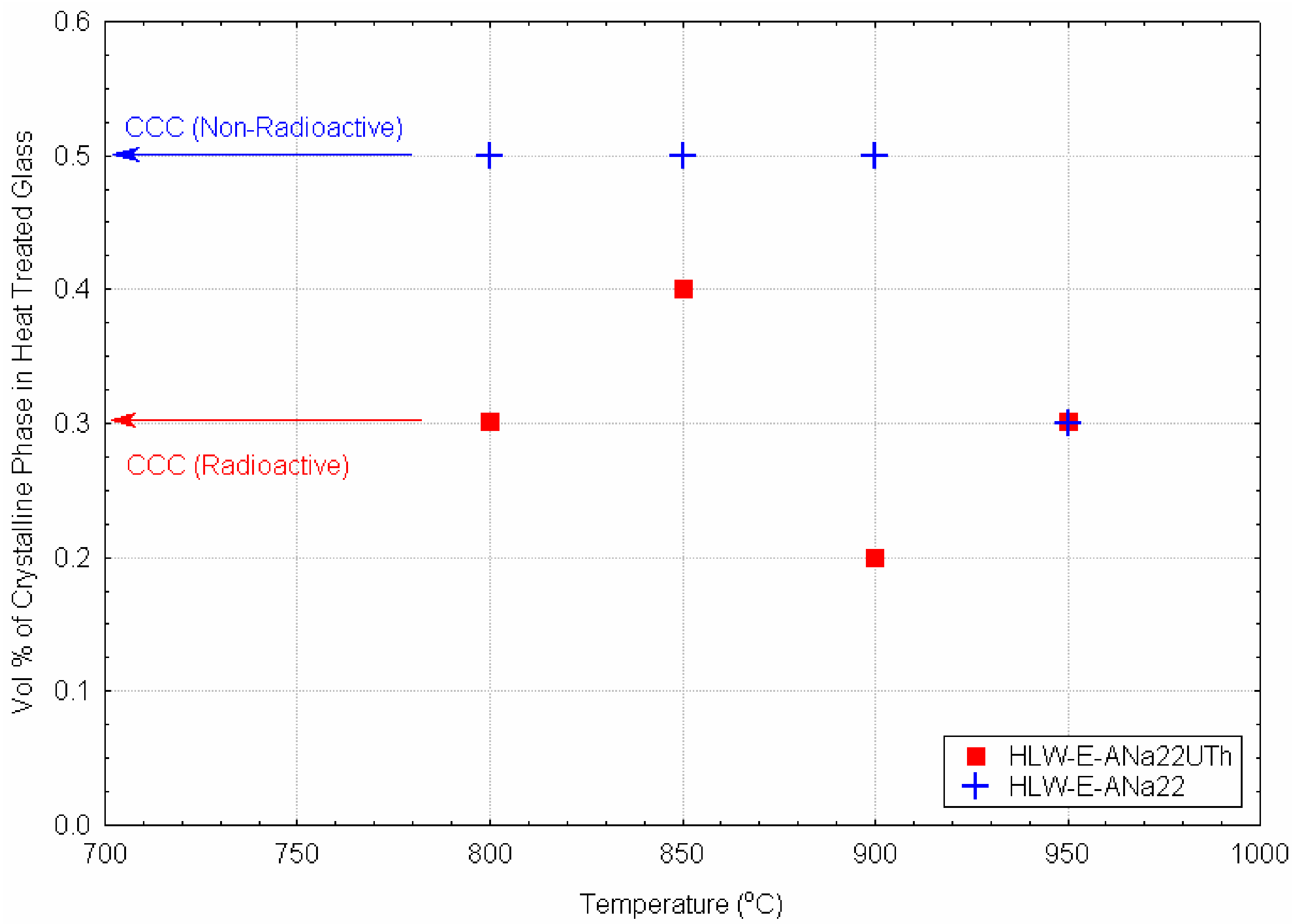
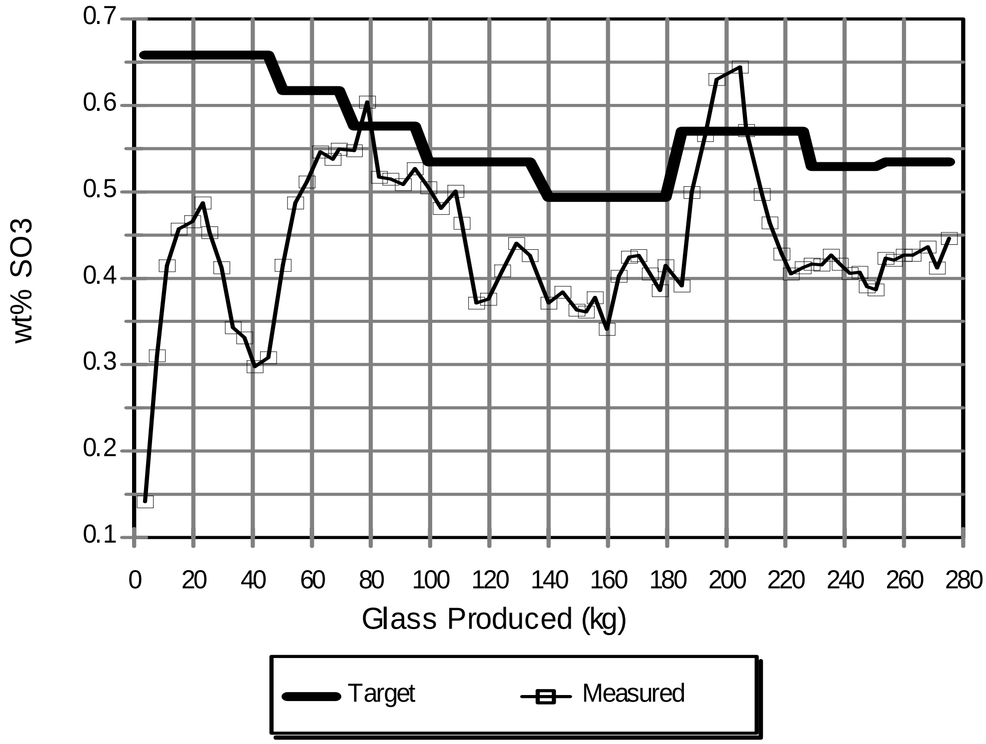


Figure 3.6. Volume% of crystalline phase in the heat treated glasses vs. heat treatment temperature for HLW-E-ANa-22 and HLW-E-ANa22UTh. Two arrows indicate the volume% of crystals in the corresponding samples after CCC treatment.



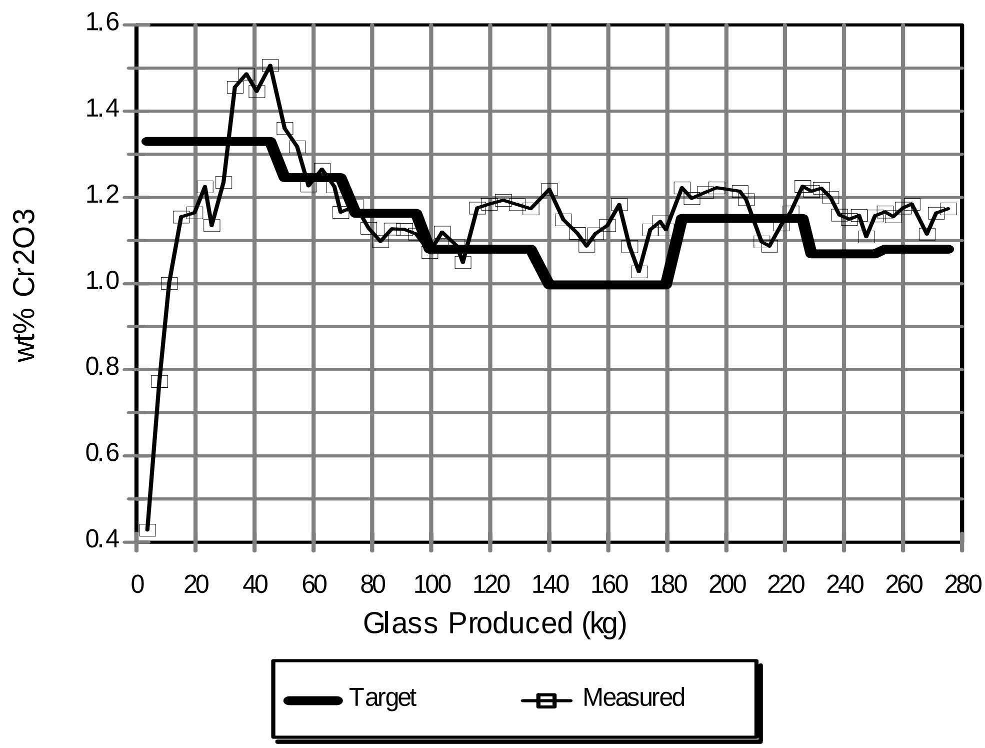
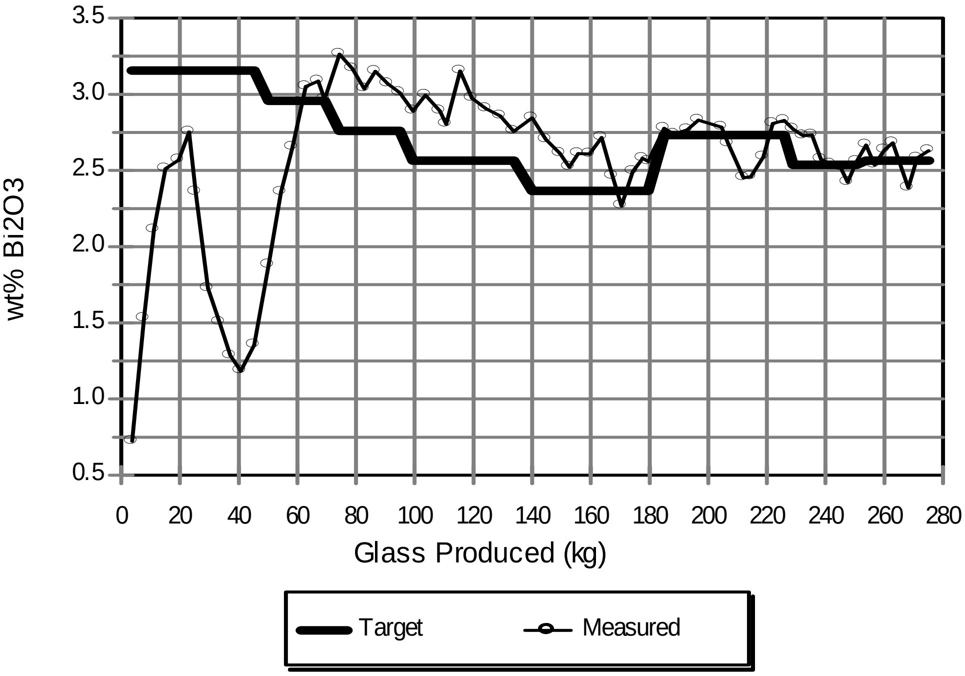


Figure 4.1. Sulfur and chromium concentrations measured by XRF in glasses from DM10 tests.



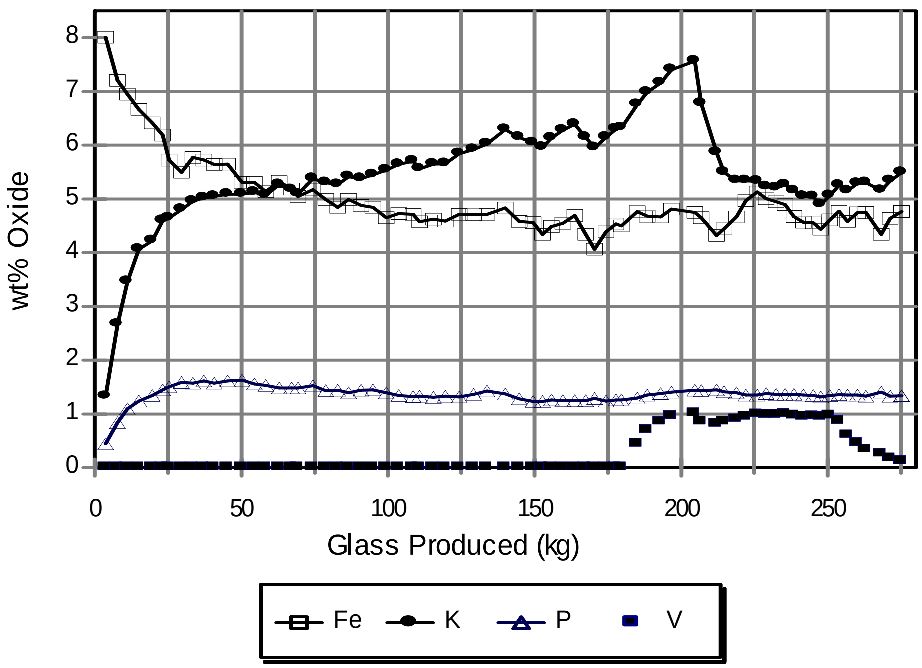


Figure 4.2. Select oxide concentrations measured by XRF in glasses from DM10 tests.

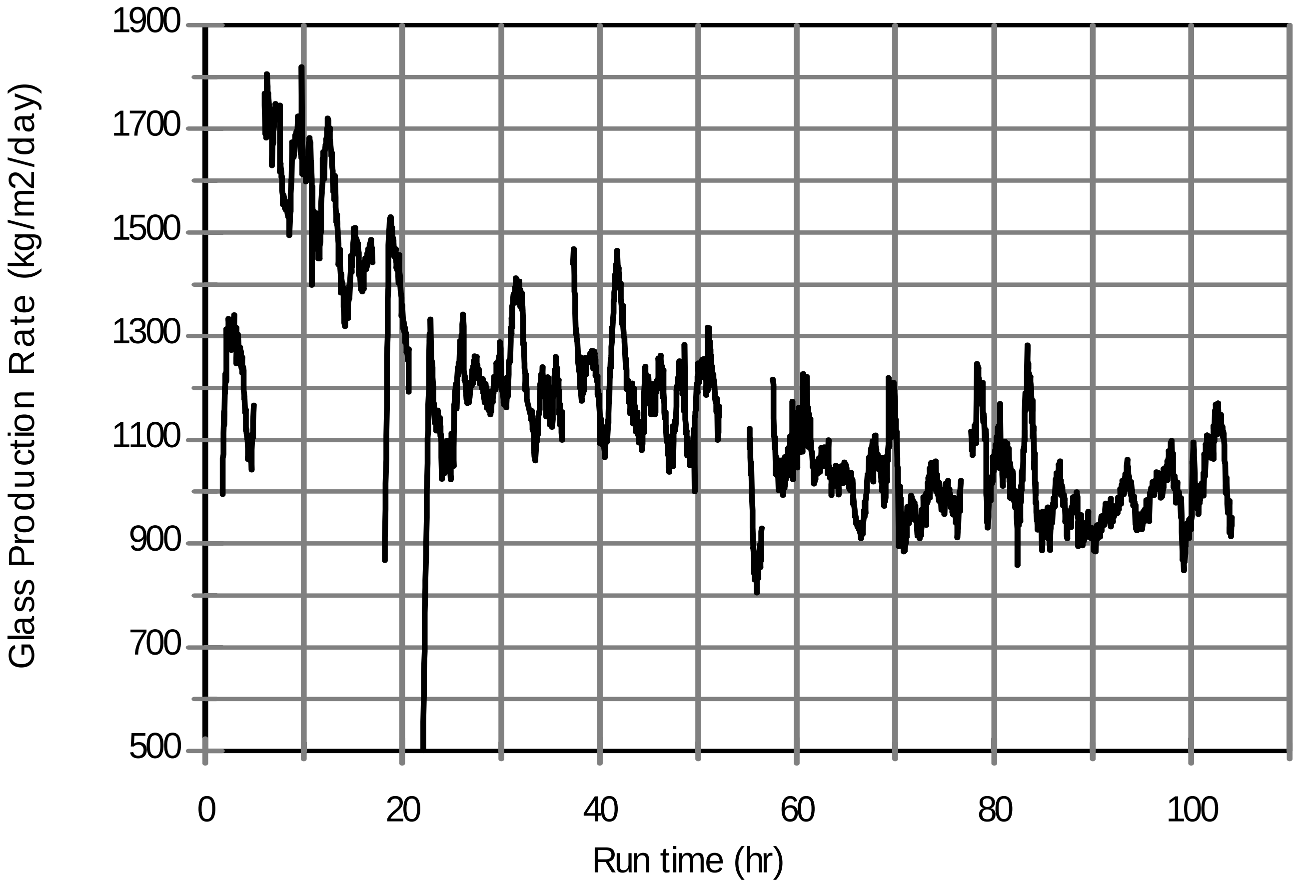


Figure 5.1.a. Glass production rates (hourly moving averages) for DM100 Tests 1A and 1B.

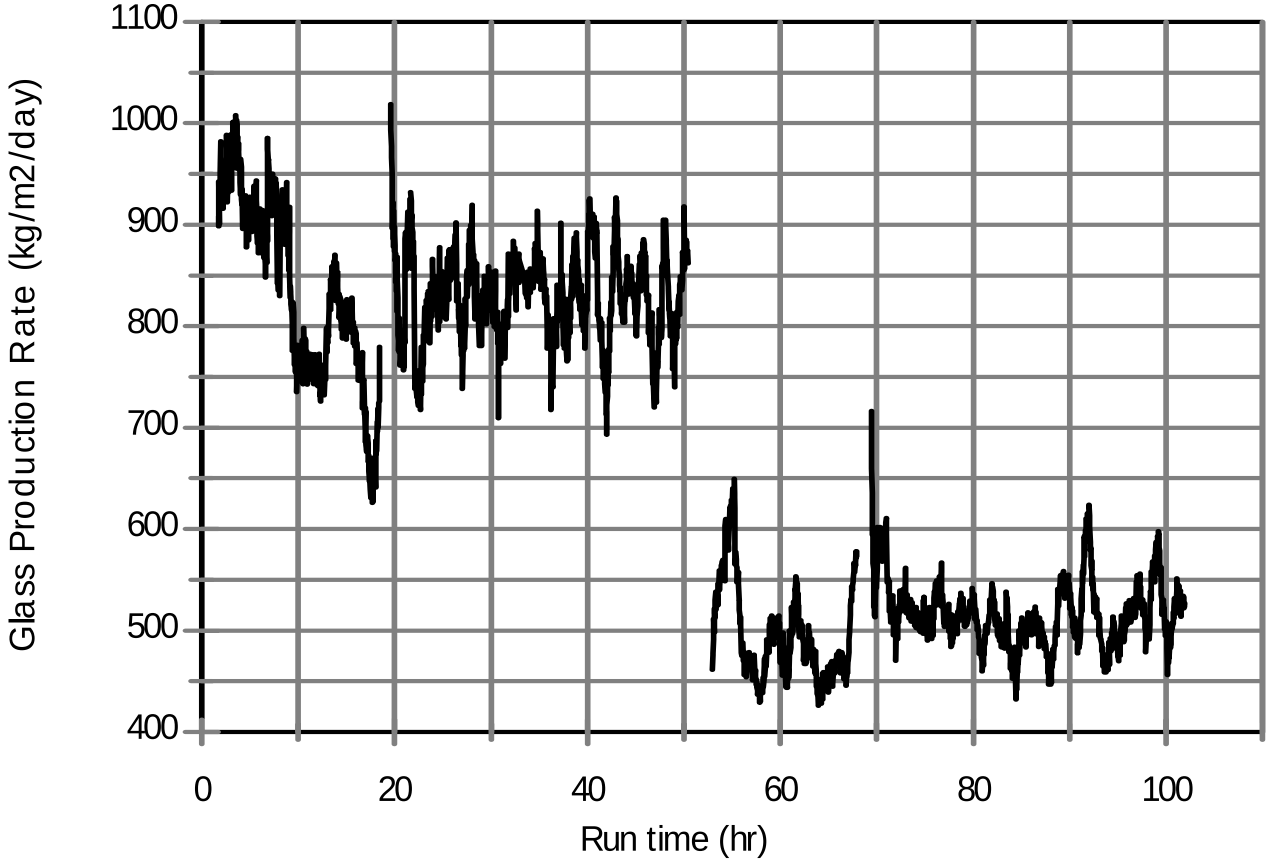


Figure 5.1.b. Glass production rates (hourly moving averages) for DM100 Tests 2A and 2B.

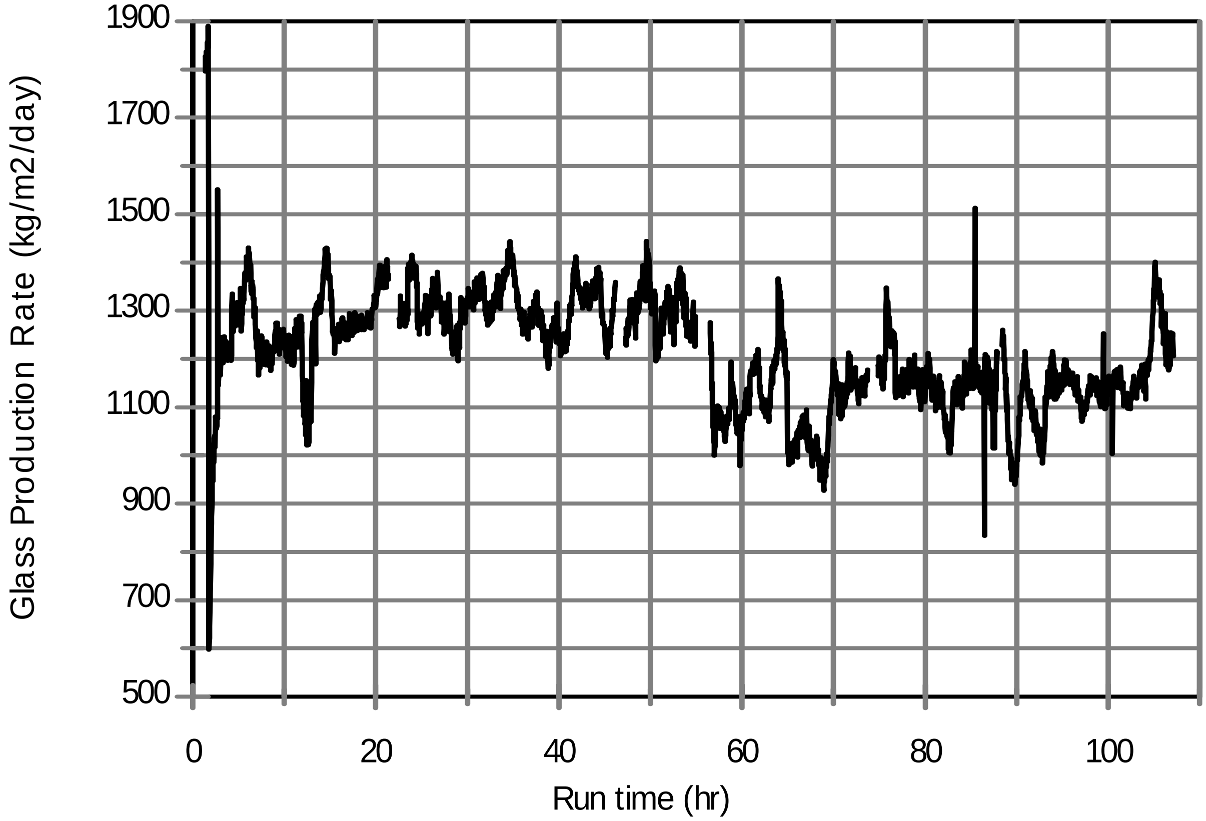


Figure 5.1.c. Glass production rates (hourly moving averages) for DM100 Tests 3B and 4A.

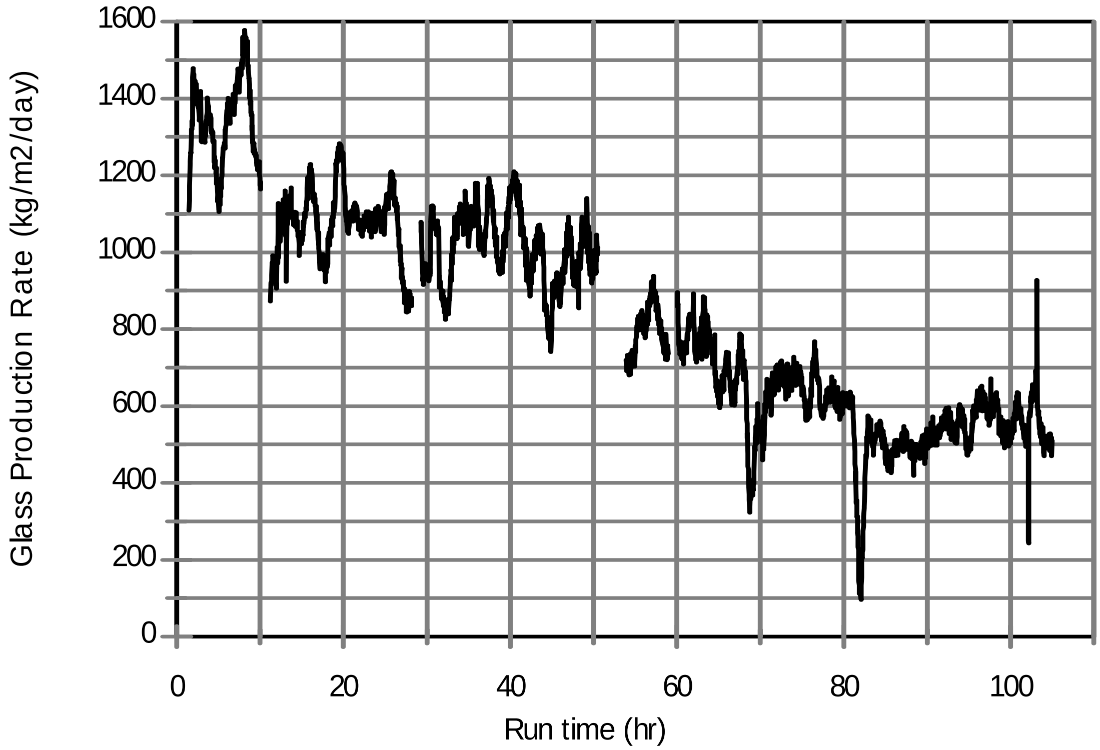


Figure 5.1.d. Glass production rates (hourly moving averages) for DM100 Tests 5A and 5B.

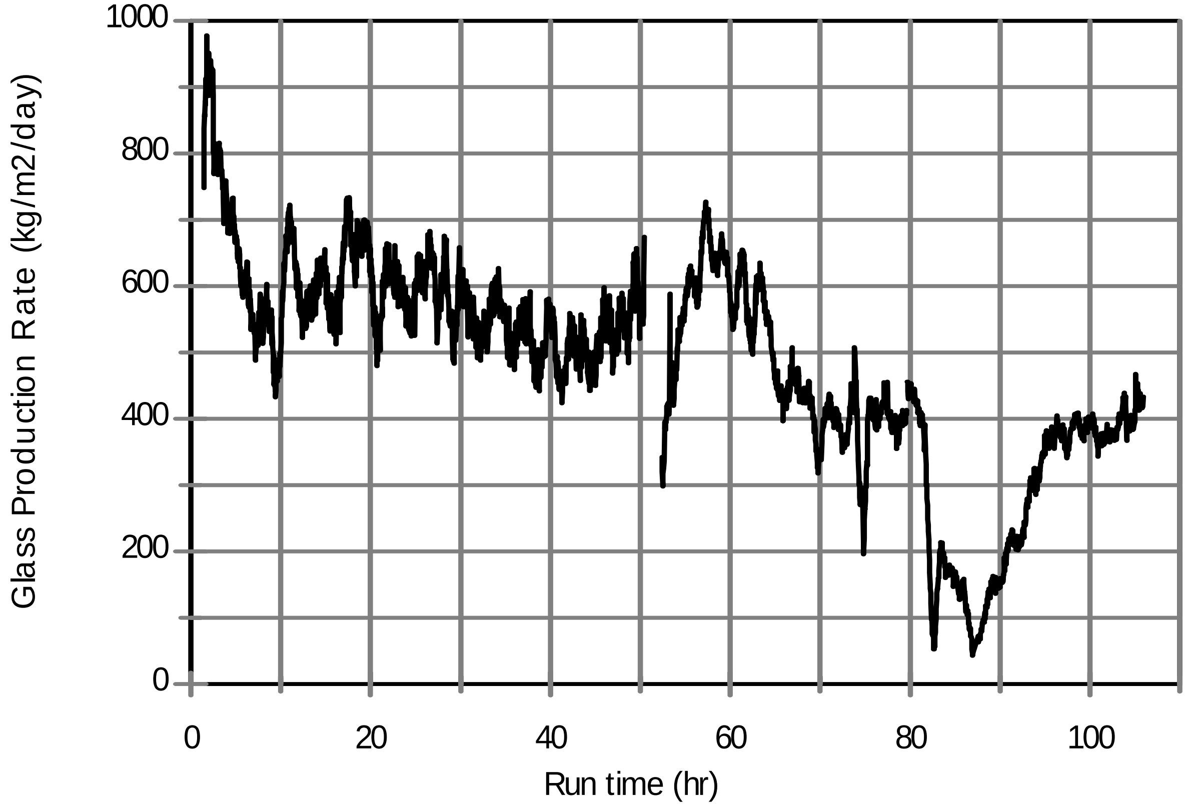


Figure 5.1.e. Glass production rates (hourly moving averages) for DM100 Tests 6A and 6B.

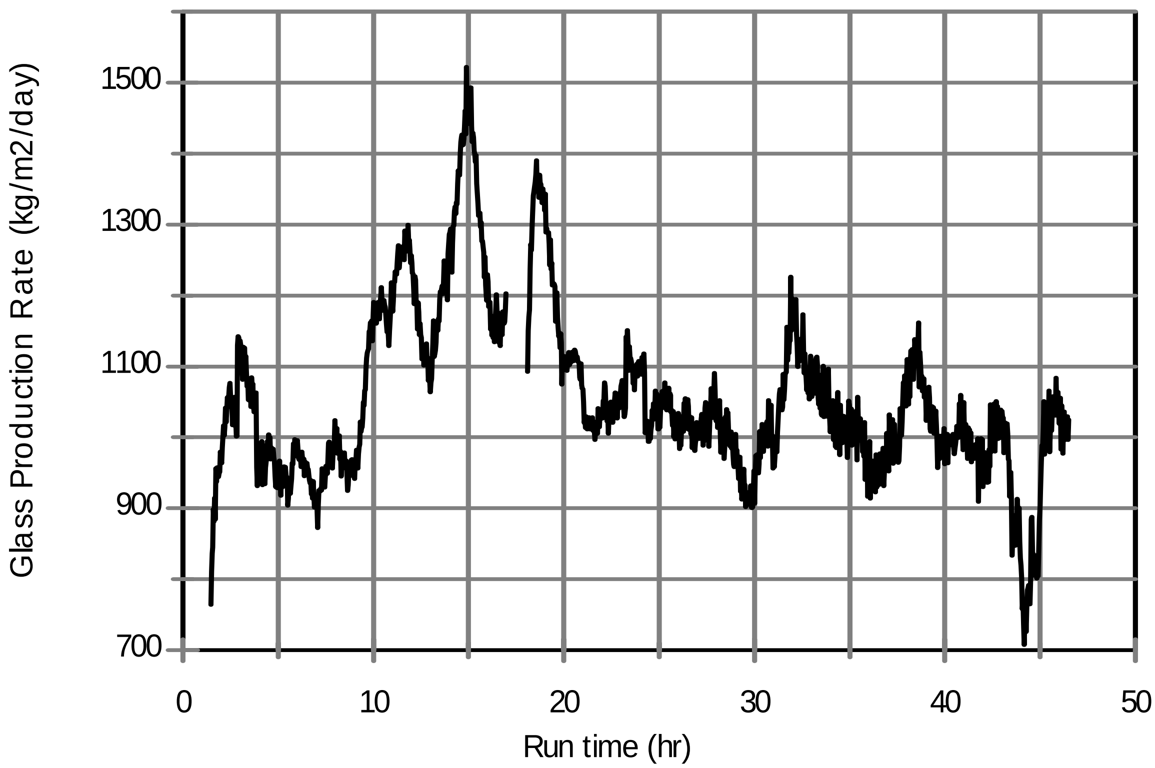


Figure 5.1.f. Glass production rates (hourly moving averages) for DM100 Test 6C.

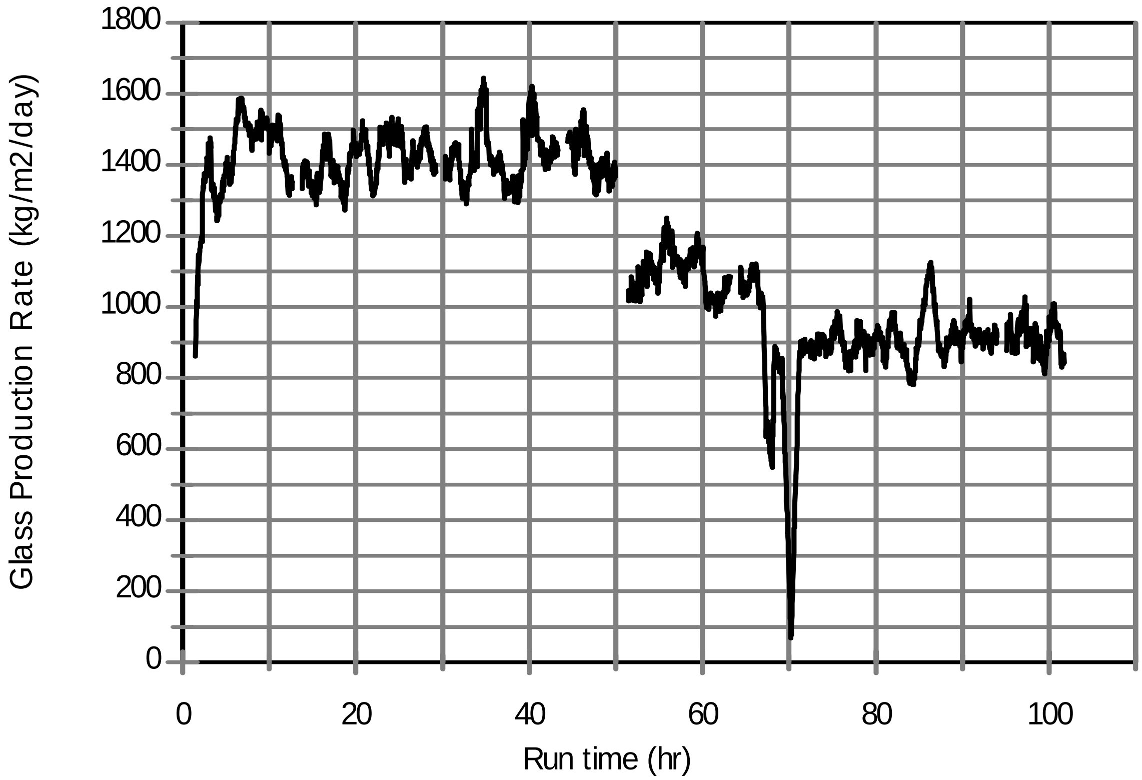


Figure 5.1.g. Glass production rates (hourly moving averages) for DM100 Tests 7A and 7B.

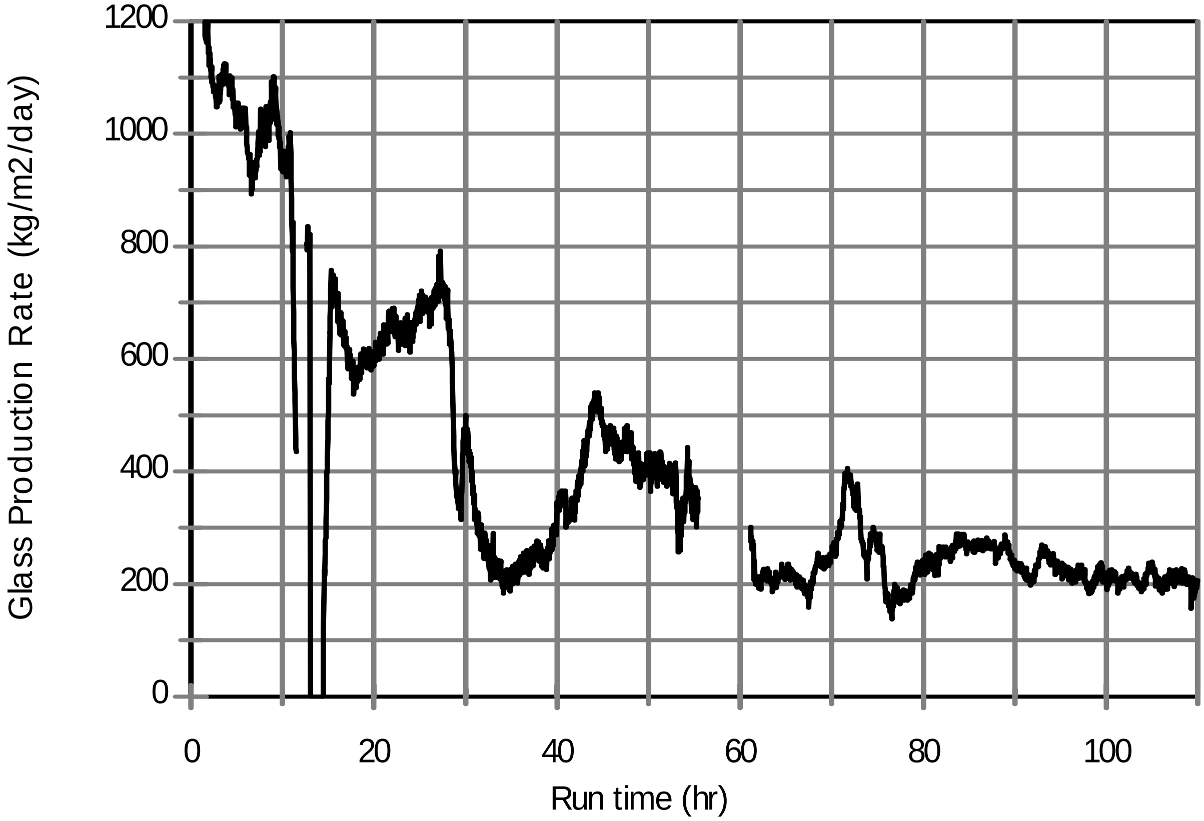


Figure 5.1.h. Glass production rates (hourly moving averages) for DM100 Tests 8A and 8B.

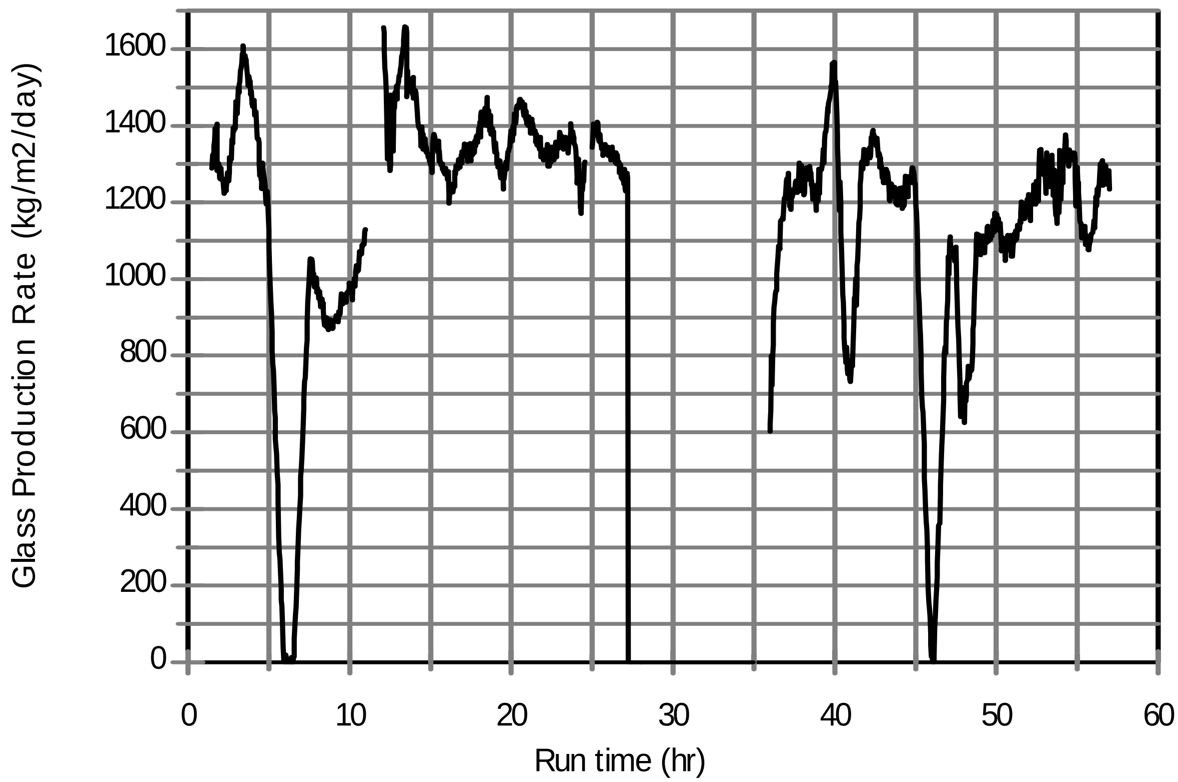


Figure 5.1.i. Glass production rates (hourly moving averages) for DM100 Test 8C.

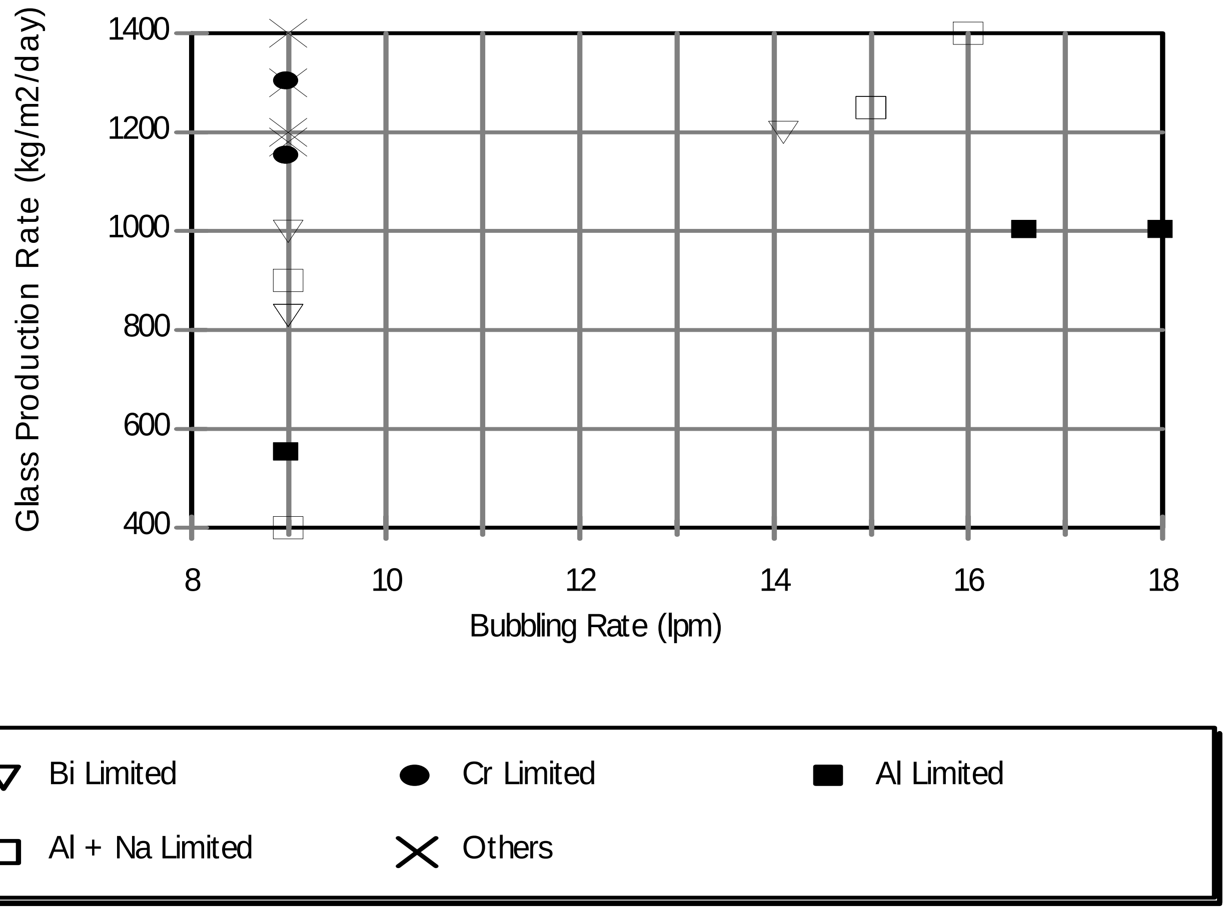


Figure 5.2. Steady-state glass production rates during DM100 tests vs. bubbling rate; feed solids content 500 (±50) g glass per liter feed.

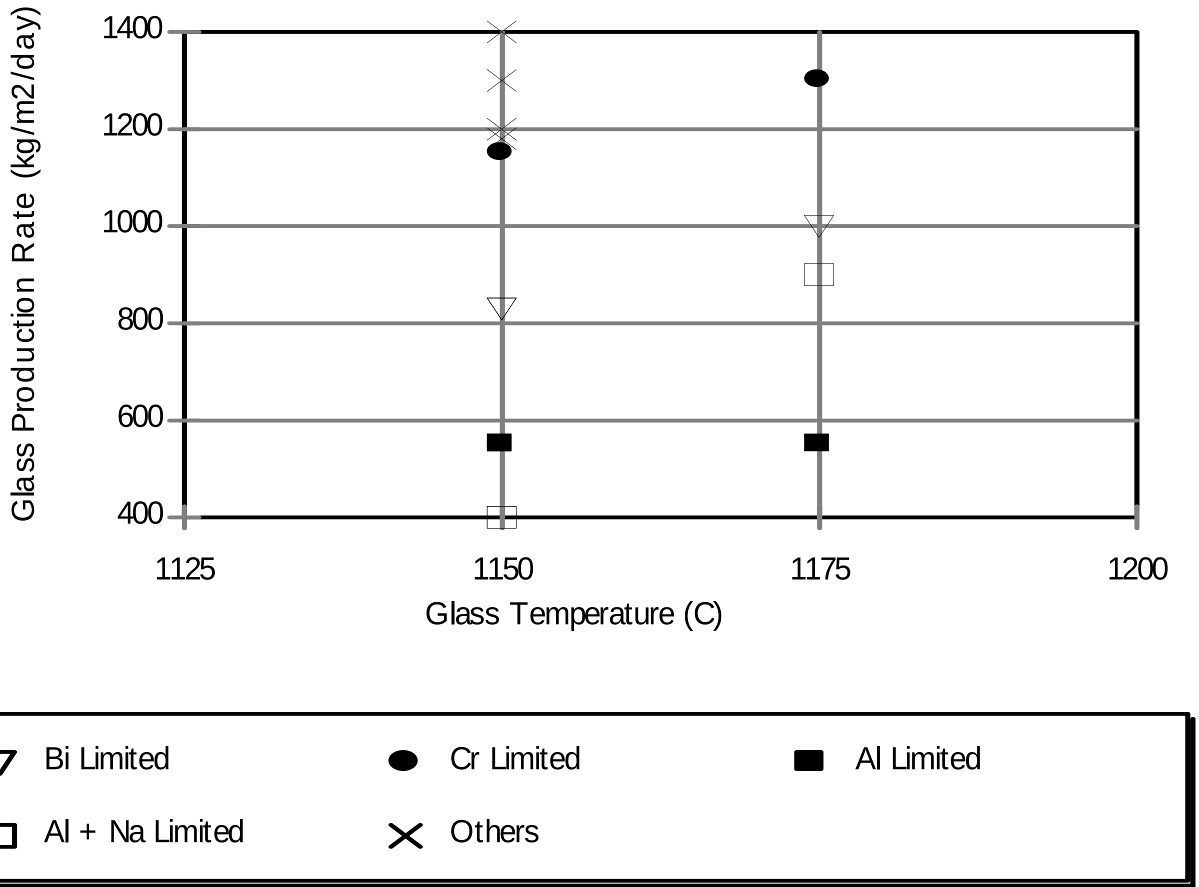


Figure 5.3. Steady-state glass production rates during DM100 tests vs. glass temperature; feed solids content 500 (±50) g glass per liter feed, glass pool bubbling rate 9 lpm.

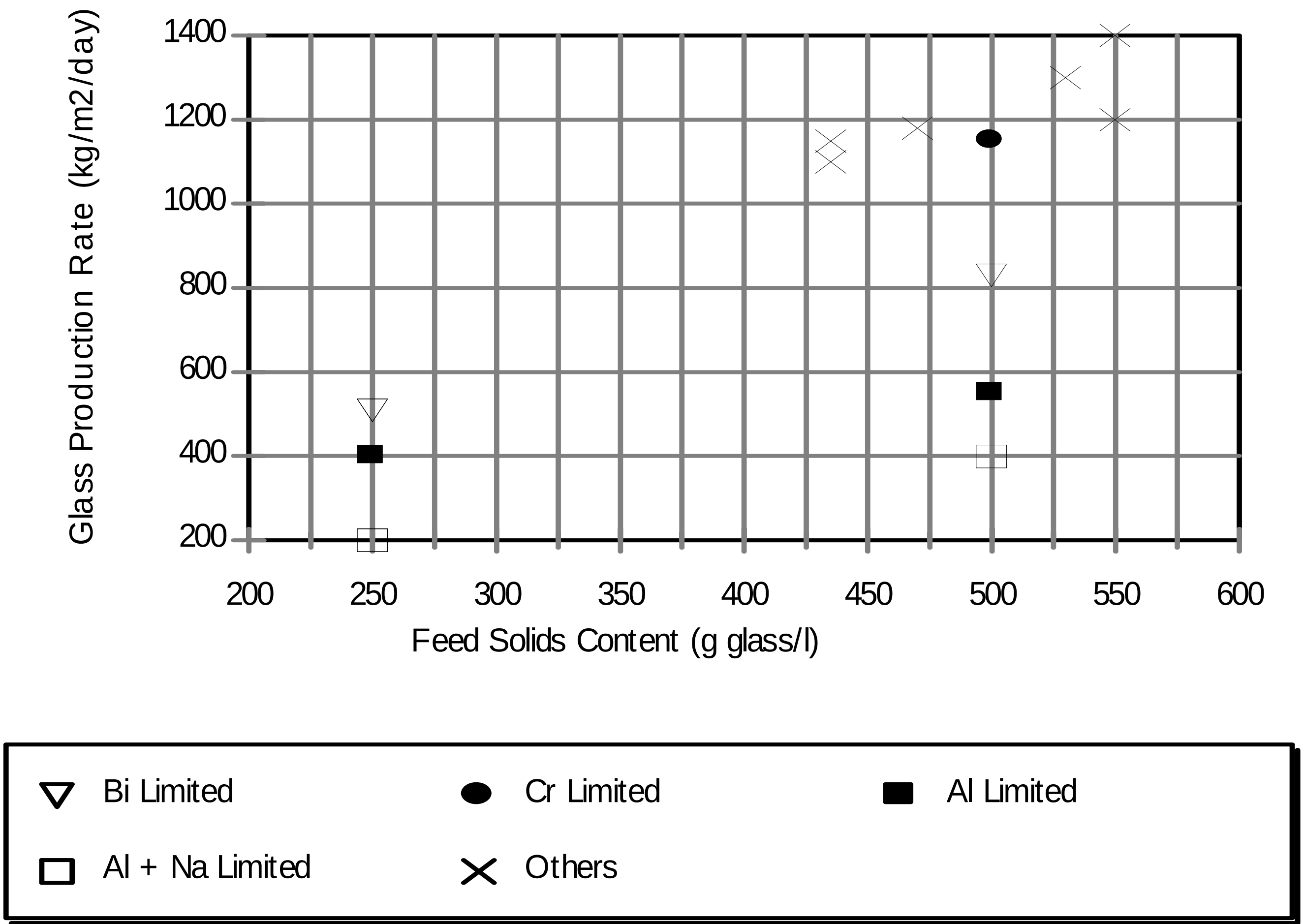


Figure 5.4. Steady-state glass production rates during DM100 tests vs. feed solids content; glass temperature 1150°C, glass pool bubbling rate 9 lpm.

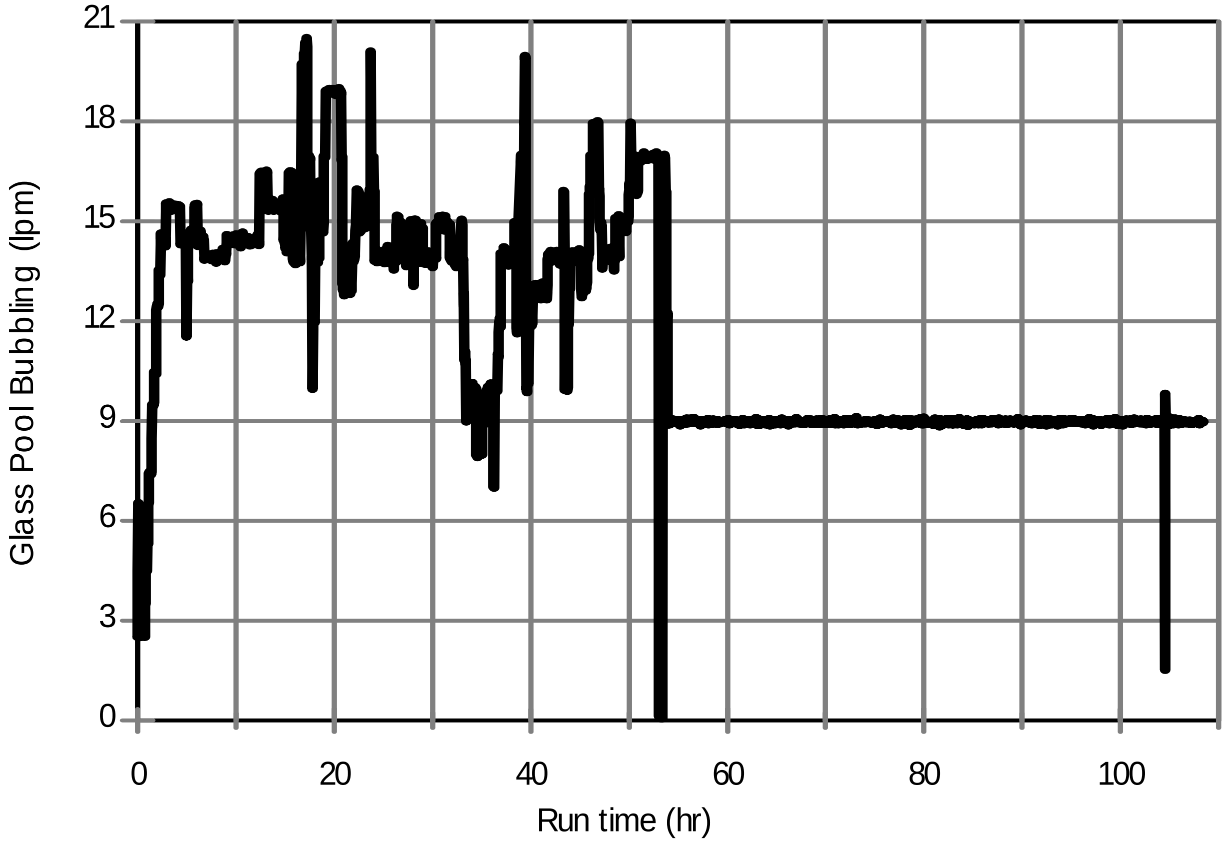


Figure 5.5.a. Glass pool bubbling rate for DM100 Tests 1A and 1B.

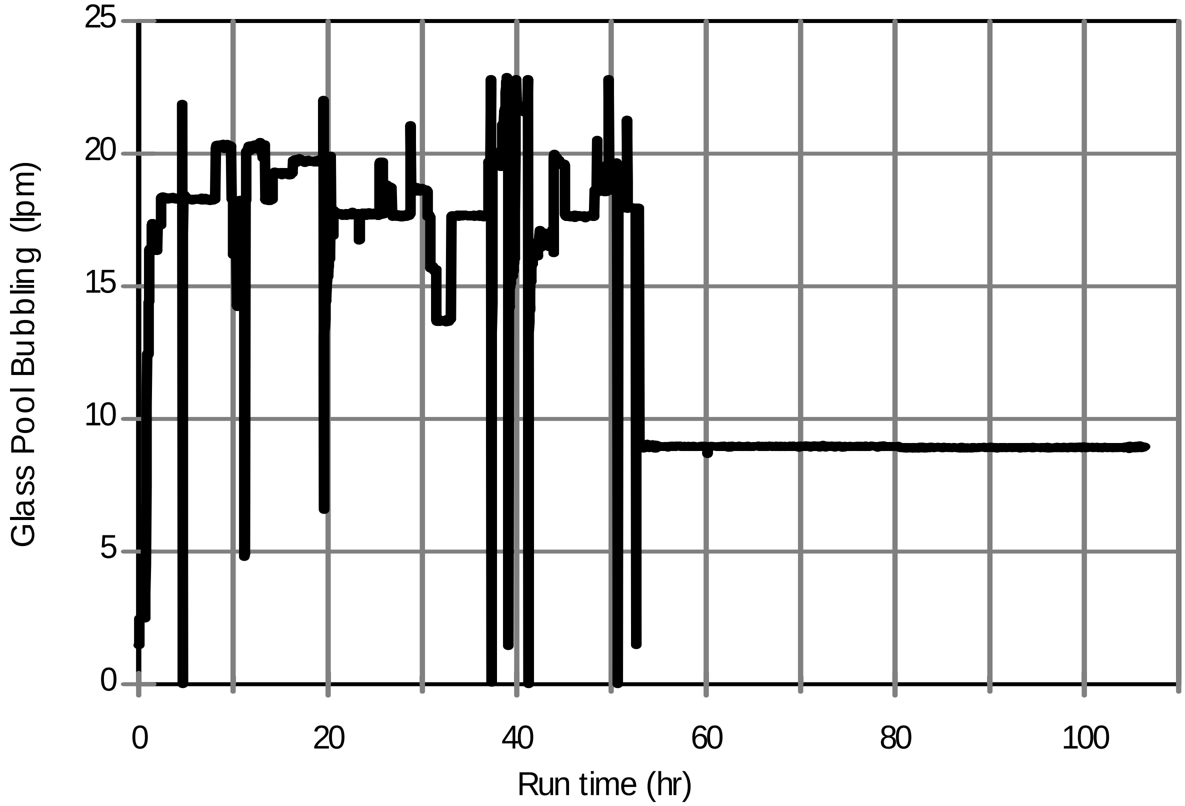


Figure 5.5.b. Glass pool bubbling rate for DM100 Tests 5A and 5B.

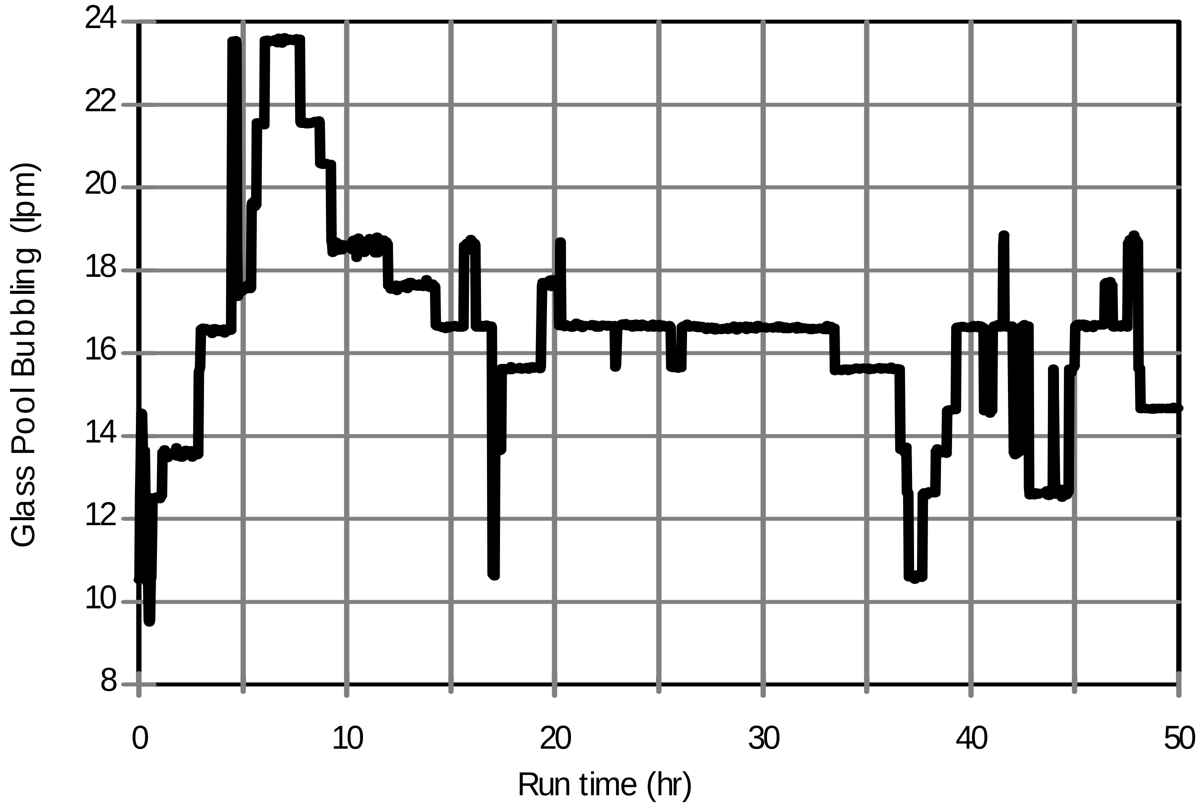


Figure 5.5.c. Glass pool bubbling rate for DM100 Test 6C.

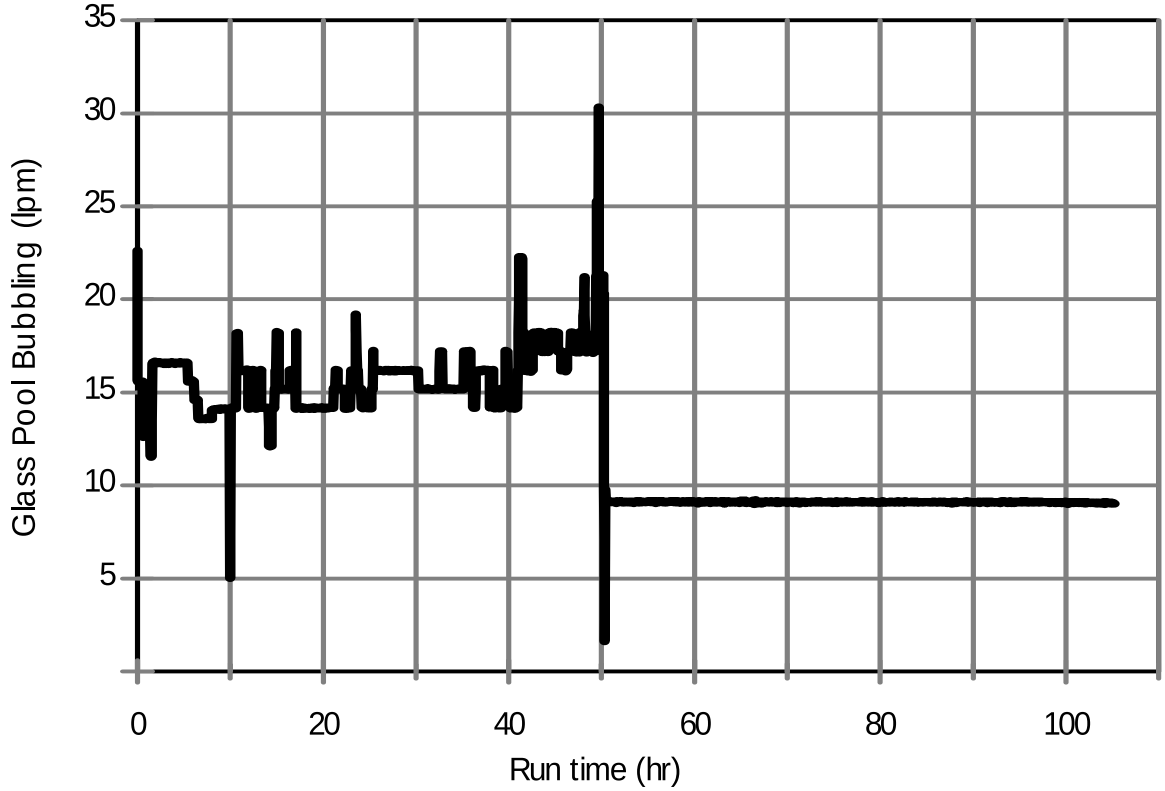


Figure 5.5.d. Glass pool bubbling rates for DM100 Tests 7A and 7B.

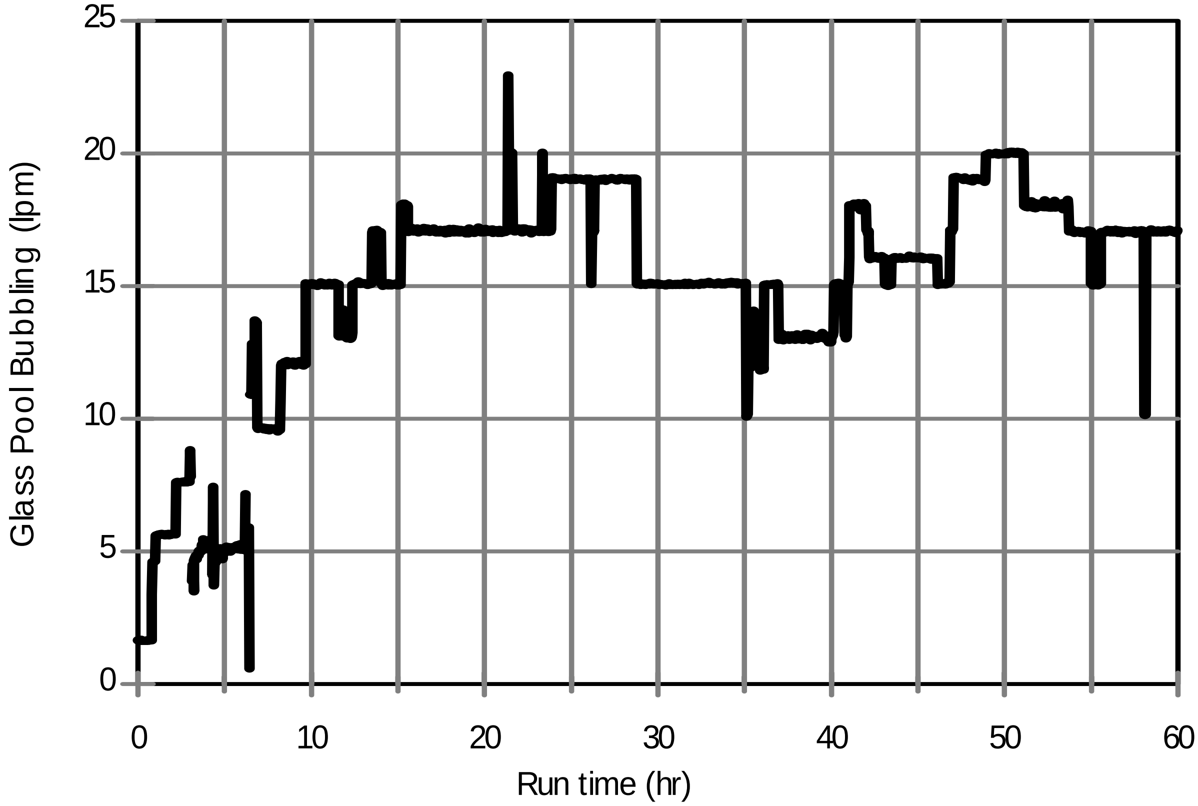


Figure 5.5.e. Glass pool bubbling rates for DM100 Test 8C.

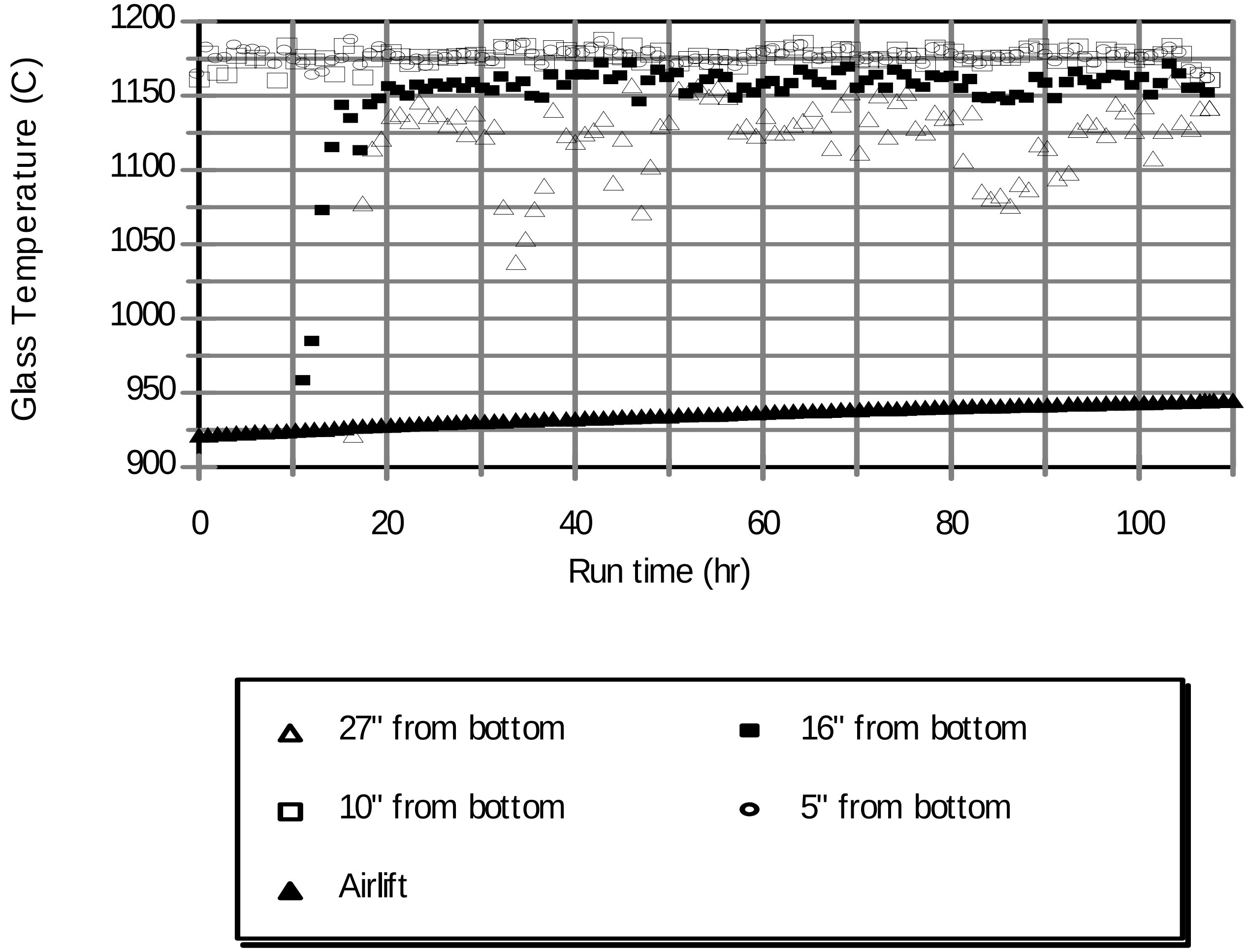


Figure 5.6.a. Glass temperatures (hourly averages) during DM100 Tests 1A and 1B.

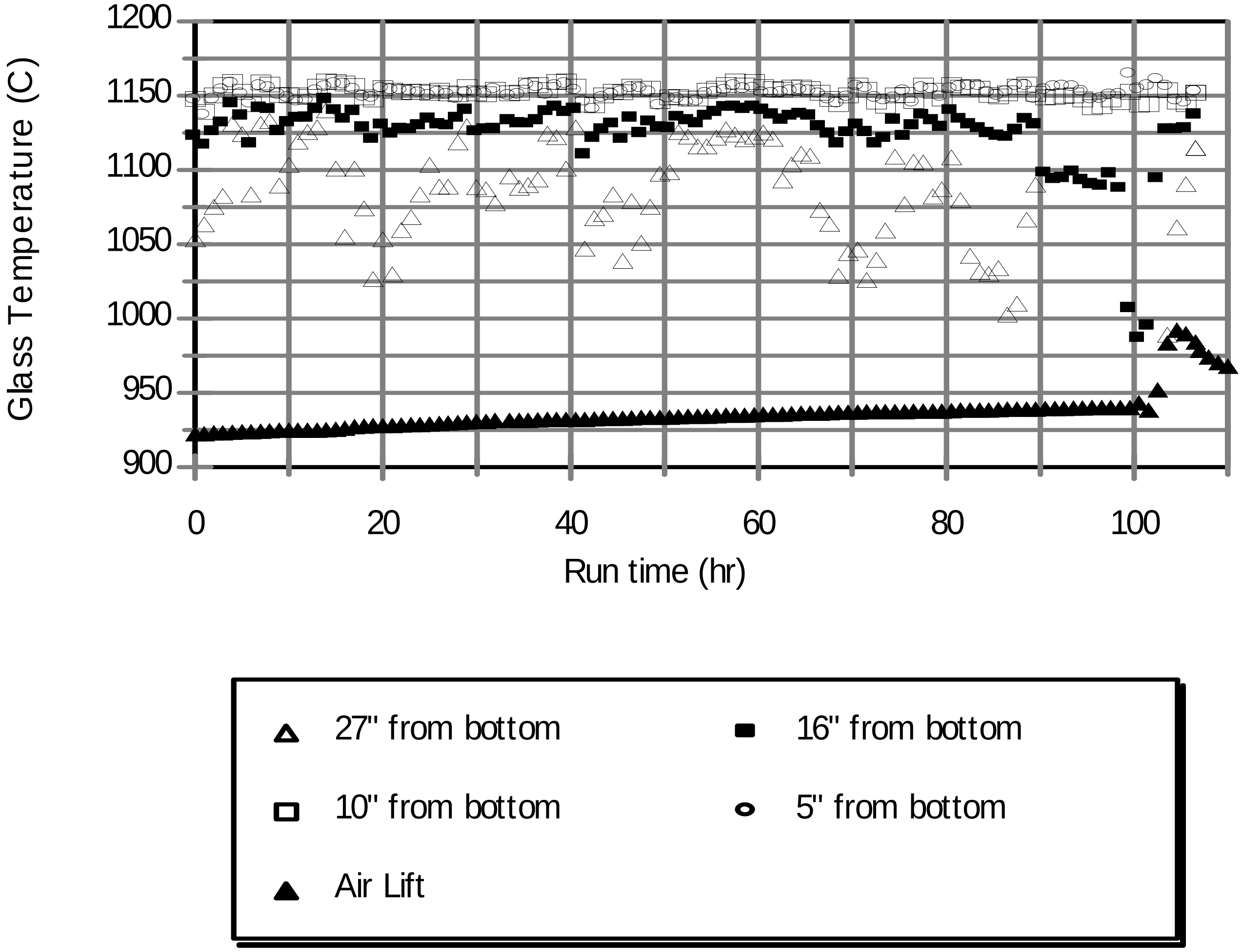


Figure 5.6.b. Glass temperatures (hourly averages) during DM100 Tests 2A and 2B.

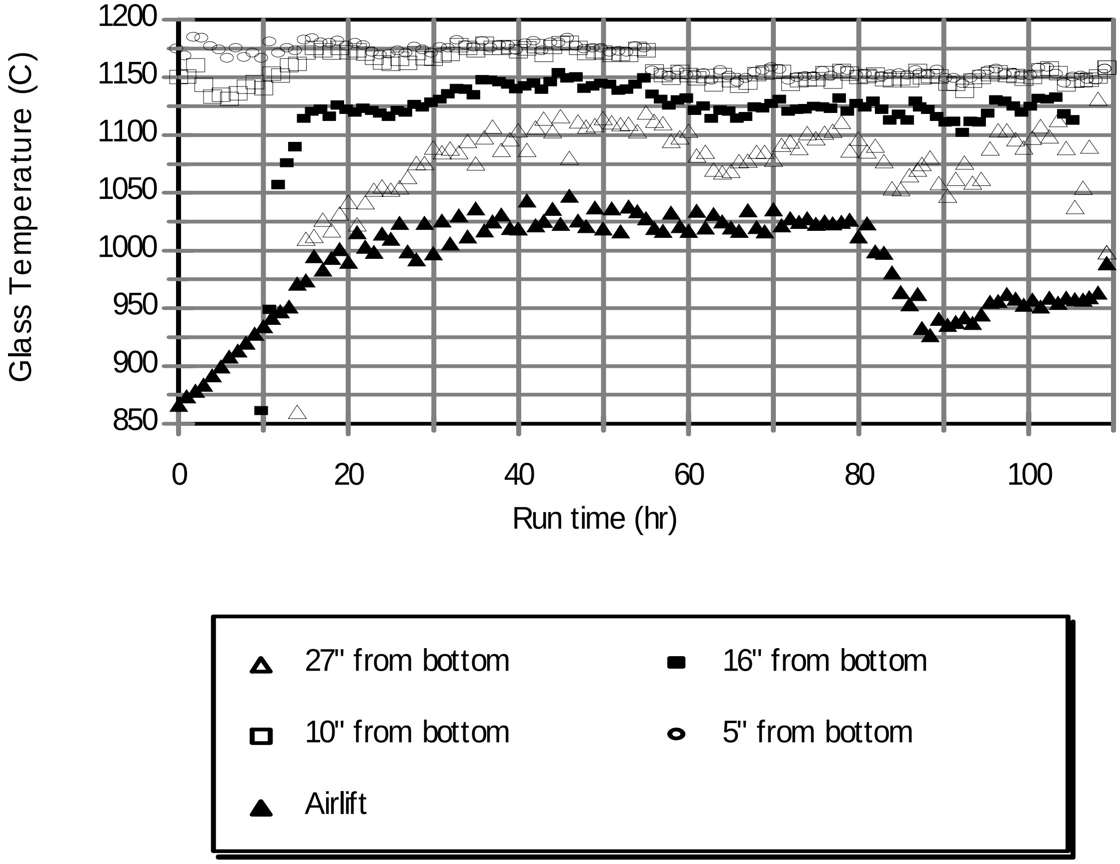


Figure 5.6.c. Glass temperatures (hourly averages) during DM100 Tests 3B and 4A.

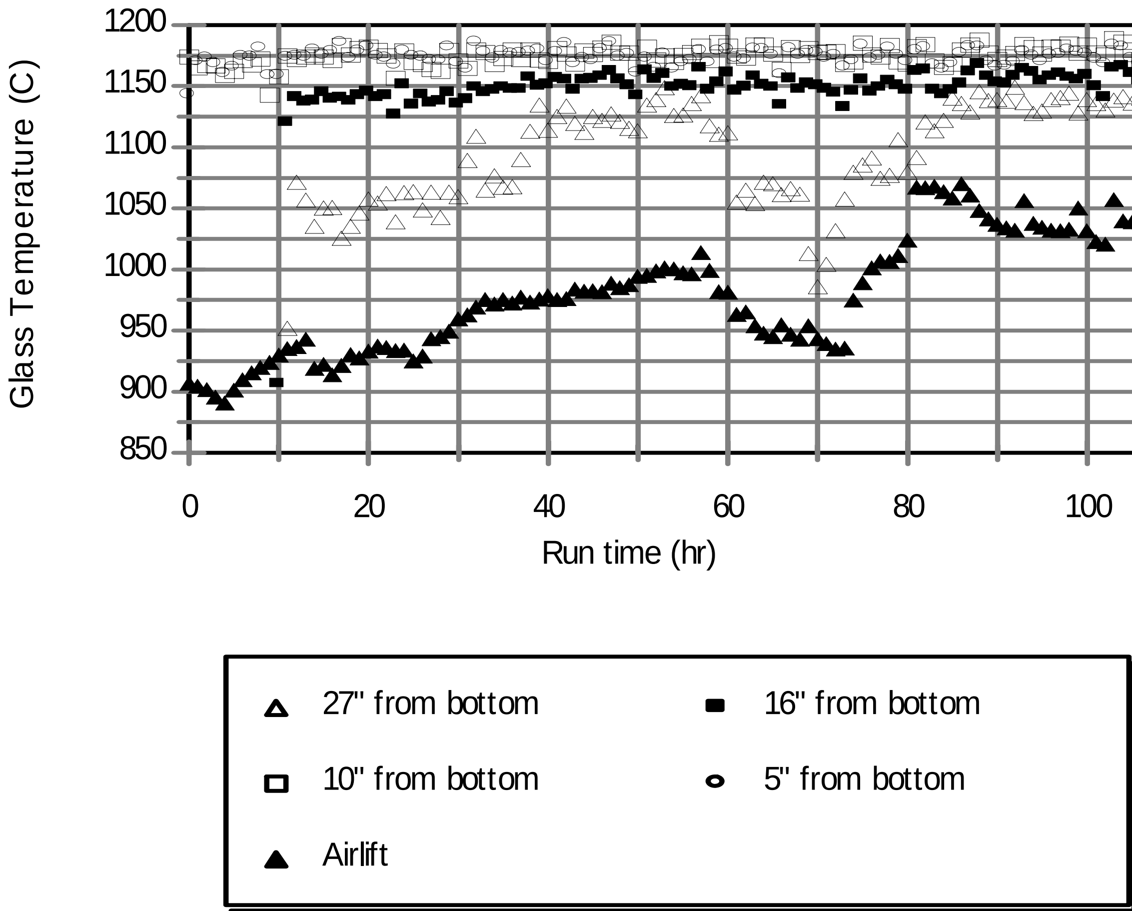


Figure 5.6.d. Glass temperatures (hourly averages) during DM100 Tests 5A and 5B.

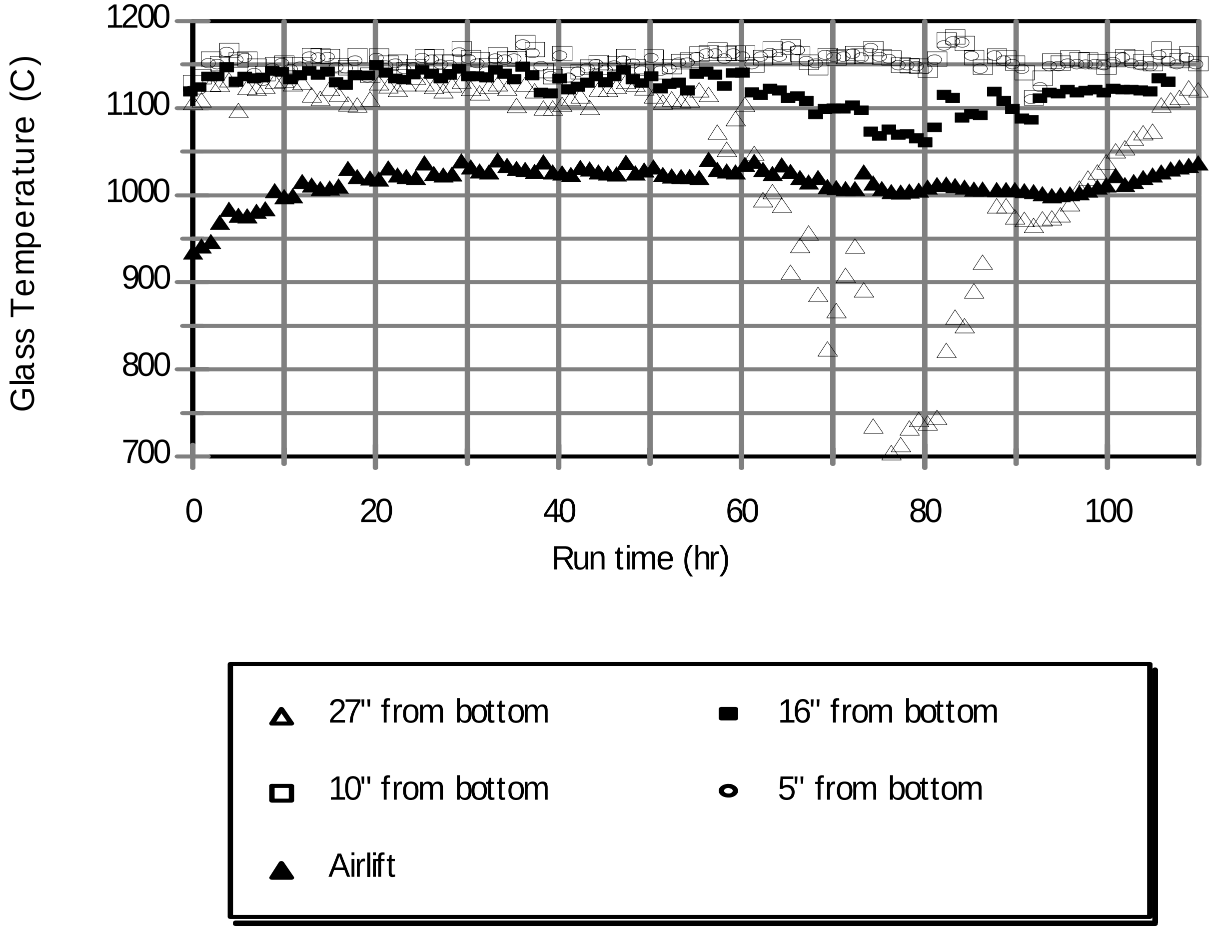


Figure 5.6.e. Glass temperatures (hourly averages) during DM100 Tests 6A and 6B.

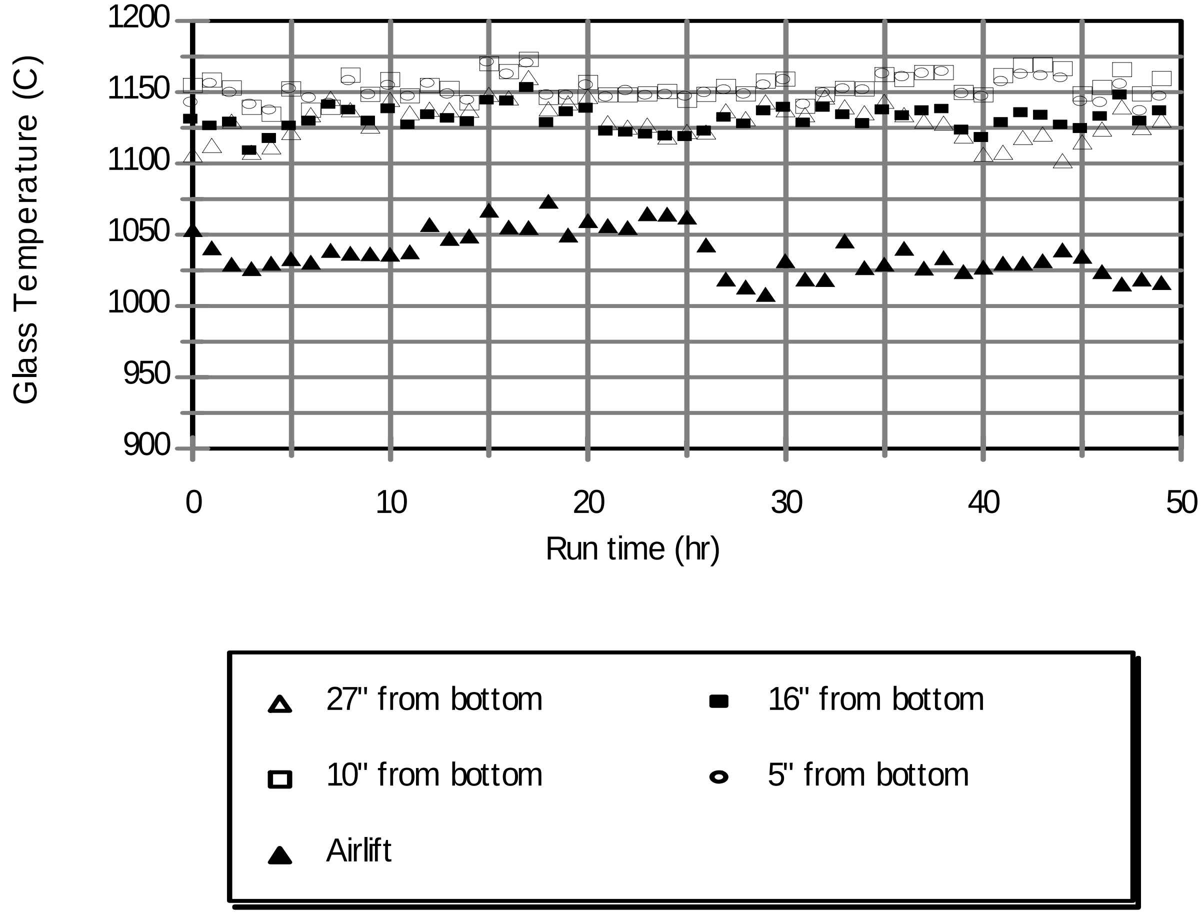


Figure 5.6.f. Glass temperatures (hourly averages) during DM100 Test 6C.

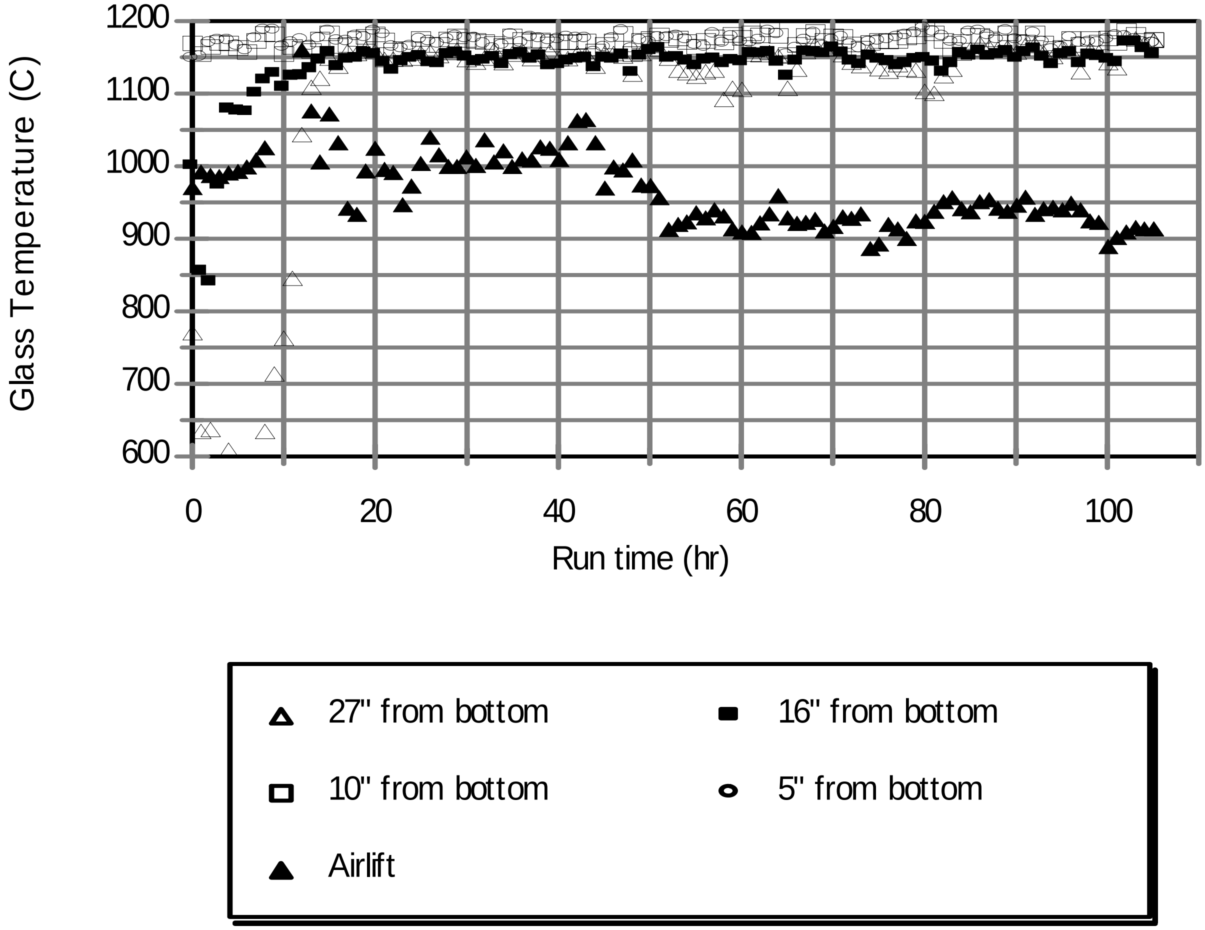


Figure 5.6.g. Glass temperatures (hourly averages) during DM100 Tests 7A and 7B.

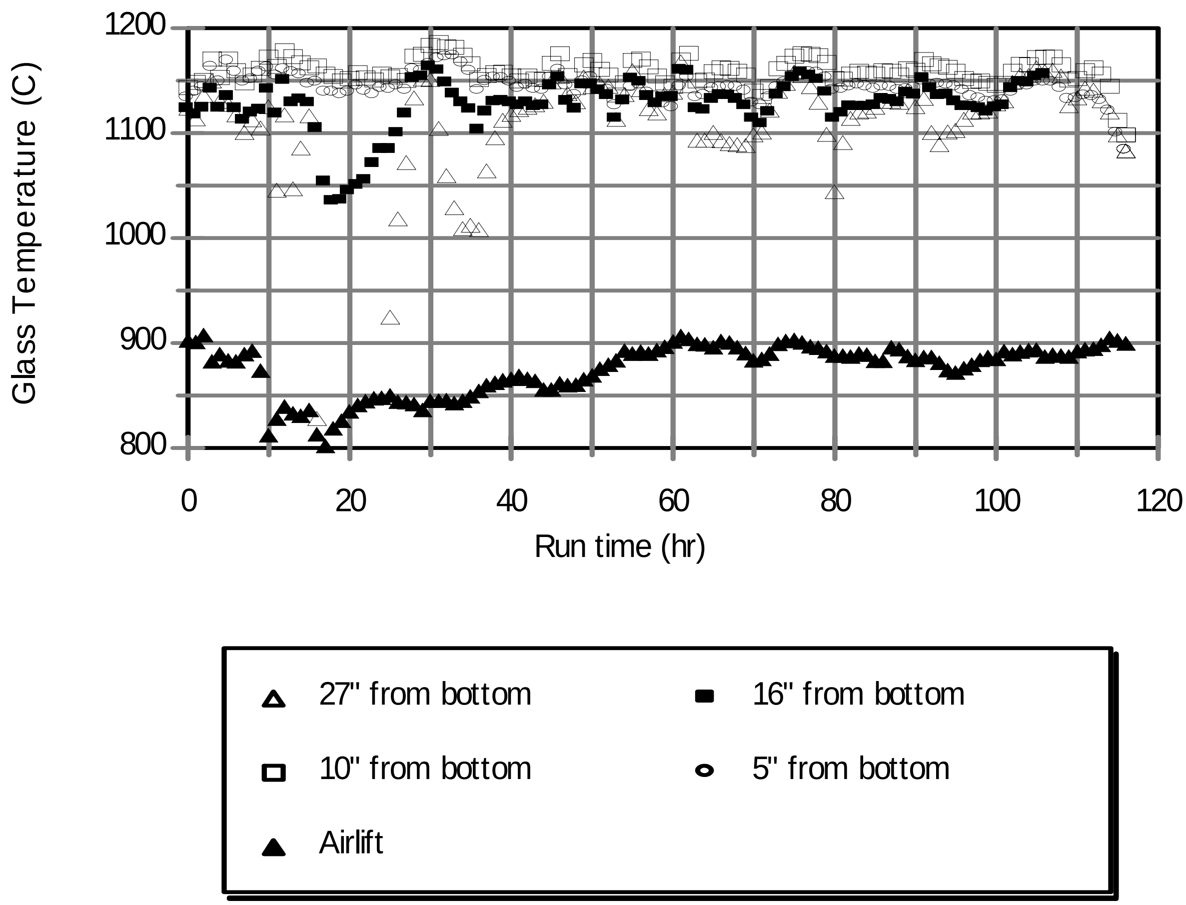


Figure 5.6.h. Glass temperatures (hourly averages) during DM100 Tests 8A and 8B.

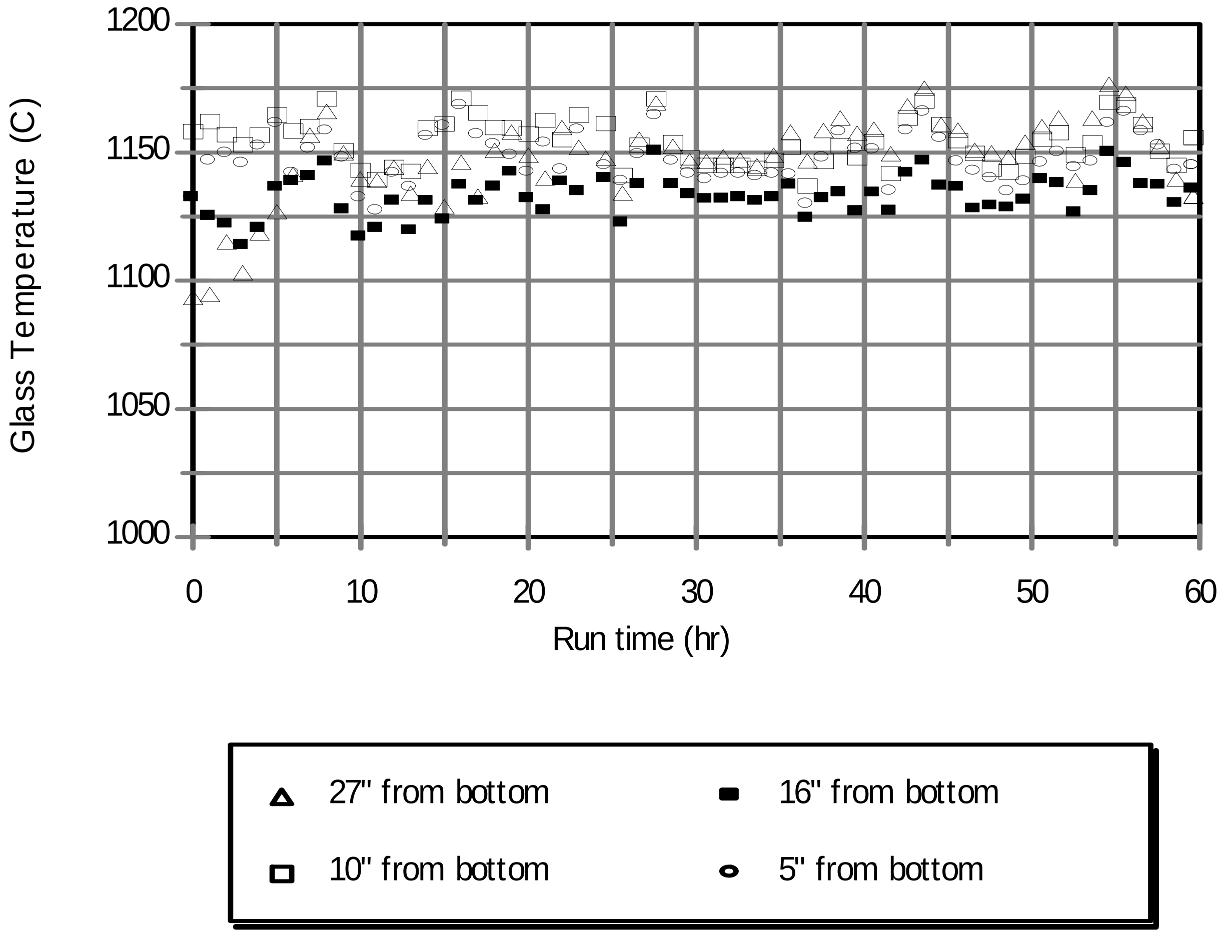


Figure 5.6.i. Glass temperatures (hourly averages) during DM100 Test 8C.

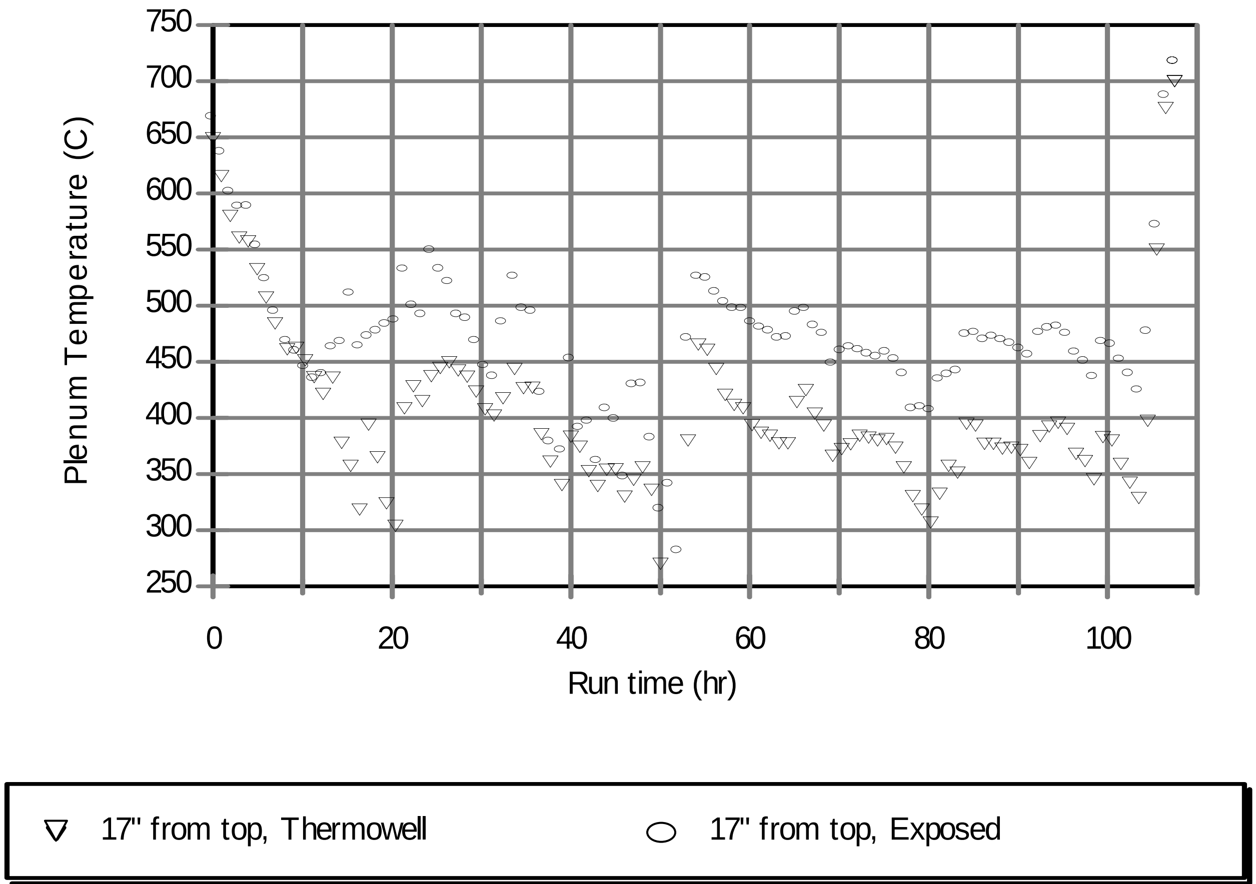


Figure 5.7.a. Plenum temperatures (hourly averages) during DM100 Tests 1A and 1B.

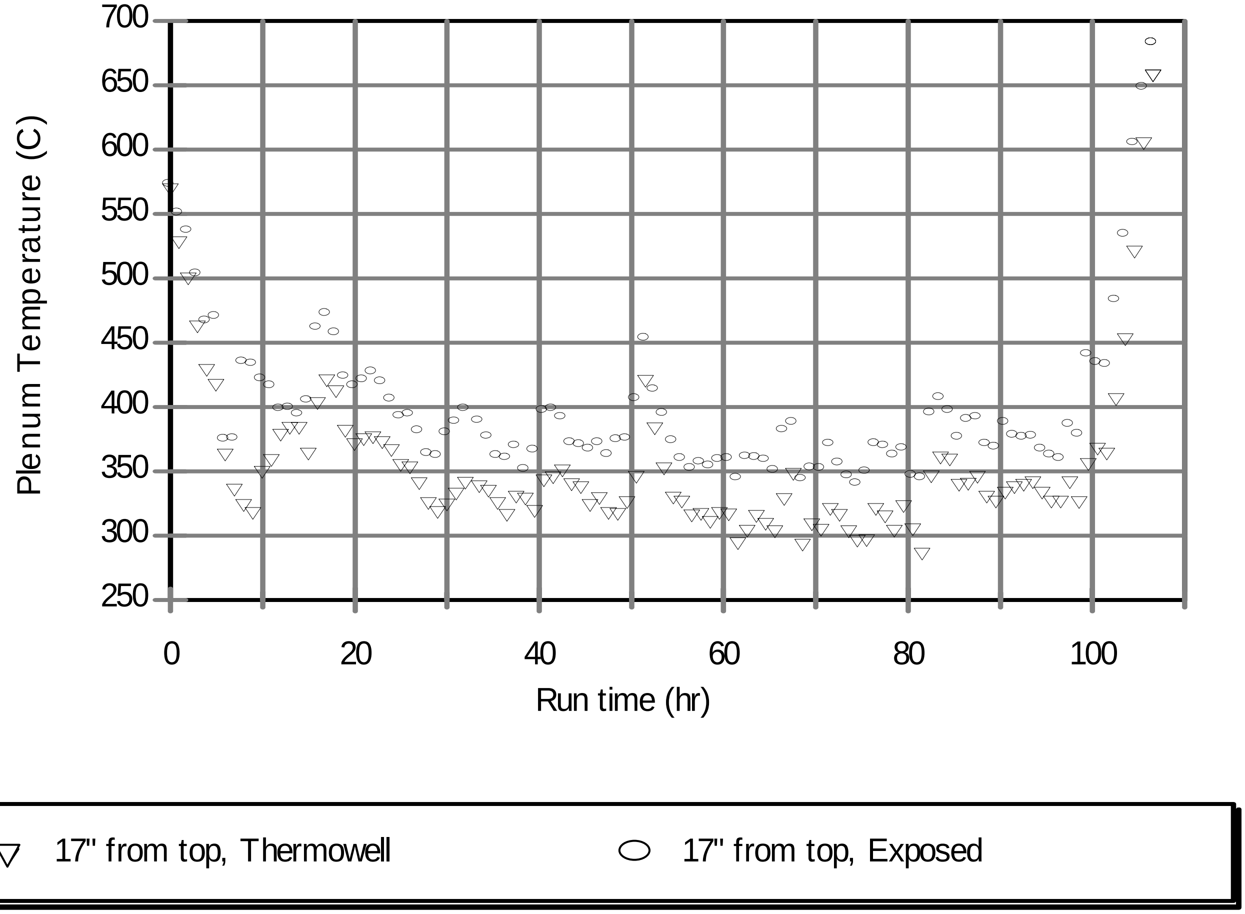


Figure 5.7.b. Plenum temperatures (hourly averages) during DM100 Tests 2A and 2B.

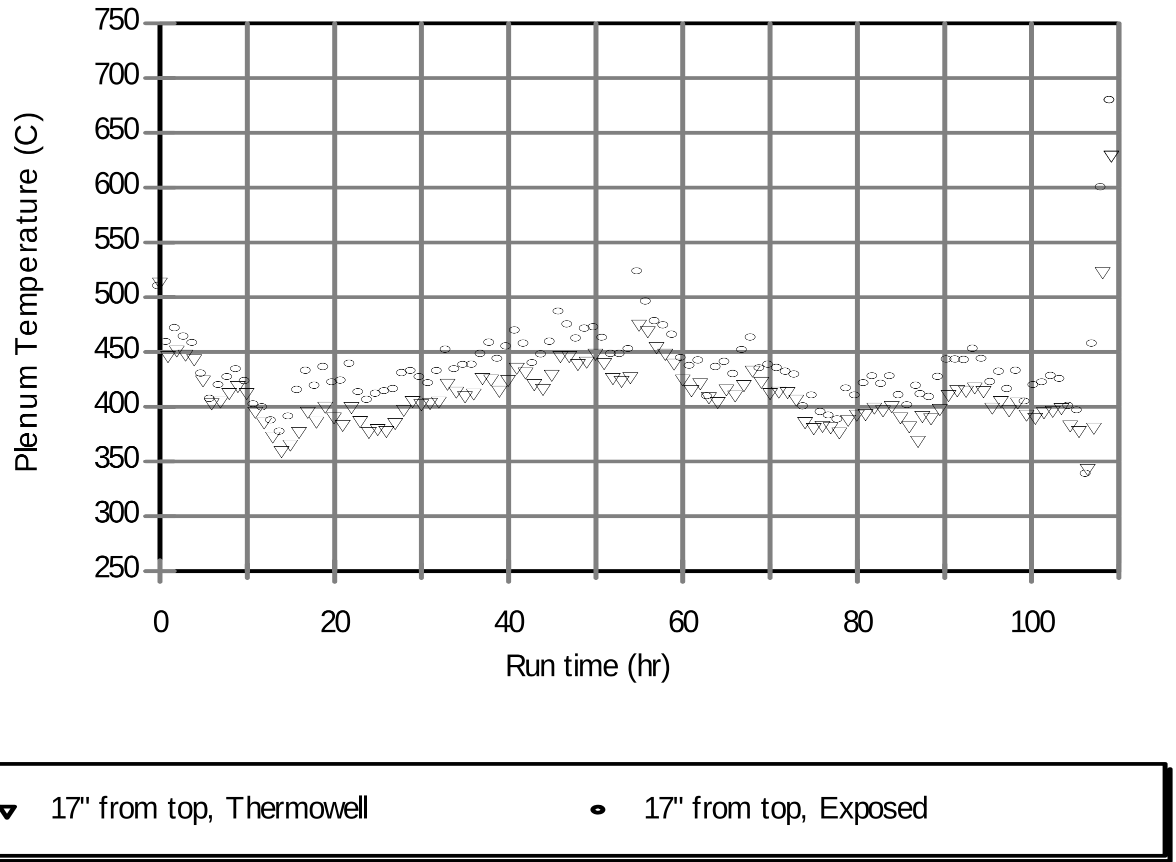


Figure 5.7.c. Plenum temperatures (hourly averages) during DM100 Tests 3B and 4A.

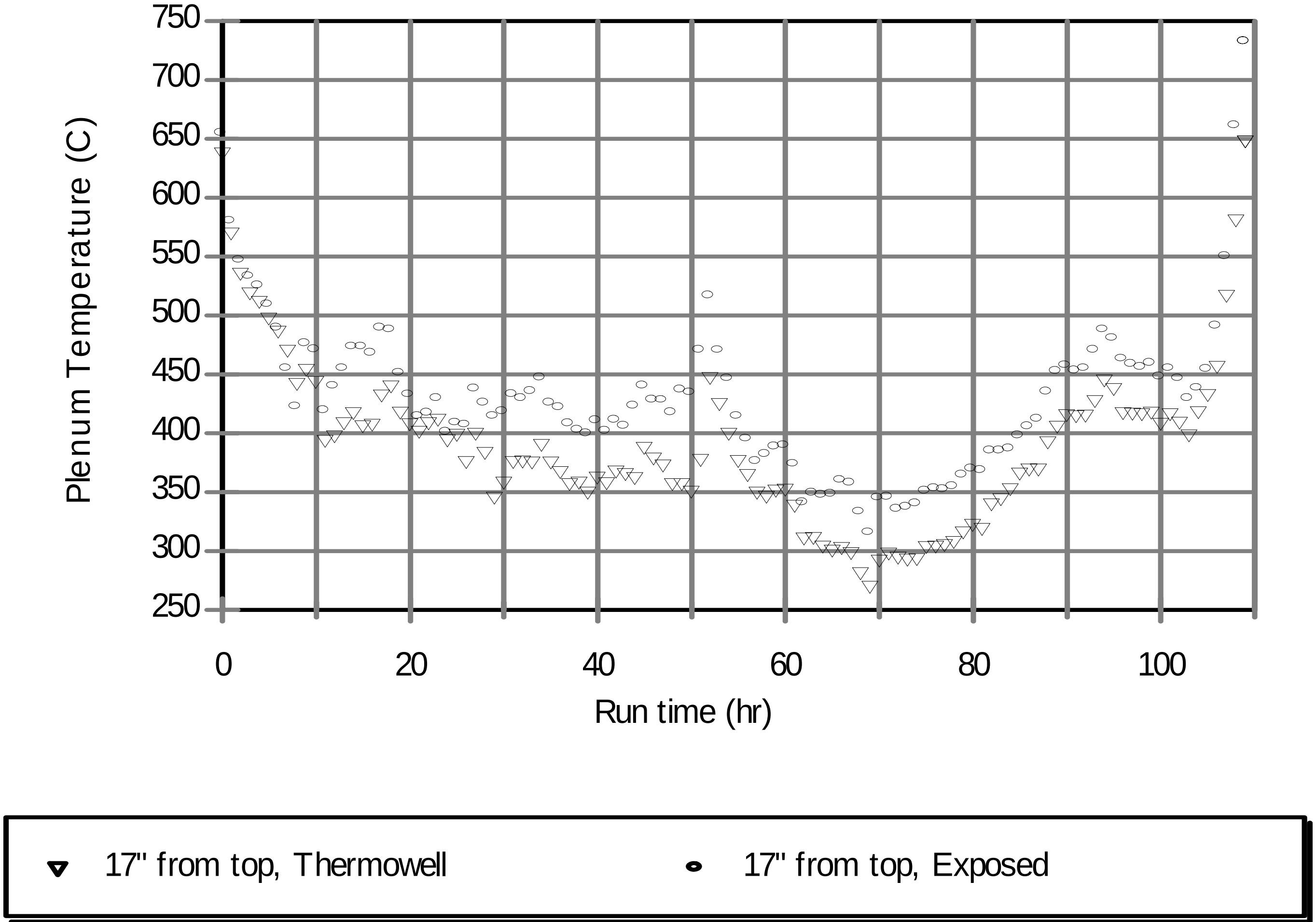


Figure 5.7.d. Plenum temperatures (hourly averages) during DM100 Tests 5A and 5B.

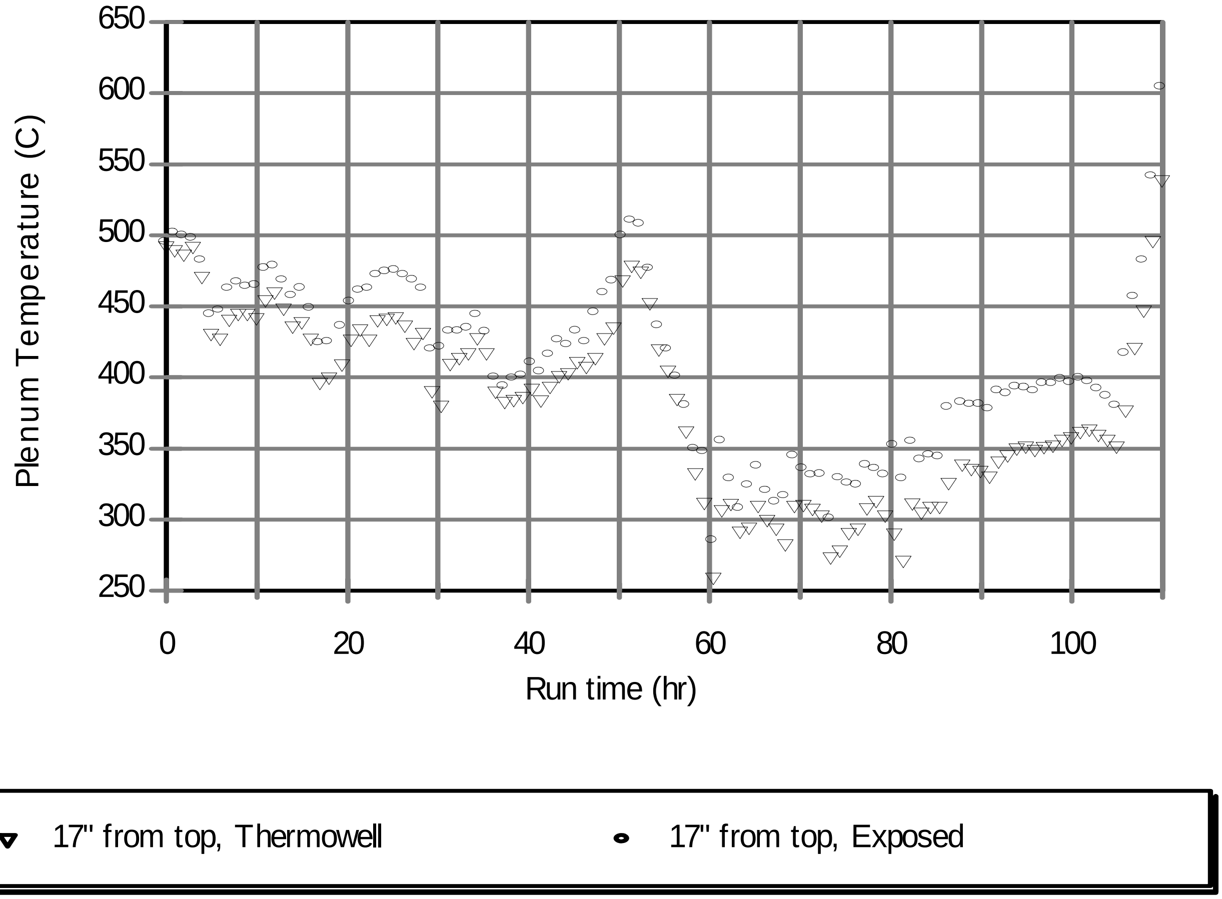


Figure 5.7.e. Plenum temperatures (hourly averages) during DM100 Tests 6A and 6B.

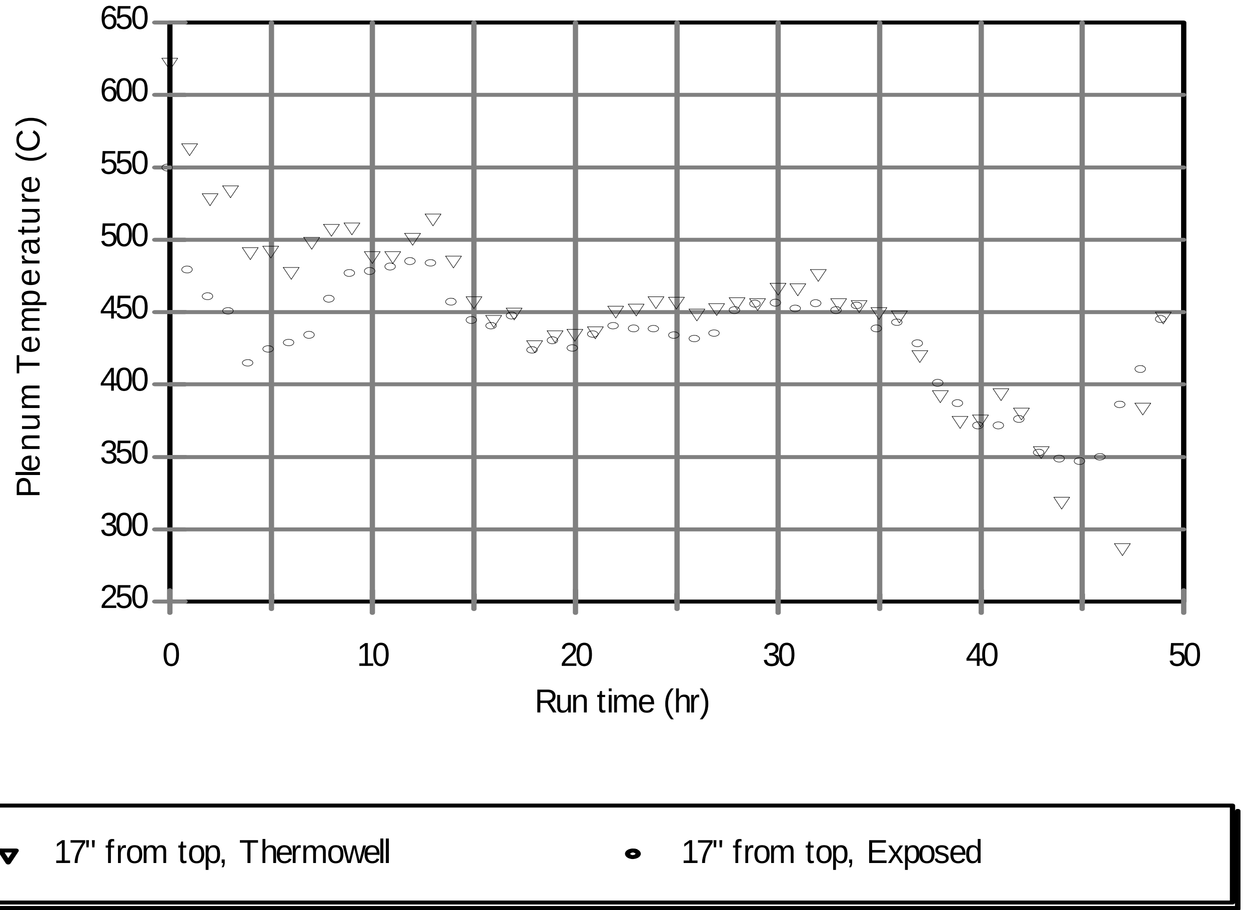


Figure 5.7.f. Plenum temperatures (hourly averages) during DM100 Test 6C.

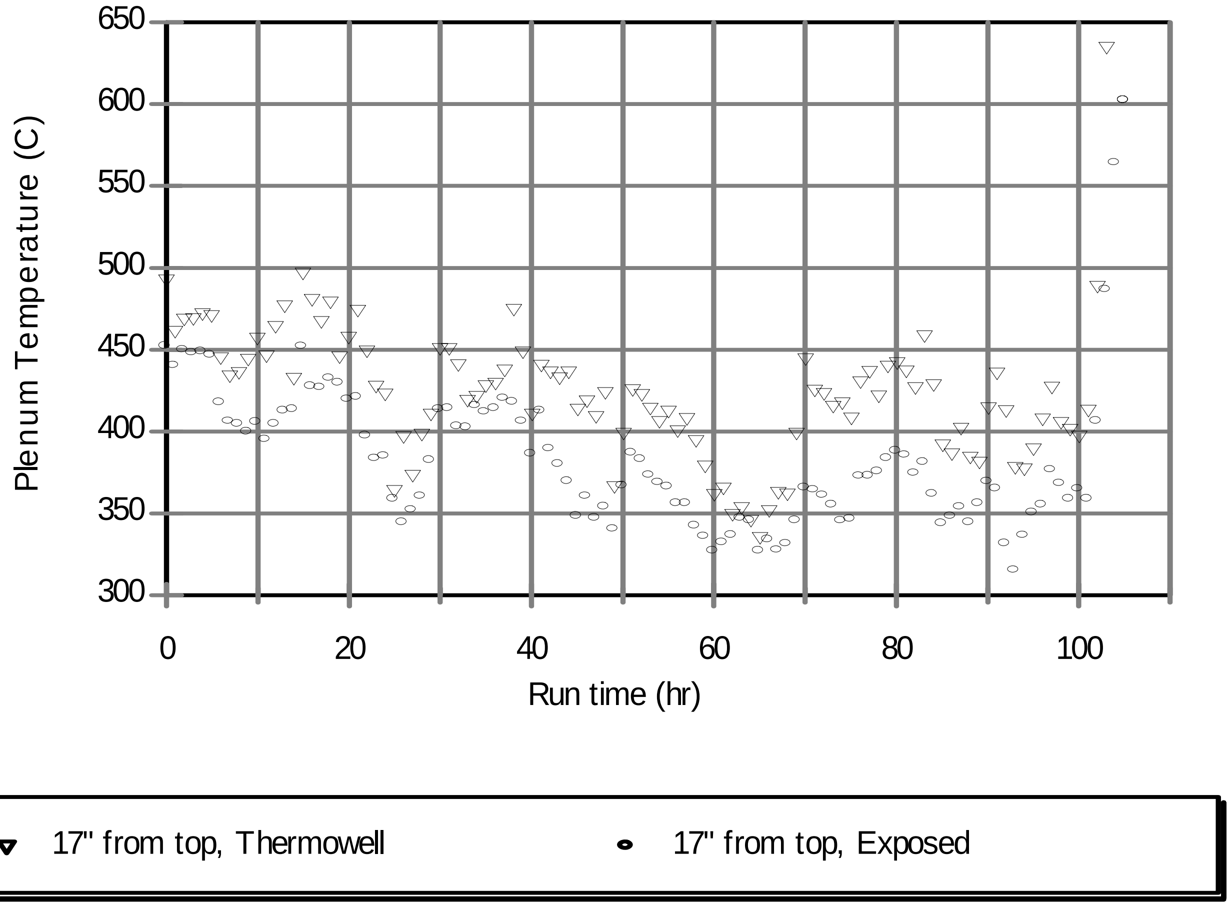


Figure 5.7.g. Plenum temperatures (hourly averages) during DM100 Tests 7A and 7B.

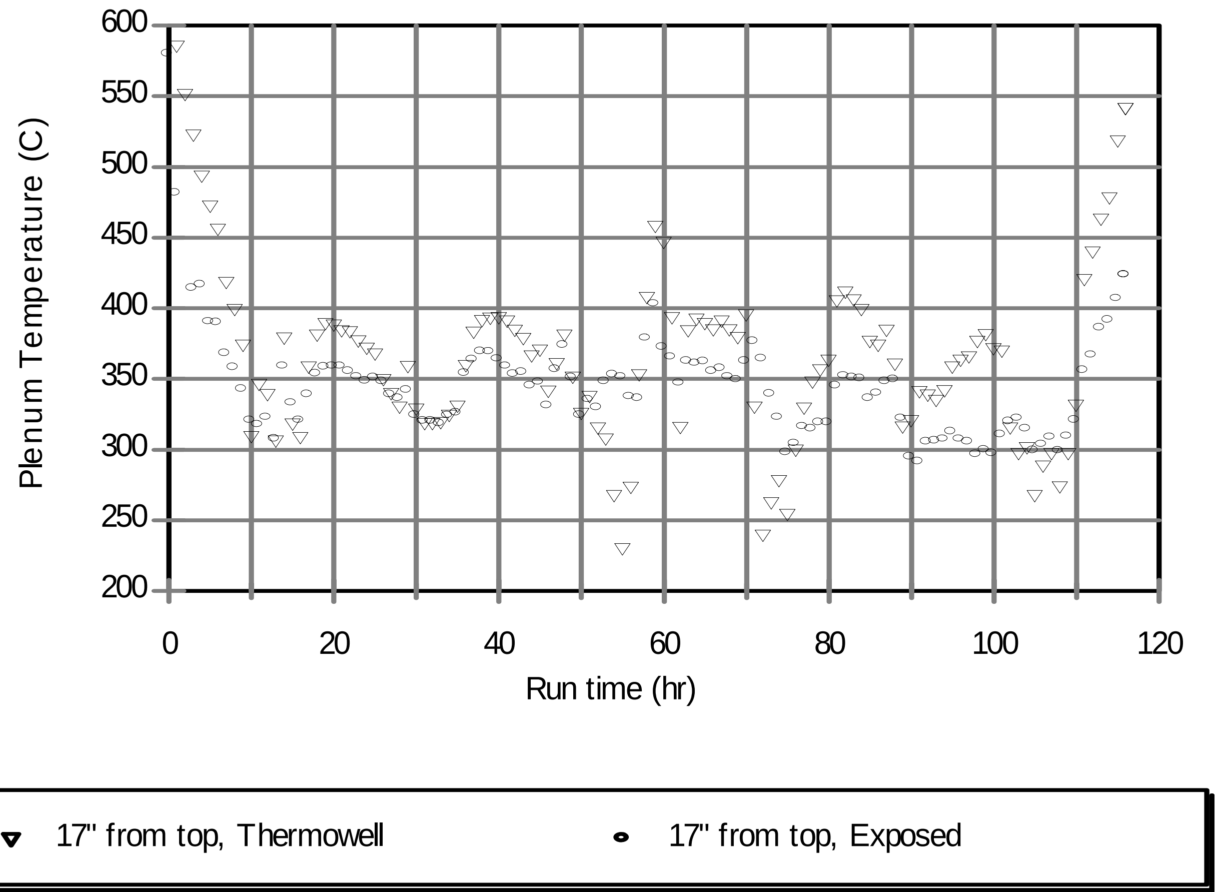


Figure 5.7.h. Plenum temperatures (hourly averages) during DM100 Tests 8A and 8B.

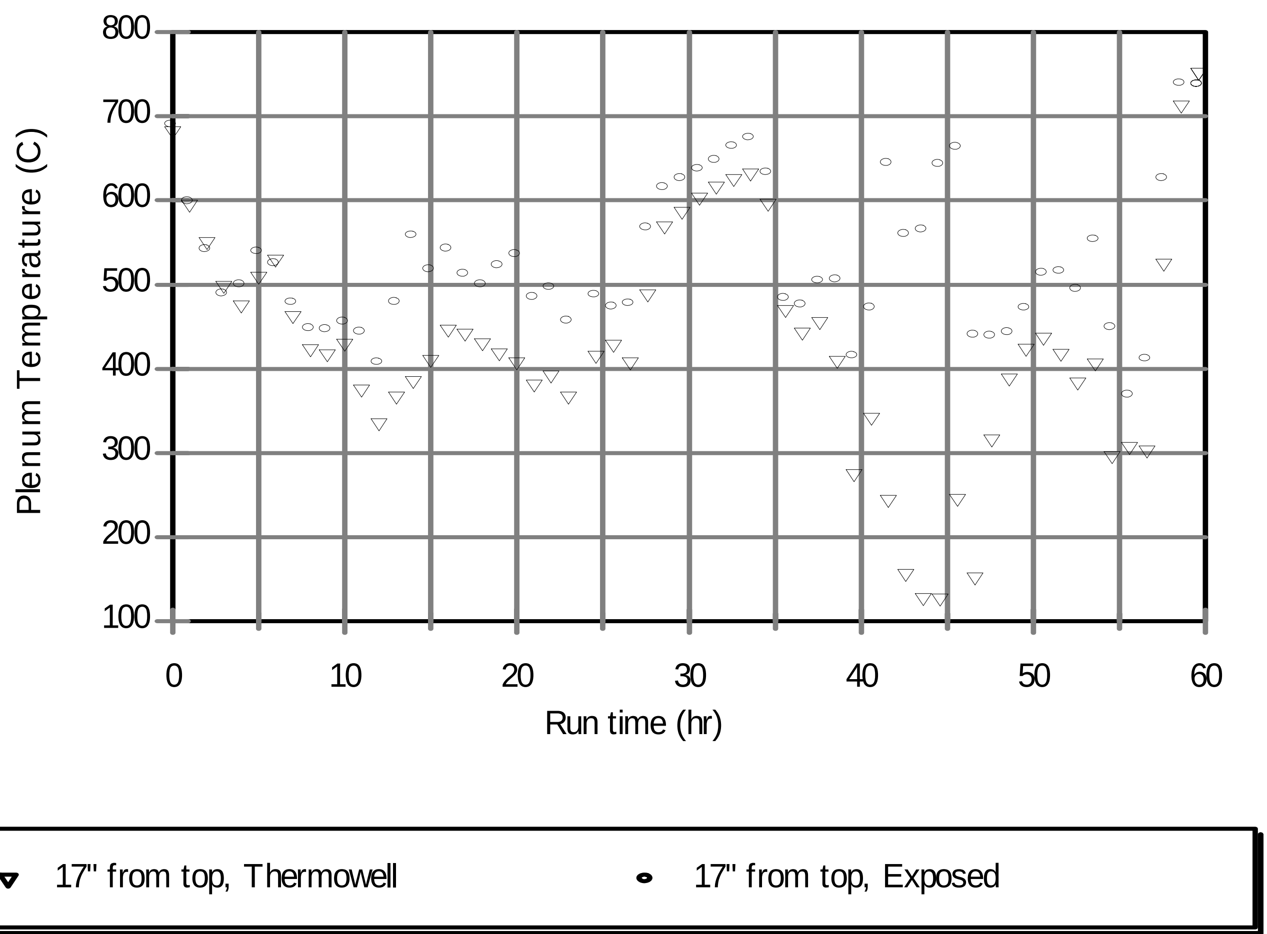


Figure 5.7.i. Plenum temperatures (hourly averages) during DM100 Test 8C.

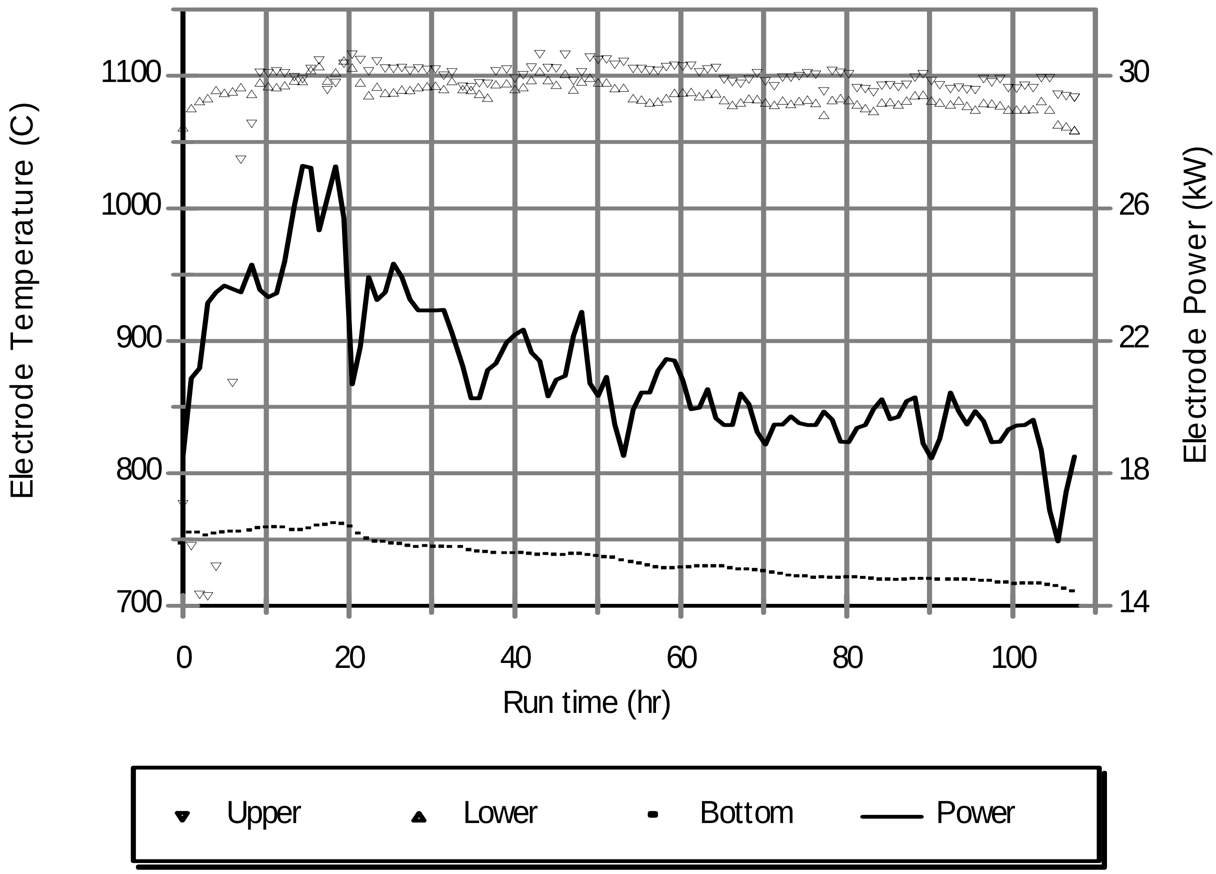


Figure 5.8.a. Electrode temperatures and power (hourly averages) during DM100 Tests 1A and 1B.

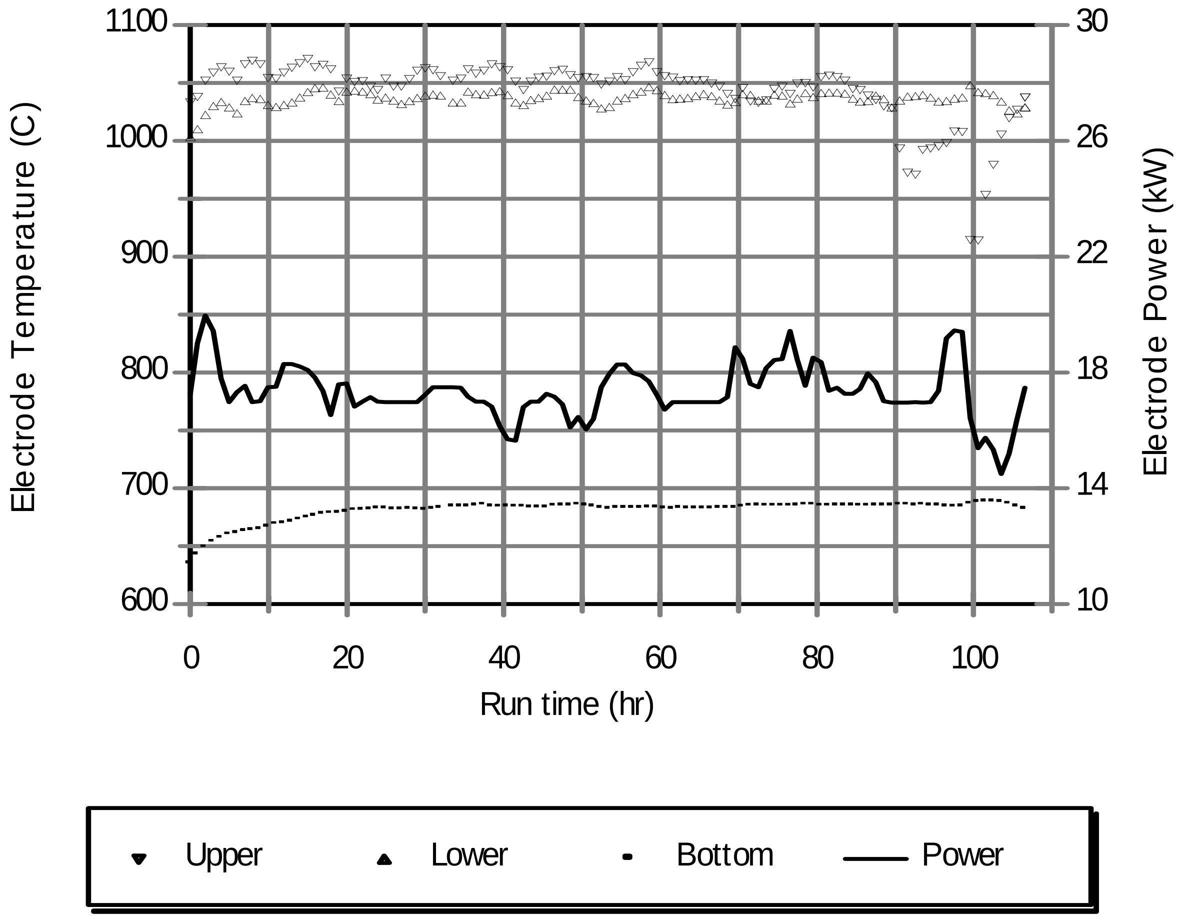


Figure 5.8.b. Electrode temperatures and power (hourly averages) during DM100 Tests 2A and 2B.

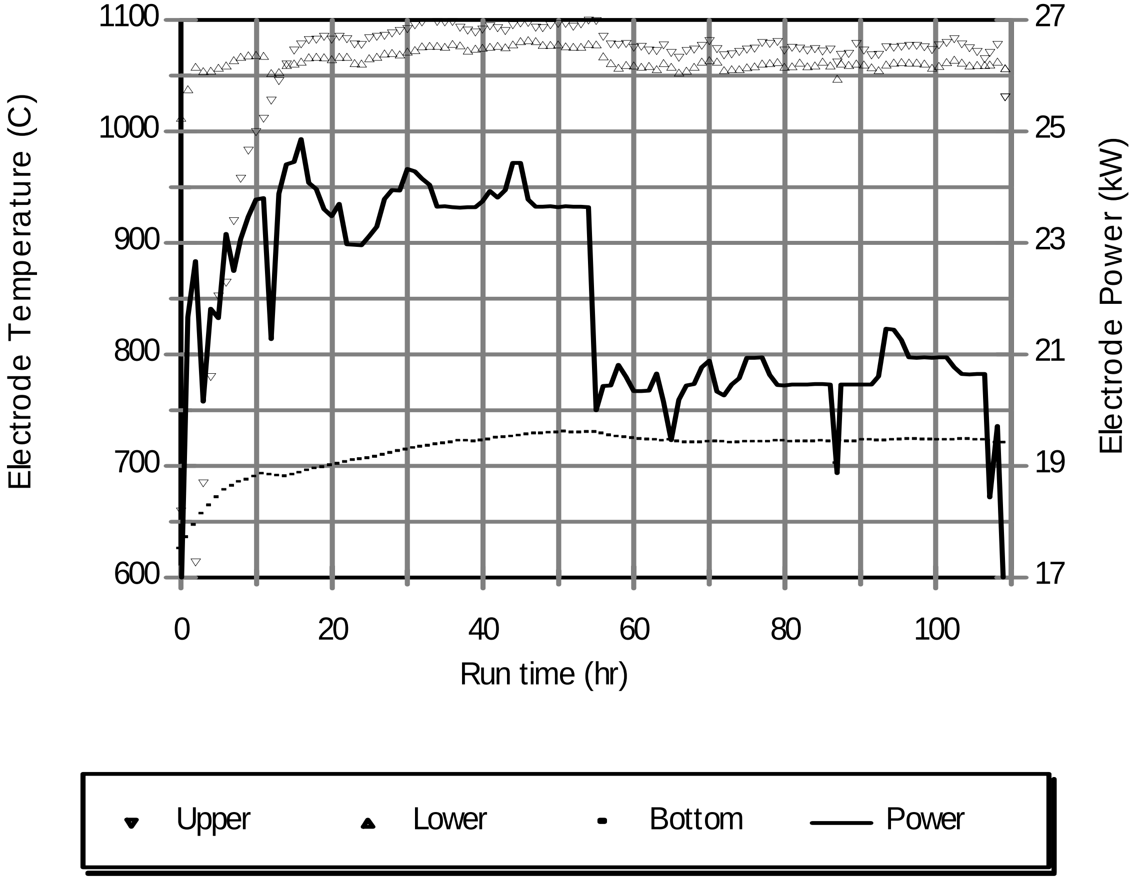


Figure 5.8.c. Electrode temperatures and power (hourly averages) during DM100 Tests 3B and 4A.

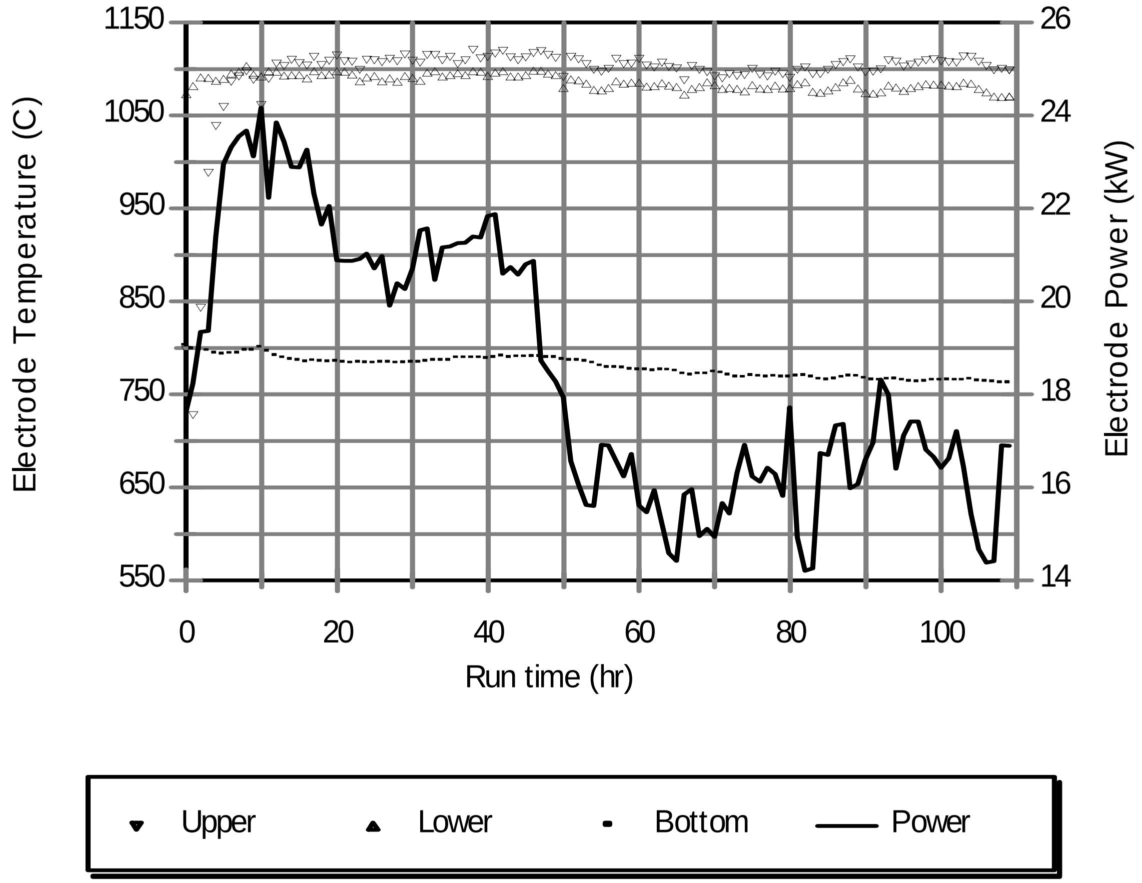


Figure 5.8.d. Electrode temperatures and power (hourly averages) during DM100 Tests 5A and 5B.

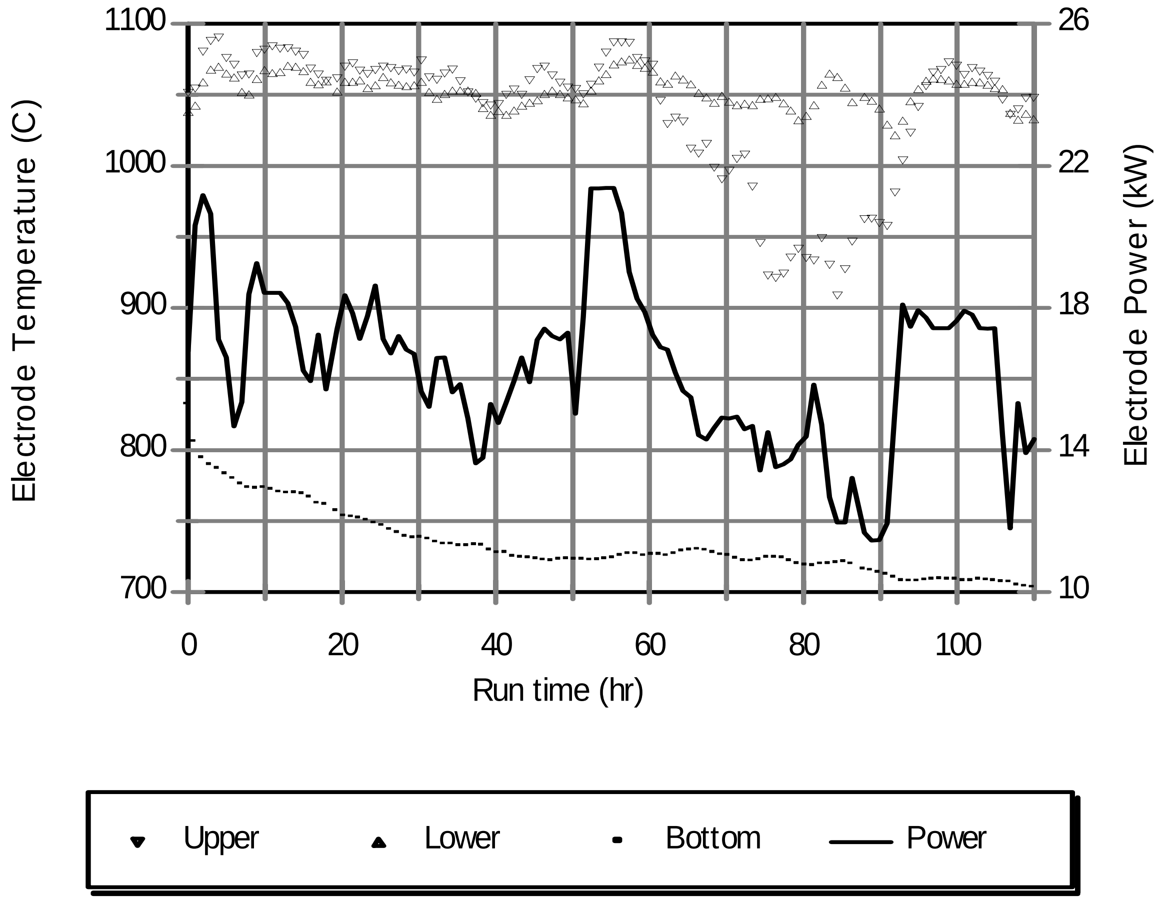


Figure 5.8.e. Electrode temperatures and power (hourly averages) during DM100 Tests 6A and 6B.

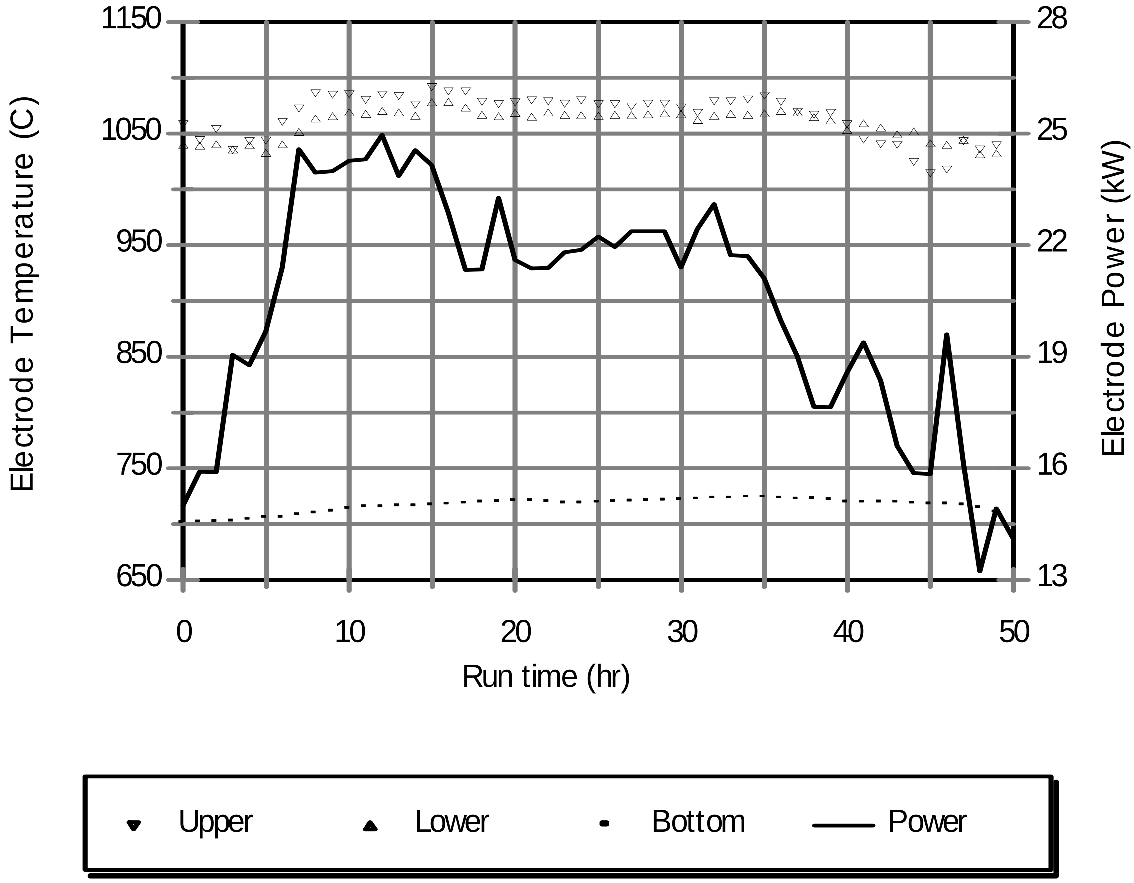


Figure 5.8.f. Electrode temperatures and power (hourly averages) during DM100 Test 6C.

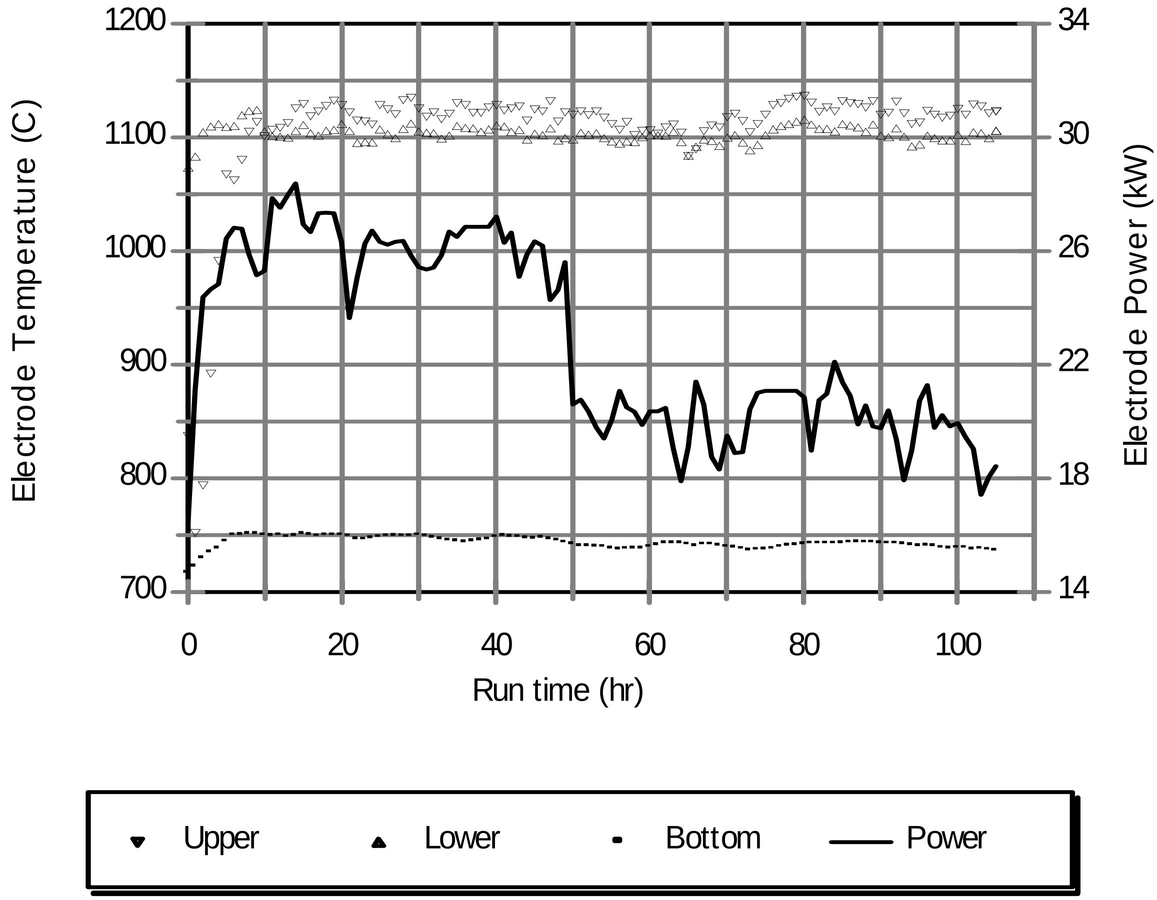


Figure 5.8.g. Electrode temperatures and power (hourly averages) during DM100 Tests 7A and 7B.

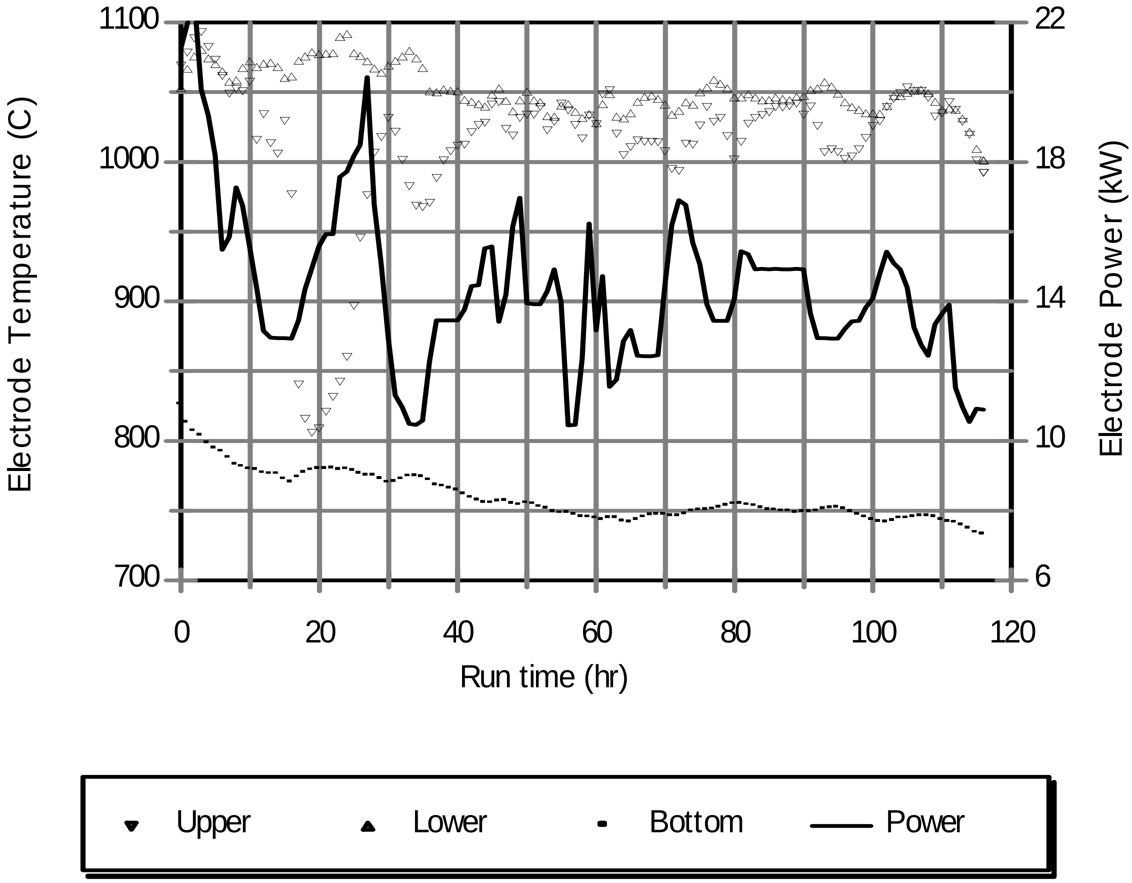


Figure 5.8.h. Electrode temperatures and power (hourly averages) during DM100 Tests 8A and 8B.

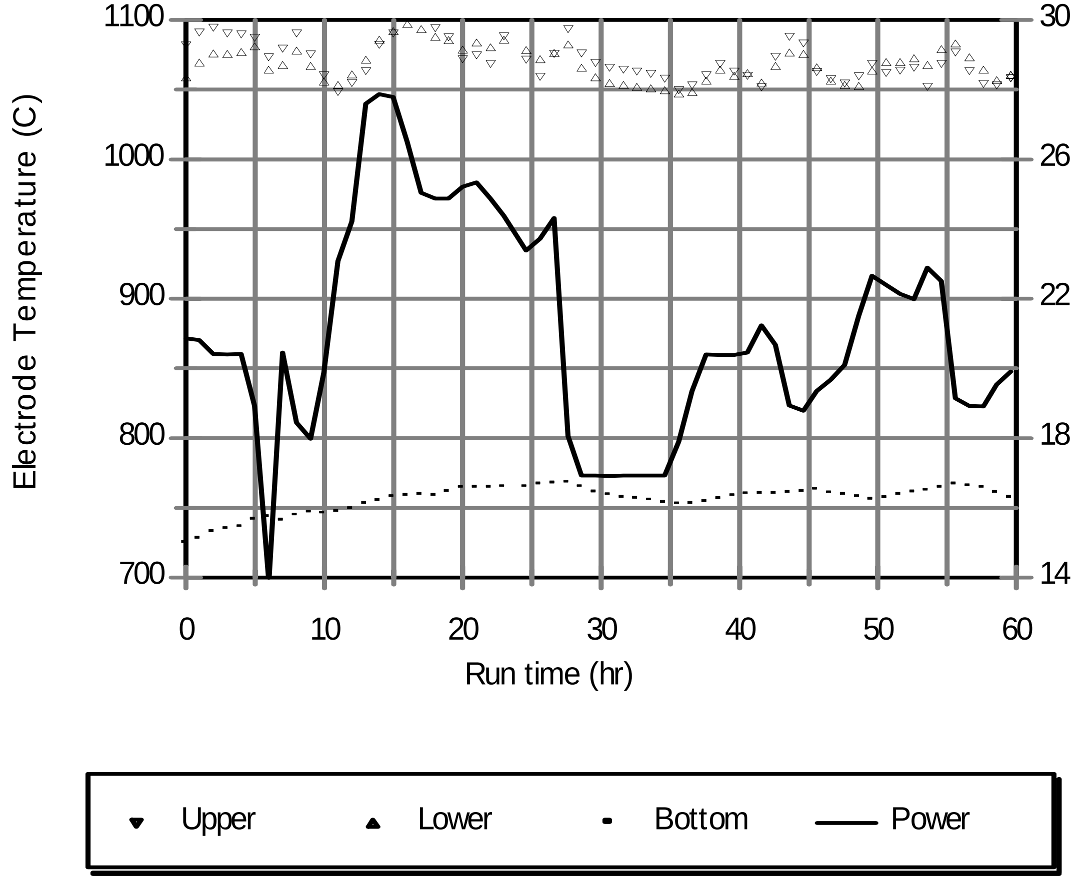


Figure 5.8.i. Electrode temperatures and power (hourly averages) during DM100 Test 8C.

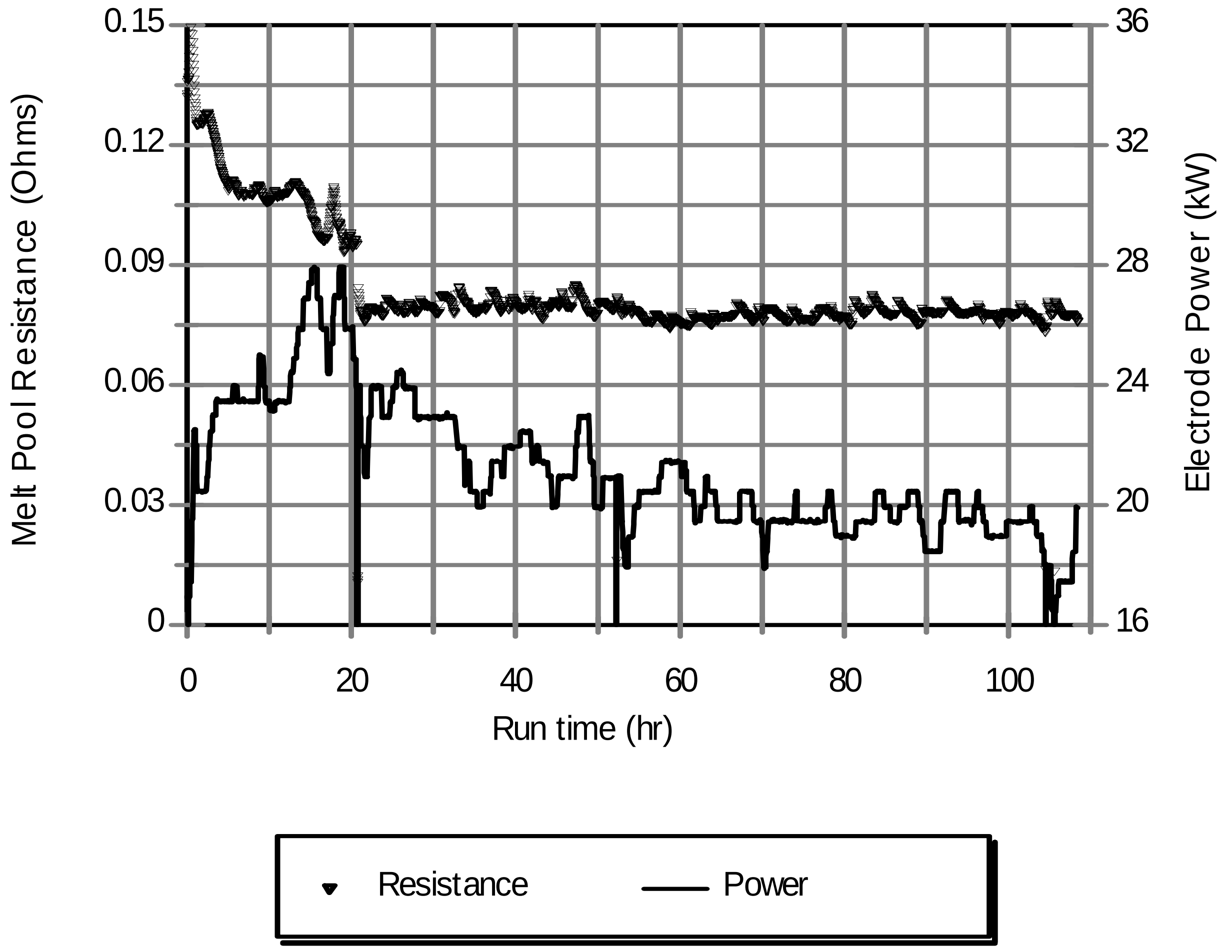


Figure 5.9.a. Melt pool resistance and total electrode power during DM100 Tests 1A and 1B.

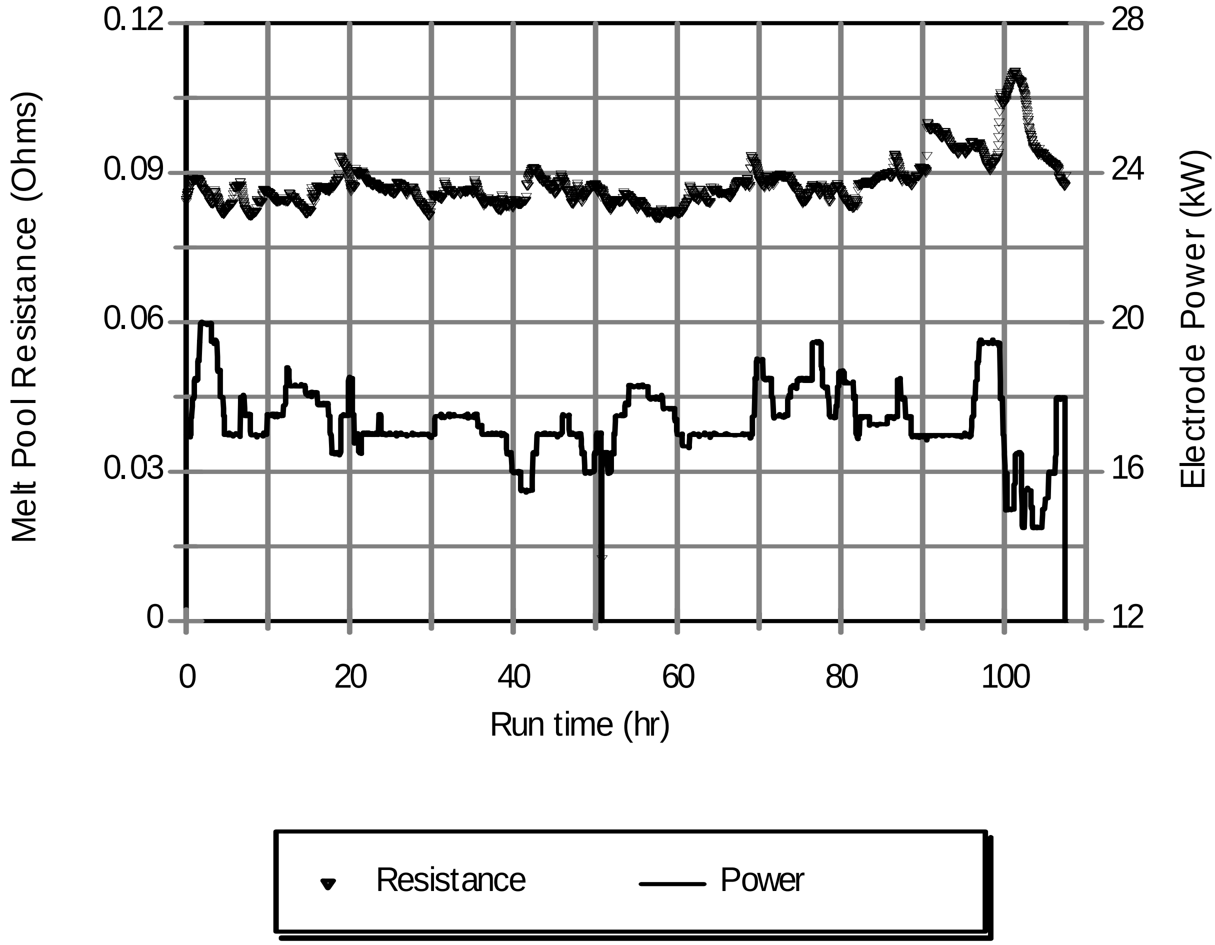


Figure 5.9.b. Melt pool resistance and total electrode power during DM100 Tests 2A and 2B.

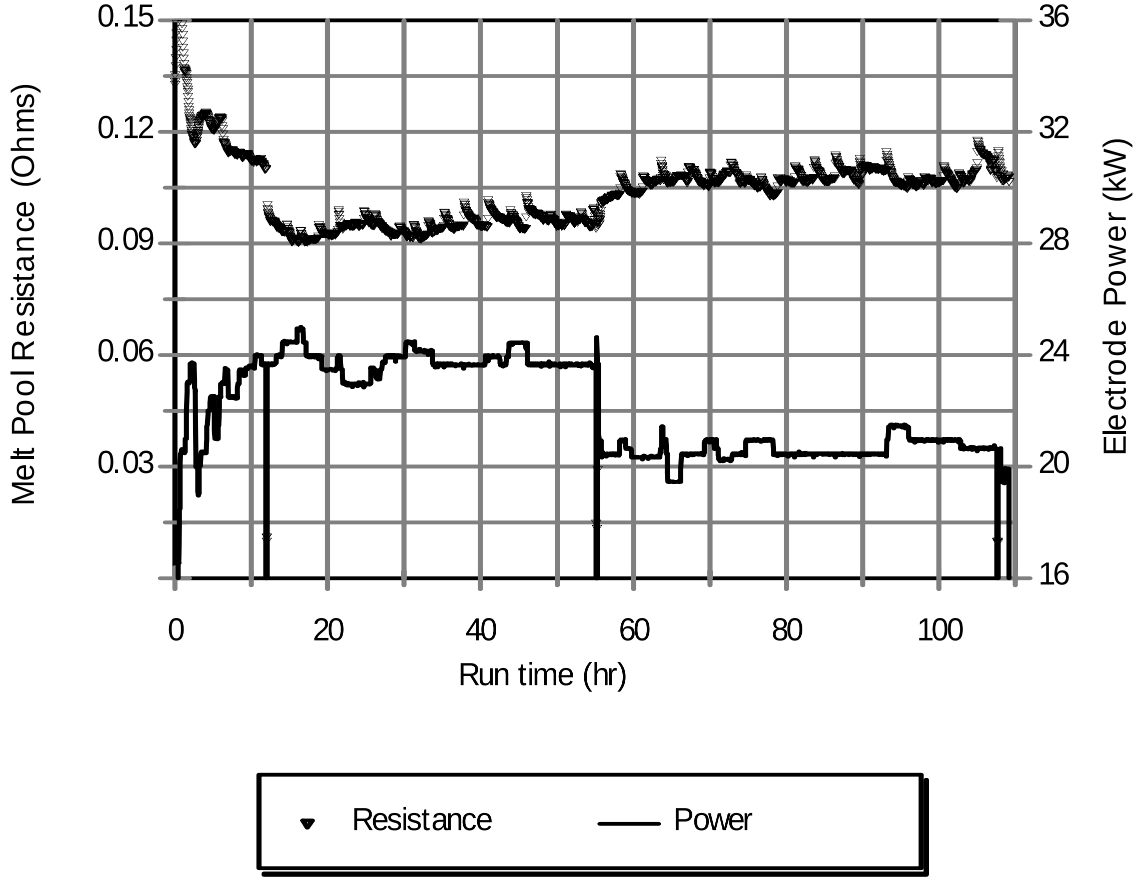


Figure 5.9.c. Melt pool resistance and total electrode power during DM100 Tests 3B and 4A.

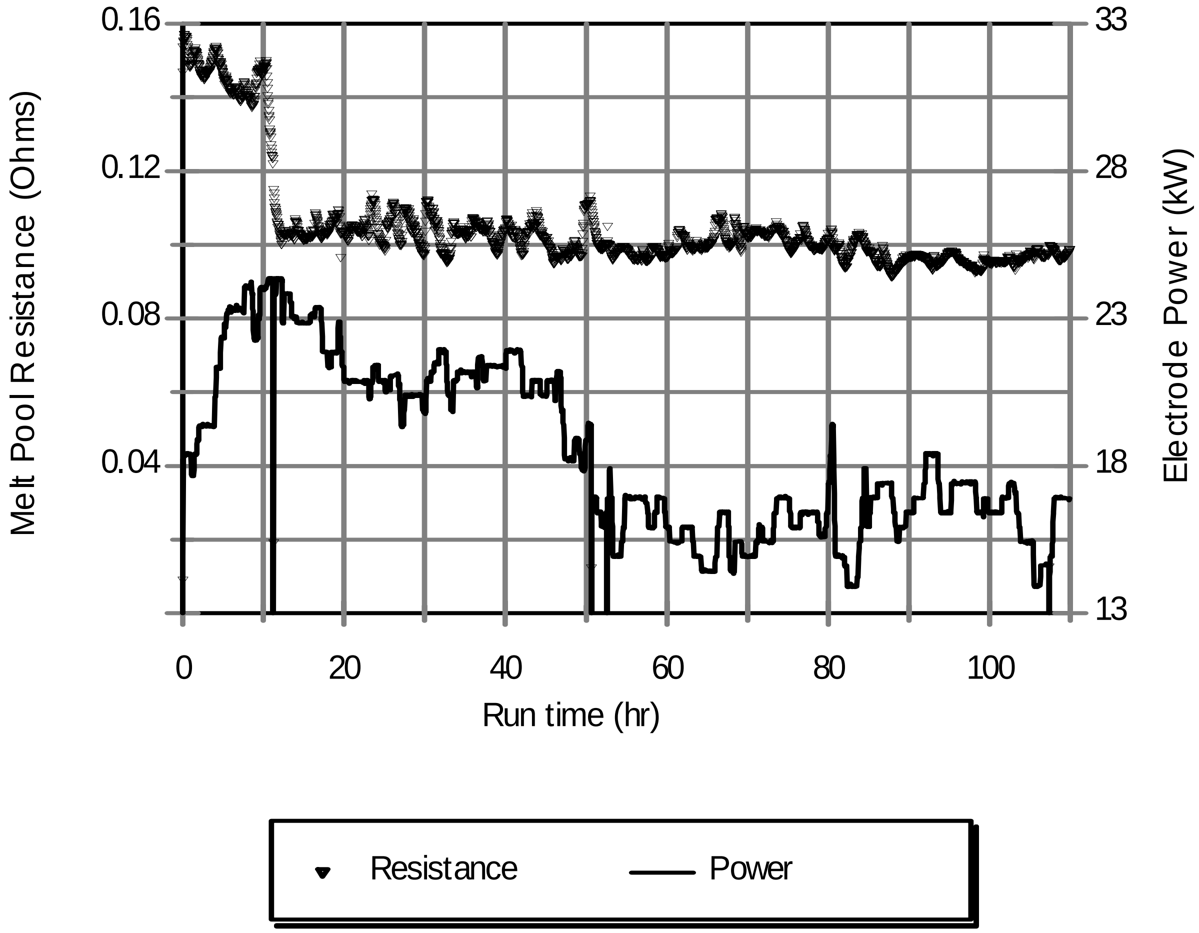


Figure 5.9.d. Melt pool resistance and total electrode power during DM100 Tests 5A and 5B.

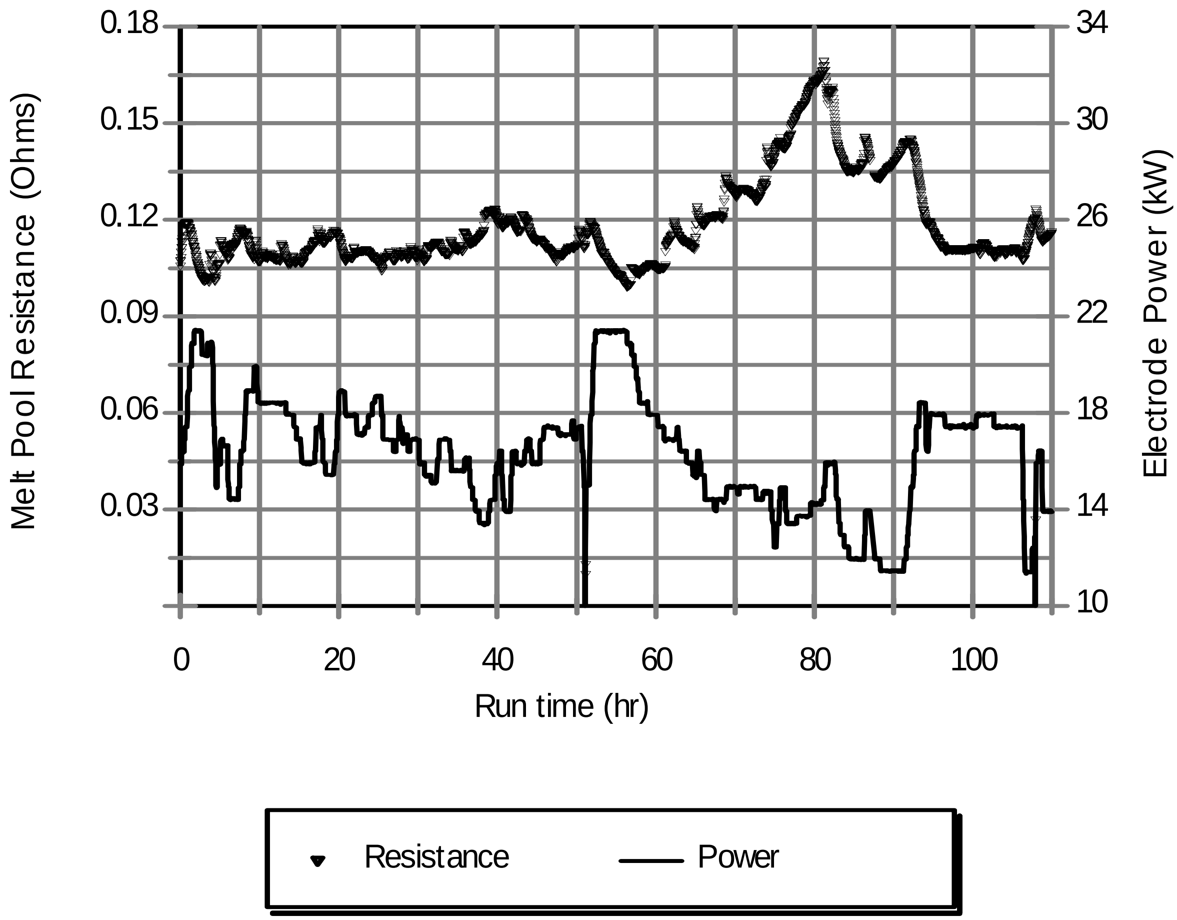


Figure 5.9.e. Melt pool resistance and total electrode power during DM100 Tests 6A and 6B.

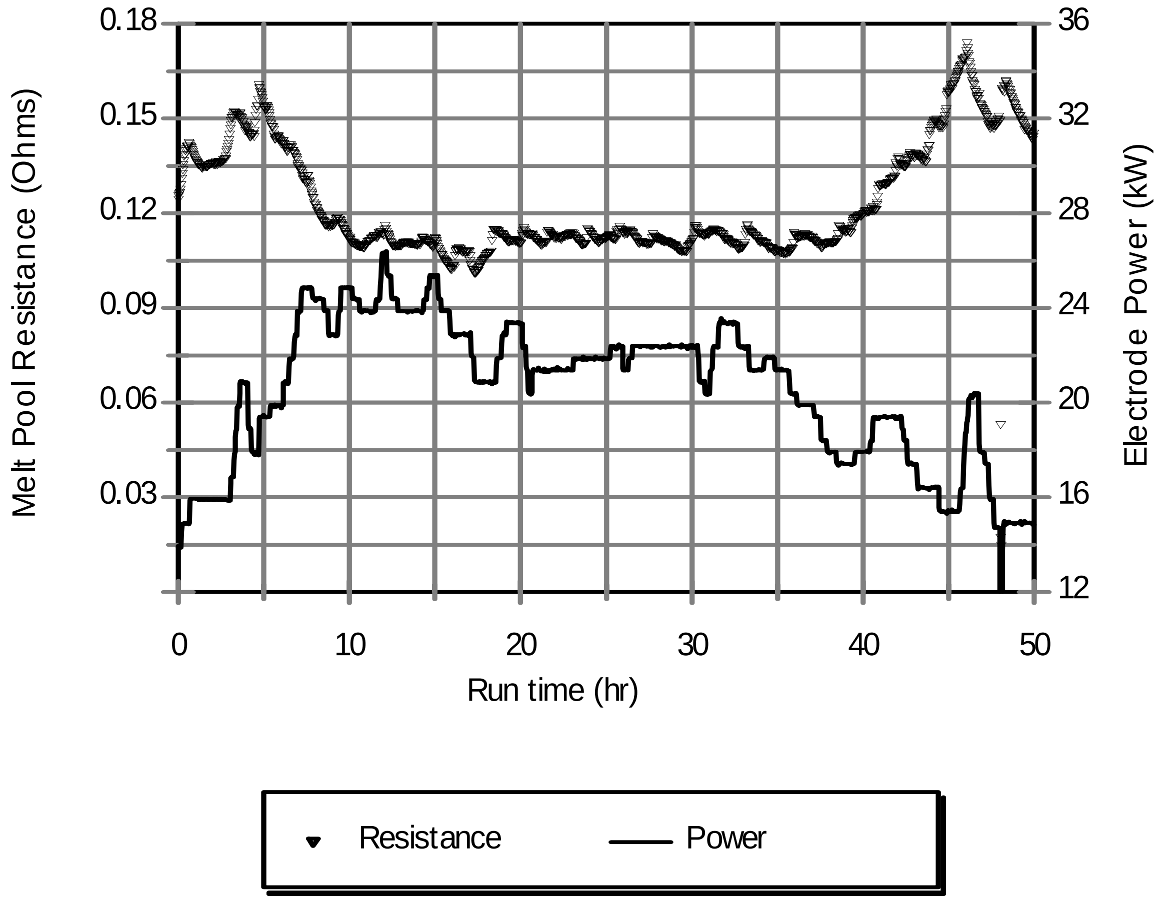


Figure 5.9.f. Melt pool resistance and total electrode power during DM100 Test 6C.

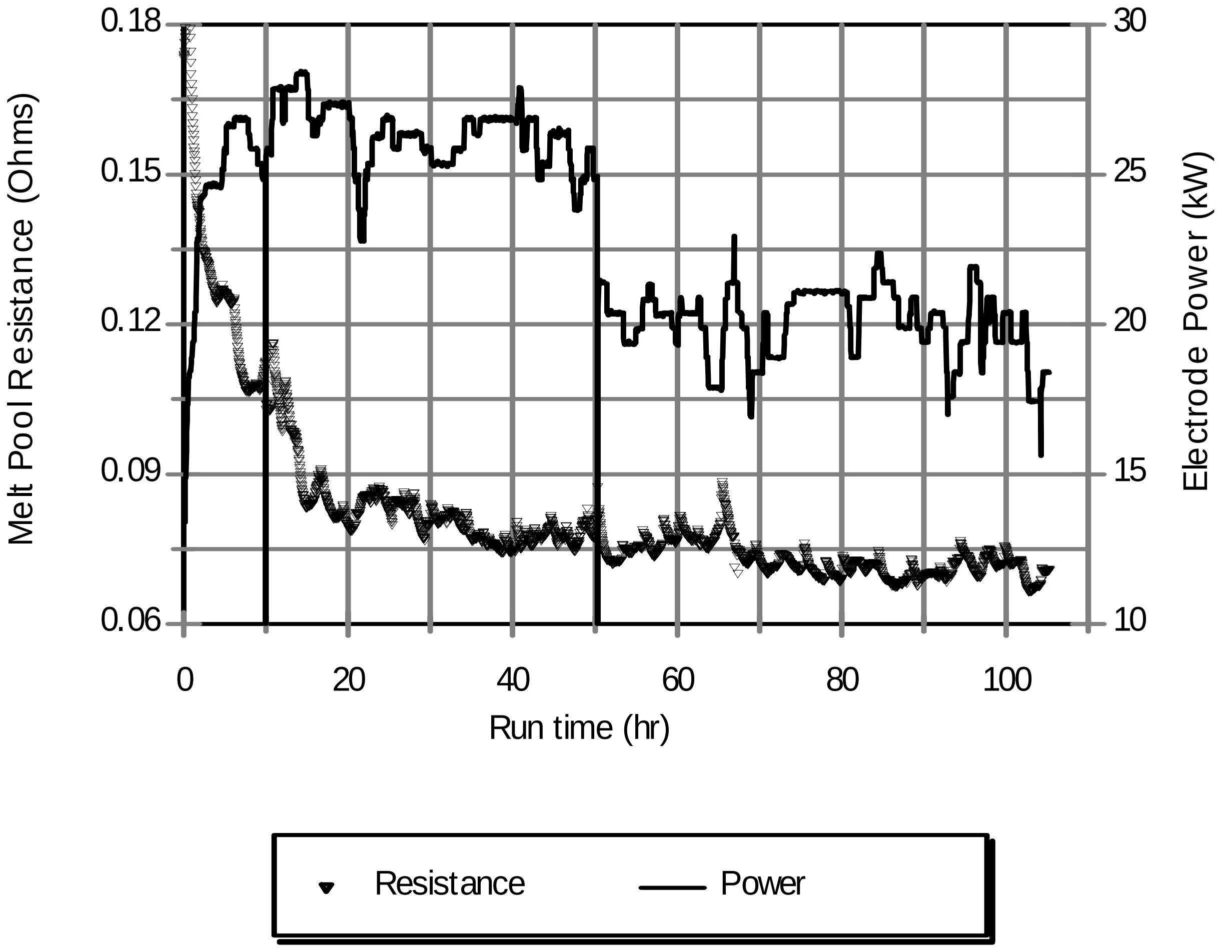


Figure 5.9.g. Melt pool resistance and total electrode power during DM100 Tests 7A and 7B.

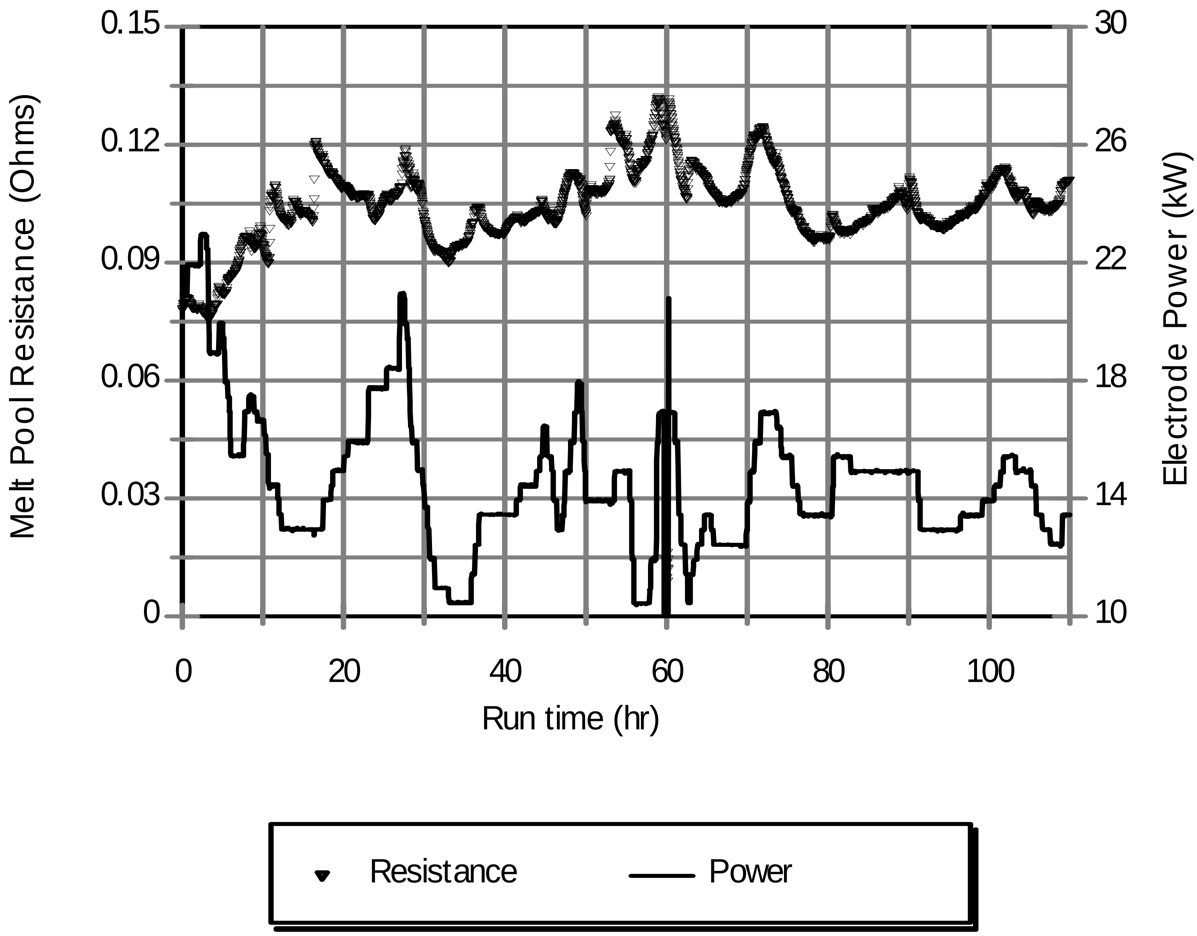


Figure 5.9.h. Melt pool resistance and total electrode power during DM100 Tests 8A and 8B.

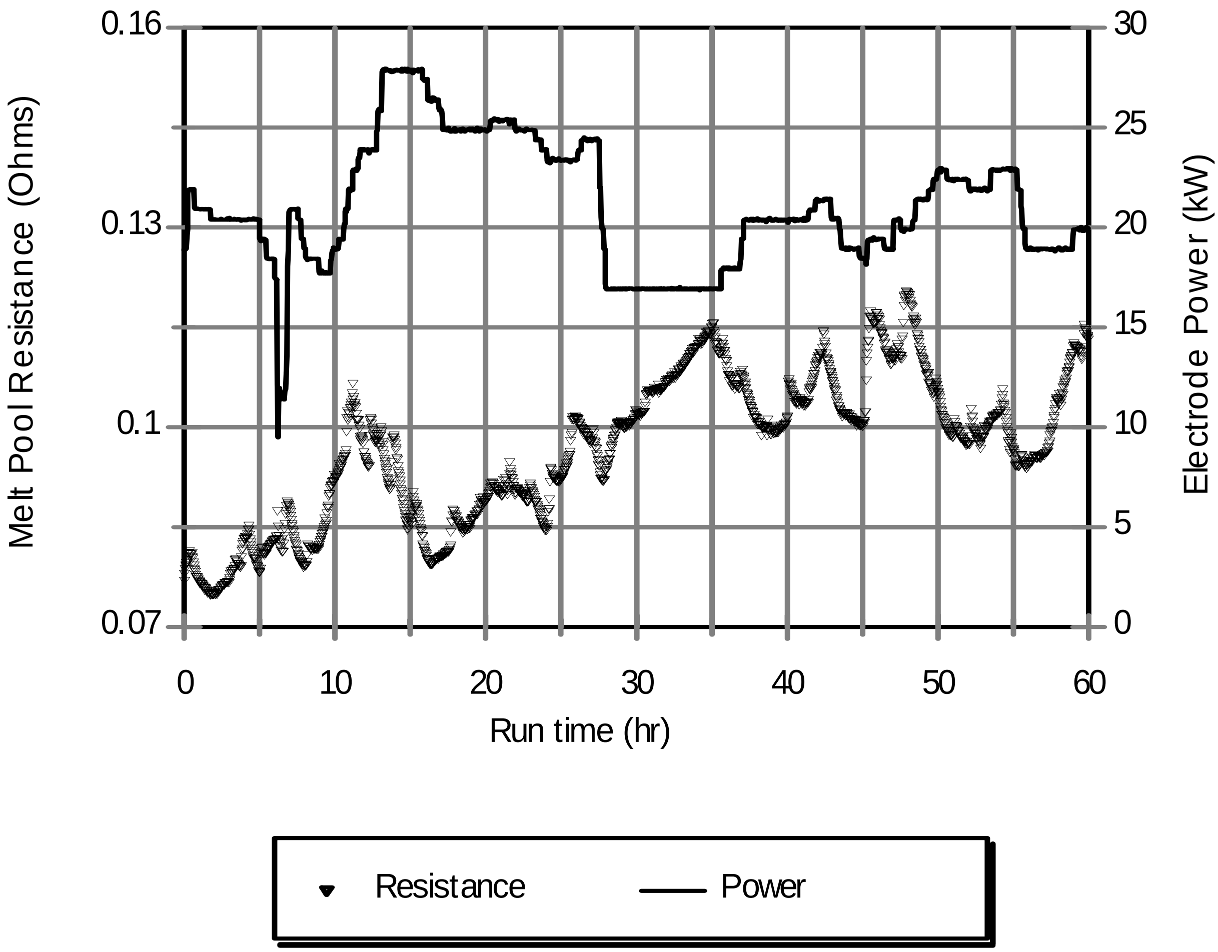


Figure 5.9.i. Melt pool resistance and total electrode power during DM100 Test 8C.

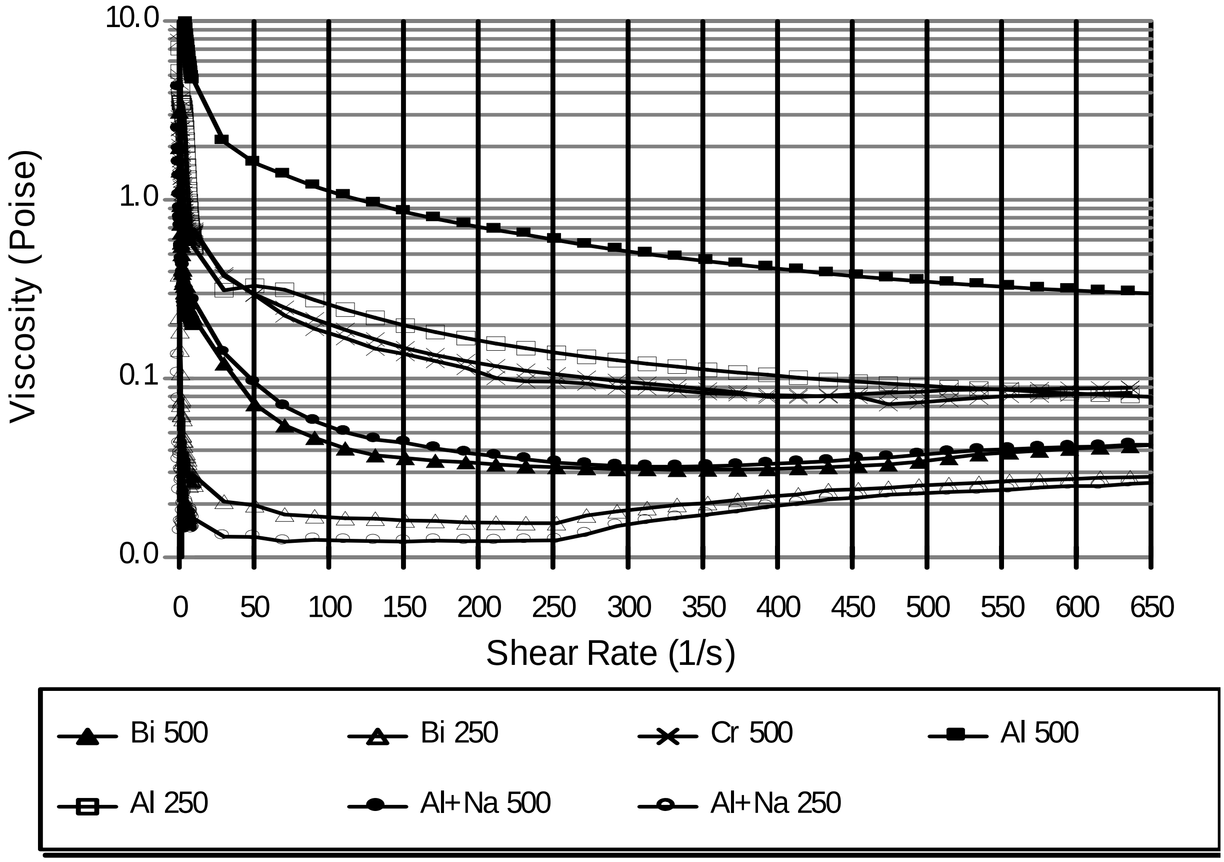
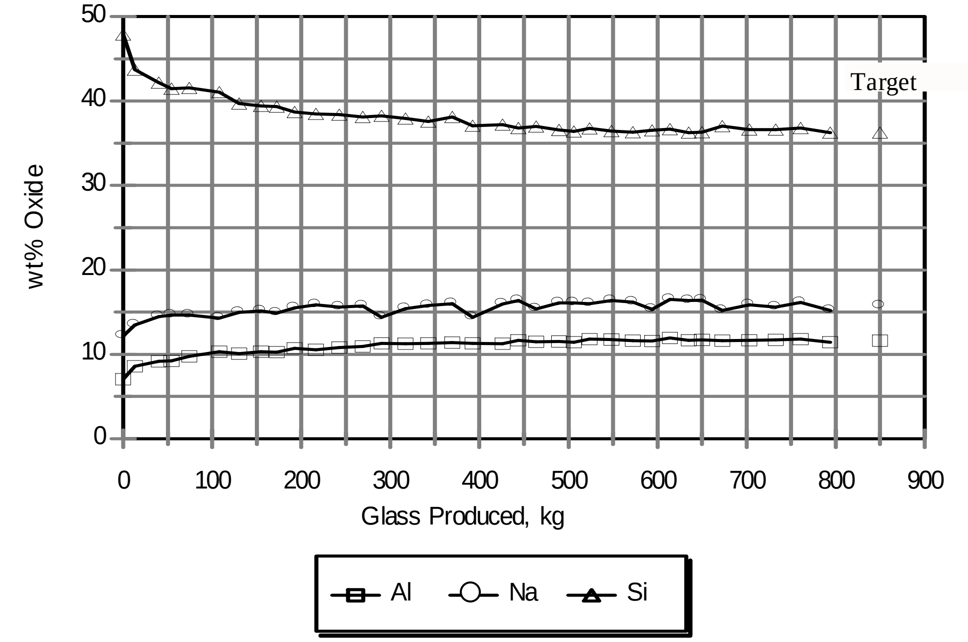


Figure 6.1. Measured viscosities of feed samples at target 250 and 500 g/l solids content.



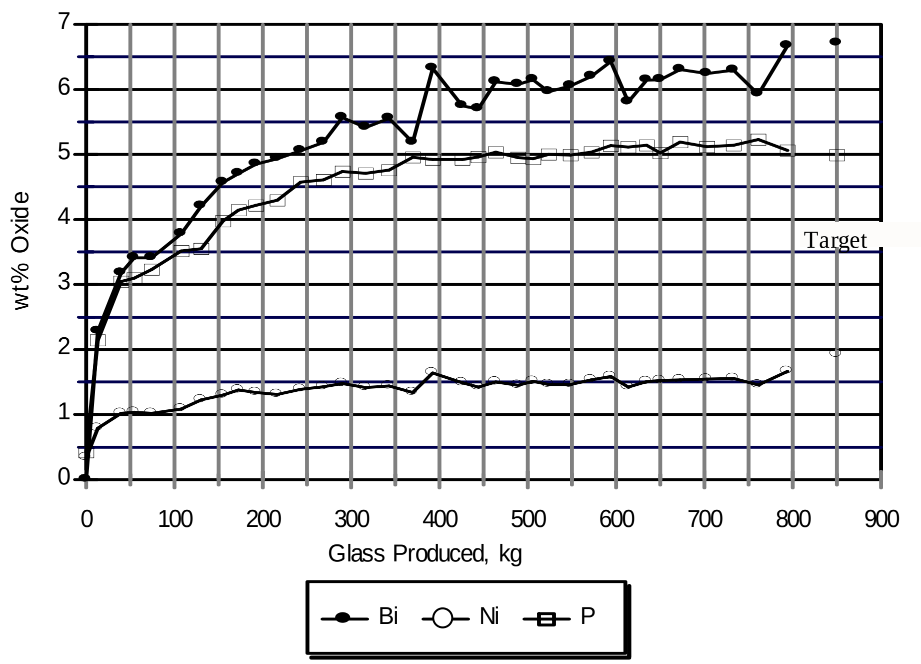
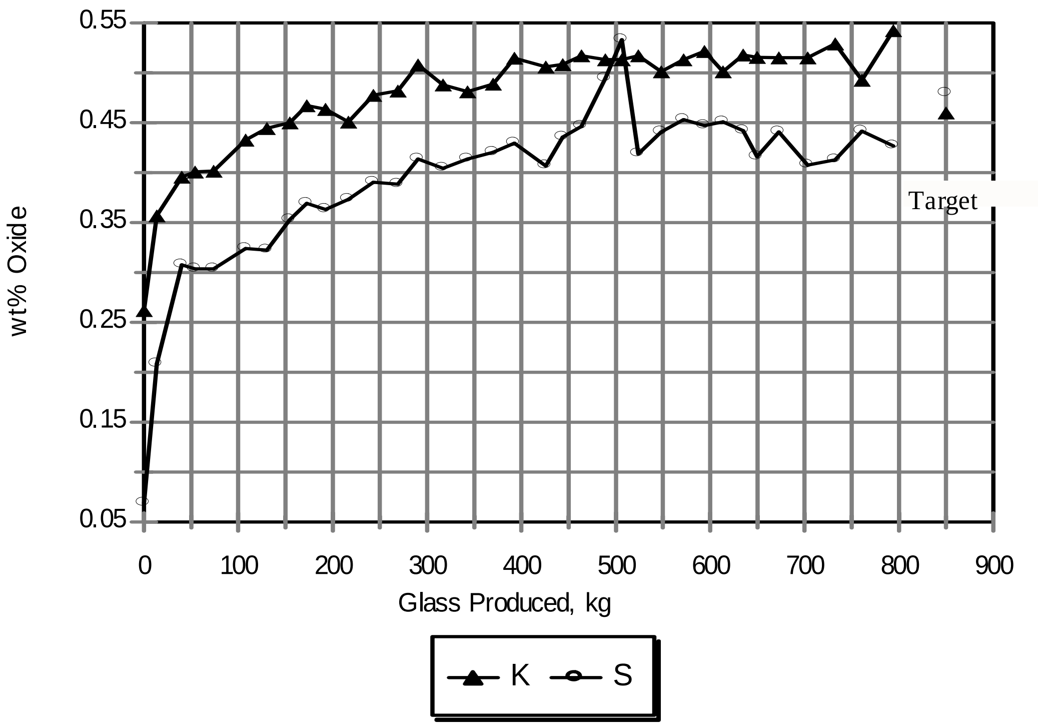


Figure 6.2.a. DM100 bismuth-limited product glass composition determined by XRF.



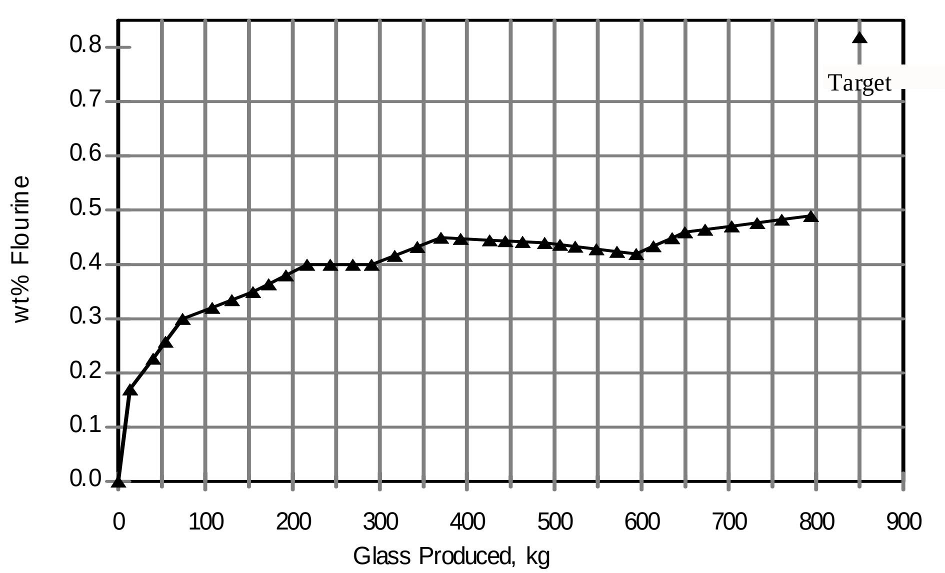


Figure 6.2.b. DM100 bismuth-limited product glass composition determined by XRF.

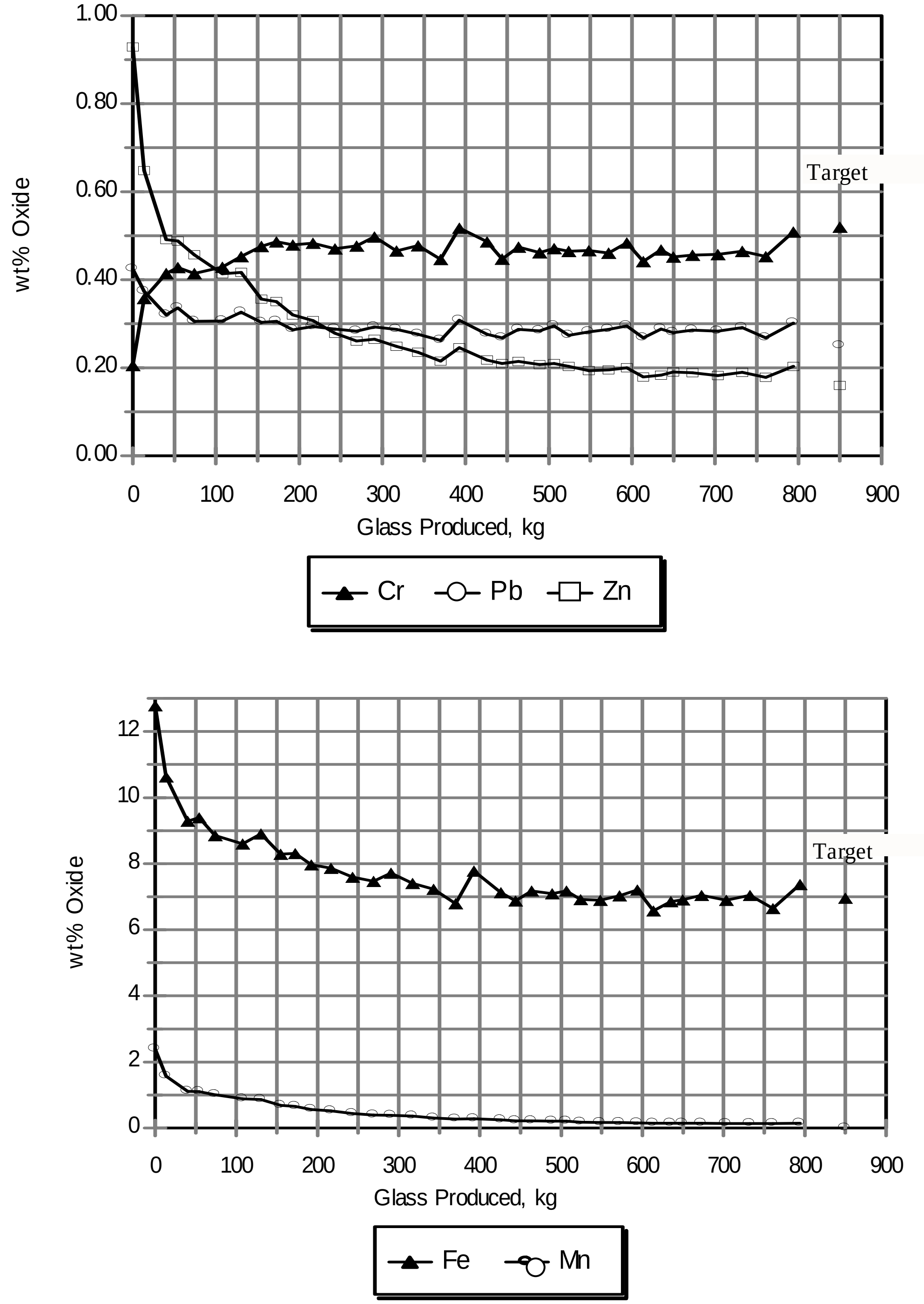
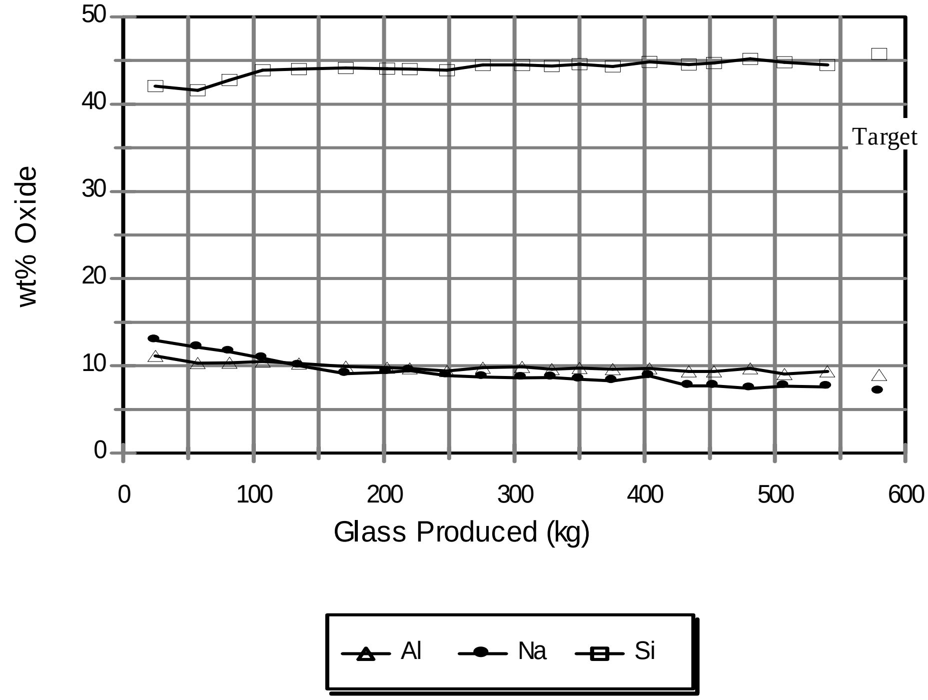


Figure 6.2.c. DM100 bismuth-limited product glass composition determined by XRF.



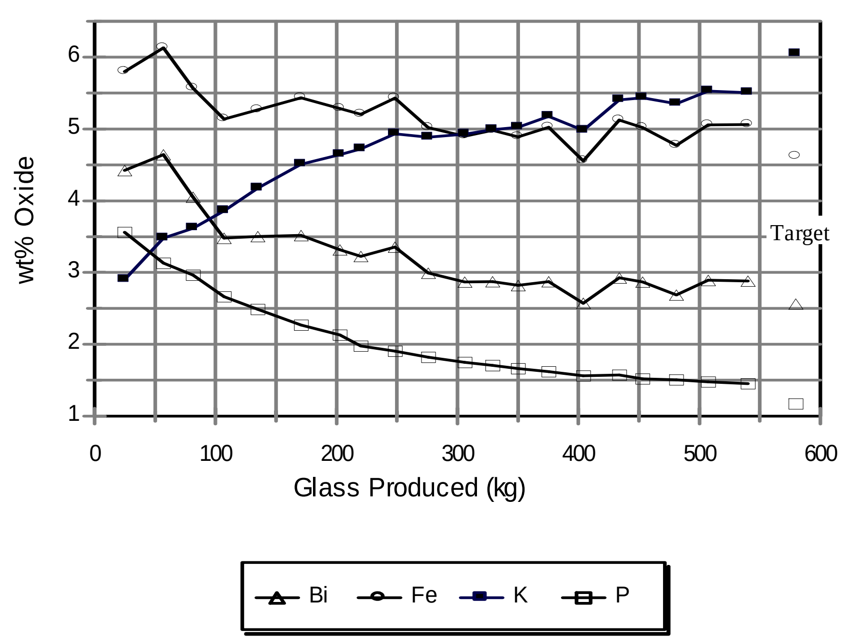


Figure 6.3.a. DM100 chromium-limited product glass composition determined by XRF.

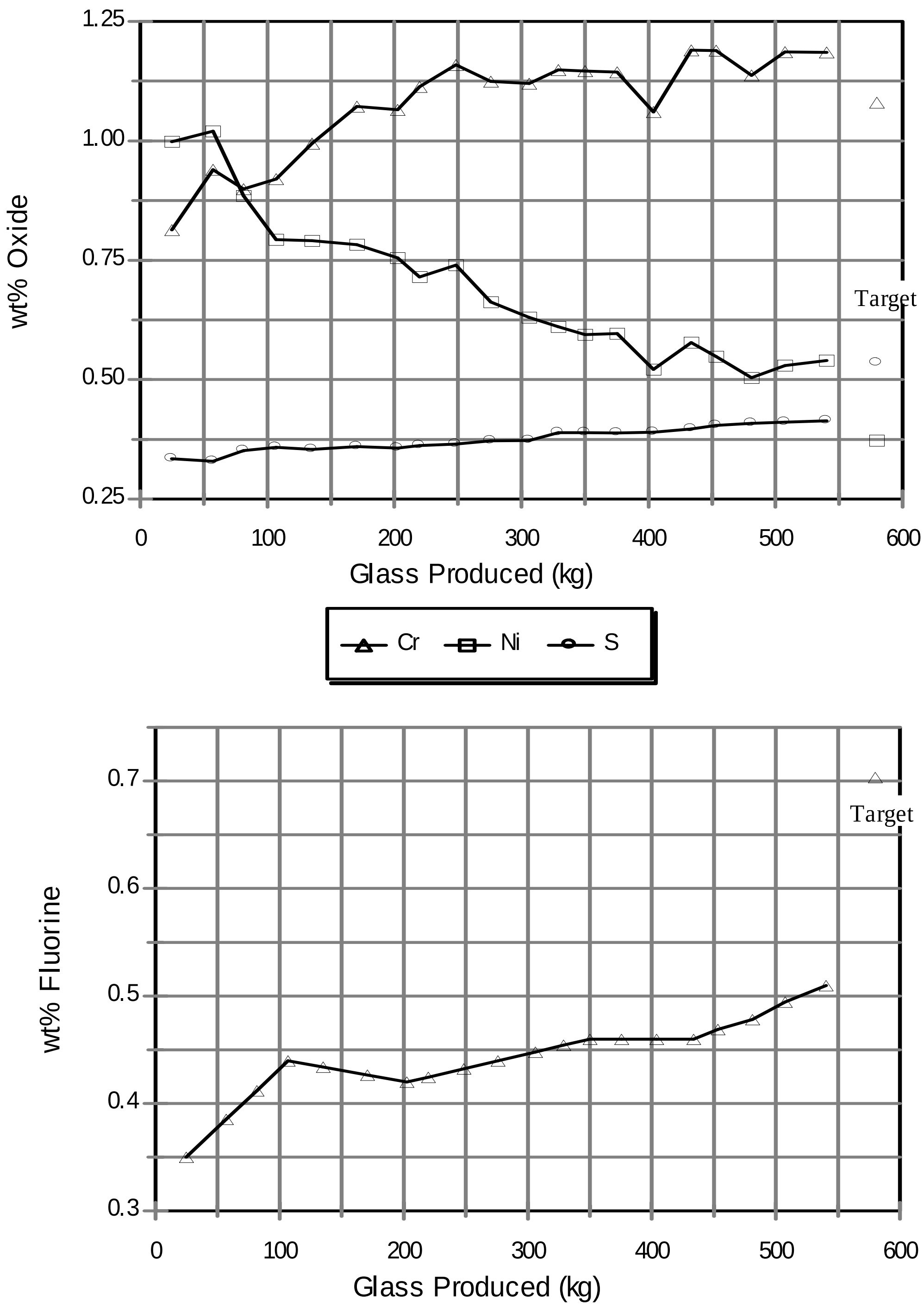
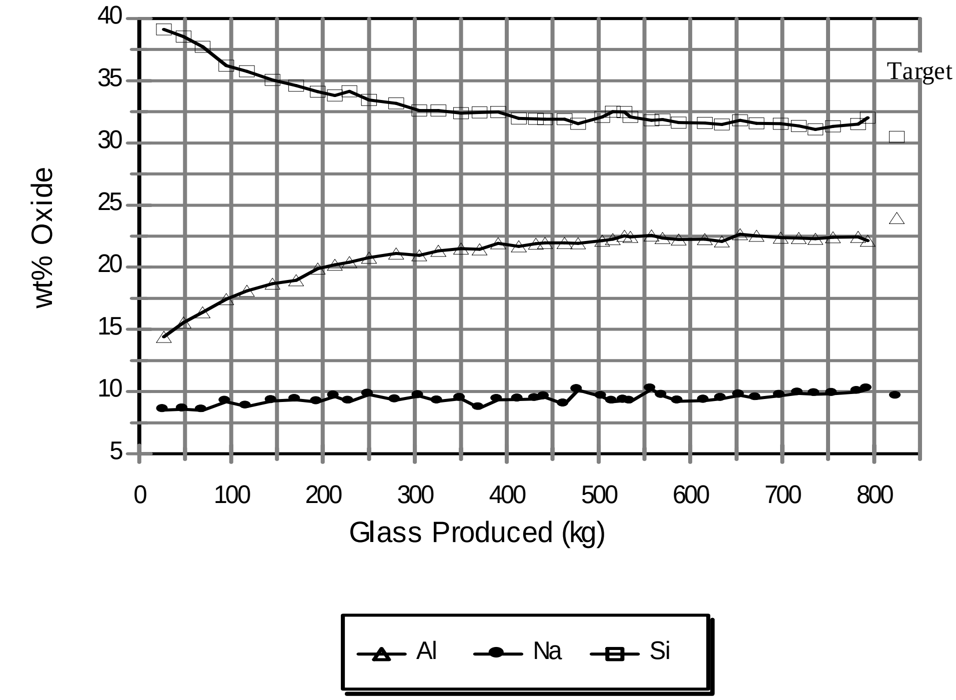


Figure 6.3.b. DM100 chromium-limited product glass composition determined by XRF.



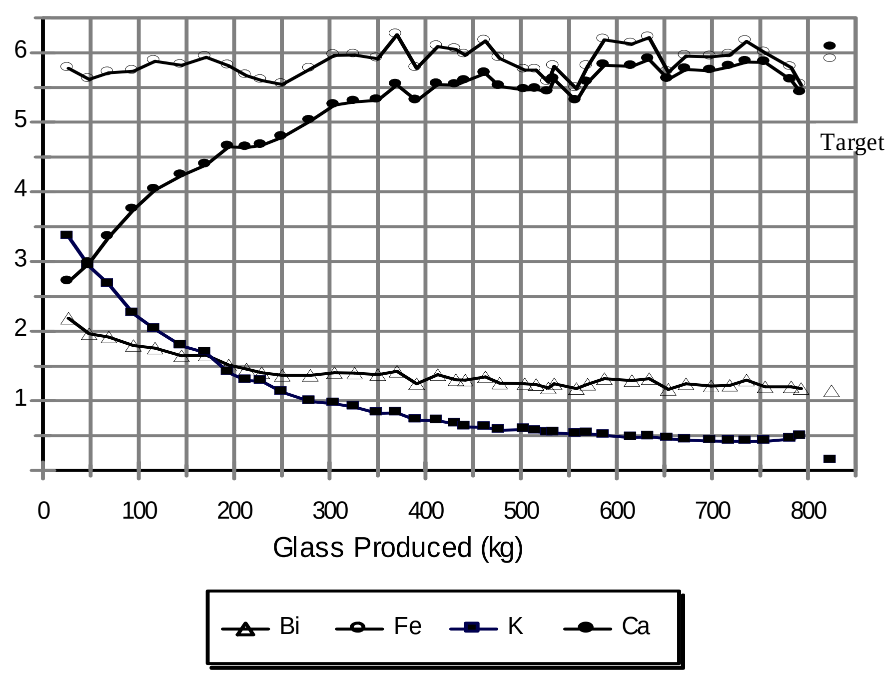
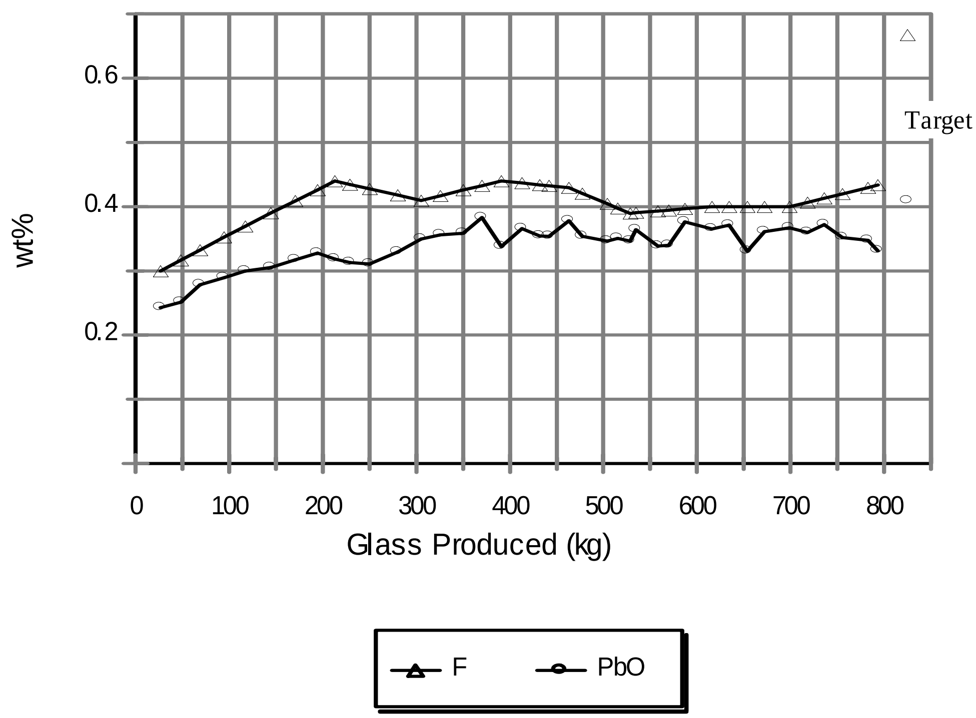


Figure 6.4.a. DM100 aluminum-limited product glass composition determined by XRF.



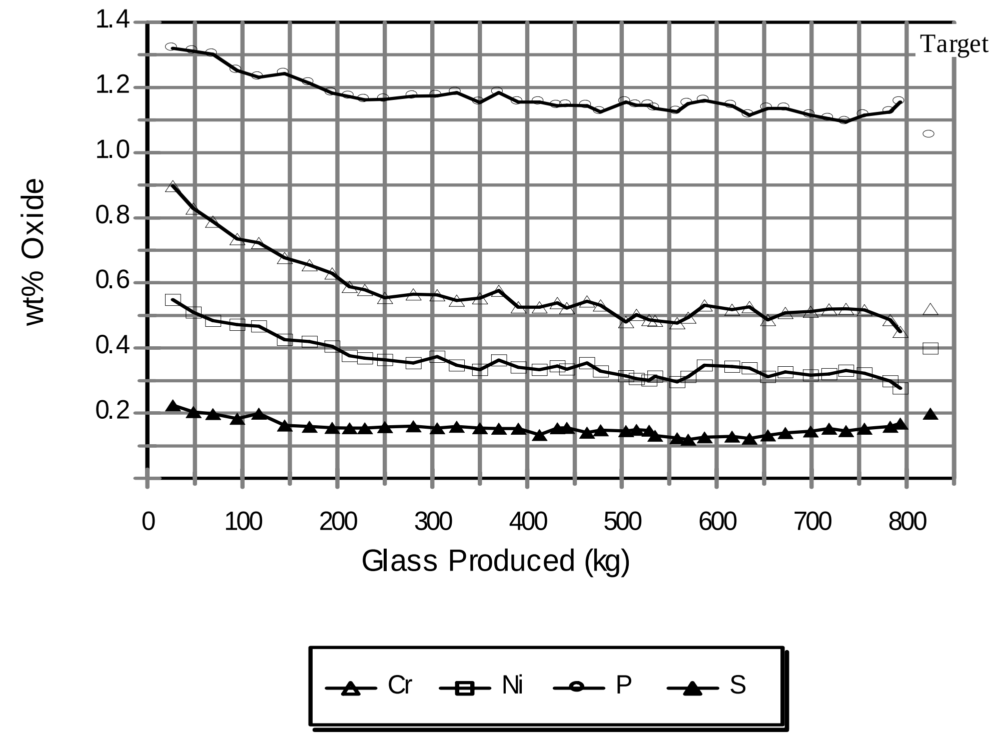
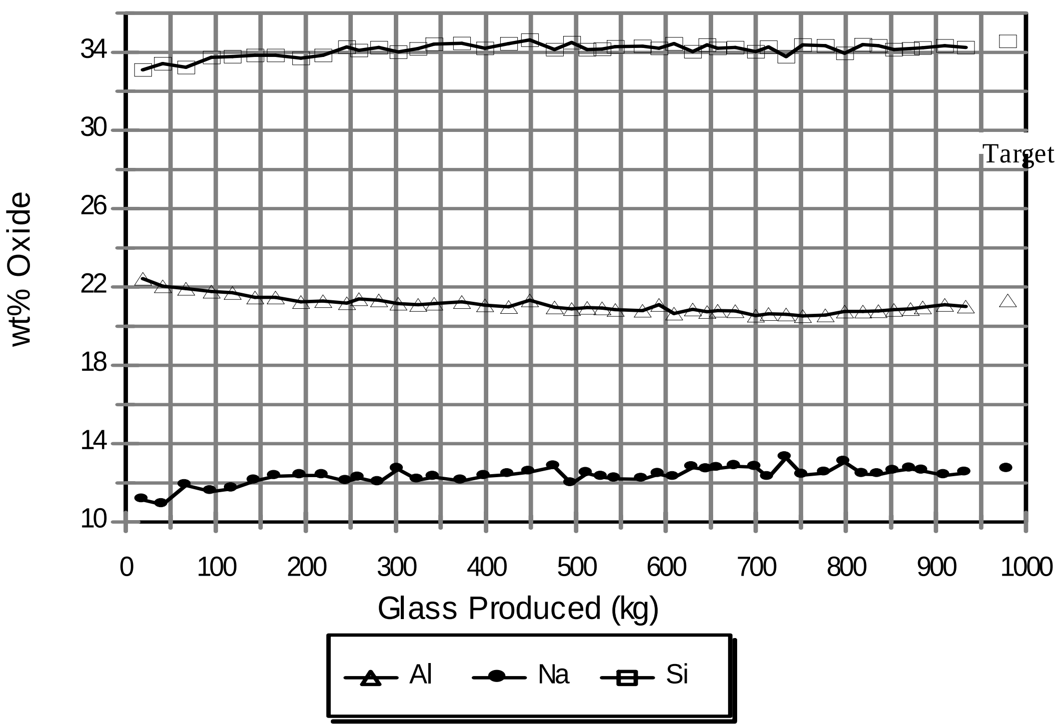


Figure 6.4.b. DM100 aluminum-limited product glass composition determined by XRF.



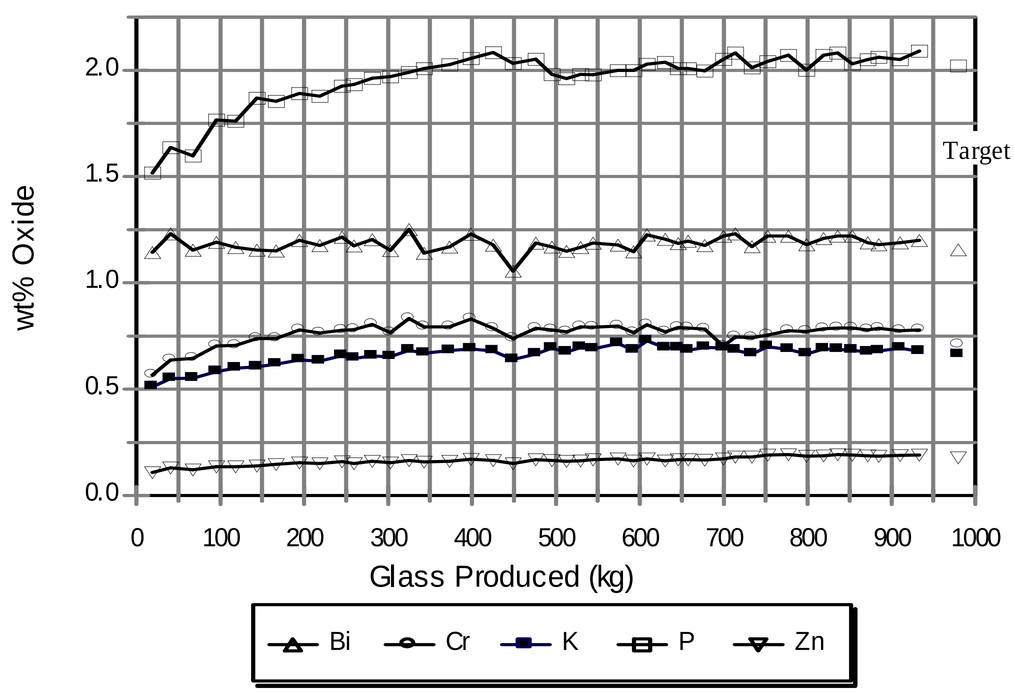
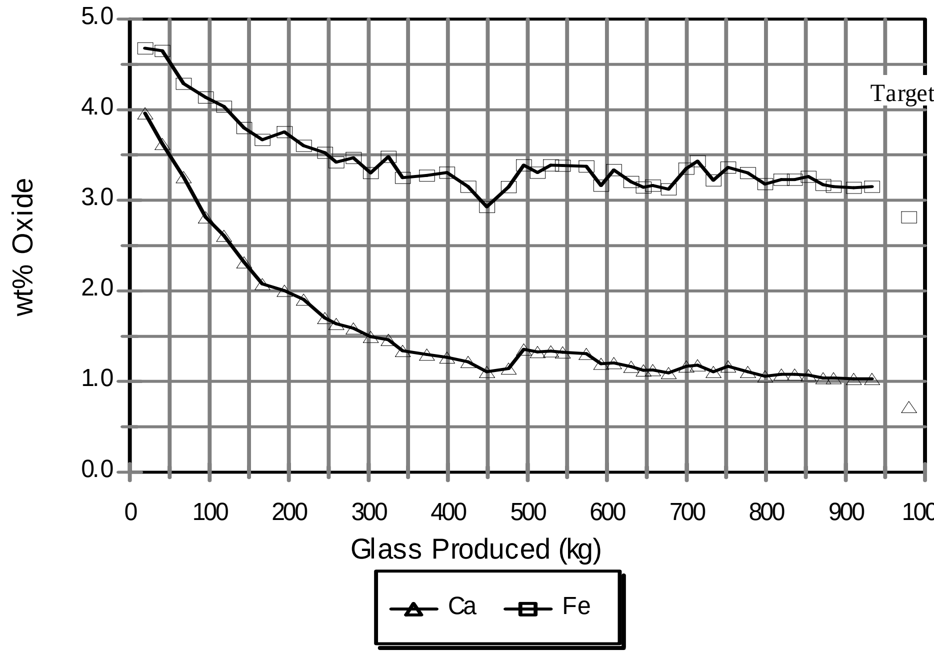


Figure 6.5.a. DM100 aluminum-plus-sodium-limited product glass composition determined by XRF.



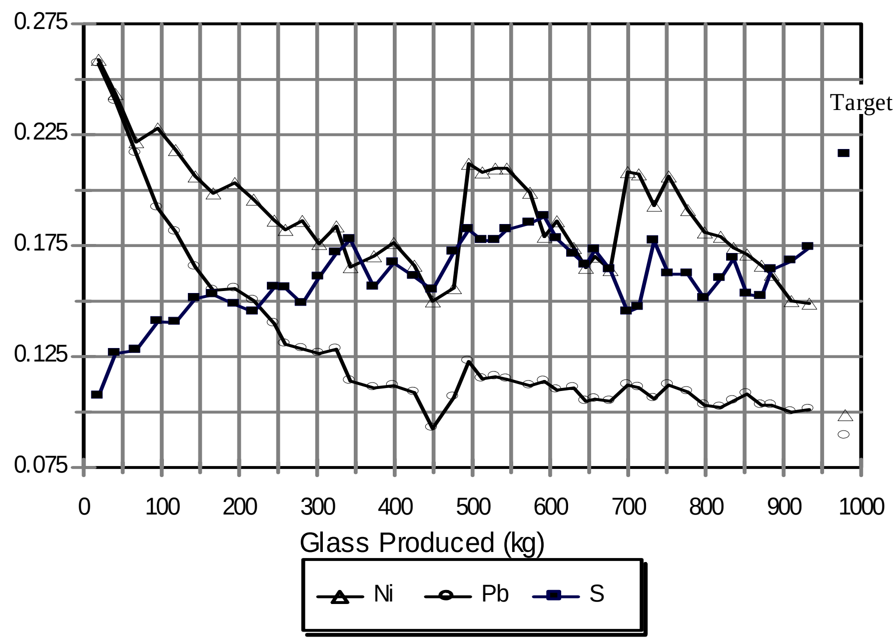


Figure 6.5.b. DM100 aluminum-plus-sodium-limited product glass composition determined by XRF.

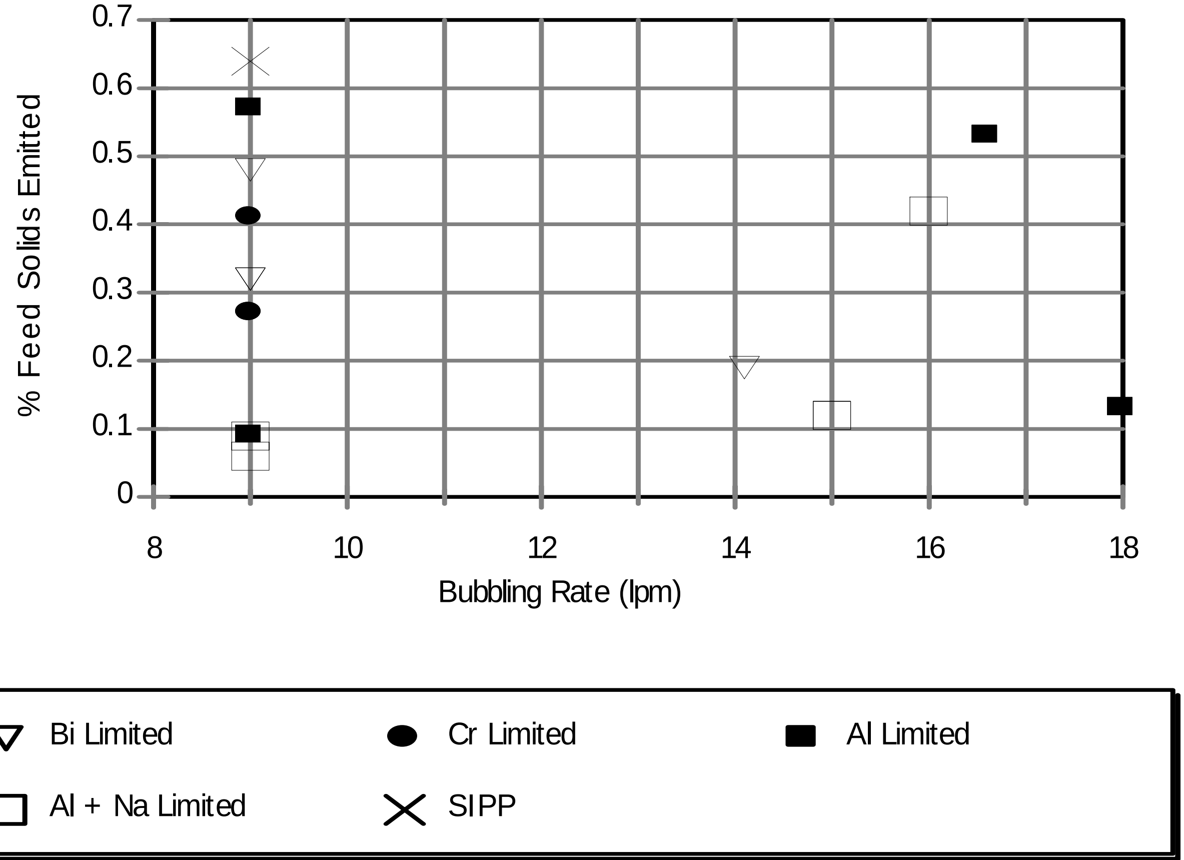


Figure 7.1. Percent feed solids emitted as particles during DM100 tests vs. bubbling rate; feed solids content 500 (±50) g glass per liter feed.

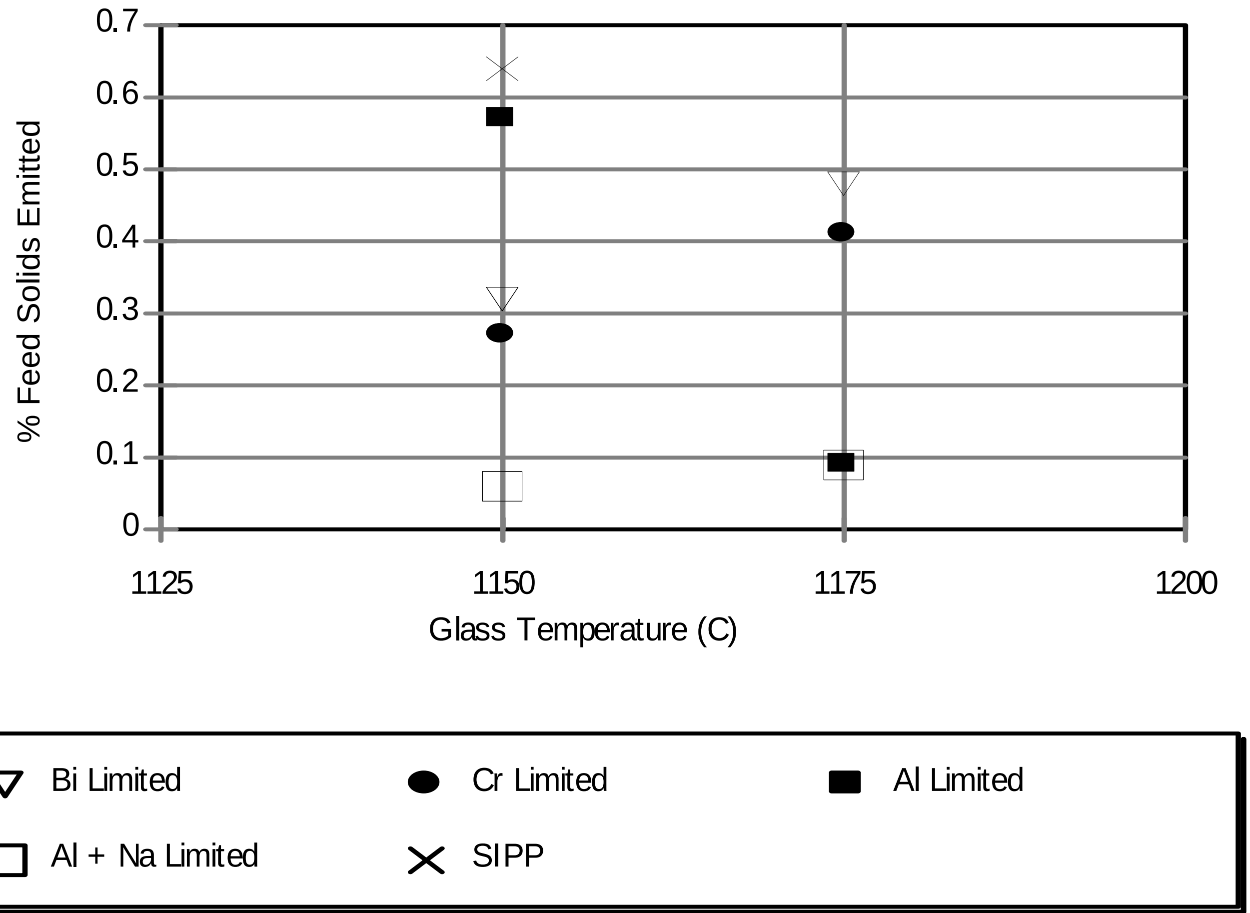


Figure 7.2. Percent feed solids emitted as particles during DM100 tests vs. glass temperature; feed solids content 500 (±50) g glass per liter feed, glass pool bubbling rate 9 lpm.

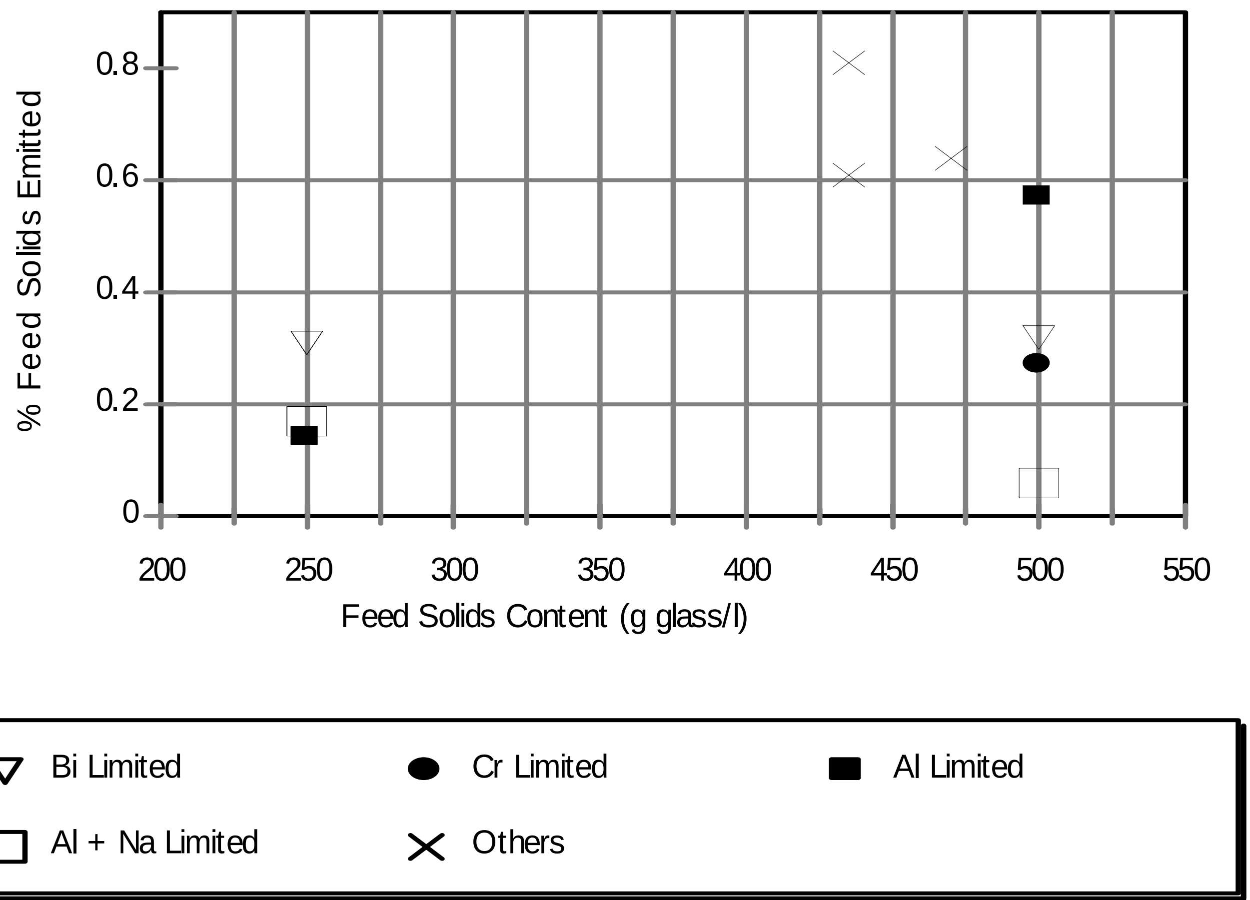


Figure 7.3. Percent feed solids emitted as particles during DM100 tests vs. feed solids content; glass temperature 1150°C, glass pool bubbling rate 9 lpm.

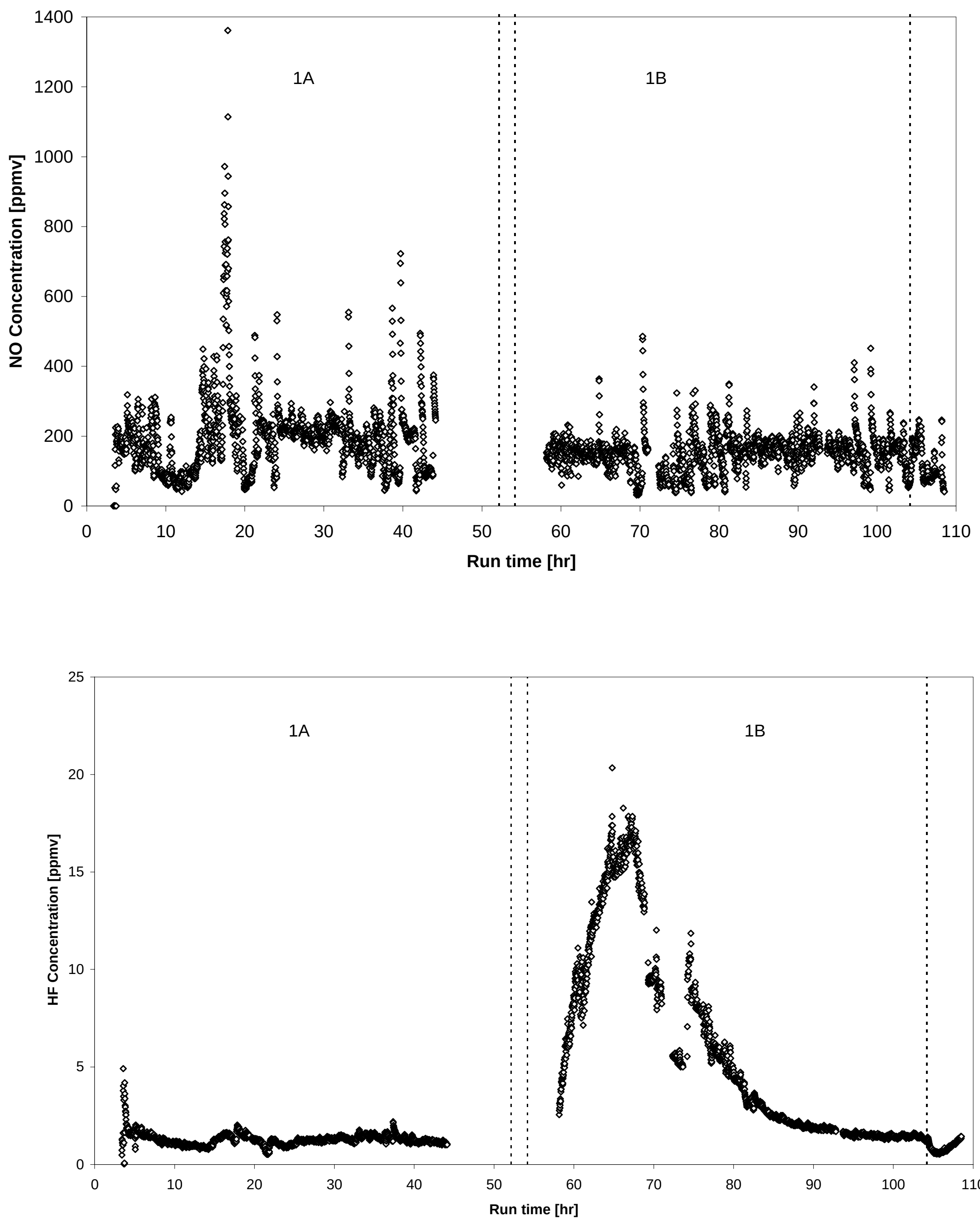


Figure 7.4. NO and HF FTIR monitored emissions during DM100 Tests 1A and 1B.

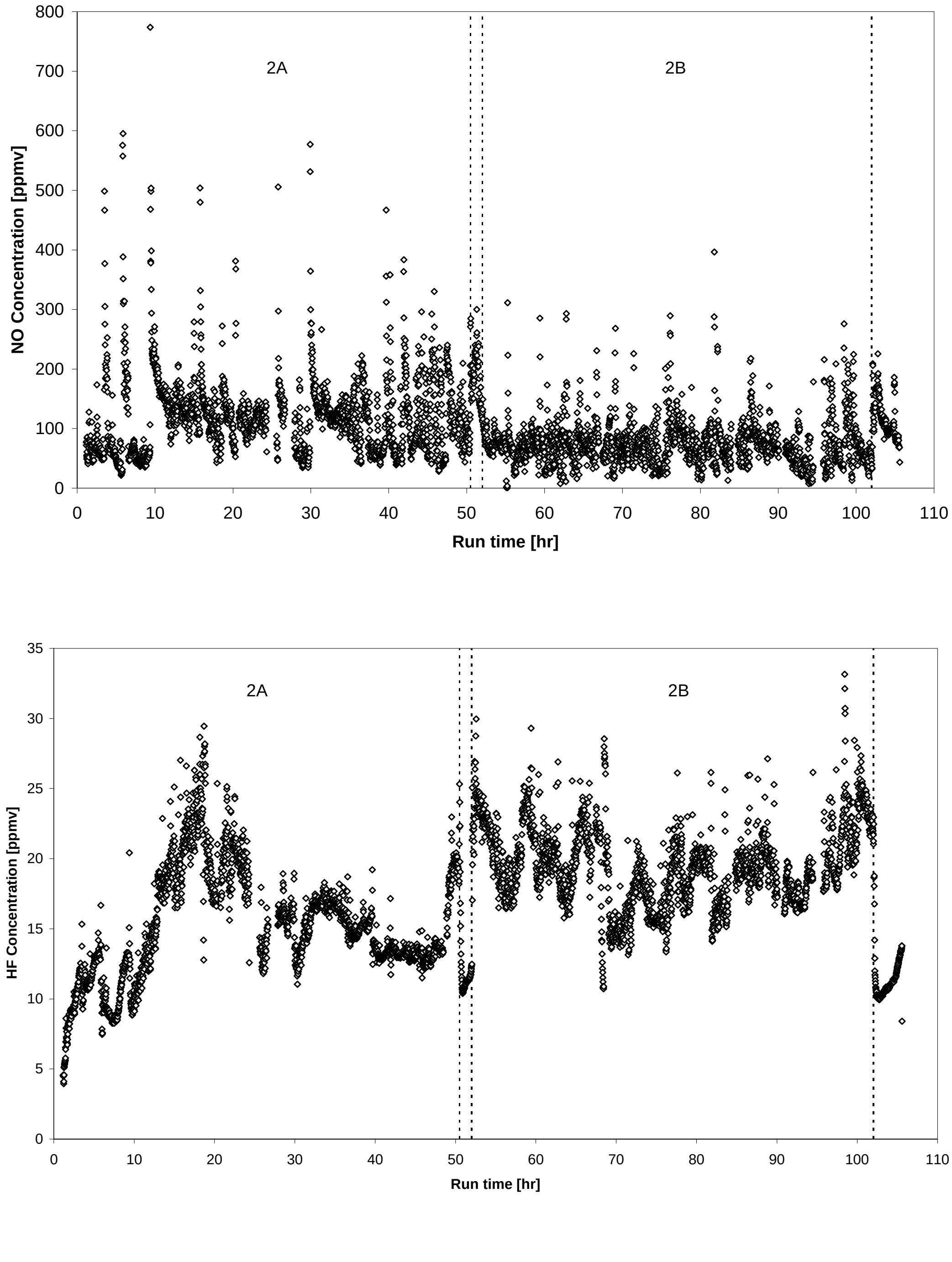
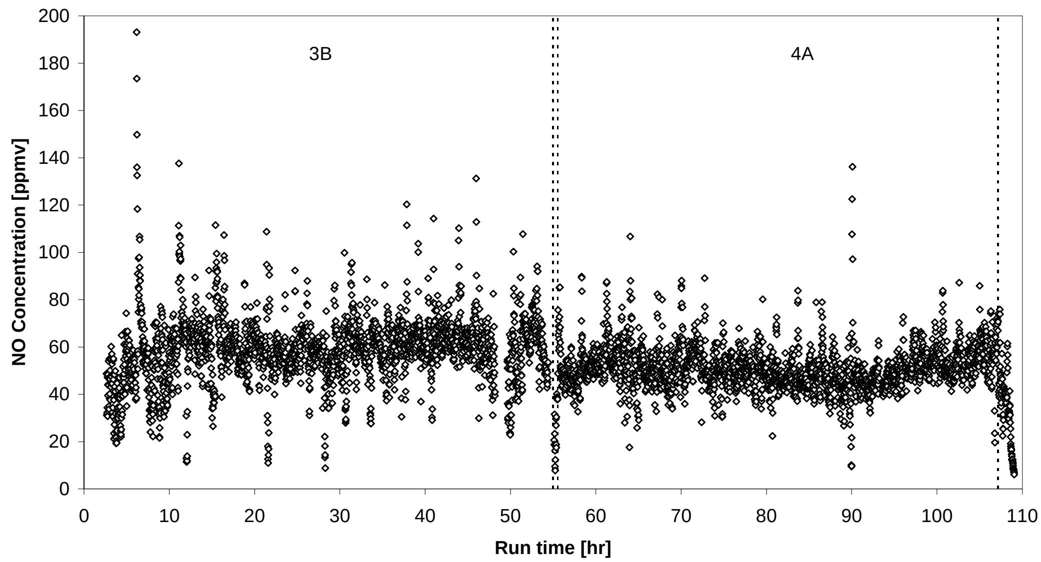


Figure 7.5. NO and HF FTIR monitored emissions during DM100 Tests 2A and 2B.



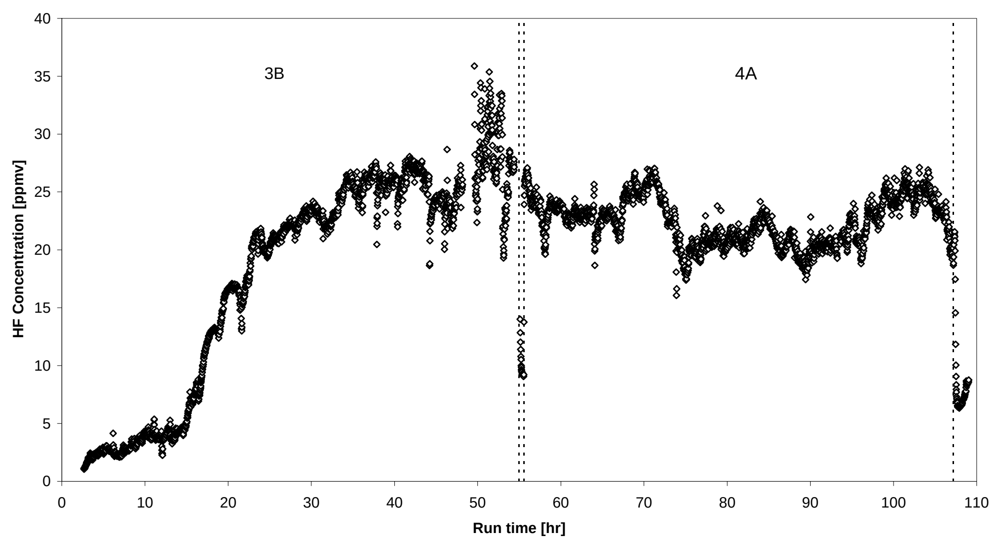
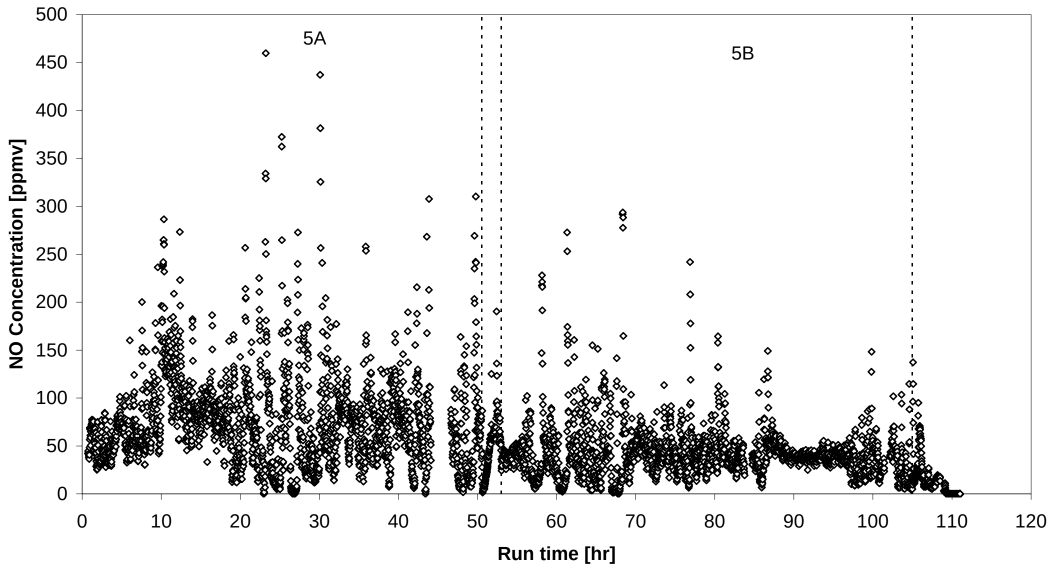


Figure 7.6. NO and HF FTIR monitored emissions during DM100 Tests 3B and 4A.



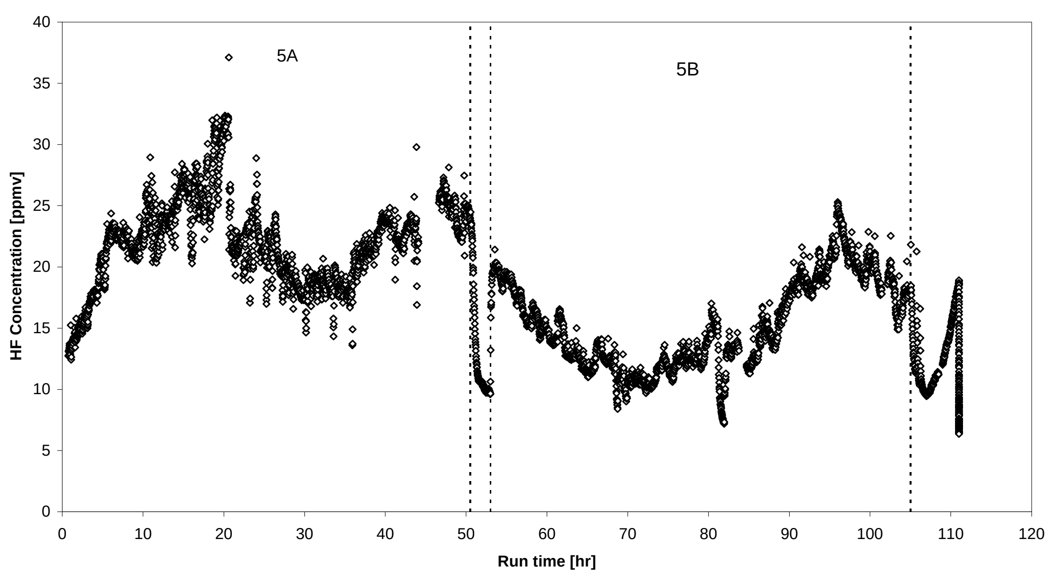


Figure 7.7. NO and HF FTIR monitored emissions during DM100 Tests 5A and 5B.

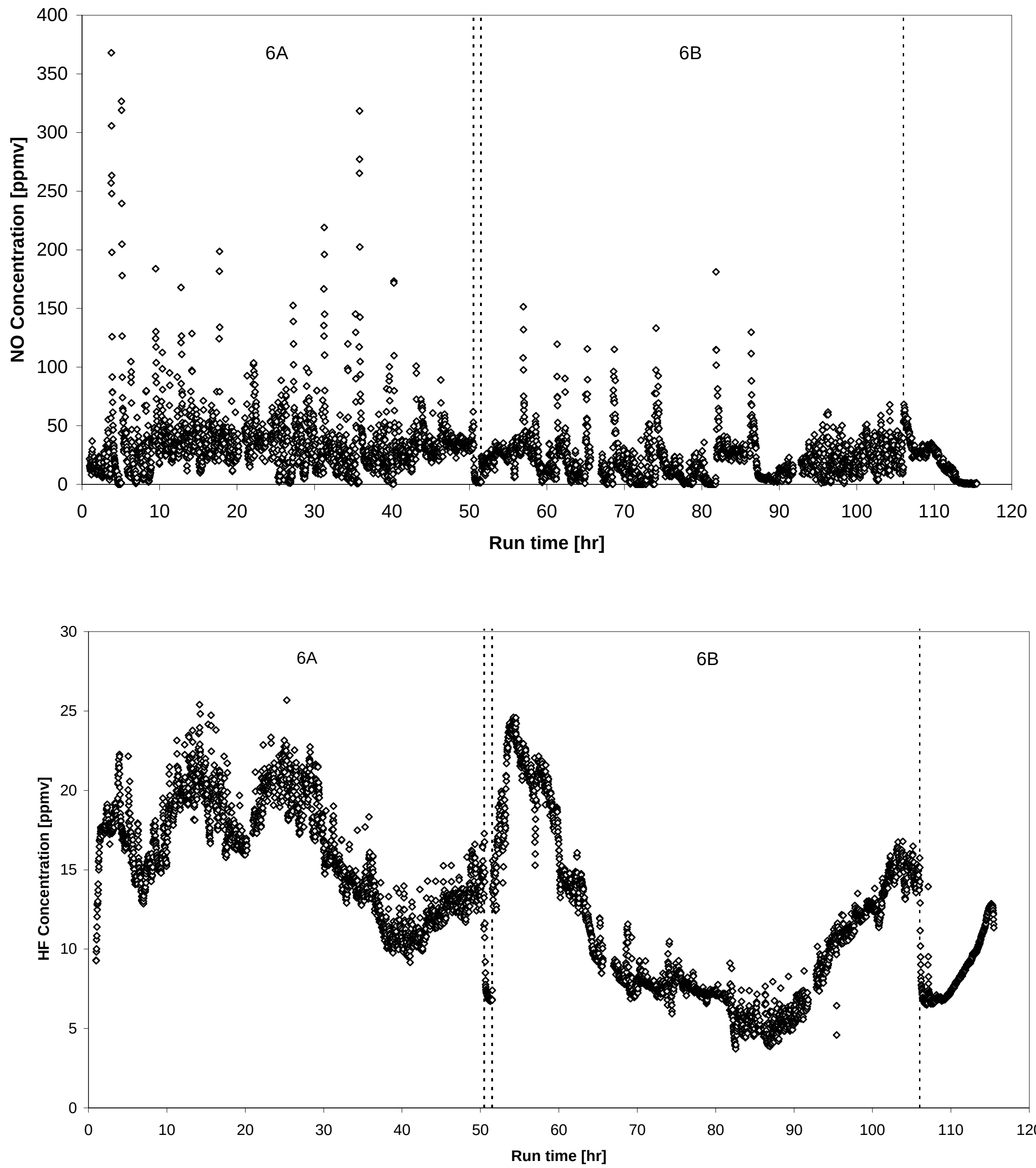
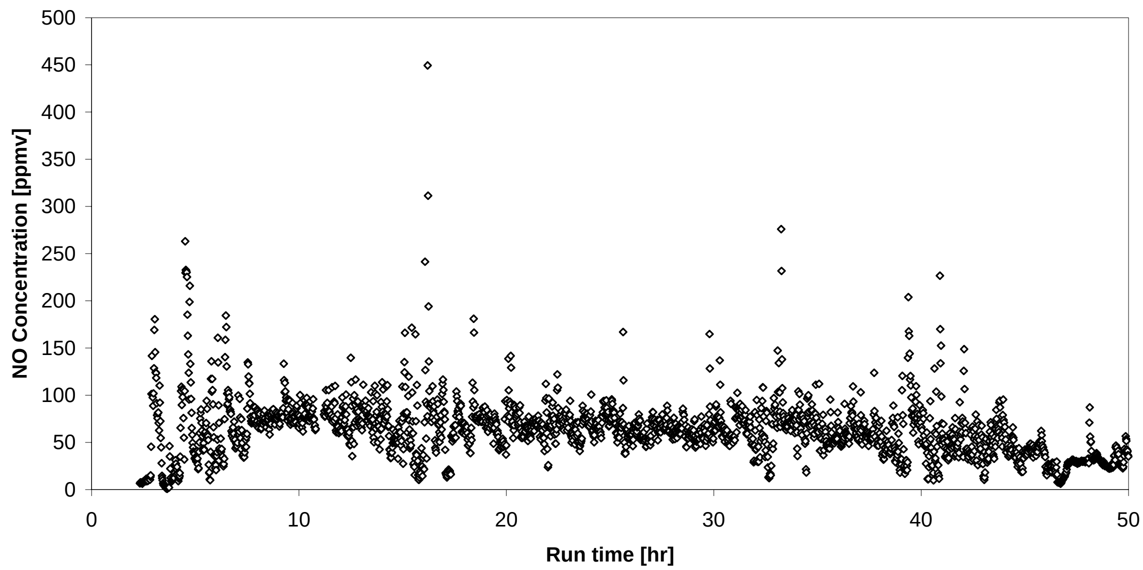


Figure 7.8. NO and HF FTIR monitored emissions during DM100 Tests 6A and 6B.



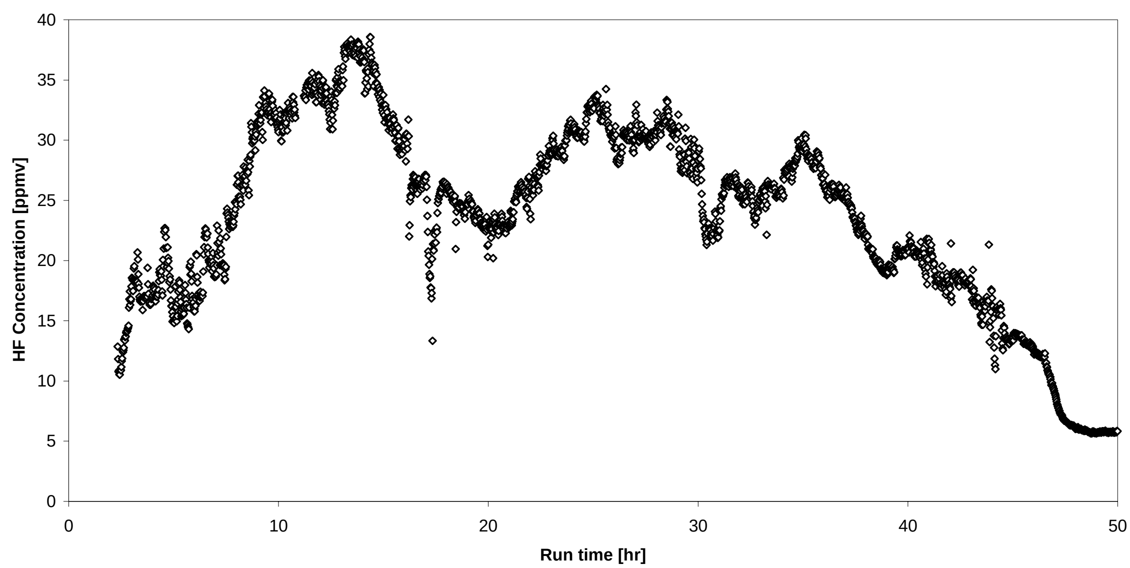


Figure 7.9. NO and HF FTIR monitored emissions during DM100 Test 6C.

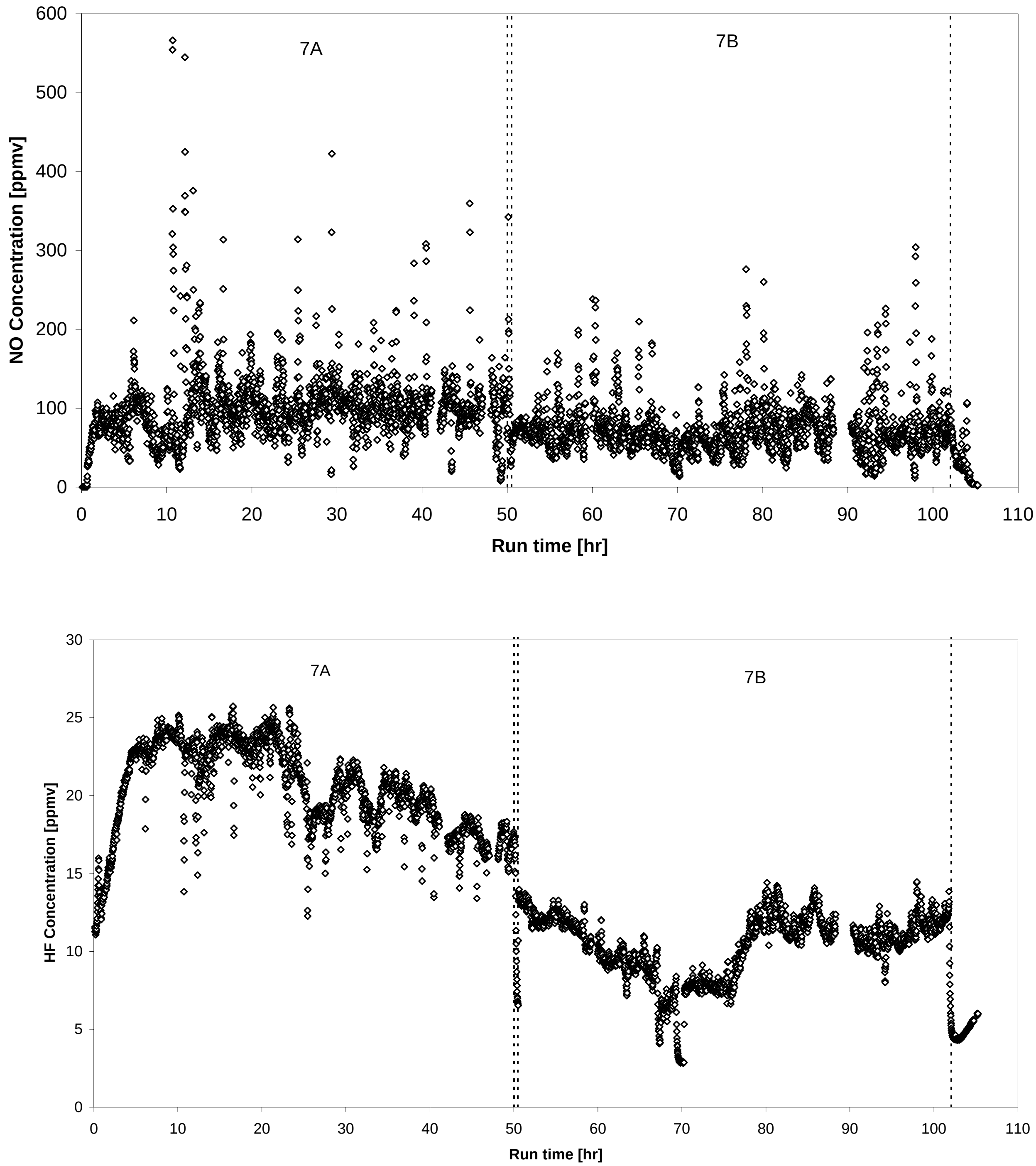
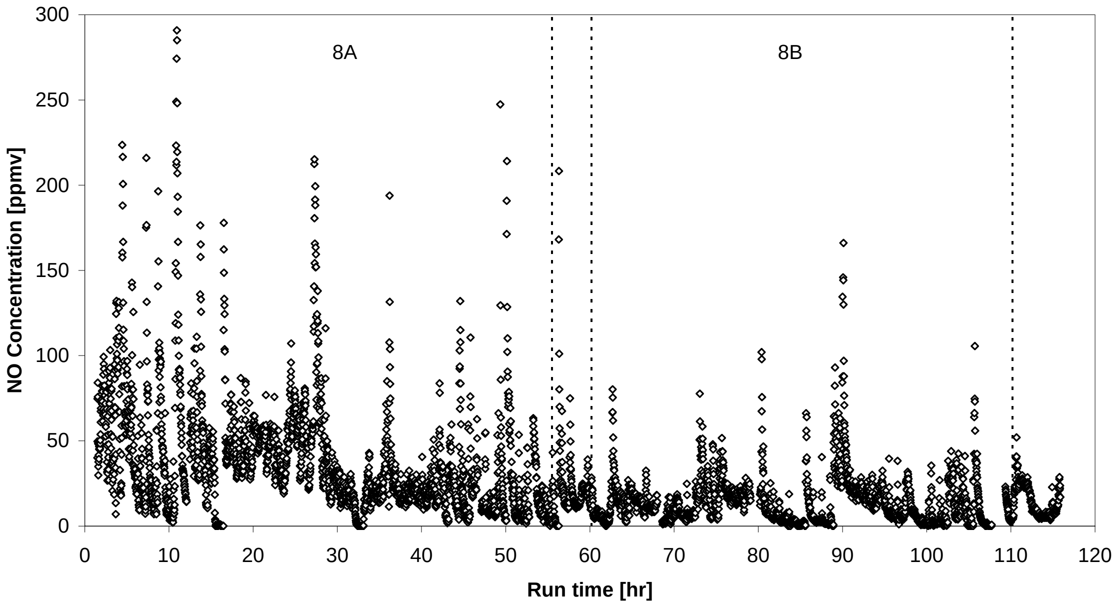


Figure 7.10. NO and HF FTIR monitored emissions during DM100 Tests 7A and 7B.



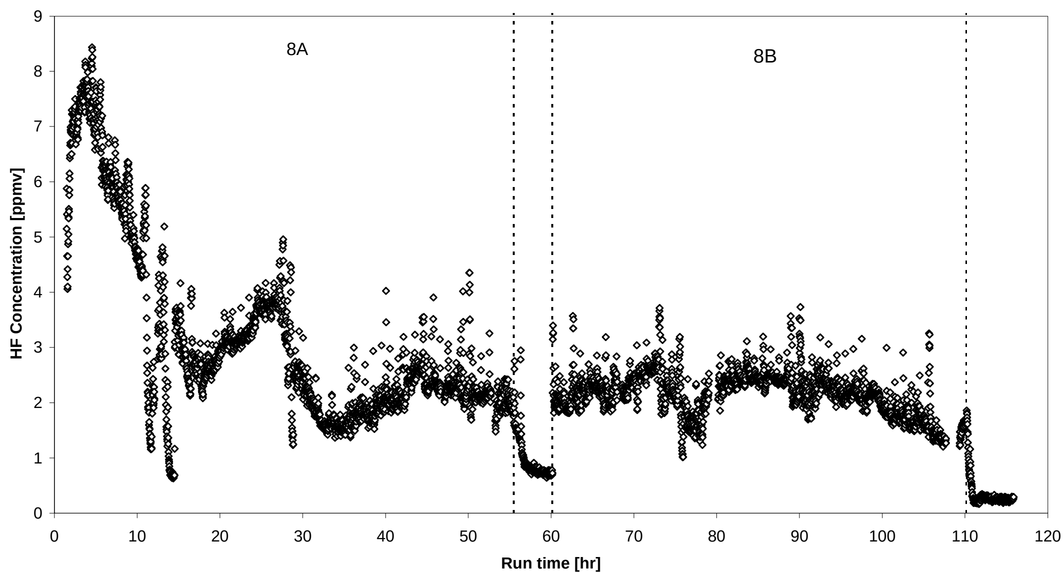


Figure 7.11. NO and HF FTIR monitored emissions during DM100 Tests 8A and 8B.

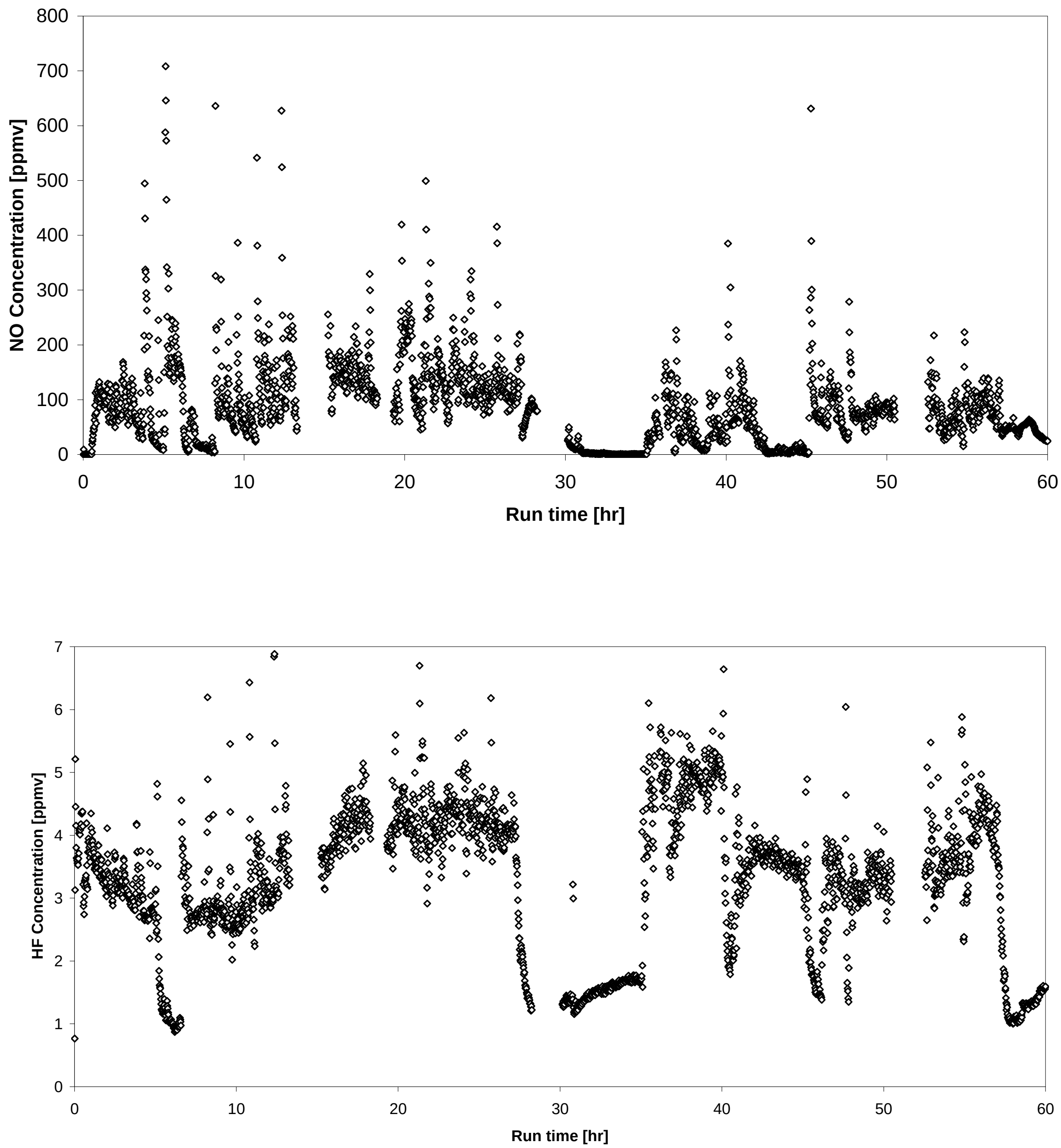


Figure 7.12. NO and HF FTIR monitored emissions during DM100 Test 8C.

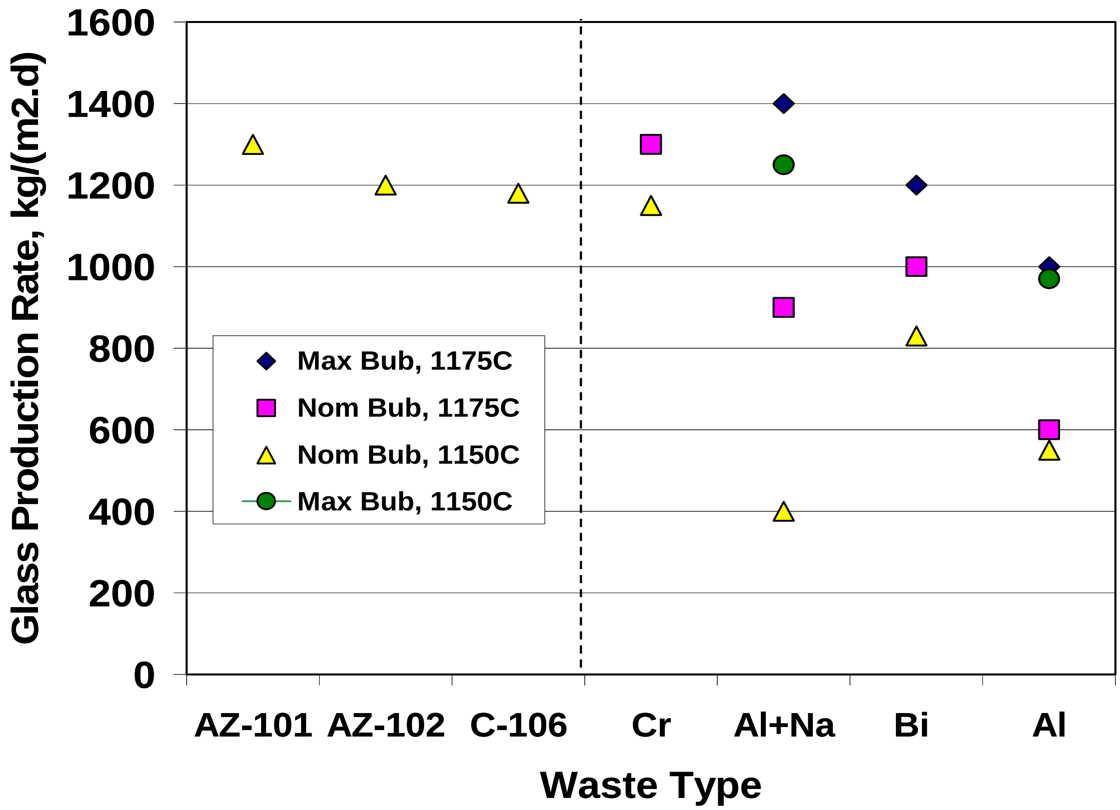


Figure 8.1. Comparison of glass production rates obtained in the present work for the high solids content feeds with comparable high-iron feeds tested previously.

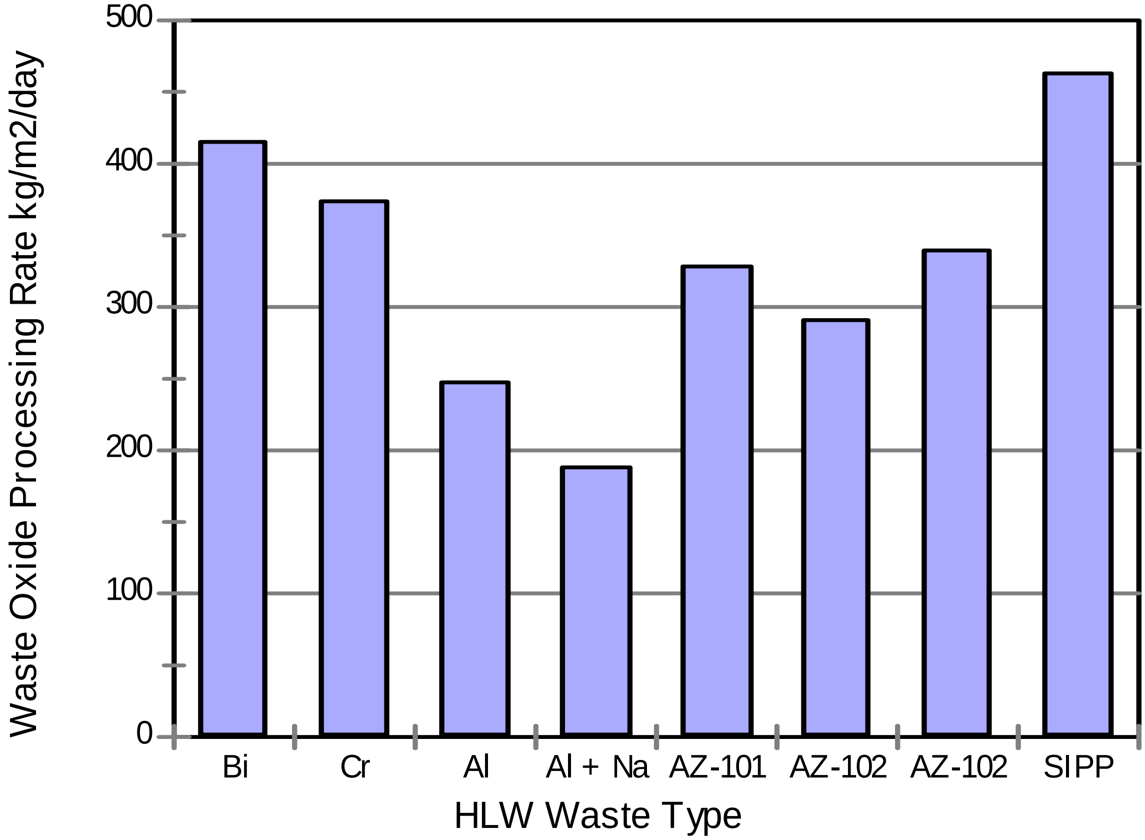


Figure 8.2. Waste oxide processing rates during DM100 tests; glass temperature 1150ºC, glass pool bubbling rate 9 lpm, and feed solids content 500 (±50) g glass per liter feed.

APPENDIX A
LITERATURE REVIEW

In parallel with the glass formulation development work to identify high waste loading HLW glasses, a literature review was conducted to identify glass formulations that have been tested with high concentrations of the components of interest, namely chromium, bismuth, aluminum, and aluminum with sodium. Since the VSL glass databases already contain most of the waste glasses, the scope of the literature review was expanded to cover a larger universe of glass compositions including commercial glasses, glass frits, glazes, basalts, volcanic glasses, etc. Journal articles, project reports, literature review reports, patents, etc. were searched for relevant glass composition data. Most of these glass compositions from other sources could not be used directly in the present work because of unacceptable properties such as high melting temperatures, high viscosities, or excessive crystallization. However, these glass compositions were helpful in identifying viable upper concentration limits of the components of interest and other glass components that may be advantageous in increasing the acceptable concentration limits of the components of interest. A compilation of the glass compositions from the literature review along with the references is provided at the end of this appendix in Table A1, where a total of 1805 glass compositions are tabulated. Where available, the melting temperature, liquidus temperature, temperature at which the glass melt viscosity is 100 poise, and PCT normalized boron release are also given in Table A1. In addition to these glass compositions, information from the VSL database, which contains several thousand glass compositions, was also used to guide the glass formulation work. While a number of the glass compositions given in this appendix have properties that are outside of the acceptable range for HLW processing at Hanford, large numbers of the glass compositions in the VSL database comply with processing and product quality requirements for Hanford.

In the following sub-sections, the chromium, bismuth, aluminum, and sodium concentrations in the glasses from the literature review are discussed and compared to their concentrations in the glasses developed during the present work.

A.1 Chromium

Seven hundred and fifty four compositions containing Cr_2O_3 are tabulated in this appendix. The highest Cr_2O_3 concentration in any of these compositions is 25 wt%, with the majority containing less than 1 wt% Cr_2O_3. The compositions with greater than 5 wt% Cr_2O_3 are mostly glazes and will not be suitable for HLW processing. A limited number of the compositions contain more than 1 wt% Cr_2O_3 and were melted at around 1150°C, but they contain comparatively lesser amounts of other transition metal oxides (e.g. Fe_2O_3) than the ORP Chromium-Limited waste stream used in this study. As noted previously, as the Cr_2O_3 concentration in the glass composition is increased, the common waste-loading limiting phenomenon is crystallization of Cr-containing spinels or Cr_2O_3 crystals. Spinel crystal formation is enhanced as the concentration of other transition metal oxides in the composition is increased. Higher concentrations of alkali oxides and B_2O_3 tend to increase Cr_2O_3 solubility in the glass. Information from the VSL database suggested that addition of K_2O and PbO are also beneficial in improving Cr_2O_3 solubility in the glass. The high Cr_2O_3 solubilities (~ 1.4 wt%) were generally seen in glasses with high alkali and low transition metal oxide concentrations. Based on available literature data, a Cr_2O_3 concentration of about 1 wt% was judged to be an achievable target for the ORP Chromium-Limited waste stream, except for the complications caused by the relatively high sulfur content in this waste stream. Information in the literature suggests that the interaction of SO_3 with Cr_2O_3 can increase the tendency for secondary phase formation, thus reducing the achievable Cr_2O_3 loading in the glass, as was confirmed in the present work. The initially selected VSL formulation for this waste stream, LAW-E-Cr-10, given in Table 3.8, has a Cr_2O_3 concentration of 1.33 wt%, which is higher than any of the Cr_2O_3 concentrations reported in the literature for similar glass compositions and property constraints. However, the Cr_2O_3 loading was indeed limited by secondary phase formation as a result of its interaction with SO_3 (sulfate-chromate salts) rather than by chromium-based crystallization. The final VSL glass composition selected after the DM10 melter test, HLW-E-Cr-M (see Table 4.2), has a Cr_2O_3 concentration of 1.08 wt%, despite the high sulfate content. Again, based on the information in the literature, the Cr_2O_3 concentration in the final glass composition is higher than what would have been expected for a fully compliant glass to be processed in a melter at a nominal operating temperature of 1150°C.

A.2 Bismuth

One hundred and eighty nine compositions containing Bi_2O_3 are tabulated in this appendix with the highest concentration being 70.8 wt%. All of the compositions with high Bi_2O_3 concentrations (> 10 wt%) have high melting temperatures (1300 – 1400°C) with applications as enamels or glazes. The compositions in the literature do not contain most of the other potentially waste loading limiting constituents in the ORP Bismuth-Limited waste stream such as Fe_2O_3, Cr_2O_3, NiO, P_2O_5, and SO_3. The literature information was, therefore, not very useful in guiding the development of suitable glass formulations to process this waste stream. However, the literature review did provide some general information about the effect of Bi_2O_3 addition on the properties of glass melts. The VSL selected glass composition for this waste stream in given in Table 3.4. The glass has a waste loading of 50 wt%. The waste loading limiting factor was crystallization of spinel and phosphate phases and not the concentration of Bi_2O_3 in the glass. As is evident from Table 3.4, the only additives are B_2O_3, Na_2O, and SiO_2, all of which are essential components of an alkali-borosilicate glass. For waste vitrification, the levels of these components are also impractically low in the highest bismuth glasses found in the literature.

A.3 Aluminum

Sixteen hundred and eighty eight glasses containing Al_2O_3 are tabulated in this appendix, with the highest concentration being 74 wt%. The majority of the glasses with high Al_2O_3 concentration (> 20 wt%) are calcium-aluminosilicates with very high melting points (> 1350°C) that have commercial applications. The literature review did reveal a number of waste glasses with medium to high Al_2O_3 concentrations (10 – 20 wt%), and nominal a processing temperature of 1150°C. The formation of nepheline ($NaAlSiO_4$) was reported as a major issue for waste glass compositions with high Al_2O_3 concentrations. To avoid the formation of nepheline, some authors (Li, et al. 1997), (Peeler, et al. 2005) use a nepheline discriminator based on the mass fractions of Al_2O_3, Na_2O, and SiO_2 in the glass with the requirement that $SiO_2/(Al_2O_3 + Na_2O + SiO_2)$ be greater than 0.62. In the VSL glass formulation development work, since increasing the Al_2O_3 loading was the primary objective, the concentrations of the other two nepheline constituents, SiO_2 and Na_2O were decreased and concentrations of B_2O_3 and Li_2O were increased. However, based on prior VSL experience, the nepheline discriminator was judged to be misleading and likely to exclude compliant high aluminum loading glasses. Accordingly, this constraint was not used in the present glass formulation development work. In agreement with the literature information, nepheline formation, especially during canister center-line cooling (CCC) heat treatment, was found to be the waste loading limiting factor in the present work. However, the compliant glass formulation for the ORP Aluminum-Limited waste stream given in Table 3.11 has a $SiO_2/(Al_2O_3 + Na_2O + SiO_2)$ ratio of 0.48, validating the decision to disregard nepheline discriminator as an overly conservative constraint in the glass formulation development for this waste stream. The Al_2O_3 loading of 23.97wt% in the selected glass is higher than what would have been expected for a fully compliant glass from the literature data.

A.4 Aluminum + Sodium

The same literature data that was used to support the development of glass formulation for ORP Aluminum-Limited waste stream was used for the Aluminum+Sodium-Limited waste stream. The only difference was that, since this waste stream contributed more Na_2O to the final glass composition than the Aluminum-Limited waste stream, the aluminum loading in the final glass composition had to be lowered slightly from 23.97 wt% to 21.34 wt% in order to obtain a compliant glass formulation. The composition of the selected glass is given in Table 3.14. Again, the nepheline discriminator was not used in glass formulation development work for the reasons discussed above. The final glass composition has a $SiO_2/(Al_2O_3+ Na_2O+ SiO_2)$ ratio of 0.50. This glass composition would have been unnecessarily excluded if the nepheline discriminator was used. While the information from the literature is valuable in supporting and guiding glass formulation development for Hanford waste steams, caution should be used in using empirical relationships from the literature to constrain composition regions to be studied because empirical relationships that may be valid in certain composition regions may not be valid in other regions. Indeed, some of the greatest gains in waste loading can be achieved by challenging such constraints.

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Table A1. Glass Compositions from Literature Review

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Ackerman, 2006	1250			11.0			2.0		0.5	25.0				5.0	1.0				15.0						38.5					2.0					
Barantseva, 2004	1425		13.6				6.1	1.0					6.4			4.0			11.5			0.8			57.2										
Barbieri, 1994			9.2				24.5									13.9									52.5										
Barbieri, 1994			9.1				24.2			0.5						13.8									52.3										
Barbieri, 1994			9.1				23.8			1.3						13.8									52.1										
Barbieri, 1994			9.0				23.5			1.8						13.7									51.9										
Barbieri, 1994			8.4				18.4			12.2						12.7									48.2										
Barbieri, 1994			8.9				22.5			3.9						13.5									51.2										
Barbieri, 1994			18.3				23.1									9.2									49.4										
Barbieri, 1994			18.2				22.8			0.5						9.2									49.2										
Barbieri, 1994			18.2				22.4			1.2						9.2									49.0										
Barbieri, 1994			18.1				22.2			1.7						9.1									48.9										
Barbieri, 1994			17.9				21.2			3.7						9.0									48.3										
Barbieri, 1994			16.9				17.5			11.5						8.5									45.6										
Battigelli, 1997		1423	18.0				8.9						10.1	0.6		6.4	0.2		3.5				0.1		51.5					0.7					
Belyusenko, 1979	1350		3.5	23.0	4.5		4.3							0.3		0.5			6.5				3.0		35.0		4.5					5.7	7.0		
Belyusenko, 1979	1350		6.0	22.6	3.6		7.7					4.7		3.0					7.1				6.0		33.0		2.4					3.9			
Bernard, 2005		1349	18.6				6.2						7.2	5.2		7.1			8.0						47.7									1260	
Bernard, 2005		1284	18.1				22.7						2.5	7.4		0.2			6.3						42.6									1200	
Bernard, 2005			17.3				21.7						3.0	7.1		0.4			6.0						44.4									1190	
Bernard, 2005		1297	17.2				15.3						6.6	7.8		0.5			6.2						45.2									1160	
Bernard, 2005		1333	18.1				13.5						7.3	8.1		0.5			6.5						45.4									1160	
Bernard, 2005		1324	17.6				15.0						8.4	7.6		0.5			6.4						43.9									1120	
Bernard, 2005			17.6				13.3						9.8	7.9		0.5			6.3						44.2									1100	
Bernard, 2005			17.6				14.2						9.2	7.9		0.5			6.4						43.8									1110	
Bernard, 2005			17.4				13.2						8.3	7.8		0.5			6.3						46.1									1140	
Bernard, 2005		1353	17.6				11.9						11.3	8.0		0.5			6.4						43.8									1160	
Bernard, 2005		1364	15.7				9.8						12.1	8.0		0.4			6.4						47.1									1200	
Bernard, 2005		1355	20.9				14.5						8.7	7.4		0.5			6.1						41.9									1140	
Bernard, 2005		1442	19.8				14.0						4.2	7.2		0.5			6.0						48.2									1160	
Bernard, 2005		1403	22.5				14.3						6.3	7.1		0.5			6.0						43.2									1140	
Bernard, 2005		1393	19.3				13.9						6.8	7.1		0.5			6.0						46.3									1110	
Bernard, 2005		1372	18.8				13.9						8.3	7.2		0.5			5.9						45.4									1110	
Bernard, 2005		1365	19.7				14.1						9.5	7.2		0.5			6.0						43.0									1110	
Bernard, 2005			19.8				13.4						9.3	3.7		0.7			8.3						44.3									1170	
Bernard, 2005		1382	21.5				14.1						7.5	7.3		0.5			6.0						43.0									1140	
Bernard, 2005		1404	18.4				13.8						6.2	7.3		0.5			6.0						47.7									1150	
Bernard, 2005		1430	22.4				13.9						4.2	7.3		0.5			6.0						45.6									1150	
Bernard, 2005		1382	21.2				14.1						7.4	7.2		0.5			6.0						43.5									1120	
Bernard, 2005		1392	22.2				14.0						6.9	7.2		0.5			6.0						43.1									1160	
Bernard, 2005		1386	25.1				13.9						6.9	7.2		0.5			6.0						40.3									1170	
Bernard, 2005			21.7				13.1						8.7	7.7		0.6			5.9						42.3									1160	
Bernard, 2005			24.6				13.2						4.0	7.6		0.6			5.9						43.9										
Bernard, 2005			24.7				13.4						6.0	7.6		0.6			6.2						41.5									1180	
Bernard, 2005			24.9				13.3						8.1	7.6		0.5			6.3						39.3									1200	
Bernard, 2005			18.2				13.9						7.5	3.9		0.6			8.1						47.3									1160	
Bernard, 2005		1323	19.2				12.9						7.5	5.7		0.8			7.9						45.3									1150	
Bernard, 2005			20.5				12.9						7.4	3.8		0.8			8.3						45.3									1180	
Bernard, 2005			22.5				12.7						7.5	3.7		0.8			7.9						44.0									1200	
Bernard, 2005		1335	19.2				12.4						7.4	3.9		0.8			8.8						46.5									1150	

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Bloomer, 1999	1375		15.4				3.0	0.3		0.1			20.0	0.2		0.4	0.1		15.0	0.1		0.3		0.3	44.2	0.1									
Bloomer, 1999	1450		18.6				3.6	0.3		0.1			24.2	0.2		0.5	0.1		2.6	0.1		0.6		0.3	48.2	0.1									
Bloomer, 1999	1280		6.0	5.9			2.3			0.0			20.0			0.4	0.0		15.0			0.1	0.1		50.0					0.1					
Bloomer, 1999	1450		5.2				6.7			0.0			58.8			1.1	0.0		1.2	0.0		0.2	0.1		25.7					0.3			0.0		
Bloomer, 1999	1300		7.8		0.1		19.3	0.4		1.1	0.3		18.1	1.7		1.6	0.1		6.0	0.4			0.1	0.1	40.0	0.1				0.4			0.4		
Bloomer, 1999	1425		8.7		0.1		21.6	0.4		1.2	0.3		20.2	1.9		1.8	0.1		1.5	0.5			0.1	0.1	38.1	0.1				0.4			0.5		
Bouhifd, 2004		1198	13.3				10.0						11.2	1.4		9.2			5.6						46.6					2.5					
Bouhifd, 2004		1325	12.8				9.6						9.9	1.5		8.1			6.1						49.3					2.1					
Bouhifd, 2004		1355	12.1				9.2						8.9	1.8		7.2			6.5						51.6					1.5					
Bouhifd, 2004		1506	9.9				5.3						7.2	2.3		4.6			9.0						59.0					1.6					
Bouhifd, 2004		1312	13.1				10.0						10.2	1.5		8.9			5.6						48.2					2.3					
Bouhifd, 2004		1696	4.2				2.0						1.2	3.4		2.0			11.3						74.8					0.5					
Bras, 1977	<1450		4.3	4.0			39.0			0.8			22.0												30.0										
Bras, 1977	<1450		4.3	4.0			37.0			0.8			22.0												32.0										
Bras, 1977	<1450		4.3	4.0			35.0			0.8			22.0												34.0										
Bras, 1977	<1450		4.3	4.0			29.0			0.8			22.0												40.0										
Bras, 1977	<1450		4.3	4.0			27.0			0.8			22.0												42.0										
Bras, 1977	<1450		4.3	4.0			25.0			0.8			22.0												44.0										
Bras, 1977	<1450		4.3	4.0			39.0			0.8			15.0												37.0										
Bras, 1977	<1450		4.3	4.0			36.0			0.8			18.0												37.0										
Bras, 1977	<1450		4.3	4.0			34.0			0.8			20.0												37.0										
Bras, 1977	<1450		4.3	4.0			30.0			0.8			24.0												37.0										
Bras, 1977	<1450		4.3	4.0			28.0			0.8			26.0												37.0										
Bras, 1977	<1450		4.3	4.0			26.0			0.8			28.0												37.0										
Bras, 1977	<1450		4.3	4.0			24.0			0.8			30.0												37.0										
Bras, 1977	<1450		4.3	4.0			32.0			0.8			15.0												44.0										
Bras, 1977	<1450		4.3	4.0			32.0			0.8			18.0												41.0										
Bras, 1977	<1450		4.3	4.0			32.0			0.8			20.0												39.0										
Bras, 1977	<1450		4.3	4.0			32.0			0.8			24.0												35.0										
Bras, 1977	<1450		4.3	4.0			32.0			0.8			26.0												33.0										
Bras, 1977	<1450		4.3	4.0			32.0			0.8			29.0												30.0										
Bras, 1977	<1450		4.3	4.0			23.0			0.8			28.0												40.0										
Bras, 1977	<1450		4.3	4.0			26.0			0.8			31.0												34.0										
Bras, 1977	<1450		4.3	4.0			42.0			0.8			15.0												34.0										
Bras, 1977	<1450		4.3	4.0			38.0			0.8			13.0												40.0										
Bras, 1977	<1450		4.3	4.0			30.0			0.8			22.0			2.0									37.0										
Bras, 1977	<1450		4.3	4.0			26.0			0.8			22.0			6.0									37.0										
Bras, 1977	<1450		4.3	4.0			22.0			0.8			22.0			10.0									37.0										
Bras, 1977	<1450		4.3	4.0			31.0			0.8			21.0						2.0						37.0										
Bras, 1977	<1450		4.3	4.0			29.0			0.8			20.0						5.0						37.0										
Bras, 1977	<1450		4.3	4.0			32.0			0.5			22.0												36.8										
Bras, 1977	<1450		4.3	4.0			31.5			2.0			21.5												36.3										
Brouns, 1988			8.1	12.1	0.1		0.6	0.1		0.2			12.2	1.3	2.0	1.3	1.3	0.0	9.3	0.3		0.2	2.5		42.6	0.3	0.0	0.2	3.6	1.0	0.6		0.3		
Brouns, 1988			8.0	12.1	0.1		0.6	0.1		0.2			12.2	1.3	2.0	1.3	1.3	0.0	9.3	0.3		0.3	2.5		42.6	0.3	0.0	0.2	3.6	1.0	0.6		0.3		
Brouns, 1988			7.8	11.7	0.1		0.6	0.1		0.2			11.8	1.3	2.0	1.3	1.3	0.0	12.2	0.3		0.2	2.4		41.2	0.3	0.0	0.2	3.5	1.0	0.5		0.3		
Brouns, 1988			8.0	12.0	0.1		0.6	0.1		0.2			12.1	1.3	2.0	1.3	1.3	0.0	9.2	0.3		0.2	3.5		42.2	0.3	0.0	0.2	3.6	1.0	0.6		0.3		
Brouns, 1988			7.9	11.9	0.1		0.6	0.1		0.2			12.0	1.3	2.0	1.3	1.3	0.0	9.1	0.3		0.2	2.5		41.8	0.3	0.0	0.2	5.4	1.0	0.6		0.3		
Brouns, 1988			8.5	7.3	0.1		0.6	0.1		0.2			12.9	1.4	2.1	1.4	1.4	0.0	9.8	0.3		0.2	2.7		44.9	0.3	0.0	0.2	3.8	1.1	0.6		0.3		
Brouns, 1988a			9.0	13.0	0.3		1.4	1.2		0.2	0.0		9.0	1.7	2.4	1.3	2.5	0.1	10.5	0.5	0.3	0.3	1.5		39.0	0.4	0.0	0.3	2.0	1.4	1.0	0.0	0.7		
Brouns, 1988a			9.0	13.0	0.3		1.4	0.4		0.1	0.1		15.0	1.4	1.9	1.3	2.2	0.0	8.4	0.2		0.1	3.5		39.0	0.1	0.0	0.1	2.0	0.4	0.2	0.0	0.2		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Brouns, 1988a			9.0	10.2	0.3		1.4	1.3		0.3	0.0		9.0	1.7	2.4	1.3	2.5	0.1	10.5	0.6		0.3	1.5		39.0	0.4	0.0	0.3	5.1	1.6	0.2	0.1	0.8		
Brouns, 1988a			9.0	11.0	0.1		0.5	0.4		0.1	0.0		15.0	1.8	2.5	0.4	0.5	0.0	11.2	0.2		0.1	1.5		42.5	0.1	0.0	0.1	2.4	0.5	0.2		0.2		
Brouns, 1988a			12.0	10.4	0.3		1.4	0.4		0.1	0.1		15.0	1.6	2.2	1.3	0.5	0.0	9.5	0.2		0.1	1.5		36.7	0.1	0.0	0.1	5.3	0.4	2.0		0.2		
Brouns, 1988a			12.0	11.1	0.3		1.4	1.3		0.3	0.0		9.0	1.5	2.0	1.3	0.5	0.1	9.0	0.6		0.3	3.5		39.4	0.4	0.0	0.3	2.0	1.6	2.0	0.0	0.8		
Brouns, 1988a			12.0	10.3	0.1		0.5	0.4		0.1	0.1		15.0	1.7	2.4	0.4	2.5	0.0	10.6	0.2		0.1	3.5		36.5	0.1	0.0	0.1	2.0	0.5	2.0	0.1	0.2		
Brouns, 1988a			12.0	11.8	0.1		0.5	1.3		0.3	0.0		15.0	1.4	1.9	0.4	2.5	0.1	8.5	0.6		0.3	1.5		36.3	0.4	0.0	0.3	2.0	1.5	0.2	0.0	0.7		
Brouns, 1988a			9.4	12.5	0.1		0.5	0.4		0.1			14.2	1.9	1.8	0.5	0.4	0.0	8.2	0.2		0.1	3.3		39.3	0.1	0.0	0.1	5.0	0.5	1.0	0.0	0.2		
Brouns, 1988a			12.3	13.2	0.1		0.5	0.4		0.1	0.0		8.7	2.5	2.1	0.6	2.0	0.0	9.6	0.2		0.1	1.4		42.1	0.1	0.0	0.1	1.9	0.5	1.0	0.0	0.2		
Brouns, 1988a			9.3	10.9	0.1		0.5	0.4		0.1	0.0		8.7	2.0	2.0	0.5	2.0	0.0	9.1	0.2		0.1	3.1		45.0	0.1	0.0	0.1	4.4	0.5	0.1		0.2		
Brouns, 1988a			12.3	13.4	0.3		1.3	0.4		0.1	0.0		8.7	2.6	2.0	1.4	0.5	0.0	9.1	0.2		0.1	1.6		41.0	0.1	0.0	0.1	3.8	0.5	0.1	0.0	0.3		
Brouns, 1988a			12.2	12.6	0.1		0.5	1.4		0.3	0.1		8.7	2.5	2.3	0.6	0.4	0.1	10.1	0.6		0.3	3.5		36.7	0.5	0.0	0.4	3.5	1.7	0.1	0.1	0.8		
Brouns, 1988a			9.7	10.7	0.1		0.5	1.3		0.3	0.1		12.1	1.4	2.1	0.6	0.4	0.1	8.9	0.6		0.3	1.5		43.4	0.4	0.0	0.4	1.7	1.6	1.0	0.1	0.8		
Brouns, 1988a			9.3	11.5	0.3		1.3	0.4		0.1	0.0		8.7	1.8	2.6	1.4	0.4	0.0	10.7	0.2		0.1	3.3		44.7	0.1	0.0	0.1	1.9	0.5	0.1	0.0	0.2		
Brouns, 1988a			10.1	11.9	0.2		0.8	0.8		0.2	0.0		11.5	1.8	2.1	1.0	1.0	0.0	9.6	0.4		0.2	2.4		40.1	0.3	0.0	0.2	3.3	0.9	0.6	0.0	0.5		
Brown, 2001	1150		6.5	6.4			1.3			0.0			13.6	3.1	3.3	0.5	3.3		8.8	1.1					49.0					1.3			0.1	1096	
Brown, 2001	1150		14.1	11.4			0.4			0.0			4.1	0.1	4.2	1.4	2.7		14.9	0.6					44.6					0.8			0.8	863	
Brown, 2001	1150		14.1	11.4			0.4			0.0			4.1	0.1	4.2	1.4	2.7		14.9	0.6					44.6					0.8			0.8	835	
Brown, 2001	1150		13.5	10.9			0.4						4.7		4.1	1.4	2.5		14.1	0.6					46.4					0.7			0.7	990	
Brown, 2001	1150		4.3	7.7			0.8			0.0			11.5	0.1	4.4	0.7	2.8		10.4	1.0					54.7					0.1			1.3	995	
Brown, 2001	1150		2.3	7.3			1.0						17.0		4.1	0.7	0.9		10.9	2.6					51.4					0.1			0.9	1035	
Brown, 2001	1150		4.4	7.6			0.8						11.9		4.3	0.7	2.6		9.9	1.0					55.0					0.1			0.9	996	
Brown, 2001	1150		1.0	7.5			1.1			0.0			17.9	0.1	4.2	0.7	1.1		11.1	2.9					51.1					0.1			1.2	1075	
Brown, 2001	1150		2.3	7.3			1.0						17.0		4.1	0.7	0.9		10.9	2.6					51.4					0.1			0.9	1035	
Brown, 2001	1150		2.3	7.3			1.0						17.0		4.1	0.7	0.9		10.9	2.6					51.4					0.1			0.9	1109	
Brown, 2001	1150		2.3	7.3			1.0						17.0		4.1	0.7	0.9		10.9	2.6					51.4					0.1			0.9	1107	
Brown, 2001	1150		6.4	7.2			1.3			0.1			13.4	3.1	4.1	1.0	3.2		6.5	1.1					50.2					1.3			0.1	1111	
Brown, 2001	1150		13.3	7.6			0.5						4.2	0.1	4.3	0.7	2.8		11.1	0.6					52.7					0.1			1.3	863	
Brown, 2001	1150		13.3	7.6			0.5						4.2	0.1	4.3	0.7	2.8		11.1	0.6					52.7					0.1			1.3	946	
Brown, 2001	1150		13.4	7.3			0.5						4.8		4.2	0.7	2.6		10.6	0.7					53.6								0.8	840	
Brown, 2001	1150		5.3	7.3			0.7			0.1			12.1	0.1	5.1	0.7	2.8		10.3	1.1					53.1					0.2			0.7	917	
Brown, 2001	1150		5.2	6.6			1.0						11.6		5.0	0.7	2.6		10.0	1.0					55.3								0.8	1000	
Brown, 2001	1150		5.1	7.3			0.9			0.0			12.0	0.1	5.1	0.7	2.8		10.2	1.0					53.3					0.1			0.8	1006	
Brown, 2001	1150		1.4	7.3			1.4						16.4		4.1	0.7	1.1		10.7	3.0					52.0								0.9	1015	
Brown, 2001	1150		1.5	7.4			1.4						16.5	0.0	4.3	0.6	1.0		11.2	2.6					49.6								0.9	1135	
Brown, 2001	1150		1.3	7.5			1.5			0.0			16.4	0.0	4.2	0.7	1.1		11.2	3.1					51.7					0.1			1.3	1102	
Brown, 2001	1150		1.3	7.5			1.5			0.0			16.4	0.0	4.2	0.7	1.1		11.2	3.1					51.7					0.1			1.3	920	
Brown, 2001	1150		1.4	7.3			1.4						16.4		4.1	0.7	1.1		10.7	3.0					52.0								0.9	1085	
Brown, 2001	1150		1.4	7.3			1.4						16.4		4.1	0.7	1.1		10.7	3.0					52.0								0.9	1086	
Brown, 2001	1150		1.4	7.3			1.4						16.4		4.1	0.7	1.1		10.7	3.0					52.0								0.9	1113	
Brown, 2001	1150		14.2	12.1			0.4			0.0			3.5	0.2	4.2	0.7	2.7		10.4	0.5					47.7					0.1			0.7	846	
Brown, 2001	1150		6.7	13.7			0.1						2.5		5.3	0.9	1.1		11.8	0.3					56.4								0.9	720	
Brown, 2001	1150		5.3	12.7			0.7			0.0			11.5	0.1	4.3	0.7	2.7		10.3	1.0					50.4					0.1			0.8	1014	
Brown, 2001	1150		5.3	12.7			0.7			0.0			11.5	0.1	4.3	0.7	2.7		10.3	1.0					50.4					0.1			0.8	925	
Brown, 2001	1150		5.6	10.6			0.7						11.1		4.2	0.7	2.6		10.1	1.0					51.6								0.7	990	
Brown, 2001	1150		5.6	10.6			0.7						11.1		4.2	0.7	2.6		10.1	1.0					51.6								0.7	980	
Brown, 2001	1150		5.3	12.7			0.7			0.0			11.5	0.1	4.3	0.7	2.7		10.3	1.0					50.4					0.1			0.8	967	
Brown, 2001	1150		5.3	12.7			0.7			0.0			11.5	0.1	4.3	0.7	2.7		10.3	1.0					50.4					0.1			0.8	971	
Brown, 2001	1150		3.3	12.0			1.3						17.4	0.0	4.0	0.7	1.0		13.8	2.7					42.5								0.7	1130	
Brown, 2001	1150		1.4	11.7			1.1			0.0			13.1	0.1	4.2	0.7	0.7		11.2	2.8					53.1					0.0			0.7	1022	
Brown, 2001	1150		2.5	11.4			1.4						15.6		4.1	0.7	1.0		10.8	2.8					48.3								0.7	1085	

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Brown, 2001	1150		2.5	11.4			1.4						15.6		4.1	0.7	1.0		10.8	2.8					48.3								0.7	900	
Brown, 2001	1150		13.9	10.3			0.6			0.0			4.0	3.3	2.6	1.3	2.6		10.9	0.6					47.7					1.8			0.0	929	
Brown, 2001	1150		13.4	10.2			0.5						4.5	3.1	2.7	1.3	2.5		10.6	0.6					48.4					1.7			0.0	845	
Brown, 2001	1150		5.2	10.2			0.9			0.0			11.3	3.2	2.7	1.3	2.8		10.1	1.0					49.2					1.6			0.1	997	
Brown, 2001	1150		5.1	10.3			0.6						11.9	3.2	2.7	1.2	2.6		9.8	1.0					49.5					1.4			0.0	985	
Brown, 2001	1150		5.9	10.1			0.7			0.0			11.6	3.1	3.2	1.2	2.7		9.8	1.0					49.0					1.3			0.1	996	
Brown, 2001	1150		2.1	10.1			0.9						15.7	3.2	2.6	1.2	1.0		10.6	2.6					47.4					1.8			0.0	1070	
Brown, 2001	1150		1.4	9.9			1.5						16.6	3.2	2.6	1.3	1.0		11.0	2.8					46.5					1.7			0.0	895	
Brown, 2001	1150		1.4	10.4			1.0			0.0			15.9	3.3	2.5	1.3	1.0		11.0	2.7					47.4					1.9			0.1	1126	
Brown, 2001	1150		2.1	10.1			0.9						15.7	3.2	2.6	1.2	1.0		10.6	2.6					47.4					1.8			0.0	1065	
Brown, 2001	1150		2.1	10.1			0.9						15.7	3.2	2.6	1.2	1.0		10.6	2.6					47.4					1.8			0.0	1113	
Brown, 2001	1150		2.1	10.1			0.9						15.7	3.2	2.6	1.2	1.0		10.6	2.6					47.4					1.8			0.0	1062	
Brown, 2001	1150		13.7	7.5			0.4			0.0			3.9	3.5	4.3	1.3	2.6		7.6	0.6					52.2					1.8			0.1	959	
Brown, 2001	1150		13.9	7.4			0.4						4.4	3.3	4.2	1.3	2.5		7.3	0.6					52.4					1.7			0.0	965	
Brown, 2001	1150		5.1	7.6			0.7			0.0			11.3	3.1	4.4	1.1	2.7		6.8	1.0					54.2					1.3			0.1	965	
Brown, 2001	1150		5.0	7.6			0.7			0.0			11.7	3.5	4.4	1.3	2.7		6.8	1.0					53.3					1.4			0.1	967	
Brown, 2001	1150		5.0	7.4			0.7						11.9	3.3	4.3	1.3	2.6		6.6	1.0					54.1					1.4			0.0	1010	
Brown, 2001	1150		1.4	7.1			1.0						15.8	3.3	4.3	1.3	1.0		7.6	2.7					52.5					1.7			0.0	1160	
Brown, 2001	1150		1.0	7.3			1.4						15.9	3.3	4.4	1.3	1.0		7.8	2.7					50.1					1.8			0.0	1100	
Brown, 2001	1150		1.4	7.3			1.0			0.0			16.7	3.5	4.2	1.3	1.0		7.7	2.9					51.0					1.8			0.1	1123	
Brown, 2001	1150		1.4	7.1			1.0						15.8	3.3	4.3	1.3	1.0		7.6	2.7					52.5					1.7			0.0	1110	
Brown, 2001	1150		1.4	7.1			1.0						15.8	3.3	4.3	1.3	1.0		7.6	2.7					52.5					1.7			0.0	1118	
Brown, 2001	1150		1.4	7.1			1.0						15.8	3.3	4.3	1.3	1.0		7.6	2.7					52.5					1.7			0.0	1127	
Brown, 2001	1150		5.5	7.0			0.7			0.0			11.4	3.2	3.8	0.6	2.6		9.2	1.0					53.1					1.3			0.0	991	
Brown, 2001	1150		6.0	8.8			0.7			0.0			11.6	3.1	3.5	0.6	2.6		9.2	1.0					50.9					1.3			0.1	1000	
Brown, 2001	1150		6.0	8.8			0.7			0.0			11.6	3.1	3.5	0.6	2.6		9.2	1.0					50.9					1.3			0.1	778	
Brown, 2001	1150		4.6	6.8			1.6						11.6	0.1	4.9	0.8	2.0		11.2	0.8					54.4					0.2			0.8	909	
Brown, 2001	1150		4.6	8.5			1.5			0.1			14.1	2.7	3.2	0.9	1.9		11.5	1.1					48.1					1.2			0.3	1066	
Brown, 2001	1150		4.5	8.4			1.5			0.1			14.3	2.7	3.2	0.9	2.0		11.5	1.1					48.0					1.2			0.2	997	
Brown, 2001	1150		4.7	8.7			1.4			0.1			14.2	2.7	3.3	0.8	1.9		11.6	1.1					47.6					1.2			0.2	1062	
Brown, 2001	1150		4.5	8.4			1.5			0.1			14.3	2.7	3.2	0.9	2.0		11.5	1.1					48.0					1.2			0.2	1012	
Brown, 2001	1150			8.5											6.9	1.0			12.8						70.1								0.8	732	
Brown, 2001	1107		2.5	10.2			2.0			0.1			14.1	3.8	5.9	0.5	1.0		6.2	2.1					42.7					0.7	4.5			1124	
Brown, 2001	1250		2.6	5.1			1.9			0.0			6.0	3.8	5.9	2.4	3.0		11.0	0.1					57.8					0.2				775	
Brown, 2001	1250		4.0	9.4			1.5			0.2			11.8	2.1	3.4	1.9	2.4		9.9	1.6					46.6					0.3	3.5			1164	
Brown, 2001	1300		8.3	4.9			0.3			0.1			14.7	1.5	6.0	2.6	1.0		6.2	2.1					51.8					0.2	0.3			1261	
Brown, 2001	1300		5.6	7.7			1.2			0.2			10.6	2.7	4.4	1.6	2.0		8.5	1.1					52.3					0.4	2.5			1084	
Brown, 2001	1284		5.6	7.8			1.1			0.2			10.4	2.5	4.0	1.4	2.0		8.6	1.1					51.1					0.4	2.4			1082	
Brown, 2001	1322		7.9	5.0			2.0			0.1			14.3	3.8	3.0	0.5	1.0		11.0	0.1					47.9					0.7	0.3			911	
Brown, 2001	1294		8.1	10.6			0.3			0.3			5.8	3.6	5.4	2.3	2.9		6.0	0.1					53.3					0.2	0.3			950	
Brown, 2001	1330		4.1	6.5			1.6			0.1			12.5	3.2	3.4	2.1	2.4		7.5	0.6					54.3					0.3	1.5			1114	
Brown, 2001	1200		8.2	10.1			2.0			0.3			14.8	1.5	5.8	0.5	1.0		6.3	0.1					44.0					0.2	4.8			1173	
Brown, 2001	1275		4.0	6.7			0.8			0.3			8.2	3.2	5.3	2.0	2.5		7.5	1.6					54.2					0.3	3.6			1098	
Brown, 2001	1264		3.9	9.5			0.8			0.1			8.1	2.1	5.1	1.9	1.5		9.7	0.6					53.5					0.3	1.5			895	
Brown, 2001	1384		2.6	5.0			0.3			0.3			14.7	1.5	3.0	2.5	1.0		11.1	0.0					56.4					0.2	0.3			1030	
Brown, 2001	1400		2.6	9.8			0.3			0.3			8.4	1.5	5.9	0.5	2.9		6.0	2.1					56.7					0.2	0.3			1063	
Brown, 2001	1160		2.7	11.0			0.3			0.1			15.1	3.7	2.7	2.6	2.9		11.3	0.1					43.3					0.2	5.1			951	
Brown, 2001	1285		2.5	10.1			1.9			0.1			5.9	1.5	6.0	2.5	0.9		6.1	2.1					55.9					0.6	0.7			935	
Brown, 2001	1250		6.9	6.3			1.6			0.1			8.4	2.1	5.2	2.0	2.4		9.9	0.6					50.1					0.5	3.7			995	
Brown, 2001	1160		4.0	7.9			1.6			0.1			12.4	3.2	5.3	1.0	1.5		10.0	1.6					45.7					0.5	3.6			1075	

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Brown, 2001	1142		2.5	10.4			0.3			0.3			14.4	1.5	5.9	0.5	2.8		10.9	0.0					46.8					0.6	0.3			859	
Brown, 2001	1142		2.7	10.3			0.3			0.3			14.7	1.5	5.9	0.5	2.9		10.9	0.0					47.8					0.6	0.3			869	
Brown, 2001	1140		6.6	10.3			0.3			0.3			5.8	3.7	5.9	0.5	1.0		10.9	2.2					44.4					0.2	4.7			929	
Brown, 2001	1240		8.3	5.0			2.0			0.1			6.1	1.5	5.9	2.6	1.0		11.1	0.1					51.5					0.6	5.0			799	
Brown, 2001	1284		4.0	8.9			1.6			0.2			7.9	2.0	5.2	1.0	2.3		7.2	1.6					53.4					0.5	1.6			987	
Brown, 2001	1246		6.9	6.5			1.5			0.3			12.7	2.1	5.2	1.0	1.5		9.8	1.6					50.0					0.3	1.6			1145	
Brown, 2001	1304		4.3	6.5			1.6			0.3			8.0	3.1	3.4	1.9	1.5		9.9	1.6					53.5					0.5	1.5			1069	
Brown, 2001	1345		2.6	5.2			0.3			0.1			11.8	1.5	5.8	0.5	1.0		6.1	0.1					58.5					0.7	4.7			995	
Brown, 2001	1333		7.9	11.5			0.4			0.1			14.4	3.7	2.7	2.4	1.0		6.6	2.1					47.1					0.2	0.3			1310	
Brown, 2001	1304		4.1	6.7			0.8			0.2			12.5	2.1	3.8	1.0	1.5		10.1	0.6					52.3					0.5	3.7			1071	
Brown, 2001	1218		7.0	9.4			1.5			0.3			11.1	3.3	5.1	2.0	1.5		7.4	0.6					47.2					0.3	3.6			1086	
Brown, 2001	1150		2.6	10.5			2.0			0.1			14.7	1.5	6.0	0.5	1.0		11.2	0.1					49.5					0.2	0.3			833	
Brown, 2001	1280		8.1	5.2			0.3			0.1			5.8	1.5	6.2	0.5	2.9		11.2	0.1					51.4					0.7	4.7			811	
Brown, 2001	1157		8.0	5.1			1.9			0.1			5.9	3.7	5.4	2.4	2.9		10.9	2.1					44.1					0.2	4.5			1030	
Brown, 2001	1149		8.4	11.1			2.0			0.1			15.2	3.7	5.3	2.7	2.9		6.2	0.1					43.1					0.7	0.3			1081	
Brown, 2001	1250		8.2	10.6			0.3			0.1			14.9	1.5	6.0	0.5	1.0		10.9	2.1					43.0					0.6	0.3			1132	
Brown, 2001	1145		8.4	10.4			2.0			0.3			6.2	3.8	5.9	0.5	2.9		10.6	2.1					47.6					0.6	0.3			943	
Brown, 2001	1320		8.3	9.6			2.0			0.3			14.6	1.5	3.0	2.5	2.9		6.4	0.1					42.1					0.6	4.8			1282	
Brown, 2001	1200		8.1	5.3			0.3			0.3			13.9	3.7	6.1	2.4	2.9		11.0	2.1					41.8					0.7	0.3			1231	
Brown, 2001	1265		2.5	10.4			2.0			0.3			5.7	3.7	3.0	0.5	1.0		11.0	0.1					51.4					0.2	4.4			813	
Brown, 2001	1268		2.6	10.3			2.0			0.3			5.8	3.8	5.9	2.4	1.0		6.0	0.3					58.2					0.7	0.3			944	
Brown, 2001	1151		2.7	11.1			0.3			0.1			14.7	3.7	2.7	2.6	3.0		11.3	0.1					43.3					0.7	5.1			897	
Brown, 2001	1322		2.6	5.4			2.0			0.3			14.4	1.5	3.0	0.5	2.9		11.2	2.1					52.2					0.6	0.3			1164	
Brown, 2001	1300		8.2	10.8			0.3			0.3			5.9	1.4	2.7	2.4	1.0		11.0	2.1					46.9					0.7	4.7			1173	
Brown, 2001	1300		8.1	11.1			2.0			0.1			14.5	1.6	2.8	0.5	2.9		6.5	2.0					42.4					0.2	4.9			1304	
Brown, 2001	1160		4.6	9.2			0.7			0.2			12.2	3.2	5.1	1.9	2.4		9.8	0.6					46.0					0.5	1.6			990	
Brown, 2001	1317		6.8	8.8			0.7			0.2			8.1	3.2	3.8	1.0	2.5		9.7	0.6					51.5					0.3	1.6			924	
Brown, 2001	1330		7.0	9.2			0.7			0.2			12.8	2.1	3.7	2.0	1.5		7.6	1.6					51.0					0.5	1.7			1244	
Brown, 2001	1317		2.6	10.6			2.0			0.1			5.8	1.5	3.0	2.4	2.9		10.8	2.1					55.9					0.2	0.3			936	
Brown, 2001	1250		2.7	5.2			0.3			0.3			14.8	3.9	5.9	2.5	1.0		6.5	2.1					49.2					0.6	4.9			1247	
Brown, 2001	1193		2.7	5.0			2.0			0.3			14.9	1.5	5.8	2.5	1.0		11.1	2.1					45.6					0.2	5.0			1144	
Brown, 2001	1356		2.7	9.8			0.3			0.1			5.7	3.7	3.0	0.5	1.0		10.7	2.1					56.7					0.7	0.3			862	
Brown, 2001	1315		2.9	5.1			0.3			0.1			8.0	3.7	5.3	0.5	2.9		6.2	0.1					59.5					0.2	4.7			877	
Brown, 2001	1320		2.7	5.4			2.0			0.3			14.9	3.7	3.0	0.5	2.9		6.3	2.1					49.3					0.6	4.8			1285	
Brown, 2001	1326		8.0	5.2			2.0			0.3			14.8	3.7	3.0	0.5	1.0		10.9	0.1					48.9					0.2	0.3			1033	
Bulkley, 1997	1242	1126	10.0	5.7	0.2		4.6	4.3		0.4	0.0	0.1	1.5	2.8	3.8	1.9		0.6	9.5	0.5		5.2	0.3	1.0	42.6			0.8		1.0			2.8		
Cantale, 1991		1060	13.8	9.7	0.1		3.0						4.4		4.7	0.3		0.1	16.1			0.4			46.8		0.3			0.0			0.1		
Cantale, 1991			13.5	10.3	0.1		2.7			0.1			0.2	0.4	4.9	0.5			17.3	0.0	4.2				45.7	0.1	0.1			0.2					
Carter, 1988		1325	10.3		0.1		3.9						5.6	0.9	0.0	1.8	0.1		17.8	0.0	0.0	2.2			52.2		3.7			1.0			0.0		
Carter, 1988		1325	10.2	0.1	0.1		18.1			0.1			5.5	1.5	0.1	1.9	0.1		3.0	0.3	0.0	2.0			51.1		3.6			0.9			0.0		
Carter, 1988		1665	12.2	0.1	0.1		4.5						6.6	1.9		2.2	0.1		3.1	0.1	0.0	2.2			61.6		3.7			1.1			0.0		
Carter, 1988		1324	13.6	0.2	0.1		13.9						3.8	3.2	0.1	10.1	0.1		1.1	0.0		2.0			48.5		4.2			0.6			0.0		
Chernushkin, 196(	1150		10.7				6.7						3.2			0.3	2.8		13.4						54.4							8.5			
Chick, 1984		1122	8.0	7.4			5.8						8.5						18.8		8.0				43.7										
Chick, 1984		1031	12.0				15.0						8.0						30.0						35.0										
Chick, 1984		1586	8.0										20.0						12.0						60.0										
Chick, 1984		1388	10.9	18.2															10.0		20.0				40.9										
Chick, 1984		1285	12.0	20.0									24.0						9.0						35.0										
Chick, 1984		1231	12.0					0.3		1.6				0.1			1.0	0.4	30.0	0.8		0.3	6.0		36.0		0.3	0.4	7.8		2.5		0.4		
Chick, 1984		1217	12.0	9.0			15.0	0.3		1.6				0.1			1.0	0.4	7.0	0.8		0.3	6.0		35.0		0.3	0.4	7.8		2.5		0.4		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Chick, 1984		810	8.0	20.0			7.0												30.0						35.0										
Chick, 1984		1380	12.0	12.0															16.0						60.0										
Chick, 1984		1240	8.0	2.0															30.0						60.0										
Chick, 1984		1220	8.0				15.0	0.3		1.6				0.1			1.0	0.4	12.0	0.8		0.3	6.0		43.0		0.3	0.4	7.8		2.5		0.4		
Chick, 1984		1294	8.0				15.0												17.0						60.0										
Chick, 1984		1233	12.0	20.0				0.3		1.6				0.1			1.0	0.4	11.0	0.8		0.3	6.0		35.0		0.3	0.4	7.8		2.5		0.4		
Chick, 1984		1327	8.0	20.0															12.0						60.0										
Chick, 1984		1189	8.0	20.0				0.3		1.6				0.1			1.0	0.4	12.0	0.8		0.3	6.0		38.0		0.3	0.4	7.8		2.5		0.4		
Chick, 1984		1112	8.0										24.0						30.0						38.0										
Chick, 1984		1481	12.0				13.0						6.0						7.0		6.0				56.0										
Chick, 1984		1366	12.0	10.5			1.0						7.0						16.5						53.0										
Chick, 1984		1191	8.0					0.3		1.6				0.1			1.0	0.4	30.0	0.8		0.3	6.0		40.0		0.3	0.4	7.8		2.5		0.4		
Chick, 1984		1202	8.0				7.5						24.0						12.0		13.5				35.0										
Chick, 1984		1324	8.0					0.3		1.6			23.0	0.1			1.0	0.4	12.0	0.8		0.3	6.0		35.0		0.3	0.4	7.8		2.5		0.4		
Chick, 1984		962	12.0	20.0			15.0												18.0						35.0										
Chick, 1984		807	8.0	20.0			7.0												30.0						35.0										
Chick, 1984		1402	8.0	20.0															12.0						60.0										
Chick, 1984			8.0	20.0									24.0						12.0						36.0										
Chick, 1984		1191	12.0										23.5						29.5						35.0										
Chick, 1984		1007	8.0				15.0						6.0						30.0		6.0				35.0										
Chick, 1984		1187	8.0				15.0						24.0						12.0						41.0										
Chick, 1984		1168	8.0	2.0															30.0						60.0										
Chick, 1984		1307	8.0				15.0												17.0						60.0										
Chick, 1984			8.0	8.0			15.0	0.3		1.6				0.1			1.0	0.4	12.0	0.8		0.3	6.0		35.0		0.3	0.4	7.8		2.5		0.4		
Chick, 1984			8.0	20.0			15.0						10.0						12.0						35.0										
Chick, 1984		1166	8.0				15.0						24.0						12.0						41.0										
Chick, 1984		1348	12.0																28.0						60.0										
Chick, 1984		1078	7.3				13.6						5.4						27.2		5.4				41.1										
Chick, 1984		1231	7.1	17.7									21.2						12.0						42.0										
Chick, 1984		1327	12.0	10.0				0.1		0.8			12.0	0.0			0.5	0.2	15.0	0.4		0.2	2.9		40.2		0.2	0.2	3.8		1.2		0.2		
Chick, 1984		1275	12.0				10.0	0.1		0.8			12.0	0.0			0.5	0.2	15.0	0.4		0.2	2.9		40.2		0.2	0.2	3.8		1.2		0.2		
Clifford, 1994			3.7	11.7		43.7									1.0				7.1						28.3					2.0			2.5		
Clifford, 1994			2.9	11.9		19.7								2.0	3.0				6.9						49.4					2.0			2.2		
Clifford, 1994			2.0	25.3		5.0	1.0							2.0	4.0				8.1						47.5					2.0			3.0		
Clifford, 1994			3.6	11.4		42.5								2.4	6.4				2.3						26.9								1.7		
Clifford, 1994			2.9	6.3		19.3	1.1							10.0	2.4				1.7						50.9								1.9		
Clifford, 1994			2.8	10.1		19.1		2.2						1.9	2.9				6.7						46.9		1.3						2.1		
Clifford, 1994			3.9	12.3		45.5													6.6						28.8					1.6			1.3		
Clifford, 1994			3.7	11.8		45.9													6.4						28.2					1.6			2.4		
Clifford, 1994			3.0	11.3		15.0	1.2							5.2	2.5				6.9						52.8								2.0		
Clifford, 1994			3.0	16.4		9.9	1.2							0.2	2.5				11.9						52.9								2.0		
Clifford, 1994			3.0	4.4		20.6	1.2							10.5	2.6				1.8						53.8								2.1		
Clifford, 1994			3.1	15.4		15.3								2.6	2.6				7.2						46.2								7.6		
Clifford, 1994			3.4	22.8		11.1	0.6							2.3	3.4				9.1						45.7								1.7		
Clifford, 1994			3.1	25.9		10.1	0.5							2.0	4.2				10.4						41.5								2.3		
Clifford, 1994			2.0	25.3		5.0	1.0							3.0	6.1				10.1						41.6					2.0			3.7		
Clifford, 1994			1.0	25.3		9.9								3.0	5.1				10.1						39.5					3.0			3.0		
Clifford, 1994			2.0	25.4		5.0	1.0							3.0	6.1				10.1						42.1								5.2		
Clifford, 1994			2.9	11.7		19.5								7.0	2.0				2.8						48.8					1.9			3.3		
Clifford, 1994			2.9	11.6		19.3								6.9	1.9				2.8						48.3					1.9			4.3		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	OthI '	P 205	PbO	SiO2	S O3	S rO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Clifford, 1994			2.9	11.7		19.4								0.9	8.4				1.8						48.6					1.9			4.3		
Clifford, 1994			2.4	14.1		3.5								1.7	4.3				2.5						67.9					2.0			1.5		
Clifford, 1994			2.3	13.4		3.4								8.0	2.2				2.4						64.9					1.9			1.4		
Clifford, 1994			2.4	14.1		3.5								1.7	4.3				2.5						67.9					2.0			1.5		
Clifford, 1994			4.2	23.7		7.1	1.7								3.4				15.4						33.4								11.0		
Clifford, 1994			1.7	18.2		4.9	1.0							3.1	6.0				9.7						43.7					2.1			9.6		
Clifford, 1994			2.8	10.4		19.3								1.9	2.9				6.7		3.0	3.5			45.8			1.7					2.1		
Clifford, 1994			2.7	1.6		30.4				1.8				9.3	2.3	0.8		1.7	1.6						47.2								0.8		
Clifford, 1994			0.4	25.4		5.8	6.2							3.0	5.2	0.6			10.1						38.3							2.6	2.4		
Clifford, 1994			4.9	6.6		56.3	0.3							0.1	0.6				3.0						27.7								0.5		
Crawford, 1998			10.1	7.0	0.0		4.0			0.0			23.0	0.9	3.0	0.1	0.4		15.7	0.1			0.7	0.2	30.2		4.2			0.2		0.0			
Dingwell, 2004		1122	5.0				6.5			0.4			8.8			32.3			0.3						46.9					0.2					
Dvorkin, 1969			13.8	4.6			8.6						9.2			3.7			4.6						55.0					1.6					
Dvorkin, 1969			11.9				8.4						9.3			4.9			6.2						57.8					1.6					
Dvorkin, 1969			10.5				7.9						7.1			4.6			7.7						61.2					1.2					
Dvorkin, 1969			15.6	6.5			11.4						13.4			4.6			2.8						43.6					2.0					
Dvorkin, 1971	~1200		14.3				10.3						14.9			5.5			3.0						49.7					2.3					
Dvorkin, 1971	~1200		10.2	13.2			7.4						10.7			4.0			2.2						47.4					1.7					
Dvorkin, 1971	~1200		8.8	7.5			6.4						9.2			3.4			9.2						54.2					1.4					
Dvorkin, 1971	~1200		9.5	7.6			6.8						9.9			3.6			6.9						54.0					1.5					
Dvorkin, 1971	~1200		12.1	9.3			8.7						12.7			4.7			7.4						42.0					2.0					
Dvorkin, 1971	~1200		8.4				6.1						8.8			3.2			13.4						60.0					1.4					
Dvorkin, 1971	~1200		9.8				7.1						10.2			3.8			12.4						55.0					1.6					
Dvorkin, 1971	~1200		7.9				5.6						8.4			3.1			10.0						64.0					1.3					
Dvorkin, 1971	~1200		10.6	8.0			7.6						11.0			4.3			2.2						54.5					1.7					
Dzhigiris, 1983	1375		16.3				5.0						14.6			9.4			2.8						50.0					0.7					
Dzhigiris, 1983	1375		13.9				7.4						12.4			9.8			3.0						49.2					1.2					
Dzhigiris, 1983	1440		15.1				10.4						10.5			6.6			3.1						52.1					0.9					
Edwards, 1999			2.5	8.0	0.1		0.9			0.1	0.6	0.0	9.9	3.4	4.8	1.4	1.7		7.9	0.9			0.0	0.1	53.7	0.2				1.1	2.0	0.1	0.1		1.5
Edwards, 1999			2.5	8.0	0.1		0.9			0.1	0.6	0.0	9.9	3.4	4.8	1.4	1.7		7.9	0.9			0.0	0.1	53.7	0.2				1.1	2.0	0.1	0.1		1.3
Edwards, 1999			2.5	9.6	0.1		0.9			0.1	1.0	0.0	9.9	6.1	4.4	1.3	1.7		8.2	0.9			0.0	0.1	49.1	0.2				1.1	2.0	0.1	0.1		1.8
Edwards, 1999			2.5	7.9	0.1		0.9			0.1	0.6	0.0	9.9	3.4	4.7	1.4	1.7		7.9	0.9			0.0	0.1	52.7	0.2				2.2	2.0	0.1	0.1		1.5
Edwards, 1999			2.5	8.7	0.1		0.9			0.1	0.8	0.0	9.9	4.7	4.5	1.4	1.7		8.1	0.9			0.0	0.1	50.5	0.2				2.2	2.0	0.1	0.1		1.3
Edwards, 1999			2.5	9.5	0.1		0.9			0.1	1.0	0.0	9.9	6.1	4.3	1.3	1.7		8.2	0.9			0.0	0.1	48.2	0.2				2.2	2.0	0.1	0.1		1.6
Edwards, 1999			2.9	7.7	0.1		1.1			0.1	0.6	0.0	11.7	3.4	4.5	1.4	2.0		8.1	1.1			0.0	0.1	50.8	0.2				1.1	2.4	0.1	0.1		
Edwards, 1999			2.9	8.5	0.1		1.1			0.1	0.8	0.0	11.7	4.7	4.3	1.3	2.0		8.3	1.1			0.0	0.1	48.5	0.2				1.1	2.4	0.1	0.1		
Edwards, 1999			2.9	9.3	0.1		1.1			0.1	1.0	0.0	11.7	6.1	4.1	1.3	2.0		8.4	1.1			0.0	0.1	46.2	0.2				1.1	2.4	0.1	0.1		
Edwards, 1999			2.9	7.6	0.1		1.1			0.1	0.6	0.0	11.7	3.4	4.4	1.4	2.0		8.2	1.1			0.0	0.1	49.8	0.2				2.2	2.4	0.1	0.1		
Edwards, 1999			2.9	8.4	0.1		1.1			0.1	0.8	0.0	11.7	4.7	4.2	1.3	2.0		8.3	1.1			0.0	0.1	47.5	0.2				2.2	2.4	0.1	0.1		
Edwards, 1999			2.9	9.2	0.1		1.1			0.1	1.0	0.0	11.7	6.1	4.0	1.2	2.0		8.5	1.1			0.0	0.1	45.3	0.2				2.2	2.4	0.1	0.1		
Edwards, 1999			3.3	7.3	0.1		1.2			0.1	0.6	0.0	13.5	3.4	4.2	1.3	2.4		8.4	1.3			0.0	0.1	47.8	0.2				1.1	2.7	0.1	0.1		
Edwards, 1999			3.2	8.2	0.1		1.2			0.1	0.8	0.0	13.5	4.8	4.0	1.3	2.4		8.5	1.3			0.0	0.1	45.6	0.2				1.1	2.7	0.1	0.1		
Edwards, 1999			3.2	9.0	0.1		1.2			0.1	1.0	0.0	13.5	6.1	3.8	1.2	2.4		8.7	1.3			0.0	0.1	43.3	0.2				1.1	2.7	0.1	0.1		
Edwards, 1999			3.3	7.2	0.1		1.2			0.1	0.6	0.0	13.5	3.4	4.2	1.3	2.4		8.4	1.3			0.0	0.1	46.9	0.2				2.2	2.7	0.1	0.1		
Edwards, 1999			3.2	8.1	0.1		1.2			0.1	0.8	0.0	13.5	4.8	3.9	1.2	2.4		8.6	1.3			0.0	0.1	44.6	0.2				2.2	2.7	0.1	0.1		
Edwards, 1999			3.2	8.9	0.1		1.2			0.1	1.0	0.0	13.5	6.1	3.7	1.2	2.4		8.7	1.3			0.0	0.1	42.3	0.2				2.2	2.7	0.1	0.1		
Edwards, 1999a			6.0	8.8	0.0		0.5			0.1	0.8	0.0	6.4	4.7	4.6	1.5	2.0		7.8	0.3			0.0	0.1	54.1	0.1				1.1	0.7	0.0	0.1	916	0.5
Edwards, 1999a			7.0	8.5	0.1		0.6			0.1	0.8	0.0	7.5	4.7	4.3	1.4	2.3		8.0	0.4			0.0	0.1	51.7	0.2				1.1	0.8	0.0	0.1	928	0.5
Edwards, 1999a			8.1	8.2	0.1		0.6			0.1	0.8	0.1	8.7	4.7	4.0	1.4	2.7		8.2	0.5			0.0	0.1	49.2	0.2				1.1	0.9	0.0	0.2	959	0.5

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Ferrara, 1998			9.7	4.3			4.5			0.0			7.4	2.3	2.1	2.1			20.0						41.0							3.3	3.1		
Ferrara, 1998			8.1	8.1			7.0			0.1			8.0	0.4	4.1	3.0			10.0						44.0							4.0	3.0		
Ferrara, 1998			9.9	3.0			4.8			0.0			6.4	0.4	4.0	3.0			20.0						42.0							3.3	3.0		
Fisher, 2005	1450						3.8												22.0						74.2										
Fisher, 2005	1450						3.5												18.6						71.1								6.8		
Fisher, 2005	1450						3.3												19.0						68.4								9.2		
Fisher, 2005	1450						2.8												15.2						70.8								11.2		
Fisher, 2005	1630						3.2												17.1						63.7								15.9		
Fisher, 2005	1630						3.0												16.7						62.8								17.5		
Fisher, 2005	1630						2.9												16.6						59.8								20.7		
Fisher, 2005	1630						3.0												16.7						58.9								21.4		
Flinn, 1981		1294	7.4				8.3						34.5	2.4		4.6			4.8						38.0										
Flinn, 1981		1481	9.0				9.1						26.4	2.5		4.0			3.9						45.1										
Flinn, 1981			9.6				9.0						18.2	5.6		3.2			7.1						47.3										
Flinn, 1981		1395	9.1				8.6						17.4	7.2		3.1			9.3						45.2										
Flinn, 1981		1541	10.3				9.7						19.6	2.6		3.5			3.2						51.0										
Flinn, 1981			11.4				10.3						13.9	2.7		3.1			2.6						56.0										
Flinn, 1981			12.1				10.0						9.5	2.8		2.8			2.2						60.6										
Francis, 2005	1350		11.8				43.5						0.3	0.5		6.2	0.7		0.1				0.1		35.8	0.8				0.8					
Francis, 2005	1350		14.8		6.2		26.6						0.3	0.7		6.7	3.3		1.4						37.0	1.1									
Francis, 2005	1350		27.9				29.4						1.8	1.5		8.0			0.4						34.4					1.0					
Francis, 2005	1350		6.8				38.8						0.6	0.7		9.7			0.8						39.7	0.6				0.6					
Fu, 1997			9.0	13.0			0.5						0.3	2.0	11.0				17.0	0.2	0.3		2.0		44.0						0.1		0.1		
Fu, 1997			9.0	13.0			0.6						0.2	2.0	4.0				22.0	0.2	0.4		2.0		46.0						0.1		0.1		
Fu, 1997			9.0	13.0			0.6						0.2	2.0	0.1				27.0	0.2	0.4		2.0		46.0						0.1				
Fu, 1997			9.0	17.0			0.6						0.2	2.0	0.1				23.0	0.2	0.4		2.0		46.0						0.1				
Fu, 1997			9.0	21.0			0.6						0.2	2.0	0.1				19.0	0.2	0.4		2.0		46.0						0.1				
Fu, 1997			9.0	16.0			0.6						0.2	2.0	11.0				13.0	0.2	0.4		2.0		45.0						0.1		0.1		
Fu, 1998	1150	963	9.0	6.9	0.0		5.6			0.0			22.6	0.1	2.9	0.1	0.4		15.6	0.1		0.1	0.7	0.2	31.4		4.1			0.2		0.0			
Fu, 1998	1150	1184	7.6	8.4	1.5		2.9	0.3	0.2	0.3	0.2	0.8	11.9	0.5	0.1	1.0	3.0	0.2	7.9	0.9	0.9	1.7	1.2	0.3	36.3	0.5	0.2	0.6		0.6	4.5		5.8		
Fu, 1998	1150	1058	7.5	8.4	1.5	0.9	2.9	0.3	0.2	0.3	0.2	0.8	11.8	0.5	0.1	1.0	3.0	0.2	12.9	0.9	0.9	1.7	1.2	0.3	30.9	0.5	0.2	0.6		0.6	4.4		5.8		
Fu, 1998	1150	1070	7.5	13.5	1.5	0.9	2.9	0.3	0.2	0.3	0.2	0.8	11.8	0.5	0.1	1.0	3.0	0.2	7.8	0.9	0.9	1.7	1.2	0.3	30.9	0.5	0.2	0.6		0.6	4.4		5.8		
Fu, 1998	1150	1076	7.5	8.4	1.5	0.9	8.0	0.3	0.2	0.3	0.2	0.8	11.8	0.5	0.1	1.0	3.0	0.2	7.8	0.9	0.9	1.7	1.2	0.3	30.9	0.5	0.2	0.6		0.6	4.4		5.8		
Fu, 1998	1150	1015	7.5	8.4	1.5	0.9	2.9	0.3	0.2	0.3	0.2	0.8	11.8	0.5	3.2	1.0	3.0	0.2	7.8	0.9	0.9	1.7	1.2	0.3	32.9	0.5	0.2	0.6		0.6	4.4		5.8		
Fu, 1998	1150	1033	11.8	6.1	0.1	0.1	1.6	0.0		0.1	0.0	0.4	26.3	1.1	3.0	0.3	0.6	0.0	14.6	0.3	0.0	0.0	1.1	0.4	28.5	0.1	2.6	0.0		0.3	0.3		0.2		
Fu, 1998	1150		13.3	6.7	0.1		0.5			0.2	0.1	0.1	21.9	0.5	4.0	0.1	0.7		11.1	0.8	0.6	0.9	0.0	0.1	27.3		2.9			0.1	0.9		6.6		
Fu, 1998	1150		16.1	6.6			1.9				0.5	2.8	5.7	1.3	3.1			0.6	9.5	0.2		2.1		0.9	29.3	1.3	2.3			1.7		0.4	12.3		
Fu, 1998	1150	1117	16.0	15.1					0.4	0.7			4.7	1.1	3.1	2.3	6.7		9.4	2.1	0.1	0.1			23.6		1.8						12.3		
Fu, 1998	1150	920	10.0	15.3	0.1	0.1	0.6	0.0		0.1	0.0		22.1	0.0	4.1	0.2	0.5	0.0	11.3	0.2	0.0	0.1	0.8	0.4	30.7	0.0	2.1	0.0		0.2	0.2	0.0	0.2		
Fu, 1998	1150		7.5	11.2	0.6	0.1	1.6	0.2	0.2	0.4	0.1	0.1	17.8	0.6	2.0	0.6	0.6		16.9	0.6	0.2	1.8	1.1	0.3	26.5	0.6	3.4		0.1	0.2	3.3	0.1	0.1		
Fu, 1998	1150		9.5	10.4	0.1		6.1			0.1	0.1	0.1	15.6	0.4	3.1	0.1	0.5		8.0	0.6	0.4	1.4	0.0	0.1	35.1		2.4			0.1	0.6	0.1	4.7		
Fu, 1998	1150	1109	8.5	6.7	1.2	0.7	2.3	0.2	0.1	0.5	0.1	0.8	15.9	0.4	2.9	0.8	2.4	0.2	7.1	1.0	0.7	1.3	0.9	0.3	31.9	0.5	2.9	0.5		0.5	3.6		4.7		
Fu, 1998	1150	1050	16.1	6.6			7.6	0.6					4.7		3.1				18.9	0.2	1.8	0.4			27.4		1.8	1.2	0.4		9.1				
Fu, 1998	1150	876	8.5	6.6	3.9	2.4							23.6		3.1				18.9	0.2		4.1	3.1		23.6		1.8								
Fu, 1998	1150	970	9.2	12.0	0.2	0.0	5.6	0.1	0.1	0.6	0.0	0.0	17.0	0.2	3.0	0.2	0.2		11.4	1.2	0.1	0.8	0.4	0.1	33.8	0.6	1.4		0.1	0.1	1.3	0.0	0.1		
Fu, 1998	1150	1018	8.3	7.1	1.0		2.0	0.3	0.1	0.2	0.1	0.7	9.7	2.1	0.1	0.7	2.1	0.2	19.5	0.6	0.6	1.2	1.9	0.2	30.2	0.4	2.5	0.4	0.2	0.4	3.1		4.0		
Fu, 1998	1150		16.2	7.6	3.9	2.4	7.6						10.5		3.2				9.5	0.2		4.1	3.1		29.6		1.8								
Fu, 1998	1150	900	16.1	16.1			7.6				0.5	2.8	8.5	1.3	3.1			0.6	9.5	0.2		2.1		0.9	23.6	1.3	2.3			1.7		0.4			
Fu, 1998	1150		16.1	6.6	3.6	2.2							4.7		3.1				18.9	0.2		3.8	2.8		23.6		1.8						12.3		
Fu, 1998	1150	950	16.1	11.3									18.9		3.1				18.9	0.2		0.1			29.3		1.8								

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Fu, 1998	1150		17.1	8.9	0.3	0.0	1.5	0.1	0.1	0.8	0.0	0.1	10.6	0.9		0.3	0.7		22.0	0.3	0.1	1.1	0.8	0.2	28.6	0.3	2.3		0.1	0.1	1.9	0.1	0.2		
Fyles, 1999			14.1				15.4						5.2	0.6		12.6	0.2		2.5						47.6					1.7					
Fyles, 1999			1.6			3.5	8.0						0.3	1.0		3.8			15.5						66.2	0.2									
Fyles, 1999		1412	1.6				8.7						0.3	0.9		4.0			15.0						69.3	0.2									
Fyles, 1999		1424	1.7				9.2						0.3	0.8		4.2			13.0						70.6	0.2									
Fyles, 1999		1480	1.7				9.2						0.3	0.8		4.2			11.0						72.6	0.2									
Fyles, 1999		1509	1.7				9.2						0.3	0.8		4.2			10.0						73.6	0.2									
Fyles, 1999		1537	1.7				9.2						0.3	0.8		4.2			9.0						74.6	0.2									
Fyles, 1999			1.7				9.2						0.3	0.8		4.2			7.0						76.6	0.2									
Fyles, 1999		1397	16.0				19.0						4.0	1.0		4.0			2.0						53.8	0.2									
Gal'Perina, 1981	<1300		14.2	12.0			5.6						5.7	1.4		2.9	0.4		3.1						48.1					0.4			6.2		
Gal'Perina, 1981	<1300		12.8	18.3			8.9						5.3	1.3		2.8	0.3		3.1						45.8					0.4					
Galushko, 1971	~1350		18.7				7.2						13.1			6.7			3.9						49.4					1.2					
Galushko, 1971	~1350		18.5				7.1			1.1			12.8			6.9			4.0						48.6					1.2					
Galushko, 1971	~1350		17.5				6.5						11.5			6.0			3.7						53.8					1.0					
Galushko, 1971	~1350		16.3				5.8						10.1			5.2			3.3						58.2					1.0					
Galushko, 1971	~1350		17.7				9.4			1.1			11.8			8.7			3.8						45.8					1.1					
Galushko, 1971	~1350		20.2				6.6			1.1			11.8			6.5			3.7						48.9					1.2					
Galushko, 1974			18.7				7.2						13.1			6.7			3.9						49.4					1.2				1300	
Galushko, 1974			18.5				7.1			1.1			12.8			6.9			4.0						48.6					1.2				>1350	
Galushko, 1974			17.5				6.5						11.5			6.0			3.7						53.8					1.0				>1200	
Galushko, 1974			16.3				5.8						10.1			5.2			3.3						58.2					1.0				>1200	
Galushko, 1974			17.7				9.4			1.1			11.8			8.7			3.8						45.8					1.1				>1350	
Galushko, 1974			20.2				6.6			1.1			11.8			6.5			3.7						48.9					1.2				>1350	
Gerasimov, 2004	1300		5.7	19.7										2.1					7.9						59.9					4.7					
Gerasimov, 2004	1250		10.6	23.6			10.4												5.4						44.4								5.4		
Gerasimov, 2004				8.0	5.5	42.5					8.0														30.0					2.0		5.5			
Gerasimov, 2004	1450		7.8	16.0	2.0											2.3			8.0						61.5								2.5		
Gerasimov, 2004	1250		10.9	18.1			6.2							3.8		5.3			5.4						50.4										
Gerasimov, 2004	1250		9.6	16.3			13.2							10.3											48.6		1.1								
Gerasimov, 2004			25.5	5.2	3.0		9.0									7.0			1.5						50.0										
Gerasimov, 2004	1400		7.5	36.0	6.0		4.3							3.3					3.5						37.0										
Gerasimov, 2004			13.5	5.7			0.7					8.5	0.6			0.3			18.6						52.7										
Gerasimov, 2004	1250		7.4				4.3						13.1	3.3		0.7			1.5			3.6			59.7							4.3			
Gerasimov, 2004			12.0	10.1	0.5			2.8			4.0		0.3	2.5					12.4						54.8										
Gerasimov, 2004			9.0	13.5			5.5						0.3	2.0		0.3			8.0						46.0							5.0	9.5		
Gerasimov, 2004a	1325		11.6	13.2	5.1		4.0												4.8						57.7		3.6								
Gerasimov, 2004a	1290		11.9	24.2			2.9						3.1	2.8		1.8	1.1		2.8						42.5					7.5					
Gerasimov, 2004a	1300		11.4	15.3			4.6						0.3	1.3		0.3			1.4						44.4							8.2	12.7		
Gerasimov, 2004a	1275		9.0	27.0										5.5					5.5						36.0							5.0	9.0		
Gerasimov, 2004a	1325		10.0	10.5			9.0							0.8		8.5			0.8						60.5										
Gerasimov, 2004a	1300		13.0	15.3			7.9						0.6	1.8		0.6			1.8						56.6								2.5		
Gerasimov, 2004a	1150		2.5	17.5		1.5							0.2	13.5											42.5	1.8				22.5					
Gerasimov, 2004a	1400		4.6	11.4			14.8							6.5		2.0			0.7						53.0	3.0				5.0					
Gerasimov, 2004a	950		7.4	36.2									0.2	0.8					17.1					11.1	21.9							3.6			
Gerasimov, 2004a	1315		5.8	17.8	6.5														7.8						40.4		3.8					7.8	6.4		
Giordano, 2002		1968	18.0				2.9						3.4	7.9		0.7	0.1		4.5				0.2		60.1					0.4					
Giordano, 2002		1951	18.0				2.9						3.8	8.4		0.9	0.1		4.1				0.2		60.0					0.4					
Giordano, 2002		1792	18.5				2.8						3.6	8.5		0.7	0.2		3.9				0.2		59.7					0.5					
Giordano, 2002		1211	12.1				15.7						10.1	3.0		11.2			2.8				1.0		41.2					2.7					

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Giordano, 2002		1360	16.3				10.5						10.1	1.9		5.2	0.2		3.8				0.6		47.0					1.6					
Giordano, 2002		2122	12.5											4.2					4.6						78.6										
Giordano, 2002		1782	19.2				2.1						3.4	6.3		0.3	0.2		5.3				0.1		60.7					0.3					
Giordano, 2002		1829	17.1				1.8						2.9	6.8		0.2	0.1		5.7				0.1		63.9					0.3					
Giordano, 2002		2045	17.3				5.8						5.4	1.4		3.4			3.9						61.2					0.8					
Giordano, 2002		1205	10.2				26.1							1.0		9.2			7.6						43.6					3.0					
Giordano, 2002		1879	17.0				0.8						2.6	6.4		0.3	0.1		6.3				0.1		64.0					0.5					
Giordano, 2002		1811	18.8				0.7						3.3	5.5		0.4	0.2		9.8				0.1		60.5					0.6					
Giordano, 2002		1758	15.2				5.0						4.1	2.2		2.2	0.1		3.8				0.1		66.0					0.4					
Giordano, 2002		1606	19.1				6.5						4.6	8.0		1.7	0.1		4.6				0.7		51.2					0.6					
Giordano, 2002		1427	16.4				10.2						7.2	6.5		5.1	0.1		2.7				0.7		49.2					0.8					
Giordano, 2002		1563	19.3				6.6						4.7	7.7		1.7	0.1		4.5				0.7		52.0					0.6					
Giordano, 2002		1528	18.6				7.3						6.1	7.9		2.5	0.1		3.8				0.4		51.2					0.7					
Giordano, 2002		1846	19.4				2.4							7.4		1.9			9.3						58.8					0.8					
Giordano, 2002		1799	16.7				5.4							3.4		2.9			6.7						64.5					0.5					
Giordano, 2002		1313	14.0				15.0							3.0		8.8			7.0						50.6					2.4					
Giordano, 2003		1212	16.3				10.5						10.9	1.9		5.2	0.2	0.0	3.8				0.6		47.0					1.6					
Giordano, 2006			18.0				2.9						3.4	7.9		0.7	0.1		4.5				0.2		60.1					0.4					
Giordano, 2006			18.0				2.9						3.8	8.4		0.9	0.1		4.1				0.2		60.0					0.4					
Giordano, 2006			18.8				2.9						3.7	8.6		0.7	0.2		4.0				0.2		60.7					0.5					
Giordano, 2006		1833	12.6				3.4						3.2	6.2		1.2	0.1		4.0				0.0		68.8					0.2					
Giordano, 2006			12.1				15.7						10.1	3.0		11.2	0.2		2.8				1.0		41.1					2.7					
Giordano, 2006			16.3				10.5						10.1	1.9		5.2	0.2		3.8				0.6		47.0					1.6					
Giordano, 2006		1600	18.4				5.8						7.3	4.6		2.4	0.2		4.2						55.4					0.7					
Giordano, 2006			12.5											4.2					4.6						78.6										
Giordano, 2006			15.6				2.1						1.0	3.8					4.4						73.6										
Giordano, 2006			17.3				4.0							3.5					4.2						71.5										
Giordano, 2006			23.1				8.7							1.9					2.6						64.0										
Giordano, 2006			27.2				13.3							1.5					1.6						56.2										
Giordano, 2006			19.2				2.1						3.4	6.3		0.3	0.2		5.3				0.1		60.7					0.3					
Giordano, 2006		2065	9.9				2.4						1.9	3.4		1.6	0.0		0.5						79.4					0.2					
Giordano, 2006			20.0				9.1						0.0	0.9		3.2	0.0		3.5				0.1		62.5					0.6					
Giordano, 2006			16.1				9.9						7.5	3.7		5.6	0.1		2.3						52.3					0.8					
Giordano, 2006			17.5				8.1						7.2	3.5		3.8	0.2		3.6						53.7					0.6					
Giordano, 2006			17.1				1.8						2.9	6.8		0.2	0.1		5.7				0.1		63.9					0.3					
Giordano, 2006		1493	19.0				9.2						9.0	1.6		3.4	0.2		3.5						53.5					0.8					
Giordano, 2006			17.1				4.7						5.0	1.3		1.8	0.1		4.3				0.1		65.3					0.6					
Giordano, 2006		1622	18.3				7.1						6.4	0.9		2.6	0.2		3.6						60.7					0.6					
Giordano, 2006			20.0				9.1						0.0	0.9		3.2	0.0		3.5				0.1		62.4					0.6					
Giordano, 2006			10.2				26.1							1.0		9.2			7.6						43.6					3.0					
Giordano, 2006			15.0				10.4						12.0	5.6		3.7	0.3		6.9				1.2		41.1					2.8					
Giordano, 2006			18.4				4.0						5.0	7.7		1.4	0.1		3.4						58.8					0.5					
Giordano, 2006			17.3				0.9						2.6	6.5		0.3	0.1		6.5				0.1		65.3					0.5					
Giordano, 2006			13.3				10.0						11.2	1.4		9.2			5.6						46.6					2.5					
Giordano, 2006			12.8				9.6						9.9	1.5		8.1			6.1						49.3					2.1					
Giordano, 2006			12.1				9.2						8.9	1.8		7.2			6.5						51.6					1.5					
Giordano, 2006			9.9				5.3						7.2	2.3		4.6			9.0						59.0					1.6					
Giordano, 2006			13.1				10.0						10.2	1.5		8.9			5.6						48.2					2.3					
Giordano, 2006			4.2				2.0						1.2	3.4		2.0			11.3						74.8					0.5					
Giordano, 2006		1204	12.5				11.5						11.3	1.1		11.4	0.3		2.7				0.9		45.8					2.3					

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Giordano, 2006		1386	16.9				10.9						8.4	2.2		5.7	0.2		2.6						49.1					1.0					
Giordano, 2006			18.8				0.7						3.3	5.5		0.4	0.2		9.8				0.1		60.5					0.6					
Giordano, 2006			15.2				5.0						4.1	2.2		2.2	0.1		3.8				0.1		66.0					0.4					
Giordano, 2006			19.1				6.5						4.6	8.0		1.7	0.1		4.6				0.7		51.2					0.6					
Giordano, 2006			16.6				10.3						7.3	6.6		5.2	0.1		2.7				0.7		49.7					0.8					
Giordano, 2006			19.3				6.6						4.7	7.7		1.7	0.1		4.5				0.7		52.0					0.6					
Giordano, 2006			18.9				7.4						6.2	8.0		2.5	0.1		3.8				0.4		51.9					0.7					
Giordano, 2006			19.4				2.4							7.4		1.9			9.3						58.8					0.8					
Giordano, 2006			16.7				5.4							3.4		2.9			6.7						64.5					0.5					
Giordano, 2006			14.0				15.0							3.0		8.8			7.0						50.6					2.4					
Grandy, 1993		973	7.4				8.3						34.5	2.4		4.6			4.8						38.0									1450	
Grandy, 1993			13.0				10.2						4.5	2.9		2.4			1.7						65.4				0.6						
Grandy, 1993		1187	9.0				9.1						26.4	2.5		4.0			3.9						45.1									1350	
Grandy, 1993		1251	10.3				9.7						19.6	2.6		3.5			3.2						51.0									1350	
Grandy, 1993		1408	11.4				10.3						13.9	2.7		3.1			2.6						56.0									1275	
Grandy, 1993		1593	12.1				10.0						9.5	2.8		2.8			2.2						60.6										
Grum-Grzhimailo, 1978			2.5	27.4	1.9		7.6					0.9							6.1						45.8								7.9	925	
Grum-Grzhimailo, 1978			2.5	27.7			8.4					1.0							6.2						46.3								7.9	850	
Grum-Grzhimailo, 1978			2.6	28.4								1.0				6.2			6.3						47.5								8.1	725	
Grum-Grzhimailo, 1978			2.5	27.4			6.9					0.9							6.1						45.8		2.6						7.9	895	
Grum-Grzhimailo, 1978			2.4	25.9								0.9							5.8						43.3		14.4						7.4	875	
Grum-Grzhimailo, 1978			2.4	26.7								0.9							5.9						44.7							11.7	7.7	720	
Grum-Grzhimailo, 1991			12.9	14.8	1.9		6.1						0.5	0.3		4.2			5.2						44.7							2.5	5.2		
Grum-Grzhimailo, 1991			12.4	16.1	1.9		6.2					0.6	0.4	0.3		4.0			5.2						44.1							2.7	5.2		
Grum-Grzhimailo, 1991			12.7	15.6	1.9		5.8					1.4	0.5	0.4		3.9			5.3						44.8							2.4	4.8		
Grum-Grzhimailo, 1991			12.9	15.4	1.9		5.6					2.2	0.6	0.4		3.8			5.6						44.3							2.4	4.7		
Grum-Grzhimailo, 1991			12.9	14.8	1.8		5.8					2.8	0.5	0.5		3.4			5.6						44.8							2.3	4.5		
Hrma, 1994	1546	1407	12.0	8.5	0.2			0.3		0.2	0.3	0.5	2.0		1.0		0.2	0.5	9.5	1.0		2.5	0.2		57.0	0.5	0.2	3.3							
Hrma, 1994	1266	1203	14.0	15.5	0.1		10.0	0.2		0.2	0.2	0.4	2.0		1.0		0.2	0.4	7.5	0.8		2.0	0.1		42.0	0.4	0.1	2.7							
Hrma, 1994	1070	1203	14.4	5.0	0.0			0.0		0.0	0.0	0.1	8.6		1.0	8.0	0.0	0.1	18.7	0.1		0.3	0.0		43.3	0.0	0.0	0.3							
Hrma, 1994	1266	1182	15.0	5.0	0.0		10.0	0.0		0.0	0.0	0.1	2.0		7.0		0.0	0.1	5.0	0.1		0.3	0.0		55.0	0.0	0.0	0.3							
Hrma, 1994	1072	1011	14.0	20.0	0.0			0.0		0.0	0.0	0.1	2.0		7.0	8.0	0.0	0.1	5.0	0.1		0.3	0.0		42.0	0.0	0.0	0.3					1.0		
Hrma, 1994	1277	1183	8.0	5.0	0.0			0.0		0.0	0.0	0.1	15.0		7.0		0.0	0.1	7.0	0.1		0.3	0.0		57.0	0.0	0.0	0.3							
Hrma, 1994	1224	1137	10.4	17.0	0.1			0.1		0.1	0.1	0.2	6.7		2.0		0.1	0.2	13.1	0.3		0.7	0.1		47.0	0.1	0.1	1.0					1.0		
Hrma, 1994			10.0	9.7			0.8						6.6		3.5	0.8			10.4		5.5				49.3								3.6		
Hrma, 1994			15.0	9.2			0.7						6.3		3.3	0.7			9.8		5.2				46.6								3.4		
Hrma, 1994	1107	1037	9.0	17.0	0.0		7.0	0.1		0.1	0.1	0.1	4.0		4.7	1.0	0.1	0.1	7.0	0.3		0.6	0.0		46.8	0.1	0.0	0.8					1.0		
Hrma, 1994	1204	1122	8.0	8.7	0.1			0.2		0.2	0.2	0.4	4.0		6.0	5.0	0.2	0.4	7.0	0.8		2.0	0.1		52.3	0.4	0.1	2.7					1.0		
Hrma, 1994	1194	1116	9.0	7.0	0.0		3.0	0.1		0.1	0.1	0.1	4.0		2.3	5.0	0.1	0.1	16.9	0.3	2.5	0.6	0.0		49.4	0.1	0.0	0.8					1.0		
Hrma, 1994	1138	1065	7.6	7.0	0.1		6.0	0.2		0.2	0.2	0.4	4.0		2.1		0.2	0.4	17.0	0.8		2.0	0.1		47.3	0.4	0.1	2.7					1.0		
Hrma, 1994	1177	1099	11.0	7.0	0.0		7.0	0.1		0.1	0.1	0.1	4.5		6.0		0.1	0.1	8.8	0.3		0.6	0.0		50.2	0.1	0.0	0.8					3.0		
Hrma, 1994	1037	970	9.6	20.0	0.2			0.3		0.2	0.3	0.5	2.0		7.0		0.2	0.5	7.4	1.0		2.4	0.2		44.7	0.5	0.2	3.1							
Hrma, 1994	1279	1191	7.8	5.0	0.0			0.0		0.0	0.0	0.1	2.0		1.6	8.0	0.0	0.1	20.0	0.1		0.3	0.0		54.6	0.0	0.0	0.3							
Hrma, 1994	1162	1090	10.3	13.2	0.0		7.0	0.1		0.1	0.1	0.1	4.5		4.4	1.0	0.1	0.1	7.0	0.3		0.6	0.0		46.5	0.1	0.0	0.8					3.7		
Hrma, 1994	1051	986	8.9	5.4	0.2			0.3		0.2	0.3	0.5	2.0		3.6	8.0	0.2	0.5	20.0	1.0		2.5	0.2		42.0	0.5	0.2	3.3							
Hrma, 1994	1012	953	13.9	17.4	0.0			0.0		0.0	0.0	0.1	2.0		3.7		0.0	0.1	20.0	0.1		0.3	0.0		42.0	0.0	0.0	0.3							
Hrma, 1994	1080	1009	13.4	5.0	0.0		8.0	0.0		0.0	0.0	0.1	6.3		4.3		0.0	0.1	20.0	0.1		0.3	0.0		42.0	0.0	0.0	0.3							
Hrma, 1994	1278	1177	14.0	8.4	0.0			0.0		0.0	0.0	0.1	2.0		7.0		0.0	0.1	10.6	0.1		0.3	0.0		57.0	0.0	0.0	0.3							
Hrma, 1994	1187	1109	10.0	6.4	0.1		2.0	0.1		0.1	0.1	0.2	2.0		4.2	5.0	0.1	0.2	15.0	0.3		0.8	0.1		50.4	0.1	0.1	1.0					2.0		
Hrma, 1994	1175	1098	10.0	6.9	0.1		5.0	0.1		0.1	0.1	0.2	3.0		7.0	2.0	0.1	0.2	7.8	0.3		0.8	0.1		53.3	0.1	0.1	1.0					2.0		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Hrma, 1994	1142	1068	7.5	12.6	0.1		2.0	0.2		0.1	0.2	0.4	2.0		7.0	2.0	0.1	0.4	5.8	0.7		1.6	0.1		52.7	0.3	0.1	2.2					2.0		
Hrma, 1994	1123	1054	8.5	14.4	0.1		5.0	0.1		0.1	0.1	0.3	2.0		3.9	2.0	0.1	0.3	9.7	0.6		1.4	0.1		47.0	0.3	0.1	1.8					2.0		
Hrma, 1994	1180	1102	7.9	13.6	0.1		2.0	0.1		0.1	0.1	0.2	5.2		4.1	2.0	0.1	0.2	9.6	0.3		0.8	0.1		50.7	0.1	0.1	1.0					2.0		
Hrma, 1994	1207	1129	8.0	15.9	0.1		3.5	0.2		0.2	0.2	0.4	4.0		2.0		0.2	0.4	10.1	0.8		2.0	0.1		47.5	0.4	0.1	2.7					1.0		
Hrma, 1994			8.0	8.7	0.1			0.2		0.2	0.2	0.4	4.0		6.0	5.0	0.2	0.4	7.0	0.8		2.0	0.1		52.3	0.4	0.1	0.9			1.8		1.0		
Hrma, 1994	1038	979	15.0	20.0	0.0		2.0	0.0		0.0	0.0	0.1	2.0		7.0	8.0	0.0	0.1	5.0	0.1		0.3	0.0		39.0	0.0	0.0	0.3					1.0		
Hrma, 1994	973	913	11.5	17.2	0.0		3.8	0.0		0.0	0.0	0.1	2.0		7.3	0.1	0.0	0.1	12.7	0.1		0.3	0.0		43.8	0.1	0.0	0.3					0.8		
Hrma, 1994	1063	988	9.3	8.8	0.0		0.6	0.0		0.0	0.0	0.1	2.0		7.4	0.1	0.0	0.1	17.3	0.1		0.3	0.0		52.8	0.1	0.0	0.4					0.8		
Hrma, 1994	1279	1182	16.3	6.6	0.0			0.0		0.0	0.0	0.1	2.0		7.3		0.0	0.1	12.0	0.1		0.3	0.0		52.8	0.1	0.0	0.4					1.8		
Hrma, 1994	1068	1003	18.0	17.2	0.0		10.0	0.0		0.0	0.0	0.1	2.0		0.5		0.0	0.1	19.0	0.1		0.3	0.0		32.3	0.0	0.0	0.3							
Hrma, 1994	1215	1128	11.8	9.2	0.1		1.0			1.1		0.1	3.9		5.2	0.6	1.2	0.6	12.1	0.5					51.9			0.4					0.3		
Hrma, 1994	1231	1137	20.4	15.9			0.2			0.1		0.1	0.0		5.8	0.0			10.9				0.5		46.0	0.0									
Hrma, 1994	1350	1223	16.4	13.6			0.1			3.0		0.6	0.5	0.2	7.0	0.0	0.2	0.1	8.0						50.4	0.0						0.1	0.0		
Hrma, 1994	1336	1236	8.2	7.8			0.8			2.4	0.2	0.1	3.3		7.2	0.3	1.2		6.7			0.7	3.3	0.1	56.8	0.7		0.2					0.1		
Hrma, 1994	1257	1162	18.2	14.2			0.1	0.1		1.2	0.2		0.8		6.9	0.1	0.3		8.1	0.1		0.8	0.1		48.6	0.0		0.1					0.1		
Hrma, 1994	1208	1121	11.8	9.2	0.1		1.0	0.1		0.1	0.1	0.2	3.9		5.2	0.6	0.1	0.2	12.1	0.4		1.1	0.1		51.8	0.2	0.1	1.4					0.3		
Hrma, 1994	1131	1054	9.5	17.0	0.1		0.9	0.2		0.1	0.2	0.3	4.0		5.9		0.1	0.3	7.0	0.7		1.6	0.1		48.2	0.3	0.1	2.2					1.0		
Hrma, 1994	1223	1133	16.4	13.6	0.1		0.1	0.1		0.1	0.1	0.2	0.5		7.0	0.0	0.1	0.2	8.0	0.4		1.0	0.1		50.4	0.2	0.1	1.4					0.0		
Hrma, 1994	1234	1144	8.2	7.8	0.2		0.8	0.2		0.2	0.2	0.5	3.3		7.1	0.3	0.2	0.5	6.6	0.9		2.3	0.2		56.6	0.5	0.2	3.0					0.1		
Hrma, 1994	1223	1132	18.2	14.2	0.1		0.1	0.1		0.1	0.1	0.2	0.8		6.9	0.1	0.1	0.2	8.1	0.3		0.8	0.1		48.6	0.2	0.1	1.0					0.1		
Hrma, 1994	1122	1047	17.0	6.0	0.1		0.5	0.1		0.1	0.1	0.2	0.5		7.0	2.0	0.1	0.2	18.0	0.5		1.1	0.1		44.0	0.2	0.1	1.5					0.5		
Hrma, 1994	1373	1275	17.0	6.0	0.1		4.0	0.1		0.1	0.1	0.2	0.5		1.4	0.5	0.1	0.2	18.0	0.5		1.1	0.1		47.7	0.2	0.1	1.5					0.5		
Hrma, 1994	1295	1207	9.9	8.0	0.0		1.4	0.1		0.0	0.1	0.1	2.5		1.8	0.5	0.0	0.1	18.0	0.2		0.5	0.0		49.8	0.1	0.0	0.7					6.1		
Hrma, 1994	1115	1050	10.5	6.0	0.0		4.0	0.1		0.0	0.1	0.1	2.5		7.0	0.5	0.0	0.1	14.0	0.2		0.5	0.0		46.0	0.1	0.0	0.7					7.5		
Hrma, 1994	934	884	7.0	16.0	0.0		4.0	0.1		0.0	0.1	0.1	2.7		5.3	0.5	0.0	0.1	18.0	0.2		0.5	0.0		44.0	0.1	0.0	0.7					0.5		
Hrma, 1994	1026	957	13.9	17.4	0.0			0.0		0.0	0.0	0.1	2.0		3.7		0.0	0.1	20.0	0.1		0.3	0.0		42.0	0.0	0.0	0.3							
Hrma, 1999			8.0	7.0						0.7			13.0		4.5	0.6	0.5		15.7	2.0					45.0								3.0		
Hrma, 1999			8.0	7.0						0.7			13.0		4.5	0.6	0.5		15.7	2.0					45.0								3.0		
Hrma, 1999			8.0	7.0						0.5			14.5		4.0	0.6	0.5		15.3	1.2					42.4								6.0		
Hrma, 1999			8.0	7.0						0.5			14.5		4.0	0.6	0.5		15.3	1.2					42.4								6.0		
Hrma, 1999			8.0	7.0						0.5			11.5		4.0	0.6	0.5		15.3	1.2					45.4								6.0		
Hrma, 1999			8.0	7.0						0.5			11.5		4.0	0.6	0.5		15.3	1.2					45.4								6.0		
Hrma, 1999			8.0	7.0						0.5			8.9		4.5	0.6	0.5		15.3	1.2					47.5								6.0		
Hrma, 1999			8.0	7.0						0.5			8.9		4.5	0.6	0.5		15.3	1.2					47.5								6.0		
Hrma, 1999			8.0	7.0						0.5			11.5		4.1	0.6	0.5		15.3	0.7					45.8								6.0		
Hrma, 1999			8.0	7.0						0.4			12.5		3.0	0.6	0.4		15.7	1.4					46.0								5.1		
Hrma, 1999			8.0	7.0						0.3			11.5		4.5	0.6	0.5		15.3	1.0					45.3								6.0		
Hrma, 1999			8.0	7.0						0.4			12.5		3.0	0.6	0.4		15.7	0.8					46.0								5.7		
Hrma, 1999			8.0	7.0						1.0			11.0		4.0	0.6	0.4		15.7	1.0					45.3								6.0		
Hrma, 1999	1250		8.0	5.0			0.3			0.1			15.0	1.5	6.0	2.5	1.0		6.0	2.0		0.1			52.4					0.1					
Hrma, 1999	1322		8.0	5.0			2.0			0.1			15.0	3.8	3.0	0.5	1.0		11.0	0.0		0.1			49.9					0.6					
Hrma, 1999	1294		8.0	10.0			0.3			0.3			6.0	3.8	6.0	2.5	3.0		6.0	0.0		0.1			53.9					0.1					
Hrma, 1999	1200		8.0	10.0			2.0			0.3			15.0	1.5	6.0	0.5	1.0		6.0	0.0		0.1			44.0					0.1	5.5				
Hrma, 1999	1140		8.0	10.0			0.3			0.3			6.0	3.8	6.0	0.5	1.0		11.0	2.0		0.1			45.4					0.1	5.5				
Hrma, 1999	1240		8.0	5.0			2.0			0.1			6.0	1.5	6.0	2.5	1.0		11.0	0.0		0.1			50.7					0.6	5.5				
Hrma, 1999	1333		8.0	10.0			0.3			0.1			15.0	3.8	3.0	2.5	1.0		6.0	2.0		0.1			48.1					0.1					
Hrma, 1999	1280		8.0	5.0			0.3			0.1			6.0	1.5	6.0	0.5	3.0		11.0	0.0		0.1			52.4					0.6	5.5				
Hrma, 1999	1157		8.0	5.0			2.0			0.1			6.0	3.8	6.0	2.5	3.0		11.0	2.0		0.1			44.9					0.1	5.5				
Hrma, 1999	1149		8.0	10.0			2.0			0.1			14.9	3.8	6.0	2.5	3.0		6.0	0.0		0.1			43.0					0.6					
Hrma, 1999	1250		8.0	10.0			0.3			0.1			15.0	1.5	6.0	0.5	1.0		11.0	2.0		0.1			44.0					0.6					

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Hrma, 1999	1145		8.0	10.0			2.0			0.3			6.0	3.8	6.0	0.5	3.0		11.0	2.0		0.1			46.8					0.6					
Hrma, 1999	1285		8.0	10.0			2.0			0.3			14.5	1.5	3.0	2.5	3.0		6.0	0.0		0.1			43.0					0.6	5.5				
Hrma, 1999	1134		8.0	5.0			0.3			0.3			14.5	3.8	6.0	2.5	3.0		11.0	2.0		0.1			43.0					0.6					
Hrma, 1999	1300		8.0	10.0			0.3			0.3			6.0	1.5	3.0	2.5	1.0		11.0	2.0		0.1			48.3					0.6	5.5				
Hrma, 1999	1300		8.0	10.0			2.0			0.1			15.0	1.5	3.0	0.5	3.0		6.0	2.0		0.1			43.2					0.1	5.5				
Hrma, 1999	1326		8.0	5.0			2.0			0.3			15.0	3.8	3.0	0.5	1.0		11.0	0.0		0.1			50.2					0.1					
Hrma, 2006	1150		8.0	12.0		1.5	1.5	0.5		**1.0**		0.5	1.5	3.0	4.0		0.5		16.0	0.2		0.3	0.8	0.1	44.2		0.5			1.3		0.3	2.5		
Huang, 2004			13.9				11.3			0.5			21.1			9.4			3.3						40.4										
Ioffe, 1987			7.8	15.3			2.0		0.9		0.4		0.5	2.6		1.4			16.5				6.3		39.3					5.4			1.6		
Ioffe, 1987			7.5	15.0			2.0		0.4		1.0			3.0		0.8			16.7				7.0		40.0					6.2			0.5		
Ioffe, 1987			7.6	15.1			2.0		0.5		0.5		0.5	2.6		1.4			16.0				7.1		39.5					6.0			1.2		
Ioffe, 1987			8.6	15.0			2.2		0.6		0.2		1.7	2.7		1.8			14.0				6.8		42.0					4.0			0.4		
Ioffe, 1987			9.0	15.5			2.5		0.1		0.9		1.5	2.8		2.0			14.7				4.0		35.0					11.0			1.0		
Ioffe, 1987			7.5	15.5			2.5		0.6		0.3		0.5		0.8	1.5			17.0				6.3		41.1					5.0			1.3		
Jain, 1990		1100	7.3	11.0	0.1		0.7	0.1	0.1	0.1			12.2	3.5	3.1	0.8	0.9		11.6	0.2	0.0	0.0	2.6		41.7	0.3	0.1	0.1		0.8		0.5	2.2		
Jain, 1990		1073	7.3	11.0	0.1		0.7	0.1	0.1	0.1			12.2	3.5	3.1	0.8	0.9		11.6	0.2	0.0	0.0	2.6		41.7	0.3	0.1	0.1		0.8		0.5	2.2		
Jantzen, 1995			13.5	10.8			0.4						4.6		4.1	1.4	2.5		14.1	0.6	0.4				46.5					0.7			0.3		
Jantzen, 1995			7.1	8.3			1.3						14.0	3.1	4.0	0.5	3.4		9.9	1.1		0.1			45.2		0.1			1.3			0.6		
Jantzen, 1995			13.5	7.4			0.5						4.6		4.2	0.7	2.6		10.7	0.7					54.2								0.8		
Jantzen, 1995			13.5	10.3			0.5						4.4	3.1	2.7	1.3	2.5		10.7	0.6					48.7					1.7			0.0		
Jantzen, 1995			14.0	7.5			0.4						4.3	3.3	4.2	1.3	2.5		7.4	0.6					52.7					1.7			0.0		
Jantzen, 1995			7.1	7.0	0.1		1.0			0.1	0.2		7.8	2.2	4.6	1.5	1.8	0.2	8.6	0.4		0.0			55.8			0.5		0.6			0.3		
Jantzen, 1995			7.1	7.0	0.1		1.0			0.1	0.2		7.8	2.2	4.6	1.5	1.8	0.2	8.6	0.4		0.0			55.8			0.5		0.6			0.3		
Jantzen, 1995			7.1	7.0	0.1		1.0			0.1	0.2		7.8	2.2	4.6	1.5	1.8	0.2	8.6	0.4		0.0			55.8			0.5		0.6			0.3		
Jantzen, 1995			7.5	6.6	0.1		0.7			0.5	0.1		9.9	1.6	4.4	1.5	2.7		10.2	0.7					52.9		0.1			0.1		0.1	0.1		
Jantzen, 1995			7.7	6.7	0.1		0.7			0.5	0.1		9.9	1.8	4.4	1.5	2.8		10.4	0.7					52.4		0.2			0.1		0.1	0.1		
Jantzen, 1995			7.5	6.7	0.1		0.7			0.4	0.1		9.4	1.9	4.6	1.5	2.7		10.5	0.6					52.7		0.1			0.1		0.1	0.1		
Jantzen, 1995			7.7	6.5	0.1		0.7			0.4	0.1		9.5	2.2	4.2	1.5	2.6		10.8	0.6					52.8		0.1			0.1		0.1	0.1		
Jantzen, 1995			8.6	6.7	0.1		0.7			0.4	0.2		10.0	2.2	4.3	1.5	2.8		10.6	0.6					51.0		0.1			0.1		0.1	0.1		
Jantzen, 1995			9.1	6.7	0.1		0.8			0.4	0.2		10.4	2.3	4.2	1.6	2.9		10.1	0.6					50.3		0.2			0.1		0.1	0.1		
Jantzen, 1995			13.1	13.9			3.0						8.3						15.7						46.0										
Jantzen, 1995			15.0	9.4									11.4						17.2						46.9										
Jantzen, 1995			8.5	6.8	0.1		0.8			0.4	0.2		9.5	2.1	4.3	1.6	2.8		10.4	0.6					51.5		0.1			0.1		0.1	0.1		
Jensen. C., 1999		1242	1.5				29.5						0.5	0.8		8.7			4.8						54.2										
Jensen. C., 1999		1191	2.0				30.5						0.5	0.7		9.9			4.6						50.8										
Jensen. C., 1999		1216	0.8				29.9						0.6	0.2		16.4			1.0						49.1					0.1					
Jensen. C., 1999		1140	2.1				22.5						4.5	0.8		12.5			3.5						53.2					0.2					
Jensen. C., 1999		1163	2.0				23.2						6.0	0.8		11.0			2.0						53.5					0.1					
Jensen. C., 1999		1257	12.2				14.3						6.9	1.1		11.7			2.4						47.6					1.8					
Jensen. C., 1999		1263	12.8				13.1						6.6	1.1		11.3			2.4						48.5					1.9					
Jiricka, 2000			4.5	14.4						**2.9**			4.5	3.8	3.2	0.4			8.0						53.2					5.3					
Jiricka, 2000			1.0				8.1						0.1	0.3		3.9			13.7						72.5	0.3									
Johnston, 1990			7.9	9.5	0.6		0.6	0.2		0.2			11.3	3.3	3.0	1.2	1.3		10.5	0.7		0.1	2.4		43.2	0.1				1.0			3.0		
Johnston, 1990			8.8	9.4	0.6		0.6	0.2		0.2			11.2	3.3	2.9	1.2	1.3		10.4	0.7		0.1	2.4		42.8	0.1				0.9			2.9		
Johnston, 1990			8.0	7.4	0.2		0.8						12.3	1.6	3.0	1.3	1.3		10.2		2.7		2.5		44.7				3.6		0.6				
Johnston, 1990			8.0	9.9	0.2		0.7						12.1	1.6	2.0	1.3	1.3		8.9		2.6		2.5		44.7				3.6		0.6				
Johnston, 1990			8.0	12.4	0.1		0.6						12.1	1.3	2.0	1.3	1.3		9.2		2.6		2.5		42.3				3.6		0.6				
Johnston, 1990			8.6	9.6	0.2		1.0						13.1	2.5	2.9	0.9	1.4		10.7		2.9		0.6		41.0				3.9		0.6				
Johnston, 1990			9.9	12.3	0.2		0.8						11.9	1.6	2.2	0.8	1.2		9.8		3.1		2.5		39.6				3.5		0.6				

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Johnston, 1990			10.2	12.6			0.2						12.2	1.0	2.0		1.0		10.9		1.9		2.6		41.1				3.6		0.6				
Johnston, 1990			10.4	13.4	0.2		0.7						12.6	1.4	4.6	0.7	1.0		8.6		1.9		2.6		42.0				0.0		0.0				
Johnston, 1990			8.8	14.0	0.2		0.8						10.9	1.6	2.4	0.9	1.2		8.9		3.2		0.6		42.0				3.9		0.7				
Johnston, 1990			10.0	12.3	0.2		0.9						12.0	2.5	2.7	1.2	1.3		9.8		2.6		0.6		39.8				3.5		0.6				
Johnston, 1990			11.9	12.3	0.2		0.9						12.0	2.5	2.7	1.3	1.3		9.8		2.6		0.6		37.8				3.5		0.6				
Johnston, 1990			10.0	12.4	0.2		0.9						12.0	2.5	2.7	1.3	1.3		9.8		2.6		2.4		37.9				3.5		0.6				
Johnston, 1990			10.0	10.4	0.2		0.9						12.0	2.5	2.7	1.3	1.3		9.8		2.6		2.5		39.9				3.5		0.6				
Johnston, 1990			9.9	12.3	0.2		0.8						11.9	1.6	2.2	0.8	1.2		9.8		3.1		2.5		39.6				3.5		0.6				
Johnston, 1990			9.7	12.1	0.2		0.8						11.7	1.6	2.2	0.8	1.2		9.6		3.0		2.4		38.9				5.2		0.6				
Johnston, 1990			9.7	12.0	0.2		0.8						11.7	1.6	2.2	0.8	1.2		11.6		3.0		2.4		38.8				3.5		0.6				
Johnston, 1990			10.1	12.5	0.2		0.8						12.2	1.6	2.3	0.8	1.2		10.0		3.0		2.5		38.5				3.6		0.6				
Johnston, 1990			9.7	14.1	0.2		0.8						11.7	1.6	2.2	0.8	1.2		9.6		3.0		2.4		38.8				3.5		0.6				
Johnston, 1990			9.5	11.8	1.8		0.8						15.3	1.5	2.1	0.8	1.2		9.4		3.0		2.4		38.1				3.4		0.6				
Johnston, 1990			9.9	10.3	0.2		0.7						11.9	1.9	2.0	1.3	1.3		11.8		2.7		2.5		39.6				3.5		0.6				
Johnston, 1990			9.8	12.2	0.2		0.8						11.9	1.6	2.2	0.8	1.2		9.7		3.1		2.5		39.4				3.5		1.2				
Johnston, 1990			9.8	12.2	0.2		0.7						11.9	1.9	2.1	1.3	1.3		8.9		2.7		3.5		39.5				3.5		0.6				
Johnston, 1990			10.1	12.5	0.2		0.8						12.2	1.6	2.3	0.8	1.2		10.0		3.0		2.5		38.5				3.6		0.6				
Johnston, 1990			10.0	12.4			0.8						12.0	0.9	2.1	0.8	1.0		10.7		2.1		2.6		40.4				3.6		0.6				
Johnston, 1990			10.0	12.4			0.8						12.0	0.9	2.1		1.0		10.7		2.9		2.6		40.4				3.6		0.6				
Johnston, 1990			9.9	12.6	0.2		0.8						12.0	1.3	4.3	0.9	1.2		8.1		3.0		2.5		39.7				3.5		0.0				
Johnston, 1990			10.1	12.9	0.2		0.8						12.2	1.3	4.4	0.9	1.2		8.3		3.1		2.5		40.4				1.8		0.0				
Johnston, 1990			9.9	12.6	0.2		0.8						12.0	1.3	4.3	0.9	1.2		8.1		6.5		2.5		39.7				0.0		0.0				
Johnston, 1990			10.1	12.9	0.2		0.8						12.2	1.3	4.4	0.9	1.2		8.3		4.8		2.5		40.5				0.0		0.0				
Johnston, 1990			13.8	12.2	0.2		0.8						11.9	1.6	2.3	0.8	1.2		9.8		2.9		2.5		35.9				3.5		0.6				
Johnston, 1990			9.9	12.2	0.2		0.8						15.9	1.6	2.3	0.8	1.2		9.8		2.9		2.5		35.9				3.5		0.6				
Johnston, 1990			9.9	12.2			0.8						11.8	0.9	2.0	1.6	1.0		10.5		2.8		2.5		39.8				3.5		0.6				
Johnston, 1990			9.9	12.2	0.2		0.8						11.9	1.6	2.3	0.8	1.2		9.8		2.9		2.5		39.8				3.5		0.6				
Johnston, 1990			9.9	12.2	0.2		0.8						11.9	1.6	2.3	0.8	1.2		9.8		6.9		2.5		35.9				3.5		0.6				
Johnston, 1990			10.0	12.3			0.8						11.9	0.9	2.1	0.8	1.0		10.6		2.9		2.6		40.1				3.5		0.6				
Johnston, 1990			10.0	12.3			0.2						11.9	0.9	2.1	1.4	1.0		10.6		2.9		2.6		40.1				3.5		0.6				
Johnston, 1990			9.9	12.7	0.2		0.8						12.0	1.3	4.4	0.9	1.0		8.2		2.1		2.5		40.0				3.5		0.6				
Johnston, 1990			10.0	12.9	0.2		0.8						12.1	1.4	2.2	0.8	1.2		8.5		2.9		2.5		40.3				3.5		0.6				
Johnston, 1990			8.1	12.8	0.2		0.8						12.1	1.6	2.3	0.8	1.2		10.2		2.9		2.5		40.2				3.6		0.6				
Johnston, 1990			9.9	12.7	0.2		0.8						12.0	1.6	2.2	0.8	1.2		10.0		2.9		1.5		39.9				3.6		0.6				
Johnston, 1990			9.8	12.5	0.2		0.9						11.9	3.4	2.9	1.0	1.2		10.5		2.9		2.5		37.5				3.5		0.6				
Johnston, 1990			9.8	12.2	0.2		0.8						11.9	1.6	2.2	0.8	1.2		9.8		3.3		2.5		39.5				3.5		0.6				
Johnston, 1990			9.7	12.0	0.2		0.8						13.7	1.6	2.2	0.8	1.2		9.6		3.0		2.4		38.8				3.5		0.6				
Johnston, 1990			9.6	12.0	0.2		0.8						11.7	1.6	2.2	0.8	1.2		9.6		3.0		2.4		41.0				3.4		0.6				
Johnston, 1990			7.4	10.6	0.2		0.8						11.9	3.6	3.1	0.9	1.2		11.3		3.0		2.3		39.5				3.5		0.6				
Johnston, 1990			8.4	10.1	0.2		0.8						11.9	3.5	3.0	0.9	1.2		10.9		3.0		2.3		39.5				3.5		0.6				
Johnston, 1990			8.4	9.2	0.2		0.8						12.0	3.3	2.8	0.9	1.2		10.1		3.0		2.4		41.6				3.5		0.6				
Johnston, 1990			9.9	9.5	0.2		0.8						12.0	3.3	2.9	0.9	1.2		10.3		3.0		2.4		39.6				3.5		0.6				
Johnston, 1990			8.2	9.3	0.2		0.9						11.6	3.3	2.8	1.2	1.4		10.2		2.6		2.3		41.9				3.4		0.6				
Karell, 2006		1337					9.3												15.4						73.8								1.5		
Karell, 2006		1338					9.2												15.3						71.0								4.5		
Karell, 2006		1331					9.1												15.1						68.4								7.4		
Karell, 2006							9.0												15.0						65.7								10.3		
Karell, 2006							9.4												15.5						75.1										
Karell, 2006		1278					9.3												15.4						73.8								1.5		
Karell, 2006		1316					9.2												15.3						71.0								4.5		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2'	Oth1'	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Karell, 2006		1340					9.1												15.1						68.4								7.4		
Karell, 2006		1370					9.0												15.0						65.7								10.3		
Khizanishvili, 1968	1300		19.9	5.3			3.2						4.3	5.5		1.3			8.6						51.3					0.3					
Khizanishvili, 1970	1130		12.9	6.7			0.7						3.9			0.1	3.4		6.4						65.6		0.3								
Khizanishvili, 1970	1100		14.3				0.8						0.5	7.5		0.2			3.7						72.7		0.3								
Khizanishvili, 1970	1200		14.9				0.8						0.5	3.7		0.2			3.9						75.7		0.3								
Khizanishvili, 1970	1130		12.7	6.7			0.7						8.5			0.1			6.3						64.7		0.3								
Khizanishvili, 1970	1335		13.8				0.7						0.5			0.2			3.6		10.6				70.3		0.3								
Khizanishvili, 1973	1275		9.3	15.5			3.2						0.4	1.5		0.3			1.6						46.9		6.6					9.4	5.6		
Kim, 1996		1409	5.6	0.1		1.6	1.4	1.9		0.6		0.4	7.8			0.1	1.3	0.1	14.1	1.6	0.3	0.1	0.9		50.1	0.2		6.9					5.0		
Kim, 1996		1344	6.0	0.1		1.7	1.6	2.1		0.7		0.4	8.4			0.1	1.4	0.1	15.3	1.7	0.3	0.1	1.0		45.7	0.3		7.5					5.4		
Kim, 1996		1282	6.5	0.1		1.8	1.7	2.3		0.7		0.5	9.1			0.1	1.5	0.1	16.5	1.9	0.4	0.1	1.1		41.3	0.3		8.1					5.9		
Kim, 1996		1229	6.9	0.1		2.0	1.8	2.4		0.8		0.5	9.7			0.1	1.6	0.1	17.5	2.0	0.4	0.1	1.1		37.8	0.3		8.5					6.2		
Kim, 1996			4.5	0.0	0.2		0.4	0.3		0.2	0.3	0.6	14.1			0.1	0.3	0.6	10.7	1.1	1.2	2.7	0.2		52.0	0.5	0.2	2.4					7.5		
Kim, 1996			4.5	4.0	0.2		0.4	0.3		0.2	0.3	0.6	14.1			0.1	0.3	0.6	10.7	1.1	1.2	2.7	0.2		48.0	0.5	0.2	2.4					7.5		
Kim, 1996			4.5	15.0	0.2		0.4	0.3		0.2	0.3	0.6	14.1			0.1	0.3	0.6	10.7	1.1	1.2	2.7	0.2		37.0	0.5	0.2	2.4					7.5		
Kim, 1996		1381	4.5	0.0	0.2		0.4	0.3		0.2	0.3	0.6	14.1			0.1	0.3	0.6	14.4	1.1	1.2	2.7	0.2		48.3	0.5	0.2	2.4					7.5		
Kim, 1996		1351	4.5	0.0	0.2		0.4	0.3		0.2	0.3	0.6	14.1		1.7	0.1	0.3	0.6	10.7	1.1	1.2	2.7	0.2		50.3	0.5	0.2	2.4					7.5		
Kim, 1996		1344	4.5	0.0	0.2		0.4	0.3		0.2	0.3	0.6	14.1			0.1	0.3	0.6	16.7	1.1	1.2	2.7	0.2		46.0	0.5	0.2	2.4					7.5		
Kim, 1996		1297	4.5	0.0	0.2		0.4	0.3		0.2	0.3	0.6	14.1		2.7	0.1	0.3	0.6	10.7	1.1	1.2	2.7	0.2		49.3	0.5	0.2	2.4					7.5		
Kim, 2001	1177		9.0	13.3			13.6			0.3			2.0			1.5			14.0						45.1										
Kim, 2001	1177		8.7	12.8			13.1			0.4			1.9			1.5			17.2						43.5										
Kukolev, 1969			6.5	18.7	4.6		6.5							1.1		0.5			4.5						45.8							2.8	8.8		
Kukolev, 1969			11.9				10.0									4.3			4.7						57.6		1.5					3.6	7.0		
Kukolev, 1969			17.7		0.1		6.8							0.2	1.6	0.4			5.4				10.5		44.4		0.5					4.6	7.8		
Kukolev, 1969			14.0				7.2					2.4			0.7	2.0			10.4				6.0		47.3		2.5					2.1	5.4		
Kukolev, 1969			7.8		0.1		5.3							0.3	0.4				10.8				7.2		54.9		8.1					2.4	2.7		
Kukolev, 1969			5.6	19.6	4.7		5.5									1.8			3.0						40.0		2.3					9.4	8.1		
Kukolev, 1969			3.8	14.2	11.3		8.6							0.2	0.2	1.0			2.0						42.6		2.8					5.1	8.1		
Li, 1997			7.8	8.6			1.2						10.6	0.1	4.8	0.7			21.7		3.1				41.1								0.3		
Li, 1997			17.7	7.6			1.1						9.5	0.1	4.3	0.7			19.4		2.7				36.6								0.3		
Li, 1997			19.3	7.5			1.1						9.3	0.1	4.2	0.6			19.0		2.7				35.9								0.3		
Li, 1997			15.0				1.2						10.8	0.1	4.9	0.7			22.0		3.1				41.7								0.3		
Li, 1997			12.0	20.0			1.0						8.6	0.1	3.9	0.6			17.6		2.5				33.4								0.3		
Li, 1997			13.8	8.0			1.1						9.9	0.1	4.5	0.7			20.3		2.9				38.4								0.3		
Li, 1997			13.9	8.1									10.1	0.1	4.6	0.7			20.5		2.9				38.8								0.3		
Li, 1997			12.5	7.3			10.0						9.1	0.1	4.1	0.6			18.5		2.6				34.9								0.3		
Li, 1997			14.4	8.4			1.2						6.0	0.1	4.7	0.7			21.2		3.0				40.1								0.3		
Li, 1997			14.1	8.2			1.2						8.0	0.1	4.6	0.7			20.8		2.9				39.3								0.3		
Li, 1997			13.3	7.7			1.1						13.0	0.1	4.4	0.7			19.6		2.8				37.1								0.3		
Li, 1997			13.4	7.8			1.1						9.7	3.0	4.4	0.7			19.7		2.8				37.3								0.3		
Li, 1997			13.0	7.5			1.1						9.4	6.0	4.2	0.6			19.1		2.7				36.1								0.3		
Li, 1997			14.4	8.4			1.2						10.4	0.1		0.7			21.2		3.0				40.2								0.3		
Li, 1997			13.3	7.7			1.1						9.6	0.1	8.0	0.7			19.5		2.8				37.0								0.3		
Li, 1997			15.0	8.7			1.2						10.8	0.1	4.9	0.7			13.3		3.1				41.7								0.3		
Li, 1997			14.7	8.6			1.2						10.6	0.1	4.8	0.7			14.8		3.1				41.0								0.3		
Li, 1997			12.2	7.1			1.0						8.8	0.1	4.0	0.6			18.0		2.5				45.3								0.3		
Li, 1997			11.8	6.8			1.0						8.5	0.1	3.8	0.6			17.3		2.4				47.4								0.3		
Mahoney, 2005			12.0				4.6			0.1		0.1	7.8	2.1		1.2			17.0				0.6		52.5	0.7				1.2					v
Mahoney, 2005			11.6				4.4			0.1		0.1	7.5	2.1		1.2			20.0				0.6		50.3	0.8				1.2					v

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2'	Oth1'	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Mahoney, 2005			11.2				4.2			0.1		0.1	7.2	2.0		1.1			23.0				0.7		48.2	1.0				1.1					v
Mahoney, 2005			10.8				4.1			0.1		0.1	6.8	1.9		1.1			26.0				0.8		46.0	1.1				1.1					v,p
Mahoney, 2005			10.9				4.2			0.1		0.1	7.0	1.9		1.1			20.0				0.6		47.1	0.8				1.1			5.0		v
Mahoney, 2005			10.9	2.5			4.2			0.1		0.1	7.0	1.9		1.1			20.0				0.6		47.1	0.8				1.1			2.5		v
Mahoney, 2005			10.5				4.0			0.1		0.1	6.7	1.9		1.0			23.0				0.7		44.9	1.0				1.0			5.0		v
Mahoney, 2005			10.5	2.5			4.0			0.1		0.1	6.7	1.9		1.0			23.0				0.7		44.9	1.0				1.0			2.5		v
Mahoney, 2005			8.5				4.1			0.1		0.1	6.9	1.9		1.1			23.0				0.7		46.4	1.0				1.1			5.0		v
Mahoney, 2005			12.5				3.8			0.1		0.1	6.5	1.8		1.0			23.0				0.7		43.4	1.0				1.0			5.0		v,c
Mahoney, 2005			10.8				4.1			0.1		0.1	4.7	1.9		1.1			23.0				0.7		46.4	1.0				1.1			5.0		v
Mahoney, 2005			10.2				3.8			0.1		0.1	8.7	1.8		1.0			23.0				0.7		43.5	1.0				1.0			5.0		v
Mahoney, 2005			9.9	5.0			3.8			0.1		0.1	6.3	1.8		1.0			20.0				0.6		42.6	0.8				1.0			7.0		
Mahoney, 2005			9.5	5.0			3.6			0.1		0.1	6.0	1.7		0.9			20.0				0.6		40.6	0.8				0.9			10.0		c
Mahoney, 2005			9.5	5.0			3.6			0.1		0.1	6.0	1.7		0.9			20.0				1.6		40.6	0.8				1.9			6.0		v
Mahoney, 2005			9.9	5.0			3.8			0.1		0.1	6.4	1.8		1.0			17.0				0.5		45.8	0.7				1.0			7.0		
Mahoney, 2005			9.1	5.0			2.8			0.1		0.0	4.3	1.5		1.4			20.0				0.6		46.8	0.4				0.8			7.0		
Mahoney, 2005			9.8	5.0			5.1			0.1		0.0	6.3	1.0		2.8			20.0				0.3		40.7	0.8				1.0			7.0		
Mahoney, 2005			9.7	5.0			5.1			0.6		0.0	6.5	1.0		2.8			20.0				0.2		40.8	0.2				1.0			7.0		
Mahoney, 2005			9.4	4.2			2.9			0.1		0.0	4.5	1.6		1.4			20.0				0.6		48.2	0.4				0.8			5.8		
Mahoney, 2005			9.7	3.3			2.9			0.1		0.0	4.6	1.6		1.4			20.0				0.6		49.6	0.4				0.8			4.7		v
Mahoney, 2005			9.9	2.5			3.0			0.1		0.0	4.7	1.6		1.5			20.0				0.6		51.0	0.4				0.9			3.5		v
Mahoney, 2005			10.2	1.7			3.1			0.1		0.0	4.9	1.7		1.5			20.0				0.6		52.4	0.4				0.9			2.3		v
Mahoney, 2005			8.9	5.0			2.7			0.2		0.0	4.2	1.5		1.3			22.0				0.7		45.3	0.4				0.8			7.0		
Mahoney, 2005			8.6	5.0			2.6			0.2		0.0	4.1	1.4		1.3			24.0				0.7		43.8	0.5				0.7			7.0		v
Mahoney, 2005			11.7	4.9			2.7			0.1		0.0	4.2	1.5		1.4			19.4				0.6		45.4	0.4				0.8			6.8		
Mahoney, 2005			14.2	4.7			2.7			0.1		0.0	4.1	1.4		1.5			18.8				0.6		44.0	0.3				0.8			6.6		
Mahoney, 2005			16.8	4.6			2.7			0.1		0.0	4.0	1.4		1.6			18.2				0.6		42.6	0.3				0.7			6.4		
Mahoney, 2005			16.0	2.0			2.5			0.4		0.1	4.0	2.5		3.0			18.0				1.6		39.0	1.0				2.0			7.8		t,p,c
Mahoney, 2005			8.0	6.0			2.5			0.4		0.1	11.0	2.5		3.0			18.0				0.2		44.0	0.1				2.0			2.0		
Mahoney, 2005			8.0	6.0			2.5			0.4		0.1	11.0	2.5		0.9			18.0				1.6		43.9	1.0				2.0			2.0		t,p
Mahoney, 2005			8.0	2.0			5.5			0.4		0.1	11.0	2.5		0.9			20.1				0.2		39.0	0.1				2.0			8.0		t,p,c
Mahoney, 2005			12.5	2.0			2.5			0.4		0.1	4.0	2.5		3.0			23.5				0.2		39.0	0.1				2.0			8.0		
Mahoney, 2005			8.0	3.0			5.5			0.4		0.1	11.0	0.9		3.0			18.0				0.2		46.1	1.0				0.7			2.0		
Mahoney, 2005			8.0	2.0			2.5			0.4		0.1	4.0	0.9		3.0			18.0				0.2		54.8	1.0				2.0			3.0		
Mahoney, 2005			8.0	2.0			5.5			0.4		0.1	4.0	0.9		0.9			19.3				1.6		47.1	0.1				2.0			8.0		c
Mahoney, 2005			11.3	2.0			2.5			0.4		0.1	11.0	0.9		3.0			18.0				1.6		39.0	1.0				1.1			8.0		c
Mahoney, 2005			14.7	6.0			5.5			0.4		0.1	4.0	2.5		3.0			18.0				1.6		39.0	0.1				0.7			4.2		c
Mahoney, 2005			16.0	6.0			2.5			0.4		0.1	11.0	0.9		0.9			18.0				0.2		39.0	0.1				2.0			2.8		c
Mahoney, 2005			16.0	2.0			5.5			0.4		0.1	4.0	0.9		0.9			21.5				0.2		39.0	1.0				2.0			6.4		t,p,c
Mahoney, 2005			14.1	2.0			5.5			0.4		0.1	11.0	2.5		0.9			18.0				1.6		39.0	0.1				0.7			4.0		t,p,c
Mahoney, 2005			9.9	5.0			3.8			0.1		0.1	6.3	1.8		1.0			20.0				0.6		42.6	0.8				1.0			7.0		
Mahoney, 2005			9.9	5.0			3.8			0.1		0.1	6.4	1.8		1.0			17.0				0.5		45.8	0.7				1.0			7.0		
Mahoney, 2005			10.3	5.0			3.9			0.1		0.1	6.7	1.8		1.0			17.0				0.5		44.7	0.7				1.0			7.0		
Mahoney, 2005			9.6	5.0			3.6			0.1		0.1	6.1	1.7		0.9			22.0				0.6		41.1	0.9				0.9			7.0		
Mahoney, 2005			9.3	5.0			3.5			0.1		0.1	5.9	1.7		0.9			24.0				0.7		39.7	1.0				0.9			7.0		v
Mangat, 1997	~1400		7.4	16.7		42.0																			33.9										
Mangat, 1997	~1400		3.4	18.9		31.1										1.7									41.0								4.0		
Mangat, 1997	~1400		4.9	19.1		47.6																			28.5										
Mangat, 1997	~1400		4.9	14.3		47.6																			33.3										
Mangat, 1997	~1400		3.4	18.8		30.9										2.4			1.5						40.7								2.3		
Mangat, 1997	~1400		3.4	19.0		31.1										1.7									40.8								4.0		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Mangat, 1997	~1400		6.4	15.8		30.9										1.7			1.5						40.7								3.0		
Mangat, 1997	~1400		3.4	18.6		30.5										1.7									40.0			2.0					3.9		
Mangat, 1997	~1400		3.4	18.7		30.7										1.7			1.5						40.3					1.0			2.7		
Mangat, 1997	~1400		5.0	20.0		31.4									1.5										34.1					1.0		4.0	3.0		
Mangat, 1997	~1400		3.0	18.2		25.3									2.0										48.2							1.0	2.3		
Mangat, 1997	~1400		3.0	18.1		24.9									3.0										47.8							1.0	2.3		
Mangat, 1997	~1400		5.0	16.0		24.9									3.7										45.4								5.0		
Mangat, 1997	~1400		3.6	19.6		32.2									0.8	1.7									42.2										
Mangat, 1997	~1400		3.4	13.9		35.8										1.7			1.5						40.7								3.0		
Mangat, 1997	~1400		3.4	15.8		33.8										1.7			1.5						40.7								3.0		
Mangat, 1997	~1400		6.5	16.2		31.5													1.6						41.3								3.0		
Mangat, 1997	~1400		3.1	16.4		32.2									1.6										42.5					1.0			3.1		
Mangat, 1997	~1400		3.6	19.6		32.2	2.1								0.8	1.7									40.1										
Mangat, 1997	~1400		7.4	20.5		41.6																			30.6										
Mangat, 1997	~1400		7.3	16.6		41.7									0.5										33.7										
Mangat, 1997	~1400		7.2	16.4		41.2									2.0										33.2										
Mangat, 1997	~1400		7.2	16.5		41.5									1.0							0.5			33.4										
Mangat, 1997	~1400		7.3	16.6		41.6								1.0											33.6										
Mangat, 1997	~1400		7.2	16.3		41.0	2.4																		33.1										
Mangat, 1997	~1400		7.2	16.4		41.2									1.0										33.2								1.0		
Mangat, 1997	~1400		9.3	16.5		41.6									1.0										31.6										
Mangat, 1997	~1400		11.2	16.5		41.6									1.0										29.6										
Mangat, 1997	~1400		5.3	14.6		27.8									0.1				1.4			2.9			43.1							2.8	2.0		
Mangat, 1997	~1400		7.0	17.0		24.9													2.0			2.0			39.9							5.0	2.2		
Mangat, 1997	~1400		5.4	15.2		27.3									1.3			1.6							42.2							3.9	3.2		
Mangat, 1997	~1400		6.1	14.9		27.6									1.6								1.5		42.1							3.9	2.3		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			7.9	8.1			4.5			0.4			6.3	2.0	4.1	2.3			8.7	0.1	0.1	0.2	2.2	0.0	43.2	1.3						4.1	3.0		
Matlack, 1997			8.0	8.1			4.6			0.4			6.4	2.0	4.1	2.3			8.8	0.1	0.1	0.2	2.2	0.0	43.5	0.7						4.1	3.0		
Matlack, 1997			8.0	8.1			4.6			0.4			6.4	2.0	4.1	2.3			8.8	0.1	0.1	0.2	2.2	0.0	43.5	0.7						4.1	3.0		
Matlack, 1997			8.0	8.1			4.6			0.4			6.4	2.0	4.1	2.3			8.8	0.1	0.1	0.2	2.2	0.0	43.5	0.7						4.1	3.0		
Matlack, 1997		1195	9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Matlack, 1997			9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Matlack, 1997			9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Matlack, 1997		1209	9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Matlack, 1997			9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Matlack, 1997		1200	9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Matlack, 1997			9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Matlack, 1997			9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Matlack, 1997			9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1	0.1	0.3	1.3	0.1	40.9	0.4		0.0				3.3	3.0		
Mcgetchin, 1978		1060	8.8				7.5						7.3	0.3		24.6			1.4						51.4										
Mcgetchin, 1978		967	11.3				9.5						14.4	0.4		17.3			1.8						44.5										
Merrill, 1993			20.0	5.0			4.7							1.8	0.5	10.2			6.0		8.1	4.1	9.4	0.2	30.0										

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Merrill, 1995	1300		33.6	4.9					0.0	0.0		0.2	0.0	1.0		0.0	0.0	0.1	18.0			0.1	41.6			0.2									
Merrill, 1995	1400		35.5	2.7					0.4					0.7		0.0			18.3				41.9			0.2									
Merrill, 1995	1400		35.7	2.7										0.2					18.8				42.0			0.3									
Merrill, 1995	1300		34.7	4.7					0.0	0.0		0.1	0.0	0.0		0.0	0.0	0.1	18.2			0.1	41.9												
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			12.0	6.7	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.0	0.3	2.9	0.6	0.3	0.0	15.0	0.5	2.8	0.9	0.4	0.2	44.0	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			16.0	6.4	0.3		0.9	0.1	0.1	0.2	0.0	0.1	11.4	0.3	2.7	0.5	0.3	0.0	14.4	0.5	2.6	0.8	0.4	0.2	42.0	0.2		0.4		0.0		0.0	1.7		
Mika, 1997			8.6		0.3		1.1	0.1	0.1	0.2	0.0	0.1	13.4	0.3	3.2	0.6	0.4	0.0	16.9	0.6	3.1	1.0	0.5	0.2	49.5	0.2		0.5		0.0		0.0	2.0		
Mika, 1997			8.5	1.0	0.3		1.1	0.1	0.1	0.2	0.0	0.1	13.3	0.3	3.2	0.6	0.4	0.0	16.7	0.6	3.1	1.0	0.5	0.2	49.0	0.2		0.5		0.0		0.0	2.0		
Mika, 1997			8.3	4.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.9	0.3	3.1	0.6	0.4	0.0	16.2	0.5	3.0	0.9	0.5	0.2	47.5	0.2		0.5		0.0		0.0	1.9		
Mika, 1997			7.6	12.0	0.3		0.9	0.1	0.1	0.2	0.0	0.1	11.8	0.3	2.8	0.6	0.3	0.0	14.9	0.5	2.7	0.9	0.4	0.2	43.5	0.2		0.4		0.0		0.0	1.7		
Mika, 1997			7.8	6.9	0.3		3.0	0.1	0.1	0.2	0.0	0.1	12.2	0.3	2.9	0.6	0.4	0.0	15.4	0.5	2.8	0.9	0.5	0.2	45.1	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			7.7	6.7	0.3		5.0	0.1	0.1	0.2	0.0	0.1	12.0	0.3	2.9	0.6	0.3	0.0	15.1	0.5	2.8	0.9	0.4	0.2	44.1	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1		0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.8	0.5	2.9	0.9	0.5	0.2	46.1	0.2		0.5		0.0		0.0	1.9		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.5	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	45.9	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.8	0.0	0.1	12.4	0.3	3.0	0.6	0.4	0.0	15.6	0.5	2.9	0.9	0.5	0.2	45.7	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			7.9	6.9	0.3		1.0	0.1	0.1	1.2	0.0	0.1	12.4	0.3	3.0	0.6	0.4	0.0	15.6	0.5	2.9	0.9	0.5	0.2	45.5	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			8.6	7.5	0.3		1.1	0.1	0.1	0.2	0.0	0.1	6.0	0.3	3.2	0.6	0.4	0.0	16.9	0.6	3.1	1.0	0.5	0.2	49.4	0.2		0.5		0.0		0.0	2.0		
Mika, 1997			8.3	7.3	0.3		1.0	0.1	0.1	0.2	0.0	0.1	9.0	0.3	3.1	0.6	0.4	0.0	16.4	0.5	3.0	1.0	0.5	0.2	47.8	0.2		0.5		0.0		0.0	1.9		
Mika, 1997			7.8	6.8	0.3		1.0	0.1	0.1	0.2	0.0	0.1	15.0	0.3	2.9	0.6	0.3	0.0	15.3	0.5	2.8	0.9	0.5	0.2	44.7	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			7.0	6.2	0.3		0.9	0.1	0.1	0.2	0.0	0.1	23.0	0.2	2.6	0.5	0.3	0.0	13.8	0.5	2.5	0.8	0.4	0.2	40.5	0.2		0.4		0.0		0.0	1.6		
Mika, 1997			7.9	6.9	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.3	2.0	2.9	0.6	0.4	0.0	15.5	0.5	2.8	0.9	0.5	0.2	45.2	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			7.7	6.7	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.0	4.0	2.9	0.6	0.3	0.0	15.1	0.5	2.8	0.9	0.4	0.2	44.3	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			8.2	7.2	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.9	0.3		0.6	0.4	0.0	16.2	0.5	3.0	0.9	0.5	0.2	47.4	0.2		0.5		0.0		0.0	1.9		
Mika, 1997			8.2	7.1	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.8	0.3	1.0	0.6	0.4	0.0	16.1	0.5	2.9	0.9	0.5	0.2	46.9	0.2		0.5		0.0		0.0	1.9		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	46.0	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			7.9	6.9	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.3	0.3	4.5	0.6	0.4	0.0	15.5	0.5	2.8	0.9	0.5	0.2	45.3	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			7.6	6.7	0.3		1.0	0.1	0.1	0.2	0.0	0.1	11.9	0.3	7.5	0.6	0.3	0.0	15.0	0.5	2.7	0.9	0.4	0.2	43.9	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.4	0.3	3.0	1.0	0.4	0.0	15.7	0.5	2.9	0.9	0.5	0.2	45.8	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			7.9	6.9	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.3	0.3	3.0	2.0	0.4	0.0	15.5	0.5	2.8	0.9	0.5	0.2	45.4	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			7.6	6.6	0.3		0.9	0.1	0.1	0.2	0.0	0.1	11.8	0.3	2.8	6.0	0.3	0.0	14.9	0.5	2.7	0.9	0.4	0.2	43.5	0.2		0.4		0.0		0.0	1.7		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.5	0.3	3.0	0.6		0.0	15.8	0.5	2.9	0.9	0.5	0.2	46.2	0.2		0.5		0.0		0.0	1.9		
Mika, 1997		1056	7.9	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.4	0.3	3.0	0.6	1.0	0.0	15.6	0.5	2.9	0.9	0.5	0.2	45.7	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			7.7	6.7	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.0	0.3	2.9	0.6	4.0	0.0	15.2	0.5	2.8	0.9	0.4	0.2	44.3	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			8.7	7.6	0.3		1.1	0.1	0.1	0.2	0.0	0.1	13.6	0.3	3.3	0.7	0.4	0.0	8.0	0.6	3.1	1.0	0.5	0.2	50.2	0.2		0.5		0.0		0.0	2.0		
Mika, 1997			8.4	7.3	0.3		1.0	0.1	0.1	0.2	0.0	0.1	13.1	0.3	3.1	0.6	0.4	0.0	12.0	0.5	3.0	1.0	0.5	0.2	48.0	0.2		0.5		0.0		0.0	1.9		
Mika, 1997			7.6	6.6	0.3		0.9	0.1	0.1	0.2	0.0	0.1	11.9	0.3	2.8	0.6	0.3	0.0	20.0	0.5	2.7	0.9	0.4	0.2	43.7	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.6	0.3	3.0	0.6	0.4	0.0	15.8		2.9	0.9	0.5	0.2	46.2	0.2		0.5		0.0		0.0	1.9		
Mika, 1997			8.0	7.0	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.4	0.3	3.0	0.6	0.4	0.0	15.7	1.0	2.9	0.9	0.5	0.2	45.8	0.2		0.5		0.0		0.0	1.8		
Mika, 1997			7.8	6.8	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.2	0.3	2.9	0.6	0.4	0.0	15.3	3.0	2.8	0.9	0.5	0.2	44.9	0.2		0.4		0.0		0.0	1.8		
Mika, 1997			9.2	8.0	0.3		1.1	0.1	0.1	0.3	0.0	0.1	14.4	0.3	3.4	0.7	0.4	0.0	18.1	0.6	3.3	1.1	0.5	0.2	38.0	0.2		0.5		0.0		0.0	2.1		
Mika, 1997			7.1	6.2	0.3		0.9	0.1	0.1	0.2	0.0	0.1	11.1	0.2	2.7	0.5	0.3	0.0	14.0	0.5	2.6	0.8	0.4	0.2	52.0	0.2		0.4		0.0		0.0	1.6		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Mohammad, 2003	1300		8.4	13.7	0.1		0.6	0.0		0.1		0.0	9.2	0.0	0.7	0.5	3.5		8.1	0.1		5.8	0.1	0.2	48.3	0.0		0.1		0.0			0.1		0.3
Mohammad, 2003	1300		11.4	8.0	0.1		0.8	0.0		0.2		0.0	12.5	0.0	0.6	0.5	4.7		10.2	0.2		7.8	0.2	0.2	42.0	0.0		0.1		0.0			0.1		0.2
Mohammad, 2003	1300		12.9	6.1	0.1		0.9	0.0		0.2		0.0	14.0	0.0	0.5	0.5	5.3		11.1	0.2		8.8	0.2	0.3	38.1	0.0		0.1		0.0			0.1		0.2
Mohammad, 2003	1300		14.3	4.6	0.1		0.9	0.0		0.2		0.0	15.5	0.0	0.4	0.5	5.9		12.0	0.2		9.7	0.2	0.3	34.0	0.0		0.1		0.1			0.2		0.2
Mohammad, 2003	1300		16.9	2.4	0.1		1.1	0.0		0.3		0.0	18.4	0.0	0.3	0.5	7.0		13.7	0.2		11.6	0.2	0.3	25.7	0.0		0.2		0.1			0.2		0.2
Mohammad, 2003	1300		6.9	21.0	0.0		0.5	0.0		0.1		0.0	7.5	0.0	0.7	0.4	2.8		6.9	0.1		4.7	0.1	0.1	47.6	0.0		0.1		0.0			0.1		3.5
Mukhamedzhanova	1250?		4.3	3.3	6.0									1.6					5.5			4.0			66.1					7.0		1.3			
Muller, 1998		1045	9.3	6.1	0.0		7.0			0.3		1.1	4.8	5.5					20.0	0.1		0.3	1.7	0.1	37.9	0.5		0.0					4.3		
Muller, 1998		1139	14.8	6.1	0.0		2.1			0.3		1.1	4.8	5.5					20.0	0.1		0.3	1.7	0.1	35.4	0.5		0.0				3.1	3.1		
Muller, 1998			12.4	6.1	0.0		2.1		2.4	0.3		1.1	4.8	5.5					20.0	0.1		0.3	1.7	0.1	35.4	0.5		0.0				3.1	3.1		
Muller, 1998			12.4	6.1	0.0		2.1			0.3	2.4	1.1	4.8	5.5					20.0	0.1		0.3	1.7	0.1	35.4	0.5		0.0				3.1	3.1		
Muller, 1998		1124	14.8	4.6	0.0		2.1			0.3		1.1	4.8	5.5	1.5				20.0	0.1		0.3	1.7	0.1	35.4	0.5		0.0				3.1	3.1		
Muller, 1998		1088	9.2	2.9	0.0		9.7			0.3		1.1	6.0	5.5					20.0	0.1		0.3	1.7	0.1	38.7	0.5		0.0					2.8		
Muller, 1998		1122	9.9	2.9			4.4			0.0		0.1	7.3	3.1	2.0	2.0			20.0				0.1		41.5	0.0						3.3	3.0		
Muller, 1998		1080	9.9	4.2			4.4			0.0		0.1	7.3	3.1	2.0	2.0			20.0				0.1		40.2	0.0						3.3	3.0		
Muller, 1998			12.4	6.1	0.0		3.3			0.3		1.1	6.0	5.5					20.0	0.1		0.3	1.7	0.1	35.4	0.5		0.0				3.1	3.1		
Muller, 1998		1133	10.7	1.8	0.0		1.7			0.4		1.3	5.7	4.1		1.0			25.5	0.2		0.4	1.0	0.1	39.7	0.3		0.0				2.8	2.8		
Muller, 1998			10.5	1.8	0.0		1.7			0.4		1.3	5.6	4.0		1.0			25.1	0.2		0.4	2.0	0.1	39.0	0.6		0.0				2.8	2.8		
Muller, 1998		1145	10.7		0.0		1.7			0.4		1.3	4.0	4.1	1.1				25.5	0.2		0.4	1.0	0.1	43.1	0.3		0.0				2.8	2.8		
Muller, 1998			10.5		0.0		1.7			0.4		1.3	3.9	4.0	1.1				25.1	0.2		0.4	2.0	0.1	42.3	0.6		0.0				2.8	2.8		
Muller, 1998		1156	9.9	6.0	0.0		3.6			0.4		0.9	8.3	2.1	2.0	2.0			12.0	0.1		0.1	2.2	0.0	41.9	1.4						3.3	3.0		
Muller, 1998		1113	8.9	6.0	0.0		3.6			0.4		0.9	8.3	2.1	3.0	2.0			13.0	0.1		0.1	2.2	0.0	40.9	1.4						3.3	3.0		
Muller, 1998		1067	8.9	6.0	0.0		3.6			0.4		0.9	6.3	2.1	3.0	2.0			15.0	0.1		0.1	2.2	0.0	40.9	1.4						3.3	3.0		
Muller, 1998		1156	8.9	6.0	0.0		3.6			0.4		0.9	6.3	2.1		2.0			18.1	0.1		0.1	2.2	0.0	40.9	1.4						3.3	3.0		
Muller, 1998			9.0	6.1	0.0		3.7			0.4		0.9	6.4	2.1	3.1	2.1			15.3	0.1		0.1	2.3	0.0	41.6	0.4						3.3	3.1		
Muller, 1998			9.0	6.1	0.0		3.7			0.4		0.9	6.4	2.1	3.1	2.1			15.2	0.1		0.1	2.3	0.0	41.4	0.7						3.3	3.1		
Muller, 1998			8.9	6.0	0.0		3.7			0.4		0.9	6.3	2.1	3.0	2.1			15.1	0.1		0.1	2.3	0.0	41.1	1.0						3.3	3.0		
Muller, 1998		1090	8.0	8.1	0.0		4.5			0.4		0.9	6.4	2.1	4.1	2.3			8.5	0.1		0.1	2.2	0.0	43.2	1.4						4.1	3.0		
Muller, 1998		1111	8.0	8.1	0.0		4.5			0.4		0.9	6.4	2.1	3.0	2.3			10.5	0.1		0.1	2.2	0.0	42.3	1.4						4.1	3.0		
Muller, 1998		1087	8.0	8.1	0.0		4.5			0.4		0.9	6.4	2.1	2.0	2.3			12.5	0.1		0.1	2.2	0.0	41.3	1.4						4.1	3.0		
Muller, 1998		1070	8.0	8.1			7.0			0.1			8.0	0.4	4.1	3.0			10.0				0.0		43.9	0.0						4.0	3.0		
Muller, 1998		1050	9.9	6.1	0.0		2.1			0.3		1.1	9.7	5.5					20.0	0.1		0.3	1.7	0.1	35.4	0.5	0.1	0.0				3.1	3.1		
Muller, 1998		1045	9.9	6.1	0.0		2.1			0.3		1.1	4.8	5.5					20.0	0.1		0.3	1.7	0.1	35.4	0.5	0.1	4.9				3.1	3.1		
Muller, 1998		1097	9.9	6.1	0.0		2.1			0.3		1.1	4.8	5.5					20.0	0.1	4.9	0.3	1.7	0.1	35.4	0.5	0.1	0.0				3.1	3.1		
Muller, 1998			9.6	3.0	0.0		10.3			0.3		1.0	6.5	5.1					18.5	0.1		0.3	0.8	0.1	40.0	0.5	0.1	0.0					3.0		
Muller, 1998		1079	9.2	2.9	0.0		6.8			0.3		1.1	6.0	5.5					20.0	0.1		0.3	1.7	0.1	38.7	0.5	0.1	0.0				2.9	2.8		
Muller, 1998		1018	9.9	3.0			4.8			0.0		0.0	6.3	0.1	4.0	3.0			20.0	0.0			0.1	0.0	41.9	0.4						3.3	3.0		
Muller, 1998		1150	9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1		0.3	1.3	0.1	40.9	0.4	0.1					3.3	3.0		
Muller, 1998		1105	9.9	4.0	0.0		2.7			0.3	3.0	0.8	6.3	4.0		2.0			20.0	0.1		0.3	1.3	0.1	38.0	0.4	0.1					3.3	3.0		
Muller, 1998		1114	9.9	4.0	0.0		2.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1		3.3	1.3	0.1	38.0	0.4	0.1					3.3	3.0		
Muller, 1998		1168	9.9	1.0	0.0		2.7			0.3	2.0	0.8	6.3	4.0		2.0			20.0	0.1		2.3	1.3	0.1	40.0	0.4	0.1					3.3	3.0		
Muller, 1998		1092	9.9	2.0	0.0		2.7			0.3		0.8	6.3	4.0	2.0	2.0			20.0	0.1		0.3	1.3	0.1	40.9	0.4	0.1					3.3	3.0		
Muller, 1998		1210	9.9	3.0			4.8			0.0		0.0	6.3	0.1	4.0	3.0			20.0	0.0			0.1	0.0	41.9	0.4						3.3	3.0		
Muller, 1998		1130	9.9	3.0			4.8			0.0		0.0	6.3	0.1	4.0	3.0			20.0	0.0			0.1	0.0	41.9	0.4						3.3	3.0		
Muller, 1998		1122	9.8	3.9	0.0		4.7			0.3		0.8	6.3	4.0		2.0			20.0	0.1		0.3	1.3	0.1	38.7	0.8	0.1					3.3	3.0		
Musick, 2000			9.3	7.2			12.3			0.1		5.1	2.8	0.2	6.2		0.1		10.7	0.0			1.3	0.0	37.1	1.1	0.3						6.1		
Musick, 2000			9.8	7.1			12.9			0.2		5.4	2.7	0.2	6.0		0.1		10.5	0.0			1.3	0.0	35.9	1.2	0.3						6.3		
Musick, 2000			9.3	6.3			12.3			0.1		5.1	3.1	0.2	6.1		0.1		11.0	0.0			1.3	0.0	38.6	1.1	0.3						5.1		
Musick, 2000			9.6	6.5			12.6			0.2		2.6	3.2	0.2	6.2		0.1		11.3	0.0			1.3	0.0	39.6	1.2	0.3						5.3		
Musick, 2000			9.3	4.5			12.3			0.1		5.1	4.6	0.2	5.6		0.1		12.3	0.0			1.3	0.0	38.1	1.1	0.3						5.1		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Musick, 2000			9.6	4.6			12.6			0.2		2.6	4.8	0.2	5.7		0.1		12.6	0.0			1.3	0.0	39.1	1.2	0.3						5.3		
Musick, 2000			9.3	4.5			12.3			0.1		5.1	2.8	0.2	7.4		0.1		10.3	0.0			1.3	0.0	40.0	1.1	0.3						5.1		
Musick, 2000			9.6	4.6			12.6			0.2		2.6	2.8	0.2	7.6		0.1		10.6	0.0			1.3	0.0	41.1	1.2	0.3						5.3		
Musick, 2000			9.3	5.7			12.3			0.1		5.1	5.3	0.2	5.6		0.1		12.2	0.0			1.3	0.0	36.3	1.1	0.3						5.1		
Musick, 2000			9.6	5.8			12.6			0.2		2.6	5.4	0.2	5.7		0.1		12.5	0.0			1.3	0.0	37.2	1.2	0.3						5.3		
Musick, 2000			9.3	6.3			12.3			0.1		5.1	0.3	0.2	6.1		0.1		11.0	0.0			1.3	0.0	38.6	1.1	0.3	2.8					5.1		
Musick, 2000			9.6	6.5			12.6			0.2		2.6	0.3	0.2	6.2		0.1		11.3	0.0			1.3	0.0	39.6	1.2	0.3	2.9					5.3		
Musick, 2000			9.3	5.7			12.3			0.1		5.1	2.2	0.2	5.6		0.1		12.2	0.0			1.3	0.0	36.3	1.1	0.3	3.1					5.1		
Musick, 2000			9.6	5.8			12.6			0.2		2.6	2.2	0.2	5.7		0.1		12.5	0.0			1.3	0.0	37.2	1.2	0.3	3.2					5.3		
Musick, 2000			9.3	7.2			12.3			0.1		5.1	0.3	0.2	6.2		0.1		10.7	0.0			1.3	0.0	37.1	1.1	0.3	2.5					6.1		
Musick, 2000			9.8	7.1			12.9			0.2		5.4	0.3	0.2	6.0		0.1		10.5	0.0			1.3	0.0	35.9	1.2	0.3	2.4					6.3		
Musick, 2000			7.3	5.3			13.3			0.1		6.3	2.9	0.3	5.8		0.1		11.1	0.0			0.1	0.0	40.7	1.3							5.3		
Musick, 2000			7.9	5.1			14.4			0.2		6.8	2.8	0.3	5.5		0.1		10.8	0.0			0.1	0.0	38.8	1.4							5.8		
Musick, 2000			8.6	5.1			11.3			0.1		4.7	3.0	0.1	6.0		0.1		11.4	0.0			1.2	0.0	42.3	1.0	0.2						4.7		
Musick, 2000			8.8	5.2			11.6			0.1		2.4	3.1	0.1	6.1		0.1		11.7	0.0			1.2	0.0	43.3	1.1	0.2						4.8		
Musick, 2000	1102		10.3	8.1			7.0			0.1		2.9	1.7	0.3	6.0		0.1		11.8	0.0			3.8		40.5	0.3		0.4					6.8		
Musick, 2000	1102		9.3	9.2			6.9			0.1		2.5	1.8	0.3	5.5		0.1		12.1	0.0			3.6		41.1	0.2		0.3					7.0		
Musick, 2000	1102		8.7	8.5			6.7			0.1		2.7	1.7	0.3	6.0		0.1		12.3	0.0			3.9		41.2	0.3		0.3					7.1		
Musick, 2000	1028		8.2	7.2			11.5			0.1		6.0	0.8	0.1	6.0		0.1		11.2	0.0			3.1		37.0	0.6		2.5					5.7		
Musick, 2000	1028		7.7	9.9			11.1			0.1		6.5	0.3	0.1	5.7		0.1		10.6	0.0			2.9		36.3	0.5		2.8					5.5		
Oksoy, 1994			16.8	16.3			8.8												14.3						43.9										
Oksoy, 1994			18.3	14.5															22.4						44.9										
Oksoy, 1994			17.5	4.8			8.4												22.9						46.4										
Oksoy, 1994			14.8	4.1									20.9						19.4						40.7										
Oksoy, 1994			11.5	13.0			7.0						19.2						11.5						37.9										
Oksoy, 1994			16.1	14.8															14.1						55.0										
Oksoy, 1994			11.3	8.8			3.2						9.6						17.0						50.2										
Oksoy, 1994			18.4	9.5			4.2						12.6						16.0						39.4										
Oksoy, 1994			22.6	7.6			2.8						8.3						15.8						42.9										
Oksoy, 1994			7.4	10.5			4.6						14.0						17.2						46.3										
Oksoy, 1994			13.0	13.7			3.0						9.4						15.5						45.5										
Oksoy, 1994			11.2	4.4			4.6						14.0						17.6						48.4										
Oksoy, 1994			14.5	8.1			7.7						9.1						15.7						45.0										
Oksoy, 1994			14.6	9.2									13.3						16.9						45.9										
Oksoy, 1994			11.5	7.4			2.7						20.2						14.0						44.3										
Oksoy, 1994			16.3	5.3			9.0												14.6						54.8										
Oksoy, 1994			10.7	12.3			5.5												19.6						51.9										
Oksoy, 1994			14.8	7.8			3.0						9.2						20.7						44.5										
Oksoy, 1994			16.3	9.3			4.3						12.9						12.3						44.9										
Oksoy, 1994			17.9	8.7			3.4						10.3						15.8						43.8										
Oksoy, 1994			17.2	4.6															23.2						55.0										
Olson, 1988			8.2	9.0	0.1		0.4	0.6		0.1	0.0		11.5	3.4	2.9	1.0	1.0	0.0	10.5	0.3	0.0	0.2	2.5		42.5	0.2	0.0	0.1	3.4	0.8	0.5	0.0	0.4		
Olson, 1988			10.0	7.2	0.1		0.7	0.3		0.1	0.0		15.0	3.7	3.1	1.7	1.6	0.0	11.3	0.1	0.0	0.1	0.1		38.0	0.1	0.0	0.1	2.8	0.4	2.5	0.0	0.2		
Olson, 1988			10.0	7.8	0.0		0.1	1.8		0.4	0.1		9.8	3.9	3.3	0.4	0.1	0.1	11.9	0.8	0.1	0.4	0.5		42.0	0.6	0.1	0.4	2.1	2.2	0.2	0.1	1.0		
Olson, 1988			10.2	7.6	0.0		0.2	1.8		0.4	0.1		9.7	3.3	2.8	0.4	1.6	0.1	10.0	0.8	0.1	0.4	0.6		40.9	0.6	0.1	0.4	4.1	2.3	0.1	0.1	1.1		
Olson, 1988			10.1	11.2	0.1		0.7	0.5		0.1	0.0		9.3	3.6	3.1	1.6	0.1	0.0	11.0	0.2	0.0	0.1	3.8		38.0	0.2	0.0	0.1	5.1	0.6	0.1	0.0	0.3		
Olson, 1988			10.0	12.4	0.0		0.2	0.4		0.1	0.0		9.5	2.7	2.3	0.5	1.6	0.0	8.2	0.2	0.0	0.1	2.4		42.0	0.1	0.0	0.1	4.1	0.5	2.0	0.0	0.2		
Olson, 1988			8.3	11.5	0.0		0.2	0.4		0.1	0.0		15.8	3.5	3.0	0.5	0.1	0.0	10.8	0.2	0.0	0.1	0.6		38.0	0.1	0.0	0.1	3.7	0.5	2.2	0.0	0.2		
Olson, 1988			10.2	7.1	0.0		0.2	0.4		0.1	0.0		15.5	3.8	3.3	0.4	1.6	0.0	11.7	0.2	0.0	0.1	3.9		38.0	0.1	0.0	0.1	1.8	0.5	0.1	0.0	0.2		
Olson, 1988			9.4	10.6	0.1		0.7	2.0		0.4	0.1		9.2	2.7	2.3	1.7	0.1	0.1	8.2	0.9	0.1	0.4	4.3		38.0	0.7	0.1	0.4	2.1	2.4	2.0	0.1	1.1		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Olson, 1993		1103	7.7	16.6	0.3		0.5	0.3		0.1			15.5	3.1	2.3	0.9	0.8		5.7	0.3			1.2		39.5	0.2	0.3		1.8	0.8	0.6	0.3	1.3		
Olson, 1993		880	7.7	16.6	0.3		0.5	0.3		0.1			8.6	6.9	5.1	0.9	0.8		10.3	0.3			1.2		35.3	0.2	0.3		1.8	0.8	0.6	0.3	1.3		
Olson, 1994		1088	7.7	9.2	0.3		0.5	0.3		0.1			8.6	3.1	4.3	0.9	0.8		10.3	0.3			1.2		47.1	0.2	0.3		1.8	0.8	0.6	0.3	1.3		
Olson, 1994		1249	7.7	9.2	0.3		0.5	0.3		0.1			8.6	6.9	2.3	0.9	0.8		5.7	0.3			1.2		46.4	0.2	0.3		5.3	0.8	0.6	0.3	1.3		
Olson, 1994		1028	7.7	9.2	0.3		0.5	0.3		0.1			15.5	6.9	2.5	0.9	0.8		10.3	0.3			1.2		34.8	0.2	0.3		5.3	0.8	0.6	0.3	1.3		
Peeler, 1999			11.9	6.5				8.4														23.0			21.9		1.4	26.9						1308	
Peeler, 1999			17.0	9.3				8.4														23.0			16.1		1.4	24.8						1257	
Peeler, 1999			11.9	9.3				8.4														23.0			16.1		2.0	29.3						1313	
Peeler, 1999			11.9	6.5				3.4														23.0			16.1		2.0	37.1						1405	
Peeler, 1999			17.0	6.5				3.4														23.0			22.9		2.0	25.2						1241	
Peeler, 1999			11.9	9.3				3.4														23.0			16.1		1.4	34.9						1309	
Peeler, 1999			17.0	6.5				3.4														23.0			22.9		1.4	25.7						1209	
Peeler, 1999			17.0	6.5				8.4														18.4			21.6		2.0	26.0						1242	
Peeler, 1999			11.9	6.5				8.4														18.4			16.1		1.4	37.3						1323	
Peeler, 1999			11.9	9.3				8.4														18.4			22.8		2.0	27.2						1255	
Peeler, 1999			17.0	6.5				8.4														18.4			16.1		1.4	32.2						1292	
Peeler, 1999			11.9	6.5				3.4														18.4			22.9		2.0	34.9						1333	
Peeler, 1999			17.0	9.3				3.4														18.4			22.9		1.4	27.6						1181	
Peeler, 1999			17.0	9.3				3.4														18.4			16.1		2.0	33.8						1250	
Peeler, 1999			11.9	9.3				3.4														18.4			22.9		1.4	32.7						1279	
Peeler, 1999			17.0	6.5				3.5														18.4			16.1		2.0	36.5						1298	
Peeler, 1999			14.4	7.9				5.8														20.6			19.4		1.7	30.2						1273	
Peeler, 1999			11.9	6.5				9.7														17.0			16.1		2.0	36.8						1366	
Peeler, 1999			11.9	9.3				9.7														24.0			22.9		2.0	20.2						1249	
Peeler, 1999			11.9	6.5				9.7														24.0			16.1		1.4	30.4						1343	
Peeler, 1999			17.0	9.3				9.7														24.0			16.1		2.0	21.9						1242	
Peeler, 1999			11.9	9.3				2.5														24.0			22.9		2.0	27.4						1284	
Peeler, 1999			17.0	6.5				2.5														24.0			16.1		2.0	31.9						1282	
Peeler, 1999			11.9	9.3				2.5														24.0			16.1		1.4	34.8						1319	
Peeler, 1999			17.0	6.5				2.5														24.0			16.1		2.0	31.9						1305	
Peeler, 1999			17.0	6.5				2.8														24.0			22.9		1.4	25.4						1208	
Peeler, 1999			16.3	6.5				9.7														16.8			22.9		1.4	26.4						1242	
Peeler, 1999			17.0	9.3				9.7														16.8			16.1		2.0	29.1						1260	
Peeler, 1999			11.9	9.3				2.5														16.8			16.1		1.4	42.0						1300	
Peeler, 1999			17.0	9.3				2.5														16.8			22.9		1.4	30.1						1192	
Peeler, 1999			11.9	6.5				2.5														16.8			22.9		2.0	37.4						1305	
Peeler, 1999			14.4	7.9				6.0														20.3			19.4		1.7	30.2						1264	
Peeler, 1999			14.4	7.9				5.6														21.0			19.5		1.7	29.9						1271	
Peeler, 1999			14.2	7.7				5.7														20.9			19.2		1.7	30.6						1232	
Peeler, 1999			13.9	7.6				5.9														20.8			18.9		1.6	31.3						1289	
Peeler, 1999			13.7	7.5				6.0														20.7			18.5		1.6	32.0						1294	
Peeler, 1999			13.4	7.3				6.1														20.6			18.2		1.6	32.7						1305	
Peeler, 1999			13.2	7.2				6.3														20.5			17.9		1.9	33.4						1308	
Peeler, 1999			12.9	7.0				6.4														20.4			17.5		1.5	34.1						1318	
Peeler, 1999			12.7	6.9				6.5														20.3			17.2		1.5	34.8						1325	
Peeler, 1999			12.4	6.8				6.7														20.2			16.8		1.5	35.5						1324	
Peeler, 1999			16.9	9.2				4.3														21.9			22.9		2.0	22.8						1180	
Peeler, 1999			15.7	8.5				4.9														21.5			21.2		1.8	26.3						1227	
Peeler, 1999			11.9	6.5				6.9														20.0			16.2		1.4	37.0						1305	
Peeler, 1999			14.4	7.9				10.9														19.9			19.5		1.7	25.7						1259	

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Peeler, 1999			13.2	7.2				6.3														20.5			17.9		1.5	33.4						1333	
Peeler, 1999			14.4	7.9				11.2														21.0			19.6		1.7	24.3						1255	
Peeler, 1999			7.7	11.0						0.1			2.4	0.2	3.7	0.1			6.8	0.0		0.1	0.0		62.4	0.0	0.1	0.0					5.4		
Peeler, 1999			7.7	11.0						0.1			2.4	0.2	3.7	0.1			6.8	0.0		0.1	0.0		62.4	0.0	0.1	0.0					5.4		
Peeler, 1999			7.5	10.6			3.0			0.1			2.4	0.1	3.5	0.1			6.6	0.0		0.1	0.0		60.5	0.0	0.1	0.0					5.2		
Peeler, 1999			7.5	10.6			3.0			0.1			2.4	0.1	3.5	0.1			6.6	0.0		0.1	0.0		60.5	0.0	0.1	0.0					5.2		
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	5.2	0.7	2.1		15.6	1.3				0.1	47.8			0.0	0.0	0.0	3.3	0.0	0.1		1.0
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4		0.7	2.1		22.1	1.3				0.1	46.5			0.0	0.0	0.0	3.3	0.0	0.1		0.9
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	3.9	0.7	2.1		17.5	1.3				0.1	47.1			0.0	0.0	0.0	3.3	0.0	0.1		1.0
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	2.6	0.7	2.1		18.8	1.3				0.1	47.1			0.0	0.0	0.0	3.3	0.0	0.1		0.9
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	1.3	0.7	2.1		20.1	1.3				0.1	47.1			0.0	0.0	0.0	3.3	0.0	0.1		0.9
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4		0.7	2.1		21.4	1.3				0.1	47.1			0.0	0.0	0.0	3.3	0.0	0.1		0.9
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	3.9	0.7	2.1		16.9	1.3				0.1	47.8			0.0	0.0	0.0	3.3	0.0	0.1		0.8
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	2.6	0.7	2.1		18.2	1.3				0.1	47.8			0.0	0.0	0.0	3.3	0.0	0.1		0.8
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	1.3	0.7	2.1		19.5	1.3				0.1	47.8			0.0	0.0	0.0	3.3	0.0	0.1		0.7
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4		0.7	2.1		20.8	1.3				0.1	47.8			0.0	0.0	0.0	3.3	0.0	0.1		0.8
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	3.3	0.7	2.1		17.5	1.3				0.1	47.8			0.0	0.0	0.0	3.3	0.0	0.1		0.8
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	3.9	0.7	2.1		18.2	1.3				0.1	46.5			0.0	0.0	0.0	3.3	0.0	0.1		1.1
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	2.6	0.7	2.1		19.5	1.3				0.1	46.5			0.0	0.0	0.0	3.3	0.0	0.1		1.0
Peeler, 2005			8.0	5.2	0.1		0.8	0.1		0.1	0.0		9.2	0.4	1.3	0.7	2.1		22.1	1.3				0.1	45.2			0.0	0.0	0.0	3.3	0.0	0.1		1.0
Peeler, 2005a	1150		12.6	4.7	0.0		0.9	0.1		0.1	0.0		8.4	0.7	4.6	0.7	1.8		17.1	0.5				0.1	43.1	0.4		0.0	0.1	0.0	2.0	0.0	0.1		0.8
Peeler, 2005a	1150		11.9	4.6	0.0		0.8	0.1		0.1	0.0		7.9	0.7	4.7	0.6	1.7		17.5	0.5				0.1	42.9	0.4		0.0	0.1	1.0	2.0	0.0	0.1		0.8
Peeler, 2005a	1150		8.6	4.7	0.1		0.9	0.1		0.1	0.0		9.2	0.4	4.7	0.7	2.2		17.1	1.2				0.1	43.3	0.5		0.0	0.1	0.9	3.4	0.1	0.1		1.2
Peeler, 2005a	1150		12.8	4.7	0.0		0.9	0.1		0.1	0.0		8.4	0.8	4.7	0.7	1.8		14.4	0.5				0.1	46.1	0.4		0.0	0.1	0.0	2.0	0.0	0.1		0.6
Peeler, 2005a	1150		9.2	4.7	0.1		0.9	0.1		0.1	0.0		9.7	0.5	4.7	0.7	2.2		16.6	1.3				0.1	43.4	0.4		0.0	0.1	0.0	3.5	0.1	0.1		1.1
Peeler, 2005a	1150		8.6	4.6	0.1		0.7	0.1		0.1	0.0		8.4	0.5	4.7	0.4	2.2		17.0	1.9				0.1	43.3	0.4		0.0	0.1	0.9	3.7	0.1	0.1		1.2
Peeler, 2005a	1150		9.3	4.7	0.1		0.7	0.1		0.1	0.0		8.9	0.5	4.8	0.4	2.3		16.3	2.1				0.1	43.6	0.4		0.0	0.2	0.0	4.2	0.1	0.1		1.1
Peeler, 2005a	1150		12.0	4.7	0.0		0.8	0.1		0.1	0.0		7.9	0.7	4.7	0.6	1.7		15.2	0.5				0.1	45.9	0.4		0.0	0.1	0.9	2.0	0.0	0.1		0.7
Peeler, 2005a	1150		11.2	5.1	0.0		0.8	0.1		0.1	0.0		7.6	0.7	5.1	0.6	1.6		16.2	0.4				0.1	47.1	0.3		0.0	0.1	0.0	1.8	0.0	0.1		0.7
Peeler, 2005a	1150		8.3	4.7	0.1		0.9	0.1		0.1	0.0		9.4	0.4	4.7	0.7	2.3		17.2	1.3				0.1	43.3	0.5		0.0	0.1	0.9	3.4	0.1	0.1		1.2
Peeler, 2005a	1150		8.9	4.7	0.1		0.9	0.1		0.1	0.0		9.7	0.4	4.7	0.8	2.3		16.3	1.3				0.1	43.6	0.4		0.0	0.2	0.0	3.7	0.1	0.1		1.1
Peeler, 2005a	1150		10.4	5.0	0.0		0.7	0.1		0.1	0.0		6.9	0.6	5.1	0.6	1.5		16.8	0.4				0.1	46.3	0.4		0.0	0.1	0.8	1.7	0.0	0.1		0.8
Peters, 1993			9.1			1.4	1.4			0.6			7.7						17.7		11.8		3.3		42.1								4.9		
Peters, 1993			9.1			1.4	1.4			0.8			7.7						17.6		11.8		3.3		42.1								4.9		
Peters, 1993			8.9			1.3	1.4			0.3			7.6						17.4		11.7		5.0		41.5								4.9		
Peters, 1993			8.7			1.3	1.4			0.3			7.4						17.0		11.4		7.0		40.7								4.8		
Peters, 1993			8.6			1.3	1.4			0.3			7.2						16.7		11.2		9.0		39.8								4.7		
Peters, 1993			9.0			1.4	1.4			0.3			7.6						17.5		11.7		3.3		41.8					1.0			4.9		
Peters, 1993			8.8			1.3	1.4			0.3			7.5						17.2		11.5		3.2		41.0					3.0			4.8		
Peters, 1993			8.6			1.3	1.4			0.3			7.3						16.8		11.3		3.1		40.2					5.0			4.7		
Peters, 1993			9.1			1.4	1.4			0.3			7.7						17.7		11.9		3.3		42.3								5.0		
Peters, 1993	1250	1141	9.7	0.1		1.5	1.5	2.0		0.3		0.4	8.2	0.2		0.1	1.1	0.1	18.9	1.7	0.1	0.1	3.5	0.3	37.5	0.3	0.3	6.9					5.3		
Peters, 1993	1350	1115	10.1	0.1		1.5	1.6	2.1		0.4		0.4	8.5	0.2		0.1	1.2	0.1	19.6	1.8	0.1	0.1	3.7	0.3	35.2	0.3	0.3	7.1					5.5		
Peters, 1993	1215	1090	10.4	0.1		1.6	1.7	2.2		0.4		0.4	8.8	0.2		0.1	1.2	0.1	20.3	1.8	0.1	0.1	3.8	0.3	33.0	0.3	0.3	7.3					5.7		
Peters, 1993	1350	1065	10.8	0.1		1.6	1.7	2.3		0.4		0.5	9.1	0.2		0.1	1.2	0.1	20.9	1.9	0.1	0.1	3.9	0.3	30.8	0.3	0.3	7.6					5.9		
Peters, 1993	1250	1041	11.1	0.1		1.7	1.8	2.3		0.4		0.5	9.4	0.2		0.1	1.3	0.1	21.6	1.9	0.2	0.1	4.0	0.3	28.5	0.3	0.4	7.8					6.1		
Peters, 1993	1350	1017	11.5	0.1		1.7	1.8	2.4		0.4		0.5	9.7	0.2		0.1	1.3	0.1	22.3	2.0	0.2	0.1	4.2	0.3	26.3	0.3	0.4	8.1					6.2		
Peters, 1993	1300	993	11.8	0.1		1.8	1.9	2.5		0.4		0.5	10.0	0.2		0.1	1.4	0.1	23.0	2.1	0.2	0.1	4.3	0.3	24.1	0.3	0.4	8.3					6.4		
Peters, 1993	1150		8.7	13.8			0.8	0.1		2.4	0.2	0.1	3.6		3.0	0.3	1.2	0.0	17.8	0.1		0.7	3.3	0.1	42.6	0.7		0.2		0.0			0.1		
Peters, 1993	1144		8.9	14.0			0.9	0.1			0.2	0.1	3.7		7.4	0.3	1.3	0.0	4.3	0.1		0.8	3.4	0.1	53.5	0.7		0.3		0.0			0.1		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Peters, 1993	1130		8.7	13.8			0.8	0.1		2.4	0.2	0.1	3.6			0.3	1.2	0.0	20.8	0.1		0.7	3.3	0.1	42.6	0.7		0.2		0.0			0.1		
Peters, 1993	1150		8.7	13.7			0.9	0.1			0.2	0.1	3.6		7.2	0.3	1.3	0.0	4.2	0.1		0.7	5.5	0.1	52.3	0.7		0.2		0.0			0.1		
Peters, 1993	1150		9.0	14.1			0.9	0.1		2.4	0.2	0.1	3.7		7.4	0.3	1.2	0.0	4.4	0.1		0.7	3.3	0.1	54.0	0.7		0.2		0.0			0.1		
Peters, 1993	1150		8.7	13.6			0.9	0.1		2.4	0.2	0.1	3.6		7.2	0.3	1.2	0.0	4.2	0.1		0.7	3.3	0.1	52.2	0.7		0.2		0.0			0.1		
Peters, 1993	1250		8.5	13.3			0.8	0.1		2.4	0.2	0.1	3.5		7.0	0.3	1.2	0.0	4.1	0.1		0.7	5.3	0.1	51.1	0.7		0.2		0.0			0.1		
Peters, 1993	1250		8.3	13.1			0.8	0.1		2.3	0.2	0.1	3.4		6.9	0.3	1.2	0.0	4.0	0.1		0.7	7.3	0.1	50.0	0.7		0.2		0.0			0.1		
Peters, 1993			9.9	12.3	0.2		0.8	0.7	0.0	0.1	0.0		11.9	1.6	2.2	0.8	1.2	0.0	9.8	0.3		0.2	2.5		39.6	0.2	0.0	0.2	3.5	0.8	0.6	0.0	0.4		
Peters, 1993			10.3	12.7	0.2		0.8	0.7	0.0	0.2	0.0		12.4	1.6	2.4	0.8	1.2	0.0	10.2	0.3		0.1	2.6		37.4	0.2	0.0	0.1	3.7	0.8	0.6	0.0	0.4		
Peters, 1993			10.1	12.5			0.5	0.7		0.1			12.9	0.2	1.8	0.2	1.0	0.0	11.4	0.3		0.1	2.6		40.8	0.2		0.3	3.6		0.6		0.2		
Peters, 1993			9.3	11.5	0.2		0.8	0.7	0.0	0.1	0.0		17.2	1.5	2.1	0.8	1.1	0.0	9.2	0.3		0.2	2.3		37.2	0.2	0.0	0.2	3.3	0.8	0.6	0.0	0.4		
Peters, 1993			8.3	10.1	0.2		0.7	0.7	0.0	0.1	0.0		12.0	3.6	3.1	0.9	1.0	0.0	11.1	0.3		0.3	2.4		39.6	0.2	0.0	0.2	3.6	0.8	0.6	0.0	0.3		
Peters, 1993			8.3	9.4	0.2		0.7	0.7	0.0	0.1	0.0		12.0	3.4	2.9	0.9	1.0	0.0	10.3	0.3		0.3	2.4		41.6	0.2	0.0	0.2	3.6	0.8	0.6	0.0	0.3		
Peters, 1993		1048	8.3	12.6	0.2		0.7	0.2	0.0	0.1	0.0		12.0	3.1	2.7	0.9	1.0	0.0	9.6	0.3		0.3	2.4		39.8	0.2	0.0	0.2	3.6	0.8	0.6	0.0	0.3		
Peters, 1993		1113	8.3	11.7	0.2		0.7	0.2	0.0	0.1	0.0		12.0	2.9	2.5	0.9	1.0	0.0	9.0	0.3		0.3	2.4		41.8	0.2	0.0	0.2	3.6	0.8	0.6	0.0	0.3		
Peters, 1993			8.3	10.1	0.2		0.7	0.7	0.0	0.1	0.0		12.0	3.6	3.1	0.9	1.0	0.0	11.1	0.3		0.3	2.4		39.6	0.2	0.0	0.2	3.6	0.8	0.6	0.0	0.3		
Peters, 1993			8.3	12.6	0.2		0.7	0.2	0.0	0.1	0.0		12.0	3.1	2.7	0.9	1.0	0.0	9.6	0.3		0.3	2.4		39.8	0.2	0.0	0.2	3.6	0.8	0.6	0.0	0.3		
Peters, 1993			10.0	12.4	0.2		0.7	0.5	0.0	0.3	0.0		12.3	2.0	2.0	1.8	1.3		9.1	0.4		0.1	2.6		38.8			0.2	3.6	0.7	0.6	0.0	0.4		
Peters, 1993			10.0	12.5	0.2		0.8	0.7	0.0	0.3	0.0		12.2	1.9	2.0	1.3	1.3		9.9	0.3		0.1	2.5		38.8			0.2	3.6	0.7	0.6	0.0	0.5		
Peters, 1993			9.8	11.2	0.2		0.7	0.8	0.0	0.3	0.0		13.6	1.9	2.2	1.3	1.3		9.6	0.3		0.1	2.5		38.1			0.2	4.0	0.7	0.7	0.0	0.4		
Peters, 1993			11.6	12.0	0.2		0.8	0.7	0.0	0.1	0.0		11.7	1.6	2.2	0.8	1.2	0.0	9.6	0.3		0.2	2.4		38.8	0.2	0.0	0.2	3.5	0.8	0.6	0.0	0.4		
Peters, 1993			9.9	12.2	0.2		0.8	0.7	0.0	0.1	0.0		11.9	1.6	2.3	0.8	1.2	0.0	9.8	0.3		0.1	2.5		35.9	0.2	0.0	0.1	3.5	4.8	0.6	0.0	0.4		
Peters, 1995	1150		20.0	5.1			5.4						0.5	4.5		0.3			11.6				38.5		10.2	1.1									0.2
Peters, 1995	1350		8.1				11.5						1.1	7.4		0.6			12.0				0.3		52.0	2.1									0.3
Peters, 1995	1150		11.9	11.3			10.2						1.0	6.6		0.6			10.6				0.2		41.4	1.8									0.3
Peters, 1995	1100		20.4				10.0						1.0	6.4		0.5			10.4				37.7		7.6	1.8									0.3
Peters, 1995	1150		15.4				10.7						1.1	6.9		0.6			11.2				39.5		8.2	1.9									0.5
Peters, 1995	1150		20.7	5.2			7.1						0.7	4.5		0.4			12.6				39.1		5.4	1.3									0.2
Peters, 1995	1200		25.0	6.3			8.5						0.8	5.5		0.5			8.9				32.8		6.5	1.5									0.2
Peters, 1995	1450		3.2				10.2						1.0	6.6		0.6			10.6				0.2		61.5	1.8									0.2
Peters, 1995	1200		19.8	3.3			8.9						0.9	5.7		0.5			9.2				39.6		6.8	1.6									0.2
Peters, 1995	1200		25.7				6.9						0.7	5.7		0.4			8.3				34.3		13.1	1.4									0.1
Pittman, 2001			12.5	6.0			15.0					4.0			7.0	8.0									36.5	0.5		2.5					8.0		
Pittman, 2001			7.0	15.0			10.0					6.5			7.0	8.0									36.0	1.5		5.0					4.0		
Pittman, 2001			7.0	15.0			10.0	5.0				4.0			7.0	8.0									36.0	1.5		2.5					4.0		
Pittman, 2001			7.0	6.0			15.0	5.0				6.5			4.5	8.0			2.5						36.0	0.5		5.0					4.0		
Pittman, 2001			7.0	6.0			15.0					6.5			7.0	8.0			2.5						36.0	1.5		2.5					8.0		
Pittman, 2001			7.0	6.0			15.0	5.0				4.0			7.0	8.0			2.5						36.0	0.5		5.0					4.0		
Pittman, 2001			7.0	6.0			15.0					4.0			4.5	8.0									45.0	1.5		5.0					4.0		
Pittman, 2001			7.0	6.0			9.5	5.0				6.5			4.5	8.0									46.5	0.5		2.5					4.0		
Pittman, 2001			7.0	6.0			9.5					6.5			7.0	13.0			2.5						41.5	0.5		2.5					4.0		
Pittman, 2001			7.0	6.0			9.5	5.0				4.0			4.5	13.0									36.5	1.5		5.0					8.0		
Pittman, 2001			7.0	6.0			9.5	5.0				4.0			7.0	13.0									37.5	0.5		2.5					8.0		
Pittman, 2001			12.5	6.0			15.0	1.0				4.0			4.5	13.0									36.0	1.5		2.5					4.0		
Pittman, 2001			7.0	6.0			10.0					4.0			4.5	8.0									47.0	0.5		5.0					8.0		
Pittman, 2001			7.0	14.5			15.0					4.0			4.5	8.0									36.0	0.5		2.5					8.0		
Pittman, 2001			7.0	6.5			9.5					6.5			7.0	13.0									36.0	1.5		5.0					8.0		
Pittman, 2001			12.0	6.0			15.0					6.5			4.5	13.0									36.0	0.5		2.5					4.0		
Pittman, 2001			8.0	6.0			9.5					4.0			7.0	8.0			2.5						47.0	1.5		2.5					4.0		
Pittman, 2001			12.5	6.0			9.5	5.0				6.5			7.0	8.0									37.5	1.5		2.5					4.0		
Pittman, 2001			12.5	6.0			9.5					6.5			4.5	8.0			2.5						36.0	1.5		5.0					8.0		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Pittman, 2001			12.5	6.0			9.5	5.0				4.0			4.5	8.0			2.5						36.0	1.5		2.5					8.0		
Pittman, 2001			12.5	6.0			9.5					4.0			7.0	13.0			2.5						36.0	0.5		5.0					4.0		
Pittman, 2001			12.5	13.5			9.5					4.0			7.0	8.0									36.0	0.5		5.0					4.0		
Pittman, 2001			7.0	15.0			9.5					6.5			4.5	8.0			2.5						36.0	0.5		2.5					8.0		
Pittman, 2001			7.0	15.0			9.5					4.0			4.5	13.0			2.5						36.5	1.5		2.5					4.0		
Pittman, 2001			9.0	9.0			12.0	2.5				5.0			5.0	10.5			1.5						38.8	1.0							5.0		
Pittman, 2001			8.6	5.1			11.3	3.0				4.7			6.0	11.4			1.2						42.3	1.1							4.7		
Pittman, 2001			8.9	8.2			11.4	1.8				5.1			5.6	9.8			1.1						38.0	1.0		3.6					5.6		
Plodinec, 1978		1280	21.6	7.5			3.9						1.5				1.2		16.9	0.2					39.4					7.5	0.4				
Plodinec, 1978		1150	11.6	7.5			4.6						7.9				2.6		16.9	0.6					39.4					7.5	1.5				
Plodinec, 1978		1094	9.0	6.5			4.3						15.2				4.1		14.6	1.8					34.1					6.5	3.9				
Plodinec, 1978		1020	8.6	9.0			4.5						0.6		3.6		0.5		16.7	0.1					47.3					9.0	0.2				
Plodinec, 1978		1104	12.9	8.5			4.3						0.9		3.4		0.7		15.7	0.1					44.6					8.5	0.2				
Plodinec, 1978		1134	17.3	8.0			4.1						1.2		3.2		1.0		14.8	0.2					42.0					8.0	0.3				
Plodinec, 1978		1027	9.3	8.0			4.7						6.3		3.2		2.1		14.8	0.5					42.0					8.0	1.2				
Plodinec, 1978		1157	21.6	7.5			3.9						1.5		3.0		1.2		13.9	0.2					39.4					7.5	0.4				
Plodinec, 1978		1036	11.6	7.5			4.6						7.9		3.0		2.6		13.9	0.6					39.4					7.5	1.5				
Plodinec, 1978		1004	7.7	7.0			4.4						13.1		2.8		3.5		13.0	1.5					36.8					7.0	3.3				
Plodinec, 1978		1180	13.9	7.0			4.5						9.5		2.8		3.1		13.0	0.7					36.8					7.0	1.8				
Plodinec, 1978			30.2	6.5			3.4						2.1		2.6		1.7		12.0	0.3					34.1					6.5	0.5				
Prunchak, 1997				7.8		63.4								0.9					1.2						19.8							5.0	2.0		
Prunchak, 1997				6.8		61.0								0.9					0.9						20.9							7.6	1.9		
Prunchak, 1997				8.6		63.1						1.2		0.9					1.3						18.6							4.9	1.3		
Pye, 1985		1055	9.3	7.4			1.1						6.4		5.1	0.8	2.2		11.8	0.7					54.3								1.0		
Quang, 2003	1200		6.2	13.0			5.7												8.8		12.0	2.0	3.7		36.0							5.6	7.1		
Radchenko, 2001	<1250		8.2	32.5			3.9						5.0	0.8		1.9	0.1		11.6			0.5			35.5										
Radchenko, 2001	<1250		12.2	5.0			10.8						7.5	1.2		2.9	0.1		12.3			0.8			47.2										
Rapp, 1985		1434	12.4				16.6					0.1	11.7	0.9		4.5	0.2		2.6				0.3		48.4	0.1				1.9				1216	
Rapp, 1985		1337	11.2				24.8					0.1	10.5	0.8		4.0	0.2		2.4				0.3		43.6	0.1				1.7				1251	
Rapp, 1985		1413	18.6				19.6					0.1	10.2	0.8		3.9	0.2		2.3				0.3		42.1	0.1				1.6				1309	
Rapp, 1985			11.5				16.3					0.1	10.8	0.8		10.7	0.2		2.4				0.3		44.7	0.1				1.7				1253	
Rapp, 1985		1259	9.9				33.2					0.1	9.4	0.7		3.6	0.2		2.1				0.3		38.7	0.1				1.5				1288	
Rapp, 1985			11.2				21.9					0.1	10.5	0.8		6.2	0.2		2.4				0.3		44.4	0.1				1.7				1254	
Rapp, 1985			11.5				16.6					0.1	10.8	0.8		10.4	0.2		2.4				0.3		44.7	0.1				1.7				1285	
Rapp, 1985			12.0				16.3					0.1	11.3	0.9		4.3	0.2		2.5				0.3		46.8	0.1				4.9				1243	
Rapp, 1985		1455	25.4				14.9					0.1	9.8	0.7		3.8	0.2		2.2				0.3		40.7	0.1				1.6				1380	
Rapp, 1985		1560	13.6				8.6					0.1	12.8	1.0		4.9	0.2		2.9				0.3		53.0	0.1				2.1				1271	
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.6	10.8	0.0		0.6	0.1		0.2			11.9	2.3	2.6	1.3	1.3	0.0	9.1	0.3	0.0	0.3	2.5		41.2	0.3	0.0	0.1	2.5	0.9	0.5		0.5		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	OthI '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.3	10.9	0.1		0.6	0.1		0.2			11.7	2.3	2.6	1.3	1.3	0.0	9.2	0.3	0.0	0.3	2.5		41.4	0.3	0.0	0.1	2.5	0.9	0.5		0.5		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.4	10.8	0.0		0.7	0.1		0.2			11.8	2.4	2.6	1.3	1.4	0.0	9.2	0.3	0.0	0.3	2.5		41.3	0.3	0.0	0.1	2.5	0.9	0.5		0.5		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.4	10.9	0.1		0.6	0.1		0.2			11.8	2.2	2.5	1.3	1.4	0.0	9.3	0.3	0.0	0.3	2.5		41.4	0.3	0.0	0.1	2.5	0.9	0.5		0.4		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.3	11.0	0.1		0.6	0.1		0.2			11.6	2.4	2.6	1.3	1.3	0.0	9.2	0.3	0.0	0.3	2.5		41.2	0.3	0.0	0.1	2.6	0.9	0.5		0.5		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.4	10.9	0.1		0.6	0.1		0.2			11.7	2.2	2.6	1.3	1.4	0.0	9.1	0.3	0.0	0.3	2.6		41.4	0.3	0.0	0.1	2.6	0.9	0.5		0.5		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			10.0	10.7	0.1		0.6	0.1		0.2			12.2	2.4	2.6	1.3	1.3	0.0	9.6	0.3	0.0	0.3	2.5		40.0	0.3	0.0	0.1	3.6	1.0	0.6		0.3		
Reimus, 1988			11.3	10.7	0.1		0.6	0.1			0.0	0.5	11.5	2.8	2.6	1.3	1.2	0.0	9.0		0.0	0.3	2.6		40.6	0.3		0.1		3.0	1.0	0.0			
Reinherz, 1990	1205	2023		13.7		41.9													6.4						30.6							3.0	1.4		
Reinherz, 1990	1205			13.7		**41.9**													6.4			3.0			30.6							3.0	1.4		
Reinherz, 1990	1205			13.4		41.0													6.2						29.8					2.6		2.9	1.0		
Reinherz, 1990	1205			13.4		**41.0**													6.2			3.0			29.8					2.6		2.9	1.0		
Reinherz, 1990	1260			13.0		37.5													7.6						32.0					2.2		3.1	1.5		
Reinherz, 1990	1260			13.0		**37.5**													7.6			3.2			32.0					2.2		3.1	1.5		
Reinherz, 1990	1205			18.7		35.0													7.1						29.9					2.0		2.9	1.4		
Reinherz, 1990	1205			18.7		**35.0**													7.1			3.0			29.9					2.0		2.9	1.4		
Reinherz, 1990	1205			17.7		38.6													6.7						28.1					2.2		2.8	1.1		
Reinherz, 1990	1205			17.7		**38.6**													6.7			2.8			28.1					2.2		2.8	1.1		
Reinherz, 1990	1175			15.7		41.8													5.5						30.3					2.7		3.0	1.0		
Reinherz, 1990	1175			15.7		**41.8**													5.5						30.3					2.7		3.0	1.0		
Reinherz, 1990	1175			15.5		41.0													7.1						29.8					2.6			1.0		
Reinherz, 1990	1175			15.5		**41.0**													7.1			3.0			29.8					2.6			1.0		
Reinherz, 1990	1260			15.5		35.2													7.1						30.0					2.1		5.9	1.4		
Reinherz, 1990	1260			15.5		**35.2**													7.1			3.0			30.0					2.1		5.9	1.4		
Reinherz, 1990	1205			17.2		37.6													6.5						27.5					1.9		5.4	1.3		
Reinherz, 1990	1205			17.2		**37.6**													6.5			2.7			27.5					1.9		5.4	1.3		
Reinherz, 1990	1205			17.9		33.5													6.8						33.9					1.4		2.8	0.9		
Reinherz, 1990	1205			17.9		**33.5**													6.8			2.8			33.9					1.4		2.8	0.9		
Reinherz, 1990	1205			16.4		37.5													6.8						27.4					1.9		2.7	1.3		
Reinherz, 1990	1205			16.4		**37.5**													6.8			6.1			27.4					1.9		2.7	1.3		
Reinherz, 1990	1175			15.2		40.4													7.0						28.9					2.6		2.9			
Reinherz, 1990	1175			15.2		**40.4**													7.0			2.9			28.9					2.6		2.9			
Reinherz, 1990	1205			19.8		35.7													7.8						26.1					1.8		5.1	1.2		
Reinherz, 1990	1205			19.8		**35.7**													7.8			2.6			26.1					1.8		5.1	1.2		
Reinherz, 1990	1205			18.9		39.3													6.8						28.6					2.5			0.9		
Reinherz, 1990	1205			18.9		**39.3**													6.8			2.9			28.6					2.5			0.9		
Reinherz, 1990	1205			20.8		38.7		1.1											5.1						28.1					2.5		2.8	0.9		
Reinherz, 1990	1205			20.8		**38.7**		1.1											5.1						28.1					2.5		2.8	0.9		
Reinherz, 1990	1175			15.4		40.9													7.1						29.7							2.9	1.0		
Reinherz, 1990	1175			15.4		**40.9**													7.1			3.0			29.7							2.9	1.0		
Reinherz, 1990	1260			19.5		29.3													8.9						30.0					2.1		5.9	1.4		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Reinherz, 1990	1260			19.5		**29.3**													8.9			3.0			30.0					2.1		5.9	1.4		
Resce, 1995	<1350		14.4	5.9	4.3		13.5						4.5						29.9	2.1				3.2	22.1										
Resce, 1995	<1350			6.3	4.6		14.4						4.8						31.7	2.2				3.4	32.6										
Resce, 1995	<1350		14.6		4.4		13.6						4.6						30.1	2.1				3.2	27.5										
Resce, 1995	<1350				4.7		14.5						4.9						32.0	2.3				3.4	38.3										
Resce, 1995	<1350		14.7	6.0	4.4		27.4						4.6						15.1	2.1				3.2	22.5										
Resce, 1995	<1350			6.4	4.7		29.2						4.9						16.1	2.3				3.4	33.1										
Resce, 1995	<1350		14.8		4.4		27.6						4.6						15.3	2.2				3.2	27.9										
Resce, 1995	<1350				4.7		29.4						4.9						16.3	2.3				3.4	38.9										
Resce, 1995	<1350		14.4	8.8	4.3		7.9						4.5						17.5	2.1				3.1	37.3										
Resce, 1995	<1350			9.4	4.6		8.4						4.8						18.6	2.2				3.3	48.6										
Resce, 1995	<1350		14.6		4.4		8.0						4.6						17.7	2.1				3.2	45.5										
Resce, 1995	<1350				4.7		8.5						4.9						18.8	2.3				3.4	57.5										
Resce, 1995	<1350		14.5	8.9	4.4		16.0						4.5						8.8	2.1				3.2	37.6										
Resce, 1995	<1350			9.5	4.6		17.0						4.8						9.4	2.3				3.4	49.1										
Resce, 1995	<1350		14.7		4.4		16.2						4.6						8.9	2.2				3.2	45.9										
Resce, 1995	<1350				4.7		17.2						4.9						9.5	2.3				3.4	58.0										
Resce, 1995	<1350		11.8	4.0	3.5		9.1						33.3						20.1	1.7				2.6	13.9										
Resce, 1995	<1350			4.2	3.7		9.5						34.9						21.1	1.8				2.7	21.9										
Resce, 1995	<1350		11.9		3.6		9.1						33.4						20.2	1.7				2.6	17.5										
Resce, 1995	<1350				3.8		9.6						35.2						21.2	1.8				2.7	25.7										
Resce, 1995	<1350		11.9	4.1	3.6		18.3						33.6						10.1	1.7				2.6	14.0										
Resce, 1995	<1350			4.3	3.8		19.3						35.3						10.7	1.8				2.7	22.1										
Resce, 1995	<1350		12.0		3.6		18.4						33.8						10.2	1.8				2.6	17.6										
Resce, 1995	<1350				3.8		19.4						35.5						10.7	1.8				2.8	26.0										
Resce, 1995	<1350		12.3	6.9	3.7		5.3						27.0						11.6	1.8				2.7	28.7										
Resce, 1995	<1350			6.7	3.7		4.8						34.8						10.5	1.8				2.7	34.9										
Resce, 1995	<1350		13.1		3.9		6.1						20.5						13.5	1.9				2.9	38.1										
Resce, 1995	<1350				3.7		4.8						35.1						10.6	1.8				2.7	41.1										
Resce, 1995	<1350		12.5	7.1	3.8		10.9						25.9						6.0	1.8				2.7	29.3										
Resce, 1995	<1350			6.8	3.7		9.6						35.0						5.3	1.8				2.7	35.1										
Resce, 1995	<1350		12.9		3.9		11.6						23.4						6.4	1.9				2.8	37.1										
Resce, 1995	<1350				3.8		9.6						35.3						5.3	1.8				2.7	41.3										
Reynolds, 1997	1150		8.3	5.0		1.3	1.3	1.8		0.3		0.4	7.1	0.1	1.9	0.1	1.0	0.1	16.2	1.5	0.1	0.1	3.0	0.2	39.6	0.2	0.3	5.9					4.5		
Riley, 2001			7.0	5.2			11.5	3.1						0.1	6.1				11.6	0.0			1.2		43.0	1.1	0.2						4.8		
Riley, 2001			12.5	4.9			10.8	2.9						0.1	5.7				10.9	0.0			1.1		40.5	1.0	0.2						4.5		
Riley, 2001			8.5	6.0			11.2	3.0						0.1	5.9				11.3	0.0			1.2		41.9	1.0	0.2						4.7		
Riley, 2001			7.7	15.0			10.1	2.7						0.1	5.4				10.2	0.0			1.1		37.9	0.9	0.2						4.2		
Roa, 1997				20.0				0.3					2.0		7.0				5.0			9.6	0.2		44.0								12.0	> 1118	
Roa, 1997				5.0			10.0	0.0					3.4		1.0				9.6			1.0	0.0		57.0								13.0	1187	
Roa, 1997				5.0				0.0					15.0		1.0	8.0			8.4			1.0	0.0		53.6								8.0	> 1118	
Roa, 1997			10.3	13.2			7.0	0.1					4.5		4.4	1.0			7.0			2.4	0.1		46.5								3.7	931	
Roa, 1997			1.4	9.4				0.1					7.1		6.0				9.2			2.4	0.1		54.3								10.0	1018	
Roa, 1997				5.0			2.0	0.2					2.0		7.0	8.0			11.9			8.6	0.2		42.1								13.0	> 1118	
Roa, 1997			6.4	11.4			2.8	0.1					5.7		3.8	3.6			10.0			3.9	0.1		48.0								4.3	916	
Roa, 1997			2.4	13.1			5.0	0.1					4.0		4.9	2.0			8.0			4.4	0.1		46.0								10.0	1090	
Roa, 1997			2.4	10.5			0.8	0.0					7.3		3.7	0.8			11.3			5.8	0.1		53.3								3.9	862	
Roa, 1997			1.0	5.0				0.0					6.0		6.7				10.3			1.0	0.0		57.0								13.0	1081	
Roa, 1997			2.6	20.0			8.0	0.0					2.0		7.0				5.1			1.0	0.0		44.3								10.0	1049	
Roa, 1997				20.0			8.0	0.3					2.0		1.0				6.8			9.6	0.2		43.9								8.3	1108	

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Roa, 1997			0.3	5.0				0.0					2.0		4.3				20.0			1.0	0.0		54.5								13.0	1054	
Roa, 1997			2.6	5.0				0.0					7.4		7.0	8.0			13.6			1.0	0.0		48.4								7.0	1029	
Roa, 1997			5.0	14.8			2.0	0.1					3.0		6.5	3.0			5.0			2.9	0.1		50.7								7.0	1090	
Roa, 1997			2.0	11.3			0.1						0.1		7.0	0.0			8.6			2.0			53.4								15.5	1168	
Roa, 1997			2.0	6.0			0.5						0.5		7.0	0.5			18.0			9.0			45.5								11.0	1027	
Roa, 1997			2.0	16.0			0.5	0.0					7.0		2.5	4.0			5.0			2.0			56.0								5.0	1129	
Roa, 1997			2.0	16.0			0.5						10.5		1.8	4.0			5.0			2.0			50.7								7.5	> 1454	
Roa, 1997			2.0	6.0			0.5						10.5		7.0	0.5			18.0			2.0			45.5								8.0	966	
Roa, 1997			10.5	6.0			4.0						2.5		7.0	0.5			14.0			2.0			46.0								7.5	929	
Roa, 1997			2.0	16.0			0.5	0.2					0.5		7.0	4.0			10.0			8.6	0.2		44.0								7.0	897	
Roa, 1997			1.0	7.5			7.0	0.2					4.0		6.0	1.0			8.3			6.4	0.1		49.2								9.4	1035	
Roa, 1997			7.5	7.7		5.1	0.9						4.1		4.3	0.3			10.8			4.0	0.8		44.3								10.1	1308	
Roa, 1997			4.0	8.0		5.3	1.0						4.3		4.5	0.3			11.2			4.2	0.9		46.0								10.5	1069	
Roa, 1997			6.0	7.8		5.2	0.9						4.2		4.4	0.3			11.0			4.1	0.8		45.0								10.3	1196	
Roa, 1997			2.5	2.0		5.8	1.0						4.7		4.9	0.3			12.2			4.5	0.9		49.9								11.4	1031	
Roa, 1997			2.4	5.0		5.6	1.0						4.5		4.7	0.3			11.8			4.4	0.9		48.4								11.1	1030	
Roa, 1997			2.2	12.0		5.2	0.9						4.2		4.4	0.3			10.9			4.1	0.8		44.8								10.3	992	
Roa, 1997			2.4	8.4		2.5	1.0						4.5		4.7	0.3			11.7			4.4	0.9		48.2								11.0	1017	
Roa, 1997			2.4	8.6			1.0						4.6		4.9	0.3			12.0			4.5	0.9		49.4								11.3	1015	
Roa, 1997			2.3	8.0		7.5	1.0						4.3		4.5	0.3			11.1			4.2	0.9		45.7								10.5	1009	
Roa, 1997			2.2	7.8		10.0	0.9						4.1		4.4	0.3			10.8			4.0	0.8		44.5								10.2	1023	
Roa, 1997			2.3	8.2		5.4	1.0						4.4		4.6	0.3			11.4			4.2	0.9		46.8								10.7	1012	
Roa, 1997			2.3	8.2		5.4	1.0						4.4		4.6	0.3			11.4			4.2	0.9		46.8								10.7	1012	
Roa, 1997			2.3	8.0		5.3	1.0	1.5					4.3		4.5	0.3			11.2			4.2	0.9		46.1								10.5	1019	
Roa, 1997			2.2	7.9		5.3	1.0	3.0					4.2		4.5	0.3			11.1			4.1	0.9		45.4								10.4	1002	
Roa, 1997			2.4	8.5		5.7	1.0						4.6			0.3			11.9			4.5	0.9		49.0								11.2	1271	
Roa, 1997			2.4	8.4		5.6	1.0						4.5		1.5	0.3			11.8			4.4	0.9		48.3								11.0	1155	
Roa, 1997			2.3	8.3		5.5	1.0						4.4		3.0	0.3			11.6			4.3	0.9		47.5								10.9	1074	
Roa, 1997			2.3	8.0		5.3	1.0						4.3		6.0	0.3			11.2			4.2	0.9		46.1								10.5	982	
Roa, 1997			2.4	8.6		5.7	1.0						4.6		4.8	0.3			7.0			4.5	0.9		49.1								11.2	1223	
Roa, 1997			2.4	8.3		5.5	1.0						4.5		4.7	0.3			9.5			4.3	0.9		47.8								10.9	1110	
Roa, 1997			2.3	8.0		5.3	1.0						4.3		4.5	0.3			13.0			4.2	0.9		45.9								10.5	930	
Roa, 1997			2.5	8.8		5.8	1.1						4.7		4.9	0.3			4.5			4.6	0.9		50.4								11.5	1350	
Roa, 1997			2.3	8.1		5.4	1.0						4.3		4.5	0.3			11.3			4.2	2.0		46.2								10.6	1040	
Roa, 1997			2.3	8.0		5.3	1.0						4.3		4.5	0.3			11.2			4.2	3.0		45.8								10.5	1052	
Roa, 1997			2.2	7.9		5.2	1.0						4.2		4.4	0.3			11.0			4.1	4.0		45.3								10.4	1057	
Roa, 1997			2.2	7.8		5.2	0.9						4.2		4.4	0.3			10.9			4.1	5.0		44.8								10.3	1065	
Roa, 1997			2.6	9.0		6.0	1.1						4.8		5.1	0.3			12.6			4.7	1.0		41.0								11.9	1012	
Roa, 1997			2.1	7.4		4.9	0.9						3.9		4.1	0.2			10.3			3.8	0.8		52.0								9.6	1022	
Roa, 1997			1.9	6.6		4.4	0.8						3.5		3.7	0.2			9.2			3.4	0.7		57.0								8.6	1022	
Roa, 1997			2.4	8.4		5.6	1.0						4.5		4.7	0.3			11.7			4.4	0.9		48.2								8.0	937	
Roa, 1997			2.3	8.0		5.3	1.0						4.3		4.5	0.3			11.2			4.2	0.9		46.1								12.0	1074	
Roa, 1997			2.2	7.9		5.2	0.9						4.2		4.4	0.3			11.0			4.1	0.8		45.0								14.0	1182	
Rocabois, 2001			24.5				33.7									0.3									41.3									1360	
Rocabois, 2001			20.0				38.2																		41.3									1347	
Rocabois, 2001			21.2				35.7									0.4									42.5									1305	
Rocabois, 2001			20.3				34.0									5.1									40.6									1387	
Rocabois, 2001			20.0				33.5									6.1									39.9									1396	
Rocabois, 2001			19.5				33.4									7.3									39.5									1408	
Rocabois, 2001			20.6				34.4									2.8									42.2									1343	

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Rocabois, 2001			17.0				21.7																		60.9									1219	
Rocabois, 2001			24.2				31.9									5.0									39.0									1380	
Rocabois, 2001			17.2				21.1									5.1									56.7									1196	
Rocabois, 2001			13.7				35.5																		50.5									1376	
Rocabois, 2001			10.3				27.8																		61.6									1323	
Rocabois, 2001			22.9				30.6									9.0									37.4									1403	
Rocabois, 2001			16.2				19.9									9.9									54.0									1244	
Rudkovskaya, 200	~1300		8.2	27.2			0.4						0.4	2.7					2.6						46.3							12.1			
Rudkovskaya, 200	~1330		8.0		0.1		4.1						0.3	1.3		1.9	3.1		7.5				0.0		49.4							25.6			
Rudkovskaya, 200	~1350		8.8				4.0						0.3	1.8		2.6			7.4	1.0					55.2					0.0		24.9			
Rudkovskaya, 200	~1250		9.2		8.3		3.5							5.6					1.9						49.1					2.6		19.8			
Rudkovskaya, 200	~1350		9.1		4.0		1.3							6.5					2.0						44.3					0.5		32.3			
Rudkovskaya, 200	~1350		9.6		9.0		3.3							6.2					1.9						49.2							20.9			
Russell, 2005		2050	19.4																11.8						68.7										
Russell, 2005		1585	32.5				15.3												2.8						49.3										
Russell, 2005		1675	28.3				10.4												5.7						55.6										
Russell, 2005		1821	23.0				4.2												9.3						63.4										
Russell, 2005		1499	36.6				20.2																		43.2										
Russell, 2005			24.8				6.3												8.1						60.8										
Russell, 2005			25.8				7.4												7.5						59.3										
Russell, 2005			26.9				8.7												6.7						57.7										
Russell, 2005		1510	29.2				11.4												5.1						54.3										
Russell, 2005		1792	30.4				12.8												4.3						52.5										
Russell, 2005		1589	33.7				16.7												2.0						47.6										
Russell, 2005		1563	35.1				18.4												1.0						45.5										
Russell, 2005		1261					35.8									25.8									38.4										
Russell, 2005			34.5				21.1									1.5									42.9										
Russell, 2005			26.7				15.3									3.0			3.9						51.1										
Russell, 2005			16.9				4.7									3.4			10.3						64.8										
Russell, 2005		1433	32.1				22.1									3.2									42.6										
Russell, 2005			18.5				7.0									3.5			9.0						62.0										
Russell, 2005		1727	16.2				5.9									4.3			9.9						63.7										
Russell, 2005			18.9				10.4									4.8			7.4						58.4										
Russell, 2005			15.5				7.3									5.2			9.4						62.6										
Russell, 2005		1413	29.5				23.2									5.0									42.3										
Russell, 2005			19.2				14.2									6.4			5.8						54.5										
Russell, 2005			15.5				11.1									6.9			7.8						58.7										
Russell, 2005		1378	26.7				24.4									7.0									41.9										
Russell, 2005			19.4				18.2									8.0			4.0						50.4										
Russell, 2005		1454	12.2				13.4									9.6			7.4						57.4										
Russell, 2005		1323	23.5				25.8									9.3									41.5										
Russell, 2005		1378	19.2				22.1									9.8			2.4						46.5										
Russell, 2005			14.7				18.9									10.8			4.6						51.1										
Russell, 2005		1299	20.6				27.0									11.3									41.1										
Russell, 2005			10.3				16.9									12.2			6.2						54.4										
Russell, 2005		1311	18.3				28.0									12.9									40.8										
Russell, 2005			8.3				20.6									14.8			5.0						51.3										
Russell, 2005		1302	7.0				23.0									16.5			4.2						49.3										
Russell, 2005		1280	11.3				31.0									17.8									39.9										
Russell, 2005			4.7				27.3									19.6			2.8						45.7										

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2'	Oth1'	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Russell, 2005		1208	6.0				33.3									21.5									39.2										
Russell, 2005		1213	1.6				32.9									23.7			1.0						40.9										
Russell, 2005		1783	18.4				2.0									1.4			11.2						67.0										
Sato, 2005			16.8				9.7						10.1	1.0		5.2	0.2		2.6				0.1		52.5					1.4				1230	
Sato, 2005			16.7				9.6						10.3	1.1		5.3	0.2		2.6				0.1		52.4					1.4				1210	
Sato, 2005			16.1				9.5						10.3	1.0		5.3	0.2		2.7				0.1		52.2					1.4				1190	
Sato, 2005			15.0				9.1						11.1	1.0		5.9	0.2		2.6				0.1		52.0					1.5				1170	
Sato, 2005			14.2				8.8						12.3	1.1		6.3	0.2		2.5				0.2		52.4					1.7				1150	
Sato, 2005			13.5				8.7						12.5	1.2		5.8	0.2		2.4				0.2		52.6					1.8				1130	
Scarfe, 1983		1444	29.3				21.3									3.7									45.7									1488	
Scarfe, 1983		1411	25.7				21.9									5.6									46.9									1438	
Scarfe, 1983		1353	22.0				22.5									7.4									48.1									1388	
Scarfe, 1983		1356	18.3				23.0									9.3									49.3									1323	
Scarfe, 1983		1331	15.4				23.5									10.8									50.3									1274	
Scarfe, 1983		1230	7.3				24.7									14.9									53.0									1343	
Scarfe, 1983		1196	3.7				25.3									16.8									54.3									1368	
Scarfe, 1983		1481	36.6				20.2																		43.2									1553	
Scarfe, 1983		1127					25.9									18.6									55.5									1392	
Scarfe, 1986		1141					25.9									18.6									55.5									1392	
Scarfe, 1986		1199	2.3				25.5									17.4									54.7									1378	
Scarfe, 1986		1280	11.0				24.2									13.0									51.8									1324	
Scarfe, 1986		1480	20.6				22.7									8.1									48.6									1272	
Scarfe, 1986		1709	29.1				21.3									3.0									45.7									1217	
Scarfe, 1986		2051	36.6				20.2																		43.2									1118	
Scholes, 2000	1178		9.0	3.0		1.4	1.4	1.9		0.3		0.4	7.6	0.2	2.0	0.1	1.0	0.1	17.6	1.6	0.1	0.1	3.3	0.2	37.0	0.2	0.3	6.4					4.9		
Scholes, 2000	1118		8.3	3.0		1.2	1.3	1.7		0.3		0.4	7.0	0.1	2.9	0.0	1.0	0.0	19.8	1.5	0.1	0.1	3.0	0.2	37.0	0.2	0.3	5.9					4.5		
Scholes, 2000	1155		8.3	8.0		1.2	1.3	1.7		0.3		0.4	7.0	0.1	1.2	0.0	1.0	0.0	16.4	1.5	0.1	0.1	3.0	0.2	37.0	0.2	0.3	5.9					4.5		
Scholes, 2000	1102		7.6	5.0		1.1	1.2	1.6		0.3		0.3	6.5	0.1	2.2	0.0	0.9	0.0	20.8	1.3	0.1	0.1	2.8	0.2	37.8	0.2	0.2	5.4					4.2		
Scholes, 2000	1155		7.6	10.0		1.1	1.2	1.6		0.3		0.3	6.5	0.1		0.0	0.9	0.0	18.6	1.3	0.1	0.1	2.8	0.2	37.1	0.2	0.2	5.4					4.2		
Scholes, 2000			8.5	9.3			4.9	0.0		0.1		2.2	2.3	0.9	4.0	0.2	0.0	0.7	12.5	0.7	0.0	0.0	1.1		42.1	0.2	1.8	2.3					6.2		
Scholes, 2000			4.5	16.3			10.6	0.0		0.1		0.4	0.5	0.2	0.8	0.2	0.0	1.4	6.5	0.2	0.0	0.0	0.2		51.6	0.4	0.4	4.5					1.2		
Scholes, 2000			4.0	5.0				0.0		0.1				2.0	0.8	0.2	0.0	1.5	20.0	1.5	0.0	0.0	2.5		42.7	0.5		5.0					14.0		
Scholes, 2000			3.5	18.0				0.0		0.1			3.0		2.7	0.2	0.0		5.0	1.5	0.0	0.0	2.5		54.3		4.0	5.0							
Scholes, 2000	1150		3.5	5.0			12.0	0.0		0.1		4.7		2.0		0.2	0.0	1.5	12.0	1.5	0.0	0.0			53.3		4.0	0.0							
Scholes, 2000	1350		4.0	5.0			12.0	0.0		0.1		3.3		2.0	3.0	0.2	0.0		5.0	1.5	0.0	0.0	2.5		42.1			5.0					14.0	>1500	
Scholes, 2000	1250		16.9	18.0				0.0		0.1			8.0			0.2	0.0	1.5	18.6	1.5	0.0	0.0			35.0			0.0							
Scholes, 2000	1275		5.4	15.4			1.5	0.0		0.1		0.7	6.3	0.3	1.2	0.2	0.0	1.3	11.9	1.3	0.0	0.0	0.3		40.9	0.4	0.6	0.7					11.7	>1350	
Scholes, 2000	1150		3.5	5.0				0.0		0.1		5.6	8.0	2.0	9.0	0.2	0.0	1.5	5.7		0.0	0.0	2.5		56.3	0.5		0.0							
Scholes, 2000	1250		4.9	16.3			1.0	0.0		0.1		3.3	4.6	1.8	3.9	0.2	0.0	0.2	6.5	1.4	0.0	0.0	0.2		36.4	0.4	3.6	2.8					12.4	>1500	
Scholes, 2000	1150		12.1	5.0			12.0	0.0		0.1			8.0		1.5	0.2	0.0		20.0		0.0	0.0			36.5	0.5	4.0	0.0						1013	
Scholes, 2000	1150		3.5	18.0			9.0	0.0		0.1			3.0			0.2	0.0		11.5		0.0	0.0			35.0	0.5	4.0	5.0					10.0	973	
Scholes, 2000	1150		4.0	7.5				0.0		0.1		6.0	8.0		4.7	0.2	0.0		13.4	1.5	0.0	0.0	1.4		35.0		4.0	0.0					14.0		
Scholes, 2000	1150		8.0	6.0			4.0	0.0		0.1		2.5	3.0	1.0	6.0	0.2	0.0	1.0	10.0	0.5	0.0	0.0	1.5		49.3	0.3	1.0	1.5					4.0	943	
Scholes, 2000	1200		10.0	6.0			8.0	0.0		0.1		2.5	0.5	1.0	4.3	0.2	0.0	1.0	10.0	1.0	0.0	0.0	0.5		40.0	0.3	3.0	3.5					8.0	1203	
Scholes, 2000	1150		9.9	7.5			8.0	0.0		0.1		1.0	0.5	1.0	6.0	0.2	0.0	1.0	10.0	0.5	0.0	0.0	1.5		40.0	0.1	3.0	1.5					8.0	1133	
Scholes, 2000	1150		8.9	6.0			8.0	0.0		0.1		1.0	3.0	1.0	6.0	0.2	0.0	1.0	10.0	0.5	0.0	0.0	1.5		40.0	0.1	3.0	1.5					8.0	1173	
Scholes, 2000	1150		12.0	6.0			4.0	0.0		0.1		1.0	0.5	1.0	5.8	0.2	0.0	1.0	15.0	1.0	0.0	0.0	1.5		40.0	0.3	3.0	1.5					6.0	1023	
Scholes, 2000	1150		12.0	6.0			8.0	0.0		0.1		2.5	1.5	1.0	6.0	0.2	0.0	1.0	10.5	0.5	0.0	0.0	1.5		40.0	0.1	1.0	3.5					4.4	893	
Scholes, 2000	1150		8.0	12.0			8.0	0.0		0.1		2.5	3.0	0.5	3.1	0.2	0.0	1.0	10.0	0.5	0.0	0.0	0.5		41.2	0.3	3.0	2.0					4.0	893	
Scholes, 2000	1150		10.0	11.2			4.0	0.0		0.1		1.0	1.5	0.5	6.0	0.2	0.0	1.0	10.0	0.5	0.0	0.0	0.5		40.8	0.1	1.0	3.5					8.0	1013	

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	OthI '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Scholes, 2000	1200		10.0	6.0			4.0	0.0		0.1		1.0	3.0	0.5	5.4	0.2	0.0	0.5	15.0	0.5	0.0	0.0	0.5		40.0	0.3	2.9	2.0					8.0	1163	
Scholes, 2000	1150		12.0	6.0			4.0	0.0		0.1		2.5	0.5	0.5	3.0	0.2	0.0	1.0	15.0	1.0	0.0	3.3	0.5		44.8			1.5					4.0	903	
Scholes, 2000	1150		12.0	6.0			4.0	0.0		0.1		2.5	0.5	0.5	3.2	0.2	0.0	0.5	15.0	1.0	0.0	1.3	0.5		45.1			3.5					4.0	883	
Scholes, 2000	1150		12.0	6.0			4.0	0.0		0.1		2.5	0.5	0.5	3.0	0.2	0.0	0.5	14.4	0.5	0.0	3.3	0.5		44.3			3.5					4.0	903	
Scholes, 2000	1150		12.0	8.4			8.0	0.0		0.1		1.0	1.5	0.5	3.0	0.2	0.0	1.0	10.0	0.5	0.0	1.2	1.5		41.5			3.5					6.0	1063	
Scholes, 2000	1150		8.4	9.2			4.8	0.0		0.1		2.2	2.3	0.9	3.9	0.2	0.0	0.7	12.4	0.7	0.0	2.9	1.1		41.7			2.3					6.2	953	
Scholes, 2000	1150		8.5	9.3			4.9	0.0		0.1		2.2	2.3	0.9	4.0	0.2	0.0	0.7	12.5	0.7	0.0	2.1	1.1		42.1			2.3					6.2	873	
Scholes, 2000	1150		15.0	15.0			0.1			0.0			0.1		8.5	0.1	0.0	0.0	5.0		0.0	0.0			53.1			0.0					3.0	873	
Scholes, 2000	1150		3.8	12.5			0.1			0.1			0.1	2.5	6.3	0.2	0.0		8.8		0.0	0.1	1.3		54.0			0.0					10.5	883	
Scholes, 2002			10.0	9.0	2.0		2.2			0.1		0.6	4.1	2.8	2.0		0.5	0.0	17.7	0.1			1.2		45.5			0.0					1.2		
Scholes, 2002			9.8	9.0	2.0		2.2			0.1		0.6	6.1	2.8	3.0		0.7	0.0	14.1	0.1			0.8		46.5			0.0					1.2		
Scholes, 2002			9.8	9.0	2.0		2.2			0.1		0.4	4.1	2.8	2.0		0.5	0.0	14.1	0.1			0.8		50.3			0.0					0.8		
Scholes, 2002			9.8	11.0	2.0		2.2			0.1		0.4	4.1	3.6	3.0		0.7	0.0	14.5	0.1			1.2		45.5			0.0					0.8		
Seetharaman, 2000		1355					21.6						10.0			9.0									59.4										
Seetharaman, 2000		1097					22.5						10.0			22.5									45.0										
Seetharaman, 2000		1327					18.8						25.0			18.8									37.5										
Sheng, 2001			24.4	4.2			2.6						6.4	1.2		1.2			6.1						45.5	0.3									
Sheng, 2001			23.0	6.4			2.4						6.0	1.1		1.1			8.9						43.0	0.3									
Sheng, 2001			21.7	8.5			2.3						5.7	1.0		1.1			11.7						40.5	0.2									
Sheng, 2001			20.3	10.6			2.2						5.3	1.0		1.1			14.5						38.0	0.2									
Sheng, 2001			19.0	12.7			2.1						5.0	0.9		1.1			17.2						35.4	0.2									
Sheng, 2001			17.6	14.9			2.0						4.6	0.8		1.1			20.0						32.9	0.2									
Sheng, 2001			16.3	17.0			1.8						4.3	0.8		1.0			22.8						30.4	0.2									
Sheng, 2001			13.6	21.2			1.6						3.6	0.7		1.0			28.4						25.3	0.2									
Sipp, 2002		2050	19.4																11.8						68.7										
Sipp, 2002		1318	3.2	4.5			7.2						0.2	1.6		3.1			15.8						64.3					0.1					
Sipp, 2002		1349	74.0				26.0																												
Sipp, 2002		1369	58.6				32.2																		9.2										
Sipp, 2002		1513	22.7				37.3																		40.0										
Sipp, 2002		1521	36.6				20.2																		43.2										
Sipp, 2002		1292					25.9									18.6									55.5										
Sipp, 2002		1414	14.3	6.4			18.4						0.5	0.3		2.7			0.5						56.7					0.1					
Sipp, 2002		1127												32.0											40.8					27.2					
Sipp, 2002		1415	0.6				8.6						0.8	0.2		3.6			14.2						72.0										
Sipp, 2002		1447																	20.5						79.5										
Sipp, 2002		1262																	16.2						62.9					20.9					
Solvang, 2002		1432	36.1				20.5																		42.6										
Solvang, 2002		1257	13.5				38.1																		47.7										
Solvang, 2002		1255	36.4				37.2																		25.5										
Solvang, 2002		1251	16.9				39.0																		43.4										
Solvang, 2002		1242	20.2				40.4																		38.8										
Solvang, 2002		1237	23.2				41.5																		34.6										
Solvang, 2002		1155	25.6				43.3																		30.3										
Solvang, 2002		1332	23.6				30.1																		45.8										
Solvang, 2002		1305	26.8				32.6																		40.0										
Solvang, 2002		1287	30.3				33.9																		35.4										
Solvang, 2002		1256	33.6				35.0																		30.6										
Solvang, 2002		1208	37.1				41.1																		21.3										
Solvang, 2002		1168	0.2				48.1																		50.9										

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Soper, 1982			14.7	10.5			0.4						4.0	0.3	4.1	1.4	3.2		14.7	0.6					44.7			0.4		0.7			0.4		
Soper, 1982		1143	14.7	10.5			0.4						4.0	0.3	2.8	1.4	3.2		14.6	0.6					45.4			0.7		1.4					
Soper, 1982			14.7	10.1			0.4						4.0	0.3	2.7	0.6	3.2		10.8	0.6					50.5					1.4			0.6		
Soper, 1982			14.7	9.9			0.4						4.0	0.3	4.0	1.4	3.2		10.6	0.6					49.7					1.4					
Soper, 1982		1130	14.7	10.6			0.4						4.0	0.3	4.2	0.7	3.2		14.7	0.6					45.8								0.7		
Soper, 1982			14.7	7.9			0.4						4.0	0.3	4.0	1.4	3.2		13.9	0.6					49.7										
Soper, 1982		1150	14.7	7.9			0.4						4.0	0.3	4.0	1.4	3.2		13.9	0.6					48.4										
Soper, 1982			14.7	9.5			0.4						4.0	0.3	3.1	0.8	3.2		12.3	0.6					51.0										
Soper, 1982		1148	14.7	10.9			0.4						4.0	0.3	4.4	1.4	3.2		11.5	0.6					47.1			0.7					0.7		
Soper, 1982			14.7	8.3			0.4						4.0	0.3	2.8	1.4	3.2		11.0	0.6					51.9			0.7					0.7		
Soper, 1982		1152	14.7	8.6			0.4						4.0	0.3	2.9	1.4	3.2		15.0	0.6					46.7					1.4			0.7		
Soper, 1982		1148	14.7	9.0			0.4						4.0	0.3	4.5	0.8	3.2		11.8	0.6					48.5			0.8		1.5					
Soper, 1982		1177	14.7	9.8			0.4						4.0	0.3	2.6	0.6	3.2		13.8	0.6					49.2			0.6							
Soper, 1982			14.7	7.8			0.4						4.0	0.3	4.5	0.5	3.2		11.9	0.6					51.6										
Soper, 1982			14.7	8.1			0.4						4.0	0.3	4.6	1.3	3.2		15.8	0.6					46.4			0.6							
Soper, 1982			14.7	7.4			0.4						4.0	0.3	3.0	0.5	3.2		14.8	0.6					49.8					1.4					
Soper, 1982			14.7	9.9			0.4						4.0	0.3	4.5	0.5	3.2		15.4	0.6					45.1					1.4					
Soper, 1982			14.7	9.3			0.4						4.0	0.3	2.5	0.6	3.2		10.4	0.6					52.3					1.4			0.3		
Soper, 1982			14.7	6.9			0.4						4.0	0.3	2.9	1.1	3.2		11.3	0.6					52.9			0.4		1.4					
Soper, 1982			14.7	9.8			0.4						4.0	0.3	3.2	1.2	3.2		12.2	0.6					50.3										
Soper, 1982			14.7	7.6			0.4						4.0	0.3	2.6	1.3	3.2		10.7	0.6					54.0			0.4					0.3		
Soper, 1982			14.7	9.3			0.4						4.0	0.3	2.9	0.7	3.2		11.3	0.6					51.6					0.7			0.4		
Soper, 1982			14.7	9.3			0.4						4.0	0.3	3.2	0.7	3.2		10.6	0.6					51.9					0.7			0.4		
Soper, 1982			14.7	8.6			0.4						4.0	0.3	3.9	0.7	3.2		12.0	0.6					51.2								0.4		
Soper, 1982			14.7	7.1			0.4						4.0	0.3	5.0	0.7	3.2		11.3	0.6					51.9								0.7		
Soper, 1982			14.7	8.6			0.4						4.0	0.3	3.9	0.7	3.2		12.0	0.6					51.2								0.4		
Sridharam, 2005					1.4	70.3								1.0	0.5										21.3			3.1				2.4			
Sridharam, 2005					2.2	54.1				4.5					1.8		13.5								19.0			2.8				2.1			
Sridharam, 2005					1.4	70.8								1.0	0.5										21.5					2.4		2.4			
Sridharam, 2005					1.4	69.2								1.0	0.5										21.0					4.6		2.3			
Sridharam, 2005				4.8		48.4								4.9	1.6										28.2					12.1					
Sridharam, 2005				4.8		48.4								4.9	1.6										20.2					20.1					
Sridharam, 2005				3.3		62.8								3.4	1.1										15.9					8.4		5.1			
Sridharam, 2005				3.6		66.5								3.6	0.6										16.8					8.9					
Sridharam, 2005				5.8		8.8								4.4	1.4										32.1					23.3		24.2			
Sridharam, 2005				5.2		23.1								4.2	1.2										28.3					19.8		18.2			
Sridharam, 2005				3.0		57.5				13.5				3.1	0.6										14.6					7.7					
Sridharam, 2005				3.4		63.3					4.8			3.4	0.6										16.0					8.5					
Staples, 1999	1150	1143	15.0	15.0	0.0		0.1	0.1			0.1		0.1		8.5			0.0	5.0			0.1			53.1		0.0						3.0		
Staples, 1999	1150	1183	13.1	4.4	0.0		0.1	0.1			0.1		0.0	8.7	7.2			0.0	8.2			0.1	13.1		42.2		0.0						2.6		
Staples, 1999	1150	1172	14.6	5.0	0.0		0.1	0.1			0.1		0.1		5.1			0.0	20.0			0.1			54.8		0.0								
Staples, 1999	1150	977	7.6	5.0	0.0		0.1	0.1			0.1		0.1	10.0	7.1			0.0	17.2			0.1			52.7		0.0								
Staples, 1999	1150	1119	10.9	7.2	0.0		0.1	0.1			0.1		0.1	2.4	5.1			0.0	16.7			0.1	3.6		50.2		0.0						3.4		
Staples, 1999	1150	1125	7.2	7.2	0.0		0.1	0.1			0.1		0.1	2.4	4.6			0.0	16.7			0.1	3.6		47.5		0.0						10.1		
Staples, 1999	1150	1041	8.9	12.1	0.0		0.1	0.1			0.1		0.1	7.2	6.5			0.0	9.5			0.1	3.6		43.2		0.0						8.5		
Staples, 1999	1150		10.1	11.2	0.0		0.1	0.1			0.1		0.1	2.3	6.1			0.0	13.2			0.1	10.2		40.4		0.0						6.1		
Staples, 1999	1150	1121	9.8	6.8	0.0		0.1	0.1			0.1		0.1	6.6	6.1			0.0	10.9			0.1	10.2		42.8		0.0						6.5		
Staples, 1999	1150	1037	8.6	12.1	0.0		0.1	0.1			0.1		0.1	7.2	6.5			0.0	9.7			0.1	3.6		43.0		0.0						8.8		
Staples, 1999	1150	1106	7.2	7.2	0.0		0.1	0.1			0.1		0.1	7.2	4.9			0.0	13.3			0.1	3.6		45.8		0.0						10.1		
Staples, 1999	1150	1178	13.1	4.4	0.0		0.1	0.1			0.1		0.0	8.7	7.2			0.0	8.2			0.1	13.1		42.2		0.0						2.6		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Staples, 1999	1150	1176	13.1	4.4	0.0		0.1	0.1			0.1		0.0	8.7	7.2			0.0	8.2			0.1	13.1		42.2		0.0						2.6		
Staples, 1999	1150	1185	14.0	8.4	0.1			0.0		0.0	0.0		2.0		7.0		0.0	0.1	10.6	0.1		0.1	0.1		57.0		0.1	0.2							
Staples, 1999	1150	963	15.0	15.0	0.0		0.1	0.1			0.1		0.1		9.0				11.9			0.2		0.0	45.7		0.0						3.0		
Staples, 1999	1150	1195	15.0	5.0	0.0		0.1	0.1			0.1		0.1	10.0	8.4				5.0			0.2	5.0	0.0	51.2		0.0								
Staples, 1999	1150	1139	7.5	15.0	0.0		0.1	0.1			0.1		0.1		0.2				20.0			0.2	5.0	0.0	51.9		0.0								
Staples, 1999	1150	1015	7.5	5.0	0.0		0.1	0.1			0.1		0.1	10.0	9.0				11.7			0.2		0.0	56.3		0.0								
Staples, 1999	1150	1093	7.6	10.1	0.0		0.1	0.1			0.1		0.1	5.0	5.7				11.9			0.2	2.6	0.0	49.0		0.0						7.6		
Staples, 1999	1150	1024	7.5	12.5	0.0		0.1	0.1			0.1		0.1	7.5	6.8				8.8			0.2	1.3	0.0	44.7		0.0						10.5		
Staples, 1999	1150	1129	10.8	7.5	0.0		0.1	0.1			0.1		0.1	7.3	6.8				8.8			0.2	3.8	0.0	47.4		0.0						7.2		
Staples, 1999	1150	1123	7.0	12.5	0.0		0.1	0.1			0.1		0.1	2.5	2.5				16.3			0.2	3.8	0.0	44.5		0.0						10.5		
Staples, 1999	1250	1325	19.9	5.0	0.0			0.0		0.1		6.0				0.2	0.0	0.0	19.9	1.5	0.0	0.1		0.0	47.2	0.2	0.1	0.0							
Staples, 1999	1250	1347	19.9	17.9	0.0		11.9	0.0		0.1						0.2	0.0	0.0	5.0		0.0	0.1	3.0	0.0	41.7	0.2	0.1	0.0							
Staples, 1999	1150	944	19.9	17.9	0.0			0.0		0.1				9.9	8.9	0.2	0.0	0.0	5.0	1.5	0.0	0.1		0.0	34.7	0.2	0.1	0.0					1.5		
Staples, 1999	1250	1254	7.9	5.0	0.0		11.9	0.0		0.1		6.0		9.9		0.2	0.0	0.0	5.0	1.5	0.0	0.1	3.0	0.0	35.2	0.2	0.1	0.0					13.9		
Staples, 1999	1150	975	19.9	5.0	0.0		11.9	0.0		0.1		6.0	7.9		7.4	0.2	0.0	0.0	5.0		0.0	0.1		0.0	36.3	0.2	0.1	0.0							
Staples, 1999	1250	1400	19.9	6.1	0.0			0.0		0.1			7.9	9.9		0.2	0.0	0.0	14.9		0.0	0.1	3.0	0.0	35.6	0.2	0.1	0.0					2.0		
Staples, 1999	1150	1050	7.9	6.0	0.0		4.0	0.0		0.1		1.0	0.5	3.0	6.0	0.2	0.0	0.0	14.9	0.5	0.0	0.1	2.0	0.0	49.6	0.2	0.1	0.0					4.0		
Staples, 1999	1150	1077	10.9	11.9	0.0		4.0	0.0		0.1		1.0	0.5	3.0	3.0	0.2	0.0	0.0	14.9	0.5	0.0	0.1	2.0	0.0	39.7	0.2	0.1	0.0					7.9		
Staples, 1999	1250	1175	7.9	6.0	0.0		7.9	0.0		0.1		2.5	0.5	3.0	3.0	0.2	0.0	0.0	9.9	0.5	0.0	0.1	2.0	0.0	48.1	0.2	0.1	0.0					7.9		
Staples, 1999	1250	1125	11.9	6.0	0.0		4.0	0.0		0.1		1.0	3.0	6.0	3.0	0.2	0.0	0.0	14.9	0.5	0.0	0.1	1.0	0.0	40.2	0.2	0.1	0.0					7.9		
Staples, 1999	1150	1043	7.9	6.0	0.0		4.0	0.0		0.1		1.0	0.5	3.0	6.0	0.2	0.0	0.0	14.9	1.0	0.0	0.1	2.0	0.0	49.1	0.2	0.1	0.0					4.0		
Staples, 1999	1150	1115	7.9	6.0	0.0		4.0	0.0		0.1		1.0	0.5	6.0	3.0	0.2	0.0	0.0	14.9	1.0	0.0	0.1	2.0	0.0	49.1	0.2	0.1	0.0					4.0		
Staples, 1999	1150	1167	7.9	6.0	0.0		7.9	0.0		0.1		1.0	2.0	6.0	3.0	0.2	0.0	0.0	9.9	1.0	0.0	0.1	1.0	0.0	49.6	0.2	0.1	0.0					4.0		
Staples, 1999	1250	1115	11.3	6.5	0.0		3.8	0.0		0.1		0.9	0.5	21.0	6.1	0.2	0.0		1.4	0.4	0.0	0.1	1.7	0.0	38.2	0.2	0.0	0.0					7.5		
Staples, 1999	1150	1058	10.5	11.9	0.0		4.0	0.0		0.1		1.4	0.5	3.0	3.0	0.2	0.0	0.0	14.9	0.5	0.0	0.1	2.0	0.0	39.7	0.2	0.1	0.0					7.9		
Staples, 1999	1250	1059	11.9	6.0	0.0		7.9	0.0		0.1		1.0	0.5	6.0	5.6	0.2	0.0	0.0	9.9	1.0	0.0	0.1	1.0	0.0	40.5	0.2	0.1	0.0					7.9		
Staples, 1999	1250	1062	11.9	6.0	0.0		7.9	0.0		0.1		1.0	0.5	6.0	5.8	0.2	0.0	0.0	9.9	0.5	0.0	0.1	1.0	0.0	40.9	0.2	0.1	0.0					7.9		
Staples, 1999	1150	1167	8.2	6.1	0.0		2.6	0.0		0.1			0.5	6.1	5.1	0.2	0.0	0.0	10.2	0.5	0.0	0.1	1.0		50.9	0.2	0.1	0.0					8.1		
Staples, 1999	1250	1185	9.8	6.0	0.0		7.9	0.0		0.1		2.5	0.5	3.0	3.1	0.2	0.0	0.0	9.9	1.0	0.0	0.1	2.0	0.0	49.6	0.2	0.1	0.0					4.0		
Staples, 1999	1150	1124	7.9	6.0	0.0		7.4	0.0		0.1		1.0	3.0	6.0	3.0	0.2	0.0	0.0	9.9	1.0	0.0	0.1	1.0	0.0	49.2	0.2	0.1	0.0					4.0		
Staples, 1999	1150	1068	9.9	9.1			4.9					2.1	2.6	4.4	3.9				11.5	0.7			1.4		43.6								5.8		
Staples, 1999	1150	1160	15.0	15.0	0.0		0.1	0.1					0.0		8.5			0.0	5.0			0.1			53.1		0.0						3.0		
Staples, 1999	1150	1081	9.8	9.1	0.0		4.9	0.0		0.1		2.1	2.5	4.4	3.9	0.2	0.0	0.0	11.5	0.7	0.0	0.1	1.4	0.0	43.3	0.2	0.1	0.0					5.8		
Staples, 1999	1150	1055	9.8	9.1	0.0		4.9	0.0		0.1		2.1	2.5	4.4	3.9	0.2	0.0	0.0	11.5	0.7	0.0	0.1	1.4	0.0	43.3	0.2	0.1	0.0					5.7		
Staples, 1999	1250	1076	9.6	8.9	0.0		4.8	0.0		0.1		2.0	2.5	4.3	3.8	0.2	0.0	2.0	11.2	0.7	0.0	0.1	1.4	0.0	42.4	0.2	0.1	0.0					5.6		
Staples, 1999	1150	1068	9.8	9.0	0.0		4.8	0.0		0.1		2.1	2.5	4.3	3.9	0.2	0.0	0.5	11.4	0.7	0.0	0.1	1.4	0.0	43.0	0.2	0.1	0.0					5.7		
Staples, 1999	1150	1064	9.6	8.9	0.0		4.8	0.0		0.1		2.0	2.5	4.3	3.8	0.2	0.0	0.0	11.2	0.7	0.0	0.1	1.4	0.0	42.4	0.2	2.1	0.0					5.6		
Staples, 1999	1150	1067	9.4	8.7	0.0		4.7	0.0		0.1		2.0	2.4	4.2	3.7	0.2	0.0	0.0	11.0	0.7	0.0	0.1	1.4	0.0	41.5	0.2	4.1	0.0					5.5		
Staples, 2000		1317	19.9	5.0								6.0							19.9	1.5		0.7			47.2										0.5
Staples, 2000		1341	19.9	17.9			11.9												5.0			0.7	3.0		41.7										0.2
Staples, 2000		NM	3.5	17.9								4.0	7.9						5.0	1.5		0.7			59.6										24.8
Staples, 2000		938	19.9	17.9										9.9	8.9				5.0	1.5		0.7			34.7								1.5		5.8
Staples, 2000		1065	3.5	5.0			11.9						7.9	1.0					19.9	1.5		0.7			34.8								13.9		1.0
Staples, 2000		913	6.5	17.9									7.9		8.9				5.0	1.5		0.7	3.0		34.8								13.9		4.1
Staples, 2000		1253	7.9	5.0			11.9					6.0		9.9					5.0	1.5		0.7	3.0		35.3								13.9		0.6
Staples, 2000		966	3.5	17.9			11.9							9.9					12.7			0.7			43.4										0.9
Staples, 2000		970	19.9	5.0			11.9					6.0	7.9		7.4				5.0			0.7			36.3										0.2
Staples, 2000		1028	3.5	5.0								6.0	7.9	9.9	8.3				5.0			0.7	3.0		50.7										2.8
Staples, 2000		939	3.5	5.0			7.5								8.9				15.9	1.5		0.7	3.0		54.1										4.0
Staples, 2000		1010	3.5	17.9								6.0			0.5				19.9			0.7			40.4								11.2		23.4

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Staples, 2000		1228	4.9	7.1											8.9				5.0			0.7			59.6								13.9		0.6
Staples, 2000		1400	19.9	6.1									7.9	9.9					14.9			0.7	3.0		35.6								2.0		0.9
Staples, 2000		1053	7.9	6.0			4.0					1.0	0.5	3.0	6.0				14.9	0.5		0.7	2.0		49.6								4.0		1.5
Staples, 2000		1077	10.9	11.9			4.0					1.0	0.5	3.0	3.0				14.9	0.5		0.7	2.0		39.7								7.9		1.5
Staples, 2000		1178	7.9	6.0			7.9					2.5	0.6	3.0	3.0				9.9	0.5		0.7	2.0		48.1								7.9		0.4
Staples, 2000		1125	11.9	6.0			4.0					1.0	3.0	6.0	3.0				14.9	0.5		0.7	1.0		40.2								7.9		0.8
Staples, 2000		1046	7.9	6.0			4.0					1.0	0.5	3.0	6.0				14.9	1.0		0.7	2.0		49.1								4.0		1.5
Staples, 2000		1120	7.9	6.0			4.0					1.0	0.5	6.0	3.0				14.9	1.0		0.7	2.0		49.1								4.0		1.2
Staples, 2000		1169	7.9	6.0			7.9					1.0	2.0	6.0	3.0				9.9	1.0		0.7	1.0		49.6								4.0		0.5
Staples, 2000		1115	11.9	6.0			4.0					1.1	0.5	3.0	6.0				14.9	0.5		0.7	2.0		41.6								7.9		1.2
Staples, 2000		1058	10.5	11.9			4.0					1.4	0.5	3.0	3.0				14.9	0.5		0.7	2.0		39.7								7.9		1.8
Staples, 2000		1059	11.9	6.0			7.9					1.0	0.5	6.0	5.6				9.9	1.0		0.7	1.0		40.5								7.9		0.8
Staples, 2000		1062	11.9	6.0			7.9					1.0	0.5	6.0	5.8				9.9	0.5		0.5	1.0		40.9								7.9		0.9
Staples, 2000		1169	8.0	6.0			4.0					1.0	0.5	6.0	4.9				9.9	0.5		0.7	1.0		49.6								7.9		0.6
Staples, 2000		1186	9.8	6.0			7.9					2.5	0.5	3.0	3.1				9.9	1.0		0.7	2.0		49.6								4.0		0.6
Staples, 2000		1128	7.9	6.0			7.4					1.0	3.0	6.0	3.0				9.9	1.0		0.7	1.0		49.2								4.0		0.8
Staples, 2000		1068	9.8	9.2			4.9					2.1	2.5	4.4	3.9				11.5	0.7			1.4		43.6								5.8		1.0
Staples, 2000		1162	15.0	15.0											8.5				5.0			0.5			53.1								3.0		1.1
Staples, 2000		1136	3.8	12.5										2.5	6.3				8.8			0.5	1.3		54.0								10.5		3.2
Staples, 2000		1081	9.8	9.1			4.9					2.1	2.5	4.4	3.9				11.5	0.7		0.7	1.4		43.3								5.8		1.1
Staples, 2000		1055	9.8	9.1			4.9					2.1	2.5	4.4	3.9				11.5	0.7		0.7	1.4		43.3								5.8		0.9
Staples, 2000		1081	9.6	8.9			4.8					2.0	2.5	4.3	3.8				11.2	0.7		2.7	1.4		42.4								5.6		1.0
Staples, 2000		1068	9.3	8.6			4.6					2.0	2.4	4.2	3.7				10.9	0.7		0.8	1.4		41.1								5.5		0.8
Staples, 2000		1065	9.6	8.9			4.8					2.0	2.5	4.3	3.8				11.2	0.7		2.7	1.4		42.4								5.6		0.7
Staples, 2000		1071	9.4	8.7			4.7					2.0	2.4	4.2	3.7				11.0	7.1		0.7	1.4		41.6								5.5		0.8
Stempin, 1985	1450		17.7		13.3							4.4				22.2									32.6		9.8								
Stempin, 1985	1450		16.8		12.6					4.2	4.6	4.2				21.0									24.1		9.2								
Stempin, 1985	1450		12.9		12.9					3.9		6.4				17.6									39.7		9.7								
Stempin, 1985	1450		15.8		11.9					2.0		7.8				12.5				0.9					37.5		8.7								
Stempin, 1985	1450		17.5		13.2					0.6	0.3	4.4				21.9				0.6					31.4		9.6								
Stempin, 1985	1450		17.4		13.1					1.1		4.3				21.8									31.2		9.6								
Stempin, 1985	1450		17.2		13.0					4.3		4.3				21.6									30.0		9.5								
Stempin, 1985	1450		17.4		13.1					2.2		4.3				21.8				1.1					30.4		9.6								
Stempin, 1985	1450		17.3		13.0					2.2	0.1	4.3				21.7				0.1					31.5		9.5								
Stempin, 1985	1450		17.6		13.2					1.1		4.4				22.0				0.5					32.0		9.7								
Stempin, 1985	1450		17.5		13.1					2.2		4.4				21.9									31.3		9.6								
Stempin, 1985	1450		17.1		12.8					2.1		4.2				21.4									29.8		9.4								
Taniguchi, 1993		1306	16.9				8.5						9.4	1.8		8.8	0.1		3.5			2.5	0.6		44.8										
Toplis, 1994		1341	10.5				9.4						13.4	0.4		4.0			2.4				9.5		47.4					3.8					
Toplis, 1994		1294	11.4				9.6						14.2	0.5		4.2			3.1				0.1		50.9					4.1					
Toplis, 1994		1315	11.1				8.5						12.6	0.5		3.9			2.9				5.6		50.5					3.4					
Toplis, 1994		1282	11.4				9.6						13.9	0.5		3.9			3.0				2.4		50.7					4.0					
Vienna, 1996	1516	1456	25.0	0.0		1.1	1.0	1.3		0.4		0.3	5.4	0.1	2.3	0.0	0.7	0.0	9.9	1.1	0.1	0.0	0.6		42.0	0.1		5.0					3.5		
Vienna, 1996	1506	1416	18.0	0.0		1.2	1.1	1.5		0.5		0.3	5.9	0.1	2.5	0.0	0.8	0.0	10.9	1.2	0.1	0.0	0.7		46.0	0.1		5.4					3.8		
Vienna, 1996	1457	1363	13.0	0.0		1.3	1.2	1.5		0.5		0.3	6.2	0.1	2.6	0.0	0.8	0.0	11.5	1.3	0.1	0.1	0.7		48.8	0.2		5.7					4.0		
Vienna, 1999		1122	9.6	9.5			0.8			0.1		0.3	7.9	2.8	1.7	0.0	0.3	0.1	17.5	0.2	0.0	0.0	0.4	0.1	44.7	1.3				2.0			0.4		
Vienna, 1999a			4.5	5.0			0.1	0.0						0.4	7.5				14.8			0.9	0.2		52.3								15.0	1005	0.3
Vienna, 1999a			4.5	10.0			0.1	0.0						0.4	7.5				11.0			0.9	0.2		51.1								15.0	1064	0.2
Vienna, 1999a			4.5	10.0			0.1	0.0						0.4	7.5				11.0			0.9	0.2		51.1								15.0	1064	0.3
Vienna, 1999a			4.5	10.0			0.1	0.0						0.4	9.0				7.8			0.9	0.2		52.9								15.0	1140	0.2

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2'	Othl'	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Vienna, 1999a			6.0	15.0			0.1	0.0						0.5	9.0				4.0			0.9	0.2		48.6								16.5	1250	0.2
Vienna, 1999a			6.0	15.0			0.1	0.0						0.5	6.0				10.5			1.0	0.2		45.1								16.5	1189	0.4
Vienna, 1999a			6.0	5.0			0.1	0.0						0.5	9.0				11.6			1.0	0.2		51.0								16.5	1314	nm
Vienna, 1999a			6.0	5.0			0.1	0.0						0.5	6.0				18.1			1.0	0.2		47.5								16.5	1336	0.2
Vienna, 1999a			4.5	10.0			0.1	0.0						0.4	7.5				11.0			0.9	0.2		51.1								15.0	1067	0.2
Vienna, 1999a			3.0	15.0			0.1	0.0						0.5	9.0				3.6			1.0	0.2		51.9								16.5	1228	0.3
Vienna, 1999a			3.0	15.0			0.1	0.0						0.5	6.0				10.1			1.0	0.2		48.4								16.5	1125	0.7
Vienna, 1999a			3.0	5.0			0.1	0.0						0.5	9.0				11.2			0.9	0.2		54.3								16.5	1034	0.3
Vienna, 1999a			4.5	10.0			0.1	0.0						0.4	7.5				11.2			0.8	0.2		52.6								13.5	964	0.3
Vienna, 1999a			3.0	5.0			0.1	0.0						0.5	6.0				17.7			1.0	0.2		50.9								16.5	1113	0.5
Vienna, 1999a			6.0	15.0			0.1	0.0						0.4	9.0				4.3			0.8	0.2		51.4								13.5	1180	0.3
Vienna, 1999a			6.0	15.0			0.1	0.0						0.4	6.0				10.8			0.8	0.2		47.9								13.5	1087	1.0
Vienna, 1999a			6.0	5.0			0.1	0.0						0.4	9.0				11.9			0.8	0.2		53.8								13.5	1003	0.3
Vienna, 1999a			6.0	5.0			0.1	0.0						0.4	6.0				18.4			0.8	0.2		50.4								13.5	1105	0.3
Vienna, 1999a			3.0	15.0			0.1	0.0						0.4	9.0				4.0			0.8	0.2		54.8								13.5	1137	0.4
Vienna, 1999a			3.0	15.0			0.1	0.0						0.4	6.0				10.4			0.8	0.2		51.3								13.5	1070	0.6
Vienna, 1999a			3.0	5.0			0.1	0.0						0.4	9.0				11.5			0.8	0.2		57.2								13.5	1081	0.6
Vienna, 1999a			4.5	10.0			0.1	0.0						0.4	7.5				11.0			0.9	0.2		51.1								15.0	1064	0.2
Vienna, 1999a			3.0	5.0			0.1	0.0						0.4	6.0				18.0			0.8	0.2		53.7								13.5	1059	3.9
Vienna, 1999a			4.5	10.0			0.1	0.0						0.5	7.5				10.8			1.0	0.2		49.7								16.5	1110	0.2
Vienna, 1999a			3.0	10.0			0.1	0.0						0.4	7.5				10.8			0.9	0.2		52.8								15.0	1038	0.3
Vienna, 1999a			6.0	10.0			0.1	0.0						0.4	7.5				11.2			0.9	0.2		49.5								15.0	1085	0.2
Vienna, 1999a			4.5	10.0			0.1	0.0						0.4	7.5				11.0			0.9	0.2		51.1								15.0	1064	0.3
Vienna, 1999a			4.5	15.0			0.1	0.0						0.4	7.5				7.2			0.9	0.2		49.9								15.0	1177	0.4
Vienna, 1999a			4.5	10.0			0.1	0.0						0.4	6.0				14.3			0.9	0.2		49.4								15.0	913	0.3
Vienna, 2000			12.9	5.0	0.9		2.8		0.0	0.2	0.0		12.5	0.3		1.8	0.4		22.1	0.2		0.1	0.9		38.5		0.0					0.0	0.5		
Vienna, 2000			12.1	5.0	0.9		2.6			0.2	0.0		11.7	0.3	2.5	1.7	0.4		18.9	0.2		0.1	0.9		41.3		0.0					0.0	0.4		
Vienna, 2000			9.4	8.3	0.7		2.0		0.0	0.2	0.0		9.1	0.2	4.0	1.3	0.3		14.6	0.1		0.0	0.7		48.1		0.0					0.0	0.3		
Vienna, 2000			16.0	18.5	0.0		0.2			0.2	0.0		8.7		3.5	0.1	0.4		13.2			0.4	1.1		37.0		0.0			0.0		0.0	0.1		
Vienna, 2000			14.4	10.9	0.0		0.2			0.2	0.0		7.8		6.0	0.1	0.4		13.1			0.4	0.9		45.0		0.0			0.0		0.0	0.1		
Vienna, 2000			8.1	10.9	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.8	0.3	1.0	0.6	0.3	0.0	17.3	0.5	0.3	1.0	0.5		41.1	0.2	0.0	0.2		0.0		0.0	1.8		
Vienna, 2000			10.1	7.0	0.5		4.0	0.1	0.2	0.0	0.1	0.1	23.0	0.9	3.0	0.1	0.6	0.0	15.8	0.1	0.5	1.6	0.8	0.3	30.2	0.3	0.1	0.3		0.2		0.1			
Vienna, 2000			11.0	6.8	0.4			0.1	0.1	0.6	0.0	0.1	12.2		2.9	0.6	0.3	0.0	12.7	2.0	0.3	1.1	0.6	0.2	44.9	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			11.0	7.0	0.4			0.1	0.1	0.6	0.0	0.1	12.5		3.0	0.6	0.4	0.0	12.7	0.1	0.3	1.2	0.6	0.2	46.0	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			11.0	6.9	0.4			0.1	0.1	0.1	0.0	0.1	12.3		3.0	0.6	0.4	0.0	12.7	2.0	0.3	1.1	0.6	0.2	45.2	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			11.0	7.1	0.4			0.1	0.1	0.0	0.0	0.1	12.6		3.0	0.6	0.4	0.0	12.7	0.1	0.3	1.2	0.6	0.2	46.4	0.2	0.0	0.2		0.0		0.1	2.4		
Vienna, 2000			11.0	7.1	0.4			0.1	0.1	0.0	0.0	0.1	12.6		3.0	0.6	0.4	0.0	12.7	0.1	0.3	1.2	0.6	0.2	46.4	0.2	0.0	0.2		0.0		0.1	2.4		
Vienna, 2000			11.0	7.0	0.4			0.1	0.1	0.2	0.0	0.1	12.5		3.0	0.6	0.4	0.0	12.7	0.5	0.3	1.2	0.6	0.2	46.0	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			7.8	6.8	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.2	0.3	2.9	0.6	0.4	0.0	15.3	0.5	0.3	0.9	0.5	0.2	44.9	0.2	0.0	0.2		2.5		0.0	1.8		
Vienna, 2000			7.6	6.7	0.3		1.0	0.1	0.1	0.2	0.0	0.1	11.9	0.3	2.9	0.6	0.3	0.0	14.9	0.5	0.3	0.9	0.4	0.2	43.7	0.2	0.0	0.2		5.0		0.0	1.8		
Vienna, 2000			16.0	15.0									5.0	4.0	6.0				10.0	3.0					36.0					5.0					
Vienna, 2000			8.0	6.8	0.4			0.1	0.1	0.6	0.0	0.1	12.2		2.9	0.6	0.3	0.0	15.7	2.0	0.3	1.1	0.6	0.2	44.9	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			8.0	6.8	0.4			0.1	0.1	0.6	0.0	0.1	12.2		2.9	0.6	0.3	0.0	15.7	2.0	0.3	1.1	0.6	0.2	44.9	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			8.0	7.0	0.4			0.1	0.1	0.6	0.0	0.1	12.5		3.0	0.6	0.4	0.0	15.7	0.1	0.3	1.2	0.6	0.2	46.0	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			8.0	6.9	0.4			0.1	0.1	0.1	0.0	0.1	12.3		3.0	0.6	0.4	0.0	15.7	2.0	0.3	1.1	0.6	0.2	45.2	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			8.0	7.1	0.4			0.1	0.1	0.0	0.0	0.1	12.6		3.0	0.6	0.4	0.0	15.7	0.1	0.3	1.2	0.6	0.2	46.4	0.2	0.0	0.2		0.0		0.1	2.4		
Vienna, 2000			8.0	7.1	0.4			0.1	0.1	0.0	0.0	0.1	12.6		3.0	0.6	0.4	0.0	15.7	0.1	0.3	1.2	0.6	0.2	46.4	0.2	0.0	0.2		0.0		0.1	2.4		
Vienna, 2000			8.0	7.0	0.4			0.1	0.1	0.2	0.0	0.1	12.5		3.0	0.6	0.4	0.0	15.7	0.5	0.3	1.2	0.6	0.2	46.0	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			7.8	6.8	0.6		1.0	0.1	0.2	0.2	0.1	0.1	12.1	0.3	2.9	0.6	0.7	0.0	15.3	0.5	0.5	1.7	0.8	0.3	44.7	0.4	0.1	0.3		0.0		0.1	1.8		
Vienna, 2000			8.0	7.0	0.4			0.1	0.1	0.2	0.0	0.1	12.5		3.0	0.6	0.4	0.0	15.7	0.5	0.3	1.2	0.6	0.2	46.0	0.2	0.0	0.2		0.0		0.1	2.3		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Vienna, 2000			8.0	7.0	0.4			0.1	0.1	0.2	0.0	0.1	12.5		3.0	0.6	0.4	0.0	15.7	0.5	0.3	1.2	0.6	0.2	46.0	0.2	0.0	0.2		0.0		0.1	2.3		
Vienna, 2000			10.4	9.1	0.4		1.3	0.1	0.1	0.3	0.0	0.1	16.2	0.4	3.9	0.8	0.5	0.0	20.4	0.7	0.4	1.2	0.6	0.2	30.0	0.2	0.0	0.2		0.0		0.1	2.4		
Vienna, 2000			7.8	6.8	0.3		1.0	0.1	0.1	0.2	0.0	0.1	12.2	0.3	2.9	0.6	0.4	0.0	15.4	0.5	0.3	0.9	0.5	0.2	45.0	0.2	0.0	0.2		0.0		0.0	4.0		
Vojtech, 1996	~1200		16.2	17.1			0.2			4.1		0.0	1.4	0.1	6.7	0.0	0.4	0.1	6.3	0.1	0.1		0.1		48.8	0.1		0.0				0.2	0.0		
Vojtech, 1996	1300		16.2	17.1			0.2			4.1		0.0	1.4	0.1		0.0	0.4	0.1	12.9	0.1	0.1		0.1		46.8	0.1		0.0				0.2	0.0		
Vojtech, 1996	~1250		13.1	17.1			0.2			4.1		0.0	1.4	0.1		0.0	0.4	0.1	16.1	0.1	0.1		0.1		46.8	0.1		0.0				0.2	0.0		
Vojtech, 1996	1150		13.1	17.1			0.2			4.1		0.0	1.4	0.1	6.7	0.0	0.4	0.1	9.4	0.1	0.1		0.1		46.8	0.1		0.0				0.2	0.0		
Vojtech, 1996	1150		10.0	17.1			0.2			4.1		0.0	1.4	0.1		0.0	0.4	0.1	19.2	0.1	0.1		0.1		46.8	0.1		0.0				0.2	0.0		
Vojtech, 1996	~1100		10.0	17.1			0.2			4.1		0.0	1.4	0.1	6.7	0.0	0.4	0.1	12.5	0.1	0.1		0.1		46.8	0.1		0.0				0.2	0.0		
Wiese HEWC Pamela			20.7	21.7			3.9								3.1				8.6			0.8			38.8	0.9				1.6					
Wroniciewicz, 199	1300		3.3				12.9	2.2		1.5			16.2	0.7		0.6			11.2	0.6					27.8					12.9	2.2		7.9		
Wroniciewicz, 199	1400		3.2				6.3	2.2		2.2			39.9	0.7		0.6			0.3	1.1				2.2	16.6					0.4	2.2	22.0			
Wroniciewicz, 199	1500		6.8				4.0			0.0			2.8	1.4		1.3			0.6			20.3			34.8					27.9		0.0	0.0		
Wroniciewicz, 199	1500		27.5				4.1			0.0			2.8	1.5		1.3			0.7			25.2			35.8					0.9		0.0	0.0		
Wroniciewicz, 199	1500		7.0				14.6	2.3		0.0			2.9	1.5		1.3			0.7					2.3	36.2					24.1	2.3	0.0	0.0		
Wroniciewicz, 199	1350		8.1				14.8	2.3		0.0			6.9	1.3		1.1			15.3				16.9		30.3					0.7	2.2	0.0	0.0		
Wroniciewicz, 199	1500		3.2				1.9	2.2		16.0			55.7	0.7		0.6			0.3						16.7					0.4	2.2				
Wroniciewicz, 199	1500		3.2				1.9	2.1					55.8	0.7		0.6			0.3	16.0					16.7					0.4	2.1				
Wroniciewicz, 199	1500		7.7				14.6	1.8		1.5			38.0	0.7		0.7			0.3	0.6				1.8	21.8					5.1	1.8	0.0	3.7		
Wroniciewicz, 199	1500		8.7				15.9	2.0		1.7			41.2	0.8		0.7			0.4	0.8				2.0	23.4					0.5	1.9				
Wroniciewicz, 199	1500		7.5				14.2	1.7		1.4			37.0	0.7		0.6			0.3	0.6				1.7	21.2					11.1	1.7	0.0			
Wroniciewicz, 199	1500		7.5				14.2	1.7		1.4			37.0	0.7		0.6			0.3	0.6				1.7	21.2					11.1	1.7	0.0			
Wroniciewicz, 199	1500		4.0				12.6	1.8		1.4			36.0	0.8		0.8			0.4	0.6				1.8	20.5					10.2	1.8		7.4		
Wroniciewicz, 199	1500		4.0				12.6	1.8		1.4			36.0	0.8		0.8			0.4	0.6				1.8	20.5					10.2	1.8		7.4		
WVNS, 1995			7.1	15.3	0.3		0.5	0.3		0.1			9.7	6.9	2.3	0.9	0.8		5.7	0.3			1.2		40.6	0.2	0.3		4.5	0.8	1.2	0.3	1.3		
WVNS, 1995			7.1	10.4	0.3		0.5	0.3		0.1			14.3	6.9	5.1	0.9	0.8		8.8	0.3			1.2		36.9	0.2	0.3		2.7	0.8	1.2	0.3	1.3		
WVNS, 1995			7.7	16.6	0.3		0.5	0.3		0.1			15.5	3.1	2.3	0.9	0.8		5.7	0.3			1.2		39.5	0.2	0.3		1.8	0.8	1.2	0.3	1.3		
WVNS, 1995			7.7	16.6	0.3		0.5	0.3		0.1			8.6	6.9	5.1	0.9	0.8		10.3	0.3			1.2		35.3	0.2	0.3		1.8	0.8	1.2	0.3	1.3		
WVNS, 1995			7.7	9.2	0.3		0.5	0.3		0.1			8.6	3.1	4.3	0.9	0.8		10.3	0.3			1.2		47.1	0.2	0.3		1.8	0.8	1.2	0.3	1.3		
WVNS, 1995			7.7	9.2	0.3		0.5	0.3		0.1			8.6	6.9	2.3	0.9	0.8		5.7	0.3			1.2		46.4	0.2	0.3		5.3	0.8	1.2	0.3	1.3		
WVNS, 1995			7.7	9.2	0.3		0.5	0.3		0.1			15.5	6.9	2.5	0.9	0.8		10.3	0.3			1.2		34.8	0.2	0.3		5.3	0.8	1.2	0.3	1.3		
WVNS, 1995			7.4	9.0	0.3		0.5	0.3		0.1			6.6	6.0	2.8	0.9	0.8		8.4	0.3			1.2		47.7	0.2	0.3		4.8	0.8	1.2	0.3	0.7		
WVNS, 1995			7.4	7.1	0.3		0.5	0.3		0.1			17.4	5.9	4.0	0.9	0.8		5.2	0.3			1.2		43.0	0.2	0.3		2.7	0.8	1.2	0.3	0.7		
WVNS, 1995			7.7	7.1	0.3		0.5	0.3		0.1			17.4	4.2	4.7	0.9	0.8		6.0	0.3			1.2		39.3	0.2	0.3		5.2	0.8	1.2	0.3	1.9		
Yamagishi, 1985	1350													5.8							26.3			16.1	46.6							4.2	0.9		
Yamagishi, 1985	1250			10.6															6.7		41.5				38.5							2.7			
Yamagishi, 1985	1300													11.1							34.8				36.9							16.7	0.5		
Yamagishi, 1985	1250			15.0															14.9		21.5				45.6							3.1			
Yamagishi, 1985	1400													17.7		6.7					35.2				39.9								0.5		
Yamagishi, 1985	1250																		9.3		42.4				44.2							4.1			
Yamagishi, 1985	1400																				41.2				35.0							23.3	0.4		
Yamagishi, 1985	1300			0.7										11.3							30.9				31.2							25.4	0.5		
Yamagishi, 1985	1250																		5.8		39.7	20.7			22.4							11.0	0.4		
Yamagishi, 1985	1300													2.7							54.8				29.1							13.1	0.4		
Yamagishi, 1985	1300													6.0							46.4				35.6					10.9			0.4		
Yamagishi, 1985	1400		1.0	1.4										9.4							40.1				41.2							6.5	0.5		
Yamagishi, 1985	1250																				74.8				25.0								0.2		
Yamagishi, 1985	1350		4.7											8.8							39.6				28.0							18.9			
Yamagishi, 1985	1250			4.8	26.6									8.2							33.2				26.1								1.2		

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Oth1 '	P2O5	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Yamagishi, 1985	1350													11.2							30.9				36.2		8.6					12.7	0.5		
Yamagishi, 1985	1300													10.7							35.8	4.0			35.8					4.8		8.9			
Yamagishi, 1985	1250						3.8							9.6					4.2		41.1				29.1							11.8	0.4		
Yamagishi, 1985	1300													16.8		6.3					33.1				37.5					5.8			0.5		
Yamagishi, 1985	1250			3.0										2.4	1.8	1.7					47.4	2.3			29.4			8.4				3.5			
Yamagishi, 1985	1200		2.2	11.2		19.8								24.0							10.8				26.0							5.5	0.4		
Yan, 2001		1277	15.2				9.4						17.1	1.4		7.8			2.8			0.9			45.5										
Yan, 2001		1282	15.7				8.5						17.0	0.6		7.1			1.6			1.1			48.0					0.4					
Yan, 2001		1230	15.7				12.5						17.0	0.7		8.0			1.6			0.6			44.0										
Yee, 1955		1112	6.6	23.5					0.6								1.7		21.7						46.0										
Yee, 1955		1004	6.0	23.6					0.5			7.2					1.5		20.8						38.9										
Yee, 1955		1065	4.2	24.9					0.5			5.1					1.5		18.7	0.5					43.5										
Yee, 1955		957	4.2	24.8					0.5			10.2					1.5		19.8	0.5					36.3										
Yee, 1955		1032	4.4	25.5					0.5			6.1					1.5		19.1	0.5					41.1										
Yee, 1955		965	5.4	25.5	8.2				0.5			5.1					1.5		19.0	0.5					33.3										
Yee, 1955		1089	6.5	23.2					0.6			1.0					1.7		21.5						45.5										
Yee, 1955		1057	6.4	22.8					0.5			3.0					1.6		21.0						44.6										
Yee, 1955		1031	6.3	22.3					0.5			4.9					1.6		20.7						43.7										
Yee, 1955		1022	6.2	22.1					0.5			5.7					1.6		20.5						43.3										
Yee, 1955		1007	6.1	21.9					0.5			6.9					1.6		20.2						42.8										
Yee, 1955		994	6.1	21.6					0.5			8.1					1.6		19.9						42.2										
Yee, 1955		972	5.9	21.1					0.5			10.3					1.5		19.5						41.2										
Yee, 1955		995	5.7	22.5					0.5			6.9	4.5				1.5		19.8						37.1										
Yee, 1955		1001	5.5	21.6					0.5			6.6	8.3				1.4		19.0						35.6										
Yee, 1955		997	5.3	20.9					0.5			6.4	11.5				1.4		18.4						34.4										
Yee, 1955		995	5.2	20.2					0.4			6.2	14.3				1.3		17.8						33.3										
Yee, 1955		1010	5.5	21.7					0.5			5.6					1.4		19.1						35.7										
Yee, 1955		1046	5.4	21.0					0.5			6.2					1.4		18.5						34.7										
Yee, 1955		1001	3.7	22.5	2.5				0.2			5.6					0.7		10.3						41.8										
Yoshida, 1993	~1300		2.0	24.0	5.0		5.0							6.0					2.0						49.0			2.0					5.0		
Yoshida, 1993	~1300		1.5	22.0	5.0									6.0					4.0						45.5			5.0				7.0	4.0		
Yoshida, 1993	~1300		2.0	21.0	4.5									5.0					3.0						50.0			5.0				4.5	5.0		
Yoshida, 1993	~1300		3.0	29.0	7.0									5.0					2.0						40.0			2.0				7.0	5.0		
Yoshida, 1993	~1300		6.0	38.0										2.0	2.0				2.0						37.0			5.0				8.0			
Yoshida, 1993	~1300		2.0	24.0	5.0									6.0					2.0						49.0		5.0	2.0					5.0		
Yoshida, 1993	~1300		2.5	22.5	4.5	13.0								5.0					2.5						39.0			2.0				4.5	4.5		
Yoshida, 1993	~1300		3.0	26.0	5.0									6.0					3.0						45.0			2.0				5.0	5.0		
Zubekhin, 1993	≤1260		20.2				18.2						4.0	6.4		3.2	2.0		5.6						40.3										
Zubekhin, 1993	≤1260		20.2				22.2						4.0	6.4		3.2	2.0		5.6						36.3										
Zubekhin, 1993	≤1260		24.2				18.2						4.0	6.4		3.2	2.0		5.6						36.3										
Zubekhin, 1993	>1260		20.2				30.2						4.0	6.4		3.2	2.0		5.6						28.2										
Zubekhin, 1993	≤1260		28.2				22.2						4.0	6.4		3.2	2.0		5.6						28.2										
Zubekhin, 1993	≤1260		36.3				14.1						4.0	6.4		3.2	2.0		5.6						28.2										
Zubekhin, 1993	>>1260		20.2				38.3						4.0	6.4		3.2	2.0		5.6						20.2										
Zubekhin, 1993	>1260		28.2				30.2						4.0	6.4		3.2	2.0		5.6						20.2										
Zubekhin, 1993	≤1260		36.3				22.2						4.0	6.4		3.2	2.0		5.6						20.2										
Zubekhin, 1993	>1260		44.3				14.1						4.0	6.4		3.2	2.0		5.6						20.2										
Zubekhin, 1993	>>1260		20.2				46.4						4.0	6.4		3.2	2.0		5.6						12.1										
Zubekhin, 1993	>>1260		28.2				38.3						4.0	6.4		3.2	2.0		5.6						12.1										

Table A1. Glass Compositions from Literature Review (continued)

Ref	T melt, C	T (100 p) C	Al2O3	B2O3	BaO	Bi2O3	CaO	Ce2O3, CeO2	CoO, Co2O3	Cr2O3	CuO	F	Fe2O3, Fe3O4	K2O	Li2O	MgO	MnO2	MoO3	Na2O	NiO	Oth2 '	Othl '	P205	PbO	SiO2	SO3	SrO	RE Oxides	ThO2	TiO2	UO2, U3O8	ZnO	ZrO2	TL(C)	NL [B(g/L)]
Zubekhin, 1993	>>1260		36.3				30.2						4.0	6.4		3.2	2.0		5.6						12.1										
Zubekhin, 1993	>>1260		44.3				22.2						4.0	6.4		3.2	2.0		5.6						12.1										
Zubekhin, 1993	>>1260		52.4				14.1						4.0	6.4		3.2	2.0		5.6						12.1										
Zubekhin, 1993	>1260		12.6				10.9						3.4	5.4		2.7	1.7		4.7						58.7										
Zubekhin, 1993	>1260		21.0				10.9						3.4	5.4		2.7	1.7		4.7						50.3										
Zubekhin, 1993	>1260		12.6				27.7						3.4	5.4		2.7	1.7		4.7						41.9										
Zubekhin, 1993	≤1260		29.4				10.9						3.4	5.4		2.7	1.7		4.7						41.9										
Zubekhin, 1993	≤1260		12.6				31.9						3.4	5.4		2.7	1.7		4.7						37.8										
Zubekhin, 1993	≤1260		33.6				10.9						3.4	5.4		2.7	1.7		4.7						37.8										
Zubekhin, 1993	>1260		13.5				36.0						3.6	5.8		2.9	1.8		5.0						31.5										
Zubekhin, 1993	>>1260		41.9				10.9						3.4	5.4		2.7	1.7		4.7						29.4										
Zubekhin, 1993	>1260		12.6				19.3						3.4	5.4		2.7	1.7		4.7						50.3										