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Experimental Design for Hanford Low-Activity Waste Glasses with High Waste Loading

July 2015

GF Piepel
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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Executive Summary

This report discusses the development of an experimental design for the initial phase of the Hanford low-activity waste (LAW) enhanced glass study. This report is based on a manuscript written for an applied statistics journal. Appendices A, B, and E include additional information relevant to the LAW enhanced glass experimental design that is not included in the journal manuscript.

The glass composition experimental region is defined by single-component constraints (SCCs), linear multiple-component constraints (MCCs), and a nonlinear MCC involving 15 LAW glass components. Traditional methods and software for designing constrained mixture experiments with SCCs and linear MCCs are not directly applicable because of the nonlinear MCC. A modification of existing methodology to account for the nonlinear MCC was developed and is described in this report.

One of the glass components, SO_3, has a solubility limit in glass that depends on the composition of the balance of the glass. A goal was to design the experiment so that SO_3 would not exceed its predicted solubility limit for any of the experimental glasses. The SO_3 solubility limit had previously been modeled by a partial quadratic mixture model expressed in the relative proportions of the 14 other components. The partial quadratic mixture model was used to construct a nonlinear MCC in terms of all 15 components. In addition, there were SCCs and linear MCCs.

This report describes how a layered design was generated to (i) account for the SCCs, linear MCCs, and nonlinear MCC and (ii) meet the goals of the study. A layered design consists of points on an outer layer, and inner layer, and a center point. There were 18 outer-layer glasses chosen using optimal experimental design software to augment 147 existing glass compositions that were within the LAW glass composition experimental region. Then 13 inner-layer glasses were chosen with the software to augment the existing and outer-layer glasses. The experimental design was completed by a center-point glass, a Vitreous State Laboratory glass, and replicates of the center point and Vitreous State Laboratory glasses.

Acknowledgments

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Acronyms and Abbreviations

HLW	high-level waste
LAW	low-activity waste
LD	layered design
MCC	multiple-component constraint
PNNL	Pacific Northwest National Laboratory
SCC	single-component constraint
SFD	space-filling design
UD	uniform design
VHT	Vapor Hydration Test
WTP	Hanford Tank Waste Treatment and Immobilization Plant

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1.0 Introduction

Existing statistical algorithms and software provide for designing mixture experiments when the experimental region is defined by (i) lower and/or upper bounds on each component, referred to as single-component constraints (SCCs), and (ii) lower and/or upper bounds on linear combinations of components, referred to as linear multiple-component constraints (MCCs). Existing algorithms and software do not allow nonlinear MCCs, which may occur in practice. This report uses a case study involving a 15-component nuclear waste glass example with a nonlinear MCC (in addition to SCCs and linear MCCs) to discuss and illustrate how a layered experimental design was generated to account for all of the constraints.

Layered designs (LDs) were first introduced by Piepel et al. (1993) and have subsequently been used many times to investigate waste glass composition regions (e.g., Cooley et al. 2003, Piepel et al. 2005, and the study discussed in this report). LDs consist of design points on two or more layers of an experimental region. LDs are useful when the goal is to boldly explore a larger outer layer, but also more conservatively explore points on the interior of the experimental region (using one or more inner layers plus a center point). Layers may be defined by (i) separate sets of SCCs and MCCs, or (ii) specifying an outer layer defined by one set of SCCs and MCCs and shrinking it to form one or more inner layers. See Piepel et al. (1993) for more discussion of LDs. In this report, we discuss a LD with points on an outer layer, an inner layer, and a center point, where the outer and inner layers are defined by separate sets of SCCs and MCCs.

Section 2 discusses the 15-component nuclear waste glass example in more detail, and presents the separate sets of SCCs, linear MCCs, and nonlinear MCC used to define the outer and inner layers. Section 3 presents and discusses the linear and nonlinear MCCs. Section 4 describes how an existing algorithm for generating vertices of a constrained mixture region was modified to account for a nonlinear MCC. Section 5 describes how the LD was constructed for the 15-component waste glass example using optimal experimental design methods and software. Finally, Section 6 summarizes the approach used this report to account for one nonlinear MCC and discusses possible approaches to account for two or more nonlinear SCCs and/or MCCs.

The work described in this document was performed under the Quality Assurance program of the Enhanced Waste Glass project, which implements the requirements of ASME NQA-1-2008, Quality Assurance Requirements for Nuclear Facility Applications, and NQA-1a-2009, Addenda to ASME NQA-1-2008, Quality Assurance Requirements for Nuclear Facility Applications, graded on the approach presented in NQA-1-2008, Part IV, Subpart 4.2.

2.0 Fifteen-Component Nuclear Waste Glass Example

The Hanford site near Richland, WA is storing approximately 56 million gallons of radioactive chemical waste from the defense mission of the site (which ended years ago) that is stored in 177 underground tanks. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is being constructed to separate the tank waste into high-level waste (HLW) and low-activity waste (LAW) and separately immobilize the HLW and LAW in borosilicate waste glasses contained in canisters for disposal. The majority of the work so far to develop glass property-composition databases, models, and acceptable glass formulations has focused on the HLW and LAW glasses for the initial few years of WTP operation. Those glasses focus on immobilizing a fraction of the tank waste at relatively low waste loadings. Other work, including the work discussed in this report, is focused on developing glass formulations and property-composition models for the balance of the WTP mission. This other work involves broader regions of HLW and LAW compositions and corresponding glass compositions that will be produced by the WTP at higher waste loadings than for the initial WTP production period.

In this section, we discuss the initial portion of the work to select new LAW glass compositions using a LD with one outer layer, one inner layer, a center point, and two replicates. Specifically, this section focuses on the LAW glass components, as well as the SCCs and MCCs that define the composition regions for the outer and inner layers. The details of how the LD was constructed using the SCCs and MCCs that define the outer and inner layers are discussed in the following section.

Based on estimates of LAW compositions that may result from processing wastes in the Hanford underground tanks, as well as estimates of LAW glass compositions that might be made from those LAW compositions, glass scientists (the third and fourth authors) selected 15 LAW glass components (see Table 2.1) to vary in the experimental design. These components were ones that were known or believed to possibly affect one or more of the several glass properties of interest (e.g., glass durability, viscosity, sulfate solubility). The 15^{th} component, “Others1,” comprises the mixture of components shown in Table 2.2. Actual LAW glasses will have many more chemical and radionuclide components with very small mass fractions, but none of those components are expected to affect LAW glass properties. Hence, nonradioactive glasses with a simplified Others1 component can be tested in the laboratory and the resulting data can be used to (i) develop property-composition models, (ii) identify the region of acceptable LAW glass compositions, and (iii) develop acceptable LAW glass formulations. Table 2.2 lists the mass fractions of the Others1 components used to construct the experimental design, as well as the mass fractions (to fewer decimal places) actually used to make the glasses.

Table 2.1. Lower and Upper Bounds of Single-Component Constraints for the Outer and Inner Layers of a 15-Component Low-Activity Waste Glass Composition Region

	Outer Layer		Inner Layer		
Component	**Lower Bound**	**Upper Bound**	**Lower Bound**	**Upper Bound**	**Center Point**
Al_2O_3	0.035	0.1385	0.0625	0.1150	0.09
B_2O_3	0.06	0.1375	0.08	0.1175	0.10
CaO	0	0.1224	0.0275	0.09	0.055
Fe_2O_3	0	0.015	0.0050	0.0125	0.01
K_2O	0	0.015	0.002	0.01	0.004
Li_2O	0	0.05	0.01	0.035	0.02
MgO	0	0.035	0.005	0.025	0.015
Na_2O	0.10	0.26	0.15	0.23	0.19
SiO_2	0.34	0.47	0.3675	0.4325	0.3955
SO_3	0.001	0.02	0.004	0.013	0.007
SnO_2	0	0.05	0.01	0.035	0.02
V_2O_5	0	0.04	0.005	0.03	0.02
ZnO	0.01	0.05	0.02	0.04	0.03
ZrO_2	0	0.065	0.015	0.0475	0.03
Others1	0.004	0.03	0.075	0.02	0.0135

(a) The lower and upper bounds of the SCCs are in terms of mass fractions of the components, such that the mass fractions of all 15 components must sum to 1.0000.

Table 2.2. Mass Fractions of Components Comprising the Others1 Component for the Experimental Design and for Making the Glasses

	Mass Fraction	
Component	**Experimental Design**	**Making the Glasses**
Cl	0.155315	0.156
Cr_2O_3	0.104383	0.104
F	0.235786	0.236
P_2O_5	0.504516	0.504
Sum	1.000000	1.000

Table 2.1 lists the 15 LAW glass components, as well as lower and upper bounds for the SCCs for the outer and inner layers of LAW glass compositions. The SCC lower and upper bounds for the outer layer were chosen to include a broad range of LAW glass compositions. The lower and upper bounds for the inner-layer SCCs were selected to be in the middles of the component ranges between the center-point values and the lower and upper bounds for the outer-layer SCCs. Additional discussion of how the SCCs for both the outer and inner layers were developed is in Appendix A. For both the outer and inner layers, SCCs alone may allow glass compositions that might be very undesirable, so it was necessary to exclude such glass

compositions using the four MCCs shown in Table 2.3. The four MCCs are discussed in detail in the following section.

Table 2.3. Lower and Upper Bounds of Multiple-Component Constraints for the Outer and Inner Layers of a 15-Component Low-Activity Waste Glass Composition Region

	Outer Layer		**Inner Layer**	
Expression (units)[(a)]	**Lower Bound**	**Upper Bound**	**Lower Bound**	**Upper Bound**
Nalk (mf)	0.15	0.265	0.195	0.2515
ZrO_2+SnO_2 (mf)	0.03	0.11	0.04	0.08
η_{1150} (poise)	10	100	30	70
SO_3 Solubility (wt%)	–	Solubility Limit[(b)]	–	Solubility Limit[(b)]

(a) mf = mass fraction, wt% = weight percent.
(b) The SO_3 solubility limit is expressed as a partial quadratic mixture model, as discussed subsequently in the text.

3.0 Multiple-Component Constraints for the 15-Component LAW Glass Example

The first MCC in Table 2.3 (Nalk) involves a normalized alkali-oxide expression

$$g_{Nalk} = g_{Na_2O} + 0.66\, g_{K_2O} + 2\, g_{Li_2O}\,, \tag{1}$$

where g_i represents the mass fraction of the i^{th} LAW glass component. Too small a value of g_{Nalk} in a LAW glass is undesirable because it represents too low a waste loading to be of practical interest for the WTP. Too large a value is undesirable because it will have such poor Vapor Hydration Test (VHT) response (a measure of glass durability) that a numerical value cannot be measured. Table 2.3 lists the lower and upper bounds of the g_{Nalk} MCCs for the outer and inner layers.

The second MCC in Table 2.3 involves $g_{ZrO_2} + g_{SnO_2}$, which includes the two components most effective at reducing the VHT response of the experimental glasses. Too small a value in a LAW glass is undesirable because the VHT response will become unmeasurable, while too large a value is undesirable because these components will not fully dissolve in the glass. Table 2.3 lists the lower and upper bounds of the $g_{ZrO_2} + g_{SnO_2}$ MCCs for the outer and inner layers.

The third MCC in Table 2.3 involves the viscosity of a LAW glass at 1150°C, which is denoted η_{1150}. This MCC was implemented using the linear mixture model

$$\begin{aligned}\ln(\eta_{1150}) = {} & 19.4927(g_{Al_2O_3}) - 8.7644(g_{B_2O_3}) - 2.4344(g_{CaO}) - 5.8891(g_{Fe_2O_3}) \\ & - 6.6993(g_{K_2O}) - 35.8273(g_{Li_2O}) - 4.7596(g_{MgO}) - 6.2100(g_{Na_2O}) \\ & + 6.9686(g_{SiO_2}) + 4.2472(g_{SO_3}) + 32.8921(g_{SnO_2}) + 58.1746(g_{V_2O_5}) \\ & - 0.7173(g_{ZnO}) + 18.5684(g_{ZrO_2}) - 11.9363(g_{Others1})\end{aligned} \tag{2}$$

that was fitted to ln(η_{1150}) values for 281 LAW glasses from previous studies (see Appendix B). The model has $R^2 = 0.984$, which is the fraction of variation in the dependent variable accounted for by the model. Using a linear mixture model allows the associated MCC to be linear, while the R^2 value is large enough for the MCC based on the model to serve its purpose. Having η_{1150} a little outside its outer-layer lower and upper limits for some test glasses as a result of model uncertainty is acceptable. Because the model in Equation (2) is for ln(η_{1150}), the natural logarithms of the lower and upper bounds on η_{1150} in Table 2.3 were used in implementing the outer- and inner-layer constraints. Glasses with η_{1150} outside the range of 10 to 100 P cannot be efficiently processed in the WTP and therefore those values were used as the bounds for the outer layer. The target WTP operating viscosity is 50 P at 1150°C, so the inner-layer bounds were set to the target value ±20 P. Finally, note that the $\ln(\eta_{1150})$ model was subsequently modified slightly as documented in Appendix B, but the version in Equation (2) is the one that was used to specify the outer- and inner-layer MCCs on η_{1150}.

The fourth MCC in Table 2.3 (SO_3 Solubility) requires that the mass fraction of the SO_3 component (g_{SO_3}) of every glass in the LAW glass composition region (and experimental design) be no greater than a model-predicted SO_3 solubility limit. It is understood that model prediction uncertainty will cause some of the glasses to have a separated sulfate salt on the melt surface. However, this is useful information, and adjustments can be made for this separated salt by further analyses. The SO_3 solubility limit for a given glass composition was predicted using the following model from Vienna et al. (2014):

$$\begin{aligned} SL_{SO_3} = & -2.091901(x_{Al_2O_3}) + 3.0440748(x_{B_2O_3}) + 4.4422886(x_{CaO}) - 22.65353(x_{Cl}) \\ & -13.14139(x_{Cr_2O_3}) + 0.615785(x_{K_2O}) + 2.4739255(x_{Li_2O}) + 2.8972089(x_{Na_2O}) \\ & +4.606083(x_{P_2O_5}) + 0.2407285(x_{SiO_2}) - 1.775325(x_{SnO_2}) + 7.5345478(x_{V_2O_5}) \\ & -1.871916(x_{ZrO_2}) - 0.280272(x_{Others2}) + 260.20302(x_{Li_2O})^2 \end{aligned} \quad (3)$$

where SL_{SO_3} denotes the predicted SO_3 solubility limit in weight percent (wt%) and x_i denotes components in that mixture other than SO_3. The x_i can be expressed as the mass fraction of the i^{th} component in the LAW glass relative to the total mass fraction of all other components:

$$x_i = \frac{g_i}{\sum_{i \neq SO_3} g_i} = \frac{g_i}{1 - g_{SO_3}}, \quad i \neq SO_3 \quad (4)$$

where g_i (i = Al_2O_3, …, Others1) are the mass fractions of the 15 LAW glass components listed in Table 2.1 (including SO_3). Hence, the fourth MCC in Table 2.3 is expressed as

$$g_{SO_3} \leq \frac{SL_{SO_3}}{100}. \quad (5)$$

Appendix C shows the derivation of the final form of the MCC after substituting Equations (3) and (4) into Equation (5) and rewriting the expression in terms of the mass fractions of the 15 components in Table 2.1 (see Appendix C). The final form of the nonlinear MCC can be written as

$$\sum_{i=1}^{15} c_i g_i + b\left(\frac{g_{Li_2O}^2}{1-g_{SO_3}}\right) + 100(g_{SO_3}^2) \geq 0 \ , \qquad (6)$$

where the c_i (i = 1, 2, …, 15) and b are the coefficients listed in Equation (C.5) of Appendix C. It is seen in Equation (6) that the fourth MCC is not a linear function of the components listed in Table 2.1, because of having squared terms involving g_{Li_2O} and g_{SO_3}.

4.0 Modifying an Existing Algorithm to Account for a Nonlinear Multiple-Component Constraint

The details of how the LD was constructed for the LAW glass example are discussed in the subsequent section. It is sufficient at this point to say that an optimal experimental design approach that used a point-exchange algorithm with a set of candidate points was used to construct the design (Atkinson et al. 2007). Existing commercial software packages can do this, but require that MCCs be written as linear combinations of the mixture components. Hence, existing software could not be used because of the two nonlinear (i.e., squared) terms in the fourth MCC, as seen in Equations (6) and (C.5).

To address this problem, the MCCVRT algorithm in the MIXSOFT software (Piepel 2014) was modified to calculate the vertices of the outer- and inner-layer mixture regions defined by the one nonlinear MCC and three linear MCCs in Table 2.3, as well as the SCCs in Table 2.1. The MCCVRT algorithm (which is based on the CONVRT algorithm discussed by Piepel 1988) starts with a mixture simplex and applies each SCC and linear MCC in turn. As each new constraint is applied (Step *i*), the vertices from Step $i-1$ that are eliminated by the new constraint are identified. For each eliminated vertex (denoted A), other vertices (denoted B) still satisfying the new constraint are found such that the A and B vertices form an edge of the constrained mixture experiment region at Step $i-1$. Then, the intersection of the new constraint in Step *i* with each such edge is calculated. Hence, each eliminated vertex at Step *i* has the opportunity to be "replaced" by one or more new vertices that satisfy all of the constraints applied up to Step *i*. At the end of Step *i*, all of the vertices for the constraints applied through that step are obtained. This process continues in the MCCVRT routine until all of the SCCs and linear MCCs have been processed. In the modified MCCVRT, the nonlinear MCC was treated as the last MCC.

The calculation to find the mixture for which the new constraint at Step *i* intersects with an edge (as described above) is very simple when constraints (SCC or MCC) are linear combinations of the mixture components. However, the calculation is more complicated for a MCC of the form in Equations (6) and (A.5), since the nonlinear MCC is a nonlinear surface whereas a linear MCC is a hyperplane. The calculations would be still more complicated if there were more than one nonlinear MCC. However, the LAW glass example involves only one nonlinear MCC, so MCCVRT was modified to address that situation. To simplify matters, the nonlinear MCC in Equation (C.5) was applied as the last MCC, after applying all SCCs and all linear MCCs.

The formula for an edge connecting a vertex A outside the nonlinear MCC $[\mathbf{g_A} = (g_{A1}, g_{A2}, \ldots, g_{Aq})]$ to a vertex B inside the nonlinear MCC $[\mathbf{g_B} = (g_{B1}, g_{B2}, \ldots, g_{Bq})]$ is given by

$$g_i = \alpha\, g_{Ai} + (1-\alpha) g_{Bi} = \alpha (g_{Ai} - g_{Bi}) + g_{Bi} \; . \tag{7}$$

The equation for the intersection between an edge expressed via Equation (7) and the nonlinear MCC represented by Equations (6) and (C.5) is derived in Appendix D, and is listed as Equation (D.4). The intersection for a given $\mathbf{g_A}$ and $\mathbf{g_B}$ (which determines a new vertex at Step *i*) is obtained by solving Equation (D.4) for the corresponding value of α. Note that Equation (D.4) is a quadratic equation in α except for the last term associated with the $(Li_2O)^2$ term in the model for SL_{SO_3}. Hence, α could not be solved for explicitly and it was necessary to use a "root finding" algorithm. After the solution α was obtained in this way for a given pair of $\mathbf{g_A}$ and $\mathbf{g_B}$, the values of α, $\mathbf{g_A}$, and $\mathbf{g_B}$ were substituted into (7) to calculate the corresponding new vertex at Step *i*.

5.0 Constructing the Layered Design

Considering the experimental budget and goals of the work, the coauthors (statisticians and materials scientists) concluded that the LD should consist of 18 outer-layer glasses, 13 inner-layer glasses, a glass of interest tested by the Vitreous State Laboratory (VSL) at the Catholic University of America, and one center glass. There were 147 existing glasses with experimental data for the glass properties of interest that fell within the LAW glass composition experimental region defined by the outer-layer SCCs in Table 2.1 and the MCCs in Table 2.3. Table E.1 in Appendix E lists the 147 LAW glass compositions in terms of the mass fractions of the 15 LAW glass components in Table 2.1. Table E.2 lists the names of the glasses, for which there was not room in Table E.1. It was decided to select the outer-layer and inner-layer glasses of the LD to augment the 147 existing glasses, because both the existing and new data will be used in the future to develop glass property-composition models. Finally, it was decided to replicate the VSL and center glasses. Typically, a few additional glasses would be replicated as well, but the set of existing glasses includes several replicates. Also, additional stages of the study in subsequent years will include replicates of the center point and other points. The steps used in generating the LD are described following.

Step 1, Select the 18 Outer-Layer Points: The modified MCCVRT routine was run to generate the 148,630 vertices on the outer layer of the LAW glass region defined by the SCCs, linear MCCs, and nonlinear MCC given in Tables 2.1 and 2.3. It is interesting that of these outer-layer vertices, ~50% lie on the nonlinear MCC (SO_3 solubility constraint) for the outer layer. Next, a point-exchange, optimal-design algorithm in the ACED software (Welch 1984, 1987) was run to augment the 147 existing glasses with 18 outer-layer points from the candidate set of 148,630 outer-layer vertices. A linear mixture experiment model

$$E(y) = \sum_{i=1}^{15} \beta_i x_i \quad (i = \mathrm{Al_2O_3}, \ldots, \mathrm{Others1}) \tag{8}$$

was used as the basis for selecting the outer-layer (and subsequently the inner-layer) points, which has been found to work well when LDs are used. ACED was used to complete 20 "tries" of selecting 18 outer-layer points using each of the D-, G-, and I-optimality criteria (although Welch uses different abbreviations for these criteria), so that 60 sets of 18 outer-layer points were generated. All 60 sets of 18 outer-layer points were unique. Measures of D-, G-, I-, and A-efficiencies of the designs (147 existing plus 18 outer-layer points) included in the ACED output were assessed to identify four sets of 18 outer-layer points that had optimal or near-optimal values of all four efficiencies. As a basis for choosing one of the four sets of 18 outer-layer points, the distributions of the values of the (i) 15 LAW glass components and (ii) predicted values of several properties (obtained using models developed during previous work) were assessed graphically. Such plots are illustrated subsequently in Step 2. The chosen set of 18 outer-layer glasses is listed in Table 5.1.

Step 2, Select the 13 Inner-Layer Points: The modified MCCVRT routine was run to generate the 174,242 vertices on the inner layer of the LAW glass region defined by the SCCs, linear MCCs, and nonlinear MCC given in Tables 2.1 and 2.3. It is interesting that of these inner-layer vertices, ~46% lie on the nonlinear MCC (SO_3 solubility constraint) for the inner layer. Next, the ACED software (Welch 1984, 1987) was run to augment the 147 existing glasses plus 18 outer-layer points (selected in Step 1) with 13 inner-layer points from the candidate set of 174,242 inner-layer vertices. ACED was used to complete 20 "tries" of selecting 13 inner-layer points using each of the D-, G-, and I-optimality criteria, so that 60 sets of 13 inner-layer points were generated (although not all sets were unique). Measures of D-, G-, I-, and A-efficiencies of the designs (147 existing + 18 outer-layer + 13 inner-layer points) included in the ACED output were assessed to identify four sets of 13 inner-layer points that had optimal or near-optimal values of all four efficiencies. As a basis for choosing one of the four sets of 13 inner-layer points, the distributions of the values of the (i) 15 LAW glass components and (ii) predicted values of several properties (obtained using models developed during previous work) were assessed graphically. Figure 5.1 illustrates these types of plots for Na_2O (the major component of LAW) and a glass durability property (referred to as PCT-Li release). The y-axis (Index) is used to spread out the values for the four sets of glasses so they can be differentiated. Although not illustrated here, other plots were used to assess the distributions of components and predicted property values for the four sets of 13 inner-layer points relative to the distributions of the values for the existing 147 LAW glasses, the 18 outer-layer glasses selected in Step 1, and the other two glasses listed in Table 5.1. The chosen set of 13 inner-layer glasses is listed in Table 5.1.

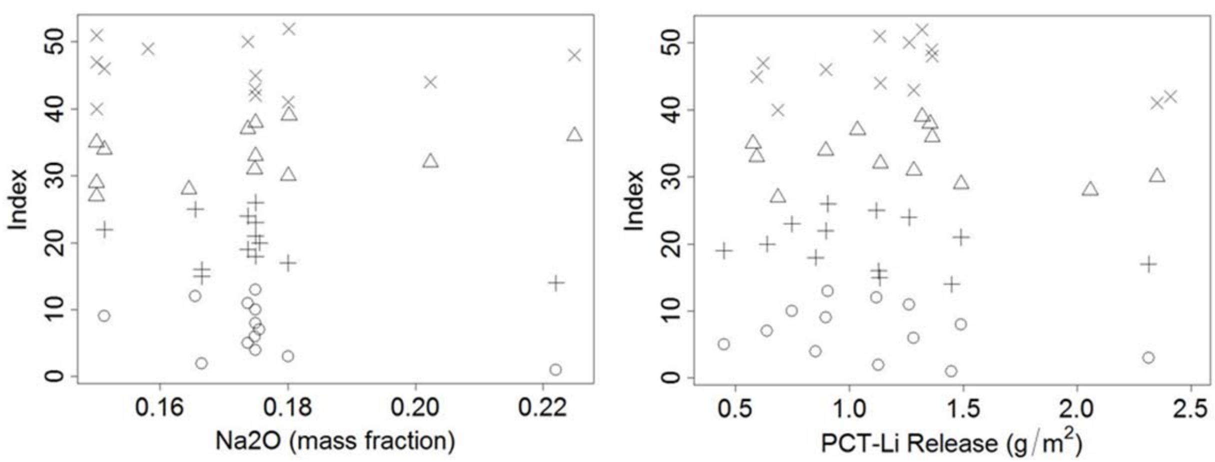

Figure 5.1. Distributions of Values for (a) Na_2O and (b) PCT-Li Release for Four Possible Sets (the four plotting symbols) of the 13 Inner-Layer LAW Glass Compositions. The triangles represent the chosen set.

Table 5.1. Compositions of the Layered Design for LAW Glasses

LAW Glass		Component														
#	Point[(a)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
1	OL-01	0.1240	0.1375	0.1224	0.0000	0.0150	0.0201	0.0350	0.1000	0.3400	0.0010	0.0000	0.0000	0.0100	0.0650	0.0300
2	OL-02	0.1385	0.0600	0.0004	0.0150	0.0150	0.0201	0.0350	0.1000	0.4700	0.0010	0.0000	0.0000	0.0500	0.0650	0.0300
3	OL-03	0.0350	0.0615	0.1224	0.0000	0.0150	0.0500	0.0350	0.1551	0.3400	0.0010	0.0000	0.0400	0.0500	0.0650	0.0300
4	OL-04	0.0350	0.0600	0.1224	0.0000	0.0150	0.0000	0.0350	0.2551	0.3925	0.0010	0.0300	0.0400	0.0100	0.0000	0.0040
5	OL-05	0.0350	0.1375	0.0165	0.0150	0.0000	0.0500	0.0000	0.1650	0.4700	0.0010	0.0300	0.0400	0.0100	0.0000	0.0300
6	OL-06	0.1385	0.0600	0.1224	0.0150	0.0000	0.0500	0.0000	0.1140	0.3400	0.0010	0.0500	0.0291	0.0500	0.0000	0.0300
7	OL-07	0.0350	0.0600	0.1117	0.0150	0.0000	0.0000	0.0350	0.1500	0.4700	0.0010	0.0500	0.0183	0.0500	0.0000	0.0040
8	OL-08	0.0350	0.1375	0.0298	0.0000	0.0150	0.0000	0.0000	0.1401	0.4700	0.0010	0.0000	0.0400	0.0500	0.0516	0.0300
9	OL-09	0.0350	0.1375	0.1224	0.0150	0.0150	0.0000	0.0000	0.1401	0.3400	0.0010	0.0450	0.0266	0.0500	0.0650	0.0074
10	OL-10	0.1385	0.0890	0.1224	0.0000	0.0000	0.0250	0.0350	0.1000	0.3400	0.0010	0.0441	0.0000	0.0100	0.0650	0.0300
11	OL-11	0.1385	0.1305	0.0000	0.0000	0.0000	0.0500	0.0350	0.1650	0.3400	0.0010	0.0500	0.0360	0.0500	0.0000	0.0040
12	OL-12	0.0350	0.1375	0.0000	0.0150	0.0150	0.0500	0.0350	0.1510	0.3400	0.0175	0.0450	0.0400	0.0500	0.0650	0.0040
13	OL-13	0.1385	0.1375	0.0000	0.0000	0.0150	0.0500	0.0350	0.1551	0.3425	0.0164	0.0300	0.0400	0.0100	0.0000	0.0300
14	OL-14	0.0350	0.0600	0.0189	0.0000	0.0000	0.0000	0.0350	0.2600	0.4700	0.0091	0.0320	0.0000	0.0500	0.0000	0.0300
15	OL-15	0.1195	0.0600	0.1000	0.0150	0.0150	0.0500	0.0000	0.1551	0.3400	0.0154	0.0500	0.0000	0.0500	0.0000	0.0300
16	OL-16	0.0350	0.0600	0.1224	0.0150	0.0000	0.0500	0.0350	0.1619	0.3400	0.0182	0.0450	0.0125	0.0100	0.0650	0.0300
17	OL-17	0.0350	0.0600	0.1224	0.0150	0.0150	0.0000	0.0000	0.1860	0.4417	0.0149	0.0300	0.0400	0.0100	0.0000	0.0300
18	OL-18	0.1344	0.1375	0.0030	0.0150	0.0150	0.0201	0.0350	0.1000	0.4700	0.0060	0.0500	0.0000	0.0100	0.0000	0.0040
19	IL-01	0.0625	0.0800	0.0900	0.0125	0.0020	0.0350	0.0250	0.1500	0.4315	0.0040	0.0350	0.0300	0.0200	0.0150	0.0075
20	IL-02	0.0625	0.1175	0.0275	0.0125	0.0100	0.0350	0.0050	0.1645	0.4325	0.0130	0.0350	0.0300	0.0200	0.0150	0.0200
21	IL-03	0.0625	0.1175	0.0275	0.0125	0.0020	0.0350	0.0250	0.1500	0.3975	0.0130	0.0350	0.0300	0.0400	0.0450	0.0075
22	IL-04	0.0625	0.1175	0.0275	0.0125	0.0020	0.0350	0.0250	0.1800	0.3675	0.0130	0.0350	0.0300	0.0400	0.0450	0.0075
23	IL-05	0.0625	0.1175	0.0275	0.0125	0.0020	0.0350	0.0250	0.1748	0.4242	0.0040	0.0100	0.0300	0.0200	0.0475	0.0075
24	IL-06	0.0625	0.0800	0.0900	0.0125	0.0100	0.0100	0.0250	0.2023	0.3872	0.0130	0.0350	0.0300	0.0200	0.0150	0.0075

Table 5.1. Compositions of the Layered Design for LAW Glasses (contd)

LAW Glass		Components														
#	Point(a)	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
25	IL-07	0.1150	0.0800	0.0900	0.0125	0.0100	0.0350	0.0050	0.1749	0.3741	0.0040	0.0270	0.0300	0.0200	0.0150	0.0075
26	IL-08	0.1150	0.1175	0.0275	0.0125	0.0100	0.0350	0.0050	0.1512	0.4325	0.0113	0.0350	0.0050	0.0200	0.0150	0.0075
27	IL-09	0.1150	0.0800	0.0353	0.0125	0.0020	0.0350	0.0250	0.1500	0.4325	0.0102	0.0350	0.0050	0.0400	0.0150	0.0075
28	IL-10	0.0625	0.0800	0.0275	0.0125	0.0100	0.0100	0.0250	0.2249	0.4184	0.0117	0.0250	0.0300	0.0400	0.0150	0.0075
29	IL-11	0.0625	0.0974	0.0900	0.0125	0.0020	0.0100	0.0250	0.1737	0.3939	0.0130	0.0350	0.0300	0.0200	0.0150	0.0200
30	IL-12	0.1125	0.1022	0.0275	0.0125	0.0100	0.0350	0.0050	0.1749	0.3675	0.0129	0.0350	0.0300	0.0400	0.0150	0.0200
31	IL-13	0.1150	0.0931	0.0275	0.0050	0.0020	0.0350	0.0250	0.1802	0.3675	0.0127	0.0320	0.0300	0.0400	0.0150	0.0200
32	Center	0.0900	0.1000	0.0550	0.0100	0.0040	0.0200	0.0150	0.1900	0.3955	0.0070	0.0200	0.0200	0.0300	0.0300	0.0135
33	Other Lab	0.1015	0.1204	0.0801	0.0100	0.0016	0.0000	0.0100	0.2098	0.3714	0.0106	0.0000	0.0100	0.0300	0.0300	0.0146(b)
34	Rep #32	0.0900	0.1000	0.0550	0.0100	0.0040	0.0200	0.0150	0.1900	0.3955	0.0070	0.0200	0.0200	0.0300	0.0300	0.0135
35	Rep #34	0.1015	0.1204	0.0801	0.0100	0.0016	0.0000	0.0100	0.2098	0.3714	0.0106	0.0000	0.0100	0.0300	0.0300	0.0146(b)

(a) OL = outer layer, IL = inner layer
(b) This glass has a different number and mixture of Other components than Others1 shown in Table 2.2.

Step 3, Select Other Design Points: As noted previously, the LD also contained a center-point glass composition, a glass tested at VSL, and a replicate of each of these two glasses. The center point was selected to be near the middle of both the outer- and inner-layer regions. The only exception was to select g_{Li_2O} = 0.02 even though the average points of the outer- and inner-layer regions have g_{Li_2O} = 0.025 and 0.0225, respectively. The 0.02 concentration moved the center point closer to the median value for the experimental glasses used to determine the Li_2O range and to the expected distribution of glasses from plant operation. The center-point and VSL glasses are listed in Table 5.1.

Figure 5.2 displays a scatterplot matrix of the 147 existing, 18 outer-layer, 13 inner-layer, center-point, and VSL glasses. This figure shows that the new glasses in the LD, along with the 147 existing glass compositions, cover reasonably well the boundary and interior of the constrained LAW glass composition region defined by the outer-layer SCCs and MCCs in Tables 2.1 and 2.3. The Na_2O-SO_3 plot, and to a lesser extent the SiO_2-SO_3 plot, show no new glasses in the upper right portions of the plots, which occurs because of the SO_3-solubility constraint.

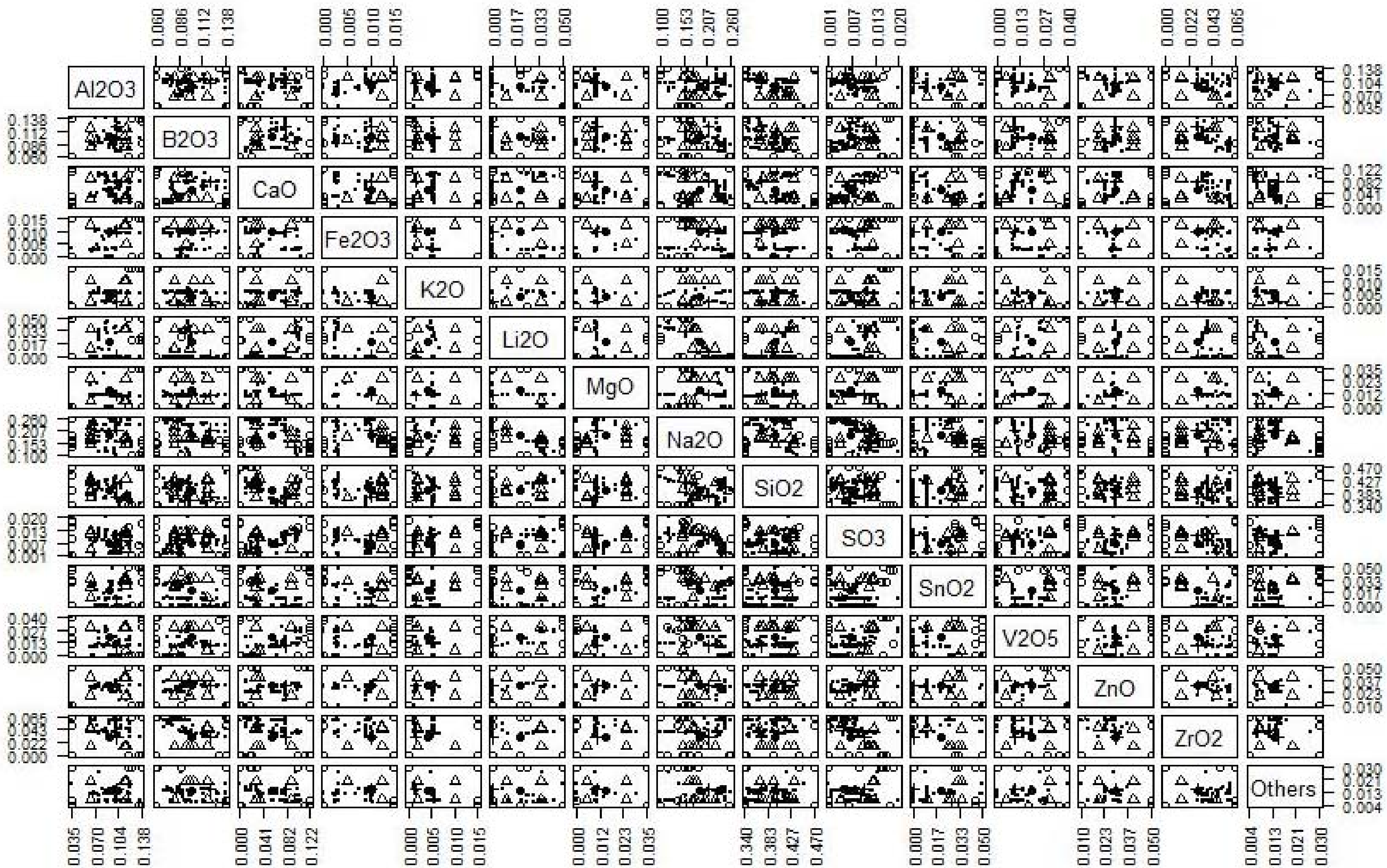

Figure 5.2. Scatterplot Matrix Display of How Well the Layered Design and Existing Glass Compositions Cover the LAW Glass Composition Region. The plotting symbols are "·" for the 147 existing glasses, "•" for the centroid composition, "+" for the VSL glass, "○" for the 18 outer-layer glasses, and "Δ" for the 13 inner-layer glasses.

6.0 Summary and Discussion

This report discusses the construction of a LD for a 15-component mixture experiment problem involving immobilizing LAW in glass. A LD was constructed to obtain glass compositions on a "bold" outer layer and "reasonable" inner layer. This approach was chosen to support developing glass property-composition models and ultimately identify the subregion of glasses containing as much LAW as possible that meets all requirements after accounting for model and other uncertainties. The outer and inner layers were specified using SCCs, linear MCCs, and one nonlinear MCC. Existing algorithms and software for designing experiments for a constrained region involving mixture components (and/or non-mixture variables) do not allow for nonlinear MCCs, so modifications were necessary.

To generate the LD, first the vertices of the outer and inner layers of the LAW glass experimental region were generated using a modified MCCVRT algorithm to account for the nonlinear MCC in addition to the SCCs and linear MCCs. Then, the ACED software (Welch 1984, 1987) was used to augment 147 existing glass compositions (in the outer-layer constrained region) with 18 outer-layer glasses and 13 inner-layer glasses. A center glass and a glass from another lab were also included in the experimental design. ACED was used to generate 20 possible sets of 18 outer-layer glasses, and subsequently 20 possible sets of 13 inner-layer glasses for each of three optimality criteria (D-, I-, and G-optimality). Efficiency values corresponding to these optimality criteria were considered simultaneously to select four of the possible 60 sets for each of 18 outer-layer and 13 inner-layer glasses. Then, graphical and analytical methods were used to compare the four sets of outer-layer glasses, and subsequently the four sets of inner-layer glasses, by assessing the distributions of values of the 15 LAW glass components and several glass properties predicted using models available from previous studies. Glass scientists and statisticians collaborated to choose one of the four sets of 18 outer-layer glasses and one of the four sets of 13 inner-layer glasses for the final experimental design.

It is unfortunate that most commercial optimal-design software only generates a single experimental design at a time. Some software will generate different designs if the software is rerun additional times (because of different random starts). However, such software provides no easy way to compare the optimality statistics for the multiple resulting designs. We used the ACED software because it (i) can generate D-, I-, and G-optimal designs for as many "tries" as desired and (ii) outputs summary tables of several optimality statistics that provide for easily comparing optimality statistics over all the "tries." Over many years we have found it very useful to down-select many possible optimal or near-optimal mixture experiment designs to a small number (2 to 4), with statisticians and discipline scientists then comparing the small number of candidate designs in other ways to select the final design.

Finally, the question arises about what to do if there are two or more nonlinear SCCs or MCCs. Modifying the MCCVRT algorithm to account for that situation would require deriving much more complicated equations and more complicated computational methods to generate the vertices of a constrained region (e.g., outer layer or inner layer) involving mixture components (and/or non-mixture variables). Rather than doing that and using the *point-exchange algorithm* (Atkinson et al. 2007), it would be preferable to modify existing software to enable specifying one or more nonlinear SCCs and/or MCCs in addition to any linear SCCs and MCCs, and then use a *coordinate-exchange algorithm* (Meyer and Nachtsheim 1995; Piepel et al. 2005; Atkinson et al. 2007). Coordinate-exchange algorithms do not require first generating candidate points to construct an optimal experimental design. However, having nonlinear SCCs and/or MCCs will likely require modifications to existing coordinate-exchange algorithms. Such modifications may be less complicated than those required for the MCCVRT algorithm.

The LD approach to constructing an experimental design could still be used with a coordinate-exchange algorithm that accounts for nonlinear SCCs and/or MCCs. A *space-filling design* (SFD) or *uniform design* (UD) is an alternative to a LD that would include points throughout the constrained experimental region. However, existing algorithms for SFDs or UDs will likely need modifications to account for nonlinear SCCs and/or MCCs in addition to linear SCCs and MCCs. Also, depending on the specifics of a problem, algorithms for SFDs and UDs over irregular constrained regions can place most if not all design points on or near the boundary of the experimental region as the number of design variables increases. This can occur even with as few as five or six design variables (Borkowski and Piepel 2009). This is a larger problem than whether SCCs and MCCs are linear or nonlinear, and hence needs future research.

In conclusion, the approach proposed in this article is a good one when the experimental region is specified by one nonlinear MCC in addition to linear SCCs and MCCs and it is desired to have some points on the boundary of the region and some on the interior. We recommend using the described methods to down-select many possible optimal or near-optimal designs to a few, and then comparing the few designs to select the final design. Additional research is needed to address problems with two or more nonlinear SCCs and/or MCCs.

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Appendix A

Development of the Single-Component Constraints

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Development of the Single-Component Constraints

This appendix describes the processes used to select the single-component constraints (SCCs) for the outer and inner layers of the low-activity waste (LAW) glass composition experimental region used to construct a layered design.

A set of experiments was performed to determine the maximum waste loading of a series of representative LAW compositions in borosilicate glasses while still meeting a set of minimum property requirements (Muller et al. 2012). The data from the experimental program were analyzed to determine the key variables that limit waste loading. The key variables were the alkali content of the waste ($w_{ALK} = w_{Na_2O} + 0.66\ w_{K_2O}$) and the sulfur trioxide concentration (w_{SO_3}), where w_i represents the mass fraction of the i^{th} oxide (or oxide group) in the waste. The initial set of SCC bounds was based on the ranges of component concentrations from the experimental glasses used to define the maximum waste loading as a function of w_{ALK} and w_{SO_3} including glasses that (i) met all property requirements and (ii) failed one or more requirements.

A few changes were made to the preliminary outer-layer SCCs based on the experimental results and revisions to the Hanford Tank Waste Treatment and Immobilization Plant (WTP) operating strategy.[a] Fourteen percent of the experimental glasses contained $g_{Fe_2O_3}$ > 0.015, but the WTP no longer plans to add Fe_2O_3 as a glass former. Hence, the $g_{Fe_2O_3}$ limits of 0 to 0.015 were selected to span the range of Fe_2O_3 that may come from waste. High K_2O concentration glasses were investigated (0.015 < g_{K_2O} < 0.0575) but less than 5% of the waste will generate glasses with K_2O concentrations that high. Further, such waste is currently planned to be processed by the WTP in the first year of operation. Hence, the g_{K_2O} limits of 0 to 0.015 were used. All glasses tested with g_{MgO} > 0.035 and g_{Na_2O} > 0.15 failed to meet an important glass durability constraint (Vapor Hydration Test response). Because MgO is a controllable additive, it can be limited to a maximum of 0.035. Less than 5% of the test glasses contained g_{Na_2O} > 0.10 and concentrations that high are sufficiently far from the glasses of interest at Hanford that they need not be considered. Hence, a limit of $g_{Na_2O} \leq 0.10$ was set. Fourteen percent of the experimental glasses contained TiO_2, but WTP no longer plans to add TiO_2 as an additive and it is not in LAW in measureable concentrations. Hence, TiO_2 was not included as a component to be varied in the experimental design. The outer-layer SCCs after these changes are listed in Table 2.1.

[a] In the discussion that follows, g_i represents the mass fraction of the i^{th} LAW glass component.

The lower and upper bounds for the inner-layer SCCs were taken to be in the middle of the ranges between the center point and the lower and upper bounds for the outer-layer SCCs (with rounding of mass fractions to 0.0025 for minor components and 0.005 for major components).

Appendix B

Data and Linear Mixture Model for Viscosity at 1150ºC of Low-Activity Waste Glasses

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Data and Linear Mixture Model for Viscosity at 1150ºC of Low-Activity Waste Glasses

Section B.1 discusses the glass compositions and viscosity property data used to develop a linear mixture model for viscosity at 1150ºC. Section B.2 presents an updated linear mixture model for viscosity at 1150ºC that was developed subsequent to the generation of the experimental design discussed in this report.

B.1 Data Used to Develop the Linear Mixture Model for Viscosity at 1150ºC of Low-Activity Waste Glasses

Table B.1 lists for each of the 281 glasses used to develop the viscosity model the (i) names of the glasses, (ii) the names of the studies in which the glasses were tested, and (iii) references for the studies. Table B.2 lists the oxide compositions of the glasses. Table B.3 lists the viscosity at 1150°C values as well as the first seven (when that many exist) temperature-viscosity pairs (T_i, η_i, $i = 1, 2, \ldots, 7$) obtained from experimentally measuring viscosity at various temperatures. Table B.4 lists the remaining temperature-viscosity pairs (T_i, η_i, $i = 8, 9, 10, 11$) when that many pairs exist.

The viscosity at 1150°C value (η_{1150}) for each of the 281 LAW glasses was obtained as follows. First, all of the (T_i, η_i) pairs for the i^{th} glass ($i = 1, 2, \ldots, 281$) were used to fit the Vogel-Fulcher-Tammann equation

$$\log(\eta) = A + \frac{B}{T - T_0} \qquad \text{(B.1)}$$

where T is temperature in K, and A, B, and T_0 are the fitted coefficients using ordinary least squares regression. Then, $T = 1423.15$ K corresponding to 1150°C was substituted into each fitted equation to calculate the $\log(\eta_{1150})$ and hence η_{1150} values for each LAW glass.

B.2 Updated Linear Mixture Model for Viscosity at 1150ºC of Low-Activity Waste Glasses

Subsequent to the use of the linear mixture model for viscosity of low-activity waste glasses at 1150°C listed in Equation (2) to develop the experimental design, a minor error in the model fitting process was found and corrected. The revised coefficients

$$
\begin{aligned}
\ln(\eta_{1150}) = {} & 19.4941(g_{Al_2O_3}) \; - 8.7662(g_{B_2O_3}) \; - 2.4337(g_{CaO}) \; - 5.8848(g_{Fe_2O_3}) \\
& - 6.6987(g_{K_2O}) \; - 35.8198(g_{Li_2O}) \; - 4.7447(g_{MgO}) \; - 6.2078(g_{Na_2O}) \\
& + 6.9677(g_{SiO_2}) + 4.2701(g_{SO_3}) + 32.8907(g_{SnO_2}) + 58.1617(g_{V_2O_5}) \\
& - 0.7274(g_{ZnO}) + 18.5704(g_{ZrO_2}) - 11.9474(g_{Others1})
\end{aligned}
\tag{B.2}
$$

are only slightly different from the coefficients of the model in Equation (2). The above model has $R^2 = 0.984$. Predictions of η_{1150} for the glass compositions in the experimental design in Table 5.1 were compared using both Equations (2) and (B.2), and the largest relative difference was a very small fraction of a percent. Hence, it was concluded there was no substantive impact from using Equation (2) to implement the multiple-component constraints on η_{1150} compared to using Equation (B.2).

Table B.1. Glass Names, Study Names, and References for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row #	Glass Name	Glass Study	Reference
1	LAWA171	ORP Advanced Glass Formulation	Muller et al. 2012
2	LAWA172	ORP Advanced Glass Formulation	Muller et al. 2012
3	LAWA173	ORP Advanced Glass Formulation	Muller et al. 2012
4	LAWA174	ORP Advanced Glass Formulation	Muller et al. 2012
5	LAWA175	ORP Advanced Glass Formulation	Muller et al. 2012
6	LAWA176	ORP Advanced Glass Formulation	Muller et al. 2012
7	LAWA179	ORP Advanced Glass Formulation	Muller et al. 2012
8	LAWA180	ORP Advanced Glass Formulation	Muller et al. 2012
9	LAWA183	ORP Advanced Glass Formulation	Muller et al. 2012
10	LAWA184	ORP Advanced Glass Formulation	Muller et al. 2012
11	LAWA185	ORP Advanced Glass Formulation	Muller et al. 2012
12	LAWA186	ORP Advanced Glass Formulation	Muller et al. 2012
13	LAWA187	ORP Advanced Glass Formulation	Muller et al. 2012
14	LAWA188	ORP Advanced Glass Formulation	Muller et al. 2012
15	LAWA189	ORP Advanced Glass Formulation	Muller et al. 2012
16	LAWA190	ORP Advanced Glass Formulation	Muller et al. 2012
17	LAWA191	ORP Advanced Glass Formulation	Muller et al. 2012
18	LAWA192	ORP Advanced Glass Formulation	Muller et al. 2012
19	LAWA193	ORP Advanced Glass Formulation	Muller et al. 2012
20	LAWA194	ORP Advanced Glass Formulation	Muller et al. 2012
21	LAWA195	ORP Advanced Glass Formulation	Muller et al. 2012
22	LAWA196	ORP Advanced Glass Formulation	Muller et al. 2012
23	LAWA197	ORP Advanced Glass Formulation	Muller et al. 2012
24	LAWB100	ORP Advanced Glass Formulation	Muller et al. 2012
25	LAWB101	ORP Advanced Glass Formulation	Muller et al. 2012
26	LAWB102	ORP Advanced Glass Formulation	Muller et al. 2012
27	LAWB103	ORP Advanced Glass Formulation	Muller et al. 2012
28	LAWB105	ORP Advanced Glass Formulation	Muller et al. 2012
29	LAWB97	ORP Advanced Glass Formulation	Muller et al. 2012
30	LAWB98	ORP Advanced Glass Formulation	Muller et al. 2012
31	LAWB99	ORP Advanced Glass Formulation	Muller et al. 2012
32	LAWC100R1	ORP Advanced Glass Formulation	Muller et al. 2012
33	LAWC101	ORP Advanced Glass Formulation	Muller et al. 2012
34	LAWC102	ORP Advanced Glass Formulation	Muller et al. 2012
35	LAWC103	ORP Advanced Glass Formulation	Muller et al. 2012
36	ORPLA1	ORP Advanced Glass Formulation	Muller et al. 2012
37	ORPLA2	ORP Advanced Glass Formulation	Muller et al. 2012

Table B.1. Glass Names, Study Names, and References for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #	Glass Name	Glass Study	Reference
38	ORPLA3	ORP Advanced Glass Formulation	Muller et al. 2012
39	ORPLA5	ORP Advanced Glass Formulation	Muller et al. 2012
40	ORPLA6	ORP Advanced Glass Formulation	Muller et al. 2012
41	ORPLA7	ORP Advanced Glass Formulation	Muller et al. 2012
42	ORPLA9	ORP Advanced Glass Formulation	Muller et al. 2012
43	ORPLA10	ORP Advanced Glass Formulation	Muller et al. 2012
44	ORPLA11	ORP Advanced Glass Formulation	Muller et al. 2012
45	ORPLA12	ORP Advanced Glass Formulation	Muller et al. 2012
46	ORPLA13	ORP Advanced Glass Formulation	Muller et al. 2012
47	ORPLA14	ORP Advanced Glass Formulation	Muller et al. 2012
48	ORPLA15	ORP Advanced Glass Formulation	Muller et al. 2012
49	ORPLA16	ORP Advanced Glass Formulation	Muller et al. 2012
50	ORPLA17	ORP Advanced Glass Formulation	Muller et al. 2012
51	ORPLA18	ORP Advanced Glass Formulation	Muller et al. 2012
52	ORPLA19	ORP Advanced Glass Formulation	Muller et al. 2012
53	ORPLA20	ORP Advanced Glass Formulation	Muller et al. 2012
54	ORPLA33-1	ORP Advanced Glass Formulation	Muller et al. 2012
55	ORPLA38-1	ORP Advanced Glass Formulation	Muller et al. 2012
56	ORPLB1	ORP Advanced Glass Formulation	Muller et al. 2012
57	ORPLB2	ORP Advanced Glass Formulation	Muller et al. 2012
58	ORPLB3	ORP Advanced Glass Formulation	Muller et al. 2012
59	ORPLB4	ORP Advanced Glass Formulation	Muller et al. 2012
60	ORPLC2	ORP Advanced Glass Formulation	Muller et al. 2012
61	ORPLC5	ORP Advanced Glass Formulation	Muller et al. 2012
62	ORPLD1	ORP Advanced Glass Formulation	Muller et al. 2012
63	ORPLD4	ORP Advanced Glass Formulation	Muller et al. 2012
64	ORPLD5	ORP Advanced Glass Formulation	Muller et al. 2012
65	ORPLD6	ORP Advanced Glass Formulation	Muller et al. 2012
66	ORPLD7	ORP Advanced Glass Formulation	Muller et al. 2012
67	ORPLD8	ORP Advanced Glass Formulation	Muller et al. 2012
68	ORPLD9	ORP Advanced Glass Formulation	Muller et al. 2012
69	ORPLE1	ORP Advanced Glass Formulation	Muller et al. 2012
70	ORPLE2	ORP Advanced Glass Formulation	Muller et al. 2012
71	ORPLE3	ORP Advanced Glass Formulation	Muller et al. 2012
72	ORPLE4	ORP Advanced Glass Formulation	Muller et al. 2012
73	ORPLE5	ORP Advanced Glass Formulation	Muller et al. 2012
74	ORPLE6	ORP Advanced Glass Formulation	Muller et al. 2012
75	ORPLE7	ORP Advanced Glass Formulation	Muller et al. 2012
76	ORPLE8	ORP Advanced Glass Formulation	Muller et al. 2012
77	ORPLE9	ORP Advanced Glass Formulation	Muller et al. 2012
78	ORPLE10	ORP Advanced Glass Formulation	Muller et al. 2012

Table B.1. Glass Names, Study Names, and References for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #	Glass Name	Glass Study	Reference
79	ORPLE11	ORP Advanced Glass Formulation	Muller et al. 2012
80	ORPLE12	ORP Advanced Glass Formulation	Muller et al. 2012
81	ORPLF1	ORP Advanced Glass Formulation	Muller et al. 2012
82	ORPLF2	ORP Advanced Glass Formulation	Muller et al. 2012
83	ORPLF3	ORP Advanced Glass Formulation	Muller et al. 2012
84	ORPLF4	ORP Advanced Glass Formulation	Muller et al. 2012
85	ORPLF7	ORP Advanced Glass Formulation	Muller et al. 2012
86	ORPLF9	ORP Advanced Glass Formulation	Muller et al. 2012
87	ORPLF10	ORP Advanced Glass Formulation	Muller et al. 2012
88	ORPLF13	ORP Advanced Glass Formulation	Muller et al. 2012
89	ORPLF14	ORP Advanced Glass Formulation	Muller et al. 2012
90	WVY-G-95A-1	ORP Advanced Glass Formulation	Muller et al. 2012
91	L4-615	Hanford LLW Glass Formulation	Feng et al. 1996
92	L4-96	Hanford LLW Glass Formulation	Feng et al. 1996
93	L4-912	Hanford LLW Glass Formulation	Feng et al. 1996
94	L4-129	Hanford LLW Glass Formulation	Feng et al. 1996
95	L4-1215	Hanford LLW Glass Formulation	Feng et al. 1996
96	L5-96	Hanford LLW Glass Formulation	Feng et al. 1996
97	L5-129	Hanford LLW Glass Formulation	Feng et al. 1996
98	L5-1215	Hanford LLW Glass Formulation	Feng et al. 1996
99	L6-3312	Hanford LLW Glass Formulation	Feng et al. 1996
100	L6-546	Hanford LLW Glass Formulation	Feng et al. 1996
101	L6-549	Hanford LLW Glass Formulation	Feng et al. 1996
102	L6-5412	Hanford LLW Glass Formulation	Feng et al. 1996
103	L6-5415	Hanford LLW Glass Formulation	Feng et al. 1996
104	L6-669	Hanford LLW Glass Formulation	Feng et al. 1996
105	L6-6612	Hanford LLW Glass Formulation	Feng et al. 1996
106	L7-15	Hanford LLW Glass Formulation	Feng et al. 1996
107	L7-25	Hanford LLW Glass Formulation	Feng et al. 1996
108	L7-35	Hanford LLW Glass Formulation	Feng et al. 1996
109	L8-1	Hanford LLW Glass Formulation	Feng et al. 1996
110	L8-2	Hanford LLW Glass Formulation	Feng et al. 1996
111	L8-3	Hanford LLW Glass Formulation	Feng et al. 1996
112	L8-4	Hanford LLW Glass Formulation	Feng et al. 1996
113	L8-5	Hanford LLW Glass Formulation	Feng et al. 1996
114	L8-6	Hanford LLW Glass Formulation	Feng et al. 1996
115	L8-7	Hanford LLW Glass Formulation	Feng et al. 1996
116	L8-8	Hanford LLW Glass Formulation	Feng et al. 1996
117	LD4-912	Hanford LLW Glass Formulation	Feng et al. 1996
118	LD5-912	Hanford LLW Glass Formulation	Feng et al. 1996
119	LD6-5314	Hanford LLW Glass Formulation	Feng et al. 1996

Table B.1. Glass Names, Study Names, and References for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #	Glass Name	Glass Study	Reference
120	LD6-5412	Hanford LLW Glass Formulation	Feng et al. 1996
121	LD6-5510	Hanford LLW Glass Formulation	Feng et al. 1996
122	LDM-912	Hanford LLW Glass Formulation	Feng et al. 1996
123	LDM-1	Hanford LLW Glass Formulation	Feng et al. 1996
124	LDM-2	Hanford LLW Glass Formulation	Feng et al. 1996
125	LDM-3	Hanford LLW Glass Formulation	Feng et al. 1996
126	LDM-4	Hanford LLW Glass Formulation	Feng et al. 1996
127	LDM-5412	Hanford LLW Glass Formulation	Feng et al. 1996
128	LDMS-1	Hanford LLW Glass Formulation	Feng et al. 1996
129	LRM-912	Hanford LLW Glass Formulation	Feng et al. 1996
130	LRM-1	Hanford LLW Glass Formulation	Feng et al. 1996
131	LRM-2	Hanford LLW Glass Formulation	Feng et al. 1996
132	LRM-3	Hanford LLW Glass Formulation	Feng et al. 1996
133	LRM-4	Hanford LLW Glass Formulation	Feng et al. 1996
134	LRM-5412	Hanford LLW Glass Formulation	Feng et al. 1996
135	LRMS-1	Hanford LLW Glass Formulation	Feng et al. 1996
136	SSHTM-3	Hanford LLW Glass Formulation	Feng et al. 1996
137	Duratek	Hanford LLW Glass Formulation	Feng et al. 1996
138	PEI	Hanford LLW Glass Formulation	Feng et al. 1996
139	Vectra	Hanford LLW Glass Formulation	Feng et al. 1996
140	WSTC	Hanford LLW Glass Formulation	Feng et al. 1996
141	LAWB61	WTP LAW	Muller and Pegg 2003a
142	LAWB87	WTP LAW	Muller and Pegg 2003a
143	LAWB93R1	WTP LAW	Muller and Pegg 2003a
144	LAWC31R1	WTP LAW	Muller and Pegg 2003a
145	A1C1-1	WTP LAW	Muller and Pegg 2003b
146	A1C1-2	WTP LAW	Muller and Pegg 2003b
147	A2B1-1	WTP LAW	Muller and Pegg 2003b
148	A2B1-2	WTP LAW	Muller and Pegg 2003b
149	A2B1-3	WTP LAW	Muller and Pegg 2003b
150	A3C2-1	WTP LAW	Muller and Pegg 2003b
151	A3C2-2	WTP LAW	Muller and Pegg 2003b
152	A3C2-3	WTP LAW	Muller and Pegg 2003b
153	A2-AP101	WTP LAW	Rielley et al. 2004
154	A3-AN104	WTP LAW	Rielley et al. 2004
155	A88Si+15	WTP LAW	Rielley et al. 2004
156	A88Si-15	WTP LAW	Rielley et al. 2004
157	B1-AZ101	WTP LAW	Rielley et al. 2004
158	C100-G-136B	WTP LAW	Rielley et al. 2004
159	C1-AN107	WTP LAW	Rielley et al. 2004
160	C22AN107	WTP LAW	Rielley et al. 2004

Table B.1. Glass Names, Study Names, and References for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #	Glass Name	Glass Study	Reference
161	C22Si+15	WTP LAW	Rielley et al. 2004
162	C22Si-15	WTP LAW	Rielley et al. 2004
163	C2-AN102C35	WTP LAW	Rielley et al. 2004
164	LAWA102R1	WTP LAW	Rielley et al. 2004
165	LAWA126	WTP LAW	Rielley et al. 2004
166	LAWA128R1	WTP LAW	Rielley et al. 2004
167	LAWA130	WTP LAW	Rielley et al. 2004
168	LAWA134	WTP LAW	Rielley et al. 2004
169	LAWA135	WTP LAW	Rielley et al. 2004
170	LAWA136	WTP LAW	Rielley et al. 2004
171	LAWA44R10	WTP LAW	Rielley et al. 2004
172	LAWB60	WTP LAW	Rielley et al. 2004
173	LAWB62	WTP LAW	Rielley et al. 2004
174	LAWB63	WTP LAW	Rielley et al. 2004
175	LAWB64	WTP LAW	Rielley et al. 2004
176	LAWB65	WTP LAW	Rielley et al. 2004
177	LAWB66	WTP LAW	Rielley et al. 2004
178	LAWB67	WTP LAW	Rielley et al. 2004
179	LAWB68	WTP LAW	Rielley et al. 2004
180	LAWB69	WTP LAW	Rielley et al. 2004
181	LAWB70	WTP LAW	Rielley et al. 2004
182	LAWB71	WTP LAW	Rielley et al. 2004
183	LAWB72	WTP LAW	Rielley et al. 2004
184	LAWB73	WTP LAW	Rielley et al. 2004
185	LAWB74	WTP LAW	Rielley et al. 2004
186	LAWB75	WTP LAW	Rielley et al. 2004
187	LAWB76	WTP LAW	Rielley et al. 2004
188	LAWB77	WTP LAW	Rielley et al. 2004
189	LAWB78	WTP LAW	Rielley et al. 2004
190	LAWB79	WTP LAW	Rielley et al. 2004
191	LAWB80	WTP LAW	Rielley et al. 2004
192	LAWB81	WTP LAW	Rielley et al. 2004
193	LAWB82	WTP LAW	Rielley et al. 2004
194	LAWB83	WTP LAW	Rielley et al. 2004
195	LAWB84	WTP LAW	Rielley et al. 2004
196	LAWB85	WTP LAW	Rielley et al. 2004
197	LAWB86	WTP LAW	Rielley et al. 2004
198	LAWB89	WTP LAW	Rielley et al. 2004
199	LAWB90	WTP LAW	Rielley et al. 2004
200	LAWB92	WTP LAW	Rielley et al. 2004
201	LAWB94	WTP LAW	Rielley et al. 2004

Table B.1. Glass Names, Study Names, and References for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #	Glass Name	Glass Study	Reference
202	LAWB95	WTP LAW	Rielley et al. 2004
203	LAWC27	WTP LAW	Rielley et al. 2004
204	LAWC29	WTP LAW	Rielley et al. 2004
205	LAWC30	WTP LAW	Rielley et al. 2004
206	LAWC32	WTP LAW	Rielley et al. 2004
207	LAWM01	WTP LAW	Rielley et al. 2004
208	LAWM10	WTP LAW	Rielley et al. 2004
209	LAWM11	WTP LAW	Rielley et al. 2004
210	LAWM13	WTP LAW	Rielley et al. 2004
211	LAWM14	WTP LAW	Rielley et al. 2004
212	LAWM15	WTP LAW	Rielley et al. 2004
213	LAWM16	WTP LAW	Rielley et al. 2004
214	LAWM17	WTP LAW	Rielley et al. 2004
215	LAWM18	WTP LAW	Rielley et al. 2004
216	LAWM19	WTP LAW	Rielley et al. 2004
217	LAWM02	WTP LAW	Rielley et al. 2004
218	LAWM20	WTP LAW	Rielley et al. 2004
219	LAWM21	WTP LAW	Rielley et al. 2004
220	LAWM22	WTP LAW	Rielley et al. 2004
221	LAWM23	WTP LAW	Rielley et al. 2004
222	LAWM24	WTP LAW	Rielley et al. 2004
223	LAWM25R1	WTP LAW	Rielley et al. 2004
224	LAWM26	WTP LAW	Rielley et al. 2004
225	LAWM27	WTP LAW	Rielley et al. 2004
226	LAWM28	WTP LAW	Rielley et al. 2004
227	LAWM29	WTP LAW	Rielley et al. 2004
228	LAWM03	WTP LAW	Rielley et al. 2004
229	LAWM30	WTP LAW	Rielley et al. 2004
230	LAWM31	WTP LAW	Rielley et al. 2004
231	LAWM32	WTP LAW	Rielley et al. 2004
232	LAWM33R1	WTP LAW	Rielley et al. 2004
233	LAWM34	WTP LAW	Rielley et al. 2004
234	LAWM35	WTP LAW	Rielley et al. 2004
235	LAWM36	WTP LAW	Rielley et al. 2004
236	LAWM37	WTP LAW	Rielley et al. 2004
237	LAWM38	WTP LAW	Rielley et al. 2004
238	LAWM39	WTP LAW	Rielley et al. 2004
239	LAWM04	WTP LAW	Rielley et al. 2004
240	LAWM40	WTP LAW	Rielley et al. 2004
241	LAWM41	WTP LAW	Rielley et al. 2004
242	LAWM42	WTP LAW	Rielley et al. 2004

Table B.1. Glass Names, Study Names, and References for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #	Glass Name	Glass Study	Reference
243	LAWM43	WTP LAW	Rielley et al. 2004
244	LAWM44	WTP LAW	Rielley et al. 2004
245	LAWM45	WTP LAW	Rielley et al. 2004
246	LAWM46	WTP LAW	Rielley et al. 2004
247	LAWM47	WTP LAW	Rielley et al. 2004
248	LAWM48	WTP LAW	Rielley et al. 2004
249	LAWM49	WTP LAW	Rielley et al. 2004
250	LAWM05	WTP LAW	Rielley et al. 2004
251	LAWM50	WTP LAW	Rielley et al. 2004
252	LAWM51	WTP LAW	Rielley et al. 2004
253	LAWM52	WTP LAW	Rielley et al. 2004
254	LAWM53	WTP LAW	Rielley et al. 2004
255	LAWM54R1	WTP LAW	Rielley et al. 2004
256	LAWM55	WTP LAW	Rielley et al. 2004
257	LAWM56	WTP LAW	Rielley et al. 2004
258	LAWM06	WTP LAW	Rielley et al. 2004
259	LAWM07	WTP LAW	Rielley et al. 2004
260	LAWM08	WTP LAW	Rielley et al. 2004
261	LAWM09	WTP LAW	Rielley et al. 2004
262	A1-AN105R2	WTP LAW	Muller et al. 2005, Piepel et al. 2007
263	LAWB88	WTP LAW Comparison	Muller et al. 2005, Piepel et al. 2007
264	LAWC21rev2	WTP LAW Comparison	Muller et al. 2005, Piepel et al. 2007
265	LAWA127R1	WTP LAW Correlation	Piepel et al. 2007
266	LAWE10H	WTP LAW Correlation	Piepel et al. 2007
267	LAWE11	WTP LAW Correlation	Piepel et al. 2007
268	LAWE12	WTP LAW Correlation	Piepel et al. 2007
269	LAWE13	WTP LAW Correlation	Piepel et al. 2007
270	LAWE16	WTP LAW Correlation	Piepel et al. 2007
271	LAWE2H	WTP LAW Correlation	Piepel et al. 2007
272	LAWE3	WTP LAW Correlation	Piepel et al. 2007
273	LAWE3H	WTP LAW Correlation	Piepel et al. 2007
274	LAWE4	WTP LAW Correlation	Piepel et al. 2007
275	LAWE4H	WTP LAW Correlation	Piepel et al. 2007
276	LAWE5	WTP LAW Correlation	Piepel et al. 2007
277	LAWE5H	WTP LAW Correlation	Piepel et al. 2007
278	LAWE7	WTP LAW Correlation	Piepel et al. 2007
279	LAWE7H	WTP LAW Correlation	Piepel et al. 2007
280	LAWE9H	WTP LAW Correlation	Piepel et al. 2007
281	LAWA129R1	WTP LAW Correlation	Piepel et al. 2007

Table B.2. Glass Oxide Compositions (mass fractions)[(a)] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row	Component														
#[(b)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
1	0.1017	0.1369	0.0565	0.0100	0.0051	0.0000	0.0100	0.2302	0.3661	0.0067	0.0000	0.0100	0.0300	0.0300	0.0067
2	0.1066	0.1280	0.0799	0.0091	0.0051	0.0000	0.0091	0.2301	0.3488	0.0068	0.0000	0.0098	0.0300	0.0300	0.0067
3	0.1066	0.1130	0.0800	0.0091	0.0051	0.0000	0.0091	0.2302	0.3488	0.0066	0.0000	0.0098	0.0300	0.0450	0.0067
4	0.1065	0.0979	0.0799	0.0091	0.0051	0.0000	0.0091	0.2301	0.3487	0.0069	0.0000	0.0098	0.0300	0.0600	0.0067
5	0.1215	0.1129	0.0799	0.0091	0.0051	0.0000	0.0091	0.2300	0.3487	0.0071	0.0000	0.0098	0.0300	0.0300	0.0067
6	0.1366	0.0980	0.0799	0.0091	0.0051	0.0000	0.0091	0.2301	0.3488	0.0067	0.0000	0.0098	0.0300	0.0300	0.0067
7	0.1086	0.0926	0.0798	0.0091	0.0056	0.0000	0.0091	0.2501	0.3534	0.0069	0.0000	0.0094	0.0235	0.0445	0.0073
8	0.1085	0.0776	0.0798	0.0091	0.0056	0.0000	0.0091	0.2501	0.3533	0.0070	0.0000	0.0094	0.0235	0.0595	0.0073
9	0.1066	0.0980	0.0800	0.0091	0.0051	0.0000	0.0091	0.2302	0.3436	0.0066	0.0000	0.0150	0.0300	0.0600	0.0067
10	0.1064	0.0941	0.0765	0.0091	0.0051	0.0000	0.0091	0.2298	0.3655	0.0083	0.0000	0.0150	0.0145	0.0599	0.0067
11	0.1215	0.0979	0.0799	0.0091	0.0051	0.0000	0.0091	0.2301	0.3689	0.0070	0.0000	0.0150	0.0195	0.0300	0.0067
12	0.1164	0.0930	0.0799	0.0091	0.0051	0.0000	0.0091	0.2300	0.3687	0.0076	0.0000	0.0150	0.0145	0.0450	0.0067
13	0.1066	0.1281	0.0649	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0062	0.0100	0.0098	0.0300	0.0300	0.0117
14	0.1066	0.1281	0.0549	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0061	0.0201	0.0098	0.0300	0.0300	0.0117
15	0.1066	0.1130	0.0750	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0061	0.0000	0.0098	0.0300	0.0451	0.0117
16	0.1217	0.1131	0.0599	0.0091	0.0051	0.0000	0.0091	0.2303	0.3491	0.0059	0.0000	0.0098	0.0300	0.0451	0.0117
17	0.1216	0.1130	0.0750	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0061	0.0000	0.0098	0.0300	0.0300	0.0117
18	0.1216	0.1130	0.0598	0.0091	0.0051	0.0000	0.0091	0.2301	0.3588	0.0068	0.0000	0.0098	0.0300	0.0400	0.0067
19	0.1216	0.1130	0.0549	0.0091	0.0051	0.0000	0.0091	0.2303	0.3590	0.0062	0.0000	0.0098	0.0300	0.0400	0.0117
20	0.1087	0.0777	0.0699	0.0091	0.0056	0.0000	0.0091	0.2504	0.3538	0.0058	0.0100	0.0094	0.0235	0.0596	0.0073
21	0.1087	0.0777	0.0649	0.0091	0.0056	0.0000	0.0091	0.2504	0.3537	0.0058	0.0100	0.0094	0.0235	0.0596	0.0124
22	0.1186	0.0777	0.0599	0.0091	0.0056	0.0000	0.0091	0.2503	0.3636	0.0062	0.0000	0.0094	0.0235	0.0596	0.0073
23	0.1187	0.0777	0.0549	0.0091	0.0056	0.0000	0.0091	0.2504	0.3637	0.0059	0.0000	0.0094	0.0235	0.0596	0.0124
24	0.0916	0.1153	0.1072	0.0115	0.0041	0.0354	0.0115	0.1001	0.4310	0.0069	0.0000	0.0124	0.0354	0.0354	0.0022
25	0.1017	0.1003	0.1123	0.0115	0.0041	0.0355	0.0115	0.1002	0.4316	0.0057	0.0000	0.0124	0.0355	0.0355	0.0022
26	0.0917	0.1004	0.1224	0.0115	0.0041	0.0355	0.0115	0.1003	0.4319	0.0051	0.0000	0.0124	0.0355	0.0355	0.0022
27	0.0916	0.1003	0.0921	0.0115	0.0041	0.0405	0.0115	0.1002	0.4566	0.0061	0.0000	0.0124	0.0355	0.0355	0.0022
28	0.0616	0.1305	0.0922	0.0115	0.0041	0.0355	0.0115	0.1002	0.4618	0.0055	0.0000	0.0124	0.0355	0.0355	0.0022
29	0.0916	0.1002	0.0921	0.0115	0.0041	0.0354	0.0115	0.1001	0.4615	0.0063	0.0000	0.0124	0.0354	0.0354	0.0022
30	0.1017	0.1103	0.0922	0.0115	0.0041	0.0355	0.0115	0.1002	0.4416	0.0058	0.0000	0.0124	0.0355	0.0355	0.0022

Table B.2. Glass Oxide Compositions (mass fractions)[(a)] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row	Component														
#[(b)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
31	0.1016	0.1102	0.1022	0.0115	0.0041	0.0354	0.0115	0.1001	0.4313	0.0064	0.0000	0.0124	0.0354	0.0354	0.0022
32	0.1019	0.1372	0.0804	0.0100	0.0015	0.0000	0.0100	0.2005	0.3672	0.0094	0.0000	0.0100	0.0301	0.0301	0.0117
33	0.1019	0.1304	0.0805	0.0100	0.0015	0.0000	0.0100	0.2006	0.3673	0.0089	0.0000	0.0100	0.0301	0.0369	0.0117
34	0.0866	0.1371	0.0804	0.0100	0.0015	0.0000	0.0100	0.2004	0.3669	0.0100	0.0000	0.0100	0.0301	0.0453	0.0117
35	0.0714	0.1373	0.0805	0.0100	0.0015	0.0000	0.0100	0.2007	0.3674	0.0087	0.0000	0.0100	0.0301	0.0606	0.0117
36	0.1000	0.0900	0.0350	0.0101	0.0056	0.0000	0.0135	0.2500	0.4131	0.0019	0.0000	0.0000	0.0236	0.0480	0.0092
37	0.1000	0.0900	0.0250	0.0101	0.0056	0.0000	0.0135	0.2500	0.4131	0.0019	0.0100	0.0000	0.0236	0.0480	0.0092
38	0.1000	0.0900	0.0304	0.0101	0.0056	0.0000	0.0135	0.2500	0.4131	0.0019	0.0000	0.0000	0.0236	0.0480	0.0139
39	0.1000	0.0700	0.0100	0.0101	0.0056	0.0000	0.0135	0.2501	0.4332	0.0020	0.0100	0.0000	0.0336	0.0480	0.0139
40	0.1088	0.0778	0.0100	0.0094	0.0056	0.0000	0.0091	0.2500	0.4192	0.0019	0.0100	0.0000	0.0236	0.0607	0.0139
41	0.1088	0.0778	0.0147	0.0094	0.0056	0.0000	0.0091	0.2500	0.4050	0.0020	0.0100	0.0094	0.0236	0.0607	0.0139
42	0.1090	0.0780	0.0652	0.0091	0.0056	0.0000	0.0091	0.2501	0.3552	0.0018	0.0200	0.0094	0.0236	0.0500	0.0139
43	0.1090	0.0780	0.0652	0.0091	0.0056	0.0000	0.0091	0.2500	0.3578	0.0019	0.0268	0.0000	0.0236	0.0500	0.0139
44	0.1090	0.0700	0.0200	0.0091	0.0056	0.0000	0.0091	0.2500	0.4015	0.0019	0.0270	0.0000	0.0236	0.0594	0.0139
45	0.1077	0.0713	0.0203	0.0093	0.0054	0.0000	0.0093	0.2400	0.4100	0.0017	0.0275	0.0000	0.0245	0.0595	0.0136
46	0.1083	0.0707	0.0201	0.0092	0.0055	0.0000	0.0092	0.2450	0.4061	0.0019	0.0272	0.0000	0.0242	0.0589	0.0136
47	0.1070	0.0720	0.0205	0.0094	0.0053	0.0000	0.0094	0.2350	0.4138	0.0017	0.0278	0.0000	0.0247	0.0600	0.0133
48	0.0946	0.0865	0.0334	0.0093	0.0054	0.0000	0.0093	0.2400	0.3950	0.0018	0.0275	0.0000	0.0245	0.0595	0.0133
49	0.0987	0.0778	0.0147	0.0094	0.0056	0.0000	0.0091	0.2501	0.4159	0.0017	0.0100	0.0094	0.0236	0.0600	0.0139
50	0.0989	0.0878	0.0299	0.0094	0.0054	0.0000	0.0091	0.2400	0.4003	0.0018	0.0100	0.0098	0.0236	0.0607	0.0133
51	0.0970	0.0880	0.0334	0.0030	0.0054	0.0000	0.0093	0.2400	0.3952	0.0017	0.0276	0.0000	0.0276	0.0600	0.0118
52	0.0970	0.0880	0.0334	0.0030	0.0054	0.0000	0.0093	0.2400	0.3952	0.0017	0.0483	0.0000	0.0276	0.0393	0.0118
53	0.0670	0.0880	0.0334	0.0030	0.0054	0.0000	0.0093	0.2400	0.4252	0.0016	0.0276	0.0000	0.0276	0.0600	0.0118
54	0.0674	0.0891	0.0318	0.0026	0.0051	0.0000	0.0100	0.2303	0.4229	0.0081	0.0246	0.0093	0.0286	0.0587	0.0114
55	0.0695	0.0822	0.0313	0.0026	0.0053	0.0000	0.0098	0.2404	0.4150	0.0083	0.0266	0.0091	0.0280	0.0601	0.0116
56	0.1201	0.0730	0.0110	0.0110	0.0012	0.0000	0.0110	0.2501	0.3800	0.0048	0.0108	0.0200	0.0365	0.0544	0.0160
57	0.1001	0.0730	0.0110	0.0110	0.0012	0.0000	0.0110	0.2501	0.4000	0.0048	0.0108	0.0200	0.0365	0.0544	0.0160
58	0.0989	0.0858	0.0300	0.0096	0.0011	0.0000	0.0093	0.2402	0.4010	0.0047	0.0100	0.0100	0.0237	0.0605	0.0151
59	0.1004	0.0853	0.0190	0.0096	0.0011	0.0000	0.0093	0.2403	0.4011	0.0045	0.0100	0.0200	0.0237	0.0605	0.0151
60	0.1067	0.1167	0.0642	0.0090	0.0054	0.0000	0.0090	0.2351	0.3453	0.0049	0.0099	0.0147	0.0297	0.0346	0.0146
61	0.1004	0.0852	0.0191	0.0097	0.0054	0.0000	0.0093	0.2358	0.4012	0.0048	0.0100	0.0200	0.0237	0.0604	0.0149

Table B.2. Glass Oxide Compositions (mass fractions)[a] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #[b]	Component														
	Al_2O_3	**B_2O_3**	**CaO**	**Fe_2O_3**	**K_2O**	**Li_2O**	**MgO**	**Na_2O**	**SiO_2**	**SO_3**	**SnO_2**	**V_2O_5**	**ZnO**	**ZrO_2**	**Others1**
62	0.1015	0.1204	0.0801	0.0100	0.0016	0.0000	0.0100	0.2098	0.3714	0.0106	0.0000	0.0100	0.0300	0.0300	0.0147
63	0.1019	0.1209	0.0804	0.0030	0.0016	0.0000	0.0100	0.2103	0.3797	0.0085	0.0000	0.0100	0.0301	0.0301	0.0134
64	0.1020	0.1005	0.0804	0.0030	0.0016	0.0000	0.0100	0.2103	0.3798	0.0083	0.0000	0.0200	0.0301	0.0406	0.0134
65	0.1014	0.0989	0.0792	0.0030	0.0017	0.0000	0.0099	0.2204	0.3740	0.0082	0.0000	0.0197	0.0298	0.0400	0.0138
66	0.1009	0.0988	0.0792	0.0030	0.0017	0.0000	0.0099	0.2203	0.3738	0.0087	0.0100	0.0100	0.0297	0.0400	0.0138
67	0.1001	0.0948	0.0734	0.0029	0.0018	0.0000	0.0097	0.2296	0.3668	0.0121	0.0100	0.0146	0.0299	0.0401	0.0142
68	0.0858	0.0951	0.0735	0.0029	0.0018	0.0000	0.0097	0.2301	0.3676	0.0099	0.0100	0.0292	0.0299	0.0402	0.0142
69	0.0761	0.0986	0.1047	0.0024	0.0055	0.0300	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0354	0.0059
70	01003	0.1148	0.0805	0.0024	0.0055	0.0300	0.0105	0.1603	0.3986	0.0109	0.0000	0.0125	0.0323	0.0355	0.0059
71	0.1002	0.1148	0.1047	0.0024	0.0055	0.0300	0.0105	0.1602	0.3744	0.0111	0.0000	0.0125	0.0322	0.0354	0.0059
72	0.0765	0.0983	0.1045	0.0023	0.0061	0.0210	0.0105	0.1803	0.4041	0.0108	0.0000	0.0121	0.0314	0.0354	0.0066
73	0.0761	0.0962	0.1025	0.0023	0.0068	0.0110	0.0099	0.2002	0.3999	0.0115	0.0000	0.0118	0.0296	0.0351	0.0071
74	0.0761	0.0986	0.0998	0.0024	0.0055	0.0300	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0362	0.0099
75	0.0761	0.0986	0.1047	0.0024	0.0055	0.0260	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0354	0.0099
76	0.0761	0.0946	0.1006	0.0105	0.0055	0.0300	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0354	0.0059
77	0.0761	0.0906	0.0966	0.0105	0.0055	0.0300	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0394	0.0099
78	0.0879	0.1045	0.0924	0.0024	0.0055	0.0300	0.0105	0.1599	0.4077	0.0133	0.0000	0.0125	0.0322	0.0354	0.0059
79	0.0761	0.0986	0.1047	0.0024	0.0055	0.0250	0.0105	0.1602	0.4146	0.0111	0.0000	0.0175	0.0322	0.0354	0.0059
80	0.0762	0.0987	0.1007	0.0024	0.0055	0.0251	0.0105	0.1603	0.4149	0.0105	0.0000	0.0175	0.0323	0.0355	0.0099
81	0.1010	0.0982	0.1007	0.0031	0.0041	0.0378	0.0102	0.1007	0.4365	0.0092	0.0089	0.0126	0.0302	0.0403	0.0066
82	0.0995	0.0967	0.0992	0.0030	0.0045	0.0372	0.0100	0.1107	0.4302	0.0115	0.0087	0.0125	0.0298	0.0397	0.0067
83	0.0986	0.0958	0.0982	0.0030	0.0051	0.0369	0.0099	0.1212	0.4257	0.0093	0.0086	0.0123	0.0294	0.0392	0.0070
84	0.0867	0.0958	0.0980	0.0030	0.0050	0.0353	0.0099	0.1210	0.4250	0.0110	0.0086	0.0252	0.0293	0.0391	0.0070
85	0.0865	0.0956	0.0978	0.0030	0.0050	0.0438	0.0099	0.1207	0.4240	0.0132	0.0000	0.0252	0.0293	0.0390	0.0069
86	0.0764	0.0890	0.0977	0.0030	0.0050	0.0352	0.0099	0.1206	0.4204	0.0143	0.0085	0.0251	0.0293	0.0390	0.0266
87	0.0866	0.0957	0.1064	0.0030	0.0050	0.0352	0.0099	0.1208	0.4244	0.0124	0.0000	0.0252	0.0293	0.0391	0.0069
88	0.0860	0.0950	0.1056	0.0000	0.0050	0.0350	0.0000	0.1199	0.4212	0.0197	0.0100	0.0272	0.0291	0.0395	0.0069
89	0.0860	0.0950	0.1057	0.0000	0.0050	0.0371	0.0000	0.1200	0.4213	0.0196	0.0100	0.0250	0.0291	0.0395	0.0069
90	0.1017	0.1369	0.0803	0.0100	0.0015	0.0000	0.0100	0.2002	0.3665	0.0102	0.0000	0.0100	0.0300	0.0300	0.0127
91	0.1500	0.0600	0.0000	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
92	0.0600	0.0900	0.0000	0.0000	0.0033	0.0000	0.0000	0.2000	0.6278	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157

Table B.2. Glass Oxide Compositions (mass fractions)[a] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row	Component														
#[b]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
93	0.1200	0.0900	0.0000	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
94	0.0900	0.1200	0.0000	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
95	0.1500	0.1200	0.0000	0.0000	0.0033	0.0000	0.0000	0.2000	0.5078	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
96	0.0600	0.0000	0.0900	0.0000	0.0033	0.0000	0.0000	0.2000	0.6278	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
97	0.0900	0.0000	0.1200	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
98	0.1500	0.0000	0.1200	0.0000	0.0033	0.0000	0.0000	0.2000	0.5078	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
99	0.1200	0.0300	0.0300	0.0000	0.0033	0.0000	0.0000	0.2000	0.5978	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
100	0.0600	0.0500	0.0400	0.0000	0.0033	0.0000	0.0000	0.2000	0.6278	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
101	0.0900	0.0500	0.0400	0.0000	0.0033	0.0000	0.0000	0.2000	0.5978	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
102	0.1200	0.0500	0.0400	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
103	0.1500	0.0500	0.0400	0.0000	0.0033	0.0000	0.0000	0.2000	0.5378	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
104	0.0900	0.0600	0.0600	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
105	0.1200	0.0600	0.0600	0.0000	0.0033	0.0000	0.0000	0.2000	0.5378	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
106	0.1245	0.0539	0.0431	0.0000	0.0025	0.0000	0.0000	0.1500	0.6119	0.0024	0.0000	0.0000	0.0000	0.0000	0.0117
107	0.1155	0.0461	0.0369	0.0000	0.0041	0.0000	0.0000	0.2500	0.5238	0.0040	0.0000	0.0000	0.0000	0.0001	0.0195
108	0.1065	0.0384	0.0307	0.0001	0.0057	0.0000	0.0000	0.3500	0.4357	0.0056	0.0000	0.0000	0.0000	0.0001	0.0273
109	0.0900	0.0600	0.0000	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0600	0.0157
110	0.0900	0.0000	0.0600	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0600	0.0157
111	0.0900	0.0300	0.0300	0.0000	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0600	0.0157
112	0.0900	0.0600	0.0000	0.0600	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
113	0.0900	0.0000	0.0600	0.0600	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
114	0.0900	0.0300	0.0300	0.0600	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0000	0.0157
115	0.0900	0.0600	0.0000	0.0300	0.0033	0.0000	0.0000	0.2000	0.5678	0.0032	0.0000	0.0000	0.0000	0.0300	0.0157
116	0.0900	0.0500	0.0000	0.0000	0.0033	0.0000	0.0400	0.2000	0.5979	0.0032	0.0000	0.0000	0.0000	0.0000	0.0156
117	0.1200	0.0900	0.0000	0.0000	0.0146	0.0000	0.0000	0.2000	0.5591	0.0022	0.0000	0.0000	0.0000	0.0000	0.0141
118	0.1200	0.0000	0.0900	0.0000	0.0146	0.0000	0.0000	0.2000	0.5591	0.0022	0.0000	0.0000	0.0000	0.0000	0.0141
119	0.1400	0.0500	0.0300	0.0000	0.0146	0.0000	0.0000	0.2000	0.5491	0.0022	0.0000	0.0000	0.0000	0.0000	0.0141
120	0.1200	0.0500	0.0400	0.0000	0.0146	0.0000	0.0000	0.2000	0.5591	0.0022	0.0000	0.0000	0.0000	0.0000	0.0141
121	0.1000	0.0500	0.0500	0.0000	0.0146	0.0000	0.0000	0.2000	0.5691	0.0022	0.0000	0.0000	0.0000	0.0000	0.0141
122	0.1200	0.0000	0.0900	0.0000	0.0143	0.0000	0.0000	0.2000	0.5514	0.0021	0.0000	0.0000	0.0000	0.0000	0.0222
123	0.1200	0.0200	0.0200	0.0600	0.0143	0.0000	0.0000	0.2000	0.5014	0.0021	0.0000	0.0000	0.0000	0.0400	0.0222

Table B.2. Glass Oxide Compositions (mass fractions)[a] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row	Component														
#[b]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
124	0.1200	0.0000	0.0600	0.0600	0.0143	0.0000	0.0000	0.2000	0.5214	0.0021	0.0000	0.0000	0.0000	0.0000	0.0222
125	0.1200	0.0600	0.0000	0.0000	0.0143	0.0000	0.0000	0.2000	0.5214	0.0021	0.0000	0.0000	0.0000	0.0600	0.0222
126	0.1000	0.0600	0.0600	0.0600	0.0143	0.0000	0.0000	0.2000	0.4414	0.0021	0.0000	0.0000	0.0000	0.0400	0.0222
127	0.1200	0.0500	0.0400	0.0000	0.0143	0.0000	0.0000	0.2000	0.5514	0.0021	0.0000	0.0000	0.0000	0.0000	0.0222
128	0.1200	0.0200	0.0200	0.0600	0.0143	0.0000	0.0000	0.2000	0.5014	0.0021	0.0000	0.0000	0.0000	0.0400	0.0222
129	0.1200	0.0000	0.0900	0.0000	0.0003	0.0000	0.0000	0.2000	0.5454	0.0101	0.0000	0.0000	0.0000	0.0000	0.0342
130	0.1200	0.0200	0.0200	0.0600	0.0003	0.0100	0.0000	0.2000	0.4854	0.0101	0.0000	0.0000	0.0000	0.0400	0.0342
131	0.1200	0.0000	0.0600	0.0600	0.0003	0.0000	0.0000	0.2000	0.5154	0.0101	0.0000	0.0000	0.0000	0.0000	0.0342
132	0.1200	0.0600	0.0000	0.0000	0.0003	0.0000	0.0000	0.2000	0.5154	0.0101	0.0000	0.0000	0.0000	0.0600	0.0342
133	0.1000	0.0600	0.0600	0.0600	0.0003	0.0050	0.0000	0.2000	0.4304	0.0101	0.0000	0.0000	0.0000	0.0400	0.0342
134	0.1200	0.0500	0.0400	0.0000	0.0003	0.0000	0.0000	0.2000	0.5454	0.0101	0.0000	0.0000	0.0000	0.0000	0.0342
135	0.1200	0.0200	0.0200	0.0600	0.0003	0.0100	0.0000	0.2000	0.4854	0.0101	0.0000	0.0000	0.0000	0.0400	0.0342
136	0.1200	0.0500	0.0400	0.0000	0.0146	0.0000	0.0000	0.2000	0.5591	0.0022	0.0000	0.0000	0.0000	0.0000	0.0141
137	0.0614	0.0615	0.0780	0.0750	0.0368	0.0000	0.0000	0.1882	0.4223	0.0020	0.0000	0.0000	0.0000	0.0509	0.0238
138	0.0600	0.0000	0.0973	0.0100	0.0150	0.0000	0.0013	0.1882	0.5922	0.0021	0.0000	0.0000	0.0000	0.0200	0.0139
139	0.1000	0.0800	0.0290	0.0100	0.0146	0.0000	0.0210	0.2000	0.5290	0.0022	0.0000	0.0000	0.0000	0.0000	0.0142
140	0.1822	0.0945	0.0465	0.0000	0.0144	0.0083	0.0000	0.1882	0.4290	0.0022	0.0000	0.0000	0.0000	0.0210	0.0137
141	0.0620	0.0997	0.0671	0.0531	0.0026	0.0582	0.0298	0.0550	0.4862	0.0128	0.0000	0.0000	0.0317	0.0317	0.0101
142	0.0649	0.1301	0.0611	0.0503	0.0020	0.0470	0.0141	0.0501	0.4916	0.0081	0.0000	0.0000	0.0489	0.0319	0.0000
143	0.0619	0.1004	0.0679	0.0530	0.0019	0.0467	0.0297	0.0479	0.4900	0.0065	0.0000	0.0000	0.0485	0.0316	0.0141
144	0.0612	0.1005	0.0741	0.0443	0.0014	0.0273	0.0150	0.1196	0.4675	0.0048	0.0000	0.0000	0.0402	0.0302	0.0137
145	0.0609	0.0913	0.0274	0.0650	0.0035	0.0062	0.0185	0.1917	0.4448	0.0024	0.0000	0.0000	0.0295	0.0296	0.0293
146	0.0607	0.0942	0.0352	0.0613	0.0025	0.0125	0.0173	0.1767	0.4514	0.0028	0.0000	0.0000	0.0298	0.0297	0.0257
147	0.0576	0.0988	0.0318	0.0548	0.0290	0.0107	0.0185	0.1523	0.4518	0.0046	0.0000	0.0000	0.0341	0.0301	0.0257
148	0.0590	0.0992	0.0437	0.0540	0.0200	0.0215	0.0223	0.1198	0.4629	0.0052	0.0000	0.0000	0.0389	0.0306	0.0227
149	0.0604	0.0997	0.0558	0.0535	0.0109	0.0322	0.0260	0.0873	0.4743	0.0059	0.0000	0.0000	0.0436	0.0311	0.0192
150	0.0606	0.0980	0.0561	0.0492	0.0027	0.0267	0.0148	0.1398	0.4641	0.0043	0.0000	0.0000	0.0328	0.0300	0.0208
151	0.0607	0.0968	0.0620	0.0448	0.0021	0.0286	0.0148	0.1332	0.4671	0.0050	0.0000	0.0000	0.0351	0.0300	0.0197
152	0.0606	0.0955	0.0677	0.0404	0.0015	0.0306	0.0149	0.1265	0.4698	0.0057	0.0000	0.0000	0.0375	0.0300	0.0191
153	0.0562	0.0982	0.0199	0.0553	0.0381	0.0000	0.0148	0.1847	0.4401	0.0040	0.0000	0.0000	0.0294	0.0296	0.0296
154	0.0605	0.0992	0.0503	0.0537	0.0033	0.0248	0.0148	0.1464	0.4609	0.0037	0.0000	0.0000	0.0304	0.0300	0.0219

Table B.2. Glass Oxide Compositions (mass fractions)[(a)] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #[(b)]	Component														
	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
155	0.0614	0.0948	0.0193	0.0535	0.0237	0.0000	0.0143	0.2218	0.4255	0.0031	0.0000	0.0000	0.0285	0.0289	0.0251
156	0.0605	0.1022	0.0207	0.0576	0.0188	0.0000	0.0154	0.1767	0.4587	0.0025	0.0000	0.0000	0.0307	0.0311	0.0249
157	0.0618	0.1003	0.0677	0.0528	0.0018	0.0431	0.0298	0.0548	0.4858	0.0065	0.0000	0.0000	0.0485	0.0317	0.0155
158	0.0613	0.1009	0.0641	0.0648	0.0015	0.0273	0.0151	0.1187	0.4673	0.0063	0.0000	0.0000	0.0301	0.0302	0.0123
159	0.0607	0.1003	0.0510	0.0542	0.0007	0.0251	0.0151	0.1447	0.4664	0.0038	0.0000	0.0000	0.0306	0.0302	0.0174
160	0.0611	0.1008	0.0511	0.0559	0.0009	0.0251	0.0151	0.1443	0.4661	0.0031	0.0000	0.0000	0.0306	0.0302	0.0156
161	0.0604	0.0984	0.0499	0.0536	0.0010	0.0246	0.0148	0.1620	0.4558	0.0034	0.0000	0.0000	0.0300	0.0296	0.0165
162	0.0616	0.1029	0.0522	0.0555	0.0008	0.0257	0.0155	0.1281	0.4768	0.0027	0.0000	0.0000	0.0314	0.0310	0.0158
163	0.0607	0.0943	0.0736	0.0360	0.0009	0.0325	0.0149	0.1198	0.4728	0.0063	0.0000	0.0000	0.0399	0.0300	0.0182
164	0.0604	0.0996	0.0504	0.0538	0.0026	0.0249	0.0148	0.1449	0.4631	0.0250	0.0000	0.0000	0.0305	0.0301	0.0000
165	0.0564	0.0982	0.0199	0.0554	0.0388	0.0000	0.0148	0.1845	0.4410	0.0035	0.0000	0.0000	0.0296	0.0299	0.0282
166	0.0603	0.0707	0.0208	0.0579	0.0388	0.0000	0.0118	0.1845	0.4606	0.0035	0.0000	0.0000	0.0309	0.0313	0.0292
167	0.0603	0.0894	0.0208	0.0286	0.0388	0.0000	0.0118	0.1845	0.4605	0.0035	0.0000	0.0000	0.0414	0.0313	0.0293
168	0.0565	0.0996	0.0202	0.0563	0.0373	0.0000	0.0150	0.1773	0.4475	0.0033	0.0000	0.0000	0.0300	0.0304	0.0267
169	0.0566	0.1009	0.0205	0.0570	0.0358	0.0000	0.0152	0.1702	0.4530	0.0032	0.0000	0.0000	0.0304	0.0308	0.0266
170	0.0566	0.1009	0.0305	0.0570	0.0358	0.0000	0.0152	0.1702	0.4430	0.0032	0.0000	0.0000	0.0304	0.0308	0.0266
171	0.0620	0.0890	0.0199	0.0698	0.0050	0.0000	0.0199	0.2001	0.4456	0.0010	0.0000	0.0000	0.0297	0.0299	0.0280
172	0.0614	0.1237	0.1191	0.0000	0.0026	0.0463	0.0298	0.0651	0.4796	0.0085	0.0000	0.0000	0.0316	0.0316	0.0008
173	0.0619	0.0995	0.1200	0.0000	0.0026	0.0581	0.0297	0.0549	0.4854	0.0128	0.0000	0.0000	0.0316	0.0316	0.0119
174	0.0658	0.0995	0.0935	0.0000	0.0026	0.0505	0.0297	0.0549	0.4894	0.0128	0.0000	0.0000	0.0582	0.0316	0.0114
175	0.0621	0.0997	0.0671	0.0330	0.0026	0.0582	0.0298	0.0550	0.4864	0.0128	0.0000	0.0000	0.0518	0.0317	0.0098
176	0.0619	0.0994	0.0669	0.0530	0.0026	0.0430	0.0297	0.0548	0.4849	0.0128	0.0000	0.0000	0.0466	0.0316	0.0128
177	0.0620	0.0996	0.0821	0.0531	0.0026	0.0431	0.0298	0.0549	0.4861	0.0128	0.0000	0.0000	0.0317	0.0317	0.0105
178	0.0619	0.0994	0.0519	0.0530	0.0026	0.0430	0.0297	0.0549	0.4850	0.0128	0.0000	0.0000	0.0316	0.0316	0.0427
179	0.0619	0.0844	0.0820	0.0530	0.0026	0.0431	0.0297	0.0548	0.4852	0.0128	0.0000	0.0000	0.0467	0.0316	0.0123
180	0.0615	0.1233	0.1046	0.0000	0.0023	0.0461	0.0297	0.0662	0.4796	0.0078	0.0000	0.0000	0.0457	0.0315	0.0016
181	0.0616	0.1235	0.0663	0.0325	0.0023	0.0462	0.0297	0.0663	0.4802	0.0078	0.0000	0.0000	0.0516	0.0315	0.0005
182	0.0616	0.1080	0.0663	0.0326	0.0023	0.0462	0.0298	0.0663	0.4805	0.0078	0.0000	0.0000	0.0516	0.0316	0.0154
183	0.0615	0.1234	0.0713	0.0325	0.0023	0.0411	0.0297	0.0662	0.4798	0.0078	0.0000	0.0000	0.0515	0.0315	0.0012
184	0.0619	0.0995	0.0934	0.0191	0.0026	0.0505	0.0297	0.0549	0.4853	0.0128	0.0000	0.0000	0.0467	0.0316	0.0120
185	0.0622	0.1011	0.0873	0.0191	0.0026	0.0533	0.0298	0.0551	0.4873	0.0128	0.0000	0.0000	0.0469	0.0317	0.0107

Table B.2. Glass Oxide Compositions (mass fractions)[(a)] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row	Component														
#[(b)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
186	0.0619	0.1179	0.0868	0.0191	0.0026	0.0530	0.0150	0.0548	0.4848	0.0128	0.0000	0.0000	0.0466	0.0316	0.0129
187	0.0618	0.1178	0.0868	0.0190	0.0026	0.0580	0.0150	0.0548	0.4933	0.0128	0.0000	0.0000	0.0466	0.0316	0.0000
188	0.0616	0.1235	0.0663	0.0220	0.0023	0.0412	0.0297	0.0663	0.4803	0.0078	0.0000	0.0000	0.0516	0.0316	0.0158
189	0.0616	0.1235	0.0713	0.0326	0.0023	0.0306	0.0298	0.0980	0.4708	0.0078	0.0000	0.0000	0.0401	0.0316	0.0002
190	0.0616	0.1234	0.0713	0.0325	0.0023	0.0351	0.0297	0.0863	0.4775	0.0078	0.0000	0.0000	0.0400	0.0315	0.0009
191	0.0616	0.1234	0.0713	0.0325	0.0199	0.0351	0.0297	0.0663	0.4799	0.0078	0.0000	0.0000	0.0400	0.0315	0.0009
192	0.0615	0.1234	0.0713	0.0325	0.0023	0.0426	0.0297	0.0663	0.4799	0.0078	0.0000	0.0000	0.0500	0.0315	0.0011
193	0.0616	0.1010	0.0713	0.0952	0.0023	0.0427	0.0148	0.0663	0.4553	0.0078	0.0000	0.0000	0.0501	0.0316	0.0000
194	0.0618	0.1004	0.0678	0.0529	0.0019	0.0431	0.0297	0.0547	0.4862	0.0065	0.0000	0.0000	0.0484	0.0316	0.0148
195	0.0619	0.1004	0.0669	0.0530	0.0019	0.0440	0.0297	0.0548	0.4865	0.0065	0.0000	0.0000	0.0485	0.0316	0.0143
196	0.0618	0.1153	0.0528	0.0529	0.0019	0.0431	0.0297	0.0547	0.4863	0.0065	0.0000	0.0000	0.0484	0.0316	0.0148
197	0.0619	0.1243	0.0574	0.0530	0.0019	0.0436	0.0297	0.0548	0.4866	0.0065	0.0000	0.0000	0.0485	0.0316	0.0003
198	0.0619	0.1004	0.0679	0.0530	0.0019	0.0501	0.0297	0.0408	0.4935	0.0065	0.0000	0.0000	0.0484	0.0316	0.0143
199	0.0619	0.1005	0.0679	0.0530	0.0019	0.0362	0.0298	0.0688	0.4800	0.0065	0.0000	0.0000	0.0485	0.0317	0.0133
200	0.0619	0.1004	0.0679	0.0530	0.0019	0.0222	0.0297	0.1012	0.4610	0.0065	0.0000	0.0000	0.0485	0.0316	0.0142
201	0.0619	0.1003	0.0678	0.0529	0.0019	0.0536	0.0297	0.0338	0.4966	0.0065	0.0000	0.0000	0.0484	0.0316	0.0149
202	0.0619	0.1003	0.0678	0.0530	0.0019	0.0576	0.0297	0.0246	0.5021	0.0065	0.0000	0.0000	0.0484	0.0316	0.0145
203	0.0612	0.1218	0.0854	0.0001	0.0014	0.0273	0.0150	0.1195	0.4887	0.0048	0.0000	0.0000	0.0302	0.0302	0.0144
204	0.0655	0.1005	0.0962	0.0001	0.0014	0.0273	0.0150	0.1196	0.4718	0.0048	0.0000	0.0000	0.0537	0.0302	0.0140
205	0.0612	0.1005	0.0641	0.0410	0.0014	0.0273	0.0150	0.1196	0.4675	0.0048	0.0000	0.0000	0.0535	0.0302	0.0137
206	0.0649	0.1005	0.0904	0.0242	0.0014	0.0273	0.0150	0.1196	0.4674	0.0048	0.0000	0.0000	0.0402	0.0302	0.0141
207	0.0904	0.0603	0.1005	0.0804	0.0402	0.0452	0.0000	0.0502	0.4467	0.0100	0.0000	0.0000	0.0502	0.0000	0.0258
208	0.0901	0.1301	0.1001	0.0000	0.0000	0.0450	0.0000	0.1307	0.4017	0.0029	0.0000	0.0000	0.0100	0.0400	0.0494
209	0.0350	0.1301	0.0941	0.0531	0.0400	0.0450	0.0000	0.1148	0.4678	0.0100	0.0000	0.0000	0.0100	0.0000	0.0000
210	0.0350	0.0600	0.1000	0.0800	0.0379	0.0000	0.0000	0.2201	0.4001	0.0052	0.0000	0.0000	0.0216	0.0000	0.0401
211	0.0350	0.0600	0.0205	0.0000	0.0000	0.0088	0.0500	0.2200	0.5200	0.0052	0.0000	0.0000	0.0500	0.0000	0.0306
212	0.0900	0.0936	0.0000	0.0628	0.0000	0.0000	0.0372	0.2200	0.4347	0.0016	0.0000	0.0000	0.0100	0.0000	0.0501
213	0.0801	0.1201	0.0801	0.0650	0.0010	0.0300	0.0100	0.1001	0.4248	0.0040	0.0000	0.0000	0.0500	0.0100	0.0248
214	0.0500	0.1200	0.0222	0.0650	0.0200	0.0050	0.0350	0.1701	0.4202	0.0024	0.0000	0.0000	0.0500	0.0350	0.0051
215	0.0800	0.1201	0.0800	0.0650	0.0010	0.0300	0.0100	0.1001	0.4203	0.0040	0.0000	0.0000	0.0200	0.0250	0.0444
216	0.0800	0.1200	0.0800	0.0200	0.0200	0.0050	0.0100	0.1317	0.4199	0.0033	0.0000	0.0000	0.0500	0.0350	0.0253

Table B.2. Glass Oxide Compositions (mass fractions)[(a)] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row	Component														
#[(b)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
217	0.0351	0.0602	0.1003	0.0803	0.0000	0.0452	0.0502	0.0502	0.4716	0.0100	0.0000	0.0000	0.0502	0.0000	0.0469
218	0.0500	0.0700	0.0800	0.0200	0.0200	0.0226	0.0350	0.1700	0.4201	0.0024	0.0000	0.0000	0.0500	0.0350	0.0247
219	0.0501	0.1090	0.0801	0.0651	0.0200	0.0300	0.0100	0.1001	0.4204	0.0056	0.0000	0.0000	0.0501	0.0350	0.0245
220	0.0799	0.0699	0.0200	0.0649	0.0200	0.0050	0.0350	0.1698	0.4195	0.0033	0.0000	0.0000	0.0499	0.0350	0.0279
221	0.0501	0.0702	0.0802	0.0200	0.0200	0.0301	0.0100	0.1002	0.4855	0.0056	0.0000	0.0000	0.0501	0.0351	0.0429
222	0.0800	0.1200	0.0200	0.0650	0.0200	0.0064	0.0100	0.1700	0.4708	0.0024	0.0000	0.0000	0.0200	0.0100	0.0054
223	0.0801	0.1202	0.0200	0.0368	0.0200	0.0300	0.0350	0.1001	0.4999	0.0040	0.0000	0.0000	0.0200	0.0100	0.0236
224	0.0801	0.1201	0.0497	0.0200	0.0010	0.0300	0.0100	0.1001	0.4991	0.0056	0.0000	0.0000	0.0500	0.0100	0.0243
225	0.0801	0.0700	0.0801	0.0650	0.0200	0.0050	0.0350	0.1338	0.4203	0.0032	0.0000	0.0000	0.0331	0.0100	0.0443
226	0.0501	0.1202	0.0802	0.0651	0.0070	0.0069	0.0100	0.1002	0.5010	0.0056	0.0000	0.0000	0.0200	0.0100	0.0236
227	0.0756	0.0701	0.0200	0.0651	0.0200	0.0300	0.0350	0.1001	0.4689	0.0040	0.0000	0.0000	0.0500	0.0350	0.0260
228	0.0900	0.0600	0.1001	0.0800	0.0000	0.0447	0.0500	0.1149	0.4002	0.0100	0.0000	0.0000	0.0100	0.0400	0.0000
229	0.0800	0.1200	0.0200	0.0650	0.0010	0.0202	0.0100	0.1701	0.4202	0.0024	0.0000	0.0000	0.0500	0.0350	0.0060
230	0.0500	0.0700	0.0800	0.0650	0.0010	0.0300	0.0100	0.1676	0.4233	0.0034	0.0000	0.0000	0.0200	0.0350	0.0446
231	0.0515	0.0700	0.0200	0.0200	0.0200	0.0300	0.0350	0.1651	0.5001	0.0035	0.0000	0.0000	0.0500	0.0100	0.0247
232	0.0500	0.1200	0.0800	0.0650	0.0172	0.0090	0.0100	0.1701	0.4202	0.0033	0.0000	0.0000	0.0200	0.0100	0.0251
233	0.0500	0.0836	0.0800	0.0629	0.0200	0.0300	0.0100	0.1701	0.4201	0.0033	0.0000	0.0000	0.0200	0.0350	0.0149
234	0.0500	0.1201	0.0618	0.0441	0.0010	0.0050	0.0350	0.1701	0.4202	0.0024	0.0000	0.0000	0.0200	0.0258	0.0444
235	0.0700	0.1100	0.0700	0.0500	0.0030	0.0250	0.0150	0.1200	0.4502	0.0040	0.0000	0.0000	0.0350	0.0200	0.0277
236	0.0675	0.1101	0.0701	0.0500	0.0030	0.0250	0.0250	0.1201	0.4504	0.0040	0.0000	0.0000	0.0350	0.0300	0.0097
237	0.0700	0.0800	0.0700	0.0300	0.0015	0.0250	0.0150	0.1400	0.4799	0.0035	0.0000	0.0000	0.0350	0.0200	0.0302
238	0.0701	0.0906	0.0500	0.0300	0.0010	0.0250	0.0250	0.1401	0.4805	0.0035	0.0000	0.0000	0.0350	0.0200	0.0290
239	0.0352	0.1306	0.1004	0.0556	0.0402	0.0452	0.0000	0.0502	0.4160	0.0100	0.0000	0.0000	0.0502	0.0402	0.0262
240	0.0600	0.1101	0.0500	0.0500	0.0010	0.0100	0.0150	0.1401	0.4803	0.0037	0.0000	0.0000	0.0350	0.0300	0.0148
241	0.0700	0.0800	0.0700	0.0500	0.0030	0.0100	0.0250	0.1400	0.4501	0.0037	0.0000	0.0000	0.0460	0.0223	0.0297
242	0.0600	0.0801	0.0500	0.0404	0.0010	0.0250	0.0150	0.1401	0.4803	0.0037	0.0000	0.0000	0.0350	0.0300	0.0393
243	0.0700	0.0868	0.0500	0.0500	0.0030	0.0250	0.0250	0.1200	0.4502	0.0042	0.0000	0.0000	0.0460	0.0300	0.0397
244	0.0632	0.1004	0.0701	0.0501	0.0010	0.0100	0.0150	0.1201	0.4806	0.0040	0.0000	0.0000	0.0461	0.0200	0.0194
245	0.0700	0.0800	0.0578	0.0500	0.0030	0.0142	0.0150	0.1401	0.4802	0.0035	0.0000	0.0000	0.0460	0.0200	0.0201
246	0.0601	0.1102	0.0652	0.0501	0.0010	0.0100	0.0251	0.1202	0.4803	0.0040	0.0000	0.0000	0.0351	0.0301	0.0085
247	0.0620	0.0800	0.0700	0.0500	0.0010	0.0100	0.0250	0.1401	0.4802	0.0035	0.0000	0.0000	0.0350	0.0300	0.0132

Table B.2. Glass Oxide Compositions (mass fractions)[(a)] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row	Component														
#[(b)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
248	0.0623	0.1102	0.0528	0.0501	0.0010	0.0100	0.0150	0.1202	0.4807	0.0040	0.0000	0.0000	0.0351	0.0200	0.0387
249	0.0700	0.1091	0.0500	0.0300	0.0010	0.0100	0.0150	0.1400	0.4754	0.0037	0.0000	0.0000	0.0460	0.0200	0.0298
250	0.0904	0.0603	0.0579	0.0804	0.0402	0.0452	0.0000	0.0502	0.4890	0.0100	0.0000	0.0000	0.0100	0.0402	0.0261
251	0.0653	0.0970	0.0611	0.0411	0.0020	0.0167	0.0203	0.1309	0.4698	0.0038	0.0000	0.0000	0.0410	0.0253	0.0255
252	0.0653	0.0970	0.0611	0.0411	0.0020	0.0167	0.0203	0.1309	0.4697	0.0038	0.0000	0.0000	0.0410	0.0253	0.0258
253	0.0609	0.0971	0.0199	0.0554	0.0259	0.0000	0.0148	0.2003	0.4405	0.0021	0.0000	0.0000	0.0295	0.0299	0.0237
254	0.0903	0.0602	0.1003	0.0803	0.0401	0.0452	0.0000	0.0502	0.4460	0.0100	0.0000	0.0000	0.0502	0.0000	0.0272
255	0.0350	0.0601	0.1001	0.0801	0.0401	0.0239	0.0000	0.0501	0.4978	0.0040	0.0000	0.0000	0.0501	0.0401	0.0186
256	0.0350	0.1300	0.0000	0.0231	0.0400	0.0450	0.0197	0.1426	0.4221	0.0027	0.0000	0.0000	0.0500	0.0400	0.0497
257	0.0499	0.1198	0.0617	0.0440	0.0010	0.0050	0.0349	0.1697	0.4191	0.0024	0.0000	0.0000	0.0200	0.0257	0.0469
258	0.0900	0.1061	0.1000	0.0800	0.0400	0.0000	0.0500	0.0900	0.4001	0.0034	0.0000	0.0000	0.0100	0.0000	0.0303
259	0.0544	0.0697	0.1003	0.0802	0.0000	0.0259	0.0501	0.0501	0.5215	0.0100	0.0000	0.0000	0.0100	0.0000	0.0278
260	0.0903	0.1304	0.0645	0.0000	0.0000	0.0209	0.0502	0.0502	0.4463	0.0100	0.0000	0.0000	0.0502	0.0401	0.0472
261	0.0351	0.0601	0.1002	0.0801	0.0401	0.0239	0.0000	0.0501	0.4979	0.0040	0.0000	0.0000	0.0501	0.0401	0.0184
262	0.0610	0.0884	0.0196	0.0687	0.0044	0.0000	0.0196	0.2066	0.4382	0.0019	0.0000	0.0000	0.0292	0.0294	0.0329
263	0.0649	0.1301	0.0799	0.0220	0.0020	0.0470	0.0141	0.0501	0.5010	0.0081	0.0000	0.0000	0.0489	0.0319	0.0001
264	0.0612	0.1006	0.0642	0.0644	0.0014	0.0273	0.0150	0.1197	0.4678	0.0048	0.0000	0.0000	0.0302	0.0302	0.0132
265	0.0565	0.1021	0.0207	0.0576	0.0343	0.0000	0.0154	0.1631	0.4583	0.0031	0.0000	0.0000	0.0307	0.0311	0.0272
266	0.0609	0.0998	0.0698	0.0550	0.0054	0.0427	0.0295	0.0573	0.4905	0.0080	0.0000	0.0000	0.0349	0.0300	0.0162
267	0.0611	0.1001	0.0232	0.0551	0.0475	0.0000	0.0148	0.1738	0.4378	0.0035	0.0000	0.0000	0.0350	0.0300	0.0180
268	0.0695	0.0875	0.0197	0.0436	0.0541	0.0000	0.0144	0.1975	0.4185	0.0035	0.0000	0.0000	0.0341	0.0392	0.0183
269	0.0695	0.0975	0.0197	0.0536	0.0541	0.0000	0.0044	0.1975	0.4185	0.0035	0.0000	0.0000	0.0341	0.0392	0.0083
270	0.0593	0.0824	0.0147	0.0536	0.0540	0.0000	0.0094	0.1972	0.4280	0.0035	0.0000	0.0000	0.0341	0.0442	0.0197
271	0.0595	0.0975	0.0197	0.0536	0.0379	0.0000	0.0144	0.2078	0.4244	0.0032	0.0000	0.0000	0.0341	0.0293	0.0185
272	0.0610	0.1000	0.0202	0.0550	0.0499	0.0000	0.0148	0.1822	0.4296	0.0035	0.0000	0.0000	0.0350	0.0300	0.0187
273	0.0594	0.0974	0.0197	0.0537	0.0541	0.0000	0.0144	0.1975	0.4186	0.0037	0.0000	0.0000	0.0341	0.0292	0.0182
274	0.0611	0.1001	0.0252	0.0551	0.0050	0.0000	0.0148	0.1966	0.4553	0.0038	0.0000	0.0000	0.0350	0.0300	0.0178
275	0.0597	0.0980	0.0246	0.0538	0.0054	0.0000	0.0145	0.2128	0.4453	0.0041	0.0000	0.0000	0.0343	0.0294	0.0180
276	0.0611	0.1001	0.0368	0.0550	0.0050	0.0051	0.0148	0.1754	0.4592	0.0043	0.0000	0.0000	0.0350	0.0300	0.0181
277	0.0600	0.0982	0.0361	0.0541	0.0054	0.0049	0.0145	0.1899	0.4510	0.0046	0.0000	0.0000	0.0343	0.0294	0.0175
278	0.0611	0.1002	0.0640	0.0551	0.0050	0.0323	0.0151	0.1252	0.4541	0.0055	0.0000	0.0000	0.0351	0.0301	0.0173

Table B.2. Glass Oxide Compositions (mass fractions)[(a)] for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #[(b)]	Component														
	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
279	0.0603	0.0988	0.0632	0.0544	0.0054	0.0317	0.0149	0.1355	0.4481	0.0059	0.0000	0.0000	0.0346	0.0296	0.0175
280	0.0607	0.0995	0.0688	0.0547	0.0054	0.0409	0.0237	0.0895	0.4692	0.0069	0.0000	0.0000	0.0348	0.0298	0.0162
281	0.0747	0.0851	0.0353	0.0000	0.0388	0.0000	0.0118	0.1845	0.4751	0.0035	0.0000	0.0000	0.0309	0.0313	0.0291

(a) The mass fractions were rounded to four decimal places for display in this table. Hence, the 15 values in a row may not sum exactly to 1.0000. The mass fractions of the glass components to more decimal places were used when fitting the viscosity at 1150ºC model, and hence the results of fitting the model using the rounded compositions in this table may not yield exactly the same results.
(b) The glass names corresponding to the row numbers are listed in Table B.1.

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row		Temperature (ºC) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150} [(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
1	21.16	951	167.77	1049	52.59	1147	21.79	1246	10.60	NA	NA	NA	NA	NA	NA
2	18.89	950	148.95	1048	46.80	1146	19.66	1245	9.61	NA	NA	NA	NA	NA	NA
3	23.83	951	219.54	1049	62.58	1146	24.71	1245	11.71	NA	NA	NA	NA	NA	NA
4	31.51	949	355.06	1047	92.19	1145	32.59	1244	14.88	NA	NA	NA	NA	NA	NA
5	25.52	951	207.21	1050	62.90	1150	25.80	1250	12.40	NA	NA	NA	NA	NA	NA
6	35.36	952	340.68	1050	97.93	1147	35.94	1246	16.22	NA	NA	NA	NA	NA	NA
7	26.38	947	247.46	1047	69.39	1147	27.23	1246	12.99	NA	NA	NA	NA	NA	NA
8	32.83	946	403.76	1046	101.52	1145	34.27	1244	14.49	NA	NA	NA	NA	NA	NA
9	43.23	949	565.33	1047	136.62	1145	44.95	1244	19.06	NA	NA	NA	NA	NA	NA
10	51.74	950	700.63	1047	169.15	1143	54.00	1241	23.28	NA	NA	NA	NA	NA	NA
11	49.59	945	601.70	1043	155.45	1140	54.21	1238	23.53	NA	NA	NA	NA	NA	NA
12	58.02	947	781.20	1044	188.08	1141	62.67	1239	27.10	NA	NA	NA	NA	NA	NA
13	20.96	952	176.51	1052	52.13	1151	20.92	1252	9.82	NA	NA	NA	NA	NA	NA
14	24.93	951	222.36	1050	62.83	1149	25.22	1248	12.47	NA	NA	NA	NA	NA	NA
15	26.18	949	261.98	1047	71.03	1146	27.03	1245	13.01	NA	NA	NA	NA	NA	NA
16	33.87	950	338.38	1049	90.45	1148	34.21	1248	16.56	NA	NA	NA	NA	NA	NA
17	27.71	949	249.60	1049	70.56	1150	27.96	1251	13.35	NA	NA	NA	NA	NA	NA
18	37.95	948	375.17	1047	106.03	1145	39.34	1245	17.95	NA	NA	NA	NA	NA	NA
19	35.47	953	339.79	1052	94.06	1151	35.06	1251	16.13	NA	NA	NA	NA	NA	NA
20	37.31	949	488.72	1047	117.43	1144	38.93	1242	17.01	NA	NA	NA	NA	NA	NA
21	36.66	950	471.67	1050	111.09	1149	36.36	1250	15.78	NA	NA	NA	NA	NA	NA
22	49.07	948	642.08	1045	158.30	1143	52.26	1241	22.02	NA	NA	NA	NA	NA	NA
23	50.55	952	668.13	1051	154.05	1150	50.35	1250	21.06	NA	NA	NA	NA	NA	NA
24	26.81	949	257.62	1049	72.43	1148	27.28	1247	12.49	NA	NA	NA	NA	NA	NA
25	35.98	947	363.80	1047	100.47	1146	36.68	1245	17.33	NA	NA	NA	NA	NA	NA
26	30.70	947	289.58	1047	79.90	1146	31.00	1245	16.26	NA	NA	NA	NA	NA	NA
27	39.16	952	356.80	1053	102.11	1153	37.90	1253	17.32	NA	NA	NA	NA	NA	NA
28	28.92	951	259.68	1051	74.58	1150	28.87	1249	13.70	NA	NA	NA	NA	NA	NA
29	47.08	949	478.41	1048	131.97	1147	47.73	1245	22.33	NA	NA	NA	NA	NA	NA
30	38.09	949	372.13	1050	103.67	1149	37.80	1249	17.58	NA	NA	NA	NA	NA	NA

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row		Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150} [(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
31	35.12	949	344.08	1049	96.38	1149	35.31	1248	16.03	NA	NA	NA	NA	NA	NA
32	24.88	946	250.25	1044	70.21	1142	26.60	1241	12.39	NA	NA	NA	NA	NA	NA
33	29.09	946	296.91	1044	80.24	1142	30.65	1241	15.35	NA	NA	NA	NA	NA	NA
34	21.78	947	226.42	1045	61.43	1144	23.12	1243	10.56	NA	NA	NA	NA	NA	NA
35	22.20	948	246.22	1046	63.85	1145	23.13	1249	10.33	NA	NA	NA	NA	NA	NA
36	56.77	971	499.59	1063	141.39	1160	52.21	1256	23.40	NA	NA	NA	NA	NA	NA
37	66.90	960	694.28	1058	182.37	1157	62.27	1255	26.63	NA	NA	NA	NA	NA	NA
38	61.42	952	771.52	1042	198.97	1129	75.73	1219	33.99	NA	NA	NA	NA	NA	NA
39	127.89	954	1898.86	1056	402.50	1158	116.41	1260	43.62	NA	NA	NA	NA	NA	NA
40	123.97	959	1510.79	1061	352.12	1162	108.94	1264	41.17	NA	NA	NA	NA	NA	NA
41	101.39	961	1619.00	1061	302.04	1160	94.18	1260	33.79	NA	NA	NA	NA	NA	NA
42	43.75	962	500.75	1062	114.77	1162	38.61	1262	17.63	NA	NA	NA	NA	NA	NA
43	46.68	974	439.77	1071	114.80	1167	38.84	1264	16.54	NA	NA	NA	NA	NA	NA
44	110.40	975	1118.82	1075	267.47	1175	84.48	1274	33.42	NA	NA	NA	NA	NA	NA
45	128.01	976	1411.66	1073	313.54	1170	107.89	1267	40.04	NA	NA	NA	NA	NA	NA
46	119.79	964	1542.94	1063	334.38	1161	109.82	1260	40.18	NA	NA	NA	NA	NA	NA
47	144.65	968	1828.14	1066	382.11	1164	132.45	1262	47.19	NA	NA	NA	NA	NA	NA
48	65.18	952	877.79	1052	201.81	1152	63.78	1252	25.37	NA	NA	NA	NA	NA	NA
49	95.18	953	1388.50	1051	303.10	1150	96.34	1248	38.00	NA	NA	NA	NA	NA	NA
50	71.41	959	933.36	1055	219.32	1150	70.86	1245	29.38	NA	NA	NA	NA	NA	NA
51	60.29	961	787.65	1061	174.15	1160	53.59	1260	21.73	NA	NA	NA	NA	NA	NA
52	56.59	958	791.73	1059	168.63	1159	51.00	1260	20.16	NA	NA	NA	NA	NA	NA
53	54.22	959	739.50	1060	157.21	1160	48.53	1261	19.62	NA	NA	NA	NA	NA	NA
54	58.03	951	932.11	1053	184.85	1157	54.08	1259	21.04	NA	NA	NA	NA	NA	NA
55	55.79	953	858.47	1055	173.41	1159	50.90	1261	19.73	NA	NA	NA	NA	NA	NA
56	82.74	957	1029.58	1060	231.27	1163	72.57	1266	28.65	NA	NA	NA	NA	NA	NA
57	76.72	965	825.39	1065	197.34	1164	67.15	1264	27.86	NA	NA	NA	NA	NA	NA

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row		Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150} [(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
58	65.25	951	808.51	1052	195.22	1153	63.30	1254	25.39	NA	NA	NA	NA	NA	NA
59	74.78	956	931.52	1052	231.41	1149	74.43	1245	31.58	NA	NA	NA	NA	NA	NA
60	26.72	957	221.74	1056	64.02	1156	25.84	1255	12.25	NA	NA	NA	NA	NA	NA
61	74.32	966	864.61	1066	193.68	1166	63.50	1266	26.49	NA	NA	NA	NA	NA	NA
62	33.63	956	295.59	1056	83.92	1155	32.10	1255	15.10	NA	NA	NA	NA	NA	NA
63	27.84	960	242.79	1060	66.51	1160	25.74	1260	12.13	NA	NA	NA	NA	NA	NA
64	35.60	955	361.31	1057	92.36	1158	32.63	1260	15.22	NA	NA	NA	NA	NA	NA
65	29.83	956	275.71	1058	74.61	1159	27.26	1261	12.74	NA	NA	NA	NA	NA	NA
66	30.84	956	332.24	1058	81.50	1159	28.38	1261	12.27	NA	NA	NA	NA	NA	NA
67	29.02	959	285.51	1059	74.30	1160	26.45	1260	11.97	NA	NA	NA	NA	NA	NA
68	23.23	962	202.46	1064	55.00	1165	20.36	1267	9.12	NA	NA	NA	NA	NA	NA
69	19.60	985	97.94	1082	35.27	1179	15.68	1276	7.93	NA	NA	NA	NA	NA	NA
70	22.07	959	158.43	1057	50.69	1155	21.34	1254	10.45	NA	NA	NA	NA	NA	NA
71	16.99	962	104.97	1061	35.53	1160	15.88	1260	8.28	NA	NA	NA	NA	NA	NA
72	19.31	959	139.79	1059	43.81	1159	18.02	1260	8.76	NA	NA	NA	NA	NA	NA
73	23.05	963	158.79	1062	49.30	1161	21.23	1261	11.22	NA	NA	NA	NA	NA	NA
74	17.07	958	143.45	1052	43.28	1148	17.52	1243	8.48	NA	NA	NA	NA	NA	NA
75	17.39	978	122.05	1068	37.08	1158	16.75	1248	8.50	NA	NA	NA	NA	NA	NA
76	17.25	969	93.10	1062	35.58	1157	16.52	1251	8.63	NA	NA	NA	NA	NA	NA
77	21.51	992	104.09	1088	36.82	1184	16.64	1280	8.28	NA	NA	NA	NA	NA	NA
78	19.59	964	127.03	1058	45.57	1153	19.04	1248	9.19	NA	NA	NA	NA	NA	NA
79	21.84	986	106.21	1077	39.70	1169	19.27	1260	10.54	NA	NA	NA	NA	NA	NA
80	21.54	977	144.46	1073	44.89	1169	18.29	1265	9.19	NA	NA	NA	NA	NA	NA
81	40.04	957	386.23	1057	103.68	1158	36.09	1260	17.69	NA	NA	NA	NA	NA	NA
82	33.61	957	325.44	1057	87.22	1158	31.23	1260	13.77	NA	NA	NA	NA	NA	NA
83	32.57	956	308.91	1057	83.22	1157	30.46	1257	13.95	NA	NA	NA	NA	NA	NA
84	27.50	958	254.92	1058	69.00	1158	25.82	1259	11.51	NA	NA	NA	NA	NA	NA
85	20.78	957	159.47	1057	48.20	1158	19.25	1259	9.97	NA	NA	NA	NA	NA	NA
86	28.83	954	282.76	1054	73.95	1156	27.34	1257	13.07	NA	NA	NA	NA	NA	NA

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row		Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150} [(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
87	24.47	955	222.67	1057	60.62	1160	22.56	1262	10.30	NA	NA	NA	NA	NA	NA
88	26.37	957	243.00	1058	64.77	1160	24.35	1261	11.35	NA	NA	NA	NA	NA	NA
89	26.33	955	247.18	1057	64.56	1159	24.45	1261	11.68	NA	NA	NA	NA	NA	NA
90	25.23	946	247.81	1044	69.08	1142	26.94	1241	13.01	NA	NA	NA	NA	NA	NA
91	175.66	1214	79.10	1264	50.10	1314	32.90	1363	18.90	1412	13.90	1413	13.50	1462	9.50
92	37.19	1139	40.80	1189	25.50	1239	16.40	1288	9.50	1337	6.80	1337	6.90	1387	4.80
93	61.40	1140	66.50	1189	40.60	1239	26.40	1289	14.30	1338	10.20	1338	10.40	1388	7.20
94	21.61	1089	41.60	1139	24.90	1189	15.80	1238	9.50	1287	6.60	1287	6.70	1336	4.70
95	40.62	1140	43.90	1189	27.60	1239	18.40	1288	10.50	1337	7.30	1338	7.60	1387	5.20
96	65.48	1139	74.50	1189	43.00	1238	26.00	1287	16.50	1287	16.60	1336	11.20	1337	11.20
97	50.47	1089	108.80	1139	58.00	1189	32.00	1238	19.50	1238	19.70	1287	12.80	1287	12.90
98	73.72	1139	85.20	1189	46.60	1238	27.10	1287	16.50	1287	16.50	1336	10.80	1337	10.80
99	142.26	1188	86.90	1238	53.20	1287	29.80	1336	19.90	1336	20.30	1386	13.60	1386	14.40
100	38.64	1089	78.60	1138	45.10	1188	25.60	1237	16.70	1238	16.40	1286	11.50	1287	11.00
101	45.80	1089	95.20	1138	55.00	1187	29.50	1236	19.60	1237	19.00	1286	12.80	1286	13.60
102	63.22	1139	71.30	1188	43.10	1238	24.60	1287	16.00	1287	16.50	1337	10.90	1337	11.70
103	78.42	1138	89.40	1188	53.20	1237	31.70	1287	20.50	1287	21.00	1336	13.60	1336	14.50
104	26.02	1090	50.70	1140	29.40	1189	17.20	1239	11.50	1239	11.60	1288	7.70	1288	8.00
105	31.76	1089	62.80	1138	36.20	1188	21.30	1238	14.20	1238	14.30	1287	9.40	1287	9.70
106	242.41	1188	154.50	1237	91.30	1287	56.30	1336	35.80	1386	23.60	1386	25.00	1436	15.70
107	19.93	1089	36.40	1138	22.60	1188	13.80	1237	9.40	1237	9.50	1286	6.40	1286	6.60
108	4.05	891	63.70	941	32.40	991	18.30	1040	11.00	1089	6.80	1089	6.80	1139	4.40
109	134.21	1189	72.50	1239	42.10	1288	26.10	1338	14.40	1388	10.00	1389	9.70	1438	6.90
110	178.98	1186	108.90	1236	60.10	1286	32.60	1336	19.80	1336	20.00	1386	12.90	1386	12.90
111	145.29	1189	83.10	1239	47.70	1288	26.70	1338	16.50	1338	17.00	1388	10.50	1388	11.30
112	36.94	1094	77.30	1145	39.70	1194	21.80	1244	13.30	1244	13.40	1294	8.10	1294	8.40
113	70.99	1091	143.30	1141	78.60	1191	45.60	1241	28.20	1291	17.80	1341	12.00	1391	8.20
114	54.93	1142	60.00	1192	35.80	1242	21.90	1292	14.90	1292	14.60	1342	10.00	1342	10.40
115	69.30	1141	76.30	1191	45.30	1240	24.10	1290	15.70	1290	15.90	1340	10.60	1340	11.20

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row #[(a)]	η_{1150} [(b)]	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi) T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
116	93.69	1190	54.50	1239	33.10	1289	19.60	1339	13.30	1339	13.40	1388	9.30	1389	9.00
117	44.24	1045	153.40	1144	48.50	1243	19.40	1342	7.40	1343	9.20	1392	5.80	1442	4.40
118	89.30	1095	179.90	1145	94.60	1244	32.20	1343	12.30	1343	12.60	1393	8.20	1443	5.80
119	77.02	1070	198.30	1119	109.40	1220	39.60	1318	14.40	1319	16.90	1368	10.60	1418	8.10
120	47.14	1046	161.00	1145	49.70	1244	19.10	1342	8.70	NA	NA	NA	NA	NA	NA
121	37.44	997	244.20	1096	69.40	1195	23.70	1294	9.60	1294	10.30	1344	7.10	NA	NA
122	64.55	1138	76.80	1186	40.90	1236	24.80	1236	25.90	1285	15.60	1285	16.50	1286	17.10
123	83.40	1092	179.30	1142	96.10	1191	50.80	1241	29.80	1241	31.10	1290	17.90	1290	19.30
124	61.91	1091	133.50	1141	72.70	1190	38.60	1239	24.70	1240	23.70	1289	15.70	1290	14.90
125	95.48	1138	111.10	1187	62.80	1236	31.80	1286	20.00	1286	20.80	1336	12.50	1336	13.90
126	11.03	941	158.70	992	72.60	1041	35.90	1090	20.10	1091	20.10	1140	12.20	1141	11.90
127	35.51	1088[(c)]	78.70[(c)]	1138	40.00	1187	24.90	1187	25.90	1236	15.80	1237	17.00	1237	18.80
128	99.43	1143	108.10	1193	60.30	1243	30.10	1292	19.90	1293	18.80	1342	12.20	1342	13.40
129	91.92	1187	59.90	1237	35.30	1286	21.80	1336	14.00	1336	14.20	1386	9.60	1386	9.70
130	61.16	1142	67.30	1192	38.30	1242	22.60	1291	14.20	1292	14.00	1341	9.20	1341	9.50
131	83.18	1191	54.90	1241	33.00	1291	20.90	1291	21.00	1340	13.70	1340	13.90	1342	13.60
132	152.36	1187	90.30	1237	51.90	1286	31.30	1336	17.90	1386	11.70	1386	12.20	1435	7.60
133	11.61	940	203.90	990	89.40	1040	41.90	1089	22.40	1090	21.30	1139	12.70	1140	12.80
134	64.71	1188	40.80	1237	23.60	1286	15.80	1287	15.30	1336	10.30	1336	11.10	1337	11.90
135	61.35	1142	67.30	1192	38.50	1243	22.50	1292	14.10	1293	14.00	1341	9.40	1342	9.60
136	89.69	1195	46.90	1245	22.40	1294	14.20	1295	13.70	1344	8.60	1345	9.10	1345	9.00
137	5.60	941	76.50	992	35.00	1041	17.30	1091	9.80	1091	9.90	1140	6.00	1141	5.90
138	55.09	1090	116.80	1140	64.70	1188	35.00	1238	21.30	1238	21.40	1287	13.60	1287	13.70
139	18.44	1090	33.40	1144	20.60	1190	12.60	1240	8.40	1240	8.40	1289	5.90	1290	6.00
140	17.30	1040	54.70	1090	30.80	1090	31.30	1139	18.60	1139	18.80	1140	20.10	1188	12.10
141	3.62	1230	1.84	1155	3.44	1058	9.28	958	33.25	NA	NA	NA	NA	NA	NA
142	6.43	1235	3.07	1139	7.25	1043	20.09	948	76.08	NA	NA	NA	NA	NA	NA
143	4.88	1250	2.07	1152	4.76	1053	14.07	955	55.43	NA	NA	NA	NA	NA	NA
144	4.09	1261	1.63	1161	3.65	1061	10.39	961	37.85	NA	NA	NA	NA	NA	NA

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row		Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150}[(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
145	5.79	1251	2.43	1152	5.66	1052	16.42	953	61.55	NA	NA	NA	NA	NA	NA
146	4.85	1253	2.18	1153	4.64	1051	12.98	950	45.86	NA	NA	NA	NA	NA	NA
147	6.15	1251	2.58	1152	6.00	1052	17.30	952	63.80	NA	NA	NA	NA	NA	NA
148	5.41	1241	2.55	1139	6.09	1037	17.20	935	70.87	NA	NA	NA	NA	NA	NA
149	5.24	1225	2.62	1128	6.64	1031	20.51	935	90.16	NA	NA	NA	NA	NA	NA
150	4.07	1220	2.33	1125	5.07	1031	13.28	936	46.18	NA	NA	NA	NA	NA	NA
151	3.47	1241	1.72	1144	3.64	1047	9.41	950	31.88	NA	NA	NA	NA	NA	NA
152	3.32	1239	1.66	1141	3.57	1043	9.55	945	33.39	NA	NA	NA	NA	NA	NA
153	5.95	1251	2.51	1153	5.78	1053	16.51	955	59.60	NA	NA	NA	NA	NA	NA
154	3.45	1244	1.66	1146	3.57	1048	9.25	950	30.95	NA	NA	NA	NA	NA	NA
155	4.18	1251	1.92	1151	4.05	1051	11.21	951	39.04	NA	NA	NA	NA	NA	NA
156	9.34	1262	3.35	1162	8.10	1062	26.21	962	111.50	NA	NA	NA	NA	NA	NA
157	5.22	1247	2.30	1149	5.28	1051	15.13	953	60.78	NA	NA	NA	NA	NA	NA
158	5.58	1271	2.14	1169	4.63	1067	13.02	965	46.38	NA	NA	NA	NA	NA	NA
159	4.55	1220	2.58	1126	5.69	1032	15.15	938	55.85	NA	NA	NA	NA	NA	NA
160	4.36	1253	1.93	1153	4.16	1053	11.56	953	39.63	NA	NA	NA	NA	NA	NA
161	3.51	1192	2.44	1143	3.81	1044	9.58	944	31.43	NA	NA	NA	NA	NA	NA
162	5.44	1189	3.90	1085	10.16	985	33.20	935	67.79	NA	NA	NA	NA	NA	NA
163	3.47	1249	1.62	1150	3.49	1051	9.08	952	32.29	NA	NA	NA	NA	NA	NA
164	5.08	1241	2.42	1145	5.28	1050	14.25	954	51.51	NA	NA	NA	NA	NA	NA
165	6.27	1261	2.41	1161	5.58	1061	16.18	960	59.86	NA	NA	NA	NA	NA	NA
166	9.40	1261	3.43	1161	8.31	1061	25.89	961	104.93	NA	NA	NA	NA	NA	NA
167	7.09	1228	3.54	1126	9.13	1023	28.13	921	124.17	NA	NA	NA	NA	NA	NA
168	6.57	1239	3.06	1143	7.12	1046	19.82	950	77.16	NA	NA	NA	NA	NA	NA
169	7.79	1233	3.71	1138	8.72	1042	25.76	948	96.30	NA	NA	NA	NA	NA	NA
170	5.49	1230	2.69	1133	6.65	1034	19.29	936	82.63	NA	NA	NA	NA	NA	NA
171	7.12	1233	3.49	1134	8.31	1034	24.72	935	100.18	NA	NA	NA	NA	NA	NA
172	2.86	1258	1.20	1159	2.68	1056	7.23	956	25.79	NA	NA	NA	NA	NA	NA
173	2.71	1225	1.45	1131	3.32	1038	8.39	945	30.20	NA	NA	NA	NA	NA	NA

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row		Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150} [(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
174	4.08	1243	1.93	1143	4.36	1043	12.33	943	49.74	NA	NA	NA	NA	NA	NA
175	3.46	1257	1.51	1156	3.33	1056	8.81	957	34.56	NA	NA	NA	NA	NA	NA
176	5.34	1264	1.96	1164	4.61	1064	13.79	964	53.09	NA	NA	NA	NA	NA	NA
177	4.48	1265	1.70	1162	3.95	1060	11.92	959	47.33	NA	NA	NA	NA	NA	NA
178	7.65	1266	2.73	1166	6.48	1066	19.71	967	80.52	NA	NA	NA	NA	NA	NA
179	5.77	1264	2.11	1164	4.97	1064	15.08	964	59.94	NA	NA	NA	NA	NA	NA
180	3.67	1247	1.66	1147	3.81	1047	10.28	947	37.35	NA	NA	NA	NA	NA	NA
181	3.75	1239	1.76	1141	4.13	1043	11.42	946	42.16	NA	NA	NA	NA	NA	NA
182	3.89	1238	1.91	1140	4.31	1042	11.35	945	40.52	NA	NA	NA	NA	NA	NA
183	4.20	1250	1.94	1150	4.11	1050	11.60	950	42.20	NA	NA	NA	NA	NA	NA
184	3.55	1246	1.54	1146	3.75	1046	10.75	947	43.05	NA	NA	NA	NA	NA	NA
185	3.34	1257	1.35	1159	3.06	1059	8.66	958	32.24	NA	NA	NA	NA	NA	NA
186	3.24	1261	1.38	1159	3.00	1057	8.15	956	30.66	NA	NA	NA	NA	NA	NA
187	3.36	1270	1.34	1168	2.87	1066	7.55	963	25.99	NA	NA	NA	NA	NA	NA
188	6.35	1252	3.29	1152	6.01	1052	16.91	967	57.25	NA	NA	NA	NA	NA	NA
189	4.17	1256	1.83	1156	4.01	1056	10.98	971	37.49	NA	NA	NA	NA	NA	NA
190	3.99	1241	1.89	1141	4.46	1041	12.26	951	45.68	NA	NA	NA	NA	NA	NA
191	5.43	1252	2.28	1152	5.30	1052	15.55	952	61.41	NA	NA	NA	NA	NA	NA
192	3.88	1253	1.65	1153	3.70	1053	10.70	946	42.59	NA	NA	NA	NA	NA	NA
193	3.29	1269	1.26	1169	2.75	1069	7.45	969	25.43	NA	NA	NA	NA	NA	NA
194	5.35	1253	2.21	1155	4.99	1058	14.90	962	56.30	NA	NA	NA	NA	NA	NA
195	5.12	1268	1.87	1168	4.25	1068	12.47	968	47.07	NA	NA	NA	NA	NA	NA
196	5.46	1255	2.25	1155	5.18	1055	14.94	957	55.27	NA	NA	NA	NA	NA	NA
197	4.78	1250	2.15	1149	5.04	1049	13.58	968	47.82	NA	NA	NA	NA	NA	NA
198	4.73	1256	1.89	1156	4.43	1055	13.27	955	52.27	NA	NA	NA	NA	NA	NA
199	5.38	1244	2.36	1144	5.89	1043	16.68	943	70.38	NA	NA	NA	NA	NA	NA
200	5.43	1227	2.85	1131	6.47	1036	18.73	941	75.71	NA	NA	NA	NA	NA	NA
201	4.80	1245	2.20	1146	5.01	1047	14.12	948	57.81	NA	NA	NA	NA	NA	NA
202	5.49	1244	2.48	1144	5.87	1043	17.23	942	74.00	NA	NA	NA	NA	NA	NA

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row		Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150} [(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
203	5.15	1246	2.36	1146	5.41	1046	14.57	946	54.35	NA	NA	NA	NA	NA	NA
204	3.93	1243	1.84	1143	4.20	1043	11.65	943	43.72	NA	NA	NA	NA	NA	NA
205	4.28	1258	1.77	1159	3.89	1059	11.00	959	40.05	NA	NA	NA	NA	NA	NA
206	3.89	1255	1.54	1162	3.49	1062	9.68	963	33.16	NA	NA	NA	NA	NA	NA
207	3.58	1252	1.69	1152	3.50	1053	9.41	953	37.70	NA	NA	NA	NA	NA	NA
208	1.40	1238	0.72	1143	1.50	1047	3.63	952	11.49	NA	NA	NA	NA	NA	NA
209	1.30	1239	0.75	1142	1.37	1045	2.91	948	7.34	NA	NA	NA	NA	NA	NA
210	1.44	1246	0.76	1148	1.47	1051	3.24	954	9.14	NA	NA	NA	NA	NA	NA
211	4.73	1234	2.51	1138	5.19	1042	13.19	945	43.06	NA	NA	NA	NA	NA	NA
212	6.58	1245	3.08	1148	6.76	1051	17.63	955	62.40	NA	NA	NA	NA	NA	NA
213	2.57	1247	1.25	1150	2.58	1052	6.46	955	21.49	NA	NA	NA	NA	NA	NA
214	3.29	1237	1.58	1143	3.51	1049	9.42	955	33.20	NA	NA	NA	NA	NA	NA
215	2.91	1243	1.44	1141	3.13	1039	8.53	939	30.65	NA	NA	NA	NA	NA	NA
216	7.43	1243	3.07	1146	7.17	1049	27.19	952	114.67	NA	NA	NA	NA	NA	NA
217	2.08	1244	0.96	1147	2.14	1051	5.99	953	25.32	NA	NA	NA	NA	NA	NA
218	2.11	1240	1.05	1142	2.25	1045	5.84	948	19.60	NA	NA	NA	NA	NA	NA
219	2.14	1242	1.06	1145	2.23	1048	5.82	952	19.89	NA	NA	NA	NA	NA	NA
220	9.89	1245	4.01	1144	10.63	1043	35.33	943	169.66	NA	NA	NA	NA	NA	NA
221	5.79	1238	2.73	1139	6.44	1040	19.16	942	79.79	NA	NA	NA	NA	NA	NA
222	7.87	1238	4.00	1142	8.42	1046	21.82	951	75.12	NA	NA	NA	NA	NA	NA
223	8.63	1240	4.08	1142	9.27	1044	25.56	947	89.10	NA	NA	NA	NA	NA	NA
224	7.71	1236	3.78	1139	8.29	1043	23.91	946	83.61	NA	NA	NA	NA	NA	NA
225	3.55	1243	1.81	1147	3.61	1051	9.03	957	29.00	NA	NA	NA	NA	NA	NA
226	9.20	1241	4.33	1143	10.33	1044	30.93	945	213.07	NA	NA	NA	NA	NA	NA
227	7.90	1248	3.42	1150	7.81	1052	22.85	955	86.02	NA	NA	NA	NA	NA	NA
228	1.79	1249	0.83	1152	1.79	1053	4.55	956	16.21	NA	NA	NA	NA	NA	NA
229	3.46	1246	1.73	1149	3.42	1052	8.72	955	27.72	NA	NA	NA	NA	NA	NA
230	2.12	1247	1.01	1149	2.01	1050	5.69	952	15.89	NA	NA	NA	NA	NA	NA
231	4.19	1248	2.04	1149	4.22	1050	10.58	951	34.56	NA	NA	NA	NA	NA	NA

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row		Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150} [(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
232	1.89	1245	0.97	1148	1.92	1051	4.57	954	13.96	NA	NA	NA	NA	NA	NA
233	1.61	1244	0.87	1147	1.67	1050	3.65	954	10.49	NA	NA	NA	NA	NA	NA
234	2.46	1249	1.12	1149	2.50	1050	6.83	950	26.99	NA	NA	NA	NA	NA	NA
235	3.69	1237	1.90	1140	3.98	1044	10.65	947	38.51	NA	NA	NA	NA	NA	NA
236	3.20	1237	1.58	1142	3.44	1047	9.05	951	31.80	NA	NA	NA	NA	NA	NA
237	5.42	1234	2.66	1138	6.05	1042	16.68	945	59.66	NA	NA	NA	NA	NA	NA
238	4.92	1230	2.53	1135	5.61	1041	15.19	946	53.19	NA	NA	NA	NA	NA	NA
239	1.32	1254	0.60	1154	1.30	1054	3.21	954	11.06	NA	NA	NA	NA	NA	NA
240	7.24	1236	3.43	1140	7.93	1044	23.16	947	92.95	NA	NA	NA	NA	NA	NA
241	6.69	1241	2.87	1143	7.30	1046	22.26	948	102.19	NA	NA	NA	NA	NA	NA
242	5.49	1233	2.75	1134	6.32	1036	18.33	937	72.12	NA	NA	NA	NA	NA	NA
243	4.43	1244	1.98	1147	4.55	1051	12.67	954	46.71	NA	NA	NA	NA	NA	NA
244	7.34	1246	3.15	1149	7.49	1052	21.75	956	90.11	NA	NA	NA	NA	NA	NA
245	6.62	1240	3.01	1146	6.90	1052	19.32	959	71.78	NA	NA	NA	NA	NA	NA
246	7.62	1243	3.28	1144	8.09	1045	25.45	945	115.99	NA	NA	NA	NA	NA	NA
247	7.06	1235	3.20	1143	7.58	1051	22.76	960	94.11	NA	NA	NA	NA	NA	NA
248	8.65	1249	3.66	1151	8.62	1053	25.73	956	114.31	NA	NA	NA	NA	NA	NA
249	7.47	1249	3.24	1149	7.51	1048	22.20	948	87.94	NA	NA	NA	NA	NA	NA
250	12.27	1246	5.21	1149	12.70	1052	36.38	956	156.23	NA	NA	NA	NA	NA	NA
251	5.81	1243	2.68	1146	6.04	1049	17.39	953	72.10	NA	NA	NA	NA	NA	NA
252	6.24	1248	2.61	1154	5.90	1060	17.10	966	62.45	NA	NA	NA	NA	NA	NA
253	5.11	1246	2.42	1149	5.15	1052	13.87	955	53.15	NA	NA	NA	NA	NA	NA
254	4.04	1248	1.68	1150	4.00	1056	10.51	958	31.43	NA	NA	NA	NA	NA	NA
255	11.16	1254	4.14	1155	10.59	1056	34.74	957	165.99	NA	NA	NA	NA	NA	NA
256	1.19	1259	0.60	1158	1.12	1057	2.45	956	6.59	NA	NA	NA	NA	NA	NA
257	2.54	1245	1.18	1148	2.58	1052	7.00	956	26.27	NA	NA	NA	NA	NA	NA
258	4.94	1244	2.11	1144	5.25	1044	17.31	944	87.21	NA	NA	NA	NA	NA	NA
259	11.64	1252	4.19	1152	11.39	1052	38.68	1002	89.42	952	199.67	NA	NA	NA	NA
260	7.40	1225	3.52	1128	9.40	1030	32.84	932	162.66	NA	NA	NA	NA	NA	NA

Table B.3. Viscosity at 1150°C Values and Temperature-Viscosity Pairs One to Seven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C (contd)

Row		Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)													
#[(a)]	η_{1150} [(b)]	T1	V1	T2	V2	T3	V3	T4	V4	T5	V5	T6	V6	T7	V7
261	12.65	1252	4.38	1150	12.64	1048	46.24	946	232.90	NA	NA	NA	NA	NA	NA
262	7.01	1250	2.94	1151	6.89	1051	20.90	952	84.53	NA	NA	NA	NA	NA	NA
263	5.19	1255	2.19	1155	4.87	1056	14.03	956	52.52	NA	NA	NA	NA	NA	NA
264	4.89	1251	2.19	1151	4.74	1052	13.40	953	47.89	NA	NA	NA	NA	NA	NA
265	8.42	1256	3.28	1156	7.85	1056	24.51	957	103.15	NA	NA	NA	NA	NA	NA
266	4.16	1248	1.84	1153	3.95	1057	10.56	951	35.76	NA	NA	NA	NA	NA	NA
267	5.94	1251	2.61	1150	5.95	1049	16.78	949	63.66	NA	NA	NA	NA	NA	NA
268	4.75	1260	1.99	1158	4.39	1057	11.96	956	41.27	NA	NA	NA	NA	NA	NA
269	5.10	1258	2.16	1157	4.79	1057	12.75	957	43.94	NA	NA	NA	NA	NA	NA
270	5.95	1260	2.45	1159	5.46	1058	15.12	956	55.48	NA	NA	NA	NA	NA	NA
271	3.18	1242	1.63	1142	3.41	1040	8.48	939	27.18	NA	NA	NA	NA	NA	NA
272	5.25	1249	2.37	1149	5.28	1051	14.37	952	52.58	NA	NA	NA	NA	NA	NA
273	3.31	1211	2.13	1109	4.61	1006	12.04	903	41.92	NA	NA	NA	NA	NA	NA
274	5.35	1255	2.27	1159	4.94	1062	13.07	966	45.15	NA	NA	NA	NA	NA	NA
275	4.43	1255	1.94	1159	4.10	1062	10.38	965	33.60	NA	NA	NA	NA	NA	NA
276	5.85	1253	2.60	1158	5.39	1062	14.15	967	47.06	NA	NA	NA	NA	NA	NA
277	3.90	1252	1.71	1157	3.66	1062	9.25	966	29.52	NA	NA	NA	NA	NA	NA
278	2.35	1226	1.39	1124	2.86	1021	7.07	917	22.29	NA	NA	NA	NA	NA	NA
279	2.14	1245	1.13	1145	2.22	1045	5.18	944	15.42	NA	NA	NA	NA	NA	NA
280	2.53	1243	1.27	1147	2.59	1051	6.28	954	19.48	NA	NA	NA	NA	NA	NA
281	10.77	1248	4.45	1148	11.13	1048	33.04	948	137.07	NA	NA	NA	NA	NA	NA

(a) The glass names corresponding to the row numbers are listed in Table B.1.
(b) The η_{1150} and the Vi values were rounded to two decimal places.
(c) This temperature-viscosity pair was judged to be an outlier and was not used to determine the η_{1150} value for this glass.

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
#[(a)]	**T8**	**V8**	**T9**	**V9**	**T10**	**V10**	**T11**	**V11**
1	NA	NA	NA	NA	NA	NA	NA	NA
2	NA	NA	NA	NA	NA	NA	NA	NA
3	NA	NA	NA	NA	NA	NA	NA	NA
4	NA	NA	NA	NA	NA	NA	NA	NA
5	NA	NA	NA	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA	NA	NA	NA
9	NA	NA	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA	NA	NA
11	NA	NA	NA	NA	NA	NA	NA	NA
12	NA	NA	NA	NA	NA	NA	NA	NA
13	NA	NA	NA	NA	NA	NA	NA	NA
14	NA	NA	NA	NA	NA	NA	NA	NA
15	NA	NA	NA	NA	NA	NA	NA	NA
16	NA	NA	NA	NA	NA	NA	NA	NA
17	NA	NA	NA	NA	NA	NA	NA	NA
18	NA	NA	NA	NA	NA	NA	NA	NA
19	NA	NA	NA	NA	NA	NA	NA	NA
20	NA	NA	NA	NA	NA	NA	NA	NA
21	NA	NA	NA	NA	NA	NA	NA	NA
22	NA	NA	NA	NA	NA	NA	NA	NA
23	NA	NA	NA	NA	NA	NA	NA	NA
24	NA	NA	NA	NA	NA	NA	NA	NA
25	NA	NA	NA	NA	NA	NA	NA	NA
26	NA	NA	NA	NA	NA	NA	NA	NA
27	NA	NA	NA	NA	NA	NA	NA	NA
28	NA	NA	NA	NA	NA	NA	NA	NA
29	NA	NA	NA	NA	NA	NA	NA	NA
30	NA	NA	NA	NA	NA	NA	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
#[(a)]	T8	V8	T9	V9	T10	V10	T11	V11
31	NA	NA	NA	NA	NA	NA	NA	NA
32	NA	NA	NA	NA	NA	NA	NA	NA
33	NA	NA	NA	NA	NA	NA	NA	NA
34	NA	NA	NA	NA	NA	NA	NA	NA
35	NA	NA	NA	NA	NA	NA	NA	NA
36	NA	NA	NA	NA	NA	NA	NA	NA
37	NA	NA	NA	NA	NA	NA	NA	NA
38	NA	NA	NA	NA	NA	NA	NA	NA
39	NA	NA	NA	NA	NA	NA	NA	NA
40	NA	NA	NA	NA	NA	NA	NA	NA
41	NA	NA	NA	NA	NA	NA	NA	NA
42	NA	NA	NA	NA	NA	NA	NA	NA
43	NA	NA	NA	NA	NA	NA	NA	NA
44	NA	NA	NA	NA	NA	NA	NA	NA
45	NA	NA	NA	NA	NA	NA	NA	NA
46	NA	NA	NA	NA	NA	NA	NA	NA
47	NA	NA	NA	NA	NA	NA	NA	NA
48	NA	NA	NA	NA	NA	NA	NA	NA
49	NA	NA	NA	NA	NA	NA	NA	NA
50	NA	NA	NA	NA	NA	NA	NA	NA
51	NA	NA	NA	NA	NA	NA	NA	NA
52	NA	NA	NA	NA	NA	NA	NA	NA
53	NA	NA	NA	NA	NA	NA	NA	NA
54	NA	NA	NA	NA	NA	NA	NA	NA
55	NA	NA	NA	NA	NA	NA	NA	NA
56	NA	NA	NA	NA	NA	NA	NA	NA
57	NA	NA	NA	NA	NA	NA	NA	NA
58	NA	NA	NA	NA	NA	NA	NA	NA
59	NA	NA	NA	NA	NA	NA	NA	NA
60	NA	NA	NA	NA	NA	NA	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
#[a]	T8	V8	T9	V9	T10	V10	T11	V11
61	NA	NA	NA	NA	NA	NA	NA	NA
62	NA	NA	NA	NA	NA	NA	NA	NA
63	NA	NA	NA	NA	NA	NA	NA	NA
64	NA	NA	NA	NA	NA	NA	NA	NA
65	NA	NA	NA	NA	NA	NA	NA	NA
66	NA	NA	NA	NA	NA	NA	NA	NA
67	NA	NA	NA	NA	NA	NA	NA	NA
68	NA	NA	NA	NA	NA	NA	NA	NA
69	NA	NA	NA	NA	NA	NA	NA	NA
70	NA	NA	NA	NA	NA	NA	NA	NA
71	NA	NA	NA	NA	NA	NA	NA	NA
72	NA	NA	NA	NA	NA	NA	NA	NA
73	NA	NA	NA	NA	NA	NA	NA	NA
74	NA	NA	NA	NA	NA	NA	NA	NA
75	NA	NA	NA	NA	NA	NA	NA	NA
76	NA	NA	NA	NA	NA	NA	NA	NA
77	NA	NA	NA	NA	NA	NA	NA	NA
78	NA	NA	NA	NA	NA	NA	NA	NA
79	NA	NA	NA	NA	NA	NA	NA	NA
80	NA	NA	NA	NA	NA	NA	NA	NA
81	NA	NA	NA	NA	NA	NA	NA	NA
82	NA	NA	NA	NA	NA	NA	NA	NA
83	NA	NA	NA	NA	NA	NA	NA	NA
84	NA	NA	NA	NA	NA	NA	NA	NA
85	NA	NA	NA	NA	NA	NA	NA	NA
86	NA	NA	NA	NA	NA	NA	NA	NA
87	NA	NA	NA	NA	NA	NA	NA	NA
88	NA	NA	NA	NA	NA	NA	NA	NA
89	NA	NA	NA	NA	NA	NA	NA	NA
90	NA	NA	NA	NA	NA	NA	NA	NA
91	1462	10.10	1464	11.10	1516[b]	9.70[b]	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row #[(a)]	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
	T8	**V8**	**T9**	**V9**	**T10**	**V10**	**T11**	**V11**
92	1387	5.00	1388	5.60	1437	3.70	1488	2.90
93	1388	7.60	1388	8.90	1438	6.00	1489	5.00
94	1337	4.90	1338	5.30	1387	3.70	1437	2.90
95	1388	5.80	1388	6.60	1437	4.40	1488	3.50
96	1338	11.40	1387	7.60	1437	5.50	1487	3.90
97	1288	12.90	1337	8.40	1387	5.80	1438	4.00
98	1338	10.80	1387	7.30	1437	4.90	1487	3.30
99	1388	15.50	1436	10.10	1487	7.40	1538	5.60
100	1287	12.20	1337	8.00	1387	5.90	1437	4.30
101	1287	14.80	1336	9.40	1386	6.90	1436	5.10
102	1337	12.60	1387	8.40	1437	6.20	NA	NA
103	1337	15.00	1386	10.00	1437	7.30	NA	NA
104	1289	8.30	1338	5.60	1388	4.10	NA	NA
105	1287	9.90	1337	6.90	1387	4.90	NA	NA
106	1436	17.70	1436	16.70	NA	NA	NA	NA
107	1287	6.70	1336	4.60	1387	3.30	NA	NA
108	1139	4.40	1140	4.40	1189	3.00	NA	NA
109	1438	7.50	1438	7.70	1488	5.70	NA	NA
110	1386	13.10	1436	8.40	1486	5.70	1536	4.00
111	1388	11.90	1438	7.80	1488	5.50	NA	NA
112	1294	8.50	1344	5.40	1344	5.70	NA	NA
113	NA	NA	NA	NA	NA	NA	NA	NA
114	1343	10.70	1392	7.30	1443	5.50	NA	NA
115	1341	12.40	1390	7.90	1442	6.00	NA	NA
116	1390	10.20	1439	7.10	1489	5.40	NA	NA
117	1492	3.70	NA	NA	NA	NA	NA	NA
118	NA	NA	NA	NA	NA	NA	NA	NA
119	NA	NA	NA	NA	NA	NA	NA	NA
120	NA	NA	NA	NA	NA	NA	NA	NA
121	NA	NA	NA	NA	NA	NA	NA	NA
122	1336	11.20	1385	7.60	1436	5.30	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
#[(a)]	T8	V8	T9	V9	T10	V10	T11	V11
123	1292	19.80	1343	13.00	1392	8.60	NA	NA
124	1290	16.10	1340	10.80	1392	7.80	NA	NA
125	1336	15.00	1386	9.70	1436	6.90	NA	NA
126	1141	12.40	1190	7.50	1240	5.20	NA	NA
127	1286	12.00	1336	8.60	1386	6.30	NA	NA
128	1344	14.40	1393	8.80	1444	6.30	NA	NA
129	1386	9.70	1436	6.60	1487	4.70	NA	NA
130	1342	9.50	1392	6.30	1442	4.30	NA	NA
131	1392	9.40	1441	6.20	1492	4.30	NA	NA
132	1436	8.20	1436	8.50	1485	6.00	NA	NA
133	1140	13.10	1189	7.90	1240	5.40	NA	NA
134	1386	8.00	1437	5.90	1488	4.80	NA	NA
135	1343	9.80	1392	6.60	1443	4.60	NA	NA
136	1395	5.80	1446	3.90	NA	NA	NA	NA
137	1141	6.20	1190	3.90	1241	2.90	NA	NA
138	1288	13.90	1337	9.10	1387	6.30	1438	4.40
139	1291	6.40	1344	4.40	1390	3.20	NA	NA
140	1237	8.20	1238	8.60	1287	5.80	1337	4.10
141	NA	NA	NA	NA	NA	NA	NA	NA
142	NA	NA	NA	NA	NA	NA	NA	NA
143	NA	NA	NA	NA	NA	NA	NA	NA
144	NA	NA	NA	NA	NA	NA	NA	NA
145	NA	NA	NA	NA	NA	NA	NA	NA
146	NA	NA	NA	NA	NA	NA	NA	NA
147	NA	NA	NA	NA	NA	NA	NA	NA
148	NA	NA	NA	NA	NA	NA	NA	NA
149	NA	NA	NA	NA	NA	NA	NA	NA
150	NA	NA	NA	NA	NA	NA	NA	NA
151	NA	NA	NA	NA	NA	NA	NA	NA
152	NA	NA	NA	NA	NA	NA	NA	NA
153	NA	NA	NA	NA	NA	NA	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row #[a]	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
	T8	V8	T9	V9	T10	V10	T11	V11
154	NA	NA	NA	NA	NA	NA	NA	NA
155	NA	NA	NA	NA	NA	NA	NA	NA
156	NA	NA	NA	NA	NA	NA	NA	NA
157	NA	NA	NA	NA	NA	NA	NA	NA
158	NA	NA	NA	NA	NA	NA	NA	NA
159	NA	NA	NA	NA	NA	NA	NA	NA
160	NA	NA	NA	NA	NA	NA	NA	NA
161	NA	NA	NA	NA	NA	NA	NA	NA
162	NA	NA	NA	NA	NA	NA	NA	NA
163	NA	NA	NA	NA	NA	NA	NA	NA
164	NA	NA	NA	NA	NA	NA	NA	NA
165	NA	NA	NA	NA	NA	NA	NA	NA
166	NA	NA	NA	NA	NA	NA	NA	NA
167	NA	NA	NA	NA	NA	NA	NA	NA
168	NA	NA	NA	NA	NA	NA	NA	NA
169	NA	NA	NA	NA	NA	NA	NA	NA
170	NA	NA	NA	NA	NA	NA	NA	NA
171	NA	NA	NA	NA	NA	NA	NA	NA
172	NA	NA	NA	NA	NA	NA	NA	NA
173	NA	NA	NA	NA	NA	NA	NA	NA
174	NA	NA	NA	NA	NA	NA	NA	NA
175	NA	NA	NA	NA	NA	NA	NA	NA
176	NA	NA	NA	NA	NA	NA	NA	NA
177	NA	NA	NA	NA	NA	NA	NA	NA
178	NA	NA	NA	NA	NA	NA	NA	NA
179	NA	NA	NA	NA	NA	NA	NA	NA
180	NA	NA	NA	NA	NA	NA	NA	NA
181	NA	NA	NA	NA	NA	NA	NA	NA
182	NA	NA	NA	NA	NA	NA	NA	NA
183	NA	NA	NA	NA	NA	NA	NA	NA
184	NA	NA	NA	NA	NA	NA	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
#[(a)]	**T8**	**V8**	**T9**	**V9**	**T10**	**V10**	**T11**	**V11**
185	NA	NA	NA	NA	NA	NA	NA	NA
186	NA	NA	NA	NA	NA	NA	NA	NA
187	NA	NA	NA	NA	NA	NA	NA	NA
188	NA	NA	NA	NA	NA	NA	NA	NA
189	NA	NA	NA	NA	NA	NA	NA	NA
190	NA	NA	NA	NA	NA	NA	NA	NA
191	NA	NA	NA	NA	NA	NA	NA	NA
192	NA	NA	NA	NA	NA	NA	NA	NA
193	NA	NA	NA	NA	NA	NA	NA	NA
194	NA	NA	NA	NA	NA	NA	NA	NA
195	NA	NA	NA	NA	NA	NA	NA	NA
196	NA	NA	NA	NA	NA	NA	NA	NA
197	NA	NA	NA	NA	NA	NA	NA	NA
198	NA	NA	NA	NA	NA	NA	NA	NA
199	NA	NA	NA	NA	NA	NA	NA	NA
200	NA	NA	NA	NA	NA	NA	NA	NA
201	NA	NA	NA	NA	NA	NA	NA	NA
202	NA	NA	NA	NA	NA	NA	NA	NA
203	NA	NA	NA	NA	NA	NA	NA	NA
204	NA	NA	NA	NA	NA	NA	NA	NA
205	NA	NA	NA	NA	NA	NA	NA	NA
206	NA	NA	NA	NA	NA	NA	NA	NA
207	NA	NA	NA	NA	NA	NA	NA	NA
208	NA	NA	NA	NA	NA	NA	NA	NA
209	NA	NA	NA	NA	NA	NA	NA	NA
210	NA	NA	NA	NA	NA	NA	NA	NA
211	NA	NA	NA	NA	NA	NA	NA	NA
212	NA	NA	NA	NA	NA	NA	NA	NA
213	NA	NA	NA	NA	NA	NA	NA	NA
214	NA	NA	NA	NA	NA	NA	NA	NA
215	NA	NA	NA	NA	NA	NA	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row #[(a)]	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
	T8	**V8**	**T9**	**V9**	**T10**	**V10**	**T11**	**V11**
216	NA	NA	NA	NA	NA	NA	NA	NA
217	NA	NA	NA	NA	NA	NA	NA	NA
218	NA	NA	NA	NA	NA	NA	NA	NA
219	NA	NA	NA	NA	NA	NA	NA	NA
220	NA	NA	NA	NA	NA	NA	NA	NA
221	NA	NA	NA	NA	NA	NA	NA	NA
222	NA	NA	NA	NA	NA	NA	NA	NA
223	NA	NA	NA	NA	NA	NA	NA	NA
224	NA	NA	NA	NA	NA	NA	NA	NA
225	NA	NA	NA	NA	NA	NA	NA	NA
226	NA	NA	NA	NA	NA	NA	NA	NA
227	NA	NA	NA	NA	NA	NA	NA	NA
228	NA	NA	NA	NA	NA	NA	NA	NA
229	NA	NA	NA	NA	NA	NA	NA	NA
230	NA	NA	NA	NA	NA	NA	NA	NA
231	NA	NA	NA	NA	NA	NA	NA	NA
232	NA	NA	NA	NA	NA	NA	NA	NA
233	NA	NA	NA	NA	NA	NA	NA	NA
234	NA	NA	NA	NA	NA	NA	NA	NA
235	NA	NA	NA	NA	NA	NA	NA	NA
236	NA	NA	NA	NA	NA	NA	NA	NA
237	NA	NA	NA	NA	NA	NA	NA	NA
238	NA	NA	NA	NA	NA	NA	NA	NA
239	NA	NA	NA	NA	NA	NA	NA	NA
240	NA	NA	NA	NA	NA	NA	NA	NA
241	NA	NA	NA	NA	NA	NA	NA	NA
242	NA	NA	NA	NA	NA	NA	NA	NA
243	NA	NA	NA	NA	NA	NA	NA	NA
244	NA	NA	NA	NA	NA	NA	NA	NA
245	NA	NA	NA	NA	NA	NA	NA	NA
246	NA	NA	NA	NA	NA	NA	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row #[(a)]	Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)							
	T8	**V8**	**T9**	**V9**	**T10**	**V10**	**T11**	**V11**
247	NA	NA	NA	NA	NA	NA	NA	NA
248	NA	NA	NA	NA	NA	NA	NA	NA
249	NA	NA	NA	NA	NA	NA	NA	NA
250	NA	NA	NA	NA	NA	NA	NA	NA
251	NA	NA	NA	NA	NA	NA	NA	NA
252	NA	NA	NA	NA	NA	NA	NA	NA
253	NA	NA	NA	NA	NA	NA	NA	NA
254	NA	NA	NA	NA	NA	NA	NA	NA
255	NA	NA	NA	NA	NA	NA	NA	NA
256	NA	NA	NA	NA	NA	NA	NA	NA
257	NA	NA	NA	NA	NA	NA	NA	NA
258	NA	NA	NA	NA	NA	NA	NA	NA
259	NA	NA	NA	NA	NA	NA	NA	NA
260	NA	NA	NA	NA	NA	NA	NA	NA
261	NA	NA	NA	NA	NA	NA	NA	NA
262	NA	NA	NA	NA	NA	NA	NA	NA
263	NA	NA	NA	NA	NA	NA	NA	NA
264	NA	NA	NA	NA	NA	NA	NA	NA
265	NA	NA	NA	NA	NA	NA	NA	NA
266	NA	NA	NA	NA	NA	NA	NA	NA
267	NA	NA	NA	NA	NA	NA	NA	NA
268	NA	NA	NA	NA	NA	NA	NA	NA
269	NA	NA	NA	NA	NA	NA	NA	NA
270	NA	NA	NA	NA	NA	NA	NA	NA
271	NA	NA	NA	NA	NA	NA	NA	NA
272	NA	NA	NA	NA	NA	NA	NA	NA
273	NA	NA	NA	NA	NA	NA	NA	NA
274	NA	NA	NA	NA	NA	NA	NA	NA
275	NA	NA	NA	NA	NA	NA	NA	NA
276	NA	NA	NA	NA	NA	NA	NA	NA
277	NA	NA	NA	NA	NA	NA	NA	NA

Table B.4. Temperature-Viscosity Pairs Eight to Eleven for the 281 Glasses Used to Develop a Model for Viscosity at 1150°C

Row	**Temperature (°C) and Viscosity (Poise) Pairs (Ti, Vi)**							
#[(a)]	**T8**	**V8**	**T9**	**V9**	**T10**	**V10**	**T11**	**V11**
278	NA	NA	NA	NA	NA	NA	NA	NA
279	NA	NA	NA	NA	NA	NA	NA	NA
280	NA	NA	NA	NA	NA	NA	NA	NA
281	NA	NA	NA	NA	NA	NA	NA	NA

(a) The glass names corresponding to the row numbers are listed in Table B.1.

(b) This temperature-viscosity pair was judged to be an outlier and was not used to determine the η_{1150} value for this glass.

Appendix C

Derivation of the Nonlinear Multiple-Component Constraint Involving SO_3 Solubility

Appendix C

Derivation of the Nonlinear Multiple-Component Constraint Involving SO_3 Solubility

This appendix derives the final mathematical form of the multiple-component constraint (MCC) for SO_3 solubility. We begin by substituting into the SO_3 solubility constraint in Equation (5) a general formula representing the expression for SL_{SO_3} in Equation (3):

$$g_{SO_3} = \frac{SL_{SO_3}}{100} \le \frac{1}{100}\left[\sum_{i \ne SO_3}^{14} a_i x_i + b(x_{Li_2O})^2\right] \tag{C.1}$$

where the a_i and b coefficient values are listed in Equation (3). All notation in this appendix is as defined in the main body of this report. Then, using Equation (4) to write the x_i s in terms of the g_i s yields

$$g_{SO_3} \le \frac{1}{100}\left[\sum_{i \ne SO_3}^{14} a_i \left(\frac{g_i}{1-g_{SO_3}}\right) + b\left(\frac{g_{Li_2O}}{1-g_{SO_3}}\right)^2\right] \tag{C.2}$$

Multiplying both sides of Equation (C.2) by $100(1-g_{SO_3})$ and collecting all terms on one side yields

$$\sum_{i \ne SO_3}^{14} a_i g_i + b\left(\frac{g_{Li_2O}^2}{1-g_{SO_3}}\right) - 100(g_{SO_3}) + 100(g_{SO_3}^2) \ge 0 \tag{C.3}$$

Now, expanding the first term using the low-activity waste (LAW) glass component names and the coefficient values yields

$$\begin{aligned}
&-2.091901(g_{Al_2O_3}) + 3.0440748(g_{B_2O_3}) + 4.4422886(g_{CaO}) - 22.65353(g_{Cl}) \\
&-13.14139(g_{Cr_2O_3}) + 0.615785(g_{K_2O}) + 2.4739255(g_{Li_2O}) + 2.8972089(g_{Na_2O}) \\
&+4.606083(g_{P_2O_5}) + 0.2407285(g_{SiO_2}) - 1.775325(g_{SnO_2}) + 7.5345478(g_{V_2O_5}) \\
&-1.871916(g_{ZrO_2}) - 0.280272(g_{Others2}) + 260.20302[(g_{Li_2O})^2/(1-g_{SO_3})] \\
&-100(g_{SO_3}) + 100(g_{SO_3})^2 \ge 0
\end{aligned} \tag{C.4}$$

Note that Equation (C.4) contains terms for three components not listed in Table 2.1, namely Cl, Cr_2O_3, and P_2O_5. These are three of the four components making up Others1, with only F not represented. Also, there are three components listed in Table 2.1 that do not appear in Equation (C.4), namely Fe_2O_3, MgO, and ZnO. Hence, $g_{Others2} = g_F + g_{Fe_2O_3} + g_{MgO} + g_{ZnO}$. Based on Table 2.2, we have the relationships $g_{Cl} = 0.155315\,(g_{Others\,1})$, $g_{Cr_2O_3} = 0.104383(g_{Others1})$, $g_F = 0.235786\,(g_{Others\,1})$, and $g_{P_2O_5} = 0.504516(g_{Others1})$. Substituting all of these relationships into Equation (C.4) and collecting like terms produces the final form of the SO_3-solubility MCC expressed in terms of the mass fractions of the 15 LAW glass components in Table 2.1:

$$\begin{aligned}
&-2.091901(g_{Al_2O_3}) + 3.0440748(g_{B_2O_3}) + 4.4422886(g_{CaO}) - 0.280272\,(g_{Fe_2O_3}) \\
&+ 0.615785(g_{K_2O}) + 2.4739255(g_{Li_2O}) - 0.280272\,(g_{MgO}) + 2.8972089(g_{Na_2O}) \\
&+ 0.2407285(g_{SiO_2}) - 100(g_{SO_3}) - 1.775325(g_{SnO_2}) + 7.5345478(g_{V_2O_5}) \\
&- 0.280272\,(g_{ZnO}) - 1.871916(g_{ZrO_2}) - 2.632412(g_{Others1}) \\
&+ 260.20302[(g_{Li_2O})^2/(1 - g_{SO_3})] + 100(g_{SO_3})^2 \geq 0\,.
\end{aligned} \qquad \text{(C.5)}$$

This inequality can be written in the condensed form given by Equation (6), where the c_i (i = 1, 2, … , 15) and b in that equation are the coefficients listed in Equation (C.5).

Appendix D

Derivation of the Intersection of a Nonlinear Multiple-Component Constraint and an Edge that Connects Two Vertices Outside and Inside the Constraint

Appendix D

Derivation of the Intersection of a Nonlinear Multiple-Component Constraint and an Edge that Connects Two Vertices Outside and Inside the Constraint

The intersection of the edge connecting two vertices A and B given by

$$g_i = \alpha\, g_{Ai} + (1-\alpha) g_{Bi} = \alpha (g_{Ai} - g_{Bi}) + g_{Bi} \tag{D.1}$$

with the nonlinear surface

$$\sum_{i=1}^{15} c_i g_i + b\left(\frac{g_{Li_2O}^2}{1 - g_{SO_3}}\right) + 100(g_{SO_3}^2) = 0 \tag{D.2}$$

associated with the nonlinear multiple-component constraint in Equation (6) in the main text is derived in this appendix. Substituting Equation (D.1) into Equation (D.2) yields

$$\begin{aligned}&\sum_{i=1}^{15} c_i [\alpha(g_{A,i} - g_{B,i}) + g_{B,i}] + b\left(\frac{[\alpha(g_{A,LiO_2} - g_{B,LiO_2}) + g_{B,LiO_2}]^2}{1 - [\alpha(g_{A,SO_3} - g_{B,SO_3}) + g_{B,SO_3}]}\right)\\ &+ 100([\alpha(g_{A,SO_3} - g_{B,SO_3}) + g_{B,SO_3}]^2) = 0\ .\end{aligned} \tag{D.3}$$

Multiplying out the squared expression in the last term and collecting terms by powers of α yields

$$\begin{aligned}&\left[100(g_{A,SO_3} - g_{B,SO_3})^2\right]\alpha^2 + \left[\sum_{i=1}^{15} c_i (g_{A,i} - g_{B,i}) + 200(g_{A,SO_3} - g_{B,SO_3})(g_{B,SO_3})\right]\alpha\\ &+ \left[\sum_{i=1}^{15} c_i g_{B,i} + 100(g_{B,SO_3})^2\right] + b\left(\frac{[\alpha(g_{A,LiO_2} - g_{B,LiO_2}) + g_{B,LiO_2}]^2}{1 - [\alpha(g_{A,SO_3} - g_{B,SO_3}) + x_{B,SO_3}]}\right) = 0\ .\end{aligned} \tag{D.4}$$

Appendix E

The 147 Existing Low-Activity Waste Glass Compositions

Appendix E

The 147 Existing Low-Activity Waste Glass Compositions

Table E.1 lists the 147 existing low-activity waste (LAW) glass compositions within the outer-layer single-component constraints (SCCs) and multiple-component constraints (MCCs) that were augmented when selecting the 18 outer-layer and 13 inner-layer points for the layered design. Table E.2 lists the glass names that correspond to the row numbers in Table E.1.

Table E. 1. The 147 Existing LAW Glass Compositions (mass fractions) Within the Outer-Layer Region SCCs and MCCs Given in Tables 2.1 and 2.3

Row	Component														
#[(a)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
1	0.1017	0.1369	0.0565	0.0100	0.0051	0.0000	0.0100	0.2302	0.3661	0.0067	0.0000	0.0100	0.0300	0.0300	0.0067
2	0.1066	0.1280	0.0799	0.0091	0.0051	0.0000	0.0091	0.2301	0.3488	0.0068	0.0000	0.0098	0.0300	0.0300	0.0067
3	0.1066	0.1130	0.0800	0.0091	0.0051	0.0000	0.0091	0.2302	0.3488	0.0066	0.0000	0.0098	0.0300	0.0450	0.0067
4	0.1065	0.0979	0.0799	0.0091	0.0051	0.0000	0.0091	0.2301	0.3487	0.0069	0.0000	0.0098	0.0300	0.0600	0.0067
5	0.1215	0.1129	0.0799	0.0091	0.0051	0.0000	0.0091	0.2300	0.3487	0.0071	0.0000	0.0098	0.0300	0.0300	0.0067
6	0.1366	0.0980	0.0799	0.0091	0.0051	0.0000	0.0091	0.2301	0.3488	0.0067	0.0000	0.0098	0.0300	0.0300	0.0067
7	0.1086	0.0926	0.0798	0.0091	0.0056	0.0000	0.0091	0.2501	0.3534	0.0069	0.0000	0.0094	0.0235	0.0445	0.0073
8	0.1085	0.0776	0.0798	0.0091	0.0056	0.0000	0.0091	0.2501	0.3533	0.0070	0.0000	0.0094	0.0235	0.0595	0.0073
9	0.1066	0.0980	0.0800	0.0091	0.0051	0.0000	0.0091	0.2302	0.3436	0.0066	0.0000	0.0150	0.0300	0.0600	0.0067
10	0.1064	0.0941	0.0765	0.0091	0.0051	0.0000	0.0091	0.2298	0.3655	0.0083	0.0000	0.0150	0.0145	0.0599	0.0067
11	0.1215	0.0979	0.0799	0.0091	0.0051	0.0000	0.0091	0.2301	0.3689	0.0070	0.0000	0.0150	0.0195	0.0300	0.0067
12	0.1164	0.0930	0.0799	0.0091	0.0051	0.0000	0.0091	0.2300	0.3687	0.0076	0.0000	0.0150	0.0145	0.0450	0.0067
13	0.1066	0.1281	0.0649	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0062	0.0100	0.0098	0.0300	0.0300	0.0117
14	0.1066	0.1281	0.0649	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0062	0.0100	0.0098	0.0300	0.0300	0.0117
15	0.1066	0.1281	0.0649	0.0091	0.0051	0.0000	0.0091	0.2303	0.3491	0.0061	0.0100	0.0098	0.0300	0.0300	0.0117
16	0.1066	0.1281	0.0549	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0061	0.0201	0.0098	0.0300	0.0300	0.0117
17	0.1066	0.1130	0.0750	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0061	0.0000	0.0098	0.0300	0.0451	0.0117
18	0.1217	0.1131	0.0599	0.0091	0.0051	0.0000	0.0091	0.2303	0.3491	0.0059	0.0000	0.0098	0.0300	0.0451	0.0117
19	0.1216	0.1130	0.0750	0.0091	0.0051	0.0000	0.0091	0.2303	0.3490	0.0061	0.0000	0.0098	0.0300	0.0300	0.0117
20	0.1216	0.1130	0.0598	0.0091	0.0051	0.0000	0.0091	0.2301	0.3588	0.0068	0.0000	0.0098	0.0300	0.0400	0.0067
21	0.1216	0.1130	0.0549	0.0091	0.0051	0.0000	0.0091	0.2303	0.3590	0.0062	0.0000	0.0098	0.0300	0.0400	0.0117
22	0.1087	0.0777	0.0699	0.0091	0.0056	0.0000	0.0091	0.2504	0.3538	0.0058	0.0100	0.0094	0.0235	0.0596	0.0073
23	0.1087	0.0777	0.0649	0.0091	0.0056	0.0000	0.0091	0.2504	0.3537	0.0058	0.0100	0.0094	0.0235	0.0596	0.0124
24	0.1186	0.0777	0.0599	0.0091	0.0056	0.0000	0.0091	0.2503	0.3636	0.0062	0.0000	0.0094	0.0235	0.0596	0.0073
25	0.1187	0.0777	0.0549	0.0091	0.0056	0.0000	0.0091	0.2504	0.3637	0.0059	0.0000	0.0094	0.0235	0.0596	0.0124
26	0.1019	0.1372	0.0804	0.0100	0.0015	0.0000	0.0100	0.2005	0.3672	0.0094	0.0000	0.0100	0.0301	0.0301	0.0117
27	0.1019	0.1304	0.0805	0.0100	0.0015	0.0000	0.0100	0.2006	0.3673	0.0089	0.0000	0.0100	0.0301	0.0369	0.0117
28	0.0866	0.1371	0.0804	0.0100	0.0015	0.0000	0.0100	0.2004	0.3669	0.0100	0.0000	0.0100	0.0301	0.0453	0.0117

Table E.1. The 147 Existing LAW Glass Compositions (mass fractions) Within the Outer-Layer Region SCCs and MCCs Given in Tables 2.1 and 2.3 (contd)

Row	Component														
#[(a)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
29	0.0714	0.1373	0.0805	0.0100	0.0015	0.0000	0.0100	0.2007	0.3674	0.0087	0.0000	0.0100	0.0301	0.0606	0.0117
30	0.1000	0.0900	0.0350	0.0101	0.0056	0.0000	0.0135	0.2500	0.4131	0.0019	0.0000	0.0000	0.0236	0.0480	0.0092
31	0.1000	0.0900	0.0250	0.0101	0.0056	0.0000	0.0135	0.2500	0.4131	0.0019	0.0100	0.0000	0.0236	0.0480	0.0092
32	0.1000	0.0900	0.0304	0.0101	0.0056	0.0000	0.0135	0.2500	0.4131	0.0019	0.0000	0.0000	0.0236	0.0480	0.0139
33	0.1000	0.0700	0.0100	0.0101	0.0056	0.0000	0.0135	0.2501	0.4332	0.0020	0.0100	0.0000	0.0336	0.0480	0.0139
34	0.1088	0.0778	0.0100	0.0094	0.0056	0.0000	0.0091	0.2500	0.4192	0.0019	0.0100	0.0000	0.0236	0.0607	0.0139
35	0.1088	0.0778	0.0147	0.0094	0.0056	0.0000	0.0091	0.2500	0.4050	0.0020	0.0100	0.0094	0.0236	0.0607	0.0139
36	0.1090	0.0780	0.0652	0.0091	0.0056	0.0000	0.0091	0.2501	0.3552	0.0018	0.0200	0.0094	0.0236	0.0500	0.0139
37	0.1090	0.0780	0.0652	0.0091	0.0056	0.0000	0.0091	0.2500	0.3578	0.0019	0.0268	0.0000	0.0236	0.0500	0.0139
38	0.1090	0.0700	0.0200	0.0091	0.0056	0.0000	0.0091	0.2500	0.4015	0.0019	0.0270	0.0000	0.0236	0.0594	0.0139
39	0.1077	0.0713	0.0203	0.0093	0.0054	0.0000	0.0093	0.2400	0.4100	0.0017	0.0275	0.0000	0.0245	0.0595	0.0136
40	0.1083	0.0707	0.0201	0.0092	0.0055	0.0000	0.0092	0.2450	0.4061	0.0019	0.0272	0.0000	0.0242	0.0589	0.0136
41	0.1070	0.0720	0.0205	0.0094	0.0053	0.0000	0.0094	0.2350	0.4138	0.0017	0.0278	0.0000	0.0247	0.0600	0.0133
42	0.0946	0.0865	0.0334	0.0093	0.0054	0.0000	0.0093	0.2400	0.3950	0.0018	0.0275	0.0000	0.0245	0.0595	0.0133
43	0.0987	0.0778	0.0147	0.0094	0.0056	0.0000	0.0091	0.2501	0.4159	0.0017	0.0100	0.0094	0.0236	0.0600	0.0139
44	0.0989	0.0878	0.0299	0.0094	0.0054	0.0000	0.0091	0.2400	0.4003	0.0018	0.0100	0.0098	0.0236	0.0607	0.0133
45	0.0970	0.0880	0.0334	0.0030	0.0054	0.0000	0.0093	0.2400	0.3952	0.0017	0.0276	0.0000	0.0276	0.0600	0.0118
46	0.0970	0.0880	0.0334	0.0030	0.0054	0.0000	0.0093	0.2400	0.3952	0.0017	0.0483	0.0000	0.0276	0.0393	0.0118
47	0.0670	0.0880	0.0334	0.0030	0.0054	0.0000	0.0093	0.2400	0.4252	0.0016	0.0276	0.0000	0.0276	0.0600	0.0118
48	0.0691	0.0864	0.0328	0.0029	0.0056	0.0000	0.0091	0.2500	0.4172	0.0018	0.0271	0.0000	0.0271	0.0588	0.0121
49	0.0946	0.0880	0.0355	0.0000	0.0054	0.0000	0.0000	0.2400	0.4029	0.0017	0.0300	0.0000	0.0300	0.0600	0.0118
50	0.0946	0.0880	0.0355	0.0000	0.0054	0.0000	0.0000	0.2400	0.4029	0.0017	0.0500	0.0000	0.0300	0.0400	0.0118
51	0.0934	0.0855	0.0352	0.0000	0.0056	0.0000	0.0000	0.2500	0.3970	0.0017	0.0300	0.0000	0.0294	0.0600	0.0121
52	0.0917	0.0839	0.0345	0.0000	0.0058	0.0000	0.0000	0.2601	0.3911	0.0018	0.0300	0.0000	0.0289	0.0600	0.0122
53	0.1058	0.1279	0.0648	0.0090	0.0051	0.0000	0.0090	0.2303	0.3485	0.0083	0.0100	0.0097	0.0299	0.0299	0.0116
54	0.0617	0.0896	0.0320	0.0026	0.0051	0.0000	0.0101	0.2318	0.4255	0.0082	0.0247	0.0094	0.0287	0.0590	0.0114
55	0.0674	0.0891	0.0318	0.0026	0.0051	0.0000	0.0100	0.2303	0.4229	0.0081	0.0246	0.0093	0.0286	0.0587	0.0114
56	0.0727	0.1008	0.0422	0.0047	0.0051	0.0000	0.0201	0.2320	0.3958	0.0082	0.0197	0.0094	0.0288	0.0490	0.0114
57	0.0838	0.1120	0.0523	0.0067	0.0051	0.0000	0.0303	0.2320	0.3656	0.0088	0.0147	0.0094	0.0288	0.0389	0.0115
58	0.0636	0.0879	0.0315	0.0026	0.0053	0.0000	0.0099	0.2419	0.4176	0.0085	0.0242	0.0092	0.0282	0.0579	0.0116
59	0.0636	0.0827	0.0314	0.0026	0.0053	0.0000	0.0198	0.2418	0.4128	0.0087	0.0242	0.0092	0.0282	0.0579	0.0116

Table E.1. The 147 Existing LAW Glass Compositions (mass fractions) Within the Outer-Layer Region SCCs and MCCs Given in Tables 2.1 and 2.3 (contd)

Row	Component														
#[(a)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
60	0.0636	0.0827	0.0314	0.0026	0.0053	0.0000	0.0099	0.2418	0.4175	0.0088	0.0268	0.0092	0.0282	0.0605	0.0116
61	0.0695	0.0822	0.0313	0.0026	0.0053	0.0000	0.0098	0.2404	0.4150	0.0083	0.0266	0.0091	0.0280	0.0601	0.0116
62	0.0997	0.0897	0.0349	0.0101	0.0056	0.0000	0.0135	0.2493	0.4119	0.0048	0.0000	0.0000	0.0235	0.0479	0.0092
63	0.0998	0.0898	0.0249	0.0101	0.0056	0.0000	0.0135	0.2494	0.4121	0.0042	0.0100	0.0000	0.0235	0.0479	0.0092
64	0.0998	0.0898	0.0303	0.0101	0.0056	0.0000	0.0135	0.2494	0.4121	0.0041	0.0000	0.0000	0.0235	0.0479	0.0139
65	0.0999	0.0699	0.0100	0.0101	0.0056	0.0000	0.0135	0.2497	0.4326	0.0034	0.0100	0.0000	0.0336	0.0479	0.0139
66	0.1086	0.0777	0.0100	0.0094	0.0056	0.0000	0.0091	0.2496	0.4186	0.0033	0.0100	0.0000	0.0236	0.0606	0.0139
67	0.1087	0.0777	0.0147	0.0094	0.0056	0.0000	0.0091	0.2498	0.4047	0.0028	0.0100	0.0094	0.0236	0.0607	0.0139
68	0.1086	0.0777	0.0650	0.0091	0.0056	0.0000	0.0091	0.2491	0.3539	0.0055	0.0199	0.0094	0.0235	0.0498	0.0139
69	0.1087	0.0778	0.0650	0.0091	0.0056	0.0000	0.0091	0.2492	0.3567	0.0049	0.0267	0.0000	0.0235	0.0498	0.0139
70	0.1089	0.0699	0.0200	0.0091	0.0056	0.0000	0.0091	0.2497	0.4011	0.0029	0.0270	0.0000	0.0236	0.0593	0.0139
71	0.1076	0.0712	0.0203	0.0093	0.0054	0.0000	0.0093	0.2397	0.4095	0.0027	0.0275	0.0000	0.0245	0.0594	0.0136
72	0.1082	0.0706	0.0201	0.0092	0.0055	0.0000	0.0092	0.2448	0.4057	0.0030	0.0272	0.0000	0.0242	0.0588	0.0136
73	0.1069	0.0719	0.0205	0.0094	0.0053	0.0000	0.0094	0.2348	0.4134	0.0028	0.0278	0.0000	0.0247	0.0599	0.0133
74	0.0945	0.0864	0.0334	0.0093	0.0054	0.0000	0.0093	0.2398	0.3946	0.0027	0.0275	0.0000	0.0245	0.0594	0.0133
75	0.0986	0.0777	0.0147	0.0094	0.0056	0.0000	0.0091	0.2497	0.4153	0.0031	0.0100	0.0094	0.0236	0.0599	0.0139
76	0.0988	0.0877	0.0299	0.0094	0.0054	0.0000	0.0091	0.2397	0.3998	0.0030	0.0100	0.0098	0.0236	0.0606	0.0133
77	0.1201	0.0730	0.0110	0.0110	0.0012	0.0000	0.0110	0.2501	0.3800	0.0048	0.0108	0.0200	0.0365	0.0544	0.0160
78	0.1001	0.0730	0.0110	0.0110	0.0012	0.0000	0.0110	0.2501	0.4000	0.0048	0.0108	0.0200	0.0365	0.0544	0.0160
79	0.0989	0.0858	0.0300	0.0096	0.0011	0.0000	0.0093	0.2402	0.4010	0.0047	0.0100	0.0100	0.0237	0.0605	0.0151
80	0.1004	0.0853	0.0190	0.0096	0.0011	0.0000	0.0093	0.2403	0.4011	0.0045	0.0100	0.0200	0.0237	0.0605	0.0151
81	0.1200	0.0730	0.0110	0.0110	0.0012	0.0000	0.0110	0.2499	0.3797	0.0056	0.0108	0.0200	0.0365	0.0544	0.0160
82	0.0999	0.0730	0.0110	0.0110	0.0012	0.0000	0.0110	0.2499	0.3996	0.0058	0.0108	0.0200	0.0365	0.0544	0.0160
83	0.0988	0.0857	0.0300	0.0096	0.0011	0.0000	0.0093	0.2399	0.4005	0.0054	0.0100	0.0100	0.0237	0.0604	0.0157
84	0.1003	0.0852	0.0190	0.0096	0.0011	0.0000	0.0093	0.2400	0.4006	0.0052	0.0100	0.0200	0.0237	0.0604	0.0157
85	0.1067	0.1167	0.0642	0.0090	0.0054	0.0000	0.0090	0.2351	0.3453	0.0049	0.0099	0.0147	0.0297	0.0346	0.0146
86	0.1065	0.1119	0.0647	0.0091	0.0054	0.0000	0.0091	0.2350	0.3487	0.0051	0.0100	0.0148	0.0300	0.0350	0.0146
87	0.1004	0.0852	0.0191	0.0097	0.0054	0.0000	0.0093	0.2358	0.4012	0.0048	0.0100	0.0200	0.0237	0.0604	0.0149
88	0.1065	0.1165	0.0641	0.0090	0.0054	0.0000	0.0090	0.2346	0.3447	0.0068	0.0099	0.0147	0.0297	0.0345	0.0146
89	0.1063	0.1117	0.0646	0.0091	0.0054	0.0000	0.0091	0.2346	0.3480	0.0070	0.0100	0.0148	0.0299	0.0349	0.0146
90	0.1004	0.0852	0.0191	0.0097	0.0054	0.0000	0.0093	0.2356	0.4009	0.0056	0.0100	0.0200	0.0237	0.0604	0.0148

Table E.1. The 147 Existing LAW Glass Compositions (mass fractions) Within the Outer-Layer Region SCCs and MCCs Given in Tables 2.1 and 2.3 (contd)

Row	Component														
#[(a)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
91	0.1015	0.1204	0.0801	0.0100	0.0016	0.0000	0.0100	0.2098	0.3714	0.0106	0.0000	0.0100	0.0300	0.0300	0.0147
92	0.0913	0.0762	0.0804	0.0075	0.0016	0.0075	0.0100	0.2104	0.3948	0.0077	0.0100	0.0100	0.0251	0.0527	0.0147
93	0.0812	0.0862	0.1003	0.0075	0.0016	0.0075	0.0100	0.2103	0.3945	0.0084	0.0000	0.0100	0.0251	0.0427	0.0147
94	0.1019	0.1209	0.0804	0.0030	0.0016	0.0000	0.0100	0.2103	0.3797	0.0085	0.0000	0.0100	0.0301	0.0301	0.0134
95	0.1020	0.1005	0.0804	0.0030	0.0016	0.0000	0.0100	0.2103	0.3798	0.0083	0.0000	0.0200	0.0301	0.0406	0.0134
96	0.1014	0.0989	0.0792	0.0030	0.0017	0.0000	0.0099	0.2204	0.3740	0.0082	0.0000	0.0197	0.0298	0.0400	0.0138
97	0.1009	0.0988	0.0792	0.0030	0.0017	0.0000	0.0099	0.2203	0.3738	0.0087	0.0100	0.0100	0.0297	0.0400	0.0138
98	0.1001	0.0948	0.0734	0.0029	0.0018	0.0000	0.0097	0.2296	0.3668	0.0121	0.0100	0.0146	0.0299	0.0401	0.0142
99	0.0858	0.0951	0.0735	0.0029	0.0018	0.0000	0.0097	0.2301	0.3676	0.0099	0.0100	0.0292	0.0299	0.0402	0.0142
100	0.1019	0.1208	0.0804	0.0100	0.0016	0.0000	0.0100	0.2106	0.3727	0.0070	0.0000	0.0100	0.0301	0.0301	0.0147
101	0.0912	0.0762	0.0803	0.0075	0.0016	0.0075	0.0100	0.2103	0.3946	0.0082	0.0100	0.0100	0.0251	0.0527	0.0147
102	0.0812	0.0862	0.1003	0.0075	0.0016	0.0075	0.0100	0.2102	0.3943	0.0089	0.0000	0.0100	0.0251	0.0426	0.0147
103	0.0761	0.0986	0.1047	0.0024	0.0055	0.0300	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0354	0.0059
104	0.1003	0.1148	0.0805	0.0024	0.0055	0.0300	0.0105	0.1603	0.3986	0.0109	0.0000	0.0125	0.0323	0.0355	0.0059
105	0.1002	0.1148	0.1047	0.0024	0.0055	0.0300	0.0105	0.1602	0.3744	0.0111	0.0000	0.0125	0.0322	0.0354	0.0059
106	0.0765	0.0983	0.1045	0.0023	0.0061	0.0210	0.0105	0.1803	0.4041	0.0108	0.0000	0.0121	0.0314	0.0354	0.0066
107	0.0761	0.0962	0.1025	0.0023	0.0068	0.0110	0.0099	0.2002	0.3999	0.0115	0.0000	0.0118	0.0296	0.0351	0.0071
108	0.0761	0.0986	0.0998	0.0024	0.0055	0.0300	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0362	0.0099
109	0.0761	0.0986	0.1047	0.0024	0.0055	0.0260	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0354	0.0099
110	0.0761	0.0946	0.1006	0.0105	0.0055	0.0300	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0354	0.0059
111	0.0761	0.0906	0.0966	0.0105	0.0055	0.0300	0.0105	0.1602	0.4146	0.0113	0.0000	0.0125	0.0322	0.0394	0.0099
112	0.0879	0.1045	0.0924	0.0024	0.0055	0.0300	0.0105	0.1599	0.4077	0.0133	0.0000	0.0125	0.0322	0.0354	0.0059
113	0.0761	0.0986	0.1047	0.0024	0.0055	0.0250	0.0105	0.1602	0.4146	0.0111	0.0000	0.0175	0.0322	0.0354	0.0059
114	0.0762	0.0987	0.1007	0.0024	0.0055	0.0251	0.0105	0.1603	0.4149	0.0105	0.0000	0.0175	0.0323	0.0355	0.0099
115	0.1010	0.0982	0.1007	0.0031	0.0041	0.0378	0.0102	0.1007	0.4365	0.0092	0.0089	0.0126	0.0302	0.0403	0.0066
116	0.0995	0.0967	0.0992	0.0030	0.0045	0.0372	0.0100	0.1107	0.4302	0.0115	0.0087	0.0125	0.0298	0.0397	0.0067
117	0.0986	0.0958	0.0982	0.0030	0.0051	0.0369	0.0099	0.1212	0.4257	0.0093	0.0086	0.0123	0.0294	0.0392	0.0070
118	0.0867	0.0958	0.0980	0.0030	0.0050	0.0353	0.0099	0.1210	0.4250	0.0110	0.0086	0.0252	0.0293	0.0391	0.0070
119	0.0972	0.0944	0.0968	0.0029	0.0055	0.0363	0.0098	0.1313	0.4197	0.0108	0.0085	0.0121	0.0290	0.0387	0.0071
120	0.0856	0.0945	0.0967	0.0029	0.0055	0.0348	0.0098	0.1313	0.4194	0.0113	0.0085	0.0249	0.0290	0.0387	0.0071
121	0.0865	0.0956	0.0978	0.0030	0.0050	0.0438	0.0099	0.1207	0.4240	0.0132	0.0000	0.0252	0.0293	0.0390	0.0069

Table E.1. The 147 Existing LAW Glass Compositions (mass fractions) Within the Outer-Layer Region SCCs and MCCs Given in Tables 2.1 and 2.3 (contd)

Row	Component														
#[(a)]	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SO_3	SnO_2	V_2O_5	ZnO	ZrO_2	Others1
122	0.0764	0.0890	0.0977	0.0030	0.0050	0.0352	0.0099	0.1206	0.4204	0.0143	0.0085	0.0251	0.0293	0.0390	0.0266
123	0.0866	0.0957	0.1064	0.0030	0.0050	0.0352	0.0099	0.1208	0.4244	0.0124	0.0000	0.0252	0.0293	0.0391	0.0069
124	0.0867	0.0957	0.0980	0.0030	0.0050	0.0353	0.0099	0.1209	0.4247	0.0116	0.0060	0.0277	0.0293	0.0391	0.0070
125	0.0860	0.0950	0.1056	0.0000	0.0050	0.0350	0.0000	0.1199	0.4212	0.0197	0.0100	0.0272	0.0291	0.0395	0.0069
126	0.0860	0.0950	0.1057	0.0000	0.0050	0.0371	0.0000	0.1200	0.4213	0.0196	0.0100	0.0250	0.0291	0.0395	0.0069
127	0.1008	0.0984	0.0788	0.0028	0.0017	0.0000	0.0100	0.2201	0.3720	0.0125	0.0000	0.0196	0.0296	0.0398	0.0138
128	0.1064	0.1277	0.0648	0.0090	0.0051	0.0000	0.0090	0.2296	0.3480	0.0080	0.0100	0.0097	0.0299	0.0299	0.0127
129	0.1064	0.1277	0.0648	0.0090	0.0051	0.0000	0.0090	0.2296	0.3480	0.0080	0.0100	0.0097	0.0299	0.0299	0.0127
130	0.1064	0.1278	0.0648	0.0090	0.0051	0.0000	0.0090	0.2297	0.3482	0.0077	0.0100	0.0097	0.0299	0.0299	0.0128
131	0.1064	0.1278	0.0648	0.0090	0.0051	0.0000	0.0090	0.2297	0.3482	0.0077	0.0100	0.0097	0.0299	0.0299	0.0128
132	0.1063	0.1277	0.0647	0.0090	0.0051	0.0000	0.0090	0.2296	0.3480	0.0083	0.0100	0.0097	0.0299	0.0299	0.0128
133	0.0695	0.0822	0.0313	0.0026	0.0052	0.0000	0.0098	0.2401	0.4157	0.0076	0.0267	0.0092	0.0282	0.0603	0.0115
134	0.0758	0.0983	0.1004	0.0024	0.0054	0.0249	0.0104	0.1602	0.4134	0.0138	0.0000	0.0174	0.0321	0.0354	0.0099
135	0.0946	0.0861	0.0332	0.0092	0.0054	0.0000	0.0092	0.2403	0.3929	0.0051	0.0273	0.0000	0.0243	0.0592	0.0131
136	0.1003	0.0851	0.0191	0.0097	0.0054	0.0000	0.0093	0.2359	0.4004	0.0061	0.0100	0.0200	0.0236	0.0603	0.0148
137	0.0998	0.0848	0.0189	0.0096	0.0011	0.0000	0.0093	0.2401	0.3990	0.0081	0.0100	0.0199	0.0236	0.0601	0.0156
138	0.1017	0.1204	0.0803	0.0100	0.0016	0.0000	0.0100	0.2104	0.3719	0.0089	0.0000	0.0100	0.0301	0.0301	0.0146
139	0.1017	0.1369	0.0803	0.0100	0.0015	0.0000	0.0100	0.2002	0.3665	0.0102	0.0000	0.0100	0.0300	0.0300	0.0127
140	0.1017	0.1369	0.0803	0.0100	0.0015	0.0000	0.0100	0.2002	0.3665	0.0102	0.0000	0.0100	0.0300	0.0300	0.0127
141	0.1017	0.1369	0.0803	0.0100	0.0015	0.0000	0.0100	0.2002	0.3665	0.0102	0.0000	0.0100	0.0300	0.0300	0.0127
142	0.1017	0.1369	0.0803	0.0100	0.0015	0.0000	0.0100	0.2002	0.3665	0.0102	0.0000	0.0100	0.0300	0.0300	0.0127
143	0.0666	0.0875	0.0332	0.0019	0.0053	0.0000	0.0092	0.2402	0.4237	0.0061	0.0274	0.0000	0.0274	0.0597	0.0117
144	0.0873	0.0964	0.0987	0.0023	0.0050	0.0441	0.0099	0.1201	0.4276	0.0076	0.0000	0.0253	0.0295	0.0393	0.0070
145	0.0866	0.0957	0.0979	0.0023	0.0050	0.0439	0.0099	0.1202	0.4245	0.0135	0.0000	0.0251	0.0293	0.0391	0.0069
146	0.1008	0.0984	0.0789	0.0028	0.0017	0.0000	0.0100	0.2199	0.3722	0.0126	0.0000	0.0196	0.0296	0.0398	0.0138
147	0.0350	0.1373	0.0000	0.0030	0.0011	0.0500	0.0000	0.1431	0.4514	0.0010	0.0500	0.0400	0.0100	0.0600	0.0181

(a) The glass names corresponding to the row numbers are listed in Table E.2.

Table E.2. Glass Names Corresponding to the Row Numbers of the 147 Existing LAW Glass Compositions in Table E.1

Row #	Glass Name	Row #	Glass Name	Row #	Glass Name	Row #	Glass Name	Row #	Glass Name
1	LAWA171	31	ORPLA2	61	ORPLA38-1	91	ORPLD1	121	ORPLF7
2	LAWA172	32	ORPLA3	62	ORPLA1S4	92	ORPLD2	122	ORPLF9
3	LAWA173	33	ORPLA5	63	ORPLA2S4	93	ORPLD3	123	ORPLF10
4	LAWA174	34	ORPLA6	64	ORPLA3S4	94	ORPLD4	124	ORPLF11
5	LAWA175	35	ORPLA7	65	ORPLA5S4	95	ORPLD5	125	ORPLF13
6	LAWA176	36	ORPLA9	66	ORPLA6S4	96	ORPLD6	126	ORPLF14
7	LAWA179	37	ORPLA10	67	ORPLA7S4	97	ORPLD7	127	10A-G-53C
8	LAWA180	38	ORPLA11	68	ORPLA9S4	98	ORPLD8	128	EWV89BCCC
9	LAWA183	39	ORPLA12	69	ORPLA10S4	99	ORPLD9	129	EWV-G-89B
10	LAWA184	40	ORPLA13	70	ORPLA11S4	100	ORPLD1S4	130	EWV-G-93B
11	LAWA185	41	ORPLA14	71	ORPLA12S4	101	ORPLD2S4	131	EWV93BCCC
12	LAWA186	42	ORPLA15	72	ORPLA13S4	102	ORPLD3S4	132	EWV-G-108B
13	LAWA187.1	43	ORPLA16	73	ORPLA14S4	103	ORPLE1	133	J10-G-24B
14	LAWA187.2	44	ORPLA17	74	ORPLA15S4	104	ORPLE2	134	Q10-G-134A
15	LAWA187CCC	45	ORPLA18	75	ORPLA16S4	105	ORPLE3	135	R10-G-155A
16	LAWA188	46	ORPLA19	76	ORPLA17S4	106	ORPLE4	136	S10-G-101B
17	LAWA189	47	ORPLA20	77	ORPLB1	107	ORPLE5	137	S10-G-45A
18	LAWA190	48	ORPLA21	78	ORPLB2	108	ORPLE6	138	T10-G-16A
19	LAWA191	49	ORPLA22	79	ORPLB3	109	ORPLE7	139	WVY-G-95A-1
20	LAWA192	50	ORPLA23	80	ORPLB4	110	ORPLE8	140	WVY-G-95A-2
21	LAWA193	51	ORPLA24	81	ORPLB1S4	111	ORPLE9	141	WVY-G-95A-3
22	LAWA194	52	ORPLA25	82	ORPLB2S4	112	ORPLE10	142	WVY-G-95A-4
23	LAWA195	53	ORPLA26	83	ORPLB3S4	113	ORPLE11	143	Y10-G-146C
24	LAWA196	54	ORPLA33	84	ORPLB4S4	114	ORPLE12	144	Z10-G-122B
25	LAWA197	55	ORPLA33-1	85	ORPLC2	115	ORPLF1	145	Z10-G-153B
26	LAWC100R1	56	ORPLA34	86	ORPLC4	116	ORPLF2	146	Z10-G-60C
27	LAWC101	57	ORPLA35	87	ORPLC5	117	ORPLF3	147	S2-07
28	LAWC102	58	ORPLA36	88	ORPLC2S4	118	ORPLF4		
29	LAWC103	59	ORPLA37	89	ORPLC4S4	119	ORPLF5		
30	ORPLA1	60	ORPLA38	90	ORPLC5S4	120	ORPLF6		

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