Compilation and Management of ORP Glass Formulation Database, VSL-12R2470-1, Rev. 0

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

**P.O. Box 450
Richland, Washington 99352**

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Date Published

September 2012

Prepared for the U.S. Department of Energy
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The logo for the Office of River Protection features the text "Office of River Protection" in a bold, sans-serif font. The text is white and is set against a dark, wavy, brush-stroke-like background that resembles a river or a stylized wave.

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VSL-12R2470-1

Final Report

Compilation and Management of ORP Glass Formulation Database

prepared by

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Richland, WA**

September 17, 2012

Rev. 0, 9/27/12

Document Title: Compilation and Management of Glass Formulation Database

**Document Number
and Revision:** VSL-12R2470-1, Rev. 0

Issue Date: 09/27/2012

Performing Organizations: Vitreous State Laboratory, The Catholic University of America

Test Plan: Compilation and Management of Glass Formulation Database,
VSL-11T2470-1, Rev. 0

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

ANL-LRM	Argonne National Laboratory – Low Activity Reference Material
ASTM	American Society for Testing and Materials
BNI	Bechtel National, Inc.
CCC	Canister Centerline Cooling
CUA	The Catholic University of America
DCP-AES	Direct Current Plasma Atomic Emission Spectroscopy
DOE	Department of Energy
DWPF	Defense Waste Processing Facility
EC	Electrical Conductivity
HLP	Hanford LAW Product
HLW	High Level Waste
ICV	In-Container Vitrification
ID	Identification
IHLW	Immobilized High Level Waste
ILAW	Immobilized Low Activity Waste
LAW	Low Activity Waste
NIST	National Institute of Standards and Technology
ORP	Office of River Protection
PCT	Product Consistency Test
PNNL	Pacific Northwest National Laboratory
QA	Quality Assurance
QARD	Office of Civilian Waste Management Quality Assurance Requirements and Description
RPM	Revolutions Per Minute
RPP	River Protection Project
RSD	Relative Standard Deviation
SEM	Scanning Electron Microscopy
SEM/EDS	Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy
SRL-EA	Savannah River Laboratory-Environmental Assessment (Glass)
STL	Severn Trent Laboratories
TCLP	Toxicity Characteristic Leaching Procedure
VHT	Vapor Hydration Test
VSL	Vitreous State Laboratory
WTP	Hanford Tank Waste Treatment and Immobilization Plant
XRF	X-Ray Fluorescence

SECTION 1.0 INTRODUCTION

1.1 Background

About 50 million gallons of high-level mixed waste is currently stored in underground tanks at the United States Department of Energy's (DOE's) Hanford site in the State of Washington. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) will provide DOE's Office of River Protection (ORP) with a means of treating this waste by vitrification for subsequent disposal. The tank waste will be separated into low- and high-activity waste fractions, which will then be vitrified respectively into Immobilized Low Activity Waste (ILAW) and Immobilized High Level Waste (IHLW) products. The ILAW product will be disposed in an engineered facility on the Hanford site while the IHLW product is designed for acceptance into a national geological disposal facility for high-level nuclear waste.

The ILAW and IHLW products must meet a variety of requirements with respect to protection of the environment before they can be accepted for disposal. Glass property-composition models will be used to control the vitrification process at the WTP to ensure that the glass meets product quality and processability requirements. The quality and the validity ranges of the property-composition models and the supporting data base will greatly influence waste treatment operations, including the waste loading that is achievable in the glass for each waste composition. The current baseline models for operation of the WTP were developed under the BNI WTP contract [1 - 4]. These models were based on LAW and HLW glass property data over a range of compositions that was guided primarily by the WTP contract and the specific set of tanks specified therein. While these models should be adequate for commissioning of the facility and processing of the specified tanks, it is likely that refinements and extensions or augmentations of these models will be required to process the balance of the tank waste inventory. Furthermore, the WTP contract includes requirements for minimum waste loadings that are generally rather modest, such that significantly higher loadings than those in the current baseline are likely achievable. However, in order to achieve these higher waste loadings, new models will be required to support the optimized operation of the WTP.

Since the development of the baseline WTP models, ORP has directed a program of work to examine various approaches for optimization of the performance of the WTP, including increasing the waste loadings in the LAW and HLW glass products [5 - 20]. As a result, a significant amount of new data has been collected that can be used for improvement of the baseline models. Inclusion of the new data in the development of new property-composition models will be beneficial in expanding the composition ranges over which they are valid and the quality of the models. A first step in this process is the collection of the relevant data in a database and maintenance of that database as additional data are collected. As was the case with the baseline WTP models [1 - 4], the data must meet the necessary quality assurance requirements if they are to support models that can be used in the WTP facility.

Results from ILAW glass testing and baseline model development were presented in 2007 [1]. That report describes the data, model development, model validation, and model uncertainty results for each of the glass properties which the WTP plans to control using glass property models. LAW models were developed for Product Consistency Test (PCT) responses, Vapor Hydration Test (VHT) response, melt viscosity, and melt electrical conductivity. The VHT model was subsequently expanded and the results were presented in 2008 [2].

For the IHLW product, the collection of data and development of the baseline models are described in a series of reports, culminating in a final report that summarizes the models developed for the WTP HLW glasses [3]. The models developed were intended for use in predicting PCT responses, one-percent crystal fraction temperature ($T_{1\%}$) for spinel phase, viscosity, and electrical conductivity. A fifth HLW property-composition model was developed for cadmium release in the Toxicity Characteristic Leaching Procedure (TCLP) to support compliance with delisting requirements [4]. The compositional ranges of the HLW glasses included for model development are discussed together with the performance of the models [3, 4]. It was anticipated that the baseline models would need to be augmented in the future if significant changes in the compositions of the waste streams and target glass compositions occur. It was further recognized that additional work would be required if the model validity constraints are too restrictive compared to the desired operating envelope or the model prediction uncertainties are too high for the desired applications.

As noted above, ORP is investigating optimization of the WTP, which includes increasing the glass waste loadings while maintaining acceptable properties with respect to processing and product quality. In that work, new higher-loading LAW formulations were developed that meet all of the WTP contract requirements [5-12]. However, these formulations fall outside the range of the current baseline WTP property-composition models.

Recent ORP efforts to enhance the WTP HLW vitrification system have centered on higher waste loadings and increased processing rates [13-20]. Development and testing at VSL was directed towards maximizing the waste loadings in HLW glasses for waste streams that were different from those specified in the WTP contract, which are primarily iron-limited. Four disparate waste streams that contain high concentrations of bismuth, chromium, aluminum, and aluminum plus sodium were specified by ORP for that work [14]. Glass formulations that meet all processing and product quality requirements for each of those four waste streams were developed with waste loadings of 40 to 50 wt% that exceed the WTP contract minimums by wide margins. These and subsequent HLW glass formulations greatly expanded the compositional region from the WTP baseline development work. For example, an HLW glass that incorporates 6.71 wt% of Bi_2O_3 was developed and processed in melter tests [14], compared to a range of 0.01-0.3 wt% Bi_2O_3 used to develop the HLW property-composition models [3]. Thus, the new data provide a natural basis on which to augment and extend the HLW property-composition models.

The present report describes the first steps in the development of a glass property-composition database for WTP LAW and HLW glasses that includes all of the data that were

used in the development of the WTP baseline models and all of the data collected subsequently as part of WTP enhancement studies performed for ORP. The data were reviewed to identify some of the more significant gaps in the composition space that will need to be filled to support waste processing at Hanford. The WTP baseline models have been evaluated against the new data in terms of range of validity and prediction performance. The results from this work will be used as a guide for the collection of additional data and the development of improved and extended models in future work.

1.2 Objectives

The objectives of this work were as follows:

- Compile a database of PCT and VHT responses and compositions of WTP LAW glasses. Data on glasses before and after heat treatments should be included, where available, and the heat treatment used specified. The database should also include data for melt viscosity and electrical conductivity of WTP LAW glasses.
- Compile a database of PCT responses and TCLP Cd response and compositions of WTP HLW glasses. Data on glasses before and after heat treatments should be included, where available, and the heat treatment used specified. The database should also include data for melt viscosity, electrical conductivity, one-percent crystal fraction temperature ($T_{1\%}$), and nepheline formation on canister centerline cooling heat treatment of WTP HLW glasses.
- Assess the performance and limitations of existing WTP baseline models over the wider data sets, including data on higher waste loading glasses developed for ORP.
- Assess the distribution of data over the LAW and HLW composition spaces and identify data gaps and composition regions over which additional information would be desirable.
- Initiate work on the development of extended models appropriate for the larger data sets.

SECTION 2.0 LAW GLASSES

The WTP databases used in the development of earlier LAW glass property-composition models (PCT, VHT, electrical conductivity, and viscosity) include data from statistically designed¹ composition matrices to cover the LAW glass composition regions of interest as well as data from actively designed glass formulations that were developed with the objective of meeting the desired glass properties. Data for two hundred and sixty four glasses were collected in the WTP database. These glasses were prepared in crucible melts, collected during melter tests of various scales, and made from actual LAW samples.

The additional data set, which is presented in this section, consists of two hundred and seven glasses (referred to as ORP-LAW glasses), which nearly doubles the total number of LAW glasses. All of the new glasses were actively designed since they were developed for ORP with the objective of exploring the extent to which waste loadings could be increased over the WTP baseline. Table 2.1 provides a comparison of the number of glasses and composition ranges for the WTP baseline datasets and the ORP-LAW datasets for each of the glass properties.

Tables 2.2 and 2.3 provide the target compositions of the ORP-LAW glasses for the main glass constituents and the minor components, respectively. Compositions normalized to 100% with XRF measured SO₃ values are given in Tables 2.4. In these tables, the data structure follows that used for the WTP baseline data [1], using major glass components as design variables while an “Others” component comprises all remaining minor glass components. However, there are two additions to the major components in the ORP-LAW compositions because tin oxide and vanadium oxide were constituents in many of those glasses but were not present in any of the baseline glasses. Tin oxide was added to improve VHT performance, especially at high sodium concentrations [21-23] while vanadium oxide was added to improve sulfate incorporation [6-12, 24-31].

The following sections describe the various studies from which the ORP-LAW glass data were generated and provide references to the corresponding development reports and/or melter testing reports. The property data that were collected from each set of glasses are also identified.

2.1 LAWA, LAWB and LAWC Glasses to Improve Sulfate Loading

Efforts to improve sulfate loading in glasses for LAW Envelopes A, B and C (focusing on tank waste compositions for AN-105, AZ-102 and AN-102, respectively) between 2004 and

¹ “Statistically designed” refers to a set of glass compositions designed using statistical experimental design methods to cover a composition space. “Actively designed” refers to glasses developed to meet certain specified requirements such as a glass composition to treat a LAW tank waste stream that has to meet all product quality and processing requirements. In this approach, information from characterization of one set of glasses is used to guide formulation of future glass compositions, with little or no intent to cover a composition space.

2006 led to the formulation and testing of the first fifty four glasses included in the current dataset. These studies [7-9] also introduced vanadium oxide, in the range of 0.94 to 2.00 wt%, as a new glass former additive based on previous work which had suggested its beneficial effects on improving sulfate incorporation [6-12, 24-31]. Small additions of chromium oxide (0.5 wt%) were also made in an effort to limit K-3 refractory corrosion in these formulations since the refractory corrosion rate increases as the sodium content in the glass is increased with increased waste loading.

This dataset also includes eight glasses from melter tests that were conducted on the DM100 melter system:

- WVW-G-11A (near replicate of crucible melt LAWA161), EWV-G-89B, EWV-G-93B and EWV-G-108B (based on LAWA187), DWV-G-123C (based on LAWB99), and WVY-G-95A (based on LAWC100).
- EWV89BCCC and EWV93BCCC are samples from the melter tests above that were heat-treated according to the LAW CCC temperature profile.

Several replicates are also included in the dataset for PCT (four replicates of melter glass WVY-G-95A) and VHT (LAWA161 and LAWA187 duplicate tests). Discussion of these and all other replicates is provided in Section 5. LAWC100R1 is a full replicate sample of glass formulation LAWC100 for which the chemical composition revealed an unacceptable deviation from target; for this reason, LAWC100R1 is included in the dataset and LAWC100 is discarded. Compositions of the replicates and near-replicates are compared in Table 2.5.

2.2 ORP-LAW Glasses Designed to Improve Overall Waste Loading

This group consists of 153 LAW glasses developed and tested at VSL for ORP from 2007 to 2010, as described below. The waste compositions covered in these tests include the range of Na and S concentrations expected in Hanford LAW. For convenience, the LAW compositions were divided into regions labeled Region A to Region F, with Region A being the high Na, low S end of the LAW compositions, Region F being the low Na, high S end, and the rest in between. In addition, LAW with high Na and K was labeled Region G.

Forty glasses in this set were tested to support the development of glass formulations for tank waste AN-105 [10-12], for which the primary source of tank waste compositional data was that given in a WTP Test Specification [32] and included a 2.5 % increase in sodium concentration to account for sodium additions in pretreatment [33]. The primary objective of this effort was to develop glass formulations that could accommodate significantly higher concentrations of Na₂O. Based on the waste composition, high sulfate loading in the glass was not a primary objective for these glass formulations. The work was later expanded to increase loading of sulfate as well as sodium, thus expanding the applicability of these formulations to a broader range of tank wastes. The glass formulations for this region (Region A) range from about 0.3 wt% SO₃ and 25 wt% Na₂O to 1 wt% SO₃ and 25 wt% Na₂O. The nominal composition of

LAW from tank AN-105 has a SO_4/Na molar ratio of 3.0×10^{-3} , which equates to an SO_3 concentration of 0.18 wt% at a Na_2O loading of 24.0 wt%; however, the glasses developed for ORP in this dataset could accommodate up to 1 wt% SO_3 at 24.0 wt% Na_2O loading. It can therefore be used to treat any LAW AN-105 type streams with SO_4/Na ratios of up to 1.36×10^{-2} . These formulations also included additions of chromium (up to 0.5 wt% Cr_2O_3) and tin (up to 5 wt% SnO_2) as new glass former additives, as well as higher concentrations of zirconium (up to 6 wt% ZrO_2). Moderate amounts of vanadium (less than 1 wt% V_2O_5) were also tested in these glasses. Three glass formulations from Region A were selected and used in subsequent DM10 melter tests. Glass samples from the melter tests include R10-G-155A (partial replicate of ORPLA15), Y10-G-146C (ORPLA20) and J10-G-24B (ORPLA38-1).

Eighteen glasses identified as ORPLB1 to ORPLB4, ORPLC1 to ORPLC5, and ORPLD1 to ORPLD9 were formulated using similar strategies to address waste streams with increasing concentrations of sulfate. These apply to waste from tanks such as AN-107, AN-104, and AN-102 in which the SO_4/Na ratios may be as high as to 2.11×10^{-2} . In these formulations, sodium varies from 21 to 25 wt%, while SO_3 ranges from 0.5 to 1.2 wt%. In view of the higher sulfate levels, additions of vanadium in the range of 1 to 2 wt% V_2O_5 were used. Five DM10 melter glasses based on these formulations were subjected to PCT and VHT: S10-G-45A (ORPLB4), S10-G-101B (ORPLC5), T10-G-16A (ORPLD1), Z10-G-60C and 10A-G-53C (ORPLD6).

Since increased sulfate incorporation was the primary objective for these formulations, the specific effect of increased sulfate on VHT alteration rate was assessed through 29 near-replicate glasses remelted with an excess of sodium sulfate: this excess amounts to 4 wt% SO_3 if all of it were retained in the glass. Such glasses were prepared for ORPLA, ORPLB, ORPLC, and ORPLD series of glasses and are identified with an S4 at the end of the sample name. Discussion of these samples as near-replicates is provided in Section 5.

Further increase in sulfate to the maximum levels expected in LAW streams is reflected in the twenty six formulations ORPLE1 to ORPLE12 and ORPLF1 to ORPLF14, for LAW from tanks AZ-101 and AZ-102, respectively. To accommodate wastes in which SO_4/Na ratios may be as high as 4.85×10^{-2} , the glasses were formulated at lower waste loadings, corresponding to sodium contents ranging from 11 to 20 wt% and with the addition of lithium (up to 5 wt% Li_2O) to improve sulfate incorporation. Some of these formulations were also produced in DM10 melter tests and subjected to PCT and VHT: Q10-G-134A (ORPLE12), Z10-G-122B (ORLF7-low SO_3), and Z10-G-153B (ORLF7-high SO_3).

Region G glass formulation development was focused on LAW for which the primary challenge is the combined effect of both high sodium and potassium, as is the case for AP-101 (71.67 wt% Na_2O + 19.61 wt% K_2O on a waste oxide basis). Twenty nine glasses were formulated in which waste loading was varied such that Na_2O loadings in the glasses increased from 18.5 wt% to 21.5 wt% (and K_2O from 5 to 5.75 wt%). Iron oxide was eliminated from the additives blend to make room for additional tin oxide and zirconia, with ZrO_2 + SnO_2 exceeding 10 wt%. Two glass samples produced in DM10 tests from these formulations are 10A-G-43B and I10-G-135A. The glass samples from the melter runs were subjected to PCT and VHT and

the results are compared with those from the crucible melts of the same target formulations (ORPLG9 and ORPLG27) in Section 5.

2.3 Summary of ORP-LAW Glasses Added for Property Modeling

Of the 207 ORP-LAW glasses, 171 have PCT data, 203 have VHT data, and 122 have viscosity and electrical conductivity data, as summarized in Table 2.1. In comparison to the WTP datasets on which the baseline models were designed, these additional datasets represent an increase of 70%, 123%, and 31% for the PCT, VHT and Viscosity-EC models, respectively. As shown in Figure 2.1 and Table 2.1, the additional data expand the compositional range for Al_2O_3 , CaO , MgO , Na_2O , SiO_2 , SO_3 and ZrO_2 and introduce the new components V_2O_5 and SnO_2 . Iron is generally much lower in the ORP data set, with a median value of 0.9 wt% Fe_2O_3 to allow for the increases made in other constituents (both glass formers and waste loading). It is also noted that the broadening of the compositional space may also allow adding back some of the twenty compositions that were identified as outliers in the WTP LAW glass dataset that was used to generate the baseline models [1].

SECTION 3.0 HLW GLASSES

This section describes the HLW property-composition database that has been compiled. Section 3.1 describes the structure of the database and the glass properties incorporated into the database. Section 3.2 summarizes the sources of the data. Section 6 provides an assessment of the compiled data to determine the performance of the baseline WTP models against the new data and to identify significant data gaps in the new combined data set.

3.1 HLW Property-Composition Database

The baseline WTP glass property models were developed to predict PCT responses (PCT-boron [PCT-B], PCT-sodium [PCT-Na], and PCT-lithium [PCT-Li] releases), spinel $T_{1\%}$, electrical conductivity, viscosity [3], and Cd release on TCLP [34]. The database used in the development of these models included all HLW data collected under the WTP project since 1998 that satisfy the applicable quality assurance (QA) requirements. Some of the model development data were from statistically designed composition matrices to cover the HLW glass composition regions of interest. Other data were from actively designed glass formulations to develop glass compositions with desired properties. Glasses made during melter tests were not included in the modeling datasets because the composition regions represented by the melter test glasses were generally covered by the data from small-scale crucible tests of glasses with similar compositions on which the melter tests were based. References [3] and [4] provide a discussion of the data collected of the WTP HLW glasses, model development, and validation data. This section provides the identifications and target compositions of ORP HLW glasses in the new database.

The data on the ORP HLW glasses in the current database were collected primarily at VSL and reported between the years 2006 and 2012. All of these glasses were actively designed, prepared in crucible melts, and meet all the applicable QA requirements. In addition to the five properties listed above, data on nepheline formation upon canister centerline cooling (CCC) were also compiled. Earlier efforts in developing WTP baseline models did not include a property-composition model for nepheline formation. The currently planned approach to control nepheline formation at WTP is the same as that employed at the Defense Waste Processing Facility (DWPF), which is based on the nepheline discriminator developed by Li et al [35, 36]. Testing has shown the present nepheline discriminator to be quite conservative, thereby limiting the ability to achieve high waste loadings with high aluminum waste streams [14, 16, 19]. The compiled data will be used to support the development of an improved nepheline discriminator.

Compilation of the current HLW database followed a similar approach and adopted a similar format as those used for the WTP database [3]. The database was compiled in

Microsoft® Excel spreadsheets that included glass identification (ID), glass composition, and the glass property data collected. Organization of the database is described as follows:

- *Glass Identification.* Each glass is identified with a unique ID, which also distinguishes the different groups of data by the study names. References to the corresponding study reports are provided. The glass ID is associated with the glass formulation and not the crucible preparation of the glass; properties data may have been collected using glass samples from different crucible preparations (of the same target composition).
- *Glass Composition.* Target glass compositions are given in wt% for the 57 glass components. The list of components used was the same as that used in the WTP model development database. Moreover, the oxide forms from the WTP database were retained for consistency (e.g., Ce_2O_3 instead of CeO_2). For glasses formulated with different oxide forms, a conversion was performed before their inclusion in the database.
- *PCT Releases.* Data for PCT are included for boron, lithium, and sodium releases. Elemental concentrations in the leachate (in ppm) are given for PCT-B, PCT-Li, and PCT-Na together with the normalized concentrations (g/L) and normalized mass loss (g/m^2). The normalization calculation was performed with target glass compositions.
- *Crystallinity and $T_{1\%}$.* Heat treatment of HLW glasses was conducted between 750°C and 1150°C at regular intervals of 50°C. The measured crystal vol% data for the heat-treated glasses are tabulated in the database. Linear regression of the data resulted in estimates of $T_{1\%}$, which are given together with the regression coefficients (slope and intercept). The dataset also includes information on the major crystalline phase(s) at $T_{1\%}$.
- *Viscosity and Electrical Conductivity.* The measured viscosity and electrical conductivity values of HLW glasses are given in poise (P) and siemens per centimeter (S/cm), respectively, together with the measurement temperature. With a few exceptions, the datasets include for each glass the viscosity and electrical conductivity values collected at four different temperatures in the range of 950°C to 1250°C. The measured data were fitted to the Vogel-Fulcher equation to give interpolated values at standard temperatures (e.g., 1150°C). The fitted data, however, are not part of the datasets.
- *TCLP Cd Release.* The measured TCLP Cd releases (c_{Cd} , mg/L) and normalized TCLP Cd releases (r_{Cd} , g/L) are given in the database. The earlier database included normalized releases to facilitate investigation of model forms that involve r_{Cd} [34]. The included TCLP data are limited to only glasses with CdO as a target component.
- *Nepheline Formation upon CCC.* The CCC heat treatment was performed on HLW glasses to simulate the cooling profile of the glass in the center of a canister after glass pouring. The CCC cooling profile was provided by the WTP project (see Section 4). The compiled database includes identity information on the crystalline phase(s) and estimates of vol% crystallinity of the CCC heat-treated glasses.

3.2 HLW Property-Composition Data Sets

Data on HLW glasses in the new database were collected primarily at VSL and reported between the years 2006 and 2012. Some data on nepheline formation were collected at PNNL using glasses supplied or formulated by VSL. This section summarizes the sources of the new data and the objectives of the studies that supplied the data. Table 3.1 provides a summary of these glass studies and the number of glasses included in the current dataset.

HLW Glasses for Enhanced AZ-102 Melter Testing (Reference [37])

Glass formulations (INEL- series of glasses) were developed and tested for two different compositions projected for Hanford AZ-102 waste; both projected waste compositions were high in iron. The test objective was to determine the increase in waste loading and glass production rates that were made possible primarily by adopting higher processing temperatures (up to 1225°C) and by relaxing the crystallization constraint (up to 3 vol%). The resulting glasses tested therefore had considerably higher waste loadings and Fe₂O₃ contents than those in the WTP glasses.

Enhanced HLW Glass Formulations for Vitrification System Improvements (Reference [14])

The principal objective of this work was to investigate maximizing the incorporation of several waste components expected to limit waste loadings and, consequently, HLW processing rates. Four waste compositions specified by ORP were the target waste streams for development of new HLW glasses; these wastes contained high concentrations of bismuth, chromium, aluminum, and aluminum plus sodium. Glass formulations that meet all processing and product quality requirements for each of the four waste streams were developed with waste loadings approaching or meeting the maximum levels specified by ORP. The series of glasses were designated as HLW-E-Bi, HLW-E-Cr, HLW-E-Al, and HLW-E-ANa, respectively, for the four different waste groups.

Extreme HLW Glasses (Reference [38])

A series of HLW (HLW-ALG) glasses was developed to support melter tests designed to evaluate the effects of glass property and composition extremes on glass processing characteristics and production rate. The extremes evaluated included glass viscosity, electrical conductivity, T_{1%}, and minimum and maximum concentrations of major and minor glass components. The effects of +/- 15% batching errors in addition of glass forming additives were also assessed. Glass compositions with predicted maximum SrO and ZrO₂ were also tested; these glass compositions were derived from calculations using the preliminary IHLW formulation algorithm and projected waste compositions with high concentrations of zirconium and strontium.

HLW Glasses for Bismuth Phosphate Wastes (Reference [39])

This study addressed the need to develop and test new HLW glass formulations for the waste streams that resulted from blending of bismuth phosphate waste with wastes from the

WTP tanks of AZ-101, AZ-102, or C-104. Dynamic flowsheet modeling runs using the Tank Utilization Gensym (G2) model provided the projected waste streams. Waste blending caused considerable increases in the concentrations of bismuth, phosphorus, and calcium in the HLW waste streams, leading to the finding that waste loadings in most of the glasses tested were limited by formation of calcium phosphate, as opposed to phases that involved iron, zirconium or thorium observed in earlier testing. Ten HLW-BP glasses were formulated and tested.

High Aluminum HLW Glass Formulations (References [16, 19])

The principal objective of this study was to evaluate enhancements of waste loadings and processing rates for the aluminum limited waste composition specified by ORP. The HWI-AL-glasses were developed with high waste loadings to meet the various processing and product quality requirements; melter tests employed several of the glass formulations developed as targets, including one with 26.63 wt% Al_2O_3 . Considerable increases in glass production rates were achieved by manipulating the glass forming additives and glass formulations.

Effects of High Spinel and Chromium Oxide Crystal Contents on Simulated HLW Vitrification (Reference [18])

The primary objective of this work was to develop and identify high waste-loading glass compositions that exhibit crystallization of (i) spinel, (ii) chromium oxide (eskolaite), and (iii) a mixture of spinel and chromium oxide phases over a range of relatively high crystal contents (> 1 vol%). Glass formulations were based on the waste compositions provided by ORP that are Al- and Cr-limited and on the Fe-limited waste found in Hanford Tank AZ-102. Three series of glasses were formulated and tested: HLW-E-SP, HLW-E-ES, and HLW-E-M.

Tests with High-Bismuth HLW (Reference [20])

This task built on earlier glass formulation work for Hanford HLW with high concentrations of bismuth, as specified by ORP. High waste loading glass compositions were previously developed to meet all process and product quality requirements. Crucible melts of these high-bismuth glasses were observed to foam during CCC heat treatment. In this work additional glass formulations to determine the causes of foaming and to identify potential mitigation strategies were developed. The glass series was designated as HLW-Bi.

Glass Formulation Development and Testing for DWPF High- Al_2O_3 HLW Sludges (Reference [40])

This work involved the development of glass frits and HLW glass formulations (HLW-ALS glass series) for a Defense Waste Processing Facility (DWPF) waste sludge that is high in aluminum (sludge batch 19) to achieve high waste loadings while meeting all relevant process and product performance criteria at DWPF. The target waste composition was specified by ORP and the Savannah River Site. The HLW processing requirements at DWPF are similar but not identical to those at WTP; some of the test conditions also differ slightly for glasses developed for the two sites (e.g., CCC temperature schedule). In the development of WTP property-composition models, glass data developed and collected for DWPF were used for validating the models [3].

Glass Formulation for Next Generation Melters (Reference [41])

The principal objective of this study was to develop and test new glass formulations to take advantage of the enhanced processing capabilities of the next generation joule-heated ceramic melters (e.g., higher operating temperature). This work was performed for Washington River Protection Solutions, LLC and targeted two different HLW streams: a high-iron HLW based on the composition of an actual waste sample from Hanford tank AZ-101 and a high-chromium/sulfur HLW specified by ORP [14]. The two series of glasses tested were HLW-N101 and HLW-NG-Cr.

Melter Throughput Enhancements for High-Iron HLW (Reference [42])

This work was directed at the development and testing of new glass and feed formulations in order to increase glass melting rates for HLW with high concentrations of iron. The target waste composition was based on an actual C-106/AY-102 waste sample from Hanford. Iron concentrations in the glasses tested (HLW-NG-Fe glasses) ranged from 14.14 wt% to 17.92 wt%.

Optical Basicity and Nepheline Crystallization in High Alumina Glasses (Reference [43])

The purpose of this study was to identify glass compositions that increase waste loading of high-alumina wastes beyond what was deemed acceptable while avoiding crystallization of nepheline on slow cooling. Optical basicity and the nepheline discriminator were the metrics used to explore nepheline crystallization and chemical durability as a function of glass compositions. From this study, only nepheline crystallization data collected on glasses supplied or formulated by VSL, which were developed during some of the studies described above [14, 16], are included in the current database.

3.3 Summary of HLW Glasses Added for Property Modeling

The target compositions of the 266 HLW glasses included in the current database are listed in Table 3.2. To distinguish these glasses from the HLW glasses used in the development of the various WTP property-composition models, they will be referred to as the ORP-HLW glasses, while glasses used to develop WTP models will be referred to as the WTP-HLW glasses. The compositions of the ORP-HLW glasses are listed in Table 3.2 in a format similar to that employed previously for the WTP-HLW glasses to facilitate comparison. Specifically, the oxide components for each glass are listed as wt% in separate columns in alphabetical order. The “Others” component in the WTP database is not used in this case since it is a component used in statistical design; all of the ORP-HLW glasses were actively designed. A total of 41 oxides are included in the ORP-HLW database; by comparison, 51 components are found in the WTP-HLW database.

Tables 3.3 and 3.4 summarizes the lower and upper limits (wt%) of the major component oxides of the HLW glasses in the WTP modeling database. Tables 3.3 and 3.4 also tabulate the lower and upper limits (wt%) of the same component oxides for the ORP glasses for comparison.

The limits of the component oxides are further divided according to groups of glasses and are listed in Table 3.5. Finally, Figure 3.1 graphically compares the ranges of selected oxides between the WTP and the ORP datasets.

In contrast to the glass formulation approaches from the WTP work, which included several statistical designs in addition to active design around selected WTP tank wastes, the ORP glasses were exclusively formulated actively to improve waste loadings while meeting the WTP contract requirements and to explore the limits of acceptable glass compositions. Consequently, there are very significant differences in the glass compositions between the WTP and ORP glasses. As shown in Tables 3.3 and 3.4 and Figure 3.1, the ORP glasses greatly expanded the ranges of many major glass oxides including Al_2O_3 , B_2O_3 , Fe_2O_3 , and SiO_2 . For example, the maximum Al_2O_3 increased from 13.1 wt% in WTP glasses to 29.5 wt% in ORP glasses, while the lower limit of SiO_2 went down from 33.0 wt% to 17.4 wt%. The ORP glasses also greatly expanded the compositional ranges for Bi_2O_3 , CaO , Cr_2O_3 , NiO , and P_2O_5 . These large compositional differences between the WTP and ORP glasses will have significant impacts on attempts to extend the existing baseline WTP property-composition models.

SECTION 4.0

EXPERIMENTAL METHODS

The experimental procedures used in the preparation and characterization of the simulated LAW and HLW glasses added to the database are presented in this section. The following subsections discuss the preparation of glass batches, crucible glass melting, glass composition analysis, normalization of target glass compositions with measured SO₃ values, and test procedures for PCT, VHT, electrical conductivity, and viscosity.

4.1 Glass Batching and Preparation

Glass preparation began with a batching sheet that provided information on the required starting materials and their weights. The information included the chemicals needed, identification of the chemicals according to vendors and catalog numbers with the associated purity, and the amounts necessary to produce a given quantity of glass. Chemicals were weighed and batched according to the batching sheets. The information found in the batching sheets, including actual weights of chemicals used and their associated purities, can be used to calculate the composition of the glasses. The batching chemicals were determined such that the calculated compositions equaled the target compositions given in Sections 2 and 3.

Preparation of all simulated LAW and HLW glasses at the VSL began with weighing and batching of chemicals according to the information in the batching sheets. The batches were prepared from reagent grade or higher purity chemicals to produce a batch size of approximately 400 to 450 g. A blender was used to mix and homogenize the starting materials before they were loaded into platinum-gold crucibles (Pt-Au) that were engraved with individual identification numbers. Most of the crucible melts were prepared at various times to support activities specific studies and subsequent melter testing and were prepared in a sequential rather than randomized order.

After the batching was completed, the loaded platinum-gold crucibles were placed inside a Deltech DT-28 (or DT-29) furnace with a Eurotherm 2404 temperature controller. LAW glasses were melted for 75 minutes at 1200°C. HLW glasses were melted 1150°C or 1200°C for 2 hours. Mixing of the melt was accomplished mechanically using a platinum stirrer, beginning 15 minutes after the furnace temperature reached the target and continuing for the next 60 minutes for LAW glasses (or 90 minutes for HLW glasses). The molten glass was poured at the end of the melting period onto a graphite plate to cool.

Samples from melter tests at the VSL were collected from glass that had been air-lift discharged into drums. In a few cases, samples were remelted at 1200°C and cooled according to the CCC profile provided by WTP [44]. A typical LAW CCC profile is given in Figure 4.1. The HLW CCC profile is described in Section 4.9.

4.2 Analyses of Glass Compositions

The primary method used for glass composition analysis at VSL was x-ray fluorescence (XRF) on powdered glass samples. An ARL 9400 wavelength dispersive XRF spectrometer was used for this purpose. The XRF spectrometer was calibrated over a range of glass compositions using standard reference materials traceable to the National Institute of Standards and Technology (NIST), as well as waste glasses such as Argonne National Laboratory – Low Activity Waste Reference Material (ANL-LRM) and Savannah River Laboratory – Environmental Assessment Glass (SRL-EA). XRF analysis provides data for most glass components of interest, except lithium and boron, which are analyzed by direct current plasma atomic emission spectroscopy (DCP-AES), as described below.

Selected glass samples for DCP-AES analysis were subjected to microwave-assisted total acid dissolution in Teflon vessels according to VSL standard operating procedures. Twenty milliliters of a 1:5 mixture of concentrated HF:HNO₃ was diluted to 50 ml and used for the dissolution. This procedure is similar to the ASTM Test Method C1412-99, which also employs a mixture of concentrated HF and HNO₃ in microwave digestion of pulverized glass samples. However, supplemental use of HCl/H₃BO₃ is not included in the VSL procedure because boron is normally one of the analytes. The resulting solutions were analyzed by DCP-AES for all constituents except sulfur, for which Dionex Ion Chromatography was used. These results complement XRF, specifically for boron and lithium.

The XRF detection limit for most components is about 0.01 wt%. The accuracy of the analysis is about ± 10 relative percent for major components (> 3.0 wt% in the glass) or 1.0 wt% absolute, whichever is smaller. However, with the exception of volatile components such as SO₃, the batched (target) glass compositions are expected to be more accurate than the analyzed compositions because the batched compositions are derived from simple weighing of pure chemicals. Hence, the target compositions for all major constituents, except SO₃, are believed to provide the best compositional representations of the tested glasses. The principal role of the compositional analyses is, therefore, to confirm the target compositions.

Because SO₃ is a constituent that limits waste loading in LAW glasses and has a tendency to volatilize during glass preparation, the SO₃ concentration to be used in modeling LAW glass properties was of particular interest. Analysis of both crucible melts and melter discharge glass samples have shown SO₃ analyzed values to be consistently below target values due to volatilization [45]. The SO₃ retention in melter glasses varied from about 70% to 95% [6-12, 45-47] depending on the SO₃ concentration in the glass, LAW waste type, amount of reductants in the feed, etc. For this reason, it was decided that XRF analyzed SO₃ values would better represent the LAW glass composition. Accordingly, XRF measured SO₃ values were collected for modeling.

In general, the chemical analysis results for non-volatile components were in good agreement with the corresponding target compositions. Chemical analyses of all glass samples used in modeling, along with discussions of the results, are given in the references cited in

Section 2 and 3 for each set of glasses. The normalized glass compositions for fifteen near-replicate sets that were evaluated (Table 2.5) generally shows good agreement for the major glass constituents (Al_2O_3 , B_2O_3 , CaO , Li_2O , Na_2O , SiO_2 , SnO_2 , V_2O_5 , ZnO and ZrO_2) with pooled RSD of 2.5% on average and somewhat higher RSDs for the minor constituents, as expected.

4.3 Product Consistency Test

The Product Consistency Test (PCT) was conducted using 4 g of crushed glass (100-200 mesh, 75-149 μm) placed in 40 ml of test solution (de-ionized water) inside 304L stainless steel vessels. These test conditions result in a ratio of the glass surface area to the solution volume of about 2000 m^{-1} . PCT tests were performed at 90°C for 7 days according to ASTM [48], in accordance with the current WTP contract requirement [49]. All tests were conducted in triplicate, in parallel with a standard glass included in each test set: the ANL-LRM glass with LAW glasses and the DWPF-EA glass with HLW glasses. The leachates were sampled after seven days. One milliliter of sampled leachate was mixed with 20 ml of 1M HNO_3 and the resulting solution was analyzed by DCP-AES. Another 3 ml of sampled leachate was used for pH measurement.

In addition to the leachate concentrations, it is convenient and conventional to also consider the normalized leachate concentrations. The normalization is performed by dividing the concentration measured in the leachate for any given component by its fraction in the glass. Thus, the *normalized concentration* C_i of element i (in g/L) is calculated from the elemental concentration c_i measured in the leachate (in ppm) as:

$$C_i = \frac{c_i}{f_i}, \quad (4.1)$$

where f_i is the mass fraction of element i in the glass.

The surface area of the glass sample tested and the volume of leachant used will also affect the measured leachate concentrations and, therefore, a standard value of their ratio (2000 m^{-1}) is specified in the PCT method [48]. A further normalization for this effect is often considered by dividing the normalized concentration by the ratio of the surface area of glass exposed to the solution volume (S/V , in m^{-1}). The *normalized mass loss* (in g/m^2) is then obtained from

$$L_i = \frac{C_i}{(S/V)}, \quad (4.2)$$

where S/V is the ratio of the glass surface area to the volume of the leachant, which for the standard PCT is nominally 2000 m^{-1} . Assuming this value of S/V , if C_i is expressed in g/L, one need only divide by two to obtain L_i in g/m^2 (because $1 \text{ g/L} = 1000 \text{ g/m}^3$). Specification

2.2.2.17.2 (for LAW) in the WTP contract [49] sets a limit of 2 g/m^2 for the normalized mass losses of Na, B, and Si on the PCT for the ILAW product. Thus, the WTP contract limit of a normalized mass loss of less than 2 g/m^2 corresponds to a normalized concentration of 4 g/L . For the IHLW product, Specification 1 of the WTP contract requires that the PCT normalized mass losses of B, Na, and Li be below the respective values for the reference DWPF-EA glass. The nominal values for normalized leachate concentrations from the DWPF-EA glass are 16.695, 9.565, and 13.346 g/L for B, Na, and Li, respectively [50].

4.4 Vapor Hydration Test of LAW Glasses

The vapor hydration tests were run in Parr series 4700 screw-cap pressure vessels made of 304L stainless steel and having either 22 or 45 ml capacity, in accordance with VSL procedure. Glass coupons were fashioned about 5 to 10 mm square and about 2 mm thick. A hole approximately 1.6 mm in diameter was drilled near one corner of the coupon to allow it to be suspended from a hanger made of 24 gauge stainless steel wire. Dimensional measurements were made to permit calculation of the area, and the coupon was weighed before and after the VHT on a balance having a resolution of $100 \text{ }\mu\text{g}$. The coupon was suspended vertically from the hanger in the pressure vessel and enough de-ionized water was added to the vessel to saturate the volume at the test temperature of 200°C and to allow for a non-dripping layer covering the coupon. The pressure vessels were flushed with argon, sealed, weighed, and placed in an oven held at 200°C . The temperature was monitored continuously with an independent thermocouple. At the completion of the test, the pressure vessels were removed and immediately partially immersed in an ice/water bath to condense the water vapor near the bottom of the vessel. Once cool, the vessels were weighed and opened, and then the coupons were removed and weighed. If the difference in the mass of the sealed pressure vessel before and after the test indicated a water loss in excess of 50% of the original amount, the test results were discarded. Otherwise, the coupons were examined using low-power optical microscopy and an X-ray diffraction pattern was taken directly off the surface of the coupon. Next, the coupons were sectioned and the pieces mounted separately to allow for microscopic examination, both of the cross section of the leached coupon and the leached surface itself, and to measure the layer thickness; Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy (SEM/EDS; JEOL JSM-35C, equipped with Noran Vantage Integrated EDS or JSM-5910LV, equipped with Oxford Instruments INCAEnergy 300 system) was used for this purpose.

For a layer thickness greater than 100 microns, the layer thickness (which can be uneven), was measured by subtracting the average remaining glass thickness measured at ten points throughout the coupon's cross-section from the original thickness of the coupon. The altered layer thickness, which (given certain assumptions) relates directly to the mean glass alteration rate over the test interval, was the variable that was used in this report. Thus, the dependence of the altered layer thickness on glass composition was investigated. All of the VHT data used in this report were collected at VSL from tests performed at 200°C for a nominal duration of 24 days.

WTP Contract Specification 2 [49] requires that the VHT alteration rate determined from tests of seven days or longer duration be below 50 g/m²/day. If it is assumed that the altered layer density is not appreciably different from that of the glass, the mean glass alteration rate over the test interval (r in g/m²/d) is related to the measured altered layer thickness D in microns by

$$r = \rho D/t, \quad (4.3)$$

where ρ is the glass density in g/cm³ and t is the test duration. Under this assumption, for a typical density of 2.65 g/cm³, a layer thickness of 453 microns in a 24-day VHT would correspond to a mean glass alteration rate of 50 g/m²/day.

Although in some previous VHT modeling work the test duration was included as a modeling variable [51], the VHT modeling work in this report is similar to that in the preceding reports [1, 52] in that modeling is restricted to VHT results obtained at a single test duration (24 days) because all of the more recent data have been collected at this test duration.

4.5 Electrical Conductivity

The electrical conductivity (EC) of LAW and HLW glasses was determined by measuring the impedance of the glass melt at temperatures around 950, 1050, 1150 and 1250°C as a function of AC frequency using a calibrated platinum-rhodium electrode probe attached to a Hewlett-Packard model 4194A impedance analyzer. The collected impedance data were analyzed to obtain the DC electrical conductivity. The probe (analyzer along with the crucible to assure that the geometry is replicated) was calibrated and checked periodically using NIST traceable standard reference materials.

The current WTP requirement for glass melt EC limits is 0.1 to 0.7 Siemens/cm at 1100 - 1200 °C [53].

4.6 Viscosity

The melt viscosity (η) of each glass was measured using a Brookfield viscometer with a platinum-rhodium spindle and crucible. The relative torque of a rotating spindle immersed in molten glass was measured as a function of rotational velocity (revolutions per minute (RPM)) at temperatures around 950, 1050, 1150 and 1250°C. The viscosity of the molten glass was then calculated from the collected data of torque versus RPM. The equipment was calibrated using viscosity standard oils and checked periodically using a NIST traceable standard reference glass.

Per current WTP requirements glass melts should satisfy the viscosity limits of 10 to 150 poise at 1100 °C with the preferred range being 40-80 poise at 1150°C [53].

4.7 Determination of One-Percent Crystal Fraction Temperature of HLW Glasses

HLW glass samples (about 3 to 5 grams each) were heat-treated in a platinum, platinum-gold, or platinum-rhodium crucible at a pre-melt temperature of 1200°C for 1 hour, followed by heat treatment for 70 hours at prescribed temperatures between 750°C and 1150°C. At the end of the heat-treatment period, the glass samples were quenched by contacting the crucible with cold water. The sample was then prepared for SEM/EDS examination to determine the volume fraction of crystalline phases and for identification of the dominant crystalline phases. To estimate the $T_{1\%}$ value of a glass, a sufficient number of heat treatments were performed to obtain non-zero vol% data for at least three different temperatures. Because of the many different objectives for the HLW glass studies described in Section 3, however, heat treatment was not always carried out for the purpose of determining $T_{1\%}$ and fewer than three heat treatments were completed in some cases. Section 6.2.1 discusses the heat-treatment data and estimated $T_{1\%}$ values obtained by regression of these data.

The crystalline phases found in the heat-treated glasses were characterized by SEM/EDS and the volume percents were estimated by performing image analysis on the SEM images. The heat treated samples were processed by grinding and sieving (-18 mesh, < 1 mm) before SEM examination in order to provide a representative measure of the overall crystal fraction in the sample.

The $T_{1\%}$ value for each glass was obtained by linear regression of the heat-treatment temperature (°C) as the dependent variable versus crystal fraction (vol%) as the independent variable. The choice of vol% (which has the larger measurement error) as the independent variable, rather than the temperature (which has the smaller measurement error), is contrary to the selection that would normally be made for regression. However, as discussed in Reference [3], this approach was adopted during the WTP baseline spinel $T_{1\%}$ model development because there are significant advantages to using such “inverse regression.” The differences in the $T_{1\%}$ values estimated using either choice of independent variable were very small [3].

4.8 Toxicity Characteristic Leaching Procedure (TCLP)

To collect TCLP data to support WTP HLW delisting compliance and to develop baseline TCLP cadmium-release model, VSL subcontracted with accredited environmental laboratories (Severn Trent Laboratories (STL)) to perform TCLP testing. For the TCLP data collected on HLW glasses in the current database, the testing was performed at VSL. The TCLP leach test (Environmental Protection Agency SW-846 Method 1311) was performed to determine the leach resistance of HLW glasses. The glass was crushed (< 3/8 inch) and placed in a sodium acetate buffer solution for 18 hours at 22°C with constant end-over-end agitation. The surface area to volume ratio for this test is about 20 m⁻¹. The leachate concentrations were measured by DCP-AES according to VSL standard operating procedures.

4.9 Canister Centerline Cooling for HLW Glasses/Nepheline Formation

Samples of HLW glasses underwent canister centerline cooling (CCC) heat treatment in order to simulate the slow cooling in the center of a canister. The HLW CCC temperature profile provided by the WTP Project [54] is shown graphically in Figure 4.2. As in the case for isothermal heat treatment, the glass sample was maintained at a pre-melt temperature of 1200°C for 1 hour before initiation of CCC treatment in a platinum crucible. The sample recovered after CCC heat treatment was processed for PCT and SEM/EDS examination for secondary phases (including nepheline). Estimates of vol% secondary phases were obtained as described in Section 4.7. The measured PCT data were reported previously but are not included in the current database.

SECTION 5.0 LAW GLASS DATA

PCT, VHT, electrical conductivity, and viscosity results for the ORP-LAW higher waste loading glasses are presented and discussed in this section. In addition, trends in the data with respect to the performance of the baseline WTP LAW property-composition models for the ORP-LAW datasets are discussed. Table 5.1 summarizes the number of glasses and their properties. In total, there are 207 ORP-LAW glasses with data for at least one of the four properties, many of which also include replicate testing, as discussed below. More than half of these (108) have all four properties measured.

The previously recommended baseline LAW model forms and coefficient estimates that were developed [1] are collected in Table 5.2 to 5.6 for PCT-B, PCT-Na, VHT, electrical conductivity, and viscosity responses, respectively.

5.1 Product Consistency Test (PCT) Results and Discussion

The PCT results are presented in Section 5.1.1 and discussed in Section 5.1.2. Replicates and near-replicates added in the new data set are presented in Section 5.1.3. The assessed performance and limitations of the existing WTP baseline models for the ORP-LAW dataset and the combined datasets is discussed in Section 5.1.4.

5.1.1 PCT Results

Of the 207 ORP-LAW glasses discussed in Section 2, 171 glasses have data on PCT boron (PCT-B), sodium (PCT-Na), and silicon (PCT-Si) releases, as summarized in Table 5.7. The PCT was performed and results were obtained for these 171 LAW glasses using the procedure described in Section 4.3. Specifically, the B, Na, and Si releases were obtained for the 171 ORP-LAW glasses. The PCT normalized concentration values (in g/L) and normalized mass loss values (in g/m²) were calculated from the PCT elemental concentrations (in ppm) using Equations (4.1) and (4.2), respectively, and the normalized glass compositions listed in Table 2.4.

The PCT-B, PCT-Na, and PCT-Si releases are given in Table 5.7 for the ORP-LAW glasses discussed in Section 2. The PCT releases vary from 0.154 g/L (0.077 g/m²) to 15.557 g/L (7.778 g/m²) for PCT-B, 0.330 g/L (0.165 g/m²) to 10.687 g/L (5.344 g/m²) for PCT-Na, and 0.111 g/L (0.055 g/m²) to 1.422 g/L (0.711 g/m²) for PCT-Si. The WTP contract limit is 2.0 g/m² (4.0 g/L) for each of the PCT-B, PCT-Na and PCT-Si releases.

As can be seen in Figure 5.1, the PCT releases of the ORP-LAW glasses are less than the contract limit of 2 g/m^2 (4.0 g/L) in the majority of the cases even though these glasses were designed to extend the composition region toward higher waste loadings. Of the 171 ORP-LAW glasses with PCT results, 16 glasses have PCT-B releases greater than 2 g/m^2 , and 10 have PCT-Na releases greater than 2 g/m^2 . With the exception of LAW177, the glasses with PCT-B or PCT-Na releases above the contract limit are from the latest series of formulations investigating the effect of magnesium (see glass labels in Figure 5.1). Although these compositions provide a wider range of PCT values, they are not compositions that are likely to be selected for LAW processing, given that their magnesia contents are beyond the recommended range based on several deleterious effects [12].

As can be seen from Figure 5.1 and Table 5.7, for every glass the normalized PCT mass losses for B and Na are higher than the normalized PCT mass loss for Si. Furthermore, and as was previously found with WTP glasses [1], for *every one* of the 171 glasses with PCT results, the normalized PCT mass loss for Si is below the PCT contract limit of 2 g/m^2 . These results suggest that: (i) if the B and Na mass losses are below the PCT limit, so too will be the Si mass loss, and (ii) the Si mass loss does not exceed the PCT limit over the composition region of interest. As discussed below, lower mass loss for silicon is expected because of the role that SiO_2 plays in the glass structure, the mechanism by which silicon is leached, and the chemistry of silicon in solution. It was therefore concluded [1] that a model for PCT Si release was not needed for the WTP dataset, and none should be needed either for ORP-LAW glasses.

5.1.2 Discussion of PCT Results

Boron forms few secondary phases that precipitate from the leachate. Consequently, its concentration in solution provides one of the best measures of the extent of the reaction of the glass with the leachant. For glasses with relatively low leaching (less than 2 g/m^2), the observed sodium and boron releases are generally congruent, as can be seen in the small extended box at the right in Figure 5.1; however, at very low levels of leaching, sodium tends to exceed boron, which is likely due to sodium ion exchange. With increased leaching (greater extent of reaction), sodium-containing secondary phases are likely to form, which causes a deviation from congruent behavior with boron exceeding sodium.

The glasses in the ORP-LAW dataset are generally higher in sodium, with a median of 22 wt% Na_2O in ORP glasses versus 14 wt% Na_2O in the WTP set (Figure 5.2). Consequently, both the PCT-B and PCT-Na responses are also higher (0.66 g/m^2 versus 0.38 g/m^2 median PCT-B and 0.72 g/m^2 versus 0.37 g/m^2 median PCT-Na).

The leachate pH is not only an indicator of the glass-water reaction, it is also a factor in determining the rate and path of subsequent reactions. Alkali ion exchange tends to rapidly increase the pH from neutral to basic. In addition, the rate of hydrolysis of the silicate matrix increases as the pH increases. Furthermore, the stability of alteration phases can be dependent on the solution pH. Certain glass constituents, such as boron, tend to buffer the solution and moderate the pH increase. It is, therefore, instructive to examine the relationships between the

measured leachate pH values, the glass composition, and PCT boron and sodium releases. The pH for the ORP-LAW glasses varies from about 10.5 to 12.5 and are generally higher than those for the previously modeled WTP glasses (from 9 to 12.5), which is consistent with the generally higher alkali content in the ORP-LAW glasses. PCT boron release as a function of leachate pH is shown in Figure 5.3, along with the contractual limit of 2.0 g/m². The boron release increases with pH but the relationship is markedly non-linear, as shown in the figure. Samples exceeding the PCT boron limit, some greatly, were found at pH values greater than 12, which reflects the combined effects of high sodium (and potassium for ORPLG glasses) with high magnesium.

5.1.3 PCT Replicates

Table 5.8 lists fifteen sets of replicate and near-replicate glasses in the ORP-LAW PCT data and the corresponding PCT-B and PCT-Na normalized releases. The table also lists estimates of percent relative standard deviations (%RSDs) for each replicate set, as well as pooled estimates over all the replicate sets. A pooled %RSD combines the separate %RSD estimates from each replicate set so that a more accurate combined estimate of the %RSD is obtained. These pooled %RSDs include uncertainties due to fabricating glasses, performing the PCT, and chemically analyzing leachates to determine elemental releases. In the case of near-replicates, the uncertainties also reflect the difference of fabrication scale, thermal history (some are also cooled according to canister centerline cooling), sulfate content, and minor components which may have been added as tracers for volatile radionuclides in melter testing (such as cesium and iodine)). Nonetheless, the magnitudes of the pooled %RSDs in Table 5.8 (18% and 18%) are very similar to those obtained with twelve replicate pairs in the datasets used to develop the WTP models (22% and 17%) previously reported for PCT-B and PCT-Na respectively, mostly comparing crucible duplicates.

5.1.4 PCT Model Assessment

The baseline WTP LAW models provided reasonable fits to the WTP baseline dataset for PCT leaching of boron and sodium (R^2 of 0.87). The two plots in Figure 5.4 show the results of applying these models to the additional 171 ORP-LAW glasses as well as the original set. The points marked as “Outlier” are data for glass samples not used in model development because of compositions outside valid composition ranges for the model, or glass samples with non representative compositions or thermal history. Both graphs show a marked decrease in R^2 when the models are applied to the ORP dataset, but most particularly for sodium release (R^2 now 0.69 for PCT-B and 0.43 for PCT-Na). This may be due in part to the extended sodium range stemming from designing higher waste loading glasses in the ORP-LAW dataset (Figure 5.2) since a primary focus of the ORP formulations was to extend the data beyond the design range of the original models.

As previously highlighted, a few high MgO glasses show extensive PCT leaching. This high PCT response with magnesium will likely need to be addressed prior to any further modeling efforts. The approach should include the following considerations:

- Extremely high MgO content glasses (7 and 10 wt% MgO), which are unlikely to be processed at the WTP, may need to be excluded from the model set as was done previously (the composition validity region was previously limited to 5.1 wt% MgO).
- New glasses covering the range of 3 to 5 wt% MgO at high alkali content may be required to improve the data distribution so that model terms on the effect of magnesium can be improved. The magnesium term is part of a two-component cross-product term with boron in the currently recommended 17-Term Reduced Partial Quadratic Mixture Model.

The combined WTP and ORP datasets provide a basis for the development of extended models to address the limitations of the baseline models over the compositions range covered by the ORP glasses. It is likely that the model will require addition of terms for SnO_2 , and possibly V_2O_5 . Preliminary investigation of models for PCT-B and PCT-Na suggests that the SnO_2 term is significant for both models and that significant improvement over the performance of the baseline models should be possible ($R^2 \sim 0.87$ or better).

5.2 VHT Results and Discussion

The VHT results are presented in Section 5.2.1 and discussed in Section 5.2.2. Replicates and near-replicates added in the new data set are presented in Section 5.2.3. The assessed performance and limitations of the existing WTP baseline models for the ORP-LAW dataset and the combined datasets is discussed in Section 5.2.4.

5.2.1 VHT Results

Of the 207 ORP-LAW glasses discussed in Section 2, 203 glasses have VHT results as summarized in Table 5.1. The VHT was performed and results obtained for these 203 LAW glasses using the procedure described in Section 4.5. Specifically, VHT alteration depths D (in μm) were obtained for the 203 LAW glasses. The VHT alteration rates r (in $\text{g/m}^2/\text{d}$) were calculated from the VHT alteration depths using Equation (4.3).

The VHT alteration depths and alteration rates are given in Table 5.9 for the ORP-LAW glasses discussed in Section 2. The VHT alteration depths and rates for the 203 glasses vary from $5 \mu\text{m}$ ($0.6 \text{ g/m}^2/\text{day}$) to greater than $1200 \mu\text{m}$ ($133 \text{ g/m}^2/\text{day}$). This range excludes the results for twenty nine glasses that were altered completely before the end of the 24-day test period.

Because the ORP-LAW glasses were aimed at optimizing the glass formulations to minimize the volume of glass produced and to shorten the plant operating schedule, they are designed to determine the likely limits of LAW sodium and sulfur in the glass. Multiple glasses were prepared at increased waste loading with the intent to approach or slightly exceed the VHT limit. In total, 111 glasses have VHT alteration rates above the $50 \text{ g/m}^2/\text{d}$ limit. The 111 glasses

with VHT alteration rates above the 50 g/m²/d limit include the 29 glasses mentioned above for which the extent of VHT alteration was so high that the entire glass coupon was altered and therefore a rate could not be calculated. The VHT alteration rates for these glasses are listed as “greater than” values in Table 5.9.

5.2.2 Discussion of VHT Results

The VHT results were reviewed in terms of the concentrations of glass network formers and modifiers in the glass composition to examine the extent to which general trends or relationships may be evident. The challenge offered by the large composition space is amplified by the fact that VHT is designed to assess relatively late-stage features of the glass corrosion. In late-stage glass corrosion: (i) the leachate (an absorbed aqueous film in the case of the VHT) is dominated by glass corrosion products which significantly modify the leachate properties, and (ii) secondary phases are formed in the leachate as reaction products. Consequently, VHT alteration is a complex process that is expected to exhibit complex dependencies on glass composition.

Figure 5.5 shows the VHT alteration rate as a function of the alkali oxide concentration as the wt% summation of Na₂O + 0.6K₂O + 2Li₂O (noted “Alk”) for 203 ORP-LAW glasses. These are compared in the figure to the 171 WTP glasses previously used to develop the baseline VHT models. Note that the number of glasses with alkali concentration exceeding 23 wt% Alk is much greater in the ORP-LAW data set. The median of the ORP-LAW 203 glasses falls at 23.5 wt% Alk. Conversely, the median for the 171 WTP glasses is at 19 wt% Alk. As was discussed in past model analyses, a noticeable effect related to the alkali content shown in this figure is a threshold at around 23 wt% Alk beyond which VHT alteration depths increase rapidly. Thus, it is apparent from the combined data that the glasses are significantly more likely to fail to meet the VHT contract requirement when the Alk content is higher than 23 wt%. This behavior is broadly consistent with expectations from a glass structure perspective, where alkali oxides act as modifiers in breaking up the glass network structure and glass network former oxides act to strengthen it. Glasses with a more highly polymerized network, which results from having more network former oxides and less alkali oxides, tend to be more durable.

5.2.3 VHT Replicates

Table 5.10 lists fifteen sets of replicate and near-replicate glasses in the ORP-LAW VHT data set. The table also lists estimates of percent relative standard deviations (%RSDs) for each replicate set, as well as pooled estimates over all the replicate sets. Note that the standard deviations in all of these sets also account for the uncertainties due to fabricating glasses in small crucibles or in melter tests, and difference in thermal history, and sulfate content of the glass. The %RSD values for most of the ORP-LAW replicate sets are within the range obtained previously from five duplicates for the WTP models (7 to 71% RSD). It exceeds the previous range for the high potassium glass pairs ORPLG9/10A-G-43B (the melter glass coupon was fully altered) and ORPLG27/I10-G-135A (127% RSD). The pooled %RSD obtained for thirteen of the

fifteen near-replicates is found to be 39%, which is similar to that obtained for the WTP replicates (42% RSD) even though it includes uncertainties due to fabricating glasses at various scales and the effect of bubbles and cracks in the glass samples collected from melter tests.

5.2.4 VHT Model Assessment

As shown in Figure 5.6, the VHT response obtained on 203 glasses in the ORP dataset covers a wider range with a median VHT alteration depth of 270 μm (versus 30 μm in the WTP dataset). The points marked as “Outlier” are data for glass samples not used in model development because of compositions outside valid composition ranges for the model, or glass samples with non representative compositions or thermal history. Also included in the “Outlier” are data for glass samples that were altered completely. The majority of the VHT results are between one third and twice the contract limit, which provides improved coverage for modeling the VHT response to improve the prediction performance near the contractual limit.

The baseline WTP VHT model fits the WTP LAW dataset with an R^2 value of 0.744. However, this model yields a negative R^2 (-0.36) when it is applied to the ORP-LAW dataset, which implies that the model prediction is worse than the simple mean of the dataset. This is not surprising in view of the challenges associated with developing a reliable VHT model [1] and the fact that the model is being applied beyond its range of validity. This is due to the increased waste loadings in the ORP-LAW glasses, and therefore increased sodium content, the wider range of VHT responses, as well as the presence of new glass components such as SnO_2 and V_2O_5 . Preliminary modeling attempts using the combined dataset of 344 glasses with additional terms for SnO_2 , V_2O_5 and a square term for $\text{SnO}_2\text{xZrO}_2$ indicate that improved models ($R^2 = 0.75$) can be developed. The results of this preliminary VHT model are shown in Figure 5.7.

5.3 Electrical Conductivity Results and Discussion

The electrical conductivity results are presented and discussed in Section 5.3.1. One near-replicate included in the electrical conductivity data set is discussed in Section 5.3.2. The assessed performance and limitations of the existing WTP baseline model for the ORP-LAW dataset and the combined dataset is discussed in Section 5.3.3.

5.3.1 Electrical Conductivity Results

Of the 207 ORP-LAW glasses discussed in Section 2, 122 glasses have electrical conductivity results, as summarized in Table 5.1. As described in Section 4.6, electrical conductivity was generally measured at four temperatures for each LAW glass. The electrical conductivity versus temperature values are given in Table 5.11 for the 122 ORP-LAW glasses. Measurements were available at only three temperatures for glasses LAW145 and ORPLA6.

The current WTP requirement [53] for glass melt electrical conductivity is that it be within 0.1 to 0.7 S/cm in the temperature range of 1100 to 1200 °C. For 122 measurements taken in this temperature range, the electrical conductivity values were mostly within the acceptable range of 0.1 to 0.7 S/cm. Among 122 ORP-LAW glasses, twelve of the measurements were above this range with values from 0.253 to 0.820 S/cm. As seen in Figure 5.8, the electrical conductivities generally increase with the alkali content of the glass, which is mostly responsible for the ionic conductivity of the melt. As a result, melts with the highest alkali contents are those found above the upper limit of 0.7 S/cm and particularly glasses in the ORPLA, ORPLB and ORPLC series formulated at 25 wt% Na₂O.

Figure 5.9 shows the distribution of temperature values at which data were collected for each LAW glass with electrical conductivity data. This figure shows that electrical conductivity was measured at temperatures not too far from the four nominal values (950, 1050, 1150, and 1250°C) for most ORP-LAW glasses. Selected glasses that have measurement temperatures much different than the nominal values are marked with the Glass ID in the figure (LAWC103 and ORPLE2). These have either a minimum measurement temperatures of 988°C instead of around 950°C or a maximum measurement temperatures of 1202°C instead of around 1250°C. These observations are noted but they do not affect the suitability of the associated data for developing electrical conductivity models.

5.3.2 Electrical Conductivity Replicates

One near-replicate pair of electrical conductivity versus temperature values is compared in Table 5.12. Figure 5.10 shows the electrical conductivity values plotted against 1/*T* (with *T* in Kelvin). The lines correspond to the fit of the Arrhenius equation:

$$\ln(EC) = A + B(1/T) \quad (5.1)$$

applied to ORP-LAW glasses LAWC100R1 and WVY-G-95A. These data indicate a 5.8% RSD over the four measured temperatures and a 3.3% RSD over the four nominal temperatures.

5.3.3 Electrical Conductivity Model Assessment

The recommended WTP model (26-Term Reduced Truncated Linear Mixture Models with Four Quadratic Terms) provides a good fit to the WTP glasses ($R^2 = 0.948$) on which it was developed. However, the prediction performance is significantly worse ($R^2 = 0.748$) for the ORP-LAW dataset; the results are plotted in Figure 5.11. The error in prediction varies from 28% under-predicted (for glass such as ORPLE12) to 100% over-predicted (in LAWC100 or LAWA194, for example). It is clear from the figure that the deviation is greater at higher conductivity, which is a likely a consequence of the increased alkali content in the ORP-LAW glasses and its effect on the ionic conductivity. Preliminary investigation of revised models suggests that the most significant changes for improvement would likely be in the quadratic terms involving sodium, calcium and lithium and the possible inclusion of SnO₂ terms.

5.4 Viscosity Results and Discussion

The viscosity results are presented and discussed in Section 5.4.1. One near-replicate included in the new data set is discussed in Section 5.4.2. The assessed performance and limitations of the existing WTP baseline models for the ORP-LAW dataset and the combined datasets is discussed in Section 5.4.3.

5.4.1 Viscosity Results

Of the 207 ORP-LAW glasses discussed in Section 2, 122 glasses have viscosity results, as summarized in Table 5.1. As described in Section 4.7, viscosity was generally measured at four temperatures for each LAW glass. The viscosity values at measurement temperatures are given in Table 5.13 for the 122 simulated LAW glasses.

Glasses ORPLA5, ORPLA6, ORPLA11, ORPLA12, ORPLA13, ORPLA14, ORPLG1, ORPLG2, ORPLG4, ORPLG5 had viscosities exceeding the recommended upper limit of 150 poise at 1100°C [53] with interpolated values in the range of 173 to 259 poise. These are glass formulations with high waste loadings for which an increased amount of zirconia and addition of tin oxide were used to compensate for the detrimental effect of higher sodium on glass leaching.

Figure 5.12 shows the distribution of temperature values at which viscosity was measured for each LAW glass with viscosity data. This figure shows that viscosity was measured at temperatures not too far from the four nominal values (950, 1050, 1150, and 1250°C) for all ORP-LAW glasses. Selected glasses that have measurement temperatures much different than the nominal 950, 1050, 1150, and 1250°C values are marked with the Glass ID in the figure. Only one temperature value is marked for each glass even if some other temperature values differ from the nominal values (such as ORPLE9). These observations are noted but they do not affect the suitability of the associated data for developing viscosity models.

The viscosity versus temperature values in Table 5.13 for the 122 LAW glasses vary from 7.93 to 2461 poise, with smaller viscosity values generally corresponding to higher temperatures and larger viscosity values corresponding to lower temperatures. The range of viscosity values for the ORP-LAW glasses was similar to that of the WTP set.

5.4.2 Viscosity Replicates

One near-replicate pair of viscosity versus temperature values is compared in Table 5.14. Figure 5.13 shows the two sets of viscosity values plotted against $1/T$ (with T in Kelvin), with a line corresponding to the fit of the Arrhenius equation (Equation 5.1 with viscosity replacing electrical conductivity) for the two LAW glasses. The data indicate a 2% RSD over the four measured temperature and also over the four nominal temperatures.

5.4.3 Viscosity Model Assessment

The WTP baseline viscosity model provided a very good fit to the WTL LAW dataset ($R^2 = 0.988$). The performance of the model is worse for the OPR-LAW dataset but still reasonable surprisingly good ($R^2 = 0.955$), suggesting considerable robustness in the viscosity model. It should be noted that for glasses with SnO_2 , the ZrO_2 coefficient was applied to the sum of SnO_2 and ZrO_2 contents assuming similar behavior of SnO_2 and ZrO_2 . Nevertheless, the measured viscosity values were found to be significantly different in most glasses that included SnO_2 , with the measured values being generally higher than predicted, as can be seen for example with ORPLG4 (marked in Figure 5.14), which contains 4.8 wt% SnO_2 . Preliminary investigations of revised models suggest that SnO_2 is a significant parameter which may need to be included as an individual terms as well as a term in the temperature dependence.

5.5 Data Gaps

While the ORP data significantly expand the number of glasses available for modeling and the composition ranges, not surprisingly, there are gaps in the combined WTP and ORP datasets. Such gaps exist in both the compositions and in the glass property responses. Figure 5.15 shows a binary scatter-plot matrix of the WTP and LAW glasses, which provides a simple visualization of the compositional gaps in the datasets. Some specific binary plots in which gaps are particularly evident are shown enlarged in Figure 5.16. Some of the more significant gaps include those for many components at the low silica end of the range, and in the distribution for many components versus tin and vanadium oxides. Such gaps will likely need to be addressed through the addition of statistically designed glass compositions to supplement the combined sets of WTP-LAW and ORP-LAW glasses. The addition of statistically designed glasses would also help offset the effects of various correlations that are present in the ORP dataset because of the active design approach that was employed in the development of these glasses (for example, tin and vanadium generally replaced iron and titanium).

Data from other studies on LAW-type glasses could also be useful for augmenting the WTP and ORP datasets such as the data for the Hanford LAW Product (HLP) and In-Container Vitrification (ICV) glasses that have been reported [55]. Figure 5.17 compares the ranges of some of the major glass components in these studies with those for the WTP and ORP datasets. It should be noted, however, the VHT data from some of these studies may not be useful since they were collected at test durations that differ from those in the WTP and ORP datasets. A further consideration in the use of other datasets is compliance with the WTP Quality Assurance requirements.

It is not necessarily the case that all of the gaps in the combined WTP and ORP datasets will need to be addressed. For example, there are significant gaps in the distributions versus the MgO content; however, based on the generally deleterious effects of high MgO content [12], it is unlikely that high MgO glasses would be produced at the WTP. Similarly, the Al_2O_3 and TiO_2 contents in the ICV and HLP [55] datasets extend significantly higher than would likely be employed at the WTP so it may not be worthwhile to fill in data gaps up to those limits.

SECTION 6.0

HLW GLASS DATA

PCT, spinel one-percent crystal fraction temperature ($T_{1\%}$), electrical conductivity, viscosity, TCLP Cd-release, and nepheline formation results for the ORP-HLW glasses are presented and discussed in this section. In addition, general compositional trends observed in the data are discussed, particularly with respect to the performance of the baseline WTP HLW models for the ORP-HLW datasets.

Table 6.1 summarizes the number of the ORP-HLW glasses and their properties collected in the database. An assessment of the baseline WTP models against these data is provided in the following sections. The baseline WTP models were obtained by estimating model coefficients using least square methods. The model validity regions for the WTP HLW models were specified using: (i) single-component constraints on HLW glass composition, (ii) single-variable constraints on HLW glass melt temperature (for electrical conductivity and viscosity), (iii) multiple-component constraints for PCT releases, spinel $T_{1\%}$, and TCLP-Cd release, and (iv) multiple-variable constraints involving HLW glass composition and melt temperature for electrical conductivity. Reference [3] describes in detail the development of the WTP HLW models and the specification of the validity regions. The glass compositional validity regions were primarily defined by the upper and lower bounds on HLW glass components found in the WTP modeling dataset. Tables 6.2 through 6.8 present, respectively, the baseline WTP HLW models for PCT-B, PCT-Li, PCT-Na, spinel $T_{1\%}$, electrical conductivity, viscosity, and TCLP Cd-releases. Tables 6.9 and 6.10 summarize the validity regions for application of these models.

6.1 PCT Results and Discussion

The PCT results for the HLW glasses are presented and discussed in Section 6.1.1. An assessment of the performance and limitations of the existing WTP baseline models as applied to the new dataset is provided in Section 6.1.2.

6.1.1 PCT Results

Of the 266 HLW glasses described in Section 3, Table 6.1 shows that 111 glasses have data on PCT-boron (PCT-B), and PCT-sodium (PCT-Na) releases. However, only 104 of these 111 glasses have PCT-lithium (PCT-Li) releases because 7 of the glasses do not contain Li_2O . The PCT was performed and results obtained for these 111 glasses using the procedure described in Section 4.3. Specifically, (i) PCT-B and PCT-Na releases were obtained for the 111 HLW glasses and (ii) PCT-Li releases were obtained for the 104 glasses. The PCT normalized concentration values (in g/L) and normalized mass loss values (in g/m^2) were calculated from the PCT elemental concentrations (in ppm) using Equations 4.1 and 4.2, respectively, and the normalized HLW glass compositions in Table 3.2.

Table 6.11 compares the lower and upper bounds on the HLW glass components between WTP glasses and ORP glasses which have PCT data. As discussed in Section 3.3, the new dataset greatly expanded the compositional ranges for the HLW glasses. A majority of the ORP glasses (87 out of 111) are compositionally outside the WTP model validity regions.

The PCT-B, PCT-Li, and PCT-Na releases are given in Table 6.12 for the ORP-HLW glasses. The PCT-B releases (normalized concentrations) vary from 0.145 g/L to 20.787 g/L, PCT-Li releases vary from 0.179 g/L to 13.463 g/L, and PCT-Na releases vary from 0.123 g/L to 12.766 g/L. These values can be compared with those obtained from the 268 WTP glasses (glasses used to develop the 2007 WTP PCT models): 0.007 g/L to 21.903 g/L for PCT-B releases, 0.006 g/L to 10.675 g/L for PCT-Li releases, and 0.050 g/L to 11.819 g/L for PCT-Na releases [3]. Figure 6.1 shows the ranges and median values of normalized PCT-B, PCT-Li, and PCT-Na releases (g/L) measured on ORP glasses and on WTP glasses. It can be seen that a vast majority of the HLW glasses in the dataset have PCT releases beneath the respective contract limits. Only one glass (HLW-ALG-43) has a PCT-B release greater than the WTP contract limit of 16.695 g/L; its PCT-Li release also exceeds the WTP contract limit (13.463 g/L vs. 9.565 g/L). This glass was formulated to include the lower limit of SiO₂ found in the statistical design for WTP glasses (33 wt%) [38]. The HLW-ALG glasses, which were formulated to challenge the boundaries of acceptable glass compositions, are found to have the widest ranges of PCT releases. The current data corroborate the previous findings, which have repeatedly shown that PCT is not a very constraining requirement and that the vast majority of all HLW glasses (including all actively designed glasses) consistently outperform the DWPF-EA reference glass.

Figure 6.2 shows the distributions of normalized PCT-B, PCT-Li, and PCT-Na releases for the HLW glasses. Compared with the PCT results from the WTP dataset, the current dataset include more glasses with larger PCT releases, although the median values for the two datasets are comparable. It is desirable for the purpose of model development to include glasses that span a wider range of PCT responses.

As discussed in Section 5.1.2, the boron concentration in the PCT leachate is a good indicator of the extent of the reaction of the glass with the leachant. The sodium and boron releases observed for LAW glasses that show relatively little leaching are generally congruent (Figure 5.1). Similar plots for the PCT releases from ORP-HLW glasses are shown in Figure 6.3. It can be seen that both lithium and sodium releases are mostly congruent with the boron releases when leach rates are low. As leaching increases, lithium and sodium dissolution behavior deviates from being congruent with boron release, which can be explained in part by the formation of lithium- and sodium-containing phases. Figure 6.4 compares the normalized PCT boron releases to the leachate pH. The overall trend of increasing pH with boron release is not nearly as evident as with the LAW glasses (Figure 5.3). This is likely a result of the much greater compositional diversity of the HLW glasses and the comparative dominance of the sodium content in the LAW glasses.

6.1.2 Discussion of PCT Modeling Results

In previous work, models were developed to relate PCT releases for boron, lithium, and sodium to the compositions of WTP glasses [3]. Models and uncertainty expressions were developed using least squares regression methods to fit empirical and semi-empirical model forms to the data. Tables 6.3 to 6.5 summarize the recommended models for PCT-B, -Li, and -Na releases, respectively. In addition to the performance of the models, the limitations of the HLW models and the regions of validity are discussed in Reference [3]; Tables 6.9 and 6.10 summarize the validity regions for applications of these models.

The baseline WTP PCT models were used to predict the PCT releases for the ORP-HLW glasses collected in the current dataset. The ORP-HLW glasses are divided into two groups: glasses that are inside the regions of validity for the WTP PCT models and glasses that are outside the regions. Of the 111 ORP HLW glasses with PCT data, only 24 are inside the regions of validity (22 for PCT-Li), with 22 coming from the glass series HLW-ALG (formulated partly using the HLW algorithm). The small number may be expected, given that most of the ORP-HLW glasses were formulated to: (i) increase waste loadings, (ii) target new waste groups that were not part of the WTP baseline mission, and (iii) explore glasses with extreme properties. The performance (in terms of the statistic R^2) of the WTP PCT models as applied to the original WTP dataset and the current ORP dataset (only glasses inside the regions of validity) are summarized as follows:

Model	WTP Dataset		ORP Dataset	
	Number of Glasses	R^2	Number of Glasses	R^2
PCT-B	264	0.791	24	0.518
PCT-Li	250	0.763	22	0.324
PCT-Na	266	0.872	24	0.743

The R^2 values are considerably lower for the ORP dataset, indicating worse prediction performances as compared to those for WTP glasses. It should be noted, however, that the outliers in the ORP dataset were not removed, which was performed for the WTP dataset. In fact, when some of the outliers were removed from the ORP dataset, the model performance improved greatly and approached those for the WTP dataset, presumably in part because of the small sample size of the ORP dataset. (A full statistical evaluation of the ORP dataset will be performed in future model development.) For example, if HLW-ALG-46 and -61 are removed from the dataset, the R^2 value increases to 0.798 for PCT-B releases. Moreover, the compositions of most of the ORP glasses, although within the WTP model validity regions, are close to the vertices where the glass population may need to be augmented (most actively designed glasses are compositionally located near the center of glass compositional space).

Figures 6.5 through 6.7 compare, respectively, the measured PCT results with the corresponding predicted releases by applying the WTP PCT-B, PCT-Li, and PCT-Na models to

the ORP glasses and the WTP glasses. The following observations can be made of the comparison figures:

- (i) As discussed above, with the exception of a few outliers, the WTP PCT models perform reasonably well for the ORP glasses that are within the model validity regions. The sample size of ORP glasses within the validity regions, however, is relatively small.
- (ii) The baseline WTP PCT models do not perform well in predicting the PCT response for ORP glasses that are outside the validity regions; very large errors resulted from applying the baseline models to these glasses. (Negative modeling R^2 values were obtained for these ORP glasses and the combined set of WTP and ORP glasses, indicating that the model performed worse than the simple average of the datasets.)
- (iii) The models over-predict for the ORP glasses developed for the aluminum-limited waste (HLW-E-Al and HWI-AL series) and for the sodium/aluminum-limited waste (HLW-ANa series).
- (iv) The models under-predict for the ORP glasses developed for the chromium-limited waste (HLW-E-Cr series) and glasses with high Cr_2O_3 .

As discussed above, the ORP glasses greatly expanded the compositional regions of HLW glasses when compared to the WTP dataset. While it is possible that a single global model may be able to effectively relate the PCT releases to glass compositions, for wide composition regions such as that found for the combined WTP and ORP dataset, it may be necessary in future modeling work to explore the use of local modeling approaches in order to obtain accurate predictions of PCT performance.

6.2 Spinel $T_{1\%}$ Results and Discussion

The spinel $T_{1\%}$ results for the HLW glasses are presented and discussed in Section 6.2.1. An assessment of the performance and limitations of the WTP baseline model as applied to the OPR-HLW dataset is provided in Section 6.2.2.

6.2.1 Spinel $T_{1\%}$ Results

Heat treatment of HLW glasses was performed between 750°C and 1150°C, at regular temperature intervals of 50°C. The measured crystal vol% data and major crystalline phase(s) for 226 ORP HLW glasses are given in Table 6.13 (42 ORP HLW glasses out of 266 do not have heat-treatment data). The predominant crystalline phase observed was spinel, while the other crystalline phases found included calcium phosphate (for HLW-BP glasses), chromium oxide (for HLW-E-ES glasses) and zirconia (HLW-E-ANa glasses). The typical relationship observed between crystal vol% and heat treatment temperature is relatively simple and can be adequately

described by a linear relationship; therefore the $T_{1\%}$ value could be obtained from linear regression of the heat treatment data. An example is given in Figure 6.8, which shows the heat treatment results of INEL-HW09. In some cases (e.g., HLW-E-M-10), the temperature dependence of the vol% data is different from that typically observed and is essentially flat. The cause of this observed behavior is not clear.

Of the 226 ORP-HLW glasses with heat treatment data, spinel $T_{1\%}$ was estimated for 103; the other glasses either did not have sufficient crystallization data to allow estimation or did not precipitate spinel as the primary crystalline phase upon heat treatment. Estimates of spinel $T_{1\%}$ also were not performed for data that showed unexpectedly flat temperature dependence. The $T_{1\%}$ estimate was obtained by fitting the temperature and vol% crystallinity data to a regression equation of the form

$$T = a_0 + a_1 v \quad (6.1)$$

where v is the vol% crystallinity at temperature T ($^{\circ}\text{C}$), and a_0 and a_1 are the fitted intercept and slope. Table 6.14 lists the fitted intercept and slope for each of the 103 HLW glasses, as well as the estimated $T_{1\%}$ value obtained and the number of data points involved in the regression estimates. The estimated spinel $T_{1\%}$ values in Table 6.14 span a very wide range of 600°C to 1580°C . For comparison, the range of spinel $T_{1\%}$ values for the 168 glasses in the WTP modeling dataset is 636°C to 1231°C . An assessment of the estimates for the ORP glasses, however, showed that there are two extreme outliers, both of which are glasses formulated to investigate the effects of high spinel crystal contents (HLW-E-SP-05 and HLW-E-M-13). Eliminating the outliers from the ORP dataset resulted in a reduced range (maximum $T_{1\%} = 1260^{\circ}\text{C}$) that is more similar to that found for the WTP glasses. Figure 6.9 is a histogram of the estimated spinel $T_{1\%}$ values for the 101 glasses in the spinel $T_{1\%}$ database. This histogram shows that the estimated spinel $T_{1\%}$ values are well distributed about the $T_{1\%}$ processability limit of 950°C , which is a desirable feature for model development [3]. Note that the regression estimates for many glasses included only 2 or 3 data points (Table 6.14), which would result in large standard deviations of the estimated values. It is recommended that additional heat treatment data be collected for these glasses such that better estimates of $T_{1\%}$ can be made before further efforts are made in $T_{1\%}$ modeling. Finally, it is noted that spinel is found to be the primary crystalline phase for a number of glasses formulated for wastes that were not iron- or chromium-limited, (e.g., HLW-E-Al-27 and HWI-Al-7, which were formulated for aluminum-limited waste), suggesting that spinel $T_{1\%}$ model may also be needed in formulating glasses for non-iron limited and non-chromium limited waste streams.

6.2.2 Discussion of Spinel $T_{1\%}$ Modeling Results

Table 6.5 presents the baseline WTP model for predicting the spinel $T_{1\%}$ for HLW glasses. The model is a 20-term truncated partial quadratic mixture model which should be applied only within appropriate composition-temperature regions of validity (see Tables 6.9 and 6.10). The regions of validity are primarily defined by the compositions of the glasses used in model development. Of the 101 ORP-HLW glasses collected into the spinel $T_{1\%}$ database, only 9

are found to lie inside the validity regions. As discussed above, it is not surprising that such a small fraction of the ORP glasses lie within the validity regions of the WTP baseline models since the glasses were formulated to explore relatively extreme compositions in attempts to maximize waste loadings for various waste groups. The nine ORP glasses inside the regions of validity are primarily members of the glass series HLW-N101. Table 6.15 compares the ORP-HLW glass compositional ranges with the WTP spinel $T_{1\%}$ model regions of validity.

Figure 6.10 compares the measured spinel $T_{1\%}$ values to the spinel $T_{1\%}$ values predicted with the baseline model. When only glasses inside the validity regions are considered, the R^2 statistic is 0.385, which is much worse than that determined for the WTP modeling dataset (0.880 for 168 glasses). When selected outliers are removed from the ORP dataset (HLW-ALG-42, HLW-N101-14, and HLW-N101-23), the model performance substantially improves, giving an R^2 value of 0.846. When the baseline model is applied to the combined dataset of WTP and ORP glasses that are inside the regions of validity, the prediction performance does not show a large change from that found during model development ($R^2 = 0.876$ for the combined set of 184 glasses vs. 0.880 for 168 WTP glasses), probably because of the small sample size of the new glasses compared to the modeling set.

Figure 6.10 shows that the baseline WTP spinel $T_{1\%}$ model performs poorly when applied to ORP glasses outside the WTP regions of validity. The WTP baseline model generally over-predicts the spinel $T_{1\%}$ of the ORP glasses, in many cases considerably so and especially for high-aluminum (HWI-Al series) and high-bismuth (HLW-E-Bi series) glasses. It is noted that B_2O_3 has a positive coefficient in the baseline $T_{1\%}$ model and that many ORP glasses (e.g., HWI-Al series) have high B_2O_3 concentrations (up to ≈ 22 wt%)

As is the case with the PCT model, the baseline WTP spinel $T_{1\%}$ model (20-term partial quadratic mixture model) appears grossly inadequate to support the extended HLW dataset because the compositions of the ORP glasses greatly exceed the compositional ranges of WTP glasses used to develop the model (Table 6.15). Consequently, revised models need to be developed based on the combined datasets.

6.3 Electrical Conductivity Results and Discussion

The electrical conductivity results for ORP-HLW glasses are presented and discussed in Section 6.3.1. An assessment of the performance and limitations of the WTP baseline electrical model as applied to the ORP-HLW dataset is provided in Section 6.3.2.

6.3.1 Electrical Conductivity Results

Of the 266 HLW glasses described in Section 3, 106 glasses have electrical conductivity results, as summarized in Table 6.1. Measurement of electrical conductivity was generally performed at four temperatures, between approximately 950°C and 1250°C, for each HLW glass. For a few selected glasses, however, the number of measurements was different than four: (i) a

few HLW-BP- glasses showed irregular behavior and/or phase separation at low temperatures and only two or three data points were collected, (ii) up to five data points were collected for glasses developed for next generation melters and high-temperature ($> 1150^{\circ}\text{C}$) melting (e.g., HLW-N101- glasses), with the highest measurement temperature at $> 1300^{\circ}\text{C}$. The electrical conductivity versus temperature values are presented in Table 6.16 for the 106 glasses.

Table 6.16 lists 420 temperature-electrical conductivity data points for 106 ORP-HLW glasses; the electrical conductivity values vary from 0.004 to 0.812 S/cm, with the smaller values generally corresponding to lower temperatures. For comparison, the WTP dataset, which includes 210 glasses, spans a wider range of 0.034 - 1.376 S/cm. The current WTP requirement for HLW glass melt electrical conductivity is that it be within 0.1 to 0.7 S/cm in the temperature range of 1100 to 1200°C. For measurements taken in this temperature range, the electrical conductivity values were all within the acceptable range for all but three glasses. The electrical conductivity values of two melts (HWI-Al-6 and HWI-Al-8) were considerably below the recommended lower limit of 0.1 S/cm; both glasses were formulated with high concentrations of Al_2O_3 (23.97 wt%) for the aluminum-limited waste. The only melt with an electrical conductivity value higher than the recommended 0.7 S/cm was HLW-ALG-47, which incorporated the maximum Na_2O (20 wt%) tested during the development of the WTP models.

Figure 6.11 shows the distribution of temperatures values at which data were collected for each HLW glass with EC data. The figure shows that there is some scatter around the nominal temperatures of 950, 1050, 1150, and 1250°C but this variation in measurement temperatures is not expected to have significant impact on model development. To determine the EC-temperature relationships for the HLW glasses, the EC values were fitted to the Arrhenius equation

$$\ln(\text{EC}) = A + B(1/T) \quad (6.2)$$

for the HLW glasses (where A is the fitted intercept and B is the fitted slope). The majority of the glasses showed relatively similar fitted slopes. A few glasses displayed considerably different EC-temperature dependence, which was substantially steeper. Figure 6.12 gives examples of these glasses, which include HLW-BP-02, HLW-E-Al-6, HLW-E-Al-8, and HLW-E-Al-11. The EC-temperature dependence of INEL-HW09 in Figure 6.12 is more typical for the new dataset. Different equations were considered in the development of WTP models to represent the temperature dependence of EC data, with the truncated-T2 equation (Table 6.6) found to be better for nearly all the glasses [3]. However, this will likely be revisited during refinement of the WTP EC-composition model or development of new models with the new data.

The EC results were reviewed to determine the extent to which general trends or relationships may be evident. The experimental EC results were fitted to the Vogel-Fulcher equation

$$\ln(\text{EC}) = A + B[1/(T - T_o)] \quad (6.3)$$

to facilitate comparison (where A is the fitted intercept, B is the fitted slope and T_o a fitted constant) at the nominal operating temperature of 1150°C for WTP HLW melter. Figure 6.13 shows the calculated EC at 1150°C as a function of alkali oxide concentration of the glass. A good correlation is observed, as would be expected based on the role of the alkalis in the ion conductivity of the melt. There is considerably more scatter when the calculated EC are plotted against the total alkali and alkaline earth oxide concentration (Figure 6.14). Specifically, there is a group of glasses that displays unexpectedly low EC; they also show substantially larger dependence on temperature, as described above. These glasses (HLW-E-Al- series) were formulated for the aluminum-limited waste with high concentrations of CaO (13 wt% – 18 wt%), which are significantly higher than the maximum CaO concentration found in WTP glasses previously included in model development (1.1 wt%).

6.3.2 Discussion of Electrical Conductivity Modeling Results

Table 6.6 presents the recommended WTP model for predicting the EC for HLW glasses. The model is a 22-term truncated T2-linear mixture model which should be applied only within appropriate composition-temperature regions of validity (see Tables 6.9 and 6.10). The regions of validity are primarily defined by the compositions of the glasses used in model development. Of the 106 ORP HLW glasses with EC data, only 21 are found to lie inside the validity regions. This is not unexpected since most of the glasses were formulated in studies to explore relatively extreme compositions in attempts to maximize waste loadings for various waste groups. In addition, the ORP glasses addressed HLW streams that were not the focus of the earlier WTP studies. It is noted that all the glasses within the validity regions are from the glass series (i) HLW-ALG, which were formulated to test extreme glass properties using the preliminary WTP glass formulation algorithm and (ii) HLW-N101, which were formulated to increase waste loadings in AZ-101 glasses by taking advantage of better capabilities of next-generation melter. Table 6.17 compares the compositional ranges of the ORP glasses with EC data to the WTP EC model regions of validity.

Figure 6.15 compares the measured EC values with the EC values predicted with the recommended model. The model provides good predictions for the new EC data when only glasses within the validity regions are included ($R^2 = 0.901$ for 21 glasses), which is comparable to that found for the WTP glasses used to develop the model ($R^2 = 0.907$ for 208 glasses). Not surprisingly, when all the glasses in the new dataset are included, the model performance significantly deteriorates and a much reduced R^2 (0.642) value is obtained. As seen in Figure 6.15, the model tends to under-predict the EC values when applied to the full dataset and there are several extreme outliers (e.g., HLW-E-Al-6 and HLW-E-Al-8). As described above, development of a new EC model for the new dataset likely will require evaluation of alternative model forms.

6.4 Viscosity Results and Discussion

The viscosity results for HLW glasses are presented and discussed in Section 6.4.1. An assessment of the performance and limitations of the WTP baseline viscosity model as applied to the new dataset is provided in Section 6.4.2.

6.4.1 Viscosity Results

Of the 266 HLW glasses described in Section 3, 107 glasses have viscosity results. However, a few of these glasses showed non-newtonian behavior and heavy crystallization during measurements; they are therefore excluded from the database. The resulting database includes viscosity data for 101 glasses, as summarized in Table 6.1. Glasses that have EC results generally also have viscosity results. Furthermore, measurement of viscosity was also performed in general at four temperatures within the same range as EC measurements, between approximately 950°C and 1250°C, for each HLW glass. For a few selected glasses, the number of measurements was different than four: (i) a few HLW-BP- glasses showed irregular behavior and/or phase separation at low temperatures and fewer than four viscosity data points were collected, (ii) up to five viscosity data points were collected for glasses developed for next generation melters and high-temperature (> 1150°C) melting (e.g., HLW-N101- glasses), with the highest measurement temperature at > 1300°C. The viscosity versus temperature values are presented in Table 6.18 for the 101 glasses. Figure 6.16 displays the distribution of temperature values at which data were collected for each HLW glass with viscosity data.

Table 6.18 lists 400 temperature-viscosity data points for 101 HLW glasses and show that the viscosity values vary from 4.03 to 4617 poise. For comparison, the WTP dataset, which includes 210 glasses, span a range of 3.60 to 3166 poise. As noted above for EC, since viscosity data were collected at different temperatures, it is convenient for comparison purpose to use the viscosity at 1150°C, calculated using the Vogel-Fulcher equation:

$$\ln(\text{viscosity}) = A[1/(T - T_o)] + C \quad (6.4)$$

where A , C , and T_o are fitted constants. Figure 6.17 shows the calculated viscosity at 1150°C as a function of the alkali oxide concentrations and Figure 6.18 as a function of the sum of alkali and alkaline earth oxide concentrations. Both figures suggest that melt viscosity decreases with increasing concentrations of alkali and alkaline earth oxides, as would be expected. A somewhat better correlation is observed with the sum of alkali and alkaline earth oxides. The outliers seen in Figure 6.18 are the same as those found in EC measurements (i.e., HLW-E-Al-6 and HLW-E-Al-8). The current WTP requirement for HLW glass melt viscosity is that it be within 10 to 150 P at 1100°C. Fifteen glasses had calculated viscosities exceeding the upper limit, while none was lower than the lower limit.

Figure 6.19 shows the viscosity values plotted against $1/T$ (with T in kelvin) for a few selected glasses, with a line corresponding to the fit of the Arrhenius equation (Equation 6.4). As seen in the figure, HLW-E-Al-6 shows the steepest temperature dependence and HLW-E-ANa-9

the shallowest. As is the case with EC, different model forms were considered in the development of WTP models to represent the temperature dependence of viscosity data, with a truncated-T2 equation (Table 6.7) found to give the best performance [3].

6.4.2 Discussion of Viscosity Modeling Results

Table 6.7 presents the recommended WTP model for predicting viscosity for HLW glasses. The model is a 29-term truncated T2-linear mixture model which should be applied only within appropriate composition-temperature regions of validity. Tables 6.19 and 6.10 summarize the WTP model regions of validity. Of the 101 ORP HLW glasses with viscosity data, only 21 are found to lie inside the validity region. The set of glasses inside the validity regions is identical to that for the EC dataset. Table 6.19 shows that the compositional ranges of ORP HLW glasses with viscosity greatly exceed the WTP model regions of validity. Figure 6.20 compares the measured viscosity values with the viscosity values predicted with the recommended model. The model provides good predictions for the new viscosity data when only glasses within the validity regions are included ($R^2 = 0.948$ for 21 glasses), which is only slightly lower than that found for the WTP glasses used to develop the model ($R^2 = 0.988$ for 197 glasses). As expected, when all the glasses in the new dataset are included, the model performance significantly deteriorates ($R^2 = 0.693$). As seen in Figure 6.20, the model tends to over-predict the viscosity values when applied to the full dataset and most of the outliers are from glasses formulated for the Al-limited waste (HLW-E-Al- and HWI-AL- series). In particular, the ORP high-aluminum glasses contain up to 26.6 wt% of Al_2O_3 and 20.2 wt% of CaO, whereas the upper limits of Al_2O_3 and CaO in the WTP model validity regions are, respectively, 13.1 wt% and 1.1 wt%.

6.5 Toxicity Characteristic Leaching Procedure (TCLP) Cadmium-Release Results and Discussion

The TCLP Cd-release results for the ORP glasses are presented and discussed in Section 6.5.1. An assessment of the performance and limitations of the WTP baseline TCLP model as applied to the new dataset is provided in Section 6.5.2.

6.5.1 TCLP Cadmium-Release Results

Of the 266 HLW glasses from the various studies described in Section 3, only 156 contain CdO as a glass component, encompassing a CdO concentration range of 0.003 to 0.961 wt%. Additionally, only a subset of these CdO-containing glasses underwent TCLP testing for Cd-release. As a result and as shown in Table 6.1, only 26 ORP HLW glasses have TCLP Cd-release data, which is a substantially smaller number compared to that (100) used to develop the WTP baseline Cd-release model [34].

Table 6.20 lists the measured unnormalized TCLP Cd-releases (c_{Cd} , mg/L); it also lists the normalized Cd-releases (r_{Cd} , g/L) calculated according to the formula:

$$r_{Cd}(\text{g/L}) = \frac{c_{Cd}(\text{mg/L})}{[1000(\text{mg/g})][m_{CdO}(\text{g CdO/g glass})][0.8754(\text{g Cd/g CdO})]}, \quad (6.5)$$

where m_{CdO} is the mass fraction of CdO in the glass. Both c_{Cd} and r_{Cd} data were considered in developing the different TCLP Cd-release models [34]. As seen in Table 6.20, the Cd-release was below the detection limit for several glasses. When those glasses are excluded, the ranges of c_{Cd} and r_{Cd} values are, respectively, (0.030-0.170) mg/L and (0.014-0.296) g/L. Table 6.21 compares the measured Cd-releases between the WTP and ORP glasses. The unnormalized Cd-releases of the ORP glasses cover a much narrower range than that of the WTP glasses, as can be expected because of the smaller size of the ORP dataset. The range of normalized Cd-releases of the ORP glasses, on the other hand, is wider than that of the WTP dataset. This is primarily a consequence of the inclusion of glasses with very low CdO concentrations (< 0.01 wt%) in the ORP dataset. For comparison, the minimum CdO concentration in the statistically designed WTP dataset is 0.05 wt%.

During the development of the WTP TCLP Cd-release models, it was observed that relatively few glasses from the modeling dataset had Cd-releases above the delisting limit of 0.48 mg/L (14 glasses out of 100) [34]. Furthermore, the examined Cd-release models showed good prediction performance up to roughly 0.25 mg/L but tended to under-predict for larger Cd-releases. It was therefore recommended that additional data be collected to assess and improve the performance of the TCLP Cd-release models for glasses with Cd-releases near and beyond the limit of 0.48 mg/L [34]. From that perspective, the ORP dataset may be of limited value to augment the TCLP Cd-release model, which would be expected since the ORP glasses were based on Cd levels in the projected tank waste compositions and were actively designed to meet the various processing and product performance constraints. However, as seen in Table 6.9, many of the single-component constraints for the TCLP Cd-release model validity regions are narrower than for the other properties modeled. The ORP glasses with TCLP Cd-release data are all compositionally outside the validity regions and could be used with additional data to update the TCLP Cd-release model if the WTP project needs to apply the model to HLW glass composition regions wider than those given in Table 6.9.

No attempts were made to correlate the Cd-release data with the glass composition for the ORP dataset because of the limited sample size.

6.5.2 Discussion of TCLP Cadmium-Release Modeling Results

Previous model development efforts [34] led to the recommendation of two models for relating TCLP Cd-releases to glass compositions, one using 20 terms and another using 10 terms. Since the predictive performance of the reduced 10-term models was similar to that of the full 20-term model, the 10-term model was proposed as the baseline WTP model for Cd-release. Table 6.8 presents the baseline WTP model for predicting TCLP Cd-releases for HLW glasses.

Application of the WTP baseline TCLP Cd-release model was intended to be limited to HLW glasses that are within the glass composition region used to develop the model. The regions of validity are primarily defined by the compositions of the glasses used in model development. Tables 6.9 and 6.10 summarize the regions of validity for the WTP Cd-release model. The 26 ORP glasses with TCLP Cd-release data are all outside the regions of validity. In fact, many of the ORP glasses show very large compositional difference when compared to the regions of validity. For example, the ORP glasses with Cd-release data have a median Al_2O_3 content of 10.28 wt% (maximum = 26.64 wt%) while the maximum Al_2O_3 found in the WTP modeling dataset is only 8.50 wt%. Table 6.22 compares the compositional ranges of ORP glasses that have TCLP Cd-release data with the regions of validity for the WTP TCLP Cd-release model. In spite of the noted compositional differences, the baseline WTP TCLP Cd-release model was applied to the ORP glasses. Figure 6.21 compares the measured TCLP Cd-releases with the predicted values for both the ORP and WTP glasses. It is apparent that the WTP baseline model greatly under-predicts for glasses with high Al_2O_3 (HWI-Al- and HLW-E-Al glass series) such that different modeling forms likely need to be examined when models for these glasses are developed.

It is noted again that data for glasses with TCLP Cd-releases above the delisting limit are needed to augment the WTP baseline model such that it can be applied to larger HLW glass composition regions similar to those for the other properties. In addition to the ORP data collected, statistically designed glass compositions will need to be tested to provide the required data.

6.6 Nepheline Formation Data and Discussion

In previous WTP work it was determined that the five properties of HLW glasses discussed above would require the development of property-composition or property-composition-temperature models to support WTP operations. It was further assumed that nepheline formation upon slow cooling would be controlled using the nepheline discriminator, which is the current approach employed at the Defense Waste Processing Facility (DWPF). The nepheline discriminator (N_{Si}) was developed by Li et al. [35, 36] and relates the concentrations of Al_2O_3 , Na_2O , and SiO_2 in glass as follows:

$$N_{Si} = \frac{x_{SiO_2}}{x_{Al_2O_3} + x_{Na_2O} + x_{Si_2O_3}} \geq 0.62, \quad (6.6)$$

where x_i is the mass fraction of component i . Glasses with $N_{Si} > 0.62$ are predicted to be free from nepheline upon slow cooling.

The nepheline discriminator does not include the effects of many glass oxides on the propensity for nepheline formation (e.g., B_2O_3). It has also been found to be very conservative, particularly with respect to high-aluminum waste streams [14, 16, 19, 56]. While it is effective in screening out glasses that form nepheline, it also screens out many compositions that do not.

This is an important limitation on the ability to achieve high waste loadings for high aluminum waste streams. Previous work performed for ORP with Hanford high aluminum HLW streams has demonstrated that while it is possible to formulate glasses with high waste loadings, they would be screened out by the current nepheline discriminator [14, 16, 19, 56]. There is therefore a need for an improved nepheline discriminator.

To support the development of an improved nepheline discriminator, existing data relating to nepheline formation upon canister centerline cooling (CCC) heat treatment have been compiled. The compiled dataset includes data collected for 153 glasses: 10 WTP glasses, 108 ORP glasses tested at VSL and 35 ORP glasses developed at VSL and tested at PNNL. Since 16 of these glasses were tested at both VSL and PNNL, there are data on nepheline formation compiled for 137 distinct ORP glasses. Only 10 WTP HLW glasses were characterized with respect to nepheline formation; many other WTP HLW glasses also underwent CCC heat treatment but the heat treated samples were tested for PCT only (the PCT data were included in the WTP database). The WTP glasses with nepheline data were from the HLW-ALG series, which were glasses designed to support the development of the preliminary WTP IHLW formulation algorithm. The set of WTP glasses tested included glasses with high PCT releases and glasses with low N_{Si} values [57]. The ORP glasses tested at PNNL were selected from the series HLW-E-Al, HWI-Al, and HLW-E-ANa (see Section 3), which were formulated for the high aluminum waste or the high sodium-aluminum waste. The ORP glasses tested at PNNL were either supplied by VSL or fabricated at PNNL. Variations of these glasses were also prepared and tested at PNNL but they are not included in the current database [43].

Table 6.23 tabulates the nepheline formation data compiled for the WTP and ORP glasses, including the glass names, estimated total vol% crystallinity upon CCC heat treatment, identity of the major crystalline phase(s) and, if applicable and available, vol% of nepheline. A lithium aluminosilicate phase was identified in some of the heat-treated glasses. While this phase may also have adverse effect on PCT of samples subjected to CCC, it is not considered as nepheline in the database. In addition, a few selected glasses have two sets of data entries because they were tested at both VSL and PNNL. Overall, the two sets of data show very good agreement in formation of nepheline; with one exception (HLW-E-ANa-24), the results show identical crystalline phases in the heat-treated samples.

The data in Table 6.23 show that, of the 153 glasses collected into the database, only 34 formed nepheline. Figure 6.22 is a plot that relates the N_{Si} values of the HLW glasses to the vol% nepheline formed upon CCC heat treatment. It is evident from Figure 6.22 that the nepheline discriminator correctly predicted no nepheline formation when N_{Si} is larger than 0.62. However, a large number (63) of HLW glasses with $N_{Si} < 0.62$ did not precipitate nepheline, including many high-aluminum glasses with low N_{Si} values. The glass HLW-E-Al-10, for example, did not precipitate nepheline in spite of a N_{Si} value of 0.363. The collected data clearly demonstrate the undue conservatism of the nepheline discriminator. Improvements to the nepheline discriminator are being developed, including the sub-lattice model [56] and the use of optical basicity [43, 58]. The current nepheline database comprised primarily of data collected on actively designed HLW glasses; it should be augmented with statistically designed glasses to enhance its value in supporting the development of an improved nepheline discriminator.

6.7 Data Gaps

To develop baseline WTP HLW composition-property models, a phased approach was adopted in the statistical design of HLW glasses. Four test glass matrices were developed and tested (namely HLW02, HLW03, HLW05, and HLW06) between 2002 and 2006 to collect property-composition data. Statistical design of experiment methods was employed to construct the test matrices and to select the glass compositions. Another glass matrix (HLW07) was developed after completion of testing of the other matrices as an augmentation to extent them to the then-current understanding of the WTP waste compositions. Another objective of the HLW07 matrix was to fill in the compositional regions with limited coverage in glass compositions and properties. Finally, another series of glasses (HLW-ALG) was designed and tested to support assessment of the HLW formulation algorithm developed by WTP. The resulting WTP database provided good coverage of the HLW glass composition region without strong correlations among components. The WTP HLW glasses formed a good basis for developing composition-property models.

As discussed above, the work performed at VSL for ORP was directed towards enhancing the WTP HLW vitrification system by optimizing waste loadings and increasing processing throughput. The ORP work was also directed at waste streams that were significantly different from those specified in the WTP contract. Consequently, the ORP glasses are compositionally rather different and cover a wider range when compared to the WTP glasses (see Section 3 and Figure 3.1). Additionally, all ORP glasses were actively designed. It is therefore expected that data gaps exist both in glass compositions and glass properties in the ORP dataset and between the ORP and WTP datasets. Some of these features are illustrated in Figures 6.23 through 6.27, Figure 6.2, and Figure 6.9. Figure 6.23 consists of histograms of the distributions of 12 major glass component oxides (Al_2O_3 , B_2O_3 , Bi_2O_3 , CaO , Cr_2O_3 , Fe_2O_3 , Li_2O , MnO , Na_2O , NiO , P_2O_5 , and SiO_2) for the 266 ORP glasses. Figure 6.24 contains pair-wise scatter plots of selected glass components. It can be seen from Figure 6.23 that the values of many glass components are unevenly distributed. Many components have at least one gap in the distribution (e.g., MnO) or heavily skewed distributions (e.g., Bi_2O_3 and CaO). Figure 6.24 identifies many compositional gaps and also demonstrates the strong correlation between Al_2O_3 and B_2O_3 .

Figures 6.2 and 6.9 display, respectively, the distributions of the PCT and spinel $T_{1\%}$ results measured for the ORP glasses. As is the case with WTP glasses, a vast majority of the ORP glasses have PCT releases well beneath the respective contract limits. For modeling purpose, however, data of higher PCT releases (including those that exceed the contract limits) are desirable and needed to fill the gaps. The compiled spinel $T_{1\%}$ values show a somewhat better distribution, although the asymmetry around the WTP processing requirement of $T_{1\%} \leq 950^\circ\text{C}$ is noticeable, a reflection of many of the ORP test objectives to increase waste loadings. Histograms of the collected data on electrical conductivity, viscosity, and TCLP Cd-release are shown in Figures 6.25 through 6.27. Distributions of these data are also uneven and gaps are evident. Glasses with higher TCLP Cd-releases are required to cover both sides of the delisting limit.

Statistical design methods similar to those employed in the WTP work can be used to generate glass formulations to optimally fill in these data gaps. Since the ORP glasses were developed for several disparate waste streams, a phased approach would likely be appropriate in future glass designs, as was previously successfully employed for the collection of the WTP HLW data.

SECTION 7.0

SUMMARY AND CONCLUSIONS

Data collected from LAW and HLW glass testing under ORP direction have been compiled and consolidated with data that were collected to support the development of the baseline WTP LAW and HLW glass property models. The compiled data include glass compositions, PCT releases, VHT response (for LAW), spinel T₁% (for HLW), electrical conductivity, viscosity, TCLP Cd-releases (for HLW), and nepheline formation upon CCC (for HLW). The LAW datasets consists of 207 ORP glasses and 271 WTP glasses while the HLW datasets consist of 266 ORP glasses and 266 WTP glasses.

Table 7.1 provides a summary of the compiled data and compares some key statistics of the ORP-LAW data with those for the WTP-LAW glass data. The ORP dataset is comprised of data from a series of LAW glass development and melter testing studies for ORP in which incremental improvements of WTP LAW facility was considered over several years. These improvements focused primarily on increasing the waste loading, particularly with respect to sulfate and sodium, but also investigated increasing the processing temperature, and increasing the fraction of the sulfur in the feed that is partitioned to the off-gas stream to increase the waste loading. Applicability of these improvements over the expected range of sodium, potassium and sulfur concentrations was demonstrated for a wide range of Hanford LAW wastes types. The resulting ORP-LAW glass compositions are significantly different from the WTP-LAW in the concentration ranges of glass components as well as in the use of SnO₂ and V₂O₅ as new glass former additives, primarily in place of Fe₂O₃ and TiO₂. With the increases in waste loadings, the concentrations of glass formers such as Al₂O₃, CaO and ZrO₂ have also been significantly increased. All of the ORP glasses were actively designed formulations. While the ORP data significantly expand the number of glasses available for modeling and the composition ranges, not surprisingly, there are gaps in the combined WTP and ORP datasets that need to be addressed. These gaps exist in both the compositions and in the glass property responses. These gaps will likely need to be addressed through the addition of statistically designed glasses to supplement the combined sets of WTP-LAW and ORP-LAW glasses. As shown in Table 7.1, only a small fraction of the ORP glasses fall within the validity range of the existing WTP baseline models. Consequently, these models need to be revised and extended in order for the WTP to be able to take advantage of these higher waste loading ORP formulations.

Table 7.2 provides a summary of the compiled data and compares some key statistics of the ORP-HLW data with those for the WTP-HLW glass data. The ORP dataset is comprised of data from various HLW glass studies performed over several years with the primary intent of determining the likely boundaries of compliant glass compositions while seeking to maximize waste loadings. The various glass studies targeted several waste streams that were different from those specified in the WTP contract; they included wastes limited by aluminum, aluminum and sodium, bismuth, and chromium (compared to the WTP waste streams, which were mainly iron-limited). As a result, the ORP HLW glass compositions are significantly different than those of

WTP HLW glasses, greatly expanding the overall HLW glass compositional space. This is evident in Table 7.2, which shows that only a small fraction of the ORP glasses fall within the validity regions of the various baseline WTP composition-property models. The glass components that have large increases in their respective compositional ranges include Al_2O_3 , B_2O_3 , Bi_2O_3 , CaO , Cr_2O_3 , Fe_2O_3 , P_2O_5 , and SiO_2 . Furthermore, in contrast to the phased statistical approach in glass formulations employed for most of the WTP HLW glasses, all of the ORP glasses were actively designed. The distributions of the resulting ORP glasses, both in terms of compositions and glass properties, therefore tend to be uneven, with correlations amongst some components. Thus, while the ORP data significantly expand the number of glasses available for modeling and the composition ranges, not surprisingly, there are gaps in the combined WTP and ORP datasets that need to be addressed. Additional HLW glass data, preferably based on statistical designs, will need to be collected to fill the data gaps identified. It is also possible that since the ORP HLW glasses were developed for several disparate waste streams, global models for relating glass properties to compositions may not be adequate to cover such a wide region of HLW compositions, in which case consideration of the development of several local models may be appropriate. Finally, Table 7.2 shows that the baseline WTP property-composition models performed significantly worse when applied to the ORP HLW glasses, even when only glasses inside the validity regions were included. While this may be partly due to the limited sample size of the ORP dataset and the presence of a few outliers, it provides a further indication that additional data collection may be needed to augment and validate the baseline HLW models. As is the case for the LAW data, Table 7.2 shows that only a small fraction of the ORP glasses fall within the validity range of the existing WTP baseline models. Consequently, these models need to be revised and extended in order for the WTP to be able to take advantage of these higher waste loading ORP formulations.

SECTION 8.0 QUALITY ASSURANCE

This work was conducted under a quality assurance program compliant with the applicable criteria of 10 CFR 830.120; the American Society of Mechanical Engineers (ASME) NQA-1, 2004; and DOE Order 414.1 C, Quality Assurance. These QA requirements are implemented through a Quality Assurance Project Plan for ORP/RPP-WTP work [59] 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 [60]. The HLW portion of the work was subject to the requirements of DOE/RW-0333P, Office of Civilian Waste Management Quality Assurance Requirements and Description (QARD), Revision 20.

SECTION 9.0 REFERENCES

- [1] “ILAW PCT, VHT, Viscosity, and Electrical Conductivity Model Development,” G.F. Piepel, S.K. Cooley, I.S. Muller, H. Gan, I. Joseph and I.L. Pegg, Final Report, VSL-07R1230-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 06/28/07.
- [2] “LAW Glass Testing and VHT Model Assessment,” I.S. Muller, I. Joseph, F. Perez-Cardenas and I.L. Pegg, Final Report, VSL-08R1410-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 09/18/08.
- [3] “IHLW PCT, Spinel T₁%, Electrical Conductivity, and Viscosity Model Development,” G.F. Piepel, S.K. Cooley, A. Heredia-Langner, S.M. Landmesser, W.K. Kot, H. Gan, and I.L. Pegg, Final Report, VSL-07R1240-4, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 01/23/08.
- [4] “Regulatory Testing of WTP HLW Glasses for Compliance with Delisting Requirements,” W.K. Kot, K. Klatt, H. Gan, I.L. Pegg, S.K. Cooley, D.J. Bates, and G.F. Piepel, Final Report, VSL-03R3780-1, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/24/03.
- [5] “Small Scale Melter Testing with LAW Simulants to Assess the Impact of Higher Temperature Melter Operations,” K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-04R4980-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 02/13/04.
- [6] “Glass Formulation Testing to Increase Sulfate Volatilization from Melter,” K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-04R4970-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 02/24/05.
- [7] “Glass Formulation Testing to Increase Sulfate Incorporation,” K.S. Matlack, M. Chaudhuri, H. Gan, I.S. Muller, W. Gong, and I.L. Pegg, Final Report, VSL-04R4960-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 02/28/05.
- [8] “LAW Envelope C Glass Formulation Testing to Increase Waste Loading,” K.S. Matlack, W. Gong, I.S. Muller, I. Joseph, and I.L. Pegg, Final Report, VSL-05R5900-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 01/27/06.

- [9] “LAW Envelope A and B Glass Formulation Testing to Increase Waste Loading,” K.S. Matlack, H. Gan, I.S. Muller, I. Joseph, and I.L. Pegg, Final Report, VSL-06R6900-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 03/23/06.
- [10] “Enhanced LAW Glass Formulation Testing,” K.S. Matlack, I. Joseph, W. Gong, I.S. Muller, and I.L. Pegg, Final Report, VSL-07R1130-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/05/07.
- [11] “Glass Formulation Development and DM10 Melter Testing with ORP LAW Glasses,” K.S. Matlack, I. Joseph, W. Gong, I.S. Muller, and I.L. Pegg, Final Report, VSL-09R1510-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 06/12/09.
- [12] “Waste Loading Enhancements for Hanford LAW Glasses,” I.S. Muller, K.S. Matlack, H. Gan, I. Joseph, and I.L. Pegg, Final Report, VSL-10R1790-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/01/10.
- [13] “HLW Enhancement Tests on the DuraMelter™ 10 with Hanford AZ-102 Tank Waste Simulants,” K.S. Matlack, W.K. Kot, H. Gan, W. Gong and I.L. Pegg, Final Report, VSL-06R6260-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 02/28/06.
- [14] “High Level Waste Vitrification System Improvements,” K.S. Matlack, H. Gan, W. Gong, I.L. Pegg, C.C. Chapman and I. Joseph, Final Report, VSL-07R1010-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 04/16/07.
- [15] “Inconel 690 Corrosion in WTP HLW Glass Melts Rich in Aluminum, Bismuth Chromium, or Aluminum/Sodium,” Z. Feng, H. Gan, and I.L. Pegg, Final Report, VSL-07R1370-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 09/23/08.
- [16] “Melt Rate Enhancement for High Aluminum HLW Glass Formulations,” K.S. Matlack, H. Gan, M. Chaudhuri, W.K. Kot, W. Gong, T. Bardakci, I. Joseph, and I.L. Pegg, Final Report, VSL-08R1360-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/19/08.
- [17] “Crystal Settling, Redox and High Temperature Properties of ORP HLW and LAW Glasses,” H. Gan, I.S. Muller, D.A. McKeown, M. Chaudhuri, Z. Feng, C. Viragh, C. Wang, R. Cecil, W. Zhao, W.K. Kot, I. Joseph, and I.L. Pegg, Final Report, VSL-09R1510-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 06/18/09.

- [18] “Effects of High Spinel and Chromium Oxide Crystal Contents on Simulated HLW Vitrification in DM100 Melter Tests,” Final Report, K.S. Matlack, W.K. Kot, W. Gong, W. Lutze, I. Joseph, and I.L. Pegg, VSL-09R1520-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 06/19/09.
- [19] “DM100 and DM1200 Melter Testing with High Waste Loading Glass Formulations for Hanford High-Aluminum HLW Streams,” K.S. Matlack, W.K. Kot, and I.L. Pegg, Final Report, VSL-10R1690-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 08/16/10.
- [20] “Tests with High-Bismuth HLW Glasses,” K.S. Matlack, H. Gan, W.K. Kot, M. Chaudhuri, R.K. Mohr, D.A. McKeown, T. Bardakci, W. Gong, A.C. Buechele, I.L. Pegg, and I. Joseph, Final Report, VSL-10T1780-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/13/10.
- [21] “Composition Effects on the Vapor Hydration of Waste Glasses,” A.C. Buechele, F. Lofaj, I.S. Muller, C.T. Mooers, and I.L. Pegg, *Ceramic Transactions*, Vol. 155, p. 289, (2004).
- [22] “Vapor Hydration Testing of Tin-Containing Glasses”, A. Buechele, C. T. Mooers, I.S. Muller, H. Gan and I.L. Pegg, 106th Annual Meeting of The American Ceramic Society, April 4, Indianapolis, 2004.
- [23] “Tin as an Additive to Improve the VHT Performance of High-Alkali Waste Glasses”, A.C. Buechele, C.T. Mooers, I.S. Muller, H. Gan, and I.L. Pegg, Materials Science and Technology 2006, Cincinnati, OH, Oct. 15-18, 2006.
- [24] “Glass Formulation and Testing with RPP-WTP LAW Simulants,” Final Report, I.S. Muller, A.C. Buechele, and I.L. Pegg, VSL-00R3560-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/23/01.
- [25] “Melter Tests with LAW Envelope B Simulants to Support Enhanced Sulfate Incorporation,” Final Report, K.S. Matlack, S. P. Morgan, and I.L. Pegg, VSL-00R3501-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 11/27/00.
- [26] “Melter Tests with LAW Envelope A and C Simulants to Support Enhanced Sulfate Incorporation,” K.S. Matlack, S. Morgan, and I.L. Pegg, VSL-01R3501-2, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 1/26/01.
- [27] “Summary of Preliminary Results on Enhanced Sulfate Incorporation During Vitrification of LAW Feeds,” I.L. Pegg, H. Gan, I.S. Muller, D.A. McKeown, and K.S. Matlack, VSL-00R3630-1, Vitreous State Laboratory, The Catholic University of America, Washington, DC, April 5 2000.

- [28] "Raman Studies of Sulfur in Borosilicate Waste Glasses: Sulfate Environments," David A. McKeown, Isabelle S. Muller, Hao Gan, Ian L. Pegg, and Christopher A. Kendziora, *J. Non-Crystalline Solids*, v. 288, p. 191-199 (2001).
- [29] "X-ray Absorption Studies of Vanadium Valence and Local Environment in Borosilicate Waste Glasses," D.A. McKeown, I.S. Muller, K.S. Matlack, and I.L. Pegg, *Scientific Basis for Nuclear Waste Management XXV*, Materials Research Society, 713, 547, (2002).
- [30] "X-ray Absorption Studies of Vanadium Valence and Local Environment in Borosilicate Waste Glasses using Vanadium Sulfide, Silicate, and Oxide Standards," David A. McKeown, Isabelle S. Muller, Keith S. Matlack, and Ian L. Pegg, *J. Non-Crystalline Solids*, v. 298, p. 160-175 (2002).
- [31] "Determination of Sulfur Environments in Borosilicate Waste Glasses Using X-ray Absorption Near-Edge Spectroscopy," D.A. McKeown, I.S. Muller, H. Gan, I.L. Pegg, and W.C. Stolte, *J. Non-Crystalline Solids*, 333, 74 (2004).
- [32] "LAW Pilot Melter and DM-100 Sub-Envelope Changeover Testing," E.V. Morrey, WTP Test Specification, 24590-LAW-TSP-RT-02-012, Rev. 0.
- [33] "Basis of Design," BNFL report, DB-W375-EG00001, Rev. 0, November 23, 1998.
- [34] "Regulatory Testing of RPP-WTP HLW Glasses to Support Delisting Compliance," W.K. Kot, K. Klatt, H. Gan, I.L. Pegg, S.K. Cooley, G.F. Piepel, and D.J. Bates, Final Report, VSL-04R4780-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/30/04.
- [35] "Nepheline Precipitation in High-Level Waste Glasses: Compositional Effects and Impacts on the Waste Form Acceptability," H. Li, J.D. Vienna, P. Hrma, D. E. Smith, and M. J. Schweiger in *Materials Research Society Vol. 465, Scientific Basis for Nuclear Waste Management XX*, MRS, 261-268, Pittsburgh, PA, 1997.
- [36] "Effects of Al_2O_3 , B_2O_3 , Na_2O , and SiO_2 on Nepheline Formation in Borosilicate Glasses: Chemical and Physical Correlations," H. Li, P. Hrma, M. Qian, Y. Su, and D.E. Smith, *J. Non-Cryst. Solids* 331, 202 (2003).
- [37] "HLW Enhancement Tests on the DuraMelter 10 with Hanford AZ-102 Tank Waste Simulants," K.S. Matlack, W.K. Kot, H. Gan, R.K. Mohr, W. Gong, and I.L. Pegg, Final Report, VSL-06R5260-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 02/28/06.

- [38] “Preparation and Testing of HLW Algorithm Glasses to Support Small Scale Melter Testing,” W.K. Kot and I.L. Pegg, Final Report, VSL-07R1240-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 08/24/07.
- [39] “Baseline HLW Glass Formulations for Bismuth Phosphate Wastes,” W.K. Kot, L. Myers, and I.L. Pegg, Final Report, VSL-07R1240-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 09/20/07.
- [40] “Glass Formulation Development and Testing for DWPF High-Al₂O₃ HLW Sludges,” K.S. Matlack, W.K. Kot, H. Gan, and I.L. Pegg, Final Report, VSL-10R1670-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/20/10.
- [41] “Glass Formulation for Next Generation Melters,” W.K. Kot, H. Gan, M. Chaudhuri, and I.L. Pegg, Final Report, VSL-11R2310-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 05/20/11.
- [42] “Melter Throughput Enhancements for High-Iron HLW,” K.S. Matlack, H. Gan, M. Chaudhuri, W.K. Kot, and I.L. Pegg, Final Report, VSL-12R2490-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 05/31/12.
- [43] “Optical Basicity and Nepheline Crystallization in High Alumina Glasses,” C.P. Rodriguez, J.S. McCloy, M.J. Schweiger, J.V. Crum, and A. Winschell, PNNL-20184, EMSP-RPT-003, Pacific Northwest National Laboratory, Richland, WA, February 2011.
- [44] Petkus, L. to Musick, C., “LAW Container Centerline Cooling Data,” RPP-WTP Memorandum, CCN# 074181, River Protection Project–Waste Treatment Plant, Richland, WA, October 16, 2003.
- [45] “Summary of Preliminary Results on Enhanced Sulfate Incorporation During Vitrification of LAW Feeds,” I.L. Pegg, H. Gan, I.S. Muller, D.A. McKeown, and K.S. Matlack, Final Report, VSL-00R3630-1, Rev. 1, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 04/05/00.
- [46] “Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope B1 Simulants,” K.S. Matlack, W. Gong, T. Bardakci, N. D’Angelo, and I.L. Pegg, Final Report, VSL-03R3851-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 05/02/03.
- [47] “DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelope A2 and B1 Feeds in Support of the LAW Pilot Melter,” K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-03R3410-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 08/22/03.

- [48] “Standard Test Methods for Determining Chemical Durability of Nuclear, Hazardous, and Mixed Waste Glasses and Multiphase Glass Ceramics: The Product Consistency Test (PCT),” ASTM-C1285-08, American Society for Testing and Materials, West Conshohocken, PA, 2008.
- [49] “Design, Construction, and Commissioning of the Hanford Tank Waste Treatment and Immobilization Plant,” Contract Number: DE-AC27-01RV14136, U. S. Department of Energy, Office of River Protection, Richland WA, 2001, (2000) as amended.
- [50] “Characterization of the Defense Waste Processing Facility (DWPF) Environmental Assessment (EA) Glass Standard Reference Material,” Jantzen, C. M., N. E. Bibler, D. C. Beam, C. L. Crawford, and M. A. Pickett, WSRC-TR-92-346, Westinghouse Savannah River Company, Aiken, SC, June, 1993.
- [51] “Development of Property-Composition Models for RPP-WTP LAW Glasses,” H. Gan and I.L. Pegg, Final Report, VSL-01R6600-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 08/06/01.
- [52] “Phase 1 LAW PCT and VHT Model Development,” I.S. Muller, H. Gan, I.L. Pegg, S.K. Cooley and G.F. Piepel, Final Report, VSL-04R4480-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 02/08/05.
- [53] “Engineering Specification for Low Activity Waste Melters,” K. Clark, 24590-LAW-3PS-AE00-T0001, River Protection Project – Waste Treatment Plant, Richland, WA, 2003.
- [54] Petkus, L. to Musick, C., “Container Centerline Cooling Data,” RPP-WTP Memorandum, CCN# 074851, River Protection Project–Waste Treatment Plant, Richland, WA, October 29, 2003.
- [55] “Formulation and Characterization of Waste Glasses with Varying Processing Temperature,” D.S. Kim, M.J. Schweiger, C.P. Rodriguez, W.C. Lepry, J.B. Lang, J.V. Crum, J.D. Vienna, F. Johnson, J.C. Marra, and D.K. Peeler, PNNL-20774, Pacific Northwest National Laboratory, Richland, WA, October 2011.
- [56] “Nepheline Formation in Aluminum-Rich HLW Glass and Potential Formulation Constraints,” H. Gan and I.L. Pegg, EM Waste Processing Technical Exchange, Atlanta, GA, November, 2010.
- [57] “Preparation and Testing of HLW Glasses to Support Development of WTP IHLW Formulation Algorithm,” W.K. Kot, and I.L. Pegg, Final Report, VSL-06R1240-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/15/06.

- [58] “Glass Composition Constraint Recommendations for Use in Life-Cycle Mission Modeling,” J.S. McCloy and J.D. Vienna, PNNL-19372, Pacific Northwest National Laboratory, Richland, WA, 2010.

- [59] “Quality Assurance Project Plan for ORP/ RPP-WTP Support Activities Conducted by VSL,” Vitreous State Laboratory, QAPP-ORP, Rev. 2, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/2/10.

- [60] “Master List of Controlled VSL Manuals and Standard Operating Procedures in Use,” QA-MLCP, Rev. 75 (and future revisions), Vitreous State Laboratory, The Catholic University of America, Washington, DC, 03/30/12.

Table 2.1. Minimums and Maximums of ORP-LAW Glass Components (in Mass Fractions) in the Datasets Used for the WTP Baseline LAW Glass Property Models [1] and the ORP-LAW Datasets.

LAW Glass Property	PCT		VHT		Viscosity & Electrical Conductivity ^(a)		Glasses in Any Property Modeling Dataset	
Number of Glasses in Baseline Modeling Set	244 (+20 excluded)		165 (+16 excluded)		171 (+10 excluded)		271	
Number of Additional ORP Glasses	171		203		122		207	
Total	416		368		399		478	
WTP-LAW Glass Component	Min	Max	Min	Max	Min	Max	Min	Max
Al ₂ O ₃	0.03499	0.09044	0.03503	0.09044	0.03499	0.09043	0.03499	0.09044
B ₂ O ₃	0.05999	0.13263	0.06008	0.13262	0.05999	0.13057	0.05999	0.13263
CaO	0	0.10463	0	0.10463	0	0.10462	0	0.10463
Fe ₂ O ₃	0	0.08412	0	0.08039	0	0.08412	0	0.08412
K ₂ O	0	0.05559	0	0.05413	0	0.05412	0	0.05559
Li ₂ O	0	0.05825	0	0.05825	0	0.05825	0	0.05825
MgO	0	0.05019	0	0.05019	0	0.05019	0	0.05019
Na ₂ O	0.02457	0.24007	0.02457	0.24007	0.02457	0.23002	0.02457	0.24007
SiO ₂	0.38007	0.52148	0.38362	0.52148	0.38007	0.52147	0.38007	0.52148
SO ₃	0.00070	0.01060	0.00070	0.01021	0.00070	0.01060	0.00070	0.01060
TiO ₂	0	0.03015	0	0.03015	0	0.03014	0	0.03015
ZnO	0.00100	0.05366	0.00999	0.05366	0.00998	0.05365	0.00998	0.05366
ZrO ₂	0	0.05003	0	0.05003	0	0.05001	0	0.05003
Others	0	0.00451	0	0.00280	0	0.00280	0	0.00451
ORP-LAW Glass Component	Min	Max	Min	Max	Min	Max	Min	Max
Al ₂ O ₃	0.05514	0.13854	0.05514	0.13854	0.05818	0.13854	0.05514	0.13854
B ₂ O ₃	0.06061	0.13740	0.06061	0.13740	0.06061	0.13740	0.06056	0.13740
CaO	0	0.12241	0	0.12241	0	0.12241	0	0.12241
Fe ₂ O ₃	0	0.03019	0	0.03019	0	0.06984	0	0.06984
K ₂ O	0.00110	0.05881	0.00110	0.05881	0.00110	0.05881	0.00110	0.05881
Li ₂ O	0	0.05023	0	0.05023	0	0.05023	0	0.05023
MgO	0	0.09939	0	0.09939	0	0.03369	0	0.09939
Na ₂ O	0.09989	0.26005	0.09989	0.26005	0.09993	0.25040	0.09989	0.26005
SiO ₂	0.29824	0.46178	0.29824	0.46178	0.34364	0.46178	0.29824	0.46178
SO ₃	0.00160	0.02170	0.00160	0.02170	0.00120	0.02100	0.00120	0.02170
TiO ₂	0	0.01549	0	0.01549	0	0.01549	0	0.01549
ZnO	0.01000	0.03652	0.01000	0.03652	0.01000	0.03652	0.00998	0.03652
ZrO ₂	0.02559	0.06753	0.02559	0.06753	0.02951	0.06753	0.02559	0.06753
SnO ₂ (new)	0	0.05001	0	0.05001	0	0.04830	0	0.05001
V ₂ O ₅ (new)	0	0.03001	0	0.03001	0	0.04001	0	0.04001
Others	0.00220	0.03780	0.00220	0.03780	0.00220	0.02931	0.00220	0.03780

(a) Viscosity and electrical conductivity data were collected on exactly the same glasses, so their information is combined.

Table 2.1. Minimums and Maximums of ORP-LAW Glass Components (in Mass Fractions) in the Datasets Used for the WTP Baseline LAW Glass Property Models [1] and ORP-LAW Datasets (Continued).

LAW Glass Property	PCT		VHT		Viscosity & Electrical Conductivity ^(a)		Glasses in Any Property Modeling Dataset	
	Min	Max	Min	Max	Min	Max	Min	Max
WTP-LAW Glass Components in “Others”								
BaO	0	0.00020	0	0.00010	0	0.01000	0	0.00020
Br	0	0.00079	0	0.00079	0	0	0	0.00079
CdO	0	0.00100	0	0.00010	0	0.00010	0	0.00100
Cl	0	0.01171	0	0.00914	0	0.01171	0	0.01171
Cr ₂ O ₃	0	0.00631	0	0.00631	0.00008	0.00592	0	0.00631
Cs ₂ O	0	0.00180	0	0.00180	0	0.00180	0	0.00180
F	0	0.00471	0	0.00470	0	0.00351	0	0.00471
I	0	0.00101	0	0	0	0	0	0.00101
MnO	0	0.00005	0	0	0	0	0	0.00005
MoO ₃	0	0.00012	0	0.00012	0	0.00010	0	0.00012
NiO	0	0.00036	0	0.00036	0	0.00031	0	0.00036
P ₂ O ₅	0	0.04752	0	0.03020	0	0.04023	0	0.04752
PbO	0	0.00031	0	0.00031	0	0.00031	0	0.00031
Re ₂ O ₇	0	0.00111	0	0.00111	0	0.00111	0	0.00111
SeO ₂	0	0.00100	0	0	0	0	0	0.00100
SrO	0	0.00002	0	0	0	0	0	0.00002
Unknown	0	0.00264	0	0	0	0	0	0.00264
ORP-LAW Glass Component in “Others”	Min	Max	Min	Max	Min	Max	Min	Max
Cl	0.0001	0.01170	0.0001	0.01170	0.0001	0.01161	0.0001	0.01170
Cr ₂ O ₃	0.0002	0.00600	0.0002	0.00600	0.00018	0.00600	0.0002	0.00600
Cs ₂ O	0	0.00190	0	0.00190	0	0.00190	0	0.00190
F	0	0.00490	0	0.00491	0	0.00490	0	0.00491
I	0	0.00100	0	0.00100	0	0.00100	0	0.00100
MnO	0	0.00060	0	0.00060	0	0.00060	0	0.00060
NiO	0	0.00040	0	0.00043	0	0.00040	0	0.00043
P ₂ O ₅	0	0.02500	0	0.02500	0	0.02010	0	0.02500
PbO	0	0.00020	0	0.00020	0	0.00020	0	0.00020

(a) Viscosity and electrical conductivity data were collected on exactly the same glasses, so their information is combined.

Table 2.2. Target Compositions of ORP-LAW Higher Loading Glasses (wt%).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others ^(a)	Sum
LAWA143	6.203	8.984	1.997	6.982	0.448	0.000	1.997	20.000	0.153	44.552	0.000	0.000	2.000	2.966	2.988	0.734	100
LAWA144	6.203	8.984	1.997	6.982	0.448	0.000	2.997	20.000	0.153	44.552	0.000	0.000	1.000	2.966	2.988	0.734	100
LAWA145	6.203	8.984	1.997	3.982	0.448	0.000	2.997	20.000	0.153	44.552	0.000	0.000	4.000	2.966	2.988	0.734	100
LAWA161	10.160	13.670	7.990	1.000	0.440	0.000	1.000	20.660	0.190	36.580	0.000	0.000	1.000	2.990	2.990	1.340	100
LAWA161S2	10.157	13.670	7.990	1.000	0.444	0.000	1.000	20.660	2.500 ^(b)	36.577	0.000	0.000	1.000	2.990	2.990	1.342	102 ^(b)
LAWA171	10.160	13.680	5.650	1.000	0.510	0.000	1.000	23.000	0.750	36.580	0.000	0.000	1.000	3.000	3.000	0.670	100
LAWA172	10.650	12.790	7.990	0.910	0.510	0.000	0.910	23.000	0.750	34.860	0.000	0.000	0.980	3.000	3.000	0.670	100
LAWA173	10.650	11.290	7.990	0.910	0.510	0.000	0.910	23.000	0.750	34.860	0.000	0.000	0.980	3.000	4.500	0.670	100
LAWA174	10.650	9.790	7.990	0.910	0.510	0.000	0.910	23.000	0.750	34.860	0.000	0.000	0.980	3.000	6.000	0.670	100
LAWA175	12.150	11.290	7.990	0.910	0.510	0.000	0.910	23.000	0.750	34.860	0.000	0.000	0.980	3.000	3.000	0.670	100
LAWA176	13.650	9.790	7.990	0.910	0.510	0.000	0.910	23.000	0.750	34.860	0.000	0.000	0.980	3.000	3.000	0.670	100
LAWA177	10.160	13.660	3.650	1.000	0.560	0.000	1.000	25.000	0.750	36.580	0.000	0.000	1.000	2.960	2.960	0.730	100
LAWA178	10.850	10.760	7.980	0.910	0.560	0.000	0.910	25.000	0.750	35.320	0.000	0.000	0.940	2.350	2.950	0.730	100
LAWA179	10.850	9.260	7.980	0.910	0.560	0.000	0.910	25.000	0.750	35.320	0.000	0.000	0.940	2.350	4.450	0.730	100
LAWA180	10.850	7.760	7.980	0.910	0.560	0.000	0.910	25.000	0.750	35.320	0.000	0.000	0.940	2.350	5.950	0.730	100
LAWA181	12.360	9.260	7.980	0.910	0.560	0.000	0.910	25.000	0.750	35.320	0.000	0.000	0.940	2.350	2.950	0.730	100
LAWA182	13.850	7.760	7.980	0.910	0.560	0.000	0.910	25.000	0.750	35.320	0.000	0.000	0.940	2.350	2.950	0.730	100
LAWA183	10.650	9.790	7.990	0.910	0.510	0.000	0.910	23.000	0.750	34.340	0.000	0.000	1.500	3.000	6.000	0.670	100
LAWA184	10.650	9.420	7.660	0.910	0.510	0.000	0.910	23.000	0.750	36.580	0.000	0.000	1.500	1.450	6.000	0.670	100
LAWA185	12.150	9.790	7.990	0.910	0.510	0.000	0.910	23.000	0.750	36.880	0.000	0.000	1.500	1.950	3.000	0.670	100
LAWA186	11.640	9.300	7.990	0.910	0.510	0.000	0.910	23.000	0.750	36.880	0.000	0.000	1.500	1.450	4.500	0.670	100
LAWA187	10.650	12.790	6.480	0.910	0.510	0.000	0.910	23.000	0.750	34.860	1.000	0.000	0.980	3.000	3.000	1.170	100
LAWA187CCC	10.650	12.790	6.480	0.910	0.510	0.000	0.910	23.000	0.750	34.860	1.000	0.000	0.980	3.000	3.000	1.170	100
LAWA188	10.650	12.790	5.480	0.910	0.510	0.000	0.910	23.000	0.750	34.860	2.010	0.000	0.980	3.000	3.000	1.170	100
LAWA189	10.650	11.290	7.490	0.910	0.510	0.000	0.910	23.000	0.750	34.860	0.000	0.000	0.980	3.000	4.500	1.170	100
LAWA190	12.150	11.290	5.980	0.910	0.510	0.000	0.910	23.000	0.750	34.860	0.000	0.000	0.980	3.000	4.500	1.170	100
LAWA191	12.150	11.290	7.490	0.910	0.510	0.000	0.910	23.000	0.750	34.860	0.000	0.000	0.980	3.000	3.000	1.170	100
LAWA192	12.150	11.290	5.980	0.910	0.510	0.000	0.910	23.000	0.750	35.860	0.000	0.000	0.980	3.000	4.000	0.670	100
LAWA193	12.150	11.290	5.480	0.910	0.510	0.000	0.910	23.000	0.750	35.860	0.000	0.000	0.980	3.000	4.000	1.170	100
LAWA194	10.850	7.760	6.980	0.910	0.560	0.000	0.910	25.000	0.750	35.320	1.000	0.000	0.940	2.350	5.950	0.730	100
LAWA195	10.850	7.760	6.480	0.910	0.560	0.000	0.910	25.000	0.750	35.320	1.000	0.000	0.940	2.350	5.950	1.240	100

(a) See Table 2.3 for the composition of the Others component.

(b) Excess SO₃ was added to test saturation sulfate solubility in the glass. For property-composition modeling, the SO₃ values as measured by XRF were used, which necessitated renormalizing the glass compositions. See Table 2.4.

Table 2.2. Target Compositions of ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others ^(a)	Sum
LAWA196	11.850	7.760	5.980	0.910	0.560	0.000	0.910	25.000	0.750	36.320	0.000	0.000	0.940	2.350	5.950	0.730	100
LAWA197	11.850	7.760	5.480	0.910	0.560	0.000	0.910	25.000	0.750	36.320	0.000	0.000	0.940	2.350	5.950	1.240	100
LAWB100	9.150	11.520	10.710	1.150	0.410	3.540	1.150	10.000	0.750	43.070	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWB101	10.150	10.010	11.210	1.150	0.410	3.540	1.150	10.000	0.750	43.080	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWB102	9.150	10.010	12.210	1.150	0.410	3.540	1.150	10.000	0.750	43.080	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWB103	9.150	10.010	9.200	1.150	0.410	4.040	1.150	10.000	0.750	45.590	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWB104	10.150	10.010	11.210	1.150	0.410	4.040	1.150	10.000	0.750	42.590	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWB105	6.150	13.020	9.200	1.150	0.410	3.540	1.150	10.000	0.750	46.080	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWB97	9.150	10.010	9.200	1.150	0.410	3.540	1.150	10.000	0.750	46.080	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWB98	10.150	11.010	9.200	1.150	0.410	3.540	1.150	10.000	0.750	44.080	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWB99	10.150	11.010	10.210	1.150	0.410	3.540	1.150	10.000	0.750	43.080	0.000	0.000	1.240	3.540	3.540	0.220	100
LAWC100R1	10.160	13.680	8.020	1.000	0.150	0.000	1.000	20.000	1.200	36.620	0.000	0.000	1.000	3.000	3.000	1.170	100
LAWC101	10.160	13.000	8.020	1.000	0.150	0.000	1.000	20.000	1.200	36.620	0.000	0.000	1.000	3.000	3.680	1.170	100
LAWC102	8.640	13.680	8.020	1.000	0.150	0.000	1.000	20.000	1.200	36.620	0.000	0.000	1.000	3.000	4.520	1.170	100
LAWC103	7.120	13.680	8.020	1.000	0.150	0.000	1.000	20.000	1.200	36.620	0.000	0.000	1.000	3.000	6.040	1.170	100
ORPLA1	10.000	9.000	3.500	1.010	0.560	0.000	1.350	25.000	0.190	41.310	0.000	0.000	0.000	2.360	4.800	0.920	100
ORPLA2	10.000	9.000	2.500	1.010	0.560	0.000	1.350	25.000	0.190	41.310	1.000	0.000	0.000	2.360	4.800	0.920	100
ORPLA3	10.000	9.000	3.040	1.010	0.560	0.000	1.350	25.000	0.190	41.310	0.000	0.000	0.000	2.360	4.800	1.390	100
ORPLA4	8.000	9.000	3.500	3.020	0.560	0.000	1.350	25.000	0.190	41.310	0.000	0.000	0.000	2.360	4.800	0.920	100
ORPLA5	10.000	7.000	1.000	1.010	0.560	0.000	1.350	25.000	0.190	43.310	1.000	0.000	0.000	3.360	4.800	1.390	100
ORPLA6	10.880	7.780	1.000	0.940	0.560	0.000	0.910	25.000	0.190	41.920	1.000	0.000	0.000	2.360	6.070	1.390	100
ORPLA7	10.880	7.780	1.470	0.940	0.560	0.000	0.910	25.000	0.190	40.500	1.000	0.000	0.940	2.360	6.070	1.390	100
ORPLA8	5.820	8.480	0.000	2.700	0.560	0.000	3.370	25.000	0.190	42.100	1.940	1.550	0.000	1.000	5.900	1.390	100
ORPLA9	10.900	7.800	6.520	0.910	0.560	0.000	0.910	25.000	0.190	35.510	2.000	0.000	0.940	2.360	5.000	1.390	100
ORPLA10	10.900	7.800	6.520	0.910	0.560	0.000	0.910	25.000	0.190	35.780	2.680	0.000	0.000	2.360	5.000	1.390	100
ORPLA11	10.900	7.000	2.000	0.910	0.560	0.000	0.910	25.000	0.190	40.150	2.700	0.000	0.000	2.360	5.940	1.390	100
ORPLA12	10.770	7.130	2.030	0.930	0.540	0.000	0.930	24.000	0.180	41.000	2.750	0.000	0.000	2.450	5.950	1.360	100
ORPLA13	10.830	7.070	2.010	0.920	0.550	0.000	0.920	24.500	0.190	40.610	2.720	0.000	0.000	2.420	5.890	1.360	100
ORPLA14	10.700	7.200	2.050	0.940	0.530	0.000	0.940	23.500	0.180	41.380	2.780	0.000	0.000	2.470	6.000	1.330	100
ORPLA15	9.460	8.650	3.340	0.930	0.540	0.000	0.930	24.000	0.180	39.500	2.750	0.000	0.000	2.450	5.950	1.330	100
ORPLA16	9.870	7.780	1.470	0.940	0.560	0.000	0.910	25.000	0.190	41.580	1.000	0.000	0.940	2.360	6.000	1.390	100

(a) See Table 2.3 for the composition of the Others component.

Table 2.2. Target Compositions of ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others ^(a)	Sum
ORPLA17	9.890	8.780	2.990	0.940	0.540	0.000	0.910	24.000	0.180	40.030	1.000	0.000	0.980	2.360	6.070	1.330	100
ORPLA18	9.700	8.800	3.340	0.300	0.540	0.000	0.930	24.000	0.180	39.520	2.760	0.000	0.000	2.760	6.000	1.180	100
ORPLA19	9.700	8.800	3.340	0.300	0.540	0.000	0.930	24.000	0.180	39.520	4.830	0.000	0.000	2.760	3.930	1.180	100
ORPLA20	6.700	8.800	3.340	0.300	0.540	0.000	0.930	24.000	0.180	42.510	2.760	0.000	0.000	2.760	6.000	1.180	100
ORPLA21	6.910	8.640	3.280	0.290	0.560	0.000	0.910	25.000	0.190	41.720	2.710	0.000	0.000	2.710	5.880	1.210	100
ORPLA22	9.460	8.800	3.550	0.000	0.540	0.000	0.000	24.000	0.180	40.290	3.000	0.000	0.000	3.000	6.000	1.180	100
ORPLA23	9.460	8.800	3.550	0.000	0.540	0.000	0.000	24.000	0.180	40.290	5.000	0.000	0.000	3.000	4.000	1.180	100
ORPLA24	9.340	8.550	3.520	0.000	0.560	0.000	0.000	25.000	0.190	39.700	3.000	0.000	0.000	2.940	6.000	1.210	100
ORPLA25	9.170	8.390	3.450	0.000	0.580	0.000	0.000	26.000	0.200	39.100	3.000	0.000	0.000	2.890	6.000	1.220	100
ORPLA26	10.570	12.770	6.470	0.900	0.510	0.000	0.900	23.000	0.950	34.800	1.000	0.000	0.970	2.990	2.990	1.160	100
ORPLA27	10.330	12.200	6.180	0.860	0.510	0.000	4.000	23.000	0.950	33.230	0.960	0.000	0.930	2.860	2.860	1.140	100
ORPLA28	10.100	11.640	5.900	0.820	0.510	0.000	7.000	23.000	0.950	31.710	0.910	0.000	0.890	2.720	2.720	1.120	100
ORPLA29	9.870	11.080	5.620	0.780	0.510	0.000	10.000	23.000	0.950	30.190	0.870	0.000	0.840	2.590	2.590	1.090	100
ORPLA30	9.560	11.730	5.430	0.900	0.510	0.000	4.000	23.000	0.950	34.800	1.000	0.000	0.970	2.990	2.990	1.160	100
ORPLA31	8.650	10.680	4.390	0.900	0.510	0.000	7.000	23.000	0.950	34.800	1.000	0.000	0.970	2.990	2.990	1.160	100
ORPLA32	7.730	9.640	3.340	0.900	0.510	0.000	10.000	23.000	0.950	34.800	1.000	0.000	0.970	2.990	2.990	1.160	100
ORPLA33	6.160	8.950	3.200	0.260	0.510	0.000	1.010	23.140	0.960	42.490	2.470	0.000	0.940	2.870	5.890	1.140	100
ORPLA33-1	6.730	8.900	3.180	0.260	0.510	0.000	1.000	23.000	0.950	42.230	2.460	0.000	0.930	2.860	5.860	1.140	100
ORPLA34	7.260	10.070	4.210	0.470	0.510	0.000	2.010	23.170	0.960	39.520	1.970	0.000	0.940	2.880	4.890	1.140	100
ORPLA35	8.370	11.190	5.230	0.670	0.510	0.000	3.030	23.190	0.960	36.540	1.470	0.000	0.940	2.880	3.890	1.150	100
ORPLA36	6.350	8.780	3.140	0.260	0.530	0.000	0.990	24.150	0.990	41.690	2.420	0.000	0.920	2.820	5.780	1.160	100
ORPLA37	6.350	8.260	3.140	0.260	0.530	0.000	1.980	24.150	0.990	41.220	2.420	0.000	0.920	2.820	5.780	1.160	100
ORPLA38	6.350	8.260	3.140	0.260	0.530	0.000	0.990	24.150	0.990	41.700	2.680	0.000	0.920	2.820	6.040	1.160	100
ORPLA38-1	6.940	8.210	3.120	0.260	0.530	0.000	0.980	24.000	0.990	41.430	2.660	0.000	0.910	2.800	6.000	1.160	100
ORPLA1S4	10.000	9.000	3.500	1.010	0.560	0.000	1.350	25.000	4.190 ^(b)	41.310	0.000	0.000	0.000	2.360	4.800	0.920	104 ^(b)
ORPLA2S4	10.000	9.000	2.500	1.010	0.560	0.000	1.350	25.000	4.190 ^(b)	41.310	1.000	0.000	0.000	2.360	4.800	0.920	104 ^(b)
ORPLA3S4	10.000	9.000	3.040	1.010	0.560	0.000	1.350	25.000	4.190 ^(b)	41.310	0.000	0.000	0.000	2.360	4.800	1.390	104 ^(b)
ORPLA4S4	8.000	9.000	3.500	3.020	0.560	0.000	1.350	25.000	4.190 ^(b)	41.310	0.000	0.000	0.000	2.360	4.800	0.920	104 ^(b)
ORPLA5S4	10.000	7.000	1.000	1.010	0.560	0.000	1.350	25.000	4.190 ^(b)	43.310	1.000	0.000	0.000	3.360	4.800	1.390	104 ^(b)
ORPLA6S4	10.880	7.780	1.000	0.940	0.560	0.000	0.910	25.000	4.190 ^(b)	41.920	1.000	0.000	0.000	2.360	6.070	1.390	104 ^(b)
ORPLA7S4	10.880	7.780	1.470	0.940	0.560	0.000	0.910	25.000	4.190 ^(b)	40.500	1.000	0.000	0.940	2.360	6.070	1.390	104 ^(b)

(a) See Table 2.3 for the composition of the Others component.

 (b) Excess SO₃ was added to test saturation sulfate solubility in the glass. For property-composition modeling, the SO₃ values as measured by XRF were used, which necessitated renormalizing the glass compositions. See Table 2.4.

Table 2.2. Target Compositions of ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others ^(a)	Sum
ORPLA8S4	5.820	8.480	0.000	2.700	0.560	0.000	3.370	25.000	4.190 ^(b)	42.100	1.940	1.550	0.000	1.000	5.900	1.390	104 ^(b)
ORPLA9S4	10.900	7.800	6.520	0.910	0.560	0.000	0.910	25.000	4.190 ^(b)	35.510	2.000	0.000	0.940	2.360	5.000	1.390	104 ^(b)
ORPLA10S4	10.900	7.800	6.520	0.910	0.560	0.000	0.910	25.000	4.190 ^(b)	35.780	2.680	0.000	0.000	2.360	5.000	1.390	104 ^(b)
ORPLA11S4	10.900	7.000	2.000	0.910	0.560	0.000	0.910	25.000	4.190 ^(b)	40.150	2.700	0.000	0.000	2.360	5.940	1.390	104 ^(b)
ORPLA12S4	10.770	7.130	2.030	0.930	0.540	0.000	0.930	24.000	4.190 ^(b)	41.000	2.750	0.000	0.000	2.450	5.950	1.360	104 ^(b)
ORPLA13S4	10.830	7.070	2.010	0.920	0.550	0.000	0.920	24.500	4.190 ^(b)	40.610	2.720	0.000	0.000	2.420	5.890	1.360	104 ^(b)
ORPLA14S4	10.700	7.200	2.050	0.940	0.530	0.000	0.940	23.500	4.190 ^(b)	41.380	2.780	0.000	0.000	2.470	6.000	1.330	104 ^(b)
ORPLA15S4	9.460	8.650	3.340	0.930	0.540	0.000	0.930	24.000	4.190 ^(b)	39.500	2.750	0.000	0.000	2.450	5.950	1.330	104 ^(b)
ORPLA16S4	9.870	7.780	1.470	0.940	0.560	0.000	0.910	25.000	4.190 ^(b)	41.580	1.000	0.000	0.940	2.360	6.000	1.390	104 ^(b)
ORPLA17S4	9.890	8.780	2.990	0.940	0.540	0.000	0.910	24.000	4.190 ^(b)	40.030	1.000	0.000	0.980	2.360	6.070	1.330	104 ^(b)
ORPLB1	12.000	7.300	1.100	1.100	0.120	0.000	1.100	25.000	0.520	37.980	1.080	0.000	2.000	3.650	5.440	1.600	100
ORPLB2	10.000	7.300	1.100	1.100	0.120	0.000	1.100	25.000	0.520	39.980	1.080	0.000	2.000	3.650	5.440	1.600	100
ORPLB3	9.880	8.570	3.000	0.960	0.110	0.000	0.930	24.000	0.500	40.060	1.000	0.000	1.000	2.370	6.040	1.510	100
ORPLB4	10.030	8.520	1.900	0.960	0.110	0.000	0.930	24.000	0.500	40.060	1.000	0.000	2.000	2.370	6.040	1.510	100
ORPLB1S4	12.000	7.300	1.100	1.100	0.120	0.000	1.100	25.000	4.520 ^(b)	37.980	1.080	0.000	2.000	3.650	5.440	1.604	104 ^(b)
ORPLB2S4	10.000	7.300	1.100	1.100	0.120	0.000	1.100	25.000	4.520 ^(b)	39.980	1.080	0.000	2.000	3.650	5.440	1.604	104 ^(b)
ORPLB3S4	9.880	8.570	3.000	0.960	0.110	0.000	0.930	24.000	4.500 ^(b)	40.060	1.000	0.000	1.000	2.370	6.040	1.569	104 ^(b)
ORPLB4S4	10.030	8.520	1.900	0.960	0.110	0.000	0.930	24.000	4.500 ^(b)	40.060	1.000	0.000	2.000	2.370	6.040	1.569	104 ^(b)
ORPLC1	9.500	6.060	3.000	1.000	0.580		1.000	25.000	0.550	38.320	2.000	1.000	3.000	3.000	4.500	1.520	100
ORPLC2	10.670	11.670	6.420	0.900	0.540	0.000	0.900	23.500	0.520	34.520	0.990	0.000	1.470	2.970	3.460	1.460	100
ORPLC3	10.670	11.670	4.110	0.900	0.540	0.000	0.900	23.500	0.520	34.520	0.990	0.000	1.470	2.970	3.460	3.780	100
ORPLC4	10.650	11.190	6.470	0.910	0.540	0.000	0.910	23.500	0.520	34.860	1.000	0.000	1.480	3.000	3.500	1.460	100
ORPLC5	10.040	8.520	1.910	0.970	0.540	0.000	0.930	23.570	0.520	40.100	1.000	0.000	2.000	2.370	6.040	1.490	100
ORPLC1S4	9.500	6.060	3.000	1.000	0.580	0.000	1.000	25.000	4.550 ^(b)	38.320	2.000	1.000	3.000	3.000	4.500	1.510	104 ^(b)
ORPLC2S4	10.670	11.670	6.420	0.900	0.540	0.000	0.900	23.500	4.520 ^(b)	34.520	0.990	0.000	1.470	2.970	3.460	1.462	104 ^(b)
ORPLC3S4	10.670	11.670	4.110	0.900	0.540	0.000	0.900	23.500	4.520 ^(b)	34.520	0.990	0.000	1.470	2.970	3.460	3.775	104 ^(b)
ORPLC4S4	10.650	11.190	6.470	0.910	0.540	0.000	0.910	23.500	4.520 ^(b)	34.860	1.000	0.000	1.480	3.000	3.500	1.462	104 ^(b)
ORPLC5S4	10.040	8.520	1.910	0.970	0.540	0.000	0.930	23.570	4.520 ^(b)	40.100	1.000	0.000	2.000	2.370	6.040	1.478	104 ^(b)
ORPLD1	10.160	12.050	8.020	1.000	0.160	0.000	1.000	21.000	0.960	37.170	0.000	0.000	1.000	3.000	3.000	1.470	100
ORPLD2	9.110	7.610	8.020	0.750	0.160	0.750	1.000	21.000	0.960	39.400	1.000	0.000	1.000	2.510	5.260	1.470	100
ORPLD3	8.110	8.610	10.020	0.750	0.160	0.750	1.000	21.000	0.960	39.400	0.000	0.000	1.000	2.510	4.260	1.470	100

(a) See Table 2.3 for the composition of the Others component.

(b) Excess SO₃ was added to test saturation sulfate solubility in the glass. For property-composition modeling, the SO₃ values as measured by XRF were used, which necessitated renormalizing the glass compositions. See Table 2.4.

Table 2.2. Target Compositions of ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others ^(a)	Sum
ORPLD4	10.180	12.070	8.030	0.300	0.160	0.000	1.000	21.000	0.960	37.920	0.000	0.000	1.000	3.010	3.010	1.340	100
ORPLD5	10.180	10.030	8.030	0.300	0.160	0.000	1.000	21.000	0.960	37.920	0.000	0.000	2.000	3.010	4.050	1.340	100
ORPLD6	10.120	9.870	7.910	0.300	0.170	0.000	0.990	22.000	1.010	37.330	0.000	0.000	1.970	2.970	3.990	1.380	100
ORPLD7	10.080	9.870	7.910	0.300	0.170	0.000	0.990	22.000	1.010	37.330	1.000	0.000	1.000	2.970	3.990	1.380	100
ORPLD8	10.030	9.500	7.350	0.290	0.180	0.000	0.970	23.000	1.060	36.740	1.000	0.000	1.460	2.990	4.020	1.420	100
ORPLD9	8.570	9.500	7.350	0.290	0.180	0.000	0.970	23.000	1.060	36.740	1.000	0.000	2.920	2.990	4.020	1.420	100
ORPLD1S4	10.160	12.050	8.020	1.000	0.160	0.000	1.000	21.000	4.960 ^(b)	37.170	0.000	0.000	1.000	3.000	3.000	1.467	104 ^(b)
ORPLD2S4	9.110	7.610	8.020	0.750	0.160	0.750	1.000	21.000	4.960 ^(b)	39.400	1.000	0.000	1.000	2.510	5.260	1.467	104 ^(b)
ORPLD3S4	8.110	8.610	10.020	0.750	0.160	0.750	1.000	21.000	4.960 ^(b)	39.400	0.000	0.000	1.000	2.510	4.260	1.467	104 ^(b)
ORPLE1	7.600	9.850	10.460	0.240	0.550	3.000	1.050	16.000	1.250	41.410	0.000	0.000	1.250	3.220	3.540	0.590	100
ORPLE2	10.010	11.460	8.040	0.240	0.550	3.000	1.050	16.000	1.250	39.800	0.000	0.000	1.250	3.220	3.540	0.590	100
ORPLE3	10.010	11.460	10.460	0.240	0.550	3.000	1.050	16.000	1.250	37.390	0.000	0.000	1.250	3.220	3.540	0.590	100
ORPLE4	7.640	9.810	10.430	0.230	0.610	2.100	1.050	18.000	1.250	40.340	0.000	0.000	1.210	3.130	3.530	0.660	100
ORPLE5	7.600	9.610	10.240	0.230	0.680	1.100	0.990	20.000	1.250	39.950	0.000	0.000	1.180	2.960	3.510	0.710	100
ORPLE6	7.600	9.850	9.970	0.240	0.550	3.000	1.050	16.000	1.250	41.410	0.000	0.000	1.250	3.220	3.620	0.990	100
ORPLE7	7.600	9.850	10.460	0.240	0.550	2.600	1.050	16.000	1.250	41.410	0.000	0.000	1.250	3.220	3.540	0.990	100
ORPLE8	7.600	9.450	10.050	1.050	0.550	3.000	1.050	16.000	1.250	41.410	0.000	0.000	1.250	3.220	3.540	0.590	100
ORPLE9	7.600	9.050	9.650	1.050	0.550	3.000	1.050	16.000	1.250	41.410	0.000	0.000	1.250	3.220	3.940	0.990	100
ORPLE10	8.800	10.460	9.250	0.240	0.550	3.000	1.050	16.000	1.250	40.810	0.000	0.000	1.250	3.220	3.540	0.590	100
ORPLE11	7.600	9.850	10.460	0.240	0.550	2.500	1.050	16.000	1.250	41.410	0.000	0.000	1.750	3.220	3.540	0.590	100
ORPLE12	7.600	9.850	10.050	0.240	0.550	2.500	1.050	16.000	1.250	41.410	0.000	0.000	1.750	3.220	3.540	0.990	100
ORPLF1	10.030	9.750	10.000	0.310	0.410	3.750	1.010	10.000	1.610	43.350	0.880	0.000	1.250	3.000	4.000	0.660	100
ORPLF2	9.890	9.610	9.860	0.300	0.450	3.700	0.990	11.000	1.770	42.740	0.860	0.000	1.240	2.960	3.940	0.670	100
ORPLF3	9.760	9.480	9.720	0.300	0.500	3.650	0.980	12.000	1.930	42.140	0.850	0.000	1.220	2.910	3.880	0.690	100
ORPLF4	8.600	9.500	9.720	0.300	0.500	3.500	0.980	12.000	1.930	42.140	0.850	0.000	2.500	2.910	3.880	0.690	100
ORPLF5	9.620	9.340	9.580	0.290	0.540	3.590	0.970	13.000	2.090	41.540	0.840	0.000	1.200	2.870	3.830	0.700	100
ORPLF6	8.480	9.360	9.580	0.290	0.540	3.450	0.970	13.000	2.090	41.540	0.840	0.000	2.470	2.870	3.830	0.700	100
ORPLF7	8.600	9.500	9.720	0.300	0.500	4.350	0.980	12.000	1.930	42.140	0.000	0.000	2.500	2.910	3.880	0.690	100
ORPLF8	8.600	8.850	9.720	0.300	0.500	5.000	0.980	12.000	1.930	42.140	0.000	0.000	2.500	2.910	3.880	0.690	100
ORPLF9	7.600	8.850	9.720	0.300	0.500	3.500	0.980	12.000	1.930	41.820	0.850	0.000	2.500	2.910	3.880	2.650	100
ORPLF10	8.600	9.500	10.570	0.300	0.500	3.500	0.980	12.000	1.930	42.140	0.000	0.000	2.500	2.910	3.880	0.690	100
ORPLF11	8.600	9.500	9.720	0.300	0.500	3.500	0.980	12.000	1.930	42.140	0.600	0.000	2.750	2.910	3.880	0.690	100

(a) See Table 2.3 for the composition of the Others component.

 (b) Excess SO₃ was added to test saturation sulfate solubility in the glass. For property-composition modeling, the SO₃ values as measured by XRF were used, which necessitated renormalizing the glass compositions. See Table 2.4.

Table 2.2. Target Compositions of ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others ^(a)	Sum
ORPLF12	8.600	9.500	9.720	0.300	0.500	3.500	0.980	12.000	1.930	42.140	0.000	0.000	2.750	2.910	4.490	0.690	100
ORPLF13	8.600	9.500	10.570	0.000	0.500	3.500	0.000	12.000	1.930	42.140	1.000	0.000	2.720	2.910	3.950	0.690	100
ORPLF14	8.600	9.500	10.570	0.000	0.500	3.710	0.000	12.000	1.930	42.140	1.000	0.000	2.500	2.910	3.950	0.690	100
ORPLG1	10.040	8.900	2.230	0.300	5.060	0.000	0.960	18.500	0.360	41.270	2.970	0.000	0.000	2.450	5.930	1.030	100
ORPLG2	9.990	8.820	2.200	0.290	5.200	0.000	0.960	19.000	0.370	40.890	2.940	0.000	0.000	2.430	5.880	1.040	100
ORPLG3	9.950	8.740	2.180	0.290	5.340	0.000	0.950	19.500	0.380	40.500	2.910	0.000	0.000	2.400	5.820	1.040	100
ORPLG4	9.950	8.740	2.180	0.290	5.340	0.000	0.950	19.500	0.380	40.500	4.800	0.000	0.000	2.400	3.930	1.040	100
ORPLG5	9.950	8.740	2.770	0.000	5.340	0.000	0.000	19.500	0.380	40.790	2.910	0.000	0.000	2.770	5.820	1.040	100
ORPLG6	6.770	8.700	2.750	0.290	5.400	0.000	0.980	19.750	0.380	41.750	2.900	0.000	0.000	3.480	5.800	1.070	100
ORPLG7	6.770	8.650	2.740	0.290	5.470	0.000	0.970	20.000	0.390	41.550	2.880	0.000	0.000	3.460	5.770	1.060	100
ORPLG8	6.750	8.570	2.710	0.290	5.610	0.000	0.960	20.500	0.400	41.150	2.860	0.000	0.000	3.430	5.710	1.070	100
ORPLG9	6.740	8.490	2.690	0.280	5.750	0.000	0.950	21.000	0.410	40.750	2.830	0.000	0.000	3.390	5.660	1.070	100
ORPLG10	6.720	8.400	2.660	0.280	5.880	0.000	0.940	21.500	0.420	40.350	2.800	0.000	0.000	3.360	5.600	1.090	100
ORPLG11	6.750	8.570	3.960	0.000	5.610	0.000	0.000	20.500	0.400	41.150	2.860	0.000	0.000	3.430	5.710	1.070	100
ORPLG12	6.750	8.570	2.710	0.290	5.610	0.000	0.960	20.500	0.400	41.150	2.860	0.000	0.000	3.430	3.860	2.930	100
ORPLG13	6.540	8.280	2.620	0.280	5.470	0.000	4.040	20.000	0.390	39.760	2.760	0.000	0.000	3.310	5.520	1.040	100
ORPLG14	6.530	8.200	2.600	0.270	5.610	0.000	4.000	20.500	0.400	39.380	2.730	0.000	0.000	3.280	5.470	1.050	100
ORPLG15	6.510	8.120	2.570	0.270	5.750	0.000	3.960	21.000	0.410	39.000	2.710	0.000	0.000	3.250	5.410	1.050	100
ORPLG16	5.520	8.260	2.730	0.290	5.640	0.000	2.050	20.610	0.400	41.380	2.870	0.000	0.000	3.450	5.740	1.070	100
ORPLG17	5.520	8.260	2.730	0.290	5.640	0.000	2.050	20.610	0.400	41.380	3.230	0.000	0.000	2.730	6.100	1.070	100
ORPLG18	5.520	8.040	2.730	0.290	5.640	0.000	1.970	20.610	0.400	42.240	2.730	0.000	0.000	2.730	6.030	1.070	100
ORPLG19	5.510	7.960	2.700	0.280	5.780	0.000	1.950	21.120	0.410	41.830	2.700	0.000	0.000	2.700	5.970	1.070	100
ORPLG20	6.040	8.000	2.710	0.290	5.610	0.000	0.960	20.500	0.400	42.010	3.710	0.000	0.000	2.710	6.000	1.070	100
ORPLG21	6.040	8.000	2.710	0.290	5.610	0.000	0.960	20.500	0.400	43.010	2.710	0.000	0.000	2.710	6.000	1.070	100
ORPLG22	6.040	8.000	2.710	0.290	5.610	0.000	0.460	20.500	0.400	42.010	3.460	0.000	0.000	2.710	6.750	1.070	100
ORPLG23	6.040	8.000	2.710	0.290	5.610	0.000	0.460	20.500	0.400	42.510	3.210	0.000	0.000	2.710	6.500	1.070	100
ORPLG24	6.030	7.920	2.690	0.280	5.750	0.000	0.940	21.000	0.410	41.600	3.690	0.000	0.000	2.690	5.940	1.070	100
ORPLG25	6.030	7.920	2.690	0.280	5.750	0.000	0.940	21.000	0.410	42.600	2.690	0.000	0.000	2.690	5.940	1.070	100
ORPLG26	6.030	7.920	2.690	0.280	5.750	0.000	0.440	21.000	0.410	41.600	3.440	0.000	0.000	2.690	6.690	1.070	100
ORPLG27	6.030	7.920	2.690	0.280	5.750	0.000	0.440	21.000	0.410	42.100	3.190	0.000	0.000	2.690	6.440	1.070	100

(a) See Table 2.3 for the composition of the Others component.

Table 2.2. Target Compositions of ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others ^(a)	Sum
10A-G-43B (ORPLG9)	6.760	8.510	2.700	0.200	5.760	0.000	0.960	21.000	0.200	40.920	2.840	0.000	0.000	3.400	5.680	1.070	100
10A-G-53C (ORPLD6)	10.080	9.840	7.880	0.280	0.170	0.000	1.000	22.000	1.300	37.190	0.000	0.000	1.960	2.960	3.980	1.380	100
DWV-G-123C (LAWB99)	10.060	10.910	10.110	1.140	0.400	3.520	1.140	9.960	1.500	42.730	0.000	0.000	1.230	3.510	3.510	0.320	100
EWV89BCCC (LAWA187)	10.620	12.750	6.470	0.900	0.510	0.000	0.900	22.930	0.950	34.750	1.000	0.000	0.970	2.990	2.990	1.270	100
EWV93BCCC (LAWA187)	10.620	12.750	6.470	0.900	0.510	0.000	0.900	22.930	0.950	34.750	1.000	0.000	0.970	2.990	2.990	1.270	100
EWV-G-89B (LAWA187)	10.610	12.740	6.460	0.900	0.510	0.000	0.900	22.910	1.050	34.720	1.000	0.000	0.970	2.980	2.980	1.273	100
EWV-G-93B (LAWA187)	10.610	12.740	6.460	0.900	0.510	0.000	0.900	22.910	1.050	34.720	1.000	0.000	0.970	2.980	2.980	1.273	100
EWV-G-108B (LAWA187)	10.610	12.740	6.460	0.900	0.510	0.000	0.900	22.910	1.050	34.720	1.000	0.000	0.970	2.980	2.980	1.273	100
I10-G-135A (ORPLG27)	6.020	7.910	2.680	0.280	5.740	0.000	0.440	21.000	0.500	42.050	3.180	0.000	0.000	2.680	6.430	1.070	100
J10-G-24B (ORPLA38-1)	6.950	8.220	3.130	0.260	0.520	0.000	0.980	24.000	0.800	41.550	2.670	0.000	0.920	2.820	6.030	1.150	100
Q10-G-134A (ORPLE12)	7.570	9.820	10.020	0.240	0.540	2.490	1.040	16.000	1.500	41.280	0.000	0.010	1.740	3.210	3.530	0.990	100
R10-G-155A (ORPLA15)	9.450	8.600	3.320	0.920	0.540	0.000	0.920	24.000	0.600	39.250	2.730	0.000	0.000	2.430	5.910	1.310	100
S10-G-101B (ORPLC5)	10.020	8.500	1.910	0.970	0.540	0.000	0.930	23.570	0.700	40.010	1.000	0.000	2.000	2.360	6.030	1.480	100
S10-G-45A (ORPLB4)	9.980	8.480	1.890	0.960	0.110	0.000	0.930	24.000	0.850	39.880	1.000	0.000	1.990	2.360	6.010	1.560	100
T10-G-16A (ORPLD1)	10.150	12.020	8.010	1.000	0.160	0.000	1.000	21.000	1.100	37.110	0.000	0.000	1.000	3.000	3.000	1.460	100
WVW-G-11A (LAWA161)	10.160	13.670	7.990	1.000	0.440	0.000	1.000	20.660	1.250	36.580	0.000	0.000	1.000	2.990	2.990	1.370	101
WVY-G-95A (LAWC100)	10.160	13.680	8.020	1.000	0.150	0.000	1.000	20.000	1.100	36.620	0.000	0.000	1.000	3.000	3.000	1.270	100
Y10-G-146C (ORPLA20)	6.650	8.740	3.320	0.190	0.530	0.000	0.920	24.000	0.700	42.330	2.740	0.000	0.000	2.740	5.960	1.170	100
Z10-G-122B (ORLF7-low SO ₃)	8.720	9.630	9.860	0.230	0.500	4.410	0.990	12.000	0.800	42.730	0.000	0.000	2.530	2.950	3.930	0.700	100
Z10-G-153B (ORLF7-high SO ₃)	8.650	9.560	9.780	0.230	0.500	4.380	0.990	12.000	1.500	42.390	0.000	0.000	2.510	2.930	3.900	0.690	100
Z10-G-60C (ORPLD6)	10.090	9.850	7.890	0.280	0.170	0.000	1.000	22.000	1.200	37.240	0.000	0.000	1.960	2.960	3.980	1.380	100

(a) See Table 2.3 for the compositions of the Others component.

Table 2.3. Target Values of Others Components in ORP-LAW Higher Loading Glasses (wt%).

Glass ID	Cl	Cr ₂ O ₃	Cs ₂ O	F	I	MnO	NiO	P ₂ O ₅	PbO	Sum
LAWA143	0.564	0.018	0.149	0.003	-	-	-	-	-	0.734
LAWA144	0.564	0.018	0.149	0.003	-	-	-	-	-	0.734
LAWA145	0.564	0.018	0.149	0.003	-	-	-	-	-	0.734
LAWA161	1.170	0.020	0.150	-	-	-	-	-	-	1.340
LAWA161S2	1.170	0.020	0.149	0.003	-	-	-	-	-	1.342
LAWA171	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA172	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA173	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA174	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA175	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA176	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA177	0.710	0.020	-	-	-	-	-	-	-	0.730
LAWA178	0.710	0.020	-	-	-	-	-	-	-	0.730
LAWA179	0.710	0.020	-	-	-	-	-	-	-	0.730
LAWA180	0.710	0.020	-	-	-	-	-	-	-	0.730
LAWA181	0.710	0.020	-	-	-	-	-	-	-	0.730
LAWA182	0.710	0.020	-	-	-	-	-	-	-	0.730
LAWA183	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA184	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA185	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA186	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA187	0.650	0.520	-	-	-	-	-	-	-	1.170
LAWA187CCC	0.650	0.520	-	-	-	-	-	-	-	1.170
LAWA188	0.650	0.520	-	-	-	-	-	-	-	1.170
LAWA189	0.650	0.520	-	-	-	-	-	-	-	1.170
LAWA190	0.650	0.520	-	-	-	-	-	-	-	1.170
LAWA191	0.650	0.520	-	-	-	-	-	-	-	1.170
LAWA192	0.650	0.020	-	-	-	-	-	-	-	0.670
LAWA193	0.650	0.520	-	-	-	-	-	-	-	1.170
LAWA194	0.710	0.020	-	-	-	-	-	-	-	0.730
LAWA195	0.710	0.530	-	-	-	-	-	-	-	1.240
LAWA196	0.710	0.020	-	-	-	-	-	-	-	0.730
LAWA197	0.710	0.530	-	-	-	-	-	-	-	1.240
LAWB100	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWB101	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWB102	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWB103	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWB104	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWB105	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWB97	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWB98	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWB99	0.010	0.110	-	0.070	-	-	-	0.030	-	0.220
LAWC100R1	0.650	0.020	-	0.190	-	-	0.030	0.270	0.010	1.170
LAWC101	0.650	0.020	-	0.190	-	-	0.030	0.270	0.010	1.170
LAWC102	0.650	0.020	-	0.190	-	-	0.030	0.270	0.010	1.170
LAWC103	0.650	0.020	0.000	0.190	-	-	0.030	0.270	0.010	1.170

- Empty data field

Table 2.3. Target Values of Others Components in ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Cl	Cr ₂ O ₃	Cs ₂ O	F	I	MnO	NiO	P ₂ O ₅	PbO	Sum
ORPLA1	0.710	0.020	0.190	-	-	-	-	-	-	0.920
ORPLA2	0.710	0.020	0.190	-	-	-	-	-	-	0.920
ORPLA3	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA4	0.710	0.020	0.190	-	-	-	-	-	-	0.920
ORPLA5	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA6	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA7	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA8	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA9	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA10	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA11	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA12	0.680	0.500	0.180	-	-	-	-	-	-	1.360
ORPLA13	0.690	0.490	0.180	-	-	-	-	-	-	1.360
ORPLA14	0.660	0.500	0.170	-	-	-	-	-	-	1.330
ORPLA15	0.680	0.500	0.150	-	-	-	-	-	-	1.330
ORPLA16	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA17	0.680	0.500	0.150	-	-	-	-	-	-	1.330
ORPLA18	0.680	0.500	-	-	-	-	-	-	-	1.180
ORPLA19	0.680	0.500	-	-	-	-	-	-	-	1.180
ORPLA20	0.680	0.500	-	-	-	-	-	-	-	1.180
ORPLA21	0.710	0.500	-	-	-	-	-	-	-	1.210
ORPLA22	0.680	0.500	-	-	-	-	-	-	-	1.180
ORPLA23	0.680	0.500	-	-	-	-	-	-	-	1.180
ORPLA24	0.710	0.500	-	-	-	-	-	-	-	1.210
ORPLA25	0.730	0.490	-	-	-	-	-	-	-	1.220
ORPLA26	0.640	0.520	-	-	-	-	-	-	-	1.160
ORPLA27	0.640	0.500	-	-	-	-	-	-	-	1.140
ORPLA28	0.640	0.480	-	-	-	-	-	-	-	1.120
ORPLA29	0.640	0.450	-	-	-	-	-	-	-	1.090
ORPLA30	0.640	0.520	-	-	-	-	-	-	-	1.160
ORPLA31	0.640	0.520	-	-	-	-	-	-	-	1.160
ORPLA32	0.640	0.520	-	-	-	-	-	-	-	1.160
ORPLA33	0.640	0.500	-	-	-	-	-	-	-	1.140
ORPLA33-1	0.640	0.500	-	-	-	-	-	-	-	1.140
ORPLA34	0.640	0.500	-	-	-	-	-	-	-	1.140
ORPLA35	0.650	0.500	-	-	-	-	-	-	-	1.150
ORPLA36	0.670	0.490	-	-	-	-	-	-	-	1.160
ORPLA37	0.670	0.490	-	-	-	-	-	-	-	1.160
ORPLA38	0.670	0.490	-	-	-	-	-	-	-	1.160
ORPLA38-1	0.670	0.490	-	-	-	-	-	-	-	1.160
ORPLA1S4	0.710	0.020	0.190	-	-	-	-	-	-	0.920
ORPLA2S4	0.710	0.020	0.190	-	-	-	-	-	-	0.920
ORPLA3S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA4S4	0.710	0.020	0.190	-	-	-	-	-	-	0.920
ORPLA5S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA6S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA7S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA8S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390

- Empty data field

Table 2.3. Target Values of Others Components in ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Cl	Cr ₂ O ₃	Cs ₂ O	F	I	MnO	NiO	P ₂ O ₅	PbO	Sum
ORPLA9S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA10S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA11S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA12S4	0.680	0.500	0.180	-	-	-	-	-	-	1.360
ORPLA13S4	0.690	0.490	0.180	-	-	-	-	-	-	1.360
ORPLA14S4	0.660	0.500	0.170	-	-	-	-	-	-	1.330
ORPLA15S4	0.680	0.500	0.150	-	-	-	-	-	-	1.330
ORPLA16S4	0.710	0.490	0.190	-	-	-	-	-	-	1.390
ORPLA17S4	0.680	0.500	0.150	0.000	-	0.000	0.000	0.000	-	1.330
ORPLB1	0.110	0.520	0.150	0.490	-	0.060	0.040	0.230	-	1.600
ORPLB2	0.110	0.520	0.150	0.490	-	0.060	0.040	0.230	-	1.600
ORPLB3	0.110	0.530	0.140	0.470	-	-	0.040	0.220	-	1.510
ORPLB4	0.110	0.530	0.140	0.470	-	-	0.040	0.220	-	1.510
ORPLB1S4	0.112	0.519	0.150	0.491	-	0.060	0.043	0.229	-	1.604
ORPLB2S4	0.112	0.519	0.150	0.491	-	0.060	0.043	0.229	-	1.604
ORPLB3S4	0.108	0.526	0.144	0.472	-	0.057	0.042	0.220	-	1.569
ORPLB4S4	0.108	0.526	0.144	0.472	-	0.057	0.042	0.220	-	1.569
ORPLC1	0.660	0.500	0.150	0.010	-	-	0.000	0.200	0.000	1.520
ORPLC2	0.620	0.510	0.140	0.010	-	-	0.000	0.180	0.000	1.460
ORPLC3	0.620	0.510	0.140	0.010	-	-	0.000	2.500	0.000	3.780
ORPLC4	0.620	0.510	0.140	0.010	-	-	0.000	0.180	0.000	1.460
ORPLC5	0.620	0.530	0.140	0.010	-	-	0.000	0.190	0.000	1.490
ORPLC1S4	0.655	0.501	0.150	0.008	-	-	0.000	0.196	0.000	1.510
ORPLC2S4	0.616	0.512	0.141	0.008	-	-	0.000	0.185	0.000	1.462
ORPLC3S4	0.616	0.512	0.141	0.008	-	-	0.000	2.498	0.000	3.775
ORPLC4S4	0.616	0.512	0.141	0.008	-	-	0.000	0.185	0.000	1.462
ORPLC5S4	0.618	0.526	0.141	0.008	-	0.000	0.000	0.185	-	1.478
ORPLD1	0.330	0.500	0.130	0.170	-	0.000	0.040	0.290	0.010	1.470
ORPLD2	0.330	0.500	0.130	0.170	-	0.000	0.040	0.290	0.010	1.470
ORPLD3	0.330	0.500	0.130	0.170	-	0.000	0.040	0.290	0.010	1.470
ORPLD4	0.330	0.500	0.000	0.170	-	-	0.040	0.290	0.010	1.340
ORPLD5	0.330	0.500	0.000	0.170	-	-	0.040	0.290	0.010	1.340
ORPLD6	0.350	0.500	0.000	0.180	-	-	0.040	0.300	0.010	1.380
ORPLD7	0.350	0.500	0.000	0.180	-	-	0.040	0.300	0.010	1.380
ORPLD8	0.360	0.500	0.000	0.190	-	-	0.040	0.310	0.020	1.420
ORPLD9	0.360	0.500	0.000	0.190	-	-	0.040	0.310	0.020	1.420
ORPLD1S4	0.331	0.503	0.126	0.172	-	-	0.036	0.285	0.014	1.467
ORPLD2S4	0.331	0.503	0.126	0.172	-	-	0.036	0.285	0.014	1.467
ORPLD3S4	0.331	0.503	0.126	0.172	-	-	0.036	0.285	0.014	1.467
ORPLE1	0.020	0.100	0.150	0.200	-	-	-	0.120	-	0.590
ORPLE2	0.020	0.100	0.150	0.200	-	-	-	0.120	-	0.590
ORPLE3	0.020	0.100	0.150	0.200	-	-	-	0.120	-	0.590
ORPLE4	0.030	0.110	0.150	0.230	-	-	-	0.140	-	0.660
ORPLE5	0.030	0.130	0.150	0.250	-	-	-	0.150	-	0.710
ORPLE6	0.020	0.500	0.150	0.200	-	-	-	0.120	-	0.990
ORPLE7	0.020	0.500	0.150	0.200	-	-	-	0.120	-	0.990
ORPLE8	0.020	0.100	0.150	0.200	-	-	-	0.120	-	0.590

- Empty data field

Table 2.3. Target Values of Others Components in ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Cl	Cr ₂ O ₃	Cs ₂ O	F	I	MnO	NiO	P ₂ O ₅	PbO	Sum
ORPLE9	0.020	0.500	0.150	0.200	-	-	-	0.120	-	0.990
ORPLE10	0.020	0.100	0.150	0.200	-	-	-	0.120	-	0.590
ORPLE11	0.020	0.100	0.150	0.200	-	-	-	0.120	-	0.590
ORPLE12	0.020	0.500	0.150	0.200	-	-	-	0.120	-	0.990
ORPLF1	0.010	0.550	-	0.070	-	-	-	0.030	-	0.660
ORPLF2	0.010	0.550	-	0.080	-	-	-	0.030	-	0.670
ORPLF3	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLF4	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLF5	0.010	0.560	-	0.090	-	-	-	0.040	-	0.700
ORPLF6	0.010	0.560	-	0.090	-	-	-	0.040	-	0.700
ORPLF7	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLF8	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLF9	0.010	0.560	-	0.080	-	-	-	2.000	-	2.650
ORPLF10	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLF11	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLF12	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLF13	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLF14	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
ORPLG1	0.200	0.600	-	0.080	-	-	0.010	0.130	0.010	1.030
ORPLG2	0.210	0.600	-	0.080	-	-	0.010	0.130	0.010	1.040
ORPLG3	0.210	0.600	-	0.080	-	-	0.010	0.130	0.010	1.040
ORPLG4	0.210	0.600	-	0.080	-	-	0.010	0.130	0.010	1.040
ORPLG5	0.210	0.600	-	0.080	-	-	0.010	0.130	0.010	1.040
ORPLG6	0.220	0.600	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG7	0.220	0.590	-	0.090	-	-	0.010	0.140	0.010	1.060
ORPLG8	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG9	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG10	0.240	0.590	-	0.090	-	-	0.010	0.150	0.010	1.090
ORPLG11	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG12	0.230	0.590	-	0.090	-	-	0.010	2.000	0.010	2.930
ORPLG13	0.220	0.570	-	0.090	-	-	0.010	0.140	0.010	1.040
ORPLG14	0.230	0.570	-	0.090	-	-	0.010	0.140	0.010	1.050
ORPLG15	0.230	0.570	-	0.090	-	-	0.010	0.140	0.010	1.050
ORPLG16	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG17	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG18	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG19	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG20	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG21	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG22	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG23	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG24	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG25	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG26	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
ORPLG27	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070

- Empty data field

Table 2.3. Target Values of Others Components in ORP-LAW Higher Loading Glasses (wt%) (Continued).

Glass ID	Cl	Cr ₂ O ₃	Cs ₂ O	F	I	MnO	NiO	P ₂ O ₅	PbO	Sum
10A-G-43B	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
10A-G-53C	0.350	0.500	-	0.180	-	-	0.040	0.300	0.010	1.380
DWV-G-123C	0.010	0.110	-	0.070	0.100	-	-	0.030	-	0.320
EWV89BCCC	0.650	0.520	-	-	0.100	-	-	-	-	1.270
EWV-G-89B	0.650	0.520	-	-	0.100	-	-	-	-	1.270
EWV-G-93B (LAWA187)	0.650	0.520	-	0.003	0.100	-	-	-	-	1.273
EWV93BCCC	0.650	0.520	-	0.003	0.100	-	-	-	-	1.273
EWV-G-108B (LAWA187)	0.650	0.520	-	0.003	0.100	-	-	-	-	1.273
I10-G-135A	0.230	0.590	-	0.090	-	-	0.010	0.140	0.010	1.070
J10-G-24B	0.660	0.490	-	-	-	-	-	-	-	1.150
Q10-G-134A	0.020	0.500	0.150	0.200	-	-	-	0.120	-	0.990
R10-G-155A	0.680	0.490	0.140	-	-	-	-	-	-	1.310
S10-G-101B	0.620	0.530	0.140	0.010	-	-	-	0.180	-	1.480
S10-G-45A	0.110	0.530	0.140	0.470	0.000	0.050	0.040	0.220	-	1.560
T10-G-16A	0.330	0.500	0.130	0.170	-	-	0.040	0.280	0.010	1.460
WVW-G-11A	1.170	0.020	0.150	-	-	-	-	0.030	-	1.370
WVY-G-95A	0.650	0.020	-	0.190	0.100	-	0.030	0.270	0.010	1.270
Y10-G-146C	0.670	0.500	-	0.000	-	-	-	-	-	1.170
Z10-G-122B	0.010	0.570	-	0.080	-	-	-	0.040	-	0.700
Z10-G-153B	0.010	0.560	-	0.080	-	-	-	0.040	-	0.690
Z10-G-60C	0.350	0.500	-	0.180	-	-	0.040	0.300	0.010	1.380

- Empty data field

Table 2.4. Normalized Compositions (wt%) of 207 ORP-LAW Higher Waste Loading Glasses with XRF Analyzed SO₃ Values and Target Values of the Remaining Components.

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
LAWA143	6.205	8.987	1.998	6.984	0.448	0.000	1.998	20.006	0.120	44.565	0.000	0.000	2.001	2.967	2.989	0.734	100.000
LAWA144	6.205	8.987	1.998	6.984	0.448	0.000	2.998	20.006	0.120	44.565	0.000	0.000	1.000	2.967	2.989	0.734	100.000
LAWA145	6.204	8.986	1.997	3.983	0.448	0.000	2.998	20.004	0.130	44.560	0.000	0.000	4.001	2.966	2.989	0.734	100.000
LAWA161	10.160	13.670	7.990	1.000	0.440	0.000	1.000	20.660	0.180	36.580	0.000	0.000	1.000	2.990	2.990	1.340	100.000
LAWA161S2	10.084	13.571	7.932	0.993	0.441	0.000	0.993	20.511	0.900	36.313	0.000	0.000	0.993	2.968	2.968	1.332	100.000
LAWA171	10.168	13.691	5.655	1.001	0.510	0.000	1.001	23.019	0.670	36.609	0.000	0.000	1.001	3.002	3.002	0.671	100.000
LAWA172	10.655	12.796	7.994	0.910	0.510	0.000	0.910	23.012	0.680	34.878	0.000	0.000	0.980	3.002	3.002	0.670	100.000
LAWA173	10.658	11.298	7.996	0.911	0.510	0.000	0.911	23.016	0.660	34.885	0.000	0.000	0.981	3.002	4.503	0.670	100.000
LAWA174	10.654	9.794	7.993	0.910	0.510	0.000	0.910	23.009	0.690	34.874	0.000	0.000	0.980	3.001	6.002	0.670	100.000
LAWA175	12.152	11.292	7.992	0.910	0.510	0.000	0.910	23.005	0.710	34.867	0.000	0.000	0.980	3.001	3.001	0.670	100.000
LAWA176	13.658	9.796	7.995	0.911	0.510	0.000	0.911	23.014	0.670	34.881	0.000	0.000	0.981	3.002	3.002	0.670	100.000
LAWA177	10.164	13.666	3.651	1.000	0.560	0.000	1.000	25.010	0.700	36.595	0.000	0.000	1.000	2.961	2.961	0.730	100.000
LAWA178	10.853	10.763	7.982	0.910	0.560	0.000	0.910	25.008	0.710	35.331	0.000	0.000	0.940	2.351	2.951	0.730	100.000
LAWA179	10.855	9.265	7.984	0.910	0.560	0.000	0.910	25.013	0.690	35.338	0.000	0.000	0.940	2.351	4.452	0.730	100.000
LAWA180	10.854	7.763	7.983	0.910	0.560	0.000	0.910	25.010	0.700	35.334	0.000	0.000	0.940	2.351	5.952	0.730	100.000
LAWA181	12.362	9.262	7.982	0.910	0.560	0.000	0.910	25.005	0.710	35.327	0.000	0.000	0.940	2.350	2.951	0.730	100.000
LAWA182	13.854	7.762	7.982	0.910	0.560	0.000	0.910	25.008	0.710	35.331	0.000	0.000	0.940	2.351	2.951	0.730	100.000
LAWA183	10.658	9.797	7.996	0.911	0.510	0.000	0.911	23.016	0.660	34.364	0.000	0.000	1.501	3.002	6.004	0.670	100.000
LAWA184	10.640	9.411	7.653	0.909	0.510	0.000	0.909	22.979	0.830	36.547	0.000	0.000	1.499	1.449	5.995	0.669	100.000
LAWA185	12.155	9.794	7.993	0.910	0.510	0.000	0.910	23.009	0.700	36.895	0.000	0.000	1.501	1.951	3.001	0.670	100.000
LAWA186	11.638	9.298	7.988	0.910	0.510	0.000	0.910	22.995	0.760	36.873	0.000	0.000	1.500	1.450	4.499	0.670	100.000
LAWA187	10.663	12.805	6.488	0.911	0.511	0.000	0.911	23.028	0.620	34.902	1.001	0.000	0.981	3.004	3.004	1.171	100.000
LAWA187CCC	10.664	12.807	6.488	0.911	0.511	0.000	0.911	23.030	0.610	34.906	1.001	0.000	0.981	3.004	3.004	1.172	100.000
LAWA188	10.663	12.805	5.487	0.911	0.511	0.000	0.911	23.028	0.610	34.902	2.012	0.000	0.981	3.004	3.004	1.171	100.000
LAWA189	10.663	11.304	7.499	0.911	0.511	0.000	0.911	23.028	0.610	34.902	0.000	0.000	0.981	3.004	4.505	1.171	100.000
LAWA190	12.168	11.307	5.989	0.911	0.511	0.000	0.911	23.035	0.590	34.913	0.000	0.000	0.981	3.005	4.507	1.172	100.000
LAWA191	12.165	11.304	7.499	0.911	0.511	0.000	0.911	23.028	0.610	34.902	0.000	0.000	0.981	3.004	3.004	1.171	100.000
LAWA192	12.157	11.297	5.984	0.911	0.510	0.000	0.911	23.014	0.680	35.882	0.000	0.000	0.981	3.002	4.002	0.670	100.000
LAWA193	12.165	11.304	5.487	0.911	0.511	0.000	0.911	23.028	0.620	35.903	0.000	0.000	0.981	3.004	4.005	1.171	100.000
LAWA194	10.867	7.773	6.991	0.911	0.561	0.000	0.911	25.040	0.580	35.377	1.002	0.000	0.942	2.354	5.960	0.731	100.000
LAWA195	10.866	7.772	6.490	0.911	0.561	0.000	0.911	25.038	0.580	35.373	1.002	0.000	0.941	2.354	5.959	1.242	100.000

Table 2.4. Normalized Compositions (wt%) of 207 ORP-LAW Higher Waste Loading Glasses with XRF Analyzed SO₃ Values and Target Values of the Remaining Components (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
LAWA196	11.864	7.769	5.987	0.911	0.561	0.000	0.911	25.030	0.620	36.364	0.000	0.000	0.941	2.353	5.957	0.731	100.000
LAWA197	11.867	7.771	5.488	0.911	0.561	0.000	0.911	25.035	0.590	36.371	0.000	0.000	0.941	2.353	5.958	1.242	100.000
LAWB100	9.156	11.528	10.718	1.151	0.410	3.542	1.151	10.007	0.690	43.100	0.000	0.000	1.241	3.542	3.542	0.220	100.000
LAWB101	10.169	10.029	11.231	1.152	0.411	3.547	1.152	10.019	0.570	43.162	0.000	0.000	1.242	3.547	3.547	0.220	100.000
LAWB102	9.173	10.035	12.241	1.153	0.411	3.549	1.153	10.025	0.510	43.189	0.000	0.000	1.243	3.549	3.549	0.221	100.000
LAWB103	9.164	10.025	9.214	1.152	0.411	4.046	1.152	10.015	0.610	45.659	0.000	0.000	1.242	3.545	3.545	0.220	100.000
LAWB104	10.143	10.003	11.202	1.149	0.410	4.037	1.149	9.993	0.820	42.560	0.000	0.000	1.239	3.538	3.538	0.220	100.000
LAWB105	6.163	13.048	9.219	1.152	0.411	3.547	1.152	10.021	0.550	46.178	0.000	0.000	1.243	3.547	3.547	0.220	100.000
LAWB97	9.163	10.024	9.213	1.152	0.411	3.545	1.152	10.014	0.630	46.145	0.000	0.000	1.242	3.545	3.545	0.220	100.000
LAWB98	10.169	11.031	9.218	1.152	0.411	3.547	1.152	10.019	0.580	44.164	0.000	0.000	1.242	3.547	3.547	0.220	100.000
LAWB99	10.162	11.023	10.222	1.151	0.410	3.544	1.151	10.012	0.640	43.132	0.000	0.000	1.241	3.544	3.544	0.220	100.000
LAWC100R1	10.187	13.716	8.041	1.003	0.150	0.000	1.003	20.053	0.940	36.716	0.000	0.000	1.003	3.008	3.008	1.173	100.000
LAWC101	10.192	13.041	8.045	1.003	0.150	0.000	1.003	20.063	0.890	36.735	0.000	0.000	1.003	3.009	3.692	1.174	100.000
LAWC102	8.657	13.708	8.036	1.002	0.150	0.000	1.002	20.040	1.000	36.694	0.000	0.000	1.002	3.006	4.529	1.172	100.000
LAWC103	7.144	13.726	8.047	1.003	0.151	0.000	1.003	20.067	0.870	36.742	0.000	0.000	1.003	3.010	6.060	1.174	100.000
ORPLA1	10.000	9.000	3.500	1.010	0.560	0.000	1.350	25.000	0.190	41.310	0.000	0.000	0.000	2.360	4.800	0.920	100.000
ORPLA2	10.000	9.000	2.500	1.010	0.560	0.000	1.350	25.000	0.190	41.310	1.000	0.000	0.000	2.360	4.800	0.920	100.000
ORPLA3	9.999	8.999	3.040	1.010	0.560	0.000	1.350	24.997	0.190	41.306	0.000	0.000	0.000	2.360	4.800	1.390	100.000
ORPLA4	7.998	8.997	3.499	3.019	0.560	0.000	1.350	24.992	0.210	41.298	0.000	0.000	0.000	2.359	4.799	0.920	100.000
ORPLA5	10.002	7.001	1.000	1.010	0.560	0.000	1.350	25.005	0.200	43.319	1.000	0.000	0.000	3.361	4.801	1.390	100.000
ORPLA6	10.880	7.780	1.000	0.940	0.560	0.000	0.910	25.000	0.190	41.920	1.000	0.000	0.000	2.360	6.070	1.390	100.000
ORPLA7	10.880	7.780	1.470	0.940	0.560	0.000	0.910	25.000	0.200	40.500	1.000	0.000	0.940	2.360	6.070	1.390	100.000
ORPLA8	5.818	8.477	0.000	2.699	0.560	0.000	3.369	24.990	0.230	42.083	1.939	1.549	0.000	1.000	5.898	1.389	100.000
ORPLA9	10.902	7.802	6.521	0.910	0.560	0.000	0.910	25.005	0.180	35.517	2.000	0.000	0.940	2.360	5.001	1.390	100.000
ORPLA10	10.900	7.800	6.520	0.910	0.560	0.000	0.910	25.000	0.190	35.780	2.680	0.000	0.000	2.360	5.000	1.390	100.000
ORPLA11	10.899	6.999	2.000	0.910	0.560	0.000	0.910	24.997	0.190	40.146	2.700	0.000	0.000	2.360	5.939	1.390	100.000
ORPLA12	10.769	7.129	2.030	0.930	0.540	0.000	0.930	23.998	0.170	40.996	2.750	0.000	0.000	2.450	5.949	1.360	100.000
ORPLA13	10.831	7.071	2.010	0.920	0.550	0.000	0.920	24.502	0.190	40.614	2.720	0.000	0.000	2.420	5.891	1.360	100.000
ORPLA14	10.701	7.201	2.050	0.940	0.530	0.000	0.940	23.502	0.170	41.384	2.780	0.000	0.000	2.470	6.001	1.330	100.000
ORPLA15	9.459	8.649	3.340	0.930	0.540	0.000	0.930	23.998	0.180	39.496	2.750	0.000	0.000	2.450	5.949	1.330	100.000
ORPLA16	9.873	7.782	1.470	0.940	0.560	0.000	0.910	25.008	0.170	41.592	1.000	0.000	0.940	2.361	6.002	1.390	100.000

Table 2.4. Normalized Compositions (wt%) of 207 ORP-LAW Higher Waste Loading Glasses with XRF Analyzed SO₃ Values and Target Values of the Remaining Components (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
ORPLA17	9.890	8.780	2.990	0.940	0.540	0.000	0.910	24.000	0.180	40.030	1.000	0.000	0.980	2.360	6.070	1.330	100.000
ORPLA18	9.700	8.800	3.340	0.300	0.540	0.000	0.930	24.000	0.170	39.520	2.760	0.000	0.000	2.760	6.000	1.180	100.000
ORPLA19	9.700	8.800	3.340	0.300	0.540	0.000	0.930	24.000	0.170	39.520	4.830	0.000	0.000	2.760	3.930	1.180	100.000
ORPLA20	6.701	8.802	3.341	0.300	0.540	0.000	0.930	24.005	0.160	42.519	2.761	0.000	0.000	2.761	6.001	1.180	100.000
ORPLA21	6.910	8.640	3.280	0.290	0.560	0.000	0.910	25.000	0.180	41.720	2.710	0.000	0.000	2.710	5.880	1.210	100.000
ORPLA22	9.461	8.801	3.550	0.000	0.540	0.000	0.000	24.002	0.170	40.294	3.000	0.000	0.000	3.000	6.001	1.180	100.000
ORPLA23	9.461	8.801	3.550	0.000	0.540	0.000	0.000	24.002	0.170	40.294	5.001	0.000	0.000	3.000	4.000	1.180	100.000
ORPLA24	9.341	8.551	3.520	0.000	0.560	0.000	0.000	25.003	0.170	39.704	3.000	0.000	0.000	2.940	6.001	1.210	100.000
ORPLA25	9.172	8.392	3.451	0.000	0.580	0.000	0.000	26.005	0.180	39.108	3.001	0.000	0.000	2.891	6.001	1.220	100.000
ORPLA26	10.585	12.788	6.479	0.901	0.511	0.000	0.901	23.033	0.830	34.849	1.001	0.000	0.971	2.994	2.994	1.162	100.000
ORPLA27	10.343	12.215	6.187	0.861	0.511	0.000	4.005	23.028	0.820	33.270	0.961	0.000	0.931	2.863	2.863	1.141	100.000
ORPLA28	10.054	11.587	5.873	0.816	0.508	0.000	6.968	22.895	1.410	31.566	0.906	0.000	0.886	2.708	2.708	1.115	100.000
ORPLA29	9.750	10.946	5.552	0.771	0.504	0.000	9.879	22.721	2.170	29.824	0.859	0.000	0.830	2.559	2.559	1.077	100.000
ORPLA30	9.568	11.739	5.434	0.901	0.510	0.000	4.003	23.019	0.880	34.828	1.001	0.000	0.971	2.992	2.992	1.161	100.000
ORPLA31	8.633	10.660	4.382	0.898	0.509	0.000	6.987	22.956	1.150	34.733	0.998	0.000	0.968	2.984	2.984	1.158	100.000
ORPLA32	7.683	9.582	3.320	0.895	0.507	0.000	9.939	22.861	1.570	34.589	0.994	0.000	0.964	2.972	2.972	1.153	100.000
ORPLA33	6.169	8.964	3.205	0.260	0.511	0.000	1.012	23.175	0.820	42.554	2.474	0.000	0.941	2.874	5.899	1.142	100.000
ORPLA33-1	6.739	8.912	3.184	0.260	0.511	0.000	1.001	23.030	0.810	42.285	2.463	0.000	0.931	2.864	5.868	1.141	100.000
ORPLA34	7.270	10.084	4.216	0.471	0.511	0.000	2.013	23.203	0.820	39.576	1.973	0.000	0.941	2.884	4.897	1.142	100.000
ORPLA35	8.375	11.197	5.233	0.670	0.510	0.000	3.032	23.204	0.880	36.562	1.471	0.000	0.941	2.882	3.892	1.151	100.000
ORPLA36	6.360	8.794	3.145	0.260	0.531	0.000	0.992	24.189	0.850	41.757	2.424	0.000	0.921	2.825	5.789	1.162	100.000
ORPLA37	6.359	8.272	3.144	0.260	0.531	0.000	1.983	24.184	0.870	41.278	2.423	0.000	0.921	2.824	5.788	1.162	100.000
ORPLA38	6.358	8.270	3.144	0.260	0.531	0.000	0.991	24.179	0.880	41.751	2.683	0.000	0.921	2.823	6.047	1.161	100.000
ORPLA38-1	6.952	8.224	3.125	0.260	0.531	0.000	0.982	24.041	0.830	41.501	2.665	0.000	0.912	2.805	6.010	1.162	100.000
ORPLA1S4	9.971	8.974	3.490	1.007	0.558	0.000	1.346	24.927	0.480	41.190	0.000	0.000	0.000	2.353	4.786	0.917	100.000
ORPLA2S4	9.977	8.979	2.494	1.008	0.559	0.000	1.347	24.942	0.420	41.215	0.998	0.000	0.000	2.355	4.789	0.918	100.000
ORPLA3S4	9.977	8.979	3.033	1.008	0.559	0.000	1.347	24.942	0.410	41.215	0.000	0.000	0.000	2.355	4.789	1.387	100.000
ORPLA4S4	7.979	8.977	3.491	3.012	0.559	0.000	1.346	24.935	0.440	41.202	0.000	0.000	0.000	2.354	4.787	0.918	100.000
ORPLA5S4	9.988	6.992	0.999	1.009	0.559	0.000	1.348	24.970	0.340	43.258	0.999	0.000	0.000	3.356	4.794	1.388	100.000
ORPLA6S4	10.865	7.769	0.999	0.939	0.559	0.000	0.909	24.965	0.330	41.861	0.999	0.000	0.000	2.357	6.061	1.388	100.000
ORPLA7S4	10.871	7.774	1.469	0.939	0.560	0.000	0.909	24.980	0.280	40.468	0.999	0.000	0.939	2.358	6.065	1.389	100.000

Table 2.4. Normalized Compositions (wt%) of 207 ORP-LAW Higher Waste Loading Glasses with XRF Analyzed SO₃ Values and Target Values of the Remaining Components (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
ORPLA8S4	5.808	8.463	0.000	2.695	0.559	0.000	3.363	24.950	0.390	42.016	1.936	1.547	0.000	0.998	5.888	1.387	100.000
ORPLA9S4	10.862	7.773	6.497	0.907	0.558	0.000	0.907	24.912	0.550	35.385	1.993	0.000	0.937	2.352	4.982	1.385	100.000
ORPLA10S4	10.867	7.777	6.500	0.907	0.558	0.000	0.907	24.925	0.490	35.672	2.672	0.000	0.000	2.353	4.985	1.386	100.000
ORPLA11S4	10.888	6.992	1.998	0.909	0.559	0.000	0.909	24.972	0.290	40.106	2.697	0.000	0.000	2.357	5.933	1.388	100.000
ORPLA12S4	10.758	7.122	2.028	0.929	0.539	0.000	0.929	23.974	0.270	40.955	2.747	0.000	0.000	2.447	5.943	1.359	100.000
ORPLA13S4	10.819	7.063	2.008	0.919	0.549	0.000	0.919	24.475	0.300	40.569	2.717	0.000	0.000	2.418	5.884	1.359	100.000
ORPLA14S4	10.689	7.193	2.048	0.939	0.529	0.000	0.939	23.476	0.280	41.339	2.777	0.000	0.000	2.468	5.994	1.329	100.000
ORPLA15S4	9.451	8.641	3.337	0.929	0.539	0.000	0.929	23.976	0.270	39.460	2.747	0.000	0.000	2.448	5.944	1.329	100.000
ORPLA16S4	9.859	7.771	1.468	0.939	0.559	0.000	0.909	24.972	0.310	41.534	0.999	0.000	0.939	2.357	5.993	1.388	100.000
ORPLA17S4	9.878	8.769	2.986	0.939	0.539	0.000	0.909	23.971	0.300	39.982	0.999	0.000	0.979	2.357	6.063	1.328	100.000
ORPLB1	12.006	7.304	1.101	1.101	0.120	0.000	1.101	25.013	0.480	37.999	1.081	0.000	2.001	3.652	5.443	1.601	100.000
ORPLB2	10.005	7.304	1.101	1.101	0.120	0.000	1.101	25.013	0.480	40.000	1.081	0.000	2.001	3.652	5.443	1.601	100.000
ORPLB3	9.890	8.579	3.003	0.961	0.110	0.000	0.931	24.024	0.470	40.100	1.001	0.000	1.001	2.372	6.046	1.512	100.000
ORPLB4	10.042	8.530	1.902	0.961	0.110	0.000	0.931	24.029	0.450	40.108	1.001	0.000	2.002	2.373	6.047	1.512	100.000
ORPLB1S4	11.996	7.298	1.100	1.100	0.120	0.000	1.100	24.991	0.560	37.967	1.080	0.000	1.999	3.649	5.438	1.603	100.000
ORPLB2S4	9.995	7.296	1.099	1.099	0.120	0.000	1.099	24.986	0.580	39.958	1.079	0.000	1.999	3.648	5.437	1.603	100.000
ORPLB3S4	9.877	8.568	2.999	0.960	0.110	0.000	0.930	23.993	0.540	40.048	1.000	0.000	1.000	2.369	6.038	1.569	100.000
ORPLB4S4	10.029	8.519	1.900	0.960	0.110	0.000	0.930	23.998	0.520	40.056	1.000	0.000	2.000	2.370	6.039	1.569	100.000
ORPLC1	9.502	6.061	3.001	1.000	0.580	0.000	1.000	25.005	0.500	38.328	2.000	1.000	3.001	3.001	4.501	1.520	100.000
ORPLC2	10.674	11.675	6.423	0.900	0.540	0.000	0.900	23.509	0.490	34.534	0.990	0.000	1.471	2.971	3.461	1.461	100.000
ORPLC3	10.670	11.670	4.110	0.900	0.540	0.000	0.900	23.500	0.520	34.520	0.990	0.000	1.470	2.970	3.460	3.780	100.000
ORPLC4	10.652	11.192	6.471	0.910	0.540	0.000	0.910	23.505	0.510	34.867	1.000	0.000	1.480	3.001	3.501	1.460	100.000
ORPLC5	10.044	8.523	1.911	0.970	0.540	0.000	0.930	23.579	0.480	40.116	1.000	0.000	2.001	2.371	6.042	1.491	100.000
ORPLC1S4	9.494	6.056	2.998	0.999	0.580	0.000	0.999	24.985	0.590	38.297	1.999	0.999	2.998	2.998	4.497	1.509	100.000
ORPLC2S4	10.654	11.652	6.410	0.899	0.539	0.000	0.899	23.464	0.680	34.467	0.988	0.000	1.468	2.965	3.455	1.460	100.000
ORPLC3S4	10.659	11.658	4.106	0.899	0.539	0.000	0.899	23.475	0.630	34.484	0.989	0.000	1.468	2.967	3.456	3.771	100.000
ORPLC4S4	10.632	11.171	6.459	0.908	0.539	0.000	0.908	23.459	0.700	34.800	0.998	0.000	1.477	2.995	3.494	1.459	100.000
ORPLC5S4	10.037	8.518	1.909	0.970	0.540	0.000	0.930	23.563	0.560	40.089	1.000	0.000	1.999	2.369	6.038	1.478	100.000
ORPLD1	10.151	12.039	8.013	0.999	0.160	0.000	0.999	20.981	1.060	37.136	0.000	0.000	0.999	2.997	2.997	1.469	100.000
ORPLD2	9.127	7.625	8.035	0.751	0.160	0.751	1.002	21.040	0.770	39.476	1.002	0.000	1.002	2.515	5.270	1.473	100.000
ORPLD3	8.120	8.620	10.032	0.751	0.160	0.751	1.001	21.025	0.840	39.448	0.000	0.000	1.001	2.513	4.265	1.472	100.000

Table 2.4. Normalized Compositions (wt%) of 207 ORP-LAW Higher Waste Loading Glasses with XRF Analyzed SO₃ Values and Target Values of the Remaining Components (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
ORPLD4	10.193	12.086	8.041	0.300	0.160	0.000	1.001	21.028	0.850	37.970	0.000	0.000	1.001	3.014	3.014	1.342	100.000
ORPLD5	10.195	10.045	8.042	0.300	0.160	0.000	1.002	21.032	0.830	37.977	0.000	0.000	2.003	3.015	4.056	1.342	100.000
ORPLD6	10.138	9.888	7.924	0.301	0.170	0.000	0.992	22.040	0.820	37.398	0.000	0.000	1.974	2.975	3.997	1.383	100.000
ORPLD7	10.094	9.884	7.921	0.300	0.170	0.000	0.991	22.031	0.870	37.383	1.001	0.000	1.001	2.974	3.996	1.382	100.000
ORPLD8	10.014	9.485	7.338	0.290	0.180	0.000	0.968	22.963	1.210	36.681	0.998	0.000	1.458	2.985	4.013	1.418	100.000
ORPLD9	8.575	9.506	7.354	0.290	0.180	0.000	0.971	23.014	0.990	36.762	1.001	0.000	2.922	2.992	4.022	1.421	100.000
ORPLD1S4	10.188	12.083	8.042	1.003	0.160	0.000	1.003	21.058	0.700	37.272	0.000	0.000	1.003	3.008	3.008	1.471	100.000
ORPLD2S4	9.123	7.621	8.032	0.751	0.160	0.751	1.001	21.030	0.820	39.457	1.001	0.000	1.001	2.514	5.268	1.469	100.000
ORPLD3S4	8.116	8.616	10.027	0.751	0.160	0.751	1.001	21.015	0.890	39.429	0.000	0.000	1.001	2.512	4.263	1.468	100.000
ORPLE1	7.608	9.861	10.472	0.240	0.551	3.003	1.051	16.018	1.130	41.456	0.000	0.000	1.251	3.224	3.544	0.591	100.000
ORPLE2	10.026	11.479	8.053	0.240	0.551	3.005	1.052	16.026	1.090	39.864	0.000	0.000	1.252	3.225	3.546	0.591	100.000
ORPLE3	10.023	11.475	10.474	0.240	0.551	3.004	1.051	16.021	1.110	37.439	0.000	0.000	1.252	3.224	3.545	0.591	100.000
ORPLE4	7.654	9.828	10.449	0.230	0.611	2.104	1.052	18.033	1.080	40.414	0.000	0.000	1.212	3.136	3.536	0.661	100.000
ORPLE5	7.607	9.619	10.249	0.230	0.681	1.101	0.991	20.018	1.150	39.986	0.000	0.000	1.181	2.963	3.513	0.711	100.000
ORPLE6	7.609	9.862	9.982	0.240	0.551	3.004	1.051	16.019	1.130	41.460	0.000	0.000	1.252	3.224	3.624	0.991	100.000
ORPLE7	7.608	9.861	10.472	0.240	0.551	2.603	1.051	16.018	1.130	41.456	0.000	0.000	1.251	3.224	3.544	0.991	100.000
ORPLE8	7.608	9.461	10.061	1.051	0.551	3.003	1.051	16.018	1.130	41.456	0.000	0.000	1.251	3.224	3.544	0.591	100.000
ORPLE9	7.608	9.060	9.661	1.051	0.551	3.003	1.051	16.018	1.130	41.456	0.000	0.000	1.251	3.224	3.944	0.991	100.000
ORPLE10	8.792	10.450	9.242	0.240	0.549	2.997	1.049	15.985	1.330	40.773	0.000	0.000	1.249	3.217	3.537	0.589	100.000
ORPLE11	7.610	9.863	10.474	0.240	0.551	2.503	1.051	16.021	1.110	41.465	0.000	0.000	1.752	3.224	3.545	0.591	100.000
ORPLE12	7.615	9.870	10.070	0.240	0.551	2.505	1.052	16.032	1.050	41.494	0.000	0.000	1.754	3.227	3.547	0.992	100.000
ORPLF1	10.099	9.817	10.069	0.312	0.413	3.776	1.017	10.069	0.920	43.650	0.886	0.000	1.259	3.021	4.028	0.665	100.000
ORPLF2	9.954	9.673	9.924	0.302	0.453	3.724	0.996	11.072	1.150	43.019	0.866	0.000	1.248	2.979	3.966	0.674	100.000
ORPLF3	9.859	9.576	9.818	0.303	0.505	3.687	0.990	12.121	0.930	42.565	0.859	0.000	1.232	2.939	3.919	0.697	100.000
ORPLF4	8.673	9.580	9.802	0.303	0.504	3.530	0.988	12.102	1.100	42.497	0.857	0.000	2.521	2.935	3.913	0.696	100.000
ORPLF5	9.719	9.436	9.679	0.293	0.546	3.627	0.980	13.134	1.080	41.969	0.849	0.000	1.212	2.900	3.870	0.707	100.000
ORPLF6	8.562	9.451	9.673	0.293	0.545	3.483	0.979	13.126	1.130	41.943	0.848	0.000	2.494	2.898	3.867	0.707	100.000
ORPLF7	8.653	9.559	9.780	0.302	0.503	4.377	0.986	12.075	1.320	42.402	0.000	0.000	2.516	2.928	3.904	0.694	100.000
ORPLF8	8.640	8.892	9.766	0.301	0.502	5.023	0.985	12.056	1.470	42.338	0.000	0.000	2.512	2.924	3.898	0.693	100.000
ORPLF9	7.640	8.896	9.771	0.302	0.503	3.518	0.985	12.062	1.430	42.038	0.854	0.000	2.513	2.925	3.900	2.664	100.000
ORPLF10	8.661	9.567	10.644	0.302	0.504	3.525	0.987	12.084	1.240	42.436	0.000	0.000	2.518	2.930	3.907	0.695	100.000
ORPLF11	8.668	9.575	9.796	0.302	0.504	3.527	0.988	12.094	1.160	42.471	0.605	0.000	2.772	2.933	3.910	0.695	100.000

Table 2.4. Normalized Compositions (wt%) of 207 ORP-LAW Higher Waste Loading Glasses with XRF Analyzed SO₃ Values and Target Values of the Remaining Components (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
ORPLF12	8.584	9.483	9.702	0.299	0.499	3.494	0.978	11.978	2.100	42.063	0.000	0.000	2.745	2.905	4.482	0.689	100.000
ORPLF13	8.596	9.495	10.565	0.000	0.500	3.498	0.000	11.994	1.970	42.119	0.999	0.000	2.719	2.909	3.948	0.690	100.000
ORPLF14	8.597	9.497	10.567	0.000	0.500	3.709	0.000	11.996	1.960	42.127	1.000	0.000	2.499	2.909	3.949	0.690	100.000
ORPLG1	10.043	8.903	2.231	0.300	5.062	0.000	0.960	18.506	0.330	41.282	2.971	0.000	0.000	2.451	5.932	1.030	100.000
ORPLG2	9.994	8.824	2.201	0.290	5.202	0.000	0.960	19.008	0.320	40.906	2.941	0.000	0.000	2.431	5.882	1.040	100.000
ORPLG3	9.952	8.742	2.180	0.290	5.341	0.000	0.950	19.504	0.360	40.508	2.911	0.000	0.000	2.400	5.821	1.040	100.000
ORPLG4	9.950	8.740	2.180	0.290	5.340	0.000	0.950	19.500	0.380	40.500	4.800	0.000	0.000	2.400	3.930	1.040	100.000
ORPLG5	9.951	8.741	2.770	0.000	5.341	0.000	0.000	19.502	0.360	40.794	2.910	0.000	0.000	2.770	5.821	1.040	100.000
ORPLG6	6.770	8.700	2.750	0.290	5.400	0.000	0.980	19.750	0.360	41.750	2.900	0.000	0.000	3.480	5.800	1.070	100.000
ORPLG7	6.773	8.653	2.741	0.290	5.472	0.000	0.970	20.008	0.350	41.567	2.881	0.000	0.000	3.461	5.772	1.060	100.000
ORPLG8	6.752	8.573	2.711	0.290	5.612	0.000	0.960	20.506	0.360	41.162	2.861	0.000	0.000	3.431	5.712	1.070	100.000
ORPLG9	6.743	8.493	2.691	0.280	5.752	0.000	0.950	21.008	0.360	40.766	2.831	0.000	0.000	3.391	5.662	1.070	100.000
ORPLG10	6.721	8.402	2.661	0.280	5.881	0.000	0.940	21.504	0.400	40.358	2.801	0.000	0.000	3.361	5.601	1.090	100.000
ORPLG11	6.751	8.571	3.960	0.000	5.611	0.000	0.000	20.502	0.380	41.154	2.860	0.000	0.000	3.430	5.711	1.070	100.000
ORPLG12	6.752	8.573	2.711	0.290	5.612	0.000	0.960	20.506	0.350	41.162	2.861	0.000	0.000	3.431	3.861	2.931	100.000
ORPLG13	6.541	8.281	2.620	0.280	5.471	0.000	4.040	20.002	0.370	39.764	2.760	0.000	0.000	3.310	5.521	1.040	100.000
ORPLG14	6.531	8.201	2.600	0.270	5.611	0.000	4.000	20.502	0.370	39.384	2.730	0.000	0.000	3.280	5.471	1.050	100.000
ORPLG15	6.511	8.121	2.570	0.270	5.751	0.000	3.960	21.002	0.390	39.004	2.710	0.000	0.000	3.250	5.411	1.050	100.000
ORPLG16	5.522	8.262	2.731	0.290	5.642	0.000	2.051	20.616	0.360	41.392	2.871	0.000	0.000	3.451	5.742	1.070	100.000
ORPLG17	5.522	8.263	2.731	0.290	5.642	0.000	2.051	20.618	0.350	41.397	3.231	0.000	0.000	2.731	6.102	1.070	100.000
ORPLG18	5.522	8.043	2.731	0.290	5.642	0.000	1.971	20.618	0.360	42.257	2.731	0.000	0.000	2.731	6.032	1.070	100.000
ORPLG19	5.514	7.966	2.702	0.280	5.784	0.000	1.951	21.135	0.360	41.859	2.702	0.000	0.000	2.702	5.974	1.071	100.000
ORPLG20	6.041	8.002	2.711	0.290	5.611	0.000	0.960	20.504	0.370	42.018	3.711	0.000	0.000	2.711	6.001	1.070	100.000
ORPLG21	6.042	8.003	2.711	0.290	5.612	0.000	0.960	20.508	0.350	43.027	2.711	0.000	0.000	2.711	6.002	1.070	100.000
ORPLG22	6.043	8.004	2.711	0.290	5.613	0.000	0.460	20.510	0.340	42.031	3.462	0.000	0.000	2.711	6.753	1.071	100.000
ORPLG23	6.043	8.004	2.711	0.290	5.613	0.000	0.460	20.510	0.340	42.531	3.212	0.000	0.000	2.711	6.503	1.071	100.000
ORPLG24	6.032	7.923	2.691	0.280	5.752	0.000	0.940	21.008	0.360	41.617	3.691	0.000	0.000	2.691	5.942	1.070	100.000
ORPLG25	6.033	7.924	2.691	0.280	5.753	0.000	0.940	21.011	0.350	42.621	2.691	0.000	0.000	2.691	5.943	1.071	100.000
ORPLG26	6.034	7.925	2.692	0.280	5.753	0.000	0.440	21.013	0.340	41.625	3.442	0.000	0.000	2.692	6.694	1.071	100.000
ORPLG27	6.033	7.924	2.691	0.280	5.753	0.000	0.440	21.011	0.350	42.121	3.192	0.000	0.000	2.691	6.443	1.071	100.000

Table 2.4. Normalized Compositions (wt%) of 207 ORP-LAW Higher Waste Loading Glasses with XRF Analyzed SO₃ Values and Target Values of the Remaining Components (Continued).

Glass ID	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃	SiO ₂	SnO ₂	TiO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
10A-G-43B	6.759	8.509	2.700	0.200	5.759	0.000	0.960	20.998	0.210	40.916	2.840	0.000	0.000	3.400	5.679	1.070	100.000
10A-G-53C	10.083	9.843	7.882	0.280	0.170	0.000	1.000	22.007	1.250	37.201	0.000	0.000	1.961	2.961	3.981	1.380	100.000
DWV-G-123C	10.090	10.942	10.140	1.143	0.401	3.530	1.143	9.989	1.170	42.856	0.000	0.000	1.234	3.520	3.520	0.321	100.000
EWV89BCCC	10.636	12.769	6.480	0.901	0.511	0.000	0.901	22.965	0.800	34.803	1.002	0.000	0.971	2.995	2.995	1.272	100.000
EWV-G-89B	10.636	12.769	6.480	0.901	0.511	0.000	0.901	22.965	0.800	34.803	1.002	0.000	0.971	2.995	2.995	1.272	100.000
EWV-G-93B	10.640	12.776	6.478	0.903	0.511	0.000	0.903	22.974	0.770	34.817	1.003	0.000	0.973	2.988	2.988	1.277	100.000
EWV93BCCC	10.640	12.776	6.478	0.903	0.511	0.000	0.903	22.974	0.770	34.817	1.003	0.000	0.973	2.988	2.988	1.277	100.000
EWV-G-108B	10.633	12.768	6.474	0.902	0.511	0.000	0.902	22.960	0.830	34.796	1.002	0.000	0.972	2.987	2.987	1.276	100.000
I10-G-135A	6.023	7.914	2.681	0.280	5.743	0.000	0.440	21.011	0.470	42.071	3.182	0.000	0.000	2.681	6.433	1.071	100.000
J10-G-24B	6.953	8.223	3.131	0.260	0.520	0.000	0.980	24.010	0.760	41.567	2.671	0.000	0.920	2.821	6.032	1.150	100.000
Q10-G-134A	7.581	9.834	10.034	0.240	0.541	2.494	1.041	16.023	1.380	41.339	0.000	0.010	1.742	3.215	3.535	0.991	100.000
R10-G-155A	9.460	8.610	3.324	0.921	0.541	0.000	0.921	24.027	0.510	39.293	2.733	0.000	0.000	2.433	5.917	1.311	100.000
S10-G-101B	10.027	8.506	1.911	0.971	0.540	0.000	0.931	23.587	0.610	40.038	1.001	0.000	2.001	2.362	6.034	1.481	100.000
S10-G-45A	9.984	8.483	1.891	0.960	0.110	0.000	0.930	24.010	0.810	39.896	1.000	0.000	1.991	2.361	6.012	1.561	100.000
T10-G-16A	10.171	12.044	8.026	1.002	0.160	0.000	1.002	21.042	0.890	37.185	0.000	0.000	1.002	3.006	3.006	1.463	100.000
WVW-G-11A	10.058	13.533	7.910	0.990	0.436	0.000	0.990	20.453	1.150	36.214	0.000	0.000	0.990	2.960	2.960	1.356	100.000
WVY-G-95A	10.168	13.691	8.026	1.001	0.150	0.000	1.001	20.016	1.020	36.650	0.000	0.000	1.001	3.002	3.002	1.271	100.000
Y10-G-146C	6.657	8.749	3.323	0.190	0.531	0.000	0.921	24.024	0.610	42.373	2.743	0.000	0.000	2.743	5.966	1.171	100.000
Z10-G-122B	8.725	9.636	9.866	0.230	0.500	4.413	0.991	12.007	0.760	42.756	0.000	0.000	2.532	2.952	3.932	0.700	100.000
Z10-G-153B	8.662	9.574	9.794	0.230	0.501	4.386	0.991	12.017	1.350	42.450	0.000	0.000	2.514	2.934	3.906	0.691	100.000
Z10-G-60C	10.084	9.844	7.885	0.280	0.170	0.000	0.999	21.987	1.260	37.217	0.000	0.000	1.959	2.958	3.978	1.379	100.000

Table 2.5. Evaluation of the Compositions of ORP-LAW Replicates and Near-Replicates.

Glass	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃ , XRF Measured	SiO ₂	SnO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
LAWA161	10.160	13.670	7.990	1.000	0.440	-	1.000	20.660	0.180	36.580	-	1.000	2.990	2.990	1.340	100.000
WVW-G-11A	10.058	13.533	7.910	0.990	0.436	-	0.990	20.453	1.150	36.214	-	0.990	2.960	2.960	1.356	100.000
%RSD	0.7%	0.7%	0.7%	0.7%	0.7%		0.7%	0.7%	103.1%	0.7%		0.7%	0.7%	0.7%	0.9%	
LAWA187	10.663	12.805	6.488	0.911	0.511	-	0.911	23.028	0.620	34.902	1.001	0.981	3.004	3.004	1.171	100.000
LAWA187CCC	10.664	12.807	6.488	0.911	0.511	-	0.911	23.030	0.610	34.906	1.001	0.981	3.004	3.004	1.172	100.000
EWV89BCCC	10.582	12.753	6.491	0.910	0.510	-	0.910	23.005	0.760	34.837	1.000	0.980	3.001	3.001	1.260	100.000
EWV-G-89B	10.636	12.769	6.480	0.901	0.511	-	0.901	22.965	0.800	34.803	1.002	0.971	2.995	2.995	1.272	100.000
%RSD	0.4%	0.2%	0.1%	0.5%	0.1%		0.5%	0.1%	13.9%	0.1%	0.1%	0.5%	0.1%	0.1%	4.5%	
LAWB99	10.162	11.023	10.222	1.151	0.410	3.544	1.151	10.012	0.640	43.132	-	1.241	3.544	3.544	0.220	100.000
DWV-G-123C	10.090	10.942	10.140	1.143	0.401	3.530	1.143	9.989	1.170	42.856	-	1.234	3.520	3.520	0.321	100.000
%RSD	0.5%	0.5%	0.6%	0.5%	1.6%	0.3%	0.5%	0.2%	41.4%	0.5%		0.5%	0.5%	0.5%	26.3%	
LAWC100R1	10.187	13.716	8.041	1.003	0.150	-	1.003	20.053	0.940	36.716	-	1.003	3.008	3.008	1.173	100.000
WVY-G-95A-1	10.179	13.712	8.037	1.001	0.150	-	1.001	20.018	1.020	36.703	-	1.001	3.003	3.003	1.171	100.000
WVY-G-95A-2	10.179	13.712	8.037	1.001	0.150	-	1.001	20.018	1.020	36.703	-	1.001	3.003	3.003	1.171	100.000
WVY-G-95A-3	10.179	13.712	8.037	1.001	0.150	-	1.001	20.018	1.020	36.703	-	1.001	3.003	3.003	1.171	100.000
WVY-G-95A-4	10.179	13.712	8.037	1.001	0.150	-	1.001	20.018	1.020	36.703	-	1.001	3.003	3.003	1.171	100.000
%RSD	0.0%	0.0%	0.0%	0.1%	0.1%		0.1%	0.1%	3.6%	0.0%		0.1%	0.1%	0.1%	0.1%	
ORPLA15	9.459	8.649	3.340	0.930	0.540	-	0.930	23.998	0.180	39.496	2.750	-	2.450	5.949	1.330	100.000
R10-G-155A	9.352	8.602	3.491	1.050	0.560	-	0.990	23.765	0.510	39.498	3.091	-	2.591	5.391	1.000	100.000
%RSD	0.8%	0.4%	3.1%	8.6%	2.6%		4.4%	0.7%	67.6%	0.0%	8.3%		3.9%	7.0%	20.0%	
ORPLA20	6.701	8.802	3.341	0.300	0.540	-	0.930	24.005	0.160	42.519	2.761	-	2.761	6.001	1.180	100.000
Y10-G-146C	6.719	8.729	3.560	0.350	0.560	-	0.950	23.088	0.610	42.776	2.870	0.010	2.870	5.349	1.510	100.000
%RSD	0.2%	0.6%	4.5%	10.9%	2.6%		1.5%	2.8%	82.6%	0.4%	2.7%		2.7%	8.1%	17.3%	
ORPLA38-1	6.952	8.224	3.125	0.260	0.531	-	0.982	24.041	0.830	41.501	2.665	0.912	2.805	6.010	1.162	100.000
J10-G-24B	6.551	8.222	3.171	0.360	0.590	-	1.190	24.715	0.760	40.608	2.841	1.010	2.811	5.781	1.340	100.000
%RSD	4.2%	0.0%	1.0%	22.7%	7.5%		13.6%	2.0%	6.2%	1.5%	4.5%	7.3%	0.1%	2.7%	10.1%	
ORPLB4	10.042	8.530	1.902	0.961	0.110	-	0.931	24.029	0.450	40.108	1.001	2.002	2.373	6.047	1.512	100.000
S10-G-45A	9.589	8.479	2.030	1.130	0.340	-	0.990	24.118	0.810	38.896	1.210	2.300	2.550	5.579	1.740	100.000
%RSD	3.3%	0.4%	4.6%	11.4%	72.2%		4.3%	0.3%	40.4%	2.2%	13.3%	9.8%	5.1%	5.7%	9.9%	

- Empty data field

Table 2.5. Evaluation of the Compositions of ORP-LAW PCT Replicates and Near-Replicates (Continued).

Glass	Al ₂ O ₃	B ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	Li ₂ O	MgO	Na ₂ O	SO ₃ , XRF Measured	SiO ₂	SnO ₂	V ₂ O ₅	ZnO	ZrO ₂	Others	Sum
ORPLC5	10.044	8.523	1.911	0.970	0.540	-	0.930	23.579	0.480	40.116	1.000	2.001	2.371	6.042	1.491	100.000
S10-G-101B	10.499	8.499	1.960	1.100	0.590	-	0.840	22.448	0.610	40.876	1.040	2.280	2.560	5.169	1.390	100.000
%RSD	3.1%	0.2%	1.8%	8.8%	6.2%		7.2%	3.5%	16.9%	1.3%	2.7%	9.2%	5.4%	11.0%	4.9%	
ORPLD1	10.151	12.039	8.013	0.999	0.160	-	0.999	20.981	1.060	37.136	-	0.999	2.997	2.997	1.469	100.000
T10-G-16A	10.171	12.044	8.026	1.002	0.160	-	1.002	21.042	0.890	37.185	-	1.002	3.006	3.006	1.463	100.000
%RSD	0.1%	0.0%	0.1%	0.2%	0.2%		0.2%	0.2%	12.3%	0.1%		0.2%	0.2%	0.2%	0.3%	
ORPLD6	10.138	9.888	7.924	0.301	0.170	-	0.992	22.040	0.820	37.398	-	1.974	2.975	3.997	1.383	100.000
Z10-G-60C	8.729	9.849	8.289	0.580	0.220	-	0.520	23.168	1.260	36.796	0.020	2.270	3.210	3.110	1.820	100.000
%RSD	10.6%	0.3%	3.2%	44.9%	18.0%		44.1%	3.5%	29.9%	1.1%		9.9%	5.4%	17.7%	19.3%	
ORPLE12	7.615	9.870	10.070	0.240	0.551	2.505	1.052	16.032	1.050	41.494	-	1.754	3.227	3.547	0.992	100.000
Q10-G-134A	7.580	9.820	10.160	0.430	0.630	2.490	0.950	15.450	1.380	41.590	-	1.980	3.180	3.090	1.100	100.000
%RSD	0.3%	0.4%	0.6%	40.0%	9.4%	0.4%	7.2%	2.6%	19.2%	0.2%		8.6%	1.0%	9.7%	7.3%	
ORPLF7	8.653	9.559	9.780	0.302	0.503	4.377	0.986	12.075	1.320	42.402	-	2.516	2.928	3.904	0.694	100.000
Z10-G-122B	8.180	9.630	9.950	0.430	0.530	4.410	1.000	11.740	0.760	42.630	0.010	2.850	3.030	3.740	0.920	100.000
Z10-G-153B	8.371	9.551	9.661	0.480	0.530	4.360	0.890	12.461	1.350	41.894	0.010	2.780	2.950	3.550	0.950	100.000
%RSD	2.8%	0.5%	1.5%	22.7%	3.0%	0.6%	6.2%	3.0%	29.1%	0.9%		6.5%	1.8%	4.7%	16.4%	
ORPLG27	6.033	7.924	2.691	0.280	5.753	-	0.440	21.011	0.350	42.121	3.192	-	2.691	6.443	1.071	100.000
I10-G-135A	5.883	7.900	2.807	0.419	6.073	-	0.459	21.764	0.470	40.781	3.316	-	2.647	5.913	1.438	100.000
%RSD	1.8%	0.2%	3.0%	28.2%	3.8%		3.0%	2.5%	20.7%	2.3%	2.7%		1.2%	6.1%	20.7%	
ORPLG9	6.743	8.493	2.691	0.280	5.752	-	0.950	21.008	0.360	40.766	2.831	-	3.391	5.662	1.070	100.000
10A-G-43B	6.410	8.510	2.710	0.310	5.680	-	0.950	21.480	0.210	40.280	3.070	0.020	3.480	5.380	1.390	100.000
%RSD	3.6%	0.1%	0.5%	7.2%	0.9%		0.0%	1.6%	37.2%	0.8%	5.7%		1.8%	3.6%	18.4%	
Pooled over 15 replicate sets %RSD	3.0%	0.3%	2.0%	17.5%	16.6%	0.2%	10.6%	1.8%	38.6%	0.9%	3.9%	4.8%	2.4%	6.1%	12.7%	-

- Empty data field

Table 3.1. Summary of Glass Studies Included in HLW Dataset and Number of Glasses Tested.

Glass Study	Name of Glass Series	Number of Glasses	Reference
HLW Glasses for Enhanced AZ-102 Melter Testing	INEL-	4	[37]
Enhanced HLW Glass Formulations for Vitrification System Improvements	HLW-E-*** (*** = Bi, Cr, Al, ANa)	94	[14]
Extreme HLW Glasses	HLW-ALG-	25	[38]
HLW Glasses for Bismuth Phosphate Wastes	HLW-BP-	10	[39]
High Aluminum HLW Glass Formulations	HWI-Al-	29	[16, 19]
Effects of High Spinel and Chromium Oxide Crystal Contents on Simulated HLW Vitrification	HLW-E-*** (*** = SP, ES, M)	40	[18]
Tests with High-Bismuth HLW	HLW-Bi-	16	[20]
Glass Formulation Development and Testing for DWPF High-Al ₂ O ₃ HLW Sludges	HWI-ALS-	13	[40]
Glass Formulation for Next Generation Melters	HLW-N101- HLW-NG-Cr-	24	[41]
Melter Throughput Enhancements for High-Iron HLW	HLW-NG-Fe-	11	[42]
Optical Basicity and Nepheline Crystallization in High Alumina Glasses	HLW-E-Al- HLW-E-AN-a	35 ^(a)	[43]
Total Number of Glasses		266	

^(a) Not included in total number of glasses because they were selected from the other glass studies.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses.

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
INEL-HW09	—	6.932	—	11.380	—	—	—	0.290	0.140	—	—	—	0.113	0.062	—	—	—	15.542
INEL-HW10	—	8.055	—	11.243	—	—	—	0.336	0.163	—	—	—	0.131	0.072	—	—	—	18.060
INEL-HLW-B3	—	7.825	—	11.722	—	—	—	0.327	0.158	—	—	—	0.128	0.070	—	—	—	17.544
INEL-HLW-B10	—	8.920	—	12.030	—	—	—	0.370	0.180	—	—	—	0.150	0.080	—	—	—	20.010
HLW-E-Bi-1	—	9.324	—	13.741	0.008	—	5.364	0.668	—	—	—	—	0.416	—	—	—	0.656	5.568
HLW-E-Bi-2	—	9.324	—	12.741	0.008	—	5.364	0.668	—	—	—	—	0.416	—	—	—	0.656	5.568
HLW-E-Bi-3	—	9.324	—	13.741	0.008	—	5.364	0.668	—	—	—	—	0.416	—	—	—	0.656	5.568
HLW-E-Bi-4	—	9.324	—	12.741	0.008	—	5.364	0.668	—	—	—	—	0.416	—	—	—	0.656	5.568
HLW-E-Bi-5	—	10.490	—	12.270	0.009	—	6.035	0.752	—	—	—	—	0.468	—	—	—	0.738	6.264
HLW-E-Bi-6	—	11.655	—	11.300	0.010	—	6.705	0.835	—	—	—	—	0.520	—	—	—	0.820	6.960
HLW-E-Bi-7	—	12.821	—	10.330	0.011	—	7.376	0.919	—	—	—	—	0.572	—	—	—	0.902	7.656
HLW-E-Bi-8	—	10.490	—	14.270	0.009	—	6.035	0.752	—	—	—	—	0.468	—	—	—	0.738	6.264
HLW-E-Bi-9	—	10.490	—	12.270	0.009	—	6.035	0.752	—	—	—	—	0.468	—	—	—	0.738	6.264
HLW-E-Bi-10	—	10.490	—	12.270	0.009	—	6.035	0.752	—	—	—	—	0.468	—	—	—	0.738	6.264
HLW-E-Bi-11	—	6.993	—	12.681	0.006	—	4.023	0.501	—	—	—	—	0.312	—	—	—	0.492	4.176
HLW-E-Bi-12	—	13.986	—	11.360	0.012	—	8.046	1.002	—	—	—	—	0.624	—	—	—	0.984	8.352
HLW-E-Bi-13	—	12.821	—	10.330	0.011	—	7.376	0.919	—	—	—	—	0.572	—	—	—	0.902	7.656
HLW-E-Bi-14	—	15.152	—	10.390	0.013	—	8.717	1.086	—	—	—	—	0.676	—	—	—	1.066	9.048
HLW-E-Bi-15	—	12.821	—	10.330	0.011	—	7.376	0.919	—	—	—	—	0.572	—	—	—	0.902	7.656
HLW-E-Bi-16	—	11.655	—	11.300	0.010	—	6.705	0.835	—	—	—	—	0.520	—	—	—	0.820	6.960
HLW-E-Bi6UTh	—	11.219	—	11.286	0.010	—	6.452	0.805	—	—	—	—	0.500	—	—	—	0.790	6.696
HLW-E-Cr-1	—	11.056	—	14.229	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-2	—	11.056	—	13.730	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-3	—	11.056	—	13.730	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-4	—	11.056	—	13.730	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-5	—	11.056	—	13.730	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-6	—	11.056	—	13.730	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-7	—	11.056	—	13.730	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-8	—	11.056	—	13.730	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-9	—	11.056	—	15.730	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
INEL-HW09	—	—	0.073	0.466	2.500	0.089	0.442	—	11.357	0.205	0.554	0.031	0.088	—	—	—	—	—
INEL-HW10	—	—	0.085	0.541	1.762	0.103	0.514	—	11.327	0.238	0.644	0.036	0.103	—	—	—	—	—
INEL-HLW-B3	—	—	4.282	0.526	3.111	0.100	0.499	—	7.047	0.231	0.626	0.035	0.100	—	—	—	—	—
INEL-HLW-B10	—	—	7.000	0.600	1.100	0.110	0.570	—	8.990	0.260	0.710	0.040	0.110	—	—	—	—	—
HLW-E-Bi-1	—	—	0.368	—	0.128	0.340	—	—	17.388	—	1.540	3.988	0.200	—	—	—	—	—
HLW-E-Bi-2	—	—	0.368	—	0.128	0.340	—	—	16.388	—	1.540	3.988	0.200	—	—	—	—	—
HLW-E-Bi-3	—	—	0.368	—	0.128	0.340	—	—	17.388	—	1.540	3.988	0.200	—	—	—	—	—
HLW-E-Bi-4	—	—	0.368	—	0.128	0.340	—	—	16.388	—	1.540	3.988	0.200	—	—	—	—	—
HLW-E-Bi-5	—	—	0.414	—	0.144	0.383	—	—	16.062	—	1.733	4.487	0.225	—	—	—	—	—
HLW-E-Bi-6	—	—	0.460	—	0.160	0.425	—	—	15.735	—	1.925	4.985	0.250	—	—	—	—	—
HLW-E-Bi-7	—	—	0.506	—	0.176	0.468	—	—	15.409	—	2.118	5.484	0.275	—	—	—	—	—
HLW-E-Bi-8	—	—	0.414	—	0.144	0.383	—	—	16.062	—	1.733	4.487	0.225	—	—	—	—	—
HLW-E-Bi-9	—	—	0.414	—	0.144	0.383	—	—	18.062	—	1.733	4.487	0.225	—	—	—	—	—
HLW-E-Bi-10	—	—	2.414	—	0.144	0.383	—	—	16.062	—	1.733	4.487	0.225	—	—	—	—	—
HLW-E-Bi-11	—	—	0.276	—	0.096	0.255	—	—	18.041	—	1.155	2.991	0.150	—	—	—	—	—
HLW-E-Bi-12	—	—	0.552	—	0.192	0.510	—	—	15.082	—	2.310	5.982	0.300	—	—	—	—	—
HLW-E-Bi-13	—	—	2.506	—	0.176	0.468	—	—	14.909	—	2.118	5.484	0.275	—	—	—	—	—
HLW-E-Bi-14	—	—	0.598	—	0.208	0.553	—	—	15.756	—	2.503	6.481	0.325	—	—	—	—	—
HLW-E-Bi-15	—	—	2.506	—	2.176	0.468	—	—	12.909	—	2.118	5.484	0.275	—	—	—	—	—
HLW-E-Bi-16	—	—	2.460	—	0.160	0.425	—	—	14.735	—	1.925	4.985	0.250	—	—	—	—	—
HLW-E-Bi6UTh	—	—	0.445	—	0.155	0.410	—	—	15.479	—	1.854	4.797	0.240	—	—	—	—	—
HLW-E-Cr-1	—	—	11.160	—	0.156	0.069	—	—	8.700	—	0.459	1.446	0.708	—	—	—	—	—
HLW-E-Cr-2	—	—	10.160	—	1.156	0.069	—	—	8.700	—	0.459	1.446	1.208	—	—	—	—	—
HLW-E-Cr-3	—	—	7.660	—	2.656	0.069	—	—	8.700	—	0.459	1.446	2.208	—	—	—	—	—
HLW-E-Cr-4	—	—	2.660	—	3.156	0.069	—	—	8.700	—	0.459	1.446	1.208	—	—	—	—	—
HLW-E-Cr-5	—	—	5.160	—	2.156	0.069	—	—	8.700	—	0.459	1.446	1.208	—	—	—	—	—
HLW-E-Cr-6	—	—	3.660	—	3.156	0.069	—	—	8.700	—	0.459	1.446	2.208	—	—	—	—	—
HLW-E-Cr-7	—	—	5.160	—	3.156	0.069	—	—	8.700	—	0.459	1.446	3.208	—	—	—	—	—
HLW-E-Cr-8	—	—	7.660	—	2.656	0.069	—	—	8.700	—	0.459	1.446	3.208	—	—	—	—	—
HLW-E-Cr-9	—	—	5.160	—	3.156	0.069	—	—	8.700	—	0.459	1.446	3.208	—	—	—	—	—

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
INEL-HW09	0.051	—	—	46.476	—	—	—	—	—	—	—	—	—	—	1.012	2.197
INEL-HW10	0.060	—	—	42.959	—	—	—	—	—	—	—	—	—	—	1.014	2.553
INEL-HLW-B3	0.058	—	—	43.117	—	—	—	—	—	—	—	—	—	—	0.014	2.480
INEL-HLW-B10	0.070	—	—	35.850	—	—	—	—	—	—	—	—	—	—	0.020	2.830
HLW-E-Bi-1	0.380	—	—	39.503	—	—	—	—	0.124	—	—	—	—	—	0.128	0.168
HLW-E-Bi-2	0.380	—	—	39.503	—	—	—	—	0.124	—	—	—	—	—	1.128	1.168
HLW-E-Bi-3	0.380	—	—	38.003	—	—	—	—	0.124	—	—	—	—	—	1.128	0.668
HLW-E-Bi-4	0.380	—	—	39.004	—	—	—	—	0.124	—	—	—	—	—	0.627	2.168
HLW-E-Bi-5	0.428	—	—	37.630	—	—	—	—	0.140	—	—	—	—	—	0.144	1.189
HLW-E-Bi-6	0.475	—	—	36.255	—	—	—	—	0.155	—	—	—	—	—	0.160	0.210
HLW-E-Bi-7	0.523	—	—	33.881	—	—	—	—	0.171	—	—	—	—	—	0.176	0.231
HLW-E-Bi-8	0.428	—	—	36.630	—	—	—	—	0.140	—	—	—	—	—	0.144	0.189
HLW-E-Bi-9	0.428	—	—	36.630	—	—	—	—	0.140	—	—	—	—	—	0.144	0.189
HLW-E-Bi-10	0.428	—	—	36.630	—	—	—	—	0.140	—	—	—	—	—	0.144	0.189
HLW-E-Bi-11	0.285	—	—	44.252	—	—	—	—	0.093	—	—	—	—	—	1.096	2.126
HLW-E-Bi-12	0.570	—	—	29.506	—	—	—	—	0.186	—	—	—	—	—	0.192	0.252
HLW-E-Bi-13	0.523	—	—	32.381	—	—	—	—	0.171	—	—	—	—	—	0.176	0.231
HLW-E-Bi-14	0.618	—	—	26.132	—	—	—	—	0.202	—	—	—	—	—	0.208	0.273
HLW-E-Bi-15	0.523	—	—	32.381	—	—	—	—	0.171	—	—	—	—	—	0.176	0.231
HLW-E-Bi-16	0.475	—	—	35.255	—	—	—	—	0.155	—	—	—	—	—	0.160	0.210
HLW-E-Bi6UTh	0.455	—	—	36.007	—	—	—	0.125	0.150	—	1.772	—	—	—	0.155	0.200
HLW-E-Cr-1	0.658	—	—	39.072	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-2	0.658	—	—	39.072	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-3	0.658	—	—	39.072	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-4	0.658	—	—	44.572	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-5	0.658	—	—	40.572	—	2.500	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-6	0.658	—	—	42.572	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-7	0.658	—	—	40.072	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-8	0.658	—	—	38.072	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-9	0.658	—	—	38.072	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
HLW-E-Cr-10	—	11.056	—	14.440	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-11	—	11.056	—	14.440	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-E-Cr-12	—	12.437	—	14.469	0.014	—	3.551	1.203	0.005	—	—	—	1.496	—	—	—	0.974	6.397
HLW-E-Cr-13	—	13.820	—	14.000	0.016	—	3.946	1.337	0.006	—	—	—	1.662	—	—	—	1.083	7.108
HLW-E-Cr-14	—	8.292	—	14.382	0.010	—	2.368	1.592	0.003	—	—	—	0.997	—	—	—	0.649	4.264
HLW-E-Cr-15	—	12.437	—	14.469	0.014	—	3.551	1.203	0.005	—	—	—	1.496	—	—	—	0.974	6.397
HLW-E-Cr-16	—	13.820	—	14.087	0.016	—	3.946	1.337	0.006	—	—	—	1.662	—	—	—	1.083	7.108
HLW-E-Cr-17	—	11.747	—	14.454	0.014	—	3.354	1.136	0.005	—	—	—	1.413	—	—	—	0.920	6.041
HLW-E-Cr-18	—	11.747	—	14.454	0.014	—	3.354	3.165	0.005	—	—	—	1.413	—	—	—	0.920	6.041
HLW-E-Cr-M	—	8.983	—	16.173	0.010	—	2.565	0.869	0.004	—	—	—	1.080	—	—	—	0.704	4.620
HLW-E-Cr-MUTh	—	8.293	—	16.151	0.010	—	2.368	0.802	0.003	—	—	—	0.997	—	—	—	0.650	4.265
HLW-E-Al-1	—	26.635	—	10.211	0.060	—	1.272	1.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-2	—	26.635	—	3.211	0.060	—	1.272	14.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-3	—	26.635	—	8.211	0.060	—	1.272	14.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-4	—	26.635	—	10.211	0.060	—	1.272	16.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-5	—	26.635	—	8.211	0.060	—	1.272	11.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-6	—	26.635	—	12.211	0.060	—	1.272	18.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-7	—	26.635	—	15.211	0.060	—	1.272	20.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-8	—	26.635	—	18.211	0.060	—	1.272	18.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-9	—	26.635	—	18.211	0.060	—	1.272	16.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-10	—	26.635	—	20.211	0.060	—	1.272	14.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-11	—	26.635	—	16.211	0.060	—	1.272	14.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-12	—	23.971	—	20.190	0.054	—	1.145	14.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-E-Al-13	—	25.303	—	19.291	0.057	—	1.208	13.545	0.026	—	—	—	0.550	—	—	—	0.704	6.227
HLW-E-Al-14	—	26.635	—	18.211	0.060	—	1.272	1.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HLW-E-Al-15	—	25.303	—	20.200	0.057	—	1.208	1.136	0.026	—	—	—	0.550	—	—	—	0.704	6.227
HLW-E-Al-16	—	23.971	—	20.190	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-E-Al-17	—	29.298	—	18.232	0.065	—	1.399	1.316	0.030	—	—	—	0.637	—	—	—	0.816	7.210
HLW-E-Al-18	—	23.971	—	19.190	0.054	—	1.145	13.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-E-Al-19	—	26.635	—	14.411	0.060	—	1.272	1.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
HLW-E-Cr-10	—	—	5.424	—	3.314	0.069	—	—	8.700	—	0.459	1.446	0.208	—	—	—	—	—
HLW-E-Cr-11	—	—	5.424	—	3.314	0.069	—	—	8.700	—	0.459	1.446	0.208	—	—	—	—	—
HLW-E-Cr-12	—	—	5.444	—	3.333	0.078	—	—	9.787	—	0.517	1.627	0.234	—	—	—	—	—
HLW-E-Cr-13	—	—	5.201	—	2.201	0.087	—	—	10.875	—	0.574	1.808	0.260	—	—	—	—	—
HLW-E-Cr-14	—	—	6.120	—	4.117	0.052	—	—	6.525	—	0.344	1.085	0.156	—	—	—	—	—
HLW-E-Cr-15	—	—	5.444	—	3.333	0.078	—	—	9.787	—	0.517	1.627	0.234	—	—	—	—	—
HLW-E-Cr-16	—	—	5.201	—	2.205	0.087	—	—	10.875	—	0.574	1.808	0.260	—	—	—	—	—
HLW-E-Cr-17	—	—	5.430	—	3.306	0.074	—	—	9.243	—	0.488	1.537	0.221	—	—	—	—	—
HLW-E-Cr-18	—	—	5.430	—	3.166	0.074	—	—	9.243	—	0.488	1.537	0.221	—	—	—	—	—
HLW-E-Cr-M	—	—	6.048	—	3.682	0.056	—	—	7.068	—	0.373	1.175	0.169	—	—	—	—	—
HLW-E-Cr-MUTh	—	—	6.035	—	3.670	0.052	—	—	6.526	—	0.344	1.085	0.156	—	—	—	—	—
HLW-E-Al-1	—	—	0.157	—	0.190	9.130	—	—	10.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-2	—	—	1.557	—	0.190	0.130	—	—	9.578	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-3	—	—	0.157	—	0.190	0.130	—	—	8.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-4	—	—	0.157	—	0.190	0.130	—	—	6.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-5	—	—	0.157	—	0.190	0.130	—	—	11.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-6	—	—	0.157	—	0.190	0.130	—	—	4.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-7	—	—	0.157	—	1.190	0.130	—	—	3.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-8	—	—	0.157	—	1.190	0.130	—	—	3.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-9	—	—	0.157	—	3.190	0.130	—	—	3.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-10	—	—	0.157	—	5.190	0.130	—	—	3.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-11	—	—	0.157	—	5.190	0.130	—	—	3.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-12	—	—	0.141	—	5.171	0.117	—	—	3.580	—	0.400	1.052	0.409	—	—	—	—	—
HLW-E-Al-13	—	—	0.149	—	4.953	0.124	—	—	3.779	—	0.422	1.111	0.432	—	—	—	—	—
HLW-E-Al-14	—	—	0.157	—	7.190	0.130	—	—	3.978	—	0.444	1.169	0.455	—	—	—	—	—
HLW-E-Al-15	—	—	0.149	—	7.680	0.124	—	—	3.779	—	0.422	1.111	0.432	—	—	—	—	—
HLW-E-Al-16	—	—	0.141	—	7.671	0.117	—	—	3.580	—	0.400	3.552	0.409	—	—	—	—	—
HLW-E-Al-17	—	—	0.173	—	7.708	0.143	—	—	4.376	—	0.488	1.286	0.500	—	—	—	—	—
HLW-E-Al-18	—	—	0.141	—	5.171	0.117	—	—	3.580	—	0.400	1.052	0.409	—	—	—	—	—
HLW-E-Al-19	—	—	0.157	—	3.490	0.130	—	—	13.978	—	0.444	1.169	0.455	—	—	—	—	—

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
HLW-E-Cr-10	0.658	—	—	41.940	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-E-Cr-11	0.658	—	—	40.940	—	—	—	—	0.004	—	—	—	—	—	0.108	1.048
HLW-E-Cr-12	0.741	—	—	37.512	—	—	—	—	0.005	—	—	—	—	—	0.122	0.054
HLW-E-Cr-13	0.823	—	—	34.996	—	—	—	—	0.006	—	—	—	—	—	0.136	0.060
HLW-E-Cr-14	0.494	—	—	45.429	—	—	—	—	0.003	—	—	—	—	—	0.081	3.036
HLW-E-Cr-15	0.741	—	—	36.012	—	—	—	—	0.005	—	—	1.500	—	—	0.122	0.054
HLW-E-Cr-16	0.823	—	—	33.405	—	—	—	—	0.006	—	—	1.500	—	—	0.136	0.060
HLW-E-Cr-17	0.700	—	—	39.748	—	—	—	—	0.005	—	—	—	—	—	0.115	0.051
HLW-E-Cr-18	0.700	—	—	37.859	—	—	—	—	0.005	—	—	—	—	—	0.115	0.051
HLW-E-Cr-M	0.535	—	—	45.757	—	—	—	—	0.004	—	—	—	—	—	0.088	0.039
HLW-E-Cr-MUTh	0.494	—	—	45.452	—	—	—	0.013	0.003	—	2.512	—	—	—	0.081	0.036
HLW-E-Al-1	0.222	—	—	29.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-2	0.222	—	—	32.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-3	0.222	—	—	29.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-4	0.222	—	—	27.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-5	0.222	—	—	29.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-6	0.222	—	—	25.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-7	0.222	—	—	20.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-8	0.222	—	—	19.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-9	0.222	—	—	19.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-10	0.222	—	—	17.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-11	0.222	—	—	21.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-12	0.200	—	—	21.896	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HLW-E-Al-13	0.211	—	—	21.395	—	—	—	—	0.010	—	—	—	—	—	0.087	0.417
HLW-E-Al-14	0.222	—	—	30.440	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HLW-E-Al-15	0.211	—	—	30.168	—	—	—	—	0.010	—	—	—	—	—	0.087	0.417
HLW-E-Al-16	0.200	—	—	29.896	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HLW-E-Al-17	0.244	—	—	25.483	—	—	—	—	0.012	—	—	—	—	—	0.101	0.482
HLW-E-Al-18	0.200	—	—	21.896	—	—	—	—	0.010	—	—	—	—	—	0.083	2.395
HLW-E-Al-19	0.222	—	—	27.940	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
HLW-E-AI-20	—	25.303	—	14.400	0.057	—	1.208	1.136	0.026	—	—	—	0.550	—	—	—	0.704	6.227
HLW-E-AI-21	—	25.303	—	14.000	0.057	—	1.208	1.136	0.026	—	—	—	0.550	—	—	—	0.704	6.227
HLW-E-AI-22	—	25.303	—	14.000	0.057	—	1.208	1.136	0.026	—	—	—	0.550	—	—	—	0.704	6.227
HLW-E-AI-23	—	23.971	—	14.190	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-E-AI-24	—	18.644	—	15.148	0.042	—	0.890	0.837	0.019	—	—	—	0.405	—	—	—	0.519	4.588
HLW-E-AI-25	—	23.971	—	14.190	0.054	—	1.145	6.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-E-AI-26	—	23.971	—	16.190	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-E-AI-27	—	23.971	—	15.190	0.054	—	1.145	6.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-E-AI-28	—	25.303	—	14.400	0.057	—	1.208	6.136	0.026	—	—	—	0.550	—	—	—	0.704	6.227
HLW-E-AI-29	—	25.303	—	14.400	0.057	—	1.208	9.136	0.026	—	—	—	0.550	—	—	—	0.704	6.227
HLW-E-AI27UTh	—	22.131	—	15.166	0.049	—	1.057	5.991	0.022	—	—	—	0.481	—	—	—	0.616	5.446
HLW-E-ANa-1	—	19.068	—	14.328	0.025	—	1.033	0.647	0.008	—	—	—	0.634	—	—	—	0.202	2.516
HLW-E-ANa-2	—	21.338	—	14.367	0.028	—	1.156	0.724	0.009	—	—	—	0.710	—	—	—	0.226	2.815
HLW-E-ANa-3	—	23.608	—	13.406	0.031	—	1.279	0.801	0.010	—	—	—	0.785	—	—	—	0.250	3.115
HLW-E-ANa-4	—	21.338	—	14.367	0.028	—	1.156	0.724	0.009	—	—	—	0.710	—	—	—	0.226	2.815
HLW-E-ANa-5	—	23.608	—	14.406	0.031	—	1.279	0.801	0.010	—	—	—	0.785	—	—	—	0.250	3.115
HLW-E-ANa-6	—	25.878	—	14.445	0.034	—	1.402	0.878	0.011	—	—	—	0.861	—	—	—	0.274	3.414
HLW-E-ANa-7	—	27.240	—	14.468	0.036	—	1.476	0.924	0.012	—	—	—	0.906	—	—	—	0.288	3.594
HLW-E-ANa-8	—	25.878	—	14.445	0.034	—	1.402	0.878	0.011	—	—	—	0.861	—	—	—	0.274	3.414
HLW-E-ANa-9	—	25.878	—	14.445	0.034	—	1.402	0.878	0.011	—	—	—	0.861	—	—	—	0.274	3.414
HLW-E-ANa-10	—	25.878	—	15.945	0.034	—	1.402	0.878	0.011	—	—	—	0.861	—	—	—	0.274	3.414
HLW-E-ANa-11	—	25.878	—	13.445	0.034	—	1.402	0.878	0.011	—	—	—	0.861	—	—	—	0.274	3.414
HLW-E-ANa-12	—	29.510	—	13.507	0.039	—	1.599	1.001	0.013	—	—	—	0.982	—	—	—	0.312	3.894
HLW-E-ANa-13	—	21.338	—	14.367	0.028	—	1.156	5.724	0.009	—	—	—	0.710	—	—	—	0.226	2.815
HLW-E-ANa-14	—	23.608	—	14.406	0.031	—	1.279	5.801	0.010	—	—	—	0.785	—	—	—	0.250	3.115
HLW-E-ANa-15	—	23.608	—	15.406	0.031	—	1.279	5.801	0.010	—	—	—	0.785	—	—	—	0.250	3.115
HLW-E-ANa-16	—	23.608	—	14.406	0.031	—	1.279	5.801	0.010	—	—	—	0.785	—	—	—	0.250	3.115
HLW-E-ANa-17	—	20.430	—	15.351	0.027	—	1.107	5.693	0.009	—	—	—	0.680	—	—	—	0.216	2.696
HLW-E-ANa-18	—	20.430	—	15.351	0.027	—	1.107	5.693	0.009	—	—	—	0.680	—	—	—	0.216	2.696
HLW-E-ANa-19	—	19.522	—	15.335	0.026	—	1.058	5.662	0.009	—	—	—	0.649	—	—	—	0.206	2.576

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
HLW-E-AI-20	—	—	0.149	—	4.180	0.124	—	—	13.779	—	0.422	1.111	0.432	—	—	—	—	—
HLW-E-AI-21	—	—	0.149	—	5.030	0.124	—	—	14.779	—	0.422	1.111	0.432	—	—	—	—	—
HLW-E-AI-22	—	—	5.149	—	5.030	0.124	—	—	9.779	—	0.422	1.111	0.432	—	—	—	—	—
HLW-E-AI-23	—	—	0.141	—	3.571	0.117	—	—	14.080	—	0.400	1.052	0.409	—	—	—	—	—
HLW-E-AI-24	—	—	0.110	—	3.533	0.091	—	—	14.785	—	0.311	0.818	0.318	—	—	—	—	—
HLW-E-AI-25	—	—	0.141	—	3.571	0.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HLW-E-AI-26	—	—	0.141	—	3.571	0.117	—	—	13.080	—	0.400	1.052	0.409	—	—	—	—	—
HLW-E-AI-27	—	—	0.141	—	3.571	0.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HLW-E-AI-28	—	—	0.149	—	3.680	0.124	—	—	9.779	—	0.422	1.111	0.432	—	—	—	—	—
HLW-E-AI-29	—	—	0.149	—	2.680	0.124	—	—	9.779	—	0.422	1.111	0.432	—	—	—	—	—
HLW-E-AI27UTh	—	—	0.130	—	3.555	0.108	—	—	9.302	—	0.369	0.971	0.378	—	—	—	—	—
HLW-E-ANa-1	—	—	0.592	—	4.067	0.193	—	—	11.357	—	0.088	3.806	0.080	—	—	—	—	—
HLW-E-ANa-2	—	—	0.663	—	3.075	0.216	—	—	12.709	—	0.099	2.021	0.089	—	—	—	—	—
HLW-E-ANa-3	—	—	0.733	—	2.583	0.239	—	—	14.061	—	0.109	2.236	0.099	—	—	—	—	—
HLW-E-ANa-4	—	—	0.663	—	4.075	0.216	—	—	12.709	—	0.099	2.021	0.089	—	—	—	—	—
HLW-E-ANa-5	—	—	0.733	—	3.583	0.239	—	—	14.061	—	0.109	2.236	0.099	—	—	—	—	—
HLW-E-ANa-6	—	—	0.804	—	2.811	0.262	—	—	15.413	—	0.120	2.451	0.108	—	—	—	—	—
HLW-E-ANa-7	—	—	0.846	—	2.816	0.276	—	—	16.224	—	0.126	2.580	0.114	—	—	—	—	—
HLW-E-ANa-8	—	—	0.804	—	3.591	0.262	—	—	15.413	—	0.120	2.451	0.108	—	—	—	—	—
HLW-E-ANa-9	—	—	0.804	—	5.091	0.262	—	—	15.413	—	0.120	2.451	0.108	—	—	—	—	—
HLW-E-ANa-10	—	—	0.804	—	3.591	0.262	—	—	15.413	—	0.120	2.451	0.108	—	—	—	—	—
HLW-E-ANa-11	—	—	0.804	—	5.091	0.262	—	—	15.413	—	0.120	2.451	0.108	—	—	—	—	—
HLW-E-ANa-12	—	—	0.917	—	2.104	0.299	—	—	17.576	—	0.137	2.795	0.124	—	—	—	—	—
HLW-E-ANa-13	—	—	0.663	—	3.075	0.216	—	—	12.709	—	0.099	2.021	0.089	—	—	—	—	—
HLW-E-ANa-14	—	—	0.733	—	2.583	0.239	—	—	14.061	—	0.109	2.236	0.099	—	—	—	—	—
HLW-E-ANa-15	—	—	0.733	—	2.583	0.239	—	—	14.061	—	0.109	2.236	0.099	—	—	—	—	—
HLW-E-ANa-16	—	—	0.733	—	3.583	0.239	—	—	14.061	—	0.109	2.236	0.099	—	—	—	—	—
HLW-E-ANa-17	—	—	0.635	—	3.072	0.207	—	—	12.168	—	0.095	1.935	0.086	—	—	—	—	—
HLW-E-ANa-18	—	—	0.635	—	3.072	0.207	—	—	12.168	—	0.095	1.935	0.086	—	—	—	—	—
HLW-E-ANa-19	—	—	0.606	—	3.569	0.198	—	—	11.627	—	0.090	1.849	0.082	—	—	—	—	—

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
HLW-E-AI-20	0.211	—	—	29.468	—	—	—	—	0.010	—	—	—	—	—	0.087	0.417
HLW-E-AI-21	0.211	—	—	28.018	—	—	—	—	0.010	—	—	—	—	—	0.087	0.417
HLW-E-AI-22	0.211	—	—	28.018	—	—	—	—	0.010	—	—	—	—	—	0.087	0.417
HLW-E-AI-23	0.200	—	—	31.996	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HLW-E-AI-24	0.155	—	—	35.808	—	—	—	—	0.008	—	—	—	—	—	0.064	2.907
HLW-E-AI-25	0.200	—	—	31.496	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HLW-E-AI-26	0.200	—	—	30.996	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HLW-E-AI-27	0.200	—	—	30.496	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HLW-E-AI-28	0.211	—	—	28.968	—	—	—	—	0.010	—	—	—	—	—	0.087	0.417
HLW-E-AI-29	0.211	—	—	26.968	—	—	—	—	0.010	—	—	—	—	—	0.087	0.417
HLW-E-AI27UTh	0.184	—	—	30.104	—	—	—	0.166	0.009	—	3.322	—	—	—	0.076	0.364
HLW-E-ANa-1	0.193	—	—	39.738	—	—	—	—	0.155	—	—	—	—	—	0.160	1.109
HLW-E-ANa-2	0.216	—	—	39.064	—	—	—	—	0.174	—	—	—	—	—	0.179	0.122
HLW-E-ANa-3	0.239	—	—	35.890	—	—	—	—	0.192	—	—	—	—	—	0.198	0.135
HLW-E-ANa-4	0.216	—	—	38.064	—	—	—	—	0.174	—	—	—	—	—	0.179	0.122
HLW-E-ANa-5	0.239	—	—	33.890	—	—	—	—	0.192	—	—	—	—	—	0.198	0.135
HLW-E-ANa-6	0.262	—	—	29.996	—	—	—	—	0.211	—	—	—	—	—	0.217	0.148
HLW-E-ANa-7	0.276	—	—	27.192	—	—	—	—	0.222	—	—	—	—	—	0.228	0.156
HLW-E-ANa-8	0.262	—	—	29.216	—	—	—	—	0.211	—	—	—	—	—	0.217	0.148
HLW-E-ANa-9	0.262	—	—	27.716	—	—	—	—	0.211	—	—	—	—	—	0.217	0.148
HLW-E-ANa-10	0.262	—	—	27.716	—	—	—	—	0.211	—	—	—	—	—	0.217	0.148
HLW-E-ANa-11	0.262	—	—	28.716	—	—	—	—	0.211	—	—	—	—	—	0.217	0.148
HLW-E-ANa-12	0.299	—	—	24.238	—	—	—	—	0.241	—	—	—	—	—	0.247	0.169
HLW-E-ANa-13	0.216	—	—	34.064	—	—	—	—	0.174	—	—	—	—	—	0.179	0.122
HLW-E-ANa-14	0.239	—	—	29.890	—	—	—	—	0.192	—	—	—	—	—	0.198	0.135
HLW-E-ANa-15	0.239	—	—	28.890	—	—	—	—	0.192	—	—	—	—	—	0.198	0.135
HLW-E-ANa-16	0.239	—	—	28.890	—	—	—	—	0.192	—	—	—	—	—	0.198	0.135
HLW-E-ANa-17	0.207	—	—	34.934	—	—	—	—	0.167	—	—	—	—	—	0.171	0.117
HLW-E-ANa-18	0.207	—	—	32.934	—	—	—	—	0.167	—	—	—	—	—	0.171	2.117
HLW-E-ANa-19	0.198	—	—	34.304	—	—	—	—	0.159	—	—	—	—	—	0.163	2.112

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
HLW-E-ANa-20	—	21.338	—	14.367	0.028	—	1.156	3.724	0.009	—	—	—	0.710	—	—	—	0.226	2.815
HLW-E-ANa-21	—	21.338	—	15.367	0.028	—	1.156	3.724	0.009	—	—	—	0.710	—	—	—	0.226	2.815
HLW-E-ANa-22	—	21.338	—	18.367	0.028	—	1.156	0.724	0.009	—	—	—	0.710	—	—	—	0.226	2.815
HLW-E-ANa-23	—	21.338	—	18.367	0.028	—	1.156	0.724	0.009	—	—	—	0.710	—	—	—	0.226	2.815
HLW-E-ANa-24	—	22.700	—	18.390	0.030	—	1.230	0.770	0.010	—	—	—	0.755	—	—	—	0.240	2.995
HLW-E-ANa-25	—	22.700	—	19.390	0.030	—	1.230	0.770	0.010	—	—	—	0.755	—	—	—	0.240	2.995
HLW-E-ANa-26	—	23.608	—	19.406	0.031	—	1.279	0.801	0.010	—	—	—	0.785	—	—	—	0.250	3.115
HLW-E-ANa22UTt	—	20.345	—	18.340	0.028	—	1.104	0.691	0.009	—	—	—	0.677	—	—	—	0.216	2.683
HLW-ALG-41	0.133	5.009	0.173	9.726	—	—	—	0.271	—	—	0.098	—	0.070	—	0.040	—	—	11.335
HLW-ALG-42	0.165	5.638	0.215	8.978	—	—	—	0.336	—	—	0.121	—	0.087	—	0.050	—	—	14.090
HLW-ALG-43	0.186	6.695	0.243	11.889	—	—	—	0.380	—	—	0.137	—	0.098	—	0.056	—	—	15.902
HLW-ALG-44	0.130	4.686	0.170	8.322	—	—	—	0.266	—	—	0.096	—	0.069	—	0.039	—	—	11.132
HLW-ALG-45	0.141	5.068	0.184	9.001	—	—	—	0.287	—	—	0.104	—	0.075	—	0.043	—	—	12.039
HLW-ALG-46	0.161	5.778	0.209	10.260	—	—	—	0.328	—	—	0.118	—	0.085	—	0.049	—	—	13.723
HLW-ALG-47	0.134	4.800	0.174	8.523	—	—	—	0.272	—	—	0.098	—	0.071	—	0.040	—	—	11.400
HLW-ALG-48	0.137	4.922	0.178	8.740	—	—	—	0.279	—	—	0.101	—	0.600	—	0.041	—	—	11.690
HLW-ALG-49	0.155	5.586	0.202	4.300	—	—	—	0.317	—	—	0.114	—	0.082	—	0.047	—	—	13.269
HLW-ALG-50	0.138	4.962	0.180	15.000	—	—	—	0.281	—	—	0.102	—	0.073	—	0.042	—	—	11.786
HLW-ALG-51	0.135	13.000	0.176	8.628	—	—	—	0.275	—	—	0.099	—	0.071	—	0.041	—	—	11.540
HLW-ALG-52	0.152	5.453	0.198	9.684	—	—	—	0.309	—	—	0.112	—	0.080	—	0.046	—	—	12.953
HLW-ALG-53	0.100	1.926	—	11.227	0.036	—	—	0.430	0.118	0.037	—	—	0.150	—	—	—	0.030	9.152
HLW-ALG-54	0.052	8.078	—	8.499	—	—	0.775	1.082	0.049	0.040	0.073	—	0.347	—	—	—	0.174	6.624
HLW-ALG-55	0.167	5.995	0.217	10.647	—	—	—	0.340	—	—	0.123	—	0.088	—	0.050	—	—	14.241
HLW-ALG-56	0.137	4.920	0.178	8.737	—	—	—	0.279	—	—	0.101	—	0.072	—	0.041	—	—	11.686
HLW-ALG-57	0.153	5.490	0.199	9.749	—	—	—	0.311	—	—	0.112	—	0.081	—	0.046	—	—	13.039
HLW-ALG-58	0.138	11.000	0.180	8.826	—	—	—	0.282	—	—	0.102	—	0.073	—	0.042	—	—	11.806
HLW-ALG-59	0.119	13.000	0.155	13.886	—	—	—	0.242	—	—	0.087	—	0.063	—	0.036	—	—	10.135
HLW-ALG-60	0.153	5.502	0.199	12.250	—	—	—	0.312	—	—	0.113	—	0.081	—	0.046	—	—	13.068
HLW-ALG-61	0.163	5.866	0.213	13.000	—	—	—	0.333	—	—	0.120	—	0.086	—	0.049	—	—	13.933
HLW-ALG-62	0.111	3.990	0.145	7.086	—	—	—	0.226	—	—	0.082	—	0.059	—	0.034	—	—	9.478

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
HLW-E-ANa-20	—	—	0.663	—	3.075	0.216	—	—	12.709	—	0.099	2.021	0.089	—	—	—	—	—
HLW-E-ANa-21	—	—	0.663	—	3.075	0.216	—	—	12.709	—	0.099	2.021	0.089	—	—	—	—	—
HLW-E-ANa-22	—	—	0.663	—	3.575	0.216	—	—	12.709	—	0.099	2.021	0.089	—	—	—	—	—
HLW-E-ANa-23	—	—	0.663	—	3.575	0.216	—	—	12.709	—	0.099	2.021	0.089	—	—	—	—	—
HLW-E-ANa-24	—	—	0.705	—	3.080	0.230	—	—	13.520	—	0.105	2.150	0.095	—	—	—	—	—
HLW-E-ANa-25	—	—	0.705	—	3.080	0.230	—	—	13.520	—	0.105	2.150	0.095	—	—	—	—	—
HLW-E-ANa-26	—	—	0.733	—	3.083	0.239	—	—	14.061	—	0.109	2.236	0.099	—	—	—	—	—
HLW-E-ANa22UTh	—	—	0.630	—	3.569	0.207	—	—	12.118	—	0.094	1.926	0.085	—	—	—	—	—
HLW-ALG-41	—	—	—	0.218	3.120	1.052	3.600	—	12.206	0.135	0.155	0.085	0.130	—	—	—	—	—
HLW-ALG-42	—	—	—	0.271	2.869	1.308	4.476	—	11.388	0.168	0.193	0.106	0.162	—	—	—	—	—
HLW-ALG-43	—	—	—	0.306	3.807	1.476	5.051	—	14.988	0.190	0.218	0.120	0.183	—	—	—	—	—
HLW-ALG-44	—	—	—	0.214	2.665	1.033	3.536	—	10.492	0.133	0.153	0.084	0.128	—	—	—	—	—
HLW-ALG-45	—	—	—	0.232	2.882	1.118	8.000	—	11.347	0.144	0.165	0.090	0.138	—	—	—	—	—
HLW-ALG-46	—	—	—	0.264	3.285	1.274	4.359	—	3.700	0.164	0.188	0.103	0.158	—	—	—	—	—
HLW-ALG-47	—	—	—	0.219	2.729	1.058	3.621	—	20.000	0.136	0.156	0.086	0.131	—	—	—	—	—
HLW-ALG-48	—	—	2.500	1.200	2.799	1.085	3.713	—	11.019	0.140	0.160	0.088	0.134	—	—	—	—	—
HLW-ALG-49	—	—	—	0.255	3.177	1.232	4.215	—	12.507	0.158	0.182	0.100	0.153	—	—	—	—	—
HLW-ALG-50	—	—	—	0.227	2.822	1.094	3.744	—	11.108	0.141	0.162	0.089	0.135	—	—	—	—	—
HLW-ALG-51	—	—	—	0.222	2.763	1.071	3.666	—	10.877	0.138	0.158	0.087	0.133	—	—	—	—	—
HLW-ALG-52	—	—	—	0.249	—	1.203	4.114	—	12.208	0.155	0.178	0.097	0.149	—	—	—	—	—
HLW-ALG-53	—	—	0.132	0.104	3.476	0.090	0.833	—	12.465	0.081	0.404	0.075	0.121	—	—	—	—	—
HLW-ALG-54	—	—	0.451	0.062	3.000	0.069	0.543	—	11.867	0.049	0.779	0.674	0.288	—	—	—	—	—
HLW-ALG-55	—	—	—	0.274	3.409	1.322	4.523	—	13.422	0.170	0.195	0.107	0.164	—	—	—	—	—
HLW-ALG-56	—	—	—	0.225	2.798	1.085	3.712	—	18.000	0.139	0.160	0.088	0.134	—	—	—	—	—
HLW-ALG-57	—	—	—	0.251	3.122	1.211	4.142	—	8.500	0.156	0.179	0.098	0.150	—	—	—	—	—
HLW-ALG-58	—	—	—	0.227	2.826	1.096	3.750	—	11.127	0.141	0.162	0.089	0.136	—	—	—	—	—
HLW-ALG-59	—	—	—	0.195	2.426	0.941	3.219	—	13.841	0.121	0.139	0.076	0.116	—	—	—	—	—
HLW-ALG-60	—	—	—	0.251	5.250	1.213	4.151	—	3.700	0.156	0.179	0.098	0.150	—	—	—	—	—
HLW-ALG-61	—	—	—	0.268	3.336	1.294	4.426	—	13.132	0.166	0.191	0.105	0.160	—	—	—	—	—
HLW-ALG-62	—	—	—	0.182	2.269	0.880	3.011	—	20.000	0.113	0.130	0.071	0.109	—	—	—	—	—

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
HLW-E-ANa-20	0.216	—	—	32.064	—	—	—	—	0.174	—	—	—	—	—	0.179	4.122
HLW-E-ANa-21	0.216	—	—	30.064	—	—	—	—	2.174	—	—	—	—	—	0.179	3.122
HLW-E-ANa-22	0.216	—	—	34.564	—	—	—	—	0.174	—	—	—	—	—	0.179	0.122
HLW-E-ANa-23	0.216	—	—	31.564	—	—	—	—	0.174	—	—	—	—	—	0.179	3.122
HLW-E-ANa-24	0.230	—	—	32.260	—	—	—	—	0.185	—	—	—	—	—	0.190	0.130
HLW-E-ANa-25	0.230	—	—	31.260	—	—	—	—	0.185	—	—	—	—	—	0.190	0.130
HLW-E-ANa-26	0.239	—	—	29.390	—	—	—	—	0.192	—	—	—	—	—	0.198	0.135
HLW-E-ANa22UTh	0.207	—	—	34.410	—	—	—	0.019	0.164	—	2.193	—	—	—	0.169	0.117
HLW-ALG-41	—	0.231	0.333	48.556	—	0.827	—	—	0.125	—	—	—	—	—	2.139	0.233
HLW-ALG-42	—	0.287	0.414	45.219	—	1.028	—	—	0.156	—	—	—	—	—	1.986	0.290
HLW-ALG-43	—	0.323	0.468	33.000	—	1.160	—	—	0.176	—	—	—	—	—	2.621	0.327
HLW-ALG-44	—	0.226	0.327	53.100	—	0.812	—	—	0.123	—	—	—	—	—	1.835	0.229
HLW-ALG-45	—	0.245	0.354	45.102	—	0.878	—	—	0.133	—	—	—	—	—	1.984	0.247
HLW-ALG-46	—	0.279	0.403	51.415	—	1.001	—	—	0.152	—	—	—	—	—	2.262	0.282
HLW-ALG-47	—	0.232	0.335	42.712	—	0.832	—	—	0.126	—	—	—	—	—	1.879	0.234
HLW-ALG-48	—	0.238	0.344	43.798	—	0.853	—	—	1.000	—	—	—	—	—	4.000	0.240
HLW-ALG-49	—	0.270	0.390	49.714	—	0.968	—	—	0.147	—	—	—	—	—	2.187	0.273
HLW-ALG-50	—	0.240	0.346	44.155	—	0.860	—	—	0.130	—	—	—	—	—	1.943	0.242
HLW-ALG-51	—	0.235	0.339	43.236	—	0.842	—	—	0.128	—	—	—	—	—	1.902	0.237
HLW-ALG-52	—	0.263	0.381	48.528	—	0.945	—	—	0.143	—	—	—	—	—	2.135	0.266
HLW-ALG-53	—	—	—	46.623	—	—	—	—	0.035	—	—	—	—	—	1.720	10.636
HLW-ALG-54	0.321	—	—	40.333	—	9.270	—	—	—	—	—	—	—	—	0.426	6.078
HLW-ALG-55	—	0.290	0.419	40.000	—	1.039	—	—	0.157	—	—	—	—	—	2.347	0.293
HLW-ALG-56	—	0.238	0.344	43.780	—	0.852	—	—	0.129	—	—	—	—	—	1.926	0.240
HLW-ALG-57	—	0.265	0.383	48.852	—	0.951	—	—	0.144	—	—	—	—	—	2.149	0.268
HLW-ALG-58	—	0.240	0.347	44.230	—	0.861	—	—	0.130	—	—	—	—	—	1.946	0.243
HLW-ALG-59	—	0.206	0.298	37.969	—	0.739	—	—	0.112	—	—	—	—	—	1.671	0.208
HLW-ALG-60	—	0.266	0.384	48.958	—	0.953	—	—	0.144	—	—	—	—	—	2.154	0.269
HLW-ALG-61	—	0.283	0.410	33.000	—	1.016	—	—	0.154	—	—	—	—	—	2.297	6.000
HLW-ALG-62	—	0.193	0.279	49.000	—	0.691	—	—	0.105	—	—	—	—	—	1.562	0.195

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
HLW-ALG-63	0.148	5.306	0.192	10.500	—	—	—	0.301	—	—	0.109	—	0.078	—	0.045	—	—	12.603
HLW-ALG-64	0.149	5.344	0.194	14.000	—	—	—	0.303	—	—	0.109	—	0.079	—	0.045	—	—	12.694
HLW-ALG-65	0.144	5.170	0.187	14.000	—	—	—	0.293	—	—	0.106	—	0.076	—	0.043	—	—	12.280
HLW-BP-01	0.057	7.139	—	10.221	0.116	—	2.077	1.444	0.044	0.062	—	—	0.126	—	0.030	—	0.485	11.021
HLW-BP-02	0.059	7.938	—	11.28	0.116	—	0.155	7.865	0.212	—	—	—	0.134	—	—	—	0.278	5.765
HLW-BP-03	0.105	6.416	—	10.263	0.209	—	0.128	1.553	0.114	—	—	—	0.182	—	0.031	—	0.308	7.511
HLW-BP-04	0.059	7.938	—	12.282	0.116	—	0.155	7.865	0.212	—	—	—	0.134	—	—	—	0.278	5.765
HLW-BP-05	0.059	7.938	—	11.281	0.116	—	0.155	7.865	0.212	—	—	—	0.134	—	—	—	0.278	5.765
HLW-BP-06	0.051	6.905	—	16.001	0.1	—	0.135	6.841	0.185	—	—	—	0.116	—	—	—	0.242	5.015
HLW-BP-07	0.047	6.276	—	19.483	0.091	—	0.122	6.218	0.168	—	—	—	0.106	—	—	—	0.220	4.558
HLW-BP-08	0.051	8.908	—	17.504	0.1	—	0.135	6.841	0.185	—	—	—	0.116	—	—	—	0.242	5.015
HLW-BP-09	0.043	7.059	—	14.586	0.082	—	0.032	7.018	0.435	0.033	—	—	0.098	—	—	—	0.164	6.202
HLW-BP-10	0.062	6.325	—	13.783	0.124	—	1.063	2.158	0.072	0.037	—	—	0.137	0.027	—	—	0.396	7.983
HWI-AI-1	—	23.971	—	18.190	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-2	—	23.971	—	17.690	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-3	—	22.639	—	18.179	0.051	—	1.081	1.017	0.023	—	—	—	0.492	—	—	—	0.630	5.571
HWI-AI-4	—	23.971	—	17.690	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-5	—	23.971	—	15.190	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-6	—	23.971	—	15.190	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-7	—	23.971	—	15.190	0.054	—	1.145	3.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-8	—	23.971	—	15.190	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-9	—	21.308	—	18.169	0.048	—	1.018	0.957	0.022	—	—	—	0.463	—	—	—	0.593	5.244
HWI-AI-10	—	21.308	—	18.669	0.048	—	1.018	0.957	0.022	—	—	—	0.463	—	—	—	0.593	5.244
HWI-AI-11	—	23.971	—	18.190	0.054	—	1.145	3.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-12	—	23.971	—	18.190	0.054	—	1.145	2.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-13	—	23.971	—	15.190	0.054	—	1.145	6.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-14	—	23.971	—	15.190	0.054	—	1.145	5.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-15	—	23.971	—	13.190	0.054	—	1.145	5.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-AI-16	—	23.252	—	17.734	0.052	—	1.110	5.894	0.024	—	—	—	0.505	—	—	—	0.647	5.722
HWI-AI-17	—	23.252	—	14.734	0.052	—	1.110	5.894	0.024	—	—	—	0.505	—	—	—	0.647	5.722

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
HLW-ALG-63	—	—	—	0.242	0.000	1.170	4.003	—	13.500	0.150	0.173	0.095	0.145	—	—	—	—	—
HLW-ALG-64	—	—	—	0.244	5.750	1.179	4.032	—	3.700	0.152	0.174	0.095	0.146	—	—	—	—	—
HLW-ALG-65	—	—	4.500	0.236	3.750	1.140	3.901	—	3.700	0.147	0.168	0.092	0.141	—	—	—	—	—
HLW-BP-01	—	—	0.132	0.059	2.767	0.257	0.729	—	11.643	0.062	1.042	2.665	0.567	—	—	—	—	0.048
HLW-BP-02	—	—	0.190	0.055	1.257	0.249	0.653	—	9.621	0.045	0.686	3.477	0.228	—	—	—	—	—
HLW-BP-03	—	—	0.223	—	2.259	0.451	1.176	—	11.34	0.029	0.951	3.305	0.346	—	—	—	—	—
HLW-BP-04	—	—	0.190	0.055	2.259	0.249	0.653	—	11.624	0.045	0.686	3.477	0.228	—	—	—	—	—
HLW-BP-05	—	—	0.190	0.055	—	0.249	0.653	—	16.133	0.045	0.686	3.477	0.228	—	—	—	—	—
HLW-BP-06	—	—	0.165	0.048	—	0.217	0.568	—	10.532	0.039	0.597	3.024	0.199	—	—	—	—	—
HLW-BP-07	—	—	0.150	0.044	1.256	0.197	0.517	—	9.573	0.036	0.542	2.749	0.180	—	—	—	—	—
HLW-BP-08	—	—	0.165	0.048	—	0.217	0.568	—	10.532	0.039	0.597	3.024	0.199	—	—	—	—	—
HLW-BP-09	—	—	0.180	0.114	—	0.169	0.460	—	11.274	0.086	0.593	2.393	0.176	—	—	—	—	—
HLW-BP-10	—	—	0.153	0.039	—	0.272	0.735	—	11.803	0.041	0.872	3.025	0.396	—	—	—	—	0.025
HWI-AI-1	—	—	0.141	—	4.571	0.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-2	—	—	0.141	—	2.171	0.117	—	—	12.580	—	0.400	2.052	0.409	—	—	—	—	—
HWI-AI-3	—	—	0.133	—	3.161	0.111	—	—	13.381	—	0.377	1.994	0.386	—	—	—	—	—
HWI-AI-4	—	—	4.141	—	2.171	0.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-5	—	—	0.141	—	3.571	5.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-6	—	—	6.141	—	2.571	0.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-7	—	—	0.141	—	3.571	3.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-8	—	—	8.141	—	2.171	0.117	—	—	9.080	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-9	—	—	0.126	—	3.152	0.104	—	—	13.182	—	0.355	0.935	0.364	—	—	—	—	—
HWI-AI-10	—	—	0.126	—	3.652	0.104	—	—	13.182	—	0.355	0.935	0.364	—	—	—	—	—
HWI-AI-11	—	—	0.141	—	3.571	0.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-12	—	—	0.141	—	3.571	0.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-13	—	—	4.141	—	3.571	0.117	—	—	6.080	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-14	—	—	5.141	—	3.571	0.117	—	—	6.080	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-15	—	—	5.141	—	3.171	0.117	—	—	8.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-16	—	—	0.137	—	3.463	0.113	—	—	9.293	—	0.388	1.021	0.397	—	—	—	—	—
HWI-AI-17	—	—	3.137	—	3.463	0.113	—	—	9.293	—	0.388	1.021	0.397	—	—	—	—	—

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
HLW-ALG-63	—	0.256	0.371	47.218	—	0.919	—	—	0.139	—	—	—	—	—	2.077	0.259
HLW-ALG-64	—	0.258	0.373	47.560	—	0.926	—	—	0.140	—	—	—	—	—	2.093	0.261
HLW-ALG-65	—	0.250	0.361	46.007	—	0.896	—	—	0.136	—	—	—	—	—	2.024	0.252
HLW-BP-01	0.163	—	—	38.977	—	0.065	—	1.383	—	—	3.592	—	0.026	—	0.067	2.934
HLW-BP-02	0.150	—	—	40.338	—	0.058	—	1.827	—	—	3.236	—	—	—	0.069	4.059
HLW-BP-03	0.109	—	—	36.075	—	0.089	—	3.603	—	—	5.557	—	—	—	0.102	7.568
HLW-BP-04	0.150	—	—	36.331	—	0.058	—	1.827	—	—	3.236	—	—	—	0.069	4.059
HLW-BP-05	0.150	—	—	35.081	—	0.058	—	1.827	—	—	3.237	—	—	—	0.069	4.059
HLW-BP-06	0.131	—	—	40.842	—	0.051	—	1.589	—	—	2.815	—	—	—	0.06	3.531
HLW-BP-07	0.119	—	—	40.035	—	0.046	—	1.445	—	—	2.559	—	—	—	0.054	3.209
HLW-BP-08	0.131	—	—	37.336	—	0.051	—	1.589	—	—	2.815	—	—	—	0.06	3.531
HLW-BP-09	0.134	—	—	42.149	—	0.039	—	1.161	—	—	2.414	—	—	—	0.057	2.852
HLW-BP-10	0.138	—	—	40.942	—	0.067	—	1.804	—	—	3.592	—	—	—	0.066	3.862
HWI-AI-1	0.200	—	—	31.496	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-2	0.200	—	—	30.396	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-3	0.189	—	—	30.124	—	—	—	—	0.009	—	—	—	—	—	0.078	0.373
HWI-AI-4	0.200	—	—	30.396	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-5	0.200	—	—	30.496	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-6	0.200	—	—	30.496	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-7	0.200	—	—	30.496	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-8	0.200	—	—	29.396	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-9	0.178	—	—	33.352	—	—	—	—	0.009	—	—	—	—	—	0.074	0.351
HWI-AI-10	0.178	—	—	32.352	—	—	—	—	0.009	—	—	—	—	—	0.074	0.351
HWI-AI-11	0.200	—	—	30.496	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-12	0.200	—	—	31.496	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-13	0.200	—	—	29.996	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AL-14	0.200	—	—	29.996	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AL-15	0.200	—	—	29.896	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-16	0.194	—	—	29.581	—	—	—	—	0.010	—	—	—	—	—	0.080	0.383
HWI-AI-17	0.194	—	—	29.581	—	—	—	—	0.010	—	—	—	—	—	0.080	0.383

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
HWI-Al-18G	—	22.575	—	20.130	0.050	—	1.078	5.722	0.023	—	—	—	0.491	—	—	—	0.628	5.555
HWI-Al-19	—	23.971	—	19.190	0.054	—	1.145	5.576	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HWI-Al-20	—	23.971	—	18.190	0.054	—	1.145	1.076	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-E-SP-01	—	25.569	—	14.384	0.057	—	1.221	5.876	0.026	—	—	—	0.556	—	—	—	0.712	6.292
HLW-E-SP-02	—	27.167	—	13.579	0.061	—	1.297	5.675	0.028	—	—	—	0.591	—	—	—	0.756	6.686
HLW-E-SP-03	—	28.765	—	12.773	0.064	—	1.374	5.474	0.029	—	—	—	0.625	—	—	—	0.801	7.079
HLW-E-SP-04	—	8.223	—	13.566	—	—	—	0.344	0.166	—	—	—	0.134	0.074	—	—	—	18.458
HLW-E-SP-05	—	9.489	—	12.081	—	—	—	0.396	0.192	—	—	—	0.154	0.085	—	—	—	21.299
HLW-E-SP-06	—	8.914	—	13.299	—	—	—	0.372	0.180	—	—	—	0.145	0.080	—	—	—	20.008
HLW-E-SP-07	—	7.533	—	13.006	—	—	—	0.315	0.152	—	—	—	0.123	0.067	—	—	—	16.908
HLW-E-SP-08	—	6.152	—	13.382	—	—	—	0.257	0.124	—	—	—	0.100	0.055	—	—	—	13.809
HLW-E-SP-09	—	8.906	—	13.288	—	—	—	0.372	0.180	—	—	—	0.145	0.080	—	—	—	19.991
HLW-E-SP-10	—	9.481	—	12.071	—	—	—	0.396	0.192	—	—	—	0.154	0.085	—	—	—	21.281
HLW-E-ES-01	—	12.548	—	13.761	0.015	—	3.583	1.214	—	—	—	—	1.509	—	—	—	0.983	6.454
HLW-E-ES-02	—	12.358	—	13.552	0.015	—	3.529	1.196	—	—	—	—	3.000	—	—	—	0.968	6.356
HLW-E-ES-03	—	12.167	—	13.343	0.014	—	3.474	1.177	—	—	—	—	4.500	—	—	—	0.953	6.258
HLW-E-ES-04	—	11.976	—	13.133	0.014	—	3.420	1.159	—	—	—	—	6.000	—	—	—	0.938	6.159
HLW-E-ES-05	—	10.858	—	14.802	0.015	—	3.529	1.196	—	—	—	—	3.000	—	—	—	0.968	6.356
HLW-E-ES-06	—	11.009	—	14.373	0.010	—	3.145	1.065	—	—	—	—	3.000	—	—	—	0.866	5.664
HLW-E-ES-07	—	11.476	—	13.765	0.013	—	3.277	1.110	—	—	—	—	3.000	—	—	—	0.899	5.902
HLW-E-ES-C16	—	4.500	—	14.400	—	—	—	—	—	—	—	—	2.850	—	—	—	—	4.500
HLW-E-ES-08	—	4.407	—	14.104	—	—	—	—	—	—	—	—	2.850	—	—	—	—	4.407
HLW-E-ES-09	—	11.058	—	14.450	0.013	—	3.158	1.070	—	—	—	—	1.330	—	—	—	0.866	5.687
HLW-E-ES-10	—	11.476	—	9.765	0.013	—	3.277	1.110	—	—	—	—	3.000	—	—	—	0.899	5.902
HLW-E-ES-11	—	11.476	—	13.765	0.013	—	3.277	1.110	—	—	—	—	3.000	—	—	—	0.899	5.902
HLW-E-ES-12	—	11.476	—	12.515	0.013	—	3.277	1.110	—	—	—	—	3.000	—	—	—	0.899	5.902
HLW-E-ES-13	—	11.058	—	14.450	0.013	—	3.158	1.070	—	—	—	—	1.988	—	—	—	0.866	5.687
HLW-E-ES-14	—	10.849	—	14.790	0.015	—	3.526	1.195	—	—	—	—	2.997	—	—	—	0.967	6.351
HLW-E-ES-15	—	11.058	—	13.980	0.013	—	3.158	7.070	—	—	—	—	1.330	—	—	—	0.866	5.687
HLW-E-ES-16	—	11.058	—	12.480	0.013	—	3.158	5.320	—	—	—	—	1.330	—	—	—	0.866	5.687

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
HWI-AI-18G	—	—	0.133	—	3.363	0.110	—	—	9.022	—	0.376	0.991	0.385	—	—	—	—	—
HWI-AI-19	—	—	0.141	—	3.571	0.117	—	—	9.580	—	0.400	1.052	0.409	—	—	—	—	—
HWI-AI-20	—	—	5.141	—	3.171	0.117	—	—	8.580	—	0.400	1.052	0.409	—	—	—	—	—
HLW-E-SP-01	—	—	0.151	—	3.396	0.125	—	—	9.492	—	0.426	1.122	0.436	—	—	—	—	—
HLW-E-SP-02	—	—	0.160	—	3.222	0.132	—	—	9.403	—	0.453	1.192	0.464	—	—	—	—	—
HLW-E-SP-03	—	—	0.170	—	3.048	0.140	—	—	9.315	—	0.479	1.263	0.491	—	—	—	—	—
HLW-E-SP-04	—	—	7.335	0.553	1.155	0.105	0.524	—	10.331	0.243	0.657	0.037	0.105	—	—	—	—	—
HLW-E-SP-05	—	—	7.010	0.638	1.104	0.122	0.605	—	9.069	0.280	0.759	0.043	0.121	—	—	—	—	—
HLW-E-SP-06	—	—	7.004	0.599	1.173	0.114	0.568	—	10.192	0.263	0.713	0.040	0.114	—	—	—	—	—
HLW-E-SP-07	—	—	7.669	0.506	1.211	0.097	0.480	—	11.068	0.223	0.602	0.034	0.096	—	—	—	—	—
HLW-E-SP-08	—	—	4.655	0.413	1.459	0.079	0.392	—	13.383	0.182	0.492	0.028	0.078	—	—	—	—	—
HLW-E-SP-09	—	—	6.998	0.599	1.172	0.114	0.568	—	10.184	0.263	0.712	0.040	0.113	0.002	—	—	0.005	0.077
HLW-E-SP-10	—	—	7.004	0.637	1.103	0.122	0.605	—	9.062	0.280	0.758	0.043	0.121	0.002	—	—	0.005	0.077
HLW-E-ES-01	—	—	4.682	—	2.677	0.079	—	—	9.874	—	—	1.642	0.236	—	—	—	—	—
HLW-E-ES-02	—	—	4.611	—	2.636	0.077	—	—	9.725	—	—	1.617	0.232	—	—	—	—	—
HLW-E-ES-03	—	—	4.540	—	2.596	0.076	—	—	9.575	—	—	1.592	0.229	—	—	—	—	—
HLW-E-ES-04	—	—	4.468	—	2.555	0.075	—	—	9.424	—	—	1.567	0.225	—	—	—	—	—
HLW-E-ES-05	—	—	5.611	—	3.136	0.077	—	—	9.725	—	—	1.617	0.232	—	—	—	—	—
HLW-E-ES-06	—	—	5.395	—	3.295	0.070	—	—	8.660	—	—	1.443	0.209	—	—	—	—	—
HLW-E-ES-07	—	—	10.250	—	0.162	0.072	—	—	9.030	—	0.476	1.501	0.216	—	—	—	—	—
HLW-E-ES-C16	—	—	3.840	—	3.150	0.360	—	—	8.000	—	—	—	—	—	—	—	—	—
HLW-E-ES-08	—	—	3.761	—	3.085	0.353	1.000	—	7.835	—	1.000	—	—	—	—	—	—	—
HLW-E-ES-09	—	—	0.160	—	3.306	0.069	—	—	8.702	—	0.459	1.447	0.208	—	—	—	—	—
HLW-E-ES-10	—	—	15.250	—	0.162	0.072	—	—	7.030	—	0.476	1.501	0.216	—	—	—	—	—
HLW-E-ES-11	—	—	5.250	—	0.162	0.072	—	—	9.030	—	0.476	1.501	0.216	—	—	—	—	—
HLW-E-ES-12	—	—	10.250	—	0.162	0.072	—	—	9.030	—	0.476	1.501	0.216	—	—	—	—	—
HLW-E-ES-13	—	—	10.440	—	0.156	0.069	—	—	8.702	—	0.459	1.447	0.208	—	—	—	—	—
HLW-E-ES-14	—	—	5.606	—	3.134	0.077	—	—	9.717	—	—	1.615	0.232	0.002	—	—	0.005	0.077
HLW-E-ES-15	—	—	5.160	—	0.156	0.069	—	—	8.702	—	0.459	1.447	0.208	—	—	—	—	—
HLW-E-ES-16	—	—	4.410	—	0.156	0.069	—	—	8.702	—	0.459	1.447	0.208	—	—	—	—	—

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
HWI-AI-18G	0.188	—	—	28.719	—	—	—	—	0.009	—	—	—	—	—	0.078	0.372
HWI-AI-19	0.200	—	—	26.996	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HWI-AI-20	0.200	—	—	28.896	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HLW-E-SP-01	0.213	—	—	29.426	—	—	—	—	0.010	—	—	—	—	—	0.088	0.421
HLW-E-SP-02	0.226	—	—	28.356	—	—	—	—	0.011	—	—	—	—	—	0.094	0.447
HLW-E-SP-03	0.240	—	—	27.286	—	—	—	—	0.012	—	—	—	—	—	0.099	0.473
HLW-E-SP-04	0.061	—	—	35.308	—	—	—	—	—	—	—	—	—	—	0.015	2.606
HLW-E-SP-05	0.070	—	—	33.459	—	—	—	—	—	—	—	—	—	—	0.017	3.007
HLW-E-SP-06	0.066	—	—	33.315	—	—	—	—	—	—	—	—	—	—	0.016	2.825
HLW-E-SP-07	0.056	—	—	37.454	—	—	—	—	—	—	—	—	—	—	0.013	2.387
HLW-E-SP-08	0.045	—	—	42.954	—	—	—	—	—	—	—	—	—	—	0.011	1.950
HLW-E-SP-09	0.066	—	—	33.287	—	—	—	—	—	—	—	—	—	—	0.016	2.823
HLW-E-SP-10	0.070	—	—	33.431	—	—	—	—	—	—	—	—	—	—	0.017	3.005
HLW-E-ES-01	—	—	—	40.690	—	—	—	—	—	—	—	—	—	—	—	0.054
HLW-E-ES-02	—	—	—	40.074	—	—	—	—	—	—	—	—	—	—	—	0.053
HLW-E-ES-03	—	—	—	39.455	—	—	—	—	—	—	—	—	—	—	—	0.052
HLW-E-ES-04	—	—	—	38.835	—	—	—	—	—	—	—	—	—	—	—	0.052
HLW-E-ES-05	—	—	—	38.824	—	—	—	—	—	—	—	—	—	—	—	0.053
HLW-E-ES-06	—	—	—	41.746	—	—	—	—	—	—	—	—	—	—	—	0.050
HLW-E-ES-07	—	—	—	38.688	—	—	—	—	—	—	—	—	—	—	0.112	0.049
HLW-E-ES-C16	—	—	—	53.150	—	—	—	—	5.250	—	—	—	—	—	—	—
HLW-E-ES-08	—	—	—	52.056	—	—	—	—	5.142	—	—	—	—	—	—	—
HLW-E-ES-09	0.658	—	—	41.954	—	—	—	—	5.250	—	—	—	—	—	0.108	0.048
HLW-E-ES-10	—	—	—	39.688	—	—	—	—	—	—	—	—	—	—	0.112	0.049
HLW-E-ES-11	—	—	—	38.438	—	—	—	—	5.250	—	—	—	—	—	0.112	0.049
HLW-E-ES-12	—	—	—	34.688	—	—	—	—	5.250	—	—	—	—	—	0.112	0.049
HLW-E-ES-13	—	—	—	40.074	—	—	—	—	—	—	—	—	—	—	0.108	0.048
HLW-E-ES-14	—	—	—	38.792	—	—	—	—	—	—	—	—	—	—	—	0.053
HLW-E-ES-15	0.658	—	—	39.824	—	—	—	—	—	—	—	—	—	—	0.108	0.048
HLW-E-ES-16	0.658	—	—	39.574	—	—	—	—	4.250	—	—	—	—	—	0.108	0.048

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
HLW-E-M-01	—	12.231	—	13.412	0.014	—	3.492	1.183	—	—	—	—	3.000	—	—	—	0.958	6.290
HLW-E-M-02	—	11.861	—	13.007	0.014	—	3.387	1.148	—	—	—	—	4.500	—	—	—	0.929	6.100
HLW-E-M-03	—	12.167	—	13.343	0.014	—	3.474	1.177	—	—	—	—	3.000	—	—	—	0.953	6.258
HLW-E-M-04	—	11.976	—	13.133	0.014	—	3.420	1.159	—	—	—	—	4.500	—	—	—	0.938	6.159
HLW-E-M-05	—	12.421	—	13.621	0.015	—	3.547	1.202	—	—	—	—	1.509	—	—	—	0.973	6.388
HLW-E-M-06	—	12.040	—	13.203	0.014	—	3.438	1.165	—	—	—	—	4.500	—	—	—	0.943	6.192
HLW-E-M-07	—	10.839	—	14.151	0.010	—	3.097	1.049	—	—	—	—	3.000	—	—	—	0.853	5.576
HLW-E-M-08	—	10.839	—	14.151	0.010	—	3.097	1.049	—	—	—	—	3.000	—	—	—	0.853	5.576
HLW-E-M-09	—	10.690	—	14.573	0.014	—	3.474	1.177	—	—	—	—	3.000	—	—	—	0.953	6.258
HLW-E-M-10	—	10.522	—	14.344	0.014	—	3.420	1.159	—	—	—	—	3.000	—	—	—	0.938	6.159
HLW-E-M-11	—	12.167	—	13.343	0.014	—	3.474	1.177	—	—	—	—	3.000	—	—	—	0.953	6.258
HLW-E-M-12	—	10.411	—	14.192	0.014	—	3.383	1.146	—	—	—	—	3.000	—	—	—	0.928	6.094
HLW-E-M-13	—	10.187	—	13.887	0.014	—	3.311	1.122	—	—	—	—	4.500	—	—	—	0.908	5.963
HWT-Al-21	—	25.031	—	20.008	0.056	—	1.195	3.024	0.025	—	—	—	0.544	—	—	—	0.697	6.160
HWT-Al-22	—	25.036	—	20.998	0.056	—	1.196	2.024	0.025	—	—	—	0.544	—	—	—	0.697	6.161
HWT-Al-23	—	25.036	—	21.898	0.056	—	1.196	1.124	0.025	—	—	—	0.544	—	—	—	0.697	6.161
HWT-Al-24	—	26.635	—	19.189	0.060	—	1.272	2.001	0.027	—	—	—	0.579	—	—	—	0.742	6.554
HWT-Al-25	—	25.036	—	20.005	0.056	—	1.196	4.024	0.025	—	—	—	0.544	—	—	—	0.697	6.161
HWT-Al-26	—	25.036	—	20.198	0.056	—	1.196	5.624	0.025	—	—	—	0.544	—	—	—	0.697	6.161
HWT-Al-27	—	25.036	—	20.198	0.056	—	1.196	8.124	0.025	—	—	—	0.544	—	—	—	0.697	6.161
HWT-Al-28	—	26.635	—	20.211	0.060	—	1.272	9.196	0.027	—	—	—	0.579	—	—	—	0.742	6.555
HWT-Al-19LW	—	24.581	—	19.190	0.054	—	1.145	4.687	0.024	—	—	—	0.521	—	—	—	0.667	5.899
HLW-Bi-2Bi	—	11.218	—	13.764	0.010	—	10.203	0.804	—	—	—	—	0.501	—	—	—	0.789	6.699
HLW-Bi-2P	—	11.281	—	13.841	0.010	—	6.490	0.808	—	—	—	—	0.503	—	—	—	0.794	6.737
HLW-Bi-BiO	—	12.493	—	15.328	0.011	—	—	0.895	—	—	—	—	0.557	—	—	—	0.879	7.460
HLW-Bi-BiPO	—	13.198	—	16.193	0.011	—	—	0.946	—	—	—	—	0.589	—	—	—	0.929	7.881
HLW-Bi-F0	—	11.751	—	14.418	0.010	—	6.760	0.842	—	—	—	—	0.524	—	—	—	—	7.018
HLW-Bi-F1	—	11.655	—	14.300	0.010	—	6.705	0.835	—	—	—	—	0.520	—	—	—	0.820	6.960
HLW-Bi-F2	—	11.655	—	14.300	0.010	—	6.705	0.835	—	—	—	—	0.520	—	—	—	0.820	6.960
HLW-Bi-F3	—	11.655	—	10.300	0.010	—	6.705	0.835	—	—	—	—	0.520	—	—	—	0.820	6.960

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
HLW-E-M-01	—	—	4.563	—	2.609	0.077	0.500	—	9.625	—	0.500	1.600	0.230	—	—	—	—	—
HLW-E-M-02	—	—	4.426	—	2.530	0.074	1.200	—	9.334	—	1.200	1.552	0.223	—	—	—	—	—
HLW-E-M-03	—	—	4.540	—	2.596	0.076	0.750	—	9.575	—	0.750	1.592	0.229	—	—	—	—	—
HLW-E-M-04	—	—	4.468	—	2.555	0.075	0.750	—	9.424	—	0.750	1.567	0.225	—	—	—	—	—
HLW-E-M-05	—	—	4.634	—	2.650	0.078	0.500	—	9.774	—	0.500	1.625	0.234	—	—	—	—	—
HLW-E-M-06	—	—	4.492	—	2.568	0.075	0.500	—	9.474	—	0.500	1.575	0.226	—	—	—	—	—
HLW-E-M-07	—	—	5.312	—	3.244	0.069	0.750	—	8.526	—	0.750	1.421	0.206	—	—	—	—	—
HLW-E-M-08	—	—	5.312	—	3.244	0.069	—	—	8.526	—	—	1.421	0.206	—	—	—	—	—
HLW-E-M-09	—	—	5.524	—	3.088	0.076	—	—	9.575	—	—	1.592	0.229	—	—	—	—	—
HLW-E-M-10	—	—	5.437	—	3.039	0.075	0.750	—	9.424	—	0.750	1.567	0.225	—	—	—	—	—
HLW-E-M-11	—	—	4.540	—	2.596	0.076	—	—	9.575	—	—	1.592	0.229	—	—	—	—	—
HLW-E-M-12	—	—	5.380	—	3.007	0.074	—	—	9.324	—	—	1.550	0.223	—	—	—	—	—
HLW-E-M-13	—	—	5.264	—	2.942	0.073	—	—	9.123	—	—	1.517	0.218	—	—	—	—	—
HWT-Al-21	—	—	0.148	—	3.578	0.122	—	—	9.639	—	0.417	1.099	0.427	—	—	—	—	—
HWT-Al-22	—	—	0.148	—	3.578	0.122	—	—	9.639	—	0.417	1.099	0.427	—	—	—	—	—
HWT-Al-23	—	—	0.148	—	3.578	0.122	—	—	9.639	—	0.417	1.099	0.427	—	—	—	—	—
HWT-Al-24	—	—	0.157	—	3.249	0.130	—	—	9.578	—	0.444	1.169	0.455	—	—	—	—	—
HWT-Al-25	—	—	0.148	—	3.178	0.122	—	—	9.338	—	0.417	1.099	0.427	—	—	—	—	—
HWT-Al-26	—	—	0.148	—	3.578	0.122	—	—	8.739	—	0.417	1.099	0.427	—	—	—	—	—
HWT-Al-27	—	—	0.148	—	4.998	0.122	—	—	5.739	—	0.417	1.099	0.427	—	—	—	—	—
HWT-Al-28	—	—	0.157	—	5.010	0.130	—	—	4.978	—	0.444	1.169	0.455	—	—	—	—	—
HWT-Al-19LW	—	—	0.141	—	3.570	0.117	—	—	9.580	—	0.399	1.202	0.409	—	—	—	—	—
HLW-Bi-2Bi	—	—	0.443	—	0.154	0.409	—	—	15.145	—	1.853	4.798	0.241	—	—	—	—	—
HLW-Bi-2P	—	—	0.445	—	0.155	0.411	—	—	15.230	—	1.863	8.034	0.242	—	—	—	—	—
HLW-Bi-BiO	—	—	0.493	—	0.171	0.456	—	—	16.866	—	2.063	5.343	0.268	—	—	—	—	—
HLW-Bi-BiPO	—	—	0.521	—	0.181	0.481	—	—	17.818	—	2.180	—	0.283	—	—	—	—	—
HLW-Bi-F0	—	—	0.464	—	0.161	0.429	—	—	15.865	—	1.941	5.026	0.252	—	—	—	—	—
HLW-Bi-F1	—	—	0.460	—	1.660	0.425	—	—	12.735	—	1.925	4.985	0.250	—	—	—	—	—
HLW-Bi-F2	—	—	0.460	—	0.160	0.425	—	—	15.735	—	1.925	4.985	0.250	—	—	—	—	—
HLW-Bi-F3	—	—	0.460	—	0.160	0.425	—	—	18.735	—	1.925	4.985	0.250	—	—	—	—	—

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
HLW-E-M-01	—	—	—	39.661	—	—	—	—	—	—	—	—	—	—	—	0.053
HLW-E-M-02	—	—	—	38.463	—	—	—	—	—	—	—	—	—	—	—	0.051
HLW-E-M-03	—	—	—	39.455	—	—	—	—	—	—	—	—	—	—	—	0.052
HLW-E-M-04	—	—	—	38.835	—	—	—	—	—	—	—	—	—	—	—	0.052
HLW-E-M-05	—	—	—	40.277	—	—	—	—	—	—	—	—	—	—	—	0.054
HLW-E-M-06	—	—	—	39.041	—	—	—	—	—	—	—	—	—	—	—	0.052
HLW-E-M-07	—	—	—	41.101	—	—	—	—	—	—	—	—	—	—	—	0.049
HLW-E-M-08	—	—	—	41.101	—	—	—	—	—	—	—	—	—	—	1.500	0.049
HLW-E-M-09	—	—	—	38.224	—	—	—	—	—	—	—	—	—	—	1.500	0.052
HLW-E-M-10	—	—	—	37.624	—	—	—	—	—	—	—	—	—	—	1.500	0.052
HLW-E-M-11	—	—	—	39.455	—	—	—	—	—	—	—	—	—	—	1.500	0.052
HLW-E-M-12	—	—	—	37.223	—	—	—	—	—	—	—	—	—	—	4.000	0.051
HLW-E-M-13	—	—	—	36.423	—	—	—	—	—	—	—	—	—	—	4.500	0.050
HWI-AI-21	0.209	—	—	27.112	—	—	—	—	0.010	—	—	—	—	—	0.086	0.412
HWI-AI-22	0.209	—	—	27.113	—	—	—	—	0.010	—	—	—	—	—	0.086	0.412
HWI-AI-23	0.209	—	—	27.113	—	—	—	—	0.010	—	—	—	—	—	0.086	0.412
HWI-AI-24	0.222	—	—	26.997	—	—	—	—	0.011	—	—	—	—	—	0.092	0.438
HWI-AI-25	0.209	—	—	26.809	—	—	—	—	0.010	—	—	—	—	—	0.086	0.412
HWI-AI-26	0.209	—	—	25.213	—	—	—	—	0.010	—	—	—	—	—	0.086	0.412
HWI-AI-27	0.209	—	—	24.293	—	—	—	—	0.010	—	—	—	—	—	0.086	0.412
HWI-AI-28	0.222	—	—	21.620	—	—	—	—	0.011	—	—	—	—	—	0.092	0.439
HWI-AI-19LW	0.330	—	—	26.996	—	—	—	—	0.010	—	—	—	—	—	0.083	0.395
HLW-Bi-2Bi	0.457	—	—	32.008	—	—	—	—	0.149	—	—	—	—	—	0.154	0.202
HLW-Bi-2P	0.460	—	—	32.188	—	—	—	—	0.150	—	—	—	—	—	0.155	0.203
HLW-Bi-BiO	0.509	—	—	35.645	—	—	—	—	0.166	—	—	—	—	—	0.171	0.225
HLW-Bi-BiP0	0.538	—	—	37.657	—	—	—	—	0.176	—	—	—	—	—	0.181	0.238
HLW-Bi-F0	0.479	—	—	33.530	—	—	—	—	0.156	—	—	—	—	—	0.161	0.212
HLW-Bi-F1	0.475	—	—	34.755	—	—	—	—	0.155	—	—	—	—	—	0.160	0.210
HLW-Bi-F2	0.475	—	—	33.255	—	—	—	—	0.155	—	—	—	—	—	0.160	0.210
HLW-Bi-F3	0.475	—	—	34.255	—	—	—	—	0.155	—	—	—	—	—	0.160	0.210

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
HLW-Bi-F4	—	16.655	—	14.300	0.010	—	6.705	0.835	—	—	—	—	0.520	—	—	—	0.820	6.960
HLW-Bi-F5	—	13.821	—	11.330	0.011	—	7.376	0.919	—	—	—	—	0.572	—	—	—	0.902	7.656
HLW-Bi-F6	—	15.655	—	14.300	0.010	—	6.705	3.835	—	—	—	—	0.520	—	—	—	0.820	6.960
HLW-Bi-F7	—	13.986	—	11.360	0.012	—	8.046	1.002	—	—	—	—	0.624	—	—	—	0.984	8.352
HLW-Bi-F8	—	12.821	—	10.330	0.011	—	7.376	0.919	—	—	—	—	0.572	—	—	—	0.902	7.656
HLW-Bi-F9	—	16.655	—	16.300	0.010	—	6.705	0.835	—	—	—	—	0.520	—	—	—	0.820	6.960
HLW-Bi-F10	—	15.821	—	15.330	0.011	—	7.376	0.919	—	—	—	—	0.572	—	—	—	0.902	7.656
HLW-Bi-P0	—	12.266	—	15.050	0.011	—	7.057	0.879	—	—	—	—	0.547	—	—	—	0.863	7.325
HWI-ALS-01	—	15.527	—	17.600	0.083	—	—	1.284	—	0.089	—	—	0.146	—	0.038	—	—	8.465
HWI-ALS-02	—	16.217	—	14.840	0.087	—	—	3.991	—	0.093	—	—	0.153	—	0.040	—	—	8.842
HWI-ALS-03	—	16.562	—	16.640	0.088	—	—	1.370	—	0.095	—	—	0.156	—	0.041	—	—	9.030
HWI-ALS-04	—	17.252	—	14.000	0.092	—	—	3.927	—	0.099	—	—	0.162	—	0.043	—	—	9.406
HWI-ALS-05	—	16.562	—	10.400	0.088	—	—	1.370	—	0.095	—	—	0.156	—	0.041	—	—	9.030
HWI-ALS-06	—	16.562	—	16.120	0.088	—	—	1.370	—	0.095	—	—	0.156	—	0.041	—	—	9.030
HWI-ALS-07	—	17.252	—	16.000	0.092	—	—	1.427	—	0.099	—	—	0.162	—	0.043	—	—	9.406
HWI-ALS-08	—	17.942	—	15.360	0.096	—	—	1.484	—	0.103	—	—	0.169	—	0.044	—	—	9.782
HWI-ALS-09	—	17.942	—	13.440	0.096	—	—	3.884	—	0.103	—	—	0.169	—	0.044	—	—	9.782
HWI-ALS-10	—	18.632	—	12.880	0.099	—	—	3.841	—	0.106	—	—	0.175	—	0.046	—	—	10.159
HWI-ALS-11	—	17.252	—	15.500	0.092	—	—	1.427	—	0.099	—	—	0.162	—	0.043	—	—	9.406
HWI-ALS-12	—	17.252	—	10.000	0.092	—	—	1.427	—	0.099	—	—	0.162	—	0.043	—	—	9.406
HWI-ALS-13	—	17.942	—	9.600	0.096	—	—	1.484	—	0.103	—	—	0.169	—	0.044	—	—	9.782
HLW-N101-11	—	10.078	—	10.000	—	—	—	0.574	0.886	0.328	—	—	0.189	0.205	—	—	—	15.445
HLW-N101-12	—	10.447	—	7.500	—	—	—	0.595	0.918	0.340	—	—	0.196	0.213	—	—	—	16.010
HLW-N101-13	—	10.877	—	7.500	—	—	—	0.620	0.956	0.354	—	—	0.204	0.221	—	—	—	16.669
HLW-N101-14	—	9.402	—	10.000	—	—	—	0.536	0.826	0.306	—	—	0.176	0.191	—	—	—	14.409
HLW-N101-15	—	10.201	—	10.750	—	—	—	0.581	0.896	0.332	—	—	0.191	0.208	—	—	—	15.633
HLW-N101-16	—	10.631	—	8.500	—	—	—	0.606	0.934	0.346	—	—	0.199	0.216	—	—	—	16.292
HLW-N101-17	—	10.938	—	8.000	—	—	—	0.623	0.961	0.356	—	—	0.205	0.223	—	—	—	16.763
HLW-N101-18	—	8.050	—	10.000	—	—	—	0.459	0.707	0.262	—	—	0.151	0.164	—	—	—	12.337

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
HLW-Bi-F4	—	—	0.460	—	3.160	0.425	—	—	10.735	—	1.925	4.985	0.250	—	—	—	—	—
HLW-Bi-F5	—	—	0.506	—	0.176	0.468	—	—	17.409	—	2.118	5.484	0.275	—	—	—	—	—
HLW-Bi-F6	—	—	0.460	—	3.160	0.425	—	—	10.735	—	1.925	4.985	0.250	—	—	—	—	—
HLW-Bi-F7	—	—	0.552	—	0.192	0.510	—	—	16.582	—	2.310	5.982	0.300	—	—	—	—	—
HLW-Bi-F8	—	—	0.506	—	0.176	0.468	—	—	18.409	—	2.118	5.484	0.275	—	—	—	—	—
HLW-Bi-F9	—	—	0.460	—	5.160	0.425	—	—	7.735	—	1.925	4.985	0.250	—	—	—	—	—
HLW-Bi-F10	—	—	0.506	—	5.176	0.468	—	—	7.409	—	2.118	5.484	0.275	—	—	—	—	—
HLW-Bi-F0	—	—	0.484	—	0.168	0.447	—	—	16.561	—	2.026	—	0.263	—	—	—	—	—
HWI-ALS-01	—	—	0.096	0.048	3.850	0.170	0.808	—	12.606	—	0.144	—	0.032	—	—	—	—	—
HWI-ALS-02	—	—	0.101	0.050	3.180	0.177	0.844	—	13.166	—	0.151	—	0.033	—	—	—	—	—
HWI-ALS-03	—	—	0.103	0.051	3.640	0.181	0.862	—	13.446	—	0.154	—	0.034	—	—	—	—	—
HWI-ALS-04	—	—	0.107	0.053	3.000	0.189	0.898	—	14.006	—	0.160	—	0.035	—	—	—	—	—
HWI-ALS-05	—	—	0.103	0.051	5.200	0.181	0.862	—	13.446	—	0.154	—	0.034	—	—	—	—	—
HWI-ALS-06	—	—	0.103	0.051	4.680	0.181	0.862	—	13.446	—	0.154	—	0.034	—	—	—	—	—
HWI-ALS-07	—	—	0.107	0.053	3.500	0.189	0.898	—	14.006	—	0.160	—	0.035	—	—	—	—	—
HWI-ALS-08	—	—	0.111	0.055	3.360	0.196	0.934	—	14.567	—	0.167	—	0.037	—	—	—	—	—
HWI-ALS-09	—	—	0.111	0.055	2.880	0.196	0.934	—	14.567	—	0.167	—	0.037	—	—	—	—	—
HWI-ALS-10	—	—	0.116	0.057	2.760	0.204	0.970	—	15.127	—	0.173	—	0.038	—	—	—	—	—
HWI-ALS-11	—	—	0.107	0.053	4.500	0.189	0.898	—	14.006	—	0.160	—	0.035	—	—	—	—	—
HWI-ALS-12	—	—	0.107	0.053	5.000	0.189	0.898	—	14.006	—	0.160	—	0.035	—	—	—	—	—
HWI-ALS-13	—	—	0.111	0.055	4.800	0.196	0.934	—	14.567	—	0.167	—	0.037	—	—	—	—	—
HLW-N101-11	—	—	4.250	0.365	3.000	—	0.373	—	7.838	0.267	0.681	0.549	—	—	—	—	—	0.062
HLW-N101-12	—	—	6.000	0.378	3.000	—	0.387	—	7.497	0.276	0.706	0.570	—	—	—	—	—	0.064
HLW-N101-13	—	—	4.000	0.394	3.000	—	0.403	—	10.182	0.288	0.735	0.593	—	—	—	—	—	0.066
HLW-N101-14	—	—	—	0.340	3.250	—	0.348	—	12.547	0.249	0.635	0.513	—	—	—	—	—	0.057
HLW-N101-15	—	—	7.000	0.369	1.250	—	0.378	—	9.391	0.270	0.689	0.556	—	—	—	—	—	0.062
HLW-N101-16	—	—	5.500	0.385	1.250	—	0.394	—	11.576	0.281	0.718	0.580	—	—	—	—	—	0.065
HLW-N101-17	—	—	3.000	0.396	2.250	—	0.405	—	11.708	0.289	0.739	0.596	—	—	—	—	—	0.067
HLW-N101-18	—	—	—	0.291	3.750	—	0.298	—	11.465	0.213	0.544	0.439	—	—	—	—	—	0.049

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
HLW-Bi-F4	0.475	—	—	30.255	—	—	—	—	0.155	—	—	—	—	—	0.160	0.210
HLW-Bi-F5	0.523	—	—	29.881	—	—	—	—	0.171	—	—	—	—	—	0.176	0.231
HLW-Bi-F6	0.475	—	—	28.255	—	—	—	—	0.155	—	—	—	—	—	0.160	0.210
HLW-Bi-F7	0.570	—	—	28.006	—	—	—	—	0.186	—	—	—	—	—	0.192	0.252
HLW-Bi-F8	0.523	—	—	30.881	—	—	—	—	0.171	—	—	—	—	—	0.176	0.231
HLW-Bi-F9	0.475	—	—	29.255	—	—	—	—	0.155	—	—	—	—	—	0.160	0.210
HLW-Bi-F10	0.523	—	—	28.881	—	—	—	—	0.171	—	—	—	—	—	0.176	0.231
HLW-Bi-P0	0.500	—	—	35.000	—	—	—	—	0.163	—	—	—	—	—	0.168	0.221
HWI-ALS-01	0.063	—	—	37.293	—	—	—	—	1.401	—	—	—	—	—	0.042	0.214
HWI-ALS-02	0.066	—	—	36.240	—	—	—	—	1.463	—	—	—	—	—	0.043	0.224
HWI-ALS-03	0.068	—	—	35.713	—	—	—	—	1.495	—	—	—	—	—	0.044	0.228
HWI-ALS-04	0.070	—	—	34.659	—	—	—	—	1.557	—	—	—	—	—	0.046	0.238
HWI-ALS-05	0.068	—	—	40.393	—	—	—	—	1.495	—	—	—	—	—	0.044	0.228
HWI-ALS-06	0.068	—	—	35.193	—	—	—	—	1.495	—	—	—	—	—	0.044	0.228
HWI-ALS-07	0.070	—	—	34.659	—	—	—	—	1.557	—	—	—	—	—	0.046	0.238
HWI-ALS-08	0.073	—	—	33.606	—	—	—	—	1.619	—	—	—	—	—	0.048	0.247
HWI-ALS-09	0.073	—	—	33.606	—	—	—	—	1.619	—	—	—	—	—	0.048	0.247
HWI-ALS-10	0.076	—	—	32.552	—	—	—	—	1.681	—	—	—	—	—	0.050	0.257
HWI-ALS-11	0.070	—	—	34.159	—	—	—	—	1.557	—	—	—	—	—	0.046	0.238
HWI-ALS-12	0.070	—	—	39.159	—	—	—	—	1.557	—	—	—	—	—	0.046	0.238
HWI-ALS-13	0.073	—	—	37.926	—	—	—	—	1.619	—	—	—	—	—	0.048	0.247
HLW-N101-11	0.156	—	—	39.796	0.271	—	—	—	—	—	—	—	—	—	—	4.690
HLW-N101-12	0.162	—	—	39.602	0.281	—	—	—	—	—	—	—	—	—	—	4.862
HLW-N101-13	0.168	—	—	37.418	0.292	—	—	—	—	—	—	—	—	—	—	5.062
HLW-N101-14	0.145	—	—	41.442	0.252	—	—	—	—	—	—	—	—	—	—	4.376
HLW-N101-15	0.158	—	—	36.065	0.274	—	—	—	—	—	—	—	—	—	—	4.748
HLW-N101-16	0.164	—	—	36.131	0.285	—	—	—	—	—	—	—	—	—	—	4.948
HLW-N101-17	0.169	—	—	36.928	0.294	—	—	—	—	—	—	—	—	—	—	5.091
HLW-N101-18	0.124	—	—	46.735	0.216	—	—	—	—	—	—	—	—	—	—	3.747

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Ag ₂ O	Al ₂ O ₃	As ₂ O ₅	B ₂ O ₃	BaO	BeO	Bi ₂ O ₃	CaO	CdO	Ce ₂ O ₃	Cl	CoO	Cr ₂ O ₃	Cs ₂ O	CuO	Dy ₂ O ₃	F	Fe ₂ O ₃
HLW-N101-19	—	8.296	—	8.500	—	—	—	0.473	0.729	0.270	—	—	0.155	0.169	—	—	—	12.714
HLW-N101-20	—	8.603	—	8.000	—	—	—	0.490	0.756	0.280	—	—	0.161	0.175	—	—	—	13.185
HLW-N101-21	—	9.095	—	7.500	—	—	—	0.518	0.799	0.296	—	—	0.170	0.185	—	—	—	13.938
HLW-N101-22	—	8.972	—	9.500	—	—	—	0.511	0.788	0.292	—	—	0.168	0.183	—	—	—	13.750
HLW-N101-23	—	9.709	—	9.000	—	—	—	0.553	0.853	0.316	—	—	0.182	0.198	—	—	—	14.880
HLW-N101-24	—	9.709	—	7.500	—	—	—	0.553	0.853	0.316	—	—	0.182	0.198	—	—	—	14.880
HLW-NG-Cr1	—	10.365	—	14.426	0.012	—	2.960	1.003	0.004	—	—	—	1.247	—	—	—	0.812	5.331
HLW-NG-Cr2	—	11.055	—	13.442	0.013	—	3.157	1.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-NG-Cr3	—	11.056	—	14.440	0.013	—	3.157	5.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-NG-Cr4	—	15.055	—	15.229	0.013	—	3.157	6.070	0.004	—	—	—	1.330	—	—	—	0.866	5.686
HLW-NG-Cr5	—	10.365	—	13.426	0.012	—	2.960	1.003	0.004	—	—	—	1.247	—	—	—	0.812	5.331
HLW-NG-Cr6	—	10.365	—	13.426	0.012	—	2.960	1.003	0.004	—	—	—	1.247	—	—	—	0.812	5.331
HLW-NG-Cr7	—	12.437	—	14.258	0.014	—	3.551	1.203	0.005	—	—	—	1.496	—	—	—	0.974	6.397
HLW-NG-Cr8	—	12.437	—	14.258	0.014	—	3.551	1.203	0.005	—	—	—	1.496	—	—	—	0.974	6.397
HLW-NG-Cr9	—	12.437	—	14.258	0.014	—	3.551	1.203	0.005	—	—	—	1.496	—	—	—	0.974	6.397
HLW-NG-Cr10	—	13.819	—	14.287	0.016	—	3.946	1.337	0.005	—	—	—	1.662	—	—	—	1.082	7.107
HLW-NG-Fe1	—	4.931	—	13.275	0.074	—	—	0.460	—	0.096	—	—	0.226	—	—	—	—	14.143
HLW-NG-Fe2	—	5.582	—	13.812	0.084	—	—	0.521	—	0.108	—	—	0.256	—	—	—	—	16.011
HLW-NG-Fe3	—	6.247	—	13.849	0.094	—	—	0.583	—	0.121	—	—	0.287	—	—	—	—	17.917
HLW-NG-Fe4	—	6.247	—	13.849	0.094	—	—	0.583	—	0.121	—	—	0.287	—	—	—	—	17.917
HLW-NG-Fe5	—	6.247	—	15.349	0.094	—	—	0.583	—	0.121	—	—	0.287	—	—	—	—	17.917
HLW-NG-Fe6	—	9.247	—	15.349	0.094	—	—	0.583	—	0.121	—	—	0.287	—	—	—	—	17.917
HLW-NG-Fe7	—	6.247	—	16.349	0.094	—	—	0.583	—	0.121	—	—	0.287	—	—	—	—	17.917
HLW-NG-Fe8	—	6.247	—	18.349	0.094	—	—	0.583	—	0.121	—	—	0.287	—	—	—	—	17.917
HLW-NG-Fe9	—	6.247	—	16.349	0.094	—	—	0.583	—	0.121	—	—	0.287	—	—	—	—	17.917
HLW-NG-Fe10	—	6.247	—	18.349	0.094	—	—	8.583	—	0.121	—	—	0.287	—	—	—	—	17.917
HLW-NG-Fe11	—	5.848	—	15.326	0.088	—	—	0.546	—	0.113	—	—	0.268	—	—	—	—	16.774

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	Gd ₂ O ₃	HfO ₂	K ₂ O	La ₂ O ₃	Li ₂ O	MgO	MnO	MoO ₃	Na ₂ O	Nd ₂ O ₃	NiO	P ₂ O ₅	PbO	PdO	Pr ₂ O ₃	Rb ₂ O	Rh ₂ O ₃	RuO ₂
HLW-N101-19	—	—	—	0.300	3.750	—	0.307	—	11.571	0.219	0.560	0.452	—	—	—	—	—	0.051
HLW-N101-20	—	—	—	0.312	3.750	—	0.319	—	12.453	0.228	0.581	0.469	—	—	—	—	—	0.053
HLW-N101-21	—	—	—	0.329	3.750	—	0.337	—	12.415	0.241	0.614	0.496	—	—	—	—	—	0.056
HLW-N101-22	—	—	—	0.325	1.500	—	0.332	—	13.362	0.237	0.606	0.489	—	—	—	—	—	0.055
HLW-N101-23	—	—	—	0.352	3.500	—	0.359	—	13.679	0.257	0.656	0.529	—	—	—	—	—	0.059
HLW-N101-24	—	—	—	0.352	4.250	—	0.359	—	13.679	0.257	0.656	0.529	—	—	—	—	—	0.059
HLW-NG-Cr1	—	—	5.414	—	3.304	0.065	—	—	8.156	—	0.431	1.356	0.195	—	—	—	—	—
HLW-NG-Cr2	—	—	2.420	—	4.816	0.069	—	—	8.699	—	0.459	1.446	0.208	—	—	—	—	—
HLW-NG-Cr3	—	—	0.160	—	4.578	0.069	—	—	8.700	—	0.459	1.446	0.208	—	—	—	—	—
HLW-NG-Cr4	—	—	0.160	—	5.316	0.069	—	—	8.700	—	0.459	1.446	0.208	—	—	—	—	—
HLW-NG-Cr5	—	—	7.414	—	2.304	0.065	—	—	8.156	—	0.431	1.356	0.195	—	—	—	—	—
HLW-NG-Cr6	—	—	5.414	—	0.304	0.065	—	—	8.156	—	0.431	1.356	0.195	—	—	—	—	—
HLW-NG-Cr7	—	—	5.180	—	1.675	0.078	—	—	9.787	—	0.517	1.627	0.234	—	—	—	—	—
HLW-NG-Cr8	—	—	2.280	—	1.675	0.078	—	—	9.787	—	0.517	1.627	0.234	—	—	—	—	—
HLW-NG-Cr9	—	—	7.180	—	1.675	0.078	—	—	9.787	—	0.517	1.627	0.234	—	—	—	—	—
HLW-NG-Cr10	—	—	8.200	—	0.195	0.086	—	—	10.874	—	0.574	1.808	0.260	—	—	—	—	—
HLW-NG-Fe1	—	—	—	0.082	2.645	0.145	2.849	—	12.597	—	0.416	0.568	0.545	—	—	—	—	—
HLW-NG-Fe2	—	—	—	0.092	1.550	0.164	3.226	—	14.166	—	0.470	0.643	0.617	—	—	—	—	—
HLW-NG-Fe3	—	—	—	0.103	2.057	0.183	3.610	—	13.400	—	0.526	0.719	0.691	—	—	—	—	—
HLW-NG-Fe4	—	—	—	0.103	0.056	0.183	3.610	—	14.400	—	0.526	0.719	0.691	—	—	—	—	—
HLW-NG-Fe5	—	—	—	0.103	0.056	0.183	3.610	—	15.901	—	0.526	0.719	0.691	—	—	—	—	—
HLW-NG-Fe6	—	—	—	0.103	0.056	0.183	3.610	—	15.901	—	0.526	0.719	0.691	—	—	—	—	—
HLW-NG-Fe7	—	—	—	0.103	2.057	0.183	3.610	—	11.900	—	0.526	0.719	0.691	—	—	—	—	—
HLW-NG-Fe8	—	—	—	0.103	3.057	0.183	3.610	—	9.900	—	0.526	0.719	0.691	—	—	—	—	—
HLW-NG-Fe9	—	—	4.000	0.103	2.057	0.183	3.610	—	7.900	—	0.526	0.719	0.691	—	—	—	—	—
HLW-NG-Fe10	—	—	—	0.103	5.057	0.183	3.610	—	6.900	—	0.526	0.719	0.691	—	—	—	—	—
HLW-NG-Fe11	—	—	—	0.097	3.053	0.172	3.379	—	12.460	—	0.493	0.673	0.647	—	—	—	—	—

— Empty data field.

Table 3.2. Target Compositions (wt%) of ORP HLW Glasses (Continued).

Glass ID	SO ₃	Sb ₂ O ₃	SeO ₂	SiO ₂	SnO ₂	SrO	TeO ₂	ThO ₂	TiO ₂	Tl ₂ O	UO ₃	V ₂ O ₅	WO ₃	Y ₂ O ₃	ZnO	ZrO ₂
HLW-N101-19	0.128	—	—	47.272	0.223	—	—	—	—	—	—	—	—	—	—	3.861
HLW-N101-20	0.133	—	—	45.820	0.231	—	—	—	—	—	—	—	—	—	—	4.004
HLW-N101-21	0.141	—	—	44.645	0.244	—	—	—	—	—	—	—	—	—	—	4.233
HLW-N101-22	0.139	—	—	44.376	0.241	—	—	—	—	—	—	—	—	—	—	4.176
HLW-N101-23	0.150	—	—	39.989	0.261	—	—	—	—	—	—	—	—	—	—	4.519
HLW-N101-24	0.150	—	—	40.739	0.261	—	—	—	—	—	—	—	—	—	—	4.519
HLW-NG-Cr1	0.617	—	—	41.654	—	—	—	—	0.004	—	—	2.500	—	—	0.102	0.045
HLW-NG-Cr2	0.658	—	—	41.940	—	—	—	—	0.004	—	—	2.500	—	—	0.108	0.048
HLW-NG-Cr3	0.658	—	—	41.940	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-NG-Cr4	0.658	—	—	35.413	—	—	—	—	0.004	—	—	—	—	—	0.108	0.048
HLW-NG-Cr5	0.617	—	—	41.654	—	—	—	—	0.004	—	—	2.500	—	—	0.102	0.045
HLW-NG-Cr6	0.617	—	—	45.655	—	—	—	—	0.004	—	—	2.500	—	—	0.102	0.045
HLW-NG-Cr7	0.741	—	—	37.144	—	—	—	—	0.005	—	—	2.500	—	—	0.122	0.054
HLW-NG-Cr8	0.741	—	—	40.044	—	—	—	—	0.005	—	—	2.500	—	—	0.122	0.054
HLW-NG-Cr9	0.741	—	—	35.144	—	—	—	—	0.005	—	—	2.500	—	—	0.122	0.054
HLW-NG-Cr10	0.823	—	—	31.216	—	—	—	—	0.005	—	—	2.500	—	—	0.135	0.059
HLW-NG-Fe1	0.193	—	—	45.498	0.063	0.171	—	—	—	—	—	—	—	—	0.030	0.994
HLW-NG-Fe2	0.218	—	—	41.054	0.071	0.193	—	—	—	—	—	—	—	—	0.034	1.126
HLW-NG-Fe3	0.244	—	—	37.775	0.080	0.216	—	—	—	—	—	—	—	—	0.038	1.260
HLW-NG-Fe4	0.244	—	—	37.775	0.080	0.216	—	—	—	—	—	1.000	—	—	0.038	1.260
HLW-NG-Fe5	0.244	—	—	35.775	0.080	0.216	—	—	—	—	—	—	—	—	0.038	1.260
HLW-NG-Fe6	0.244	—	—	32.775	0.080	0.216	—	—	—	—	—	—	—	—	0.038	1.260
HLW-NG-Fe7	0.244	—	—	36.775	0.080	0.216	—	—	—	—	—	—	—	—	0.038	1.260
HLW-NG-Fe8	0.244	—	—	35.775	0.080	0.216	—	—	—	—	—	—	—	—	0.038	1.260
HLW-NG-Fe9	0.244	—	—	36.775	0.080	0.216	—	—	—	—	—	—	—	—	0.038	1.260
HLW-NG-Fe10	0.244	—	—	28.774	0.080	0.216	—	—	—	—	—	—	—	—	0.038	1.260
HLW-NG-Fe11	0.229	—	—	38.343	0.075	0.202	—	—	—	—	—	—	—	—	0.035	1.179

— Empty data field.

Table 3.3. Minimums and Maximums of HLW Glass Components (in Mass Fractions) for Compositions in the WTP Modeling Dataset and ORP Dataset.

Dataset	WTP		ORP	
Number of Glasses in Dataset	285		266	
HLW Glass Component	Min	Max	Min	Max
Al ₂ O ₃	0.01428	0.13025	0.01926	0.29510
B ₂ O ₃	0.03785	0.15000	0.03211	0.21898
CaO	0	0.01000	0	0.20196
CdO	0	0.01646	0	0.00961
Cr ₂ O ₃	0	0.00600	0.00059	0.06000
Fe ₂ O ₃	0.01400	0.15052	0.02516	0.21299
K ₂ O	0	0.01640	0	0.15250
La ₂ O ₃	0	0.01234	0	0.01200
Li ₂ O	0	0.06013	0	0.07708
MgO	0	0.01364	0	0.09130
MnO	0	0.08000	0	0.08000
Na ₂ O	0.03700	0.20000	0.03580	0.20000
NiO	0	0.01002	0	0.02503
PbO	0	0.01010	0	0.03208
Sb ₂ O ₃	0	0.00400	0	0.00323
SeO ₂	0	0.00432	0	0.00468
SiO ₂	0.33000	0.53100	0.17440	0.53150
SrO	0	0.10287	0	0.09270
ThO ₂	0	0.06013	0	0.03603
TiO ₂	0	0.01000	0	0.05250
Tl ₂ O	0	0.00307	0	0.00000
UO ₃	0	0.06500	0	0.05557
ZnO	0	0.04000	0	0.04500
ZrO ₂	0	0.11500	0	0.10636
Others	0.00220	0.05145	NA ^(a)	NA

(a) NA = Not applicable. ORP glasses were actively designed, in contrast to the WTP glasses, which were mostly statistically designed and the statistical designs included an “Others” category.

Table 3.4. Minimums and Maximums of HLW Glass Components (in Mass Fractions) Included in the Others Group in Table 3.3 for Compositions in the WTP Modeling Dataset.

Dataset	WTP		ORP	
Number of Glasses in Dataset	285		266	
HLW Glass Component	Min	Max	Min	Max
Ag ₂ O	0	0.00236	0	0.00186
As ₂ O ₅	0	0.00236	0	0.00243
BaO	0	0.00500	0	0.00209
BeO	0	0.00005	0	0
Bi ₂ O ₃	0	0.00300	0	0.10203
Ce ₂ O ₃	0	0.02585	0	0.00356
Cl	0	0.00340	0	0.00137
CoO	0	0.00230	0	0
Cs ₂ O	0	0.00250	0	0.00223
CuO	0	0.00240	0	0.00056
Dy ₂ O ₃	0	0.00030	0	0
F	0	0.00440	0	0.01083
Gd ₂ O ₃	0	0.00010	0	0
HfO ₂	0	0.03292	0	0
MoO ₃	0	0.00390	0	0
Nd ₂ O ₃	0	0.01657	0	0.00289
P ₂ O ₅	0	0.00640	0	0.08034
PdO	0	0.01010	0	0.03208
Pr ₂ O ₃	0	0.00128	0	0.00002
Rb ₂ O	0	0.00160	0	0
Rh ₂ O ₃	0	0.00080	0	0
RuO ₂	0	0.00800	0	0.00005
SO ₃	0	0.00130	0	0.00077
SnO ₂	0	0.00330	0	0.00823
TeO ₂	0	0.00010	0	0
V ₂ O ₅	0	0.00101	0	0.02500
WO ₃	0	0.00124	0	0.00026
Y ₂ O ₃	0	0.00080	0	0

Table 3.5. Components with Lower and Upper Limits (wt%) for Groups of HLW Glasses.

Glass Oxide	INEL-HW		HLW-ALG		HLW-BP		HLW-E		HWI-AI		HLW-Bi		HWI-ALS		HLW-NG	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Al ₂ O ₃	6.93	8.92	1.93	13.00	6.28	8.91	4.41	29.51	21.31	26.63	11.22	16.66	15.53	18.63	4.93	15.06
B ₂ O ₃	11.24	12.03	4.30	15.00	10.22	19.48	3.21	20.21	13.19	21.90	10.30	16.30	9.60	17.60	7.5	18.35
CdO	0.14	0.18	0.00	0.12	0.04	0.44	0.00	0.19	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.96
Cr ₂ O ₃	0.11	0.15	0.06	0.60	0.10	0.18	0.10	6.00	0.46	0.58	0.50	0.62	0.15	0.18	0.15	1.66
Fe ₂ O ₃	15.54	20.01	6.62	15.90	4.56	11.02	2.52	21.3	5.24	6.55	6.70	8.35	8.47	10.16	5.33	17.92
Li ₂ O	1.10	3.11	0.00	5.75	0.00	2.77	0.10	7.71	2.17	5.01	0.15	5.18	2.76	5.20	0.06	5.32
MnO	0.44	0.57	0.54	8.00	0.46	1.18	0.00	1.2	0.00	0.00	0.00	0.00	0.81	0.97	0.00	3.61
Na ₂ O	7.05	11.36	3.70	20.00	9.57	16.13	3.58	18.06	4.98	13.38	7.41	18.74	12.61	15.13	6.9	15.9
NiO	0.55	0.71	0.13	0.78	0.54	1.04	0.00	2.5	0.36	0.44	1.85	2.31	0.14	0.17	0.42	0.74
SiO ₂	35.85	46.48	33.00	53.10	35.08	42.15	17.44	53.15	21.62	33.35	28.01	37.66	32.55	40.39	28.77	47.27
SrO	0.00	0.00	0.00	9.27	0.04	0.09	0.00	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
ThO ₂	0.00	0.00	0.00	0.00	1.16	3.60	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UO ₃	0.00	0.00	0.00	0.00	2.41	5.56	0.00	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	0.01	1.01	0.43	4.00	0.05	0.10	0.00	4.5	0.07	0.09	0.15	0.19	0.04	0.05	0.00	0.14
ZrO ₂	2.20	2.83	0.20	10.64	2.85	7.57	0.00	4.12	0.35	0.44	0.20	0.25	0.21	0.26	0.04	5.09

**Table 5.1. ORP-LAW Glasses Having Data for PCT, VHT,
 Viscosity, and Electrical Conductivity.**

Glass ID	VHT	PCT	Viscosity	Electrical Conductivity	Source document
LAWA143	0 ^(a)	0	1	1	VSL-04R4970-1, Rev. 0, 2/24/05
LAWA144	0	0	1	1	VSL-04R4970-1, Rev. 0, 2/24/05
LAWA145	0	0	1	1	VSL-04R4970-1, Rev. 0, 2/24/05
LAWA161	1	1	0	0	VSL-04R4960-1, Rev. 0, 2/28/05
LAWA161-duplicate	1	0	0	0	VSL-04R4960-1, Rev. 0, 2/28/05
LAWA161S2	0	0	1	1	VSL-04R4960-1, Rev. 0, 2/28/05
LAWA171	1 ^{*(b)}	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA172	1*	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA173	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA174	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA175	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA176	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA177	1*	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA178	1*	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA179	1*	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA180	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA181	1*	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA182	1*	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA183	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA184	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA185	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA186	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA187	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA187-duplicate	1	0	0	0	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA187CCC	0	1	0	0	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA188	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA189	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA190	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA191	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA192	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA193	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA194	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA195	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA196	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWA197	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB97	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB98	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB99	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB100	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB101	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB102	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB103	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB104	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06
LAWB105	1	1	1	1	VSL-06R6900-1, Rev. 0, 3/23/06

(a) An entry of 1 indicates data is available for that property on that glass, while an entry of 0 indicates no data is available for that property on that glass.

(b) An entry of 1* for VHT denotes tests for which the glass test coupon was fully reacted and only “greater than” is available.

Table 5.1. ORP-LAW Glasses Having Data for PCT, VHT, Viscosity, and Electrical Conductivity (Continued).

Glass ID	VHT	PCT	Viscosity	Electrical Conductivity	Source document
LAWC100R1	1 ^(a)	1	1	1	VSL-05R5900-1, Rev. 0, 1/27/06
LAWC101	1	1	1	1	VSL-05R5900-1, Rev. 0, 1/27/06
LAWC102	1	1	1	1	VSL-05R5900-1, Rev. 0, 1/27/06
LAWC103	1	1	1	1	VSL-05R5900-1, Rev. 0, 1/27/06
ORPLA1	1 ^{*(b)}	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA1S4	1*	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA2	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA2S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA3	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA3S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA4	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA4S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA5	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA5S4	1*	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA6	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA6S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA7	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA7S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA8	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA8S4	1*	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA9	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA9S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA10	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA10S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA11	1*	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA11S4	1*	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA12	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA12S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA13	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA13S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA14	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA14S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA15	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA15S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA16	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA16S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA17	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA17S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLA18	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLA19	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLA20	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLA21	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLA22	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLA23	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09

(a) An entry of 1 indicates data is available for that property on that glass, while an entry of 0 indicates no data is available for that property on that glass.

(b) An entry of 1* for VHT denotes tests for which the glass test coupon was fully reacted and only “greater than” is available.

**Table 5.1. ORP-LAW Glasses Having Data for PCT, VHT, Viscosity, and
 Electrical Conductivity (Continued).**

Glass ID	VHT	PCT	Viscosity	Electrical Conductivity	Source document
ORPLA24	1 ^(a)	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLA25	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLA26	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA27	1 ^{*(b)}	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA28	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA29	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA30	1*	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA31	1*	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA32	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA33	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA33-1	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA34	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA35	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA36	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA37	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA38	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLA38-1	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLB1	1*	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLB1S4	1*	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLB2	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLB2S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLB3	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLB3S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLB4	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLB4S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC1	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC1S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC2	1*	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC2S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC3	1*	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC3S4	1*	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC4	1*	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC4S4	1*	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC5	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLC5S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLD1	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLD1S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLD2	1	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLD2S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLD3	1	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLD3S4	1	0	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLD4	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLD5	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLD6	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLD7	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLD8	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLD9	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09

(a) An entry of 1 indicates data is available for that property on that glass, while an entry of 0 indicates no data is available for that property on that glass.

(b) An entry of 1* for VHT denotes tests for which the glass test coupon was fully reacted and only “greater than” is available.

Table 5.1. ORP-LAW Glasses Having Data for PCT, VHT, Viscosity, and Electrical Conductivity (Continued).

Glass ID	VHT	PCT	Viscosity	Electrical Conductivity	Source document
ORPLE1	1 ^(a)	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE2	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE3	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE4	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE5	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE6	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE7	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE8	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE9	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE10	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE11	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLE12	1	1	1	1	VSL-07R1130-1, Rev. 0, 10/5/07
ORPLF1	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF2	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF3	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF4	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF5	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF6	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF7	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF8	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF9	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF10	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF11	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF12	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF13	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLF14	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG1	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG2	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG3	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG4	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG5	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG6	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG7	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG8	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG9	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG10	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG11	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG12	1	1	1	1	VSL-09R1510-2, Rev. 0, 6/12/09
ORPLG13	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG14	1 ^{*(b)}	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG15	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG16	1*	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG17	1*	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG18	1*	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG19	1*	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10

(a) An entry of 1 indicates data is available for that property on that glass, while an entry of 0 indicates no data is available for that property on that glass.

(b) An entry of 1* for VHT denotes tests for which the glass test coupon was fully reacted and only “greater than” is available.

Table 5.1. ORP-LAW Glasses Having Data for PCT, VHT, Viscosity, and Electrical Conductivity (Continued).

Glass ID	VHT	PCT	Viscosity	Electrical Conductivity	Source document
ORPLG20	1 ^(a)	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG21	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG22	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG23	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG24	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG25	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG26	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
ORPLG27	1	1	1	1	VSL-10R1790-1, Rev. 0, 12/1/10
Q10-G-134A (ORPLE12)	1	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
R10-G-155A (ORPLA15)	1	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
S10-G-101B (ORPLC5)	1	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
S10-G-45A (ORPLB4)	1	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
T10-G-16A (ORPLD1)	1	1	0	0	VSL-07R1130-1, Rev. 0, 10/5/07
WVW-G-11A (LAWA161)	1	1	0	0	VSL-04R4960-1, Rev. 0, 2/28/05
Y10-G-146C (ORPLA20)	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
Z10-G-122B (ORLF7-low SO ₃)	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
Z10-G-153B (ORLF7-high SO ₃)	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
Z10-G-60C (ORPLD6)	0	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
10A-G-53C (ORPLD6)	1	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
10A-G-43B (ORPLG9)	1 ^{*(b)}	1	0	0	VSL-09R1510-2, Rev. 0, 6/12/09
DWV-G-123C (LAWB99)	1	1	0	0	VSL-06R6900-1, Rev. 0, 3/23/06
EWV-G-89B (LAWA187)	1	1	0	0	VSL-06R6900-1, Rev. 0, 3/23/06
EWV89BCCC (LAWA187)	1	1	0	0	VSL-06R6900-1, Rev. 0, 3/23/06
EWV-G-93B (LAWA187)	1	0	0	0	VSL-06R6900-1, Rev. 0, 3/23/06
EWV93BCCC (LAWA187)	1	0	0	0	VSL-06R6900-1, Rev. 0, 3/23/06
EWV-G-108B (LAWA187)	1	0	0	0	VSL-06R6900-1, Rev. 0, 3/23/06
WVY-G-95A (LAWC100)	1	1	1	1	VSL-05R5900-1, Rev. 0, 1/27/06
J10-G-24B (ORPLA38-1)	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
I10-G-135A (ORPLG27)	1	1	0	0	VSL-10R1790-1, Rev. 0, 12/1/10
Totals (# Glasses = 207)	203	171	122	122	

(a) An entry of 1 indicates data is available for that property on that glass, while an entry of 0 indicates no data is available for that property on that glass.

(b) An entry of 1* for VHT denotes tests for which the glass test coupon was fully reacted and only “greater than” is available.

Table 5.2. Model Summary for the Selected 17-Term Reduced Partial Quadratic Mixture Model on the Natural Logarithm of ILAW PCT-B.

Model form to predict the natural logarithm of the normalized PCT-B release (in g/L): $\ln(PCT - B) = \sum_{i=1}^q b_i x_i + \text{Selected} \left\{ \sum_{i=1}^{q-1} \sum_{j=i+1}^q b_{ij} x_i x_j \right\}$ The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide components such that $\sum_{i=1}^q x_i = 1$. The b_i ($i = 1, 2, \dots, q$) and selected b_{ij} are coefficients listed below.		
ln(PCT-B) Reduced PQM Model Term	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	-31.3612	2.1310
B ₂ O ₃	11.8101	2.5505
CaO	-13.8404	3.0142
Fe ₂ O ₃	-16.5948	3.2161
K ₂ O	7.9687	1.7452
Li ₂ O	83.3036	8.4889
MgO	-21.2343	8.2492
Na ₂ O	46.1599	5.2140
P ₂ O ₅	-19.2540	2.8180
SiO ₂	-1.6161	1.1133
ZrO ₂	-6.6289	2.7866
Others ^(a)	-5.1690	1.8573
CaO×Li ₂ O	-251.2654	53.4354
B ₂ O ₃ ×MgO	488.8612	89.5443
B ₂ O ₃ ×Li ₂ O	-374.9533	72.1448
Na ₂ O×SiO ₂	-74.3462	13.1157
CaO×Fe ₂ O ₃	212.0947	46.0965
Modeling Data Statistic (applied to 244 WTP Glasses):		R² = 0.866

(a) "Others" component includes Ag₂O, BaO, Br, CdO, Cs₂O, I, La₂O₃, MnO, MoO₃, NiO, PbO, Re₂O₇, SeO₂, SrO, and "Unknown" plus Cl, Cr₂O₃, F, SO₃, TiO₂, and ZnO.

Table 5.3. Model Summary for the Selected 17-Term Reduced Partial Quadratic Mixture Model on the Natural Logarithm of ILAW PCT-Na.

<p>Model form to predict the natural logarithm of the normalized PCT-Na release (in g/L):</p> $\ln(PCT - Na) = \sum_{i=1}^q b_i x_i + \text{Selected} \left\{ \sum_{i=1}^q b_{ii} x_i^2 + \sum_{i < j}^{q-1} \sum_j^q b_{ij} x_i x_j \right\}$ <p>The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide components such that $\sum_{i=1}^q x_i = 1$.</p> <p>The b_i ($i = 1, 2, \dots, q$) and selected b_{ii} and b_{ij} are coefficients listed below.</p>		
ln(PCT-Na) Reduced PQM Model Term	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	-20.7142	1.6238
B ₂ O ₃	-6.5489	2.7610
CaO	0.0151	2.5591
Fe ₂ O ₃	-8.4617	2.6039
K ₂ O	-0.8724	3.9729
Li ₂ O	44.7604	3.5466
MgO	-13.8667	7.2503
Na ₂ O	9.9942	1.6770
P ₂ O ₅	-14.5324	2.4027
SiO ₂	-4.8834	0.5143
ZrO ₂	-0.6200	2.2096
Others ^(a)	3.3450	1.4341
CaO×Li ₂ O	-232.1695	46.7097
CaO×Fe ₂ O ₃	182.6191	40.4128
B ₂ O ₃ ×MgO	437.4267	77.8463
B ₂ O ₃ ×Na ₂ O	87.6716	19.0092
K ₂ O×K ₂ O	315.6867	83.2397
Modeling Data Statistic (applied to 244 WTP Glasses):		R² = 0.870

(a) "Others" component includes Ag₂O, BaO, Br, CdO, Cs₂O, I, La₂O₃, MnO, MoO₃, NiO, PbO, Re₂O₇, SeO₂, SrO, and "Unknown" plus Cl, Cr₂O₃, F, SO₃, TiO₂, and ZnO.

Table 5.4. Model Summary for the Selected 15-Term Reduced Partial Cubic Mixture Model on the Natural Logarithm of ILAW VHT Alteration Depth.

<p>Model form to predict the natural logarithm of the VHT alteration depth, D, in microns:</p> $\ln(D) = \sum_{i=1}^q b_i x_i + \text{Selected} \left\{ \sum_{i=1}^q b_{iii} x_i^3 + \sum_{i < j}^{q-1} \sum_{j=1}^q b_{ijj} x_i^2 x_j + \sum_{i < j < k}^{q-2} \sum_{j=1}^{q-1} \sum_{k=1}^q b_{ijk} x_i x_j x_k \right\}$ <p>The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide components such that $\sum_{i=1}^q x_i = 1$.</p> <p>The b_i ($i = 1, 2, \dots, q$) and selected b_{iii}, b_{ijj} and b_{ijk} are coefficients listed below.</p>		
ln(D) Reduced Partial Cubic Mixture Model Term	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	19.5685	6.0850
B ₂ O ₃	18.5336	5.9232
CaO	38.2412	9.4479
Fe ₂ O ₃	-8.4126	4.7225
K ₂ O	-39.3124	10.7075
Li ₂ O	-17.8250	20.0670
MgO	-8.3068	8.0413
Na ₂ O	-20.6518	10.4755
SiO ₂	-0.5137	2.2871
ZrO ₂	-62.8457	7.5911
Others ^(a)	-0.4293	5.3481
(K ₂ O) ² ×Na ₂ O	10138.2817	1198.5167
(Na ₂ O) ³	872.6563	130.6419
Li ₂ O×Na ₂ O×SiO ₂	2139.8048	387.6038
B ₂ O ₃ ×CaO×Na ₂ O	-1943.0687	773.3618
Modeling Data Statistic (applied to 165 WTP Glasses)		R² = 0.744

(a) “Others” component includes Ag₂O, BaO, Br, CdO, Cs₂O, I, La₂O₃, MnO, MoO₃, NiO, PbO, Re₂O₇, SeO₂, SrO, and “Unknown” plus Cl, Cr₂O₃, F, SO₃, TiO₂, and ZnO.

Table 5.5. Model Summary for the Selected 25-Term Reduced Arrhenius-Linear Mixture Model with Three Crossproduct Terms on the Natural Logarithm of ILAW Electrical Conductivity.

Model form to predict the natural logarithm of EC, in ln(S/cm):					
$\ln(EC) = \sum_{i=1}^q a_i x_i + a_{CaOLi_2O} x_{CaO} x_{Li_2O} + a_{CaONa_2O} x_{CaO} x_{Na_2O} + a_{Li_2ONa_2O} x_{Li_2O} x_{Na_2O} + \sum_{i=1}^q b_i \frac{x_i}{T/1000}$					
The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide components such that $\sum_{i=1}^q x_i = 1$.					
The b_i ($i = 1, 2, \dots, q$) and selected a_{ij} are coefficients listed below.					
Mixture Terms (a_i)	Coefficient Estimate	Coefficient Stand. Dev.	Mixture-Temp. Terms [$x_i/(T/1000)$]	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	2.3854	2.5456	Al ₂ O ₃ /(T/1000)	-9.0593	3.1966
B ₂ O ₃	7.9750	1.7536	B ₂ O ₃ /(T/1000)	-11.0983	2.1885
CaO	5.2093	3.0161	CaO/(T/1000)	-30.6535	1.8797
Fe ₂ O ₃	4.3935	1.6656	Fe ₂ O ₃ /(T/1000)	-9.2407	2.0700
K ₂ O	7.6774	2.1834	K ₂ O/(T/1000)	-11.5299	2.7137
Li ₂ O	4.2464	5.0291	Li ₂ O/(T/1000)	30.4827	4.2400
MgO	15.1675	3.2610	MgO/(T/1000)	-25.0634	4.0719
Na ₂ O	-2.0291	1.2653	Na ₂ O/(T/1000)	12.3822	1.2516
SiO ₂	3.6811	0.7384	SiO ₂ /(T/1000)	-10.1563	0.9047
ZrO ₂	7.8740	3.3302	ZrO ₂ /(T/1000)	-16.5390	4.1850
Others ^(a)	11.2069	2.1288	Others/(T/1000)	-17.7117	2.6254
CaO×Li ₂ O	144.9519	44.2208			
CaO×Na ₂ O	79.0190	14.6533			
Li ₂ O×Na ₂ O	-130.1441	17.2032			
Modeling Data Statistic (applied to 171 WTP Glasses)				R ² = 0.951	

(a) The “Others” component includes Ag₂O, BaO, Br, CdO, Cs₂O, I, La₂O₃, MnO, MoO₃, NiO, PbO, Re₂O₇, SeO₂, SrO, and “Unknown” plus Cl, Cr₂O₃, F, P₂O₅, SO₃, TiO₂, and ZnO.

Table 5.6. Model Summary for the Selected 26-Term Reduced Truncated T2-Linear Mixture Model with Four Quadratic Terms on the Natural Logarithm of ILAW Viscosity.

Model form to predict the natural logarithm of viscosity, in $\ln(P)$ $\ln(\eta) = \sum_{i=1}^q a_i x_i + \text{Selected} \left\{ \sum_{i=1}^q a_{ii} x_i^2 + \sum_{i < j}^{q-1} \sum_{j=1}^q a_{ij} x_i x_j \right\} + \sum_{i=1}^q b_i \frac{x_i}{(T/1000)^2}$ <p>The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide components such that $\sum_{i=1}^q x_i = 1$.</p> <p>The b_i ($i = 1, 2, \dots, q$) and selected a_{ii} or a_{ij} are coefficients listed below.</p> <p>The temperature (T in Kelvin) is divided by the scaling factor of 1000 so that the b_i coefficients are similar in magnitude to the a_i coefficients.</p>					
Mixture Terms (x_i)	Coefficient Estimate	Coefficient Stand. Dev.	Mixture-Temp. Terms $[x_i/(T/1000)^2]$	Coefficient Estimate	Coefficient Stand. Dev.
Al_2O_3	5.5124	2.0960	$\text{Al}_2\text{O}_3/(T/1000)^2$	24.6423	2.2683
B_2O_3	-42.3772	6.8657	$\text{B}_2\text{O}_3/(T/1000)^2$	(b)	(b)
CaO	-10.6445	0.9836	$\text{CaO}/(T/1000)^2$	13.7793	1.3498
Fe_2O_3	-4.6220	1.0390	$\text{Fe}_2\text{O}_3/(T/1000)^2$	15.2036	1.4269
K_2O	-0.8689	0.9358	$\text{K}_2\text{O}/(T/1000)^2$	(b)	(b)
Li_2O	10.9390	4.5502	$\text{Li}_2\text{O}/(T/1000)^2$	-82.4815	2.9954
MgO	-5.6188	5.5224	$\text{MgO}/(T/1000)^2$	22.7608	2.8130
Na_2O	0.9073	0.6740	$\text{Na}_2\text{O}/(T/1000)^2$	-14.5621	0.8958
P_2O_5	-0.8081	2.8760	$\text{P}_2\text{O}_5/(T/1000)^2$	24.0339	4.2324
SiO_2	1.5575	0.5247	$\text{SiO}_2/(T/1000)^2$	24.4077	0.5709
ZrO_2	-12.0741	2.0755	$\text{ZrO}_2/(T/1000)^2$	48.2286	2.9522
Others ^(a)	-9.3903	1.4313	Others $/(T/1000)^2$	17.3800	2.0519
$(\text{B}_2\text{O}_3)^2$	198.7360	36.5259			
$(\text{Li}_2\text{O})^2$	133.6906	43.1873			
$\text{Al}_2\text{O}_3 \times \text{Li}_2\text{O}$	-136.5095	56.0571			
$(\text{MgO})^2$	-179.8249	103.5284			
Modeling Data Statistic (applied to 171 WTP Glasses)				$R^2 = 0.988$	

(a) The "Others" component includes Ag_2O , BaO , Br , CdO , Cs_2O , I , La_2O_3 , MnO , MoO_3 , NiO , PbO , Re_2O_7 , SeO_2 , SrO , and "Unknown" plus Cl , Cr_2O_3 , F , P_2O_5 , SO_3 , TiO_2 , and ZnO .

(b) This term was not statistically significant and hence was omitted from the model.

Table 5.7. PCT Results^(a) for ORP-LAW Higher Waste Loading Glasses.

Glass ID	pH	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)		
		B	Na	Si	B	Na	Si	B	Na	Si
LAWA161	11.39	57.03	204.30	49.79	1.343	1.333	0.291	0.672	0.666	0.146
LAWA171	11.48	111.50	349.70	70.80	2.622	2.048	0.414	1.311	1.024	0.207
LAWA172	11.58	67.81	275.30	63.13	1.706	1.613	0.387	0.853	0.806	0.194
LAWA173	11.75	68.65	318.20	68.84	1.957	1.864	0.422	0.978	0.932	0.211
LAWA174	11.80	58.50	382.70	66.86	1.923	2.242	0.410	0.962	1.121	0.205
LAWA175	11.70	61.91	366.20	71.55	1.765	2.146	0.439	0.883	1.073	0.220
LAWA176	11.61	26.25	234.40	51.57	0.863	1.373	0.316	0.431	0.686	0.158
LAWA177	11.88	283.40	864.20	115.30	6.678	4.658	0.674	3.339	2.329	0.337
LAWA178	12.09	100.30	630.70	129.50	3.001	3.400	0.784	1.500	1.700	0.392
LAWA179	12.07	68.88	542.10	104.10	2.394	2.921	0.630	1.197	1.461	0.315
LAWA180	12.15	48.68	545.00	103.00	2.019	2.937	0.624	1.010	1.469	0.312
LAWA181	12.08	58.53	510.20	108.30	2.035	2.750	0.656	1.017	1.375	0.328
LAWA182	12.08	28.05	420.60	93.27	1.164	2.267	0.565	0.582	1.134	0.282
LAWA183	11.35	34.30	172.30	41.61	1.127	1.009	0.259	0.564	0.505	0.130
LAWA184	11.43	35.40	210.70	52.04	1.211	1.236	0.305	0.606	0.618	0.152
LAWA185	11.34	22.75	166.80	50.35	0.748	0.977	0.292	0.374	0.489	0.146
LAWA186	11.38	24.80	182.00	49.77	0.859	1.067	0.289	0.429	0.533	0.144
LAWA187	11.68	136.00	499.00	79.87	3.420	2.921	0.490	1.710	1.461	0.245
LAWA187CCC	11.55	81.73	286.60	58.69	2.055	1.678	0.360	1.027	0.839	0.180
LAWA188	11.58	132.10	444.90	70.96	3.322	2.604	0.435	1.661	1.302	0.217
LAWA189	11.75	81.74	403.90	71.40	2.328	2.364	0.438	1.164	1.182	0.219
LAWA190	11.68	90.82	387.90	63.57	2.586	2.270	0.390	1.293	1.135	0.195
LAWA191	11.75	74.81	387.01	71.16	2.131	2.265	0.436	1.066	1.133	0.218
LAWA192	11.65	77.80	335.50	63.51	2.218	1.965	0.379	1.109	0.983	0.189
LAWA193	11.68	96.22	417.80	68.90	2.741	2.446	0.411	1.370	1.223	0.205
LAWA194	12.06	45.02	504.00	82.73	1.865	2.713	0.500	0.933	1.357	0.250
LAWA195	12.03	51.15	525.30	84.51	2.119	2.828	0.511	1.060	1.414	0.256
LAWA196	11.88	36.52	354.20	67.37	1.514	1.908	0.396	0.757	0.954	0.198
LAWA197	11.85	37.60	362.10	68.69	1.558	1.950	0.404	0.779	0.975	0.202

(a) 7-Day PCT, stainless steel vessel with S/V = 2000 m⁻¹. The PCT concentrations (ppm) are as measured. Normalized concentrations (g/L) and normalized mass losses (g/m²) are normalized based on the normalized compositions discussed in Section 2.

Table 5.7. PCT Results^(a) for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	pH	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)		
		B	Na	Si	B	Na	Si	B	Na	Si
LAWB100	10.64	9.57	31.60	29.82	0.267	0.426	0.148	0.134	0.213	0.074
LAWB101	10.74	6.88	30.67	29.00	0.221	0.413	0.144	0.110	0.206	0.072
LAWB102	10.68	8.49	33.39	28.58	0.272	0.449	0.142	0.136	0.224	0.071
LAWB103	10.61	8.26	30.17	32.17	0.265	0.406	0.151	0.133	0.203	0.075
LAWB104	10.75	6.73	30.24	27.39	0.217	0.408	0.138	0.108	0.204	0.069
LAWB105	10.46	20.81	48.83	51.85	0.514	0.657	0.240	0.257	0.328	0.120
LAWB97	10.58	7.44	27.86	33.52	0.239	0.375	0.155	0.119	0.188	0.078
LAWB98	10.53	8.29	26.26	28.94	0.242	0.353	0.140	0.121	0.177	0.070
LAWB99	10.65	8.09	30.70	28.82	0.236	0.413	0.143	0.118	0.207	0.071
LAWC100R1	11.06	71.49	224.30	51.12	1.678	1.508	0.298	0.839	0.754	0.149
LAWC101	11.08	54.71	185.70	43.31	1.351	1.248	0.252	0.675	0.624	0.126
LAWC102	11.15	77.14	243.90	51.61	1.812	1.641	0.301	0.906	0.820	0.150
LAWC103	11.25	91.20	287.40	61.39	2.140	1.931	0.357	1.070	0.965	0.179
ORPLA1	11.74	51.36	287.20	78.22	1.838	1.549	0.405	0.919	0.774	0.203
ORPLA10	11.99	42.11	358.70	77.32	1.738	1.934	0.462	0.869	0.967	0.231
ORPLA11	11.67	21.12	224.00	74.37	0.972	1.208	0.396	0.486	0.604	0.198
ORPLA12	11.50	16.64	180.30	75.36	0.752	1.013	0.393	0.376	0.506	0.197
ORPLA13	11.58	19.29	198.60	75.54	0.878	1.093	0.398	0.439	0.546	0.199
ORPLA14	11.45	14.33	159.90	70.40	0.641	0.917	0.364	0.320	0.459	0.182
ORPLA15	11.58	35.39	242.40	69.91	1.318	1.362	0.379	0.659	0.681	0.189
ORPLA16	11.61	36.25	258.70	76.51	1.500	1.394	0.394	0.750	0.697	0.197
ORPLA17	11.55	42.33	238.70	66.98	1.552	1.341	0.358	0.776	0.670	0.179
ORPLA18	11.67	30.34	206.20	67.09	1.110	1.158	0.363	0.555	0.579	0.182
ORPLA19	11.75	36.03	247.50	81.98	1.318	1.390	0.444	0.659	0.695	0.222
ORPLA2	11.75	55.35	291.10	75.22	1.980	1.570	0.390	0.990	0.785	0.195
ORPLA20	11.77	39.61	261.40	91.43	1.449	1.468	0.460	0.725	0.734	0.230
ORPLA21	11.95	51.06	350.60	106.50	1.903	1.890	0.546	0.951	0.945	0.273
ORPLA22	11.74	28.77	224.70	66.71	1.053	1.262	0.354	0.526	0.631	0.177
ORPLA23	11.67	24.86	210.40	70.49	0.910	1.182	0.374	0.455	0.591	0.187

(a) 7-Day PCT, stainless steel vessel with S/V = 2000 m⁻¹. The PCT concentrations (ppm) are as measured. Normalized concentrations (g/L) and normalized mass losses (g/m²) are normalized based on the normalized compositions discussed in Section 2.

Table 5.7. PCT Results^(a) for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	pH	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)		
		B	Na	Si	B	Na	Si	B	Na	Si
ORPLA24	11.70	32.10	274.30	72.94	1.209	1.479	0.393	0.604	0.739	0.197
ORPLA25	11.93	44.00	375.80	85.02	1.688	1.948	0.465	0.844	0.974	0.233
ORPLA26	11.71	73.15	264.70	63.40	1.842	1.549	0.389	0.921	0.775	0.195
ORPLA27	12.15	208.10	674.10	101.30	5.486	3.946	0.651	2.743	1.973	0.326
ORPLA28	12.41	336.60	1195.00	97.55	9.354	7.036	0.661	4.677	3.518	0.331
ORPLA29	12.44	239.10	947.50	61.68	7.034	5.621	0.442	3.517	2.811	0.221
ORPLA3	11.70	50.28	278.40	74.00	1.799	1.501	0.383	0.900	0.751	0.192
ORPLA30	12.16	208.30	627.70	118.90	5.713	3.676	0.730	2.857	1.838	0.365
ORPLA31	12.51	515.00	1820.00	172.60	15.557	10.687	1.063	7.778	5.344	0.532
ORPLA32	12.54	349.60	1402.00	129.20	11.749	8.267	0.799	5.874	4.133	0.400
ORPLA33	11.70	53.70	278.30	107.50	1.929	1.619	0.540	0.965	0.809	0.270
ORPLA33-1	11.68	37.00	205.90	83.77	1.337	1.205	0.424	0.668	0.603	0.212
ORPLA34	11.85	81.23	354.60	101.50	2.594	2.060	0.549	1.297	1.030	0.274
ORPLA35	12.10	191.20	693.50	136.70	5.499	4.029	0.800	2.749	2.014	0.400
ORPLA36	11.93	77.82	393.20	132.80	2.849	2.191	0.680	1.425	1.096	0.340
ORPLA37	12.05	117.70	570.10	180.50	4.582	3.178	0.935	2.291	1.589	0.468
ORPLA38	11.78	42.49	264.90	102.30	1.654	1.477	0.524	0.827	0.738	0.262
ORPLA38-1	11.78	37.11	240.70	88.53	1.453	1.350	0.456	0.726	0.675	0.228
ORPLA4	11.85	66.42	396.10	104.90	2.377	2.136	0.543	1.189	1.068	0.272
ORPLA5	11.76	27.53	276.30	90.10	1.266	1.489	0.445	0.633	0.745	0.222
ORPLA6	11.66	27.78	233.90	72.40	1.150	1.261	0.369	0.575	0.631	0.185
ORPLA7	11.68	31.69	243.10	71.97	1.312	1.311	0.380	0.656	0.655	0.190
ORPLA8	11.85	75.46	381.10	109.10	2.866	2.056	0.555	1.433	1.028	0.277
ORPLA9	11.97	43.27	348.60	77.16	1.786	1.879	0.465	0.893	0.940	0.232
ORPLB1	11.65	27.45	242.30	73.97	1.210	1.306	0.416	0.605	0.653	0.208
ORPLB2	11.74	38.24	285.10	82.30	1.686	1.536	0.440	0.843	0.768	0.220
ORPLB3	11.46	29.41	205.20	65.43	1.104	1.151	0.349	0.552	0.576	0.175
ORPLB4	11.53	37.18	236.30	69.70	1.403	1.326	0.372	0.702	0.663	0.186
ORPLC1	11.87	20.91	283.80	80.06	1.111	1.530	0.447	0.555	0.765	0.223

(a) 7-Day PCT, stainless steel vessel with S/V = 2000 m⁻¹. The PCT concentrations (ppm) are as measured. Normalized concentrations (g/L) and normalized mass losses (g/m²) are normalized based on the normalized compositions discussed in Section 2.

Table 5.7. PCT Results^(a) for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	pH	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)		
		B	Na	Si	B	Na	Si	B	Na	Si
ORPLC2	11.77	81.20	392.20	73.28	2.240	2.249	0.454	1.120	1.124	0.227
ORPLC3	11.61	126.30	446.30	68.20	3.485	2.560	0.423	1.742	1.280	0.211
ORPLC4	11.75	72.72	359.60	71.01	2.092	2.062	0.436	1.046	1.031	0.218
ORPLC5	11.38	44.97	260.50	67.71	1.699	1.489	0.361	0.849	0.745	0.181
ORPLD1	11.45	49.32	223.60	53.61	1.319	1.437	0.309	0.660	0.718	0.154
ORPLD2	11.71	26.95	234.00	70.99	1.138	1.499	0.385	0.569	0.750	0.192
ORPLD3	11.72	22.44	203.90	66.27	0.838	1.307	0.359	0.419	0.654	0.180
ORPLD4	11.46	43.46	205.90	56.04	1.158	1.320	0.316	0.579	0.660	0.158
ORPLD5	11.58	31.38	195.90	56.39	1.006	1.256	0.318	0.503	0.628	0.159
ORPLD6	11.67	34.64	219.60	63.40	1.128	1.343	0.363	0.564	0.672	0.181
ORPLD7	11.71	35.36	228.70	63.13	1.152	1.399	0.361	0.576	0.700	0.181
ORPLD8	11.77	40.64	268.80	69.30	1.380	1.578	0.404	0.690	0.789	0.202
ORPLD9	11.78	44.62	287.10	76.22	1.511	1.682	0.444	0.756	0.841	0.222
ORPLE1	11.48	16.67	152.30	59.71	0.544	1.282	0.308	0.272	0.641	0.154
ORPLE10	11.25	14.70	87.78	41.03	0.453	0.740	0.215	0.226	0.370	0.108
ORPLE11	11.34	9.57	81.96	35.61	0.312	0.690	0.184	0.156	0.345	0.092
ORPLE12	11.32	15.42	94.32	45.91	0.503	0.793	0.237	0.252	0.397	0.118
ORPLE2	11.18	25.44	108.40	49.62	0.714	0.912	0.266	0.357	0.456	0.133
ORPLE3	11.34	21.03	119.30	43.90	0.590	1.004	0.251	0.295	0.502	0.125
ORPLE4	11.48	16.97	140.70	52.62	0.556	1.052	0.279	0.278	0.526	0.139
ORPLE5	11.61	21.83	213.30	65.85	0.731	1.436	0.352	0.365	0.718	0.176
ORPLE6	11.39	13.68	108.90	48.96	0.447	0.916	0.253	0.223	0.458	0.126
ORPLE7	11.32	13.13	102.20	46.69	0.429	0.860	0.241	0.214	0.430	0.120
ORPLE8	11.34	7.06	90.43	37.63	0.240	0.761	0.194	0.120	0.381	0.097
ORPLE9	11.38	9.48	89.49	36.34	0.337	0.753	0.188	0.168	0.377	0.094
ORPLF1	10.75	4.71	38.53	22.64	0.154	0.516	0.111	0.077	0.258	0.055
ORPLF10	10.89	10.52	81.49	30.13	0.354	0.909	0.152	0.177	0.454	0.076
ORPLF11	10.98	9.60	51.49	33.48	0.323	0.574	0.169	0.161	0.287	0.084
ORPLF12	10.99	10.40	54.77	35.28	0.353	0.616	0.179	0.177	0.308	0.090

(a) 7-Day PCT, stainless steel vessel with S/V = 2000 m⁻¹. The PCT concentrations (ppm) are as measured. Normalized concentrations (g/L) and normalized mass losses (g/m²) are normalized based on the normalized compositions discussed in Section 2.

Table 5.7. PCT Results^(a) for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	pH	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)		
		B	Na	Si	B	Na	Si	B	Na	Si
ORPLF13	11.02	5.98	44.61	29.10	0.203	0.501	0.148	0.101	0.251	0.074
ORPLF14	11.05	7.66	49.37	35.27	0.260	0.555	0.179	0.130	0.277	0.090
ORPLF2	10.85	4.75	53.11	24.77	0.158	0.647	0.123	0.079	0.323	0.062
ORPLF3	10.91	8.32	54.73	27.02	0.280	0.609	0.136	0.140	0.304	0.068
ORPLF4	10.99	9.03	43.36	32.18	0.303	0.483	0.162	0.152	0.241	0.081
ORPLF5	10.88	9.15	114.60	24.22	0.312	1.176	0.123	0.156	0.588	0.062
ORPLF6	10.98	9.53	66.50	29.38	0.325	0.683	0.150	0.162	0.341	0.075
ORPLF7	11.09	9.78	63.48	32.28	0.329	0.709	0.163	0.165	0.354	0.081
ORPLF8	11.28	10.21	57.61	40.77	0.370	0.644	0.206	0.185	0.322	0.103
ORPLF9	10.98	17.04	65.59	50.31	0.617	0.733	0.256	0.308	0.366	0.128
ORPLG1	11.18	13.06	87.99	46.65	0.472	0.641	0.242	0.236	0.320	0.121
ORPLG10	11.78	42.17	267.00	84.53	1.616	1.674	0.448	0.808	0.837	0.224
ORPLG11	11.68	24.40	196.70	74.25	0.917	1.293	0.386	0.458	0.647	0.193
ORPLG12	11.52	25.89	191.10	86.53	0.972	1.256	0.450	0.486	0.628	0.225
ORPLG13	12.41	249.80	987.40	234.70	9.713	6.654	1.263	4.857	3.327	0.631
ORPLG14	12.45	262.50	1068.00	245.70	10.307	7.022	1.335	5.153	3.511	0.667
ORPLG15	12.54	273.00	1146.00	259.20	10.825	7.355	1.422	5.412	3.678	0.711
ORPLG16	12.12	139.30	610.40	200.70	5.429	3.991	1.037	2.714	1.996	0.519
ORPLG17	12.11	117.10	507.20	175.10	4.563	3.316	0.905	2.282	1.658	0.452
ORPLG18	12.10	123.10	544.10	196.70	4.928	3.557	0.996	2.464	1.779	0.498
ORPLG19	12.32	172.20	753.50	251.30	6.961	4.806	1.284	3.480	2.403	0.642
ORPLG2	11.32	15.48	121.60	49.27	0.565	0.862	0.258	0.282	0.431	0.129
ORPLG20	11.90	30.45	224.00	83.28	1.225	1.473	0.424	0.613	0.736	0.212
ORPLG21	11.91	34.49	233.30	91.20	1.388	1.533	0.453	0.694	0.767	0.227
ORPLG22	11.91	23.33	218.50	73.93	0.939	1.436	0.376	0.469	0.718	0.188
ORPLG23	11.90	22.66	213.80	74.54	0.912	1.405	0.375	0.456	0.703	0.187
ORPLG24	11.98	33.85	262.60	86.20	1.376	1.685	0.443	0.688	0.842	0.222
ORPLG25	11.92	34.24	248.90	97.03	1.391	1.597	0.487	0.696	0.798	0.244
ORPLG26	11.94	31.17	237.80	80.73	1.266	1.526	0.415	0.633	0.763	0.207

(a) 7-Day PCT, stainless steel vessel with S/V = 2000 m⁻¹. The PCT concentrations (ppm) are as measured. Normalized concentrations (g/L) and normalized mass losses (g/m²) are normalized based on the normalized compositions discussed in Section 2.

Table 5.7. PCT Results^(a) for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	pH	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)		
		B	Na	Si	B	Na	Si	B	Na	Si
ORPLG27	11.95	32.65	240.00	84.69	1.327	1.540	0.430	0.663	0.770	0.215
ORPLG3	11.42	16.23	127.70	49.69	0.598	0.883	0.262	0.299	0.441	0.131
ORPLG4	11.42	16.64	132.90	55.52	0.613	0.919	0.293	0.307	0.459	0.147
ORPLG5	11.45	16.09	131.10	51.92	0.593	0.906	0.272	0.296	0.453	0.136
ORPLG6	11.60	27.42	172.50	63.57	1.015	1.177	0.326	0.507	0.589	0.163
ORPLG7	11.52	25.48	168.40	65.68	0.948	1.135	0.338	0.474	0.567	0.169
ORPLG8	11.58	29.38	185.80	69.84	1.104	1.221	0.363	0.552	0.611	0.181
ORPLG9	11.68	39.18	238.50	79.60	1.485	1.530	0.418	0.743	0.765	0.209
10A-G-43B	11.78	34.33	248.30	82.28	1.299	1.594	0.430	0.650	0.797	0.215
10A-G-53C	11.45	29.80	183.90	59.73	0.975	1.126	0.343	0.487	0.563	0.172
DWV-G-123C	11.65	6.13	24.49	24.44	0.180	0.330	0.122	0.090	0.165	0.061
EWV89BCCC	11.53	89.04	290.90	58.55	2.245	1.708	0.360	1.123	0.854	0.180
EWV-G-89B	11.55	84.06	323.70	63.07	2.120	1.900	0.388	1.060	0.950	0.194
I10-G-135A	11.93	45.57	329.10	101.20	1.854	2.111	0.515	0.927	1.056	0.257
J10-G-24B	11.77	44.78	302.30	100.90	1.753	1.697	0.519	0.877	0.849	0.260
Q10-G-134A	11.32	15.38	88.70	48.40	0.504	0.746	0.250	0.252	0.373	0.125
R10-G-155A	11.58	49.84	292.80	75.35	1.864	1.643	0.410	0.932	0.821	0.205
S10-G-101B	11.28	35.64	201.40	61.94	1.349	1.151	0.331	0.675	0.576	0.165
S10-G-45A	11.42	43.02	251.90	68.79	1.633	1.414	0.369	0.816	0.707	0.184
T10-G-16A	10.65	25.66	106.30	44.04	0.686	0.681	0.253	0.343	0.340	0.127
WVW-G-11A	11.23	53.44	174.60	48.58	1.272	1.151	0.287	0.636	0.575	0.143
WVY-G-95A-1	11.08	78.03	233.77	49.20	1.835	1.574	0.287	0.918	0.787	0.144
WVY-G-95A-2	11.09	78.55	232.59	49.92	1.847	1.566	0.291	0.924	0.783	0.146
WVY-G-95A-3	11.04	74.66	232.81	44.98	1.756	1.568	0.263	0.878	0.784	0.131
WVY-G-95A-4	11.04	77.37	240.43	45.44	1.820	1.619	0.265	0.910	0.810	0.133
Y10-G-146C	11.58	35.34	226.40	90.87	1.301	1.270	0.459	0.650	0.635	0.229
Z10-G-122B	11.12	12.13	51.74	46.16	0.405	0.581	0.231	0.203	0.290	0.115
Z10-G-153B	11.11	12.86	58.12	41.56	0.433	0.652	0.209	0.216	0.326	0.105
Z10-G-60C	11.65	38.10	272.30	76.13	1.246	1.669	0.438	0.623	0.835	0.219

(a) 7-Day PCT, stainless steel vessel with S/V = 2000 m⁻¹. The PCT concentrations (ppm) are as measured. Normalized concentrations (g/L) and normalized mass losses (g/m²) are normalized based on the normalized compositions discussed in Section 2.

Table 5.8. Variation in PCT-Boron and PCT-Sodium Responses for Replicate and Near-Replicate Pairs.

Glass IDs of Near-Replicates	PCT-Boron		PCT-Sodium	
	g/L	ln(g/L)	g/L	ln(g/L)
LAWA161	1.343	0.29517	1.333	0.28741
WVW-G-11A	1.272	0.24021	1.151	0.14039
	%RSD^(a) = 11.14	SD = 0.0389	%RSD = 10.38	SD = 0.1040
LAWA187	3.420	1.22958	2.921	1.07193
LAWA187CCC ^(b)	2.055	0.72024	1.678	0.51731
EWV-G-89B	2.120	0.75128	1.900	0.64188
EWV89BCCC ^(b)	2.248	0.81015	1.705	0.53331
	%RSD = 26.19	SD = 0.2375	%RSD = 28.70	SD = 0.2598
LAWB99	0.236	-1.44259	0.413	-0.88351
DWV-G-123C	0.180	-1.71263	0.330	-1.10723
	%RSD = 18.98	SD = 0.1909	%RSD = 15.75	SD = 0.1582
LAWC100R1	1.678	0.51779	1.508	0.41065
WVY-G-95A-1	1.832	0.60558	1.574	0.45372
WVY-G-95A-2	1.845	0.61222	1.566	0.44866
WVY-G-95A-3	1.753	0.56143	1.568	0.44960
WVY-G-95A-4	1.817	0.59709	1.619	0.48181
	%RSD = 3.88	SD = 0.0393	%RSD = 2.53	SD = 0.0253
ORPLA15	1.318	0.27576	1.362	0.30866
R10-G-155A	1.866	0.62365	1.661	0.50731
	%RSD = 24.35	SD = 0.2460	%RSD = 14.00	SD = 0.1405
ORPLA20	1.449	0.37092	1.468	0.38382
Y10-G-146C	1.304	0.26514	1.322	0.27903
	%RSD = 7.47	SD = 0.0748	%RSD = 7.40	SD = 0.0741
ORPLA38-1	1.453	0.37361	1.350	0.29980
J10-G-24B	1.754	0.56178	1.649	0.50003
	%RSD = 13.27	SD = 0.1331	%RSD = 4.26	SD = 0.0426
ORPLB4	1.403	0.33894	1.326	0.28187
S10-G-45A	1.634	0.49085	1.408	0.34211
	%RSD = 10.72	SD = 0.1074	%RSD = 4.26	SD = 0.0426
ORPLC5	1.699	0.52997	1.489	0.39825
S10-G-101B	1.350	0.30030	1.209	0.19013
	%RSD = 16.17	SD = 0.1624	%RSD = 14.66	SD = 0.1472
ORPLD1	1.319	0.27697	1.437	0.36227
T10-G-16A	0.686	-0.37687	0.681	-0.38425
	%RSD = 44.65	SD = 0.4623	%RSD = 50.46	SD = 0.5279
ORPLD6	1.128	0.12049	1.343	0.29497
Z10-G-60C	1.246	0.21964	1.584	0.46017
	%RSD = 7.01	SD = 0.0701	%RSD = 11.65	SD = 0.1168
ORPLE12	0.503	-0.68704	0.793	-0.23190
Q10-G-134A	0.504	-0.68456	0.774	-0.25633
	%RSD = 0.18	SD = 0.0018	%RSD = 1.73	SD = 0.173
ORPLF7	0.329	-1.11036	0.709	-0.34436
Z10-G-122B	0.406	-0.90241	0.594	-0.52075
Z10-G-153B	0.434	-0.83573	0.629	-0.46409
	%RSD = 13.83	SD = 0.1432	%RSD = 9.13	SD = 0.0901
ORPLG9	1.485	0.39567	1.530	0.42547
10A-G-43B	1.299	0.26157	1.558	0.44354
	%RSD = 9.47	SD = 0.0948	%RSD = 1.28	SD = 0.0128
ORPLG27	1.327	0.28274	1.540	0.43164
I10-G-135A	1.857	0.61912	2.038	0.71214
	%RSD = 23.56	SD = 0.2379	%RSD = 19.71	SD = 0.1983
Pooled Over 15 sets of Replicates	%RSD = 17.9	SD = 0.177	%RSD = 18.0	SD = 0.177

^(a) %RSD = 100 × (Standard Deviation / Mean); ^(b) Container centerline cooled (CCC) sample of above samples.

Table 5.9. VHT Results for ORP-LAW Higher Waste Loading Glasses.

Glass ID	Alteration Depth (μm)	Days	Rate ($\text{g}/\text{m}^2/\text{d}$) Calculated for Estimated Average Density of 2.65 g/cc	Comparison to Limit of 50 $\text{g}/\text{m}^2/\text{d}$
LAWA161	223	24	24.6	49%
LAWA161-duplicate	230	24	25.4	51%
LAWA171	>895	24	>99	>198%
LAWA172	>940	24	>104	>208%
LAWA173	696	24	76.9	154%
LAWA174	251	24	27.7	55%
LAWA175	415	24	45.8	92%
LAWA176	152	24	16.8	34%
LAWA177	>865	24	>96	>191%
LAWA178	>820	24	>91	>181%
LAWA179	>780	24	>86	>172%
LAWA180	585	24	64.6	129%
LAWA181	>915	24	>101	>202%
LAWA182	>795	24	>88	>176%
LAWA183	230	24	25.4	51%
LAWA184	70	24	7.7	15%
LAWA185	129	24	14.2	28%
LAWA186	90	24	9.9	20%
LAWA187	230	24	25.4	51%
LAWA187-duplicate	334	26.4	33.5	67%
LAWA188	96	24	10.6	21%
LAWA189	135	24	14.9	30%
LAWA190	239	24	26.4	53%
LAWA191	171	24	18.9	38%
LAWA192	252	24	27.8	56%
LAWA193	207	24	22.9	46%
LAWA194	207	24	22.9	46%
LAWA195	229	24	25.3	51%
LAWA196	712	24	78.6	157%
LAWA197	212	24	23.4	47%
LAWB100	118	24	13.0	26%
LAWB101	121	24	13.4	27%
LAWB102	156	24	17.2	34%
LAWB103	62	24	6.8	14%
LAWB104	273	24	30.1	60%
LAWB105	30	24	3.3	7%
LAWB97	172	24	19.0	38%
LAWB98	145	24	16.0	32%
LAWB99	135	24	14.9	30%
LAWC100R1	144	24	15.9	32%
LAWC101	67	24	7.4	15%

Table 5.9. VHT Results for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	Alteration Depth (μm)	Days	Rate ($\text{g/m}^2/\text{d}$) Calculated for Estimated Average Density of 2.65 g/cc	Comparison to Limit of 50 $\text{g/m}^2/\text{d}$
LAWC102	141	24	15.6	31%
LAWC103	5	24	0.6	1%
ORPLA1	>1362	24	>150	>300%
ORPLA1S4	>1264	24	>140	>280%
ORPLA2	1179	24	130.2	260%
ORPLA2S4	858	24	94.7	189%
ORPLA3	1039	24	114.7	229%
ORPLA3S4	1212	24	133.8	268%
ORPLA4	1031	24	113.8	228%
ORPLA4S4	918	24	101.4	203%
ORPLA5	934	24	103.1	206%
ORPLA5S4	>1225	24	>135	>270%
ORPLA6	821	24	90.7	181%
ORPLA6S4	561	24	61.9	124%
ORPLA7	613	24	67.7	135%
ORPLA7S4	680	24	75.1	150%
ORPLA8	894	24	98.7	197%
ORPLA8S4	>1238	24	>137	>274%
ORPLA9	514	24	56.8	114%
ORPLA9S4	340	24	37.5	75%
ORPLA10	136	24	15.0	30%
ORPLA10S4	114	24	12.6	25%
ORPLA11	>1252	24	>138	>276%
ORPLA11S4	>1301	24	>144	>288%
ORPLA12	145	24	16.0	32%
ORPLA12S4	168	24	18.6	37%
ORPLA13	183	24	20.2	40%
ORPLA13S4	695	24	76.7	153%
ORPLA14	77	24	8.5	17%
ORPLA14S4	5	24	0.6	1%
ORPLA15	230	24	25.4	51%
ORPLA15S4	279	24	30.8	62%
ORPLA16	975	24	107.7	215%
ORPLA16S4	1016	24	112.2	224%
ORPLA17	674	24	74.4	149%
ORPLA17S4	1115	24	123.1	246%
ORPLA18	324	24	35.8	72%
ORPLA19	202	24	22.3	45%
ORPLA20	65	24	7.2	14%
ORPLA21	387	24	42.7	85%
ORPLA22	24	24	2.7	5%
ORPLA23	109	24	12.0	24%

Table 5.9. VHT Results for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	Alteration Depth (μm)	Days	Rate ($\text{g/m}^2/\text{d}$) Calculated for Estimated Average Density of 2.65 g/cc	Comparison to Limit of 50 $\text{g/m}^2/\text{d}$
ORPLA24	113	24	12.5	25%
ORPLA25	381	24	42.1	84%
ORPLA26	459	24	50.7	101%
ORPLA27	>1305	24	>144	>288%
ORPLA28	1012	24	111.7	223%
ORPLA29	633	24	69.9	140%
ORPLA30	>1320	24	>146	292%
ORPLA31	>1360	24	>150	300%
ORPLA32	982	24	108.4	217%
ORPLA33	5	24	0.6	1%
ORPLA33-1	8	24	0.9	2%
ORPLA34	103	24	11.4	23%
ORPLA35	1066	24	117.7	235%
ORPLA36	57	24	6.3	13%
ORPLA37	125	24	13.8	28%
ORPLA38	90	24	9.9	20%
ORPLA38-1	71	24	7.8	16%
ORPLB1	>1200	24	>133	265%
ORPLB1S4	>1175	24	>130	260%
ORPLB2	995	24	109.9	220%
ORPLB2S4	526	24	58.1	116%
ORPLB3	344	24	38.0	76%
ORPLB3S4	797	24	88.0	176%
ORPLB4	369	24	40.7	81%
ORPLB4S4	320	24	35.3	71%
ORPLC1	1116	24	123.2	246%
ORPLC1S4	1066	24	117.7	235%
ORPLC2	>1200	24	>133	265%
ORPLC2S4	753	24	83.1	166%
ORPLC3	>1200	24	>133	265%
ORPLC3S4	>1200	24	>133	265%
ORPLC4	>1200	24	>133	265%
ORPLC4S4	>1200	24	>133	265%
ORPLC5	362	24	40.0	80%
ORPLC5S4	224	24	24.7	49%
ORPLD1	99	24	10.9	22%
ORPLD1S4	141	24	15.6	31%
ORPLD2	99	24	10.9	22%
ORPLD2S4	34	24	3.8	8%
ORPLD3	99	24	10.9	22%
ORPLD3S4	209	24	23.1	46%
ORPLD4	122	24	13.5	27%

Table 5.9. VHT Results for ORP-LAW Higher Waste Loading Glasses (Continued)

Glass ID	Alteration Depth (μm)	Days	Rate (g/m ² /d) Calculated for Estimated Average Density of 2.65 g/cc	Comparison to Limit of 50 g/m ² /d
ORPLD5	131	24	14.5	29%
ORPLD6	164	24	18.1	36%
ORPLD7	134	24	14.8	30%
ORPLD8	116	24	12.8	26%
ORPLD9	377	24	41.6	83%
ORPLE1	180	24	19.9	40%
ORPLE2	264	24	29.2	58%
ORPLE3	171	24	18.9	38%
ORPLE4	376	24	41.5	83%
ORPLE5	950	24	104.9	210%
ORPLE6	221	24	24.4	49%
ORPLE7	368	24	40.6	81%
ORPLE8	315	24	34.8	70%
ORPLE9	248	24	27.4	55%
ORPLE10	293	24	32.4	65%
ORPLE11	285	24	31.5	63%
ORPLE12	277	24	30.6	61%
ORPLF1	43	24	4.7	9%
ORPLF2	168	24	18.6	37%
ORPLF3	131	24	14.5	29%
ORPLF4	193	24	21.3	43%
ORPLF5	200	24	22.1	44%
ORPLF6	151	24	16.7	33%
ORPLF7	164	24	18.1	36%
ORPLF8	95	24	10.5	21%
ORPLF9	273	24	30.1	60%
ORPLF10	122	24	13.5	27%
ORPLF11	236	24	26.1	52%
ORPLF12	222	24	24.5	49%
ORPLF13	108	24	11.9	24%
ORPLF14	94	24	10.4	21%
ORPLG1	17	24	1.9	4%
ORPLG2	22	24	2.4	5%
ORPLG3	105	24	11.6	23%
ORPLG4	185	24	20.4	41%
ORPLG5	36	24	4.0	8%
ORPLG6	102	24	11.3	23%
ORPLG7	200	24	22.1	44%
ORPLG8	400	24	44.2	88%
ORPLG9	450	24	49.7	99%
ORPLG10	825	24	91.1	182%
ORPLG11	78	24	8.6	17%

Table 5.9. VHT Results for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	Alteration Depth (μm)	Days	Rate (g/m ² /d) Calculated for Estimated Average Density of 2.65 g/cc	Comparison to Limit of 50 g/m ² /d
ORPLG12	925	24	102.1	204%
ORPLG13	1236	24	136.5	273%
ORPLG14	1138	24	125.7	251%
ORPLG15	1081	24	119.4	239%
ORPLG16	>1200	24	>132.5	>265%
ORPLG17	>1150	24	>127	>254%
ORPLG18	>1285	24	>142	>284%
ORPLG19	>1190	24	>131	>263%
ORPLG20	31	24	3.4	7%
ORPLG21	415	24	45.8	92%
ORPLG22	32	24	3.5	7%
ORPLG23	52	24	5.7	11%
ORPLG24	648	24	71.6	143%
ORPLG25	722	24	79.7	159%
ORPLG26	32	24	3.5	7%
ORPLG27	34	24	3.8	8%
10A-G-43B (ORPLG9)	>1200	24	>133	>265%
10A-G-53C (ORPLD6)	246	24	27.2	54%
DWV-G-123C (LAWB99)	198	24	21.9	44%
EWV89BCCC (LAWA187)	230	26.4	23.1	46%
EWV-G-89B (LAWA187)	736	24	81.3	163%
EWV-G-93B (LAWA187)	719	26.4	72.2	144%
EWV93BCCC (LAWA187)	223	26.4	22.4	45%
EWV-G-108B (LAWA187)	291	26.4	29.2	58%
I10-G-135A (ORPLG27)	658	24	72.7	145%
J10-G-24B (ORPLA38-1)	102	24	11.3	23%
Q10-G-134A (ORPLE12)	301	24	33.2	66%
R10-G-155A (ORPLA15)	751	24	82.9	166%
S10-G-101B (ORPLB4)	292	24	32.2	64%
S10-G-45A (ORPLB4)	481	24	53.1	106%
T10-G-16A (ORPLD1)	99	24	10.9	22%
WVW-G-11A (LAWA161)	113	24	12.5	25%
WVY-G-95A (LAWC100)	102	24	11.3	23%
Y10-G-146C (ORPLA20)	140	24	15.5	31%
Z10-G-122B (ORLF7-low SO ₃)	164	24	18.1	36%
Z10-G-153B (ORLF7-high SO ₃)	209	24	23.1	46%

Table 5.10. Variation in VHT Responses for Replicate and Near-Replicate Pairs.

Glass IDs of Replicate and Near-Replicate Pairs	VHT Alteration Depth	
	μm	$\ln(\mu\text{m})$
LAWA161	223	5.4072
LAWA161-duplicate	230	5.4381
WVW-G-11A (LAWA161)	113	4.7274
	%RSD^(a) = 34.78%	SD = 0.4017
LAWA187	230	5.4381
LAWA187-duplicate	334	5.8111
EWV89BCCC (LAWA187)	230	5.4381
EWV-G-89B (LAWA187)	736	6.6012
EWV-G-93B (LAWA187)	719	6.5779
EWV93BCCC (LAWA187)	223	5.4072
EWV-G-108B (LAWA187)	291	5.6733
Variation for the crucible pair	%RSD = 26.08%	SD = 0.2638
Variation for all Seven Glasses	%RSD = 58.49%	SD = 0.5264
LAWB99	135	4.9053
DWV-G-123C (LAWB99)	198	5.2883
	%RSD = 26.76%	SD = 0.2708
LAWC100R1	144	4.9698
WVY-G-95A (LAWC100)	102	4.6250
	%RSD = 24.15%	SD = 0.2438
ORPLA15	230	5.4381
ORPLA15S4	279	5.6312
R10-G-155A (ORPLA15)	751	6.6214
	%RSD = 68.50%	SD = 0.6348
ORPLA20	65	4.1744
Y10-G-146C (ORPLA20)	140	4.9416
	%RSD = 51.74%	SD = 0.5425
ORPLA38-1	71	4.2627
J10-G-24B (ORPLA38-1)	102	4.6250
	%RSD = 25.34%	SD = 0.2562
ORPLB4	369	5.9108
ORPLB4S4	320	5.7683
S10-G-45A (ORPLB4)	481	6.1759
	%RSD = 21.16%	SD = 0.2068
ORPLC5	362	5.8916
S10-G-101B (ORPLC5)	292	5.6768
	%RSD = 15.14%	SD = 0.1520

 (a) %RSD = $100 \times (\text{Standard Deviation} / \text{Mean})$.

Table 5.10. Variation in VHT Responses for Replicate and Near-Replicate Pairs (Continued).

Glass IDs of Replicate and Near-Replicate Pairs	VHT Alteration Depth	
	μm	$\ln(\mu\text{m})$
ORPLD1	99	4.5951
ORPLD1S4	141	4.9488
T10-G-16A (ORPLD1)	99	4.5951
	%RSD ^(a) = 21.46%	SD =0.2042
ORPLD6	164	5.0999
10A-G-53C (ORPLD6)	246	5.5053
	%RSD = 28.28%	SD =0.2867
ORPLE12	277	5.6240
Q10-G-134A (ORPLE12)	301	5.7071
	%RSD = 5.87%	SD =0.0588
ORPLF7	164	5.0999
Z10-G-122B (ORPLF7-low SO ₃)	164	5.0999
Z10-G-153B (ORPLF7-high SO ₃)	209	5.3423
	%RSD = 14.51%	SD =0.1400
ORPLG9	450	24
10A-G-43B (ORPLG9)	>1200	NA
	%RSD = NA	SD =NA
ORPLG27	34	3.5264
I10-G-135A (ORPLG27)	658	6.4892
	%RSD = 127.52%	SD =2.0950
Pooled over all 14 replicate sets that can be used for modeling (excluding ORPLG9 and 10A-G-43B)	%RSD = 46.47%	SD =0.5622
Pooled over 13 replicate pairs (excluding also ORPLG27 and I10-G-135A)	%RSD = 39.32%	SD =0.3729

(a) %RSD = $100 \times (\text{Standard Deviation} / \text{Mean})$.

Table 5.11. Melt Electrical Conductivity Data for ORP-LAW Higher Waste Loading Glasses.

Glass ID	Temp1 (°C)	EC1 (S/cm)	Temp2 (°C)	EC2 (S/cm)	Temp3 (°C)	EC3 (S/cm)	Temp4 (°C)	EC4 (S/cm)
LAWA143	954	0.219	1054	0.320	1154	0.505	1253	0.585
LAWA144	948	0.208	1045	0.300	1146	0.434	1248	0.672
LAWA145	NA	NA	1047	0.34	1146	0.453	1245	0.582
LAWA161S2	943	0.155	1035	0.244	1129	0.342	1221	0.476
LAWA171	942	0.268	1035	0.395	1127	0.542	1218	0.718
LAWA172	941	0.258	1032	0.371	1125	0.515	1214	0.689
LAWA173	946	0.259	1037	0.395	1129	0.528	1221	0.715
LAWA174	946	0.251	1038	0.367	1131	0.529	1223	0.667
LAWA175	939	0.253	1031	0.381	1123	0.521	1216	0.694
LAWA176	942	0.265	1031	0.384	1124	0.538	1216	0.689
LAWA177	942	0.349	1037	0.526	1128	0.595	1218	0.706
LAWA178	948	0.319	1040	0.494	1133	0.661	1221	0.811
LAWA179	938	0.309	1029	0.459	1123	0.649	1215	0.795
LAWA180	945	0.322	1036	0.442	1127	0.613	1217	0.813
LAWA181	949	0.344	1041	0.503	1132	0.640	1224	0.864
LAWA182	947	0.338	1041	0.481	1128	0.642	1218	0.831
LAWA183	953	0.184	1046	0.282	1140	0.415	1232	0.564
LAWA184	947	0.174	1039	0.282	1131	0.403	1221	0.513
LAWA185	946	0.189	1038	0.290	1129	0.394	1222	0.533
LAWA186	951	0.167	1041	0.265	1135	0.369	1225	0.488
LAWA187	945	0.253	1035	0.375	1127	0.513	1215	0.629
LAWA188	948	0.274	1040	0.405	1147	0.516	1222	0.684
LAWA189	946	0.268	1039	0.379	1130	0.552	1221	0.714
LAWA190	945	0.234	1035	0.354	1125	0.498	1214	0.647
LAWA191	939	0.238	1028	0.376	1118	0.492	1206	0.586
LAWA192	948	0.239	1039	0.350	1130	0.483	1221	0.628
LAWA193	948	0.230	1040	0.350	1132	0.481	1224	0.619
LAWA194	947	0.287	1038	0.431	1129	0.452	1217	0.593
LAWA195	948	0.299	1038	0.440	1130	0.597	1220	0.798
LAWA196	955	0.315	1047	0.464	1139	0.667	1232	0.804
LAWA197	951	0.279	1042	0.399	1134	0.578	1224	0.751
LAWB97	948	0.098	1037	0.165	1129	0.255	1220	0.359
LAWB98	943	0.102	1036	0.172	1126	0.256	1217	0.373
LAWB99	948	0.106	1039	0.181	1132	0.271	1224	0.485
LAWB100	947	0.104	1038	0.181	1129	0.277	1219	0.383
LAWB101	952	0.094	1044	0.157	1137	0.252	1228	0.366
LAWB102	943	0.102	1036	0.172	1127	0.282	1218	0.411
LAWB103	947	0.114	1039	0.193	1131	0.290	1222	0.426
LAWB104	947	0.106	1037	0.184	1132	0.287	1222	0.403
LAWB105	949	0.095	1040	0.164	1132	0.257	1224	0.368
LAWC100R1	956	0.186	1049	0.245	1145	0.407	1238	0.529

NA – Not available; data collected only at three temperatures

Table 5.11. Melt Electrical Conductivity Data for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	Temp1 (°C)	EC1 (S/cm)	Temp2 (°C)	EC2 (S/cm)	Temp3 (°C)	EC3 (S/cm)	Temp4 (°C)	EC4 (S/cm)
LAWC101	932	0.167	1024	0.266	1115	0.382	1206	0.494
LAWC102	931	0.188	1023	0.278	1110	0.393	1206	0.551
LAWC103	926	0.175	1018	0.280	1110	0.382	1202	0.480
ORPLA1	979	0.414	1074	0.590	1171	0.720	1265	1.000
ORPLA2	977	0.390	1072	0.545	1169	0.681	1266	0.942
ORPLA3	981	0.342	1078	0.505	1174	0.773	1269	0.936
ORPLA4	980	0.398	1077	0.552	1174	0.705	1270	1.015
ORPLA5	977	0.373	1071	0.559	1166	0.785	1260	0.945
ORPLA6	972	0.240	1067	0.569	NA	NA	1259	1.098
ORPLA7	977	0.357	1067	0.474	1161	0.655	1263	0.839
ORPLA8	975	0.417	1069	0.548	1165	0.802	1259	1.038
ORPLA9	972	0.348	1067	0.493	1168	0.607	1260	0.850
ORPLA10	981	0.359	1078	0.573	1177	0.737	1275	1.013
ORPLA11	970	0.345	1066	0.488	1160	0.648	1257	0.894
ORPLA12	961	0.281	1055	0.400	1149	0.584	1243	0.779
ORPLA13	965	0.261	1060	0.487	1155	0.595	1251	0.805
ORPLA14	960	0.213	1057	0.388	1149	0.528	1246	0.762
ORPLA15	973	0.379	1067	0.528	1161	0.730	1258	0.957
ORPLA16	974	0.331	1070	0.513	1165	0.732	1262	0.953
ORPLA17	972	0.298	1067	0.480	1162	0.596	1260	0.762
ORPLA18	978	0.303	1072	0.451	1168	0.551	1262	0.807
ORPLA19	970	0.279	1064	0.409	1159	0.535	1253	0.793
ORPLA20	979	0.287	1075	0.419	1170	0.530	1266	0.737
ORPLA33-1	943	0.273	1043	0.375	1140	0.531	1237	0.690
ORPLA38-1	936	0.314	1044	0.452	1141	0.632	1238	0.812
ORPLB1	980	0.422	1075	0.656	1173	0.767	1268	1.028
ORPLB2	982	0.433	1077	0.601	1173	0.755	1269	1.086
ORPLB3	972	0.398	1068	0.582	1162	0.702	1260	0.922
ORPLB4	975	0.351	1069	0.509	1164	0.650	1263	0.895
ORPLC1	973	0.384	1069	0.598	1167	0.820	1264	1.036
ORPLC2	977	0.270	1068	0.413	1161	0.568	1254	0.805
ORPLC5	977	0.255	1070	0.402	1163	0.545	1255	0.736
ORPLD1	979	0.170	1071	0.264	1165	0.358	1258	0.481
ORPLD4	973	0.217	1067	0.318	1163	0.426	1257	0.593
ORPLD5	973	0.228	1067	0.339	1161	0.435	1256	0.619
ORPLD6	973	0.251	1067	0.367	1162	0.450	1257	0.619
ORPLD7	950	0.210	1050	0.294	1148	0.415	1243	0.515
ORPLD8	978	0.270	1072	0.384	1167	0.508	1262	0.655
ORPLD9	976	0.282	1070	0.413	1165	0.571	1260	0.724
ORPLE1	983	0.213	1080	0.334	1178	0.499	1274	0.753
ORPLE2	988	0.236	1085	0.370	1182	0.533	1279	0.749

NA – Not available; data collected only at three temperatures

Table 5.11. Melt Electrical Conductivity Data for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	Temp1 (°C)	EC1 (S/cm)	Temp2 (°C)	EC2 (S/cm)	Temp3 (°C)	EC3 (S/cm)	Temp4 (°C)	EC4 (S/cm)
ORPLE3	981	0.229	1079	0.354	1177	0.482	1274	0.757
ORPLE4	982	0.236	1080	0.354	1178	0.525	1273	0.760
ORPLE5	985	0.246	1080	0.369	1179	0.518	1275	0.749
ORPLE6	977	0.232	1072	0.341	1168	0.518	1264	0.745
ORPLE7	943	0.207	1041	0.320	1138	0.482	1231	0.602
ORPLE8	975	0.225	1071	0.370	1168	0.534	1263	0.836
ORPLE9	985	0.230	1082	0.354	1180	0.521	1276	0.676
ORPLE10	976	0.237	1072	0.372	1169	0.520	1264	0.689
ORPLE11	982	0.211	1080	0.337	1179	0.469	1276	0.715
ORPLE12	957	0.248	1046	0.378	1141	0.518	1237	0.732
ORPLF1	967	0.098	1061	0.154	1156	0.259	1251	0.388
ORPLF2	966	0.111	1061	0.178	1157	0.267	1251	0.414
ORPLF3	968	0.120	1062	0.220	1157	0.306	1252	0.449
ORPLF4	970	0.129	1064	0.191	1159	0.300	1253	0.470
ORPLF7	954	0.162	1048	0.276	1142	0.412	1235	0.541
ORPLF8	950	0.181	1049	0.284	1146	0.424	1242	0.635
ORPLF9	947	0.126	1044	0.208	1140	0.315	1235	0.495
ORPLF10	956	0.125	1053	0.210	1150	0.304	1245	0.457
ORPLF12	953	0.125	1050	0.212	1147	0.315	1243	0.506
ORPLF13	951	0.120	1051	0.215	1148	0.315	1245	0.453
ORPLF14	955	0.157	1053	0.253	1151	0.372	1246	0.492
ORPLG1	972	0.136	1066	0.227	1160	0.321	1255	0.422
ORPLG2	972	0.135	1066	0.238	1161	0.323	1256	0.450
ORPLG4	973	0.179	1068	0.294	1162	0.374	1256	0.544
ORPLG5	973	0.177	1067	0.279	1161	0.391	1256	0.530
ORPLG6	975	0.196	1069	0.277	1164	0.402	1258	0.592
ORPLG7	950	0.178	1049	0.250	1146	0.375	1243	0.547
ORPLG8	960	0.247	1054	0.337	1147	0.438	1241	0.608
ORPLG9	936	0.202	1033	0.360	1129	0.503	1222	0.643
ORPLG10	957	0.206	1055	0.360	1152	0.525	1248	0.771
ORPLG11	953	0.199	1050	0.330	1147	0.439	1243	0.589
ORPLG12	939	0.193	1036	0.336	1132	0.462	1226	0.661
ORPLG21	949	0.245	1047	0.354	1143	0.460	1239	0.666
ORPLG22	947	0.225	1042	0.348	1142	0.465	1238	0.671
ORPLG23	952	0.244	1049	0.354	1145	0.482	1242	0.699
ORPLG24	954	0.204	1051	0.383	1148	0.513	1243	0.693
ORPLG25	940	0.244	1044	0.349	1143	0.495	1240	0.698
ORPLG26	943	0.239	1043	0.419	1142	0.532	1238	0.711
ORPLG27	946	0.245	1041	0.370	1137	0.501	1232	0.680
WVY-G-95A	959	0.177	1050	0.286	1144	0.412	1236	0.544

Table 5.12. Variation in Electrical Conductivity Values for Near-Replicate Pairs.

Glass IDs of Near Replicate Pair	EC Values For Measurement Temperatures at Each Nominal Temperature ^(a)								Pooled Over Temp.	
	Near 950°C		Near 1050°C		Near 1150°C		Near 1250°C		%RSD	SD
	T (°C)	S/cm	T (°C)	S/cm	T (°C)	S/cm	T (°C)	S/cm	S/cm	ln(S/cm)
LAWC100R1	956	0.186	1049	0.245	1145	0.407	1238	0.529		
WVY-G-95A	959	0.177	1050	0.286	1144	0.412	1236	0.544		
%RSD^(b)	0.2%	3.5%	0.1%	10.9%	0.1%	0.9%	0.1%	2.0%	5.83%	0.0585
Glass IDs of Replicate Pairs	Electrical Conductivity Values at Nominal Temperatures								Pooled Over Temp.	
	950°C		1050°C		1150°C		1250°C		%RSD	SD
	S/cm	ln(S/cm)	S/cm	ln(S/cm)	S/cm	ln(S/cm)	S/cm	ln(S/cm)	S/cm	ln(S/cm)
LAWC100R1	0.173	-1.753	0.270	-1.311	0.395	-0.930	0.549	-0.600		
WVY-G-95A	0.168	-1.784	0.285	-1.255	0.420	-0.868	0.566	-0.569		
%RSD^(b), SD^(c)	2.1%	0.0215	3.9%	0.0391	4.4%	0.0442	2.1%	0.0215	3.32%	0.0332

(a) Electrical conductivity values are listed at the measurement temperatures corresponding to the nominal temperature values listed in Table 5.11.

(b) %RSD = $100 \times (\text{Standard Deviation} / \text{Mean})$, calculated using the S/cm values.

(c) Calculated using ln(S/cm) values.

Table 5.13. Melt Viscosity Data for ORP-LAW Higher Waste Loading Glasses.

Glass ID	Temp1 (°C)	Vis1 (P)	Temp2 (°C)	Vis2 (P)	Temp3 (°C)	Vis3 (P)	Temp4 (°C)	Vis4 (P)
LAWA143	953	665.11	1053	172.67	1153	59.98	1253	26.25
LAWA144	950	629.27	1045	165.45	1139	61.60	1234	26.58
LAWA145	950	568.50	1050	155.13	1150	55.65	1250	24.71
LAWA161S2	961	255.70	1055	71.95	1150	27.88	1245	13.43
LAWA171	951	167.77	1049	52.59	1147	21.79	1246	10.60
LAWA172	950	148.95	1048	46.80	1146	19.66	1245	9.61
LAWA173	951	219.54	1049	62.58	1146	24.71	1245	11.71
LAWA174	949	355.06	1047	92.19	1145	32.59	1244	14.88
LAWA175	951	207.21	1050	62.90	1150	25.80	1250	12.40
LAWA176	952	340.68	1050	97.93	1147	35.94	1246	16.22
LAWA177	951	140.42	1049	46.81	1146	19.92	1245	9.87
LAWA178	951	168.06	1049	53.75	1147	22.54	1246	11.20
LAWA179	947	247.46	1047	69.39	1147	27.23	1246	12.99
LAWA180	946	403.76	1046	101.52	1145	34.27	1244	14.49
LAWA181	948	267.90	1047	77.65	1145	29.55	1243	13.42
LAWA182	948	453.60	1047	124.03	1146	44.04	1244	19.60
LAWA183	949	565.33	1047	136.62	1145	44.95	1244	19.06
LAWA184	950	700.63	1047	169.15	1143	54.00	1241	23.28
LAWA185	945	601.70	1043	155.45	1140	54.21	1238	23.53
LAWA186	947	781.20	1044	188.08	1141	62.67	1239	27.10
LAWA187	952	176.51	1052	52.13	1151	20.92	1252	9.82
LAWA188	951	222.36	1050	62.83	1149	25.22	1248	12.47
LAWA189	949	261.98	1047	71.03	1146	27.03	1245	13.01
LAWA190	950	338.38	1049	90.45	1148	34.21	1248	16.56
LAWA191	949	249.60	1049	70.56	1150	27.96	1251	13.35
LAWA192	948	375.17	1047	106.03	1145	39.34	1245	17.95
LAWA193	953	339.79	1052	94.06	1151	35.06	1251	16.13
LAWA194	949	488.72	1047	117.43	1144	38.93	1242	17.01
LAWA195	950	471.67	1050	111.09	1149	36.36	1250	15.78
LAWA196	948	642.08	1045	158.30	1143	52.26	1241	22.02
LAWA197	952	668.13	1051	154.05	1150	50.35	1250	21.06
LAWB97	949	478.41	1048	131.97	1147	47.73	1245	22.33
LAWB98	949	372.13	1050	103.67	1149	37.80	1249	17.58
LAWB99	949	344.08	1049	96.38	1149	35.31	1248	16.03
LAWB100	949	257.62	1049	72.43	1148	27.28	1247	12.49
LAWB101	947	363.80	1047	100.47	1146	36.68	1245	17.33
LAWB102	947	289.58	1047	79.90	1146	31.00	1245	16.26
LAWB103	952	356.80	1053	102.11	1153	37.90	1253	17.32
LAWB104	950	259.28	1051	71.26	1151	27.48	1251	12.78
LAWB105	951	259.68	1051	74.58	1150	28.87	1249	13.70
LAWC100R1	946	250.25	1044	70.21	1142	26.60	1241	12.39

Table 5.13. Melt Viscosity Data for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	Temp1 (°C)	Vis1 (P)	Temp2 (°C)	Vis2 (P)	Temp3 (°C)	Vis3 (P)	Temp4 (°C)	Vis4 (P)
LAWC101	946	296.91	1044	80.24	1142	30.65	1241	15.35
LAWC102	947	226.42	1045	61.43	1144	23.12	1243	10.56
LAWC103	948	246.22	1046	63.85	1145	23.13	1249	10.33
ORPLA1	971	499.59	1063	141.39	1160	52.21	1256	23.40
ORPLA2	960	694.28	1058	182.37	1157	62.27	1255	26.63
ORPLA3	952	771.52	1042	198.97	1129	75.73	1219	33.99
ORPLA4	931	509.20	1035	126.38	1138	43.41	1242	18.24
ORPLA5	954	1898.86	1056	402.50	1158	116.41	1260	43.62
ORPLA6	959	1510.79	1061	352.12	1162	108.94	1264	41.17
ORPLA7	961	1619.00	1061	302.04	1160	94.18	1260	33.79
ORPLA8	959	680.41	1059	156.32	1159	49.62	1259	20.27
ORPLA9	962	500.75	1062	114.77	1162	38.61	1262	17.63
ORPLA10	974	439.77	1071	114.80	1167	38.84	1264	16.54
ORPLA11	975	1118.82	1075	267.47	1175	84.48	1274	33.42
ORPLA12	976	1411.66	1073	313.54	1170	107.89	1267	40.04
ORPLA13	964	1542.94	1063	334.38	1161	109.82	1260	40.18
ORPLA14	968	1828.14	1066	382.11	1164	132.45	1262	47.19
ORPLA15	952	877.79	1052	201.81	1152	63.78	1252	25.37
ORPLA16	953	1388.50	1051	303.10	1150	96.34	1248	38.00
ORPLA17	959	933.36	1055	219.32	1150	70.86	1245	29.38
ORPLA18	961	787.65	1061	174.15	1160	53.59	1260	21.73
ORPLA19	958	791.73	1059	168.63	1159	51.00	1260	20.16
ORPLA20	959	739.50	1060	157.21	1160	48.53	1261	19.62
ORPLA33-1	951	932.11	1053	184.85	1157	54.08	1259	21.04
ORPLA38-1	953	858.47	1055	173.41	1159	50.90	1261	19.73
ORPLB1	957	1029.58	1060	231.27	1163	72.57	1266	28.65
ORPLB2	965	825.39	1065	197.34	1164	67.15	1264	27.86
ORPLB3	951	808.51	1052	195.22	1153	63.30	1254	25.39
ORPLB4	956	931.52	1052	231.41	1149	74.43	1245	31.58
ORPLC1	972	594.47	1070	141.52	1169	49.98	1267	21.90
ORPLC2	957	221.74	1056	64.02	1156	25.84	1255	12.25
ORPLC5	966	864.61	1066	193.68	1166	63.50	1266	26.49
ORPLD1	956	295.59	1056	83.92	1155	32.10	1255	15.10
ORPLD4	960	242.79	1060	66.51	1160	25.74	1260	12.13
ORPLD5	955	361.31	1057	92.36	1158	32.63	1260	15.22
ORPLD6	956	275.71	1058	74.61	1159	27.26	1261	12.74
ORPLD7	956	332.24	1058	81.50	1159	28.38	1261	12.27
ORPLD8	959	285.51	1059	74.30	1160	26.45	1260	11.97
ORPLD9	962	202.46	1064	55.00	1165	20.36	1267	9.12
ORPLE1	985	97.94	1082	35.27	1179	15.68	1276	7.93
ORPLE2	959	158.43	1057	50.69	1155	21.34	1254	10.45

Table 5.13. Melt Viscosity Data for ORP-LAW Higher Waste Loading Glasses (Continued).

Glass ID	Temp1 (°C)	Vis1 (P)	Temp2 (°C)	Vis2 (P)	Temp3 (°C)	Vis3 (P)	Temp4 (°C)	Vis4 (P)
ORPLE3	962	104.97	1061	35.53	1160	15.88	1260	8.28
ORPLE4	959	139.79	1059	43.81	1159	18.02	1260	8.76
ORPLE5	963	158.79	1062	49.30	1161	21.23	1261	11.22
ORPLE6	958	143.45	1052	43.28	1148	17.52	1243	8.48
ORPLE7	978	122.05	1068	37.08	1158	16.75	1248	8.50
ORPLE8	969	93.10	1062	35.58	1157	16.52	1251	8.63
ORPLE9	992	104.09	1088	36.82	1184	16.64	1280	8.28
ORPLE10	964	127.03	1058	45.57	1153	19.04	1248	9.19
ORPLE11	986	106.21	1077	39.70	1169	19.27	1260	10.54
ORPLE12	977	144.46	1073	44.89	1169	18.29	1265	9.19
ORPLF1	957	386.23	1057	103.68	1158	36.09	1260	17.69
ORPLF2	957	325.44	1057	87.22	1158	31.23	1260	13.77
ORPLF3	956	308.91	1057	83.22	1157	30.46	1257	13.95
ORPLF4	958	254.92	1058	69.00	1158	25.82	1259	11.51
ORPLF7	957	159.47	1057	48.20	1158	19.25	1259	9.97
ORPLF8	955	135.60	1056	41.48	1158	16.89	1259	8.10
ORPLF9	954	282.76	1054	73.95	1156	27.34	1257	13.07
ORPLF10	955	222.67	1057	60.62	1160	22.56	1262	10.30
ORPLF12	956	245.81	1057	67.66	1159	24.94	1260	11.29
ORPLF13	957	243.00	1058	64.77	1160	24.35	1261	11.35
ORPLF14	955	247.18	1057	64.56	1159	24.45	1261	11.68
ORPLG1	952	2461.29	1051	469.60	1151	129.92	1251	47.25
ORPLG2	955	1975.49	1054	385.12	1154	109.78	1254	39.55
ORPLG4	951	1693.12	1050	341.85	1150	97.47	1250	41.73
ORPLG5	957	1457.02	1057	300.69	1159	89.25	1260	36.37
ORPLG6	958	885.70	1060	186.37	1161	56.89	1263	25.67
ORPLG7	955	1061.29	1056	211.32	1158	58.68	1259	23.45
ORPLG8	957	744.39	1057	167.48	1159	51.79	1260	20.48
ORPLG9	952	675.96	1054	151.56	1156	47.03	1259	19.40
ORPLG10	958	507.12	1060	117.21	1162	37.59	1264	15.39
ORPLG11	954	740.91	1055	155.45	1157	47.85	1258	19.56
ORPLG12	953	639.80	1055	154.15	1157	48.10	1260	20.22
ORPLG21	952	1023.45	1055	211.60	1158	61.42	1261	23.23
ORPLG22	950	1199.48	1053	230.38	1158	63.61	1261	23.34
ORPLG23	949	1214.95	1052	237.84	1157	67.01	1260	25.40
ORPLG24	950	913.91	1052	184.76	1155	53.15	1257	20.33
ORPLG25	952	958.87	1053	201.69	1156	59.66	1257	22.93
ORPLG26	952	1031.34	1053	204.18	1155	58.37	1256	21.98
ORPLG27	950	907.71	1052	187.18	1156	54.35	1258	20.66
WVY-G-95A	946	247.81	1044	69.08	1142	26.94	1241	13.01

Table 5.14. Variation in Melt Viscosity Values for Near-Replicate Pair.

Glass IDs of Near Replicate Pair	Viscosity Values For Measurement Temperatures at Each Nominal Temperature ^(a)								Pooled Over Temp.	
	Near 950°C		Near 1050°C		Near 1150°C		Near 1250°C		%RSD	SD
	T (°C)	Viscosity (P)	T (°C)	Viscosity (P)	T (°C)	Viscosity (P)	T (°C)	Viscosity (P)	S/cm	ln(Visc)
LAWC100R1	956	0.186	1049	0.245	1145	0.407	1238	0.529		
WVY-G-95A	959	0.177	1050	0.286	1144	0.412	1236	0.544		
%RSD^(b)	0.0%	0.7%	0.0%	1.1%	0.0%	0.9%	0.0%	3.5%	1.91%	0.0191
Glass IDs of Replicate Pairs	Electrical Conductivity Values at Nominal Temperatures ^(g)								Pooled Over Temp.	
	950°C		1050°C		1150°C		1250°C		%RSD	SD
	Viscosity (P)	ln(Visc)	Viscosity (P)	ln(Visc)	Viscosity (P)	ln(Visc)	Viscosity (P)	ln(Visc)	Viscosity (P)	ln(Visc)
LAWC100R1	233.21	5.452	64.64	4.169	25.22	3.228	12.28	2.508		
WVY-G-95A	235.77	5.463	65.59	4.183	24.88	3.214	11.64	2.454		
%RSD^(b), SD^(c)	0.8%	0.0077	1.0%	0.0103	1.0%	0.0096	3.8%	0.0378	2.06%	0.0206

(a) Viscosity values are listed at the measurement temperatures corresponding to the nominal temperature values listed in Table 5.13.

(b) %RSD = $100 \times (\text{Standard Deviation} / \text{Mean})$, calculated using the Viscosity values.

(c) Calculated using $\ln(\text{S/cm})$ values.

Table 6.1. HLW Glasses Having Data for PCT, Spinel T_{1%}, Viscosity, Electrical Conductivity, TCLP Cd-Release, and Nepheline Formation.

Glass ID	PCT ^(a)	T _{1%} ^(a)	Viscosity ^(a)	Electrical Conductivity ^(a)	TCLP Cd ^(a)	Nepheline ^(a)	Source document
INEL-HW09	1	1	1	1	1	1	VSL-06R5260-1, Rev 0, 02/28/06
INEL-HW10	1	1	1	1	1	1	VSL-06R5260-1, Rev 0, 02/28/06
INEL-HLW-B3	1	1	1	1	1	1	VSL-06R5260-1, Rev 0, 02/28/06
INEL-HLW-B10	1	1	1	1	1	1	VSL-06R5260-1, Rev 0, 02/28/06
HLW-E-Bi-1	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-2	1	1	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-3	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-4	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-5	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-6	1	1	1	1	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-7	1	1	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-8	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-9	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-10	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-11	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-12	1	1	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-13	1	1	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-14	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-15	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi-16	0	0	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Bi6UTh	1	1	1	1	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-1	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-2	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-3	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-4	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-5	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-6	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-7	0	1	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-8	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-9	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-10	1	0	1	1	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-11	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-12	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-13	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-14	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07

(a) An entry of 1 indicates data for that property on that glass were compiled into database, while an entry of 0 indicates no data were compiled for that property on that glass. For nepheline formation, an entry of 2 indicates 2 sets of data were compiled.

Table 6.1. HLW Glasses Having Data for PCT, Spinel T_{1%}, Viscosity, Electrical Conductivity, TCLP Cd-Release, and Nepheline Formation (Continued).

Glass ID	PCT ^(a)	T _{1%} ^(a)	Viscosity ^(a)	Electrical Conductivity ^(a)	TCLP Cd ^(a)	Nepheline ^(a)	Source document
HLW-E-Cr-15	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-16	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-17	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-18	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-M	1	0	1	1	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Cr-MUTh	1	1	1	1	1	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-1	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-2	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-3	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-4	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-5	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-6	0	0	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-7	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-8	0	0	1	1	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-9	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-10	1	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-11	1	0	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-12	1	1	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-13	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-14	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-15	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-16	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-17	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-18	1	0	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-19	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-20	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-21	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-22	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-23	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-24	0	0	0	0	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-25	0	0	1	1	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-26	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-27	1	1	1	1	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-28	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-Al-29	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07

(a) An entry of 1 indicates data for that property on that glass were compiled into database, while an entry of 0 indicates no data were compiled for that property on that glass. For nepheline formation, an entry of 2 indicates 2 sets of data were compiled.

Table 6.1. HLW Glasses Having Data for PCT, Spinel $T_{1\%}$, Viscosity, Electrical Conductivity, TCLP Cd-Release, and Nepheline Formation (Continued).

Glass ID	PCT ^(a)	$T_{1\%}$ ^(a)	Viscosity ^(a)	Electrical Conductivity ^(a)	TCLP Cd ^(a)	Nepheline ^(a)	Source document
HLW-E-AI27UTh	1	1	1	1	1	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-1	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-2	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-3	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-4	1	1	1	1	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-5	1	1	1	1	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-6	1	1	1	1	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-7	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-8	1	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-9	1	1	1	1	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-10	1	1	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-11	1	0	1	1	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-12	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-13	0	0	1	1	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-14	0	0	0	0	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-15	0	0	0	0	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-16	0	0	0	0	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-17	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-18	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-19	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-20	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-21	0	0	0	0	0	0	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-22	1	1	1	1	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-23	0	0	0	0	0	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-24	0	1	0	0	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-25	1	1	1	1	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa-26	0	1	0	0	0	2	VSL-07R1010-1, Rev 0, 04/16/07
HLW-E-ANa22UTh	1	1	1	1	1	1	VSL-07R1010-1, Rev 0, 04/16/07
HLW-ALG-41	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-42	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-43	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-44	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-45	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-46	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-47	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07

(a) An entry of 1 indicates data for that property on that glass were compiled into database, while an entry of 0 indicates no data were compiled for that property on that glass. For nepheline formation, an entry of 2 indicates 2 sets of data were compiled.

Table 6.1. HLW Glasses Having Data for PCT, Spinel $T_{1\%}$, Viscosity, Electrical Conductivity, TCLP Cd-Release, and Nepheline Formation (Continued).

Glass ID	PCT ^(a)	$T_{1\%}$ ^(a)	Viscosity ^(a)	Electrical Conductivity ^(a)	TCLP Cd ^(a)	Nepheline ^(a)	Source document
HLW-ALG-48	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-49	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-50	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-51	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-52	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-53	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-54	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-55	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-56	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-57	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-58	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-59	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-60	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-61	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-62	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-63	1	0	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-64	1	1	1	1	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-ALG-65	1	1	1	0	0	1	VSL-07R1240-1, Rev 0, 08/24/07
HLW-BP-01	1	1	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-02	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-03	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-04	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-05	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-06	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-07	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-08	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-09	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HLW-BP-10	1	0	1	1	0	1	VSL-07R1240-2, Rev 0, 09/20/07
HWI-AI-1	0	1	1	1	0	0	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-2	0	0	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-3	0	0	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-4	0	0	0	0	1	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-5	0	1	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-6	0	0	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-7	1	1	1	1	1	1	VSL-08R1360-1, Rev 0, 12/19/08

(a) An entry of 1 indicates data for that property on that glass were compiled into database, while an entry of 0 indicates no data were compiled for that property on that glass. For nepheline formation, an entry of 2 indicates 2 sets of data were compiled.

Table 6.1. HLW Glasses Having Data for PCT, Spinel $T_{1\%}$, Viscosity, Electrical Conductivity, TCLP Cd-Release, and Nepheline Formation (Continued).

Glass ID	PCT ^(a)	$T_{1\%}$ ^(a)	Viscosity ^(a)	Electrical Conductivity ^(a)	TCLP Cd ^(a)	Nepheline ^(a)	Source document
HWI-AI-8	0	0	0	0	0	0	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-9	1	1	1	1	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-10	0	1	0	0	0	2	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-11	0	0	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-12	0	0	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-13	0	1	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AL-14	0	0	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AL-15	0	0	0	0	0	0	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-16	1	1	1	1	1	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-17	0	1	0	0	0	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-18G	1	1	1	1	1	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-19	1	1	1	1	1	1	VSL-08R1360-1, Rev 0, 12/19/08
HWI-AI-20	0	1	1	1	1	2	VSL-08R1360-1, Rev 0, 12/19/08
HLW-E-SP-01	0	1	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-02	0	1	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-03	0	1	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-04	0	1	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-05	1	0 ^(b)	1	0 ^(c)	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-06	1	1	1	0 ^(c)	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-07	0	1	0	1	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-08	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-09	0	1	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-SP-10	0	1	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-01	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-02	1	0	0	0 ^(c)	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-03	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-04	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-05	0	0	1	0 ^(c)	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-06	0	0	1	0 ^(c)	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-07	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-C16	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-08	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-09	0	1	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-10	1	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-11	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09

(a) An entry of 1 indicates data for that property on that glass were compiled into database, while an entry of 0 indicates no data were compiled for that property on that glass. For nepheline formation, an entry of 2 indicates 2 sets of data were compiled.

(b) Spinel $T_{1\%}$ was estimated for this glass but was removed from database as an outlier.

(c) Viscosity data for this glass were available but excluded from database because of phase separation and non-newtonian behavior.

Table 6.1. HLW Glasses Having Data for PCT, Spinel $T_{1\%}$, Viscosity, Electrical Conductivity, TCLP Cd-Release, and Nepheline Formation (Continued).

Glass ID	PCT ^(a)	$T_{1\%}$ ^(a)	Viscosity ^(a)	Electrical Conductivity ^(a)	TCLP Cd ^(a)	Nepheline ^(a)	Source document
HLW-E-ES-12	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-13	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-14	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-15	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-ES-16	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-01	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-02	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-03	1	0	1	0 ^(c)	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-04	1	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-05	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-06	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-07	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-08	0	0	1	1	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-09	1	0	1	1	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-10	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-11	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-12	0	0	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HLW-E-M-13	1	0 ^(b)	0	0	0	0	VSL-09R1520-1, Rev 0, 06/22/09
HWI-AI-21	0	1	0	0	0	1	VSL-10R1690-1, Rev 0, 08/16/10
HWI-AI-22	0	1	0	0	0	1	VSL-10R1690-1, Rev 0, 08/16/10
HWI-AI-23	0	1	0	0	0	1	VSL-10R1690-1, Rev 0, 08/16/10
HWI-AI-24	0	1	1	1	0	1	VSL-10R1690-1, Rev 0, 08/16/10
HWI-AI-25	0	1	0	0	0	1	VSL-10R1690-1, Rev 0, 08/16/10
HWI-AI-26	0	1	0	0	0	1	VSL-10R1690-1, Rev 0, 08/16/10
HWI-AI-27	1	1	1	1	1	1	VSL-10R1690-1, Rev 0, 08/16/10
HWI-AI-28	1	1	1	1	1	1	VSL-10R1690-1, Rev 0, 08/16/10
HWI-AI-19LW	0	0	1	1	0	1	VSL-10R1690-1, Rev 0, 08/16/10
HLW-Bi-2Bi	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-2P	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-Bi0	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-BiP0	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F0	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F1	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F2	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F3	1	1	1	1	0	0	VSL-10R1780-1, Rev 0, 12/13/10

(a) An entry of 1 indicates data for that property on that glass were compiled into database, while an entry of 0 indicates no data were compiled for that property on that glass. For nepheline formation, an entry of 2 indicates 2 sets of data were compiled.

(b) Spinel $T_{1\%}$ was estimated for this glass but was removed from database as an outlier.

(c) Viscosity data for this glass were available but excluded from database because of phase separation and non-newtonian behavior.

Table 6.1. HLW Glasses Having Data for PCT, Spinel T_{1%}, Viscosity, Electrical Conductivity, TCLP Cd-Release, and Nepheline Formation (Continued).

Glass ID	PCT ^(a)	T _{1%} ^(a)	Viscosity ^(a)	Electrical Conductivity ^(a)	TCLP Cd ^(a)	Nepheline ^(a)	Source document
HLW-Bi-F4	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F5	1	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F6	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F7	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F8	1	1	1	1	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F9	1	1	1	1	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-F10	1	1	1	1	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HLW-Bi-P0	0	0	0	0	0	0	VSL-10R1780-1, Rev 0, 12/13/10
HWI-ALS-01	0	0	1	1	0	0	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-02	0	0	0	0	0	0	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-03	1	0	1	1	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-04	1	0	1	1	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-05	1	0	1	1	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-06	1	0	1	1	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-07	1	0	1	1	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-08	0	1	1	1	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-09	1	0	1	1	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-10	0	0	0	0	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-11	0	0	0	0	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-12	0	0	0	0	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HWI-ALS-13	0	0	0	0	0	1	VSL-10R1670-1, Rev 0, 12/20/10
HLW-N101-11	0	1	0	0	1	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-12	0	1	0	0	1	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-13	0	0	0	0	0	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-14	1	1	1	1	1	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-15	0	1	0	0	1	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-16	0	1	0	0	1	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-17	0	0	0	0	0	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-18	0	0	0	0	1	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-19	0	1	0	0	1	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-20	0	1	1	1	1	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-21	0	1	1	1	1	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-22	0	1	1	1	1	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-N101-23	0	1	0	0	0	1	VSL-11R2310-1, Rev 0, 05/20/11

(a) An entry of 1 indicates data for that property on that glass were compiled into database, while an entry of 0 indicates no data were compiled for that property on that glass. For nepheline formation, an entry of 2 indicates 2 sets of data were compiled.

Table 6.1. HLW Glasses Having Data for PCT, Spinel T_{1%}, Viscosity, Electrical Conductivity, TCLP Cd-Release, and Nepheline Formation (Continued).

Glass ID	PCT ^(a)	T _{1%} ^(a)	Viscosity ^(a)	Electrical Conductivity ^(a)	TCLP Cd ^(a)	Nepheline ^(a)	Source document
HLW-NI01-24	1	1	1	1	0	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr1	1	0	0	0	1	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr2	1	1	1	1	0	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr3	1	0	0	0	0	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr4	0	1	0	0	0	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr5	0	0	0	0	0	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr6	0	0	0	0	0	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr7	1	0	1	1	0	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr8	0	0	0	0	0	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr9	0	1	0	0	0	0	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Cr10	0	1	0	0	0	1	VSL-11R2310-1, Rev 0, 05/20/11
HLW-NG-Fe1	1	1	0	0	0	0	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe2	1	1	1	1	0	1	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe3	0	1	0	0	0	0	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe4	0	1	0	0	0	0	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe5	0	1	0	0	0	0	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe6	0	1	0	0	0	0	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe7	1	1	0	0	0	0	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe8	0	1	0	0	0	0	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe9	1	1	1	1	0	1	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe10	0	1	0	0	0	0	VSL-12R2490-1, Rev 0, 05/31/12
HLW-NG-Fe11	0	1	1	1	0	0	VSL-12R2490-1, Rev 0, 05/31/12

(a) An entry of 1 indicates data for that property on that glass were compiled into database, while an entry of 0 indicates no data were compiled for that property on that glass. For nepheline formation, an entry of 2 indicates 2 sets of data were compiled.

Table 6.2. Model Summary for the Recommended 19-Term Model (18-Term Partial Quadratic Mixture Model with Bias Correction) for the Natural Logarithm of IHLW PCT-B.

Model form to predict the natural logarithm of the normalized PCT-B release (in g/L): $\ln(PCT - B) = \begin{cases} \hat{y} & \text{if } \hat{y} \leq \text{PCT - B cutoff} \\ \hat{y} + a_0 & \text{if } \hat{y} > \text{PCT - B cutoff} \end{cases},$ with $\hat{y} = \sum_{i=1}^q b_i x_i + \text{Selected} \left\{ \sum_{i=1}^q b_{ii} x_i^2 + \sum_{i < j}^{q-1} b_{ij} x_i x_j \right\}.$ The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide or halogen components such that $\sum_{i=1}^q x_i = 1$. The b_i ($i = 1, 2, \dots, q$) and selected b_{ii} and b_{ij} are model coefficients, a_0 is a bias-correction constant, which are listed below.		
ln(PCT-B) Model Term	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	-43.7679	4.6452
B ₂ O ₃	8.9421	0.8678
Fe ₂ O ₃	-5.6911	1.2828
Li ₂ O	22.5985	1.9611
MnO	-7.7193	4.1556
Na ₂ O	17.0391	0.8067
SiO ₂	-2.4959	0.4182
SrO	-0.0577	1.0318
ThO ₂	2.4230	1.6631
UO ₃	-11.3780	2.4566
ZnO	-28.0347	6.6929
ZrO ₂	-13.2496	1.6845
Others ^(a)	5.0368	1.5768
(Al ₂ O ₃) ²	169.7017	33.1963
UO ₃ ×ZnO	511.2763	105.4536
(MnO) ²	214.6560	60.5468
Fe ₂ O ₃ ×ZnO	193.2526	58.9749
Al ₂ O ₃ ×ZrO ₂	79.4113	25.9429
Bias Correction a_0 ^(b)	0.3644	0.0595
Modeling Data Statistic (264 WTP HLW glasses):		R ² = 0.791

(a) The "Others" component includes Ag₂O, As₂O₅, BaO, BeO, Bi₂O₃, Ce₂O₃, Cl, CoO, Cs₂O, CuO, Dy₂O₃, Eu₂O₃, F, Gd₂O₃, HfO₂, HgO, MoO₃, Nd₂O₃, P₂O₅, PdO, Pr₂O₃, Rb₂O, Re₂O₇, Rh₂O₃, RuO₂, SO₃, Sm₂O₃, SnO₂, Te₂O₇, TeO₂, V₂O₅, WO₃, Y₂O₃, CaO, CdO, Cr₂O₃, K₂O, La₂O₃, MgO, NiO, PbO, Sb₂O₃, SeO₂, TiO₂, and Tl₂O.

(b) The bias correction is a constant adjustment applied to glasses with predicted PCT-B releases > 0.5 ln(g/L).

Table 6.3. Model Summary for the Recommended 19-Term Model (18-Term Partial Quadratic Mixture Model with Bias Correction) for the Natural Logarithm of IHLW PCT-Li.

<p>Model form to predict the natural logarithm of the normalized PCT-Li release (in g/L):</p> $\ln(PCT - Li) = \begin{cases} \hat{y} & \text{if } \hat{y} \leq \text{PCT - Li cutoff} \\ \hat{y} + a_0 & \text{if } \hat{y} > \text{PCT - Li cutoff} \end{cases}$ <p>with $\hat{y} = \sum_{i=1}^q b_i x_i + \text{Selected} \left\{ \sum_{i=1}^q b_{ii} x_i^2 + \sum_{i < j}^{q-1} b_{ij} x_i x_j \right\}$.</p> <p>The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide or halogen components such that $\sum_{i=1}^q x_i = 1$. The b_i ($i = 1, 2, \dots, q$) and selected b_{ii} and b_{ij} are model coefficients, a_0 is a bias-correction constant, which are listed below.</p>		
ln(PCT-B) Model Term	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	-36.7423	3.6001
B ₂ O ₃	6.6931	0.7720
Fe ₂ O ₃	-6.7440	1.4956
Li ₂ O	8.2175	3.6817
MnO	6.1378	1.1547
Na ₂ O	11.1232	0.6796
SiO ₂	-1.1853	0.3585
SrO	-1.3780	1.2437
ThO ₂	0.9472	1.4250
UO ₃	-8.9335	2.1257
ZnO	-12.4629	3.0251
ZrO ₂	-11.7027	1.4941
Others ^(a)	1.7236	1.2977
(Al ₂ O ₃) ²	159.2293	26.2788
UO ₃ ×ZnO	427.8549	93.8998
Fe ₂ O ₃ ×Li ₂ O	153.3909	38.3031
SrO×ZrO ₂	73.0947	22.6465
Al ₂ O ₃ ×ZrO ₂	72.7130	23.0100
Bias Correction a_0 ^(b)	0.3539	0.0543
Modeling Data Statistic (250 WTP HLW glasses):		$R^2 = 0.763$

- (a) The “Others” component includes Ag₂O, As₂O₃, BaO, BeO, Bi₂O₃, Ce₂O₃, Cl, CoO, Cs₂O, CuO, Dy₂O, Eu₂O₃, F, Gd₂O₃, HfO₂, HgO, MoO₃, Nd₂O₃, P₂O₅, PdO, Pr₂O₃, Rb₂O, Re₂O₇, Rh₂O₃, RuO₂, SO₃, Sm₂O₃, SnO₂, Te₂O₇, TeO₂, V₂O₅, WO₃, Y₂O₃, CaO, CdO, Cr₂O₃, K₂O, La₂O₃, MgO, NiO, PbO, Sb₂O₃, SeO₂, TiO₂, and Tl₂O.
- (b) The bias correction is a constant adjustment applied to glasses with predicted PCT-Li releases > 0.5 ln(g/L).

Table 6.4. Model Summary for the Recommended 19-Term Model (18-Term Partial Quadratic Mixture Model with Bias Correction) on the Natural Logarithm of IHLW PCT-Na.

<p>Model form to predict the natural logarithm of the normalized PCT-Na release (in g/L):</p> $\ln(PCT - Na) = \begin{cases} \hat{y} & \text{if } \hat{y} \leq \text{PCT - Na cutoff} \\ \hat{y} + a_0 & \text{if } \hat{y} > \text{PCT - Na cutoff} \end{cases}$ <p>with $\hat{y} = \sum_{i=1}^q b_i x_i + \text{Selected} \left\{ \sum_{i=1}^q b_{ii} x_i^2 + \sum_{i < j}^{q-1} \sum_{j=1}^q b_{ij} x_i x_j \right\}$.</p> <p>The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide or halogen components such that $\sum_{i=1}^q x_i = 1$. The b_i ($i = 1, 2, \dots, q$) and selected b_{ii} and b_{ij} are model coefficients, a_0 is a bias-correction constant, which are listed below.</p>		
ln(PCT-B) Model Term	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	-46.8613	3.0497
B ₂ O ₃	3.1358	0.6464
Fe ₂ O ₃	-4.4268	0.9741
Li ₂ O	11.2111	2.5782
MnO	4.4626	0.9152
Na ₂ O	17.7654	0.6496
SiO ₂	-2.2193	0.4341
SrO	2.0646	0.7611
ThO ₂	0.9885	1.1863
UO ₃	20.9346	6.9809
ZnO	44.6454	12.7840
ZrO ₂	-17.1359	1.2146
Others ^(a)	2.1508	1.0981
(Al ₂ O ₃) ²	190.5345	21.6255
Al ₂ O ₃ ×ZrO ₂	163.4298	18.4861
Fe ₂ O ₃ ×Li ₂ O	108.0349	26.4100
SiO ₂ ×ZnO	-102.2282	31.2527
SiO ₂ ×UO ₃	-53.6409	17.2447
Bias Correction a_0 ^(b)	0.2922	0.0832
<p>Modeling Data Statistic (266 WTP HLW glasses): $R^2 = 0.872$</p>		

- (a) The "Others" component includes Ag₂O, As₂O₃, BaO, BeO, Bi₂O₃, Ce₂O₃, Cl, CoO, Cs₂O, CuO, Dy₂O, Eu₂O₃, F, Gd₂O₃, HfO₂, HgO, MoO₃, Nd₂O₃, P₂O₅, PdO, Pr₂O₃, Rb₂O, Re₂O₇, Rh₂O₃, RuO₂, SO₃, Sm₂O₃, SnO₂, Te₂O₇, TeO₂, V₂O₅, WO₃, Y₂O₃, CaO, CdO, Cr₂O₃, K₂O, La₂O₃, MgO, NiO, PbO, Sb₂O₃, SeO₂, TiO₂, and Tl₂O.
- (b) The bias correction is a constant adjustment applied to glasses with predicted PCT-Na releases > 1.0 ln(g/L).

Table 6.5. Model Summary for the Recommended 20-Term Partial Quadratic Mixture Model on IHLW Spinel $T_{1\%}$.

<p>Model form to predict the one-percent spinel crystal fraction temperature:</p> $\text{Spinel } T_{1\%} = \sum_{i=1}^q b_i x_i + \text{Selected} \left\{ \sum_{i=1}^q b_{ii} x_i^2 + \sum_{i < j}^{q-1} \sum_{j=1}^q b_{ij} x_i x_j \right\},$ <p>The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide or halogen components such that $\sum_{i=1}^q x_i = 1$. The b_i ($i = 1, 2, \dots, q$) and selected b_{ii} and b_{ij} are model coefficients, which are listed below.</p>		
In(PCT-B) Model Term	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	4301.9031	301.7802
B ₂ O ₃	962.6031	334.9961
Cr ₂ O ₃	8936.8818	2443.5932
Fe ₂ O ₃	4144.6963	296.7529
Li ₂ O	-1947.5122	487.9694
MnO	-163.7335	886.6175
Na ₂ O	-1146.0980	332.0013
NiO	21966.7988	2014.7494
SiO ₂	-2566.0459	1043.4802
SrO	1474.0702	359.8276
ThO ₂	2154.2912	397.5112
UO ₃	2591.2652	397.7276
ZnO	5028.5598	482.3861
ZrO ₂	466.9017	657.6080
Others ^(a)	2842.9261	339.5348
(ZrO ₂) ²	33632.6338	6855.0610
MnO×Na ₂ O	29256.3805	4928.1384
Li ₂ O×MnO	47617.3683	11745.2530
MnO×NiO	-216741.7305	44154.0496
(SiO ₂) ²	4736.9006	1535.1562
Modeling Data Statistic (168 WTP HLW glasses):		$R^2 = 0.880$

(a) The "Others" component includes Ag₂O, As₂O₅, BaO, BeO, Bi₂O₃, CaO, CdO, Ce₂O₃, Cl, CoO, Cs₂O, CuO, Dy₂O, Eu₂O₃, F, Gd₂O₃, HfO₂, HgO, K₂O, La₂O₃, MgO, MoO₃, Nd₂O₃, P₂O₅, PbO, PdO, Pr₂O₃, Rb₂O, Re₂O₇, Rh₂O₃, RuO₂, SO₃, Sb₂O₃, SeO₂, Sm₂O₃, SnO₂, Tc₂O₇, TeO₂, TiO₂, Tl₂O, V₂O₅, WO₃, and Y₂O₃.

Table 6.6. Model Summary for the Recommended 22-Term Truncated T2 Linear Mixture Model (with One Crossproduct Term) for the Natural Logarithm of IHLW Electrical Conductivity.

Model form to predict the natural logarithm of EC, in ln(S/cm): $\ln(EC) = \sum_{i=1}^q a_i x_i + \text{Selected} \left\{ \sum_{i=1}^{q-1} \sum_{j=i+1}^q a_{ij} x_i x_j \right\} + \sum_{i=1}^q b_i \frac{x_i}{(T/1000)^2} .$ The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide or halogen components such that $\sum_{i=1}^q x_i = 1 .$ The a_i and b_i ($i = 1, 2, \dots, q$) and selected a_{ij} are coefficients listed below.					
Mixture Term (x_i or $x_i x_j$)	Coefficient Estimate	Coefficient Stand. Dev.	Mixture-Temp. Terms [$x_i/(T/1000)$]	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	-4.3754	0.5166	B ₂ O ₃ /(T/1000) ²	-7.7965	0.6450
B ₂ O ₃	0.7852	0.5703	MnO/(T/1000) ²	-7.3668	0.9937
Fe ₂ O ₃	-2.9876	0.4931	SiO ₂ /(T/1000) ²	-7.2800	0.1774
Li ₂ O	32.2034	2.2768	SrO/(T/1000) ²	-16.0518	0.7550
MgO	16.3440	8.0548	UO ₃ /(T/1000) ²	-7.2864	1.2025
MnO	1.5985	0.8216	ZnO/(T/1000) ²	-16.5091	2.1792
Na ₂ O	11.3872	0.6634	ZrO ₂ /(T/1000) ²	-7.2539	0.7239
SiO ₂	-0.3215	0.2193			
SrO	5.7863	0.6803			
ThO ₂	-1.5427	0.8259			
UO ₃	3.2523	1.0576			
ZnO	5.4527	1.8495			
ZrO ₂	0.2269	0.6505			
Others ^(a)	-7.1088	1.0699			
Na ₂ O×Li ₂ O	-113.7300	19.0671			
Modeling Data Statistic (208 WTP HLW Glasses)				R ² = 0.907	

- (a) The "Others" component includes Ag₂O, As₂O₅, BaO, BeO, Bi₂O₃, Ce₂O₃, Cl, CoO, Cs₂O, CuO, Dy₂O₃, Eu₂O₃, F, Gd₂O₃, HfO₂, HgO, K₂O, La₂O₃, MoO₃, P₂O₅, PdO, Pr₂O₃, Rb₂O, Re₂O₇, Rh₂O₃, RuO₂, SO₃, Sm₂O₃, SnO₂, Tc₂O₇, TeO₂, TiO₂, V₂O₅, WO₃ and Y₂O₃.

Table 6.7. Model Summary for the Recommended 29-Term Truncated T2-Linear Mixture Model (With Five Quadratic Terms) for the Natural Logarithm of IHLW Viscosity.

Model form to predict the natural logarithm of viscosity, in $\ln(P)$ $\ln(\eta) = \sum_{i=1}^q a_i x_i + \text{Selected} \left\{ \sum_{i=1}^q a_{ii} x_i^2 + \sum_{i < j}^{q-1} \sum_{j=1}^q a_{ij} x_i x_j \right\} + E_G + \sum_{i=1}^q b_i \frac{x_i}{(T/1000)^2} + E_T$ <p>The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide components such that $\sum_{i=1}^q x_i = 1$. The b_i ($i = 1, 2, \dots, q$) and selected a_{ii} or a_{ij} are coefficients listed below. E_G and E_T are random errors associated with determining viscosity with zero means.</p>					
Mixture Term (x_i , x_i^2 or $x_i x_j$)	Coefficient Estimate	Coefficient Stand. Dev.	Mixture-Temp. Terms [$x_i/(T/1000)^2$]	Coefficient Estimate	Coefficient Stand. Dev.
Al ₂ O ₃	12.5333	2.8226	Al ₂ O ₃ /(T/1000) ²	30.5925	1.3388
B ₂ O ₃	-3.1161	0.8768	Fe ₂ O ₃ /(T/1000) ²	14.5535	1.3379
CaO	-3.7004	7.6447	Li ₂ O/(T/1000) ²	-70.0777	2.7284
Fe ₂ O ₃	-6.7690	0.8304	Na ₂ O/(T/1000) ²	-8.9510	1.0881
Li ₂ O	-13.4090	2.8847	SiO ₂ /(T/1000) ²	23.1245	0.4449
MgO	-6.8977	6.3479	SrO/(T/1000) ²	19.1357	1.2718
MnO	-2.8771	0.4744	ThO ₂ /(T/1000) ²	22.0504	2.3209
Na ₂ O	-4.6897	1.0507	UO ₃ /(T/1000) ²	27.8595	2.3066
SiO ₂	1.3479	0.3883	ZrO ₂ /(T/1000) ²	48.4524	1.3882
SrO	-14.0315	0.7968	Al ₂ O ₃ /(T/1000) ²	30.5925	1.3388
ThO ₂	-15.2911	2.2807	Fe ₂ O ₃ /(T/1000) ²	14.5535	1.3379
UO ₃	-10.3115	1.3898	Li ₂ O/(T/1000) ²	-70.0777	2.7284
ZnO	-5.8582	2.5771	Standard Deviation of E_G (σ_G)		0.1283
ZrO ₂	-15.2230	0.8548	Standard Deviation of E_T (σ_T)		0.0869
Others ^(a)	2.3371	0.8797			
Al ₂ O ₃ ×SiO ₂	-30.4134	6.6928			
B ₂ O ₃ ×Na ₂ O	-21.8792	7.2738			
Li ₂ O×ZnO	165.7600	67.1844			
Na ₂ O×ThO ₂	52.6720	14.5725			
(Li ₂ O) ²	127.0900	38.7202			
Modeling Data Statistic (197 WTP HLW Glasses)				R² = 0.988	

(a) The "Others" component includes Ag₂O, As₂O₅, BaO, BeO, Bi₂O₃, CdO, Cr₂O₃, Ce₂O₃, Cl, CoO, Cs₂O, CuO, Dy₂O₃, Eu₂O₃, F, Gd₂O₃, HfO₂, HgO, K₂O, La₂O₃, MoO₃, NiO, P₂O₅, PbO, PdO, Pr₂O₃, Rb₂O, Re₂O₇, Rh₂O₃, RuO₂, Sb₂O₃, SeO₂, SO₃, Sm₂O₃, SnO₂, Te₂O₇, TeO₂, TiO₂, Tl₂O, V₂O₅, WO₃ and Y₂O₃.

Table 6.8. Model Summary for the Recommended 10-Term TCLP Cadmium Release Model for the IHLW.

<p>Model form to predict the natural logarithm of TCLP unnormalized Cd-release $\ln(c_{Cd})$:</p> $\ln(c_{Cd}) = \sum_{i=1}^9 b_i x_i + d \ln(m_{CdO}),$ <p>The x_i ($i = 1, 2, \dots, q$) are normalized mass fractions of q glass oxide components such that $\sum_{i=1}^q x_i = 1$. In the $\ln(m_{CdO})$ term, m_{CdO} is the unnormalized mass fraction of CdO in glass, given by $m_{CdO} = W_{CdO} / 100$, where W_{CdO} is the original wt% of CdO in glass.</p> <p>The b_i ($i = 1, 2, \dots, 9$) and d are model coefficients, which are listed below.</p>		
$\ln(c_{Cd})$ Model Term	Coefficient Estimate	Coefficient Stand. Dev.
Al_2O_3	0.3206	1.1555
B_2O_3	8.0629	0.6037
Fe_2O_3	1.5634	0.8189
Li_2O	11.3524	1.6133
MnO	10.7668	1.0398
Na_2O	9.3299	0.7349
SiO_2	0.1629	0.2913
ZnO	15.4380	3.2358
ZrO_2	2.0457	1.0479
$\ln(m_{CdO})$	0.9858	0.0169
<p>Modeling Data Statistic (100 WTP HLW glasses):</p>		$R^2 = 0.977$

Table 6.9. Minimums and Maximums of HLW Glass Components (in Mass Fractions) that Partially Define the Composition Validity Regions for IHLW Property Models.

Property	PCT		Spinel T _{1%}		Viscosity		Electrical Conductivity		TCLP-Cd	
Number of Glasses in Modeling Set	266 ^(a)		168		197		208		100	
HLW Glass Component	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Al ₂ O ₃	0.014	0.131	0.0170	0.131	0.014	0.131	0.014	0.131	0.019	0.086
B ₂ O ₃	0.037	0.151	0.042	0.151	0.044	0.151	0.044	0.151	0.048	0.141
CaO	0	0.011	0	0.011	0	0.011	0	0.011	0	0.006
CdO	0	0.017	0	0.017	0	0.017	0	0.017	0	0.017
Cr ₂ O ₃	0	0.007	0	0.007	0	0.007	0	0.007	0	0.005
Fe ₂ O ₃	0.013	0.151	0.013	0.151	0.013	0.151	0.013	0.151	0.019	0.141
K ₂ O	0	0.017	0	0.017	0	0.017	0	0.017	0	0.001
La ₂ O ₃	0	0.013	0	0.006	0	0.013	0	0.013	0	0.004
Li ₂ O	0 ^(b)	0.061	0	0.061	0	0.061	0	0.061	0.019	0.061
MgO	0	0.014	0	0.012	0	0.014	0	0.014	0	0.002
MnO	0	0.081 ^(c)	0	0.081	0	0.081	0	0.081	0	0.070
Na ₂ O	0.037	0.201	0.036	0.201	0.039	0.201	0.039	0.201	0.038	0.151
NiO	0	0.011	0	0.011	0	0.011	0	0.011	0	0.011
PbO	0	0.011	0	0.011	0	0.011	0	0.011	0	0.005
Sb ₂ O ₃	0	0.005	0	0.005	0	0.005	0	0.005	0	0.004
SeO ₂	0	0.005	0	0.003	0	0.005	0	0.005	0	0.003
SiO ₂	0.330	0.532	0.350	0.531	0.330	0.531	0.330	0.531	0.351	0.531
SrO	0	0.103	0	0.101	0	0.103	0	0.103	0	0.010
ThO ₂	0	0.061	0	0.060	0	0.061	0	0.061	0	0.060
TiO ₂	0	0.011	0	0.011	0	0.011	0	0.011	0	0.001
Tl ₂ O	0	0.004	0	0.004	0	0.004	0	0.004	0	0.004
UO ₃	0	0.066	0	0.066	0	0.066	0	0.066	0	0.064
ZnO	0	0.041	0	0.041	0	0.040	0	0.040	0	0.040
ZrO ₂	0	0.116	0	0.097	0	0.116	0	0.116	0	0.040
Others ^(d)	0	0.052	0	0.038	0	0.038	0	0.038	0.012	0.022

(a) The results are given for the 266 glasses in the PCT-Na modeling dataset. There were only 264 glasses in the PCT-B modeling dataset and 250 glasses in the PCT-Li dataset.

(b) The Li₂O lower bound is 0 for the PCT-B and PCT-Na datasets and is 0.002 for the PCT-Li dataset.

(c) The MnO upper bound is 0.081 for the PCT-B and PCT-Na datasets and is 0.071 for the PCT-Li dataset.

(d) The components in Others are listed in the second half of the table on the following page.

Table 6.9. Minimums and Maximums of HLW Glass Components (in Mass Fractions) that Partially Define the Composition Validity Regions for IHLW Property Models (Continued).

Property	PCT		Spinel T _{1%}		Viscosity		Electrical Conductivity		TCLP-Cd	
Number of Glasses in Modeling Set	266 ^(a)		168		197		208		100	
HLW Glass Component in Others	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Ag ₂ O	0	0.003	0	0.003	0	0.003	0	0.003	0	0.003
As ₂ O ₅	0	0.003	0	0.003	0	0.003	0	0.003	0	0.003
BaO	0	0.004	0	0.006	0	0.006	0	0.006	0	0.004
BeO	0	0.001	0	0	0	0	0	0	0	0
Bi ₂ O ₃	0	0.004	0	0.004	0	0.004	0	0.004	0	0.001
Ce ₂ O ₃	0	0.005	0	0.004	0	0.005	0	0.026	0	0.001
Cl	0	0.004	0	0.004	0	0.004	0	0.004	0	0.003
CoO	0	0.003	0	0.003	0	0.003	0	0.003	0	0.001
Cs ₂ O	0	0.003	0	0.003	0	0.003	0	0.003	0	0.001
CuO	0	0.003	0	0.003	0	0.003	0	0.003	0	0.002
Dy ₂ O ₃	0	0.001	0	0	0	0	0	0	0	0
F	0	0.005	0	0.005	0	0.005	0	0.005	0	0.001
Gd ₂ O ₃	0	0.001	0	0	0	0	0	0	0	0
HfO ₂	0	0.033	0	0	0	0	0	0.033	0	0
MoO ₃	0	0.004	0	0.004	0	0.004	0	0.004	0	0
Nd ₂ O ₃	0	0.017	0	0.005	0	0.009	0	0.017	0	0
P ₂ O ₅	0	0.007	0	0.007	0	0.007	0	0.007	0	0.006
PdO	0	0.002	0	0.002	0	0.002	0	0.002	0	0.002
Pr ₂ O ₃	0	0.002	0	0.002	0	0.002	0	0.002	0	0
Rb ₂ O	0	0.001	0	0.001	0	0.001	0	0.001	0	0
Rh ₂ O ₃	0	0.001	0	0.001	0	0.009	0	0.009	0	0.001
RuO ₂	0	0.002	0	0.002	0	0.002	0	0.002	0	0.001
SO ₃	0	0.004	0	0.004	0	0.004	0	0.004	0	0.002
SnO ₂	0	0.007	0	0.003	0	0.007	0	0.007	0	0
TeO ₂	0	0.001	0	0.001	0	0.001	0	0.001	0	0.001
V ₂ O ₅	0	0.002	0	0.002	0	0.002	0	0.002	0	0.002
WO ₃	0	0.002	0	0.002	0	0.002	0	0.002	0	0
Y ₂ O ₃	0	0.001	0	0.001	0	0.001	0	0.001	0	0

(a) The results are given for the 266 glasses in the PCT-Na modeling dataset. There were only 264 glasses in the PCT-B modeling dataset and 250 glasses in the PCT-Li dataset. The results are the same for the PCT-B, PCT-Li, and PCT-Na modeling datasets.

Table 6.10. Minimum and Maximum Values of Glass Properties that Partially Define the Composition Validity Regions for IHLW Property Models.

HLW Glass Property	Minimum^(a)	Maximum^(a)
PCT-B (g/L)	None	6.61
PCT-Li (g/L)	None	4.27
PCT-Na (g/L)	None	5.53
Spinel T _{1%} (°C)	630	1240
EC as fct(<i>T</i> , °C) (S/cm)	$EC \geq \exp[1.45 - 4753.46 (1/T)]$	$EC \leq \exp[4.35 - 4753.46 (1/T)]$
Viscosity (η) as fct(<i>T</i> , °C) (poise)	$\eta \geq \exp[-9.17 + 11944.20 (1/T)]$	$\eta \leq \exp[-3.67 + 11944.20 (1/T)]$
TCLP-Cd (mg/L)	None	0.80

(a) See Reference [3] for how these constraints were determined.

Table 6.11. Comparison of Minimums and Maximums of HLW Glass Components (in Mass Fractions) in ORP Glasses that Have PCT Data with the WTP PCT Model Regions of Validity.

Dataset	WTP		ORP	
Number of Glasses	266 ^(a)		111	
HLW Glass Component	Min	Max	Min	Max
Al ₂ O ₃	0.014	0.131	0.019	0.266 ^(d)
B ₂ O ₃	0.037	0.151	0.043	0.202
CaO	0	0.011	0.002	0.142
CdO	0	0.017	0	0.009
Cr ₂ O ₃	0	0.007	0	0.045
Fe ₂ O ₃	0.013	0.151	0.027	0.213
K ₂ O	0	0.017	0	0.153
La ₂ O ₃	0	0.013	0	0.012
Li ₂ O	0 ^(b)	0.061	0	0.058
MgO	0	0.014	0	0.031
MnO	0	0.081 ^(c)	0	0.080
Na ₂ O	0.037	0.201	0.036	0.200
NiO	0	0.011	0	0.023
PbO	0	0.011	0	0.032
Sb ₂ O ₃	0	0.005	0	0.003
SeO ₂	0	0.005	0	0.005
SiO ₂	0.330	0.532	0.174	0.531
SrO	0	0.103	0	0.093
ThO ₂	0	0.061	0	0.036
TiO ₂	0	0.011	0	0.016
Tl ₂ O	0	0.004	0	0
UO ₃	0	0.066	0	0.056
ZnO	0	0.041	0	0.045
ZrO ₂	0	0.116	0	0.106
Others	0	0.052	0.003	0.156
X				

Dataset	WTP		ORP	
Number of Glasses	266 ^(a)		111	
HLW Glass Component	Min	Max	Min	Max
Ag ₂ O	0	0.003	0	0.002
As ₂ O ₃	0	0.003	0	0.002
BaO	0	0.004	0	0.002
BeO	0	0.001	0	0
Bi ₂ O ₃	0	0.004	0	0.080
Ce ₂ O ₃	0	0.005	0	0.003
Cl	0	0.004	0	0.001
CoO	0	0.003	0	0
Cs ₂ O	0	0.003	0	0.002
CuO	0	0.003	0	0.001
Dy ₂ O ₃	0	0.001	0	0
F	0	0.005	0	0.011
Gd ₂ O ₃	0	0.001	0	0
HfO ₂	0	0.033	0	0
MoO ₃	0	0.004	0	0
Nd ₂ O ₃	0	0.017	0	0.003
P ₂ O ₅	0	0.007	0	0.060
PdO	0	0.002	0	0
Pr ₂ O ₃	0	0.002	0	0
Rb ₂ O	0	0.001	0	0
Rh ₂ O ₃	0	0.001	0	0
RuO ₂	0	0.002	0	0.001
SO ₃	0	0.004	0	0.008
SnO ₂	0	0.007	0	0.003
TeO ₂	0	0.001	0	0
V ₂ O ₅	0	0.002	0	0.025
WO ₃	0	0.002	0	0
Y ₂ O ₃	0	0.001	0	0

(a) The results are given for the 266 glasses in the PCT-Na modeling dataset. There were only 264 glasses in the PCT-B modeling dataset and 250 glasses in the PCT-Li dataset.

(b) The Li₂O minimum is 0 for the PCT-B and PCT-Na datasets and is 0.002 for the PCT-Li dataset.

(c) The MnO maximum is 0.081 for the PCT-B and PCT-Na datasets and is 0.071 for the PCT-Li dataset.

(d) Shaded cells indicate the associated values are outside the WTP PCT model regions of validity.

Table 6.12. PCT Results for HLW Glasses in ORP Dataset.

Glass ID	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)			Leach-ate pH
	PCT-B	PCT-Li	PCT-Na	PCT-B	PCT-Li	PCT-Na	PCT-B	PCT-Li	PCT-Na	
INEL-HW09	18.20	7.26	32.30	0.515	0.625	0.383	0.257	0.313	0.192	9.98
INEL-HW10	14.41	4.17	27.20	0.413	0.510	0.324	0.206	0.255	0.162	9.88
INEL-HLW-B3	16.90	7.60	22.50	0.464	0.526	0.430	0.232	0.263	0.215	9.96
INEL-HLW-B10	17.91	2.22	28.94	0.479	0.434	0.434	0.240	0.217	0.217	9.96
HLW-E-Bi-1	158.80	1.59	243.60	3.721	2.674	1.888	1.860	1.337	0.944	9.71
HLW-E-Bi-2	61.39	0.58	111.90	1.551	0.976	0.920	0.776	0.488	0.460	9.65
HLW-E-Bi-4	52.67	0.40	89.39	1.331	0.673	0.735	0.665	0.336	0.368	9.65
HLW-E-Bi-5	31.12	0.33	73.77	0.817	0.498	0.619	0.408	0.249	0.310	9.60
HLW-E-Bi-6	17.17	0.13	61.85	0.489	0.179	0.530	0.245	0.089	0.265	9.65
HLW-E-Bi-7	15.82	0.15	58.57	0.493	0.180	0.512	0.247	0.090	0.256	9.62
HLW-E-Bi-12	27.82	0.59	83.46	0.788	0.662	0.746	0.394	0.331	0.373	9.43
HLW-E-Bi-13	21.40	0.42	71.96	0.667	0.514	0.651	0.333	0.257	0.325	9.67
HLW-E-Bi6UTh	17.22	0.40	54.77	0.491	0.556	0.477	0.246	0.278	0.238	9.61
HLW-E-Cr-9	312.20	62.24	225.10	6.390	4.246	3.488	3.195	2.123	1.744	9.58
HLW-E-Cr-10	130.10	30.58	96.66	2.901	1.987	1.498	1.450	0.993	0.749	9.74
HLW-E-Cr-11	138.30	31.15	104.20	3.084	2.024	1.614	1.542	1.012	0.807	9.72
HLW-E-Cr-12	98.45	17.09	89.12	2.191	1.104	1.227	1.095	0.552	0.614	9.65
HLW-E-Cr-13	174.35	24.93	153.03	4.010	2.438	1.897	2.005	1.219	0.948	9.51
HLW-E-Cr-17	133.10	31.24	102.30	2.965	2.034	1.492	1.482	1.017	0.746	9.74
HLW-E-Cr-M	229.70	57.47	112.00	4.573	3.360	2.136	2.286	1.680	1.068	9.58
HLW-E-Cr-MUTh	238.50	62.39	132.80	4.754	3.660	2.743	2.377	1.830	1.371	9.65
HLW-E-Al-10	111.90	44.31	55.48	1.783	1.838	1.880	0.891	0.919	0.940	9.61
HLW-E-Al-11	22.78	13.14	15.46	0.452	0.545	0.524	0.226	0.273	0.262	9.98
HLW-E-Al-12	32.66	12.17	14.22	0.521	0.507	0.535	0.260	0.253	0.268	9.97
HLW-E-Al-18	42.16	15.19	18.37	0.707	0.632	0.692	0.354	0.316	0.346	9.65
HLW-E-Al-22	81.80	35.00	93.20	1.881	1.498	1.285	0.941	0.749	0.642	9.50
HLW-E-Al-27	12.74	7.33	21.54	0.270	0.442	0.303	0.135	0.221	0.152	9.65
HLW-E-Al27UTh	12.62	6.36	18.87	0.268	0.385	0.273	0.134	0.193	0.137	9.61
HLW-E-ANa-2	15.49	9.36	26.95	0.347	0.655	0.286	0.174	0.328	0.143	9.46
HLW-E-ANa-3	13.72	8.02	40.47	0.330	0.668	0.388	0.165	0.334	0.194	9.58
HLW-E-ANa-4	18.65	11.42	31.89	0.418	0.603	0.338	0.209	0.302	0.169	9.61
HLW-E-ANa-5	28.74	13.47	62.48	0.642	0.809	0.599	0.321	0.405	0.299	9.74
HLW-E-ANa-6	58.00	15.61	106.80	1.293	1.195	0.934	0.646	0.598	0.467	9.74
HLW-E-ANa-8	83.51	25.15	140.90	1.861	1.508	1.232	0.931	0.754	0.616	9.78
HLW-E-ANa-9	121.80	47.39	201.80	2.715	2.004	1.765	1.357	1.002	0.882	10.28
HLW-E-ANa-10	111.80	28.26	162.30	2.257	1.694	1.419	1.129	0.847	0.710	9.75
HLW-E-ANa-11	97.09	37.36	172.10	2.325	1.580	1.505	1.163	0.790	0.753	10.43

Table 6.12. PCT Results for HLW Glasses in ORP Dataset (Continued).

Glass ID	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)			Leach-ate pH
	PCT-B	PCT-Li	PCT-Na	PCT-B	PCT-Li	PCT-Na	PCT-B	PCT-Li	PCT-Na	
HLW-E-ANa-22	145.20	34.78	111.40	2.545	2.094	1.182	1.273	1.047	0.591	9.45
HLW-E-ANa-25	229.30	42.82	183.50	3.807	2.993	1.829	1.904	1.497	0.915	9.46
HLW-EANa-22UTh	102.30	25.67	76.23	1.796	1.548	0.848	0.898	0.774	0.424	9.48
HLW-ALG-41	25.61	11.57	66.41	0.848	0.798	0.733	0.424	0.399	0.367	10.32
HLW-ALG-42	23.04	10.60	63.14	0.826	0.795	0.747	0.413	0.398	0.374	10.34
HLW-ALG-43	767.61	238.07	1419.50	20.787	13.463	12.766	10.394	6.731	6.383	12.03
HLW-ALG-44	14.48	8.63	42.10	0.560	0.697	0.541	0.280	0.349	0.270	10.34
HLW-ALG-45	33.54	14.19	84.68	1.200	1.060	1.006	0.600	0.530	0.503	10.28
HLW-ALG-46	16.33	11.96	3.37	0.512	0.784	0.123	0.256	0.392	0.061	9.48
HLW-ALG-47	73.76	25.46	355.99	2.786	2.008	2.399	1.393	1.004	1.200	11.63
HLW-ALG-48	24.61	10.39	65.40	0.907	0.799	0.800	0.453	0.400	0.400	10.47
HLW-ALG-49	10.70	11.91	74.93	0.801	0.807	0.808	0.401	0.404	0.404	10.86
HLW-ALG-50	70.38	17.55	84.38	1.511	1.339	1.024	0.755	0.669	0.512	9.88
HLW-ALG-51	11.08	7.80	32.77	0.413	0.608	0.406	0.207	0.304	0.203	10.16
HLW-ALG-52	12.92	— ^(a)	40.92	0.430	—	0.452	0.215	—	0.226	9.68
HLW-ALG-53	23.63	12.07	54.55	0.678	0.748	0.590	0.339	0.374	0.295	10.45
HLW-ALG-54	11.58	7.55	47.51	0.439	0.542	0.540	0.219	0.271	0.270	10.85
HLW-ALG-55	49.17	19.23	122.98	1.487	1.214	1.235	0.743	0.607	0.618	10.62
HLW-ALG-56	57.59	20.64	251.58	2.122	1.588	1.884	1.061	0.794	0.942	11.38
HLW-ALG-57	18.45	9.39	31.77	0.609	0.648	0.504	0.305	0.324	0.252	9.75
HLW-ALG-58	14.58	8.23	40.74	0.532	0.627	0.494	0.266	0.313	0.247	9.97
HLW-ALG-59	33.37	7.52	61.00	0.774	0.667	0.594	0.387	0.334	0.297	10.05
HLW-ALG-60	19.78	14.14	4.08	0.520	0.580	0.149	0.260	0.290	0.074	9.61
HLW-ALG-61	166.10	54.78	239.50	4.114	3.535	2.458	2.057	1.768	1.229	10.84
HLW-ALG-62	73.58	27.14	369.20	3.343	2.575	2.488	1.672	1.288	1.244	11.25
HLW-ALG-63	16.25	—	51.70	0.498	—	0.516	0.249	—	0.258	9.82
HLW-ALG-64	31.02	18.79	13.62	0.713	0.704	0.496	0.357	0.352	0.248	9.72
HLW-ALG-65	24.20	10.06	14.61	0.557	0.578	0.532	0.278	0.289	0.266	9.54
HLW-BP-01	14.98	8.07	47.44	0.472	0.628	0.549	0.236	0.314	0.275	10.03
HLW-BP-02	5.08	2.56	22.55	0.145	0.438	0.316	0.072	0.219	0.158	9.65
HLW-BP-03	9.56	5.70	38.66	0.300	0.543	0.460	0.150	0.272	0.230	9.94
HLW-BP-04	15.38	5.62	48.82	0.403	0.536	0.566	0.202	0.268	0.283	10.15
HLW-BP-05	23.29	—	74.81	0.665	—	0.625	0.332	—	0.313	10.45
HLW-BP-06	32.36	—	44.55	0.651	—	0.570	0.326	—	0.285	9.32
HLW-BP-07	255.20	21.07	171.80	4.217	3.612	2.419	2.109	1.806	1.209	9.26
HLW-BP-08	71.09	0.18	62.79	1.308	—	0.804	0.654	—	0.402	9.20
HLW-BP-09	21.59	0.03	40.21	0.477	—	0.481	0.238	—	0.240	9.45

 (a) A dash (—) denotes that the corresponding glass did not contain Li₂O and so did not have PCT-Li data.

Table 6.12. PCT Results for HLW Glasses in ORP Dataset (Continued).

Glass ID	Concentration (ppm)			Normalized Concentration (g/L)			Normalized Mass Loss (g/m ²)			Leachate pH
	PCT-B	PCT-Li	PCT-Na	PCT-B	PCT-Li	PCT-Na	PCT-B	PCT-Li	PCT-Na	
HLW-BP-10	18.11	— ^(a)	36.92	0.423	—	0.422	0.212	—	0.211	9.30
HLW-E-SP-05	23.94	3.31	40.98	0.638	0.646	0.609	0.319	0.323	0.305	9.89
HLW-E-SP-06	50.75	5.64	72.25	1.229	1.035	0.955	0.614	0.518	0.478	9.96
HLW-E-ES-02	54.82	12.79	59.76	1.303	1.044	0.828	0.651	0.522	0.414	9.62
HLW-E-ES-10	23.40	0.63	31.00	0.772	0.838	0.594	0.386	0.419	0.297	9.65
HLW-E-M-03	37.31	8.49	48.22	0.901	0.704	0.679	0.450	0.352	0.339	9.60
HLW-E-M-04	37.33	9.09	49.21	0.915	0.766	0.704	0.458	0.383	0.352	9.61
HLW-E-M-09	211.80	53.33	196.40	4.681	3.718	2.765	2.340	1.859	1.382	9.80
HLW-E-M-13	182.20	44.42	169.60	4.226	3.250	2.506	2.113	1.625	1.253	9.91
HWI-AI-7	12.57	7.74	21.68	0.266	0.467	0.305	0.133	0.233	0.153	9.46
HWI-AI-9	80.95	16.83	75.95	1.434	1.150	0.777	0.717	0.575	0.388	9.45
HWI-AI-16	17.31	6.34	19.65	0.314	0.394	0.285	0.157	0.197	0.143	9.42
HWI-AI-18G	23.53	6.25	21.53	0.376	0.400	0.322	0.188	0.200	0.161	9.18
HWI-AI-19	38.65	13.17	44.53	0.648	0.794	0.627	0.324	0.397	0.313	9.42
HWI-AI-27	38.48	14.55	23.58	0.613	0.627	0.554	0.307	0.313	0.277	9.42
HWI-AI-28	42.25	16.05	24.63	0.673	0.690	0.667	0.337	0.345	0.333	9.42
HLW-Bi-F3	29.32	0.24	112.90	0.916	0.323	0.812	0.458	0.161	0.406	10.32
HLW-Bi-F5	39.04	0.50	115.00	1.109	0.612	0.890	0.555	0.306	0.445	9.85
HLW-Bi-F8	25.02	0.16	101.00	0.780	0.196	0.740	0.390	0.098	0.370	10.28
HLW-Bi-F9	157.50	45.56	75.14	3.111	1.901	1.309	1.555	0.950	0.655	9.35
HLW-Bi-F10	122.40	39.11	61.36	2.571	1.627	1.116	1.285	0.813	0.558	9.37
HWI-ALS-03	52.62	16.34	67.71	1.018	0.966	0.679	0.509	0.483	0.339	10.05
HWI-ALS-04	26.76	8.32	65.51	0.615	0.597	0.630	0.308	0.299	0.315	10.52
HWI-ALS-05	18.66	14.72	53.09	0.578	0.609	0.532	0.289	0.305	0.266	10.91
HWI-ALS-06	59.85	20.77	82.77	1.195	0.955	0.830	0.598	0.478	0.415	10.38
HWI-ALS-07	42.52	11.52	66.54	0.856	0.709	0.640	0.428	0.354	0.320	10.06
HWI-ALS-09	30.15	9.25	79.42	0.722	0.691	0.735	0.361	0.346	0.367	10.65
HLW-N101-14	17.50	9.19	40.92	0.563	0.609	0.440	0.282	0.304	0.220	10.45
HLW-N101-24	13.58	10.87	61.03	0.583	0.551	0.601	0.291	0.275	0.301	10.95
HLW-NG-Cr1	115.60	29.65	97.40	2.580	1.932	1.610	1.290	0.966	0.805	9.72
HLW-NG-Cr2	38.93	20.11	38.21	0.932	0.899	0.592	0.466	0.449	0.296	9.82
HLW-NG-Cr3	15.51	11.24	20.35	0.346	0.529	0.315	0.173	0.264	0.158	9.97
HLW-NG-Cr7	155.50	18.67	125.20	3.511	2.399	1.724	1.756	1.199	0.862	9.31
HLW-NG-Fe1	37.20	10.40	66.99	0.902	0.847	0.717	0.451	0.423	0.358	9.92
HLW-NG-Fe2	42.27	6.00	85.86	0.985	0.833	0.817	0.493	0.417	0.408	9.96
HLW-NG-Fe7	54.76	9.13	72.66	1.078	0.956	0.823	0.539	0.478	0.411	9.72
HLW-NG-Fe9	57.74	9.47	52.62	1.137	0.991	0.898	0.569	0.496	0.449	9.52

 (a) A dash (—) denotes that the corresponding glass did not contain Li₂O and so did not have PCT-Li data.

Table 6.13. Temperature and Volume %-Crystallinity Data for ORP HLW Glasses.

Glass ID	Temperature (°C)									Crystalline Phase(s)
	750	800	850	900	950	1000	1050	1100	1150	
INEL-HW09	— ^(a)	—	3.1	1.7	—	0.6	—	0.1	—	Spinel
INEL-HW10	—	—	—	4.6	—	2.5	—	2.4	1.6	Spinel
INEL-HLW-B3	—	—	—	2.4	—	1.1	—	0.9	—	Spinel
INEL-HLW-B10	—	—	—	4.6	—	2.5	—	1.8	—	Spinel
HLW-E-Bi-1 ^(b)	—	—	—	—	0.13	—	—	—	—	Spinel
HLW-E-Bi-2	—	0.5 ^(b)	1.0	0.1	0.1	—	—	—	—	Spinel
HLW-E-Bi-3	—	—	—	—	0.1	—	—	—	—	Spinel
HLW-E-Bi-5	—	—	—	—	0.4	—	—	—	—	Spinel
HLW-E-Bi-6	—	4.0	3.3	2.3	1.8	—	—	—	—	Spinel + Phosphate
HLW-E-Bi-7	—	5.5	4.9	3.5	2.7	—	—	—	—	Spinel + Phosphate
HLW-E-Bi-8	—	—	—	—	0.5	—	—	—	—	Spinel
HLW-E-Bi-9	—	—	—	—	0.5	—	—	—	—	Spinel
HLW-E-Bi-10	—	—	—	—	0.4	—	—	—	—	Spinel
HLW-E-Bi-11	—	—	—	—	<0.1	—	—	—	—	Spinel
HLW-E-Bi-12	—	5.0	5.6	5.0	4.2	—	—	—	—	Spinel + Phosphate
HLW-E-Bi-13	—	5.3	4.5	3.4	3.2	—	—	—	—	Spinel + Phosphate
HLW-E-Bi-14	—	—	—	—	3.3	—	—	—	—	Spinel + Phosphate
HLW-E-Bi-15	—	—	—	—	2.1	—	—	—	—	Spinel
HLW-E-Bi-16	—	—	—	—	2.7	—	—	—	—	Spinel + Phosphate
HLW-E-Bi6UTh	—	3.5	2.8	1.9	1.4	—	—	—	—	Spinel + Phosphate
HLW-E-Cr-1	—	—	—	—	0.5	—	—	—	—	Spinel + Phosphate
HLW-E-Cr-2	—	—	—	—	0.3	—	—	—	—	Spinel + Phosphate
HLW-E-Cr-3	—	—	—	—	0.3	—	—	—	—	Spinel
HLW-E-Cr-4	—	—	—	—	0.8	—	—	—	—	Spinel
HLW-E-Cr-5	—	—	—	—	0.9	—	—	—	—	Spinel + Phosphate
HLW-E-Cr-6	—	—	—	—	0.9	—	—	—	—	Spinel + Cr/Fe
HLW-E-Cr-7	—	1.2	0.6	0.6	0.5	—	—	—	—	Spinel
HLW-E-Cr-8	—	—	—	—	0.2	—	—	—	—	Spinel
HLW-E-Cr-9	—	—	—	—	0.7	—	—	—	—	Spinel

(a) A dash (—) denotes that no data were collected for the specific temperature.

(b) A shaded cell indicates either that $T_{1\%}$ was not estimated for the corresponding glass or that the data point was excluded from the calculation to determine the $T_{1\%}$ value.

Table 6.13. Temperature and Volume %-Crystallinity Data for ORP HLW Glasses (Continued).

Glass ID	Temperature (°C)									Crystalline Phase(s)
	750	800	850	900	950	1000	1050	1100	1150	
HLW-E-Cr-10 ^(b)	— ^(a)	2.0	0.8	0.8	0.6	—	—	—	—	Unidentified
HLW-E-Cr-12	—	—	—	—	0.7 ^(b)	—	—	—	—	Spinel
HLW-E-Cr-13	—	—	—	—	1.2	—	—	—	—	Spinel + Cr + Fe
HLW-E-Cr-14	—	—	—	—	0.1	—	—	—	—	Spinel
HLW-E-Cr-15	—	—	—	—	0.7	—	—	—	—	Spinel
HLW-E-Cr-16	—	—	—	—	2.0	—	—	—	—	Spinel + Cr + Fe
HLW-E-Cr-17	—	—	—	—	1.1	—	—	—	—	Spinel + Phosphate
HLW-E-Cr-18	—	—	—	—	0.6	—	—	—	—	Spinel
HLW-E-Cr-M	—	2.9	—	0.9	0.8	—	—	—	—	Ni-rich Oxide
HLW-E-Cr-MUTh	—	0.1	0.4	0.2	0.2	—	—	—	—	Spinel + Cr + Fe
HLW-E-Al-4	—	—	—	—	34.0	—	—	—	—	Sodium Aluminosilicate + Phosphate + Spinel
HLW-E-Al-6	—	—	—	—	31.9	—	—	—	—	Sodium Aluminosilicate + Phosphate + Spinel
HLW-E-Al-7	—	—	—	—	6.7	—	—	—	—	Phosphate + Sodium Aluminosilicate + Spinel
HLW-E-Al-8	—	—	—	—	6.8	—	—	—	—	Spinel + Sodium Aluminosilicate
HLW-E-Al-9	—	—	—	—	4.0	—	—	—	—	Spinel + Phosphate
HLW-E-Al-10	—	—	—	—	2.1	—	—	—	—	Spinel + Phosphate
HLW-E-Al-11	—	7.8	5.3	4.2	2.9	—	—	—	—	Spinel + Phosphate
HLW-E-Al-12	—	4.1	3.5	—	1.6	—	—	—	—	Spinel
HLW-E-Al-13	—	—	—	—	1.5	—	—	—	—	Spinel + Apatite
HLW-E-Al-18	—	—	—	—	~1.8	—	—	—	—	Spinel + ZrO ₂
HLW-E-Al-19	—	2.7	5.2	3.2	4.1	—	—	—	—	Spinel + Sodium Aluminosilicate
HLW-E-Al-20	—	—	—	—	1.1	—	—	—	—	Spinel
HLW-E-Al-21	—	—	—	—	0.5	—	—	—	—	Spinel
HLW-E-Al-22	—	—	—	—	2.2	—	—	—	—	Spinel
HLW-E-Al-23	—	12.3	—	—	—	—	—	—	—	Unidentified
HLW-E-Al-24	—	0.2	—	—	—	—	—	—	—	Unidentified
HLW-E-Al-25	—	5.5	5.1	3.7	2.0	—	—	—	—	Spinel + Phosphate
HLW-E-Al-27	—	7.2	3.4	3.8	1.0	—	—	—	—	Spinel
HLW-E-Al-28	—	—	—	—	2.8	—	—	—	—	Spinel + Phosphate
HLW-E-Al27UTh	—	3.1	3.0	—	1.0	—	—	—	—	Spinel

(a) A dash (—) denotes that no data were collected for the specific temperature.

(b) A shaded cell indicates either that T_{1%} was not estimated for the corresponding glass or that the data point was excluded from the calculation to determine the T_{1%} value.

Table 6.13. Temperature and Volume %-Crystallinity Data for ORP HLW Glasses (Continued).

Glass ID	Temperature (°C)									Crystalline Phase(s)
	750	800	850	900	950	1000	1050	1100	1150	
HLW-E-ANa-1 ^(b)	— ^(a)	3.9	1.2	0.3	0.3	—	—	—	—	Cr + Fe oxide
HLW-E-ANa-2	—	—	—	—	0.3	—	—	—	—	Spinel
HLW-E-ANa-3	—	—	—	—	0.5	—	—	—	—	Spinel
HLW-E-ANa-4	—	2.1	0.2	0.2	0.2	—	—	—	—	Spinel
HLW-E-ANa-5	—	5.7	5.4	0.5	0.3	—	—	—	—	Spinel
HLW-E-ANa-6	—	~11 ^(b)	16	5.6	0.8	—	—	—	—	Spinel
HLW-E-ANa-8	—	—	—	5.4	—	—	—	—	—	Unidentified
HLW-E-ANa-9	—	~35	6.6	2.5	0.4	—	—	—	—	Spinel
HLW-E-ANa-10	—	~16	10.0	5.7	1.6	—	—	—	—	Spinel + Sodium Aluminosilicate
HLW-E-ANa-12	—	—	—	—	10	—	—	—	—	Sodium Aluminosilicate + Spinel
HLW-E-ANa-14	—	—	—	—	1.7	—	—	—	—	Phosphate + Spinel
HLW-E-ANa-15	—	—	—	—	5.4	—	—	—	—	Sodium Aluminosilicate + Spinel + Phosphate
HLW-E-ANa-16	—	~36	—	—	8.8	—	—	—	—	Spinel + Phosphate + Sodium Aluminosilicate
HLW-E-ANa-17	—	5.4	—	—	—	—	—	—	—	Spinel + Phosphate
HLW-E-ANa-18	—	8.2	—	—	—	—	—	—	—	Spinel + Phosphate
HLW-E-ANa-19	—	4.1	—	—	—	—	—	—	—	Spinel + Phosphate
HLW-E-ANa-20	—	~12.5	4.6	3.3	1.9	—	—	—	—	Silicate
HLW-E-ANa-21	—	~20	2.6	1.6	0.4	—	—	—	—	ZrO ₂ + Spinel
HLW-E-ANa-22	—	0.5	0.5	0.5	0.3	—	—	—	—	Spinel
HLW-E-ANa-23	—	1.8	1.2	1.0	1.0	—	—	—	—	ZrO ₂ + Spinel
HLW-E-ANa-24	—	1.0	0.7	0.7	0.5	—	—	—	—	Spinel
HLW-E-ANa-25	—	0.9	0.7	0.7	0.5	—	—	—	—	Spinel
HLW-E-ANa-26	—	0.6	0.9	0.7	0.6	—	—	—	—	Spinel
HLW-E-ANa22UTh	—	0.3	0.4	0.2	0.3	—	—	—	—	Spinel
HLW-ALG-41	—	0.2	0.3	—	0	0	0	—	—	Spinel
HLW-ALG-42	—	4.0	1.0	1.5	0.9	—	0.2	—	—	Spinel
HLW-ALG-43	—	—	—	2.6	2.8	1.7	0.9	0.8	—	Spinel
HLW-ALG-44	—	0.4	<0.1	0.1	<0.1	—	0	—	—	Spinel
HLW-ALG-45	—	1.2	—	2.5	1.1	2.1	0	—	—	Spinel
HLW-ALG-46	—	—	—	—	4.1	2.9	1.6	0.9	0.6	Spinel

(a) A dash (—) denotes that no data were collected for the specific temperature.

 (b) A shaded cell indicates either that $T_{1\%}$ was not estimated for the corresponding glass or that the data point was excluded from the calculation to determine the $T_{1\%}$ value.

Table 6.13. Temperature and Volume %-Crystallinity Data for ORP HLW Glasses (Continued).

Glass ID	Temperature (°C)									Crystalline Phase(s)
	750	800	850	900	950	1000	1050	1100	1150	
HLW-ALG-47 ^(b)	— ^(a)	0.1	0	0	0	—	0	—	—	Spinel
HLW-ALG-48	—	—	2.5	2.6	1.3	0.6	0.7	—	—	Spinel
HLW-ALG-49	—	0.8	0.9	0.3	0.3	—	0	—	—	Spinel
HLW-ALG-50	—	0.3 ^(b)	1.1	0.2	0	0	—	—	—	Spinel
HLW-ALG-51	—	—	—	4.3	2.4	3.1	2.2	1.5	0.8	Spinel
HLW-ALG-52	—	3.1	0.4	2.1	0.7	0.4	—	—	—	Spinel
HLW-ALG-53	—	0.1	0.1	< 0.1	< 0.1	0	—	—	—	Spinel + Zircon
HLW-ALG-54	—	0.1	0.1	0.1	0	0	—	—	—	Spinel
HLW-ALG-55	—	—	2.5	2.6	1.5	0.4	—	—	—	Unidentified Fe/Mn Phase
HLW-ALG-56	—	—	< 0.1	0	0	—	—	—	—	Unidentified
HLW-ALG-57	—	—	—	1.7	0.9	0.9	0.1	—	—	Spinel
HLW-ALG-58	—	—	4	2.8	2	1.5	1.1	0.3	—	Spinel
HLW-ALG-59	—	—	3.4	1.9	0.6	0.7	< 0.1	—	—	Spinel
HLW-ALG-60	—	—	4.7	—	2.2	0.5	0.8	0.2	—	Spinel
HLW-ALG-61	—	—	2.6	2.7	2.6	1.9	1	0	—	Spinel + Zircon
HLW-ALG-62	—	—	< 0.1	—	0.1	—	—	—	—	—
HLW-ALG-63	—	—	0.2	0.4	0.1	0.2	—	—	—	Spinel
HLW-ALG-64	—	—	2.4	2.7	0.7	0.2	0.2	—	—	Spinel
HLW-ALG-65	—	—	—	0.8	0.6	0.7	0.1	0	—	Spinel
HLW-BP-01	—	1.8	0.9	0.8	0.9	0.3	—	—	—	Spinel
HLW-BP-02	—	—	5.3	4.4	1.5-4.0	1.0-3.0	0.5-1.0	0	—	Calcium Phosphate
HLW-BP-03	—	—	1.5	1.2	—	—	0.2	—	—	Zirconia and Spinel
HLW-BP-04	—	—	3.1	2.9	1.2	0.1	0	0	—	Calcium (sodium) Phosphate
HLW-BP-05	—	—	4.3	4.0-7.0	2.8	1.5	1.1	0	—	Calcium (sodium) Phosphate
HLW-BP-06	—	—	4.5	4.9	3.8	2.9	2.1	—	—	Calcium Phosphate
HLW-BP-07	—	—	4.3	3.6	3.2	0.5	0.5	—	—	Calcium Phosphate
HLW-BP-08	—	—	6	5	4.1	3	2.3	—	—	Calcium Phosphate
HLW-BP-09	—	—	—	3.2	3.3	3	2.3	0.7	—	Calcium (sodium) Phosphate
HLW-BP-10	—	—	—	2.7	1.4	1	<0.1	0	—	Calcium Phosphate and Spinel
HWI-Al-1	—	2.3	1.4	1.6	1.7	—	—	—	—	Spinel

(a) A dash (—) denotes that no data were collected for the specific temperature.

 (b) A shaded cell indicates either that $T_{1\%}$ was not estimated for the corresponding glass or that the data point was excluded from the calculation to determine the $T_{1\%}$ value.

Table 6.13. Temperature and Volume %-Crystallinity Data for ORP HLW Glasses (Continued).

Glass ID	Temperature (°C)									Crystalline Phase(s)
	750	800	850	900	950	1000	1050	1100	1150	
HWI-AI-5	— ^(a)	5.3	—	—	3.4	—	—	—	—	Spinel
HWI-AI-7	—	3.9	3.2	2.8	2.7	—	—	—	—	Spinel
HWI-AI-9	—	1.1	0.9	0.8	0.7	—	—	—	—	Spinel
HWI-AI-10	—	0.8 ^(b)	0.9	0.8	0.4	—	—	—	—	Spinel
HWI-AI-13	—	4.4	3.4	3.0	2.5	—	—	—	—	Spinel + Apatite
HWI-AI-16	—	3.4	2.8	2.2	1.6	—	—	—	—	Spinel + Apatite
HWI-AI-17	—	3.3	2.8	1.9	1.1	—	—	—	—	Spinel + Apatite
HWI-AI-18G	—	3.6	2.8	2.4	1.1	—	—	—	—	Spinel
HWI-AI-19	—	3.7	3.0	2.1	1.3	—	—	—	—	Spinel
HWI-AI-20	—	2.4	2.1	1.9	1.6	—	—	—	—	Spinel
HLW-E-SP-01	10.3	—	5.2	—	2.4	—	2.9	—	0.8	Spinel
HLW-E-SP-02	12.4	—	6.8	—	3.9	—	3.3	—	1.0	Spinel
HLW-E-SP-03	20.6	—	7.8	—	4.7	—	4.1	—	1.6	Spinel
HLW-E-SP-04	—	—	—	—	2.6	—	1.3	—	1.0	Spinel
HLW-E-SP-05	—	—	—	5.2	4.2	4.0	—	4.0	2.9	Spinel
HLW-E-SP-06	—	—	—	2.9	2.2	1.4	—	1.0	1.3	Spinel
HLW-E-SP-07	—	—	—	3.0	1.9	1.0	—	0	0	Spinel
HLW-E-SP-08	—	—	—	0	0	0	—	0	0	—
HLW-E-SP-09	—	—	—	4.1	3.8	2.9	—	2.4	2.1	Spinel
HLW-E-SP-10	—	—	—	5.3	5.1	4.4	—	2.7	3.1	Spinel
HLW-E-ES-01 ^(b)	—	—	—	0.7	0.6	0.6	—	0.7	0.5	Eskolaite
HLW-E-ES-02	—	—	—	1.7	2.0	2.0	—	1.3	1.6	Eskolaite
HLW-E-ES-03	—	—	—	3.0	2.7	2.7	—	2.6	2.2	Eskolaite
HLW-E-ES-04	—	—	—	4.1	3.6	3.7	—	3.6	4.3	Eskolaite
HLW-E-ES-05	—	—	—	1.7	2	1.4	—	1.1	1.4	Eskolaite
HLW-E-ES-06	—	—	—	1.4	1.3	1.3	—	1.1	1.7	Eskolaite
HLW-E-ES-07	—	—	—	1.9	1.9	1.4	—	0.9	1.2	Eskolaite
HLW-E-ES-C16	—	—	—	1.2	1.5	1.1	—	1.4	1.7	Eskolaite
HLW-E-ES-08	—	—	—	—	1.7	—	—	2.2	—	Eskolaite
HLW-E-ES-09	—	—	—	—	2.0	—	—	1.5	—	Spinel

(a) A dash (—) denotes that no data were collected for the specific temperature.

(b) A shaded cell indicates either that $T_{1\%}$ was not estimated for the corresponding glass or that the data point was excluded from the calculation to determine the $T_{1\%}$ value.

Table 6.13. Temperature and Volume %-Crystallinity Data for ORP HLW Glasses (Continued).

Glass ID	Temperature (°C)									Crystalline Phase(s)
	750	800	850	900	950	1000	1050	1100	1150	
HLW-E-ES-10 ^(b)	— ^(a)	—	—	—	3.2	—	—	0.1	—	Potassium Aluminum Silicate
HLW-E-ES-11	—	—	—	—	4.5	—	—	2.5	—	Eskolaite
HLW-E-ES-12	—	—	—	—	1.9	—	—	1.6	—	Eskolaite
HLW-E-ES-13	—	—	—	—	1.1	—	—	0.8	—	Eskolaite + Spinel
HLW-E-ES-14	—	—	—	1.4	1.1	—	—	1.4	—	Eskolaite + Spinel
HLW-E-ES-15	—	—	—	3.7	3.1	—	—	2.2	—	Eskolaite + Calcium Phosphate
HLW-E-ES-16	—	—	—	5.0	3.0	—	—	1.8	—	Eskolaite + Calcium Phosphate
HLW-E-M-01	—	—	—	2.5	2.8	2.8	—	1.8	1.8	Eskolaite
HLW-E-M-02	—	—	—	3.9	3.8	3.2	—	4.0	3.5	Spinel
HLW-E-M-03	—	—	—	2.2	2.5	2.4	—	2.1	2.2	Spinel
HLW-E-M-04	—	—	—	3.6	4.3	4.0	—	3.2	2.6	Eskolaite + Spinel
HLW-E-M-05	—	—	—	1.2	1.0	1.1	—	0.8	1.0	Eskolaite
HLW-E-M-06	—	—	—	3.1	2.8	3.0	—	3.5	3.8	Eskolaite + Spinel
HLW-E-M-07	—	—	—	2.7	2.4	2.9	—	2.5	1.8	Eskolaite + Spinel
HLW-E-M-08	—	—	—	1.8	1.8	2.1	—	1.9	2.4	Spinel
HLW-E-M-09	—	—	—	2.0	1.6	1.8	—	2.4	2.5	Spinel
HLW-E-M-10	—	—	—	2.2	2.5	2.4	—	2.3	2.8	Spinel
HLW-E-M-11	—	—	—	2.6	2.3	2.3	—	2.5	2.5	Spinel
HLW-E-M-12	—	—	—	2.4	2.2	4.0	—	2.6	2.8	Spinel
HLW-E-M-13	—	—	—	—	3.1	—	—	2.6	—	Spinel
HWI-AI-21	—	—	—	—	1.8	—	1.3	—	—	Spinel
HWI-AI-22	—	—	—	—	2.4	—	1.4	—	—	Spinel
HWI-AI-23	—	—	—	—	2.9	—	1.5	—	—	Spinel
HWI-AI-24	—	—	—	—	3	—	2.3	—	—	Spinel
HWI-AI-25	—	—	—	—	1.9	—	1	—	—	Spinel
HWI-AI-26	—	4.2	—	—	1.8	—	1.1	—	—	Spinel
HWI-AI-27	—	4	—	—	1.8	—	1.4	—	—	Spinel
HWI-AI-28	—	4.6	—	—	2.4	—	2.5	—	—	Spinel
HWI-AI-19LW	—	—	—	—	1.7	—	—	—	—	Spinel
HLW-Bi-F3	—	—	2.6	1.0	1.0	—	—	—	—	Fe-Cr-Ni Spinel

(a) A dash (—) denotes that no data were collected for the specific temperature.

 (b) A shaded cell indicates either that $T_{1\%}$ was not estimated for the corresponding glass or that the data point was excluded from the calculation to determine the $T_{1\%}$ value.

**Table 6.13. Temperature and Volume %-Crystallinity Data for ORP HLW Glasses
(Continued).**

Glass ID	Temperature (°C)									Crystalline Phase(s)
	750	800	850	900	950	1000	1050	1100	1150	
HLW-Bi-F8	— ^(a)	5.6	4.1	2.8	2.5	—	—	—	—	Fe-Cr-Ni Spinel and Phosphate
HLW-Bi-F9	—	6.3	4.5	2.1	2.2	—	—	—	—	Fe-Cr-Ni Spinel
HLW-Bi-F10	—	7.5	5.4	3.4	3.2	—	—	—	—	Fe-Cr-Ni Spinel
HWI-ALS-01 ^(b)	—	—	—	—	0.3	—	0	—	—	Spinel
HWI-ALS-02	—	—	—	—	0.2	—	0	—	—	Spinel
HWI-ALS-03	—	—	—	—	0.6	—	0	—	—	Spinel
HWI-ALS-04	—	—	—	—	0.3	—	0	—	—	Spinel
HWI-ALS-05	—	—	—	—	0.3	—	0	—	—	Spinel
HWI-ALS-06	—	—	—	—	0.2	—	0	—	—	Spinel
HWI-ALS-07	—	—	—	—	0.3	—	0	—	—	Spinel
HWI-ALS-08	—	—	—	—	0.6	—	0.1	—	—	Spinel
HWI-ALS-09	—	—	—	—	1.0	—	0	—	—	Spinel
HWI-ALS-10	—	—	—	—	0.8	—	0.8	—	—	Spinel
HWI-ALS-12	—	—	—	—	0.2	—	0	—	—	Spinel
HWI-ALS-13	—	—	—	—	0.9	—	0	—	—	Spinel
HLW-N101-11	—	—	—	—	—	3.4	1.9	2.9 ^(b)	—	Spinel
HLW-N101-12	—	—	—	—	—	3.2	3.2	2.3	—	Spinel + Zirconia
HLW-N101-14	—	—	—	—	2.9	3.2	0.2	0.3	—	Spinel + Iron Oxide
HLW-N101-15	—	—	—	—	—	2.2	2.3	1.8	—	Spinel + Zirconia
HLW-N101-16	—	—	—	—	2.9	2.2	2.5	1.5	—	Spinel + Zirconia
HLW-N101-18	—	—	—	—	—	1.1	2.1	0	—	Spinel
HLW-N101-19	—	—	—	—	—	0.4	0.4	0.1	—	Spinel
HLW-N101-20	—	—	—	—	0.8	0.6	0.3	0	—	Spinel
HLW-N101-21	—	—	—	—	1.3	0.9	0.4	0.5	—	Spinel
HLW-N101-22	—	—	—	—	1.1	1.1	0.7	0.4	—	Spinel
HLW-N101-23	—	—	—	—	3.5	2	1.4	1.1	—	Spinel
HLW-N101-24	—	—	—	—	3.5	1.7	0.9	0.6	—	Spinel
HLW-NG-Cr1	—	—	—	—	0.4	0.9	0.4	0.4	—	Cr ₂ O ₃ + Spinel
HLW-NG-Cr2	—	—	—	—	0.6	0.8	0.8	0.6	—	Spinel + Cr ₂ O ₃
HLW-NG-Cr3	—	—	—	—	1.4	0.9	1	0.6	—	Cr ₂ O ₃ + Spinel

(a) A dash (—) denotes that no data were collected for the specific temperature.

(b) A shaded cell indicates either that T_{1%} was not estimated for the corresponding glass or that the data point was excluded from the calculation to determine the T_{1%} value.

Table 6.13. Temperature and Volume %-Crystallinity Data for ORP HLW Glasses (Continued).

Glass ID	Temperature (°C)									Crystalline Phase(s)
	750	800	850	900	950	1000	1050	1100	1150	
HLW-NG-Cr4	— ^(a)	—	—	—	1.8	0.8	1.4	1	—	Spinel + Apatite
HLW-NG-Cr5 ^(b)	—	—	—	—	0.5	0.7	0.5	0.4	—	Cr ₂ O ₃ + Spinel
HLW-NG-Cr6	—	—	—	—	2.1	2	1.6	1.2	—	Chromium Oxide
HLW-NG-Cr7	—	—	—	—	1.6	1.3	1.5	1.1	—	Cr ₂ O ₃ + Spinel
HLW-NG-Cr9	—	—	—	—	1.1 ^(b)	1.1	1.2	0.9	—	Spinel
HLW-NG-Cr10	—	—	—	—	2.8	1.6	1.1	1.2	—	Spinel + Cr ₂ O ₃
HLW-NG-Fe1	—	1.8	1.52	0.57	0.33	—	—	—	—	Spinel
HLW-NG-Fe2	—	2.41	2.04	1.66	0.65	—	—	—	—	Spinel
HLW-NG-Fe3	—	3.93	3.64	2.98	2.53	—	—	—	—	Spinel
HLW-NG-Fe4	—	4.1	3.43	2.68	2.69	—	—	—	—	Spinel
HLW-NG-Fe5	—	9.6	8.8	4	2.9	—	—	—	—	Spinel
HLW-NG-Fe6	—	6.6	5.7	5.2	4.5	—	—	—	—	Spinel
HLW-NG-Fe7	—	6.75	6	4.33	3.11	—	—	—	—	Spinel
HLW-NG-Fe8	—	6.14	7.48	4.37	2.85	—	—	—	—	Spinel
HLW-NG-Fe9	—	7.83	6.4	4.92	3.58	—	—	—	—	Spinel
HLW-NG-Fe10	—	4.81	5.13	3.51	2.72	—	—	—	—	Spinel
HLW-NG-Fe11	—	3.51	3.42	2.81	1.29	—	—	—	—	Spinel

(a) A dash (—) denotes that no data were collected for the specific temperature.

(b) A shaded cell indicates either that T_{1%} was not estimated for the corresponding glass or that the data point was excluded from the calculation to determine the T_{1%} value.

Table 6.14. Number of Temperature vs. Vol%-Crystallinity Data Points, Intercepts, Slopes, and Estimated Spinel $T_{1\%}$ Values for 101 ORP HLW Glasses Having Spinel as the Primary Crystalline Phase.

Glass ID	Primary & Secondary Crystalline Phase(s)	Inverse Regression Used to Calculate $T_{1\%}$			Estimated Spinel $T_{1\%}$ (°C) ^(b)
		Number of Data Points	Intercept ^(a)	Slope ^(a)	
INEL-HW09	Spinel	4	1070.98	-78.90	992.1
INEL-HW10	Spinel	4	1260.65	-80.42	1180.2
INEL-HLW-B3	Spinel	3	1165.83	-113.07	1052.8
INEL-HLW-B10	Spinel	3	1195.60	-65.93	1129.7
HLW-E-Bi-2	Spinel	3	933.33	-83.33	850.0
HLW-E-Bi-6	Spinel + Phosphate	4	1059.81	-64.85	995.0
HLW-E-Bi-7	Spinel + Phosphate	4	1082.08	-49.90	1032.2
HLW-E-Bi-12	Spinel + Phosphate	3	1250.00	-70.95	1179.1
HLW-E-Bi-13	Spinel + Phosphate	4	1136.55	-63.79	1072.8
HLW-E-Bi6UTh	Spinel + Phosphate	4	1039.89	-68.70	971.2
HLW-E-Cr-7	Spinel	4	998.78	-170.73	828.0
HLW-E-Cr-MUTh	Spinel + Cr/Fe	3	1000.00	-375.00	625.0
HLW-E-Al-12	Spinel	3	1045.21	-58.22	987.0
HLW-E-Al-27	Spinel	4	964.60	-23.27	941.3
HLW-E-Al27UTh	Spinel	3	1012.83	-61.76	951.1
HLW-E-ANa-4	Spinel	4	910.53	-52.63	857.9
HLW-E-ANa-5	Spinel	4	934.02	-19.84	914.2
HLW-E-ANa-6	Spinel	3	947.00	-6.29	940.7
HLW-E-ANa-9	Spinel	3	949.36	-15.59	933.8
HLW-E-ANa-10	Spinel + Sodium Aluminosilicate	3	968.64	-11.90	956.7
HLW-E-ANa-22	Spinel	4	1100.00	-500.00	600.0
HLW-E-ANa-24	Spinel	4	1088.24	-294.12	794.1
HLW-E-ANa-25	Spinel	4	1137.50	-375.00	762.5
HLW-E-ANa-26	Spinel	3	1235.71	-321.43	914.3
HLW-E-ANa22UTh	Spinel	3	975.00	-250.00	725.0
HLW-ALG-42	Spinel	3	1052.60	-127.91	924.7
HLW-ALG-43	Spinel	5	1140.20	-79.66	1060.5
HLW-ALG-45	Spinel	3	986.54	-19.23	967.3
HLW-ALG-46	Spinel	5	1156.30	-52.64	1103.7
HLW-ALG-48	Spinel	5	1066.80	-75.84	991.0
HLW-ALG-49	Spinel	4	973.17	-170.73	802.4
HLW-ALG-50	Spinel	2	911.11	-55.56	855.6
HLW-ALG-51	Spinel	6	1192.44	-70.26	1122.2
HLW-ALG-52	Spinel	4	1016.59	-66.09	950.5

(a) The intercept and slope are obtained from inverse regression of the temperature vs. vol% crystallinity data.

(b) Estimated $T_{1\%}$ values have been rounded to one decimal place.

Table 6.14. Number of Temperature vs. Vol%-Crystallinity Data Points, Intercepts, Slopes, and Estimated Spinel T_{1%} Values for 101 ORP HLW Glasses Having Spinel as the Primary Crystalline Phase (Continued).

Glass ID	Primary & Secondary Crystalline Phase(s)	Inverse Regression Used to Calculate T _{1%}			Estimated Spinel T _{1%} (°C) ^(b)
		Number of Data Points	Intercept ^(a)	Slope ^(a)	
HLW-ALG-57	Spinel	4	1059.40	-93.75	965.7
HLW-ALG-58	Spinel	5	1112.00	-70.26	1041.7
HLW-ALG-59	Spinel	4	1000.60	-45.81	954.8
HLW-ALG-60	Spinel	5	1072.00	-48.81	1023.2
HLW-ALG-61	Spinel + Zircon	3	1114.00	-62.18	1051.8
HLW-ALG-64	Spinel	5	1022.10	-58.16	963.9
HLW-ALG-65	Spinel	4	1069.80	-172.41	897.4
HLW-BP-01	Spinel	5	1070.31	-127.99	942.3
HWI-AI-1	Spinel	4	1030.56	-88.89	941.7
HWI-AI-5	Spinel	2	1218.42	-78.95	1139.5
HWI-AI-7	Spinel	4	1228.93	-112.36	1116.6
HWI-AI-9	Spinel	4	1200.00	-371.43	828.6
HWI-AI-10	Spinel	3	1025.00	-178.57	846.4
HWI-AI-13	Spinel + Apatite	4	1135.37	-78.31	1057.1
HWI-AI-16	Spinel + Apatite	4	1083.33	-83.33	1000.0
HWI-AI-17	Spinel + Apatite	4	1024.80	-65.85	959.0
HWI-AI-18G	Spinel	4	1024.60	-60.44	964.2
HWI-AI-19	Spinel	4	1030.53	-61.60	968.9
HWI-AI-20	Spinel	4	1257.35	-191.18	1066.2
HLW-E-SP-01	Spinel	4	1154.40	-42.58	1111.8
HLW-E-SP-02	Spinel	5	1137.30	-34.18	1103.1
HLW-E-SP-03	Spinel	5	1093.45	-18.49	1075.0
HLW-E-SP-04	Spinel	3	1230.65	-110.60	1120.1
HLW-E-SP-06	Spinel	5	1225.04	-116.50	1108.5
HLW-E-SP-07	Spinel	3	1048.01	-49.83	998.2
HLW-E-SP-09	Spinel	5	1376.60	-116.53	1260.1
HLW-E-SP-10	Spinel	4	1297.02	-70.75	1226.3
HLW-E-ES-09	Spinel	2	1550.00	-300.00	1250.0
HWI-AI-21	Spinel	2	1310.00	-200.00	1110.0
HWI-AI-22	Spinel	2	1190.00	-100.00	1090.0
HWI-AI-23	Spinel	2	1157.14	-71.43	1085.7
HWI-AI-24	Spinel	2	1378.57	-142.86	1235.7
HWI-AI-25	Spinel	2	1161.11	-111.11	1050.0

(a) The intercept and slope are obtained from inverse regression of the temperature vs. vol% crystallinity data.

(b) Estimated T_{1%} values have been rounded to one decimal place.

Table 6.14. Number of Temperature vs. Vol%-Crystallinity Data Points, Intercepts, Slopes, and Estimated Spinel T_{1%} Values for 101 ORP HLW Glasses Having Spinel as the Primary Crystalline Phase (Continued).

Glass ID	Primary & Secondary Crystalline Phase(s)	Inverse Regression Used to Calculate T _{1%}			Estimated Spinel T _{1%} (°C) ^(b)
		Number of Data Points	Intercept ^(a)	Slope ^(a)	
HWI-AI-26	Spinel	3	1113.15	-75.98	1037.2
HWI-AI-27	Spinel	3	1141.50	-86.73	1054.8
HWI-AI-28	Spinel	3	1222.30	-91.25	1131.0
HLW-Bi-F3	Spinel	3	971.88	-46.88	925.0
HLW-Bi-F8	Spinel and Phosphate	4	1040.35	-44.09	996.3
HLW-Bi-F9	Spinel	4	988.83	-30.15	958.7
HLW-Bi-F10	Spinel	4	1024.49	-30.66	993.8
HWI-ALS-08	Spinel	2	1070.00	-200.00	870.0
HLW-N101-11	Spinel	2	1113.33	-33.33	1080.0
HLW-N101-12	Spinel + Zirconia	3	1291.67	-83.33	1208.3
HLW-N101-14	Spinel + Iron Oxide	4	1081.46	-34.22	1047.2
HLW-N101-15	Spinel + Zirconia	3	1350.00	-142.86	1207.1
HLW-N101-16	Spinel + Zirconia	4	1236.75	-93.08	1143.7
HLW-N101-19	Spinel	2	1116.67	-166.67	950.0
HLW-N101-20	Spinel	3	1111.84	-197.37	914.5
HLW-N101-21	Spinel	3	1095.90	-110.66	985.3
HLW-N101-22	Spinel	3	1154.05	-141.89	1012.2
HLW-N101-23	Spinel	4	1139.04	-57.02	1082.0
HLW-N101-24	Spinel	4	1103.19	-46.68	1056.5
HLW-NG-Cr2	Spinel + Chromium Oxide	3	1325.00	-375.00	950.0
HLW-NG-Cr4	Spinel + Apatite	4	1120.34	-76.27	1044.1
HLW-NG-Cr9	Spinel	2	1550.00	-500.00	1050.0
HLW-NG-Cr10	Spinel + Chromium Oxide	4	1146.44	-72.50	1073.9
HLW-NG-Fe1	Spinel	4	967.27	-87.46	879.8
HLW-NG-Fe2	Spinel	4	1013.76	-82.11	931.7
HLW-NG-Fe3	Spinel	4	1204.93	-100.90	1104.0
HLW-NG-Fe4	Spinel	4	1163.67	-89.51	1074.2
HLW-NG-Fe5	Spinel	4	990.85	-18.32	972.5
HLW-NG-Fe6	Spinel	4	1274.57	-72.65	1201.9
HLW-NG-Fe7	Spinel	4	1071.76	-38.98	1032.8
HLW-NG-Fe8	Spinel	3	1001.83	-20.78	981.0
HLW-NG-Fe9	Spinel	4	1074.59	-35.12	1039.5
HLW-NG-Fe10	Spinel	3	1051.15	-39.92	1011.2
HLW-NG-Fe11	Spinel	4	1033.53	-57.49	976.0

(a) The intercept and slope are obtained from inverse regression of the temperature vs. vol% crystallinity data.

(b) Estimated T_{1%} values have been rounded to one decimal place.

Table 6.15. Comparison of Minimums and Maximums of HLW Glass Components (in Mass Fractions) in ORP Glasses that Have Estimated Spinel $T_{1\%}$ Values with the WTP Spinel $T_{1\%}$ Model Regions of Validity.

Dataset	WTP		ORP	
Number of Glasses	168		101	
HLW Glass Component	Min	Max	Min	Max
Al ₂ O ₃	0.0170	0.131	0.049	0.288 ^(a)
B ₂ O ₃	0.042	0.151	0.043	0.219
CaO	0	0.011	0.002	0.141
CdO	0	0.017	0	0.009
Cr ₂ O ₃	0	0.007	0.001	0.030
Fe ₂ O ₃	0.013	0.151	0.027	0.213
K ₂ O	0	0.017	0	0.082
La ₂ O ₃	0	0.006	0	0.012
Li ₂ O	0	0.061	0	0.058
MgO	0	0.012	0	0.051
MnO	0	0.081	0	0.080
Na ₂ O	0.036	0.201	0.036 ^(b)	0.187
NiO	0	0.011	0	0.023
PbO	0	0.011	0	0.032
Sb ₂ O ₃	0	0.005	0	0.003
SeO ₂	0	0.003	0	0.005
SiO ₂	0.350	0.531	0.216	0.514
SrO	0	0.101	0	0.012
ThO ₂	0	0.060	0	0.014
TiO ₂	0	0.011	0	0.053
Tl ₂ O	0	0.004	0	0
UO ₃	0	0.066	0	0.036
ZnO	0	0.041	0	0.040
ZrO ₂	0	0.097	0.000	0.060
Others	0	0.038	0.003	0.156
X				

Dataset	WTP		ORP	
Number of Glasses	168		101	
HLW Glass Component	Min	Max	Min	Max
Ag ₂ O	0	0.003	0	0.002
As ₂ O ₅	0	0.003	0	0.002
BaO	0	0.006	0	0.001
BeO	0	0	0	0
Bi ₂ O ₃	0	0.004	0	0.080
Ce ₂ O ₃	0	0.004	0	0.003
Cl	0	0.004	0	0.001
CoO	0	0.003	0	0
Cs ₂ O	0	0.003	0	0.002
CuO	0	0.003	0	0.001
Dy ₂ O ₃	0	0	0	0
F	0	0.005	0	0.011
Gd ₂ O ₃	0	0	0	0
HfO ₂	0	0	0	0
MoO ₃	0	0.004	0	0
Nd ₂ O ₃	0	0.005	0	0.003
P ₂ O ₅	0	0.007	0	0.060
PdO	0	0.002	0	0.000
Pr ₂ O ₃	0	0.002	0	0
Rb ₂ O	0	0.001	0	0
Rh ₂ O ₃	0	0.001	0	0.000
RuO ₂	0	0.002	0	0.001
SO ₃	0	0.004	0	0.008
SnO ₂	0	0.003	0	0.003
TeO ₂	0	0.001	0	0
V ₂ O ₅	0	0.002	0	0.025
WO ₃	0	0.002	0	0.000
Y ₂ O ₃	0	0.001	0	0

(a) Shaded cells indicate the associated values are outside the WTP PCT model regions of validity.

(b) The minimum Na₂O mass fraction value (0.03580) in ORP glasses was rounded to three decimal places.

Table 6.16. Temperature and Electrical Conductivity (EC) Data for the ORP HLW Glasses.

Glass ID	Temp1 (°C)	EC1 (S/cm)	Temp2 (°C)	EC2 (S/cm)	Temp3 (°C)	EC3 (S/cm)	Temp4 (°C)	EC4 (S/cm)
INEL-HW09	964	0.133	1055	0.204	1148	0.294	1239	0.357
INEL-HW10	964	0.106	1056	0.167	1149	0.248	1242	0.292
INEL-HLW-B3	953	0.077	1045	0.123	1137	0.186	1229	0.250
INEL-HLW-B10	966	0.086	1058	0.132	1152	0.162	1243	0.224
HLW-E-Bi-2	984	0.177	1083	0.271	1182	0.369	1281	0.488
HLW-E-Bi-6	976	0.269	1072	0.355	1169	0.521	1267	0.625
HLW-E-Bi-7	986	0.234	1083	0.346	1180	0.470	1277	0.617
HLW-E-Bi-13	985	0.147	1084	0.319	1183	0.421	1282	0.562
HLW-E-Bi-16	984	0.222	1053	0.321	1181	0.425	1279	0.552
HLW-E-Bi6UTh	937	0.153	1037	0.247	1133	0.338	1227	0.444
HLW-E-Cr-7	983	0.133	1082	0.205	1180	0.282	1280	0.364
HLW-E-Cr-10	968	0.160	1063	0.261	1159	0.385	1254	0.487
HLW-E-Cr-M	938	0.085	1035	0.134	1131	0.188	1228	0.264
HLW-E-Cr-MUTh	934	0.083	1033	0.146	1130	0.227	1219	0.283
HLW-E-Al-6	970	0.004	1061	0.011	1153	0.026	1244	0.056
HLW-E-Al-8	977	0.016	1069	0.035	1158	0.068	1250	0.134
HLW-E-Al-11	982	0.119	1079	0.215	1175	0.350	1272	0.536
HLW-E-Al-12	982	0.113	1081	0.187	1179	0.284	1278	0.412
HLW-E-Al-18	974	0.083	1072	0.133	1171	0.205	1269	0.328
HLW-E-Al-25	978	0.117	1074	0.193	1172	0.284	1271	0.367
HLW-E-Al-27	958	0.107	1055	0.182	1154	0.263	1252	0.346
HLW-E-Al27UTh	929	0.106	1029	0.176	1127	0.252	1222	0.378
HLW-E-ANa-4	980	0.191	1076	0.285	1176	0.331	1274	0.484
HLW-E-ANa-5	975	0.190	1073	0.270	1171	0.355	1269	0.516
HLW-E-ANa-6	982	0.274	1082	0.388	1179	0.522	1275	0.697
HLW-E-ANa-9	976	0.304	1076	0.383	1174	0.511	1273	0.652
HLW-E-ANa-11	975	0.290	1075	0.404	1173	0.514	1271	0.704
HLW-E-ANa-13	976	0.155	1074	0.238	1173	0.341	1271	0.445
HLW-E-ANa-22	951	0.185	1049	0.277	1148	0.380	1243	0.471
HLW-E-ANa-25	965	0.167	1063	0.259	1161	0.366	1259	0.492
HLW-E-ANa22UTh	934	0.175	1033	0.280	1121	0.392	1225	0.536
HLW-ALG-41	988	0.203	1084	0.303	1182	0.393	1280	0.538
HLW-ALG-42	973	0.161	1069	0.254	1167	0.351	1264	0.497
HLW-ALG-43	978	0.345	1073	0.467	1170	0.695	1266	0.972
HLW-ALG-44	964	0.119	1057	0.173	1151	0.252	1244	0.372
HLW-ALG-45	957	0.149	1049	0.255	1141	0.338	1235	0.486
HLW-ALG-46	973	0.068	1068	0.124	1165	0.182	1263	0.257

Table 6.16. Temperature and Electrical Conductivity (EC) Data for the ORP HLW Glasses (Continued).

Glass ID	Temp1 (°C)	EC1 (S/cm)	Temp2 (°C)	EC2 (S/cm)	Temp3 (°C)	EC3 (S/cm)	Temp4 (°C)	EC4 (S/cm)
HLW-ALG-47	973	0.412	1069	0.592	1167	0.823	1264	1.046
HLW-ALG-48	974	0.144	1070	0.234	1168	0.348	1265	0.448
HLW-ALG-49	977	0.201	1072	0.261	1170	0.397	1268	0.529
HLW-ALG-50	958	0.151	1050	0.223	1143	0.319	1239	0.414
HLW-ALG-51	975	0.149	1070	0.222	1163	0.323	1261	0.357
HLW-ALG-52	971	0.083	1066	0.135	1160	0.184	1257	0.225
HLW-ALG-53	977	0.179	1072	0.308	1164	0.409	1263	0.479
HLW-ALG-54	974	0.161	1068	0.239	1161	0.355	1255	0.526
HLW-ALG-55	975	0.236	1073	0.374	1170	0.480	1266	0.742
HLW-ALG-56	978	0.344	1074	0.508	1171	0.689	1269	0.905
HLW-ALG-57	972	0.115	1067	0.194	1162	0.269	1258	0.384
HLW-ALG-58	963	0.142	1056	0.206	1149	0.312	1247	0.416
HLW-ALG-59	940	0.172	1034	0.249	1133	0.344	1224	0.570
HLW-ALG-60	972	0.093	1065	0.147	1160	0.217	1258	0.284
HLW-ALG-61	976	0.188	1069	0.311	1162	0.464	1259	0.616
HLW-ALG-62	975	0.325	1068	0.458	1163	0.632	1257	0.776
HLW-ALG-63	981	0.093	1076	0.159	1172	0.198	1266	0.241
HLW-ALG-64	977	0.141	1071	0.213	1165	0.317	1261	0.378
HLW-ALG-65	935	0.053	1036	0.102	1135	0.161	1235	0.223
HLW-BP-01	930	0.158	1030	0.209	1128	0.315	1228	0.403
HLW-BP-02	— ^(a)	—	1007	0.070	1118	0.133	1217	0.194
HLW-BP-03	930	0.134	1028	0.194	1129	0.367	1229	0.434
HLW-BP-04	—	—	1036	0.175	1133	0.318	1231	0.395
HLW-BP-05	937	0.113	1037	0.199	1136	0.277	1234	0.370
HLW-BP-06	—	—	—	—	1138	0.124	1237	0.179
HLW-BP-07	—	—	—	—	1130	0.159	1229	0.239
HLW-BP-08	—	—	—	—	1133	0.104	1228	0.172
HLW-BP-09	—	—	—	—	1125	0.132	1231	0.203
HLW-BP-10	932	0.072	1032	0.099	1130	0.142	1228	0.200
HWI-AI-1	977	0.173	1070	0.242	1163	0.347	1257	0.417
HWI-AI-7	979	0.130	1073	0.181	1168	0.259	1263	0.372
HWI-AI-9	982	0.168	1077	0.251	1172	0.352	1267	0.459
HWI-AI-16	980	0.105	1074	0.176	1170	0.262	1265	0.365
HWI-AI-18G	978	0.105	1072	0.157	1168	0.227	1263	0.296
HWI-AI-19	981	0.116	1075	0.192	1171	0.293	1266	0.402
HWI-AI-20	980	0.102	1074	0.166	1170	0.245	1264	0.347
HLW-E-SP-05	973	0.085	1067	0.127	1163	0.182	1257	0.251

(a) A dash (—) denotes an empty data field because EC data were collected at fewer than 4 temperatures for that glass.

Table 6.16. Temperature and Electrical Conductivity (EC) Data for the ORP HLW Glasses (Continued).

Glass ID	Temp1 (°C)	EC1 (S/cm)	Temp2 (°C)	EC2 (S/cm)	Temp3 (°C)	EC3 (S/cm)	Temp4 (°C)	EC4 (S/cm)	Temp 5 (°C)	EC5 (S/cm)
HLW-E-SP-06	967	0.086	1061	0.144	1155	0.225	1249	0.319	— ^(a)	—
HLW-E-ES-05	974	0.118	1068	0.189	1162	0.268	1256	0.364	—	—
HLW-E-ES-06	974	0.094	1069	0.155	1163	0.237	1257	0.320	—	—
HLW-E-M-03	974	0.122	1069	0.166	1165	0.236	1259	0.329	—	—
HLW-E-M-08	967	0.102	1061	0.146	1156	0.230	1250	0.313	—	—
HLW-E-M-09	961	0.162	1055	0.248	1148	0.358	1242	0.485	—	—
HWI-AL-24	944	0.105	1040	0.166	1135	0.245	1230	0.335	—	—
HWI-AL-27	952	0.098	1049	0.175	1143	0.285	1238	0.420	—	—
HWI-AL-28	941	0.088	1040	0.151	1132	0.248	1229	0.386	—	—
HWI-AL-19LW	949	0.109	1046	0.17	1141	0.238	1239	0.314	—	—
HLW-Bi-F3	951	0.229	1049	0.314	1146	0.437	1243	0.535	—	—
HLW-Bi-F8	941	0.231	1043	0.324	1140	0.421	1238	0.596	—	—
HLW-Bi-F9	944	0.192	1044	0.263	1142	0.381	1239	0.525	—	—
HLW-Bi-F10	940	0.209	1041	0.303	1137	0.404	1232	0.541	—	—
HWI-ALS-01	952	0.172	1049	0.267	1143	0.388	1235	0.522	—	—
HWI-ALS-03	954	0.187	1050	0.278	1145	0.397	1239	0.618	—	—
HWI-ALS-04	950	0.165	1046	0.266	1140	0.390	1236	0.536	—	—
HWI-ALS-05	953	0.234	1050	0.364	1145	0.502	1241	0.667	—	—
HWI-ALS-06	954	0.254	1051	0.393	1146	0.556	1243	0.786	—	—
HWI-ALS-07	955	0.183	1051	0.287	1147	0.418	1242	0.586	—	—
HWI-ALS-08	955	0.186	1051	0.294	1146	0.421	1240	0.567	—	—
HWI-ALS-09	953	0.160	1049	0.262	1145	0.385	1240	0.542	—	—
HLW-N101-14	964	0.172	1061	0.279	1159	0.399	1255	0.541	1304	0.606
HLW-N101-20	963	0.193	1061	0.292	1158	0.417	1254	0.575	1303	0.644
HLW-N101-21	964	0.212	1061	0.333	1158	0.460	1253	0.606	1303	0.685
HLW-N101-22	965	0.132	1063	0.200	1159	0.289	1256	0.400	1306	0.427
HLW-N101-24	949	0.249	1050	0.387	1149	0.562	1247	0.642	1294	0.812
HLW-NG-Cr2	964	0.203	1063	0.299	1159	0.399	1256	0.451	—	—
HLW-NG-Cr7	965	0.104	1063	0.165	1159	0.236	1254	0.339	1304	0.344
HLW-NG-Fe2	966	0.152	1062	0.239	1157	0.338	1250	0.468	—	—
HLW-NG-Fe9	964	0.078	1060	0.135	1155	0.213	1249	0.290	—	—
HLW-NG-Fe11	972	0.185	1065	0.287	1158	0.395	1252	0.584	—	—

(a) A dash (—) denotes an empty data field because EC data were collected at only 4 temperatures for that glass.

Table 6.17. Comparison of Minimums and Maximums of HLW Glass Components (in Mass Fractions) in ORP Glasses that Have EC Data with the WTP EC Model Regions of Validity.

Dataset	WTP		ORP	
Number of Glasses	208		106	
HLW Glass Component	Min	Max	Min	Max
Al ₂ O ₃	0.014	0.131	0.019	0.266 ^(a)
B ₂ O ₃	0.044	0.151	0.043	0.202
CaO	0	0.011	0.002	0.182
CdO	0	0.017	0	0.009
Cr ₂ O ₃	0	0.007	0.001	0.030
Fe ₂ O ₃	0.013	0.151	0.027	0.213
K ₂ O	0	0.017	0	0.070
La ₂ O ₃	0	0.013	0	0.012
Li ₂ O	0	0.061	0	0.058
MgO	0	0.014	0	0.031
MnO	0	0.081	0	0.080
Na ₂ O	0.039	0.201	0.036	0.200
NiO	0	0.011	0	0.021
PbO	0	0.011	0	0.032
Sb ₂ O ₃	0	0.005	0	0.003
SeO ₂	0	0.005	0	0.005
SiO ₂	0.330	0.531	0.194	0.531
SrO	0	0.103	0	0.093
ThO ₂	0	0.061	0	0.036
TiO ₂	0	0.011	0	0.016
Tl ₂ O	0	0.004	0	0
UO ₃	0	0.066	0	0.056
ZnO	0	0.040	0	0.040
ZrO ₂	0	0.116	0.000	0.106
Others	0	0.038	0.003	0.143
X				

Dataset	WTP		ORP	
Number of Glasses	208		106	
HLW Glass Component	Min	Max	Min	Max
Ag ₂ O	0	0.003	0	0.002
As ₂ O ₅	0	0.003	0	0.002
BaO	0	0.006	0	0.002
BeO	0	0	0	0
Bi ₂ O ₃	0	0.004	0	0.074
Ce ₂ O ₃	0	0.026	0	0.003
Cl	0	0.004	0	0.001
CoO	0	0.003	0	0
Cs ₂ O	0	0.003	0	0.002
CuO	0	0.003	0	0.001
Dy ₂ O ₃	0	0	0	0
F	0	0.005	0	0.010
Gd ₂ O ₃	0	0	0	0
HfO ₂	0	0.033	0	0
MoO ₃	0	0.004	0	0
Nd ₂ O ₃	0	0.017	0	0.003
P ₂ O ₅	0	0.007	0	0.055
PdO	0	0.002	0	0
Pr ₂ O ₃	0	0.002	0	0
Rb ₂ O	0	0.001	0	0
Rh ₂ O ₃	0	0.009	0	0
RuO ₂	0	0.002	0	0.001
SO ₃	0	0.004	0	0.007
SnO ₂	0	0.007	0	0.003
TeO ₂	0	0.001	0	0
V ₂ O ₅	0	0.002	0	0.025
WO ₃	0	0.002	0	0
Y ₂ O ₃	0	0.001	0	0

(a) Shaded cells indicate the associated values are outside the WTP PCT model regions of validity.

Table 6.18. Temperature and Viscosity Data for the ORP HLW Glasses.

Glass ID	Temp1 (°C)	Vis1 (P)	Temp2 (°C)	Vis2 (P)	Temp3 (°C)	Vis3 (P)	Temp4 (°C)	Vis4 (P)
INEL-HW09	965	682.00	1065	203.00	1166	77.40	1265	35.57
INEL-HW10	961	1074.08	1064	260.64	1168	85.84	1270	35.69
INEL-HLW-B3	957	696.40	1057	213.06	1158	80.62	1257	36.64
INEL-HLW-B10	968	874.20	1071	229.70	1173	73.16	1275	28.21
HLW-E-Bi-2	961	685.57	1060	188.09	1160	70.48	1260	32.15
HLW-E-Bi-6	959	864.14	1059	241.55	1159	87.99	1260	39.46
HLW-E-Bi-7	954	994.86	1054	271.82	1154	92.77	1255	36.69
HLW-E-Bi-13	960	616.66	1062	185.92	1162	67.86	1264	28.93
HLW-E-Bi-16	955	596.84	1056	182.09	1158	69.85	1260	31.99
HLW-E-Bi6UTh	982	644.66	1074	179.05	1166	71.82	1258	33.90
HLW-E-Cr-7	963	370.41	1062	104.38	1162	43.24	1262	21.24
HLW-E-Cr-10	955	433.15	1054	141.41	1152	56.98	1250	30.16
HLW-E-Cr-M	967	531.62	1066	169.00	1166	68.87	1265	32.47
HLW-E-Cr-MUTh	973	375.43	1068	119.67	1163	48.13	1258	24.98
HLW-E-Al-6	1005	1531.51	1057	505.17	1158	88.57	1259	26.41
HLW-E-Al-8	955	606.45	1058	91.58	1161	23.82	1264	8.79
HLW-E-Al-11	955	102.47	1056	33.38	1157	13.11	1257	6.06
HLW-E-Al-12	958	85.57	1058	25.03	1159	10.01	1260	5.26
HLW-E-Al-18	986	57.93	1079	19.84	1173	8.33	1267	4.08
HLW-E-Al-25	956	607.37	1057	160.39	1157	55.50	1258	23.34
HLW-E-Al-27	957	438.63	1054	125.06	1151	44.95	1249	19.69
HLW-E-Al27UTh	973	286.52	1072	85.28	1171	31.93	1270	15.18
HLW-E-ANa-4	953	717.01	1054	217.99	1154	86.01	1256	40.95
HLW-E-ANa-5	979	461.08	1071	173.64	1164	72.80	1256	33.82
HLW-E-ANa-6	968	1065.30	1067	275.19	1166	100.90	1266	42.53
HLW-E-ANa-9	987	153.84	1085	62.81	1182	31.41	1281	19.10
HLW-E-ANa-11	985	196.79	1081	77.20	1178	35.73	1276	18.22
HLW-E-ANa-13	953	369.63	1051	118.49	1150	46.68	1249	22.24
HLW-E-ANa-22	954	408.16	1055	137.83	1156	57.06	1258	27.17
HLW-E-ANa-25	963	404.49	1057	133.43	1151	54.91	1246	26.32
HLW-E-ANa22UTh	988	387.81	1081	122.50	1174	52.22	1267	26.05
HLW-ALG-41	941	600.33	1044	178.89	1147	68.23	1250	31.92
HLW-ALG-42	945	482.01	1047	140.70	1149	52.23	1251	24.38
HLW-ALG-43	970	38.83	1067	15.43	1164	7.19	1261	4.03
HLW-ALG-44	973	667.13	1068	244.41	1163	102.53	1259	50.90
HLW-ALG-45	976	176.15	1072	64.00	1167	29.56	1263	14.91
HLW-ALG-46	— ^(a)	—	1074	431.62	1168	153.81	1262	65.38
HLW-ALG-47	983	63.16	1073	29.11	1162	16.57	1251	9.92

(a) A dash (—) denotes an empty data field because viscosity data were collected at fewer than 4 temperatures for that glass.

Table 6.18. Temperature and Viscosity Data for the ORP HLW Glasses (Continued).

Glass ID	Temp1 (°C)	Vis1 (P)	Temp2 (°C)	Vis2 (P)	Temp3 (°C)	Vis3 (P)	Temp4 (°C)	Vis4 (P)
HLW-ALG-48	976	188.52	1072	70.60	1168	31.61	1265	16.73
HLW-ALG-49	972	506.31	1069	167.52	1167	67.51	1264	32.35
HLW-ALG-50	968	168.63	1066	58.84	1165	26.86	1263	14.03
HLW-ALG-51	960	1082.79	1060	288.62	1161	105.03	1261	44.73
HLW-ALG-52	962	2417.91	1062	604.44	1163	199.47	1263	79.48
HLW-ALG-53	958	643.90	1056	156.49	1154	53.03	1252	22.34
HLW-ALG-54	961	545.60	1059	124.44	1156	42.93	1254	19.00
HLW-ALG-55	971	81.95	1069	32.14	1167	15.65	1265	8.34
HLW-ALG-56	980	97.10	1078	39.85	1176	21.07	1274	12.94
HLW-ALG-57	962	727.95	1061	187.83	1159	71.62	1258	34.79
HLW-ALG-58	964	709.23	1059	222.76	1152	83.96	1245	38.47
HLW-ALG-59	956	320.16	1054	106.23	1151	43.13	1249	20.49
HLW-ALG-60	960	567.19	1056	170.67	1154	66.10	1250	31.92
HLW-ALG-61	961	60.15	1060	22.41	1159	9.87	1258	5.18
HLW-ALG-62	961	172.91	1061	63.18	1162	28.93	1262	16.00
HLW-ALG-63	968	1477.67	1068	353.88	1168	120.85	1268	51.31
HLW-ALG-64	957	227.35	1058	73.05	1158	30.65	1259	15.25
HLW-BP-01	974	287.63	1073	87.65	1171	34.49	1269	17.17
HLW-BP-02	1179	79.89	1220	46.52	1261	31.69	1282	24.88
HLW-BP-03	973	509.10	1065	124.63	1156	42.07	1247	18.13
HLW-BP-04	— ^(a)	—	1074	59.64	1173	22.80	1270	10.58
HLW-BP-05	976	500.65	1075	94.28	1175	32.15	1273	14.84
HLW-BP-06	—	—	—	—	1175	94.19	1270	35.42
HLW-BP-07	—	—	—	—	—	—	1271	21.54
HLW-BP-08	—	—	—	—	1174	72.63	1271	29.42
HLW-BP-09	—	—	—	—	1166	92.90	1264	36.77
HLW-BP-10	974	4617.00	1073	448.57	1172	135.80	1270	52.28
HWI-AI-1	968	351.27	1068	119.03	1168	46.99	1268	21.37
HWI-AI-7	970	576.44	1068	152.99	1167	50.97	1265	20.09
HWI-AI-9	966	444.54	1065	141.09	1165	54.88	1264	27.22
HWI-AI-16	962	363.13	1063	103.60	1163	38.05	1264	17.10
HWI-AI-18G	958	421.49	1057	113.73	1157	40.98	1256	18.59
HWI-AI-19	961	279.65	1060	81.00	1160	30.61	1259	13.93
HWI-AI-20	962	643.07	1062	191.50	1161	69.43	1261	31.93
HLW-E-SP-07	962	317.02	1061	101.43	1161	39.73	1261	20.55
HLW-E-M-08	960	366.41	1061	125.97	1162	52.20	1264	25.85
HLW-E-M-09	959	230.49	1059	81.03	1160	35.72	1261	16.75
HWI-AL-24	955	933.40	1057	228.83	1158	68.07	1260	24.79

(b) A dash (—) denotes an empty data field because viscosity data were collected at fewer than 4 temperatures for that glass.

Table 6.18. Temperature and Viscosity Data for the ORP HLW Glasses (Continued).

Glass ID	Temp1 (°C)	Vis1 (P)	Temp2 (°C)	Vis2 (P)	Temp3 (°C)	Vis3 (P)	Temp4 (°C)	Vis4 (P)	Temp 5 (°C)	Vis5 (P)
HWI-AL-27	956	146.23	1057	42.90	1157	15.99	1258	7.23	— ^(a)	—
HWI-AL-28	953	154.14	1055	41.96	1156	15.01	1258	6.61	—	—
HWI-AL-19LW	961	294.81	1063	82.33	1164	30.39	1265	13.82	—	—
HLW-Bi-F3	955	366.09	1058	111.98	1161	42.81	1263	20.19	—	—
HLW-Bi-F8	955	301.09	1058	89.75	1160	35.03	1262	16.32	—	—
HLW-Bi-F9	956	131.97	1058	42.32	1162	16.86	1264	7.96	—	—
HLW-Bi-F10	956	185.73	1059	51.93	1162	18.04	1264	7.83	—	—
HWI-ALS-01	956	181.67	1057	62.67	1157	27.39	1258	14.24	—	—
HWI-ALS-03	959	165.80	1058	58.38	1157	25.56	1256	12.86	—	—
HWI-ALS-04	961	200.04	1061	64.83	1159	26.90	1258	12.90	—	—
HWI-ALS-05	957	224.62	1058	77.45	1160	33.15	1260	16.44	—	—
HWI-ALS-06	958	108.73	1060	40.00	1162	18.34	1263	9.69	—	—
HWI-ALS-07	960	166.76	1060	57.37	1160	25.00	1259	12.34	—	—
HWI-ALS-08	960	170.04	1060	58.87	1159	25.37	1258	12.55	—	—
HWI-ALS-09	960	215.93	1060	69.33	1160	28.60	1259	13.86	—	—
HLW-N101-14	954	484.04	1057	130.08	1161	46.60	1263	22.97	1315	14.73
HLW-N101-20	956	715.41	1058	190.4	1161	67.27	1263	29.91	1313	20.23
HLW-N101-21	957	676.51	1060	179.04	1162	62.74	1264	28.10	1315	19.01
HLW-N101-22	957	1891.24	1059	415.83	1160	128.31	1261	54.73	1312	33.84
HLW-N101-24	956	333.58	1058	93.06	1159	34.74	1260	16.01	1311	11.08
HLW-NG-Cr2	956	346.33	1058	104.01	1161	36.14	1262	16.38	1313	11.65
HLW-NG-Cr7	954	635.51	1057	190.74	1161	72.52	1263	32.77	1315	22.87
HLW-NG-Fe2	958	232.44	1059	69.18	1162	27.93	1264	13.42	—	—
HLW-NG-Fe9	960	230.83	1060	63.60	1162	24.48	1263	11.84	—	—
HLW-NG-Fe11	957	90.84	1059	31.20	1161	13.55	1264	6.85	—	—

(b) A dash (—) denotes an empty data field because viscosity data were collected at only 4 temperatures for that glass.

Table 6.19. Comparison of Minimums and Maximums of HLW Glass Components (in Mass Fractions) in ORP Glasses that Have Viscosity Data with the WTP Viscosity Model Regions of Validity.

Dataset	WTP		ORP	
Number of Glasses	197		101	
HLW Glass Component	Min	Max	Min	Max
Al ₂ O ₃	0.014	0.131	0.019	0.266
B ₂ O ₃	0.044	0.151	0.043 ^(a)	0.202
CaO	0	0.011	0.002	0.182
CdO	0	0.017	0	0.009
Cr ₂ O ₃	0	0.007	0.001	0.030
Fe ₂ O ₃	0.013	0.151	0.027	0.200
K ₂ O	0	0.017	0	0.077
La ₂ O ₃	0	0.013	0	0.012
Li ₂ O	0	0.061	0	0.058
MgO	0	0.014	0	0.031
MnO	0	0.081	0	0.080
Na ₂ O	0.039	0.201	0.036	0.200
NiO	0	0.011	0	0.021
PbO	0	0.011	0	0.032
Sb ₂ O ₃	0	0.005	0	0.003
SeO ₂	0	0.005	0	0.005
SiO ₂	0.330	0.531	0.194	0.531
SrO	0	0.103	0.000	0.093
ThO ₂	0	0.061	0.000	0.036
TiO ₂	0	0.011	0	0.016
Tl ₂ O	0	0.004	0	0
UO ₃	0	0.066	0	0.056
ZnO	0	0.040	0	0.040
ZrO ₂	0	0.116	0	0.106
Others	0	0.038	0.014	0.199
X				

Dataset	WTP		ORP	
Number of Glasses	197		101	
HLW Glass Component	Min	Max	Min	Max
Ag ₂ O	0	0.003	0	0.002
As ₂ O ₅	0	0.003	0	0.002
BaO	0	0.006	0	0.002
BeO	0	0	0	0
Bi ₂ O ₃	0	0.004	0	0.074
Ce ₂ O ₃	0	0.005	0	0.003
Cl	0	0.004	0	0.001
CoO	0	0.003	0	0
Cs ₂ O	0	0.003	0	0.002
CuO	0	0.003	0	0.001
Dy ₂ O ₃	0	0	0	0
F	0	0.005	0	0.010
Gd ₂ O ₃	0	0	0	0
HfO ₂	0	0	0	0
MoO ₃	0	0.004	0	0
Nd ₂ O ₃	0	0.009	0	0.003
P ₂ O ₅	0	0.007	0	0.055
PdO	0	0.002	0	0
Pr ₂ O ₃	0	0.002	0	0
Rb ₂ O	0	0.001	0	0
Rh ₂ O ₃	0	0.009	0	0
RuO ₂	0	0.002	0	0.001
SO ₃	0	0.004	0	0.007
SnO ₂	0	0.007	0	0.003
TeO ₂	0	0.001	0	0
V ₂ O ₅	0	0.002	0	0.025
WO ₃	0	0.002	0	0
Y ₂ O ₃	0	0.001	0	0

(a) Shaded cells indicate the associated values are outside the WTP PCT model regions of validity.

Table 6.20. TCLP Cadmium Releases for ORP HLW Glasses.

Glass ID	Unnormalized (mg/L)	Normalized (g/L)	Glass ID	Unnormalized (mg/L)	Normalized (g/L)
INEL-HW09	< 0.03	< 0.024	HWI-Al-27	0.06	0.270
INEL-HW10	< 0.03	< 0.021	HWI-Al-28	0.07	0.296
INEL-HLW-B3	< 0.03	< 0.022	HLW-N101-11	0.11	0.014
INEL-HLW-B10	0.03	0.019	HLW-N101-12	0.13	0.016
HLW-E-Cr-MUTh	<0.03	< 1.055	HLW-N101-14	0.11	0.015
HLW-E-Al27UTh	0.04	0.203	HLW-N101-15	0.16	0.020
HLW-E-ANa22UTh	<0.03	< 0.365	HLW-N101-16	0.17	0.021
HWI-Al-4	<0.03	< 0.141	HLW-N101-18	0.09	0.015
HWI-Al-7	<0.03	< 0.141	HLW-N101-19	0.09	0.014
HWI-Al-16	<0.03	< 0.145	HLW-N101-20	0.10	0.015
HWI-Al-18G	0.04	0.200	HLW-N101-21	0.10	0.014
HWI-Al-19	<0.03	< 0.141	HLW-N101-22	0.12	0.017
HWI-Al-20	<0.03	< 0.141	HLW-NG-Cr1	< 0.03	< 0.831

Table 6.21. Comparison of TCLP Cadmium Releases between WTP and ORP Glasses.

	WTP Glasses		ORP Glasses	
	Minimum	Maximum	Minimum	Maximum
CdO in glass (wt%)	0.050	1.600	0.003	0.934
Unnormalized TCLP Cd-Release, c_{Cd} (mg/L)	0.007	1.240	<0.030	0.170
Normalized TCLP Cd-Release, r_{Cd} (g/L)	0.014	0.120	0.014	0.296
Number of Glasses with $c_{Cd} >$ delisting limit (0.48 mg/L)	14		0	

Table 6.22. Comparison of Minimums and Maximums of HLW Glass Components (in Mass Fractions) in ORP Glasses that Have TCLP Cd-Release Data with the WTP TCLP Cd-Release Model Regions of Validity.

Dataset	WTP		ORP	
Number of Glasses	100		26	
HLW Glass Component	Min	Max	Min	Max
Al ₂ O ₃	0.019	0.086	0.069	0.266 ^(a)
B ₂ O ₃	0.048	0.141	0.075	0.202
CaO	0	0.006	0.003	0.092
CdO	0	0.017	0.000	0.009
Cr ₂ O ₃	0	0.005	0.001	0.012
Fe ₂ O ₃	0.019	0.141	0.027	0.200
K ₂ O	0	0.001	0	0.070
La ₂ O ₃	0	0.004	0	0.006
Li ₂ O	0.019	0.061	0.011	0.050
MgO	0	0.002	0	0.031
MnO	0	0.070	0	0.006
Na ₂ O	0.038	0.151	0.050	0.134
NiO	0	0.011	0.001	0.007
PbO	0	0.005	0	0.005
Sb ₂ O ₃	0	0.004	0	0
SeO ₂	0	0.003	0	0
SiO ₂	0.351	0.531	0.216	0.473
SrO	0	0.010	0	0
ThO ₂	0	0.060	0	0.002
TiO ₂	0	0.001	0	0.002
Tl ₂ O	0	0.004	0	0
UO ₃	0	0.064	0	0.033
ZnO	0	0.040	0	0.010
ZrO ₂	0	0.040	0.000	0.049
Others	0.012	0.022	0.003	0.083
X				

Dataset	WTP		ORP	
Number of Glasses	100		26	
HLW Glass Component	Min	Max	Min	Max
Ag ₂ O	0	0.003	0	0
As ₂ O ₅	0	0.003	0	0
BaO	0	0.004	0	0.001
BeO	0	0	0	0
Bi ₂ O ₃	0	0.001	0	0.030
Ce ₂ O ₃	0	0.001	0	0.003
Cl	0	0.003	0	0
CoO	0	0.001	0	0
Cs ₂ O	0	0.001	0	0.002
CuO	0	0.002	0	0
Dy ₂ O ₃	0	0	0	0
F	0	0.001	0	0.008
Gd ₂ O ₃	0	0	0	0
HfO ₂	0	0	0	0
MoO ₃	0	0	0	0
Nd ₂ O ₃	0	0	0	0.003
P ₂ O ₅	0	0.006	0	0.019
PdO	0	0.002	0	0
Pr ₂ O ₃	0	0	0	0
Rb ₂ O	0	0	0	0
Rh ₂ O ₃	0	0.001	0	0
RuO ₂	0	0.001	0	0.001
SO ₃	0	0.002	0.001	0.006
SnO ₂	0	0	0	0.003
TeO ₂	0	0.001	0	0
V ₂ O ₅	0	0.002	0	0.025
WO ₃	0	0	0	0
Y ₂ O ₃	0	0	0	0

(a) Shaded cells indicate the associated values are outside the WTP PCT model regions of validity.

Table 6.23. Crystallinity Data for CCC Heat-Treated HLW Glasses.

Glass ID	Total Vol%	Major Crystalline Phase(s)	Glass ID	Total Vol%	Major Crystalline Phase(s)
<i>WTP Glasses</i>			HLW-E-ANa-5	50	Nepheline
HLW-ALG-01	0.3	Nepheline (0.2%) + Spinel (0.1%)	HLW-E-ANa-9	> 50	Nepheline + Sodalite
HLW-ALG-03	< 0.1	Spinel	HLW-E-ANa-11	> 50	Nepheline + Sodalite
HLW-ALG-08	1.9	Spinel + Zirconia	HLW-E-ANa-13	12	Apatite + Nepheline + Spinel
HLW-ALG-11	4.7	Zirconia + Thoria	HLW-E-ANa-14	50-60	Nepheline + Apatite + Spinel
HLW-ALG-14	1.2	Spinel	HLW-E-ANa-15	20-50	Nepheline + Apatite + Spinel
HLW-ALG-27	21.4	Nepheline (20%) + Spinel (1.4%)	HLW-E-ANa-16	30-50	Nepheline + Apatite + Spinel
HLW-ALG-29	0.2	Spinel	HLW-E-ANa-17	5.6	Phosphate + Spinel + Nepheline
HLW-ALG-32	2.5	Spinel	HLW-E-ANa-18	3.6	Phosphate + Spinel + Nepheline
HLW-ALG-33	17.9	Nepheline (15%) + Spinel/Zirconia (2.9%)	HLW-E-ANa-20	31	Nepheline + Phosphate + ZrO ₂
HLW-ALG-34	0.1	Spinel	HLW-E-ANa-22	0.5	Spinel
<i>ORP Glasses Tested at VSL</i>			HLW-E-ANa-23	1.3	Spinel
INEL-HW09	4.4	Spinel + Hematite	HLW-E-ANa-24	3	Spinel + Nepheline
INEL-HW10	5.2	Spinel + Hematite	HLW-E-ANa-25	2	Spinel + Nepheline
INEL-HLW-B3	8.6	Spinel	HLW-E-ANa-26	5.6	Nepheline + Spinel
INEL-HLW-B10	5.4	Spinel	HLW-E-ANa-22UTH	0.3	Spinel
HLW-E-Bi-6	5.6	Spinel + Phosphate	HLW-ALG-41	0.3	Spinel
HLW-E-Bi6UTh	5.0	Spinel + Phosphate	HLW-ALG-42	0.2	Spinel
HLW-E-Cr-10	0.7	Spinel + Cr/Fe	HLW-ALG-43	0.3	Spinel + Silver
HLW-E-Cr-M	1.3	Spinel + Phosphate	HLW-ALG-44	3.8	Spinel + Silver
HLW-E-Cr-MUTh	0.3	Cr/Fe + Spinel	HLW-ALG-45	0.1	Silver particles
HLW-E-Al-24	0.1	Spinel	HLW-ALG-46	0.2	Spinel
HLW-E-Al-25	1.9	Spinel + Phosphate	HLW-ALG-47	6.3	Spinel + Silver
HLW-E-Al-27	1.9	Spinel	HLW-ALG-48	0.1	Silver particles
HLW-E-Al-27UTH	1.7	Spinel	HLW-ALG-49	3.1	Spinel
HLW-E-ANa-4	2-5	Spinel + Nepheline	HLW-ALG-50	0.6	Spinel + Silver

Table 6.23. Crystallinity Data for CCC Heat-Treated HLW Glasses (Continued).

Glass ID	Total Vol%	Major Crystalline Phase(s)	Glass ID	Total Vol%	Major Crystalline Phase(s)
HLW-ALG-51	5.5	Spinel + Silver	HWI-AI-7	3.7	Spinel
HLW-ALG-52	0.1	Spinel + Silver	HWI-AI-9	0.7	Spinel
HLW-ALG-53	< 0.1	Spinel	HWI-AI-10	1.3	Spinel
HLW-ALG-54	< 0.1	Spinel	HWI-AI-13	2.6	Spinel + Apatite
HLW-ALG-55	0.3	Spinel + Silver	HWI-AI-16	1.6	Spinel + Apatite
HLW-ALG-56	0.2	Silver particles	HWI-AI-17	1.3	Spinel
HLW-ALG-57	0.5	Spinel + Silver	HWI-AI-18G	1.8	Spinel
HLW-ALG-58	5.2	Spinel + Silver	HWI-AI-19	1.9	Spinel + Apatite
HLW-ALG-59	0.3	Spinel + Silver	HWI-AI-20	3.3	Spinel
HLW-ALG-60	6.8	Spinel + Silver	HWI-AI-21	3.1	Spinel
HLW-ALG-61	9.2	Spinel	HWI-AI-22	3.2	Spinel
HLW-ALG-62	0	None	HWI-AI-23	3.3	Spinel
HLW-ALG-63	< 0.1	Spinel	HWI-AI-24	4.0	Spinel
HLW-ALG-64	2.8	Spinel + Silver	HWI-AI-25	3.1	Spinel
HLW-ALG-65	0.6	Spinel	HWI-AI-26	2.7	Spinel + Apatite
HLW-BP-01	2.2	Spinel	HWI-AI-27	2.8	Spinel + Apatite
HLW-BP-02	5.5	Calcium Phosphate	HWI-AI-28	3.8	Spinel + Apatite
HLW-BP-03	1.0	Zirconia + Spinel	HWI-AI-19LW	2.9	Spinel
HLW-BP-04	6.2	Calcium Phosphate	HWI-ALS-03	10.0	Spinel
HLW-BP-05	6.1	Calcium Phosphate + Aluminum Oxide	HWI-ALS-04	9.5	Spinel + Trace Nepheline
HLW-BP-06	5.5	Calcium Phosphate	HWI-ALS-05	0.6	Spinel
HLW-BP-07	4.4	Calcium Phosphate	HWI-ALS-06	2.2	Spinel
HLW-BP-08	5.9	Calcium Phosphate	HWI-ALS-07	9.8	Spinel
HLW-BP-09	4.1	Calcium Phosphate	HWI-ALS-08	7.9	Spinel
HLW-BP-10	3.3	Calcium Phosphate + Spinel	HWI-ALS-09	8.2	Spinel (5.8%) + Nepheline (2.4%)
HWI-AI-5	5.2	Spinel	HWI-ALS-10	12.2	Spinel (6.2%) + Nepheline (6%)

Table 6.23. Crystallinity Data for CCC Heat-Treated HLW Glasses (Continued).

Glass ID	Total Vol%	Major Crystalline Phase(s)	Glass ID	Total Vol%	Major Crystalline Phase(s)
HWI-ALS-11	9.2	Spinel	HLW-E-AI-24	0.6	Spinel
HWI-ALS-12	30	Nepheline (20%) + Spinel (10%)	HLW-E-AI-25	6.3	Spinel
HWI-ALS-13	25	Nepheline (20%) + Spinel (5%)	HLW-E-AI-26	6.6	Spinel
HLW-N101-14	9.8	Spinel	HLW-E-AI-27	6.1	Spinel
HLW-N101-15	6.6	Spinel + Zirconium Oxide	HLW-E-AI-29	0.6	Spinel
HLW-N101-21	3.4	Spinel	HLWE-ANa-4	30.7	Nepheline (27.8%) + Spinel (2.9%)
HLW-N101-23	4.3	Spinel	HLW-E-ANa-5	54.9	Nepheline (50.7%) + Spinel (4.2%)
HLW-N101-24	3.4	Spinel	HLWE-ANa-9	43.1	Nepheline
HLW-NG-Cr1	4.0	Chromium Oxide + Spinel + Apatite	HLW-E-ANa-10	43.9	Nepheline (38.1%) + Spinel (5.8%)
HLW-NG-Cr2	5.0	Spinel + Phosphate	HLW-E-ANa-11	52.7	Nepheline (48.3%) + Spinel (4.4%)
HLW-NG-Cr3	4.0	Apatite + Spinel + Cr ₂ O ₃	HLW-E-ANa-13	41.2	Nepheline (36.5%) + Spinel (1.4%) + Fluorapatite (3.3%)
HLW-NG-Cr4	4.3	Apatite + Spinel + Cr ₂ O ₃	HLW-E-ANa-14	41.5	Nepheline (34.6%) + Spinel (3.2%) + Fluorapatite (3.7%)
HLW-NG-Cr7	3.9	Apatite + Spinel + Cr ₂ O ₃	HLW-E-ANa-15	28	Nepheline (21.5%) + Spinel (2.5%) + Fluorapatite (5.0%)
HLW-NG-Cr10	5.1	Spinel + Apatite + Cr ₂ O ₃	HLWE-ANa-16	54	Nepheline (46.5%) + Spinel (3.8%) + Fluorapatite (3.7%)
HLW-NG-Fe2	4.9	Spinel	HLWE-ANa-24	1.7	Spinel
HLW-NG-Fe9	9.1	Spinel	HLWE-ANa-25	31.6	Nepheline (28.7%) + Spinel (2.9%)
<i>ORP Glasses Tested at PNNL</i>			HLWE-ANa-26	17.4	Nepheline (13.7%) + Spinel (3.7%)
HLW-E-AI-3	6.6	Spinel	HWI-AI-2	7.3	Spinel + Fluorapatite
HLW-E-AI-8	24	Iron Oxide + Fluorapatite	HWI-AI-3	7.0	Spinel + Fluorapatite
HLW-E-AI-9	7.9	Spinel	HWI-AI-4	6.1	Spinel + Chromite
HLW-E-AI-10	9.6	Spinel	HWI-AI-6	5.2	Spinel
HLW-E-AI-14	15	Spinel	HWI-AI-10	4.2	Spinel
HLW-E-AI-15	10.7	Spinel + Lithium Aluminosilicate	HWI-AI-11	7.0	Spinel
HLW-E-AI-16	11	Spinel	HWI-AI-12	7.4	Spinel
HLW-E-AI-17	32.4	Spinel + Lithium Aluminosilicate	HWI-AI-14	11.2	Spinel + Fluorapatite
HLWE-AI-23	52.7	Nepheline (43.5%) + Spinel (9.2%)	HWI-AI-20	4.6	Spinel

Table 7.1. Summary of LAW Glasses Collected in the ORP Database Compared to the WTP Model Validity Region.

LAW Models	PCT-B	PCT-Na	VHT	Electrical Conductivity	Viscosity
Number of LAW Glasses in ORP Database ^(a)	171	171	203	122	122
Number of ORP Glasses inside WTP Model Validity Regions	3	3	6	3	3
Statistical R ² Value for Prediction with WTP Baseline Model ^(b)	0.687	0.425	-0.356	0.748	0.955
Number of WTP Glasses	244	244	165	171	171
Statistical R ² Value of Fit to WTP Baseline Model	0.866	0.870	0.744	0.951	0.988

(a) Total number of LAW glasses in ORP database = 207.

(b) Only glasses inside the WTP baseline model validity regions are included.

Table 7.2. Summary of HLW Glasses Collected in the ORP Database.

	PCT-B	PCT-Li	PCT-Na	Electrical Conductivity	Viscosity	Spinel T ₁ %	TCLP Cd-Release	Nepheline Formation
Number of HLW Glasses in ORP Database ^(a)	111	104	111	106	101	101	26	143
Number of ORP Glasses inside WTP Model Validity Regions	24	22	24	21	21	9	0	NA ^(c)
Statistical R ² Value for Prediction with WTP Baseline Model ^(b)	0.518	0.324	0.743	0.901	0.948	0.385	NA	NA
Number of WTP Glasses	264	250	266	208	197	247	100	NA
Statistical R ² Value of Fit to WTP Baseline Model	0.791	0.763	0.872	0.907	0.988	0.808	0.977	NA

(a) Total number of HLW glasses in ORP database = 266.

(b) Only glasses inside the WTP baseline model validity regions are included.

(c) NA = not applicable (Data on nepheline formation were not collected previously for WTP model development).

Figure 2.1. Plots showing ranges and distributions of mass fractions for the 15 major components in 478 LAW glasses prepared at VSL; the WTP data set (x) and the ORP data (o) are shown separately.

Figure 3.1. Compositional comparisons (wt%) of selected oxides between WTP HLW glasses (x) and ORP HLW glasses (o).

Figure 4.1. Canister centerline cooling curve used for heat treatment of ORP-LAW glasses.

Figure 4.2. HLW canister centerline cooling (CCC) temperature profile.

Figure 5.1. PCT sodium and silicon releases (g/m^2) as a function of PCT boron release for 171 ORP-LAW glasses with PCT data. Na and B leach nearly congruently in glasses with low leach rates, as shown in the expanded figure on the right.

Figure 5.2. PCT sodium release (g/m²) as a function of the glass soda content for 171 ORP-LAW and 244 WTP-LAW glasses with PCT data.

Figure 5.3. PCT boron release as a function of the pH measured at 20°C in the 7-day PCT leachate for 171 ORP-LAW glasses with PCT data.

Figure 5.4. Comparison of predicted versus measured PCT-B and PCT-Na for the WTP (including outliers) and ORP glasses using the recommended 17-Term Reduced Partial Quadratic Mixture models. The red lines represent the WTP contract limit (4 g/L) for PCT-Na release.

Figure 5.5. VHT alteration rates for 203 ORP-LAW glasses and 171 WTP-LAW glasses as a function of their alkali content.

Figure 5.6. Comparison of predicted versus measured VHT for the WTP (including outliers) and ORP glasses using the recommended WTP 15-Term Reduced Partial Cubic Mixture model for LAW VHT alteration depth (D). The red lines mark the WTP contract limit corresponding to $50 \text{ g/m}^2/\text{day}$ ($D = 453 \mu\text{m}$).

Figure 5.7. Comparison of measured and predicted VHT alteration depth for a preliminary 18-Term Reduced Partial Quadratic Mixture model for VHT alteration depth (D) for the combined WTP-LAW and ORP-LAW datasets.

Figure 5.8. Melt electrical conductivity for 122 ORP-LAW glasses as a function of their alkali content.

Figure 5.9. Distribution of temperature values for each of 122 ORP-LAW glasses with melt electrical conductivity data.

Figure 5.10. Melt electrical conductivity data measured on near-replicate glasses LAWC100R1 (crucible) and WVY-G-95A (DM100 melter glass).

Figure 5.11. Comparison of predicted versus measured electrical conductivity for the WTP and ORP glasses using the recommended 26-Term Reduced Truncated Linear Mixture model with four quadratic terms.

Figure 5.12. Distribution of temperature values for each of 122 ORP-LAW glasses with melt viscosity data.

Figure 5.13. Melt viscosity data measured on near-replicate glasses LAW C100R1 (crucible) and W V Y-G-95A (DM100 meter glass).

Figure 5.14. Comparison of predicted versus measured viscosity for the WTP and ORP glasses using the recommended 26-Term Reduced Truncated Linear Mixture model with four quadratic terms.

Figure 5.15. Scatterplot matrix of 16 components (wt%) in 207 WTP glasses (green) and 271 ORP-LAW glasses (black).

Figure 5.16. Binary plots (wt%) showing various gaps in the combined WTP (green) and ORP-LAW (black) dataset.

Figure 5.16. Binary plots (wt%) showing various gaps in the combined WTP (green) and ORP-LAW (black) dataset (continued).

Figure 5.16. Binary plots (wt%) showing various gaps in the combined WTP (green) and ORP-LAW (black) dataset (continued).

Figure 5.17. Range of concentrations for major components in the WTP and ORP datasets (487 glass samples) and other LAW glass datasets (88 glasses from the HLP and ICV series).

Figure 6.1. Comparison of the normalized PCT releases (B, Li, and Na (g/L)) between the WTP and ORP glasses.

Figure 6.2. Distribution of normalized PCT releases of boron, lithium and sodium for the 111 HLW glasses with PCT data.

Figure 6.3. Comparison of normalized releases of sodium and lithium with normalized PCT release of boron for ORP-HLW glasses.
The figure on the right is a blow-up of the region between 0 and 5 g/L.

Figure 6.4. Normalized PCT releases of boron versus pH of PCT leachates for the ORP glasses with PCT data.

Figure 6.5. Comparison of predicted versus measured normalized PCT-B releases for the WTP and ORP HLW glasses using the baseline WTP HLW PCT-B model. The red lines represent the WTP contract limit (16.695 g/L) for HLW PCT-B release.

Figure 6.6. Comparison of predicted versus measured normalized PCT-Li releases for the WTP and ORP HLW glasses using the baseline WTP HLW PCT-Li model. The red lines represent the WTP contract limit (9.565 g/L) for HLW PCT-Li release.

Figure 6.7. Comparison of predicted versus measured normalized PCT-Na releases for the WTP and ORP HLW glasses using the baseline WTP HLW PCT-Na model. The red lines represent the WTP contract limit (13.346 g/L) for HLW PCT-Na release.

Figure 6.8. Volume % crystalline (spinel) phase in heat treated HLW glass (INEL-HW09).

Figure 6.9. Distribution of estimated one-percent crystal fraction temperature ($T_{1\%}$) for 101 ORP HLW glasses with spinel as the primary crystalline phase.

Figure 6.10. Comparison of predicted versus measured spinel $T_{1\%}$ for the WTP and ORP HLW glasses using the baseline WTP IHLW spinel $T_{1\%}$ model.

Figure 6.11. Distribution of temperature values for each of the 106 HLW glasses with electrical conductivity data.

Figure 6.12. Temperature dependence of electrical conductivity for selected HLW glasses.

Figure 6.13. Glass melt electrical conductivity (S/cm) at 1150°C calculated with the Vogel-Fulcher equation as a function of the alkali oxides ($\text{Li}_2\text{O}+\text{Na}_2\text{O}+\text{K}_2\text{O}$) content for HLW glasses.

Figure 6.14. Glass melt electrical conductivity (S/cm) at 1150°C calculated with the Vogel-Fulcher equation as a function of the content of the oxides $\text{Li}_2\text{O}+\text{Na}_2\text{O}+\text{K}_2\text{O}+\text{CaO}+\text{MgO}+\text{SrO}$ for HLW glasses.

Figure 6.15. Comparison of predicted versus measured electrical conductivity for the WTP and ORP glasses using the baseline WTP HLW electrical conductivity model.

Figure 6.16. Distribution of temperature values for each of the 101 HLW glasses with viscosity data.

Figure 6.17. Glass melt viscosity (P) at 1150°C calculated with the Vogel-Fulcher equation as a function of the alkali oxides content ($\text{Li}_2\text{O}+\text{Na}_2\text{O}+\text{K}_2\text{O}$) for HLW glasses.

Figure 6.18. Glass melt viscosity (P) at 1150°C calculated with the Vogel-Fulcher equation as a function of the content of the oxides $\text{Li}_2\text{O}+\text{Na}_2\text{O}+\text{K}_2\text{O}+\text{CaO}+\text{MgO}+\text{SrO}$ for HLW glasses.

Figure 6.19. Temperature dependence of viscosity for selected HLW glasses.

Figure 6.20. Comparison of predicted versus measured viscosity for the WTP and ORP glasses using the baseline WTP HLW viscosity model.

Figure 6.21. Comparison of predicted versus measured unnormalized TCLP cadmium release for the WTP and ORP HLW glasses using the baseline WTP HLW TCLP cadmium-release model. The blue lines represent the TCLP Cd delisting limit of 0.48 mg/L.

Figure 6.22. Nepheline (vol%) in CCC samples of WTP and ORP HLW glasses as a function of the nepheline discriminator. The critical value of 0.62 for the nepheline discriminator is indicated by the red line.

Figure 6.23. Distribution of selected component oxides (wt%) for the ORP HLW glasses.

Figure 6.23. Distribution of selected component oxides (wt%) for the ORP HLW glasses (continued).

Figure 6.23. Distribution of selected component oxides (wt%) for the ORP HLW glasses (continued).

Figure 6.24. Selected pair-wise scatter plots of component oxides for ORP HLW glasses.

Figure 6.25. Distribution of electrical conductivity at 1150°C (S/cm) for the ORP HLW glasses.

Figure 6.26. Distribution of viscosity at 1150°C (P) for the ORP HLW glasses.

Figure 6.27. Distribution of un-normalized TCLP cadmium releases (mg/L) for the ORP HLW glasses.