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Selecting Compositions for Phase 1 of the PCT Assessment Study

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A. D. Cozzi
K. G. Brown
D. K. Peeler
T. B. Edwards

Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, SC 29808

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Document Approvals

A.D. Cozzi, Immobilization Technology Section Author	Date
D.K. Peeler, Immobilization Technology Section Author	Date
T.B. Edwards, Statistical Consulting Section Author	Date
C.C. Herman, Immobilization Technology Section Technical Reviewer	Date
R.C. Tuckfield, Statistical Consulting Section Section Manager	Date
S.L. Marra, Glass Formulation and Process Development Group Immobilization Technology Section Manager	Date
E.W. Holtzscheiter, Immobilization Technology Section Section Manager Authorized Derivative Classifier	Date

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1. Introduction

In the Defense Waste Processing Facility (DWPF), glass durability is predicted based on the **T**hermodynamic **H**ydration **E**nergy **R**eaction **Mo**del (THERMO™) [1], which models the response of glass to the Product Consistency Test (PCT) [2] as a function of composition. Periodically during research and development, a glass is fabricated in which the predicted PCT response fails the durability constraint in the Product Composition Control System (PCCS) [3], but has a measured durability that is acceptable [4]. A recent example of this is the development of Frit 304, which was developed as part of an improved melt rate task for Sludge Batch 2 [5].

Thus far, the predicted liquidus temperature has primarily limited the waste loading in the DWPF. Recently, a new liquidus temperature model had been developed that can predict liquidus temperatures more accurately than the original model [6]. Additionally, a new frit has been recommended to DWPF for Sludge Batch 2 [7] and an effort is underway to relax or eliminate the homogeneity constraint in PCCS [8].

PCCS evaluation of proposed Sludge Batches 3 and 4 have indicated that the implementation of the new liquidus model and the relaxation (or elimination) of the homogeneity constraint in conjunction with the changeover to Frit 320 could make durability the limiting constraint for DWPF operation [9].

The purpose of this task [10] is to generate the glass property/composition data and model necessary for enhancing operational processing windows. This effort is intended to be both generally applicable to all Department of Energy (DOE) High-Level Waste (HLW) glasses and specific to individual waste processing plants such as the DWPF and the planned High-Level and Low Activity Waste (HLW and LAW) plants at Hanford. Phase 1 consists of determining the glass compositional region where the existing durability model is not dependable in identifying durable glasses. Phase 2 will be devoted to developing a method of ensuring that durable glass compositions are not excluded from processing.

2. Discussion

In the sections that follow, the glass compositions that are to be studied in this first phase of the PCT assessment task are selected. Section 2.1 presents the bounding concentrations (as weight percents, wt%'s) for the major oxides (including an "Others" term of minor components) associated with DWPF sludge-only processing (as defined in Rev. 12 of the HLW system Plan), which were previously developed [11]. In Section 2.2, the bounding glass composition region defined in Section 2.1 is further restricted by imposing property/composition model (and other) constraints. These constraints are imposed so that they restrict the compositional region to glasses that are predicted to be processable by DWPF but which challenge the current durability models (i.e., the current durability models predict the glasses to have an unacceptable normalized release of boron). Thus, the batching and testing (by means of the PCT-A) of glasses selected from this region explores the possibly that the current durability models have an overly restrictive impact on DWPF's compositional operating window. Section 2.2 provides the candidate compositions that are generated from the extremes of the bounding glass region and a set of compositions selected to be a part of the experimental work. Section 2.3 identifies an interior glass composition region (less extreme than the bounding region) and a set of glass compositions from this region that was selected to complement the initially selected glasses. Section 2.4 identifies a modified, interior glass composition region and a set of glass compositions from this region that were selected to complement the previously selected glasses. In Section 2.5, a final glass composition is added to the selected compositions and the complete test matrix is provided.

2.1 Defining the Glass Composition Region for Sludge-Only Processing

The development of a bounding glass composition region for DWPF sludge-only processing was a necessary activity of Phase 2 of the Reduction of Constraints task [8]. As part of that effort, the major components in the waste and/or frit that were anticipated to have a measurable impact on glass properties were identified. The respective upper and lower bounds for the concentrations of these oxides were established using criteria defined based on glass science issues, information regarding sludge types and/or blends, and solubility or imposed processing limits for individual oxides. The approach used in Reference 11 led to the oxides and their ranges given in Table 1. For example, to determine the ranges for sodium, the following logic was used. The Tank Farm will target a minimum sodium content of 6 wt% in the washed sludge. On a calcined oxide basis it is equal to approximately 10 wt% Na_2O. If a waste loading of 50% is used as in Reference 11, then the sludge contribution is approximately 5 wt%. In all frit compositions considered for DWPF, the frit will also contribute to the total Na_2O content. If the minimum Na_2O frit containing 4 wt% Na_2O is considered, at a 50% waste loading the total glass content would be roughly 7 wt%. Therefore, the minimum Na_2O was set at the slightly higher concentration of 7.5 wt%. Quantities of alkali metal oxides (such as Na_2O) greater than 20 wt% will often result in a reduction in durability for borosilicate glasses [1]. High sodium glasses (up to 25 wt%), which are being considered for Hanford Low Activity Waste (LAW), that meet durability requirements have been identified [12, 13]. Therefore, the upper limit was set at 25 wt%. This limit also builds in the flexibility to accommodate compositions of sludge that has been underwashed.

Table 1. Upper and Lower Bounds for the Major Oxides and "Others" Used in This Study.

Oxide	Lower	Upper
Al_2O_3	3.0	15.0
B_2O_3	5.0	12.0
CaO	0.5	4.0
Fe_2O_3	5.0	18.0
Li_2O	3.0	7.0
MgO	0.0	4.0
MnO	0.5	8.0
Na_2O	7.5	25.0
NiO	0.0	5.0
SiO_2	40.0	65.0
TiO_2	0.0	1.75
U_3O_8	0.0	8.0
Others	0.0	2.0

The "Others" component of Table 1 is defined by the oxides identified in Table 2. See Reference 11 for the complete discussion of this component of the glass composition region.
The information in Table 1 and was used to define the DWPF sludge-only processing region to support Phase 2 of the Reduction of Constraints task [11]. This sludge-only region is also the starting point for this first phase of the PCT assessment study. In the next section, constraints are imposed on this region so that they restrict the compositional region to glasses that are predicted to be processable by DWPF but which challenge the current durability models (i.e., the current durability models predict the glasses to have unacceptable normalized release of boron).

Table 2. Components Making Up "Others" for This Study

	% of Others
BaO	1.96%
CdO	7.68%
CoO	1.06%
Cr_2O_3	13.19%
CuO	3.16%
La_2O_3	2.29%
RuO_2	3.25%
MoO_3	0.38%
P_2O_5	49.92%
PbO	5.20%
SnO_2	1.13%
SrO	1.15%
V_2O_5	1.51%
ZnO	3.32%
ZrO_2	4.80%
SUM	100.00

2.2 Bounding the Glass Composition Region

The oxides and their ranges utilized to bound the glass compositional region of interest for this study were identified in Table 1. Any glass whose composition falls within the region defined by this table would be within this bounded region. However, portions of the glass region defined by Table 1 would be deemed unacceptable by DWPF's PCCS system (i.e., such glasses would not be considered processable or they would be considered to have questionable durability). Then, too, glass science would suggest the exclusion of some glass compositions within the region defined by Table 1 (e.g., glasses that would lead to a nepheline primary phase). In this section, constraints are described that were imposed on the region defined by Table 1 to restrict the compositional region to glasses that are predicted to be processable by DWPF but which challenge the current durability models (i.e., the current durability models predict the glasses to have unacceptable durabilities). This approach was used to facilitate the selection of glasses for this first phase of the PCT assessment task. The batching and testing (by means of the PCT) of such glasses allows for the investigation into the possibly that the current durability models have an overly restrictive impact on DWPF's compositional operating window.

A glass within the region defined by Table 1 is a mixture of the 13 "components" defined in that table. Statistical methods and algorithms are available in the packages such as JMP Version 4.0.5 [14] and MIXSOFT Version 2.3.1 [15] to assist in the design and analysis of mixture experiments. One approach would be to generate the extreme vertices (EVs) of the bounding region of Table 1, and statistical algorithms are available to assist in this approach. The MIXSOFT [15] algorithms also provide the capability of imposing linear (in the 13 components) constraints on the glass composition region. Such constraints, gleaned from PCCS and glass science, will be imposed to restrict the compositions to a more feasible or processable glass region for the purposes of this task.

Predictions from the current DWPF models that relate glass composition to product properties (such as durability) and processability properties (such as viscosity and liquidus temperature) were used to evaluate the feasibility of glass compositions of interest in this study. These models were also used (where possible) to restrict the glass composition region from which the feasible glass compositions were generated.

As described in the task plan [10], the primary property of concern (the only one that is to be measured) in this study is the glass durability as defined by the PCT [2]. From the discussions in Reference 3, the property acceptability region (PAR) for durability is expressed as a limit on the free energy of hydration (ΔG_p) values for the boron, lithium, and sodium models of -12.8215, -12.7178, and -13.0167, kcal/mol respectively.* For a given glass composition, its ΔG_p value will be computed to determine if the durability PAR constraint(s) (conservatively bounded by -12.7178 kcal/mol) is satisfied.

The details of the product acceptance and processability constraints considered in this study are as follows:†

<u>Product Acceptance Constraints</u>

The homogeneity constraint [16] in terms of oxide mass fractions is given by

$$1.603(B_2O_3 + Li_2O + Na_2O + SiO_2) + 5.6478(Al_2O_3 + CaO + Fe_2O_3) > 210.92034.$$

Compositions that meet this constraint satisfy the homogeneity PAR. The glass region for this study of durability will not employ the homogeneity constraint. The exclusion of the homogeneity constraint is founded on the assumption that the task in Reference 8 is successful. Thus, the region defined by Table 1 will not be restricted by the homogeneity constraint. The Al_2O_3-Al_2O_3+R_2O criteria [9] will also be excluded in order to explore a greater portion of the composition range.

The determination of ΔG_p in terms of molar oxides and its PAR limit (bounded by the value for Li) are given by

$$\Delta G_p = 37.68[Al_2O_3] - 10.43[B_2O_3] - 13.79[CaO] + 14.56[Fe_2O_3] - 24.04[Li_2O] - 6.57[MgO] - 24.44[MnO] - 53.09[Na_2O] + 0.37[NiO] + 4.05[SiO_2] - 23.77[U_3O_8].$$

The calculation assumes that iron is completely oxidized. This assumption is consistent with the DWPF technical basis [17]. As the glasses in this study are to be made from batch chemicals and melted in open crucibles, the assumption should be valid.

The durability (PCT) prediction (in g/L) for each element of concern is given by

$$NL_B = 10^{(-1.9014 - 0.1812*\Delta G_p)} \text{ for boron,}$$

$$NL_{Li} = 10^{(-1.5459 - 0.1468*\Delta G_p)} \text{ for lithium, and}$$

$$NL_{Na} = 10^{(-1.8012 - 0.1710*\Delta G_p)} \text{ for sodium.}$$

For Phase 1 of this study, the glass region will be restricted to compositions that fail to satisfy the durability PAR. For a given glass composition, its ΔG_p value will be computed to determine if the durability PAR constraint(s) (conservatively bounded by the -12.7178 kcal/mol) is(are) satisfied. Once again, the intent is to restrict the composition region to glasses with ΔG_p values less than (or more negative than) –12.7178 kcal/mol.

<u>Processability Constraints</u>

Two processability constraints, liquidus temperature (T_L) and melt viscosity (η) at 1150°C, were considered. (These properties are not to be measured during this study for any of the glasses, only

* The property acceptability region (PAR) for a constraint incorporates the model uncertainty into the limit for that constraint.

† In the property models that follow, oxides not involved in this variability study are not represented in these models. Their values are assumed to be zero. The minor components represented in "Others" are not shown in the models presented here for simplicity, but they are included in the actual model predictions for each glass composition.

predicted.) The first, T_L [3], can be predicted from molar oxide concentrations and whose PAR is currently defined by

$$T_L = \{2276.8723\left(\frac{-134.0[Fe_2O_3]}{-155.6[SiO_2]-(-359.88[Al_2O_3])}\right)+803.8696\} \le 1024.9$$

The glass region was not restricted for this T_L constraint, as the DWPF will implement the new T_L constraint before additional sludge batches are processed. However, this T_L model was used to assess the selected glasses and for future comparison with historical glass T_L data generated when this model was in place.

A new T_L model [6], which has been developed by the SRTC for the DWPF, also is to be evaluated for each glass. The property model for this new T_L constraint is given by:

$$T_L\left({}^{o}C\right)=\left\{\ln\left[(M_2)^a(M_1)^b(M_T)^c\right]+d\right\}^{-1}-273$$

where

$$\Sigma_{MT} \equiv \phi_{T,SiO_2}[SiO_2]+\phi_{T,Al_2O_3}[Al_2O_3]+\phi_{T,Fe_2O_3}[Fe_2O_3]$$
$$\Sigma_{M1} \equiv \phi_{M1,Al_2O_3}[Al_2O_3]+\phi_{M1,Fe_2O_3}[Fe_2O_3]+\phi_{M1,TiO_2}[TiO_2]+\phi_{M1,Cr_2O_3}[Cr_2O_3] + \phi_{M1,ZrO_2}[ZrO_2]+\phi_{M1,MgO}[MgO]+\phi_{M1,MnO}[MnO]$$
$$\Sigma_{M2} \equiv \phi_{M2,NiO}[NiO]+\phi_{M2,MgO}[MgO]+\phi_{M2,MnO}[NiO]+\phi_{M2,CaO}[CaO] + \phi_{M2,K_2O}[K_2O]+\phi_{M2,Li_2O}[Li_2O]+\phi_{M2,Na_2O}[Na_2O]$$
$$\Sigma_{T1} \equiv \phi_{T1,SiO_2}[SiO_2]+\phi_{T1,Al_2O_3}[Al_2O_3]+\phi_{T1,Fe_2O_3}[Fe_2O_3]+\phi_{T1,TiO_2}[TiO_2]$$
$$\Sigma_{N1} \equiv \phi_{N1,K_2O}[K_2O]+\phi_{N1,Li_2O}[Li_2O]+\phi_{N1,Na_2O}[Na_2O]$$

and

$$M_2 \equiv \frac{\Sigma_{M2}}{\Sigma}, M_1 \equiv \frac{\Sigma_{M1}}{\Sigma}, M_T \equiv \frac{\Sigma_T}{\Sigma}, \text{and } \Sigma \equiv \Sigma_{M2}+\Sigma_{M1}+\Sigma_{MT}+\Sigma_{T1}+\Sigma_{N1}.$$

The PAR for this relationship is composition-dependent but will be conservatively set at 1010°C to assess selected glasses. No attempt was made in this study to incorporate the actual PAR determinations for the new model.

Also, note that this is not a linear function of the glass components. So, liquidus temperature, at least in this model form, could not be used to restrict the feasible glass region using MIXSOFT [15]. However, restrictions will be imposed on the glass region using a linear approximation to this model. This is more fully explained in the discussion that follows.

The PAR for the second processability constraint, viscosity (in Poise) at 1150°C, is defined by [3 and 18]:

$$21.5308 \le 10^{\left(-1.5342\cdot\left(\frac{2([Fe_2O_3]-[Al_2O_3]+[Li_2O]+[Na_2O])+[B_2O_3]}{[SiO_2]}\right)+3.2788\right)} \le 105.4437\ .$$

This constraint was used to restrict the glass region, and a modified form of the constraint (where the lower and upper limits were set to the Expected Property Acceptance Region {EPAR} limits of 20 and 110 Poise, respectively) was also used to restrict the glass region for some situations. The distinction in the use of these limits is discussed in what follows.

A summary of the property limits or constraints being implemented in this study is shown Table 3. These limits were used to assess all glass compositions that were generated as part of this study, and as indicated above, in the discussion that follows various forms of constraints based upon these models were used to define a bounding glass composition for this study.

Table 3. Summary of Constraints.

Constraint	**Units**	**Limit(s)**	**Impact on Glass Region**
Homogeneity	wt%	> 210.92034	Not used to restrict region in any manner.
Durability (ΔG_P)	Kcal/mol	-12.7178	Used to restrict region to glasses that fail to satisfy durability PAR
Liquidus Temperature (T_L)	°C	≤ 1024.9°C	Since model is being phased out, it is not used to restrict region only to assess selected glasses
Viscosity at 1150°C ($\eta_{1150°C}$)	Poise	$21.5308 \leq \eta_{1150°C} \geq 105.4437$	PAR limits used to restrict region as described below.
Viscosity at 1150°C ($\eta_{1150°C}$)	Poise	$20 \leq \eta_{1150°C} \geq 110$	EPAR limits used to provide the least restriction on the region as described below.
Liquidus Temperature (T_L) – New Model	°C	≤ 1010°C	Since model is nonlinear, it is not used to restrict region, only to assess selected glasses. A "linear" version of the T_L model is used as described below.

The strategy to bound the glass region to be more applicable to DWPF processing revolves around the oxide ranges of Table 1 and the constraints that were discussed above. The software MIXSOFT [15] was used to determine the EVs of the constrained glass region. The region was defined in the 13 oxides (including "Others") of Table 1. An obvious constraint on the concentration values (as weight fractions) of these oxides is that each must be between 0 and 1 and that for a given glass composition; they must sum to one. The additional information needed by MIXSOFT to fully define the initial glass region of interest for this durability task is given in Table 4 and specifications concerning the constraints are provided below.

Table 4. MIXSOFT Input for Initial, Bounding Glass Region.

Row	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others	Constant	Comment
1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0.15	Upper Al_2O_3 limit
2	1	0	0	0	0	0	0	0	0	0	0	0	0	-0.03	Lower Al_2O_3 limit
3	0	-1	0	0	0	0	0	0	0	0	0	0	0	0.12	Upper B_2O_3 limit
4	0	1	0	0	0	0	0	0	0	0	0	0	0	-0.05	Lower B_2O_3 limit
5	0	0	-1	0	0	0	0	0	0	0	0	0	0	0.04	Upper CaO limit
6	0	0	1	0	0	0	0	0	0	0	0	0	0	-0.005	Lower CaO limit
7	0	0	0	-1	0	0	0	0	0	0	0	0	0	0.18	Upper Fe_2O_3 limit
8	0	0	0	1	0	0	0	0	0	0	0	0	0	-0.05	Lower Fe_2O_3 limit
9	0	0	0	0	-1	0	0	0	0	0	0	0	0	0.07	Upper Li_2O limit
10	0	0	0	0	1	0	0	0	0	0	0	0	0	-0.03	Lower Li_2O limit
11	0	0	0	0	0	-1	0	0	0	0	0	0	0	0.04	Upper MgO limit
12	0	0	0	0	0	0	-1	0	0	0	0	0	0	0.08	Upper MnO limit
13	0	0	0	0	0	0	1	0	0	0	0	0	0	-0.005	Lower MnO limit
14	0	0	0	0	0	0	0	-1	0	0	0	0	0	0.25	Upper Na_2O limit
15	0	0	0	0	0	0	0	1	0	0	0	0	0	-0.075	Lower Na_2O limit
16	0	0	0	0	0	0	0	0	-1	0	0	0	0	0.05	Upper NiO limit
17	0	0	0	0	0	0	0	0	0	-1	0	0	0	0.65	Upper SiO_2 limit
18	0	0	0	0	0	0	0	0	0	1	0	0	0	-0.4	Lower SiO_2 limit
19	0	0	0	0	0	0	0	0	0	0	-1	0	0	0.0175	Upper TiO_2 limit
20	0	0	0	0	0	0	0	0	0	0	0	-1	0	0.08	Upper U_3O_8 limit
21	0	0	0	0	0	0	0	0	0	0	0	0	-1	0.02	Upper Others limit
22	0	1	0	0	1	0	0	0	0	1	0	0	0	-0.525	Lower frit limit
23	-0.62	0	0	0	0	0	0	-0.62	0	0.38	0	0	0	0	Nepheline limit
24	-3.01	2.204	0	1.92	10.27	0	0	4.951	0	-2.06	0	0	0	0	Lower Visc. EPAR
25	3.01	-2.204	0	-1.92	-10.27	0	0	-4.951	0	3.2917	0	0	0	0	Upper Visc. EPAR
26	-36.96	14.98	24.59	-9.1	80.5	16.3	34.45	85.7	-0.5	-6.74	-20.4	2.8	0	-12.72	Fail Durability PAR

The details of Table 4 are as follows:

- Rows 1 through 21 provide constraints on the individual oxides to reflect the values of Table 1.

- Row 22 provides a constraint on the sum of uniquely frit components of the form

$$B_2O_3 + Li_2O + SiO_2 \geq 0.525$$

This helps ensure that the region contains glasses representing feasible (up to 40% waste loading, or no less than 60% frit if Na_2O is at a minimum of 7.5 wt%).

- Row 23 provides protection from possible nepheline phases via the constraint [19]:

$$\frac{SiO_2}{Al_2O_3 + Na_2O + SiO_2} \geq 0.62$$

- Rows 24 and 25 specify the lower and upper EPAR limits for viscosity. The glass region is restricted to be within the viscosity EPAR. Using the EPAR limits versus the PAR limits for viscosity makes these constraints less restrictive; thus expanding the glass region explored by this approach.

- Row 26 specifies the constraint for the durability PAR. The glass region is restricted to be outside of the durability PAR.

As discussed previously, the homogeneity constraint is not being used to restrict this region. The omission of the homogeneity constraint coupled with the forced failure of the durability constraint will provide additional data for a concurrent study [8].

Also, note that initially no liquidus temperature constraint is imposed on this region. The MIXSOFT program generated 8,786 EVs for the region defined by Table 4. These EVs were imported into JMP Version 4.0.5 [14], and JMP was used to generate Exhibit A1 in the Appendix, which provides descriptive statistics for these EV glasses including both the compositions and property predictions. Also, shown in this exhibit is a set of descriptive statistics for the sum of alkali for the glass compositions. For this study, this is the sum $Li_2O + Na_2O$.

Some observations regarding this exhibit may be helpful: The maximum value of Al_2O_3 is not attained (14.1 wt% versus 15 wt%). Note that the T_L predictions generated by the new T_L model approach 1491°C, well above the DWPF nominal operating temperature of 1150°C. Thus, the region defined by the information of Table 4 includes glasses that will not be considered processable for the DWPF. Application of a T_L constraint is needed to further restrict the bounding glass composition region.

Using JMP, the T_L predictions from the new liquidus temperature model that were generated for the EVs were used to fit a linear model (in composition space). Table 5 provides summary information from that fit.

Table 5. JMP Linear Fit to T_L Predictions.

Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept	Zeroed	0	0	.	.
Al_2O_3		2836.3583	13.32462	212.87	0.0000
B_2O_3		1011.6776	10.57598	95.66	0.0000
CaO		911.82455	19.78207	46.09	0.0000
Fe_2O_3		2620.1618	9.469932	276.68	0.0000
Li_2O		-1127.001	27.41747	-41.11	0.0000
MgO		3882.0247	17.33216	223.98	0.0000
MnO		-333.6101	10.37321	-32.16	<.0001
Na_2O		-840.5823	13.99965	-60.04	0.0000
NiO		8656.2189	14.10926	613.51	0.0000
SiO_2		675.93909	7.013935	96.37	0.0000
TiO_2		1441.9322	39.46674	36.54	<.0001
U_3O_8		913.1056	9.232983	98.90	0.0000
Others		5332.2317	34.21829	155.83	0.0000

This linear T_L model was used to add a T_L constraint on the glass space defined in Table 4 to the input to MIXSOFT as shown in Table 6. The T_L constraint is in the last row of this table, and its limit is set at 1050°C (i.e., the EPAR limit for liquidus temperature) to make this constraint, at least initially, less restrictive.

Table 6. MIXSOFT Input for Initial, Bounding Glass Region with a Linear T_L Constraint.

Row	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others	Constant	Comment
1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0.15	Upper Al_2O_3 limit
2	1	0	0	0	0	0	0	0	0	0	0	0	0	-0.03	Lower Al_2O_3 limit
3	0	-1	0	0	0	0	0	0	0	0	0	0	0	0.12	Upper B_2O_3 limit
4	0	1	0	0	0	0	0	0	0	0	0	0	0	-0.05	Lower B_2O_3 limit
5	0	0	-1	0	0	0	0	0	0	0	0	0	0	0.04	Upper CaO limit
6	0	0	1	0	0	0	0	0	0	0	0	0	0	-0.005	Lower CaO limit
7	0	0	0	-1	0	0	0	0	0	0	0	0	0	0.18	Upper Fe_2O_3 limit
8	0	0	0	1	0	0	0	0	0	0	0	0	0	-0.05	Lower Fe_2O_3 limit
9	0	0	0	0	-1	0	0	0	0	0	0	0	0	0.07	Upper Li_2O limit
10	0	0	0	0	1	0	0	0	0	0	0	0	0	-0.03	Lower Li_2O limit
11	0	0	0	0	0	-1	0	0	0	0	0	0	0	0.04	Upper MgO limit
12	0	0	0	0	0	0	-1	0	0	0	0	0	0	0.08	Upper MnO limit
13	0	0	0	0	0	0	1	0	0	0	0	0	0	-0.005	Lower MnO limit
14	0	0	0	0	0	0	0	-1	0	0	0	0	0	0.25	Upper Na_2O limit
15	0	0	0	0	0	0	0	1	0	0	0	0	0	-0.075	Lower Na_2O limit
16	0	0	0	0	0	0	0	0	-1	0	0	0	0	0.05	Upper NiO limit
17	0	0	0	0	0	0	0	0	0	-1	0	0	0	0.65	Upper SiO_2 limit
18	0	0	0	0	0	0	0	0	0	1	0	0	0	-0.4	Lower SiO_2 limit
19	0	0	0	0	0	0	0	0	0	0	-1	0	0	0.0175	Upper TiO_2 limit
20	0	0	0	0	0	0	0	0	0	0	0	-1	0	0.08	Upper U_3O_8 limit
21	0	0	0	0	0	0	0	0	0	0	0	0	-1	0.02	Upper Others limit
22	0	1	0	0	1	0	0	0	0	1	0	0	0	-0.525	Lower frit limit
23	-0.62	0	0	0	0	0	0	-0.62	0	0.38	0	0	0	0	Nepheline limit
24	-3.01	2.204	0	1.92	10.27	0	0	4.951	0	-2.06	0	0	0	0	Lower Visc. EPAR
25	3.01	-2.204	0	-1.92	-10.27	0	0	-4.951	0	3.2917	0	0	0	0	Upper Visc. EPAR
26	-36.96	14.98	24.59	-9.1	80.5	16.3	34.45	85.7	-0.5	-6.74	-20.4	2.8	0	-12.72	Fail Durability PAR
27	-2836	-1012	-912	-2620	1127	-3882	334	841	-8656	-676	-1442	-913	-5332	1050	Linear T_L onstraint

The MIXSOFT program generated 10,249 EVs for the region defined by Table 6. These EVs were imported into JMP [14], and JMP was used to generate Exhibit A2 in the Appendix, which provides descriptive statistics for these EV glasses including both the compositions and property predictions. Once, again, the maximum for Al_2O_3 was not attained, but the maximum T_L prediction (from the new model) was 1129°C, much more in line with the DWPF nominal temperature limit than the previous value of 1491°C. Thus, the glass region bounded by the information of Table 6 was deemed to be representative of DWPF's sludge-only operating window. The initial set of glasses to be batched and tested for this first phase of the PCT assessment study was selected from this set of 10.249 EVs.

To select glasses, the EVs were imported into JMP Version 3.2.6 [20] to take advantage of the D-Optimality routine available in that software. This routine selects a design of a specified size (i.e., number of design points) from a set of candidate points (i.e., the set of EVs) that optimizes the fitting of a specified model form. The optimization is relative to efficiency measures of the fitted model. The optimal design criterion used by JMP is D-optimality (i.e., to maximize the D-efficiency), but other measures, specifically, the G-efficiency and A-efficiency, of the optimal design are presented along with the D-efficiency:

$$\text{D-efficiency} = 100\left(\frac{1}{N_D}\left|X'X\right|^{1/p}\right) \qquad \text{G-efficiency} = 100\left(\frac{\sqrt{p/N_D}}{\sigma_M}\right)$$

$$\text{A-efficiency} = 100\left(\frac{p}{\text{trace}\left(N_D\left(X'X\right)^{-1}\right)}\right)$$

where N_D is the number of points desired in the design, p is the number of effects in the model, **X** denotes a potential N_D x *p* design matrix, and σ_M is the maximum standard error for prediction over the design points. The prime on **X**' denotes matrix transpose, and the superscript -1 on $(\mathbf{X'X})^{-1}$ denotes matrix inverse. The matrix **X** has *p* columns, corresponding to the number of terms in the model form assumed to be adequate for relating a property of interest to the components making up the glass.

Although there is no need to specify a "y" for this routine, the form of the model for the X's must be specified. A linear model in the 12 major oxides and "Others" was specified, and the routine was used to select 20 "D-optimal" glasses from the set of EVs. The results of that selection process are provided in Table 7.

Table 7. D-Optimality Results from JMP Version 3.2.6 for Initial Set of 20 Glasses.

Optimal Design Controls

N Desired	20
N Random	7
K Value	3
Trips	500

Best Design

D-efficiency	13.7339
A-efficiency	5.3975
G-efficiency	85.4974
AvgPredSE	0.8041
N	20.0000

Correlations

Corr	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others
Al_2O_3	1.000	-0.234	-0.043	0.147	-0.512	0.226	-0.032	-0.479	-0.002	0.335	0.104	-0.006	0.075
B_2O_3	-0.234	1.000	0.083	-0.159	-0.016	-0.271	-0.122	0.115	0.036	-0.270	-0.034	-0.164	0.020
CaO	-0.043	0.083	1.000	-0.278	-0.060	0.131	-0.080	-0.054	-0.075	-0.062	-0.037	-0.081	-0.016
Fe_2O_3	0.147	-0.159	-0.278	1.000	-0.010	-0.011	-0.045	-0.060	0.074	-0.145	0.023	0.092	0.014
Li_2O	-0.512	-0.016	-0.060	-0.010	1.000	-0.137	-0.021	0.573	-0.094	-0.666	-0.048	-0.113	-0.192
MgO	0.226	-0.271	0.131	-0.011	-0.137	1.000	-0.055	-0.196	-0.034	0.092	-0.007	0.056	0.027
MnO	-0.032	-0.122	-0.080	-0.045	-0.021	-0.055	1.000	0.120	-0.069	-0.134	-0.047	-0.019	-0.036
Na_2O	-0.479	0.115	-0.054	-0.060	0.573	-0.196	0.120	1.000	-0.149	-0.825	-0.067	0.003	-0.105
NiO	-0.002	0.036	-0.075	0.074	-0.094	-0.034	-0.069	-0.149	1.000	0.031	-0.047	0.053	-0.008
SiO_2	0.335	-0.270	-0.062	-0.145	-0.666	0.092	-0.134	-0.825	0.031	1.000	-0.079	0.023	0.031
TiO_2	0.104	-0.034	-0.037	0.023	-0.048	-0.007	-0.047	-0.067	-0.047	-0.079	1.000	-0.044	-0.005
U_3O_8	-0.006	-0.164	-0.081	0.092	-0.113	0.056	-0.019	0.003	0.053	0.023	-0.044	1.000	-0.139
Others	0.075	0.020	-0.016	0.014	-0.192	0.027	-0.036	-0.105	-0.008	0.031	-0.005	-0.139	1.000

As indicated in Table 7, 500 iterations of the D-optimality routine were used in the selection of the 20 glasses. The values of the correlations provided as part of the output from this routine suggest that the mixture aspects of this problem do limit the opportunity for a truly independent assessment of the effects of these 13 glass components. The desire for the design points is that they be orthogonal, which would be illustrated by zeros in the off-diagonal terms of the correlations in Table 7. For example, the values of SiO_2 and Na_2O over these design points have a 0.82 linear correlation (the maximum seen in Table 7). Although the correlations are greater than desired, it is understood that they are artifacts of the design space.

The 20 selected compositions are given in Table 8. Exhibit A3 in the Appendix provides descriptive statistics for the composition and property predictions for these 20 glasses. Identifiers for these selected glasses beginning with the prefix "ND" and using the numbers 1 through 20 are provided in Table 8. The property predictions for these 20 glasses are provided in Table 9, which also contains a summary column detailing the status of each glass composition relative to the PAR (or EPAR) limits outlined in Table 3.

Table 8. Initial Set of 20 Selected Glass Compositions.

ID	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others
ND01	0.0300	0.0500	0.0400	0.0500	0.0300	0.0000	0.0800	0.2361	0.0000	0.4839	0.0000	0.0000	0.0000
ND02	0.0300	0.1200	0.0050	0.0500	0.0300	0.0000	0.0800	0.1645	0.0000	0.4230	0.0175	0.0800	0.0000
ND03	0.0300	0.0500	0.0050	0.0500	0.0700	0.0400	0.0800	0.1533	0.0000	0.4842	0.0175	0.0000	0.0200
ND04	0.0300	0.1200	0.0050	0.0500	0.0700	0.0400	0.0050	0.1037	0.0000	0.4763	0.0000	0.0800	0.0200
ND05	0.1348	0.0500	0.0400	0.0500	0.0700	0.0000	0.0800	0.1274	0.0000	0.4278	0.0000	0.0000	0.0200
ND06	0.0301	0.0500	0.0050	0.0500	0.0700	0.0000	0.0050	0.1399	0.0000	0.6500	0.0000	0.0000	0.0000
ND07	0.0300	0.0500	0.0400	0.0500	0.0300	0.0000	0.0050	0.1683	0.0000	0.6092	0.0175	0.0000	0.0000
ND08	0.1119	0.1200	0.0050	0.0500	0.0300	0.0400	0.0800	0.1446	0.0000	0.4185	0.0000	0.0000	0.0000
ND09	0.0915	0.0500	0.0050	0.0500	0.0300	0.0000	0.0050	0.1906	0.0000	0.4604	0.0175	0.0800	0.0200
ND10	0.0300	0.1200	0.0400	0.1474	0.0300	0.0400	0.0050	0.1418	0.0000	0.4458	0.0000	0.0000	0.0000
ND11	0.0300	0.0500	0.0400	0.1054	0.0700	0.0400	0.0800	0.0804	0.0000	0.4068	0.0175	0.0800	0.0000
ND12	0.0300	0.0500	0.0400	0.1780	0.0300	0.0000	0.0050	0.1701	0.0000	0.4594	0.0175	0.0000	0.0200
ND13	0.0300	0.0500	0.0050	0.0500	0.0300	0.0376	0.0050	0.2370	0.0500	0.4853	0.0000	0.0000	0.0200
ND14	0.0493	0.0500	0.0400	0.0500	0.0300	0.0400	0.0050	0.2225	0.0500	0.4457	0.0175	0.0000	0.0000
ND15	0.0300	0.1200	0.0400	0.0500	0.0700	0.0000	0.0800	0.0761	0.0474	0.4491	0.0175	0.0000	0.0200
ND16	0.1089	0.0500	0.0400	0.0500	0.0700	0.0000	0.0050	0.1426	0.0431	0.4104	0.0000	0.0800	0.0000
ND17	0.0300	0.0500	0.0050	0.0500	0.0300	0.0400	0.0800	0.1335	0.0489	0.5151	0.0175	0.0000	0.0000
ND18	0.0300	0.0500	0.0400	0.0500	0.0300	0.0000	0.0800	0.1193	0.0488	0.4519	0.0000	0.0800	0.0200
ND19	0.0300	0.0500	0.0050	0.1800	0.0412	0.0000	0.0800	0.1344	0.0376	0.4418	0.0000	0.0000	0.0000
ND20	0.1145	0.0955	0.0050	0.0500	0.0700	0.0000	0.0050	0.1564	0.0440	0.4421	0.0175	0.0000	0.0000

Table 9. Property Predictions for the Initial Set of 20 Selected Glass Compositions.

ID	Property PAR Status	alkalis (wt fraction)	Viscosity (Poise)	Homogeneity wt %	PCCS ΔG_p (kcal/mol)	Old T_L (^oC)	New T_L (^oC)
ND01	Not Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.266	19.99	196.1	-22.300	887.1	427.6
ND02	Not Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.195	19.98	166.3	-16.635	900.4	529.1
ND03	Not Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.223	20.00	169.5	-17.988	887.0	662.4
ND04	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.174	24.18	171.5	-12.839	888.6	822.9
ND05	Not Durable; Visc; TL ; Homo; New TL ; Al2O3 ; Not alkali	0.197	46.06	235.2	-12.842	955.0	800.1
ND06	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.210	73.64	194.0	-12.711	864.4	498.5
ND07	Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.198	109.34	205.3	-12.708	868.7	556.7
ND08	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.175	59.50	208.6	-12.717	942.5	831.4
ND09	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.221	54.40	200.0	-12.840	913.7	756.2
ND10	Durable; Not Visc; Not TL; Homo; New TL ; Al2O3 ; alkali	0.172	19.99	241.1	-12.708	1072.4	927.7
ND11	Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.150	19.99	196.4	-12.714	1016.4	806.7
ND12	Not Durable; Not Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali	0.200	20.00	253.8	-12.833	1117.6	883.1
ND13	Not Durable; Not Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.267	20.00	176.7	-19.640	886.8	1018.3
ND14	Not Durable; Not Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.253	19.97	198.7	-18.366	901.3	1025.3
ND15	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; alkali	0.146	28.29	182.5	-12.843	894.2	1032.2
ND16	Durable; Visc; TL ; Homo; Not New TL; Al2O3 ; Not alkali	0.213	23.47	220.3	-12.710	944.6	1025.7
ND17	Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; alkali	0.164	103.08	164.8	-12.712	881.6	1045.2
ND18	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; alkali	0.149	85.05	172.2	-12.841	893.6	1049.1
ND19	Durable; Not Visc; Not TL; Homo; Not New TL; Al2O3 ; alkali	0.176	19.99	228.4	-12.711	1135.1	1028.6
ND20	Durable; Not Visc; TL ; Homo; New TL ; Al2O3 ; Not alkali	0.226	20.01	218.2	-12.710	932.8	1008.2

2.3 Inner Layer Glass Composition Region

The next step taken to select additional compositions for testing involved moving in 20% of the range from the lower and the upper limits for each of the oxides of interest in the study. These inner layer limits (as the resulting values were called) are given in Table 10.

Table 10. Oxide Ranges for Inner Layer Glass Region.

	Inner Layer Limits	
	Lower	Upper
Al_2O_3	0.054	0.126
B_2O_3	0.064	0.106
CaO	0.012	0.033
Fe_2O_3	0.076	0.154
Li_2O	0.038	0.062
MgO	0.008	0.032
MnO	0.02	0.065
Na_2O	0.11	0.215
NiO	0.01	0.04
SiO_2	0.45	0.60
TiO_2	0.0035	0.014
U_3O_8	0.016	0.064
Others	0.004	0.016

Once again MIXSOFT was used to determine the EVs of this inner glass region defined by the information provided in Table 10 and the appropriate property prediction models. Viscosity was set to its PAR limits for the inner layer (as opposed to the EPAR for the outer layer) and again no T_L constraint was imposed. The MIXSOFT input used was as given in Table 11.

Table 11. MIXSOFT Input for Inner Layer Glass Region without T_L Constraint.

Row	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others	constant	Comment
1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0.126	Upper Al_2O_3 limit
2	1	0	0	0	0	0	0	0	0	0	0	0	0	-0.054	Lower Al_2O_3 limit
3	0	-1	0	0	0	0	0	0	0	0	0	0	0	0.106	Upper B_2O_3 limit
4	0	1	0	0	0	0	0	0	0	0	0	0	0	-0.064	Lower B_2O_3 limit
5	0	0	-1	0	0	0	0	0	0	0	0	0	0	0.033	Upper CaO limit
6	0	0	1	0	0	0	0	0	0	0	0	0	0	-0.012	Lower CaO limit
7	0	0	0	-1	0	0	0	0	0	0	0	0	0	0.154	Upper Fe_2O_3 limit
8	0	0	0	1	0	0	0	0	0	0	0	0	0	-0.076	Lower Fe_2O_3 limit
9	0	0	0	0	-1	0	0	0	0	0	0	0	0	0.062	Upper Li_2O limit
10	0	0	0	0	1	0	0	0	0	0	0	0	0	-0.038	Lower Li_2O limit
11	0	0	0	0	0	-1	0	0	0	0	0	0	0	0.032	Upper MgO limit
12	0	0	0	0	0	1	0	0	0	0	0	0	0	-0.008	Lower MgO limit
13	0	0	0	0	0	0	-1	0	0	0	0	0	0	0.065	Upper MnO limit
14	0	0	0	0	0	0	1	0	0	0	0	0	0	-0.02	Lower MnO limit
15	0	0	0	0	0	0	0	-1	0	0	0	0	0	0.215	Upper Na_2O limit
16	0	0	0	0	0	0	0	1	0	0	0	0	0	-0.11	Lower Na_2O limit
17	0	0	0	0	0	0	0	0	-1	0	0	0	0	0.04	Upper NiO limit
18	0	0	0	0	0	0	0	0	1	0	0	0	0	-0.01	Lower NiO limit
19	0	0	0	0	0	0	0	0	0	-1	0	0	0	0.6	Upper SiO_2 limit
20	0	0	0	0	0	0	0	0	0	1	0	0	0	-0.45	Lower SiO_2 limit
21	0	0	0	0	0	0	0	0	0	0	-1	0	0	0.014	Upper TiO_2 limit
22	0	0	0	0	0	0	0	0	0	0	1	0	0	-0.0035	Lower TiO_2 limit
23	0	0	0	0	0	0	0	0	0	0	0	-1	0	0.064	Upper U_3O_8 limit
24	0	0	0	0	0	0	0	0	0	0	0	1	0	-0.016	Lower U_3O_8 limit
25	0	0	0	0	0	0	0	0	0	0	0	0	-1	0.016	Upper Others limit
26	0	0	0	0	0	0	0	0	0	0	0	0	1	-0.004	Lower Others limit
27	0	1	0	0	1	0	0	0	0	1	0	0	0	-0.525	Lower frit limit
28	-0.62	0	0	0	0	0	0	-0.62	0	0.38	0	0	0	0	Nepheline limit
29	-1.96	1.44	0	1.25	6.69	0	0	3.23	0	-1.362	0	0	0	0	Lower Visc. PAR
30	1.96	-1.44	0	-1.25	-6.69	0	0	-3.23	0	2.11	0	0	0	0	Upper Visc. PAR
31	-36.96	14.98	24.59	-9.1	80.5	16.3	34.45	85.7	-0.5	-6.74	-20.4	2.8	0	-12.72	Fail Durability PAR

The details of Table 11 are as follows:

- Rows 1 through 26 provide constraints on the individual oxides to reflect the values of Table 10.

- Row 27 provides a constraint on the sum of uniquely frit components of the form
  $B_2O_3 + Li_2O + SiO_2 \geq 0.525$
  This helps ensure that the region contains glasses representing feasible (up to 40% waste loading, or no less than 60% frit if Na_2O is at a minimum of 7.5 wt%).

- Row 28 provides protection from possible nepheline phases via the constraint [19]

$$\frac{SiO_2}{Al_2O_3 + Na_2O + SiO_2} \geq 0.62$$

- Rows 29 and 30 specify the lower and upper PAR limits for viscosity. The inner layer, glass region is restricted to be within the viscosity PAR.

- Row 31 specifies the constraint for the durability PAR. The inner layer, glass region is restricted to be outside of the durability PAR.

Also, note that initially no liquidus temperature constraint is imposed on this inner layer region. The MIXSOFT program generated 2,645 EVs for the region defined by Table 11. These EVs were imported into JMP Version 4.0.5 [14], and JMP was used to generate Exhibit A4 in the Appendix, which provides descriptive statistics for these EV glasses including both the compositions and property predictions. Also, shown in this exhibit is a set of descriptive statistics for the sum of alkali for the glass compositions.

Some observations regarding this exhibit may be helpful: The maximum value of Al_2O_3 is not attained (11.51 wt% versus 12.6 wt%). Note that the T_L predictions generated by the new T_L model approach 1241^{o}C, above the DWPF nominal operating temperature of 1150^{o}C. Thus, the region defined by the information of Table 11 includes glasses that would not be considered processable for the DWPF. An additional constraint is needed to further restrict the bounding glass composition region.

Using JMP, the T_L predictions from the new liquidus temperature model that were generated for the EVs were used to fit a linear model (in composition space). Table 12 provides summary information from that fit.

Table 12. Linear Model Fit to T_L Predictions for the Inner Layer Glass Region.

Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept	Zeroed	0	0	.	.
Al_2O_3		2635.7583	18.36062	143.55	0.0000
B_2O_3		1016.2993	10.40107	97.71	0.0000
CaO		935.05275	16.86151	55.45	0.0000
Fe_2O_3		2749.9925	13.72118	200.42	0.0000
Li_2O		-1091.511	20.71006	-52.70	0.0000
MgO		3973.9494	15.30602	259.63	0.0000
MnO		-393.0218	10.7704	-36.49	<.0001
Na_2O		-974.6499	13.23055	-73.67	0.0000
NiO		8892.6725	13.36164	665.54	0.0000
SiO_2		761.22526	9.717559	78.34	0.0000
TiO_2		1507.3868	31.63736	47.65	0.0000
U_3O_8		925.03257	10.86	85.18	0.0000
Others		5349.053	27.41731	195.10	0.0000

This linear T_L model was used to add a T_L constraint on the inner layer, glass space defined in Table 11 to the input to MIXSOFT as shown in Table 13. The T_L constraint is in the last row of this table, and its limit is set at 1050^{o}C (the EPAR limit for liquidus temperature) to make this constraint, at least initially, less restrictive.

Table 13. MIXSOFT Input for Inner Layer Glass Region with Linear T_L Constraint.

row	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others	Constant	Comment
1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0.126	Upper Al_2O_3 limit
2	1	0	0	0	0	0	0	0	0	0	0	0	0	-0.054	Lower Al_2O_3 limit
3	0	-1	0	0	0	0	0	0	0	0	0	0	0	0.106	Upper B_2O_3 limit
4	0	1	0	0	0	0	0	0	0	0	0	0	0	-0.064	Lower B_2O_3 limit
5	0	0	-1	0	0	0	0	0	0	0	0	0	0	0.033	Upper CaO limit
6	0	0	1	0	0	0	0	0	0	0	0	0	0	-0.012	Lower CaO limit
7	0	0	0	-1	0	0	0	0	0	0	0	0	0	0.154	Upper Fe_2O_3 limit
8	0	0	0	1	0	0	0	0	0	0	0	0	0	-0.076	Lower Fe_2O_3 limit
9	0	0	0	0	-1	0	0	0	0	0	0	0	0	0.062	Upper Li_2O limit
10	0	0	0	0	1	0	0	0	0	0	0	0	0	-0.038	Lower Li_2O limit
11	0	0	0	0	0	-1	0	0	0	0	0	0	0	0.032	Upper MgO limit
12	0	0	0	0	0	1	0	0	0	0	0	0	0	-0.008	Lower MgO limit
13	0	0	0	0	0	0	-1	0	0	0	0	0	0	0.065	Upper MnO limit
14	0	0	0	0	0	0	1	0	0	0	0	0	0	-0.02	Lower MnO limit
15	0	0	0	0	0	0	0	-1	0	0	0	0	0	0.215	Upper Na_2O limit
16	0	0	0	0	0	0	0	1	0	0	0	0	0	-0.11	Lower Na_2O limit
17	0	0	0	0	0	0	0	0	-1	0	0	0	0	0.04	Upper NiO limit
18	0	0	0	0	0	0	0	0	1	0	0	0	0	-0.01	Lower NiO limit
19	0	0	0	0	0	0	0	0	0	-1	0	0	0	0.6	Upper SiO_2 limit
20	0	0	0	0	0	0	0	0	0	1	0	0	0	-0.45	Lower SiO_2 limit
21	0	0	0	0	0	0	0	0	0	0	-1	0	0	0.014	Upper TiO_2 limit
22	0	0	0	0	0	0	0	0	0	0	1	0	0	-0.0035	Lower TiO_2 limit
23	0	0	0	0	0	0	0	0	0	0	0	-1	0	0.064	Upper U_3O_8 limit
24	0	0	0	0	0	0	0	0	0	0	0	1	0	-0.016	Lower U_3O_8 limit
25	0	0	0	0	0	0	0	0	0	0	0	0	-1	0.016	Upper Others limit
26	0	0	0	0	0	0	0	0	0	0	0	0	1	-0.004	Lower Others limit
27	0	1	0	0	1	0	0	0	0	1	0	0	0	-0.525	Lower frit limit
28	-0.62	0	0	0	0	0	0	-0.62	0	0.38	0	0	0	0	Nepheline limit
29	-1.96	1.44	0	1.25	6.69	0	0	3.23	0	-1.362	0	0	0	0	Lower Visc. PAR
30	1.96	-1.44	0	-1.25	-6.69	0	0	-3.23	0	2.11	0	0	0	0	Upper Visc. PAR
31	-36.96	14.98	24.59	-9.1	80.5	16.3	34.45	85.7	-0.5	-6.74	-20.4	2.8	0	-12.72	Fail Durability PAR
33	-2636	-1016	-935	-2750	1092	-3974	393	975	-8893	-761	-1507	-925	-5349	1050	Linear T_L limit

The MIXSOFT program generated 3,147 EVs for this interior region defined by Table 13. These EVs were imported into JMP Version 4.0.5 [14], and JMP was used to generate Exhibit A5 in the Appendix, which provides descriptive statistics for these EV glasses including both the compositions and property predictions. Once, again, the maximum for Al_2O_3 was not attained, but the maximum T_L prediction (from the new model) was 1064^{o}C, much more in line with the DWPF operating limit of 1050°C than the previous value of 1241^{o}C. Thus, the glass region bounded by the information of Table 13 was deemed to be within DWPF's sludge-only operating window. The second set of glasses to be batched and tested for this first phase of the durability study was selected from this set of 3,147 EVs in a manner to complement the initial set of 20 glasses.

To select the glasses to complement the first set of 20, the 3,147 EVs were imported into JMP Version 3.2.6 [16] along with the 20 compositions of Table 8. Once again, the JMP's D-Optimality routine was used. This time it was initiated with the 20 originally selected points pre-selected and with five additional compositions being requested. The full set of 25 compositions was selected using the D-Optimality criterion for a linear model in the 13 glass components (including the "Others"). The results from this process are provided in Table 14.

Table 14. D-Optimality Results from JMP Version 3.2.6 for Second Set of 5 Glasses to Complement Initial 20.

Optimal Design Controls

N Desired	25
N Random	7
K Value	3
Trips	500

Best Design

D-efficiency	12.3671
A-efficiency	4.8062
G-efficiency	86.4891
AvgPredSE	0.4579
N	25.0000

Correlations

Corr	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others
Al_2O_3	1.000	-0.210	-0.034	0.120	-0.483	0.142	-0.010	-0.483	0.054	0.313	0.134	-0.009	0.056
B_2O_3	-0.210	1.000	0.041	-0.135	-0.020	-0.253	-0.086	0.144	-0.027	-0.290	-0.005	-0.106	-0.020
CaO	-0.034	0.041	1.000	-0.194	-0.009	0.115	-0.104	-0.022	-0.060	-0.094	-0.064	-0.050	-0.056
Fe_2O_3	0.120	-0.135	-0.194	1.000	-0.024	-0.015	0.001	-0.083	0.096	-0.150	0.079	0.057	-0.025
Li_2O	-0.483	-0.020	-0.009	-0.024	1.000	-0.085	-0.024	0.570	-0.157	-0.665	-0.048	-0.171	-0.129
MgO	0.142	-0.253	0.115	-0.015	-0.085	1.000	-0.030	-0.162	0.031	0.046	0.014	0.011	0.029
MnO	-0.010	-0.086	-0.104	0.001	-0.024	-0.030	1.000	0.106	-0.057	-0.132	-0.099	-0.015	-0.023
Na_2O	-0.483	0.144	-0.022	-0.083	0.570	-0.162	0.106	1.000	-0.173	-0.823	-0.081	-0.007	-0.086
NiO	0.054	-0.027	-0.060	0.096	-0.157	0.031	-0.057	-0.173	1.000	0.057	-0.036	0.080	0.023
SiO_2	0.313	-0.290	-0.094	-0.150	-0.665	0.046	-0.132	-0.823	0.057	1.000	-0.079	0.031	0.012
TiO_2	0.134	-0.005	-0.064	0.079	-0.048	0.014	-0.099	-0.081	-0.036	-0.079	1.000	-0.038	0.005
U_3O_8	-0.009	-0.106	-0.050	0.057	-0.171	0.011	-0.015	-0.007	0.080	0.031	-0.038	1.000	-0.104
Others	0.056	-0.020	-0.056	-0.025	-0.129	0.029	-0.023	-0.086	0.023	0.012	0.005	-0.104	1.000

As indicated in Table 14, 500 iterations of the D-optimality routine were used in the selection of the five additional glasses. As for the previous selection results, the correlations are provided as part of the output from this routine. The largest correlation is between SiO_2 and Na_2O with a value of 0.82.

The five newly selected compositions are given in Table 15 along with their identifiers. Exhibit A6 in the Appendix provides descriptive statistics for the compositions and property predictions for all 25 glasses. The property predictions for five new glasses are provided in Table 16.

Table 15. Compositions for Second Set of Five Glasses (Selected from the Inner Layer Region).

ID	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others
ND21	0.0540	0.1060	0.0120	0.0760	0.0620	0.0080	0.0200	0.1323	0.0400	0.4662	0.0035	0.0160	0.0040
ND22	0.0540	0.1060	0.0330	0.0760	0.0380	0.0320	0.0200	0.1383	0.0100	0.4572	0.0035	0.0160	0.0160
ND23	0.0540	0.0640	0.0120	0.1455	0.0380	0.0080	0.0200	0.1630	0.0100	0.4500	0.0035	0.0160	0.0160
ND24	0.0540	0.0640	0.0120	0.0955	0.0620	0.0320	0.0200	0.1290	0.0100	0.4500	0.0035	0.0640	0.0040
ND25	0.1025	0.0640	0.0120	0.0760	0.0380	0.0320	0.0200	0.1720	0.0100	0.4500	0.0035	0.0160	0.0040

Table 16. Property Predictions for Second Set of Five Glasses (Selected from the Inner Layer Region).

ID	Property PAR Status	alkalis (wt fraction)	Viscosity (Poise)	Homogeneity wt %	PCCS ΔG_p (kcal/mol)	Old T_L (°C)	New T_L (°C)
ND21	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.194	21.59	203.1	-13.173	946.7	1050.8
ND22	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.176	38.09	210.6	-12.816	950.0	976.4
ND23	Not Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali	0.201	21.66	234.1	-12.809	1089.0	971.3
ND24	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.191	22.89	204.2	-12.734	990.9	925.3
ND25	Not Durable; Visc; TL ; Homo; New TL ; Al2O3 ; Not alkali	0.210	44.60	223.7	-12.736	984.5	924.1

2.4 Modified Inner Layer Glass Composition Region

The next step taken to select additional compositions for testing involved a modification of inner layer region of the last section. The modification concerned the range for Al_2O_3. Based upon previous studies for DWPF [9], [21], [22] [23], [24] the durability of glasses containing less than 4 wt% of this oxide are of concern. The inner layer limits of Table 10 were left intact except for the range of Al_2O_3, which was restricted to the interval from 3 to 3.9 wt%. The bounds of the resulting glass region are given in Table 17.

Table 17. Oxide Ranges for the Modified Inner Layer Glass Region.

	Inner Layer Limits	
	Lower	Upper
Al_2O_3	0.03	0.039
B_2O_3	0.064	0.106
CaO	0.012	0.033
Fe_2O_3	0.076	0.154
Li_2O	0.038	0.062
MgO	0.008	0.032
MnO	0.02	0.065
Na_2O	0.11	0.215
NiO	0.01	0.04
SiO_2	0.45	0.60
TiO_2	0.0035	0.014
U_3O_8	0.016	0.064
Others	0.004	0.016

MIXSOFT was again used to determine the EVs of the modified interior glass region defined by the information provided in Table 17. The appropriate property prediction models were used where the melt viscosity was set to its PAR limits for the inner layer and no T_L constraint was imposed. The inputs used were as given in Table 18. Finally, a new constraint was added as input to the MIXSOFT routine. This constraint was on the sum of alkali and it restricted the composition region to glasses with alkali content greater than or equal to 19.3 wt% Note that no corresponding upper limit for the sum of alkali was imposed.

Table 18. MIXSOFT Input for Inner Layer Glass Region without T_L Constraint.

Row	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others	Constant	Comment
1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0.039	Upper Al_2O_3 limit
2	1	0	0	0	0	0	0	0	0	0	0	0	0	-0.030	Lower Al_2O_3 limit
3	0	-1	0	0	0	0	0	0	0	0	0	0	0	0.106	Upper B_2O_3 limit
4	0	1	0	0	0	0	0	0	0	0	0	0	0	-0.064	Lower B_2O_3 limit
5	0	0	-1	0	0	0	0	0	0	0	0	0	0	0.033	Upper CaO limit
6	0	0	1	0	0	0	0	0	0	0	0	0	0	-0.012	Lower CaO limit
7	0	0	0	-1	0	0	0	0	0	0	0	0	0	0.154	Upper Fe_2O_3 limit
8	0	0	0	1	0	0	0	0	0	0	0	0	0	-0.076	Lower Fe_2O_3 limit
9	0	0	0	0	-1	0	0	0	0	0	0	0	0	0.062	Upper Li_2O limit
10	0	0	0	0	1	0	0	0	0	0	0	0	0	-0.038	Lower Li_2O limit
11	0	0	0	0	0	-1	0	0	0	0	0	0	0	0.032	Upper MgO limit
12	0	0	0	0	0	1	0	0	0	0	0	0	0	-0.008	Lower MgO limit
13	0	0	0	0	0	0	-1	0	0	0	0	0	0	0.065	Upper MnO limit
14	0	0	0	0	0	0	1	0	0	0	0	0	0	-0.02	Lower MnO limit
15	0	0	0	0	0	0	0	-1	0	0	0	0	0	0.215	Upper Na_2O limit
16	0	0	0	0	0	0	0	1	0	0	0	0	0	-0.11	Lower Na_2O limit
17	0	0	0	0	0	0	0	0	-1	0	0	0	0	0.04	Upper NiO limit
18	0	0	0	0	0	0	0	0	1	0	0	0	0	-0.01	Lower NiO limit
19	0	0	0	0	0	0	0	0	0	-1	0	0	0	0.6	Upper SiO_2 limit
20	0	0	0	0	0	0	0	0	0	1	0	0	0	-0.45	Lower SiO_2 limit
21	0	0	0	0	0	0	0	0	0	0	-1	0	0	0.014	Upper TiO_2 limit
22	0	0	0	0	0	0	0	0	0	0	1	0	0	-0.0035	Lower TiO_2 limit
23	0	0	0	0	0	0	0	0	0	0	0	-1	0	0.064	Upper U_3O_8 limit
24	0	0	0	0	0	0	0	0	0	0	0	1	0	-0.016	Lower U_3O_8 limit
25	0	0	0	0	0	0	0	0	0	0	0	0	-1	0.016	Upper Others limit
26	0	0	0	0	0	0	0	0	0	0	0	0	1	-0.004	Lower Others limit
27	0	1	0	0	1	0	0	0	0	1	0	0	0	-0.525	Lower frit limit
28	-0.62	0	0	0	0	0	0	-0.62	0	0.38	0	0	0	0	Nepheline limit
29	-1.96	1.44	0	1.25	6.69	0	0	3.23	0	-1.362	0	0	0	0	Lower Visc. PAR
30	1.96	-1.44	0	-1.25	-6.69	0	0	-3.23	0	2.11	0	0	0	0	Upper Visc. PAR
31	-36.96	14.98	24.59	-9.1	80.5	16.3	34.45	85.7	-0.5	-6.74	-20.4	2.8	0	-12.72	Fail Durability PAR
32	0	0	0	0	1	0	0	1	0	0	0	0	0	-0.193	Lower Alkali limit

The details of Table 18 are as follows:

- Rows 1 through 26 provide constraints on the individual oxides to reflect the values of Table 17.

- Row 27 provides a constraint on the sum of uniquely frit components of the form

  $$B_2O_3 + Li_2O + SiO_2 \geq 0.525$$

  This helps ensure that the region contains glasses representing feasible (up to 40% waste loading, or no less than 60% frit if Na_2O is at a minimum of 7.5 wt%).

- Row 28 provides protection from possible nepheline phases via the constraint [19]

  $$\frac{SiO_2}{Al_2O_3 + Na_2O + SiO_2} \geq 0.62$$

- Rows 29 and 30 specify the lower and upper PAR limits for viscosity. The inner layer, glass region is restricted to be within the viscosity PAR.

- Row 31 specifies the constraint for the durability PAR. The inner layer, glass region is restricted to be outside of the durability PAR.

- Row 32 specifies the lower bound on the sum of alikali which was imposed on the modified inner layer.

Also, note that initially no liquidus temperature constraint is imposed on this modified inner layer region. The MIXSOFT program generated 4,657 EVs for the region defined by Table 18. These EVs were imported into JMP Version 4.0.5 [14], and JMP was used to generate Exhibit A7 in the Appendix, which provides descriptive statistics for these EV glasses including both the compositions and property predictions. Also, shown in this exhibit is a set of descriptive statistics for the sum of alkali for the glass compositions.

Some observations regarding this exhibit may be helpful: The maximum value of Al_2O_3 is now attained (3.9 wt%). Note that the T_L predictions generated by the new T_L model approach 1214°C, above the DWPF nominal operating temperature of 1150°C. Thus, the region defined by the information of Table 18 includes glasses that would not be considered processable for the DWPF. An additional constraint is needed to further restrict the bounding glass composition region.

Using JMP, the T_L predictions from the new liquidus temperature model that were generated for the EVs were used to fit a linear model (in composition space). Table 19 provides summary information from that fit.

Table 19. Linear Model Fit to T_L Predictions for the Modified Inner Layer Glass Region.

Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept	Zeroed	0	0	.	.
Al_2O_3		3999.7023	30.08194	132.96	0.0000
B_2O_3		922.05276	7.810208	118.06	0.0000
CaO		835.42256	13.62755	61.30	0.0000
Fe_2O_3		2599.6219	7.055071	368.48	0.0000
Li_2O		-1251.018	24.53935	-50.98	0.0000
MgO		3812.371	12.1614	313.48	0.0000
MnO		-654.8366	7.539628	-86.85	0.0000
Na_2O		-1097.078	14.73111	-74.47	0.0000
NiO		8613.8819	9.894117	870.61	0.0000
SiO_2		761.94005	6.27054	121.51	0.0000
TiO_2		1461.3857	25.79309	56.66	0.0000
U_3O_8		915.98479	7.265263	126.08	0.0000
Others		5243.2664	22.68308	231.15	0.0000

This linear T_L model was used to add a T_L constraint on the modified inner layer, glass space defined in Table 18 to the input to MIXSOFT as shown in Table 20. The T_L constraint is in the last row of this table, and its limit is set at 1050°C (the EPAR limit for liquidus temperature) to make this constraint, at least initially, less restrictive.

Table 20. MIXSOFT Input for Modified Inner Layer Glass Region with Linear T_L Constraint.

row	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others	Constant	Comment
1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0.126	Upper Al_2O_3 limit
2	1	0	0	0	0	0	0	0	0	0	0	0	0	-0.054	Lower Al_2O_3 limit
3	0	-1	0	0	0	0	0	0	0	0	0	0	0	0.106	Upper B_2O_3 limit
4	0	1	0	0	0	0	0	0	0	0	0	0	0	-0.064	Lower B_2O_3 limit
5	0	0	-1	0	0	0	0	0	0	0	0	0	0	0.033	Upper CaO limit
6	0	0	1	0	0	0	0	0	0	0	0	0	0	-0.012	Lower CaO limit
7	0	0	0	-1	0	0	0	0	0	0	0	0	0	0.154	Upper Fe_2O_3 limit
8	0	0	0	1	0	0	0	0	0	0	0	0	0	-0.076	Lower Fe_2O_3 limit
9	0	0	0	0	-1	0	0	0	0	0	0	0	0	0.062	Upper Li_2O limit
10	0	0	0	0	1	0	0	0	0	0	0	0	0	-0.038	Lower Li_2O limit
11	0	0	0	0	0	-1	0	0	0	0	0	0	0	0.032	Upper MgO limit
12	0	0	0	0	0	1	0	0	0	0	0	0	0	-0.008	Lower MgO limit
13	0	0	0	0	0	0	-1	0	0	0	0	0	0	0.065	Upper MnO limit
14	0	0	0	0	0	0	1	0	0	0	0	0	0	-0.02	Lower MnO limit
15	0	0	0	0	0	0	0	-1	0	0	0	0	0	0.215	Upper Na_2O limit
16	0	0	0	0	0	0	0	1	0	0	0	0	0	-0.11	Lower Na_2O limit
17	0	0	0	0	0	0	0	0	-1	0	0	0	0	0.04	Upper NiO limit
18	0	0	0	0	0	0	0	0	1	0	0	0	0	-0.01	Lower NiO limit
19	0	0	0	0	0	0	0	0	0	-1	0	0	0	0.6	Upper SiO_2 limit
20	0	0	0	0	0	0	0	0	0	1	0	0	0	-0.45	Lower SiO_2 limit
21	0	0	0	0	0	0	0	0	0	0	-1	0	0	0.014	Upper TiO_2 limit
22	0	0	0	0	0	0	0	0	0	0	1	0	0	-0.0035	Lower TiO_2 limit
23	0	0	0	0	0	0	0	0	0	0	0	-1	0	0.064	Upper U_3O_8 limit
24	0	0	0	0	0	0	0	0	0	0	0	1	0	-0.016	Lower U_3O_8 limit
25	0	0	0	0	0	0	0	0	0	0	0	0	-1	0.016	Upper Others limit
26	0	0	0	0	0	0	0	0	0	0	0	0	1	-0.004	Lower Others limit
27	0	1	0	0	1	0	0	0	0	1	0	0	0	-0.525	Lower frit limit
28	-0.62	0	0	0	0	0	0	-0.62	0	0.38	0	0	0	0	Nepheline limit
29	-1.96	1.44	0	1.25	6.69	0	0	3.23	0	-1.362	0	0	0	0	Lower Visc. PAR
30	1.96	-1.44	0	-1.25	-6.69	0	0	-3.23	0	2.11	0	0	0	0	Upper Visc. PAR
31	-36.96	14.98	24.59	-9.1	80.5	16.3	34.45	85.7	-0.5	-6.74	-20.4	2.8	0	-12.72	Fail Durability PAR
32	0	0	0	0	1	0	0	1	0	0	0	0	0	-0.193	Lower Alkali limit
33	-4000	-922	-835	-2600	1251	-3812	655	1097	-8614	-762	-1461	-916	-5243	1050	Linear T_L limit

The MIXSOFT program generated 5,756 EVs for the modified inner region defined by Table 20. These EVs were imported into JMP Version 4.0.5 [14], and JMP was used to generate Exhibit A8 in the Appendix, which provides descriptive statistics for these EV glasses including both the compositions and property predictions. The maximum for Al_2O_3 was not attained, but the maximum T_L prediction (from the new model) was 1066^oC, much more in line with the DWPF operating limit than the previous value of 1214^oC. Thus, the glass region bounded by the information of Table 20 was deemed to be within DWPF's sludge-only operating window. The final set of glasses to be batched and tested for this first phase of the durability study was selected from this set of 3,147 EVs in a manner to complement the previously-selected set of 25 glasses.

To select the glasses to modify the set of 25, the 5,756 EVs were imported into JMP Version 3.2.6 [20] along with the 25 compositions previously selected (those of Table 8 and Table 15). Once again, the JMP's D-Optimality routine was used. This time it was initiated with the 25 previously selected points pre-loaded and with five additional compositions being requested. The full set of 30 compositions was selected using the D-Optimality criterion for a linear model in the 13 glass components (including the "Others"). The results from this process are provided in Table 21.

Table 21. D-Optimality Results from JMP Version 3.2.6 for Second Set of Five Glasses to Complement Previous 25.

Optimal Design Controls

N Desired	30
N Random	7
K Value	3
Trips	500

Best Design

D-efficiency	11.3343
A-efficiency	4.2948
G-efficiency	82.5426
AvgPredSE	0.4423
N	30.0000

Correlations

Corr	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others
Al_2O_3	1.0000	-0.1517	-0.0247	0.1343	-0.4597	0.0993	-0.0351	-0.4546	0.0851	0.2819	0.1205	0.0448	0.0286
B_2O_3	-0.1517	1.0000	-0.0429	-0.1069	-0.0480	-0.1960	-0.0452	0.1202	-0.0384	-0.2733	-0.0049	-0.0617	-0.0455
CaO	-0.0247	-0.0429	1.0000	-0.1311	-0.0185	0.1419	-0.0758	-0.0135	-0.0727	-0.0929	-0.0632	0.0109	-0.0584
Fe_2O_3	0.1343	-0.1069	-0.1311	1.0000	-0.0153	-0.0045	0.0138	-0.0883	0.1102	-0.1642	0.0347	0.0469	-0.0780
Li_2O	-0.4597	-0.0480	-0.0185	-0.0153	1.0000	-0.0868	-0.0000	0.5806	-0.1701	-0.6712	-0.0523	-0.2223	-0.0799
MgO	0.0993	-0.1960	0.1419	-0.0045	-0.0868	1.0000	-0.0287	-0.1246	-0.0035	0.0128	0.0326	-0.0099	0.0531
MnO	-0.0351	-0.0452	-0.0758	0.0138	-0.0000	-0.0287	1.0000	0.0828	-0.0241	-0.1409	-0.0720	-0.0691	-0.0013
Na_2O	-0.4546	0.1202	-0.0135	-0.0883	0.5806	-0.1246	0.0828	1.0000	-0.1815	-0.8236	-0.0531	-0.0652	-0.0676
NiO	0.0851	-0.0384	-0.0727	0.1102	-0.1701	-0.0035	-0.0241	-0.1815	1.0000	0.0591	0.0174	0.0565	-0.0024
SiO_2	0.2819	-0.2733	-0.0929	-0.1642	-0.6712	0.0128	-0.1409	-0.8236	0.0591	1.0000	-0.0935	0.0521	0.0003
TiO_2	0.1205	-0.0049	-0.0632	0.0347	-0.0523	0.0326	-0.0720	-0.0531	0.0174	-0.0935	1.0000	0.0271	-0.0146
U_3O_8	0.0448	-0.0617	0.0109	0.0469	-0.2223	-0.0099	-0.0691	-0.0652	0.0565	0.0521	0.0271	1.0000	-0.0635
Others	0.0286	-0.0455	-0.0584	-0.0780	-0.0799	0.0531	-0.0013	-0.0676	-0.0024	0.0003	-0.0146	-0.0635	1.0000

As indicated in Table 21, 500 iterations of the D-optimality routine were used in the selection of the five additional glasses. As for the previous selection results, the correlations are provided as part of the output from this routine. The largest correlation is between SiO_2 and Na_2O with a value of 0.82. The mixture aspects of the design are as in Table 7.

The set of five newly selected compositions is given in Table 22 along with their identifiers. Exhibit A9 in the Appendix provides descriptive statistics for the compositions and property predictions for all 30 glasses. The property predictions for the five new glasses are provided in Table 23.

Table 22. Compositions for the Five Glasses Selected from the Modified Inner Layer.

ID		Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others
ND26	MIL w TL at 1050	0.0300	0.0640	0.0120	0.0760	0.0380	0.0080	0.0650	0.1755	0.0100	0.4500	0.0035	0.0640	0.0040
ND27	MIL w TL at 1050	0.0300	0.1060	0.0330	0.0760	0.0380	0.0080	0.0200	0.1594	0.0400	0.4541	0.0035	0.0160	0.0160
ND28	MIL w TL at 1050	0.0300	0.1060	0.0330	0.0760	0.0620	0.0080	0.0200	0.1323	0.0100	0.4887	0.0140	0.0160	0.0040
ND29	MIL w TL at 1050	0.0300	0.0640	0.0120	0.1499	0.0380	0.0080	0.0200	0.1569	0.0100	0.4652	0.0140	0.0160	0.0160
ND30	MIL w TL at 1050	0.0300	0.0640	0.0120	0.0760	0.0620	0.0320	0.0200	0.1325	0.0397	0.4603	0.0035	0.0640	0.0040

Table 23. Property Predictions for the Five Glasses Selected from the Modified Inner Layer.

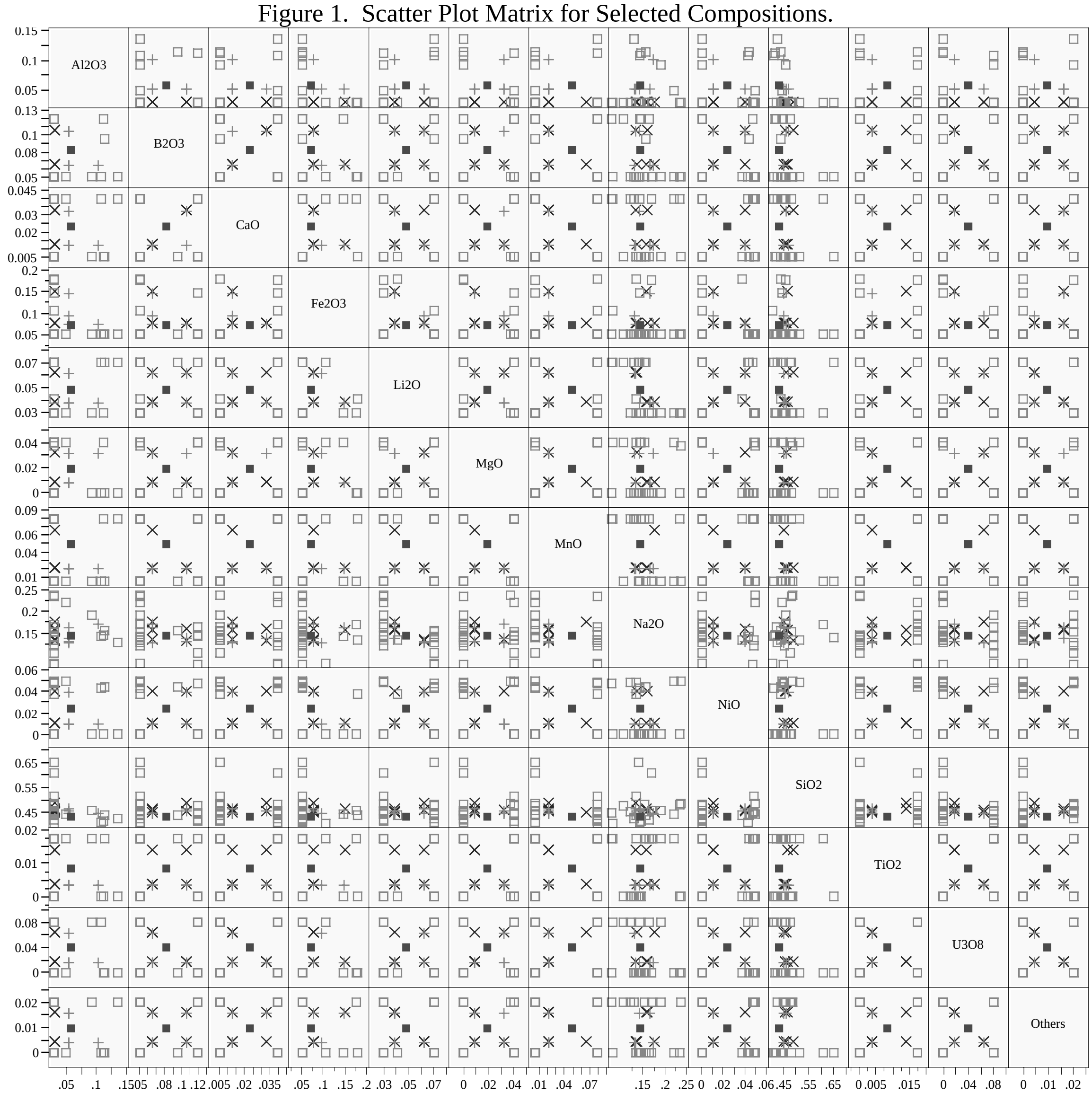
ID	Property PAR Status	alkalis (wt fraction)	Viscosity (Poise)	Homogeneity wt %	PCCS ΔG_p (kcal/mol)	Old T_L (^oC)	New T_L (^oC)
ND26	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.214	21.62	183.3	-17.010	940.9	662.6
ND27	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.197	21.65	200.0	-15.125	939.5	1041.3
ND28	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.194	21.62	205.0	-14.225	929.0	748.6
ND29	Not Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali	0.195	21.57	224.5	-12.818	1064.5	931.0
ND30	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.195	21.60	181.9	-14.014	937.5	1062.7

2.5 Complete Set of Selected Glass Compositions for Phase 1

Before the compositions and predicted properties of the complete set of selected glasses are provided, an additional glass is identified that was added to the test matrix. The glass is the centroid of the outer layer EVs from the bounding glass compositional region (where this value is computed by averaging the 10,249 outer layer EVs generated by MIXSOFT for the input defined by Table 6).

Figure 1 provides a scatter plot matrix of the 31 glass compositions selected for testing as part of the first phase of the PCT assessment study.

Figure 1. Scatter Plot Matrix for Selected Compositions.



The correlations of the 31 compositions are provided in Table 24. These correlations reveal the impact of the mixture aspects of this problem.

Table 24. Property Predictions for the Five Glasses Selected from the Modified Inner Layer.

	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others
Al2O3	1.0000	-0.0021	-0.0571	-0.2633	0.1880	-0.0940	-0.0722	0.0284	-0.0338	-0.3595	-0.1526	-0.0157	-0.0446
B2O3	-0.0021	1.0000	-0.0556	-0.0735	0.0936	0.1131	-0.0387	-0.3417	-0.0532	-0.2444	-0.0543	-0.0051	-0.0131
CaO	-0.0571	-0.0556	1.0000	0.0529	-0.0407	-0.1874	0.0161	-0.0929	0.0229	-0.1258	0.0498	-0.0697	0.0449
Fe2O3	-0.2633	-0.0735	0.0529	1.0000	-0.1970	-0.0610	-0.1246	-0.0944	-0.1690	-0.2012	-0.0444	-0.1521	0.0306
Li2O	0.1880	0.0936	-0.0407	-0.1970	1.0000	-0.0242	-0.0073	-0.6027	0.0248	-0.0020	-0.0174	0.1561	0.0214
MgO	-0.0940	0.1131	-0.1874	-0.0610	-0.0242	1.0000	-0.0310	-0.0448	-0.0164	-0.1443	-0.0541	-0.0119	-0.0776
MnO	-0.0722	-0.0387	0.0161	-0.1246	-0.0073	-0.0310	1.0000	-0.2749	-0.0289	-0.2821	0.0384	0.0279	-0.0352
Na2O	0.0284	-0.3417	-0.0929	-0.0944	-0.6027	-0.0448	-0.2749	1.0000	0.0006	0.1336	-0.0160	-0.2682	-0.0585
NiO	-0.0338	-0.0532	0.0229	-0.1690	0.0248	-0.0164	-0.0289	0.0006	1.0000	-0.1585	-0.0218	-0.0656	-0.0186
SiO2	-0.3595	-0.2444	-0.1258	-0.2012	-0.0020	-0.1443	-0.2821	0.1336	-0.1585	1.0000	0.0515	-0.3385	-0.1079
TiO2	-0.1526	-0.0543	0.0498	-0.0444	-0.0174	-0.0541	0.0384	-0.0160	-0.0218	0.0515	1.0000	-0.0567	0.0045
U3O8	-0.0157	-0.0051	-0.0697	-0.1521	0.1561	-0.0119	0.0279	-0.2682	-0.0656	-0.3385	-0.0567	1.0000	0.0369
Others	-0.0446	-0.0131	0.0449	0.0306	0.0214	-0.0776	-0.0352	-0.0585	-0.0186	-0.1079	0.0045	0.0369	1.0000

The full set of compositions are provided in Table 25 and the corresponding property prediction are in Table 26.

Table 25. Compositions for Phase 1 of the PCT assessment Study.

ID		Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	U_3O_8	Others
ND01	OL w TL at 1050	0.0300	0.0500	0.0400	0.0500	0.0300	0.0000	0.0800	0.2361	0.0000	0.4839	0.0000	0.0000	0.0000
ND02	OL w TL at 1050	0.0300	0.1200	0.0050	0.0500	0.0300	0.0000	0.0800	0.1645	0.0000	0.4230	0.0175	0.0800	0.0000
ND03	OL w TL at 1050	0.0300	0.0500	0.0050	0.0500	0.0700	0.0400	0.0800	0.1533	0.0000	0.4842	0.0175	0.0000	0.0200
ND04	OL w TL at 1050	0.0300	0.1200	0.0050	0.0500	0.0700	0.0400	0.0050	0.1037	0.0000	0.4763	0.0000	0.0800	0.0200
ND05	OL w TL at 1050	0.1348	0.0500	0.0400	0.0500	0.0700	0.0000	0.0800	0.1274	0.0000	0.4278	0.0000	0.0000	0.0200
ND06	OL w TL at 1050	0.0301	0.0500	0.0050	0.0500	0.0700	0.0000	0.0050	0.1399	0.0000	0.6500	0.0000	0.0000	0.0000
ND07	OL w TL at 1050	0.0300	0.0500	0.0400	0.0500	0.0300	0.0000	0.0050	0.1683	0.0000	0.6092	0.0175	0.0000	0.0000
ND08	OL w TL at 1050	0.1119	0.1200	0.0050	0.0500	0.0300	0.0400	0.0800	0.1446	0.0000	0.4185	0.0000	0.0000	0.0000
ND09	OL w TL at 1050	0.0915	0.0500	0.0050	0.0500	0.0300	0.0000	0.0050	0.1906	0.0000	0.4604	0.0175	0.0800	0.0200
ND10	OL w TL at 1050	0.0300	0.1200	0.0400	0.1474	0.0300	0.0400	0.0050	0.1418	0.0000	0.4458	0.0000	0.0000	0.0000
ND11	OL w TL at 1050	0.0300	0.0500	0.0400	0.1054	0.0700	0.0400	0.0800	0.0804	0.0000	0.4068	0.0175	0.0800	0.0000
ND12	OL w TL at 1050	0.0300	0.0500	0.0400	0.1780	0.0300	0.0000	0.0050	0.1701	0.0000	0.4594	0.0175	0.0000	0.0200
ND13	OL w TL at 1050	0.0300	0.0500	0.0050	0.0500	0.0300	0.0376	0.0050	0.2370	0.0500	0.4853	0.0000	0.0000	0.0200
ND14	OL w TL at 1050	0.0493	0.0500	0.0400	0.0500	0.0300	0.0400	0.0050	0.2225	0.0500	0.4457	0.0175	0.0000	0.0000
ND15	OL w TL at 1050	0.0300	0.1200	0.0400	0.0500	0.0700	0.0000	0.0800	0.0761	0.0474	0.4491	0.0175	0.0000	0.0200
ND16	OL w TL at 1050	0.1089	0.0500	0.0400	0.0500	0.0700	0.0000	0.0050	0.1426	0.0431	0.4104	0.0000	0.0800	0.0000
ND17	OL w TL at 1050	0.0300	0.0500	0.0050	0.0500	0.0300	0.0400	0.0800	0.1335	0.0489	0.5151	0.0175	0.0000	0.0000
ND18	OL w TL at 1050	0.0300	0.0500	0.0400	0.0500	0.0300	0.0000	0.0800	0.1193	0.0488	0.4519	0.0000	0.0800	0.0200
ND19	OL w TL at 1050	0.0300	0.0500	0.0050	0.1800	0.0412	0.0000	0.0800	0.1344	0.0376	0.4418	0.0000	0.0000	0.0000
ND20	OL w TL at 1050	0.1145	0.0955	0.0050	0.0500	0.0700	0.0000	0.0050	0.1564	0.0440	0.4421	0.0175	0.0000	0.0000
ND21	IL w TL at 1050	0.0540	0.1060	0.0120	0.0760	0.0620	0.0080	0.0200	0.1323	0.0400	0.4662	0.0035	0.0160	0.0040
ND22	IL w TL at 1050	0.0540	0.1060	0.0330	0.0760	0.0380	0.0320	0.0200	0.1383	0.0100	0.4572	0.0035	0.0160	0.0160
ND23	IL w TL at 1050	0.0540	0.0640	0.0120	0.1455	0.0380	0.0080	0.0200	0.1630	0.0100	0.4500	0.0035	0.0160	0.0160
ND24	IL w TL at 1050	0.0540	0.0640	0.0120	0.0955	0.0620	0.0320	0.0200	0.1290	0.0100	0.4500	0.0035	0.0640	0.0040
ND25	IL w TL at 1050	0.1025	0.0640	0.0120	0.0760	0.0380	0.0320	0.0200	0.1720	0.0100	0.4500	0.0035	0.0160	0.0040
ND26	MIL w TL at 1050	0.0300	0.0640	0.0120	0.0760	0.0380	0.0080	0.0650	0.1755	0.0100	0.4500	0.0035	0.0640	0.0040
ND27	MIL w TL at 1050	0.0300	0.1060	0.0330	0.0760	0.0380	0.0080	0.0200	0.1594	0.0400	0.4541	0.0035	0.0160	0.0160
ND28	MIL w TL at 1050	0.0300	0.1060	0.0330	0.0760	0.0620	0.0080	0.0200	0.1323	0.0100	0.4887	0.0140	0.0160	0.0040
ND29	MIL w TL at 1050	0.0300	0.0640	0.0120	0.1499	0.0380	0.0080	0.0200	0.1569	0.0100	0.4652	0.0140	0.0160	0.0160
ND30	MIL w TL at 1050	0.0300	0.0640	0.0120	0.0760	0.0620	0.0320	0.0200	0.1325	0.0397	0.4603	0.0035	0.0640	0.0040
ND31	Centroid of OL EVs w TL at 1050	0.0569	0.0811	0.0232	0.0698	0.0481	0.0184	0.0482	0.1413	0.0233	0.4324	0.0083	0.0398	0.0092

Table 26. Property Predictions for Final Set of Phase 2 Test Glasses.

ID	Property PAR Status	alkalis (wt fraction)	Viscosity (Poise)	Homogeneity wt %	PCCS ΔG_p (kcal/mol)	Old T_L (^oC)	New T_L (^oC)
ND01	Not Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.266	19.99	196.1	-22.300	887.1	427.6
ND02	Not Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.195	19.98	166.3	-16.635	900.4	529.1
ND03	Not Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.223	20.00	169.5	-17.988	887.0	662.4
ND04	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.174	24.18	171.5	-12.839	888.6	822.9
ND05	Not Durable; Visc; TL ; Homo; New TL ; Al2O3 ; Not alkali	0.197	46.06	235.2	-12.842	955.0	800.1
ND06	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.210	73.64	194.0	-12.711	864.4	498.5
ND07	Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.198	109.34	205.3	-12.708	868.7	556.7
ND08	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.175	59.50	208.6	-12.717	942.5	831.4
ND09	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.221	54.40	200.0	-12.840	913.7	756.2
ND10	Durable; Not Visc; Not TL; Homo; New TL ; Al2O3 ; alkali	0.172	19.99	241.1	-12.708	1072.4	927.7
ND11	Durable; Not Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.150	19.99	196.4	-12.714	1016.4	806.7
ND12	Not Durable; Not Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali	0.200	20.00	253.8	-12.833	1117.6	883.1
ND13	Not Durable; Not Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.267	20.00	176.7	-19.640	886.8	1018.3
ND14	Not Durable; Not Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.253	19.97	198.7	-18.366	901.3	1025.3
ND15	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; alkali	0.146	28.29	182.5	-12.843	894.2	1032.2
ND16	Durable; Visc; TL ; Homo; Not New TL; Al2O3 ; Not alkali	0.213	23.47	220.3	-12.710	944.6	1025.7
ND17	Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; alkali	0.164	103.08	164.8	-12.712	881.6	1045.2
ND18	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; alkali	0.149	85.05	172.2	-12.841	893.6	1049.1
ND19	Durable; Not Visc; Not TL; Homo; Not New TL; Al2O3 ; alkali	0.176	19.99	228.4	-12.711	1135.1	1028.6
ND20	Durable; Not Visc; TL ; Homo; New TL ; Al2O3 ; Not alkali	0.226	20.01	218.2	-12.710	932.8	1008.2
ND21	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.194	21.59	203.1	-13.173	946.7	1050.8
ND22	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.176	38.09	210.6	-12.816	950.0	976.4
ND23	Not Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali	0.201	21.66	234.1	-12.809	1089.0	971.3
ND24	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.191	22.89	204.2	-12.734	990.9	925.3
ND25	Not Durable; Visc; TL ; Homo; New TL ; Al2O3 ; Not alkali	0.210	44.60	223.7	-12.736	984.5	924.1
ND26	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.214	21.62	183.3	-17.010	940.9	662.6
ND27	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.197	21.65	200.0	-15.125	939.5	1041.3
ND28	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; Not alkali	0.194	21.62	205.0	-14.225	929.0	748.6
ND29	Not Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali	0.195	21.57	224.5	-12.818	1064.5	931.0
ND30	Not Durable; Visc; TL ; Not Homo; Not New TL; Al2O3 ; Not alkali	0.195	21.60	181.9	-14.014	937.5	1062.7
ND31	Not Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali	0.189	26.57	197.4	-14.052	949.0	943.9

3. Concluding Comments

A total of 31 glass compositions were identified for batching and testing as part of Phase 1 of the PCT assessment task. These glasses were intentionally selected to challenge the current durability models over the glass composition region anticipated for DWPF sludge-only operation. However, a broader glass compositional region was selected to bound this phase of the study, which should provide more flexibility for future changes in sludge or frit composition in sludge-only processing.

The first twenty glasses for this study were chosen using the composition range in Table 1 from Reference 11. In addition to the compositional limits, limits for low frit, nepheline formation, viscosity (low and high) and liquidus were imposed to ensure that the glasses produced would be processable. To satisfy the objective of this task, a constraint was imposed to force the glasses chosen to fail the durability limit at the PAR.

A set of five glasses was chosen to represent interior compositions to the above glasses. The compositional ranges were decreased 20% from the lower and upper limits as listed in Table 10. The processing limits discussed above again were imposed. The viscosity limits were adjusted for the more conservative compositional region. Again a constraint was imposed to force the glasses chosen to fail the durability limit at the PAR.

A second set of five inner layer glasses was selected from the compositional region in Table 17. The only variations in the compositional region or the selection process were that the alumina content was restricted to $3 \leq$ wt% $Al_2O_3 \leq 3.9$ and the total alkali ($Na_2O + Li_2O$) was limited to values greater than 19.3 wt%. The intent of these glasses is to exercise the Al_2O_3-Al_2O_3+R_2O criteria from Reference 9.

If any problems arise during the batching or testing of these glasses or if the understanding of the sludge-only region, anticipated in this investigation, changes, then this analysis should be revisited to ensure that the glasses selected in this study are still viable and/or to select additional glasses to support the completion of the durability study.

4. References

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Appendix:

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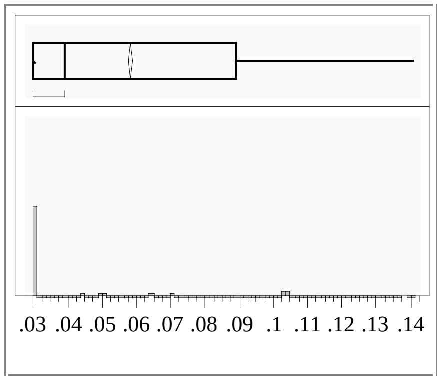
Appendix

Exhibit A1. Descriptive Statistics for EV Compositions Generated Using Table 4 as Input to MIXSOFT

Al2O3



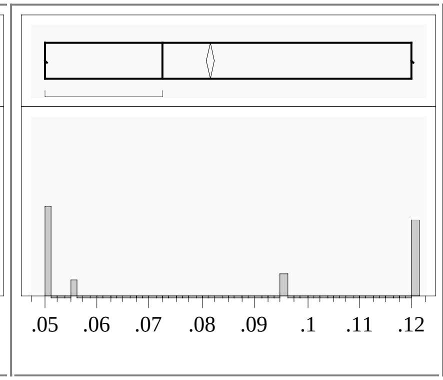
Quantiles

100.0%	maximum	0.14050
99.5%		0.12892
97.5%		0.12270
90.0%		0.10890
75.0%	quartile	0.08922
50.0%	median	0.03912
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0583616
Std Dev	0.0331292
Std Err Mean	0.0003534
upper 95% Mean	0.0590544
lower 95% Mean	0.0576687
N	8786

B2O3



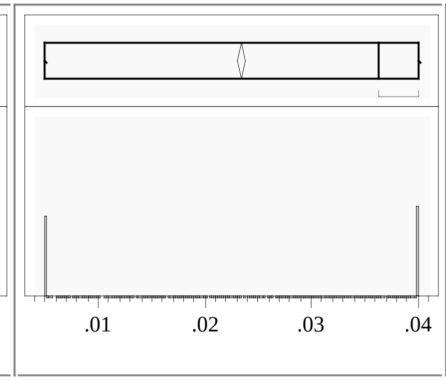
Quantiles

100.0%	maximum	0.12000
99.5%		0.12000
97.5%		0.12000
90.0%		0.12000
75.0%	quartile	0.12000
50.0%	median	0.07237
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

Moments

Mean	0.0815475
Std Dev	0.0314377
Std Err Mean	0.0003354
upper 95% Mean	0.0822049
lower 95% Mean	0.08089
N	8786

CaO



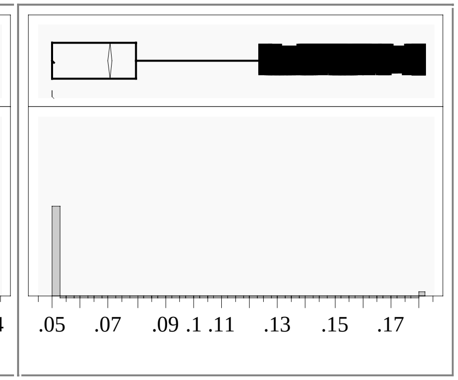
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.03642
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.0233632
Std Dev	0.0171336
Std Err Mean	0.0001828
upper 95% Mean	0.0237215
lower 95% Mean	0.0230048
N	8786

Fe2O3



Quantiles

100.0%	maximum	0.18000
99.5%		0.18000
97.5%		0.18000
90.0%		0.12863
75.0%	quartile	0.07998
50.0%	median	0.05000
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

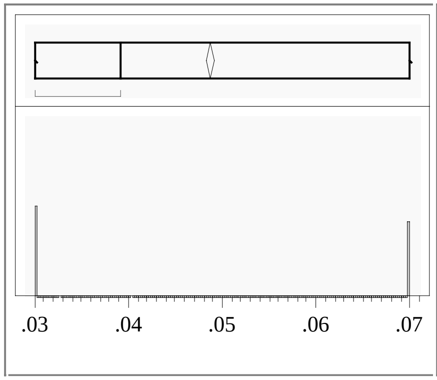
Moments

Mean	0.0703801
Std Dev	0.0363198
Std Err Mean	0.0003875
upper 95% Mean	0.0711397
lower 95% Mean	0.0696206
N	8786

Appendix

Exhibit A1. Descriptive Statistics for EV Compositions Generated Using Table 4 as Input to MIXSOFT (continued)

Li2O



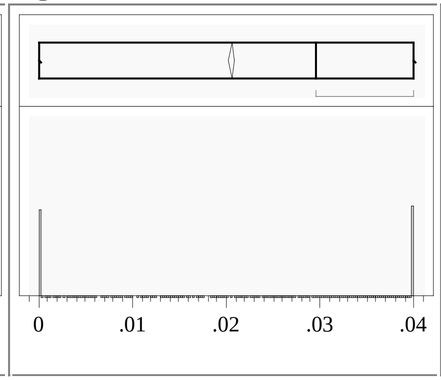
Quantiles

100.0%	maximum	0.07000
99.5%		0.07000
97.5%		0.07000
90.0%		0.07000
75.0%	quartile	0.07000
50.0%	median	0.03911
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0487455
Std Dev	0.0191712
Std Err Mean	0.0002045
upper 95% Mean	0.0491464
lower 95% Mean	0.0483445
N	8786

MgO



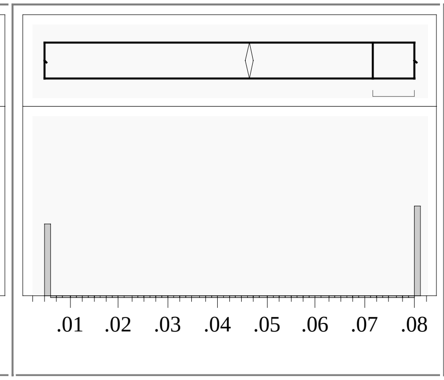
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.02965
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0205436
Std Dev	0.0195956
Std Err Mean	0.0002091
upper 95% Mean	0.0209534
lower 95% Mean	0.0201338
N	8786

MnO



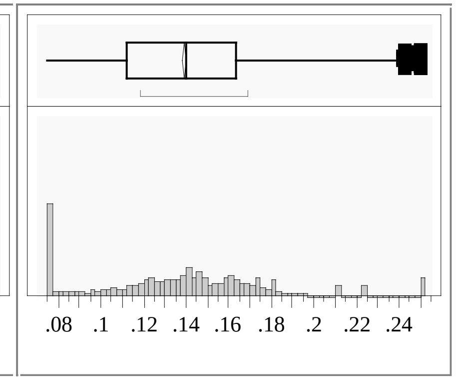
Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.08000
50.0%	median	0.07150
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.0464734
Std Dev	0.0356037
Std Err Mean	0.0003798
upper 95% Mean	0.0472179
lower 95% Mean	0.0457288
N	8786

Na2O



Quantiles

100.0%	maximum	0.25000
99.5%		0.25000
97.5%		0.25000
90.0%		0.18880
75.0%	quartile	0.16350
50.0%	median	0.14000
25.0%	quartile	0.11210
10.0%		0.07500
2.5%		0.07500
0.5%		0.07500
0.0%	minimum	0.07500

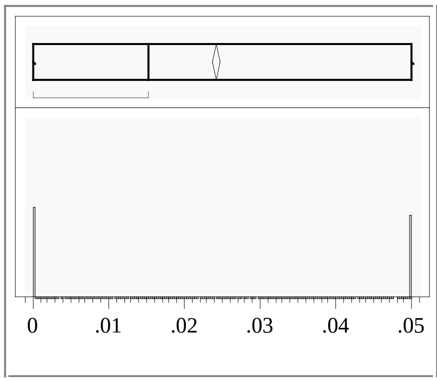
Moments

Mean	0.1391348
Std Dev	0.0422818
Std Err Mean	0.0004511
upper 95% Mean	0.140019
lower 95% Mean	0.1382506
N	8786

Appendix

Exhibit A1. Descriptive Statistics for EV Compositions Generated Using Table 4 as Input to MIXSOFT (continued)

NiO



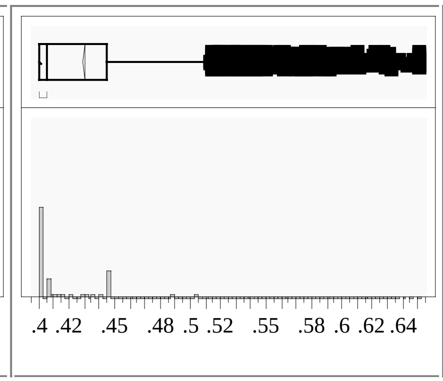
Quantiles

100.0%	maximum	0.05000
99.5%		0.05000
97.5%		0.05000
90.0%		0.05000
75.0%	quartile	0.05000
50.0%	median	0.01517
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0242144
Std Dev	0.024317
Std Err Mean	0.0002594
upper 95% Mean	0.0247229
lower 95% Mean	0.0237059
N	8786

SiO2



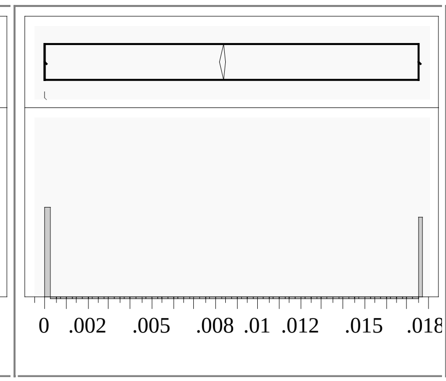
Quantiles

100.0%	maximum	0.65000
99.5%		0.62191
97.5%		0.55160
90.0%		0.48903
75.0%	quartile	0.44500
50.0%	median	0.40500
25.0%	quartile	0.40000
10.0%		0.40000
2.5%		0.40000
0.5%		0.40000
0.0%	minimum	0.40000

Moments

Mean	0.4300197
Std Dev	0.0431648
Std Err Mean	0.0004605
upper 95% Mean	0.4309224
lower 95% Mean	0.429117
N	8786

TiO2



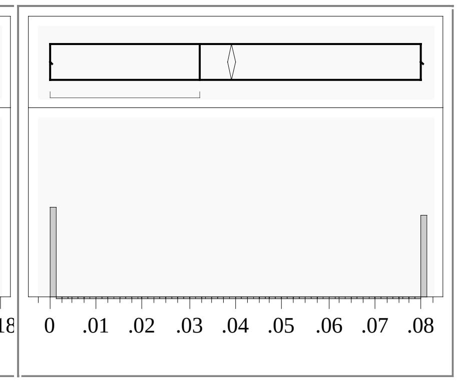
Quantiles

100.0%	maximum	0.01750
99.5%		0.01750
97.5%		0.01750
90.0%		0.01750
75.0%	quartile	0.01750
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.008334
Std Dev	0.0086449
Std Err Mean	0.0000922
upper 95% Mean	0.0085148
lower 95% Mean	0.0081533
N	8786

U3O8



Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.08000
50.0%	median	0.03226
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

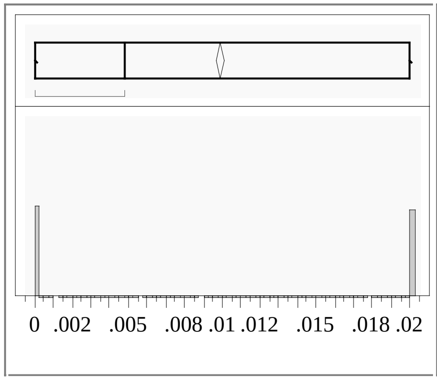
Moments

Mean	0.0390178
Std Dev	0.038412
Std Err Mean	0.0004098
upper 95% Mean	0.0398211
lower 95% Mean	0.0382145
N	8786

Appendix

Exhibit A1. Descriptive Statistics for EV Compositions Generated Using Table 4 as Input to MIXSOFT (continued)

Others



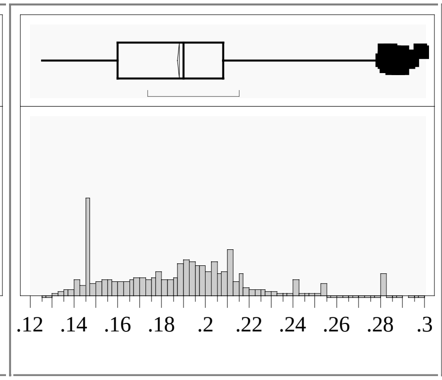
Quantiles

100.0%	maximum	0.02000
99.5%		0.02000
97.5%		0.02000
90.0%		0.02000
75.0%	quartile	0.02000
50.0%	median	0.00484
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0098644
Std Dev	0.0099034
Std Err Mean	0.0001057
upper 95% Mean	0.0100715
lower 95% Mean	0.0096573
N	8786

alkalis



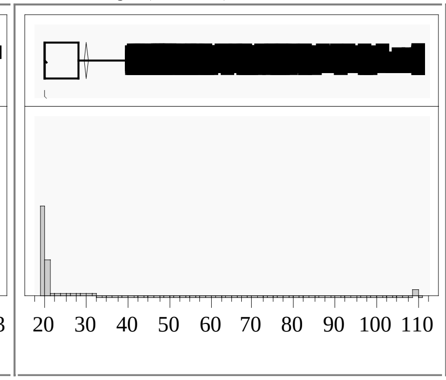
Quantiles

100.0%	maximum	0.29825
99.5%		0.28000
97.5%		0.28000
90.0%		0.22880
75.0%	quartile	0.20810
50.0%	median	0.18980
25.0%	quartile	0.15970
10.0%		0.14500
2.5%		0.13951
0.5%		0.13159
0.0%	minimum	0.12520

Moments

Mean	0.1878803
Std Dev	0.0335626
Std Err Mean	0.0003581
upper 95% Mean	0.1885822
lower 95% Mean	0.1871784
N	8786

Viscosity (Poise)



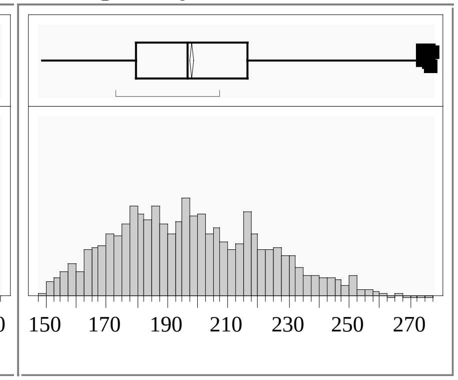
Quantiles

100.0%	maximum	110.03
99.5%		109.96
97.5%		109.87
90.0%		55.26
75.0%	quartile	28.23
50.0%	median	20.00
25.0%	quartile	19.99
10.0%		19.98
2.5%		19.98
0.5%		19.97
0.0%	minimum	19.96

Moments

Mean	29.815799
Std Dev	21.245962
Std Err Mean	0.2266631
upper 95% Mean	30.260112
lower 95% Mean	29.371486
N	8786

Homogeneity



Quantiles

100.0%	maximum	276.87
99.5%		260.65
97.5%		249.18
90.0%		231.24
75.0%	quartile	216.51
50.0%	median	196.74
25.0%	quartile	179.49
10.0%		167.35
2.5%		156.77
0.5%		151.46
0.0%	minimum	148.62

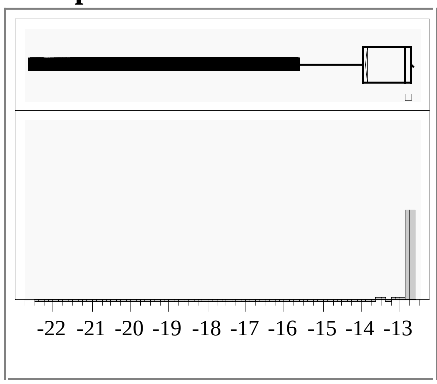
Moments

Mean	198.06217
Std Dev	24.333607
Std Err Mean	0.2596037
upper 95% Mean	198.57106
lower 95% Mean	197.55329
N	8786

Appendix

Exhibit A1. Descriptive Statistics for EV Compositions Generated Using Table 4 as Input to MIXSOFT (continued)

del Gp



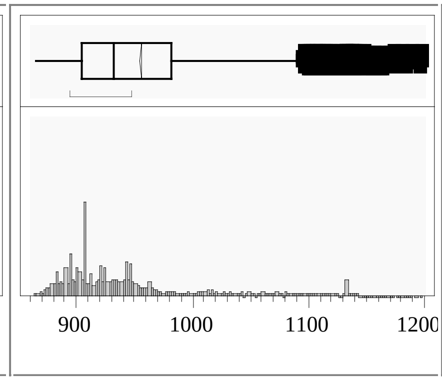
Quantiles

100.0%	maximum	-12.70
99.5%		-12.71
97.5%		-12.71
90.0%		-12.71
75.0%	quartile	-12.72
50.0%	median	-12.84
25.0%	quartile	-13.95
10.0%		-17.28
2.5%		-20.12
0.5%		-21.21
0.0%	minimum	-22.49

Moments

Mean	-13.86712
Std Dev	2.0932497
Std Err Mean	0.0223319
upper 95% Mean	-13.82334
lower 95% Mean	-13.91089
N	8786

TL



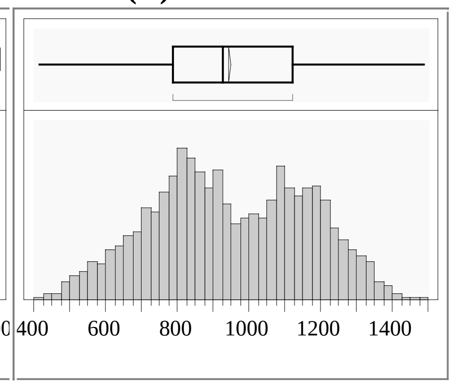
Quantiles

100.0%	maximum	1197.8
99.5%		1166.7
97.5%		1137.5
90.0%		1081.0
75.0%	quartile	981.1
50.0%	median	931.5
25.0%	quartile	905.1
10.0%		889.5
2.5%		876.5
0.5%		868.1
0.0%	minimum	864.4

Moments

Mean	955.44047
Std Dev	72.791927
Std Err Mean	0.7765825
upper 95% Mean	956.96276
lower 95% Mean	953.91819
N	8786

Pred TL(C)



Quantiles

100.0%	maximum	1490.9
99.5%		1402.9
97.5%		1331.5
90.0%		1230.4
75.0%	quartile	1123.9
50.0%	median	929.3
25.0%	quartile	787.2
10.0%		661.3
2.5%		535.8
0.5%		469.9
0.0%	minimum	419.3

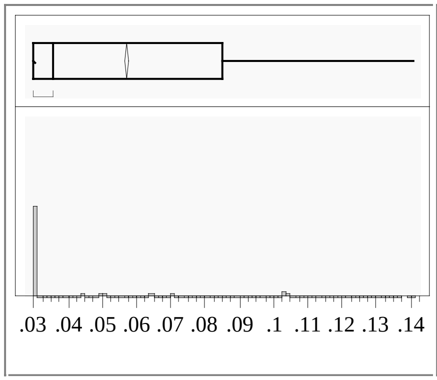
Moments

Mean	946.61693
Std Dev	216.96655
Std Err Mean	2.3147131
upper 95% Mean	951.15431
lower 95% Mean	942.07955
N	8786

Appendix

Exhibit A2. . Descriptive Statistics for EV Compositions Generated Using Table 6 as Input to MIXSOFT

Al2O3



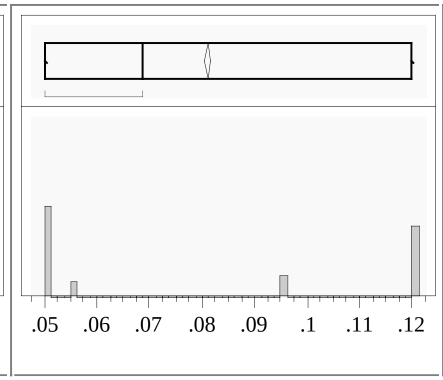
Quantiles

100.0%	maximum	0.14050
99.5%		0.12860
97.5%		0.12220
90.0%		0.10780
75.0%	quartile	0.08475
50.0%	median	0.03560
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0568983
Std Dev	0.0323594
Std Err Mean	0.0003196
upper 95% Mean	0.0575249
lower 95% Mean	0.0562718
N	10249

B2O3



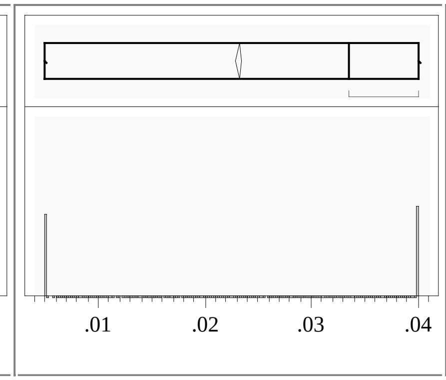
Quantiles

100.0%	maximum	0.12000
99.5%		0.12000
97.5%		0.12000
90.0%		0.12000
75.0%	quartile	0.12000
50.0%	median	0.06885
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

Moments

Mean	0.0810558
Std Dev	0.0313663
Std Err Mean	0.0003098
upper 95% Mean	0.0816632
lower 95% Mean	0.0804485
N	10249

CaO



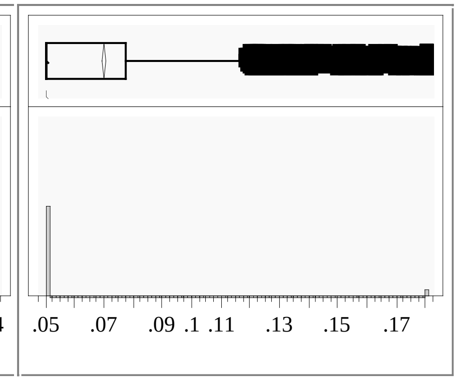
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.03361
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.0231896
Std Dev	0.0171122
Std Err Mean	0.000169
upper 95% Mean	0.023521
lower 95% Mean	0.0228583
N	10249

Fe2O3



Quantiles

100.0%	maximum	0.18000
99.5%		0.18000
97.5%		0.18000
90.0%		0.12610
75.0%	quartile	0.07734
50.0%	median	0.05000
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

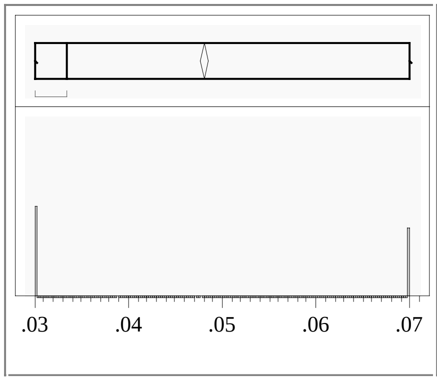
Moments

Mean	0.0698176
Std Dev	0.0362208
Std Err Mean	0.0003578
upper 95% Mean	0.070519
lower 95% Mean	0.0691163
N	10249

Appendix

Exhibit A2. Descriptive Statistics for EV Compositions Generated Using Table 6 as Input to MIXSOFT (continued)

Li2O



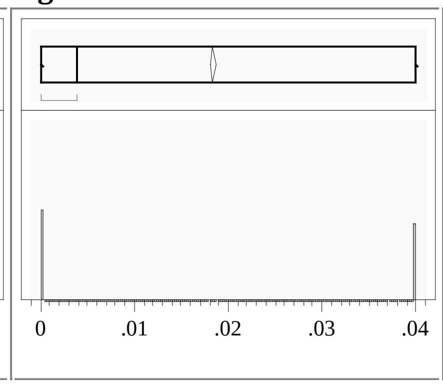
Quantiles

100.0%	maximum	0.07000
99.5%		0.07000
97.5%		0.07000
90.0%		0.07000
75.0%	quartile	0.07000
50.0%	median	0.03339
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0480717
Std Dev	0.0190926
Std Err Mean	0.0001886
upper 95% Mean	0.0484414
lower 95% Mean	0.0477021
N	10249

MgO



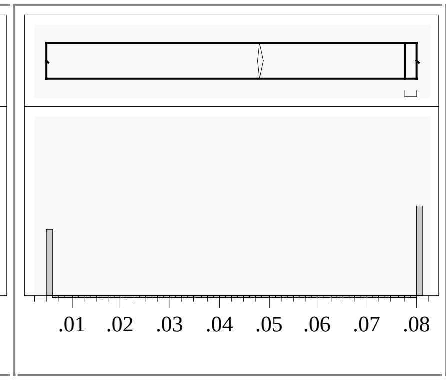
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.00381
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0183817
Std Dev	0.0192921
Std Err Mean	0.0001906
upper 95% Mean	0.0187552
lower 95% Mean	0.0180081
N	10249

MnO



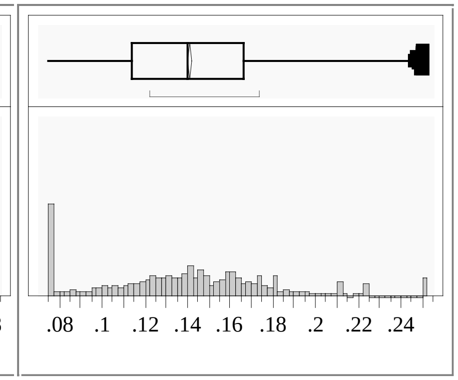
Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.08000
50.0%	median	0.07751
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.048235
Std Dev	0.0352112
Std Err Mean	0.0003478
upper 95% Mean	0.0489167
lower 95% Mean	0.0475532
N	10249

Na2O



Quantiles

100.0%	maximum	0.25000
99.5%		0.25000
97.5%		0.24132
90.0%		0.19520
75.0%	quartile	0.16660
50.0%	median	0.14050
25.0%	quartile	0.11390
10.0%		0.07500
2.5%		0.07500
0.5%		0.07500
0.0%	minimum	0.07500

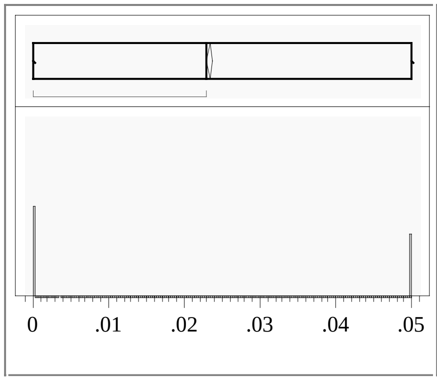
Moments

Mean	0.14127
Std Dev	0.0419574
Std Err Mean	0.0004144
upper 95% Mean	0.1420824
lower 95% Mean	0.1404576
N	10249

Appendix

Exhibit A2. Descriptive Statistics for EV Compositions Generated Using Table 6 as Input to MIXSOFT (continued)

NiO



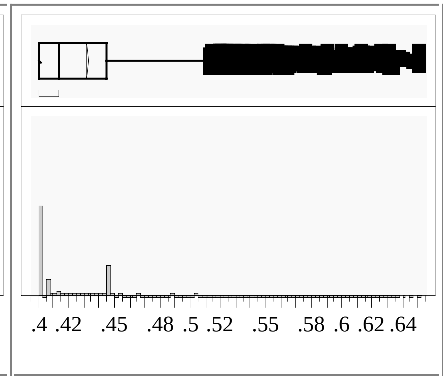
Quantiles

100.0%	maximum	0.05000
99.5%		0.05000
97.5%		0.05000
90.0%		0.05000
75.0%	quartile	0.05000
50.0%	median	0.02296
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0233406
Std Dev	0.0220601
Std Err Mean	0.0002179
upper 95% Mean	0.0237678
lower 95% Mean	0.0229135
N	10249

SiO2



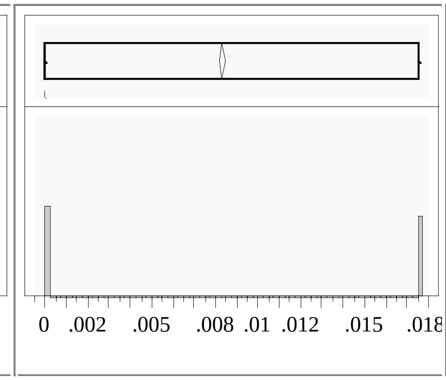
Quantiles

100.0%	maximum	0.65000
99.5%		0.61343
97.5%		0.54848
90.0%		0.49230
75.0%	quartile	0.44500
50.0%	median	0.41330
25.0%	quartile	0.40000
10.0%		0.40000
2.5%		0.40000
0.5%		0.40000
0.0%	minimum	0.40000

Moments

Mean	0.4324188
Std Dev	0.0428032
Std Err Mean	0.0004228
upper 95% Mean	0.4332475
lower 95% Mean	0.43159
N	10249

TiO2



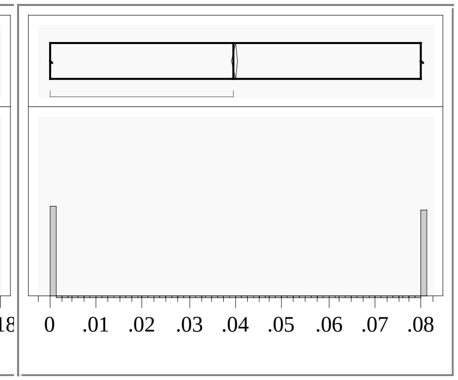
Quantiles

100.0%	maximum	0.01750
99.5%		0.01750
97.5%		0.01750
90.0%		0.01750
75.0%	quartile	0.01750
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0083147
Std Dev	0.0086193
Std Err Mean	0.0000851
upper 95% Mean	0.0084816
lower 95% Mean	0.0081478
N	10249

U3O8



Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.08000
50.0%	median	0.03970
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

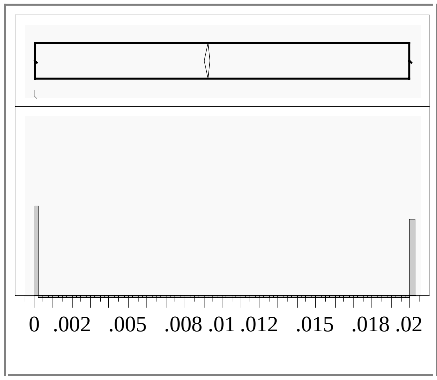
Moments

Mean	0.0397884
Std Dev	0.0382731
Std Err Mean	0.0003781
upper 95% Mean	0.0405294
lower 95% Mean	0.0390473
N	10249

Appendix

Exhibit A2. Descriptive Statistics for EV Compositions Generated Using Table 6 as Input to MIXSOFT (continued)

Others



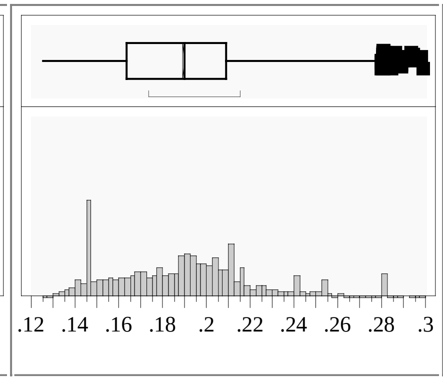
Quantiles

100.0%	maximum	0.02000
99.5%		0.02000
97.5%		0.02000
90.0%		0.02000
75.0%	quartile	0.02000
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0092175
Std Dev	0.0097836
Std Err Mean	0.0000966
upper 95% Mean	0.0094069
lower 95% Mean	0.009028
N	10249

alkalis



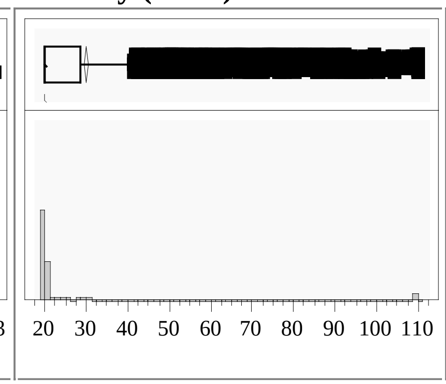
Quantiles

100.0%	maximum	0.29825
99.5%		0.28000
97.5%		0.27292
90.0%		0.23270
75.0%	quartile	0.20950
50.0%	median	0.19020
25.0%	quartile	0.16345
10.0%		0.14500
2.5%		0.14021
0.5%		0.13235
0.0%	minimum	0.12520

Moments

Mean	0.1893417
Std Dev	0.0330762
Std Err Mean	0.0003267
upper 95% Mean	0.1899821
lower 95% Mean	0.1887013
N	10249

Viscosity (Poise)



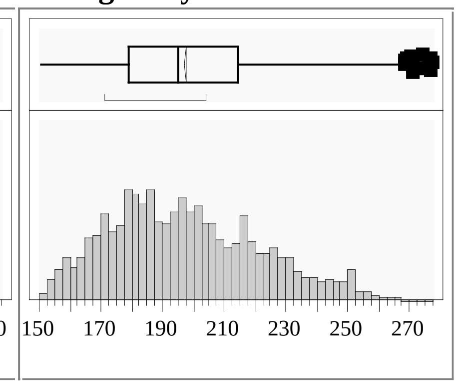
Quantiles

100.0%	maximum	110.03
99.5%		109.96
97.5%		109.86
90.0%		56.46
75.0%	quartile	28.57
50.0%	median	20.00
25.0%	quartile	19.99
10.0%		19.98
2.5%		19.98
0.5%		19.97
0.0%	minimum	19.96

Moments

Mean	30.002526
Std Dev	21.294733
Std Err Mean	0.2103446
upper 95% Mean	30.414842
lower 95% Mean	29.590209
N	10249

Homogeneity



Quantiles

100.0%	maximum	276.87
99.5%		259.94
97.5%		250.50
90.0%		231.24
75.0%	quartile	214.61
50.0%	median	194.96
25.0%	quartile	179.29
10.0%		167.61
2.5%		157.78
0.5%		153.40
0.0%	minimum	150.39

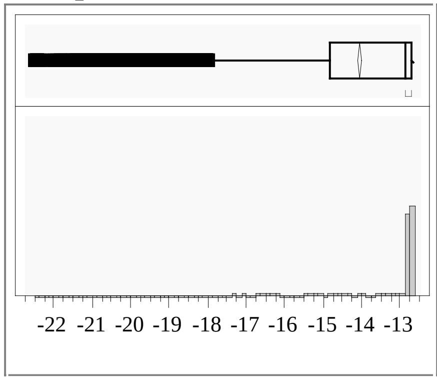
Moments

Mean	197.36028
Std Dev	24.310762
Std Err Mean	0.2401363
upper 95% Mean	197.831
lower 95% Mean	196.88957
N	10249

Appendix

Exhibit A2. Descriptive Statistics for EV Compositions Generated Using Table 6 as Input to MIXSOFT (continued)

del Gp



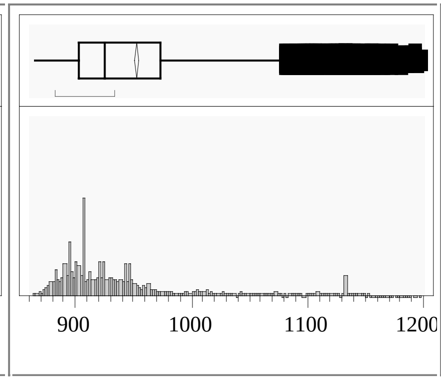
Quantiles

100.0%	maximum	-12.70
99.5%		-12.71
97.5%		-12.71
90.0%		-12.71
75.0%	quartile	-12.72
50.0%	median	-12.84
25.0%	quartile	-14.84
10.0%		-17.37
2.5%		-19.98
0.5%		-21.14
0.0%	minimum	-22.49

Moments

Mean	-14.05151
Std Dev	2.1006952
Std Err Mean	0.0207502
upper 95% Mean	-14.01083
lower 95% Mean	-14.09218
N	10249

TL



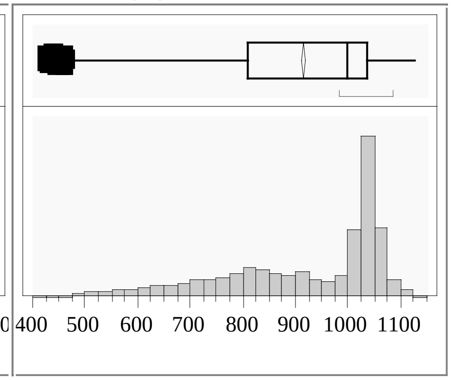
Quantiles

100.0%	maximum	1197.8
99.5%		1164.2
97.5%		1138.4
90.0%		1083.7
75.0%	quartile	973.8
50.0%	median	925.8
25.0%	quartile	902.5
10.0%		888.9
2.5%		877.1
0.5%		868.6
0.0%	minimum	864.4

Moments

Mean	952.60769
Std Dev	73.071735
Std Err Mean	0.7217864
upper 95% Mean	954.02254
lower 95% Mean	951.19285
N	10249

Pred TL(C)



Quantiles

100.0%	maximum	1128.8
99.5%		1111.5
97.5%		1083.6
90.0%		1055.9
75.0%	quartile	1037.9
50.0%	median	998.5
25.0%	quartile	809.1
10.0%		682.3
2.5%		547.9
0.5%		477.2
0.0%	minimum	419.3

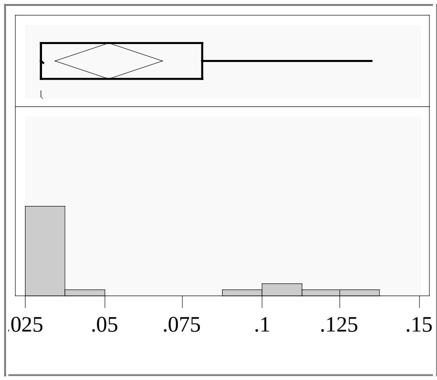
Moments

Mean	916.23933
Std Dev	154.68432
Std Err Mean	1.5279374
upper 95% Mean	919.23439
lower 95% Mean	913.24428
N	10249

Appendix

Exhibit A3. Descriptive Statistics for Glasses Selected from the Outer Layer EVs

Al2O3



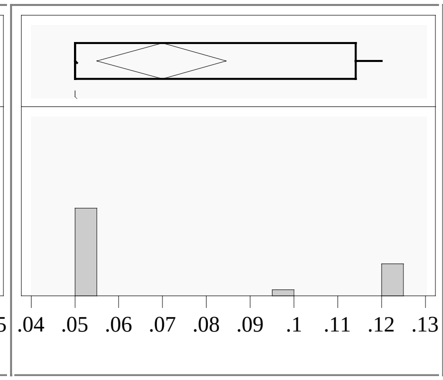
Quantiles

100.0%	maximum	0.13480
99.5%		0.13480
97.5%		0.13480
90.0%		0.11424
75.0%	quartile	0.08098
50.0%	median	0.03000
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0515525
Std Dev	0.0369395
Std Err Mean	0.0082599
upper 95% Mean	0.0688407
lower 95% Mean	0.0342643
N	20

B2O3



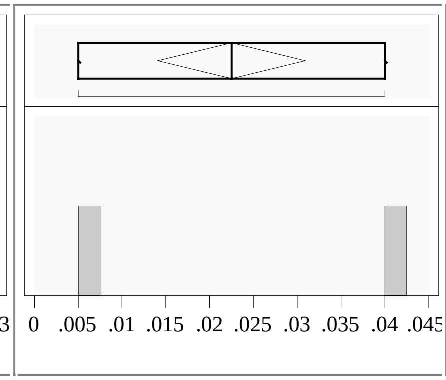
Quantiles

100.0%	maximum	0.12000
99.5%		0.12000
97.5%		0.12000
90.0%		0.12000
75.0%	quartile	0.11387
50.0%	median	0.05000
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

Moments

Mean	0.0697745
Std Dev	0.031413
Std Err Mean	0.0070242
upper 95% Mean	0.0844762
lower 95% Mean	0.0550728
N	20

CaO



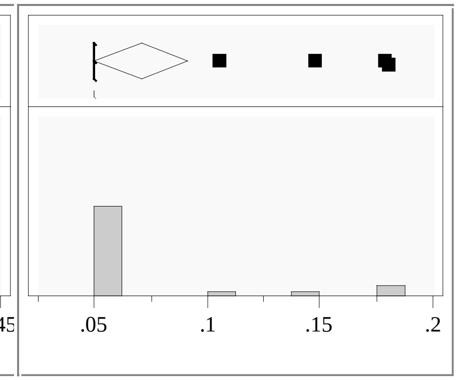
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.02250
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.0225
Std Dev	0.0179546
Std Err Mean	0.0040148
upper 95% Mean	0.030903
lower 95% Mean	0.014097
N	20

Fe2O3



Quantiles

100.0%	maximum	0.18000
99.5%		0.18000
97.5%		0.18000
90.0%		0.17494
75.0%	quartile	0.05000
50.0%	median	0.05000
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

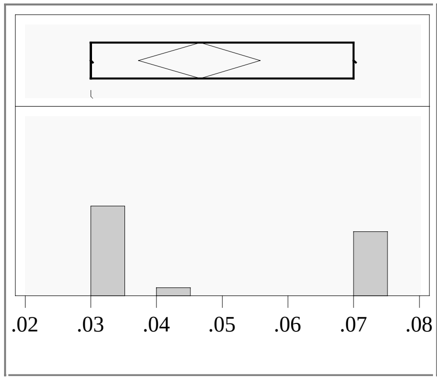
Moments

Mean	0.07054
Std Dev	0.0443681
Std Err Mean	0.009921
upper 95% Mean	0.0913049
lower 95% Mean	0.0497751
N	20

Appendix

Exhibit A3. Descriptive Statistics for Glasses Selected from the Outer Layer EVs (continued)

Li2O



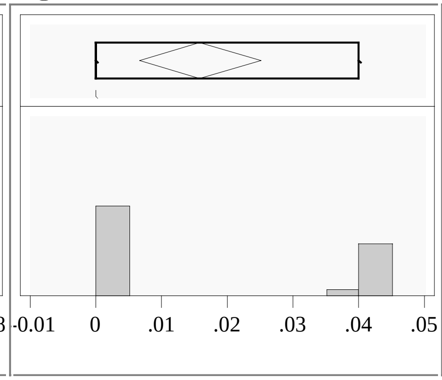
Quantiles

100.0%	maximum	0.07000
99.5%		0.07000
97.5%		0.07000
90.0%		0.07000
75.0%	quartile	0.07000
50.0%	median	0.03000
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.046561
Std Dev	0.0197891
Std Err Mean	0.004425
upper 95% Mean	0.0558226
lower 95% Mean	0.0372994
N	20

MgO



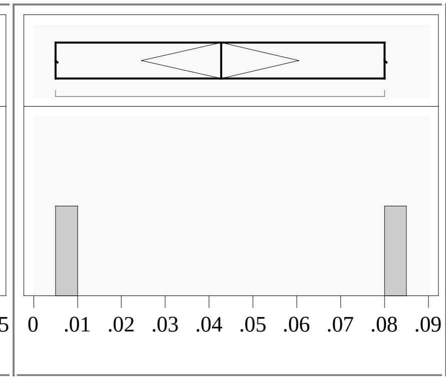
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0158815
Std Dev	0.0199626
Std Err Mean	0.0044638
upper 95% Mean	0.0252243
lower 95% Mean	0.0065387
N	20

MnO



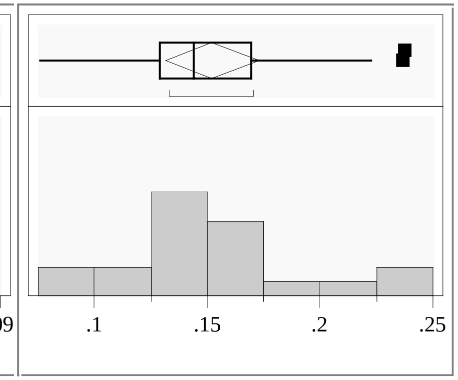
Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.08000
50.0%	median	0.04250
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.0425
Std Dev	0.0384742
Std Err Mean	0.0086031
upper 95% Mean	0.0605065
lower 95% Mean	0.0244935
N	20

Na2O



Quantiles

100.0%	maximum	0.23700
99.5%		0.23700
97.5%		0.23700
90.0%		0.23474
75.0%	quartile	0.16965
50.0%	median	0.14360
25.0%	quartile	0.12893
10.0%		0.08269
2.5%		0.07607
0.5%		0.07607
0.0%	minimum	0.07607

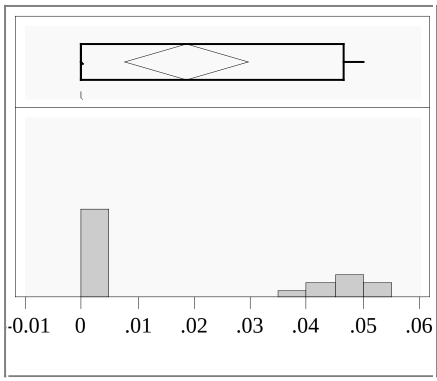
Moments

Mean	0.1521215
Std Dev	0.0444137
Std Err Mean	0.0099312
upper 95% Mean	0.1729077
lower 95% Mean	0.1313353
N	20

Appendix

Exhibit A3. Descriptive Statistics for Glasses Selected from the Outer Layer EVs (continued)

NiO



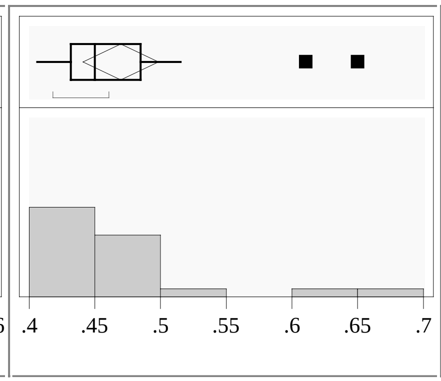
Quantiles

100.0%	maximum	0.05000
99.5%		0.05000
97.5%		0.05000
90.0%		0.04989
75.0%	quartile	0.04654
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.018491
Std Dev	0.0233839
Std Err Mean	0.0052288
upper 95% Mean	0.029435
lower 95% Mean	0.007547
N	20

SiO2



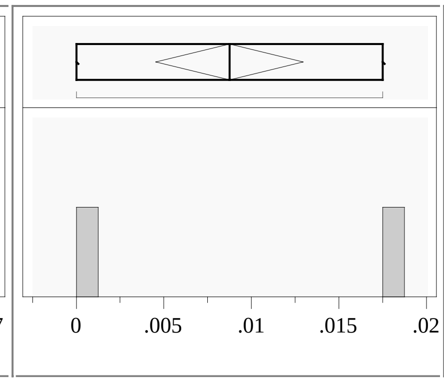
Quantiles

100.0%	maximum	0.65000
99.5%		0.65000
97.5%		0.65000
90.0%		0.59979
75.0%	quartile	0.48413
50.0%	median	0.45050
25.0%	quartile	0.43130
10.0%		0.41121
2.5%		0.40680
0.5%		0.40680
0.0%	minimum	0.40680

Moments

Mean	0.469335
Std Dev	0.0617199
Std Err Mean	0.013801
upper 95% Mean	0.4982208
lower 95% Mean	0.4404492
N	20

TiO2



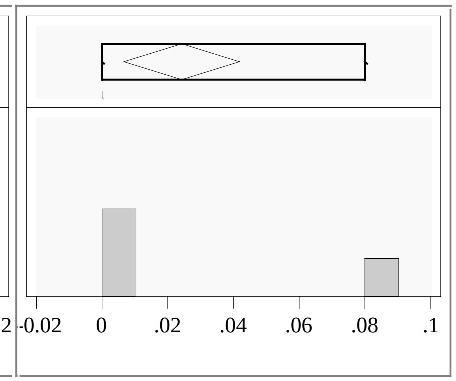
Quantiles

100.0%	maximum	0.01750
99.5%		0.01750
97.5%		0.01750
90.0%		0.01750
75.0%	quartile	0.01750
50.0%	median	0.00875
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.00875
Std Dev	0.0089773
Std Err Mean	0.0020074
upper 95% Mean	0.0129515
lower 95% Mean	0.0045485
N	20

U3O8



Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.08000
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

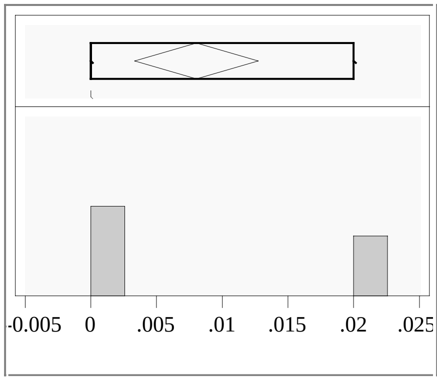
Moments

Mean	0.024
Std Dev	0.037613
Std Err Mean	0.0084105
upper 95% Mean	0.0416034
lower 95% Mean	0.0063966
N	20

Appendix

Exhibit A3. Descriptive Statistics for Glasses Selected from the Outer Layer EVs (continued)

Others



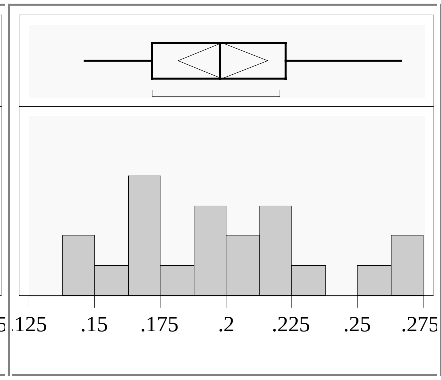
Quantiles

100.0%	maximum	0.02000
99.5%		0.02000
97.5%		0.02000
90.0%		0.02000
75.0%	quartile	0.02000
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.008
Std Dev	0.0100525
Std Err Mean	0.0022478
upper 95% Mean	0.0127047
lower 95% Mean	0.0032953
N	20

alkalis



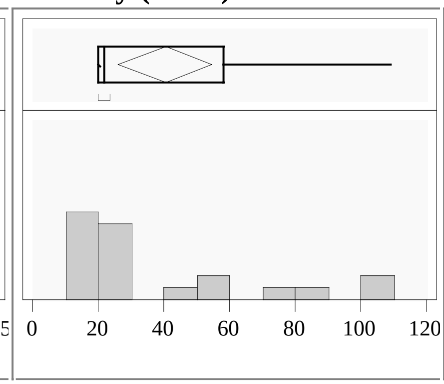
Quantiles

100.0%	maximum	0.26700
99.5%		0.26700
97.5%		0.26700
90.0%		0.26474
75.0%	quartile	0.22262
50.0%	median	0.19785
25.0%	quartile	0.17228
10.0%		0.14941
2.5%		0.14607
0.5%		0.14607
0.0%	minimum	0.14607

Moments

Mean	0.1986825
Std Dev	0.0366652
Std Err Mean	0.0081986
upper 95% Mean	0.2158423
lower 95% Mean	0.1815227
N	20

Viscosity (Poise)



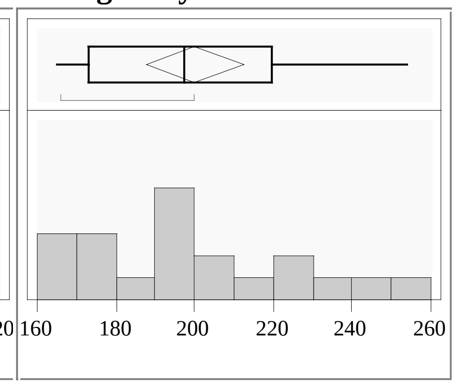
Quantiles

100.0%	maximum	109.33
99.5%		109.33
97.5%		109.33
90.0%		101.28
75.0%	quartile	58.23
50.0%	median	21.74
25.0%	quartile	19.99
10.0%		19.98
2.5%		19.97
0.5%		19.97
0.0%	minimum	19.97

Moments

Mean	40.346592
Std Dev	30.116808
Std Err Mean	6.7343229
upper 95% Mean	54.441691
lower 95% Mean	26.251492
N	20

Homogeneity



Quantiles

100.0%	maximum	253.83
99.5%		253.83
97.5%		253.83
90.0%		240.47
75.0%	quartile	219.75
50.0%	median	197.54
25.0%	quartile	173.31
10.0%		166.59
2.5%		164.84
0.5%		164.84
0.0%	minimum	164.84

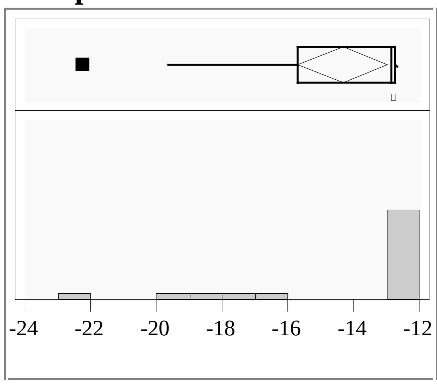
Moments

Mean	199.9679
Std Dev	26.449265
Std Err Mean	5.9142354
upper 95% Mean	212.34654
lower 95% Mean	187.58926
N	20

Appendix

Exhibit A3. Descriptive Statistics for Glasses Selected from the Outer Layer EVs (continued)

del Gp



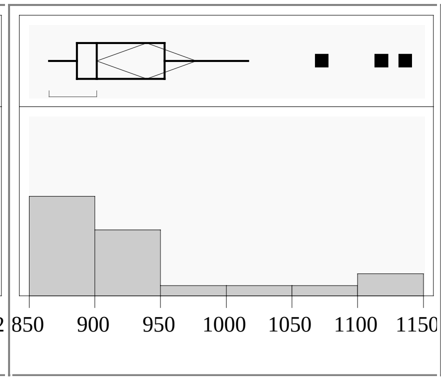
Quantiles

100.0%	maximum	-12.71
99.5%		-12.71
97.5%		-12.71
90.0%		-12.71
75.0%	quartile	-12.71
50.0%	median	-12.84
25.0%	quartile	-15.69
10.0%		-19.51
2.5%		-22.30
0.5%		-22.30
0.0%	minimum	-22.30

Moments

Mean	-14.31846
Std Dev	2.9345282
Std Err Mean	0.6561805
upper 95% Mean	-12.94506
lower 95% Mean	-15.69186
N	20

TL



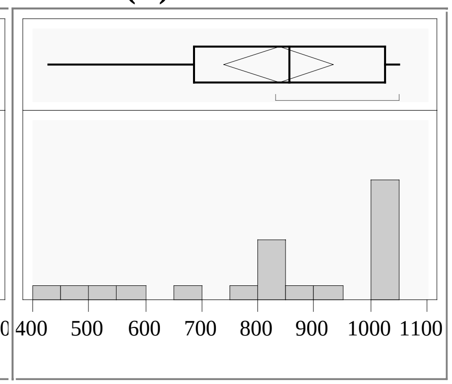
Quantiles

100.0%	maximum	1135.1
99.5%		1135.1
97.5%		1135.1
90.0%		1113.1
75.0%	quartile	952.4
50.0%	median	900.8
25.0%	quartile	887.1
10.0%		870.0
2.5%		864.4
0.5%		864.4
0.0%	minimum	864.4

Moments

Mean	939.19816
Std Dev	81.607298
Std Err Mean	18.247947
upper 95% Mean	977.39155
lower 95% Mean	901.00477
N	20

Pred TL(C)



Quantiles

100.0%	maximum	1049.1
99.5%		1049.1
97.5%		1049.1
90.0%		1043.9
75.0%	quartile	1025.6
50.0%	median	857.2
25.0%	quartile	685.9
10.0%		501.6
2.5%		427.6
0.5%		427.6
0.0%	minimum	427.6

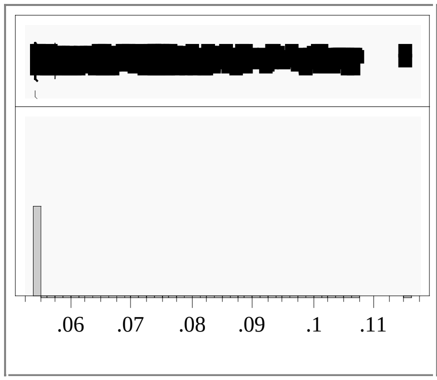
Moments

Mean	836.75147
Std Dev	205.42376
Std Err Mean	45.934149
upper 95% Mean	932.89275
lower 95% Mean	740.61019
N	20

Appendix

Exhibit A4. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 11

Al2O3



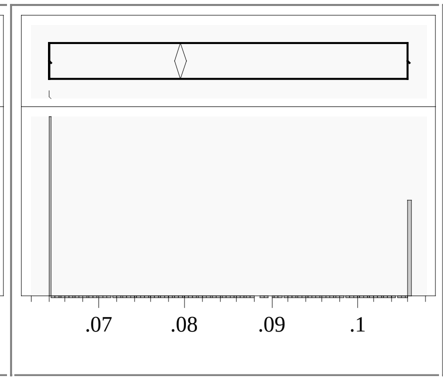
Quantiles

100.0%	maximum	0.11510
99.5%		0.10460
97.5%		0.09336
90.0%		0.06839
75.0%	quartile	0.05400
50.0%	median	0.05400
25.0%	quartile	0.05400
10.0%		0.05400
2.5%		0.05400
0.5%		0.05400
0.0%	minimum	0.05400

Moments

Mean	0.0575655
Std Dev	0.0096368
Std Err Mean	0.0001874
upper 95% Mean	0.0579329
lower 95% Mean	0.0571981
N	2645

B2O3



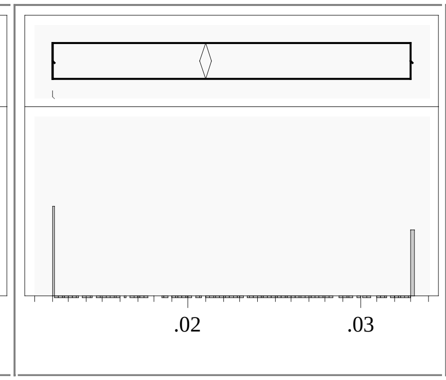
Quantiles

100.0%	maximum	0.10600
99.5%		0.10600
97.5%		0.10600
90.0%		0.10600
75.0%	quartile	0.10600
50.0%	median	0.06400
25.0%	quartile	0.06400
10.0%		0.06400
2.5%		0.06400
0.5%		0.06400
0.0%	minimum	0.06400

Moments

Mean	0.0794429
Std Dev	0.0194887
Std Err Mean	0.0003789
upper 95% Mean	0.0801859
lower 95% Mean	0.0786998
N	2645

CaO



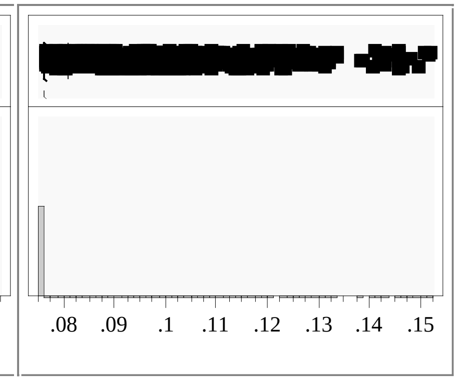
Quantiles

100.0%	maximum	0.03300
99.5%		0.03300
97.5%		0.03300
90.0%		0.03300
75.0%	quartile	0.03300
50.0%	median	0.01200
25.0%	quartile	0.01200
10.0%		0.01200
2.5%		0.01200
0.5%		0.01200
0.0%	minimum	0.01200

Moments

Mean	0.0209726
Std Dev	0.0101704
Std Err Mean	0.0001978
upper 95% Mean	0.0213604
lower 95% Mean	0.0205848
N	2645

Fe2O3



Quantiles

100.0%	maximum	0.15210
99.5%		0.14280
97.5%		0.12091
90.0%		0.09776
75.0%	quartile	0.07600
50.0%	median	0.07600
25.0%	quartile	0.07600
10.0%		0.07600
2.5%		0.07600
0.5%		0.07600
0.0%	minimum	0.07600

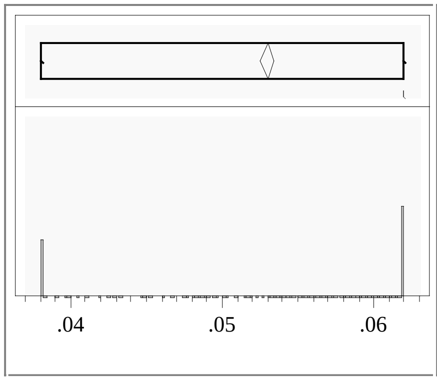
Moments

Mean	0.0809026
Std Dev	0.0122651
Std Err Mean	0.0002385
upper 95% Mean	0.0813703
lower 95% Mean	0.080435
N	2645

Appendix

Exhibit A4. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 11 (continued)

Li2O



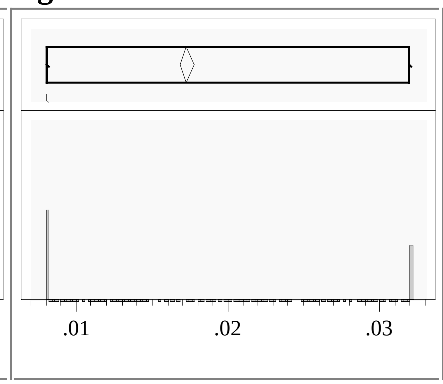
Quantiles

100.0%	maximum	0.06200
99.5%		0.06200
97.5%		0.06200
90.0%		0.06200
75.0%	quartile	0.06200
50.0%	median	0.06200
25.0%	quartile	0.03800
10.0%		0.03800
2.5%		0.03800
0.5%		0.03800
0.0%	minimum	0.03800

Moments

Mean	0.0529566
Std Dev	0.0113461
Std Err Mean	0.0002206
upper 95% Mean	0.0533892
lower 95% Mean	0.052524
N	2645

MgO



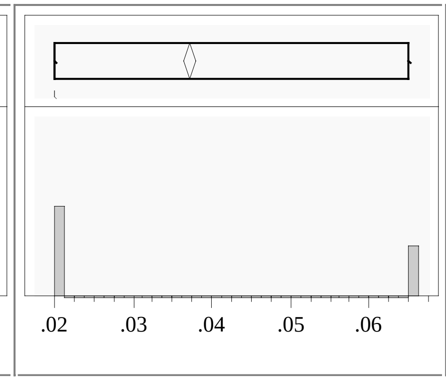
Quantiles

100.0%	maximum	0.03200
99.5%		0.03200
97.5%		0.03200
90.0%		0.03200
75.0%	quartile	0.03200
50.0%	median	0.00800
25.0%	quartile	0.00800
10.0%		0.00800
2.5%		0.00800
0.5%		0.00800
0.0%	minimum	0.00800

Moments

Mean	0.017303
Std Dev	0.0114394
Std Err Mean	0.0002224
upper 95% Mean	0.0177391
lower 95% Mean	0.0168668
N	2645

MnO



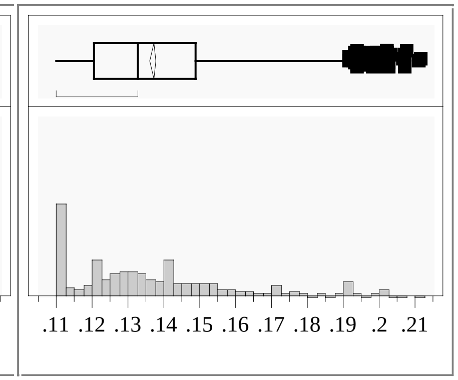
Quantiles

100.0%	maximum	0.06500
99.5%		0.06500
97.5%		0.06500
90.0%		0.06500
75.0%	quartile	0.06500
50.0%	median	0.02000
25.0%	quartile	0.02000
10.0%		0.02000
2.5%		0.02000
0.5%		0.02000
0.0%	minimum	0.02000

Moments

Mean	0.0372301
Std Dev	0.0209257
Std Err Mean	0.0004069
upper 95% Mean	0.0380279
lower 95% Mean	0.0364323
N	2645

Na2O



Quantiles

100.0%	maximum	0.21160
99.5%		0.20210
97.5%		0.19380
90.0%		0.17140
75.0%	quartile	0.14880
50.0%	median	0.13250
25.0%	quartile	0.12050
10.0%		0.11000
2.5%		0.11000
0.5%		0.11000
0.0%	minimum	0.11000

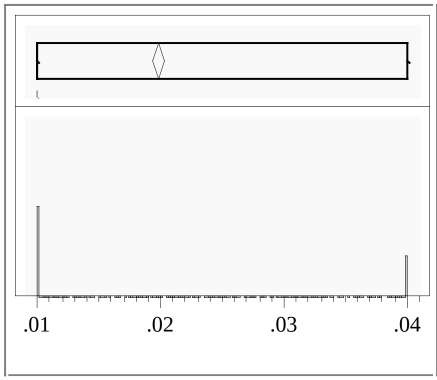
Moments

Mean	0.1370364
Std Dev	0.0234464
Std Err Mean	0.0004559
upper 95% Mean	0.1379303
lower 95% Mean	0.1361424
N	2645

Appendix

Exhibit A4. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 11 (continued)

NiO



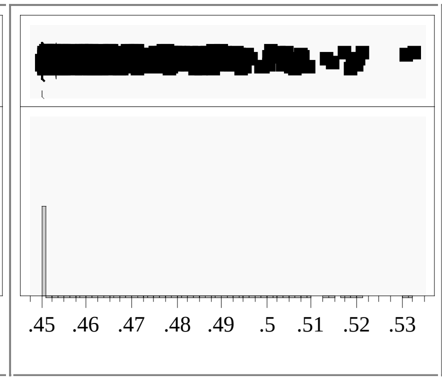
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.01000
25.0%	quartile	0.01000
10.0%		0.01000
2.5%		0.01000
0.5%		0.01000
0.0%	minimum	0.01000

Moments

Mean	0.0198726
Std Dev	0.0136406
Std Err Mean	0.0002652
upper 95% Mean	0.0203927
lower 95% Mean	0.0193526
N	2645

SiO2



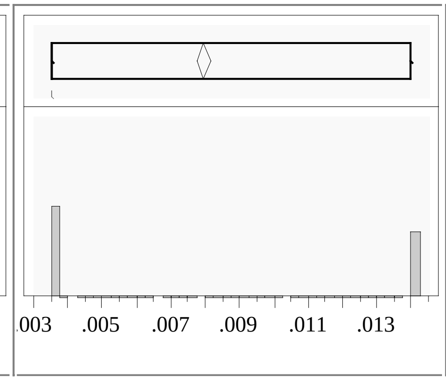
Quantiles

100.0%	maximum	0.53240
99.5%		0.50740
97.5%		0.48485
90.0%		0.46050
75.0%	quartile	0.45000
50.0%	median	0.45000
25.0%	quartile	0.45000
10.0%		0.45000
2.5%		0.45000
0.5%		0.45000
0.0%	minimum	0.45000

Moments

Mean	0.4530617
Std Dev	0.0093919
Std Err Mean	0.0001826
upper 95% Mean	0.4534198
lower 95% Mean	0.4527037
N	2645

TiO2



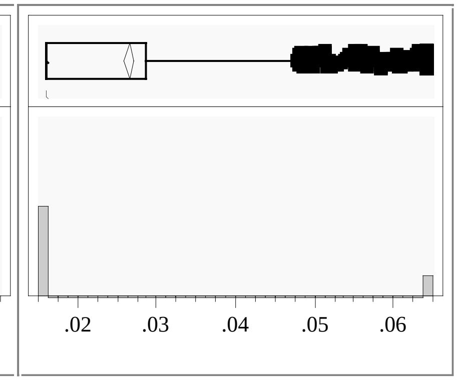
Quantiles

100.0%	maximum	0.01400
99.5%		0.01400
97.5%		0.01400
90.0%		0.01400
75.0%	quartile	0.01400
50.0%	median	0.00350
25.0%	quartile	0.00350
10.0%		0.00350
2.5%		0.00350
0.5%		0.00350
0.0%	minimum	0.00350

Moments

Mean	0.0079465
Std Dev	0.0051169
Std Err Mean	0.0000995
upper 95% Mean	0.0081416
lower 95% Mean	0.0077514
N	2645

U3O8



Quantiles

100.0%	maximum	0.06400
99.5%		0.06400
97.5%		0.06400
90.0%		0.06400
75.0%	quartile	0.02869
50.0%	median	0.01600
25.0%	quartile	0.01600
10.0%		0.01600
2.5%		0.01600
0.5%		0.01600
0.0%	minimum	0.01600

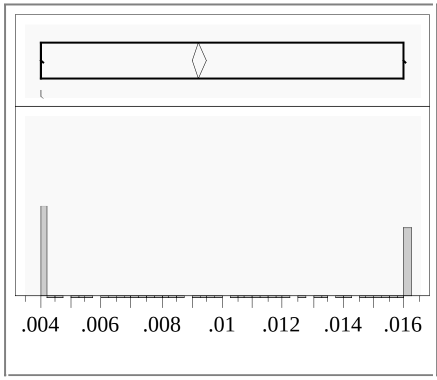
Moments

Mean	0.0264904
Std Dev	0.0184163
Std Err Mean	0.0003581
upper 95% Mean	0.0271925
lower 95% Mean	0.0257882
N	2645

Appendix

Exhibit A4. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 11 (continued)

Others



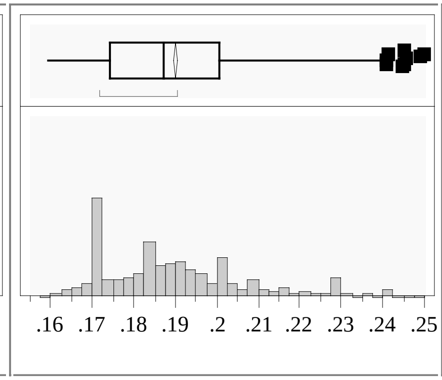
Quantiles

100.0%	maximum	0.01600
99.5%		0.01600
97.5%		0.01600
90.0%		0.01600
75.0%	quartile	0.01600
50.0%	median	0.00400
25.0%	quartile	0.00400
10.0%		0.00400
2.5%		0.00400
0.5%		0.00400
0.0%	minimum	0.00400

Moments

Mean	0.0092202
Std Dev	0.0058838
Std Err Mean	0.0001144
upper 95% Mean	0.0094445
lower 95% Mean	0.0089958
N	2645

alkalis



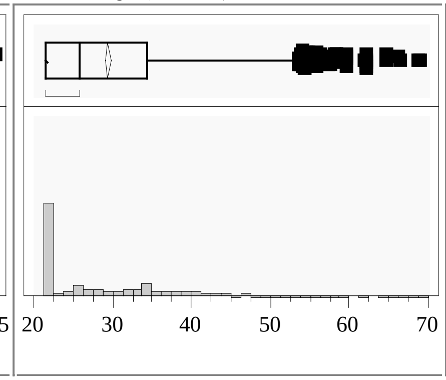
Quantiles

100.0%	maximum	0.24960
99.5%		0.24010
97.5%		0.23297
90.0%		0.21510
75.0%	quartile	0.20075
50.0%	median	0.18700
25.0%	quartile	0.17430
10.0%		0.17200
2.5%		0.16619
0.5%		0.16222
0.0%	minimum	0.15910

Moments

Mean	0.189993
Std Dev	0.017611
Std Err Mean	0.0003424
upper 95% Mean	0.1906645
lower 95% Mean	0.1893215
N	2645

Viscosity (Poise)



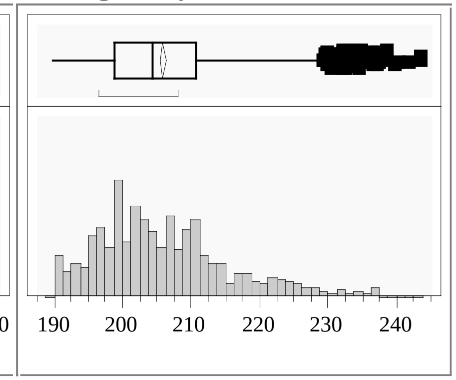
Quantiles

100.0%	maximum	68.908
99.5%		59.567
97.5%		53.541
90.0%		43.482
75.0%	quartile	34.339
50.0%	median	25.798
25.0%	quartile	21.615
10.0%		21.591
2.5%		21.583
0.5%		21.572
0.0%	minimum	21.565

Moments

Mean	29.38412
Std Dev	9.4644791
Std Err Mean	0.184028
upper 95% Mean	29.744973
lower 95% Mean	29.023266
N	2645

Homogeneity



Quantiles

100.0%	maximum	243.43
99.5%		236.94
97.5%		229.40
90.0%		219.69
75.0%	quartile	210.83
50.0%	median	204.28
25.0%	quartile	198.79
10.0%		195.07
2.5%		190.92
0.5%		190.20
0.0%	minimum	189.81

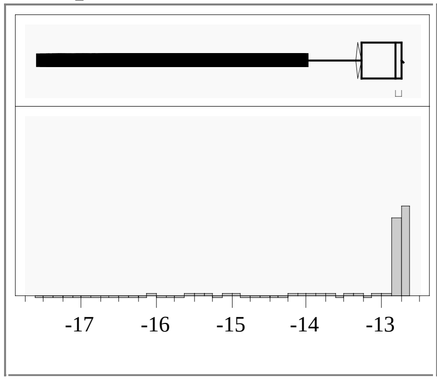
Moments

Mean	205.90142
Std Dev	9.7114718
Std Err Mean	0.1888305
upper 95% Mean	206.27169
lower 95% Mean	205.53115
N	2645

Appendix

Exhibit A4. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 11 (continued)

del Gp



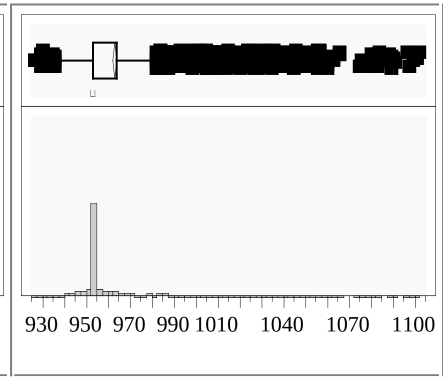
Quantiles

100.0%	maximum	-12.73
99.5%		-12.73
97.5%		-12.73
90.0%		-12.74
75.0%	quartile	-12.74
50.0%	median	-12.81
25.0%	quartile	-13.27
10.0%		-15.15
2.5%		-16.37
0.5%		-17.09
0.0%	minimum	-17.52

Moments

Mean	-13.31333
Std Dev	1.05581
Std Err Mean	0.0205292
upper 95% Mean	-13.27308
lower 95% Mean	-13.35359
N	2645

TL



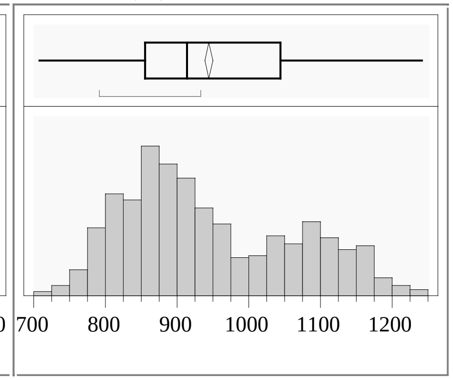
Quantiles

100.0%	maximum	1102.0
99.5%		1083.7
97.5%		1040.8
90.0%		995.7
75.0%	quartile	964.3
50.0%	median	952.8
25.0%	quartile	952.8
10.0%		949.4
2.5%		940.2
0.5%		933.1
0.0%	minimum	926.0

Moments

Mean	963.46808
Std Dev	24.841741
Std Err Mean	0.4830245
upper 95% Mean	964.41522
lower 95% Mean	962.52093
N	2645

Pred TL(C)



Quantiles

100.0%	maximum	1241.0
99.5%		1225.5
97.5%		1177.7
90.0%		1124.5
75.0%	quartile	1043.1
50.0%	median	913.8
25.0%	quartile	854.2
10.0%		804.6
2.5%		769.9
0.5%		728.4
0.0%	minimum	707.3

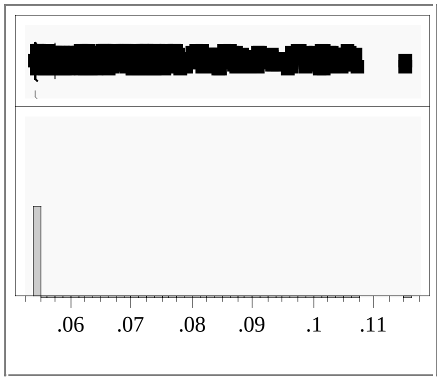
Moments

Mean	944.72695
Std Dev	119.43632
Std Err Mean	2.3223282
upper 95% Mean	949.28071
lower 95% Mean	940.17318
N	2645

Appendix

Exhibit A5. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 13

Al2O3



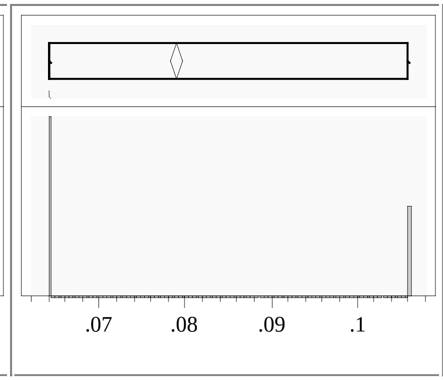
Quantiles

100.0%	maximum	0.11510
99.5%		0.10443
97.5%		0.08958
90.0%		0.06768
75.0%	quartile	0.05400
50.0%	median	0.05400
25.0%	quartile	0.05400
10.0%		0.05400
2.5%		0.05400
0.5%		0.05400
0.0%	minimum	0.05400

Moments

Mean	0.0574356
Std Dev	0.0092858
Std Err Mean	0.0001655
upper 95% Mean	0.0577601
lower 95% Mean	0.057111
N	3147

B2O3



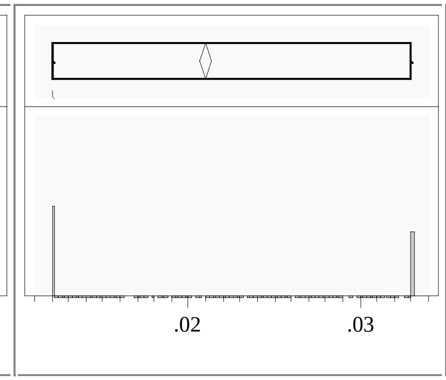
Quantiles

100.0%	maximum	0.10600
99.5%		0.10600
97.5%		0.10600
90.0%		0.10600
75.0%	quartile	0.10600
50.0%	median	0.06400
25.0%	quartile	0.06400
10.0%		0.06400
2.5%		0.06400
0.5%		0.06400
0.0%	minimum	0.06400

Moments

Mean	0.0789043
Std Dev	0.0192067
Std Err Mean	0.0003424
upper 95% Mean	0.0795756
lower 95% Mean	0.078233
N	3147

CaO



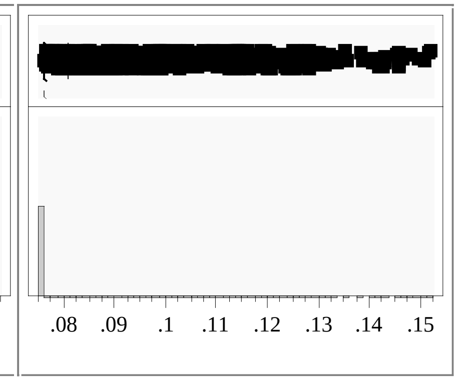
Quantiles

100.0%	maximum	0.03300
99.5%		0.03300
97.5%		0.03300
90.0%		0.03300
75.0%	quartile	0.03300
50.0%	median	0.01200
25.0%	quartile	0.01200
10.0%		0.01200
2.5%		0.01200
0.5%		0.01200
0.0%	minimum	0.01200

Moments

Mean	0.020952
Std Dev	0.0101526
Std Err Mean	0.000181
upper 95% Mean	0.0213069
lower 95% Mean	0.0205972
N	3147

Fe2O3



Quantiles

100.0%	maximum	0.15210
99.5%		0.14243
97.5%		0.12023
90.0%		0.09631
75.0%	quartile	0.07600
50.0%	median	0.07600
25.0%	quartile	0.07600
10.0%		0.07600
2.5%		0.07600
0.5%		0.07600
0.0%	minimum	0.07600

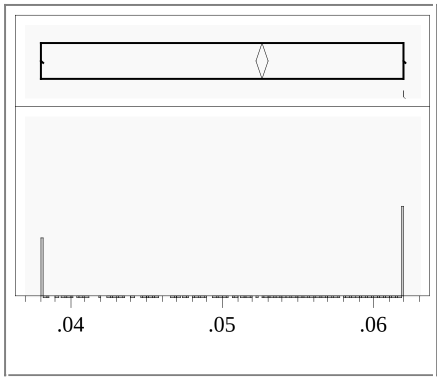
Moments

Mean	0.0807251
Std Dev	0.0119758
Std Err Mean	0.0002135
upper 95% Mean	0.0811437
lower 95% Mean	0.0803065
N	3147

Appendix

Exhibit A5. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 13 (continued)

Li2O



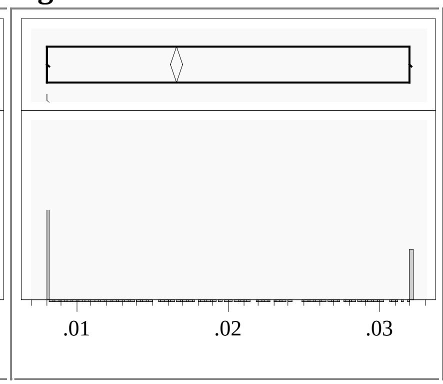
Quantiles

100.0%	maximum	0.06200
99.5%		0.06200
97.5%		0.06200
90.0%		0.06200
75.0%	quartile	0.06200
50.0%	median	0.06200
25.0%	quartile	0.03800
10.0%		0.03800
2.5%		0.03800
0.5%		0.03800
0.0%	minimum	0.03800

Moments

Mean	0.0526398
Std Dev	0.0113834
Std Err Mean	0.0002029
upper 95% Mean	0.0530377
lower 95% Mean	0.0522419
N	3147

MgO



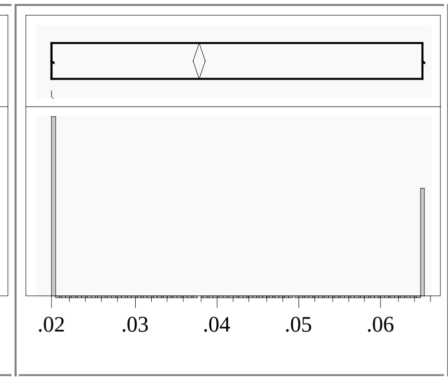
Quantiles

100.0%	maximum	0.03200
99.5%		0.03200
97.5%		0.03200
90.0%		0.03200
75.0%	quartile	0.03200
50.0%	median	0.00800
25.0%	quartile	0.00800
10.0%		0.00800
2.5%		0.00800
0.5%		0.00800
0.0%	minimum	0.00800

Moments

Mean	0.0166137
Std Dev	0.0111832
Std Err Mean	0.0001994
upper 95% Mean	0.0170046
lower 95% Mean	0.0162228
N	3147

MnO



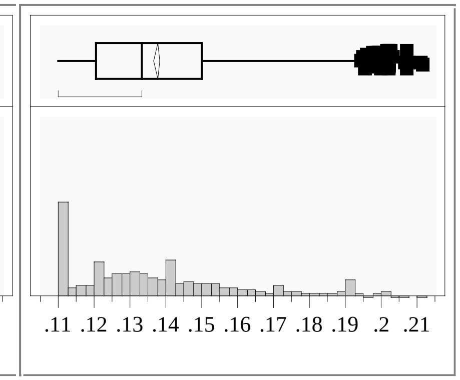
Quantiles

100.0%	maximum	0.06500
99.5%		0.06500
97.5%		0.06500
90.0%		0.06500
75.0%	quartile	0.06500
50.0%	median	0.02000
25.0%	quartile	0.02000
10.0%		0.02000
2.5%		0.02000
0.5%		0.02000
0.0%	minimum	0.02000

Moments

Mean	0.0377841
Std Dev	0.0208827
Std Err Mean	0.0003723
upper 95% Mean	0.038514
lower 95% Mean	0.0370542
N	3147

Na2O



Quantiles

100.0%	maximum	0.21160
99.5%		0.20210
97.5%		0.19149
90.0%		0.17460
75.0%	quartile	0.15000
50.0%	median	0.13340
25.0%	quartile	0.12050
10.0%		0.11000
2.5%		0.11000
0.5%		0.11000
0.0%	minimum	0.11000

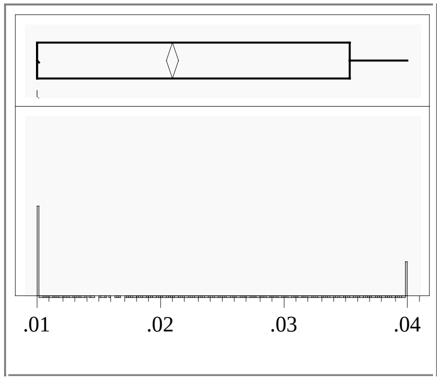
Moments

Mean	0.1377126
Std Dev	0.0237312
Std Err Mean	0.000423
upper 95% Mean	0.1385421
lower 95% Mean	0.1368832
N	3147

Appendix

Exhibit A5. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 13 (continued)

NiO



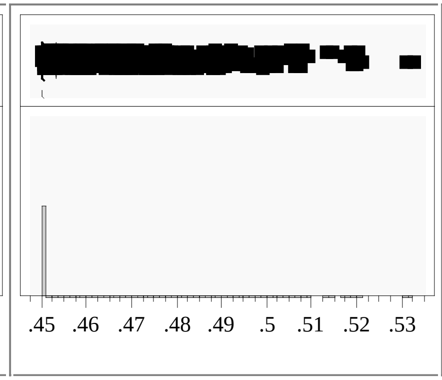
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.03533
50.0%	median	0.01000
25.0%	quartile	0.01000
10.0%		0.01000
2.5%		0.01000
0.5%		0.01000
0.0%	minimum	0.01000

Moments

Mean	0.0209651
Std Dev	0.0127883
Std Err Mean	0.000228
upper 95% Mean	0.0214121
lower 95% Mean	0.0205181
N	3147

SiO2



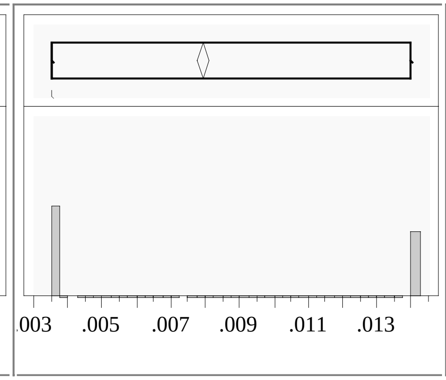
Quantiles

100.0%	maximum	0.53240
99.5%		0.50618
97.5%		0.48605
90.0%		0.46200
75.0%	quartile	0.45000
50.0%	median	0.45000
25.0%	quartile	0.45000
10.0%		0.45000
2.5%		0.45000
0.5%		0.45000
0.0%	minimum	0.45000

Moments

Mean	0.453282
Std Dev	0.0095207
Std Err Mean	0.0001697
upper 95% Mean	0.4536148
lower 95% Mean	0.4529493
N	3147

TiO2



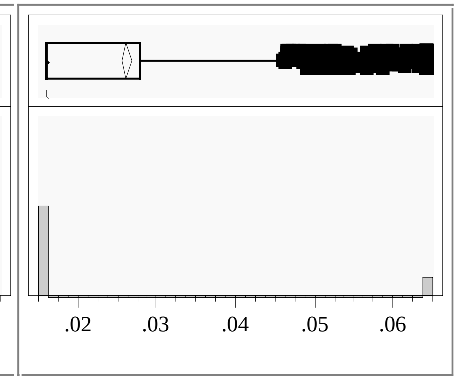
Quantiles

100.0%	maximum	0.01400
99.5%		0.01400
97.5%		0.01400
90.0%		0.01400
75.0%	quartile	0.01400
50.0%	median	0.00350
25.0%	quartile	0.00350
10.0%		0.00350
2.5%		0.00350
0.5%		0.00350
0.0%	minimum	0.00350

Moments

Mean	0.0079336
Std Dev	0.005102
Std Err Mean	0.0000909
upper 95% Mean	0.0081119
lower 95% Mean	0.0077552
N	3147

U3O8



Quantiles

100.0%	maximum	0.06400
99.5%		0.06400
97.5%		0.06400
90.0%		0.06400
75.0%	quartile	0.02785
50.0%	median	0.01600
25.0%	quartile	0.01600
10.0%		0.01600
2.5%		0.01600
0.5%		0.01600
0.0%	minimum	0.01600

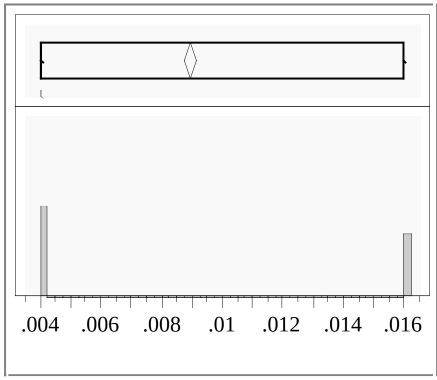
Moments

Mean	0.0261123
Std Dev	0.018031
Std Err Mean	0.0003214
upper 95% Mean	0.0267425
lower 95% Mean	0.0254821
N	3147

Appendix

Exhibit A5. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 13 (continued)

Others



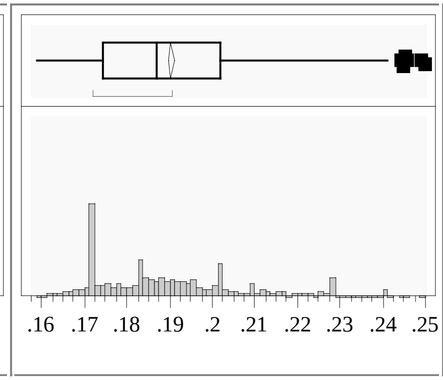
Quantiles

100.0%	maximum	0.01600
99.5%		0.01600
97.5%		0.01600
90.0%		0.01600
75.0%	quartile	0.01600
50.0%	median	0.00400
25.0%	quartile	0.00400
10.0%		0.00400
2.5%		0.00400
0.5%		0.00400
0.0%	minimum	0.00400

Moments

Mean	0.0089406
Std Dev	0.0057955
Std Err Mean	0.0001033
upper 95% Mean	0.0091431
lower 95% Mean	0.008738
N	3147

alkalis



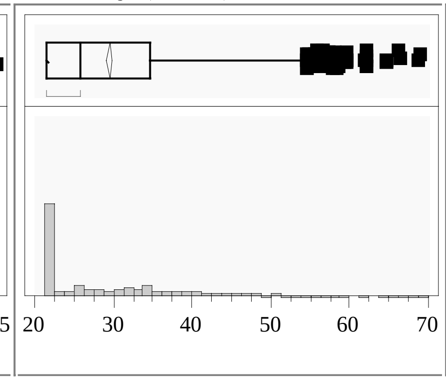
Quantiles

100.0%	maximum	0.24960
99.5%		0.24010
97.5%		0.23113
90.0%		0.21690
75.0%	quartile	0.20190
50.0%	median	0.18710
25.0%	quartile	0.17430
10.0%		0.17200
2.5%		0.16620
0.5%		0.16230
0.0%	minimum	0.15910

Moments

Mean	0.1903524
Std Dev	0.0178744
Std Err Mean	0.0003186
upper 95% Mean	0.1909772
lower 95% Mean	0.1897277
N	3147

Viscosity (Poise)



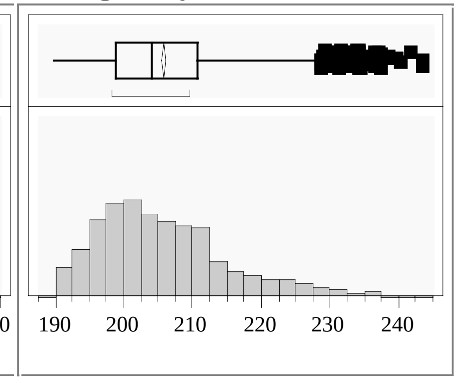
Quantiles

100.0%	maximum	68.908
99.5%		59.417
97.5%		53.602
90.0%		43.722
75.0%	quartile	34.741
50.0%	median	25.798
25.0%	quartile	21.616
10.0%		21.593
2.5%		21.584
0.5%		21.572
0.0%	minimum	21.565

Moments

Mean	29.548638
Std Dev	9.5437187
Std Err Mean	0.1701254
upper 95% Mean	29.882207
lower 95% Mean	29.21507
N	3147

Homogeneity



Quantiles

100.0%	maximum	243.43
99.5%		236.86
97.5%		228.65
90.0%		218.94
75.0%	quartile	210.65
50.0%	median	204.02
25.0%	quartile	198.79
10.0%		195.07
2.5%		191.32
0.5%		190.20
0.0%	minimum	189.81

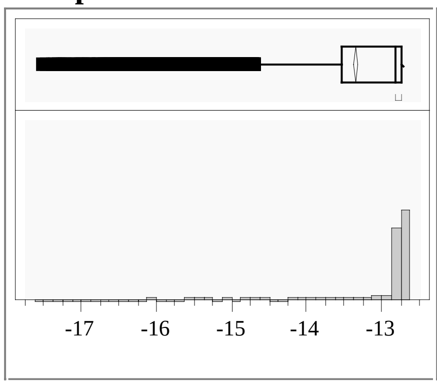
Moments

Mean	205.72277
Std Dev	9.4806079
Std Err Mean	0.1690004
upper 95% Mean	206.05413
lower 95% Mean	205.39141
N	3147

Appendix

Exhibit A5. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 13 (continued)

del Gp



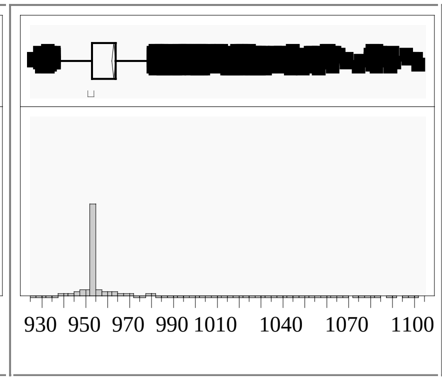
Quantiles

100.0%	maximum	-12.73
99.5%		-12.73
97.5%		-12.73
90.0%		-12.74
75.0%	quartile	-12.74
50.0%	median	-12.81
25.0%	quartile	-13.53
10.0%		-15.23
2.5%		-16.28
0.5%		-17.03
0.0%	minimum	-17.52

Moments

Mean	-13.34684
Std Dev	1.0478945
Std Err Mean	0.0186797
upper 95% Mean	-13.31021
lower 95% Mean	-13.38346
N	3147

TL



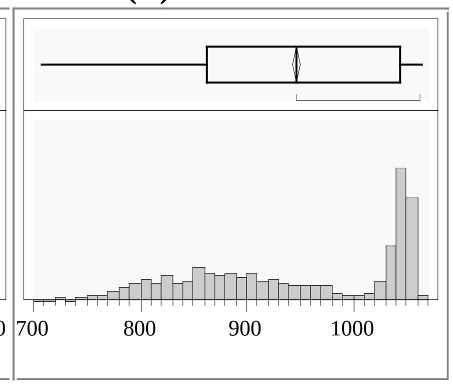
Quantiles

100.0%	maximum	1102.0
99.5%		1083.0
97.5%		1039.4
90.0%		993.2
75.0%	quartile	964.0
50.0%	median	952.8
25.0%	quartile	952.8
10.0%		948.9
2.5%		940.1
0.5%		933.5
0.0%	minimum	926.0

Moments

Mean	962.9441
Std Dev	24.296123
Std Err Mean	0.4331004
upper 95% Mean	963.79328
lower 95% Mean	962.09491
N	3147

Pred TL(C)



Quantiles

100.0%	maximum	1063.7
99.5%		1060.7
97.5%		1057.9
90.0%		1052.0
75.0%	quartile	1043.4
50.0%	median	947.1
25.0%	quartile	863.3
10.0%		811.9
2.5%		772.7
0.5%		731.8
0.0%	minimum	707.3

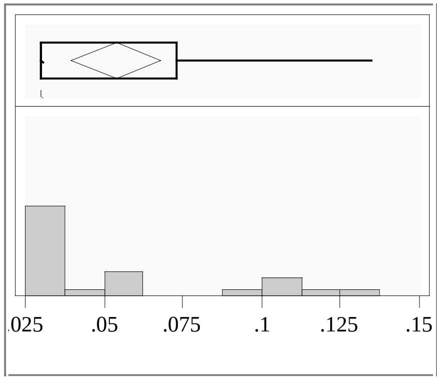
Moments

Mean	946.33926
Std Dev	95.906167
Std Err Mean	1.7096144
upper 95% Mean	949.69133
lower 95% Mean	942.98719
N	3147

Appendix

Exhibit A6. Descriptive Statistics for Glasses Selected from the Inner and Outer Layer EVs

Al2O3



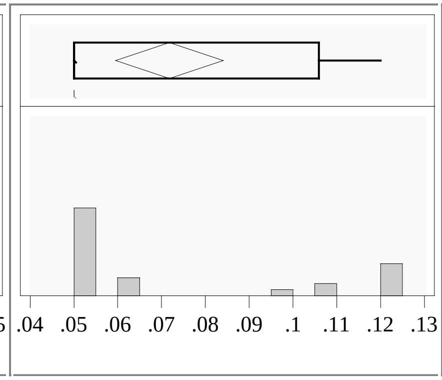
Quantiles

100.0%	maximum	0.13480
99.5%		0.13480
97.5%		0.13480
90.0%		0.11294
75.0%	quartile	0.07277
50.0%	median	0.03000
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.053982
Std Dev	0.0343984
Std Err Mean	0.0068797
upper 95% Mean	0.068181
lower 95% Mean	0.039783
N	25

B2O3



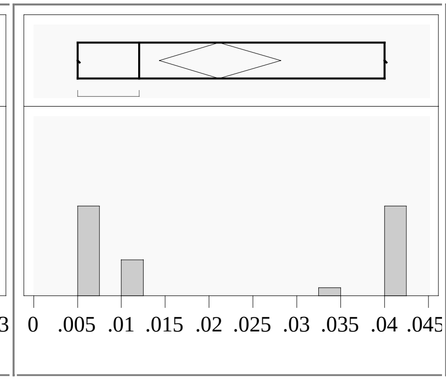
Quantiles

100.0%	maximum	0.12000
99.5%		0.12000
97.5%		0.12000
90.0%		0.12000
75.0%	quartile	0.10600
50.0%	median	0.05000
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

Moments

Mean	0.0719796
Std Dev	0.0298271
Std Err Mean	0.0059654
upper 95% Mean	0.0842916
lower 95% Mean	0.0596676
N	25

CaO



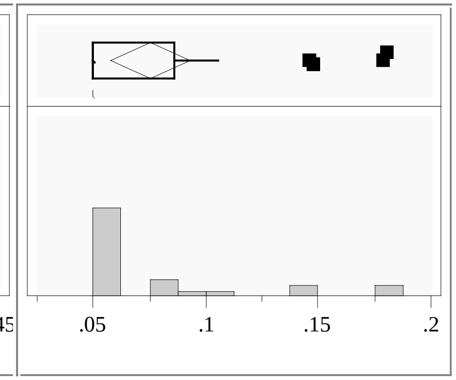
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.01200
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.02124
Std Dev	0.016629
Std Err Mean	0.0033258
upper 95% Mean	0.0281041
lower 95% Mean	0.0143759
N	25

Fe2O3



Quantiles

100.0%	maximum	0.18000
99.5%		0.18000
97.5%		0.18000
90.0%		0.15964
75.0%	quartile	0.08572
50.0%	median	0.05000
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

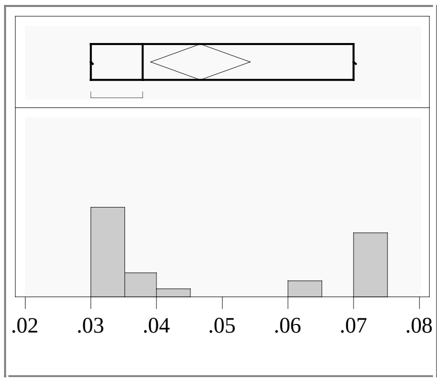
Moments

Mean	0.07519
Std Dev	0.0424217
Std Err Mean	0.0084843
upper 95% Mean	0.0927008
lower 95% Mean	0.0576792
N	25

Appendix

Exhibit A6. Descriptive Statistics for Glasses Selected from the Inner and Outer Layer EVs (continued)

Li2O



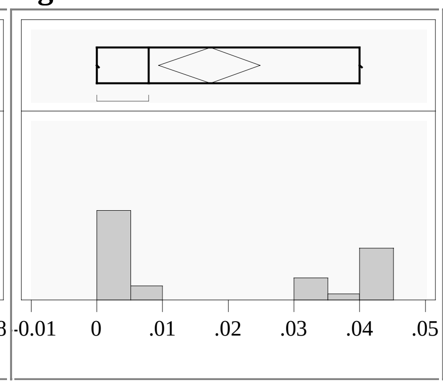
Quantiles

100.0%	maximum	0.07000
99.5%		0.07000
97.5%		0.07000
90.0%		0.07000
75.0%	quartile	0.07000
50.0%	median	0.03800
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0467688
Std Dev	0.018412
Std Err Mean	0.0036824
upper 95% Mean	0.0543689
lower 95% Mean	0.0391687
N	25

MgO



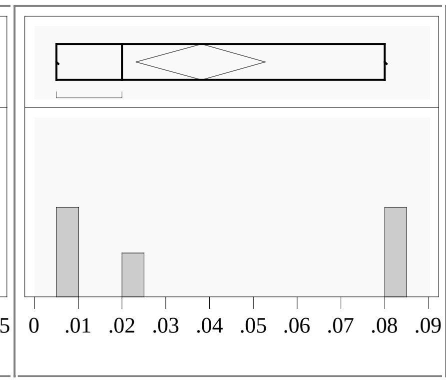
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.00800
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0171852
Std Dev	0.0187447
Std Err Mean	0.0037489
upper 95% Mean	0.0249226
lower 95% Mean	0.0094478
N	25

MnO



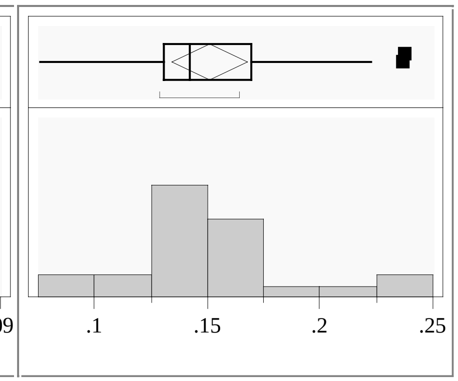
Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.08000
50.0%	median	0.02000
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.038
Std Dev	0.0354436
Std Err Mean	0.0070887
upper 95% Mean	0.0526304
lower 95% Mean	0.0233696
N	25

Na2O



Quantiles

100.0%	maximum	0.23700
99.5%		0.23700
97.5%		0.23700
90.0%		0.22794
75.0%	quartile	0.16920
50.0%	median	0.14260
25.0%	quartile	0.13065
10.0%		0.09436
2.5%		0.07607
0.5%		0.07607
0.0%	minimum	0.07607

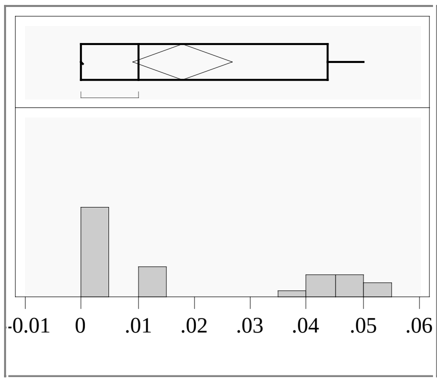
Moments

Mean	0.1510812
Std Dev	0.0403546
Std Err Mean	0.0080709
upper 95% Mean	0.1677388
lower 95% Mean	0.1344236
N	25

Appendix

Exhibit A6. Descriptive Statistics for Glasses Selected from the Inner and Outer Layer EVs (continued)

NiO



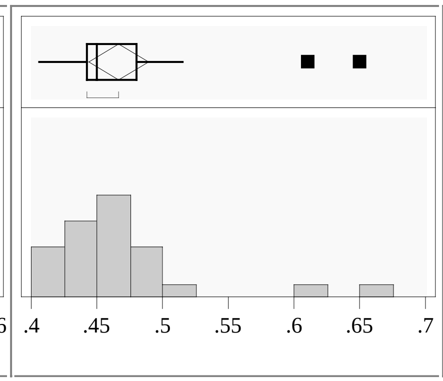
Quantiles

100.0%	maximum	0.05000
99.5%		0.05000
97.5%		0.05000
90.0%		0.04931
75.0%	quartile	0.04357
50.0%	median	0.01000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0179928
Std Dev	0.0215389
Std Err Mean	0.0043078
upper 95% Mean	0.0268836
lower 95% Mean	0.009102
N	25

SiO2



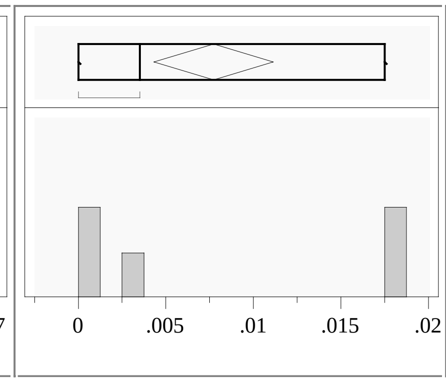
Quantiles

100.0%	maximum	0.65000
99.5%		0.65000
97.5%		0.65000
90.0%		0.55274
75.0%	quartile	0.48010
50.0%	median	0.45000
25.0%	quartile	0.44195
10.0%		0.41526
2.5%		0.40680
0.5%		0.40680
0.0%	minimum	0.40680

Moments

Mean	0.466404
Std Dev	0.0553178
Std Err Mean	0.0110636
upper 95% Mean	0.4892381
lower 95% Mean	0.4435699
N	25

TiO2



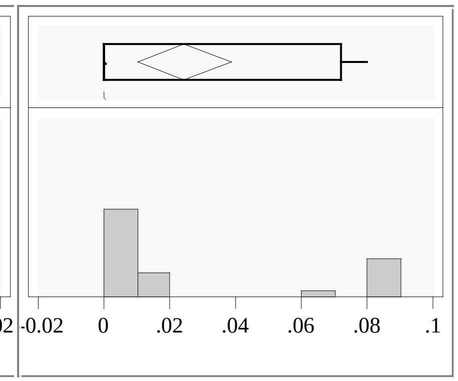
Quantiles

100.0%	maximum	0.01750
99.5%		0.01750
97.5%		0.01750
90.0%		0.01750
75.0%	quartile	0.01750
50.0%	median	0.00350
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0077
Std Dev	0.0082702
Std Err Mean	0.001654
upper 95% Mean	0.0111138
lower 95% Mean	0.0042862
N	25

U3O8



Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.07200
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

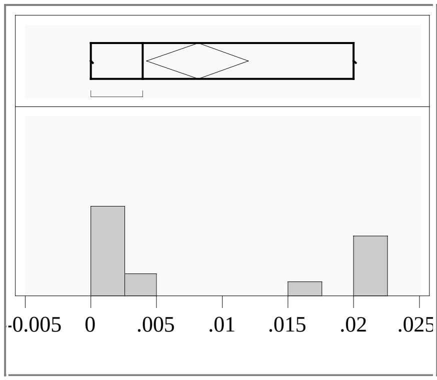
Moments

Mean	0.02432
Std Dev	0.034601
Std Err Mean	0.0069202
upper 95% Mean	0.0386026
lower 95% Mean	0.0100374
N	25

Appendix

Exhibit A6. Descriptive Statistics for Glasses Selected from the Inner and Outer Layer EVs (continued)

Others



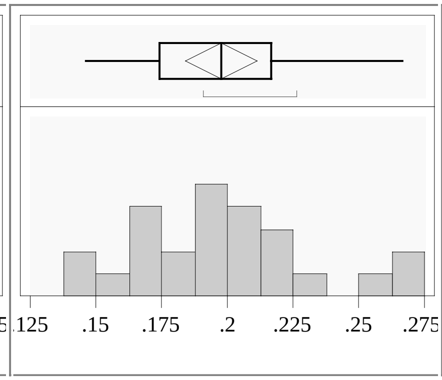
Quantiles

100.0%	maximum	0.02000
99.5%		0.02000
97.5%		0.02000
90.0%		0.02000
75.0%	quartile	0.02000
50.0%	median	0.00400
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.00816
Std Dev	0.0093438
Std Err Mean	0.0018688
upper 95% Mean	0.0120169
lower 95% Mean	0.0043031
N	25

alkalis



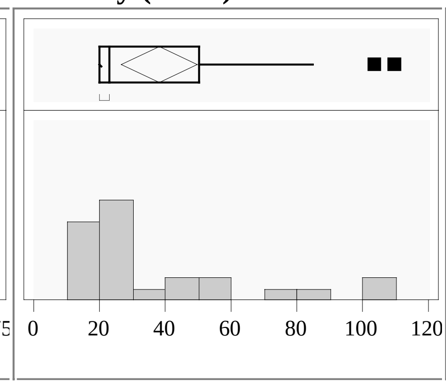
Quantiles

100.0%	maximum	0.26700
99.5%		0.26700
97.5%		0.26700
90.0%		0.25794
75.0%	quartile	0.21660
50.0%	median	0.19740
25.0%	quartile	0.17415
10.0%		0.14994
2.5%		0.14607
0.5%		0.14607
0.0%	minimum	0.14607

Moments

Mean	0.19785
Std Dev	0.0330642
Std Err Mean	0.0066128
upper 95% Mean	0.2114982
lower 95% Mean	0.1842018
N	25

Viscosity (Poise)



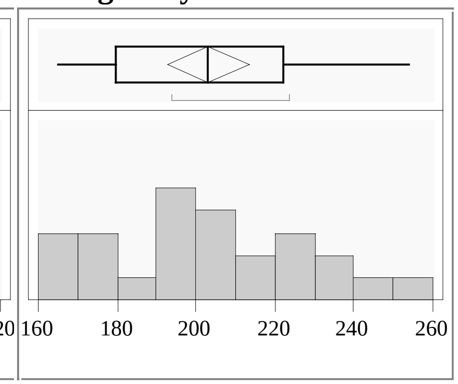
Quantiles

100.0%	maximum	109.33
99.5%		109.33
97.5%		109.33
90.0%		92.26
75.0%	quartile	50.23
50.0%	median	22.89
25.0%	quartile	20.00
10.0%		19.98
2.5%		19.97
0.5%		19.97
0.0%	minimum	19.97

Moments

Mean	38.230238
Std Dev	27.500358
Std Err Mean	5.5000716
upper 95% Mean	49.581828
lower 95% Mean	26.878648
N	25

Homogeneity



Quantiles

100.0%	maximum	253.83
99.5%		253.83
97.5%		253.83
90.0%		237.56
75.0%	quartile	221.97
50.0%	median	203.11
25.0%	quartile	179.55
10.0%		168.19
2.5%		164.84
0.5%		164.84
0.0%	minimum	164.84

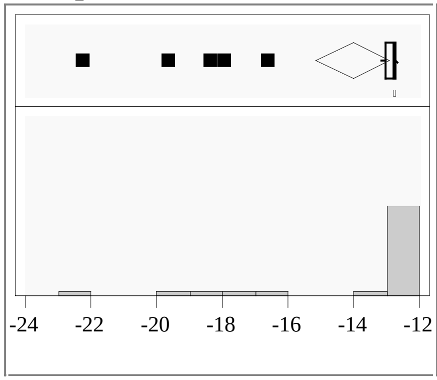
Moments

Mean	203.00475
Std Dev	24.942065
Std Err Mean	4.9884129
upper 95% Mean	213.30033
lower 95% Mean	192.70917
N	25

Appendix

Exhibit A6. Descriptive Statistics for Glasses Selected from the Inner and Outer Layer EVs (continued)

del Gp



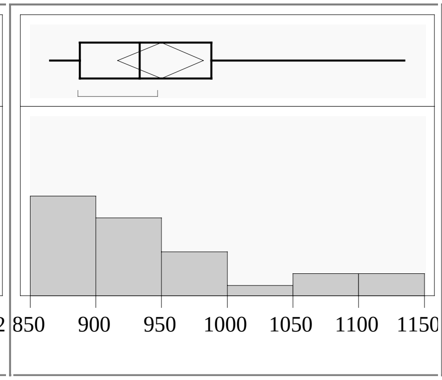
Quantiles

100.0%	maximum	-12.71
99.5%		-12.71
97.5%		-12.71
90.0%		-12.71
75.0%	quartile	-12.71
50.0%	median	-12.82
25.0%	quartile	-13.01
10.0%		-18.88
2.5%		-22.30
0.5%		-22.30
0.0%	minimum	-22.30

Moments

Mean	-14.02547
Std Dev	2.6796724
Std Err Mean	0.5359345
upper 95% Mean	-12.91935
lower 95% Mean	-15.13158
N	25

TL



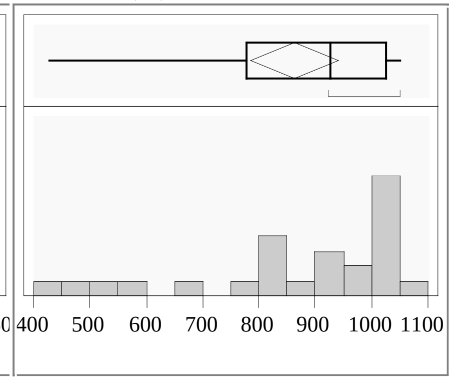
Quantiles

100.0%	maximum	1135.1
99.5%		1135.1
97.5%		1135.1
90.0%		1100.5
75.0%	quartile	987.7
50.0%	median	932.8
25.0%	quartile	887.8
10.0%		876.5
2.5%		864.4
0.5%		864.4
0.0%	minimum	864.4

Moments

Mean	949.80454
Std Dev	79.339682
Std Err Mean	15.867936
upper 95% Mean	982.55435
lower 95% Mean	917.05472
N	25

Pred TL(C)



Quantiles

100.0%	maximum	1050.8
99.5%		1050.8
97.5%		1050.8
90.0%		1046.8
75.0%	quartile	1025.5
50.0%	median	925.3
25.0%	quartile	778.2
10.0%		516.9
2.5%		427.6
0.5%		427.6
0.0%	minimum	427.6

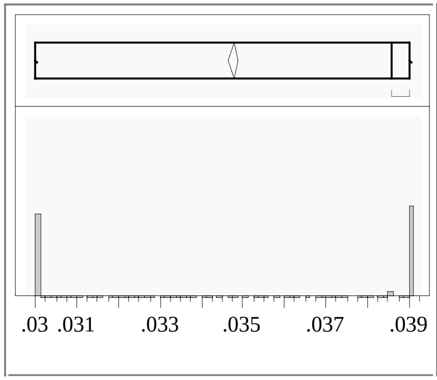
Moments

Mean	863.32092
Std Dev	191.81705
Std Err Mean	38.363411
upper 95% Mean	942.49911
lower 95% Mean	784.14273
N	25

Appendix

Exhibit A7. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 18

Al2O3



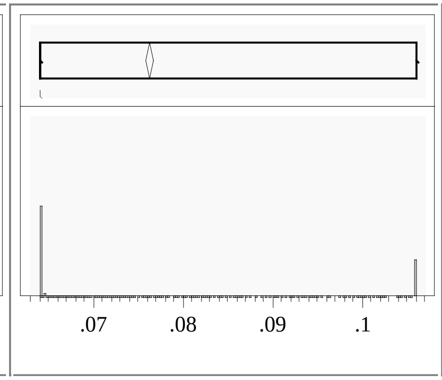
Quantiles

100.0%	maximum	0.03900
99.5%		0.03900
97.5%		0.03900
90.0%		0.03900
75.0%	quartile	0.03900
50.0%	median	0.03856
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0347694
Std Dev	0.0044316
Std Err Mean	0.0000649
upper 95% Mean	0.0348967
lower 95% Mean	0.0346421
N	4657

B2O3



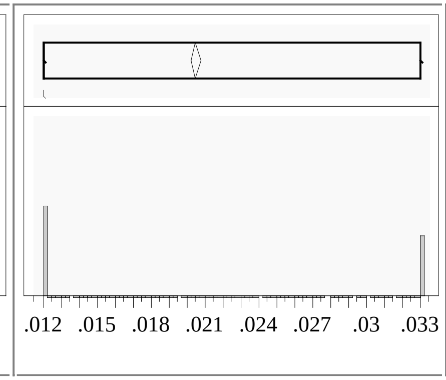
Quantiles

100.0%	maximum	0.10600
99.5%		0.10600
97.5%		0.10600
90.0%		0.10600
75.0%	quartile	0.10600
50.0%	median	0.06400
25.0%	quartile	0.06400
10.0%		0.06400
2.5%		0.06400
0.5%		0.06400
0.0%	minimum	0.06400

Moments

Mean	0.0763219
Std Dev	0.018365
Std Err Mean	0.0002691
upper 95% Mean	0.0768495
lower 95% Mean	0.0757943
N	4657

CaO



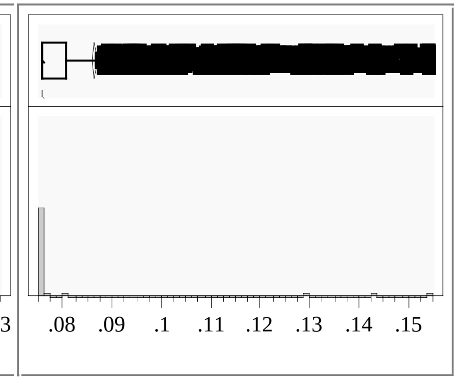
Quantiles

100.0%	maximum	0.03300
99.5%		0.03300
97.5%		0.03300
90.0%		0.03300
75.0%	quartile	0.03300
50.0%	median	0.01200
25.0%	quartile	0.01200
10.0%		0.01200
2.5%		0.01200
0.5%		0.01200
0.0%	minimum	0.01200

Moments

Mean	0.0205343
Std Dev	0.0100695
Std Err Mean	0.0001476
upper 95% Mean	0.0208235
lower 95% Mean	0.020245
N	4657

Fe2O3



Quantiles

100.0%	maximum	0.15400
99.5%		0.15400
97.5%		0.15400
90.0%		0.12872
75.0%	quartile	0.08063
50.0%	median	0.07600
25.0%	quartile	0.07600
10.0%		0.07600
2.5%		0.07600
0.5%		0.07600
0.0%	minimum	0.07600

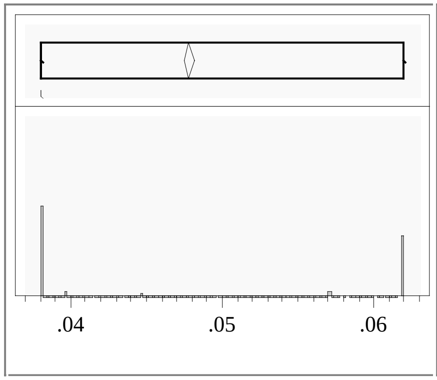
Moments

Mean	0.0863449
Std Dev	0.0212356
Std Err Mean	0.0003112
upper 95% Mean	0.086955
lower 95% Mean	0.0857348
N	4657

Appendix

Exhibit A7. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 18 (continued)

Li2O



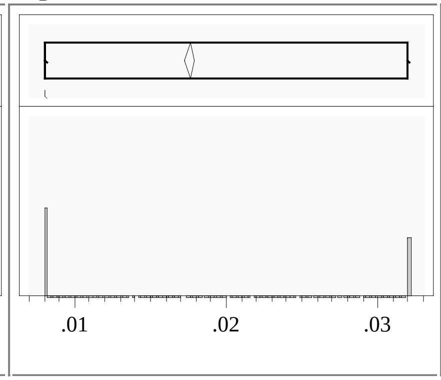
Quantiles

100.0%	maximum	0.06200
99.5%		0.06200
97.5%		0.06200
90.0%		0.06200
75.0%	quartile	0.06200
50.0%	median	0.03800
25.0%	quartile	0.03800
10.0%		0.03800
2.5%		0.03800
0.5%		0.03800
0.0%	minimum	0.03800

Moments

Mean	0.0477776
Std Dev	0.0111991
Std Err Mean	0.0001641
upper 95% Mean	0.0480994
lower 95% Mean	0.0474559
N	4657

MgO



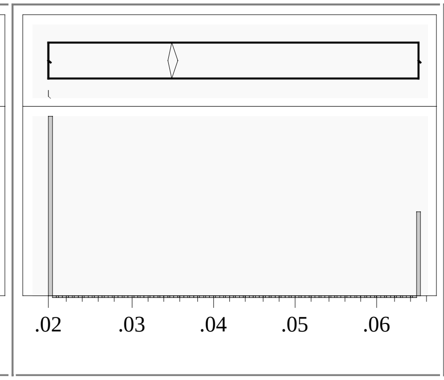
Quantiles

100.0%	maximum	0.03200
99.5%		0.03200
97.5%		0.03200
90.0%		0.03200
75.0%	quartile	0.03200
50.0%	median	0.00800
25.0%	quartile	0.00800
10.0%		0.00800
2.5%		0.00800
0.5%		0.00800
0.0%	minimum	0.00800

Moments

Mean	0.0175904
Std Dev	0.0114351
Std Err Mean	0.0001676
upper 95% Mean	0.0179189
lower 95% Mean	0.0172619
N	4657

MnO



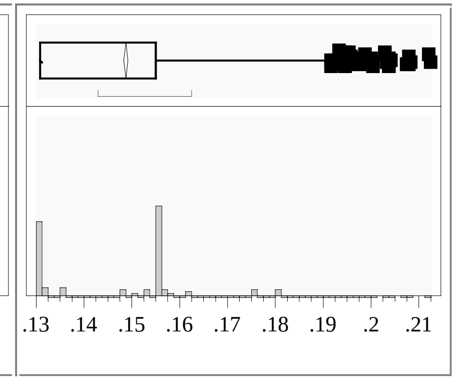
Quantiles

100.0%	maximum	0.06500
99.5%		0.06500
97.5%		0.06500
90.0%		0.06500
75.0%	quartile	0.06500
50.0%	median	0.02000
25.0%	quartile	0.02000
10.0%		0.02000
2.5%		0.02000
0.5%		0.02000
0.0%	minimum	0.02000

Moments

Mean	0.0350673
Std Dev	0.0202014
Std Err Mean	0.000296
upper 95% Mean	0.0356477
lower 95% Mean	0.034487
N	4657

Na2O



Quantiles

100.0%	maximum	0.21230
99.5%		0.19621
97.5%		0.18100
90.0%		0.16814
75.0%	quartile	0.15500
50.0%	median	0.15500
25.0%	quartile	0.13100
10.0%		0.13100
2.5%		0.13100
0.5%		0.13100
0.0%	minimum	0.13100

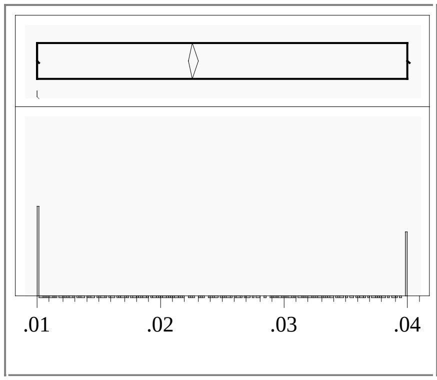
Moments

Mean	0.1487159
Std Dev	0.0153609
Std Err Mean	0.0002251
upper 95% Mean	0.1491572
lower 95% Mean	0.1482746
N	4657

Appendix

Exhibit A7. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 18 (continued)

NiO



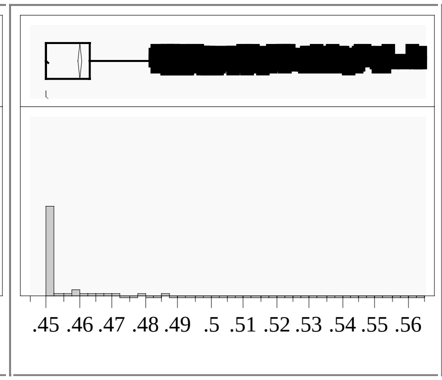
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.01000
25.0%	quartile	0.01000
10.0%		0.01000
2.5%		0.01000
0.5%		0.01000
0.0%	minimum	0.01000

Moments

Mean	0.022626
Std Dev	0.0143937
Std Err Mean	0.0002109
upper 95% Mean	0.0230395
lower 95% Mean	0.0222125
N	4657

SiO2



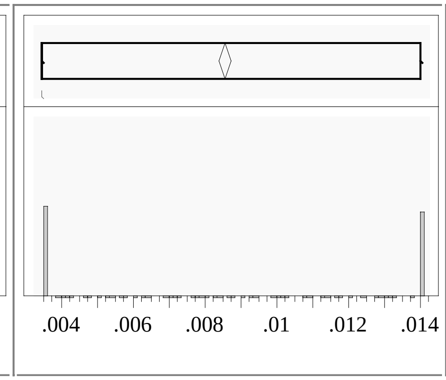
Quantiles

100.0%	maximum	0.56350
99.5%		0.54957
97.5%		0.52226
90.0%		0.48660
75.0%	quartile	0.46315
50.0%	median	0.45000
25.0%	quartile	0.45000
10.0%		0.45000
2.5%		0.45000
0.5%		0.45000
0.0%	minimum	0.45000

Moments

Mean	0.4601912
Std Dev	0.0192989
Std Err Mean	0.0002828
upper 95% Mean	0.4607456
lower 95% Mean	0.4596368
N	4657

TiO2



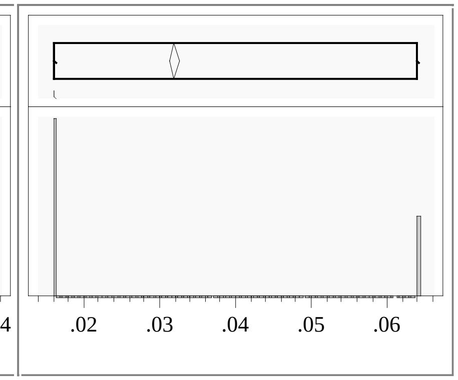
Quantiles

100.0%	maximum	0.01400
99.5%		0.01400
97.5%		0.01400
90.0%		0.01400
75.0%	quartile	0.01400
50.0%	median	0.00350
25.0%	quartile	0.00350
10.0%		0.00350
2.5%		0.00350
0.5%		0.00350
0.0%	minimum	0.00350

Moments

Mean	0.0085766
Std Dev	0.0051925
Std Err Mean	0.0000761
upper 95% Mean	0.0087257
lower 95% Mean	0.0084274
N	4657

U3O8



Quantiles

100.0%	maximum	0.06400
99.5%		0.06400
97.5%		0.06400
90.0%		0.06400
75.0%	quartile	0.06400
50.0%	median	0.01600
25.0%	quartile	0.01600
10.0%		0.01600
2.5%		0.01600
0.5%		0.01600
0.0%	minimum	0.01600

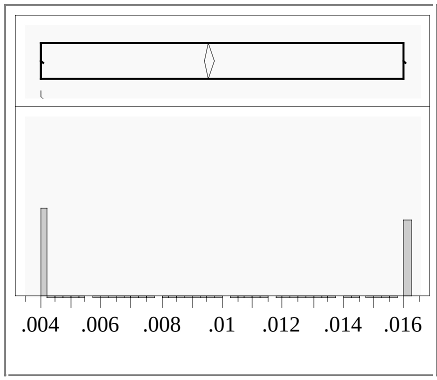
Moments

Mean	0.031915
Std Dev	0.0213358
Std Err Mean	0.0003126
upper 95% Mean	0.0325279
lower 95% Mean	0.031302
N	4657

Appendix

Exhibit A7. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 18 (continued)

Others



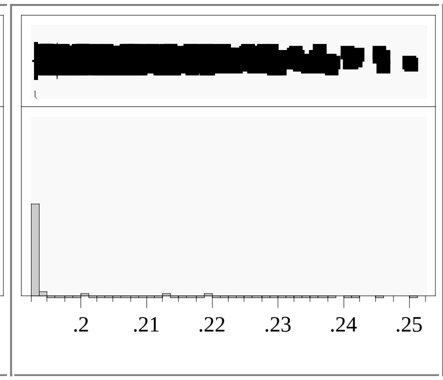
Quantiles

100.0%	maximum	0.01600
99.5%		0.01600
97.5%		0.01600
90.0%		0.01600
75.0%	quartile	0.01600
50.0%	median	0.00400
25.0%	quartile	0.00400
10.0%		0.00400
2.5%		0.00400
0.5%		0.00400
0.0%	minimum	0.00400

Moments

Mean	0.0095672
Std Dev	0.0059172
Std Err Mean	0.0000867
upper 95% Mean	0.0097372
lower 95% Mean	0.0093972
N	4657

alkalis



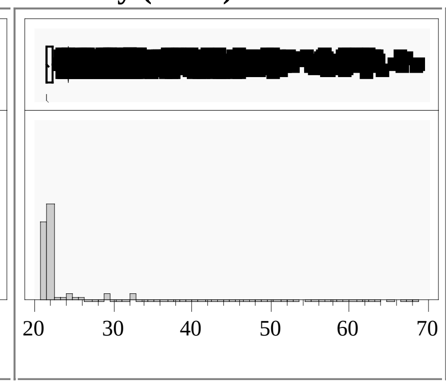
Quantiles

100.0%	maximum	0.25030
99.5%		0.23464
97.5%		0.21900
90.0%		0.21110
75.0%	quartile	0.19330
50.0%	median	0.19300
25.0%	quartile	0.19300
10.0%		0.19300
2.5%		0.19295
0.5%		0.19295
0.0%	minimum	0.19295

Moments

Mean	0.1964936
Std Dev	0.0083199
Std Err Mean	0.0001219
upper 95% Mean	0.1967326
lower 95% Mean	0.1962545
N	4657

Viscosity (Poise)



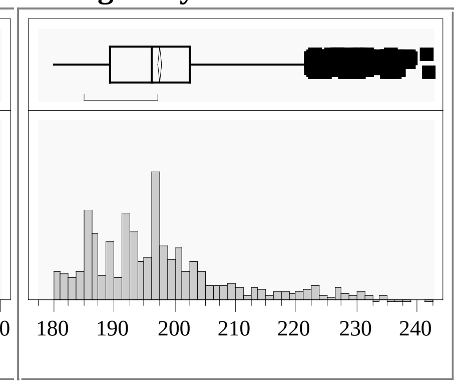
Quantiles

100.0%	maximum	68.543
99.5%		60.556
97.5%		46.424
90.0%		32.103
75.0%	quartile	22.251
50.0%	median	21.615
25.0%	quartile	21.594
10.0%		21.583
2.5%		21.578
0.5%		21.570
0.0%	minimum	21.562

Moments

Mean	24.301686
Std Dev	6.5778447
Std Err Mean	0.0963897
upper 95% Mean	24.490656
lower 95% Mean	24.112717
N	4657

Homogeneity



Quantiles

100.0%	maximum	241.65
99.5%		234.85
97.5%		228.13
90.0%		215.52
75.0%	quartile	202.35
50.0%	median	196.12
25.0%	quartile	189.22
10.0%		185.09
2.5%		181.28
0.5%		180.00
0.0%	minimum	180.00

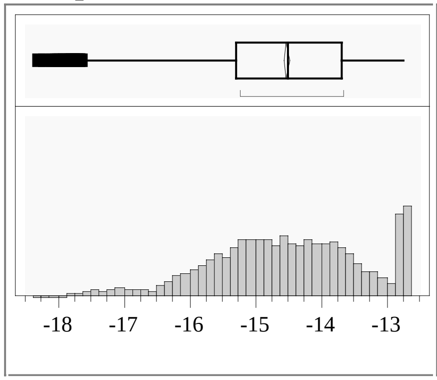
Moments

Mean	197.53788
Std Dev	11.839457
Std Err Mean	0.1734917
upper 95% Mean	197.87801
lower 95% Mean	197.19776
N	4657

Appendix

Exhibit A7. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 18 (continued)

del Gp



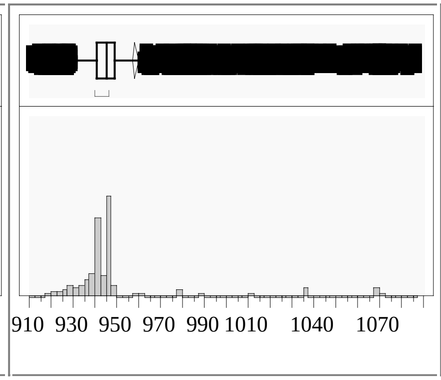
Quantiles

100.0%	maximum	-12.73
99.5%		-12.73
97.5%		-12.74
90.0%		-12.81
75.0%	quartile	-13.68
50.0%	median	-14.50
25.0%	quartile	-15.28
10.0%		-15.99
2.5%		-17.11
0.5%		-17.70
0.0%	minimum	-18.31

Moments

Mean	-14.51781
Std Dev	1.1529872
Std Err Mean	0.0168955
upper 95% Mean	-14.48469
lower 95% Mean	-14.55093
N	4657

TL



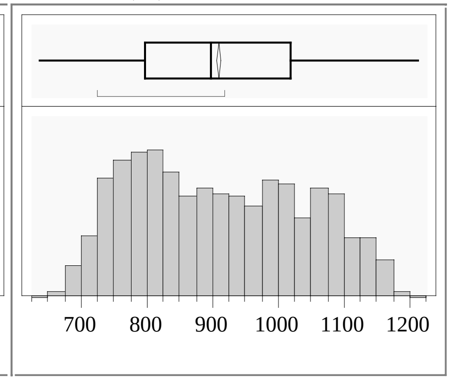
Quantiles

100.0%	maximum	1085.6
99.5%		1085.0
97.5%		1069.9
90.0%		1034.4
75.0%	quartile	949.2
50.0%	median	945.1
25.0%	quartile	940.9
10.0%		931.9
2.5%		922.0
0.5%		914.5
0.0%	minimum	911.1

Moments

Mean	958.57386
Std Dev	38.937533
Std Err Mean	0.5705784
upper 95% Mean	959.69247
lower 95% Mean	957.45526
N	4657

Pred TL(C)



Quantiles

100.0%	maximum	1214.4
99.5%		1165.9
97.5%		1144.8
90.0%		1093.0
75.0%	quartile	1018.9
50.0%	median	899.2
25.0%	quartile	797.8
10.0%		745.7
2.5%		703.7
0.5%		681.6
0.0%	minimum	637.8

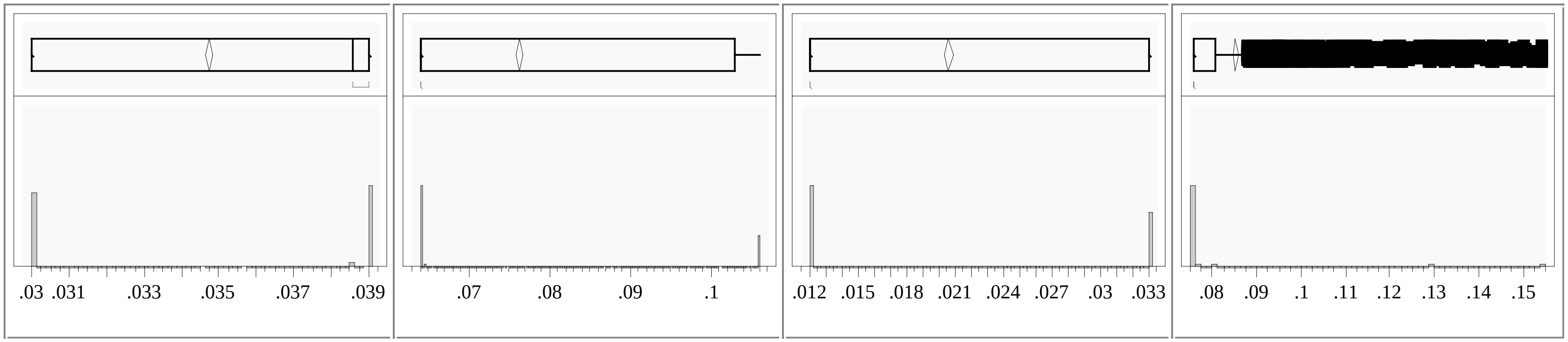
Moments

Mean	909.69917
Std Dev	129.96872
Std Err Mean	1.9045208
upper 95% Mean	913.43293
lower 95% Mean	905.96541
N	4657

Appendix

Exhibit A8. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 20

Al2O3 | B2O3 | CaO | Fe2O3



Al2O3

Quantiles

100.0%	maximum	0.03900
99.5%		0.03900
97.5%		0.03900
90.0%		0.03900
75.0%	quartile	0.03900
50.0%	median	0.03856
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0347417
Std Dev	0.0044135
Std Err Mean	0.0000582
upper 95% Mean	0.0348557
lower 95% Mean	0.0346276
N	5756

B2O3

Quantiles

100.0%	maximum	0.10600
99.5%		0.10600
97.5%		0.10600
90.0%		0.10600
75.0%	quartile	0.10310
50.0%	median	0.06400
25.0%	quartile	0.06400
10.0%		0.06400
2.5%		0.06400
0.5%		0.06400
0.0%	minimum	0.06400

Moments

Mean	0.076354
Std Dev	0.0182726
Std Err Mean	0.0002408
upper 95% Mean	0.0768261
lower 95% Mean	0.0758818
N	5756

CaO

Quantiles

100.0%	maximum	0.03300
99.5%		0.03300
97.5%		0.03300
90.0%		0.03300
75.0%	quartile	0.03300
50.0%	median	0.01200
25.0%	quartile	0.01200
10.0%		0.01200
2.5%		0.01200
0.5%		0.01200
0.0%	minimum	0.01200

Moments

Mean	0.0206622
Std Dev	0.0100402
Std Err Mean	0.0001323
upper 95% Mean	0.0209216
lower 95% Mean	0.0204028
N	5756

Fe2O3

Quantiles

100.0%	maximum	0.15400
99.5%		0.15400
97.5%		0.14839
90.0%		0.11743
75.0%	quartile	0.08063
50.0%	median	0.07600
25.0%	quartile	0.07600
10.0%		0.07600
2.5%		0.07600
0.5%		0.07600
0.0%	minimum	0.07600

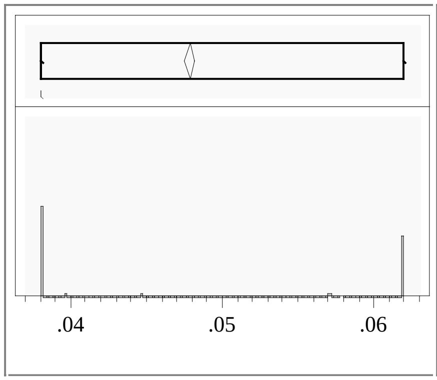
Moments

Mean	0.085223
Std Dev	0.0196461
Std Err Mean	0.000259
upper 95% Mean	0.0857307
lower 95% Mean	0.0847154
N	5756

Appendix

Exhibit A8. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 20 (continued)

Li2O



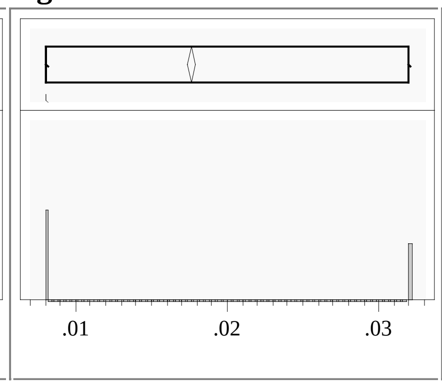
Quantiles

100.0%	maximum	0.06200
99.5%		0.06200
97.5%		0.06200
90.0%		0.06200
75.0%	quartile	0.06200
50.0%	median	0.03800
25.0%	quartile	0.03800
10.0%		0.03800
2.5%		0.03800
0.5%		0.03800
0.0%	minimum	0.03800

Moments

Mean	0.0478568
Std Dev	0.0111755
Std Err Mean	0.0001473
upper 95% Mean	0.0481455
lower 95% Mean	0.047568
N	5756

MgO



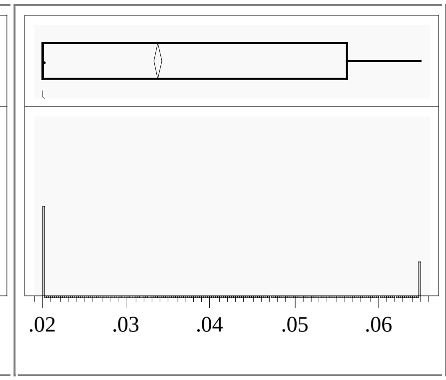
Quantiles

100.0%	maximum	0.03200
99.5%		0.03200
97.5%		0.03200
90.0%		0.03200
75.0%	quartile	0.03200
50.0%	median	0.00800
25.0%	quartile	0.00800
10.0%		0.00800
2.5%		0.00800
0.5%		0.00800
0.0%	minimum	0.00800

Moments

Mean	0.0176208
Std Dev	0.0112574
Std Err Mean	0.0001484
upper 95% Mean	0.0179117
lower 95% Mean	0.0173299
N	5756

MnO



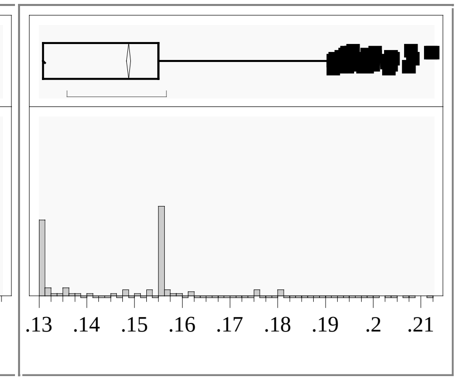
Quantiles

100.0%	maximum	0.06500
99.5%		0.06500
97.5%		0.06500
90.0%		0.06500
75.0%	quartile	0.05636
50.0%	median	0.02000
25.0%	quartile	0.02000
10.0%		0.02000
2.5%		0.02000
0.5%		0.02000
0.0%	minimum	0.02000

Moments

Mean	0.0336727
Std Dev	0.0191002
Std Err Mean	0.0002518
upper 95% Mean	0.0341662
lower 95% Mean	0.0331792
N	5756

Na2O



Quantiles

100.0%	maximum	0.21230
99.5%		0.19456
97.5%		0.18100
90.0%		0.16830
75.0%	quartile	0.15500
50.0%	median	0.15500
25.0%	quartile	0.13100
10.0%		0.13100
2.5%		0.13100
0.5%		0.13100
0.0%	minimum	0.13100

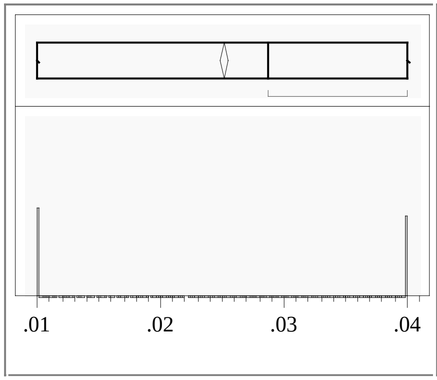
Moments

Mean	0.1487121
Std Dev	0.0152621
Std Err Mean	0.0002012
upper 95% Mean	0.1491065
lower 95% Mean	0.1483178
N	5756

Appendix

Exhibit A8. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 20 (continued)

NiO



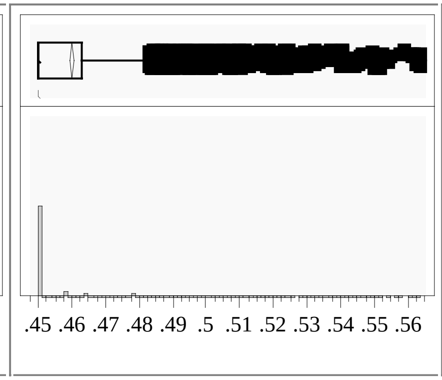
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.02872
25.0%	quartile	0.01000
10.0%		0.01000
2.5%		0.01000
0.5%		0.01000
0.0%	minimum	0.01000

Moments

Mean	0.0251583
Std Dev	0.0141499
Std Err Mean	0.0001865
upper 95% Mean	0.0255239
lower 95% Mean	0.0247927
N	5756

SiO2



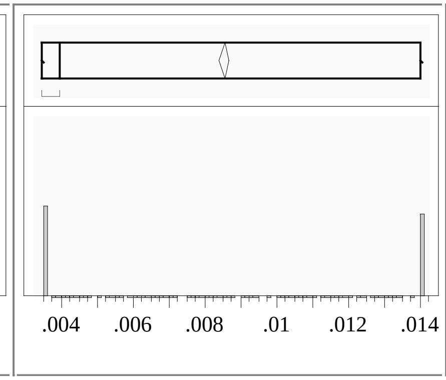
Quantiles

100.0%	maximum	0.56350
99.5%		0.54652
97.5%		0.51850
90.0%		0.48550
75.0%	quartile	0.46300
50.0%	median	0.45000
25.0%	quartile	0.45000
10.0%		0.45000
2.5%		0.45000
0.5%		0.45000
0.0%	minimum	0.45000

Moments

Mean	0.4599294
Std Dev	0.0185682
Std Err Mean	0.0002447
upper 95% Mean	0.4604092
lower 95% Mean	0.4594497
N	5756

TiO2



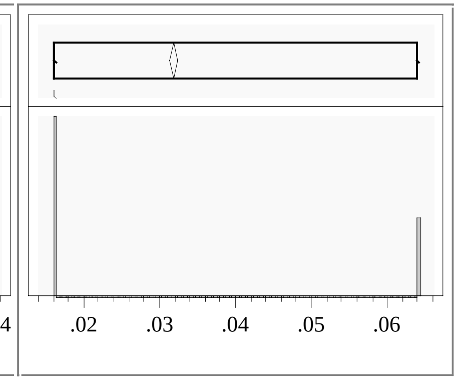
Quantiles

100.0%	maximum	0.01400
99.5%		0.01400
97.5%		0.01400
90.0%		0.01400
75.0%	quartile	0.01400
50.0%	median	0.00395
25.0%	quartile	0.00350
10.0%		0.00350
2.5%		0.00350
0.5%		0.00350
0.0%	minimum	0.00350

Moments

Mean	0.0085641
Std Dev	0.0051788
Std Err Mean	0.0000683
upper 95% Mean	0.0086979
lower 95% Mean	0.0084303
N	5756

U3O8



Quantiles

100.0%	maximum	0.06400
99.5%		0.06400
97.5%		0.06400
90.0%		0.06400
75.0%	quartile	0.06400
50.0%	median	0.01600
25.0%	quartile	0.01600
10.0%		0.01600
2.5%		0.01600
0.5%		0.01600
0.0%	minimum	0.01600

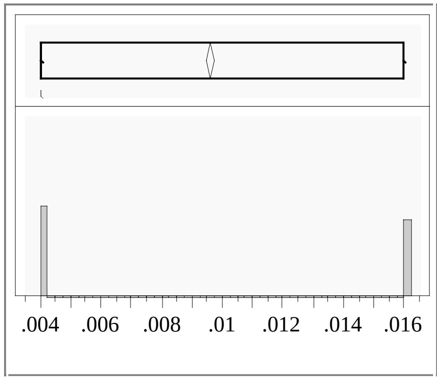
Moments

Mean	0.0319014
Std Dev	0.021189
Std Err Mean	0.0002793
upper 95% Mean	0.0324489
lower 95% Mean	0.0313539
N	5756

Appendix

Exhibit A8. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 20 (continued)

Others



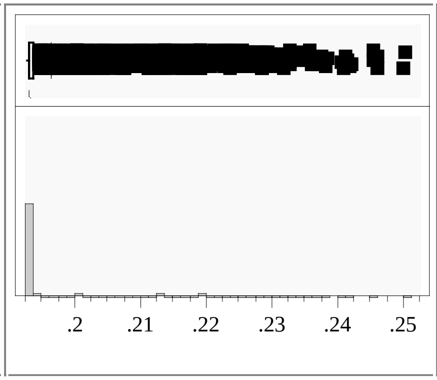
Quantiles

100.0%	maximum	0.01600
99.5%		0.01600
97.5%		0.01600
90.0%		0.01600
75.0%	quartile	0.01600
50.0%	median	0.00400
25.0%	quartile	0.00400
10.0%		0.00400
2.5%		0.00400
0.5%		0.00400
0.0%	minimum	0.00400

Moments

Mean	0.0096015
Std Dev	0.0058646
Std Err Mean	0.0000773
upper 95% Mean	0.009753
lower 95% Mean	0.0094499
N	5756

alkalis



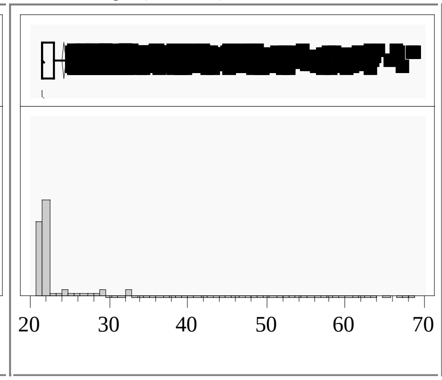
Quantiles

100.0%	maximum	0.25030
99.5%		0.23316
97.5%		0.21900
90.0%		0.21070
75.0%	quartile	0.19358
50.0%	median	0.19300
25.0%	quartile	0.19300
10.0%		0.19300
2.5%		0.19295
0.5%		0.19295
0.0%	minimum	0.19295

Moments

Mean	0.1965689
Std Dev	0.0081294
Std Err Mean	0.0001072
upper 95% Mean	0.1967789
lower 95% Mean	0.1963588
N	5756

Viscosity (Poise)



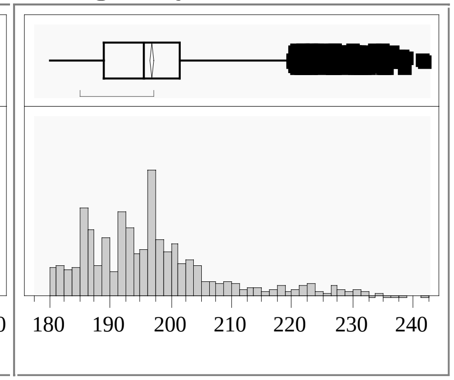
Quantiles

100.0%	maximum	68.543
99.5%		59.645
97.5%		45.097
90.0%		32.103
75.0%	quartile	23.061
50.0%	median	21.617
25.0%	quartile	21.594
10.0%		21.584
2.5%		21.579
0.5%		21.571
0.0%	minimum	21.557

Moments

Mean	24.310734
Std Dev	6.354538
Std Err Mean	0.0837575
upper 95% Mean	24.47493
lower 95% Mean	24.146538
N	5756

Homogeneity



Quantiles

100.0%	maximum	241.65
99.5%		234.85
97.5%		227.69
90.0%		212.91
75.0%	quartile	201.32
50.0%	median	195.40
25.0%	quartile	188.83
10.0%		185.09
2.5%		181.28
0.5%		180.00
0.0%	minimum	180.00

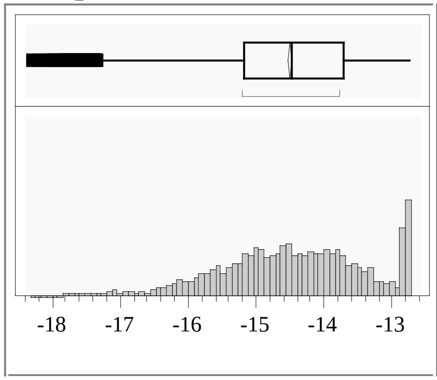
Moments

Mean	196.93612
Std Dev	11.390323
Std Err Mean	0.1501328
upper 95% Mean	197.23044
lower 95% Mean	196.64181
N	5756

Appendix

Exhibit A8. Descriptive Statistics for EVs Generated by MIXSOFT for Inner Layer Region Defined by Table 20 (continued)

del Gp



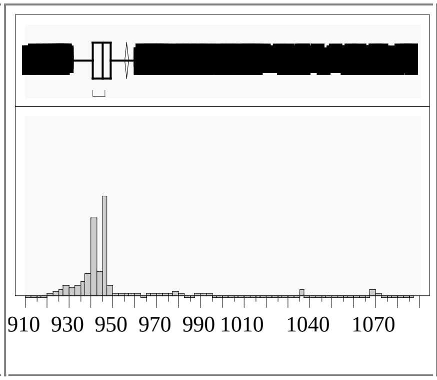
Quantiles

100.0%	maximum	-12.73
99.5%		-12.74
97.5%		-12.74
90.0%		-12.85
75.0%	quartile	-13.72
50.0%	median	-14.47
25.0%	quartile	-15.18
10.0%		-15.89
2.5%		-16.99
0.5%		-17.66
0.0%	minimum	-18.31

Moments

Mean	-14.49212
Std Dev	1.0913566
Std Err Mean	0.0143849
upper 95% Mean	-14.46392
lower 95% Mean	-14.52032
N	5756

TL



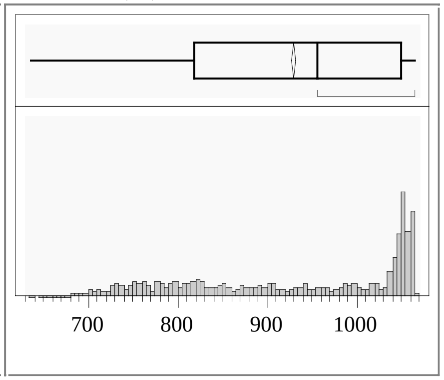
Quantiles

100.0%	maximum	1085.6
99.5%		1083.4
97.5%		1069.9
90.0%		1011.2
75.0%	quartile	949.2
50.0%	median	945.1
25.0%	quartile	940.9
10.0%		932.8
2.5%		923.4
0.5%		915.6
0.0%	minimum	911.1

Moments

Mean	956.5723
Std Dev	35.859812
Std Err Mean	0.4726587
upper 95% Mean	957.49889
lower 95% Mean	955.64572
N	5756

Pred TL(C)



Quantiles

100.0%	maximum	1066.1
99.5%		1064.7
97.5%		1063.3
90.0%		1057.6
75.0%	quartile	1049.6
50.0%	median	956.4
25.0%	quartile	819.1
10.0%		753.7
2.5%		708.0
0.5%		683.2
0.0%	minimum	637.8

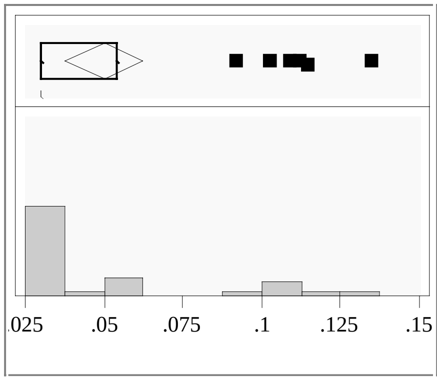
Moments

Mean	929.83179
Std Dev	120.84031
Std Err Mean	1.5927641
upper 95% Mean	932.95421
lower 95% Mean	926.70937
N	5756

Appendix

Exhibit A9. Descriptive Statistics for Glasses Selected from the EVs

Al2O3



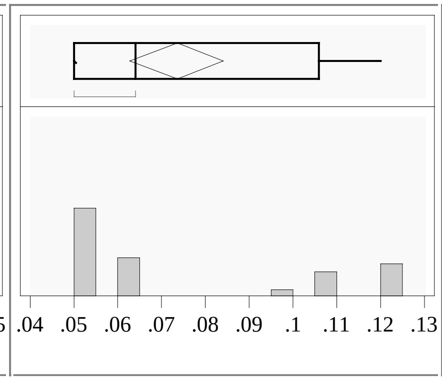
Quantiles

100.0%	maximum	0.13480
99.5%		0.13480
97.5%		0.13480
90.0%		0.11160
75.0%	quartile	0.05400
50.0%	median	0.03000
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.049985
Std Dev	0.0325864
Std Err Mean	0.0059494
upper 95% Mean	0.062153
lower 95% Mean	0.037817
N	30

B2O3



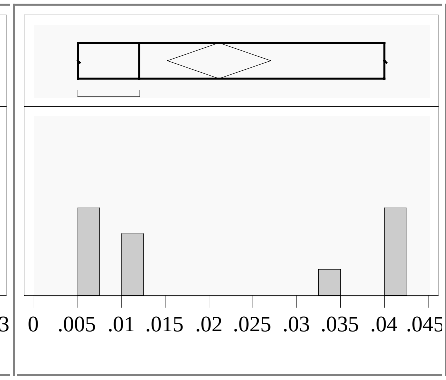
Quantiles

100.0%	maximum	0.12000
99.5%		0.12000
97.5%		0.12000
90.0%		0.12000
75.0%	quartile	0.10600
50.0%	median	0.06400
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

Moments

Mean	0.0734497
Std Dev	0.0286433
Std Err Mean	0.0052295
upper 95% Mean	0.0841453
lower 95% Mean	0.0627541
N	30

CaO



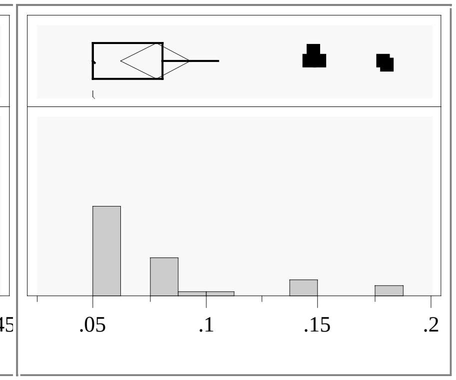
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.04000
50.0%	median	0.01200
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.0211
Std Dev	0.0157225
Std Err Mean	0.0028705
upper 95% Mean	0.0269709
lower 95% Mean	0.0152291
N	30

Fe2O3



Quantiles

100.0%	maximum	0.18000
99.5%		0.18000
97.5%		0.18000
90.0%		0.14965
75.0%	quartile	0.08086
50.0%	median	0.05000
25.0%	quartile	0.05000
10.0%		0.05000
2.5%		0.05000
0.5%		0.05000
0.0%	minimum	0.05000

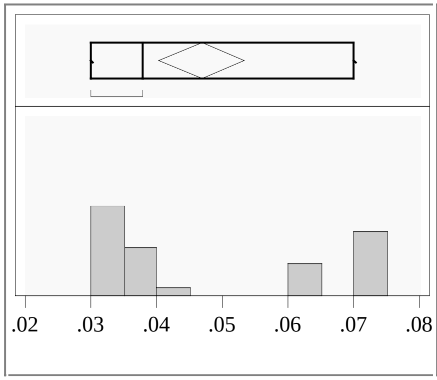
Moments

Mean	0.0777883
Std Dev	0.0409256
Std Err Mean	0.007472
upper 95% Mean	0.0930702
lower 95% Mean	0.0625065
N	30

Appendix

Exhibit A9. Descriptive Statistics for Glasses Selected from the EVs (continued)

Li2O



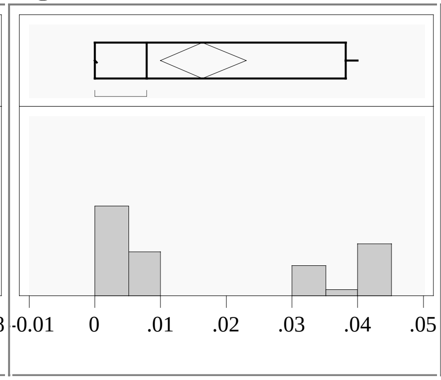
Quantiles

100.0%	maximum	0.07000
99.5%		0.07000
97.5%		0.07000
90.0%		0.07000
75.0%	quartile	0.07000
50.0%	median	0.03800
25.0%	quartile	0.03000
10.0%		0.03000
2.5%		0.03000
0.5%		0.03000
0.0%	minimum	0.03000

Moments

Mean	0.0469073
Std Dev	0.0174496
Std Err Mean	0.0031858
upper 95% Mean	0.0534231
lower 95% Mean	0.0403916
N	30

MgO



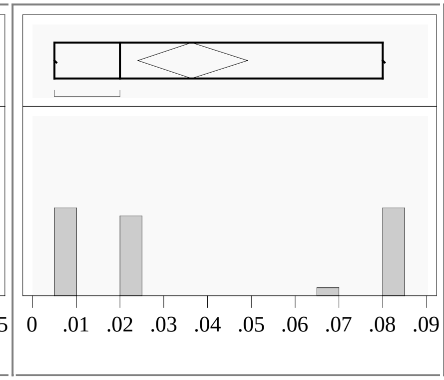
Quantiles

100.0%	maximum	0.04000
99.5%		0.04000
97.5%		0.04000
90.0%		0.04000
75.0%	quartile	0.03822
50.0%	median	0.00800
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0164543
Std Dev	0.0175908
Std Err Mean	0.0032116
upper 95% Mean	0.0230229
lower 95% Mean	0.0098858
N	30

MnO



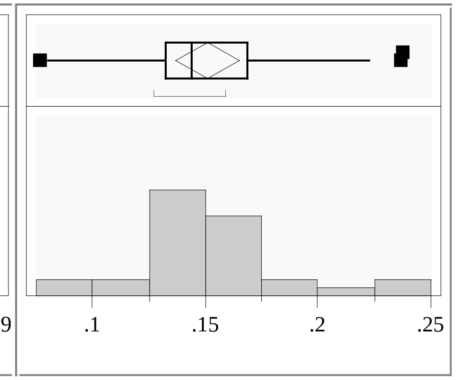
Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.08000
50.0%	median	0.02000
25.0%	quartile	0.00500
10.0%		0.00500
2.5%		0.00500
0.5%		0.00500
0.0%	minimum	0.00500

Moments

Mean	0.0365
Std Dev	0.0332739
Std Err Mean	0.006075
upper 95% Mean	0.0489247
lower 95% Mean	0.0240753
N	30

Na2O



Quantiles

100.0%	maximum	0.23700
99.5%		0.23700
97.5%		0.23700
90.0%		0.21931
75.0%	quartile	0.16875
50.0%	median	0.14360
25.0%	quartile	0.13230
10.0%		0.10526
2.5%		0.07607
0.5%		0.07607
0.0%	minimum	0.07607

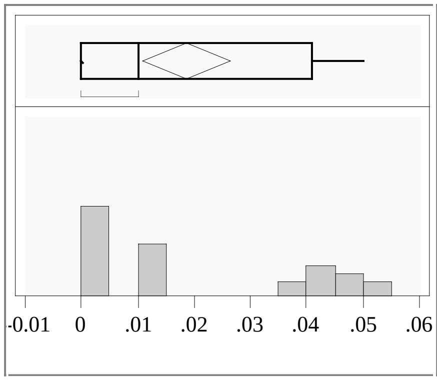
Moments

Mean	0.151121
Std Dev	0.0373618
Std Err Mean	0.0068213
upper 95% Mean	0.1650721
lower 95% Mean	0.1371699
N	30

Appendix

Exhibit A9. Descriptive Statistics for Glasses Selected from the EVs (continued)

NiO



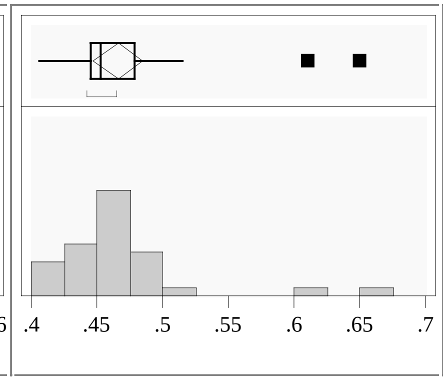
Quantiles

100.0%	maximum	0.05000
99.5%		0.05000
97.5%		0.05000
90.0%		0.04885
75.0%	quartile	0.04078
50.0%	median	0.01000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0186507
Std Dev	0.0205681
Std Err Mean	0.0037552
upper 95% Mean	0.0263309
lower 95% Mean	0.0109704
N	30

SiO2



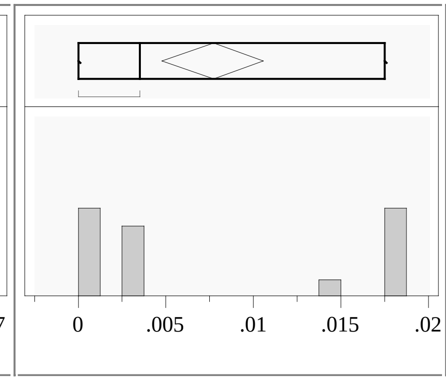
Quantiles

100.0%	maximum	0.65000
99.5%		0.65000
97.5%		0.65000
90.0%		0.51246
75.0%	quartile	0.47820
50.0%	median	0.45300
25.0%	quartile	0.44480
10.0%		0.41895
2.5%		0.40680
0.5%		0.40680
0.0%	minimum	0.40680

Moments

Mean	0.4659467
Std Dev	0.050648
Std Err Mean	0.009247
upper 95% Mean	0.484859
lower 95% Mean	0.4470344
N	30

TiO2



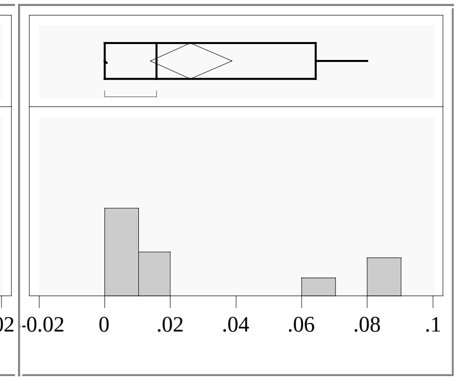
Quantiles

100.0%	maximum	0.01750
99.5%		0.01750
97.5%		0.01750
90.0%		0.01750
75.0%	quartile	0.01750
50.0%	median	0.00350
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0077
Std Dev	0.0078208
Std Err Mean	0.0014279
upper 95% Mean	0.0106203
lower 95% Mean	0.0047797
N	30

U3O8



Quantiles

100.0%	maximum	0.08000
99.5%		0.08000
97.5%		0.08000
90.0%		0.08000
75.0%	quartile	0.06400
50.0%	median	0.01600
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

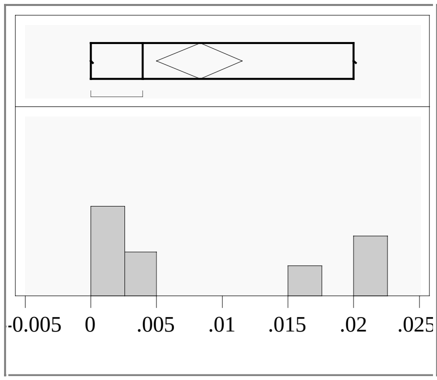
Moments

Mean	0.0261333
Std Dev	0.0332138
Std Err Mean	0.006064
upper 95% Mean	0.0385356
lower 95% Mean	0.0137311
N	30

Appendix

Exhibit A9. Descriptive Statistics for Glasses Selected from the EVs (continued)

Others



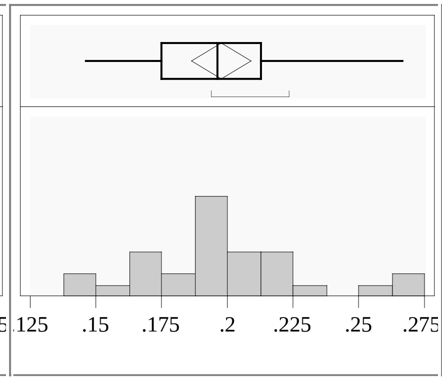
Quantiles

100.0%	maximum	0.02000
99.5%		0.02000
97.5%		0.02000
90.0%		0.02000
75.0%	quartile	0.02000
50.0%	median	0.00400
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0082667
Std Dev	0.0088471
Std Err Mean	0.0016153
upper 95% Mean	0.0115702
lower 95% Mean	0.0049631
N	30

alkalis



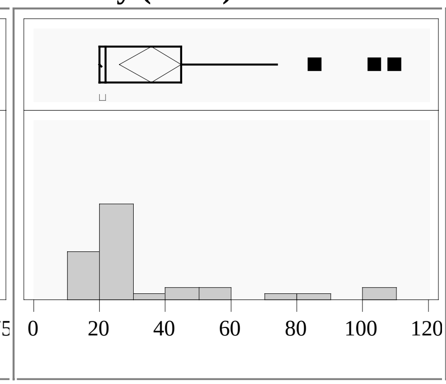
Quantiles

100.0%	maximum	0.26700
99.5%		0.26700
97.5%		0.26700
90.0%		0.24989
75.0%	quartile	0.21283
50.0%	median	0.19615
25.0%	quartile	0.17536
10.0%		0.15167
2.5%		0.14607
0.5%		0.14607
0.0%	minimum	0.14607

Moments

Mean	0.1980283
Std Dev	0.0302373
Std Err Mean	0.0055205
upper 95% Mean	0.2093191
lower 95% Mean	0.1867376
N	30

Viscosity (Poise)



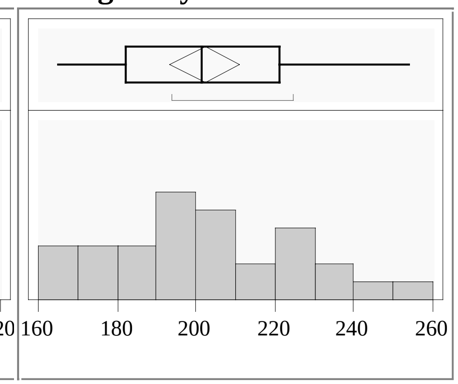
Quantiles

100.0%	maximum	109.33
99.5%		109.33
97.5%		109.33
90.0%		83.91
75.0%	quartile	44.96
50.0%	median	21.64
25.0%	quartile	20.00
10.0%		19.99
2.5%		19.97
0.5%		19.97
0.0%	minimum	19.97

Moments

Mean	35.460799
Std Dev	25.798252
Std Err Mean	4.7100949
upper 95% Mean	45.094025
lower 95% Mean	25.827574
N	30

Homogeneity



Quantiles

100.0%	maximum	253.83
99.5%		253.83
97.5%		253.83
90.0%		235.12
75.0%	quartile	221.11
50.0%	median	201.54
25.0%	quartile	182.31
10.0%		169.67
2.5%		164.84
0.5%		164.84
0.0%	minimum	164.84

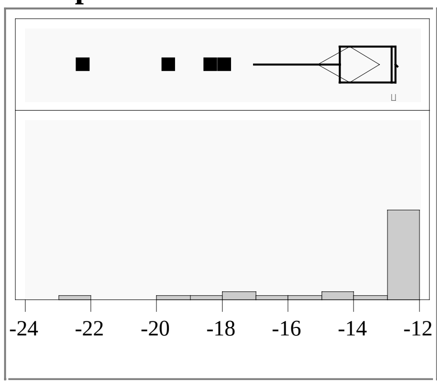
Moments

Mean	202.32673
Std Dev	23.65359
Std Err Mean	4.3185349
upper 95% Mean	211.15912
lower 95% Mean	193.49433
N	30

Appendix

Exhibit A9. Descriptive Statistics for Glasses Selected from the EVs (continued)

del Gp



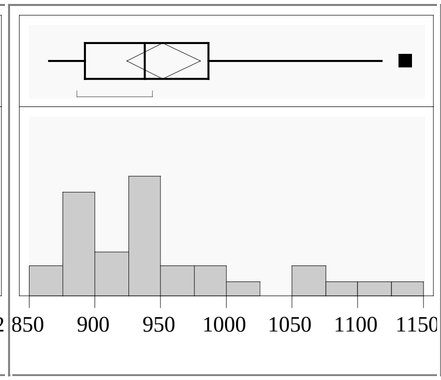
Quantiles

100.0%	maximum	-12.71
99.5%		-12.71
97.5%		-12.71
90.0%		-12.71
75.0%	quartile	-12.71
50.0%	median	-12.84
25.0%	quartile	-14.45
10.0%		-18.33
2.5%		-22.30
0.5%		-22.30
0.0%	minimum	-22.30

Moments

Mean	-14.12759
Std Dev	2.5163962
Std Err Mean	0.459429
upper 95% Mean	-13.18796
lower 95% Mean	-15.06723
N	30

TL



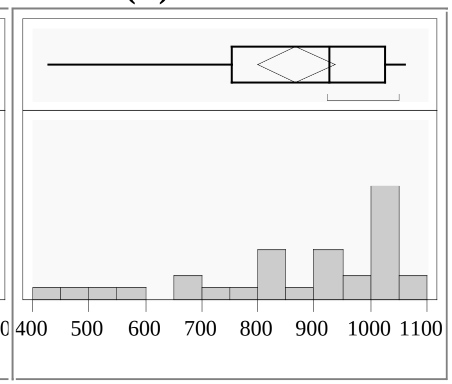
Quantiles

100.0%	maximum	1135.1
99.5%		1135.1
97.5%		1135.1
90.0%		1087.4
75.0%	quartile	986.1
50.0%	median	938.5
25.0%	quartile	892.3
10.0%		882.1
2.5%		864.4
0.5%		864.4
0.0%	minimum	864.4

Moments

Mean	951.88621
Std Dev	75.397908
Std Err Mean	13.765712
upper 95% Mean	980.04025
lower 95% Mean	923.73216
N	30

Pred TL(C)



Quantiles

100.0%	maximum	1062.7
99.5%		1062.7
97.5%		1062.7
90.0%		1048.7
75.0%	quartile	1026.4
50.0%	median	926.5
25.0%	quartile	754.3
10.0%		531.9
2.5%		427.6
0.5%		427.6
0.0%	minimum	427.6

Moments

Mean	867.64123
Std Dev	186.80204
Std Err Mean	34.10523
upper 95% Mean	937.39425
lower 95% Mean	797.8882
N	30

Distribution

T.B.	Edwards,	773-42A
C.C.	Herman,	773-43A
E.W.	Holtzscheiter,	773-A
C.M.	Jantzen,	773-A
S.L.	Marra,	999-W
J.E.	Occhipinti,	704-27S
D.K.	Peeler,	999-W
M.A.	Rios-Armstrong,	704-27S
R.H.	Spires,	773-A
R.C.	Tuckfield,	773-43A