ERRORS OF DWPF FRIT ANALYSIS - FINAL REPORT (U)

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ERRORS OF DWPF FRIT ANALYSIS - FINAL REPORT - (U)

SUMMARY

Glass frit will be a major raw material for the operation of the Defense Waste Processing Facility. The frit will be controlled by certificate of conformance and a confirmatory analysis from a commercial analytical laboratory. The following effort provides additional quantitative information on the variability of frit chemical analyses at two commercial laboratories.

Identical samples of IDMS Frit 202 were chemically analyzed at two commercial laboratories and at three different times over a period of four months. Similar samples were analyzed once by SRL's ADS laboratory. The vendor also supplied an analysis for one of the samples. The variability of the oxide determinations was shown to be critical to the frit acceptance process. All of the laboratories provided reasonably good chemical analyses. However, the CELS laboratory consistently provided a better level of precision. The standard deviations of the Monarch analyses for individual elements were at least two times greater than the CELS analyses. The variability's of the results were analyzed and it was concluded that the Monarch analyses were more variable and at least twice as many analyses would be required to obtain similar levels of confidence. It is strongly suggested that the CELS laboratory be used as a sole source supplier of the chemical analyses for DWPF Frit until such time as it is shown through trials that other laboratories can provide similar levels of analytical precision.

The SRL-ADS analyses, after correction with the reference standard and normalization, provided confirmatory information, but did not detect the low silica level in one of the frit samples.

A methodology utilizing elliptical limits for confirming the certificate of conformance or confirmatory analysis was introduced and recommended for use when the analysis values are close but not within the specification limits. It was also suggested that the lithia specification limits might be reduced as long as CELS is used to confirm the analysis.

INTRODUCTION

The Waste Acceptance Preliminary Specifications, (WAPS)¹ require that the Defense Waste Processing Facility (DWPF) control the consistency of the waste glass product. As described in the Waste Form Compliance Plan (WCP)² this will be achieved through control of the chemical composition of the glass product. Since the glass frit purchased by the DWPF will constitute approximately two thirds of the waste glass product, control of the composition of the frit is an important part of meeting the chemical composition specifications.

Current plans are to control the composition of the frit through the procurement specifications and chemical analyses of representative lot samples. Until the present effort, little data has been available on the errors involved in the chemical analyses of frit. The objective of this task is to quantify the errors involved in the chemical analysis of frit and based on this information, consider modification of the current specification.

The frit specification for the Integrated DWPF Melter System (IDMS) runs was put into the format of an Essential Materials Specification (EMS No. 206) and was used to obtain initial orders of frit for qualification. The composition limits were based on previous frit procurement specifications and general knowledge of the manufacturer's capabilities. Of the four suppliers evaluated under the EMS 206 specifications, three suppliers provided material which marginally met the specifications. Each of the three materials was at the limit of at least one of the specifications. A new specification for DWPF Cold Runs was prepared based on the EMS 206 and published as Specification No. OPS-DTE-910003. The chemical portion of the new specification was essentially unchanged. Table 1 is a summary of the chemical portion of the specification, which must be met for each composite sample from each "Lot" of Frit 202. The lot shall be in multiple increments of 5,000 pounds.

The "Total Undesirable Components" is defined as 100 wt% minus the actual analysis of the five major constituents listed below and includes but is not limited to Al, Fe, Mn, Ni, Cr, Pb, Ti, F, and Cl. Additional undesirable components > 0.05 wt% shall be reported along with their amount in the certificate of conformance. The moisture content of each lot of material shall be less than 0.1 wt% and the total reducible material as measured by a "Chemical Oxygen Demand" determination shall be less than 0.1 wt%. In addition, the particle size distribution of each lot of frit must be such that ≥ 99.0 wt% passes through a Tyler 80 mesh screen, and < 10 wt% passes through a Tyler 200 mesh screen. The material must be free flowing.

Table 1
Chemical Composition Specification for Frit 202

Component	Concentration (Wt%)
SiO ₂	77.0 ± 1.0
Na ₂ O	6.0 ± 0.5
B ₂ O ₃	8.0 ± 0.5
Li ₂ O	7.0 ± 0.5
MgO	2.0 ± 0.25

Each lot of material shall have less than the following
 undesirable components in the frit.

Chemical	Maximum (Wt.%)
Al	1.0
Fe	0.2
Mn	0.2
Ni	0.2
Cr	0.1
Pb	0.1
Ti	0.15
F	0.05
Cl	0.05

Total Undesirable Components as oxides: < 2.25 wt%

The specification presently requires the vendor to obtain a representative sample of frit for each lot of material. One representative sample will be analyzed by the vendor and the analysis delivered as a certificate of conformance. A second sample will be submitted to an independent certified laboratory for a confirmatory analysis. The chemical analyses will be used to confirm that the lot of frit meets the procurement specification prior to the delivery of the material. When the frit is used in the DWPF process the chemical composition of the frit will be employed in the "Process Composition Control System" (PCCS) to achieve an acceptable chemical composition for the waste-frit, slurry mixture.

The difficulty in meeting the multiple interrelated frit specification limits as previously described in the Frit 202 specification has been discussed by Postles⁴. For example, if there are "N" simultaneous and independent specification limits and each has been established such that it has a false rejection rate of about 0.05 or 5%; then when all "N" limits are applied simultaneously, the false rejection rate would be $1-(.95)^N$. This would provide a false rejection rate of 0.226 or in other words, nearly a fourth of the material would be rejected unjustly when five independent limits are applied. While the frit specifications are not independent limits, (they must total to a number approaching 100%) the effect of multiple specifications persists and can be compensated for somewhat, by adapting the simultaneous confidence ellipsoid theory due to Hotelling⁵. In addition, it was felt that the elliptical limits provided a more just criteria for acceptance when compared to the upper and lower polyhedral limit approach.

A simple graphical representation of an elliptical limit for two components is shown in Figure 1. The area of the ellipse compared to the rectangle was expanded by approximately 25% and the original 1:2 ratio in the limits was maintained. A similar approach was taken for the other major specifications and the ratios and resulting areas are presented in Table 2.

Table 2
Ellipsoid Radius Ratios and Expanded Areas of Acceptance

Oxide Pair	Spec. Ratio (Wt%)	Ratio	Ellipse Radii (Wt%)	Polyhedral Area	Ellipse Area
SiO ₂ /R ₂ O	2/1	2	1.26/0.63	2.0	2.49
SiO ₂ /MgO	2/0.5	4	1.26/0.32	1.0	1.27
SiO ₂ /Tot. Maj.	2/2.25	0.89	1.26/1.42	4.5	5.625

It was possible to adjust the ellipsoids and maintain the major silica radius at about 1.26 and increase all the ellipse areas by 25%. The area of an ellipse can be calculated using π times the product of the major and minor radii of the ellipse.

When the frit is chemically analyzed to determine if it meets the chemical specification, there will be a confidence band on either side of each oxide measurement. In a strict sense this uncertainty should remain with the analytical measurement. However, for the convenience of the DWPF plant personnel, the measurement of uncertainty was transferred to the elliptical acceptance limits. In order to ensure a reasonable probability that the analytic value is acceptable, the measured value should be at least two standard deviations inside the ellipse. Conversely when the analytic value is more than two standard deviations outside the ellipse the probability is high that the result is not within specification. When the analysis falls in the region of the ellipse $\pm$ two standard deviations ($\pm 2\sigma$) the conformance to the specification is a matter of probability. A single analysis directly on the ellipse should have an even chance of being in or out of specification. This concept is graphically presented in Figure 2. In order to simplify this approach further it is suggested that, any value inside the original elliptical limit is assumed to be acceptable, while any value outside the ellipse is assumed to be not acceptable.

EXPERIMENTAL

Experimental Design

A partially nested experimental design was used to assess the contributions of various sources of uncertainty ^{4a}. A Reference Standard Frit 6, whose chemical composition had been determined to a high level of reliability was included as a control sample. After development of the Reference Frit it was planned to determine the composition of three IDMS frit samples at three commercial laboratories and at three different times. The fourth sample would be the Reference Frit sample. A Task Plan⁷ was prepared and included the experimental design shown in Table 3.

Table 3
Planned Design of Experiment

	Lab. 1	Lab. 2	Lab. 3	SRL-ADS
Sample 1	Time 1,2,3	Time 1,2,3	Time 1,2,3	Time 1
Sample 2	"	"	"	"
Sample 3	"	"	"	"
Ref. Stand.	"	"	"	"

Material Acquisition

The Reference Frit standard, a 100 pound sample of SRL Frit 202, was obtained from Ferro Corporation under purchase order number 0402593 and under procurement specification DWPT-QA-89-1019, at procurement level 1. The material was initially glass flake which was ground as a lot to less than 200 mesh powder ($< 74 \mu$) and blended to form a homogeneous sample prior to shipment to SRL in three six gallon metal containers. A sample from the number 1 container was used in this study (E-51768-49-101) as the reference standard glass. This glass was well analyzed chemically and a best estimate of the chemical composition was reported⁶. The best estimate composition is reproduced as Table 4. This estimate was largely based on the high level of reliability obtained from an accumulation of CELS analyses of the reference standard and, to a lesser extent, analyses by other chemical laboratories. The best estimate composition accounts for 99.9 wt% of the metallic oxides. It was felt that any improvement in the analytic chemical composition determination would require an extensive "Round Robin" analyses with little corresponding benefit.

Table 4
Chemical Analysis Frit 202 Reference Frit Standard
(Best Estimate of Chemical Composition - Ref. 6)

Oxide	Wt%	Oxide	Wt%	Oxide	Wt%	Oxide	Wt%
SiO ₂	76.6	Na ₂ O	5.9	NiO	<.01	Cl	0.01
B ₂ O ₃	7.7	Li ₂ O	6.7	PbO	0.01	COD	<.02
Al ₂ O ₃	0.40	K ₂ O	0.19	TiO ₂	0.11	Total	99.9
Fe ₂ O ₃	0.03	ZrO ₂	0.02	BaO	0.04		
CaO	0.12	MnO ₂	<.01	Sb ₂ O ₃	<.1		
MgO	2.0	Cr ₂ O ₃	<.01	F	0.03		

Three samples of SRL Frit 202 were obtained as grab samples (approximately 1 pound) from containers of frit ordered for the IDMS runs at TNX. The samples were labeled as E-51768-2 : -1, -2, and -3. This frit was also supplied by Ferro Corporation and markings from the bin identification are presented as Appendix A.

Sample Splitting

The three IDMS samples and the reference standard material were split into twenty identical samples with the Quantachrome Rotary Riffler, Model SRR-2, under procedure GTOP-3-024, Rev. 0. The use of this type of splitter provides an extremely low sample variability due to the rotary splitting process. Table 5 provides the sample number identification.

Table 5
Sample Identification

<u>Sample No.</u>	<u>Identification</u>	<u>Split Sample No.</u>
E-517 68-2-1	IDMS SRL Frit 202 Ferro Corp (7-1-88)	E-51768-98-6 to 25 (Twenty Samples)
E-51768-2-2	SRL Frit 202 Ferro Corp. (6-30-88)	E-51768-99-6 to 25 (Twenty Samples)
E-51768-2-3	IDMS SRL Frit 202 Ferro Corp. (7-5-88)	E-51768-100- 6 to 25 (Twenty Samples)
E-51768-49-101	Reference Standard Frit 202 (Can 1)	E-51768-101-6 to 25 (Twenty Samples)

Chemical Analysis

From the twenty identical samples of each large frit sample, eight samples were randomly selected and submitted to SRL - Analytic Development Section (ADS) for dissolution and chemical analysis by Inductively Coupled Plasma (ICP) and Atomic Absorption (AA). Eight samples of the 202 Reference Frit standard were included to provide corrections for the SRL-ADS analyses. Previous experiments during the DWPF frit qualification studies³ found that approximately 8 to 10 samples provided a reasonably reliable average chemical analysis when the results were bias corrected with a standard and then normalized to approximately 100%.

From the remaining twelve samples of each frit, a single random sample for each of the four Frit 202 samples was sent to Corning Engineering Laboratory Services (CELS) and to Monarch Analytical Laboratories (MAL) at three different times i.e., April 6, June 29, and August 6, 1990. The third laboratory, Sharp Schurtz Co., declined to bid on this work and was not replaced. These two commercial laboratories are representative of the best analytical laboratories which tend to specialize in glass analysis. The CELS analyses were carried out under purchase order AA10904 and the MAL analyses under AA15342N. Both orders were conducted under QA level 2. It was requested that the laboratories use what they felt were their best analytical methods e.g. ICP, AA, X-ray fluorescence, titrations, specific ion electrodes, etc. for any glass component greater than 0.10 wt%. The expected ranges of elements were provided with the order. Both laboratories were informed that the SiO₂ level exceeded 50 wt%, the Na₂O, B₂O₃, Li₂O, MgO, and Al₂O₃ could be between 1 to 15 wt%. and that the Fe₂O₃, TiO₂, MnO, K₂O, NiO, Cr₂O₃, PbO, F, Cl, were less than 1 wt%.

The cost of the Monarch analyses of four samples was \$2320 while the cost of the CELS analyses was \$2220. The final experimental design is shown in Table 6.

Table 6 Experimental Sample Analysis Design				
Frit 202 Sample	E-51768-98-	99-	100-	101- (Ref. Std)
SRL - ADS (8 samples)	Time (1)	Time (1)	Time (1)	Time (1)
Corning (CELS) (3 samples)	Time(1,2,3)	Time(1,2,3)	Time(1,2,3)	Time(1,2,3)
Monarch (MAL) (3 samples)	Time(1,2,3)	Time(1,2,3)	Time(1,2,3)	Time(1,2,3)
Vendor (Ferro)	(Cert. Conform.)			

In the past samples of another reference standard, Frit 165, were extensively analyzed at the CELS laboratory. Additional analyses nearly five years later provided an impressive demonstration of the repeatability and consistency of the CELS laboratory. Table 7 provides the comparison of CELS analyses over this five year period.

Table 7 CELS Chemical Analyses of SRL Frit 165								
Analysis:		3-15-85		11-22-89		1-11-90		4 Samp.
Oxide	No. Samples	Oxide (Wt%)	Std. Dev.	Oxide (Wt%)	Oxide (Wt%)	Oxide (Wt%)	Oxide (Wt%)	Stand. Dev.
B ₂ O ₃	(16)	9.32	0.064	9.36	9.44	9.37	9.38	0.04
Na ₂ O	(16)	12.16	0.045	12.2	12.1	12.1	12.1	0.05
Li ₂ O	(16)	6.96	0.029	6.87	6.83	6.83	6.81	0.02
MgO	(16)	0.99	0.010	1.00	1.01	1.02	1.02	0.01
ZrO ₂	(16)	0.99	0.017	0.97	0.96	0.98	0.96	0.01
SiO ₂	(10)	68.89	0.075	68.9	68.9	69.3	69.3	0.23
Total		99.31		99.30	99.24	99.6	99.67	0.21

RESULTS AND DISCUSSION

Monarch Analytic Laboratory

The Monarch Analytical Laboratories provided two analyses of each sample sent to them. The original data is presented in Appendix B. In order to simplify the comparison with the CELS data, the average analyses for each set of two results was obtained and presented as a single value along with the CELS determinations in Tables 8 to 11. MAL did not perform a qualitative analysis or determine all of the oxides above 0.10 wt.% as requested. An attempt was made to reduce the variance of the MAL results by correcting with the reference standard, however, this appeared to reduce all of the oxide variability except for silica and since this was the most variable oxide, this approach was not used.

Corning Engineering Laboratory Services

CELS conducted an initial qualitative analysis in order to determine the relative amounts of oxides present, then analyzed for all the oxides above 0.10 wt%. The results of the CELS and MAL analyses are presented in Tables 8 to 11 with the values outside of the rectangular specifications in

" Bold Underline "

It should also be noted that some of the frit samples were outside of the DWPF Frit 202 specification. Comparing the number of oxides analyzed which were outside the rectangular specifications: CELS showed a total of eleven oxide analyses out of specification while the MAL analyses had 19 out of specification. In general, sample 98 appeared to be on the lower limit for boron but within specification. Sample 99 was on the lower limit for lithia but within specification. Sample 100 was out of specification, and below the lower limit on lithia, magnesia, silica and the total of the major oxides. Sample 101, the reference standard, was within specification for all oxides. The average of the values, variance, standard deviation, and relative standard deviation for the data were included in Tables 8 to 11.

The variances for the analyses of each oxide were pooled (summed and divided by n) to form the average standard deviation for the CELS and MAL laboratories. The variances, pooled variance, and average standard deviations, are presented in Table 12. The pooled variance provided an excellent estimate of the standard deviation for the given oxide determination capability for each laboratory. The average standard deviations from CELS were similar to those obtained for the 165 Reference Frit (See Table 7). The average standard deviations for the CELS analyses were about 1/7 of the MAL standard deviations. Since the elliptical limits include $\pm 2 \sigma$, a listing of 2σ values was included in Table 12. The standard deviations for silica and the total of the major oxide analyses for both laboratories were comparable.

A multivariate F test was used to compare the precision of the two laboratories. This is shown in Table 7 A. Since four of the five parameters are significantly more variable for Monarch, one may conclude that CELS precision is significantly better (by a factor of about 5).

Table 7A
Multivariate "F" Test Comparison of the CELS and MAL Laboratories.

Major Oxide	CELS Average Std. Dev.	MAL Average Std. Dev.	F Ratio (MAL/CELS) ²
SiO ₂	0.158	0.152	0.93
Na ₂ O	0.012	0.070	34.03
Li ₂ O	0.037	0.205	30.70
B ₂ O ₃	0.024	0.196	66.69
MgO	0.012	0.058	23.36

$$F(0.95) = 3.44$$

An ASTM Standard Practice⁸ was utilized to calculate an estimate of the number of chemical analyses required from the CELS and MAL laboratories to provide a reasonably precise chemical composition for Frit 202. The formula for calculating "n", the number of analyses required was:

$$n = (3 \sigma_0 / E)^2$$

where:

- σ = the advance estimate of the standard deviation of the oxide analyses
- E = the maximum allowable error between the estimate to be made from the oxide analysis and the result of repetitive measurement of the oxide.
- 3 = a factor corresponding to a low probability that the difference between the sample estimate and the result of measuring the oxide repeatedly is greater than E .

The choice of the factor 3 is recommended for general use. With the factor 3 and with a process standard deviation equal to the advance estimate, it is practically certain that the sampling error will not exceed E . Probability of exceeding E is 3 in 1000.

The above formula is recommended when the analytical process is in statistical control and the measurements are distributed normally about a mean. A reasonable estimate of the analytic standard deviation for each oxide is also required. As stated previously the average standard deviations for each oxide in Table 12 should provide an excellent estimate of the population standard deviation. This ASTM formula was then used to calculate the number of analyses required to provide a maximum error of one half of the specification limit, i.e. for silica the specification limit is ± 1.0 - a maximum error of 0.5 was selected. The results of these calculations are presented as Table 12A.

Table 12A shows the number of analyses required to obtain an analysis within the error limits presented under E . For the CELS analyses "n" is less than one. For the MAL analyses "n" is less than six. Again many more analyses would be required from the Monarch Laboratory. This would increase the cost of verifying the certificate of conformance.

The 2σ values from Table 12 were also used to construct the elliptical limits for the CELS and MAL analyses of the four frit samples. These values are presented in Table 13. Review Figure 2 for the location of the limits for SiO_2 . Figures 3 to 6 summarize the positions of the three analyses for each of the five major oxides from CELS using the elliptical limits. It should be noted that the three analyses for sample 98 are within both the rectangular and elliptical chemical limits for the oxides (Figure 3). The boron level is definitely acceptable. The lithia level for sample 99 (Figure 4) is in the region of uncertainty where there is approximately a 50:50 probability of being acceptable. As long as all other specifications were within the limits this material would be acceptable. For sample 100 (Figure 5), the low levels of silica, lithium, and magnesium are quite obvious. This material could be rejected. Sample 101 (Figure 6) is within specification for all five oxides. The "Best Estimate" values are included on this figure for comparison and it can be seen that the CELS average value is very near the best estimate. Figure 7 plots the ellipse comparing the silica analysis to the sum of major oxides. Sample 100 is again outside of the acceptable region.

In order to provide a comparison with the MAL analyses, the analyses of samples 98 and 101 are presented in Figures 8 and 9. The effect of the increased variability in the analyses is immediately apparent. The acceptance of the lithia and boron oxide are in some doubt for sample 98 and the low silica level obtained for the reference standard sample 101 makes it difficult to assure the acceptance of this material. Both samples 98 and 101 were acceptable by the CELS analyses and variability. It is believed that the MAL analysis is low in silica and this also affects the sum of the majors which is particularly low for this sample. If in the future, the variability of the measurements from MAL could not be reduced, it would be more difficult to confirm the acceptability of these types of frit and they could be rejected.

The lithia analysis by CELS was quite reproducible and had an average standard deviation of .037 wt %. Reviewing previous data on frit qualification it is apparent that all suppliers provided frit on the low half of the specification. That is, all analyses for acceptable samples were between 6.0 to 7.0 wt %, while the specification was between 6.5 to 7.5 wt%. It appears probable that the frit vendors are controlling the level of lithia to the low end of the specification. The reason for this is the cost of the lithia in this glass probably exceeds the sum of the cost of all the other raw materials. If the frit with higher lithia levels would significantly improve the waste product and CELS is used to confirm the analysis, it should be possible to reduce the specification limits for lithia to between 6.75 to 7.25 wt%.

Analysis of Variance for CELS and MAL Analyses

Because this was a statistically designed study, it was possible to develop an analysis of variance for each oxide and laboratory. The results of these statistical analyses are presented in Tables 14 to 16 and they reinforce the importance of obtaining as low a variability in the chemical analyses as possible. The results which were outside of the specifications were again in "Bold Underline". The analysis of variance for the silica results from both laboratories (CELS and MAL) produced an "F" value which indicates a significant difference between the sample means for each sample⁸. The F value provided more than a 99% confidence that the sample means for silica for each sample were indeed different. The Corning F value was slightly higher than the MAL F value. The CELS data indicates that sample 100 is below the specification for SiO₂, while the MAL analyses indicates that samples 99, 100, and 101 may be below the specification. A brief table of confidence levels and F values is outlined in the right quadrant of each Table.

The averages of the B₂O₃ contents were within specification, however, two of the MAL analyses gave values just below the limit. The ANOV indicated that the difference in samples was very significant for the CELS analyses while the F value for the MAL analyses was not significant. In other words, the samples were not significantly different when the analysis error was considered.

All of the values and averages for the Na₂O content were within the specifications, however again the differences in the means observed by the CELS analysis were significant while the MAL were not able to detect a significant difference in the samples.

The lithia levels were at the lower limit of the specification for all of the samples. That is all values obtained were between 6.0 and 7.0 wt%. Samples 99 and 100 for the CELS analyses were at or below the limit of 6.50 wt%. All four samples analyzed by MAL had at least one value outside the specification. The CELS analysis provided significant differences between the samples while the MAL did not. The average values were similar.

The magnesia level from both laboratories for sample 100 was outside the specification. Both laboratories indicated significant differences between the samples and provided similar results.

An analysis of variance was carried out on the total of the major oxides. Both laboratories were able to detect the differences in the samples and both indicated that sample No. 100 was outside the specification.

The variance between laboratories was not calculated as it has already been shown that the variability between labs is significant with CELS having much less variability.

SRL-ADS

The ICP data obtained from the SRL ADS laboratory is presented in Appendix C. The element weight percent data obtained from the eight analyses of the reference standard (E-51768-101-XX), as presented on page one, were averaged and used to calculate the oxide weight percent of the major components as shown on page two. The total oxide weight percent outputs should have summed to almost 100% but only 91.37 wt% was reported. A first attempt to normalize the data to 100% was not effective, so the data from the best estimate analysis of the reference standard was used to develop correction factors for each oxide. These correction factors (outlined) were then used to adjust the data obtained for the next three SRL Frit 202 analyses. This procedure was similar to that used to correct and normalize data for Frit 202 Qualification studies³, and based on the 165 Frit standard.

The ICP data from the SRL ADS analyses of the three IDMS frit samples are presented in Appendix C on pages 3, 5, & 7. This data was used to calculate oxide weight percentages on pages 4, 6, & 8. The data was then corrected with the analysis of the reference standard and then normalized to 100%. These results agree closely to the analytical results from the two commercial laboratories. The SRL-ADS results are compared to the other analyses in Tables 16 to 19. The SRL-ADS analyses were unable to show that sample 100 was below the silica specification. The other oxide analyses were reasonably good predictors that the oxides were either within or outside the specifications and may aid in determining acceptance of frit materials, if required.

CONCLUSIONS

The results of this investigation provided the following conclusions:

1. The CELS laboratory demonstrated a superior level of precision during this and other frit analyses. The CELS laboratory provided oxide analyses of Frit 202 with less variability than the MAL laboratory. This was demonstrated with Analysis of Variance, an F test, and an estimate of the number of samples required for an analysis. In order to provide results with similar levels of confidence, it would require at least twice the number of analyses at MAL and this would essentially double the cost of confirming the certificate of conformance. The CELS laboratory should be strongly considered as a sole source vendor for the analysis of DWPF frit until such time as other analytical laboratories can demonstrate a similar level of precision.
2. Use of the elliptical limits with or without $\pm 2 \sigma$ regions should be considered as the basis for acceptance of DWPF frit outside the specification limits.
3. The SRL-ADS laboratory can be used to support the certificate of conformance, but will require the inclusion of standard material and at least eight or ten multiple analyses. The reference standard (E-51768-49-101 Can #1) should be used for this purpose.

4. It should be emphasized that both the CELS and MAL laboratories are two of the finest glass analytical laboratories in the United States and while comparisons were made it should not be construed that there was any intent to criticize the capabilities of any of the facilities, including SRL-ADS or the frit vendors.
5. After additional experience in frit procurement is obtained, future specifications might consider the reduction in the acceptable limits from ± 0.50 wt% to ± 0.25 wt%. Both the vendors and the CELS analytic laboratory appear to have sufficient control to maintain this limit.

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FIGURE 1. Graphical Representation of Portions of the Specification and 25% Area Expansion of Limits Due to Multiple Oxide Requirements.

FIGURE 2. Graphical Representation of Expanded Specifications Due to Multiple Limits and Inclusion of ± 2 Sigma Bands.

Sample No E-51768-98

FIGURE 3. CELS CHEMICAL ANALYSIS OF FRIT 202 SAMPLE E-51768-98

FIGURE 4. CELS CHEMICAL ANALYSES OF FRIT 202 SAMPLE NO. E-51768-99

FIGURE 5. CELS CHEMICAL ANALYSES OF FRIT 202 SAMPLE NO. E-51768-100

FIGURE 6. CELS CHEMICAL ANALYSES OF FRIT 202 SAMPLE NO. E-51768-101

FIGURE 7. Graphical Representation of the Total Major Oxides with Variability Limits due to Uncertainty of Three Determinations by CELS

Sample No E-51768-98

FIGURE 8 MAL CHEMICAL ANALYSIS OF FRIT 202 SAMPLE E-51768-98

FIGURE 9 MAL CHEMICAL ANALYSIS OF FRIT 202 SAMPLE E-51768-101

CORNING CELS ANALYSIS GLASS #98

OXIDE: Wt%	4/25/90 98#9	6/29/90 98#19	8/21/90 98#17	Average	Variance	Std. Dev.	RSD %*
K ₂ O	0.13	0.12	0.12	0.123	0.000	0.006	4.68%
Li ₂ O	6.67	6.69	6.69	6.683	0.000	0.012	0.17%
Na ₂ O	5.88	5.92	5.90	5.900	0.000	0.020	0.34%
Al ₂ O ₃	0.24	0.24	0.24	0.240	0.000	0.000	0.00%
B ₂ O ₃	7.55	7.52	7.57	7.547	0.001	0.025	0.33%
CaO	0.13	0.13	0.13	0.130	0.000	0.000	0.00%
MgO	2.13	2.13	2.13	2.130	0.000	0.000	0.00%
TiO ₂	0.096	0.096	0.096	0.096	0.000	0.000	0.00%
SiO ₂	76.8	76.7	76.78	76.760	0.003	0.053	0.07%
Total	99.03	98.96	99.07	99.020	0.003	0.056	0.06%

Total = Sum of Majors

RSD=Std. Dev./Mean
Range = Max-Min

MONARCH ANALYSIS GLASS #98

OXIDE	5/3/90 98#15 Avg. of 2	7/18/90 98#23 Avg. of 2	8/31/90 98#6 Avg. of 2	Average	Variance	Std. Dev.	RSD %*
OXIDE: Wt%							
K ₂ O		0.12	0.12	0.120	0.000	0.000	0.00%
Li ₂ O	6.72	6.48	6.79	6.663	0.026	0.163	2.44%
Na ₂ O	5.92	5.74	5.83	5.830	0.008	0.090	1.54%
Al ₂ O ₃	0.19	0.22	0.22	0.210	0.000	0.017	8.25%
B ₂ O ₃	7.44	7.87	7.41	7.573	0.066	0.257	3.40%
CaO		0.12	0.13	0.125	0.000	0.007	5.66%
MgO	2.06	2.12	2.2	2.127	0.005	0.070	3.30%
SiO ₂	76.64	76.57	76.63	76.613	0.001	0.038	0.05%
Total	98.78	98.78	98.86	98.807	0.002	0.046	0.05%

TABLE 8 CELS & MAL CHEMICAL ANALYSES OF SRL FRIT-202 (E-51768-98)

CELS ANALYSIS GLASS #99

OXIDE: Wt%	4/25/90 99#10	6/29/90 99#18	8/21/90 99#19	Average	Variance -98	Std. Dev. -99	RSD%
K ₂ O	0.37	0.36	0.35	0.360	0.000	0.010	2.70%
Li ₂ O	6.51	6.47	6.46	6.480	0.001	0.026	0.41%
Na ₂ O	5.97	5.97	5.97	5.970	0.000	0.000	0.00%
Al ₂ O ₃	0.30	0.32	0.32	0.313	0.000	0.012	3.69%
B ₂ O ₃	7.79	7.74	7.78	7.770	0.001	0.026	0.34%
CaO	0.26	0.24	0.23	0.243	0.000	0.015	6.28%
MgO	1.94	1.96	1.98	1.960	0.000	0.020	1.02%
TiO ₂	0.31	0.31	0.32	0.313	0.000	0.006	1.84%
SiO ₂	76.2	76.3	76.4	76.300	0.010	0.100	0.13%
Total	98.41	98.44	98.59	98.480	0.009	0.096	0.10%

Total = Sum of Majors

RSD=Std. Dev./Mean

Range = Max-Min

MONARCH ANALYSIS GLASS #99

OXIDE	5/3/90 99#20 Avg. of 2	7/18/90 99#12 Avg. of 2	8/31/90 99#6 Avg. of 2	Average	Variance -98	Std. Dev. -99	RSD%
OXIDE: Wt%							
K ₂ O		0.34	0.35	0.345	0.000	0.007	2.05%
Li ₂ O	6.44	6.19	6.6	6.410	0.043	0.207	3.22%
Na ₂ O	5.86	5.8	5.92	5.860	0.004	0.060	1.02%
Al ₂ O ₃	0.28	0.28	0.29	0.283	0.000	0.006	2.04%
B ₂ O ₃	7.70	8.02	7.78	7.833	0.028	0.167	2.13%
CaO		0.22	0.22	0.220	0.000	0.000	0.00%
MgO	1.90	1.94	1.99	1.943	0.002	0.045	2.32%
SiO ₂	76.00	75.96	75.92	75.960	0.002	0.040	0.05%
Total	97.9	97.91	98.21	98.007	0.031	0.176	0.18%

TABLE 9. CELS & MAL CHEMICAL ANALYSIS OF SRL FRIT-202 (E-51768-99)

CCRRNING ANALYSES GLASS # 100

OXIDE:	4/25/90 100#18	6/29/90 100#16	8/21/90 100#12	Average	Variance	Std. Dev.	RSD %
K2O	0.55	0.55	0.54	0.547	0.000	0.006	1.06%
Li2O	6.37	6.26	6.25	6.293	0.004	0.067	1.06%
Na2O	5.86	5.87	5.85	5.860	0.000	0.010	0.17%
Al2O3	0.45	0.47	0.47	0.463	0.000	0.012	2.49%
B2O3	7.93	7.97	7.96	7.953	0.000	0.021	0.26%
CaO	0.40	0.40	0.40	0.400	0.000	0.000	0.00%
MgO	1.63	1.61	1.63	1.623	0.000	0.012	0.71%
TiO2	0.47	0.47	0.47	0.470	0.000	0.000	0.00%
SiO2	75.8	75.4	75.7	75.633	0.043	0.208	0.28%
Total	97.59	97.11	97.39	97.363	0.058	0.241	0.25%

Total = Sum of Majors

RSD=Std. Dev./Mean
Range = Max-Min

MCNARCH ANALYSIS GLASS# 100

OXIDE	5/3/90 100#20 Avg. of 2	7/18/90 100#6 Avg. of 2	8/31/90 100#22 Avg. of 2	Average	Variance	Std. Dev.	RSD %
K2O		0.54	0.54	0.540	0.000	0.000	0.00%
Li2O	6.26	5.96	6.40	6.207	0.051	0.225	3.62%
Na2O	5.76	5.64	5.79	5.730	0.006	0.079	1.39%
Al2O3	0.44	0.44	0.44	0.440	0.000	0.000	0.00%
B2O3	7.95	8.13	7.78	7.953	0.031	0.175	2.20%
CaO		0.39	0.40	0.395	0.000	0.007	1.79%
MgO	1.56	1.58	1.66	1.600	0.003	0.053	3.31%
SiO2	75.65	75.54	75.70	75.630	0.007	0.082	0.11%
Total	97.18	96.85	97.33	97.120	0.060	0.246	0.25%

TABLE 10 CELS & MAL CHEMICAL ANALYSES OF SRL FRIT-202 (E-51768-100)

CELS Analysis #101 Reference Standard

OXIDE:	4/25/90 101#25	6/29/90 101#17	8/21/90 101#13	Average	Variance	Std. Dev.	RSD%
K ₂ O	0.21	0.19	0.18	0.193	0.000	0.015	7.90%
Li ₂ O	6.63	6.65	6.65	6.643	0.000	0.012	0.17%
Na ₂ O	5.88	5.88	5.87	5.877	0.000	0.006	0.10%
Al ₂ O ₃	0.38	0.42	0.43	0.410	0.001	0.026	6.45%
B ₂ O ₃	7.60	7.58	7.63	7.603	0.001	0.025	0.33%
CaO	0.11	0.12	0.11	0.113	0.000	0.006	5.09%
MgO	2.03	2.03	2.03	2.030	0.000	0.000	0.00%
TiO ₂	0.11	0.11	0.11	0.110	0.000	0.000	0.00%
SiO ₂	76.4	76.5	76.8	76.567	0.043	0.208	0.27%
Total	98.54	98.64	98.98	98.720	0.053	0.231	0.23%
Total = Sum of Majors							

MONARCH GLASS ANALYSIS GLASS#101 Reference Standard

OXIDE	5/3/90 101#15 Avg. of 2	7/18/90 101#22 Avg. of 2	8/31/90 101#14 Avg. of 2	Average	Variance	Std. Dev.	RSD%
K ₂ O		0.18	0.18	0.180	0.000	0.000	0.00%
Li ₂ O	6.60	6.39	6.83	6.607	0.048	0.220	3.33%
Na ₂ O	5.77	5.76	5.83	5.787	0.001	0.038	0.65%
Al ₂ O ₃	0.34	0.34	0.35	0.343	0.000	0.006	1.68%
B ₂ O ₃	7.64	7.89	7.56	7.697	0.030	0.172	2.24%
CaO		0.10	0.12	0.110	0.000	0.014	12.86%
MgO	1.95	2.02	2.07	2.013	0.004	0.060	2.99%
SiO ₂	76.01	75.49	75.96	75.820	0.082	0.287	0.38%
Total	97.97	97.55	98.25	97.923	0.124	0.352	0.36%

TABLE 11. CELS & MAL CHEMICAL ANALYSES OF SRL FRIT-202 (E-512768-101)

CORNING ANALYSES

OXIDE:	Variance -98	Variance -99	Variance -100	Variance -101	Average Variance (pooled)	Avg. SD $\sqrt{(\text{Var})}$	2 SIGMA (Best Est.)
K ₂ O	0.000	0.000	0.000	0.000	0.000	0.010	
Li ₂ O	0.000	0.001	0.004	0.000	0.001	0.037	0.07
Na ₂ O	0.000	0.000	0.000	0.000	0.000	0.012	0.02
Al ₂ O ₃	0.000	0.000	0.000	0.001	0.000	0.016	
B ₂ O ₃	0.001	0.001	0.000	0.001	0.001	0.024	0.05
CaO	0.000	0.000	0.000	0.000	0.000	0.008	
MgO	0.000	0.000	0.000	0.000	0.000	0.012	0.02
TiO ₂	0.000	0.000	0.000	0.000	0.000	0.003	
SiO ₂	0.003	0.010	0.043	0.043	0.025	0.158	0.32
Total Maj.	0.003	0.009	0.058	0.053	0.031	0.176	0.35

MONARCH ANALYSES

OXIDE	Variance -98	Variance -99	Variance -100	Variance -101	Average Variance (pooled)	$\sqrt{(\text{Var})}$	2 SIGMA (Best Est.)
K ₂ O	0.000	0.000	0.000	0.000	0.000	0.004	
Li ₂ O	0.026	0.043	0.051	0.048	0.042	0.205	0.41
Na ₂ O	0.008	0.004	0.006	0.001	0.005	0.070	0.14
Al ₂ O ₃	0.000	0.000	0.000	0.000	0.000	0.010	
B ₂ O ₃	0.066	0.028	0.031	0.030	0.039	0.196	0.39
CaO	0.000	0.000	0.000	0.000	0.000	0.009	
MgO	0.005	0.002	0.003	0.004	0.003	0.058	0.12
SiO ₂	0.001	0.002	0.007	0.082	0.023	0.152	0.30
Total	0.002	0.031	0.060	0.124	0.054	0.233	0.47

TABLE 12. COMPARISON OF VARIANCE OF OXIDE DETERMINATION WITH TIME

OXIDE	CORNING ANALYSIS		Stand. Dev. s (Wt%)	n=(3s/E)²		No. Analyses n
	Specification (Wt%)	Specification Limits (Wt%)		Max. Error E (Wt%)		
SiO2	77	1	0.158	0.5	0.90	
Na2O	6	0.5	0.012	0.4	0.02	
Li2O	7	0.5	0.037	0.25	0.20	
B2O3	8	0.5	0.024	0.25	0.08	
MgO	2	0.25	0.012	0.125	0.08	
Total	>97.75	<2.25	0.176			

MONARCH ANALYSIS						
OXIDE	Specification (Wt%)	Specification Limits (Wt%)	Stand. Dev. s (Wt%)	n=(3s/E)²		No. Analyses n
				Max. Error E (Wt%)		
SiO2	77	1	0.152	0.5	0.83	
Na2O	6	0.5	0.07	0.25	0.71	
Li2O	7	0.5	0.205	0.25	6.05	
B2O3	8	0.5	0.196	0.25	5.53	
MgO	2	0.25	0.058	0.125	1.94	
Total	>97.75	<2.25	0.233			

TABLE 12 A ESTIMATE OF NUMBER OF CHEMICAL ANALYSES REQUIRED

CELS										
Oxide Spec	2sigma	-2sigma	Lo Ellipse	+2sigma	Lower Spec	Target	Upper Spec	-2sigma	Up. Ellipse	+2sigma
SiO2	0.32	75.42	75.74	76.06	76	77	78	77.94	78.26	78.58
Li2O	0.07	6.3	6.37	6.44	6.5	7	7.5	7.56	7.63	7.7
Na2O	0.02	5.35	5.37	5.39	5.5	6	6.5	6.61	6.63	6.65
B2O3	0.05	7.32	7.37	7.42	7.5	8	8.5	8.58	8.63	8.68
MgO	0.02	1.66	1.68	1.7	1.75	2	2.25	2.3	2.32	2.34
Total Ox.	0.35	97.1	97.45	97.8	97.75	98.88		99.95	100.3	100.65
MAL										
Oxide Spec	2sigma	-2sigma	Lo Ellipse	+2sigma	Lower Spec	Target	Upper Spec	-2sigma	Up. Ellipse	+2sigma
SiO2	0.3	75.44	75.74	76.04	76	77	78	77.96	78.26	78.56
Li2O	0.41	5.96	6.37	6.78	6.5	7	7.5	7.22	7.63	8.04
Na2O	0.14	5.23	5.37	5.51	5.5	6	6.5	6.49	6.63	6.77
B2O3	0.39	6.98	7.37	7.76	7.5	8	8.5	8.24	8.63	9.02
MgO	0.12	1.56	1.68	1.8	1.75	2	2.25	2.2	2.32	2.44
Total Ox.	0.47	96.98	97.45	97.92	97.75	98.88		99.83	100.3	100.77

TABLE 13. ELLIPTICAL LIMITS WITH 2 SIGMA LIMITS

CELLS ANALYSIS										MAL ANALYSIS												
treatment = 4 replication = 3					t = 4 n = 3					t = 4 n = 3					t = 4 n = 3							
Treatment					Silica Content					Total					Silica Content							
					98	99	100	101						98	99	100	101	Total				
					76.8	76.2	75.8	76.4						76.4	76	75.65	76.01					
					76.7	76.3	75.4	76.5						76.6	75.96	75.54	75.49					
					76.8	76.4	75.7	76.8						76.6	75.92	75.7	75.96					
Sum Xij					230.28	228.9	226.9	229.7	915.78					229.6	227.88	226.89	227.46	911.83				
Sum (Xij) ²					17676.30	17465.09	17161.29	17587.45	69890.13					17572.08	17309.77	17159.70	17246.18	69287.74				
CTj					17676.29	17465.07	17161.20	17587.36	69889.93					17572.05	17309.76	17159.69	17246.02	69287.53				
Sum Sqj					0.01	0.02	0.09	0.09	0.20					0.03	0.00	0.01	0.16	0.21				
Sum Sq j/n-1					0.00	0.01	0.04	0.04	0.20					0.01	0.00	0.01	0.08					
s					0.05	0.10	0.21	0.21						0.12	0.04	0.08	0.29	F Table				
Mean					76.76	76.30	75.63	76.57						76.53	75.96	75.63	75.82	90% @ 4.07				
CT					69887.75									69286.16				95% @ 5.42				
Source of Var.					df	Sum Sqs	Mean Sq.	F						df	Sum Sqs	Mean Sq.	F	99% @ 9.60				
Total					11	2.38								11	1.57							
Treat.					3	2.18	0.73	29.21 > 99%						3	1.36	0.45	17.34 > 99%					
Error					8	0.20	0.02							8	0.21	0.03						

t = 4 n = 3										t = 4 n = 3												
Treatment					B2O3 Content					Total					B2O3 Content							
					98	99	100	101						98	99	100	101	Total				
					7.55	7.79	7.93	7.60						7.44	7.70	7.95	7.64					
					7.52	7.74	7.97	7.58						7.87	8.02	8.13	7.89					
					7.57	7.78	7.96	7.63						7.41	7.78	7.78	7.56					
Sum Xij					22.64	23.31	23.86	22.81	92.62					22.72	23.5	23.86	23.09	93.17				
Sum (Xij) ²					170.96	181.12	189.77	173.43	715.18					172.20	184.14	189.83	177.78	723.94				
CTj					170.86	181.12	189.77	173.43	715.17					172.07	184.08	189.77	177.72	723.63				
Sum Sqj					0.001	0.001	0.001	0.001	0.005					0.132	0.055	0.061	0.059	0.308				
Sum Sq j/n-1					0.001	0.001	0.000	0.001	0.005					0.066	0.028	0.031	0.030					
s					0.025	0.026	0.021	0.025	0.025					0.257	0.167	0.175	0.172					
Mean					7.55	7.77	7.95	7.60						7.57	7.83	7.95	7.70					
CT					714.87									723.39								
Source of Var.					df	Sum Sqs	Mean Sq.	F						df	Sum Sqs	Mean Sq.	F					
Total					11	0.31								11	0.55							
Treat.					3	0.30	0.10	167.65 > 99%						3	0.24	0.08	2.11 Not Sig.					
Error					8	0.00	0.00							8	0.31	0.04						

TABLE 14. ANALYSIS OF VARIANCE FOR SiO₂ AND B₂O₃

CELS ANALYSIS										MAL ANALYSIS									
t = 4 n = 3										t = 4 n = 3									
Treatment	98	99	100	101	Total	Na2O Content	98	99	100	101 Total	Treatment	98	99	100	Na2O Content	98	99	100	101 Total
Sum Xij	5.88	5.97	5.86	5.88	70.82	17.58	17.49	17.58	17.36	69.62	Sum Xij	5.92	5.86	5.76	5.77	5.92	5.86	5.76	5.77
Sum (Xij) ²	5.92	5.97	5.87	5.88	417.98	103.61	101.98	103.03	98.51	403.98	Sum (Xij) ²	5.74	5.80	5.64	5.76	5.74	5.80	5.64	5.76
CTj	5.90	5.97	5.85	5.87	417.98	103.61	101.97	103.02	98.50	403.94	CTj	5.83	5.92	5.79	5.83	5.83	5.92	5.79	5.83
Sum Sqj	0.001	0.000	0.000	0.000	0.001	0.000	0.016	0.007	0.013	0.039	Sum Sqj	0.016	0.007	0.013	0.003	0.016	0.007	0.013	0.003
Sum Sq j/n-1	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.004	0.006	0.001	Sum Sq j/n-1	0.008	0.004	0.006	0.001	0.008	0.004	0.006	0.001
s	0.020	0.000	0.010	0.006	s	0.006	0.090	0.060	0.079	0.038	s	0.090	0.060	0.079	0.038	0.090	0.060	0.079	0.038
Mean	5.90	5.97	5.86	5.88	Mean	5.86	5.83	5.86	5.73	5.79	Mean	5.83	5.86	5.73	5.73	5.83	5.86	5.73	5.79
CT	417.96				CT	403.91	403.91			95% @ 4.07	CT	403.91			95% @ 4.07	403.91			95% @ 4.07
Source of Var	df	Sum Sqs	Mean Sq.	F	Source of Var	df	Sum Sqs	Mean Sq.	F	99% @ 5.42	Source of Var	df	Sum Sqs	Mean Sq.	F	99% @ 5.42			99% @ 5.42
Total	11	0.02			Total	11	0.07				Total	11	0.07						
Treat.	3	0.02	0.01	52.75 > 99%	Treat.	3	0.03	0.01			Treat.	3	0.03	0.01					
Error	8	0.00	0.00		Error	8	0.04	0.00			Error	8	0.04	0.00					

t = 4 n = 3										t = 4 n = 3									
Treatment	98	99	100	101	Total	Li2O Content	98	99	100	101 Total	Treatment	98	99	100	Li2O Content	98	99	100	101 Total
Sum Xij	6.67	6.51	6.37	6.63	78.30	19.93	6.72	6.44	6.26	6.60	Sum Xij	6.79	6.60	6.40	6.83	6.79	6.60	6.40	6.83
Sum (Xij) ²	6.69	6.47	6.26	6.65	511.20	132.40	133.25	123.35	115.67	503.31	Sum (Xij) ²	19.99	19.23	18.62	19.82	19.99	19.23	18.62	19.82
CTj	6.69	6.46	6.25	6.65	511.19	132.40	133.20	123.26	115.57	502.98	CTj	133.20	123.26	115.57	130.94	133.20	123.26	115.57	130.94
Sum Sqj	0.000	0.001	0.009	0.000	0.011	0.000	0.053	0.085	0.101	0.336	Sum Sqj	0.053	0.085	0.101	0.097	0.053	0.085	0.101	0.097
Sum Sq j/n-1	0.000	0.001	0.004	0.000	0.000	0.000	0.026	0.043	0.051	0.048	Sum Sq j/n-1	0.026	0.043	0.051	0.048	0.026	0.043	0.051	0.048
s	0.012	0.026	0.067	0.012	s	0.012	0.163	0.207	0.225	0.220	s	0.163	0.207	0.225	0.220	0.163	0.207	0.225	0.220
Mean	6.68	6.48	6.29	6.64	Mean	6.66	6.66	6.41	6.21	6.61	Mean	6.66	6.41	6.21	6.61	6.66	6.41	6.21	6.61
CT	510.91				CT	502.59	502.59				CT	502.59				502.59			
Source of Var	df	Sum Sqs	Mean Sq.	F	Source of Var	df	Sum Sqs	Mean Sq.	F		Source of Var	df	Sum Sqs	Mean Sq.	F				
Total	11	0.30			Total	11	0.72				Total	11	0.72						
Treat.	3	0.28	0.09	70.20 > 99%	Treat.	3	0.39	0.13			Treat.	3	0.39	0.13					
Error	8	0.01	0.00		Error	8	0.34	0.04			Error	8	0.34	0.04					

TABLE 15 ANALYSIS OF VARIANCE FOR Na2O AND Li2O

FINAL ANALYSIS

[illegible]

t = 4 n = 3					t = 4 n = 3				
Treatment	Total Comparison				Treatment	Total Comparison			
	98	99	100	101 Total		98	99	100	101 Total
Sum Xij	297.06	295.44	292.09	296.16	Sum Xij	296.42	294.02	291.36	293.77
Sum (Xij) ²	29414.89	29094.95	28438.97	29237.02	Sum (Xij) ²	29288.28	28815.98	28297.00	28767.19
CTj	29414.88	29094.93	28438.86	29236.92	CTj	29288.27	28815.92	28296.88	28766.94
Sum Sqj	0.006	0.019	0.116	0.106	Sum Sqj	0.004	0.062	0.121	0.248
Sum Sq j/n-1	0.003	0.009	0.058	0.053	Sum Sq j/n-1	0.002	0.031	0.060	0.124
s	0.056	0.096	0.241	0.231	s	0.046	0.176	0.246	0.352
Mean	99.02	98.48	97.36	98.72	Mean	98.81	98.01	97.12	97.92
CT	116180.88				CT	115163.74			
Source of Var	df	Sum Sqs	Mean Sq.	F	Source of Var	df	Sum Sqs	Mean Sq.	F
Total	11	4.95			Total	11	4.71		
Treat.	3	4.70	1.57	50.68 >99%	Treat.	3	4.28	1.43	26.21 >99%
Error	8	0.25	0.03		Error	8	0.44	0.05	

TABLE 16 ANALYSIS OF VARIANCE FOR MgO AND TOTAL MAJOR OXIDES

GLASS: E-51768-98		SRS Specification		Avg. CELS		Avg. MAL		SRL-ADS		Stand. Dev.	
OXIDE		Min. Wt%		Max. Wt%		Wt%		Wt%		Wt%	
SiO ₂		76.0		78.0		76.76		77.08		0.240	
Na ₂ O		5.5		6.5		5.90		5.78		0.060	
Li ₂ O		6.5		7.5		6.68		6.70		0.019	
MgO		1.75		2.25		2.13		2.11		0.011	
B ₂ O ₃		7.5		8.5		7.55		7.68		0.069	
TOTAL		97.75		100		99.02		99.35		0.275	
Undesirables				2.25		0.98		0.65		0.275	
ZrO ₂								0.03			
Al ₂ O ₃				1.89		0.24		0.20		0.021	
Fe ₂ O ₃				0.29				0.03			
MnO ₂				0.32							
Cr ₂ O ₃				0.15							
NiO				0.25							
PbO				0.11				0.01			
TiO ₂				0.25		0.10		0.09		0.004	
F				0.05							
Cl				0.05							
K ₂ O						0.12		0.12		0.002	
CaO						0.13		0.16		0.019	
BaO								0.03			
Sb ₂ O ₃											
Total Undesir.						0.589		0.67		0.109	

TABLE 17. COMPARISON OF THREE LABORATORY ANALYSES E-51768-98

GLASS: E-51768-99						
OXIDE	SRS Specification		Avg. CELS		Avg. MAL	
	Min. Wt%	Max. Wt%	Wt%		Wt%	
SiO2	76.0	78.0	76.30	75.96	76.63	0.335
Na2O	5.5	6.5	5.97	5.86	5.68	0.146
Li2O	6.5	7.5	6.48	6.41	6.51	0.051
MgO	1.75	2.25	1.96	1.94	1.99	0.025
B2O3	7.5	8.5	7.77	7.83	7.92	0.075
TOTAL	97.75	100	98.48	98.00	98.73	0.371
Undesirables		2.25	1.52	2.00	1.27	0.371
ZrO2					0.04	
Al2O3		1.89	0.31	0.28	0.27	0.021
Fe2O3		0.29			0.03	
MnO2		0.32				
Cr2O3		0.15				
NiO		0.25				
PbO		0.11			0.01	
TiO2		0.25	0.31		0.30	0.007
F		0.05				
Cl		0.05				
K2O			0.36	0.34	0.35	0.010
CaO			0.24	0.22	0.28	0.031
BaO					0.04	
Sb2O3						
Total:			1.22	0.84	1.32	0.253

TABLE 18. COMPARISON OF THREE LABORATORY ANALYSES E-51768-99

GLASS: E-51768-100							
OXIDE	SRS Specification		Avg. CELS		Avg. MAL		Stand. Dev.
	Min. Wt%	Max. Wt%	Wt%	Wt%	Wt%	Wt%	
SiO2	76.0	78.0	75.63	75.63			
Na2O	5.5	6.5	5.86	5.73		76.59	0.553
Li2O	6.5	7.5	6.29	6.21		5.70	0.085
MgO	1.75	2.25	1.62	1.60		6.38	0.087
B2O3	7.5	8.5	7.95	7.95		1.66	0.030
TOTAL	97.75	100	97.36	97.12		8.01	0.033
Undesirables		2.25	2.64	2.88		98.34	0.646
ZrO2						1.66	0.646
Al2O3		1.89	0.46			0.08	
Fe2O3		0.29		0.44		0.23	0.128
MnO2		0.32				0.03	
Cr2O3		0.15					
NiO		0.25					
PbO		0.11					
TiO2		0.25				0.01	
F		0.05	0.47			0.41	0.042
Cl		0.05					
K2O							
CaO			0.55	0.54		0.55	0.005
BaO			0.40	0.40		0.36	0.022
Sb2O3						0.05	
Total:			1.88	1.375		1.72	0.258

TABLE 19. COMPARISON OF THREE LABORATORY ANALYSES E-51768-100

GLASS: E-51768-101							
SRS Specification		Avg. CELS		Avg. MAL		Best Est.*	
OXIDE	Min. Wt%	Max. Wt%	Wt%	Wt%	Wt%	Wt%	Vendor
SiO2	76.0	78.0	76.57	75.82	76.6	(Ferro)	76.0
Na2O	5.5	6.5	5.88	5.79	5.9		5.8
Li2O	6.5	7.5	6.64	6.61	6.7		7.2
MgO	1.75	2.25	2.03	2.01	2.0		1.9
B2O3	7.5	8.5	7.60	7.70	7.7		7.8
TOTAL	97.75	100	98.72	97.92	98.90		98.7
Undesirables		2.25	1.28	2.08	1.10		1.30
ZrO2					0.02		
Al2O3		1.89	0.41	0.34	0.40		0.81
Fe2O3		0.29			0.03		0.04
MnO2		0.32			<.01	<.01	
Cr2O3		0.15			<.01	<.01	
NiO		0.25			<.01	<.01	
PbO		0.11					
TiO2		0.25	0.11		0.01		0.01
F		0.05			0.11		0.13
Cl		0.05			0.03		0.05
K2O			0.19	0.18	0.01		0.00
CaO			0.11	0.11	0.19		0.19
BaO					0.12		
Sb2O3					0.05		0.13
Total:			0.82	0.633	<.1		1.42

* Reference: WSRC-RP-90-1219

TABLE 20. COMPARISON OF THREE LABORATORY ANALYSES E-51768-101

APPENDIX A

IDENTIFICATION OF IDMS FRIT SAMPLES

E-51768-2-1	Frit 202, SG-562, QUC-9942 Mfg. 1 July-88, -80+200 Mesh Ferro Corp. AX 845144-2, #3 NH
E-51768-2-2	Frit 202, SG-562, QUC-9940 Mfg. 30 June-88, -80+200 Mesh Ferro Corp. AX845144-2, #2NH
E-51768-2-3	Frit 202, SG-562, QUC-9944 Mfg. 5 July-88, -80+200 Mesh Ferro Corp. AX 845144-3 #4

Samples obtained from tops of bins and numbered 4-17-89.

ACTUAL MONARCH ANALYSIS - SRL FRIT 202

MONARCH ANALYSIS GLASS E-51768-98

DATE:	5/3/90	7/18/90	8/31/90
SAMPLE:	98#15 98#15	98#23 98#23	98#6 98#6
OXIDE			
K2O		0.12 0.12	0.12 0.12
Li2O	6.72 6.72	6.51 6.46	6.92 6.66
Na2O	5.95 5.89	5.72 5.76	5.85 5.81
Al2O3	0.19 0.19	0.22 0.23	0.22 0.23
B2O3	7.46 7.43	7.87 7.87	7.39 7.43
CaO		0.12 0.12	0.13 0.13
MgO	2.07 2.06	2.13 2.11	2.21 2.19
SiO2	76.63 76.65	76.63 76.51	76.62 76.64
Total	99.02 98.94	99.32 99.18	99.46 99.21

MONARCH ANALYSIS GLASS E-51768-99

DATE:	5/3/90	7/18/90	8/31/90
SAMPLE:	98#20 98#20	98#12 98#12	99#6 99#6
OXIDE			
K2O		0.34 0.34	0.35 0.35
Li2O	6.44 6.43	6.21 6.17	6.58 6.61
Na2O	5.81 5.90	5.83 5.77	5.91 5.92
Al2O3	0.27 0.28	0.28 0.27	0.30 0.28
B2O3	7.71 7.69	8.04 8.01	7.73 7.84
CaO		0.22 0.22	0.22 0.23
MgO	1.89 1.90	1.93 1.94	1.99 1.99
SiO2	75.95 76.06	75.9 76.02	75.96 75.88
Total	98.07 98.26	98.75 98.74	99.04 99.10

MONARCH ANALYSIS GLASS E-51768-100

DATE:	5/3/90	7/18/90	8/31/90
SAMPLE:	100#20 00#20	100#6 100#6	100#22 100#22
OXIDE			
K2O		0.54 0.54	0.54 0.54
Li2O	6.24 6.28	6.06 5.87	6.34 6.47
Na2O	5.73 5.80	5.72 5.55	5.74 5.84
Al2O3	0.43 0.44	0.45 0.43	0.44 0.43
B2O3	7.96 7.94	8.12 8.14	7.62 7.75
CaO		0.39 0.39	0.40 0.40
MgO	1.56 1.55	1.56 1.60	1.65 1.68
SiO2	75.71 75.59	75.52 75.56	75.71 75.70
Total	97.63 97.6	98.36 98.08	98.44 98.81

MONARCH ANALYSIS GLASS E-51768-101

DATE:	5/3/90	7/18/90	8/31/90
SAMPLE:	101#15 101#15	101#22 101#22	101#14 101#14
OXIDE			
K2O		0.18 0.18	0.18 0.18
Li2O	6.59 6.60	6.36 6.42	6.89 6.77
Na2O	5.76 5.78	5.73 5.78	5.81 5.85
Al2O3	0.34 0.34	0.33 0.34	0.35 0.35
B2O3	7.64 7.63	7.86 7.92	7.57 7.55
CaO		0.10 0.11	0.12 0.12
MgO	1.95 1.95	2.01 2.04	2.08 2.06
SiO2	76.02 76.00	75.44 75.54	76.01 75.92
Total	98.30 98.30	98.01 98.33	99.01 98.80

ADS ANALYSIS REFERENCE STANDARD E-51768-101

E-51768		101#7	101#10	101#11	101#12	101#16	101#18	101#20	101#23	AVG.	SD.
Code:	40412	413	414	415	416	417	418	419			
Time:	17:58	18:02	18:05	18:09	18:12	18:15	18:18	18:21			
Date:	4/17/90	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr			
Ca	0.000	-	-	-	-	-	-	-	0.023		
Cd	<.001	-	-	-	-	-	-	-	-		
Co	<.004	-	-	-	-	-	-	-	-		
Cu	<.001	-	-	-	-	-	-	-	-		
Mg	1.071	1.047	1.079	1.120	1.036	1.110	1.117	1.086	0.035		
Mn	<.000	-	-	-	-	-	-	-	-		
Pb	<.020	<.019	<.019	<.020	0.098	0.232	0.086	0.087	0.108	0.053	
Zn	0.086	0.090	0.095	0.182	0.158	0.173	0.173	0.173	0.016		
Al	0.186	0.187	0.172	0.020	0.019	0.025	0.020	0.021	0.002		
Ba	0.022	0.023	-	-	-	-	-	-	-		
Fe	<.002	-	-	-	-	-	-	-	-		
La	<.003	-	-	-	-	-	-	-	-		
Li	2.926	2.992	2.842	2.875	3.047	2.774	3.012	2.980	2.931	0.102	
Mo	<.004	-	-	-	-	-	-	-	-		
Ni	<.005	-	-	-	-	-	-	-	-		
Sn	<.007	-	-	-	-	-	-	-	-		
Sr	0.000	-	-	-	-	-	-	-	-		
Ti	0.039	0.050	0.044	0.044	0.047	0.048	0.043	0.042	0.045	0.003	
V	<.001	-	-	-	-	-	-	-	-		
B	2.207	2.231	2.109	2.124	2.264	2.082	2.232	2.236	2.186	0.074	
Cr	<.004	-	-	-	-	-	-	-	-		
P	<.010	-	-	-	-	-	-	-	-		
Si	32.660	33.661	31.631	31.166	33.085	31.477	33.957	33.177	32.602	1.140	
Time:	13:49	13:53	3:58	14:09	14:12	14:16	14:19	14:23			
Date:	3-May	3-May	3-May	3-May	3-May	3-May	3-May	3-May			
Na	4.373	4.409	4.461	4.307	4.355	4.458	4.355	4.385	4.388	0.057	
Zr	0.022	0.024	0.026	0.018	0.017	0.015	0.015	0.017	0.019	0.004	
Cl-ppm											
C-ppm											
K-wt%	0.149	0.148	0.146	0.14	0.143	0.146	0.146	0.146	0.146	0.003	
F-ppm											

CORRECTION FACTORS FROM REFERENCE STANDARD FOR ADS ANALYSES.

ELEMENT WEIGHT TO OXIDE WEIGHT CONVERSION							Ref. Std. 202 Frit		E-51768-101	
OXIDE	MOL WT	Norm. Wt%	Wt. % output	Ref.Std.	Corr Wt%		ELE	ELE WT	Wt% Input	Wt. % output
SiO2	60.06	76.29	69.707	76.60	6.893		Si	28.09	32.602	
Na2O *	61.99	6.47	5.916	5.90	-0.016		Na	22.991	4.388	
Li2O	29.88	6.91	6.310	6.70	0.390		Li	6.94	2.931	
MgO	40.32	1.97	1.800	2.00	0.200		Mg	24.32	1.086	
B2O3	69.64	7.70	7.035	7.70	0.665		B	10.82	2.186	
		0.00								
ZrO2 *	123.22	0.03	0.026	0.02	-0.006		Zr	91.22	0.019	
Al2O3	101.94	0.36	0.327	0.40	0.073		Al	26.98	0.173	
Fe2O3	159.7	0.00	0.000	0.03	0.030		Fe	55.85	0	
MnO2	86.93	0.00	0.000				Mn	54.94	0	
Cr2O3	152.02	0.00	0.000				Cr	52.01	0	
NiO	74.69	0.00	0.000				Ni	58.71	0	
PbO	223.21	0.00	0.000	0.01	0.010		Pb	207.21	0	
TiO2	79.9	0.08	0.075	0.11	0.035		Ti	47.9	0.045	
F2	38	0.00	0.000				F2	38	0	
Cl2	70.91	0.00	0.000				Cl2	70.91	0	
		0.00								
ZrO	81.38	0.00	0.000				Zn	65.38	0	
CaO	56.08	0.00	0.000	0.12	0.120		Ca	40.08	0	
P2O5	141.96	0.00	0.000				P	30.975	0	
K2O **	94.19	0.19	0.176	0.19	0.014		K	39.1	0.146	
BaO	153.36	0.03	0.023	0.04	0.017		Ba	137.36	0.021	
TOTAL		100.00	91.371	99.82						

.. AA

ADS CORRECTED/NORMALIZED ANALYSIS E-51768-98

ELEMENT WEIGHT TO OXIDE WEIGHT CONVERSION					E-51768-98 Avg/ of 8				
OXIDE	MOL WT	Wt. % output	Corr F	Corr. Wt%	Norm. 100%	ELE	ELE WT	Wt% Input	Wt.% output
SiO2	60.06	71.839	6.893	78.73	77.08	Si	28.09	33.599	0.000
Na2O *	61.99	5.922	-0.016	5.91	5.78	Na	22.991	4.393	0.000
Li2O	29.88	6.454	0.390	6.84	6.70	Li	6.94	2.998	0.000
MgO	40.32	1.951	0.200	2.15	2.11	Mg	24.32	1.177	0.000
B2O3	69.64	7.183	0.665	7.85	7.68	B	10.82	2.232	0.000
ZrO2 *	123.22	0.036	-0.006	0.03	0.03	Zr	91.22	0.027	0.000
Al2O3	101.94	0.136	0.073	0.21	0.20	Al	26.98	0.072	0.000
Fe2O3	159.7	0.000	0.030	0.03	0.03	Fe	55.85	0	0.000
MnO2	86.93	0.000				Mn	54.94	0	0.000
Cr2O3	152.02	0.000				Cr	52.01	0	0.000
NiO	74.69	0.000				Ni	58.71	0	0.000
PbO	223.21	0.000	0.010	0.01	0.01	Pb	207.21	0	0.000
TiO2	79.9	0.062	0.035	0.10	0.09	Ti	47.9	0.037	0.000
F2	38	0.000				F2	38	0	0.000
Cl2	70.91	0.000				Cl2	70.91	0	0.000
ZnO	81.38	0.000				Zn	65.38	0	0.000
CaO	56.08	0.042	0.120	0.16	0.16	Ca	40.08	0.03	0.000
P2O5	141.96	0.000				P	30.975	0	0.000
K2O **	94.19	0.105	0.014	0.12	0.12	K	39.1	0.087	0.000
BaO	153.36	0.012	0.017	0.03	0.03	Ba	137.36	0.011	0.000
TOTAL		93.730		102.138	100.000				

From Atomic Absorbtion

ADS ANALYSIS SRL FRIT 202, E-51768-99

E-51768	-99#7	-99#8	-99#11	-99#15	-99#16	99#17	99#22	99#23	AVG.	S.D.
Code:	40396	397	398	399	400	401	402	403		
Time:	10:23	10:26	10:30	10:33	10:36	10:40	10:43	10:46		
Date:	4/17/90	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr		
Ca	0.084	0.191	0.106	0.077	0.132	0.183	0.105	0.064	0.118	0.049
Cd	0.001	-	-	-	-	-	-	-		
Co	<.004	<.004	-	-	-	-	-	-		
Cu	<.001	-	-	-	-	-	-	-		
Mg	1.120	1.146	1.133	1.094	1.193	1.116	1.081	1.094	1.122	0.039
Mn	0.012	<0.000	0.015	-	-	-	-	-		
Pb	<.020	-	-	-	-	-	-	-		
Zn	0.104	0.107	0.109	0.105	0.097	0.108	0.106	0.114	0.106	0.005
Al	0.138	0.154	0.131	0.103	0.087	0.113	0.088	0.062	0.110	0.031
Ba	0.020	0.021	0.020	0.018	0.019	0.016	0.015	0.014	0.018	0.003
Fe	<.002	0.135	0.042	<.002	-	0.066	-	-		
La	<.003	-	-	-	-	-	-	-		
Li	2.932	2.969	2.962	2.937	3.073	2.947	2.843	2.911	2.947	0.069
Mo	<.004	-	-	-	-	-	-	-		
Ni	<.005	-	-	-	-	-	-	-		
Sn	<.007	-	-	-	-	-	-	-		
Sr	0.001	0.002	-	-	-	-	-	-		
Ti	0.163	0.177	0.161	0.167	0.158	0.158	0.152	0.156	0.162	0.008
V	<.001	-	-	-	-	-	-	-		
B	2.325	2.350	2.357	2.335	2.433	2.342	2.257	2.302	2.338	0.054
Cr	<.004	-	-	-	-	-	-	-		
P	<.010	-	-	-	-	-	-	-		
Si	33.870	34.088	33.986	33.844	35.564	33.005	32.810	33.651	33.852	0.899
Time:	15:07	15:10	15:13	15:16	15:19	15:23	15:27	15:31		
Date:	1-May	1-May	1-May	1-May	1-May	1-May	1-May	1-May		
Na	4.437	4.171	4.441	4.761	4.218	4.409	4.458	4.083	4.372	0.228
Zr	0.045	0.036	0.032	0.037	0.030	0.034	0.035	0.035	0.036	0.002
Cl-ppm										
C-ppm										
K-wt%	0.286	0.294	0.29	0.312	0.27	0.291	0.293	0.267	0.288	0.015
F-ppm										

ADS CORRECTED/NORMALIZED ANALYSIS E-51768-99

E-51768-99										
ELEMENT WEIGHT TO OXIDE WEIGHT CONVERSION										
OXIDE	MOL WT	Wt % Input	Wt. % output	Corr F	Corr. Wt%	Norm. 100%	ELE	ELE WT	Wt% Input	Wt. % output
SiO2	60.06		72.380	6.893	79.27	76.63	Si	28.09	33.852	0.000
Na2O *	61.99		5.894	-0.016	5.88	5.68	Na	22.991	4.372	0.000
Li2O	29.88		6.344	0.390	6.73	6.51	Li	6.94	2.947	0.000
MgO	40.32		1.860	0.200	2.06	1.99	Mg	24.32	1.122	0.000
B2O3	69.64		7.524	0.665	8.19	7.92	B	10.82	2.338	0.000
ZrO2 *	123.22		0.049	-0.006	0.04	0.04	Zr	91.22	0.036	0.000
Al2O3	101.94		0.208	0.073	0.28	0.27	Al	26.98	0.11	0.000
Fe2O3	159.7		0.000	0.030	0.03	0.03	Fe	55.85	0	0.000
MnO2	86.93		0.000				Mn	54.94	0	0.000
Cr2O3	152.02		0.000				Cr	52.01	0	0.000
NiO	74.69		0.000				Ni	58.71	0	0.000
PbO	223.21		0.000	0.010	0.01	0.01	Pb	207.21	0	0.000
TiO2	79.9		0.270	0.035	0.31	0.30	Ti	47.9	0.162	0.000
F2	38		0.000				F2	38	0	0.000
Cl2	70.91		0.000				Cl2	70.91	0	0.000
ZnO	81.38		0.000				Zn	65.38	0	0.000
CaO	56.08		0.165	0.120	0.29	0.28	Ca	40.08	0.118	0.000
P2O5	141.96		0.000				P	30.975	0	0.000
K2O **	94.19		0.347	0.014	0.36	0.35	K	39.1	0.288	0.000
BaO	153.36		0.020	0.017	0.04	0.04	Ba	137.36	0.018	0.000
TOTAL			95.041		103.449	100.000				

** From Atomic absorption

ADS ANALYSIS SRL FRIT 202, E-51768-100

E-51768	100#8	100#11	100#13	100#14	100#17	100#19	100#23	0.489	AVG.	SD.
Code:	40404	405	406	407	408	409	410	411		
Time:	17:30	17:33	17:39	17:42	17:45	17:48	17:52	17:55		
Date:	4/17/90	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr	17-Apr		
Ca	0.185	0.187	0.162	0.180	0.201	0.181	0.169	0.171	0.180	0.013
Cd	<.001	-	-	-	-	-	-	-		
Co	<.004	<.004	-	-	-	-	-	-		
Cu	<.001	-	-	-	-	-	-	-		
Mg	0.884	0.929	0.937	0.888	0.881	0.895	0.910	0.885	0.901	0.022
Mn	<.000	-	-	-	-	-	-	-		
Pb	<.020	<.019	-	-	-	-	-	-		
Zn	0.143	0.150	0.160	0.142	0.150	0.139	0.143	0.146	0.147	0.007
Al	0.084	0.101	0.109	0.096	0.080	0.073	0.070	0.053	0.083	0.020
Ba	0.029	0.028	0.026	0.026	0.026	0.027	0.025	0.025	0.027	0.001
Fe	0.005	<.002	-	-	-	0.066	-	-		
La	<.003	-	-	-	-	-	-	-		
Li	2.844	2.930	2.882	2.810	2.840	2.820	2.837	2.775	2.842	0.051
Mo	<.004	-	-	-	-	-	-	-		
Ni	<.005	-	-	-	-	-	-	-		
Sn	<.007	-	-	-	-	-	-	-		
Sr	0.000	-	-	-	-	-	-	-		
Ti	0.232	0.234	0.237	0.219	0.222	0.223	0.232	0.223	0.228	0.007
V	<.001	-	-	-	-	-	-	-		
B	2.360	2.417	2.377	2.294	2.325	2.306	2.323	2.263	2.333	0.052
Cr	<.004	-	-	-	-	-	-	-		
P	<.010	-	-	-	-	-	-	-		
Si	33.617	34.685	34.498	33.253	33.414	31.975	32.513	32.846	33.350	0.996
Time:	12:56	12:59	13:02	13:06	13:13	13:24	13:34	13:44		
Date:	3-May	3-May	3-May	3-May	3-May	3-May	3-May	3-May		
Na	4.537	4.394	3.940	4.459	4.176	4.367	4.168	4.591	4.329	0.218
Zr	0.075	0.066	0.060	0.064	0.058	0.072	0.065	0.069	0.066	0.005
Cl-ppm										
C-ppm										
K-wt%	0.467	0.456	0.424	0.472	0.449	0.448	0.435	0.489	0.455	0.022
F-ppm										

ADS CORRECTED/NORMALIZED ANALYSIS E-51768-100

ELEMENT WEIGHT TO OXIDE WEIGHT CONVERSION										E-51768-100			ADS Avg 8	
OXIDE	MOL WT	Wt %	Wt. % output	Corr F	Corr. Wt%	Norm. 100%	ELE	ELE WT	Wt% Input	Wt. % output				
SiO2	60.06		71.307	6.89	78.20	76.59	Si	28.09	33.350	0.000				
Na2O *	61.99		5.836	-0.02	5.82	5.70	Na	22.991	4.329	0.000				
Li2O	29.88		6.118	0.39	6.51	6.37	Li	6.94	2.842	0.000				
MgO	40.32		1.494	0.20	1.69	1.66	Mg	24.32	0.901	0.000				
B2O3	69.64		7.508	0.67	8.17	8.00	B	10.82	2.333	0.000				
ZrO2 *	123.22		0.089	-0.01	0.08	0.08	Zr	91.22	0.066	0.000				
Al2O3	101.94		0.157	0.07	0.23	0.23	Al	26.98	0.083	0.000				
Fe2O3	159.7		0.000	0.03	0.03	0.03	Fe	55.85	0	0.000				
MnO2	86.93		0.000				Mn	54.94	0	0.000				
Cr2O3	152.02		0.000				Cr	52.01	0	0.000				
NiO	74.69		0.000				Ni	58.71	0	0.000				
PbO	223.21		0.000	0.01	0.01	0.01	Pb	207.21	0	0.000				
TiO2	79.9		0.380	0.04	0.42	0.41	Ti	47.9	0.228	0.000				
F2	38		0.000				F2	38	0	0.000				
Cl2	70.91		0.000				Cl2	70.91	0	0.000				
ZnO	81.38		0.000				Zn	65.38	0	0.000				
CaO	56.08		0.252	0.12	0.37	0.36	Ca	40.08	0.180	0.000				
P2O5	141.96		0.000				P	30.975	0	0.000				
K2O **	94.19		0.548	0.01	0.56	0.55	K	39.1	0.455	0.000				
BaO	153.36		0.030	0.02	0.05	0.05	Ba	137.36	0.027	0.000				
TOTAL			93.689		102.097	100.000								

.. From AA

END

DATE
FILMED
5/11/193