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Sensitivity of Hanford Immobilized High-Level Waste Glass Mass to Chromium and Aluminum Partitioning Assumptions

Paul J. Certa
CH2MHILL Hanford Group, Inc.
Richland, WA 99352
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Abstract: The mass of HLW glass produced using different partitioning assumptions (including oxidative leaching) for chromium and aluminum was estimated for various degrees of waste blending. The major influences for HLW glass mass and blending were identified, as were the degree of pretreatment assumed for the source tanks. Candidate tanks for opportunistic sampling were also identified.

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SENSITIVITY OF HANFORD IMMOBILIZED HIGH-LEVEL WASTE GLASS MASS TO CHROMIUM AND ALUMINUM PARTITIONING ASSUMPTIONS

P. J. Certa
T. M. Hohl
A. M. Johnson
S. L. Orcutt
R. S. Wittman
CH2M HILL Hanford Group, Inc.

D-S. Kim
Pacific Northwest National Laboratory

Date Published
June 2004

CH2MHILL
Hanford Group, Inc.
Post Office Box 1500
Richland, Washington

Prepared for the U.S. Department of Energy
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EXECUTIVE SUMMARY

The strategy for the treatment of the Hanford Site tank wastes involves water and caustic washing of the tank waste sludges to reduce sludge mass and the corresponding mass of high-level waste (HLW) glass that will be generated by the Waste Treatment and Immobilization Plant (WTP). During fiscal year (FY) 2003 CH2M HILL Hanford Group, Inc. (CH2M HILL) developed revised water wash and caustic leach factors for chromium (RPP-10222) and aluminum (RPP-11079) to estimate the waste treatment behavior of the tank waste compositions. Subsequently, the U.S. Department of Energy, Office of River Protection (ORP) requested that CH2M HILL evaluate the potential impacts to the HLW glass mass due to these revised water wash and caustic leach factors. ORP plans to use the results of this study in conjunction with separate information regarding the process impacts of implementing oxidative leaching at the WTP to determine whether oxidative leaching is adequate to mitigate potential increases in HLW glass production or whether additional strategies are required.

The purpose of this sensitivity study of immobilized HLW glass mass to chromium and aluminum partitioning assumptions was to:

- Identify the impacts of the revised water wash and caustic leach factors for chromium and aluminum on the mass of HLW glass.
- Understand the effect of oxidative leaching on the mass of HLW glass.
- Identify the major influences for HLW glass mass and waste blending.
- Characterize the degree of pretreatment (water washing, caustic leaching, and oxidative leaching) assumed for different source tanks.
- Identify candidate tanks for opportunistic sampling and testing to confirm the inventory and better understand the behavior of chromium during retrieval, staging, and subsequent processing.

The study concluded that:

- Application of the revised chromium and aluminum wash and leach factors will increase the HLW glass mass by about 60 to 100 percent (using the relaxed glass properties model) to about 150 to 300 percent (using the default glass properties model) above the baseline.
- The use of oxidative leaching for chromium removal, if implementable as assumed, will offset the increase in HLW glass mass resulting from the use of the revised chromium and aluminum wash and leach factors. The revised HLW glass mass estimate is comparable to the current ORP baseline. This study does not address the ability to implement an oxidative leaching process in the WTP, or impacts that such a process might have on pretreatment capacity or the overall process flowsheet – these factors should be addressed separately from this report.
- The major parameters affecting the glass mass will change from Cr_2O_3 solubility and spinel liquidus temperature (T_L) constraints to SO_3 solubility and spinel T_L constraints.

- The HLW glass mass will increase by about 15 percent (3,044 MT) if the transuranic (TRU) waste from fourteen single-shell tanks and three double-shell tanks currently designated for direct packaging is treated in the WTP as HLW, assuming a hypothetical total blend of all tank wastes. This represents an increase in mission duration of about 20 months at a net HLW production rate of 5 MT glass per day. For the hypothetical processing of wastes on a tank farm blend basis, processing the TRU tank wastes in the WTP will increase the HLW glass mass by about 4,170 MT (14 percent) and increase the mission duration by about 28 months. The effect of incidental blending on the HLW glass mass was not evaluated for a case that did not include the TRU tank wastes.
- All of the HLW sludge was assumed to require water washing. The majority (~80%) of the tanks requires caustic leaching, either with or without oxidative leaching. Oxidative leaching provides a significant benefit when it is used in conjunction with caustic leaching.
- Ten of the fifty tanks allocated for early retrieval as part of the M-45 pool of tanks contain a significant quantity of chromium and, thus, are candidates for opportunistic sampling and analysis.

The following recommendations are made based on the results of this study:

- The revised water wash and caustic leach factors for chromium and aluminum should be adopted for mission planning purposes, either in conjunction with oxidative leaching or another strategy to produce an acceptable quantity of HLW glass. This recommendation will bring the planning basis into alignment with the current technical understanding of the major factors affecting HLW glass.
- Review and select the appropriate glass property models and limits for future HLW glass mass projections for mission planning purposes. Consider a combination of the models presented in PNNL-14060 and WTP-RPT-085. These models should be augmented with a Toxicity Characteristic Leaching Procedure (TCLP) property constraint for use in predicting HLW glass waste loadings. Together, these should provide more accurate estimates of the mass of HLW glass, the specific drivers for the glass mass, and waste blending behavior.
- The sulfate partitioning assumptions used for mission modeling should be evaluated to verify that SO_3 really is limiting HLW glass waste oxide loading. Based on the results of this evaluation, studies to increase the sulfate loading in HLW may be determined to be beneficial in reducing the HLW glass mass.
- The feasibility of obtaining opportunistic samples to confirm the tank waste inventory and partitioning behavior of chromium during preparation of the process flowsheets for the ten high chromium content tanks identified for retrieval prior to commencing WTP operations (see Table 8) should be evaluated.
- Revisit the degree of pretreatment analysis on a feed batch basis rather than a source tank basis to see if there is an opportunity to apply less aggressive pretreatment to certain feed batches with little or no impact on HLW glass mass.

- Evaluate whether a simple blending strategy can be used to augment incidental blending to significantly reduce the HLW glass mass. The HLW glass mass for the incidental blend is about one-and-a-half times greater than the total blend; it may be possible to approach the total blend using simple blending strategies.

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TERMS AND ABBREVIATIONS

Al	aluminum
BL	baseline
CH2M HILL	CH2M HILL Hanford Group, Inc.
Cr	chromium
DST	double-shell tank
EA	Environmental Assessment
EPA	U.S. Environmental Protection Agency
FY	fiscal year
g	grams
g/m^2	grams per square meter
GPM	Glass Property Model
HLW	High-level waste
HTWOS	Hanford Tank Waste Operations Simulator
kg	kilograms
LAW	low-activity waste
M	molar concentration (moles per liter)
MT	metric tons
OH^-	hydroxide
OP	Operating point
ORP	U.S. Department of Energy, Office of River Protection
Pa·s	Pascal-seconds
PCT	Product Consistency Test
PNNL	Pacific Northwest National Laboratory
RPP	River Protection Project
SST	single-shell tank
TCLP	Toxicity Characteristic Leaching Procedure
TFCOUP	*Tank Farm Contractor Operation and Utilization Plan*
T_L	Liquidus temperature
TRU	transuranic
WIPP	Waste Isolation Pilot Plant
wt%	weight percent
WTP	Waste Treatment and Immobilization Plant
°C	degrees Celsius
µg	micrograms

1.0 INTRODUCTION

1.1 BACKGROUND

The *River Protection Project System Plan* (ORP-11242) identified key issues and uncertainties related[1] to the potential increase in high-level waste (HLW) glass mass due to the recently revised water wash and caustic leach factors for chromium (Cr) (RPP-10222) and aluminum (Al) (RPP-11079). The System Plan identified oxidative leaching as a potential treatment step to offset the expected increase in HLW glass mass[2].

In addition, the U.S. Department of Energy, Office of River Protection (ORP) conducted a technical design oversight review (D-03-DESIGN-005) of the revised water wash and caustic leach factors for chromium (RPP-10222) and aluminum (RPP-11079) and of oxidative leach behavior (RPP-15522). Three key conclusions from the oversight review were:

- The revised estimates are a significant improvement over the previous estimates.
- CH2M HILL Hanford Group, Inc. should perform sensitivity studies on HLW glass estimates using the revised wash and leach factors and assuming oxidative leaching with permanganate. *"Based on the results from the recommended sensitivity analysis, ORP should determine whether oxidative leaching is adequate to mitigate potential increases in HLW glass production or whether additional strategies are required."*
- ORP should capitalize on *"opportunities to conduct selective testing to confirm inventory and predict the fate of chromium in tank farms and Waste Treatment and Immobilization Plant (WTP) systems."*

1.2 PURPOSE

The purpose of this sensitivity study is to:

- Identify the impacts of the revised water wash and caustic leach factors for chromium and aluminum on the mass of HLW glass.
- Understand the effect of oxidative leaching on the mass of HLW glass.
- Identify the major influences for HLW glass mass and waste blending.
- Characterize the degree of pretreatment (water washing, caustic leaching, and oxidative leaching) assumed for different source tanks.
- Identify candidate tanks for opportunistic sampling and testing to confirm the inventory and better understand the behavior of chromium during retrieval, staging, and subsequent processing.

[1] See Table 4-2 of the River Protection Project (RPP) System Plan, Item numbers 3 and 4.
[2] See Table 4-2 of the RPP System Plan, Item number 4, Potential Mitigation Actions 2 and 3.

1.3 ORGANIZATION OF REPORT

The key technical assumptions are discussed in Section 1.4.

The parametric analysis which evaluates the impacts on HLW glass mass from the revised wash and leach factors and oxidative leaching is presented in Section 2.0. This section also discusses the impact that sending transuranic (TRU) waste to the WTP would have on glass mass. Ranges of glass masses are presented to account for different degrees of waste blending.

The new drivers for HLW glass mass are discussed in Section 3.0 based on the Case 5 results. Section 3.3.1 examines the No Blend results, while Section 3.3.2 examines the Incidental Blend results. Observations on the glass properties models used in the analysis are discussed in Section 3.3.3 .

Section 4.0 characterizes the degree of pretreatment required for different source tanks.

Section 5.0 identifies candidate tanks for opportunistic sampling and testing.

Conclusions, recommendations, and caveats are presented in Section 6.0.

1.4 KEY ASSUMPTIONS

The key technical assumptions used in this study are documented in this section.

1.4.1 Starting Tank Inventory

The starting tank inventory was taken from the *Tank Farm Contractor Operation and Utilization Plan* (TFCOUP) (HNF-SD-WM-SP-012, Revision 5A, Appendix B). This inventory represents the waste inventory in the single-shell tanks (SSTs) and double-shell tanks (DSTs) as of July 1, 2003, except for tanks AP-103 and AW-102. The effective date for those two tanks is July 4, 2003 (HNF-SD-WM-SP-012, Revision 5A, Appendix A, A4.1). This starting inventory is referred to as "All" in Table 3. Study Matrix for Parametric Analysis. The starting inventory for the SSTs and DSTs was taken from the TFCOUP to provide a common tank waste inventory to compare the previous analysis of HLW glass mass produced to the present analyses contained in this document.

1.4.2 List of TRU Tanks

Several tanks contain sludge that may potentially be treated and packaged as TRU waste for disposal at Waste Isolation Pilot Plant (WIPP), thus reducing the amount of solids that would be incorporated into the HLW glass. This sensitivity study used the same list of tanks containing TRU sludge as was used in the TFCOUP (HNF-SD-WM-SP-012, Revision 5A, Appendix A,

A2.3.1), again, to provide a common basis of comparison. These tanks comprise[3] AW-103, AW-105, B-110, B-111, B-201, B-202, B-203, B-204, SY-102, T-104, T-110, T-111, T-112, T-201, T-202, T-203, and T-204. The inventory that results when these tanks are excluded from the list of tanks to be treated as HLW is referred to as "Less TRU" in Table 3.

1.4.3 Water Wash and Caustic Leach Factors

The water wash and caustic leach factors in the Tank Waste Information Network System (TWINS) on May 14, 2003 were used for partitioning tank waste into solid and liquid phases to estimate the solids remaining after retrieval, staging, and caustic leaching. These water wash and caustic leach factors are the same as those used in Revision 2 of the System Plan (ORP-11242) and Revision 5A of the TFCOUP (HNF-SD-WM-SP-012) and are referred to as "Baseline W&L" in Table 3. Revised water wash and caustic leach factors for chromium and aluminum were obtained from RPP-10222 and RPP-11079, respectively, and supplant the baseline values for chromium and aluminum only. This set of wash and leach factors are referred to as "New W&L" in Table 3.

The calculations for the No Blend, Total Blend, and Farm Blends assume that sufficient hydroxide (OH^-) is present to allow the leach reactions to reach the extent of completion defined by the caustic leach factors. The Incidental Blend uses a degree of caustic leaching similar to that previously assumed in the WTP by using a 3 M free [OH^-] starting concentration as discussed in the WTP's Flowsheet Bases, Assumptions, and Requirements document (24590-WTP-RPT-PT-02-005, Rev. 2). Since the Incidental Blend model tracks the free OH^-, in some cases leaching does not proceed to completion because the free OH^- is depleted. Note that in a recent assessment (D-04-DESIGN-005), it was determined that additional caustic would be needed in order to properly leach the aluminum and maintain it in solution in downstream processes.

1.4.4 Oxidative Leach Behavior

Oxidative leaching of chromium from the waste was modeled per RPP-15522, which states: "Independent of the starting concentration of chromium, oxidative leaching of Hanford tank waste will achieve less than 5000 μg Cr / g dried solids provided sufficient permanganate is added." The leach reaction on page B-21 of the reference was used to estimate the amount of permanganate to be added to the sludge – one mole of solid MnO_2 was formed for every mole of chromium leached from the sludge. Since a process flowsheet has not yet been developed for oxidative leaching, this sensitivity study did not address partitioning of analytes other than chromium during oxidative leaching, and no competing reactions were addressed.

[3] Three tanks (B-107, T-105, and T-107) in addition to those listed in the TFCOUP are being controlled as candidates for packaging as TRU waste per HNF-SD-WM-OCD-015, Rev 11, Appendix A, Table A-1, Feed Control List. These three tanks were treated as HLW in this sensitivity study to maintain consistency with the TFCOUP. Therefore, this analysis will understate the benefit from packaging this candidate TRU waste for disposal at WIPP.

1.4.5 Solid-Liquid Separation

The calculations for the No Blend, Total Blend, and Farm Blends assume perfect solid-liquid separation during washing, leaching, and oxidative leaching to simplify the analysis. The Incidental Blend assumes a more realistic degree[4] of solid-liquid separation and post-leach wash effectiveness based on that expected in the WTP (HNF-SD-WM-SP-012, Revision 5A, Appendix A, A2.2.8).

1.4.6 Glass Property Model (GPM)

This study formulated HLW glass compositions using the same mathematical model and computer code that was used for the RPP System Plan (ORP-11242, Revision 2) and the TFCOUP (HNF-SD-WM-SP-012, Revision 5A). The references for the various property models and constraints are taken from a variety of sources and are consolidated in RPP-18592. The physical property constraints used in the analysis are summarized in Table 1. Glass Property Constraints. The terms "default" and "relaxed," identified in Table 1, refer to two levels of parameters as used in Table 3. Study Matrix for Parametric Analysis (see Section 2.1). The "relaxed" levels, discussed in Section 2.3.6.4 of the System Plan (ORP-11242), incorporate potential improvements in the HLW waste oxide loading by relaxing the glass viscosity, Cr_2O_3 solubility, and the spinel liquidus temperature constraints. The melter was assumed to operate at a nominal temperature of 1150 °C. The "default" levels are the more conservative levels that had been previously used for HLW glass projections.

Table 1. Glass Property Constraints.

Property	Lower Limit	Upper Limit
Liquidus Temperature (Spinel)	850 °C	1100 °C (relaxed) 1050 °C (default)
Liquidus Temperature (Zircon)	None	1050 °C
Melt Viscosity at 1150 °C	4.5 Pa·s	10 Pa·s (relaxed) 5.5 Pa·s (default)
PCT (B, Li, Na)	None	2 g/m^2
Nepheline precipitation rule $\frac{[SiO_2]}{[SiO_2]+[Al_2O_3]+[Na_2O]}$	0.62	None

The requirements for Product Consistency Test (PCT) releases are 8.35, 4.79, and 6.68 g/m^2 for B, Li, and Na, respectively, based on the U.S. Environmental Protection Agency (EPA) Environmental Assessment (EA) glass standard material releases. However, it is typically set at 2 g/m^2 for all components to account for uncertainties involved in the model prediction. The nepheline precipitation rule included in the glass property constraints in Table 1 is used to help avoid the formation of nepheline ($NaAlSiO_4$) type crystals during slow cooling of glass in the canister. Formation of nepheline may significantly increase the PCT releases, which cannot be

[4] Using Case 0 as a reference, it was determined that the pretreated waste resulting from the Incidental Blend contains about 10% more waste oxides than the No Blend, Total Blend, or Farm Blends.

predicted by the current models for PCT responses. According to Li et al. (1996), glasses with $[SiO_2]/([SiO_2] + [Al_2O_3] + [Na_2O]) \geq 0.62$ are less susceptible to nepheline formation, where the brackets [ ] represent the component concentration in mass fraction.

Additional constraints (Table 2) were also applied to either limit the glass composition to the approximate region of validity (domain) of the various property models, or to limit the allowable concentration of components that impact the waste oxide loading in the resulting glass. The limits in Table 2 should not be confused with those in Table TS-1.1 of the WTP contract (DE-AC27-01RV14136) which establishes minimum component limits in HLW glass for contractual purposes.

Table 2. Glass Composition Constraints.

	Component	Minimum (wt %)	Maximum (wt %)	Allowed as glass additive?
Model Domain	SiO_2	38.0	57.0	Yes
	B_2O_3	5.0	20.0	Yes
	Na_2O	5.0	20.0	Yes
	Li_2O	1.0	4.0	Yes
	Al_2O_3	None	17.0	Yes
	Fe_2O_3	2.0	15.0	Yes
	CaO	None	10.0	No
	MgO	None	8.0	No
	ZrO_2	None	15.0	No
Solubility	Cr_2O_3	None	0.5 (default) 1.0 (relaxed)	No
	P_2O_5	None	3.0	No
	SO_3	None	0.5	No
	$Rh_2O_3 + Ru_2O_3$	None	0.25[5]	No

The first nine constraints in Table 2 define the approximate composition range over which the glass composition property models are valid.

The last four constraints in Table 2 address the solubility of components (Cr_2O_3, P_2O_5, and SO_3) that could limit waste loading by causing product quality or glass processing problems, and noble metals ($Rh_2O_3 + Ru_2O_3$) that might precipitate from the glass. The solubility of these components strongly depends on glass composition. However, there are no models that accurately predict their upper limits as a function of glass composition. Therefore, it is customary to use a single limiting value for each troublesome component as given in Table 2. The upper limits of 1 wt% for Cr_2O_3 ("relaxed") and 3.0 wt% for P_2O_5 are the same or close to

[5] An older limit of 2.5-wt% taken from the Composition Variability Study (PNL-10359, Vol. 1) was inadvertently used for this sensitivity analysis. This has a negligible impact on the results of the sensitivity analysis since only one source tank (TY-102) exceeded the 0.25-wt% limit with a concentration of 0.32-wt%. This represents an increase in HLW (across all cases) of approximately 20 MT glass.

the limits used in a previous study (PNNL-13582) (2.5 wt% for P_2O_5). However, the limit of 0.5 wt% for SO_3 is lower than used in that study of 0.8 wt%.

The limit on the combined concentrations of Rh_2O_3 and Ru_2O_3 is used to avoid noble metal accumulation in the melter, which could cause melter operational problems. The limit of 0.25 wt% is based on the WTP contract (DE-AC27-01RV14136) design basis. However, this concentration of noble metals has not been successfully processed in similarly designed melter systems. The previous study (PNNL-13582) used more conservative limit of 0.1 wt% which is not expected to make any practical difference because only three batches would become limited by noble metal constraint.

2.0 IMPACTS ON HIGH-LEVEL WASTE GLASS MASS

2.1 INTRODUCTION

A parametric analysis of high-level waste glass (HLW) mass was performed. The HLW glass masses for a variety of blending Subcases ("Total Blend", "No Blend", "Farm Blend" and "Incidental Blend") were calculated for various Cases (combinations of other factors). The factors and their associated levels for each Case and the blending Subcases are detailed in Table 3. Study Matrix for Parametric Analysis. The shaded cells indicate the factors and levels for each Case and the selected blending Subcases.

Case 0 represents the current baseline (BL) as defined in the TFCOUP, Revision 5A. For this study, Case 5, which incorporates the revised wash and leach factors and oxidative leaching, is assumed to represent a future baseline. Therefore, Case 5 was used as an operating point[6] (OP) for further analysis in Section 3.0, Drivers for Glass Mass and Blending and Section 4.0, Degree of Pretreatment. Case 5 also includes a Farm Blend and Incidental Blend subcase. The Incidental Blend subcase for Case 5 required a rerun of the Hanford Tank Waste Operations Simulator (HTWOS) model used for TFCOUP, Revision 5A, using the updated factors and levels.

The remaining cases are used to help understand the response of the HLW glass masses to changes in the other factors.

[6] In this context, an "operating point" is a reference case around which further calculations are performed.

Table 3. Study Matrix for Parametric Analysis.

	Factors and Levels								Sub-Case			
	W&L		OL		GPM Limits		Inventory		Blending			
Case	Baseline	New	No	Yes	Relaxed	Default	All	Less TRU	Total	No	Farm	Incidental
0 - BL												
1												
2												
3												
4												
5 - OP												
6												
7												

W&L = Water Wash and Caustic Leach Factors
- Baseline = Existing values in TFCOUP Rev 5A
- New = Updated with revised Cr and Al values

OL = Oxidative Leach
- No = No oxidative leaching (baseline)
- Yes = Oxidative leaching applied

GPM Limits = Glass Property Model Limits
- Relaxed = Existing values in TFCOUP Rev 5A and System Plan Rev 2.
- Default = Standard published values

Inventory = Quantity of Sludge directed to WTP
- All = all sludge, including TRU waste
- Less TRU = All sludge, less tanks thought to contain sludge suitable for treatment and disposal as TRU

Blending = Degree of Waste Blending
- No = no blending between tanks
- Farm = each farm is blended together
- Total = all tanks are blended together
- Incidental = blending occurring as a consequence of retrieval and feed staging activities (modeled via HTWOS model).

Note: The shaded cells indicate the factors and levels for each Case and the selected blending Subcases.

2.2 METHODOLOGY

The approach used in this portion of the analysis was to calculate and compare the mass of HLW glass that would be produced for the various cases, varying the factors as shown in Table 3. For example, a comparison of the mass of HLW glass produced by Case 0 with Case 3 will show the impact of using the revised wash and leach factors while a comparison of Case 0 with Case 5 will show the overall impact of using the revised wash and leach factors along with oxidative leaching. These comparisons are discussed in Section 2.3.

One of the major drivers for HLW glass mass is the degree of blending that occurs before vitrification of the waste. Therefore, a series of blending subcases (discussed in Section 2.1) were used to control for blending and to facilitate the comparisons. These Subcases were the

Total Blend, No Blend, Farm Blend, and Incidental Blend. The following is a detailed description of how these methods were employed.

For the Total Blend, the wastes from all the tanks were blended together to create a single large uniform batch of feed. This feed was processed according to the specific case assumptions, and the corresponding amount of HLW glass was determined for each case.

For the No Blend, the waste from each tank was kept segregated in separate batches. Each of these individual tank batches was processed separately according to the specific case assumptions, and the corresponding amount of HLW glass was determined for each tank for each case. The total amount of HLW glass produced for a given case was determined by summing the HLW glass produced from each of the tanks.

The Total Blend and No Blend glass masses are hypothetical because neither subcase can be realistically achieved. For glass models that only include single component solubility limits and model domain limits, the Total Blend represents the minimum glass that can be produced and the No Blend represents the maximum glass. The introduction of non-linear glass properties as used by the current glass properties model confounds this interpretation in that the Total Blend and No Blend do not necessarily provide the absolute mathematical minimum or maximum glass masses. In any case, for most intents and purposes, the Total Blend and No Blend glass masses can be considered as representing the minimum and maximum glass masses for a given case.

For the Farm Blend, the wastes from each tank within a given tank farm were blended together to create a uniform batch of HLW feed. Each of these tank farm batches was processed separately according to the specific case assumptions, and the corresponding amount of HLW glass was determined for each farm for each case. The total amount of HLW glass produced from all of the batches is determined by summing the HLW glass contributions from each tank farm. The Farm Blend is a hypothetical blending subcase that attempts to show how the tendency to want to retrieve and close tanks on a farm-by-farm basis, would, in the extreme, influence the HLW glass mass.

For the Incidental Blend, the HTWOS model was used to simulate the delivery of HLW feed to the WTP using the baseline retrieval sequence logic, and waste feed staging and delivery strategy. The HTWOS model accounts for the blending that occurs during the retrieval, staging, and delivery of each feed batch to the WTP (most of this blending is incidental to those activities, hence the term Incidental Blending). Each of these individual feed batches (numbering between 400 – 500 feed batches with about 121 unique compositions) was processed separately according to the specific case assumptions, and the corresponding amount of HLW glass was determined for each batch for each case. The total amount of HLW glass produced for a given case was determined by summing the HLW glass produced from each of the feed batches.

The degree of incidental blending is driven by the specific SST retrieval sequence and timing, and the overall configuration of the waste retrieval and staging system. The Incidental Blend represents our best estimate of the HLW glass mass that would result given the assumptions for each Case.

2.3 DISCUSSION

The detailed results (Total Blend, No Blend, Farm Blend and Incidental Blend glass masses, along with the contributions from each farm and tank) for each case are shown in Appendix A, Table A-1 and summarized on Figure 1.

Figure 1 depicts the HLW glass mass[7] ranges defined by the Total Blend and No Blend results for each combination of factors and levels, along with the Farm Blend and Incidental Blend results for select cases. The figure also shows the major differences between the cases to facilitate comparison.

The following discussion reviews the results with several case-by-case comparisons. The percent change in HLW glass mass is given as a range that represents the minimum and maximum percent difference based on the different blending scenarios.

Case 5 versus Case 0. Case 0, the baseline case, calculated the HLW glass mass using the baseline wash and leach factors, no oxidative leaching, the relaxed GPM limits, and an inventory which does not include the TRU tanks ("less TRU"). Case 5 calculated the glass mass using the revised wash and leach factors, oxidative leaching, the relaxed GPM limits, and the "less TRU" inventory. Comparing these two cases showed that the revised wash and leach factors together with oxidative leaching had almost no impact on the mass of HLW glass produced.

Case 1 versus Case 0. Case 1 shows the effects of using the complete inventory, which includes the TRU tanks. Case 1 results showed that the HLW glass mass increased by 14 – 16% over that in Case 0 with the addition of the TRU tanks.

Case 2 versus Case 0. Case 2 shows the effect of using the default GPM limits with the baseline wash and leach factors. With all other factors the same, Case 2 resulted in a 19 – 21% increase of HLW glass over that in Case 0.

Case 3 versus Case 0. Case 3 was modeled using the revised wash and leach factors, no oxidative leaching, the relaxed GPM limits, and the "less TRU" inventory. Comparison with Case 0 shows that the addition of the revised wash and leach factors increases the HLW glass mass by 63 – 106 %.

Case 4 versus Case 0 and Case 3. Case 4 calculated the HLW glass mass using the revised wash and leach factors, no oxidative leaching, the default GPM limits, and the "less TRU" inventory. Using Case 0 as a comparison shows that the revised wash and leach factors coupled with the default GPM limits results in a 150 – 300% HLW glass increase. Comparison with Case 3 shows that the increase in glass mass solely due to returning to the default GPM limits was 57 – 100%.

[7] The equivalent number of HLW canisters can be calculated from the glass mass by dividing by 3.2 MT glass per thin-walled canister (see assumption C3.4.11, Appendix C, of the RPP System Plan).

Case 5 versus Case 3. Case 5, as described above, was modeled using the revised wash and leach factors, oxidative leaching, the relaxed GPM limits, and the "less TRU" inventory. Comparing Case 5 with Case 3 shows that oxidative leaching results in a 40 – 51% decrease of HLW glass.

Case 5 versus Case 0 and Case 3. An overall comparison of Case 5 versus Case 0 showed that the increase in HLW glass caused by the revised wash and leach factors as seen in the Case 5 versus Case 3 comparison can be offset with the addition of oxidative leaching.

Case 6 versus Case 5. Case 6 calculated the HLW glass mass using the revised wash and leach factors, oxidative leaching, the default GPM limits, and the "less TRU" inventory. A comparison with Case 5 shows only a 2 – 5% increase in HLW glass was caused by the default GPM limits. Switching to the default GPM limits had almost no effect on the mass of HLW glass produced when the revised wash and leach factors were coupled with oxidative leaching.

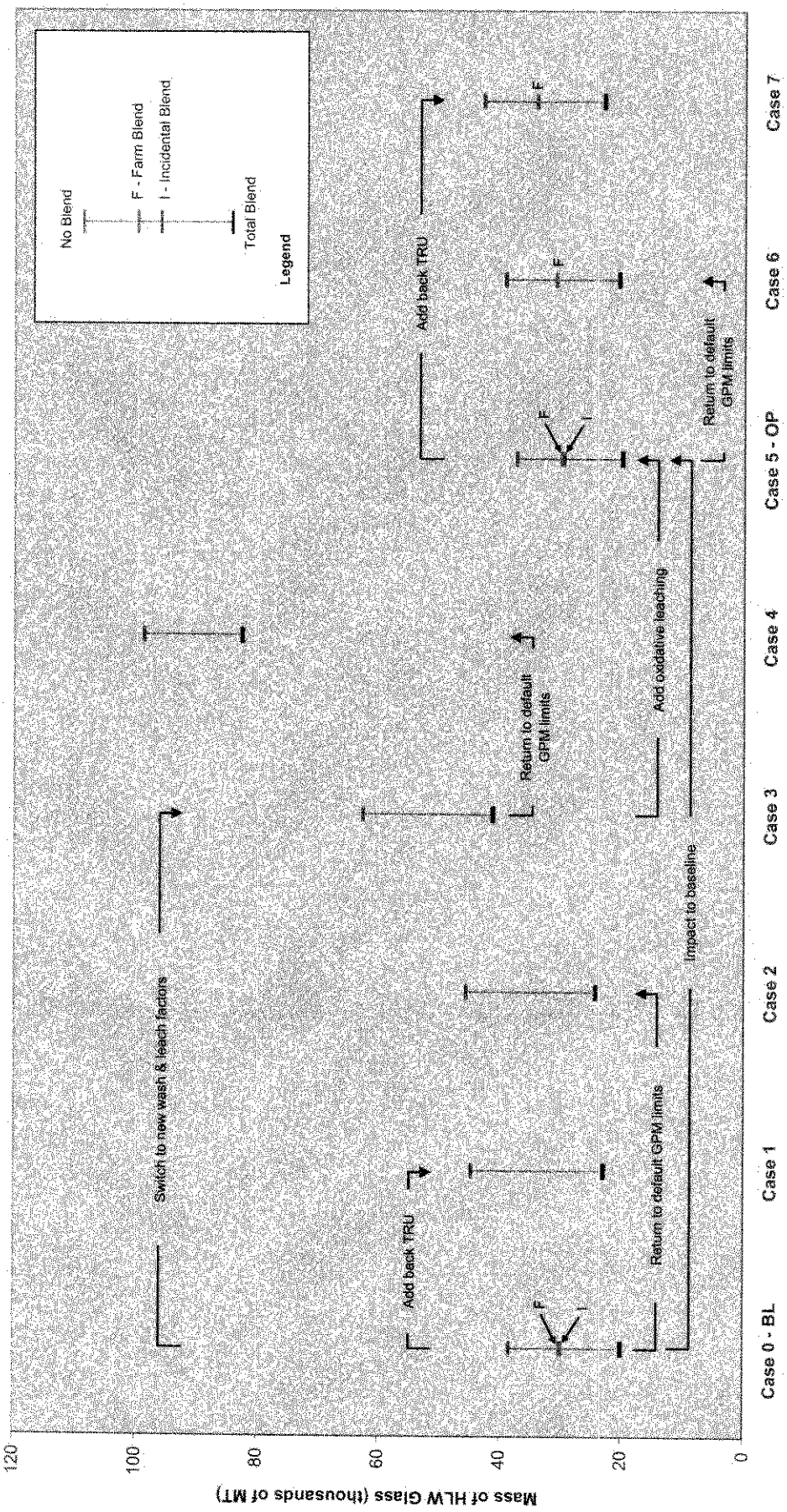
Case 7 versus Case 5. Case 7 was modeled using the revised wash and leach factors, oxidative leaching, the relaxed GPM limits, and the complete inventory. A comparison with Case 5 shows that adding the TRU tanks[8] to the inventory results in a 15% increase (3,044 MT based on the total blend subcase) to the HLW glass mass. This is roughly the same percent increase as was seen in Case 1 with the baseline wash and leach factors and no oxidative leaching.

Relaxed versus Default GPM Limits. Three case comparisons were made that looked at how the change in HLW glass mass was affected by two sets of GPM limits. The Case 2 (default) versus Case 0 (relaxed) comparison showed a 19 – 21% glass mass increase; both used the baseline wash and leach factors and no oxidative leaching. The Case 4 (default) versus Case 3 (relaxed) comparison showed a 57 – 100% increase; both used the revised wash and leach factors and no oxidative leaching. The Case 6 (default) versus Case 5 (relaxed) comparison showed only a 2 – 5% increase; both used the revised wash and leach factors and oxidative leaching.

The relative impact of the two sets of GPM limits is driven by the amount of chromium that has been removed from the waste. Setting the GPM limits to the default changes the Spinel Liquidus Temperature, the maximum Cr_2O_3 weight percent, and the maximum viscosity. Both the Spinel Liquidus Temperature and the Cr_2O_3 weight percent are sensitive to the increase in chromium. Therefore, more glass was produced with the revised wash and leach factors which remove less chromium from the waste.

[8] Three tanks (B-107, T-105, and T-107) in addition to those listed in the TFCOUP are being controlled as candidates for packaging as TRU waste per HNF-SD-WM-OCD-015, Rev 11, Appendix A, Table A-1, Feed Control List. These three tanks were treated as HLW in this sensitivity study to maintain consistency with the TFCOUP. Therefore, this analysis will understate the benefit from packaging this candidate TRU waste for disposal at WIPP.

Figure 1. HLW Glass Mass Ranges.



3.0 DRIVERS FOR GLASS MASS AND BLENDING

3.1 INTRODUCTION

The glass limit report for the Case 5 was reviewed to identify the specific constraints and analytes that may be driving the HLW glass mass under the assertion that oxidative leaching will diminish the importance of chromium in driving the HLW glass mass. Patterns in the distribution of these analytes among the different tanks may suggest alternative approaches towards blending or segregation and suggest which water wash and caustic leach factors should be reevaluated in future work.

3.2 METHODOLOGY

In each HTWOS run, glass formulation is optimized for each waste feed batch by adjusting the composition and fraction of glass additive until the maximum waste loading (minimum glass mass) is achieved while satisfying the glass property and glass composition constraints listed in Table 1 and Table 2. For example, if a certain property constrained the loading of a particular waste, the additive composition would be adjusted until at least one additional property constraint or model validity constraint is met. The optimization stops when no additional adjustment of additive composition (within the tolerance limits for model convergence) can be found that will increase the waste loading while meeting the model validity constraints. Therefore, when the waste loading is limited by property constraints, at least one of the model validity constraints is always met. In this case, the glass formulation results in a unique glass composition. If the waste loading is limited by one of the composition constraints before any property constraint is met, that is the only constraint, and optimization does not generate a unique glass composition.

The 153 waste feed batches involved in Case 5 – No Blend were divided into different groups depending on the constraints that limit the waste loading of each batch. These are discussed in the next section.

3.3 DISCUSSION

3.3.1 Case 5 (No Blend Subcase)

As explained in the previous section, the 153 waste feed batches involved in Case 5 – No Blend were divided into different groups depending on the constraints that limit the waste loading of each batch. Table 4 summarizes the number of waste feed batches, waste oxide mass, glass mass, and waste loading for each group of waste batches that are limited by the same constraint. More details are provided in Table B-1, Appendix B.

Table 4. Summary of Case 5 (No Blend Subcase) Results.

Constraints			Number of waste feed batches	Waste oxide mass (MT)	Glass mass (MT)	Waste loading in glass*
Glass composition constraints	Solubility limited	SO_3	52	2564.7	16820.5	0.152
		P_2O_5	10	745.5	2934.3	0.254
		Cr_2O_3	3	104.5	242.0	0.432
		Subtotal	65	3414.8	19996.9	0.171
	Model validity limited	Al_2O_3	21	1084.4	4211.0	0.258
		Fe_2O_3	17	1011.1	3502.1	0.289
		CaO	2	198.0	679.7	0.291
		Na_2O	3	347.4	1228.8	0.283
		SiO_2	3	136.2	182.0	0.748
		Subtotal	46	2777.2	9803.6	0.283
	Glass composition constraints subtotal		111	6191.9	29800.5	0.208
Glass property constraints	Spinel T_L involved		38	2520.6	7025.1	0.359
	Spinel T_L NOT involved		4	190.7	677.2	0.282
	Glass property constraints subtotal		42	2711.3	7702.3	0.352
Total			153	8903.2	37502.8	0.237
Total Blend			--	8903.2	20054.9	0.444

Note: *Represents the weighted average waste loading in the glasses with the batches that are limited by the same (or same group of) constraints.

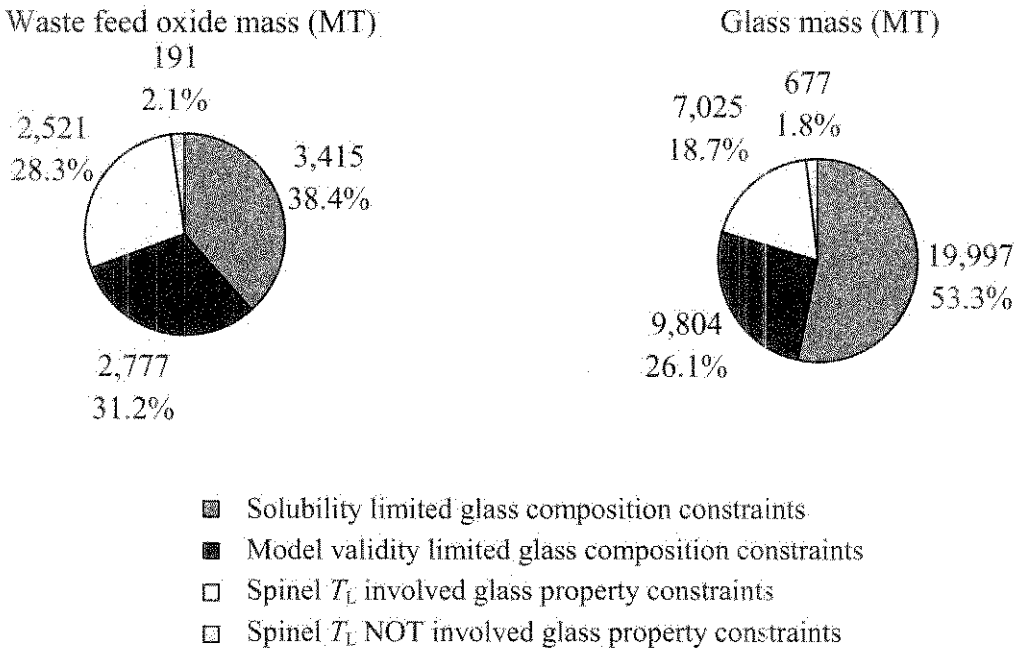
Among glass composition constraints, SO_3 constraint was the main driver that limited waste loading based on the large number (52 out of 153) of waste feed batches and the low weighted average waste loading of 0.15. This very low average waste loading in these glasses implies that any relaxation of the SO_3 constraint (or increase in SO_3 incorporation in glass) has a very high potential for waste loading increase. Likewise, any changes in the partitioning assumptions for sulfate would affect the HLW glass mass. The next significant composition constraints that have impact on waste loading were the Al_2O_3 and Fe_2O_3 constraints. The average waste loadings in these glasses are moderate (e.g., compared to the spinel T_L involved glass property constraint), which suggests that the reduction of glass mass expected from expanded model validity (i.e., relaxed Al_2O_3 and Fe_2O_3 constraints) will not be significant (e.g., compared to SO_3 limited wastes). In addition, there is not much room to expand the model validity range considering that such an expansion can shift the composition to outside of the glass forming region (easy and fast crystallization). If additional aluminum was removed during caustic leaching, then the HLW glass mass would be reduced. The Cr_2O_3 constraint was not a significant driver at all with only three batches limited by Cr_2O_3 and the high weighted average waste loading at 0.43, suggesting that the oxidative leaching is effective in preventing the chromium concentration from being a

major constraint for waste loading. However, only a limited number of HLW sludges have been tested to support the oxidative leaching assumptions.

As mentioned before, the wastes that are limited by the property constraints are limited by more than one constraint with at least one of the model validity constraints involved. For the current Case 5 (No Blend), the waste loading is limited by one, two, or three constraints in addition model validity constraint(s). Among the 42 batches that are limited by property constraints, 38 batches involved the spinel T_L constraint which was the major limiting property in Hanford Site waste in a previous study (PNNL-13582). It was shown in PNNL-13582 that the increase of waste loading by relieving or removing the constraints other than T_L is smaller compared to the Spinel T_L constraint. Based on this past study, it is expected that the spinel T_L constraint would be the most dominant driver for glass mass in the 38 batches with the T_L spinel constraint involved. There are four batches that are limited by the constraints other than spinel T_L and account for only a very small fraction of glass mass. As expected, the zircon T_L constraint was never met. This is because the high zirconium waste contained in tanks AW-103 and AW-105 are designated as remote-handled TRU tank waste. Since both the remote-handled and contract-handled TRU tank wastes are assumed to be treated and packaged for disposal at WIPP, the WTP does not receive a HLW feed that would be constrained by the zircon T_L property constraint.

The distribution of waste feed mass and glass mass for four major groups of wastes are plotted in Figure 2. Figure 2 shows that the solubility limited glass composition constraints are the main drivers for the glass mass and account for 53.3% of total glass mass resulting from 38.4% of waste feed. Especially, as shown in Table 4, it can be seen that the SO_3 constraint is the single most dominant driver for the glass mass. Recently, the study of sulfate loading in Hanford Site low-activity waste (LAW) glasses by Vienna et al. (2004) (PNNL-14649) concluded that it is possible to process the glass with 0.8 wt% SO_3 without sulfate segregation. The same 0.8 wt% SO_3 loading was used as an upper limit in a previous sensitivity study on HLW glass volume (PNNL-13582) although there are differences in chemical compositions between LAW and HLW. However, the PNNL-14649 study also suggests that the 0.8 wt% SO_3 loading may only be achieved through careful glass formulations within certain composition region, which may not be feasible for some wastes due to other constraints, especially for HLW. If it is concluded that the SO_3 is still the major driver in the final pretreatment plan, it would be necessary to perform a systematic study to accurately predict the SO_3 loading as a function of glass composition.

Figure 2. Distribution of Waste Oxide Mass and Glass Mass for Each Group of Batches in Case 5 (No Blend).



In summary of the Case 5 (No Blend) results, SO_3 concentration is a major constraint whereas Cr_2O_3 concentration is limiting for only 3 out of the 153 waste feed batches, less than 1% of the HLW glass mass for the No Blend subcase. This is reversed from the previous result (PNNL-13582) in that the Cr_2O_3 was the main driver, and no waste was limited by SO_3, which can be mainly attributed to the effect of oxidative leaching.

Below is a qualitative discussion on the effect of various blending scenarios, specifically illustrated for the current Case 5 results, to identify the major factors that need to be considered for developing a sensible blending strategy without performing time-consuming quantitative calculations. For simplicity of discussion, the scenario of blending two wastes is illustrated. The following discussion also assumes the wastes being blended have similar masses to further simplify the analysis.

1. Blending of waste feeds limited by glass composition constraints.
   - If both wastes have the same constraint (e.g., SO_3 concentration), there will be no impact of blending on waste loading.
   - If the wastes have different glass composition constraints, there is a high potential for increased waste loading based on the dilution of the concentration of limiting components in each waste by the other waste. The benefit will be maximum when the concentrations of the constraint component in the other feed is zero in each waste (e.g., the waste with SO_3 constraint has zero P_2O_5 while the waste with P_2O_5 constraint has zero SO_3),

assuming the glass properties are relatively away from the limits. For the present Case 5, it is likely that the glass property constraint will be met only after significant increase of waste loading provided that the concentration of other major components in these wastes are not grossly different from those in the wastes limited by glass property constraint. This assumption is reasonable considering a very low average waste loading in feeds limited by SO_3, Al_2O_3, or Fe_2O_3 constraints as compared to feeds limited by glass property constraints.

2. Blending of waste feeds limited by glass property constraint in at least one waste.
   - In principle, blending of the wastes with the same property constraint will not increase the waste loading significantly. Minimal increase of waste loading is possible due to the dilution effect of major components that limit the waste loading by model validity range constraints. In Case 5 (No Blend) results, the majority of the wastes involve spinel T_L constraint, which implies that the blending of the wastes limited by property constraints would not cause any significant increase of waste loading.
   - In the case of blending of wastes with different property constraints or blending of a waste limited by glass composition constraint with a waste limited by glass property constraint, the increase of waste loading will be determined by the difference between the predicted property or limiting component concentration and the limiting constraints. This case has, in general, a greater potential for increased waste loading than the case of blending of the feeds with the same property constraint discussed above.

In summary, the blending of wastes with different glass composition or glass property constraints is likely to offer significant increase in waste oxide loading, whereas little or no increase of waste loading is expected from blending of the wastes with the same glass composition constraints or with the same glass property constraints. The above discussion is based on a simplified qualitative discussion of blending two wastes. In principle, blending of multiple wastes with different constraints has better potential for increased waste loading compared to the blending of just two wastes, eventually leading to a theoretical maximum in the Total Blend subcase in Case 5. Table 4 shows that the Total Blend subcase decreases the glass mass by 47% from 37,501 MT in Case 5 No Blend subcase to 20,055 MT (see also Figure 1).

3.3.2 Case 5 (Incidental Blend Subcase)

Table 5 summarizes the number of waste feed batches, waste oxide mass, glass mass, and waste loading for each group of waste batches for the Case 5 Incidental Blend subcase. The incidental blending decreases the glass mass by 21% from 37,501 to 29,750 MT, which corresponds to the increase of total weighted average waste loading from 0.237 to 0.354 wt%. Figure 3 shows the distribution of waste feed mass and glass mass for four major groups of wastes for the Case 5 Incidental Blend subcase. The Incidental Blend subcase involves several model assumptions that are different from those used in all other subcases including the No Blend and Total Blend[9].

[9] These differences include less than perfect solid-liquid separation during the post-leach wash, insufficient free hydroxide to complete some of the leaching reactions, the treatment of remote-handled TRU heels, the addition of Sr and Mn for Envelope C processing, and an immobile heel in tank AY-102.

This increased the total waste feed oxide mass by 18% from 8,902 to 10,539 MT as shown in Table 5. More importantly, there is no one-to-one correspondence between the feed batches for the Incidental Blend and the source tanks for the No Blend subcase. Therefore, it is not possible to perform a "batch-to-batch" analysis of how the waste loading and its drivers change between the No Blend and Incidental Blend subcases on an absolute basis; relative comparisons must be used. The following discussion is based on the comparison of waste feed and glass mass fractions in each group of waste feeds for baseline and Incidental Blend subcases.

Compared to the Case 5 No Blend subcase shown in Figure 2, the Incidental Blend subcase shown in Figure 3 decreases the mass fraction of the waste feeds with the model validity limited glass composition constraints and corresponding glasses, apparently shifting this group of waste feeds to the remaining three groups, especially to two major groups of waste feeds: solubility limited glass composition constraints and spinel T_L involved glass property constraints. The incidental blending increases the waste loading in all groups and subgroups of waste feeds. The most significant increase is achieved in the waste feeds limited by the SO_3 constraint, increasing the waste oxide loading from 0.152 in the No Blend to 0.300 wt%. This is in general agreement with the qualitative discussion above in Section 3.3.1 that the most potential benefit is likely from blending of wastes with different glass composition constraints. Another significant increase in waste loading is observed in the waste feeds with spinel T_L NOT involved glass property constraints from 0.282 to 0.489 wt%. However, the fraction of the waste feeds in this group is much smaller than those in the two major groups of waste feeds.

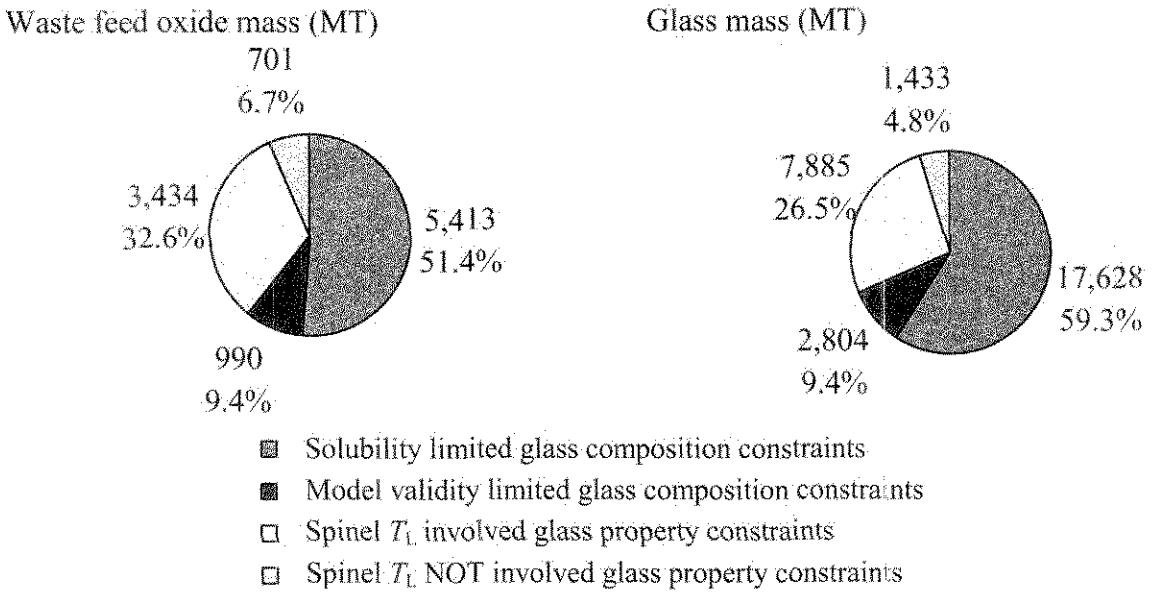
The increase of waste loading by current incidental blending based on the baseline retrieval sequence and feed delivery logic is roughly at a point halfway to the theoretical maximum of the total blending. In general, the retrieval sequence and staging strategy will affect the extent of blending and, therefore, the glass mass. The decision on additional efforts to increase the extent of blending should be made based on the balance between the required resources and associated constraints imposed on the SST retrieval and closure plans for the additional blending and the benefit gained from the increased waste loading. This balance is especially important considering that the benefit of any further increase in the extent of blending is likely to diminish as the average waste loading increases.

Table 5. Summary of Case 5 Incidental Blend Subcase Results.

Constraints			Number of waste feed batches	Waste oxide mass (MT)	Glass mass (MT)	Waste loading in glass*
Glass composition constraints	Solubility limited	SO_3	40	4006.1	13349.4	0.300
		P_2O_5	13	1407.0	4278.5	0.329
		Cr_2O_3	0			
		Subtotal	53	5413.1	17627.9	0.307
	Model validity limited	Al_2O_3	6	647.2	1909.3	0.339
		Fe_2O_3	10	256.7	688.5	0.373
		CaO	0			
		Na_2O	1	86.4	205.9	0.420
		SiO_2	0			
		Subtotal	17	990.3	2803.7	0.353
	Glass composition constraints subtotal		70	6403.4	20431.7	0.313
Glass property constraints	Spinel T_L involved		43	3434.0	7885.1	0.436
	Spinel T_L NOT involved		8	701.0	1432.9	0.489
	Glass property constraints subtotal		51	4135.0	9318.0	0.444
Total			121	10538.5	29749.7	0.354

Note: *Represents the weighted average waste loading in the glasses with the batches that are limited by the same (or same group of) constraints.

Figure 3. Distribution of Waste Feed Oxide Mass and Glass Mass for Each Group of Batches in Incidental Blending Subcase of Case 5.



3.3.3 Observations on Glass Model

The glass composition-property models used in this sensitivity study, and presented in RPP-18592 are out-of-date. Vienna et al. (2002) (PNNL-14060) developed and reported updated property models that are applicable to both HLW and LAW glasses for major properties including viscosity, PCT responses, and liquidus temperatures (T_L) for spinel and zircon. The HLW melter study conducted by Perez et al. (2001) (PNNL-13582), similar to the current sensitivity study, showed that the spinel T_L constraint is one of the major limiting constraints for Hanford Site HLW because of relatively high concentrations of Fe_2O_3, NiO, and Cr_2O_3. A recent study by Vienna et al. (2003) (WTP-RPT-085) focused only on the liquidus temperature of spinel crystals and developed the improved models using additional data. These updated models should give a more accurate estimate of the glass properties and, therefore, the glass mass for similar studies in the future.

The T_L constraints of 1050 °C ("default") or 1100 °C ("relaxed") used in this study are higher than used in the previous study (PNNL-13582). Recently, Vienna et al. (2003) (WTP-RPT-085) suggested that it is more appropriate to use a constraint based on $T_{0.01}$, defined as the temperature at which the total volume fraction of crystals in glass is 0.01, rather than T_L. This is based on past studies by Hrma and colleagues (Hrma et al. 2001; Schill et al. 2001; and VSL-01R2540-2), who reported that crystal layer growth at the melter bottom is much more sensitive to crystal size and fraction than T_L. The current proposed constraint at the WTP is that $T_{0.01}$ should remain below the limit of 950 °C. It is likely that this constraint would result in higher waste loading than the current the $T_L \leq 1100$ °C ("relaxed") constraint.

The viscosity constraint of 4.5 to 5.5 Pa·s ("default") or 4.5 to 10 Pa·s ("relaxed") at 1150 °C used in this study is much tighter than that used in the study by Perez et al. (2001) (PNNL-13582), which used more typical range of 2 to10 Pa·s at 1150 °C. The lower viscosity limit of 4.5 Pa·s seems too conservative and may also be relaxed to provide higher waste loading in future studies.

The model validity composition range should also be changed if the updated glass composition-property models are used. The newer models with more glass data are likely to expand the valid concentration ranges.

Not included in this study is the constraint on the release of toxic metals from the glass. The HLW glass is intended for disposal at the proposed geologic repository, which will not accept hazardous wastes for disposal. One of the criteria typically applied to determine whether a material is toxic is the release of certain toxic elements under the conditions of the EPA Toxicity Characteristic Leaching Procedure (TCLP) (62 FR 26041). Recently, models to predict the TCLP releases have been developed and reported in PNNL-14061 and VSL-03R3780-1. Preliminary observation of glass compositions from the Case 5 results suggests that the TCLP constraints may limit the oxide loading of some of the waste batches. It is recommended to include the TCLP constraints in future studies for more accurate estimation of the glass mass.

4.0 DEGREE OF PRETREATMENT

4.1 INTRODUCTION

This section identifies which tanks contain waste that could benefit from different degrees of pretreatment (caustic and/or oxidative leaching). Since tank waste is not delivered without significant amounts of incidental blending, this information cannot be used to predict the required degree of pretreatment for a specific batch of feed delivered to the WTP. Additionally, only a simple screening process was used – a cost / benefit analysis was not performed. None-the-less, this tank-by-tank analysis may suggest general trends in the required degree of pretreatment.

4.2 METHODLOLGY

Tanks were screened by comparing tank-by-tank glass masses under different pretreatment assumptions – water wash only (Case A[10]); water wash plus caustic leach (Case B); and water wash, caustic leach and oxidative leach (Case C); and water wash plus oxidative leach (Case D). All four cases used the revised wash factors, the relaxed glass property model limits, and the total tank inventory. The revised caustic leach factors were used for cases in which a caustic leach is performed; the oxidative leach assumptions were used for the cases in which an oxidative leach is performed. Case C is the same as Case 7 from Section 2.0, Impacts on High-Level Waste Glass Mass.

The metric selected to compare the different cases is the percent increase in HLW glass mass – differences greater than maximum of 10% of the minimum glass mass for a specific tank or $1/177^{th}$ of 10% of the minimum for the No Blend Case were assumed to represent a significant difference. The degree of pretreatment was assumed to be the least amount of pretreatment that yields a glass mass not significantly different from the minimum glass mass for a specific tank. This is discussed in more detail in Appendix C.

Table 6. Study Matrix for Degree of Pretreatment.

	Factors and Levels			
	Caustic Leach		Oxidative Leach	
Case[10]	No	Yes	No	Yes
A				
B				
C				
D				

Note: Shaded cells indicate the selected levels

[10] Cases A, B, C and D are not related to feed envelopes A, B, C and D.

4.3 DISCUSSION

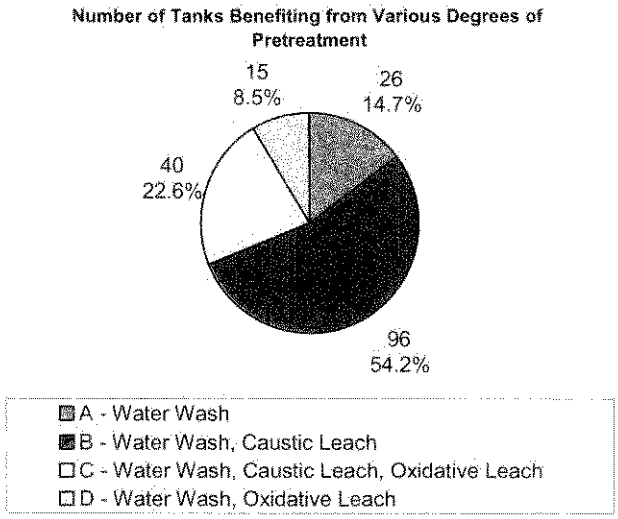
Table 7 and Figure 4 summarize the assumed degree of pretreatment for Hanford Site tank waste – the more detailed tank-by-tank results are presented in Table C-1 in Appendix C. All of the waste was assumed to require water washing. The majority of the tanks (about 80%) requires caustic leaching, either with (Case C) or without (Case B) oxidative leaching. Oxidative leaching provides a significant benefit when it is used in conjunction with caustic leaching.

The overall mass of glass resulting from the selected degrees of pretreatment (43,278 MT) is less than 1% larger than the water-washed, caustic-leached, oxidative leached No Blend mass for Case C (42,993 MT).

Table 7. Assumed Degree of Pretreatment.

Degree of Pretreatment	Tanks	% of Tanks	MT Glass	% of Total MT Glass
A	26	14.7%	6,055	14.0%
B	96	54.2%	28,266	65.3%
C	40	22.6%	7,932	18.3%
D	15	8.5%	1,026	2.4%
Totals	177	100.0%	43,278	100.0%

Figure 4. Assumed Degree of Pretreatment.



5.0 OPPORTUNISTIC SAMPLING

5.1 INTRODUCTION

A list of candidate tanks for opportunistic sampling and testing to confirm the inventory and better understand the partitioning behavior of chromium during retrieval, staging, and subsequent processing was developed. In this context, opportunistic sampling refers to taking additional grab samples during planned retrieval activities or sharing of samples that will be taken to support other activities such as retrieval and closure.

5.2 METHODOLOGY

The 177 tanks were sorted by decreasing chromium inventory. The tanks with the highest chromium inventory, that together account for 80% of the total inventory, are shown in Figure 5. Tanks which may be retrieved early in the mission, before the WTP begins operation, are identified with solid red bars. These tanks were taken from the draft pool of tanks selected for early retrieval as part of the M-45 negotiations. The rationale for this pool is described in RPP-21217. Table 8 is a list of the high chromium content M-45 pool tanks taken from Figure 5.

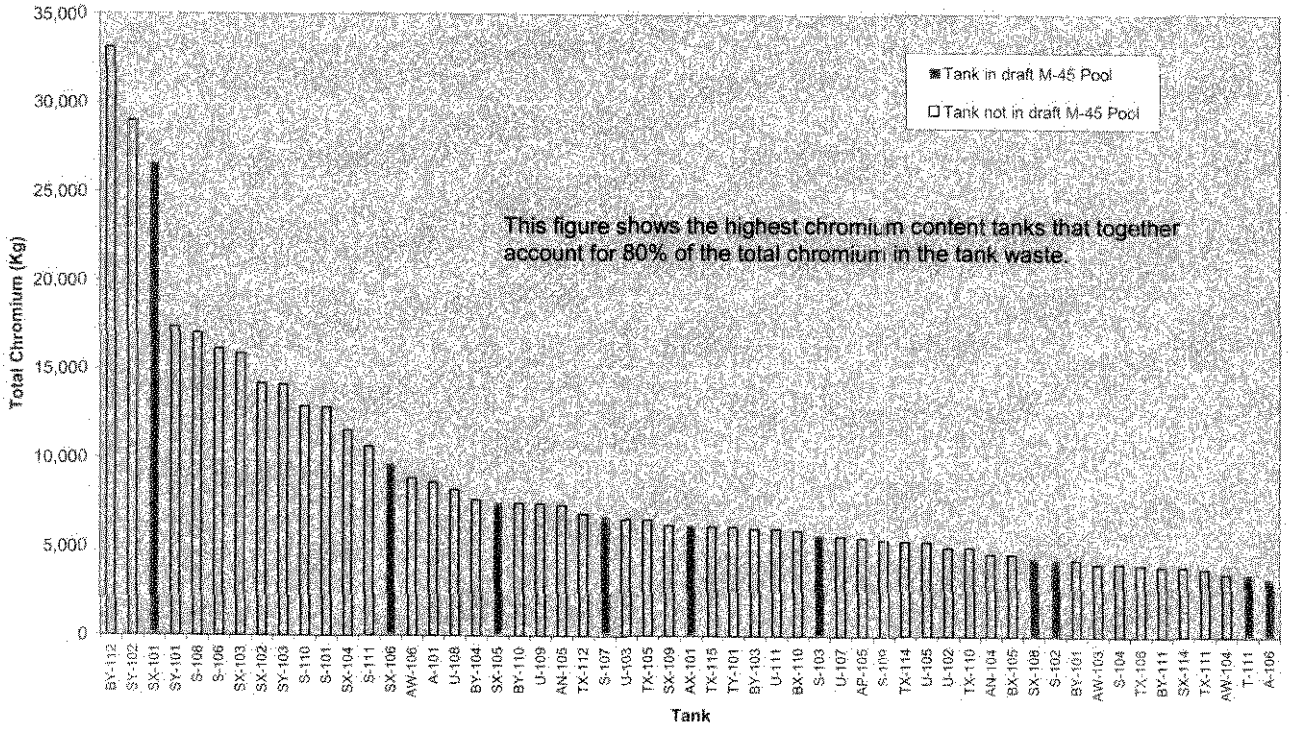
Table 8. Candidate Tanks for Opportunistic Sampling.

Tank	Cr (Kg)	Comments
SX-101	26,625	Cr inventory is sample-based.
SX-106	9,617	Cr inventory is sample-based.
SX-105	7,462	Cr inventory is sample-based.
S-107	6,670	Oxidative leaching studies with S-107 sludge samples have already been conducted and are reported in PNNL-11571.
AX-101	6,219	None.
S-103	5,657	None.
SX-108	4,380	Oxidative leaching studies with SX-108 sludge samples have already been conducted and are reported in PNNL-11571 and PNNL-11908.
S-102	4,303	None.
T-111	3,510	The waste in tank T-111 is designated as TRU waste and is planned for treatment and packaging for disposal at the WIPP. Tank T-111 contains a mixture of 2C and 224 waste types. Only one other tank, T-110, contains both these waste types.
A-106	3,262	None.

5.3 DISCUSSION

As explained in Section 5.1, the purpose of opportunistic sampling is to confirm the inventory and obtain a better understanding of the partitioning behavior of chromium during retrieval, staging, and subsequent processing. In order to do this (short of pulling full tank cores and performing laboratory testing), sufficient samples would need to be taken during and after retrieval to establish a mass balance around chromium. The difficulty and cost of doing this will vary depending on the selected retrieval technology and the details of the process flowsheet developed for that tank and the specific questions being asked. Therefore, at this time, no definitive statements can be made about the ability to obtain meaningful opportunistic samples.

Figure 5. Chromium Inventory by Tank – Top 80 Percent.



6.0 CONCLUSIONS, RECOMMENDATIONS AND CAVEATS

6.1 CONCLUSIONS

The following conclusions, addressing the points made in Section 1.2, Purpose, were reached:

- Application of the revised chromium and aluminum wash and leach factors will increase the HLW glass mass by about 60 to 100 percent (using the relaxed glass properties model) to about 150 to 300 percent (using the default glass properties model) above the baseline.
- The use of oxidative leaching for chromium removal, if implementable as assumed, will offset the increase in HLW glass mass resulting from the use of the revised chromium and aluminum wash and leach factors. The revised HLW glass mass estimate is comparable to the current ORP baseline. This study does not address the ability to implement an oxidative leaching process in the WTP, or impacts that such a process might have on pretreatment capacity or the overall process flowsheet – these factors should be addressed separately from this report.
- The major parameters affecting the glass mass will change from Cr_2O_3 solubility and spinel liquidus temperature (T_L) constraints to SO_3 solubility and spinel T_L constraints.
- The HLW glass mass will increase by about 15 percent (3,044 MT) if the TRU waste from fourteen SSTs and three DSTs currently designated for direct packaging is treated in the WTP as HLW, assuming a hypothetical total blend of all tank wastes. This represents an increase in mission duration of about 20 months at a net HLW production rate of 5 MT glass per day. For the hypothetical processing of wastes on a tank farm blend basis, processing the TRU tank wastes in the WTP will increase the HLW glass mass by about 4,170 MT (14 percent) and increase the mission duration by about 28 months. The effect of incidental blending on the HLW glass mass was not evaluated for a case that did not include the TRU tank wastes.
- All of the HLW sludge was assumed to require water washing. The majority (~80%) of the tanks requires caustic leaching, either with or without oxidative leaching. Oxidative leaching provides a significant benefit when it is used in conjunction with caustic leaching.
- Ten of the fifty tanks allocated for early retrieval as part of the M-45 pool of tanks contain a significant quantity of chromium and, thus, are candidates for opportunistic sampling and analysis.

6.2 RECOMMENDATIONS

The following recommendations, listed in no particular order, should be considered for future implementation (see PER 2004-3058).

- The revised water wash and caustic leach factors for chromium and aluminum should be adopted for mission planning purposes, either in conjunction with oxidative leaching

or another strategy to produce an acceptable quantity of HLW glass. This recommendation will bring the planning basis into alignment with the current technical understanding of the major factors affecting HLW glass.

- Review and select the appropriate glass property models and limits for future HLW glass mass projections for mission planning purposes. Consider a combination of the models presented in PNNL-14060 and WTP-RPT-085. These models should be augmented with a Toxicity Characteristic Leaching Procedure (TCLP) property constraint for use in predicting HLW glass waste loadings. Together, these should provide more accurate estimates of the mass of HLW glass, the specific drivers for the glass mass, and waste blending behavior.
- The sulfate partitioning assumptions used for mission modeling should be evaluated to verify that SO_3 really is limiting HLW glass waste oxide loading. Based on the results of this evaluation, studies to increase the sulfate loading in HLW may be determined to be beneficial in reducing the HLW glass mass.
- The feasibility of obtaining opportunistic samples to confirm the tank waste inventory and partitioning behavior of chromium during preparation of the process flowsheets for the ten high chromium content tanks identified for retrieval prior to commencing WTP operations (see Table 8) should be evaluated.
- Revisit the degree of pretreatment analysis on a feed batch basis rather than a source tank basis to see if there is an opportunity to apply less aggressive pretreatment to certain feed batches with little or no impact on HLW glass mass.
- Evaluate whether a simple blending strategy can be used to augment incidental blending to significantly reduce the HLW glass mass. The HLW glass mass for the incidental blend is about one-and-a-half times greater than the total blend; it may be possible to approach the total blend using simple blending strategies.

6.3 CAVEATS

The following limitations should be considered when interpreting or applying the results of this report:

- No assessment on the ability to implement an oxidative leaching process in the WTP, or impacts that such a process might have on pretreatment capacity or the overall process flowsheet has been made. The WTP has not completed an assessment of the partitioning of radionuclides, such as Pu and Am, from the sludge during oxidative leaching. These factors should be addressed as part of selecting a strategy for producing an acceptable quantity of HLW glass.
- The degree of pretreatment analysis does not take into account the incidental blending that will occur during retrieval and feed staging. It is not obvious if the results of a similar analysis using as-delivered feed batches would produce similar results.
- No assessment of the impact of the newer glass property models, including the TCLP model, on HLW glass mass was performed as part of this study.

7.0 REFERENCES

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APPENDIX A

IMPACTS TO HLW GLASS MASS

Table A-1 presents the mass of HLW glass for each of the cases defined in Table 3 (Section 2.1). First, the glass mass for each of the blending subcases (Total Blend, No Blend, Incidental Blend, and Farm Blend) are stated. Combinations of cases and subcases that were not included in Table 3 are indicated with a "--". Then, for cases which include the Farm Blend, the contributions from each farm are shown, otherwise a "--" is shown. Finally, for the No Blend subcase, the contributions from each tank are provided. A "--" is shown for tanks that are designated as candidate for TRU processing when those tanks are excluded from the inventory of waste to be treated at the WTP.

Table A-1. HLW Glass Production for Each Case.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)							
	0 – BL	**1**	**2**	**3**	**4**	**5 – OP**	**6**	**7**
Total	20,055	22,935	24,305	41,319	82,638	20,055	20,595	23,099
No	38,458	44,797	45,689	62,769	98,840	37,503	39,384	42,993
Incidental	29,938	--	--	--	--	29,750	--	--
Farm	30,097	--	--	--	--	30,073	31,016	34,242
A-Farm	683	--	--	--	--	683	683	683
AX-Farm	262	--	--	--	--	262	262	262
B-Farm	3,560	--	--	--	--	3,560	3,560	3,863
BX-Farm	1,688	--	--	--	--	1,696	1,830	1,696
BY-Farm	3,660	--	--	--	--	3,660	3,660	3,660
C-Farm	3,422	--	--	--	--	3,457	3,590	3,457
S-Farm	2,287	--	--	--	--	3,350	3,350	3,350
SX-Farm	1,942	--	--	--	--	1,472	1,503	1,472
T-Farm	898	--	--	--	--	898	898	2,207
TX-Farm	4,327	--	--	--	--	4,327	4,327	4,327
TY-Farm	1,564	--	--	--	--	1,564	1,564	1,564
U-Farm	1,337	--	--	--	--	1,244	1,553	1,244
AN-Farm	1,473	--	--	--	--	1,473	1,547	1,473
AP-Farm	225	--	--	--	--	225	225	225
AW-Farm	348	--	--	--	--	243	243	2,777
AY-Farm	1,046	--	--	--	--	1,046	1,046	1,046
AZ-Farm	391	--	--	--	--	391	403	391
SY-Farm	984	--	--	--	--	522	772	544
A-101	255	255	511	957	1,914	121	201	121
A-102	52	52	105	177	354	40	43	40
A-103	95	95	140	239	477	95	95	95
A-104	279	279	279	279	279	279	279	279
A-105	182	182	182	182	182	182	182	182
A-106	161	161	201	240	480	161	161	161
AX-101	262	262	262	649	1,298	262	262	262
AX-102	65	65	65	65	65	65	65	65

Table A-1. HLW Glass Production for Each Case.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)							
	0 – BL	1	2	3	4	5 – OP	6	7
AX-103	47	47	63	211	422	43	43	43
AX-104	130	130	130	130	130	130	130	130
B-101	186	186	201	211	222	212	222	211
B-102	109	109	109	109	109	109	109	109
B-103	211	211	211	211	211	211	211	211
B-104	403	403	403	403	403	403	403	403
B-105	1,270	1,270	1,270	1,270	1,270	1,270	1,270	1,270
B-106	200	200	200	200	200	200	200	200
B-107	581	581	581	581	581	581	581	581
B-108	430	430	430	430	430	430	430	430
B-109	147	147	154	144	151	144	151	144
B-110	--	279	--	--	--	--	--	289
B-111	--	241	--	--	--	--	--	256
B-112	34	34	36	39	58	35	38	35
B-201	--	108	--	--	--	--	--	111
B-202	--	53	--	--	--	--	--	54
B-203	--	82	--	--	--	--	--	84
B-204	--	95	--	--	--	--	--	95
BX-101	84	84	88	64	64	64	64	64
BX-102	117	117	123	105	105	105	105	105
BX-103	78	78	81	66	66	66	66	66
BX-104	235	235	243	240	349	236	292	236
BX-105	150	150	300	119	238	116	125	116
BX-106	74	74	134	112	223	74	98	74
BX-107	675	675	675	675	675	675	675	675
BX-108	92	92	92	92	92	92	92	92
BX-109	279	279	279	279	279	279	279	279
BX-110	217	217	286	252	504	217	217	217
BX-111	200	200	200	200	344	200	200	200
BX-112	708	708	708	708	708	708	708	708
BY-101	334	334	334	334	592	334	376	334
BY-102	236	236	236	236	410	236	236	236
BY-103	263	263	263	434	868	263	331	263
BY-104	243	243	323	553	1,106	216	233	215
BY-105	456	456	456	456	456	456	456	456
BY-106	116	116	125	210	420	131	211	131
BY-107	233	233	233	233	233	233	233	233
BY-108	164	164	169	155	164	155	164	155
BY-109	670	670	670	670	670	670	670	670
BY-110	211	211	226	567	1,135	220	238	220
BY-111	537	537	537	537	595	537	537	537

Table A-1. HLW Glass Production for Each Case.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)							
	0 – BL	1	2	3	4	5 – OP	6	7
BY-112	1,069	1,069	1,532	2,563	5,125	1,069	1,069	1,069
C-101	197	197	205	151	151	151	151	151
C-102	352	352	369	388	406	388	406	388
C-103	259	259	274	244	257	244	257	244
C-104	889	889	960	897	968	897	968	897
C-105	420	420	420	157	165	157	165	157
C-106	43	43	43	43	44	43	44	43
C-107	982	982	982	982	982	982	982	982
C-108	105	105	112	108	115	108	115	108
C-109	150	150	160	171	179	171	179	171
C-110	207	207	207	207	207	207	207	207
C-111	180	180	192	211	221	211	221	211
C-112	295	295	313	296	313	296	313	296
C-201	14	14	14	14	14	14	14	14
C-202	4	4	4	4	4	4	4	4
C-203	10	10	11	28	55	11	12	11
C-204	9	9	10	25	50	10	11	10
S-101	362	362	580	1,053	1,769	1,053	1,053	1,053
S-102	129	129	258	496	992	61	121	61
S-103	164	164	328	680	1,359	31	32	31
S-104	450	450	450	1,105	1,105	1,105	1,105	1,105
S-105	44	44	69	250	500	44	44	44
S-106	286	286	571	1,813	3,626	185	185	185
S-107	537	537	570	692	747	679	721	679
S-108	319	319	639	2,019	4,038	249	249	249
S-109	51	51	103	560	1,120	41	64	41
S-110	233	233	466	693	1,385	121	129	121
S-111	261	261	521	986	1,973	210	395	210
S-112	710	710	710	1,518	3,037	710	710	710
SX-101	457	457	913	2,044	4,088	87	140	87
SX-102	188	188	376	1,542	3,085	140	140	140
SX-103	361	361	645	606	1,213	361	361	361
SX-104	216	216	432	506	1,013	108	113	108
SX-105	139	139	279	816	1,631	112	112	112
SX-106	248	248	497	1,223	2,447	97	195	97
SX-107	184	184	184	184	184	184	184	184
SX-108	88	88	91	129	257	86	89	86
SX-109	339	339	339	339	339	339	339	339
SX-110	99	99	99	99	99	99	99	99
SX-111	209	209	209	209	209	209	209	209
SX-112	145	145	145	145	145	145	145	145

Table A-1. HLW Glass Production for Each Case.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)							
	0 – BL	1	2	3	4	5 – OP	6	7
SX-113	49	49	49	49	49	49	49	49
SX-114	190	190	190	190	190	190	190	190
SX-115	12	12	12	12	12	12	12	12
T-101	88	88	92	87	91	87	91	87
T-102	80	80	80	80	80	80	80	80
T-103	44	44	47	45	47	45	47	45
T-104	--	547	--	--	--	--	--	547
T-105	176	176	187	192	206	192	206	192
T-106	32	32	34	33	35	33	35	33
T-107	756	756	756	756	756	756	756	756
T-108	41	41	41	41	41	41	41	41
T-109	18	18	18	18	18	18	18	18
T-110	--	239	--	--	--	--	--	244
T-111	--	595	--	--	--	--	--	601
T-112	--	87	--	--	--	--	--	91
T-201	--	105	--	--	--	--	--	106
T-202	--	34	--	--	--	--	--	34
T-203	--	60	--	--	--	--	--	59
T-204	--	78	--	--	--	--	--	76
TX-101	158	158	158	158	242	158	233	158
TX-102	138	138	138	138	159	138	138	138
TX-103	95	95	95	95	104	95	95	95
TX-104	48	48	48	48	94	48	76	48
TX-105	408	408	408	408	474	408	408	408
TX-106	79	79	90	136	271	79	80	79
TX-107	15	15	20	15	29	15	15	15
TX-108	88	88	88	88	98	88	88	88
TX-109	302	302	326	347	377	317	343	317
TX-110	330	330	330	330	391	330	330	330
TX-111	255	255	255	255	311	255	255	255
TX-112	449	449	449	449	494	449	449	449
TX-113	1,059	1,059	1,059	1,059	1,059	1,059	1,059	1,059
TX-114	368	368	368	368	397	368	368	368
TX-115	395	395	395	395	434	395	395	395
TX-116	398	398	398	398	398	398	398	398
TX-117	275	275	275	275	275	275	275	275
TX-118	216	216	321	444	888	216	216	216
TY-101	400	400	430	397	427	397	427	397
TY-102	31	31	31	31	31	31	31	31
TY-103	367	367	392	371	397	371	397	371
TY-104	97	97	103	98	104	98	104	98

Table A-1. HLW Glass Production for Each Case.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)							
	0 – BL	1	2	3	4	5 – OP	6	7
TY-105	901	901	901	901	901	901	901	901
TY-106	27	27	27	27	27	27	27	27
U-101	50	50	50	50	63	50	59	50
U-102	194	194	258	337	674	194	194	194
U-103	387	387	387	782	1,565	387	387	387
U-104	77	77	77	222	444	84	168	84
U-105	204	204	314	539	1,079	204	204	204
U-106	63	63	126	246	491	25	31	25
U-107	137	137	274	649	1,297	67	132	67
U-108	359	359	498	975	1,950	359	359	359
U-109	201	201	402	840	1,679	133	225	133
U-110	298	298	310	300	312	300	312	300
U-111	156	156	311	737	1,473	67	121	67
U-112	98	98	98	98	98	98	98	98
U-201	9	9	9	9	9	9	9	9
U-202	7	7	7	7	7	7	7	7
U-203	3	3	3	3	3	3	3	3
U-204	6	6	6	6	6	6	6	6
AN-101	0	0	0	0	0	0	0	0
AN-102	60	60	67	60	108	60	60	60
AN-103	147	147	147	147	147	147	147	147
AN-104	502	502	531	502	505	505	548	505
AN-105	541	541	541	541	658	541	541	541
AN-106	14	14	28	22	44	17	17	17
AN-107	419	419	454	415	449	415	449	415
AP-101	0	0	0	0	0	0	0	0
AP-102	224	224	224	224	224	224	224	224
AP-103	0	0	0	0	0	0	0	0
AP-104	0	0	0	0	0	0	0	0
AP-105	97	97	97	97	97	97	97	97
AP-106	0	0	0	0	0	0	0	0
AP-107	0	0	0	0	0	0	0	0
AP-108	0	0	0	0	0	0	0	0
AW-101	127	127	127	127	127	127	127	127
AW-102	48	48	49	49	51	49	51	49
AW-103	--	1,758	--	--	--	--	--	1,758
AW-104	208	208	417	141	283	89	95	89
AW-105	--	986	--	--	--	--	--	986
AW-106	121	121	242	400	800	115	115	115
AY-101	383	383	383	383	383	383	383	383
AY-102	663	663	663	663	663	663	663	663

Table A-1. HLW Glass Production for Each Case.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)							
	0 – BL	1	2	3	4	5 – OP	6	7
AZ-101	192	192	201	191	199	191	199	191
AZ-102	221	221	221	221	221	221	221	221
SY-101	533	533	1,065	2,077	4,153	122	185	122
SY-102	--	991	--	--	--	--	--	101
SY-103	455	455	903	1,761	3,523	455	587	455

APPENDIX B

DRIVERS FOR GLASS MASS AND BLENDING

This appendix contains key glass properties and results from the various blending subcases for Case 5. Table B-1 contains glass output results for the Total Blend and No Blend Subcases; Table B-2 contains results from the Incidental Blend Subcase.

Cells which have been shaded indicate values that are at the lower limit (green) or upper limit (red). If the parameter is a glass additive (frit oxide) and enough of that oxide had been added to the glass to reach its upper limit, then its value is colored red and no other shading applied.

Table B-1. Case 5 Glass Output for the Total Blend and No Blend Subcases.

HLW Glass Batch Number	Glass (MT)	Frit (MT)	Feed Oxides (MT)	Waste oxide loading	number of canisters (x m^3 each)	Liquidus Temp. (Spinel) (degrees C)	Liquidus Temp. (Zirc) (degrees C)	Wt. Fr. SiO2/ (SiO2+Na2O +Al2O3)	Glass viscosity (Pa-s)	Elect. Cond. (ohm-m)^-1	silicon (g/m^2)	boron (g/m^2)	lithium (g/m^2)	sodium (g/m^2)	SiO_2	B_2O_3	Na_2O	Li_2O	Al_2O_3	Fe_2O_3	CaO	MgO	ZrO_2	Cr_2O_3	F	P_2O_5	SO_3	Rh_2O_3	Rh_2O_3 + Ru_2O_3	NiO	Pu (g/L)
					Upper Limit:	1100	1050	1	10	100	2	2	2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	1	0.03	0.005	0.025	0.025	1	1
					Lower Limit:	850	-	0.62	4.5	10	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0
	Summary					Physical characteristics					Normalized Elemental Releases				[illegible] (weight fraction in glass)									Simple Limits (weight fraction in glass)							
A-101	120.8	101.9	18.9	0.16	37.8	1054	700	0.851	4.51	26.7	0.369	1.551	0.420	0.812	0.570	0.168	[illegible]	0.064	0.050	0.018	0.0097	2.99E-03	0.00E+00	8.30E-03	0.00E+00	1.27E-03	[illegible]	0.00E+00	6.04E-16	4.17E-03	5.34E-02
A-102	40.0	23.3	16.7	0.42	12.5	[illegible]	758	0.722	8.00	27.3	0.322	[illegible]	0.013	0.674	[illegible]	[illegible]	0.128	[illegible]	0.034	0.125	0.0041	0.00E+00	2.91E-03	2.28E-03	0.00E+00	1.01E-03	0.00E+00	0.00E+00	9.13E-17	2.30E-03	3.78E-01
A-103	94.8	54.8	40.0	0.42	29.6	1086	718	[illegible]	9.93	41.0	0.145	0.176	0.077	0.186	0.472	[illegible]	0.119	0.057	0.170	0.020	0.0321	1.94E-02	3.63E-03	2.53E-03	2.00E-04	3.30E-04	[illegible]	0.00E+00	2.65E-16	1.58E-03	5.86E-02
A-104	279.2	216.2	63.0	0.23	87.3	[illegible]	753	0.647	9.96	34.5	0.391	0.947	0.757	0.591	0.487	[illegible]	0.198	[illegible]	0.068	[illegible]	0.0054	1.69E-03	1.30E-04	3.08E-04	0.00E+00	2.79E-04	0.00E+00	0.00E+00	6.19E-17	4.09E-03	1.13E-01
A-105	181.7	130.0	51.7	0.28	56.8	995	782	[illegible]	4.51	38.3	0.356	1.709	1.094	0.768	0.430	0.089	0.200	[illegible]	0.064	[illegible]	0.0105	0.00E+00	6.09E-03	1.74E-03	0.00E+00	1.14E-03	0.00E+00	0.00E+00	8.71E-16	1.62E-02	1.47E-01
A-106	160.9	72.4	88.4	0.55	50.3	[illegible]	793	0.714	9.97	27.5	0.168	0.323	0.290	0.352	0.499	[illegible]	0.132	0.029	0.068	[illegible]	0.0283	2.45E-03	6.40E-03	3.39E-03	0.00E+00	3.66E-03	0.00E+00	0.00E+00	5.44E-15	3.11E-03	2.96E-01
AX-101	261.8	242.8	19.0	0.07	81.8	[illegible]	648	0.628	9.79	58.7	0.246	0.275	0.148	0.186	0.502	[illegible]	0.128	0.070	0.170	0.029	0.0045	7.73E-04	2.87E-04	5.67E-04	0.00E+00	1.96E-03	[illegible]	0.00E+00	4.87E-16	9.01E-04	3.46E-02
AX-102	65.1	49.5	15.6	0.24	20.4	[illegible]	768	[illegible]	10.00	37.9	0.119	0.239	0.353	0.178	0.446	[illegible]	0.142	0.037	0.131	[illegible]	0.0052	1.76E-03	2.10E-04	1.40E-03	0.00E+00	2.59E-03	0.00E+00	0.00E+00	8.63E-14	5.00E-03	1.15E-01
AX-103	43.0	26.6	16.3	0.38	13.4	[illegible]	864	0.742	5.32	17.4	0.135	1.412	0.211	0.636	[illegible]	0.156	0.099	[illegible]	0.047	[illegible]	0.0109	0.00E+00	6.61E-03	2.35E-03	0.00E+00	6.68E-03	0.00E+00	0.00E+00	2.52E-15	7.93E-03	1.00E-01
AX-104	129.7	104.9	24.8	0.19	40.5	907	760	[illegible]	9.98	37.4	0.268	0.667	0.878	0.446	0.472	[illegible]	0.200	0.014	0.089	[illegible]	0.0042	9.86E-04	1.96E-03	1.37E-04	0.00E+00	1.82E-04	0.00E+00	0.00E+00	7.92E-16	7.22E-03	9.96E-02
B-101	211.6	149.7	61.9	0.29	66.1	[illegible]	680	[illegible]	[illegible]	59.2	0.439	1.221	0.458	0.955	0.461	[illegible]	0.193	0.036	0.089	0.100	0.0106	0.00E+00	1.31E-04	1.79E-03	4.93E-05	1.82E-04	4.31E-03	0.00E+00	2.69E-14	3.83E-02	7.83E-02
B-102	109.0	92.0	17.0	0.16	34.1	[illegible]	727	[illegible]	4.55	33.3	0.149	1.809	0.722	1.027	0.445	0.200	0.118	0.044	0.155	[illegible]	0.0016	0.00E+00	8.25E-05	1.18E-03	6.71E-03	1.07E-02	[illegible]	0.00E+00	6.82E-23	6.88E-05	1.07E-03
B-103	211.0	177.3	33.7	0.16	66.0	948	698	0.769	9.85	27.5	0.183	0.227	0.169	0.115	0.570	0.148	[illegible]	0.070	0.121	[illegible]	0.0016	0.00E+00	8.48E-05	1.24E-03	6.73E-03	1.07E-02	[illegible]	0.00E+00	7.03E-23	7.46E-05	1.18E-02
B-104	403.1	303.9	99.2	0.25	126.0	[illegible]	694	[illegible]	10.00	44.8	0.173	0.387	0.077	0.257	0.458	[illegible]	0.148	0.040	0.132	0.070	0.0021	0.00E+00	4.22E-04	1.34E-03	6.18E-03	1.12E-02	[illegible]	0.00E+00	9.77E-23	3.02E-04	1.01E-02
B-105	1270.2	1105.4	164.7	0.13	397.0	970	736	0.687	5.85	29.2	0.202	0.706	0.369	0.239	0.482	0.200	[illegible]	0.070	0.170	0.006	0.0000	0.00E+00	8.96E-05	5.13E-04	6.85E-03	0.00E+00	[illegible]	0.00E+00	6.91E-23	7.33E-05	1.52E-03
B-106	199.5	155.6	43.9	0.22	62.4	1071	774	[illegible]	9.55	23.2	0.090	0.521	0.115	0.292	[illegible]	0.135	0.139	[illegible]	0.118	0.063	0.0073	2.27E-03	2.56E-04	8.77E-04	5.54E-03	2.28E-02	[illegible]	0.00E+00	8.16E-23	1.90E-04	5.43E-03
B-107	581.3	483.1	98.2	0.17	181.7	[illegible]	720	0.854	6.21	37.1	0.425	0.802	0.183	0.480	0.570	[illegible]	0.066	0.070	0.031	0.150	0.0010	0.00E+00	2.69E-04	4.42E-04	2.18E-02	1.02E-02	[illegible]	0.00E+00	8.87E-20	7.34E-05	1.24E-02
B-108	429.8	395.3	34.6	0.08	134.3	[illegible]	719	0.810	5.98	23.0	0.246	1.190	0.562	0.733	0.570	0.200	[illegible]	0.060	0.084	[illegible]	0.0015	0.00E+00	1.48E-04	1.23E-04	1.51E-02	7.30E-04	[illegible]	0.00E+00	2.44E-19	9.74E-04	2.86E-04
B-109	144.0	81.1	62.9	0.44	45.0	[illegible]	646	[illegible]	[illegible]	57.7	0.378	1.605	0.033	0.810	0.427	[illegible]	0.171	0.034	0.091	0.041	0.0061	0.00E+00	7.94E-04	4.83E-03	5.21E-02	1.14E-02	4.83E-03	0.00E+00	1.17E-18	4.56E-03	9.27E-03
B-112	35.3	21.6	13.7	0.39	11.0	[illegible]	692	0.625	6.76	42.5	0.509	[illegible]	0.117	0.875	0.444	[illegible]	0.200	[illegible]	0.066	0.086	0.0070	0.00E+00	7.50E-05	4.57E-03	1.55E-02	1.80E-02	4.84E-03	0.00E+00	2.26E-17	6.89E-04	5.20E-04
BX-101	63.7	41.5	22.2	0.35	19.9	1068	793	[illegible]	9.97	32.5	0.180	0.553	0.246	0.341	0.437	[illegible]	0.181	[illegible]	0.087	[illegible]	0.0104	0.00E+00	7.19E-03	2.22E-04	1.37E-03	1.51E-02	9.86E-04	0.00E+00	1.86E-18	7.08E-03	8.71E-02
BX-102	105.1	24.2	80.9	0.77	32.8	[illegible]	773	0.823	9.95	28.1	0.223	0.361	0.258	0.309	[illegible]	[illegible]	0.076	0.056	0.046	0.150	0.0126	3.76E-03	5.46E-03	7.26E-05	1.04E-03	2.92E-03	2.45E-04	0.00E+00	1.41E-18	5.30E-03	1.57E-01
BX-103	66.3	43.9	22.4	0.34	20.7	[illegible]	734	0.855	4.53	39.9	0.474	1.200	0.211	0.724	0.548	[illegible]	0.071	0.070	0.023	[illegible]	0.0118	0.00E+00	5.58E-03	2.65E-04	1.06E-03	1.79E-02	1.30E-03	0.00E+00	1.49E-18	5.83E-03	4.86E-01
BX-104	235.9	138.4	97.5	0.41	73.7	[illegible]	680	[illegible]	9.60	41.3	0.141	0.422	0.006	0.218	[illegible]	[illegible]	0.125	0.037	0.132	0.019	0.0063	1.01E-03	2.97E-03	6.19E-03	1.06E-05	5.08E-04	6.28E-05	0.00E+00	2.03E-19	4.96E-04	3.73E-02
BX-105	115.7	63.1	52.5	0.45	36.2	[illegible]	797	0.704	5.46	16.6	0.103	1.674	0.101	0.984	[illegible]	0.200	0.096	[illegible]	0.081	0.041	0.0233	0.00E+00	1.79E-03	5.41E-03	1.91E-03	[illegible]	2.03E-03	0.00E+00	9.37E-21	6.83E-04	2.35E-02
BX-106	74.5	33.1	41.3	0.56	23.3	1064	685	0.772	4.50	40.2	0.582	1.727	0.266	1.990	0.540	[illegible]	0.120	0.052	0.040	0.036	0.0370	2.40E-02	1.98E-03	6.60E-03	5.56E-04	[illegible]	1.47E-04	0.00E+00	4.96E-21	7.97E-04	4.18E-02
BX-107	675.1	472.1	203.0	0.30	211.0	[illegible]	640	[illegible]	4.52	67.9	0.311	0.922	0.061	0.528	0.445	[illegible]	0.154	0.054	0.119	0.043	0.0020	7.37E-04	5.03E-04	2.98E-03	1.38E-02	[illegible]	1.68E-03	0.00E+00	8.36E-23	3.82E-05	6.17E-03
BX-108	91.9	68.8	23.1	0.25	28.7	[illegible]	704	[illegible]	9.43	43.5	0.148	0.303	0.077	0.209	0.449	[illegible]	0.137	0.044	0.138	0.078	0.0086	0.00E+00	1.95E-04	7.91E-04	6.62E-03	[illegible]	2.77E-03	0.00E+00	1.02E-22	2.39E-04	5.40E-03
BX-109	279.1	198.9	80.2	0.29	87.2	[illegible]	714	0.645	4.51	48.0	0.201	0.641	0.062	0.385	[illegible]	[illegible]	0.134	0.044	0.098	0.105	0.0144	4.64E-03	2.40E-07	2.49E-04	0.00E+00	[illegible]	3.57E-03	0.00E+00	1.14E-22	3.80E-04	2.53E-03
BX-110	217.0	169.4	47.6	0.22	67.8	[illegible]	631	0.738	7.75	46.6	1.091	1.998	0.306	1.808	0.570	[illegible]	0.159	0.042	0.043	0.042	0.0044	0.00E+00	4.92E-04	2.30E-03	0.00E+00	7.57E-03	[illegible]	0.00E+00	3.71E-17	6.36E-04	1.14E-02
BX-111	199.6	163.8	35.8	0.18	62.4	951	631	[illegible]	8.66	65.9	0.291	0.372	0.152	0.255	0.501	[illegible]	0.140	0.070	0.168	0.019	0.0011	4.32E-04	1.82E-04	3.18E-03	6.21E-03	5.84E-03	[illegible]	0.00E+00	5.76E-17	9.34E-05	3.34E-03
BX-112	707.6	631.0	76.6	0.11	221.2	981	755	[illegible]	9.59	36.2	0.275	0.836	0.442	0.442	0.455	[illegible]	0.195	[illegible]	0.083	0.150	0.0016	5.93E-04	8.48E-05	1.03E-03	1.37E-02	9.59E-03	[illegible]	0.00E+00	2.55E-23	3.85E-06	5.93E-03
BY-101	333.7	217.6	116.0	0.35	104.3	1037	647	0.772	7.63	38.9	0.698	1.337	0.193	1.398	0.570	[illegible]	0.131	0.045	0.038	0.048	0.0205	0.00E+00	1.72E-04	5.63E-03	1.21E-02	[illegible]	5.11E-04	0.00E+00	9.41E-17	1.24E-02	5.90E-03
BY-102	235.6	185.3	50.3	0.21	73.6	[illegible]	668	0.629	9.86	54.1	0.204	0.237	0.114	0.136	0.485	[illegible]	0.116	0.069	0.170	0.047	0.0043	0.00E+00	1.25E-04	3.91E-03	3.43E-02	3.05E-03	[illegible]	0.00E+00	7.75E-17	1.40E-03	1.55E-02
BY-103	262.7	193.6	69.0	0.26	82.1	1026	630	[illegible]	4.58	77.0	0.314	0.589	0.164	0.407	0.473	[illegible]	0.148	0.070	0.142	0.040	0.0064	0.00E+00	6.33E-04	6.29E-03	3.18E-02	8.58E-03	[illegible]	0.00E+00	1.15E-16	2.63E-03	1.84E-02
BY-104	215.6	159.6	56.0	0.26	67.4	[illegible]	692	0.623	5.35	42.8	0.540	[illegible]	0.104	1.061	0.434	0.050	0.200	[illegible]	0.062	0.078	0.0191	2.85E-03	1.73E-04	3.29E-03	1.39E-02	2.29E-03	4.76E-03	0.00E+00	1.22E-16	1.76E-02	2.71E-02
BY-105	455.7	288.7	167.0	0.37	142.4	1074	733	0.828	9.29	16.9	0.243	0.683	0.399	1.558	0.570	[illegible]	0.109	0.019	0.010	0.076	[illegible]	2.07E-03	8.04E-05	2.86E-03	4.31E-03	2.04E-03	1.73E-03	0.00E+00	9.18E-17	7.96E-03	2.83E-02
BY-106	131.4	106.5	24.9	0.19	41.1	[illegible]	640	0.629	4.56	57.1	0.647	[illegible]	0.153	1.415	0.465	[illegible]	0.200	0.027	0.074	0.046	0.0151	0.00E+00	2.14E-04	8.04E-03	0.00E+00	2.46E-04	2.10E-03	0.00E+00	1.61E-16	2.79E-02	1.12E-02
BY-107	233.1	172.0	61.1	0.26	72.9	981	793	0.640	4.51	29.8	0.212	1.513	0.833	0.631	[illegible]	0.123	0.168	[illegible]	0.069	0.150	0.0071	0.00E+00	5.03E-05	2.42E-03	0.00E+00	5.47E-03	[illegible]	0.00E+00	6.15E-17	4.68E-03	4.52E-03
BY-108	154.8	102.2	52.5	0.34	48.4	[illegible]	704	0.656	[illegible]	36.9	0.572	[illegible]	0.071	1.334	0.431	[illegible]	0.180	[illegible]	0.046	0.078	0.0362	5.90E-03	1.27E-04	2.25E-03	0.00E+00	7.59E-03	7.38E-04	0.00E+00	7.50E-17	1.73E-02	1.17E-02
BY-109	669.6	610.5	59.1	0.09	209.3	[illegible]	717	0.793	9.94	35.9	0.204	0.222	0.160	0.151	0.570	[illegible]	0.071	0.070	0.077	0.123	0.0008	0.00E+00	1.51E-04	2.29E-03	2.25E-02	2.09E-03	[illegible]	0.00E+00	2.14E-17	4.27E-04	4.48E-03
BY-110	220.4	146.7	73.7	0.33	68.9	[illegible]	686	0.638	[illegible]	41.3	0.657	[illegible]	0.132	1.419	0.445	0.053	0.200	[illegible]	0.052	0.068	0.0338	4.14E-03	1.69E-04	4.59E-03	1.52E-02	6.35E-03	4.05E-03	0.00E+00	9.63E-17	2.19E-02	1.04E-02
BY-111	536.9	435.0	101.8	0.19	167.8	[illegible]	626	0.663	9.98	60.0	0.315	0.308	0.251	0.289	0.552	[illegible]	0.139	0.070	0.142	0.022	0.0020	0.00E+00	5.70E-05	3.47E-03	0.00E+00	7.78E-03	[illegible]	0.00E+00	3.59E-17	6.20E-04	9.72E-03
BY-112	1068.8	997.8	71.0	0.07	334.0	911	810	[illegible]	4.87	28.3	0.142	1.354	[illegible]	0.600	[illegible]	0.144	0.169	[illegible]	0.089	0.150	0.0012	0.00E+00	3.43E-05	1.30E-03	4.04E-03	1.88E-03	[illegible]	0.00E+00	2.07E-17	3.75E-04	3.64E-03
C-101	151.4	84.3	67.1	0.44	47.3	[illegible]	773	0.651	6.29	30.5	0.238	0.789	0.107	0.537	[illegible]	[illegible]	0.164	[illegible]	0.062	[illegible]	0.0322	0.00E+00	1.70E-03	1.86E-03	0.00E+00	8.15E-03	1.37E-03	0.00E+00	9.96E-21	7.05E-03	1.61E-01
C-102	387.8	214.9	172.9	0.45	121.2	[illegible]	758	[illegible]	[illegible]	52.4	0.250	0.665	0.205	0.664	0.442	[illegible]	0.170	0.040	0.100	0.074	0.0231	1.14E-02	1.72E-02	2.08E-03	0.00E+00	1.33E-03	4.82E-04	0.00E+00	6.01E-18	2.17E-02	3.99E-01
C-103	244.5	141.4	103.0	0.42	76.4	[illegible]	788	[illegible]	7.70	59.3	0.143	0.205	0.185	0.160	0.467	[illegible]	0.129	0.070	0.157	0.050	0.0103	0.00E+00	3.44E-02	2.49E-03	0.00E+00	8.93E-04	0.00E+00	0.00E+00	3.60E-17	1.17E-02	5.18E-01
C-104	897.2	597.3	299.9	0.33	280.4	[illegible]	1027	0.638	9.21	38.2	0.255	[illegible]	0.079	0.912	[illegible]	[illegible]	0.196	[illegible]	0.043	0.044	0.0046	3.81E-04	9.77E-02	1.36E-03	0.00E+00	2.84E-04	0.00E+00	1.98E-04	1.98E-04	3.58E-03	2.80E-01
C-105	157.2	50.0	107.2	0.68	49.1	[illegible]	704	[illegible]	[illegible]	51.9	0.216	0.516	0.036	0.436	0.428	[illegible]	0.136	0.051	0.126	0.025	0.0169	3.02E-02	1.52E-03	4.22E-04	0.00E+00	3.42E-03	0.00E+00	0.00E+00	1.75E-20	1.34E-02	5.92E-01
C-106	43.0	27.7	15.3	0.36	13.4	[illegible]	755	[illegible]	7.16	43.1	0.143	0.372	0.231	0.230	0.428	[illegible]	0.143	0.039	0.119	[illegible]	0.0036	1.15E-03	1.17E-04	2.01E-03	1.14E-05	9.79E-04	0.00E+00	3.79E-05	8.11E-04	4.47E-03	1.13E-01
C-107	981.7	726.1	255.7	0.26	306.8	[illegible]	733	[illegible]	4.53	57.9	0.178	0.454	0.336	0.247	0.424	[illegible]	0.135	0.057	0.125	[illegible]	0.0017	8.06E-04	4.16E-04	5.70E-04	5.21E-05	4.42E-03	0.00E+00	5.48E-05	1.24E-03	4.01E-03	9.97E-02
C-108	107.7	67.1	40.5	0.38	33.6	[illegible]	656	0.629	[illegible]	42.9	0.400	0.725	0.129	1.188	0.468	[illegible]	0.200	0.018	0.077	0.031	0.0577	0.00E+00	3.90E-04	7.86E-04	0.00E+00	8.50E-03	0.00E+00	0.00E+00	2.40E-22	3.59E-02	1.28E-03
C-109	170.8	113.8	57.0	0.33	53.4	[illegible]	667	[illegible]	[illegible]	47.3	0.287	0.612	0.121	0.805	0.453	[illegible]	0.182	0.029	0.095	0.051	0.0446	0.00E+00	8.08E-05	2.05E-04	9.91E-04	1.83E-02	5.81E-04	0.00E+00	1.21E-18	3.39E-02	1.59E-02
C-110	206.9	135.1	71.8	0.35	64.7	[illegible]	723	[illegible]	6.64	33.9	0.217	1.244	0.083	0.506	[illegible]	0.095	0.172	[illegible]	0.086	0.064	0.0051	1.07E-03	9.08E-04	9.08E-04	1.99E-02	[illegible]	0.00E+00	0.00E+00	1.00E-22	1.33E-04	1.38E-02
C-111	210.7	146.3	64.4	0.31	65.9	[illegible]	688	[illegible]	[illegible]	52.2	0.285	0.719	0.210	0.676	0.446	[illegible]	0.175	0.036	0.098	0.090	0.0257	0.00E+00	3.21E-04	2.69E-04	0.00E+00	8.06E-03	0.00E+00	0.00E+00	8.21E-19	2.95E-02	2.77E-02
C-112	296.0	195.9	100.1	0.34	92.5	[illegible]	687	0.684	[illegible]	33.8	0.662	1.911	0.080	1.714	0.456	[illegible]	0.176	[illegible]	0.035	0.062	0.0527	1.85E-03	4.41E-05	8.75E-05	3.77E-04	1.49E-02	7.99E-04	4.25E-05	5.97E-05	3.15E-02	1.24E-02
C-201	13.7	10.5	3.2	0.24	4.3	[illegible]	784	[illegible]	9.96	31.3	0.103	0.307	0.153	0.177	[illegible]	0.064	0.142	0.023	0.116	[illegible]	0.0029	8.77E-04	1.35E-06	1.77E-03	3.12E-04	1.51E-03	0.00E+00	0.00E+00	3.52E-18	1.32E-03	1.40E-01
C-202	4.1	2.6	1.5	0.36	1.3	[illegible]	765	0.710	7.31	28.3	0.347	[illegible]	0.025	0.690	[illegible]	[illegible]	0.136	[illegible]	0.036	0.147	0.0036	2.19E-03	3.56E-06	2.54E-03	0.00E+00	1.52E-04	0.00E+00	0.00E+00	9.24E-18	2.88E-03	3.30E-01
C-203	11.1	7.0	4.1	0.37	3.5	[illegible]	714	0.735	8.48	26.1	0.304	[illegible]	0.004	0.712	[illegible]	[illegible]	0.116	[illegible]	0.036	0.065	0.0114	2.79E-03	3.57E-06	2.88E-03	0.00E+00	2.36E-04	0.00E+00	0.00E+00	9.29E-18	2.55E-03	1.17E-01
C-204	10.0	6.3	3.7	0.37	3.1	[illegible]	714	0.734	8.47	26.1	0.304	[illegible]	0.004	0.712	[illegible]	[illegible]	0.116	[illegible]	0.036	0.065	0.0115	2.79E-03	3.58E-06	2.89E-03	0.00E+00	3.31E-04	0.00E+00	0.00E+00	9.31E-18	2.56E-03	1.16E-01
S-101	1053.3	800.9	252.5	0.24	329.2	892	760	[illegible]	9.91	22.8	0.109	0.967	0.582	0.705	0.461	0.200	0.112	0.031	[illegible]	[illegible]	0.0008	1.36E-04	5.40E-05	2.22E-03	0.00E+00	2.18E-04	9.95E-04	0.00E+00	9.58E-18	2.23E-04	2.20E-02
S-102	60.6	47.5	13.0	0.22	18.9	[illegible]	666	0.883	4.56	34.4	0.518	1.557	0.109	0.704	0.567	0.095	[illegible]	0.070	0.025	0.039	0.0148	2.77E-03	5.76E-04	[illegible]	0.00E+00	2.22E-03	0.00E+00	0.00E+00	2.46E-16	7.13E-04	7.60E-02
S-103	31.0	20.9	10.0	0.32	9.7	[illegible]	676	[illegible]	5.58	60.8	0.189	0.319	0.100	0.165	0.445	[illegible]	0.116	0.070	0.157	0.066	0.0119	0.00E+00	6.29E-04	2.94E-03	0.00E+00	7.67E-03	0.00E+00	0.00E+00	4.12E-16	7.44E-03	2.65E-01

HLW Glass Batch Number	Glass (MT)	Frit (MT)	Feed Oxides (MT)	Waste oxide loading	number of canisters (x m^3 each)	Liquidus Temp. (Spinel) (degrees C)	Liquidus Temp. (Zirc) (degrees C)	Wt. Fr. SiO2/ (SiO2+Na2O +Al2O3)	Glass viscosity (Pa-s)	Elect. Cond. (ohm-m)^-1	silicon (g/m^2)	boron (g/m^2)	lithium (g/m^2)	sodium (g/m^2)
	Summary					Physical characteristics					Normalized Elemental Releases			
Upper Limit:						1100	1050	1	10	100	2	2	2	2
Lower Limit:						850	-	0.62	4.5	10	-	-	-	-
S-104	1104.8	859.2	245.6	0.22	345.3		763		10.00	22.8	0.109	0.954	0.728	0.713
S-105	43.6	31.1	12.5	0.29	13.6		864	0.744	4.62	16.2	0.109	1.790	0.906	1.004
S-106	184.5	153.5	31.1	0.17	57.7		763		9.99	38.8	0.132	0.278	0.396	0.202
S-107	679.0	480.2	198.8	0.29	212.2		861			52.7	0.107	0.148	0.097	0.106
S-108	249.4	208.1	41.3	0.17	78.0		670	0.787	5.00	37.9	0.357	0.743	0.433	0.450
S-109	41.2	19.1	22.1	0.54	12.9		742	0.630		32.6	0.258	1.996	0.277	0.883
S-110	121.5	87.0	34.5	0.28	38.0		688	0.779	10.00	34.9	0.231	0.390	0.048	0.271
S-111	210.3	144.9	65.4	0.31	65.7	953	618		9.91	66.7	0.331	0.374	0.231	0.319
S-112	709.6	691.3	18.3	0.03	221.8	1074	759	0.824	8.74	29.0	0.164	0.178	0.289	0.102
SX-101	87.1	55.1	32.0	0.37	27.2		672			60.2	0.243	0.769	0.051	0.423
SX-102	140.3	123.9	16.4	0.12	43.9		774	0.671	6.62	24.0	0.141	0.590	0.245	0.232
SX-103	360.6	337.6	23.0	0.06	112.7	1004	836		9.64	16.8	0.060	0.828	0.703	0.600
SX-104	107.7	69.0	38.7	0.36	33.7		672			58.7	0.234	0.714	0.057	0.422
SX-105	111.8	86.4	25.4	0.23	34.9	909	635	0.767	5.64	53.4	0.571	0.922	0.209	0.818
SX-106	97.3	58.1	39.2	0.40	30.4	982	644	0.655	9.99	50.8	0.300	0.453	0.171	0.453
SX-107	184.2	131.7	52.5	0.28	57.6	872	628		9.90	64.0	0.298	0.345	0.195	0.271
SX-108	86.0	50.1	35.9	0.42	26.9		777	0.629	8.34	32.3	0.201	0.747	0.103	0.399
SX-109	338.7	224.5	114.1	0.34	105.9		672		5.02	54.8	0.235	0.505	0.396	0.229
SX-110	98.9	77.4	21.5	0.22	30.9	987	736	0.670	4.60	32.1	0.199	0.878	0.380	0.277
SX-111	209.4	163.4	45.9	0.22	65.4	1020	740	0.678	4.99	30.3	0.194	0.772	0.336	0.238
SX-112	144.6	112.8	31.8	0.22	45.2	854	624		9.39	66.4	0.312	0.361	0.213	0.283
SX-113	49.4	16.7	32.7	0.66	15.5		679	0.720	9.53	43.6	0.242	0.247	0.357	0.219
SX-114	190.4	128.0	62.4	0.33	59.5	1091	724		8.06	52.6	0.157	0.202	0.338	0.095
SX-115	12.1	8.7	3.4	0.28	3.8	936	763		5.42	38.5	0.399	1.206	0.454	0.810
T-101	86.9	53.5	33.4	0.38	27.1	851	628			61.7	0.294	0.391	0.185	0.347
T-102	80.2	59.7	20.6	0.26	25.1		765	0.661	4.52	32.6	0.156	0.475	0.343	0.120
T-103	44.6	28.2	16.4	0.37	13.9		719		8.12	54.2	0.162	0.213	0.202	0.110
T-105	191.6	123.5	68.1	0.36	59.9		735		5.78	41.6	0.446		0.177	0.788
T-106	33.4	19.5	13.9	0.42	10.4		652			69.4	0.248	0.580	0.071	0.307
T-107	756.3	635.1	121.2	0.16	236.4		858	0.859	9.72	11.3	0.208	1.559	0.395	0.937
T-108	40.7	32.2	8.6	0.21	12.7	991	651	0.635	9.93	54.4	0.234	0.262	0.105	0.146
T-109	17.7	9.4	8.3	0.47	5.5	992	725		5.84	42.2	0.467		0.185	0.811
TX-101	157.7	107.7	50.0	0.32	49.3	1011	634		8.95	63.8	0.275	0.340	0.136	0.229
TX-102	137.8	115.5	22.3	0.16	43.1		739		9.52	35.5	0.267	0.829	0.715	0.459
TX-103	94.5	80.1	14.5	0.15	29.5		799	0.640	5.79	24.4	0.115	0.726	0.561	0.307
TX-104	48.4	35.3	13.0	0.27	15.1	1006	685		4.52	52.5	0.223	0.536	0.419	0.230
TX-105	407.6	340.5	67.1	0.16	127.4		708	0.633	9.75	49.9	0.163	0.183	0.203	0.091
TX-106	79.0	55.1	23.9	0.30	24.7		734		9.97	33.4	0.119	0.220	0.115	0.113
TX-107	15.4	11.9	3.5	0.23	4.8	1008	690	0.666	9.79	39.0	0.186	0.200	0.142	0.087
TX-108	87.9	72.5	15.4	0.17	27.5		732		4.52	60.0	0.164	0.350	0.399	0.176
TX-109	317.0	226.4	90.6	0.29	99.1		703		6.35	42.4	0.451		0.091	0.805
TX-110	329.7	270.6	59.1	0.18	103.0		622	0.703	9.50	55.3	0.344	0.346	0.168	0.327
TX-111	254.6	205.4	49.2	0.19	79.6		616		5.42	79.1	0.364	0.605	0.233	0.473
TX-112	448.9	379.4	69.5	0.15	140.3	1086	733	0.818	8.28	35.0	0.234	0.304	0.212	0.203
TX-113	1059.4	981.4	78.0	0.07	331.1		639		9.60	64.3	0.291	0.331	0.297	0.256
TX-114	368.2	307.7	60.5	0.16	115.1		738	0.815	9.44	32.5	0.217	0.280	0.187	0.197
TX-115	394.8	333.2	61.6	0.16	123.4	1013	732	0.857	4.73	35.5	0.469	0.930	0.494	0.531
TX-116	397.6	264.2	133.4	0.34	124.3		859	0.744	9.17	14.2	0.098	0.663	0.639	0.438
TX-117	274.6	195.5	79.0	0.29	85.8		768	0.627	5.39	28.7	0.128	0.742	0.359	0.307
TX-118	216.2	175.4	40.8	0.19	67.6		708	0.637	9.90	37.1	0.400	1.176	0.325	0.626
TY-101	397.4	234.3	163.1	0.41	124.2		717	0.626		41.4	0.509		0.275	1.002
TY-102	30.9	27.9	3.0	0.10	9.7		733	0.761	9.90	32.0	0.760	1.270	0.867	1.111
TY-103	371.0	249.5	121.6	0.33	116.0		699	0.627	5.64	41.0	0.448		0.056	0.876
TY-104	98.4	58.5	39.9	0.41	30.7		738	0.667	4.67	34.4	0.489		0.080	1.073
TY-105	900.6	792.5	108.1	0.12	281.5		710		7.93	53.4	0.164	0.214	0.241	0.103
TY-106	27.5	4.8	22.7	0.82	8.6		748	0.864	6.77	30.6	0.252	0.507	0.230	0.303
U-101	50.0	38.7	11.2	0.23	15.6		739	0.671	4.56	31.7	0.194	0.850	0.331	0.255
U-102	194.1	158.4	35.7	0.18	60.7	1084	770	0.668	9.91	20.7	0.124	0.536	0.257	0.302
U-103	386.9	312.2	74.8	0.19	120.9		659	0.772	9.48	40.7	0.348	0.622	0.061	0.469
U-104	84.2	31.8	52.3	0.62	26.3		747			26.8	0.107	0.411	0.281	0.292
U-105	203.6	148.7	54.9	0.27	63.6		681		9.95	49.0	0.167	0.248	0.040	0.124
U-106	25.1	14.1	11.0	0.44	7.9		753	0.629	5.99	39.6	0.414		0.144	0.757
U-107	67.1	33.6	33.5	0.50	21.0	1069	712			37.3	0.228	0.580	0.133	0.454
U-108	358.9	252.6	106.2	0.30	112.2		672		9.99	46.3	0.361	0.896	0.246	0.631
U-109	133.0	115.9	17.1	0.13	41.6		695		9.98	33.1	0.230	1.031	0.668	0.649

HLW Glass Batch Number	SiO_2	B_2O_3	Na_2O	Li_2O	Al_2O_3	Fe_2O_3	CaO	MgO	ZrO_2	Cr_2O_3	F	P_2O_5	SO_3	Rh_2O_3	Rh_2O_3 + Ru_2O_3	NiO	Pu (g/L)
	Domain (weight fraction in glass)									Simple Limits (weight fraction in glass)							
Upper Limit:	0.57	0.2	0.2	0.07	0.17	0.15	0.1	0.08	0.13	0.01	1	0.03	0.005	0.025	0.025	1	1
Lower Limit:	0.42	0.05	0.05	0.01	0	0.02	0	0	0	0	0	0	0	0	0	0	0
S-104	0.464	0.200	0.114	0.031		0.009	0.0005	1.20E-04	6.70E-05	4.41E-04	0.00E+00	1.51E-05	0.00E+00	0.00E+00	2.02E-18	1.06E-04	1.38E-02
S-105	0.440	0.200	0.084	0.018	0.067		0.0050	0.00E+00	3.62E-04	2.22E-03	0.00E+00	6.61E-04	0.00E+00	0.00E+00	1.09E-15	2.20E-03	1.38E-02
S-106	0.450		0.149	0.035	0.127	0.150	0.0023	1.44E-03	1.15E-04	2.77E-03	2.54E-03	3.98E-03		0.00E+00	2.21E-16	5.51E-04	1.27E-02
S-107	0.464	0.072	0.118	0.070	0.167	0.009	0.0017	6.91E-04	5.65E-02	4.20E-03	0.00E+00	4.30E-04	2.20E-05	0.00E+00	1.47E-17	4.70E-03	1.04E-01
S-108	0.570	0.132	0.080	0.070	0.074	0.026	0.0040	0.00E+00	4.85E-04	2.93E-03	2.56E-03	4.45E-03		0.00E+00	1.99E-16	1.83E-03	1.08E-01
S-109	0.423	0.126	0.174		0.074	0.064	0.0097	7.53E-03	7.66E-04	7.73E-03	0.00E+00	1.77E-02	2.65E-03	0.00E+00	1.01E-15	4.21E-03	8.63E-02
S-110	0.546		0.084	0.058	0.071	0.071	0.0077	1.98E-03	4.49E-04	5.29E-03	9.50E-04	1.01E-03		0.00E+00	2.55E-16	1.85E-03	1.83E-01
S-111	0.525		0.152	0.069			0.0017	6.53E-04	6.81E-05	9.39E-03	0.00E+00	4.23E-03	4.65E-03	0.00E+00	1.01E-16	3.55E-04	6.11E-03
S-112	0.570	0.078		0.070	0.071	0.150	0.0008	0.00E+00	3.98E-05	5.43E-04	5.88E-05	3.30E-04		0.00E+00	9.24E-17	2.79E-04	3.83E-03
SX-101	0.426		0.145	0.051	0.116	0.065	0.0051	3.16E-03	9.32E-04	8.04E-03	5.79E-04	2.93E-03	1.47E-03	0.00E+00	1.48E-16	1.61E-03	3.58E-01
SX-102	0.449	0.200		0.057	0.170	0.023	0.0049	1.61E-03	7.62E-04	2.38E-03	4.08E-04	1.05E-03		0.00E+00	1.83E-16	2.00E-03	8.64E-02
SX-103		0.200	0.115		0.142	0.078	0.0028	9.66E-04	1.93E-04	3.34E-04	2.00E-04	6.29E-04		0.00E+00	1.04E-16	1.14E-03	3.94E-02
SX-104	0.427		0.146	0.050	0.115	0.068	0.0103	0.00E+00	1.21E-03	3.99E-03	3.37E-03	2.99E-04	0.00E+00	0.00E+00	2.10E-16	1.78E-02	4.11E-01
SX-105	0.570		0.113	0.070	0.061	0.050	0.0092	2.46E-03	7.68E-04	4.84E-03	4.82E-04	2.69E-03		0.00E+00	2.13E-16	3.29E-03	2.41E-01
SX-106	0.527		0.160	0.048	0.118	0.032	0.0060	0.00E+00	4.61E-04		0.00E+00	8.52E-03	2.42E-03	0.00E+00	2.06E-16	1.71E-03	1.11E-01
SX-107	0.514		0.145	0.068		0.014	0.0021	0.00E+00	2.78E-04	2.58E-03	0.00E+00	4.29E-04	2.17E-04	0.00E+00	1.51E-18	5.41E-03	1.04E-01
SX-108			0.170		0.078	0.143	0.0110	2.51E-03	3.29E-03	2.83E-03	0.00E+00	3.92E-04	1.17E-04	0.00E+00	3.21E-20	8.45E-03	4.43E-01
SX-109	0.469	0.120	0.118	0.070		0.019	0.0018	0.00E+00	1.84E-04	8.98E-04	0.00E+00	5.56E-04	2.28E-04	0.00E+00	1.29E-17	2.37E-03	5.48E-02
SX-110	0.460	0.200	0.056	0.070		0.011	0.0019	0.00E+00	1.88E-04	1.66E-03	0.00E+00	5.17E-04	0.00E+00	0.00E+00	6.54E-18	3.84E-03	7.67E-02
SX-111	0.463	0.200		0.070		0.012	0.0020	0.00E+00	2.08E-04	2.02E-03	0.00E+00	4.76E-04	0.00E+00	0.00E+00	3.30E-18	4.71E-03	9.07E-02
SX-112	0.516		0.146	0.070		0.013	0.0020	0.00E+00	2.13E-04	2.24E-03	0.00E+00	4.62E-04	0.00E+00	0.00E+00	2.31E-18	4.98E-03	9.51E-02
SX-113		0.068	0.106	0.070	0.115	0.047	0.0067	9.49E-03	5.60E-05	2.74E-04	0.00E+00	1.38E-04	0.00E+00	2.12E-06	2.47E-05	2.56E-04	6.48E-03
SX-114	0.452		0.107	0.070		0.117	0.0019	0.00E+00	2.00E-04	9.67E-04	0.00E+00	5.33E-04	2.27E-04	0.00E+00	1.08E-17	2.91E-03	6.34E-02
SX-115	0.432		0.200		0.065		0.0210	9.32E-03	1.85E-04	2.37E-03	0.00E+00	8.62E-04	0.00E+00	0.00E+00	1.06E-20	4.64E-03	
T-101	0.515		0.157	0.061	0.158	0.012	0.0025	0.00E+00	7.02E-04	3.86E-03	6.22E-05	2.68E-03	1.25E-03	0.00E+00	5.87E-17	1.38E-03	4.11E-02
T-102	0.430	0.175		0.070		0.060	0.0017	2.54E-04	9.52E-05	4.30E-04	1.91E-06	6.39E-04	3.67E-05	1.92E-03	3.19E-03	1.53E-04	7.37E-03
T-103	0.456		0.111	0.070	0.169	0.088	0.0046	0.00E+00	5.09E-03	9.36E-04	2.36E-05	1.12E-03	1.05E-04	0.00E+00	1.32E-18	5.09E-03	1.51E-01
T-105	0.421		0.195		0.063	0.135	0.0044	2.38E-03	2.61E-04	4.35E-03	1.11E-05	2.13E-04	2.13E-03	0.00E+00	1.62E-22	2.30E-04	2.46E-02
T-106	0.443		0.134	0.066	0.137	0.054	0.0046	0.00E+00	1.07E-03	2.88E-03	1.68E-04	9.53E-03	6.07E-04	0.00E+00	1.19E-21	1.11E-03	2.86E-02
T-107	0.522	0.166	0.066		0.020	0.150	0.0024	6.03E-04	8.83E-05	2.52E-04	5.60E-03	1.25E-03		0.00E+00	2.71E-20	2.29E-04	7.76E-03
T-108	0.499	0.063	0.117	0.070	0.170	0.020	0.0010	0.00E+00	1.37E-04	3.40E-04	7.25E-03		3.89E-03	0.00E+00	7.82E-23	4.11E-05	5.75E-03
T-109	0.427		0.198		0.063	0.129	0.0062	0.00E+00	2.40E-04	4.71E-04	6.90E-02	7.91E-03	2.68E-04	0.00E+00	5.07E-22	1.94E-04	6.75E-03
TX-101	0.499		0.136	0.070		0.019	0.0029	0.00E+00	3.04E-04	7.40E-03	0.00E+00	7.11E-04	6.29E-04	0.00E+00	8.79E-18	5.83E-03	1.47E-01
TX-102	0.472	0.073	0.200		0.089	0.115	0.0022	0.00E+00	2.41E-04	2.66E-03	0.00E+00	3.46E-03		0.00E+00	1.30E-16	4.54E-04	7.45E-02
TX-103		0.200	0.066	0.050	0.170	0.061	0.0021	0.00E+00	2.35E-04	2.58E-03	0.00E+00	3.93E-03		0.00E+00	1.28E-16	4.38E-04	7.18E-02
TX-104	0.459	0.130	0.112	0.070		0.022	0.0032	1.94E-03	1.63E-04	7.83E-03	0.00E+00	2.91E-03	2.62E-04	0.00E+00	3.62E-17	1.02E-04	4.82E-02
TX-105	0.471		0.103	0.070	0.170	0.091	0.0023	0.00E+00	2.43E-04	2.66E-03	0.00E+00	3.45E-03		0.00E+00	1.30E-16	4.58E-04	7.55E-02
TX-106	0.443	0.108	0.102	0.049		0.048	0.0075	0.00E+00	4.66E-04	3.53E-03	0.00E+00	3.93E-03	0.00E+00	0.00E+00	4.18E-16	2.28E-03	2.27E-01
TX-107	0.504	0.111	0.083	0.070	0.170	0.017	0.0027	0.00E+00	2.80E-04	3.30E-03	0.00E+00	3.60E-03		0.00E+00	1.36E-16	5.63E-04	6.77E-01
TX-108	0.426		0.123	0.066	0.138	0.150	0.0032	0.00E+00	2.34E-04	2.68E-03	0.00E+00	4.14E-03		0.00E+00	1.27E-16	4.70E-04	7.31E-02
TX-109	0.428		0.195		0.067	0.094	0.0062	0.00E+00	7.19E-04	2.23E-03	0.00E+00	1.72E-03	0.00E+00	0.00E+00	1.58E-22	1.61E-04	2.25E-02
TX-110	0.570		0.126	0.070	0.115	0.022	0.0025	0.00E+00	3.13E-04	2.84E-03	0.00E+00	4.44E-03		0.00E+00	1.25E-16	4.37E-04	7.16E-02
TX-111	0.495		0.157	0.070	0.146	0.026	0.0028	0.00E+00	3.53E-04	2.98E-03	0.00E+00	4.94E-03		0.00E+00	1.23E-16	4.34E-04	7.14E-02
TX-112	0.570		0.067	0.070	0.060	0.150	0.0022	0.00E+00	2.35E-04	2.59E-03	0.00E+00	4.31E-03		0.00E+00	1.28E-16	4.36E-04	7.11E-02
TX-113	0.513		0.145	0.069	0.170	0.030	0.0010	0.00E+00	1.12E-04	8.02E-04	0.00E+00	3.14E-03		0.00E+00	6.24E-17	6.95E-05	2.37E-03
TX-114	0.570		0.069	0.066	0.060	0.148	0.0023	0.00E+00	2.41E-04	2.64E-03	0.00E+00	5.96E-03		0.00E+00	1.23E-16	4.30E-04	6.98E-02
TX-115	0.570	0.081	0.066	0.070	0.029	0.150	0.0025	0.00E+00	2.33E-04	2.56E-03	0.00E+00	3.69E-03		0.00E+00	1.29E-16	4.47E-04	7.18E-02
TX-116	0.477	0.167	0.096		0.068	0.150	0.0039	0.00E+00	1.78E-04	3.13E-03	0.00E+00	0.00E+00		0.00E+00	7.03E-17	3.01E-04	4.06E-02
TX-117		0.187	0.079	0.051	0.170	0.040	0.0037	6.16E-04	2.26E-04	4.01E-03	0.00E+00	1.52E-02		0.00E+00	9.92E-17	3.92E-04	6.09E-02
TX-118	0.484	0.061	0.200		0.076	0.089	0.0026	0.00E+00	3.05E-04	2.12E-03	0.00E+00		7.84E-04	0.00E+00	7.80E-17	6.29E-04	
TY-101	0.433	0.069	0.200	0.010	0.059	0.105	0.0193	0.00E+00	9.46E-04	4.73E-03	7.43E-05	2.08E-02	0.00E+00	0.00E+00	1.28E-22	1.17E-02	1.42E-02
TY-102	0.570		0.149	0.031	0.031	0.150	0.0027	0.00E+00	7.53E-05	3.85E-04	0.00E+00	5.40E-03		0.00E+00	1.01E-16	2.13E-04	6.19E-04
TY-103			0.188		0.062	0.085	0.0145	0.00E+00	7.87E-04	9.63E-04	3.56E-05	2.63E-02	8.18E-04	0.00E+00	8.83E-18	7.29E-03	9.76E-03
TY-104			0.169		0.040	0.129	0.0307	0.00E+00	6.70E-04	9.63E-04	0.00E+00	1.23E-02	2.06E-03	0.00E+00	1.77E-22	5.25E-03	2.05E-02
TY-105	0.453		0.108	0.070	0.170	0.100	0.0046	0.00E+00	1.09E-07	8.64E-05	0.00E+00		1.44E-03	0.00E+00	5.98E-23	1.56E-04	1.41E-03
TY-106		0.059		0.070	0.040	0.142	0.0130	8.51E-03	2.81E-05	1.36E-04	7.61E-05	1.87E-02	1.25E-03	0.00E+00	3.13E-23	3.70E-04	2.67E-03
U-101	0.454	0.200	0.053	0.070		0.014	0.0021	0.00E+00	2.27E-04	5.95E-03	0.00E+00	7.40E-04	0.00E+00	0.00E+00	1.28E-20	5.61E-03	8.08E-03
U-102	0.471	0.200	0.064	0.046	0.170	0.011	0.0035	0.00E+00	2.12E-04	4.41E-03	0.00E+00	2.28E-03		0.00E+00	1.00E-16	2.96E-03	8.43E-02
U-103	0.570		0.092	0.065	0.076	0.013	0.0044	1.93E-02	1.67E-04	1.84E-03	7.91E-04	2.45E-03		0.00E+00	6.63E-17	8.47E-04	1.52E-02
U-104	0.458	0.151	0.124	0.032	0.156	0.025	0.0075	2.58E-03	1.75E-04		0.00E+00	1.01E-03	0.00E+00	0.00E+00	5.71E-20	5.37E-03	9.62E-02
U-105	0.453		0.109	0.062	0.168	0.044	0.0044	1.52E-03	4.37E-04	3.46E-03	2.50E-04	2.32E-03		0.00E+00	9.93E-17	1.59E-03	1.15E-01
U-106		0.053	0.188		0.060	0.132	0.0031	2.20E-03	4.74E-03	6.21E-03	0.00E+00	5.50E-03	4.86E-03	0.00E+00	3.85E-16	7.90E-03	6.30E-01
U-107	0.462		0.184	0.017	0.099	0.080	0.0148	2.89E-03	4.26E-04	9.80E-03	0.00E+00	5.80E-03	0.00E+00	0.00E+00	2.07E-16	1.49E-03	3.61E-01
U-108	0.490			0.023	0.100	0.059	0.0017	7.30E-04	4.96E-05	4.20E-03	0.00E+00	9.40E-04	0.00E+00	0.00E+00	5.87E-17	3.77E-04	7.67E-02
U-109	0.497	0.120	0.200		0.105	0.020	0.0037	1.37E-03	1.09E-04	8.47E-03	0.00E+00	1.55E-02		0.00E+00	1.66E-16	6.22E-04	1.59E-02

HLW Glass Batch Number	Glass (MT)	Frit (MT)	Feed Oxides (MT)	Waste oxide loading	number of canisters (x m^3 each)	Liquidus Temp. (Spinel) (degrees C)	Liquidus Temp. (Zirc) (degrees C)	Wt. Fr. SiO2/ (SiO2+Na2O +Al2O3)	Glass viscosity (Pa-s)	Elect. Cond. (ohm-m)^-1	silicon (g/m^2)	boron (g/m^2)	lithium (g/m^2)	sodium (g/m^2)	SiO_2	B_2O_3	Na_2O	Li_2O	Al_2O_3	Fe_2O_3	CaO	MgO	ZrO_2	Cr_2O_3	F	P_2O_5	SO_3	Rh_2O_3	Rh_2O_3 + Ru_2O_3	NiO	Pu (g/L)
					Upper Limit:	1100	1050	1	10	100	2	2	2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	1	0.03	0.005	0.025	0.025	1	1
					Lower Limit:	850	-	0.62	4.5	10	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0
	Summary					Physical characteristics					Normalized Elemental Releases				[illegible]									Simple Limits (weight fraction in glass)							
U-110	300.2	175.0	125.2	0.42	93.8	[illegible]	681	[illegible]	5.54	53.7	0.204	0.643	0.025	0.331	[illegible]	[illegible]	0.135	0.048	0.122	0.053	0.0023	7.46E-03	5.64E-04	6.55E-04	0.00E+00	2.54E-03	7.55E-05	0.00E+00	8.59E-21	5.72E-04	3.12E-02
U-111	67.5	41.1	26.3	0.39	21.1	[illegible]	714	[illegible]	9.96	39.3	0.244	0.668	0.180	0.441	0.462	[illegible]	0.185	0.018	0.098	0.096	0.0061	0.00E+00	6.64E-04	8.95E-03	0.00E+00	1.01E-02	[illegible]	0.00E+00	1.63E-16	3.37E-03	1.27E-01
U-112	97.6	75.7	22.0	0.22	30.5	1061	729	0.697	10.00	28.8	0.165	0.196	0.167	0.070	0.506	0.150	[illegible]	0.070	[illegible]	0.019	0.0022	0.00E+00	4.46E-04	1.00E-03	0.00E+00	1.26E-03	0.00E+00	0.00E+00	6.02E-21	2.91E-03	2.65E-03
U-201	8.5	6.9	1.6	0.19	2.7	969	727	0.703	10.00	27.4	0.185	0.256	0.269	0.101	0.522	0.168	[illegible]	0.070	[illegible]	0.008	0.0001	7.30E-05	1.54E-05	3.06E-04	0.00E+00	8.43E-03	0.00E+00	0.00E+00	9.56E-22	1.48E-05	1.84E-04
U-202	7.3	5.9	1.4	0.19	2.3	[illegible]	741	[illegible]	8.12	51.6	0.149	0.184	0.613	0.088	0.453	[illegible]	0.107	0.070	[illegible]	0.139	0.0001	8.05E-05	6.77E-06	2.64E-04	0.00E+00	7.70E-03	0.00E+00	0.00E+00	9.26E-22	1.20E-05	2.52E-04
U-203	3.3	2.6	0.7	0.22	1.0	[illegible]	762	0.690	9.57	29.0	0.137	0.144	0.345	0.049	0.490	0.136	[illegible]	0.070	[illegible]	0.071	0.0009	5.00E-04	3.04E-05	5.76E-04	0.00E+00	4.54E-03	0.00E+00	0.00E+00	1.61E-21	7.68E-05	3.10E-04
U-204	5.5	4.4	1.1	0.20	1.7	[illegible]	736	[illegible]	7.97	51.7	0.151	0.188	0.497	0.093	0.452	[illegible]	0.107	0.070	[illegible]	0.129	0.0027	1.29E-03	4.76E-05	1.48E-04	9.34E-05	1.80E-04	0.00E+00	0.00E+00	8.55E-22	1.03E-05	3.67E-03
AN-101	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AN-102	60.3	45.6	14.7	0.24	18.8	1026	675	[illegible]	8.94	57.6	0.209	0.277	0.112	0.187	0.482	[illegible]	0.129	0.067	0.167	0.032	0.0071	1.07E-03	5.89E-03	4.44E-03	1.42E-04	2.61E-03	[illegible]	0.00E+00	2.34E-16	3.47E-03	2.44E-02
AN-103	146.6	134.3	12.3	0.08	45.8	[illegible]	766	[illegible]	9.70	21.0	0.092	1.123	0.398	0.847	0.451	0.200	0.124	0.020	0.152	[illegible]	0.0030	1.63E-03	1.11E-04	3.78E-04	1.15E-03	6.45E-04	[illegible]	0.00E+00	3.53E-16	2.48E-04	1.17E-03
AN-104	505.4	389.9	115.5	0.23	158.0	[illegible]	751	[illegible]	[illegible]	38.2	0.273	0.691	0.845	0.441	0.472	[illegible]	0.199	0.015	0.091	0.150	0.0014	3.21E-04	1.02E-04	1.46E-03	7.84E-05	4.17E-04	2.63E-03	0.00E+00	7.91E-17	3.71E-04	6.55E-04
AN-105	541.3	422.5	118.8	0.22	169.2	[illegible]	787	[illegible]	4.89	32.6	0.214	1.353	1.716	0.605	0.431	0.118	0.185	[illegible]	0.079	0.150	0.0046	3.62E-04	7.48E-05	1.34E-03	1.99E-04	1.23E-03	[illegible]	0.00E+00	9.40E-17	2.43E-04	4.66E-04
AN-106	17.1	12.5	4.6	0.27	5.4	[illegible]	644	[illegible]	9.13	63.6	0.274	0.315	0.269	0.238	0.507	[illegible]	0.141	0.070	[illegible]	0.033	0.0035	0.00E+00	6.07E-04	1.42E-03	8.22E-05	2.34E-03	2.05E-03	0.00E+00	1.10E-16	1.68E-03	1.58E-01
AN-107	414.6	315.4	99.2	0.24	129.6	[illegible]	750	0.621	10.00	38.8	0.277	0.669	1.003	0.448	0.477	[illegible]	[illegible]	0.016	0.092	0.150	0.0017	9.12E-05	4.47E-04	8.99E-04	1.32E-05	2.76E-04	3.54E-04	1.27E-04	1.27E-04	5.29E-04	7.61E-03
AP-101	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AP-102	223.9	193.0	31.0	0.14	70.0	[illegible]	795	0.853	9.12	[illegible]	0.089	0.427	0.613	0.678	0.570	0.200	0.066	0.011	0.032	0.017	[illegible]	0.00E+00	4.50E-06	3.46E-05	7.26E-07	3.02E-03	1.55E-05	0.00E+00	2.92E-18	6.27E-06	1.41E-05
AP-103	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AP-104	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AP-105	97.2	90.9	6.3	0.06	30.4	[illegible]	653	[illegible]	9.81	61.3	0.265	0.303	0.324	0.227	0.507	[illegible]	0.141	0.068	0.170	0.042	0.0009	4.86E-04	6.19E-05	3.44E-04	1.47E-05	2.13E-03	[illegible]	0.00E+00	7.94E-17	9.33E-05	1.73E-03
AP-106	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AP-107	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AP-108	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AW-101	127.2	102.3	25.0	0.20	39.8	[illegible]	764	0.652	6.69	33.8	0.328	1.469	0.090	0.620	[illegible]	[illegible]	0.168	[illegible]	0.056	0.150	0.0078	2.05E-03	1.48E-03	1.09E-03	4.35E-03	6.69E-03	[illegible]	0.00E+00	2.98E-16	9.08E-04	3.57E-02
AW-102	48.8	28.4	20.4	0.42	15.3	[illegible]	722	[illegible]	5.38	45.3	0.138	0.324	0.087	0.248	[illegible]	[illegible]	0.132	0.046	0.125	0.099	0.0281	0.00E+00	1.82E-03	2.10E-03	7.02E-05	1.03E-03	1.60E-04	0.00E+00	1.12E-20	6.76E-03	5.90E-02
AW-104	88.7	53.8	34.8	0.39	27.7	[illegible]	811	0.630	[illegible]	32.4	0.151	0.578	0.017	0.398	[illegible]	[illegible]	0.160	0.014	0.087	0.042	0.0194	4.62E-03	3.06E-02	5.34E-03	2.73E-02	1.37E-03	0.00E+00	0.00E+00	1.73E-16	1.27E-03	2.60E-01
AW-106	114.6	104.8	9.8	0.09	35.8	[illegible]	651	0.726	9.17	41.7	0.239	0.244	0.177	0.181	0.570	0.093	0.097	0.070	0.118	0.006	0.0074	0.00E+00	1.16E-03	1.11E-03	6.40E-04	2.38E-03	[illegible]	0.00E+00	2.30E-16	4.03E-03	3.38E-01
AY-101	382.8	304.7	78.1	0.20	119.6	[illegible]	751	0.810	9.85	30.3	0.276	0.420	0.260	0.348	0.570	[illegible]	0.086	0.055	0.048	[illegible]	0.0046	1.91E-03	2.01E-03	2.24E-03	7.46E-04	7.19E-04	0.00E+00	3.41E-05	3.41E-05	5.52E-03	8.60E-02
AY-102	663.1	461.7	201.4	0.30	207.3	[illegible]	863	0.696	5.72	16.8	0.088	1.128	0.624	0.606	[illegible]	0.181	0.105	[illegible]	0.079	[illegible]	0.0054	1.55E-03	3.10E-04	1.57E-03	2.18E-05	7.98E-04	0.00E+00	2.98E-05	6.29E-04	3.36E-03	8.91E-02
AZ-101	191.0	127.1	63.9	0.33	59.7	[illegible]	867	[illegible]	5.02	55.3	0.136	0.425	0.324	0.330	[illegible]	[illegible]	0.150	0.051	0.107	0.134	0.0041	1.11E-03	4.00E-02	5.36E-04	1.76E-03	1.06E-03	0.00E+00	3.03E-04	1.47E-03	5.36E-03	1.28E-01
AZ-102	221.0	151.1	69.9	0.32	69.1	[illegible]	833	[illegible]	6.36	43.4	0.175	0.647	0.267	0.411	[illegible]	[illegible]	0.168	0.029	0.089	[illegible]	0.0044	1.34E-03	2.33E-02	8.24E-04	5.68E-04	1.09E-03	0.00E+00	5.45E-05	2.97E-04	8.40E-03	3.28E-01
SY-101	121.7	79.1	42.6	0.35	38.0	1046	662	0.646	10.00	48.8	0.217	0.224	0.141	0.129	0.509	0.078	0.109	0.070	[illegible]	0.015	0.0048	9.68E-04	3.50E-04	7.60E-03	1.01E-04	4.21E-03	7.34E-04	0.00E+00	8.44E-17	2.79E-03	1.48E-02
SY-103	455.3	313.4	142.0	0.31	142.3	959	753	[illegible]	9.97	37.4	0.278	0.719	0.773	0.448	0.470	[illegible]	[illegible]	0.013	0.088	0.150	0.0028	3.75E-04	2.87E-04	6.45E-03	7.39E-05	1.57E-03	6.67E-04	1.60E-05	1.20E-04	4.82E-04	1.17E-02
Total Blend	20054.9	11151.7	8903.2	0.44	6268.1	[illegible]	735	0.621	4.50	45.7	0.206	0.778	0.118	0.477	[illegible]	0.076	0.158	0.034	0.098	0.078	0.0141	2.16E-03	8.59E-03	4.04E-03	6.38E-03	1.08E-02	[illegible]	2.81E-05	1.29E-04	6.45E-03	1.35E-01

Table B-2. Case 5 Glass Output for the Incidental Blend Subcase.

					Upper Limit:	1100	1050	1	10	100	2	2	2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	1	0.03	0.005	0.025	0.025	1	1
					Lower Limit:	850	-	0.62	4.5	10	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0
	Summary					Physical characteristics					Normalized Elemental Releases				Domain (weight fraction in glass)									Simple Limits (weight fraction in glass)							
HLW Glass Batch Number	Glass (MT)	Frit (MT)	Feed Oxides (MT)	Waste oxide loading	number of canisters (x m^3 each)	Liquidus Temp. (Spinel) (degrees C)	Liquidus Temp. (Zirc) (degrees C)	Wt. Fr. SiO2/ (SiO2+Na2O+ Al2O3)	Glass viscosity (Pa-s)	Elect. Cond. (ohm-m)^-1	silicon (g/m^2)	boron (g/m^2)	lithium (g/m^2)	sodium (g/m^2)	SiO_2	B_2O_3	Na_2O	Li_2O	Al_2O_3	Fe_2O_3	CaO	MgO	ZrO_2	Cr_2O_3	F	P_2O_5	SO_3	Rh_2O_3	Rh_2O_3 + Ru_2O_3	NiO	Pu (g/L)
1	130.5	83.8	46.7	0.36	40.8	[redacted]	859	0.688	6.05	17.4	0.087	0.947	0.585	0.507	[redacted]	0.173	0.109	[redacted]	0.082	[redacted]	0.0054	0.00155	0.0003	1.64E-03	3.57E-05	9.61E-04	3.05E-05	2.98E-05	6.29E-04	3.36E-03	8.90E-02
2	131.0	84.1	46.8	0.36	40.9	957	791	[redacted]	5.52	31.5	0.185	1.029	0.762	0.462	[redacted]	0.106	0.176	[redacted]	0.082	[redacted]	0.0054	0.00155	0.0003	1.63E-03	3.57E-05	9.59E-04	3.04E-05	2.98E-05	6.29E-04	3.36E-03	8.90E-02
3	131.0	84.1	46.8	0.36	40.9	[redacted]	859	0.688	6.04	17.4	0.087	0.952	0.586	0.510	[redacted]	0.173	0.109	[redacted]	0.082	[redacted]	0.0054	0.00155	0.0003	1.63E-03	3.57E-05	9.59E-04	3.04E-05	2.98E-05	6.29E-04	3.36E-03	8.90E-02
4	124.9	80.3	44.7	0.36	39.0	[redacted]	758	0.733	10.00	32.2	0.164	0.279	0.179	0.215	0.511	[redacted]	0.105	0.047	0.082	[redacted]	0.0054	0.00155	0.0003	1.63E-03	2.66E-05	9.48E-04	1.63E-05	2.98E-05	6.29E-04	3.36E-03	8.90E-02
5	34.2	21.8	12.3	0.36	10.7	[redacted]	822	[redacted]	[redacted]	63.8	0.138	0.323	0.314	0.222	0.426	[redacted]	0.132	0.067	0.129	0.120	0.0042	0.00093	0.0323	6.27E-04	1.46E-03	3.46E-03	6.45E-04	2.45E-04	1.20E-03	4.38E-03	1.05E-01
6	34.1	21.8	12.3	0.36	10.7	[redacted]	823	[redacted]	[redacted]	64.0	0.138	0.321	0.312	0.221	0.426	[redacted]	0.132	0.067	0.130	0.119	0.0042	0.00091	0.0328	6.06E-04	1.48E-03	3.50E-03	6.46E-04	2.49E-04	1.21E-03	4.39E-03	1.05E-01
7	34.1	21.8	12.3	0.36	10.6	[redacted]	823	[redacted]	[redacted]	64.1	0.138	0.320	0.313	0.220	0.426	[redacted]	0.132	0.067	0.130	0.119	0.0042	0.00091	0.0328	6.06E-04	1.48E-03	3.50E-03	6.47E-04	2.49E-04	1.21E-03	4.39E-03	1.05E-01
8	34.1	21.8	12.3	0.36	10.6	[redacted]	823	[redacted]	[redacted]	64.1	0.138	0.320	0.313	0.220	0.426	[redacted]	0.132	0.067	0.130	0.119	0.0042	0.00091	0.0328	6.06E-04	1.48E-03	3.50E-03	6.47E-04	2.49E-04	1.21E-03	4.39E-03	1.05E-01
9	34.1	21.8	12.3	0.36	10.6	[redacted]	823	[redacted]	[redacted]	64.1	0.138	0.320	0.313	0.220	0.426	[redacted]	0.132	0.067	0.130	0.119	0.0042	0.00091	0.0328	6.06E-04	1.48E-03	3.50E-03	6.47E-04	2.49E-04	1.21E-03	4.39E-03	1.05E-01
10	32.6	20.8	11.7	0.36	10.2	[redacted]	823	[redacted]	[redacted]	64.0	0.138	0.320	0.313	0.221	0.426	[redacted]	0.132	0.067	0.130	0.119	0.0042	0.00091	0.0328	6.07E-04	1.48E-03	3.51E-03	6.53E-04	2.49E-04	1.21E-03	4.39E-03	1.05E-01
11	30.7	17.8	12.9	0.42	9.6	[redacted]	861	[redacted]	8.51	32.2	0.159	0.686	0.291	0.352	[redacted]	0.067	0.178	[redacted]	0.079	[redacted]	0.0045	0.00133	0.0236	1.22E-03	6.32E-04	1.45E-03	6.78E-04	5.83E-05	3.15E-04	8.40E-03	3.28E-01
12	30.8	17.9	12.9	0.42	9.6	1045	839	[redacted]	8.00	37.1	0.264	1.084	0.334	0.529	0.431	[redacted]	0.195	[redacted]	0.069	[redacted]	0.0044	0.00134	0.0234	1.22E-03	6.16E-04	1.44E-03	6.78E-04	5.51E-05	2.99E-04	8.43E-03	3.30E-01
13	30.7	17.9	12.9	0.42	9.6	[redacted]	872	0.641	7.17	29.1	0.161	0.834	0.351	0.401	[redacted]	0.090	0.166	[redacted]	0.069	[redacted]	0.0044	0.00134	0.0233	1.22E-03	6.14E-04	1.43E-03	6.80E-04	5.46E-05	2.97E-04	8.44E-03	3.30E-01
14	30.7	17.9	12.9	0.42	9.6	[redacted]	851	[redacted]	[redacted]	33.4	0.171	0.637	0.245	0.356	0.430	[redacted]	0.182	0.011	0.081	[redacted]	0.0044	0.00134	0.0233	1.22E-03	6.14E-04	1.43E-03	6.80E-04	5.46E-05	2.97E-04	8.44E-03	3.30E-01
15	30.7	17.9	12.9	0.42	9.6	1044	839	[redacted]	7.97	37.2	0.265	1.092	0.335	0.532	0.431	[redacted]	0.195	[redacted]	0.069	[redacted]	0.0044	0.00134	0.0233	1.22E-03	6.14E-04	1.43E-03	6.80E-04	5.46E-05	2.97E-04	8.44E-03	3.30E-01
16	17.6	10.2	7.4	0.42	5.5	[redacted]	832	[redacted]	6.33	43.1	0.188	0.719	0.270	0.443	[redacted]	[redacted]	0.172	0.027	0.086	[redacted]	0.0044	0.00134	0.0233	1.23E-03	6.20E-04	1.47E-03	7.66E-04	5.47E-05	2.97E-04	8.44E-03	3.30E-01
17	165.0	90.7	74.3	0.45	51.6	[redacted]	944	0.626	7.38	41.7	0.304	[redacted]	0.137	0.903	[redacted]	[redacted]	0.200	0.012	0.051	0.077	0.0051	0.00086	0.0697	4.10E-03	2.81E-04	9.56E-04	7.70E-04	1.50E-04	1.59E-04	4.28E-03	2.27E-01
18	168.0	92.3	75.7	0.45	52.5	[redacted]	942	0.626	7.39	41.4	0.307	[redacted]	0.139	0.898	[redacted]	[redacted]	0.200	0.012	0.051	0.079	0.0051	0.00088	0.0686	4.11E-03	2.79E-04	1.04E-03	7.71E-04	1.48E-04	1.71E-04	4.28E-03	2.25E-01
19	182.8	100.2	82.6	0.45	57.1	[redacted]	931	0.627	7.43	40.3	0.318	[redacted]	0.151	0.872	[redacted]	[redacted]	0.200	0.010	0.050	0.090	0.0054	0.00099	0.0631	4.16E-03	2.80E-04	1.43E-03	7.75E-04	1.40E-04	2.28E-04	4.35E-03	2.17E-01
20	193.5	105.9	87.6	0.45	60.5	[redacted]	923	0.627	7.35	40.0	0.325	[redacted]	0.159	0.865	[redacted]	[redacted]	0.199	[redacted]	0.050	0.096	0.0055	0.00105	0.0596	4.20E-03	2.82E-04	1.67E-03	7.80E-04	1.34E-04	2.64E-04	4.39E-03	2.13E-01
21	178.9	98.1	80.8	0.45	55.9	[redacted]	933	0.626	7.42	40.7	0.315	[redacted]	0.147	0.879	[redacted]	[redacted]	0.200	0.011	0.051	0.087	0.0053	0.00096	0.0644	4.15E-03	2.81E-04	1.33E-03	7.76E-04	1.42E-04	2.13E-04	4.33E-03	2.19E-01
22	171.2	93.9	77.2	0.45	53.5	[redacted]	939	0.626	7.40	41.2	0.309	[redacted]	0.142	0.892	[redacted]	[redacted]	0.200	0.012	0.051	0.082	0.0052	0.00091	0.0674	4.13E-03	2.81E-04	1.13E-03	7.75E-04	1.47E-04	1.84E-04	4.30E-03	2.23E-01
23	167.4	91.9	75.5	0.45	52.3	[redacted]	942	0.626	7.39	41.5	0.306	[redacted]	0.138	0.899	[redacted]	[redacted]	0.200	0.012	0.051	0.079	0.0051	0.00088	0.0689	4.11E-03	2.81E-04	1.02E-03	7.74E-04	1.49E-04	1.68E-04	4.28E-03	2.25E-01
24	71.5	39.2	32.2	0.45	22.3	[redacted]	945	0.626	7.37	41.9	0.303	[redacted]	0.135	0.908	[redacted]	[redacted]	0.200	0.012	0.051	0.076	0.0050	0.00085	0.0704	4.11E-03	2.86E-04	9.22E-04	7.83E-04	1.51E-04	1.51E-04	4.25E-03	2.27E-01
25	308.8	210.1	98.7	0.32	96.5	[redacted]	690	0.798	9.71	32.1	0.316	0.570	0.103	0.505	0.566	[redacted]	0.094	0.051	0.049	0.079	0.0171	0.00055	0.0004	4.34E-04	1.32E-03	[redacted]	2.96E-04	2.17E-05	3.77E-04	1.19E-02	4.68E-02
26	310.1	211.8	98.3	0.32	96.9	[redacted]	754	0.693	9.81	28.2	0.358	0.981	0.171	0.643	0.481	[redacted]	0.164	[redacted]	0.049	0.137	0.0171	0.00054	0.0004	4.20E-04	1.32E-03	[redacted]	2.92E-04	2.13E-05	3.74E-04	1.19E-02	4.61E-02
27	310.5	212.5	98.0	0.32	97.0	[redacted]	752	[redacted]	5.73	38.8	0.297	1.053	0.216	0.599	[redacted]	[redacted]	0.185	0.013	0.072	0.150	0.0170	0.00054	0.0003	4.13E-04	1.32E-03	[redacted]	2.89E-04	2.12E-05	3.72E-04	1.18E-02	4.57E-02
28	306.7	202.3	104.3	0.34	95.8	[redacted]	695	0.763	9.88	31.3	0.350	0.748	0.088	0.647	0.538	[redacted]	0.118	0.037	0.049	0.079	0.0173	0.00054	0.0003	4.67E-04	1.33E-03	[redacted]	3.11E-04	2.14E-05	3.75E-04	1.20E-02	4.61E-02
29	301.7	187.8	113.8	0.38	94.3	[redacted]	707	[redacted]	7.83	37.0	0.282	0.972	0.063	0.566	0.434	[redacted]	0.185	[redacted]	0.081	0.080	0.0176	0.00056	0.0004	5.35E-04	1.36E-03	[redacted]	3.37E-04	2.18E-05	3.81E-04	1.22E-02	4.69E-02
30	296.2	188.4	107.8	0.36	92.6	[redacted]	682	[redacted]	[redacted]	51.1	0.299	1.064	0.067	0.676	0.423	[redacted]	0.168	0.032	0.091	0.078	0.0170	0.00053	0.0003	4.07E-04	1.32E-03	[redacted]	2.88E-04	2.11E-05	3.70E-04	1.18E-02	4.55E-02
31	183.9	97.1	86.8	0.47	57.5	[redacted]	741	[redacted]	[redacted]	58.1	0.198	0.500	0.155	0.382	0.434	[redacted]	0.146	0.054	0.120	0.084	0.0127	0.00788	0.0130	1.58E-03	1.09E-03	4.42E-03	1.63E-04	1.58E-05	3.24E-04	1.22E-02	3.43E-01
32	183.8	97.1	86.8	0.47	57.5	[redacted]	741	[redacted]	[redacted]	58.1	0.198	0.500	0.155	0.382	0.434	[redacted]	0.146	0.054	0.120	0.084	0.0127	0.00788	0.0130	1.58E-03	1.09E-03	4.42E-03	1.63E-04	1.58E-05	3.24E-04	1.22E-02	3.43E-01
33	184.0	97.2	86.8	0.47	57.5	[redacted]	741	[redacted]	[redacted]	58.1	0.198	0.501	0.155	0.383	0.434	[redacted]	0.146	0.054	0.120	0.084	0.0127	0.00788	0.0130	1.58E-03	1.09E-03	4.42E-03	1.63E-04	1.58E-05	3.24E-04	1.22E-02	3.43E-01
34	183.8	97.1	86.8	0.47	57.5	[redacted]	741	[redacted]	[redacted]	58.1	0.198	0.500	0.155	0.382	0.434	[redacted]	0.146	0.054	0.120	0.084	0.0127	0.00788	0.0130	1.58E-03	1.09E-03	4.42E-03	1.63E-04	1.58E-05	3.24E-04	1.22E-02	3.43E-01
35	169.4	87.9	81.5	0.48	52.9	[redacted]	750	[redacted]	[redacted]	55.6	0.203	0.556	0.172	0.429	0.430	[redacted]	0.151	0.049	0.112	0.095	0.0130	0.00732	0.0128	1.54E-03	1.16E-03	5.46E-03	1.37E-04	1.42E-05	2.94E-04	1.20E-02	3.28E-01
36	155.3	79.0	76.3	0.49	48.6	[redacted]	759	[redacted]	[redacted]	53.0	0.212	0.634	0.192	0.484	0.426	[redacted]	0.158	0.043	0.103	0.108	0.0134	0.00669	0.0126	1.49E-03	1.24E-03	6.61E-03	1.08E-04	1.24E-05	2.61E-04	1.18E-02	3.12E-01
37	132.4	59.0	73.4	0.55	41.4	[redacted]	711	[redacted]	4.63	53.3	0.209	0.660	0.066	0.427	[redacted]	[redacted]	0.148	0.044	0.109	0.081	0.0132	0.00327	0.0059	4.27E-03	9.12E-04	4.77E-03	1.95E-04	8.55E-06	1.65E-04	7.67E-03	1.49E-01
38	155.7	69.2	86.5	0.56	48.6	[redacted]	684	[redacted]	[redacted]	63.0	0.202	0.466	0.072	0.268	0.433	[redacted]	0.129	0.063	0.137	0.064	0.0108	0.00239	0.0043	4.29E-03	7.01E-04	7.68E-03	2.36E-04	6.46E-06	1.24E-04	6.04E-03	1.09E-01
39	193.8	107.4	86.4	0.45	60.6	[redacted]	699	[redacted]	[redacted]	51.8	0.412	1.442	0.152	0.947	0.436	[redacted]	0.188	0.027	0.079	0.085	0.0152	0.00239	0.0041	5.72E-03	3.93E-04	1.72E-02	1.15E-03	4.29E-06	8.80E-05	9.90E-03	1.21E-01
40	193.8	107.4	86.4	0.45	60.6	[redacted]	699	[redacted]	[redacted]	51.8	0.412	1.443	0.152	0.947	0.436	[redacted]	0.188	0.027	0.079	0.085	0.0152	0.00239	0.0041	5.71E-03	3.93E-04	1.72E-02	1.15E-03	4.28E-06	8.80E-05	9.91E-03	1.21E-01

HLW Glass Batch Number	Glass (MT)	Frit (MT)	Feed Oxides (MT)	Waste oxide loading	number of canisters (x m^3 each)	Liquidus Temp. (Spinel) (degrees C)	Liquidus Temp. (Zirc) (degrees C)	Wt. Fr. SiO2/ (SiO2+Na2O+ Al2O3)	Glass viscosity (Pa-s)	Elect. Cond. (ohm-m)^-1	silicon (g/m^2)	boron (g/m^2)	lithium (g/m^2)	sodium (g/m^2)	SiO_2	B_2O_3	Na_2O	Li_2O	Al_2O_3	Fe_2O_3	CaO	MgO	ZrO_2	Cr_2O_3	F	P_2O_5	SO_3	Rh_2O_3	Rh_2O_3 + Ru_2O_3	NiO	Pu (g/L)
					Upper Limit:	1100	1050	1	10	100	2	2	2	2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0.01	1	0.03	0.005	0.025	0.025	1	1
					Lower Limit:	850	-	0.62	4.5	10	-	-	-	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0	0	0	0	0	0	0	0
	Summary					Physical characteristics					Normalized Elemental Releases				Oxides (weight fraction in glass)									Simple Limits (weight fraction in glass)							
41	190.0	102.3	87.7	0.46	59.4	[redacted]	693	[redacted]	[redacted]	55.5	0.302	0.969	0.105	0.693	0.436	[redacted]	0.170	0.038	0.097	0.071	0.0141	0.00292	0.0051	5.51E-03	2.51E-03	1.59E-02	2.86E-03	6.98E-06	3.58E-05	1.16E-02	8.82E-02
42	188.6	100.5	88.1	0.47	58.9	[redacted]	690	[redacted]	[redacted]	56.8	0.278	0.856	0.093	0.615	0.436	[redacted]	0.164	0.042	0.103	0.066	0.0137	0.00310	0.0054	5.44E-03	3.24E-03	1.55E-02	3.45E-03	7.91E-06	1.78E-05	1.21E-02	7.69E-02
43	188.5	100.5	88.0	0.47	58.9	[redacted]	690	[redacted]	[redacted]	56.8	0.278	0.857	0.093	0.616	0.436	[redacted]	0.164	0.042	0.103	0.066	0.0137	0.00311	0.0054	5.44E-03	3.24E-03	1.55E-02	3.45E-03	7.92E-06	1.78E-05	1.21E-02	7.69E-02
44	311.0	212.1	98.9	0.32	97.2	[redacted]	711	[redacted]	9.97	41.8	0.161	0.341	0.114	0.271	0.459	[redacted]	0.153	0.036	0.128	0.080	0.0097	0.00089	0.0015	3.34E-03	7.51E-04	[redacted]	2.97E-03	2.08E-06	7.54E-06	4.85E-03	5.47E-02
45	357.9	256.2	101.7	0.28	111.9	874	698	0.662	9.99	35.7	0.568	1.395	0.385	0.868	0.509	0.060	0.200	[redacted]	0.060	0.077	0.0089	0.00064	0.0011	2.98E-03	5.31E-04	[redacted]	2.84E-03	1.41E-06	3.05E-06	4.03E-03	4.85E-02
46	233.2	133.8	99.3	0.43	72.9	[redacted]	750	0.742	9.89	22.2	0.357	1.388	0.171	0.732	0.503	0.101	0.137	[redacted]	0.039	0.084	0.0086	0.00107	0.0013	4.38E-03	4.56E-03	2.59E-02	[redacted]	2.54E-05	3.02E-05	2.90E-03	3.91E-02
47	249.5	151.5	98.0	0.39	78.0	978	666	0.772	9.47	35.9	0.918	1.918	0.187	1.524	0.569	[redacted]	0.138	0.037	0.030	0.062	0.0054	0.00104	0.0010	3.98E-03	6.17E-03	1.39E-02	[redacted]	3.57E-05	4.13E-05	1.02E-03	1.84E-02
48	231.0	125.8	105.1	0.46	72.2	[redacted]	729	0.688	9.89	31.3	0.476	1.512	0.117	0.773	0.481	[redacted]	0.171	[redacted]	0.048	0.109	0.0066	0.00120	0.0012	4.31E-03	8.91E-03	1.57E-02	[redacted]	3.49E-05	4.04E-05	1.53E-03	2.42E-02
49	78.0	49.3	28.7	0.37	24.4	[redacted]	667	0.626	7.50	40.4	0.376	[redacted]	0.014	0.712	[redacted]	[redacted]	0.178	[redacted]	0.073	0.035	0.0032	0.00045	0.0006	1.08E-03	7.18E-03	5.46E-03	3.27E-04	4.51E-07	8.73E-07	1.34E-03	1.55E-02
50	375.4	205.7	169.7	0.45	117.3	[redacted]	690	[redacted]	[redacted]	59.0	0.223	0.645	0.097	0.385	0.428	[redacted]	0.145	0.052	0.117	0.088	0.0079	0.00113	0.0015	2.70E-03	1.80E-02	1.32E-02	8.17E-04	9.63E-07	9.63E-07	3.32E-03	3.88E-02
51	236.4	131.0	105.4	0.45	73.9	[redacted]	699	[redacted]	[redacted]	35.9	0.304	0.517	0.136	0.917	0.446	[redacted]	0.198	[redacted]	0.075	0.061	0.0695	0.00145	0.0011	4.28E-03	4.16E-03	7.67E-03	4.90E-03	1.41E-05	1.68E-05	1.32E-03	2.09E-02
52	230.0	147.1	82.9	0.36	71.9	975	792	0.660	4.57	20.9	0.115	1.101	0.148	0.804	[redacted]	0.180	0.131	[redacted]	0.085	0.025	0.0383	0.00193	0.0088	5.69E-03	9.96E-03	9.39E-03	[redacted]	6.72E-06	8.16E-06	1.27E-03	8.34E-02
53	326.5	223.7	102.8	0.31	102.0	[redacted]	670	0.651	8.47	40.1	0.661	[redacted]	0.127	1.108	0.485	[redacted]	0.200	0.011	0.060	0.048	0.0097	0.00349	0.0005	4.20E-03	1.31E-03	1.35E-02	3.79E-03	8.00E-06	1.25E-04	2.54E-02	8.31E-02
54	334.8	230.6	104.3	0.31	104.7	[redacted]	669	0.652	8.53	40.1	0.666	[redacted]	0.129	1.112	0.487	[redacted]	0.200	0.011	0.060	0.048	0.0095	0.00349	0.0002	4.10E-03	9.34E-04	1.35E-02	3.73E-03	8.11E-06	1.27E-04	2.58E-02	8.13E-02
55	334.2	230.4	103.7	0.31	104.4	[redacted]	669	0.652	8.51	40.1	0.665	[redacted]	0.129	1.111	0.486	[redacted]	0.200	0.011	0.060	0.048	0.0095	0.00350	0.0002	4.04E-03	9.35E-04	1.34E-02	3.74E-03	8.13E-06	1.28E-04	2.58E-02	8.15E-02
56	721.7	591.7	130.0	0.18	225.6	[redacted]	608	0.734	6.05	60.7	0.603	0.868	0.189	0.806	0.570	[redacted]	0.129	0.070	0.077	0.024	0.0039	0.00162	0.0002	1.44E-03	9.22E-03	9.99E-03	[redacted]	9.34E-07	1.43E-05	3.54E-03	2.52E-02
57	538.2	403.1	135.2	0.25	168.2	[redacted]	760	0.697	4.55	24.9	0.129	1.182	0.174	0.549	0.443	0.200	0.068	0.047	0.124	0.026	0.0050	0.00247	0.0003	2.85E-03	6.47E-03	1.76E-02	[redacted]	2.27E-08	1.05E-07	1.56E-03	2.78E-02
58	302.7	190.4	112.3	0.37	94.6	[redacted]	764	[redacted]	9.95	23.6	0.097	0.540	0.125	0.330	0.432	0.136	0.145	[redacted]	0.120	0.046	0.0085	0.00451	0.0004	5.20E-03	4.97E-04	1.07E-02	[redacted]	1.02E-09	1.56E-08	3.03E-03	4.63E-02
59	302.4	190.2	112.2	0.37	94.5	952	726	0.734	9.91	22.1	0.383	1.731	0.318	1.028	0.525	0.127	0.145	[redacted]	0.046	0.036	0.0085	0.00452	0.0004	5.19E-03	4.91E-04	1.07E-02	[redacted]	9.91E-12	4.68E-11	3.03E-03	4.63E-02
60	292.3	184.7	107.6	0.37	91.4	1076	672	[redacted]	9.94	47.5	0.192	0.357	0.067	0.284	0.473	[redacted]	0.147	0.046	0.143	0.035	0.0082	0.00415	0.0004	5.28E-03	7.93E-04	1.00E-02	[redacted]	1.15E-06	8.32E-06	2.91E-03	4.67E-02
61	195.3	121.8	73.5	0.38	61.0	1084	734	0.629	4.66	50.1	0.313	1.046	0.365	0.637	0.435	[redacted]	0.173	0.033	0.083	0.150	0.0058	0.00156	0.0006	7.54E-03	3.22E-03	5.54E-03	[redacted]	1.00E-05	7.34E-05	2.15E-03	5.31E-02
62	185.9	114.4	71.4	0.38	58.1	[redacted]	676	[redacted]	4.50	49.8	0.428	1.859	0.612	1.082	0.466	0.096	0.200	0.025	0.086	0.051	0.0059	0.00159	0.0006	7.97E-03	3.28E-03	5.63E-03	[redacted]	1.02E-05	7.46E-05	2.19E-03	5.42E-02
63	172.7	86.9	85.8	0.50	54.0	1093	689	[redacted]	[redacted]	40.6	0.228	0.635	0.061	0.443	0.459	[redacted]	0.175	0.023	0.107	0.051	0.0084	0.00279	0.0012	7.71E-03	1.16E-02	9.80E-03	4.40E-03	7.51E-06	5.52E-05	3.45E-03	9.66E-02
64	202.6	103.5	99.0	0.49	63.3	[redacted]	670	[redacted]	[redacted]	57.4	0.295	1.022	0.055	0.617	0.429	[redacted]	0.161	0.041	0.102	0.058	0.0087	0.00322	0.0015	5.91E-03	1.62E-02	1.13E-02	2.99E-03	3.73E-06	2.76E-05	3.80E-03	1.12E-01
65	184.2	91.9	92.3	0.50	57.6	[redacted]	678	[redacted]	[redacted]	55.3	0.428	1.588	0.099	0.973	0.437	[redacted]	0.185	0.030	0.083	0.064	0.0107	0.00274	0.0036	7.70E-03	5.07E-03	1.44E-02	2.81E-03	3.70E-06	3.44E-05	7.15E-03	1.58E-01
66	171.7	78.2	93.5	0.54	53.7	[redacted]	686	[redacted]	5.04	49.1	0.526	[redacted]	0.107	1.127	0.439	[redacted]	0.199	0.018	0.071	0.062	0.0138	0.00397	0.0040	8.12E-03	1.05E-02	1.44E-02	4.48E-03	3.03E-06	3.03E-05	7.64E-03	1.62E-01
67	370.9	249.2	121.7	0.33	115.9	[redacted]	674	[redacted]	9.45	51.7	0.189	0.251	0.073	0.159	0.471	[redacted]	0.119	0.064	0.170	0.034	0.0100	0.00416	0.0010	3.37E-03	2.13E-02	5.51E-03	[redacted]	2.56E-06	2.94E-06	1.89E-03	4.42E-02
68	205.9	119.5	86.4	0.42	64.4	1003	715	[redacted]	9.96	37.9	0.323	0.940	0.212	0.555	0.465	[redacted]	[redacted]	[redacted]	0.085	0.093	0.0071	0.00202	0.0008	6.33E-03	1.24E-03	4.02E-03	2.00E-03	7.54E-05	8.40E-05	6.69E-03	1.42E-01
69	212.1	120.7	91.4	0.43	66.3	1062	667	[redacted]	[redacted]	51.8	0.197	0.293	0.085	0.203	0.478	[redacted]	0.133	0.058	0.160	0.038	0.0056	0.00107	0.0006	4.63E-03	9.77E-04	2.36E-03	1.84E-03	2.38E-05	3.31E-05	7.39E-03	1.60E-01
70	204.4	125.7	78.7	0.39	63.9	[redacted]	724	[redacted]	[redacted]	54.2	0.216	0.624	0.245	0.408	0.427	[redacted]	0.153	0.046	0.108	0.131	0.0086	0.00275	0.0005	4.78E-03	2.13E-03	5.30E-03	2.21E-03	2.20E-07	1.37E-06	5.69E-03	1.69E-01
71	199.7	108.0	91.7	0.46	62.4	[redacted]	716	[redacted]	[redacted]	47.5	0.226	0.582	0.186	0.542	0.431	[redacted]	0.165	0.035	0.099	0.106	0.0291	0.00242	0.0010	5.85E-03	2.34E-03	5.34E-03	3.24E-03	1.89E-07	1.52E-06	7.19E-03	1.42E-01
72	191.1	88.7	102.4	0.54	59.7	1068	710	[redacted]	6.17	34.4	0.250	0.469	0.130	0.691	0.451	[redacted]	0.194	[redacted]	0.083	0.066	0.0567	0.00185	0.0016	7.37E-03	2.47E-03	4.50E-03	3.61E-03	1.80E-07	1.68E-06	9.00E-03	9.71E-02
73	188.6	87.4	101.2	0.54	58.9	1073	711	[redacted]	6.23	34.2	0.244	0.457	0.128	0.676	0.451	[redacted]	0.193	[redacted]	0.084	0.066	0.0569	0.00186	0.0016	7.45E-03	2.47E-03	4.39E-03	3.44E-03	1.77E-07	1.67E-06	9.04E-03	9.76E-02
74	188.4	87.3	101.1	0.54	58.9	1072	710	[redacted]	6.23	34.2	0.245	0.457	0.129	0.678	0.451	[redacted]	0.193	[redacted]	0.084	0.066	0.0569	0.00185	0.0016	7.45E-03	2.47E-03	4.38E-03	3.44E-03	1.77E-07	1.67E-06	9.04E-03	9.75E-02
75	191.8	97.3	94.5	0.49	60.0	[redacted]	664	[redacted]	6.53	58.6	0.201	0.278	0.101	0.178	0.464	[redacted]	0.119	0.070	0.165	0.040	0.0182	0.00251	0.0007	5.09E-03	1.52E-03	4.39E-03	2.49E-03	2.87E-07	3.24E-06	5.44E-03	1.15E-01
76	242.3	131.8	110.6	0.46	75.7	1086	666	[redacted]	8.16	58.1	0.212	0.285	0.097	0.154	0.469	[redacted]	0.118	0.070	[redacted]	0.044	0.0052	0.00188	0.0004	4.70E-03	6.25E-04	5.01E-03	3.19E-03	2.25E-06	3.94E-06	3.26E-03	1.05E-01
77	243.4	129.7	113.7	0.47	76.1	861	668	[redacted]	[redacted]	45.8	0.294	0.672	0.153	0.561	0.488	[redacted]	0.190	0.027	0.109	0.043	0.0080	0.00145	0.0009	3.79E-03	2.71E-04	2.43E-03	3.90E-03	2.25E-06	4.61E-06	4.33E-03	1.25E-01
78	258.6	134.1	124.5	0.48	80.8	[redacted]	690	[redacted]	6.96	52.1	0.171	0.352	0.062	0.209	0.442	[redacted]	0.127	0.056	0.144	0.064	0.0075	0.00301	0.0012	3.29E-03	2.09E-04	2.30E-03	1.76E-03	3.70E-07	2.26E-06	5.08E-03	1.55E-01
79	408.6	302.3	106.3	0.26	127.7	[redacted]	696	0.686	4.51	41.9	0.170	0.352	0.120	0.136	0.469	0.126	0.078	0.070	0.137	0.032	0.0118	0.00034	0.0005	2.42E-03	1.98E-02	1.32E-02	[redacted]	2.11E-08	2.08E-07	3.90E-03	2.36E-02
80	396.5	293.8	102.8	0.26	123.9	[redacted]	705	0.811	9.13	32.3	0.350	0.621	0.146	0.516	0.570	[redacted]	0.090	0.054	0.043	0.105	0.0118	0.00029	0.0004	2.44E-03	1.97E-02	1.32E-02	[redacted]	1.99E-08	1.96E-07	3.83E-03	2.20E-02
81	329.7	204.3	125.4	0.38	103.1	[redacted]	661	[redacted]	6.73	61.5	0.214	0.348	0.065	0.170	0.456	[redacted]	0.117	0.070	0.162	0.044	0.0037	0.00201	0.0005	3.04E-03	8.06E-05	3.96E-03	1.61E-03	1.10E-08	1.25E-07	1.92E-03	8.31E-02

HLW Glass Batch Number	Glass (MT)	Frit (MT)	Feed Oxides (MT)	Waste oxide loading	number of canisters (x m^3 each)	Liquidus Temp. (Spinel) (degrees C)	Liquidus Temp. (Zirc) (degrees C)	Wt. Fr. SiO2/(SiO2+Na2O+Al2O3)	Glass viscosity (Pa-s)	Elect. Cond. (ohm-m)^-1	silicon (g/m^2)	boron (g/m^2)	lithium (g/m^2)	sodium (g/m^2)	SiO_2	B_2O_3	Na_2O	Li_2O	Al_2O_3	Fe_2O_3	CaO	MgO	ZrO_2	Cr_2O_3	F	P_2O_5	SO_3	Rh_2O_3	Rh_2O_3 + Ru_2O_3	NiO	Pu (g/L)
					Upper Limit:	1100	1050	1	10	100	2	2	2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	1	0.03	0.005	0.025	0.025	1	1
					Lower Limit:	850	-	0.62	4.5	10	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0
	Summary					Physical characteristics					Normalized Elemental Releases				Domain (weight fraction in glass)									Simple Limits (weight fraction in glass)							
82	313.3	181.0	132.4	0.42	97.9	[illegible]	671	[illegible]	[illegible]	60.5	0.243	0.748	0.062	0.421	0.429	[illegible]	0.146	0.051	0.116	0.070	0.0064	0.00091	0.0007	2.90E-03	3.05E-05	4.94E-03	4.18E-03	1.13E-07	2.93E-07	2.21E-03	1.27E-01
83	295.6	190.8	104.7	0.35	92.4	[illegible]	682	[illegible]	9.96	43.9	0.181	0.398	0.060	0.301	0.461	[illegible]	0.153	0.037	0.130	0.050	0.0089	0.00066	0.0005	3.31E-03	1.09E-02	9.83E-03	[illegible]	5.33E-08	1.58E-07	5.51E-03	6.12E-02
84	322.9	234.6	88.3	0.27	100.9	1011	641	0.748	9.75	43.2	0.320	0.414	0.090	0.381	0.570	[illegible]	0.109	0.062	0.083	0.032	0.0096	0.00043	0.0002	3.20E-03	1.66E-02	1.19E-02	[illegible]	9.65E-09	5.56E-08	7.02E-03	1.28E-02
85	243.7	148.5	95.2	0.39	76.2	[illegible]	783	[illegible]	8.44	21.2	0.081	0.749	0.205	0.448	[illegible]	0.168	0.133	[illegible]	0.124	0.052	0.0084	0.00048	0.0003	4.08E-03	1.31E-02	1.07E-02	[illegible]	7.53E-09	4.36E-08	5.73E-03	7.70E-02
86	254.9	155.6	99.3	0.39	79.7	1047	678	[illegible]	5.03	52.8	0.207	0.405	0.163	0.158	0.449	0.109	0.105	0.070	[illegible]	0.024	0.0057	0.00040	0.0002	3.82E-03	7.58E-03	7.47E-03	3.88E-03	4.36E-09	2.53E-08	3.50E-03	1.07E-01
87	236.4	135.2	101.3	0.43	73.9	1019	636	[illegible]	5.22	70.8	0.271	0.469	0.116	0.309	0.470	[illegible]	0.138	0.070	0.150	0.034	0.0091	0.00073	0.0004	4.40E-03	9.48E-03	8.91E-03	[illegible]	1.17E-07	1.35E-07	4.93E-03	1.03E-01
88	320.9	218.9	102.0	0.32	100.3	1049	758	0.736	9.97	26.7	0.732	1.853	0.379	1.164	0.519	0.050	0.164	[illegible]	0.022	0.150	0.0139	0.00125	0.0008	3.88E-03	9.74E-03	8.33E-03	[illegible]	3.68E-07	3.71E-07	6.40E-03	3.93E-02
89	290.1	191.6	98.5	0.34	90.7	967	641	0.775	4.50	51.0	0.538	0.973	0.260	0.796	0.561	0.067	0.106	0.070	0.057	0.048	0.0149	0.00135	0.0009	4.23E-03	1.03E-02	8.88E-03	[illegible]	3.97E-07	3.99E-07	6.88E-03	4.23E-02
90	289.8	191.4	98.4	0.34	90.6	[illegible]	662	0.671	9.58	40.5	0.708	1.383	0.351	1.220	0.533	[illegible]	0.200	0.018	0.061	0.048	0.0149	0.00135	0.0009	4.23E-03	1.03E-02	8.88E-03	[illegible]	3.97E-07	3.99E-07	6.88E-03	4.22E-02
91	290.1	191.6	98.4	0.34	90.7	982	741	0.814	9.98	17.8	0.433	1.773	0.540	1.312	0.570	0.142	0.106	0.019	0.024	0.048	0.0149	0.00135	0.0009	4.23E-03	1.03E-02	8.88E-03	[illegible]	3.97E-07	3.99E-07	6.89E-03	4.23E-02
92	487.6	391.9	95.6	0.20	152.4	1071	710	0.679	10.00	34.1	0.166	0.176	0.127	0.068	0.499	0.122	0.066	0.070	0.170	0.023	0.0035	0.00027	0.0003	2.13E-03	1.38E-03	4.95E-03	[illegible]	2.63E-08	3.56E-08	1.03E-03	5.30E-02
93	486.1	391.0	95.2	0.20	151.9	[illegible]	626	0.706	9.73	53.7	0.329	0.328	0.156	0.303	0.570	0.051	0.123	0.070	0.115	0.022	0.0027	0.00027	0.0003	2.10E-03	6.48E-04	4.72E-03	[illegible]	1.22E-09	9.64E-09	6.60E-04	5.80E-02
94	397.1	302.7	94.5	0.24	124.1	[illegible]	734	[illegible]	4.62	56.7	0.173	0.440	0.325	0.244	0.424	[illegible]	0.135	0.056	0.125	0.150	0.0029	0.00062	0.0003	2.62E-03	3.00E-05	4.91E-03	[illegible]	2.62E-10	2.77E-09	7.65E-04	7.73E-02
95	327.6	204.9	122.7	0.37	102.4	1041	793	[illegible]	9.88	18.6	0.075	0.977	0.282	0.682	0.428	0.200	0.114	0.015	0.149	0.029	0.0030	0.00051	0.0003	3.97E-03	4.66E-05	8.83E-03	[illegible]	2.50E-09	7.56E-09	7.47E-04	7.71E-02
96	307.8	200.0	107.8	0.35	96.2	918	633	[illegible]	9.02	64.1	0.281	0.344	0.146	0.236	0.501	[illegible]	0.137	0.070	[illegible]	0.018	0.0025	0.00035	0.0002	3.31E-03	4.71E-05	3.98E-03	4.10E-03	3.76E-09	9.88E-09	6.11E-04	6.42E-02
97	389.8	279.2	110.6	0.28	121.8	[illegible]	827	0.621	10.00	18.0	0.076	0.607	0.549	0.395	[illegible]	0.200	0.086	0.027	[illegible]	0.065	0.0015	0.00019	0.0001	2.44E-03	2.16E-04	2.87E-03	1.83E-03	1.09E-09	2.81E-09	3.77E-04	1.00E-01
98	408.3	298.7	109.5	0.27	127.6	[illegible]	634	0.624	10.00	63.6	0.295	0.322	0.249	0.250	0.518	[illegible]	0.142	0.070	[illegible]	0.022	0.0012	0.00016	0.0001	2.25E-03	2.42E-04	2.55E-03	1.29E-03	1.32E-10	7.69E-10	3.22E-04	1.09E-01
99	306.2	196.8	109.4	0.36	95.7	1086	727	0.663	9.96	38.6	0.156	0.166	0.108	0.072	0.489	0.106	0.079	0.070	[illegible]	0.022	0.0033	0.00037	0.0087	3.18E-03	9.32E-04	6.38E-03	3.22E-03	2.97E-08	3.88E-08	1.65E-03	1.84E-01
100	294.6	198.0	96.6	0.33	92.1	[illegible]	844	0.738	4.57	22.2	0.112	1.199	0.286	0.715	0.451	0.200	0.069	0.041	0.091	0.052	0.0054	0.00057	0.0191	3.06E-03	1.66E-03	7.88E-03	[illegible]	6.53E-08	8.45E-08	3.12E-03	2.29E-01
101	396.3	303.0	93.3	0.24	123.9	[illegible]	738	0.661	9.83	38.7	0.148	0.157	0.118	0.069	0.486	0.104	0.079	0.070	0.170	0.028	0.0044	0.00038	0.0106	2.71E-03	2.35E-03	6.78E-03	[illegible]	3.10E-07	4.33E-06	2.16E-03	1.25E-01
102	444.5	358.6	85.9	0.19	138.9	953	671	0.624	9.97	59.8	0.233	0.266	0.162	0.190	0.502	[illegible]	0.132	0.070	0.170	0.025	0.0040	0.00032	0.0077	2.46E-03	2.60E-03	5.00E-03	[illegible]	3.97E-07	5.84E-06	1.82E-03	8.92E-02
103	350.6	237.2	113.5	0.32	109.6	[illegible]	858	0.685	4.53	22.0	0.092	1.472	0.416	0.898	[illegible]	0.200	0.095	0.029	0.098	0.072	0.0046	0.00047	0.0172	4.03E-03	2.14E-03	1.21E-02	[illegible]	2.63E-07	3.87E-06	2.87E-03	2.63E-01
104	269.9	165.9	104.0	0.39	84.4	[illegible]	750	[illegible]	7.77	60.2	0.158	0.248	0.071	0.155	0.459	[illegible]	0.122	0.070	0.159	0.033	0.0042	0.00057	0.0271	4.33E-03	9.20E-04	1.05E-02	3.60E-03	1.87E-11	2.13E-10	3.72E-03	4.56E-01
105	316.7	196.8	120.0	0.38	99.0	[illegible]	687	0.713	9.97	38.9	0.286	0.568	0.064	0.445	0.519	[illegible]	0.130	0.043	0.079	0.055	0.0060	0.00127	0.0041	4.46E-03	7.17E-03	[illegible]	4.15E-03	4.62E-05	7.66E-05	1.16E-03	8.16E-02
106	315.5	203.2	112.3	0.36	98.6	1088	646	0.789	5.42	49.7	0.494	0.995	0.086	0.647	0.550	[illegible]	0.094	0.070	0.054	0.058	0.0063	0.00137	0.0013	4.00E-03	8.02E-03	[illegible]	4.25E-03	5.24E-05	8.69E-05	8.52E-04	3.64E-02
107	315.5	203.2	112.3	0.36	98.6	1059	639	0.774	4.52	55.2	0.580	1.265	0.104	0.838	0.539	[illegible]	0.104	0.070	0.054	0.058	0.0063	0.00137	0.0013	4.00E-03	8.02E-03	[illegible]	4.25E-03	5.24E-05	8.69E-05	8.52E-04	3.64E-02
108	315.5	203.2	112.3	0.36	98.6	[illegible]	692	[illegible]	9.92	42.1	0.204	0.536	0.066	0.375	0.458	[illegible]	0.166	0.028	0.115	0.058	0.0063	0.00137	0.0013	4.00E-03	8.02E-03	[illegible]	4.25E-03	5.24E-05	8.69E-05	8.52E-04	3.64E-02
109	512.4	383.9	128.5	0.25	160.2	[illegible]	610	0.757	4.50	64.2	1.037	1.858	0.291	1.692	0.570	[illegible]	0.133	0.069	0.050	0.036	0.0042	0.00084	0.0024	2.88E-03	4.43E-03	[illegible]	2.87E-03	2.84E-05	4.71E-05	7.92E-04	3.85E-02
110	235.9	147.7	88.2	0.37	73.7	1088	849	0.633	9.55	17.1	0.060	0.890	0.252	0.670	[illegible]	0.200	0.114	[illegible]	0.129	0.040	0.0061	0.00068	0.0125	4.57E-03	7.56E-04	7.22E-03	[illegible]	1.28E-06	2.12E-06	2.51E-03	1.44E-01
111	241.4	159.6	81.8	0.34	75.4	948	676	0.749	9.81	38.5	0.262	0.316	0.156	0.250	0.570	0.078	0.100	0.062	0.091	0.035	0.0036	0.00027	0.0039	3.87E-03	6.78E-04	8.47E-03	[illegible]	8.42E-06	1.40E-05	1.24E-03	7.99E-02
112	260.8	173.6	87.1	0.33	81.5	[illegible]	720	[illegible]	9.62	35.3	0.261	0.927	0.497	0.519	0.478	0.089	0.200	[illegible]	0.093	0.066	0.0034	0.00045	0.0028	3.78E-03	8.60E-04	7.84E-03	[illegible]	5.43E-06	9.00E-06	9.47E-04	6.01E-02
113	265.3	183.0	82.3	0.31	82.9	1025	688	0.780	9.03	34.7	0.214	0.243	0.131	0.144	0.570	0.091	0.069	0.070	0.092	0.047	0.0031	0.00071	0.0011	3.52E-03	1.12E-03	3.96E-03	[illegible]	1.36E-06	2.26E-06	5.29E-04	3.26E-02
114	386.1	280.1	106.0	0.27	120.7	[illegible]	766	[illegible]	9.92	35.4	0.147	0.412	0.220	0.259	0.438	[illegible]	0.162	0.022	0.107	0.150	0.0030	0.00070	0.0003	2.52E-03	4.54E-03	2.92E-03	[illegible]	6.07E-05	1.01E-04	3.23E-04	2.18E-02
115	395.7	289.6	106.0	0.27	123.7	1057	804	0.832	9.12	13.1	0.157	1.365	0.309	0.990	0.532	0.200	0.052	0.026	0.056	0.062	0.0030	0.00070	0.0003	2.39E-03	4.78E-03	2.59E-03	[illegible]	6.49E-05	1.08E-04	3.09E-04	2.11E-02
116	433.4	317.9	115.5	0.27	135.5	1020	720	0.847	5.90	30.8	0.294	0.568	0.221	0.282	0.570	0.116	[illegible]	0.070	0.053	0.068	0.0029	0.00072	0.0043	2.06E-03	3.85E-03	2.34E-03	[illegible]	6.71E-05	1.79E-04	1.34E-03	5.55E-02
117	306.0	177.7	128.3	0.42	95.6	[illegible]	691	[illegible]	[illegible]	58.4	0.360	1.229	0.135	0.816	0.441	[illegible]	0.178	0.038	0.092	0.072	0.0085	0.00258	0.0065	5.77E-03	2.18E-03	1.24E-02	4.07E-03	1.06E-05	2.05E-04	1.41E-02	1.23E-01
118	411.3	282.6	128.7	0.31	128.5	[illegible]	740	[illegible]	9.98	26.9	0.126	0.629	0.137	0.376	0.447	0.123	0.161	[illegible]	0.113	0.035	0.0081	0.00255	0.0019	4.65E-03	3.26E-03	1.02E-02	[illegible]	3.40E-06	5.90E-05	1.38E-02	6.63E-02
119	306.4	231.6	74.7	0.24	95.8	[illegible]	759	[illegible]	9.96	22.4	0.090	0.536	0.144	0.362	0.437	0.150	0.142	[illegible]	0.125	0.033	0.0134	0.00128	0.0002	3.60E-03	1.80E-02	5.61E-03	[illegible]	3.61E-12	8.02E-11	1.08E-02	9.72E-03
120	280.9	187.6	93.3	0.33	87.8	[illegible]	671	0.780	9.68	31.1	0.601	1.281	0.176	0.970	0.570	0.078	0.122	0.037	0.039	0.041	0.0059	0.00031	0.0005	9.20E-03	2.62E-03	1.83E-02	[illegible]	8.76E-06	9.76E-06	2.70E-03	2.55E-02
121	0.1	0.05	0.01	0.19	0.02	[illegible]	747	[illegible]	[illegible]	41.2	0.229	0.493	1.163	0.378	0.481	[illegible]	0.189	0.025	0.106	0.150	4.66E-13	4.46E-14	7.41E-15	9.62E-14	6.24E-13	1.45E-13	1.55E-13	1.26E-22	2.80E-21	3.78E-13	3.39E-13

APPENDIX C

DEGREE OF PRETREATMENT

This appendix contains the results of the four cases (Cases A, B, C and D) that were used to identify the degree of pretreatment that each tank could benefit. Table C-1. Degree of Pretreatment Case Results contains that calculated glass mass for the Total Blend, No Blend, and individual tanks for each Case. The shaded cells highlight the glass mass associated with the selected degree of pretreatment for the waste in each tank.

The right hand side of the table contains the calculations that were used to select the degree of pretreatment. A straw man cut-off value was computed, which represents the maximum amount of glass that would be accepted from a given tank before switching to a more aggressive degree of pretreatment. The cut-off was set equal to the sum of the minimum glass produced for that tank for any case (degree of pretreatment) plus the maximum of the following two terms:

- "Tol-1": 10% of the minimum glass produced for that tank for any case (degree of pretreatment), and
- "Tol-2": $1/177^{th}$ of 10% of the minimum glass for the No Blend Case.

The assumed degree of pretreatment was selected by using the least aggressive degree of pretreatment for which the corresponding glass is less than or equal to the cut-off for that tank. For purposes of this study, the degrees of pretreatment, in increasing degrees of aggressiveness, are:

- Case A – Water Wash,
- Case D – Water Wash and Oxidative Leach,
- Case B – Water Wash and Caustic Leach, and
- Case C – Water Wash, Caustic Leach and Oxidative Leach.

Table C-1. Degree of Pretreatment Case Results.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)				Percent decrease				MT Glass				
									Pretreatment Selection Logic				
	A	B	C	D	A→B	B→C	A→C	A→D	Tol - 1	Tol - 2	Cut Off	Use	MT Glass
Total	53,591	43,955	23,099	45,883	18%	47%	57%	14%					
No	112,161	69,304	42,993	86,278	38%	38%	62%	23%					
A-101	1,199	957	121	161	20%	87%	90%	87%	12	13	134	C	121
A-102	222	177	40	42	20%	77%	82%	81%	4	13	53	D	42
A-103	299	239	95	126	20%	60%	68%	58%	9	13	108	C	95
A-104	281	279	279	281	1%	0%	1%	0%	28	13	307	A	281
A-105	183	182	182	183	1%	0%	1%	0%	18	13	200	A	183
A-106	466	240	161	178	49%	33%	66%	62%	16	13	177	C	161
AX-101	817	649	262	349	21%	60%	68%	57%	26	13	288	C	262
AX-102	66	65	65	66	1%	0%	1%	0%	7	13	78	A	66
AX-103	266	211	43	47	21%	80%	84%	82%	4	13	56	D	47
AX-104	131	130	130	131	1%	0%	1%	0%	13	13	143	A	131
B-101	270	211	211	270	22%	0%	22%	0%	21	13	233	B	211
B-102	155	109	109	155	30%	0%	30%	0%	11	13	122	B	109
B-103	301	211	211	301	30%	0%	30%	0%	21	13	232	B	211
B-104	601	403	403	601	33%	0%	33%	0%	40	13	443	B	403
B-105	1,694	1,270	1,270	1,694	25%	0%	25%	0%	127	13	1,397	B	1,270
B-106	607	200	200	607	67%	0%	67%	0%	20	13	219	B	200
B-107	789	581	581	789	26%	0%	26%	0%	58	13	639	B	581
B-108	573	430	430	573	25%	0%	25%	0%	43	13	473	B	430
B-109	436	144	144	436	67%	0%	67%	0%	14	13	158	B	144
B-110	854	292	289	854	66%	1%	66%	0%	29	13	318	B	292
B-111	660	266	256	660	60%	4%	61%	0%	26	13	282	B	266
B-112	85	39	35	85	54%	10%	58%	0%	4	13	48	B	39
B-201	125	116	111	119	7%	4%	11%	5%	11	13	124	D	119
B-202	64	61	54	58	6%	10%	16%	10%	5	13	67	A	64
B-203	100	96	84	87	4%	13%	16%	14%	8	13	97	D	87
B-204	113	109	95	98	4%	13%	16%	13%	9	13	108	D	98
BX-101	312	64	64	312	80%	0%	80%	0%	6	13	77	B	64
BX-102	397	105	105	397	74%	0%	74%	0%	11	13	118	B	105
BX-103	200	66	66	200	67%	0%	67%	0%	7	13	79	B	66
BX-104	825	240	236	825	71%	2%	71%	0%	24	13	259	B	240
BX-105	463	119	116	463	74%	3%	75%	0%	12	13	129	B	119
BX-106	298	112	74	298	62%	33%	75%	0%	7	13	88	C	74
BX-107	2,700	675	675	2,700	75%	0%	75%	0%	68	13	743	B	675
BX-108	367	92	92	367	75%	0%	75%	0%	9	13	105	B	92
BX-109	1,117	279	279	1,117	75%	0%	75%	0%	28	13	307	B	279
BX-110	511	252	217	298	51%	14%	58%	42%	22	13	239	C	217
BX-111	266	200	200	266	25%	0%	25%	0%	20	13	220	B	200
BX-112	943	708	708	943	25%	0%	25%	0%	71	13	778	B	708
BY-101	1,335	334	334	1,335	75%	0%	75%	0%	33	13	367	B	334
BY-102	314	236	236	314	25%	0%	25%	0%	24	13	259	B	236
BY-103	452	434	263	417	4%	40%	42%	8%	26	13	289	C	263
BY-104	572	553	215	274	3%	61%	62%	52%	22	13	237	C	215
BY-105	482	456	456	482	5%	0%	5%	0%	46	13	501	A	482
BY-106	218	210	131	134	4%	37%	40%	39%	13	13	144	D	134

Table C-1. Degree of Pretreatment Case Results.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)				Percent decrease				MT Glass				
									Pretreatment Selection Logic				
	A	B	C	D	A→B	B→C	A→C	A→D	Tol - 1	Tol - 2	Cut Off	Use	MT Glass
Total	53,591	43,955	23,099	45,883	18%	47%	57%	14%					
No	112,161	69,304	42,993	86,278	38%	38%	62%	23%					
BY-107	362	233	233	362	36%	0%	36%	0%	23	13	256	B	233
BY-108	327	155	155	327	53%	0%	53%	0%	15	13	170	B	155
BY-109	893	670	670	893	25%	0%	25%	0%	67	13	737	B	670
BY-110	587	567	220	243	3%	61%	62%	59%	22	13	242	C	220
BY-111	716	537	537	716	25%	0%	25%	0%	54	13	591	B	537
BY-112	2,670	2,563	1,069	1,425	4%	58%	60%	47%	107	13	1,176	C	1,069
C-101	671	151	151	671	77%	0%	77%	0%	15	13	167	B	151
C-102	913	388	388	913	58%	0%	58%	0%	39	13	427	B	388
C-103	1,125	244	244	1,125	78%	0%	78%	0%	24	13	269	B	244
C-104	1,326	897	897	1,326	32%	0%	32%	0%	90	13	987	B	897
C-105	1,912	157	157	1,912	92%	0%	92%	0%	16	13	173	B	157
C-106	44	43	43	44	2%	0%	2%	0%	4	13	56	A	44
C-107	1,006	982	982	1,006	2%	0%	2%	0%	98	13	1,080	A	1,006
C-108	211	108	108	211	49%	0%	49%	0%	11	13	121	B	108
C-109	416	171	171	416	59%	0%	59%	0%	17	13	188	B	171
C-110	828	207	207	828	75%	0%	75%	0%	21	13	228	B	207
C-111	339	211	211	339	38%	0%	38%	0%	21	13	232	B	211
C-112	590	296	296	590	50%	0%	50%	0%	30	13	326	B	296
C-201	14	14	14	14	1%	0%	1%	0%	1	13	27	A	14
C-202	4	4	4	4	4%	1%	5%	1%	0	13	17	A	4
C-203	39	28	11	12	28%	60%	71%	70%	1	13	24	D	12
C-204	35	25	10	10	29%	60%	71%	70%	1	13	23	D	10
S-101	1,638	1,053	1,053	1,638	36%	0%	36%	0%	105	13	1,159	B	1,053
S-102	532	496	61	65	7%	88%	89%	88%	6	13	74	D	65
S-103	705	680	31	51	4%	95%	96%	93%	3	13	44	C	31
S-104	2,081	1,105	1,105	2,081	47%	0%	47%	0%	110	13	1,215	B	1,105
S-105	250	250	44	44	0%	83%	83%	82%	4	13	57	D	44
S-106	1,813	1,813	185	246	0%	90%	90%	86%	18	13	203	C	185
S-107	2,297	692	679	2,297	70%	2%	70%	0%	68	13	747	B	692
S-108	2,025	2,019	249	333	0%	88%	88%	84%	25	13	274	C	249
S-109	565	560	41	97	1%	93%	93%	83%	4	13	54	C	41
S-110	1,437	693	121	229	52%	82%	92%	84%	12	13	135	C	121
S-111	1,155	986	210	956	15%	79%	82%	17%	21	13	231	C	210
S-112	1,523	1,518	710	946	0%	53%	53%	38%	71	13	781	C	710
SX-101	2,468	2,044	87	271	17%	96%	96%	89%	9	13	100	C	87
SX-102	1,600	1,542	140	187	4%	91%	91%	88%	14	13	154	C	140
SX-103	1,571	606	361	481	61%	41%	77%	69%	36	13	397	C	361
SX-104	1,064	506	108	333	52%	79%	90%	69%	11	13	121	C	108
SX-105	851	816	112	182	4%	86%	87%	79%	11	13	125	C	112
SX-106	1,282	1,223	97	306	5%	92%	92%	76%	10	13	110	C	97
SX-107	837	184	184	837	78%	0%	78%	0%	18	13	203	B	184
SX-108	193	129	86	179	34%	33%	56%	8%	9	13	99	C	86
SX-109	1,540	339	339	1,540	78%	0%	78%	0%	34	13	373	B	339
SX-110	449	99	99	449	78%	0%	78%	0%	10	13	112	B	99
SX-111	952	209	209	952	78%	0%	78%	0%	21	13	230	B	209

Table C-1. Degree of Pretreatment Case Results.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)				Percent decrease			
	A	B	C	D	A→B	B→C	A→C	A→D
Total	53,591	43,955	23,099	45,883	18%	47%	57%	14%
No	112,161	69,304	42,993	86,278	38%	38%	62%	23%
SX-112	657	145	145	657	78%	0%	78%	0%
SX-113	77	49	49	77	36%	0%	36%	0%
SX-114	865	190	190	865	78%	0%	78%	0%
SX-115	15	12	12	15	21%	0%	21%	0%
T-101	368	87	87	368	76%	0%	76%	0%
T-102	365	80	80	365	78%	0%	78%	0%
T-103	201	45	45	201	78%	0%	78%	0%
T-104	2,189	547	547	2,189	75%	0%	75%	0%
T-105	312	192	192	312	39%	0%	39%	0%
T-106	123	33	33	123	73%	0%	73%	0%
T-107	1,008	756	756	1,008	25%	0%	25%	0%
T-108	163	41	41	163	75%	0%	75%	0%
T-109	33	18	18	33	45%	0%	45%	0%
T-110	466	258	244	466	45%	5%	48%	0%
T-111	771	641	601	768	17%	6%	22%	0%
T-112	112	101	91	100	9%	10%	19%	10%
T-201	122	114	106	111	6%	7%	13%	9%
T-202	42	40	34	35	5%	15%	19%	16%
T-203	75	71	59	62	5%	17%	21%	18%
T-204	97	93	76	80	5%	17%	22%	18%
TX-101	717	158	158	717	78%	0%	78%	0%
TX-102	184	138	138	184	25%	0%	25%	0%
TX-103	126	95	95	126	25%	0%	25%	0%
TX-104	220	48	48	220	78%	0%	78%	0%
TX-105	543	408	408	543	25%	0%	25%	0%
TX-106	359	136	79	359	62%	42%	78%	0%
TX-107	28	15	15	28	46%	0%	46%	0%
TX-108	117	88	88	117	25%	0%	25%	0%
TX-109	427	347	317	404	19%	9%	26%	5%
TX-110	440	330	330	440	25%	0%	25%	0%
TX-111	340	255	255	340	25%	0%	25%	0%
TX-112	599	449	449	599	25%	0%	25%	0%
TX-113	1,413	1,059	1,059	1,413	25%	0%	25%	0%
TX-114	491	368	368	491	25%	0%	25%	0%
TX-115	526	395	395	526	25%	0%	25%	0%
TX-116	722	398	398	722	45%	0%	45%	0%
TX-117	558	275	275	558	51%	0%	51%	0%
TX-118	865	444	216	865	49%	51%	75%	0%
TY-101	1,103	397	397	1,103	64%	0%	64%	0%
TY-102	41	31	31	41	25%	0%	25%	0%
TY-103	1,299	371	371	1,299	71%	0%	71%	0%
TY-104	161	98	98	161	39%	0%	39%	0%
TY-105	3,602	901	901	3,602	75%	0%	75%	0%
TY-106	69	27	27	69	60%	0%	60%	0%
U-101	227	50	50	227	78%	0%	78%	0%

MT Glass				
Pretreatment Selection Logic				
Tol - 1	Tol - 2	Cut Off	Use	MT Glass
14	13	159	B	145
5	13	62	B	49
19	13	209	B	190
1	13	25	A	15
9	13	100	B	87
8	13	93	B	80
4	13	58	B	45
55	13	602	B	547
19	13	211	B	192
3	13	46	B	33
76	13	832	B	756
4	13	54	B	41
2	13	31	B	18
24	13	269	B	258
60	13	661	B	641
9	13	104	D	100
11	13	119	D	111
3	13	47	A	42
6	13	72	D	62
8	13	89	D	80
16	13	173	B	158
14	13	152	B	138
9	13	108	B	95
5	13	61	B	48
41	13	448	B	408
8	13	92	C	79
2	13	28	A	28
9	13	101	B	88
32	13	349	B	347
33	13	363	B	330
25	13	280	B	255
45	13	494	B	449
106	13	1,165	B	1,059
37	13	405	B	368
39	13	434	B	395
40	13	437	B	398
27	13	302	B	275
22	13	238	C	216
40	13	437	B	397
3	13	44	A	41
37	13	408	B	371
10	13	111	B	98
90	13	991	B	901
3	13	41	B	27
5	13	63	B	50

Table C-1. Degree of Pretreatment Case Results.

Tank or Blend	Case (MT of HLW Glass Produced for Each Case)				Percent decrease				MT Glass				
									Pretreatment Selection Logic				
	A	B	C	D	A→B	B→C	A→C	A→D	Tol - 1	Tol - 2	Cut Off	Use	MT Glass
Total	53,591	43,955	23,099	45,883	18%	47%	57%	14%					
No	112,161	69,304	42,993	86,278	38%	38%	62%	23%					
U-102	393	337	194	347	14%	42%	51%	12%	19	13	213	C	194
U-103	803	782	387	516	3%	51%	52%	36%	39	13	426	C	387
U-104	352	222	84	352	37%	62%	76%	0%	8	13	97	C	84
U-105	618	539	204	373	13%	62%	67%	40%	20	13	224	C	204
U-106	246	246	25	41	0%	90%	90%	83%	3	13	38	C	25
U-107	705	649	67	178	8%	90%	90%	75%	7	13	80	C	67
U-108	1,034	975	359	665	6%	63%	65%	36%	36	13	395	C	359
U-109	897	840	133	274	6%	84%	85%	69%	13	13	146	C	133
U-110	979	300	300	979	69%	0%	69%	0%	30	13	330	B	300
U-111	774	737	67	177	5%	91%	91%	77%	7	13	81	C	67
U-112	444	98	98	444	78%	0%	78%	0%	10	13	111	B	98
U-201	39	9	9	39	78%	0%	78%	0%	1	13	22	B	9
U-202	33	7	7	33	78%	0%	78%	0%	1	13	20	B	7
U-203	15	3	3	15	78%	0%	78%	0%	0	13	16	A	15
U-204	25	6	6	25	78%	0%	78%	0%	1	13	19	B	6
AN-101	0	0	0	0	0%	0%	0%	0%	0	13	13	A	0
AN-102	108	60	60	80	44%	0%	44%	25%	6	13	73	B	60
AN-103	195	147	147	195	25%	0%	25%	0%	15	13	161	B	147
AN-104	930	502	505	930	46%	1%	46%	0%	50	13	553	B	502
AN-105	928	541	541	928	42%	0%	42%	0%	54	13	595	B	541
AN-106	44	22	17	17	50%	23%	61%	61%	2	13	30	D	17
AN-107	774	415	415	774	46%	0%	46%	0%	41	13	456	B	415
AP-101	0	0	0	0	0%	0%	0%	0%	0	13	13	A	0
AP-102	231	224	224	231	3%	0%	3%	0%	22	13	246	A	231
AP-103	0	0	0	0	0%	0%	0%	0%	0	13	13	A	0
AP-104	0	0	0	0	0%	0%	0%	0%	0	13	13	A	0
AP-105	130	97	97	130	25%	0%	25%	0%	10	13	110	B	97
AP-106	0	0	0	0	0%	0%	0%	0%	0	13	13	A	0
AP-107	0	0	0	0	0%	0%	0%	0%	0	13	13	A	0
AP-108	0	0	0	0	0%	0%	0%	0%	0	13	13	A	0
AW-101	170	127	127	170	25%	0%	25%	0%	13	13	140	B	127
AW-102	163	49	49	163	70%	0%	70%	0%	5	13	62	B	49
AW-103	1,758	1,758	1,758	1,758	0%	0%	0%	0%	176	13	1,933	A	1,758
AW-104	397	141	89	397	64%	37%	78%	0%	9	13	102	C	89
AW-105	987	986	986	987	0%	0%	0%	0%	99	13	1,085	A	987
AW-106	502	400	115	153	20%	71%	77%	70%	11	13	128	C	115
AY-101	487	383	383	487	21%	0%	21%	0%	38	13	421	B	383
AY-102	663	663	663	663	0%	0%	0%	0%	66	13	729	A	663
AZ-101	384	191	191	384	50%	0%	50%	0%	19	13	210	B	191
AZ-102	282	221	221	282	22%	0%	22%	0%	22	13	243	B	221
SY-101	2,200	2,077	122	553	6%	94%	94%	75%	12	13	135	C	122
SY-102	1,380	987	101	260	29%	90%	93%	81%	10	13	114	C	101
SY-103	1,866	1,761	455	949	6%	74%	76%	49%	46	13	501	C	455