

NIST Technical Note 1816

**PERFORMANCE CRITERIA FOR AN
ASTM XRF STANDARD TEST METHOD
FOR HYDRAULIC CEMENTS:
INTER-LABORATORY STUDY ON
CEMENTS A AND B**

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Abstract

Bulk oxide determinations from a pair of portland cements provide the basis for calculating the precision and accuracy values for X-ray fluorescence (XRF) analysis for both the fused glass bead and the pressed powder sample preparation methods. The measurements were collected through an interlaboratory study using two cements (Cement A and Cement B), and the two sample preparation methods were divided (roughly evenly) among the laboratories. Each of the approximately 45 participating laboratories provided six replicate measurements, analyzed in duplicate, for each of the two separate portland cements. Each laboratory reported an estimate for the mass fraction of eleven analytes: CaO, SiO₂, Al₂O₃, Fe₂O₃, SO₃, MgO, Na₂O, K₂O, TiO₂, P₂O₅, and Cl. Chemical data using traditional chemical analyses (the Reference Methods) from the Cement and Concrete Reference Laboratory (CCRL) proficiency test program were included for comparison to the XRF results. Precision measures for within- and between-laboratory performance are presented as 1- σ and 95 % limits (ASTM d2s). Accuracy criteria are based upon a two-sided 95 % prediction interval for the mean of two test results, defining the range of values one might expect for each analyte relative to a certified value of a reference material.

Keywords: accuracy; hydraulic cement; precision; qualification; X-ray fluorescence

Table of Contents

Abstract	iii
Table of Contents.....	iv
List of Tables	vi
List of Figures	vii
Introduction	1
Development of a Test Method for XRF Analysis of Hydraulic Cements.....	3
Measurement Precision.....	6
Measurement Accuracy and Method Bias	6
Outlier Identification.....	7
Included Appendices	8
Measurement Precision.....	9
Prediction Intervals	12
Summary	12
Appendix A. Individual Oxide Analysis.....	13
SiO ₂	14
Al ₂ O ₃	24
Fe ₂ O ₃	34
CaO	44
MgO.....	54
SO ₃	64
Na ₂ O	74
K ₂ O.....	84
P ₂ O ₅	104
Cl	114
Appendix B. Request for Participants Letter.....	121
Appendix C. XRF Glass Summary by Material and Replicate.	124
Appendix D. XRF Powder Summary by Material and Replicate.....	126
Appendix E. Raw Data by Analyte.....	128
SiO ₂	128
Al ₂ O ₃	134
Fe ₂ O ₃	140
CaO	146
MgO.....	152
SO ₃	159
Na ₂ O.....	165
K ₂ O.....	171
TiO ₂	178
P ₂ O ₅	183
Cl	189
Acknowledgements	191

References	191
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List of Tables

Table 1 Pooled Results for XRF-Glass, XRF-Powder and Combined Powder and Glass Methods, when the results are expressed as a percent. The values include the 1σ within-laboratory (Sr), the 1σ between-laboratory (sR), and the ASTM d2s values for the 95% limit on the difference between two test results (r) and (R).	11
Table 2 95 % Prediction Interval designed to bracket values of a mean of $k = 2$ measurements. The mean result should differ from the known value of the certified reference material by no more than the value shown for each analyte.	12
Table 3 Precision Statistics SiO_2 XRF, Cements A B	23
Table 4 Precision Statistics Al_2O_3 by XRF glass and powder preparations for replicates 1 and 2.....	33
Table 5 Precision Statistics Fe_2O_3 by XRF glass and powder preparations for replicates 1 and 2.....	43
Table 6 Precision Statistics CaO by XRF glass and powder preparations for replicates 1 and 2.....	53
Table 7 Precision Statistics CaO by XRF glass and powder preparations for replicates 1 and 2.....	63
Table 8 Precision Statistics SO_3 by XRF glass and powder preparations for replicates 1 and 2.....	73
Table 9 Precision Statistics Na_2O by XRF glass and powder preparations for replicates 1 and 2.....	83
Table 10 Precision Statistics K_2O by XRF glass and powder preparations for replicates 1 and 2.....	93
Table 11 Precision Statistics TiO_2 by XRF glass and powder preparations for replicates 1 and 2.....	103
Table 12 Precision Statistics P_2O_5 by XRF glass and powder preparations for replicates 1 and 2.....	113

List of Figures

Figure 1. ASTM C114 performance criteria for the chemical analysis of portland cements. From a letter by W.C. Hanna to the Working Committee on Methods of Chemical Analysis, June 12, 1946.	2
Figure 2 Reference and instrumental methods popularity from CCRL proficiency test data shows that over 80 % of the labs use X-ray methods for bulk chemical analysis by either energy- or wavelength-dispersive analysis, using either powder or glass specimens.	2
Figure 3 Calculated values for the determination of within and between lab precision	5
Figure 4 Scatter plot for CaO, XRF-powder preparation as boxes with the “o” symbol noting excluded data due to exceeding the h or k statistics.	8
Figure 5 Lab means and standard deviations for CaO, powder preparation for cement A (Material 1) and cement B (Material 2).	9
Figure 6 h and k statistic plots illustrate the within- (k) and between-laboratory (h) precision and are useful in identifying unusual results that may be considered outliers. The dashed line marks the limits for each statistic.	10
Figure 7 Box plots for SiO ₂ for XRF glass and powder, and reference methods.	14
Figure 8 SiO ₂ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	23
Figure 9 Box plots for Al ₂ O ₃ XRF glass and powder, and reference methods.	24
Figure 10 Al ₂ O ₃ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	33
Figure 11 Box plots for Fe ₂ O ₃ XRF glass and powder, and reference methods.	34
Figure 12 Fe ₂ O ₃ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	43
Figure 13 Box plots for CaO XRF glass and powder, and reference methods.	44
Figure 14 CaO precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	53
Figure 15 Box plots for MgO XRF glass and powder, and reference methods.	54
Figure 16 MgO precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	63
Figure 17 Box plots for SO ₃ XRF glass and powder, and reference methods.	64
Figure 18 SO ₃ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	73
Figure 19 Box plots for Na ₂ O XRF glass and powder, and reference methods.	74
Figure 20 Na ₂ O precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	83
Figure 21 Box plots for K ₂ O XRF glass and powder, and reference methods.	84

Figure 22 K ₂ O precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	93
Figure 23 Box plots for TiO ₂ XRF glass and powder, and reference methods	94
Figure 24 TiO ₂ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	103
Figure 25 Box plots for P ₂ O ₅ XRF glass and powder, and reference methods.	104
Figure 26 P ₂ O ₅ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (S _R).	113
Figure 27 Box plots for Cl XRF glass and powder, and reference methods.	114

Introduction

Chemical analysis of portland cement is used for process control in clinker and cement manufacture, for demonstration specification compliance, and for relating chemical properties to performance attributes. Reporting requirements for the chemical composition of portland cements in North America date back to the *1915 Joint Conference on Uniform Methods of Tests and Standard Specifications for Cement* which involved the American Society of Civil Engineers, the American Society for Testing Materials, and the United States Government and included the following analytes: SiO_2 , Fe_2O_3 , Al_2O_3 , CaO , MgO , SO_3 , Ignition Loss, and Insoluble Residue [1].

In 1946, work on harmonizing the Federal and ASTM Cement Specifications resulted in the development of ASTM C150, Specification for Portland Cement within ASTM C1 on Cement. Standard Methods of Chemical Analysis of Portland Cement, ASTM C114-44 was also published and contained a performance-based qualification scheme [Figure 1] that is very similar to that used today where duplicate determinations on different days are made and the two results must be within the limit of permissive variation with their average accepted as the correct value [2]. Using reference cements to qualify, this process was repeated if the criteria were not met.

The 1960's through the 1970's saw a shift from classical analytical "wet" chemistry measurements (referred to as the reference and the alternate methods) to instrumental methods, including atomic absorption spectrometry, X-ray spectrometry, and a spectrophotometric/titrimetric scheme. Forrester et al. [3], Midgley [4], Harrison et al. [5], Aldridge et al. [6,7], Stutzman and Lane [8], EN 196-2.2 [9], and a National Cooperative Highway Research Program report [10] have investigated uncertainty in chemical analyses of portland cements, with the latter three being based upon standardized methods. ASTM Subcommittee C 1.23, Chemical Analysis, amended the precision requirements with accuracy requirements in 1977 by replacing the third column in Figure 1 with a maximum difference between the mean of two replicate determinations and the value of a certified reference material. This amended set of criteria is now Table 1 of ASTM C114 and is the basis of method qualification for instrumental methods other than the reference methods, for example, those by X-ray fluorescence (XRF) [2]. While the column one requirements originated in the 1946 edition of ASTM C114 and are based upon the reference methods, none of the qualification requirements have supporting data available. The development of a standard test for XRF analysis of hydraulic cements provides an opportunity to collect the data and calculate appropriate qualification values.

Maximum Limits of Permissive Variation		
Component	Between two results	Between the extreme values in three results
Silicon dioxide, SiO_2	0.16	0.24
Aluminum oxide, Al_2O_3	0.20	0.30
Ferric oxide, Fe_2O_3	0.10	0.15
Calcium oxide, CaO	0.20	0.30
Magnesium oxide, MgO	0.16	0.24
Sulfur trioxide, SO_3	0.10	0.15
Loss on ignition	0.10	0.15
Sodium oxide, Na_2O	0.03	0.05
Potassium oxide, K_2O	0.03	0.05
Phosphorus pentoxide, P_2O_5	0.03	0.05
Manganic oxide, Mn_2O_3	0.03	0.05
Insoluble residue	0.10	0.15
Chloroform - soluble organic substances	0.004	0.006
Free calcium oxide	0.20	0.30
Water - soluble alkali	0.05	0.08

Figure 1. ASTM C114 performance criteria for the chemical analysis of portland cements. From a letter by W.C. Hanna to the Working Committee on Methods of Chemical Analysis, June 12, 1946.

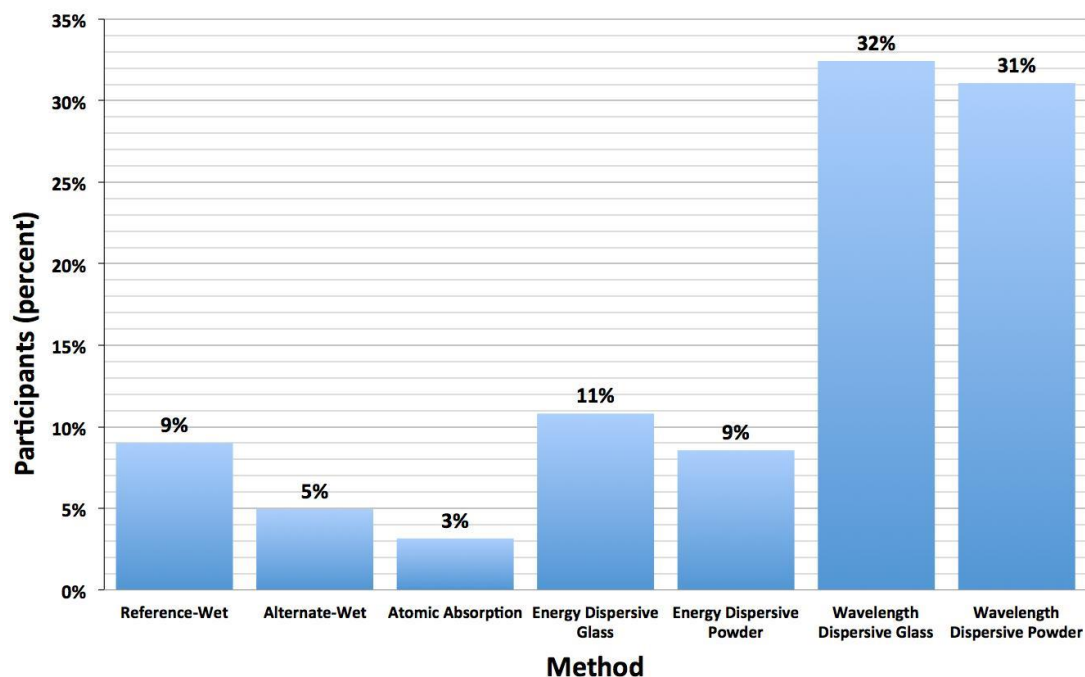


Figure 2 Reference and instrumental methods popularity from CCRL proficiency test data shows that over 80 % of the labs use X-ray methods for bulk chemical analysis by either energy- or wavelength-dispersive analysis, using either powder or glass specimens.

Development of a Test Method for XRF Analysis of Hydraulic Cements

Over 80 % of the participants in the CCRL proficiency test program conduct XRF analysis using either a wavelength- or an energy-dispersive spectrometer [11]. The percentage of cement manufacturers that use XRF analysis is probably higher, and the remaining instrumental and traditional chemical methods of analysis are generally reserved as backup in case the principal XRF instrument is down for repair. In ASTM C114 terminology, the XRF method, atomic absorption and inductively coupled plasma spectrometry fall under rapid methods, reflecting the longer times required to perform the traditional chemical analyses. Current practice for chemical analysis follows ASTM C114, which states that any method of analysis may be used as long as it can be demonstrated to conform to precision and bias performance criteria of Table 1 in ASTM C114 [2]. This means that the rapid methods require qualification where results of six of seven certified reference materials must fall within the qualification criteria of Table 1; the seventh measurement must fall within twice the precision criteria in Table 1. The qualification limits were originally published in 1946 and remain the same today. Bias criteria were originally based upon the maximum difference of three determinations, whereas today the criteria are a maximum limit on the difference of the mean of two determinations and an accepted reference value.

ASTM C 1.23 initiated an inter-laboratory study for XRF Analysis to establish a data set for assessing precision of the method being developed. This method does not provide a set of instructions to prepare specimens and perform an analysis, but rather outlines a goal of analysis of major and minor elements by XRF with use of either of two specimen preparation procedures: pressed powder and fused glass. Guidelines as a draft standard are provided for both the pressed pellet and the fused glass preparations.

For the inter-laboratory study, three pairs of cements were distributed to participants with approximately 45 laboratories participating. This report covers the first set of cements, which will be referred to as Cement A and Cement B, originating from the CCRL proficiency test program cements 163 and 164, respectively. Each laboratory was asked to follow their own standard operating procedure (SOP), as long as it fell within the draft standard guidelines, and prepare and analyze three specimens (replicates) to be analyzed twice each (duplicates) on two different days for a total of six specimens and twelve analyses (Appendix A). Subsequent studies will contain ASTM C595 1s cements (samples C D), portland cements with ca. 5 % limestone addition (samples E F), and ASTM C595 1p cements with fly ash (samples G H). Results and data from each sample set will be reported separately.

Sample preparation for XRF can be achieved using either of two distinct methods: a pressed powder and a fused glass disk. Pressed powder specimens are typically ground in a tungsten carbide ring and puck mill with a binding agent to reduce the particle size and provide a packed powder mount that will remain intact for transport and analysis. The advantages of this preparation method include the simplicity and better detection limits while disadvantages include what is known as the “mineralogical effect”, which requires a similar matrix between a bracketed calibration and unknown specimens for the calibrations to be valid. The potential for bias due to the mineralogical effect will be greater for the

second, third, and fourth cement pairs, which will contain slag additions at the 50 % level and limestone additions at a level of less than 5 %, and fly ash, respectively. The fused disk preparation eliminates the potentially adverse effects of discrete mineral phases by dissolving the cement in a flux and fusing the mixture into a homogeneous glass disk. However, the fluxing process is subject to volatilization of some analytes if the heating process is not carefully controlled.

The data analysis follows ASTM E 691 [12]“Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method,” and was performed using the Dataplot¹ software. Data were compiled by the CCRL staff into a database and exported to a spreadsheet format for subsequent processing and analysis. The terms used in ASTM E691 and the means of their calculation are presented in Figure 3, with the last six terms being used subsequently in the evaluation and presentation of the results.

The layout of this report consists of some background for chemical analysis of cements, information on the interlaboratory study, methodology behind the precision calculations, a summary table for all reported elements, and individual analyte (as oxides) results in table and graphical form, along with comparisons to previous studies. The calculations provide precision estimates for consideration by the C01.23 Subcommittee on compositional analysis for use in developing a draft standard test method for XRF analysis of hydraulic cements. The draft method uses a qualification approach, similar to that used in ASTM C114, having criteria for precision as well as accuracy. Unfortunately, the process and data used to develop the C114 Table 1 criteria are no longer available, so while precision is calculated here, criteria for accuracy will require careful consideration by the subcommittee. If the predominant sources of uncertainty lie in the laboratory protocol – the sample preparation, the calibrations, and the analyses – the differences between laboratory results reflect the combined within-laboratory uncertainties and laboratory-specific bias based upon protocol. As was done with the XRD test method C1365, the proposed measure of accuracy uses the prediction interval to establish criteria for laboratory bias limits.

¹ <http://www.itl.nist.gov/div898/software/dataplot/homepage.htm>

n = number of test results per cell

p = number of laboratories

x = individual test result

$\bar{x}$ = cell average

$\bar{X}$ = average of cell averages for one material

s = cell standard deviation

d = cell deviation

$S_{\bar{x}}$ = standard deviation of cell averages

S_r = repeatability standard deviation

s_R = reproducibility standard deviation

h = between-laboratory consistency

k = within-laboratory consistency

r = 95 % repeatability statistic

R = 95 % reproducibility statistic

$$\sum_{i=1}^n \bar{x} / n$$

$$\sum_{i=1}^p \bar{x} / p$$

$$\sum_{i=1}^n (x - \bar{x})^2 / (n - 1)$$

$$(\bar{x} - \bar{X})$$

$$\sum_{i=1}^p (d)^2 / (p - 1)$$

$$\sqrt{\sum_{i=1}^p s^2 / p}$$

$$\sqrt{s_{\bar{x}}^2 + s_r^2 (n - 1) / n}$$

$$d / s_{\bar{x}}$$

$$s / s_r$$

$$2.8 * s_r$$

$$2.8 * s_R$$

Figure 3 Calculated values for the determination of within and between lab precision

Measurement Precision

Uncertainties in bulk oxide measurements originate from a number of sources: consistency and bias in specimen preparations, standardization, data collection procedures, and analysis protocol. Measurements are estimates of the actual value being measured and ideally have some statement of uncertainty. This may also be estimated through an interlaboratory study, which provides estimates on precision, or random error (Type A) and bias, or systematic error (Type B) uncertainty. ASTM defines precision as “the closeness of agreement between independent test results obtained under stipulated conditions (the standard test procedure), which may be expressed as a standard deviation ($1-\sigma$).” Precision is further differentiated by that achieved within a laboratory by a single instrument (and operator, or procedure), called repeatability, and that between different laboratories, called reproducibility as a single standard deviation or a 95 % limit as defined by E691 and presented below:

Repeatability: Precision under repeatability conditions

Repeatability limit (r): “The value below which the *absolute difference between two individual test results* obtained under repeatability conditions may be expected to occur with a probability of approximately 0.95 (95 %)”

The repeatability limit is 2.8 ($1.96 \times \sqrt{2}$) times the repeatability standard deviation

Reproducibility: Precision under reproducibility conditions

Reproducibility limit (R): The value below which the absolute difference between two test results obtained under reproducibility conditions may be expected to occur with a probability of approximately 0.95 (95 %)

The reproducibility limit is 2.8 ($1.96 \times \sqrt{2}$) times the reproducibility standard deviation

Measurement Accuracy and Method Bias

ASTM defines accuracy as “the closeness of agreement between a test result and a accepted reference value”, which includes both random and systematic error. The qualification criteria in C 114, Table 1, Column 3 addresses accuracy. Bias is defined as “the difference between the expectation of the test results and an accepted reference value”, and reflects the systematic error. A meaningful estimate of method bias is more difficult to extract from interlaboratory studies if an explicit protocol is not available, even if certified reference materials are available. Systematic error introduced by individual lab protocols dominates that of the method, making a universal bias correction difficult to estimate and apply. In addition, the cements used in this program were not reference materials (due to the number of participants), so a bias calculation is not possible. These materials were specially homogenized and packaged as part of the CCRL chemical proficiency test program.

Outlier Identification

Participation in the inter-laboratory study (ILS) was open to all interested laboratories and was not restricted based on the laboratory staff's years of experience. In addition, the ILS did not specify an explicit method for preparation and analysis. These two factors contributed to the overall uncertainty in the measurement data. Some means of identification of outlying data was necessary to exclude any outlying results and their influences on the calculated precision and consensus values. A graphical representation of this process is provided in Figure 4 where the individual replicate data from powder data with results plotted with cement A on the x-axis and cement B on the y-axis. The vertical and horizontal axes represent the consensus value means for cements A and B, respectively for the original data (before outlier identification). Like a Youden plot, this plot of the data pairs provides some insight, based on the degree and directions of dispersion of the results. In the absence of bias, the point pattern is roughly circular, and the dispersion along a diagonal from the lower-left, to the upper-right quadrant represents systematic error, and dispersion that is orthogonal to this direction represents the random error (precision).

In the example for CaO by the powder preparation, there were three laboratories that reported data that were considered outliers. Lab 1 (labeled O 1) data, which was clustered along the diagonal well below the other values, exhibits significant systematic error for both cements, which may represent either a calibration or preparation error. Lab 3 (O 3) data, which was scattered in both along the diagonal and perpendicular to the diagonal, exhibit significant systematic and random errors. Finally, lab 20 (O 20) reported an errant value for one replicate of cement A. This might represent an error in the sample preparation or a data entry error. It was determined that the latter was most likely as the duplicate of this sample did not exhibit a similarly low value for cement A. In this case, no attempt was made to fix the data, and that analyte from that lab was removed for the final analysis to maintain the balanced data set required by E691.

The plots in Figure 5 of the laboratory means and standard deviation are also useful for rapid visualization of overall performance by laboratory and material. The means plots represent the mean of the three replicates for cements A and B (labeled as Material 1 and 2) against the consensus value. The mean values by laboratory have the effect of averaging out the random error in the analyses, providing a more robust estimate for each lab. Lab 1 stands out in producing consistently low values, which are those in the lower-left quadrant (O 1) of Figure 4. Precision problems of Lab 3 (cement B, material 2) and Lab 20 (cement A, material 1) are seen in the standard deviation (SD) plot.

Quantitative assessment of within- and between-lab precision is represented by the h and k statistics [12], which can take the table form or be expressed in a plot. The h and k consistency statistics, measures of the lab's within- and between-laboratory precision, are shown in Figure 6. These statistics were used to identify outlying lab data in the original data set, which were subsequently excluded on an analyte-by-analyte basis. The rationale for this being applied on a one time only basis was that it aided in the identification of unusual data due to standardization and procedural error, or errors on the reported values due to data entry. No attempt was made to evaluate the data and fix errant values due to

Included Appendices

8

CaO XRF, Powder Prep., Cements A B, Rep. 1

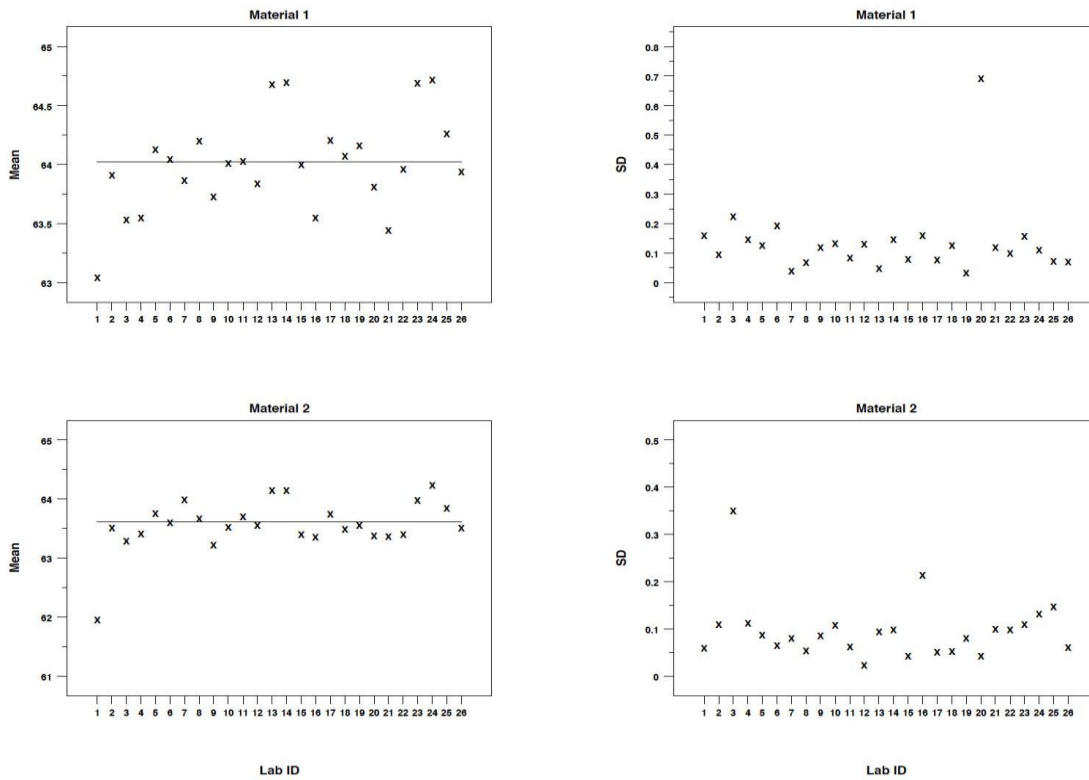


Figure 5 Lab means and standard deviations for CaO, powder preparation for cement A (Material 1) and cement B (Material 2).

Measurement Precision

The results in Appendix A are condensed into Table 1, which presents the results by method, and includes the 1σ within-laboratory (S_r), the 1σ between-laboratory (s_R). The table also includes the appropriate ASTM d2s, the 95 % limits on the difference between two test results, as r and R , which represent a pooled standard deviation for the two replicates for both cements A and B. In addition, the results were pooled across glass and powder methods for consideration and are shown in the right-hand side of the table. More detailed summaries by method and cement are found in Appendix B for the glass preparation and Appendix C for the powder preparation. Appendix D contains the raw data used in this analysis.

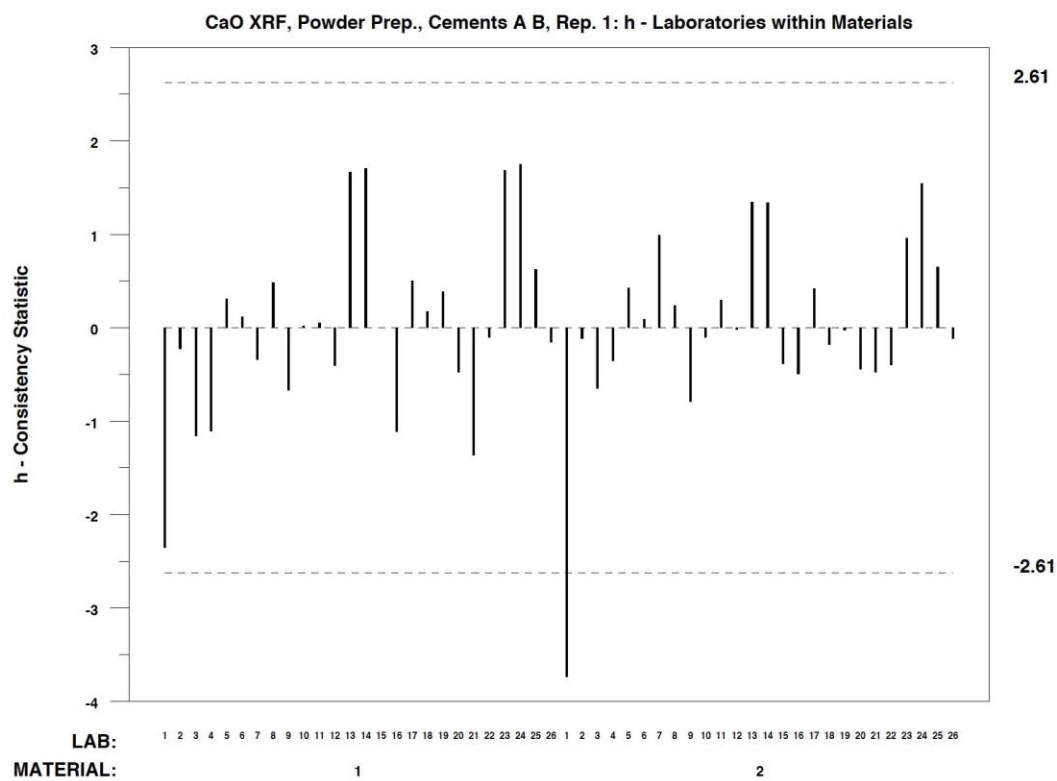
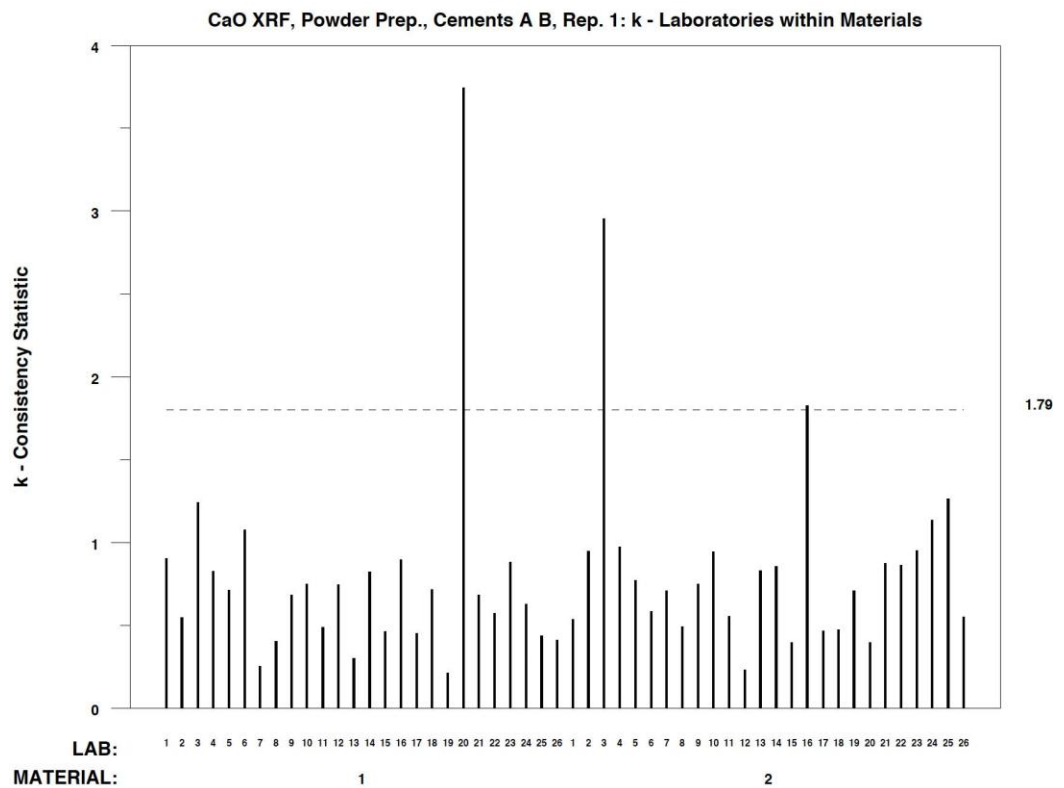


Figure 6 *h* and *k* statistic plots illustrate the within- (*k*) and between-laboratory (*h*) precision and are useful in identifying unusual results that may be considered outliers. The dashed line marks the limits for each statistic.

Table 1 Pooled Results for XRF-Glass, XRF-Powder and Combined Powder and Glass Methods, when the results are expressed as a percent. The values include the 1σ within-laboratory (Sr), the 1σ between-laboratory (sR), and the ASTM d2s values for the 95% limit on the difference between two test results (r) and (R).

Analyte	Glass				Powder				Pooled Glass and Powder			
	Sr	sR	r	R	Sr	sR	r	R	Sr	sR	r	R
CaO	0.119	0.372	0.334	1.043	0.109	0.337	0.306	0.942	0.114	0.355	0.321	0.994
SiO ₂	0.054	0.106	0.151	0.298	0.056	0.161	0.155	0.450	0.055	0.136	0.153	0.381
Al ₂ O ₃	0.021	0.057	0.058	0.160	0.022	0.096	0.063	0.266	0.022	0.079	0.060	0.220
Fe ₂ O ₃	0.013	0.032	0.038	0.090	0.016	0.046	0.045	0.130	0.015	0.040	0.042	0.112
SO ₃	0.056	0.085	0.156	0.236	0.024	0.119	0.065	0.334	0.043	0.104	0.120	0.289
MgO	0.012	0.026	0.034	0.077	0.012	0.065	0.033	0.185	0.012	0.050	0.033	0.142
Na ₂ O	0.023	0.029	0.062	0.080	0.005	0.019	0.013	0.055	0.016	0.025	0.045	0.069
K ₂ O	0.004	0.009	0.010	0.025	0.004	0.012	0.010	0.035	0.004	0.011	0.010	0.031
TiO ₂	0.004	0.008	0.010	0.020	0.003	0.007	0.010	0.020	0.004	0.008	0.010	0.020
P ₂ O ₅	0.003	0.004	0.010	0.016	0.007	0.009	0.017	0.025	0.005	0.007	0.014	0.021
Cl (both)	0.007	0.050	0.021	0.142	0.007	0.050	0.021	0.142	0.007	0.050	0.021	0.142

Prediction Intervals

ASTM C114 qualification criteria specified in Table 1 includes an accuracy criterion for each analyte, by limiting the maximum difference between the mean of two duplicates and a certificate value from a certified reference material. A two-sided 95 % prediction interval for the mean of two test results is presented in Table 2 for each analyte. This interval defines the maximum difference one might expect relative to a certified value of a reference material based upon the mean of two separate determinations [13]. This table provides the qualification criteria of column 3 of Table 1 in ASTM C114, titled “Maximum difference of the average of duplicates from CRM certificate values”.

Table 2 95 % Prediction Interval designed to bracket values of a mean of $k = 2$ measurements. The mean result should differ from the known value of the certified reference material by no more than the value shown for each analyte.

	Prediction Interval $k=2$		
	Glass	Powder	Pooled
CaO	0.569	0.477	0.492
SiO ₂	0.222	0.367	0.287
Al ₂ O ₃	0.106	0.149	0.122
Fe ₂ O ₃	0.057	0.069	0.059
SO ₃	0.132	0.175	0.147
MgO	0.037	0.085	0.063
Na ₂ O	0.038	0.031	0.032
K ₂ O	0.017	0.023	0.019
TiO ₂	0.013	0.011	0.011
P ₂ O ₅	0.007	0.017	0.012
Cl (both)			0.064

Summary

Precision and accuracy estimates from analysis of data from an ASTM interlaboratory test program provide the basis for qualification statement for the new XRF standard test method now in development. The current qualification criteria are based upon traditional wet chemistry test methods, and the original data and means of their calculation of the qualification criteria data being no longer available. Following ASTM E691, precision values for within- and between-laboratory and their 95 % limits have been determined. The accuracy criterion in ASTM C114, Table 1 is developed here using a two-point mean and 95 % prediction interval. Together, these performance criteria will aid in facilitating accurate and consistent analyses of the bulk chemical compositions of hydraulic cements.

Appendix A. Individual Oxide Analysis

The results by analyte and method are represented by a consistent set of plots and tables to illustrate the results, and by a summary table to provide a comparison to previous studies on precision. These results include:

- A box plot for Cement A and Cement B, which includes Reference Methods data from the CCRL proficiency test program,
- Summary tables of means, standard deviations, cell deviation, and h and k statistics (see Fig. 3),
- Summary tables by method and replicate for within- and between-laboratory precision expressed as a standard deviation and ASTM d2s 95 % limits, and
- A bar chart comparing between lab standard deviation (reproducibility) to that of previous studies.

Each analyte, expressed as an oxide, is represented by box plots for both cements A and B that include the reference data from the CCRL proficiency test program for these cements for comparison, a table of results for each duplicate and replicate by sample preparation (glass and powder), a summary table for the precision calculations by cement, duplicate and replicate, and a bar chart illustrating the pooled results against the ASTM C114 criteria and reproducibility values calculated in other studies on analytical uncertainty.

Box plots are a graphical one-way ANOVA, enabling comparison of the two XRF preparation and the reference methods results through assessment of the alignment or misalignment of median values, differences in interquartile ranges, and the extent of the data extremes. The box plots presented represent the XRF data after outliers from the initial analysis have been removed.

Important features of the box plot are:

- the width of each box is proportional to sample size,
- the median value, identified by the X within the box, is used for its resistance to outliers,
- the interquartile range ("middle half") of the data are represented by the body of the box,
- the top and the bottom of the box represent the estimated 75 % and 25 % point, respectively, and
- the extremes (minimum and maximum) are represented by the ends of the straight lines projecting from the box.

SiO₂

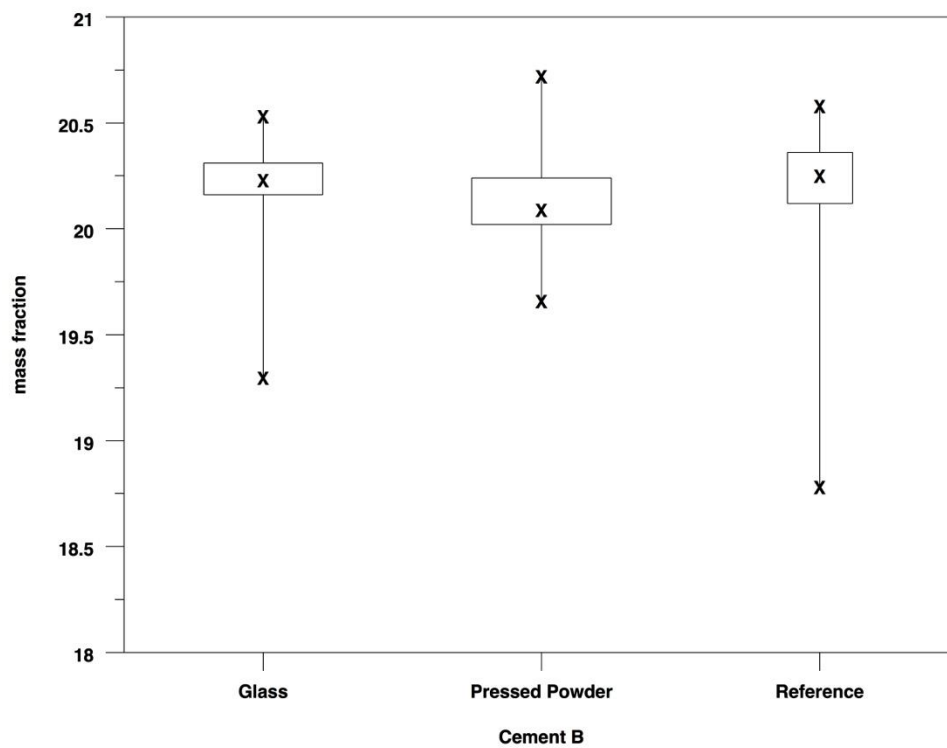
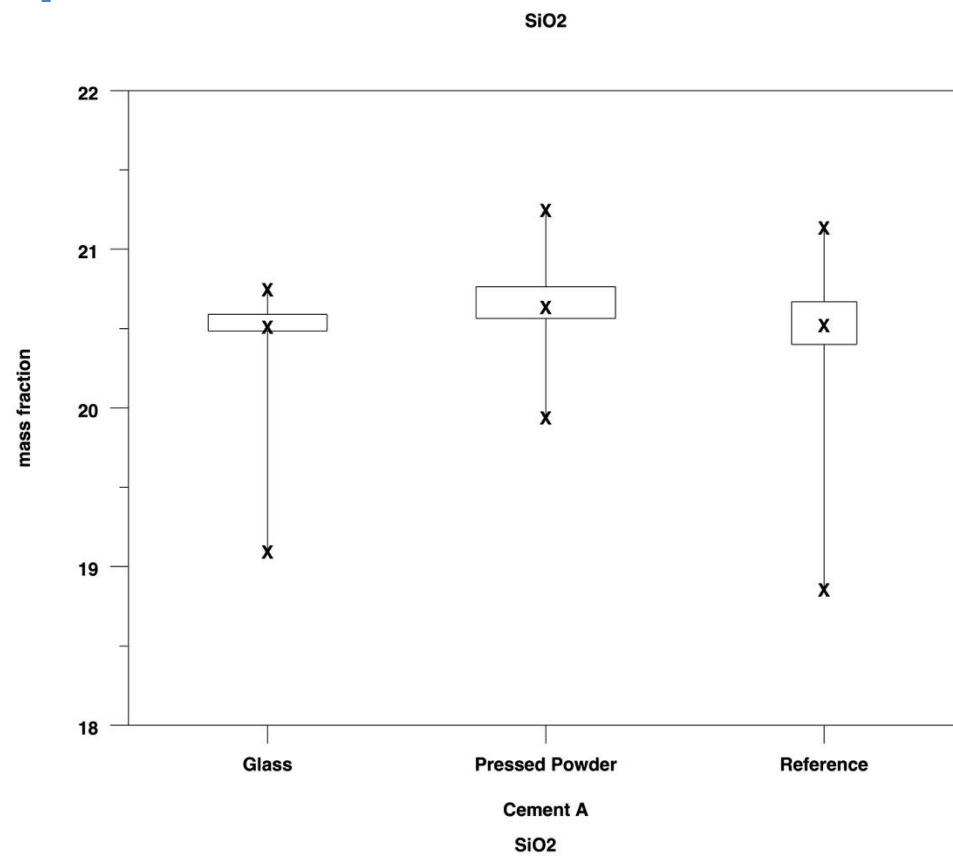


Figure 7 Box plots for SiO₂ for XRF glass and powder, and reference methods.

SiO₂ XRF, Cements A B, Glass, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	20.3965	0.0797	-0.1385	-1.85	1.62
2	20.3835	0.0794	-0.1515	-2.02	1.61
3	20.5300	0.0185	-0.0050	-0.07	0.37
4	20.5267	0.0163	-0.0084	-0.11	0.33
5	20.6005	0.0401	0.0655	0.87	0.81
6	20.5283	0.0366	-0.0067	-0.09	0.74
7	20.6633	0.0728	0.1283	1.71	1.48
8	20.5020	0.0304	-0.0330	-0.44	0.62
9	20.5167	0.0308	-0.0184	-0.24	0.62
10	20.5383	0.0598	0.0033	0.04	1.21
11	20.4650	0.0451	-0.0700	-0.93	0.91
12	20.5817	0.0331	0.0466	0.62	0.67
13	20.5660	0.0659	0.0310	0.41	1.34
14	20.5233	0.0378	-0.0117	-0.16	0.77
15	20.5450	0.0742	0.0100	0.13	1.50
16	20.6633	0.0294	0.1283	1.71	0.60
17	20.4952	0.0303	-0.0399	-0.53	0.61
18	20.6050	0.0259	0.0700	0.93	0.52
Average of cell averages		=	20.53502		
Standard Deviation of cell averages		=	0.07503		
Repeatability Standard Deviation		=	0.04934		
Reproducibility Standard Deviation		=	0.08751		
Critical values h, k		=	2.53, 1.78		

SiO₂ XRF, Cements A B, Glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	20.2365	0.0805	-0.0024	-0.02	1.40
2	20.2210	0.0873	-0.0179	-0.16	1.52
3	20.1612	0.0169	-0.0777	-0.71	0.29
4	20.2950	0.0327	0.0561	0.51	0.57
5	20.3387	0.0279	0.0998	0.91	0.49
6	20.2983	0.0744	0.0594	0.54	1.30
7	20.3517	0.0809	0.1128	1.03	1.41
8	20.2447	0.0229	0.0058	0.05	0.40
9	20.1883	0.0194	-0.0506	-0.46	0.34
10	20.1950	0.0497	-0.0439	-0.40	0.87
11	19.9533	0.0622	-0.2856	-2.60	1.08
12	20.2817	0.0279	0.0428	0.39	0.49
13	20.1127	0.0735	-0.1262	-1.15	1.28
14	20.2767	0.0367	0.0378	0.34	0.64
15	20.2667	0.1141	0.0278	0.25	1.99
16	20.4517	0.0492	0.2128	1.93	0.86
17	20.1205	0.0197	-0.1184	-1.08	0.34
18	20.3067	0.0216	0.0678	0.62	0.38

Average of cell averages = 20.23890
 Standard Deviation of cell averages = 0.10998
 Repeatability Standard Deviation = 0.05744
 Reproducibility Standard Deviation = 0.12184
 Critical values h, k = 2.53, 1.78

SiO₂ XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	20.3812	0.0655	-0.1504	-1.84	1.40
2	20.3577	0.0782	-0.1739	-2.13	1.67
3	20.5403	0.0151	0.0087	0.11	0.32
4	20.5233	0.0234	-0.0083	-0.10	0.50
5	20.6037	0.0416	0.0721	0.88	0.89
6	20.5183	0.0640	-0.0133	-0.16	1.37
7	20.6567	0.0659	0.1251	1.53	1.41
8	20.4963	0.0483	-0.0353	-0.43	1.03
9	20.4833	0.0308	-0.0483	-0.59	0.66
10	20.5133	0.0383	-0.0183	-0.22	0.82
11	20.4800	0.0316	-0.0516	-0.63	0.68
12	20.5567	0.0468	0.0251	0.31	1.00
13	20.6117	0.0486	0.0801	0.98	1.04
14	20.5033	0.0314	-0.0283	-0.35	0.67
15	20.5617	0.0605	0.0301	0.37	1.30
16	20.6533	0.0333	0.1217	1.49	0.71
17	20.5030	0.0246	-0.0286	-0.35	0.53
18	20.6250	0.0351	0.0934	1.14	0.75

Average of cell averages = 20.53160
 Standard Deviation of cell averages = 0.08179
 Repeatability Standard Deviation = 0.04668
 Reproducibility Standard Deviation = 0.09222
 Critical values h, k = 2.53, 1.78

SiO₂ XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	20.1507	0.0755	-0.0829	-0.81	1.24
2	20.1672	0.1104	-0.0664	-0.65	1.82
3	20.1625	0.0236	-0.0711	-0.69	0.39
4	20.2950	0.0302	0.0614	0.60	0.50
5	20.3352	0.0500	0.1016	0.99	0.82
6	20.2683	0.0783	0.0348	0.34	1.29
7	20.3617	0.0781	0.1281	1.25	1.29
8	20.2377	0.0227	0.0041	0.04	0.37
9	20.2217	0.0512	-0.0119	-0.12	0.84
10	20.1983	0.0700	-0.0352	-0.34	1.15
11	19.9800	0.0790	-0.2536	-2.47	1.30
12	20.2233	0.0273	-0.0102	-0.10	0.45
13	20.1775	0.0370	-0.0561	-0.55	0.61
14	20.2867	0.0266	0.0531	0.52	0.44
15	20.2583	0.1134	0.0248	0.24	1.87
16	20.4400	0.0297	0.2064	2.01	0.49
17	20.1300	0.0160	-0.1036	-1.01	0.26
18	20.3100	0.0352	0.0764	0.74	0.58

Average of cell averages = 20.23355
 Standard Deviation of cell averages = 0.10279
 Repeatability Standard Deviation = 0.06074
 Reproducibility Standard Deviation = 0.11679
 Critical values h, k = 2.53, 1.78

SiO₂ XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	20.6900	0.0874	0.0200	0.16	1.56
2	20.6093	0.0540	-0.0606	-0.48	0.96
3	20.6337	0.0546	-0.0363	-0.29	0.97
4	20.6283	0.0500	-0.0416	-0.33	0.89
5	20.6617	0.0705	-0.0083	-0.07	1.26
6	20.9333	0.0197	0.2634	2.09	0.35
7	20.7717	0.0382	0.1017	0.81	0.68
8	20.7500	0.0219	0.0800	0.64	0.39
9	20.4383	0.0407	-0.2316	-1.84	0.73
10	20.7512	0.0294	0.0812	0.65	0.52
11	20.5513	0.0341	-0.1186	-0.94	0.61
12	20.6817	0.0838	0.0117	0.09	1.49
13	20.5812	0.0326	-0.0888	-0.71	0.58
14	20.6105	0.0690	-0.0595	-0.47	1.23
15	20.6467	0.0592	-0.0233	-0.19	1.06
16	20.4917	0.0299	-0.1783	-1.42	0.53
17	20.5500	0.0805	-0.1200	-0.95	1.44
18	20.5432	0.0553	-0.1268	-1.01	0.99
19	20.8183	0.0725	0.1484	1.18	1.29
20	20.7950	0.0812	0.1250	0.99	1.45
21	20.7055	0.0404	0.0355	0.28	0.72
22	20.8967	0.0432	0.2267	1.80	0.77

Average of cell averages = 20.66996
 Standard Deviation of cell averages = 0.12579
 Repeatability Standard Deviation = 0.05606
 Reproducibility Standard Deviation = 0.13580
 Critical values h, k = 2.58, 1.78

SiO₂ XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	20.1433	0.0339	0.0263	0.15	0.63
2	19.7277	0.0464	-0.3894	-2.21	0.86
3	20.0672	0.0822	-0.0499	-0.28	1.53
4	20.2650	0.0288	0.1480	0.84	0.54
5	20.3067	0.0463	0.1896	1.08	0.86
6	20.3750	0.0547	0.2580	1.47	1.02
7	20.5217	0.0417	0.4046	2.30	0.77
8	20.0450	0.0592	-0.0720	-0.41	1.10
9	19.8967	0.0413	-0.2204	-1.25	0.77
10	20.4022	0.0481	0.2851	1.62	0.89
11	19.9907	0.0290	-0.1264	-0.72	0.54
12	20.0833	0.0771	-0.0337	-0.19	1.43
13	20.0695	0.0285	-0.0475	-0.27	0.53
14	19.9770	0.0715	-0.1400	-0.80	1.33
15	20.0850	0.0451	-0.0320	-0.18	0.84
16	20.0917	0.0445	-0.0254	-0.14	0.83
17	19.9800	0.0860	-0.1370	-0.78	1.60
18	20.0770	0.0656	-0.0400	-0.23	1.22
19	20.1617	0.0436	0.0446	0.25	0.81
20	20.0467	0.0520	-0.0704	-0.40	0.97
21	20.0870	0.0594	-0.0300	-0.17	1.10
22	20.1750	0.0423	0.0580	0.33	0.79

Average of cell averages = 20.11704
 Standard Deviation of cell averages = 0.17596
 Repeatability Standard Deviation = 0.05377
 Reproducibility Standard Deviation = 0.18268
 Critical values h, k = 2.58, 1.78

SiO₂ XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	20.7250	0.0628	0.0474	0.38	1.08
2	20.5675	0.1028	-0.1101	-0.88	1.76
3	20.6398	0.0484	-0.0378	-0.30	0.83
4	20.6283	0.0611	-0.0493	-0.39	1.05
5	20.6767	0.0812	-0.0010	-0.01	1.39
6	20.9267	0.0137	0.2490	1.98	0.23
7	20.7900	0.0335	0.1124	0.90	0.57
8	20.7450	0.0187	0.0674	0.54	0.32
9	20.4617	0.0392	-0.2160	-1.72	0.67
10	20.7458	0.0279	0.0682	0.54	0.48
11	20.5480	0.0412	-0.1296	-1.03	0.71
12	20.6950	0.0896	0.0174	0.14	1.54
13	20.6213	0.0259	-0.0563	-0.45	0.44
14	20.6280	0.0709	-0.0496	-0.40	1.21
15	20.6500	0.0740	-0.0276	-0.22	1.27
16	20.5200	0.0363	-0.1576	-1.26	0.62
17	20.5350	0.0771	-0.1426	-1.14	1.32
18	20.5572	0.0614	-0.1205	-0.96	1.05
19	20.8467	0.0717	0.1690	1.35	1.23
20	20.8050	0.0493	0.1274	1.01	0.84
21	20.6850	0.0492	0.0074	0.06	0.84
22	20.9100	0.0424	0.2324	1.85	0.73

Average of cell averages = 20.67762
 Standard Deviation of cell averages = 0.12550
 Repeatability Standard Deviation = 0.05835
 Reproducibility Standard Deviation = 0.13634
 Critical values h, k = 2.58, 1.79

SiO₂ XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	20.1467	0.0216	0.0248	0.14	0.40
2	19.7477	0.0374	-0.3742	-2.13	0.69
3	20.0790	0.0811	-0.0428	-0.24	1.50
4	20.2533	0.0320	0.1315	0.75	0.59
5	20.3017	0.0286	0.1798	1.02	0.53
6	20.3717	0.0578	0.2498	1.42	1.07
7	20.5383	0.0343	0.4165	2.37	0.63
8	20.0300	0.0498	-0.0918	-0.52	0.92
9	19.9117	0.0431	-0.2102	-1.20	0.80
10	20.4063	0.0496	0.2845	1.62	0.92
11	19.9875	0.0357	-0.1343	-0.77	0.66
12	20.0983	0.0833	-0.0235	-0.13	1.54
13	20.1020	0.0293	-0.0198	-0.11	0.54
14	19.9942	0.0684	-0.1277	-0.73	1.26
15	20.0333	0.0561	-0.0885	-0.50	1.04
16	20.0983	0.0475	-0.0235	-0.13	0.88
17	19.9717	0.0842	-0.1502	-0.86	1.56
18	20.0747	0.0752	-0.0472	-0.27	1.39
19	20.2017	0.0392	0.0798	0.45	0.72
20	20.0517	0.0591	-0.0702	-0.40	1.09
21	20.0875	0.0677	-0.0343	-0.20	1.25
22	20.1933	0.0372	0.0715	0.41	0.69

Average of cell averages = 20.12184
 Standard Deviation of cell averages = 0.17560
 Repeatability Standard Deviation = 0.05416
 Reproducibility Standard Deviation = 0.18243
 Critical values h, k = 2.58, 1.79

Table 3 Precision Statistics SiO₂ XRF, Cements A B

XRF Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	20.5350	0.0750	0.0493	0.0875	0.14	0.25
2	20.2389	0.1100	0.0574	0.1218	0.16	0.34

XRF Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	20.5316	0.0818	0.0467	0.0922	0.13	0.26
2	20.2336	0.1028	0.0607	0.1168	0.17	0.33

XRF Powder Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	20.6700	0.1258	0.0561	0.1358	0.16	0.38
2	20.1170	0.1760	0.0538	0.1827	0.15	0.51

XRF Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	20.6776	0.1255	0.0584	0.1363	0.16	0.38
2	20.1218	0.1756	0.0542	0.1824	0.15	0.51

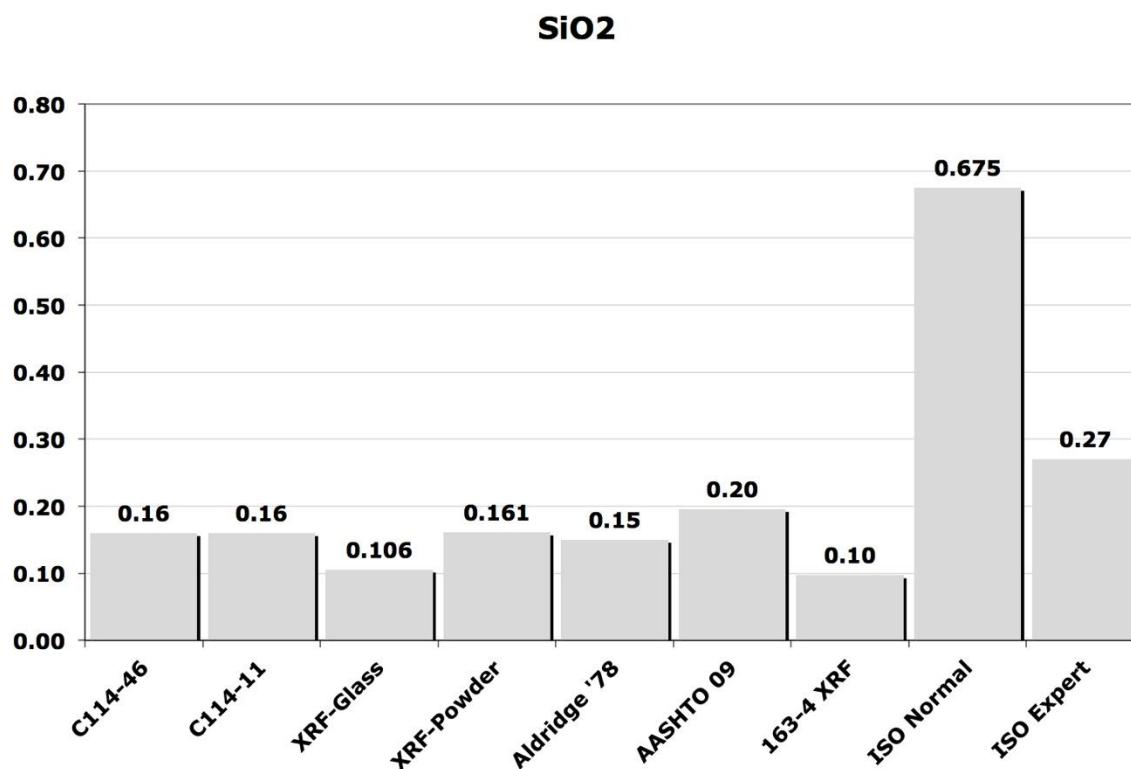


Figure 8 SiO₂ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

Al_2O_3

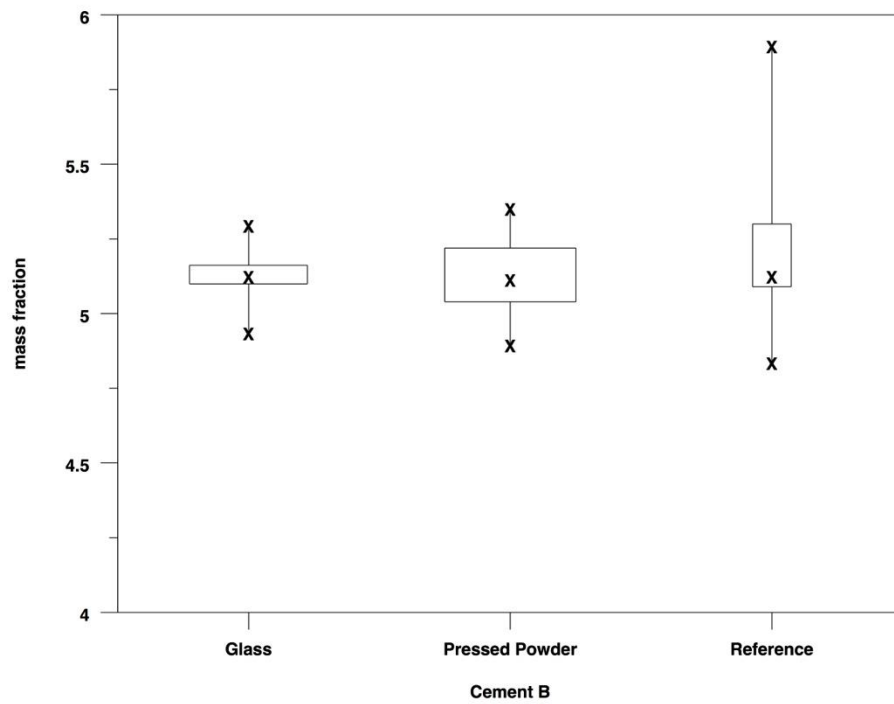
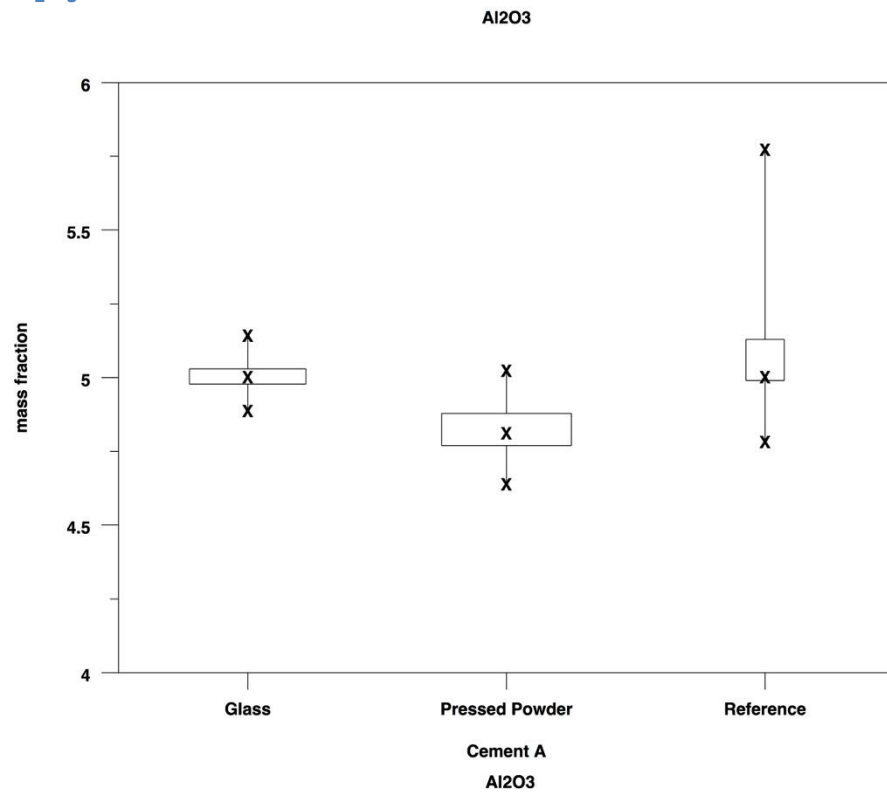


Figure 9 Box plots for Al_2O_3 XRF glass and powder, and reference methods.

Al₂O₃ XRF, Cements A B, Glass, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.9298	0.0239	-0.0780	-1.58	1.11
2	5.0260	0.0114	0.0182	0.37	0.53
3	4.9683	0.0098	-0.0395	-0.80	0.46
4	4.9777	0.0144	-0.0302	-0.61	0.67
5	4.9733	0.0266	-0.0345	-0.70	1.23
6	5.1367	0.0082	0.1288	2.60	0.38
7	5.0002	0.0223	-0.0077	-0.16	1.04
8	5.0133	0.0163	0.0055	0.11	0.76
9	4.9683	0.0279	-0.0395	-0.80	1.29
10	4.9450	0.0281	-0.0628	-1.27	1.30
11	5.0117	0.0214	0.0038	0.08	0.99
12	5.0638	0.0403	0.0560	1.13	1.87
13	4.9883	0.0248	-0.0195	-0.39	1.15
14	5.0150	0.0105	0.0072	0.14	0.49
15	5.0450	0.0302	0.0372	0.75	1.40
16	5.0492	0.0047	0.0413	0.84	0.22
17	5.0217	0.0075	0.0138	0.28	0.35

Average of cell averages = 5.00784
 Standard Deviation of cell averages = 0.04946
 Repeatability Standard Deviation = 0.02156
 Reproducibility Standard Deviation = 0.05323
 h, k Critical Values = 2.51000, 1.78000

Al₂O₃ XRF, Cements A B, Glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	5.0475	0.0165	-0.0825	-1.45	0.74
2	5.1378	0.0091	0.0078	0.14	0.41
3	5.1150	0.0084	-0.0150	-0.26	0.37
4	5.1015	0.0117	-0.0285	-0.50	0.52
5	5.1133	0.0294	-0.0167	-0.29	1.32
6	5.2583	0.0172	0.1283	2.26	0.77
7	5.1467	0.0181	0.0167	0.29	0.81
8	5.1233	0.0197	-0.0067	-0.12	0.88
9	5.0933	0.0301	-0.0367	-0.64	1.35
10	5.0117	0.0407	-0.1183	-2.08	1.82
11	5.1283	0.0172	-0.0017	-0.03	0.77
12	5.1747	0.0234	0.0447	0.79	1.05
13	5.0917	0.0392	-0.0383	-0.67	1.76
14	5.1433	0.0207	0.0133	0.23	0.93
15	5.2067	0.0197	0.0767	1.35	0.88
16	5.1702	0.0026	0.0402	0.71	0.12
17	5.1467	0.0163	0.0167	0.29	0.73

Average of cell averages = 5.13000
 Standard Deviation of cell averages = 0.05686
 Repeatability Standard Deviation = 0.02232
 Reproducibility Standard Deviation = 0.06040
 h, k Critical Values = 2.51000, 1.78000

Al₂O₃ XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.9332	0.0270	-0.0753	-1.51	1.43
2	5.0187	0.0074	0.0102	0.20	0.39
3	4.9767	0.0052	-0.0318	-0.64	0.27
4	4.9707	0.0107	-0.0378	-0.76	0.57
5	4.9750	0.0207	-0.0335	-0.67	1.10
6	5.1350	0.0138	0.1265	2.54	0.73
7	4.9952	0.0200	-0.0133	-0.27	1.06
8	5.0050	0.0138	-0.0035	-0.07	0.73
9	4.9567	0.0207	-0.0518	-1.04	1.10
10	4.9483	0.0256	-0.0601	-1.21	1.36
11	5.0117	0.0306	0.0032	0.06	1.63
12	5.0805	0.0206	0.0720	1.45	1.10
13	5.0133	0.0121	0.0049	0.10	0.64
14	5.0200	0.0167	0.0115	0.23	0.89
15	5.0467	0.0273	0.0382	0.77	1.45
16	5.0377	0.0099	0.0292	0.59	0.53
17	5.0200	0.0126	0.0115	0.23	0.67

Average of cell averages = 5.00848
 Standard Deviation of cell averages = 0.04977
 Repeatability Standard Deviation = 0.01880
 Reproducibility Standard Deviation = 0.05265
 h, k Critical Values = 2.51000, 1.78000

Al₂O₃ XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	5.0528	0.0174	-0.0802	-1.38	0.84
2	5.1357	0.0082	0.0027	0.05	0.40
3	5.1150	0.0105	-0.0180	-0.31	0.51
4	5.1038	0.0181	-0.0292	-0.50	0.87
5	5.1100	0.0283	-0.0230	-0.40	1.37
6	5.2717	0.0240	0.1387	2.39	1.16
7	5.1485	0.0144	0.0155	0.27	0.69
8	5.1250	0.0138	-0.0080	-0.14	0.67
9	5.0733	0.0121	-0.0597	-1.03	0.58
10	5.0300	0.0253	-0.1030	-1.77	1.22
11	5.1200	0.0141	-0.0130	-0.22	0.68
12	5.1952	0.0281	0.0622	1.07	1.36
13	5.1050	0.0389	-0.0280	-0.48	1.88
14	5.1550	0.0302	0.0220	0.38	1.46
15	5.2083	0.0160	0.0753	1.30	0.77
16	5.1635	0.0016	0.0305	0.52	0.08
17	5.1483	0.0160	0.0153	0.26	0.77

Average of cell averages = 5.13301
 Standard Deviation of cell averages = 0.05808
 Repeatability Standard Deviation = 0.02071
 Reproducibility Standard Deviation = 0.06109
 h, k Critical Values = 2.57000, 1.79000

Al₂O₃ XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.7500	0.0522	-0.0713	-0.92	2.18
2	4.7317	0.0194	-0.0896	-1.16	0.81
3	4.7213	0.0305	-0.0999	-1.29	1.28
4	4.8473	0.0365	0.0261	0.34	1.53
5	4.9483	0.0133	0.1271	1.64	0.56
6	4.8267	0.0186	0.0054	0.07	0.78
7	4.7917	0.0117	-0.0296	-0.38	0.49
8	4.9850	0.0138	0.1637	2.12	0.58
9	4.8267	0.0082	0.0054	0.07	0.34
10	4.8400	0.0167	0.0187	0.24	0.70
11	4.8853	0.0066	0.0641	0.83	0.27
13	4.7647	0.0155	-0.0566	-0.73	0.65
14	4.7867	0.0250	-0.0346	-0.45	1.05
15	4.7527	0.0166	-0.0686	-0.89	0.70
16	4.9555	0.0405	0.1342	1.74	1.69
17	4.7783	0.0223	-0.0429	-0.56	0.93
18	4.8283	0.0075	0.0071	0.09	0.32
19	4.8280	0.0261	0.0067	0.09	1.09
20	4.8083	0.0306	-0.0129	-0.17	1.28
21	4.8867	0.0175	0.0654	0.85	0.73
22	4.7033	0.0109	-0.1179	-1.53	0.45

Average of cell averages = 4.82126
 Standard Deviation of cell averages = 0.07731
 Repeatability Standard Deviation = 0.02388
 Reproducibility Standard Deviation = 0.08032
 h, k Critical Value = 2.57000, 1.79000

Al₂O₃ XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.9433	0.0234	-0.1858	-1.68	1.20
2	5.2250	0.0084	0.0958	0.87	0.43
3	5.3067	0.0207	0.1775	1.61	1.06
4	5.1215	0.0196	-0.0077	-0.07	1.00
5	5.2733	0.0175	0.1442	1.31	0.90
6	5.0650	0.0105	-0.0642	-0.58	0.54
7	5.0267	0.0103	-0.1025	-0.93	0.53
8	5.2833	0.0175	0.1542	1.40	0.90
9	5.1367	0.0137	0.0075	0.07	0.70
10	5.1883	0.0331	0.0592	0.54	1.69
11	5.0728	0.0284	-0.0563	-0.51	1.45
13	5.3123	0.0125	0.1832	1.66	0.64
14	5.0383	0.0194	-0.0908	-0.82	0.99
15	4.9863	0.0263	-0.1428	-1.29	1.35
16	5.2137	0.0128	0.0845	0.77	0.66
17	5.1367	0.0186	0.0075	0.07	0.95
18	5.0383	0.0214	-0.0908	-0.82	1.09
19	5.0770	0.0188	-0.0522	-0.47	0.96
20	5.0733	0.0137	-0.0558	-0.51	0.70
21	5.1883	0.0286	0.0592	0.54	1.46
22	5.0055	0.0116	-0.1237	-1.12	0.59

Average of cell averages = 5.12917
 Standard Deviation of cell averages = 0.11033
 Repeatability Standard Deviation = 0.01956
 Reproducibility Standard Deviation = 0.11177
 h, k Critical Value = 2.57000, 1.79000

Al₂O₃ XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.7600	0.0460	-0.0667	-0.87	1.88
2	4.7333	0.0207	-0.0933	-1.22	0.85
3	4.7257	0.0414	-0.1010	-1.32	1.70
4	4.8528	0.0411	0.0262	0.34	1.68
5	4.9467	0.0121	0.1200	1.57	0.50
6	4.8350	0.0243	0.0083	0.11	0.99
7	4.7933	0.0082	-0.0333	-0.44	0.33
8	4.9883	0.0133	0.1617	2.12	0.54
9	4.8333	0.0082	0.0067	0.09	0.33
10	4.8467	0.0197	0.0200	0.26	0.80
11	4.8878	0.0088	0.0612	0.80	0.36
13	4.7662	0.0134	-0.0605	-0.79	0.55
14	4.7783	0.0214	-0.0483	-0.63	0.87
15	4.7917	0.0085	-0.0350	-0.46	0.35
16	4.9592	0.0395	0.1325	1.74	1.62
17	4.7883	0.0204	-0.0383	-0.50	0.84
18	4.8333	0.0103	0.0067	0.09	0.42
19	4.8313	0.0273	0.0047	0.06	1.12
20	4.8233	0.0314	-0.0033	-0.04	1.29
21	4.8867	0.0207	0.0600	0.79	0.85
22	4.6983	0.0113	-0.1283	-1.68	0.46

Average of cell averages = 4.82665
 Standard Deviation of cell averages = 0.07627
 Repeatability Standard Deviation = 0.02443
 Reproducibility Standard Deviation = 0.07946
 h, k Critical Value = 2.57000, 1.79000

Al₂O₃ XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.9483	0.0279	-0.1837	-1.72	1.38
2	5.2117	0.0183	0.0796	0.75	0.91
3	5.3157	0.0284	0.1836	1.72	1.40
4	5.1247	0.0222	-0.0074	-0.07	1.10
5	5.2733	0.0103	0.1413	1.33	0.51
6	5.0650	0.0138	-0.0671	-0.63	0.68
7	5.0250	0.0105	-0.1071	-1.00	0.52
8	5.2783	0.0147	0.1463	1.37	0.73
9	5.1400	0.0110	0.0079	0.07	0.54
10	5.1867	0.0344	0.0546	0.51	1.70
11	5.0717	0.0207	-0.0604	-0.57	1.02
13	5.3052	0.0118	0.1731	1.62	0.58
14	5.0367	0.0207	-0.0954	-0.89	1.02
15	5.0317	0.0171	-0.1004	-0.94	0.85
16	5.2122	0.0111	0.0801	0.75	0.55
17	5.1333	0.0175	0.0013	0.01	0.86
18	5.0333	0.0197	-0.0987	-0.93	0.97
19	5.0877	0.0334	-0.0444	-0.42	1.65
20	5.1017	0.0075	-0.0304	-0.29	0.37
21	5.1917	0.0279	0.0596	0.56	1.38
22	4.9995	0.0149	-0.1326	-1.24	0.74

Average of cell averages = 5.13206
 Standard Deviation of cell averages = 0.10658
 Repeatability Standard Deviation = 0.02025
 Reproducibility Standard Deviation = 0.10817
 h, k Critical Value = 2.57000, 1.79000

Table 4 Precision Statistics Al_2O_3 by XRF glass and powder preparations for replicates 1 and 2

Al_2O_3 Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	5.0078	0.0495	0.0216	0.0532	0.06	0.15
2	5.1300	0.0569	0.0223	0.0604	0.06	0.17

Al_2O_3 Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	5.0085	0.0498	0.0188	0.0526	0.05	0.15
2	5.1330	0.0581	0.0207	0.0611	0.06	0.17

Al_2O_3 Powder, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	4.8213	0.0773	0.0239	0.0803	0.07	0.22
2	5.1292	0.1103	0.0196	0.1118	0.05	0.31

Al_2O_3 Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	4.8267	0.0763	0.0244	0.0795	0.07	0.22
2	5.1321	0.1066	0.0203	0.1082	0.06	0.30

Al_2O_3

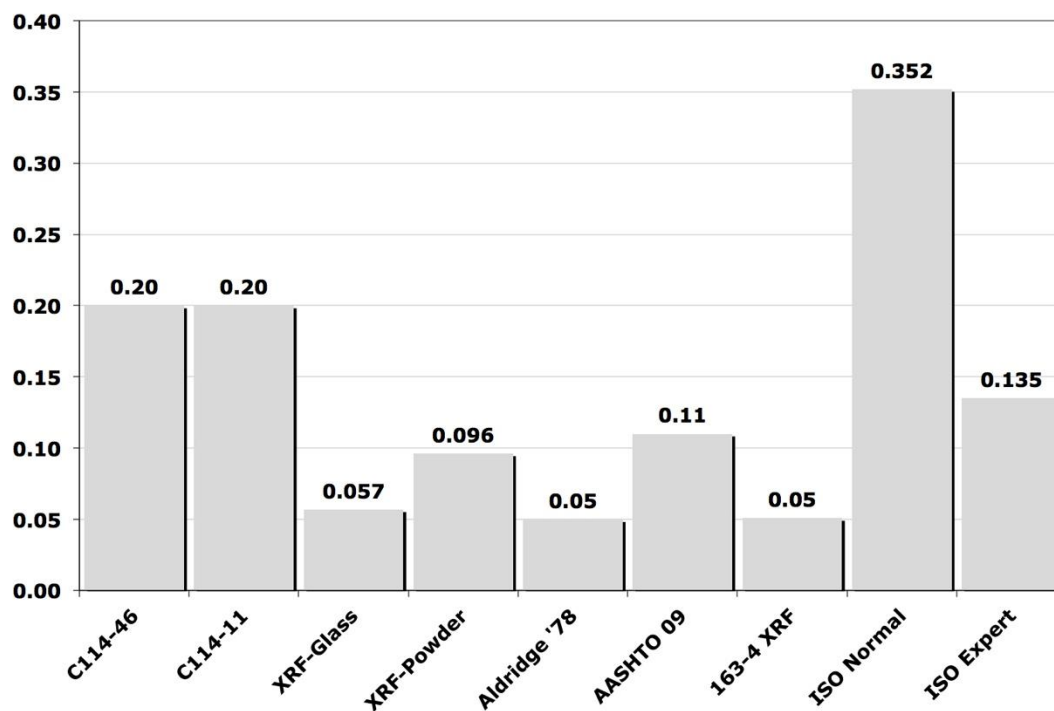


Figure 10 Al_2O_3 precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

Fe_2O_3

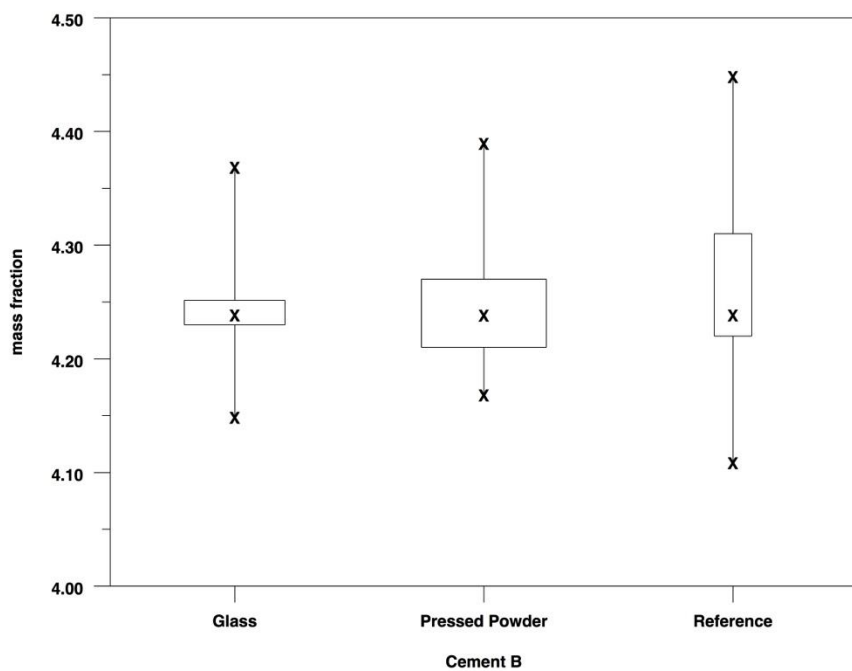
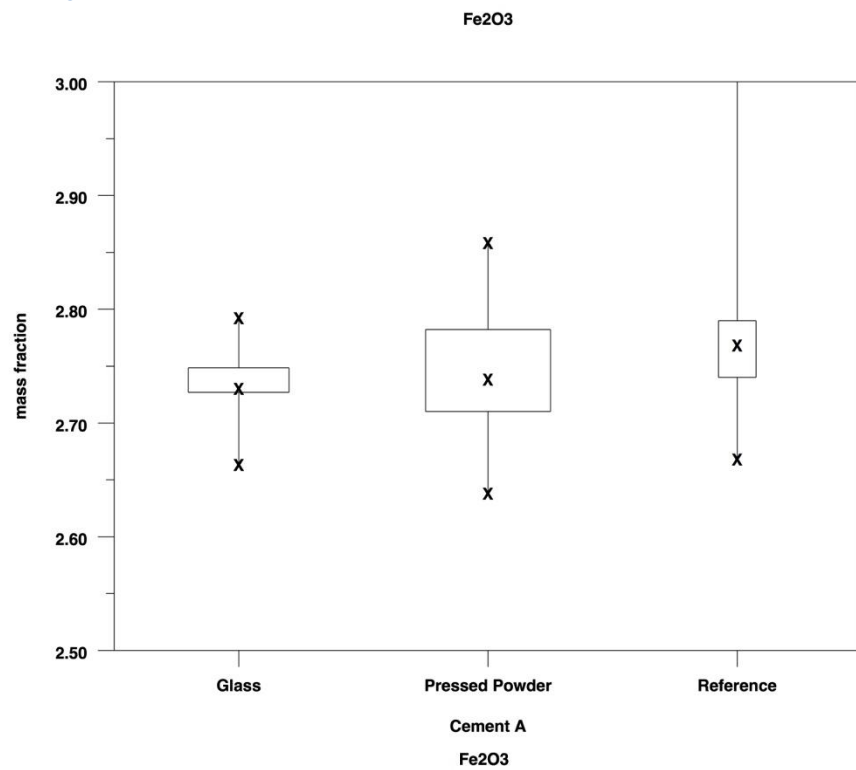


Figure 11 Box plots for Fe_2O_3 XRF glass and powder, and reference methods.

Fe₂O₃ XRF, Cements A B, glass, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	2.7280	0.0158	-0.0083	-0.29	1.15
2	2.7313	0.0338	-0.0050	-0.18	2.46
3	2.7287	0.0034	-0.0077	-0.27	0.25
4	2.7317	0.0041	-0.0047	-0.16	0.30
5	2.7295	0.0025	-0.0068	-0.24	0.18
6	2.7333	0.0052	-0.0030	-0.11	0.38
7	2.6900	0.0089	-0.0463	-1.64	0.65
8	2.7390	0.0064	0.0027	0.09	0.47
9	2.7850	0.0055	0.0487	1.72	0.40
10	2.6900	0.0297	-0.0463	-1.64	2.16
11	2.7383	0.0075	0.0020	0.07	0.55
12	2.7750	0.0130	0.0387	1.37	0.94
13	2.7283	0.0098	-0.0080	-0.28	0.71
14	2.7883	0.0041	0.0520	1.84	0.30
15	2.7283	0.0041	-0.0080	-0.28	0.30

Average of cell averages = 2.73632
Standard Deviation of cell averages = 0.02832
Repeatability Standard Deviation = 0.01376
Reproducibility Standard Deviation = 0.03098
h, k Critical Values = 2.47000, 1.77000

Fe₂O₃ XRF, Cements A B, glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.2225	0.0081	-0.0176	-0.60	0.75
2	4.2363	0.0259	-0.0038	-0.13	2.40
3	4.2460	0.0037	0.0059	0.20	0.35
4	4.2167	0.0082	-0.0234	-0.80	0.76
5	4.2398	0.0052	-0.0003	-0.01	0.49
6	4.2517	0.0075	0.0116	0.40	0.70
7	4.1683	0.0117	-0.0718	-2.46	1.08
8	4.2408	0.0063	0.0007	0.02	0.58
9	4.3000	0.0063	0.0599	2.06	0.59
10	4.2583	0.0194	0.0182	0.63	1.80
11	4.2300	0.0063	-0.0101	-0.35	0.59
12	4.2528	0.0095	0.0127	0.44	0.88
13	4.2300	0.0089	-0.0101	-0.35	0.83
14	4.2767	0.0052	0.0366	1.25	0.48
15	4.2317	0.0041	-0.0084	-0.29	0.38

Average of cell averages = 4.24011
 Standard Deviation of cell averages = 0.02914
 Repeatability Standard Deviation = 0.01079
 Reproducibility Standard Deviation = 0.03076
 h, k Critical Values = 2.47000, 1.77000

Fe₂O₃ XRF, Cements A B, glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	2.7250	0.0059	-0.0121	-0.42	0.54
2	2.7333	0.0335	-0.0038	-0.13	3.07
3	2.7295	0.0028	-0.0076	-0.27	0.26
4	2.7317	0.0041	-0.0055	-0.19	0.37
5	2.7313	0.0022	-0.0058	-0.20	0.20
6	2.7367	0.0052	-0.0005	-0.02	0.47
7	2.6917	0.0075	-0.0455	-1.59	0.69
8	2.7423	0.0044	0.0052	0.18	0.40
9	2.7850	0.0055	0.0479	1.67	0.50
10	2.6867	0.0082	-0.0505	-1.76	0.75
11	2.7367	0.0121	-0.0005	-0.02	1.11
12	2.7790	0.0097	0.0419	1.46	0.89
13	2.7300	0.0089	-0.0071	-0.25	0.82
14	2.7867	0.0052	0.0495	1.73	0.47
15	2.7317	0.0075	-0.0055	-0.19	0.69

Average of cell averages = 2.73714
 Standard Deviation of cell averages = 0.02866
 Repeatability Standard Deviation = 0.01091
 Reproducibility Standard Deviation = 0.03035
 h, k Critical Values = 2.47000, 1.77000

Fe₂O₃ XRF, Cements A B, glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.2173	0.0096	-0.0225	-0.73	0.55
2	4.2268	0.0286	-0.0130	-0.42	1.65
3	4.2448	0.0038	0.0050	0.16	0.22
4	4.2150	0.0084	-0.0249	-0.81	0.48
5	4.2385	0.0012	-0.0014	-0.04	0.07
6	4.2483	0.0075	0.0085	0.27	0.43
7	4.1667	0.0151	-0.0732	-2.37	0.87
8	4.2450	0.0068	0.0051	0.17	0.39
9	4.2983	0.0075	0.0585	1.89	0.43
10	4.2700	0.0514	0.0301	0.98	2.96
11	4.2317	0.0133	-0.0082	-0.27	0.77
12	4.2603	0.0080	0.0205	0.66	0.46
13	4.2283	0.0098	-0.0115	-0.37	0.57
14	4.2783	0.0041	0.0385	1.25	0.24
15	4.2283	0.0117	-0.0115	-0.37	0.67

Average of cell averages = 4.23986
Standard Deviation of cell averages = 0.03086
Repeatability Standard Deviation = 0.01734
Reproducibility Standard Deviation = 0.03469
h, k Critical Values = 2.47000, 1.77000

Fe₂O₃ XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	2.6600	0.0063	-0.0844	-1.92	0.50
2	2.7083	0.0194	-0.0360	-0.82	1.53
4	2.7218	0.0212	-0.0225	-0.51	1.67
5	2.7383	0.0041	-0.0060	-0.14	0.32
6	2.7500	0.0063	0.0056	0.13	0.50
7	2.7233	0.0052	-0.0210	-0.48	0.41
8	2.8317	0.0133	0.0873	1.99	1.05
9	2.7833	0.0327	0.0390	0.89	2.58
10	2.8067	0.0082	0.0623	1.42	0.64
11	2.7887	0.0085	0.0443	1.01	0.67
12	2.6765	0.0098	-0.0679	-1.54	0.77
13	2.7270	0.0095	-0.0174	-0.40	0.75
14	2.7685	0.0164	0.0241	0.55	1.29
15	2.7200	0.0063	-0.0244	-0.55	0.50
16	2.7817	0.0041	0.0373	0.85	0.32
17	2.7066	0.0169	-0.0377	-0.86	1.33
18	2.7468	0.0103	0.0025	0.06	0.82
19	2.7117	0.0160	-0.0327	-0.74	1.26
20	2.7967	0.0052	0.0523	1.19	0.41
21	2.7513	0.0065	0.0070	0.16	0.51
22	2.7117	0.0041	-0.0327	-0.74	0.32
23	2.7100	0.0063	-0.0344	-0.78	0.50
24	2.8000	0.0089	0.0556	1.27	0.71

Average of cell averages = 2.74438
 Standard Deviation of cell averages = 0.04396
 Repeatability Standard Deviation = 0.01268
 Reproducibility Standard Deviation = 0.04546
 h, k Critical Values = 2.59000, 1.79000

Fe₂O₃ XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.2567	0.0137	0.0079	0.19	0.73
2	4.2633	0.0532	0.0146	0.35	2.84
4	4.2250	0.0246	-0.0238	-0.56	1.31
5	4.2333	0.0103	-0.0154	-0.37	0.55
6	4.2450	0.0055	-0.0038	-0.09	0.29
7	4.2500	0.0089	0.0012	0.03	0.48
8	4.3333	0.0082	0.0846	2.00	0.44
9	4.2533	0.0175	0.0046	0.11	0.93
10	4.2917	0.0075	0.0429	1.02	0.40
11	4.3159	0.0110	0.0672	1.59	0.58
12	4.1978	0.0062	-0.0509	-1.21	0.33
13	4.2055	0.0140	-0.0433	-1.02	0.75
14	4.1987	0.0100	-0.0501	-1.19	0.53
15	4.2600	0.0237	0.0113	0.27	1.26
16	4.2717	0.0147	0.0229	0.54	0.79
17	4.2046	0.0137	-0.0442	-1.05	0.73
18	4.3403	0.0450	0.0916	2.17	2.40
19	4.2067	0.0052	-0.0421	-1.00	0.28
20	4.2683	0.0041	0.0196	0.46	0.22
21	4.2651	0.0029	0.0163	0.39	0.16
22	4.2100	0.0063	-0.0388	-0.92	0.34
23	4.2067	0.0121	-0.0421	-1.00	0.65
24	4.2183	0.0117	-0.0304	-0.72	0.62

Average of cell averages = 4.24875
 Standard Deviation of cell averages = 0.04222
 Repeatability Standard Deviation = 0.01875
 Reproducibility Standard Deviation = 0.04555
 h, k Critical Values = 2.59000, 1.79000

Fe₂O₃ XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	2.6533	0.0082	-0.0909	-2.03	0.58
2	2.6933	0.0333	-0.0509	-1.13	2.37
4	2.7228	0.0212	-0.0214	-0.48	1.51
5	2.7400	0.0063	-0.0042	-0.09	0.45
6	2.7467	0.0103	0.0025	0.05	0.74
7	2.7350	0.0105	-0.0092	-0.21	0.75
8	2.8317	0.0160	0.0875	1.95	1.14
9	2.7750	0.0295	0.0308	0.69	2.10
10	2.8067	0.0082	0.0625	1.39	0.58
11	2.7945	0.0105	0.0503	1.12	0.75
12	2.6788	0.0051	-0.0654	-1.46	0.36
13	2.7258	0.0109	-0.0184	-0.41	0.78
14	2.7705	0.0165	0.0263	0.59	1.18
15	2.7217	0.0075	-0.0225	-0.50	0.54
16	2.7850	0.0084	0.0408	0.91	0.60
17	2.7064	0.0173	-0.0378	-0.84	1.23
18	2.7480	0.0097	0.0038	0.08	0.69
19	2.7117	0.0160	-0.0325	-0.73	1.14
20	2.7950	0.0055	0.0508	1.13	0.39
21	2.7465	0.0048	0.0023	0.05	0.34
22	2.7117	0.0041	-0.0325	-0.73	0.29
23	2.7150	0.0055	-0.0292	-0.65	0.39
24	2.8017	0.0075	0.0575	1.28	0.54

Average of cell averages = 2.74421
 Standard Deviation of cell averages = 0.04483
 Repeatability Standard Deviation = 0.01404
 Reproducibility Standard Deviation = 0.04662
 h, k Critical Values = 1.79000, 2.59000

Fe₂O₃ XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	4.2600	0.0167	0.0125	0.29	0.92
2	4.2683	0.0504	0.0208	0.48	2.78
4	4.2227	0.0198	-0.0248	-0.57	1.10
5	4.2333	0.0103	-0.0142	-0.33	0.57
6	4.2483	0.0075	0.0008	0.02	0.42
7	4.2433	0.0082	-0.0042	-0.10	0.45
8	4.3350	0.0055	0.0875	2.02	0.30
9	4.2017	0.0223	-0.0458	-1.06	1.23
10	4.2950	0.0055	0.0475	1.10	0.30
11	4.3177	0.0113	0.0703	1.62	0.62
12	4.2007	0.0118	-0.0468	-1.08	0.65
13	4.2120	0.0130	-0.0355	-0.82	0.72
14	4.2000	0.0147	-0.0475	-1.10	0.81
15	4.2483	0.0194	0.0008	0.02	1.07
16	4.2783	0.0147	0.0308	0.71	0.81
17	4.2062	0.0141	-0.0413	-0.95	0.78
18	4.3398	0.0431	0.0923	2.13	2.38
19	4.2083	0.0075	-0.0392	-0.90	0.42
20	4.2683	0.0041	0.0208	0.48	0.23
21	4.2663	0.0042	0.0189	0.44	0.23
22	4.2150	0.0055	-0.0325	-0.75	0.30
23	4.2067	0.0082	-0.0408	-0.94	0.45
24	4.2167	0.0082	-0.0308	-0.71	0.45

Average of cell averages = 4.24748
 Standard Deviation of cell averages = 0.04331
 Repeatability Standard Deviation = 0.01812
 Reproducibility Standard Deviation = 0.04636
 h, k Critical Values = 1.79000, 2.59000

Table 5 Precision Statistics Fe_2O_3 by XRF glass and powder preparations for replicates 1 and 2

Fe_2O_3 Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	2.7363	0.0283	0.0138	0.0310	0.04	0.09
2	4.2401	0.0291	0.0108	0.0308	0.03	0.09

Fe_2O_3 Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	2.7371	0.0287	0.0109	0.0303	0.03	0.08
2	4.2399	0.0309	0.0173	0.0347	0.05	0.10

Fe_2O_3 Powder, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	2.7444	0.0440	0.0127	0.0455	0.04	0.13
2	4.2488	0.0422	0.0187	0.0456	0.05	0.13

Fe_2O_3 Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	2.7442	0.0448	0.0140	0.0466	0.04	0.13
2	4.2475	0.0433	0.0181	0.0464	0.05	0.13

Fe2O3

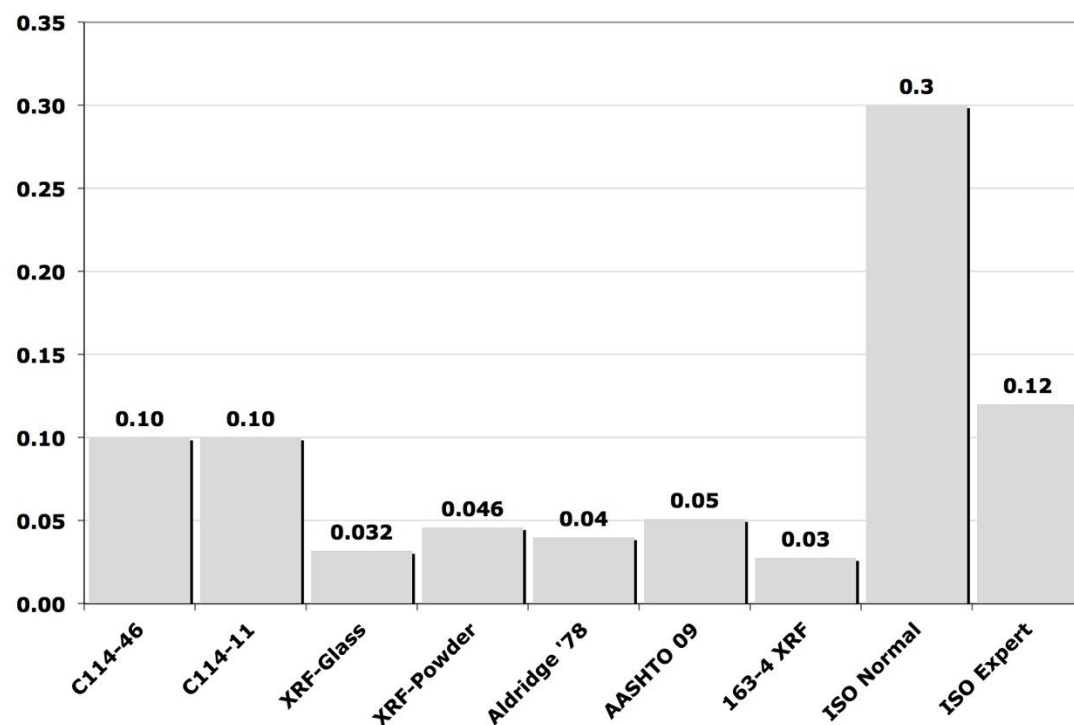


Figure 12 Fe_2O_3 precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

CaO

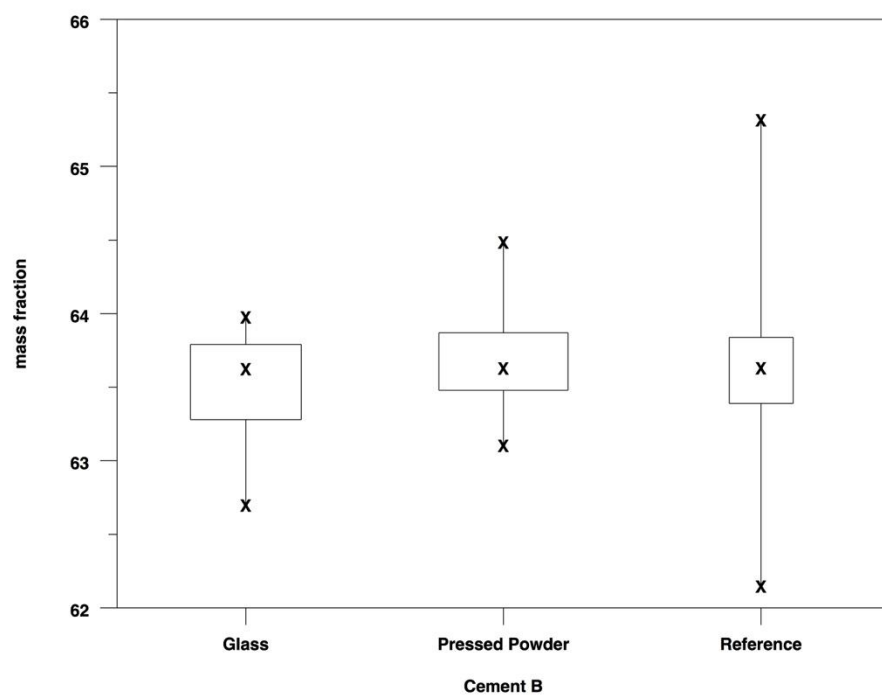
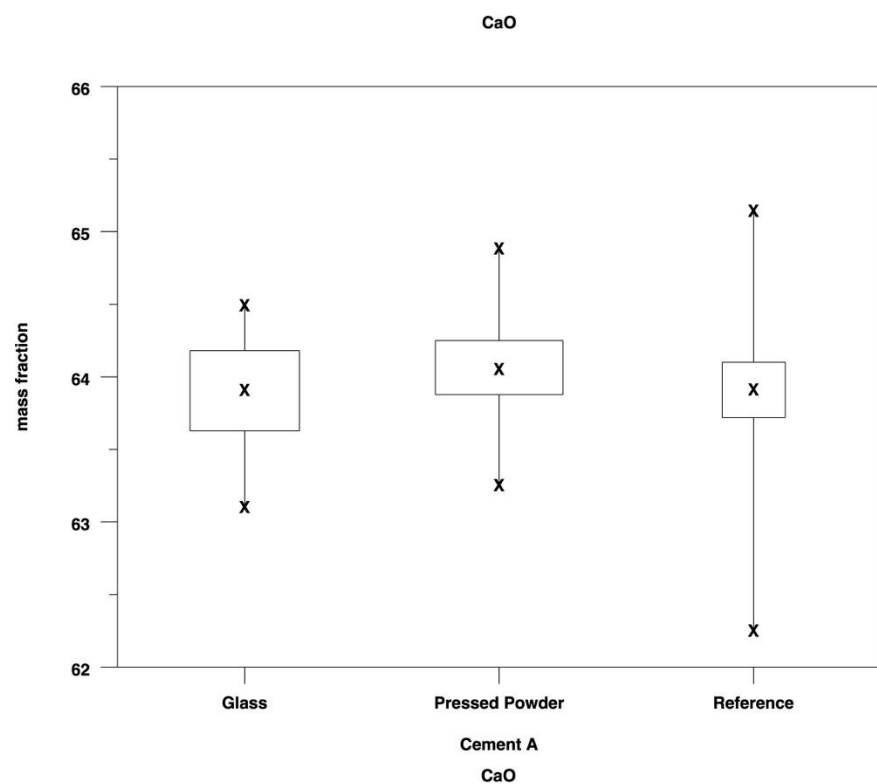


Figure 13 Box plots for CaO XRF glass and powder, and reference methods.

CaO XRF, Cements A B, Glass, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	64.1400	0.0636	0.2613	0.75	0.60
2	64.1667	0.1593	0.2880	0.82	1.50
3	63.8800	0.1188	0.0013	0.00	1.12
4	63.2650	0.1199	-0.6137	-1.75	1.13
5	63.6978	0.0798	-0.1808	-0.52	0.75
6	64.0700	0.1664	0.1913	0.55	1.57
7	63.6200	0.0856	-0.2587	-0.74	0.81
8	64.3000	0.0465	0.4213	1.20	0.44
9	63.6295	0.1095	-0.2492	-0.71	1.03
10	63.9867	0.0520	0.1080	0.31	0.49
11	63.3730	0.1117	-0.5057	-1.45	1.05
12	64.1167	0.1340	0.2380	0.68	1.26
13	63.8780	0.0258	-0.0007	0.00	0.24
14	64.2683	0.0889	0.3897	1.11	0.84
15	63.2773	0.1387	-0.6013	-1.72	1.31
16	64.3417	0.1221	0.4630	1.32	1.15
17	63.9267	0.0455	0.0480	0.14	0.43

Average of cell averages = 63.87867
 Standard Deviation of cell averages = 0.34980
 Repeatability Standard Deviation = 0.10610
 Reproducibility Standard Deviation = 0.36296
 h, k Critical Values = 2.51000, 1.78000

CaO XRF, Cements A B, Glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	63.7133	0.1498	0.1971	0.58	1.19
2	63.7000	0.2320	0.1838	0.54	1.84
3	63.6033	0.1350	0.0871	0.26	1.07
4	62.8905	0.1192	-0.6257	-1.85	0.95
5	63.4462	0.1039	-0.0701	-0.21	0.82
6	63.7450	0.1787	0.2288	0.68	1.42
7	63.0617	0.0454	-0.4546	-1.34	0.36
8	63.8283	0.0407	0.3121	0.92	0.32
9	62.8667	0.1388	-0.6496	-1.92	1.10
10	63.8050	0.0848	0.2888	0.85	0.67
11	63.0392	0.0276	-0.4771	-1.41	0.22
12	63.7183	0.0567	0.2021	0.60	0.45
13	63.6280	0.0458	0.1118	0.33	0.36
14	63.7733	0.0857	0.2571	0.76	0.68
15	63.4070	0.2229	-0.1092	-0.32	1.77
16	63.7583	0.1560	0.2421	0.72	1.24
17	63.7917	0.0355	0.2754	0.81	0.28

Average of cell averages = 63.51622
 Standard Deviation of cell averages = 0.33836
 Repeatability Standard Deviation = 0.12610
 Reproducibility Standard Deviation = 0.35740
 h, k Critical Values = 2.51000, 1.78000

CaO XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	64.1583	0.1206	0.2863	0.79	1.14
2	64.1617	0.1412	0.2897	0.80	1.34
3	63.7717	0.0962	-0.1003	-0.28	0.91
4	63.2313	0.0610	-0.6407	-1.77	0.58
5	63.6963	0.0448	-0.1757	-0.48	0.42
6	64.1283	0.1876	0.2563	0.71	1.78
7	63.6500	0.0600	-0.2220	-0.61	0.57
8	64.3050	0.0532	0.4330	1.19	0.50
9	63.5303	0.0934	-0.3417	-0.94	0.88
10	63.9833	0.1065	0.1113	0.31	1.01
11	63.3885	0.0757	-0.4835	-1.33	0.72
12	64.1483	0.1347	0.2763	0.76	1.28
13	63.8647	0.0214	-0.0073	-0.02	0.20
14	64.2767	0.0301	0.4047	1.12	0.29
15	63.2727	0.1657	-0.5993	-1.65	1.57
16	64.3433	0.1421	0.4713	1.30	1.35
17	63.9133	0.0742	0.0413	0.11	0.70

Average of cell averages = 63.87199
 Standard Deviation of cell averages = 0.36279
 Repeatability Standard Deviation = 0.10558
 Reproducibility Standard Deviation = 0.37538
 h, k Critical Values = 2.51000, 1.78000

CaO XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	63.6733	0.1934	0.1711	0.46	1.44
2	63.6983	0.2303	0.1961	0.53	1.71
3	63.6117	0.1606	0.1095	0.29	1.19
4	62.8562	0.1561	-0.6460	-1.74	1.16
5	63.4400	0.0577	-0.0622	-0.17	0.43
6	63.7383	0.1668	0.2361	0.63	1.24
7	62.9967	0.0356	-0.5055	-1.36	0.26
8	63.8200	0.0518	0.3178	0.85	0.39
9	62.7257	0.0616	-0.7765	-2.09	0.46
10	63.8283	0.1333	0.3261	0.88	0.99
11	63.0040	0.0575	-0.4982	-1.34	0.43
12	63.7067	0.0712	0.2045	0.55	0.53
13	63.6203	0.0333	0.1181	0.32	0.25
14	63.8417	0.0833	0.3395	0.91	0.62
15	63.4047	0.2306	-0.0975	-0.26	1.72
16	63.7633	0.1936	0.2611	0.70	1.44
17	63.8083	0.0534	0.3061	0.82	0.40

Average of cell averages = 63.50220
 Standard Deviation of cell averages = 0.37193
 Repeatability Standard Deviation = 0.13443
 Reproducibility Standard Deviation = 0.39165
 h, k Critical Values = 2.51000, 1.78000

CaO XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	63.9297	0.1025	-0.1635	-0.45	0.85
2	63.5705	0.1548	-0.5226	-1.45	1.28
3	64.1467	0.1334	0.0536	0.15	1.10
4	64.0683	0.2013	-0.0248	-0.07	1.67
5	63.8833	0.0476	-0.2098	-0.58	0.39
6	64.2200	0.0759	0.1269	0.35	0.63
7	63.7500	0.1278	-0.3431	-0.95	1.06
8	64.0300	0.1401	-0.0631	-0.18	1.16
9	64.0450	0.0914	-0.0481	-0.13	0.76
10	63.8583	0.1395	-0.2348	-0.65	1.16
11	64.7017	0.0567	0.6086	1.69	0.47
12	64.7167	0.1538	0.6236	1.73	1.27
13	64.0217	0.0866	-0.0714	-0.20	0.72
14	63.5695	0.1675	-0.5236	-1.45	1.39
15	64.2267	0.0850	0.1336	0.37	0.70
16	64.0937	0.1335	0.0005	0.00	1.11
17	64.1800	0.0400	0.0869	0.24	0.33
18	63.4662	0.1279	-0.6269	-1.74	1.06
19	63.9800	0.1073	-0.1131	-0.31	0.89
20	64.7093	0.1647	0.6162	1.71	1.36
21	64.7350	0.1178	0.6419	1.78	0.98
22	64.2778	0.0818	0.1847	0.51	0.68
23	63.9617	0.0773	-0.1315	-0.36	0.64

Average of cell averages = 64.09312
 Standard Deviation of cell averages = 0.36027
 Repeatability Standard Deviation = 0.12072
 Reproducibility Standard Deviation = 0.37674
 h, k Critical Values = 2.59000, 1.79000

CaO XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	63.5562	0.1137	-0.1417	-0.50	1.11
2	63.4558	0.1165	-0.2420	-0.86	1.14
3	63.7900	0.0925	0.0921	0.33	0.90
4	63.6467	0.0703	-0.0512	-0.18	0.69
5	64.0333	0.0850	0.3355	1.19	0.83
6	63.7083	0.0591	0.0105	0.04	0.58
7	63.2683	0.0900	-0.4295	-1.53	0.88
8	63.5617	0.1134	-0.1362	-0.48	1.11
9	63.7367	0.0665	0.0388	0.14	0.65
10	63.5983	0.0279	-0.0995	-0.35	0.27
11	64.1850	0.0997	0.4871	1.73	0.97
12	64.1817	0.1025	0.4838	1.72	1.00
13	63.4417	0.0479	-0.2562	-0.91	0.47
14	63.3940	0.2189	-0.3039	-1.08	2.14
15	63.7867	0.0561	0.0888	0.32	0.55
16	63.5303	0.0568	-0.1675	-0.60	0.55
17	63.5967	0.0850	-0.1012	-0.36	0.83
18	63.4042	0.1049	-0.2937	-1.05	1.02
19	63.4367	0.1037	-0.2612	-0.93	1.01
20	64.0197	0.1144	0.3218	1.15	1.12
21	64.2733	0.1363	0.5755	2.05	1.33
22	63.8872	0.1513	0.1893	0.67	1.48
23	63.5583	0.0659	-0.1395	-0.50	0.64

Average of cell averages = 63.69785
 Standard Deviation of cell averages = 0.28098
 Repeatability Standard Deviation = 0.10254
 Reproducibility Standard Deviation = 0.29616
 h, k Critical Values = 2.59000, 1.79000

CaO XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	63.9270	0.1337	-0.1910	-0.53	1.18
2	63.5670	0.1663	-0.5510	-1.52	1.47
3	64.2083	0.1005	0.0904	0.25	0.89
4	64.1217	0.1155	0.0037	0.01	1.02
5	63.9333	0.0579	-0.1846	-0.51	0.51
6	64.3000	0.0651	0.1820	0.50	0.57
7	63.8967	0.1162	-0.2213	-0.61	1.03
8	64.1133	0.1134	-0.0046	-0.01	1.00
9	64.0717	0.0755	-0.0463	-0.13	0.67
10	63.8350	0.1536	-0.2830	-0.78	1.36
11	64.7167	0.0524	0.5987	1.65	0.46
12	64.7350	0.1247	0.6170	1.71	1.10
13	64.0350	0.1050	-0.0830	-0.23	0.93
14	63.5732	0.1811	-0.5448	-1.51	1.60
15	64.2483	0.0605	0.1304	0.36	0.53
16	64.0127	0.0696	-0.1053	-0.29	0.61
17	64.1950	0.0288	0.0770	0.21	0.25
18	63.4852	0.1265	-0.6328	-1.75	1.12
19	64.0150	0.1283	-0.1030	-0.28	1.13
20	64.7488	0.1806	0.6309	1.74	1.59
21	64.7400	0.1103	0.6220	1.72	0.97
22	64.2910	0.0932	0.1730	0.48	0.82
23	63.9433	0.0753	-0.1746	-0.48	0.66

Average of cell averages = 64.11797
 Standard Deviation of cell averages = 0.36181
 Repeatability Standard Deviation = 0.11330
 Reproducibility Standard Deviation = 0.37630
 h, k Critical Values = 2.59000, 1.79000

CaO XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	63.6030	0.0795	-0.1167	-0.42	0.83
2	63.4658	0.1136	-0.2539	-0.92	1.18
3	63.8383	0.1034	0.1186	0.43	1.08
4	63.6700	0.0616	-0.0497	-0.18	0.64
5	64.0017	0.0643	0.2820	1.03	0.67
6	63.7783	0.0608	0.0586	0.21	0.63
7	63.3767	0.0845	-0.3430	-1.25	0.88
8	63.5850	0.0841	-0.1347	-0.49	0.87
9	63.7433	0.0927	0.0236	0.09	0.96
10	63.6083	0.0688	-0.1114	-0.41	0.72
11	64.2083	0.0747	0.4886	1.78	0.78
12	64.2417	0.0838	0.5220	1.90	0.87
13	63.4667	0.0794	-0.2530	-0.92	0.83
14	63.4353	0.2025	-0.2844	-1.04	2.11
15	63.7883	0.0402	0.0686	0.25	0.42
16	63.4985	0.0454	-0.2212	-0.81	0.47
17	63.6167	0.0918	-0.1030	-0.38	0.95
18	63.4195	0.1002	-0.3002	-1.09	1.04
19	63.4617	0.0601	-0.2580	-0.94	0.63
20	64.0592	0.0942	0.3395	1.24	0.98
21	64.2517	0.1339	0.5320	1.94	1.39
22	63.8885	0.1602	0.1688	0.61	1.67
23	63.5467	0.0731	-0.1730	-0.63	0.76

Average of cell averages = 63.71970
 Standard Deviation of cell averages = 0.27469
 Repeatability Standard Deviation = 0.09613
 Reproducibility Standard Deviation = 0.28837
 h, k Critical Values = 2.59000, 1.79000

Table 6 Precision Statistics CaO by XRF glass and powder preparations for replicates 1 and 2

CaO Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	63.8787	0.3498	0.1061	0.3630	0.30	1.02
2	63.5162	0.3384	0.1261	0.3574	0.35	1.00

CaO Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	63.8720	0.3628	0.1056	0.3754	0.30	1.05
2	63.5022	0.3719	0.1344	0.3916	0.38	1.10

CaO Powder, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	64.0931	0.3603	0.1207	0.3767	0.34	1.05
2	63.6979	0.2810	0.1025	0.2962	0.29	0.83

CaO Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	64.1180	0.3618	0.1133	0.3763	0.32	1.05
2	63.7197	0.2747	0.0961	0.2884	0.27	0.81

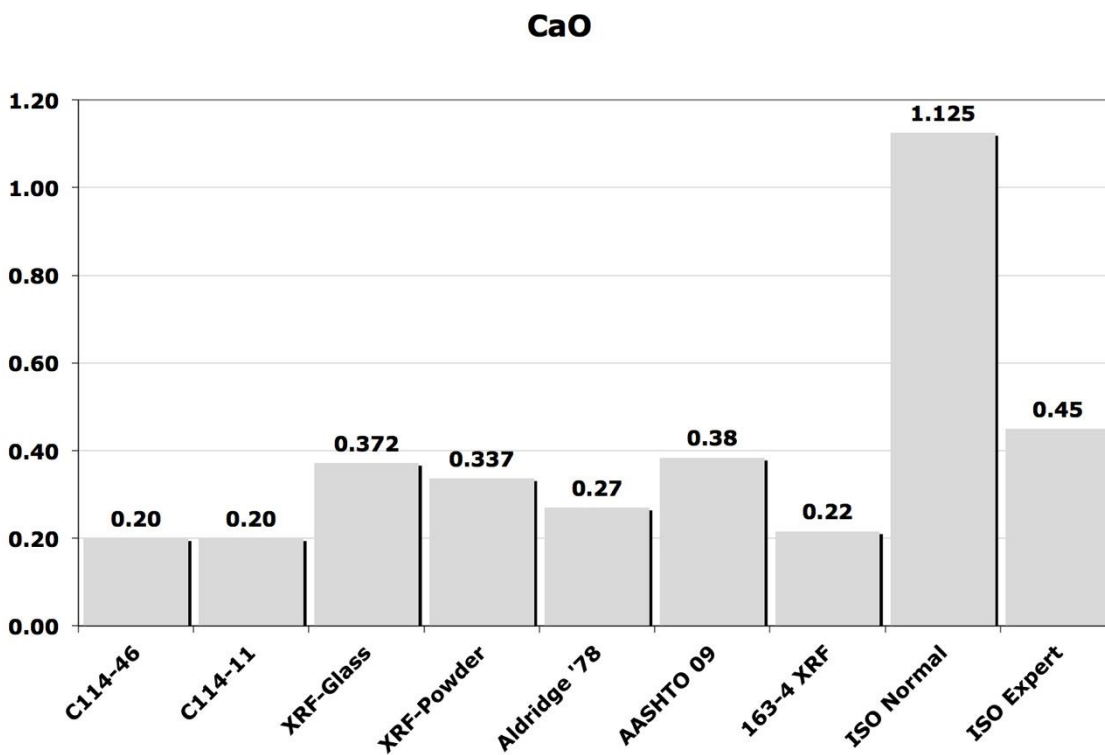


Figure 14 CaO precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

MgO

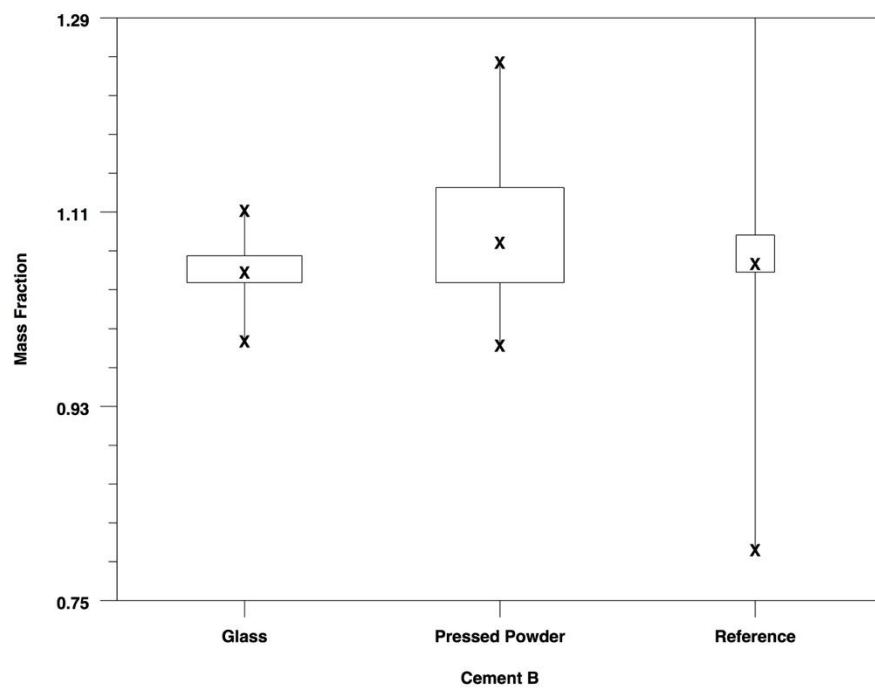
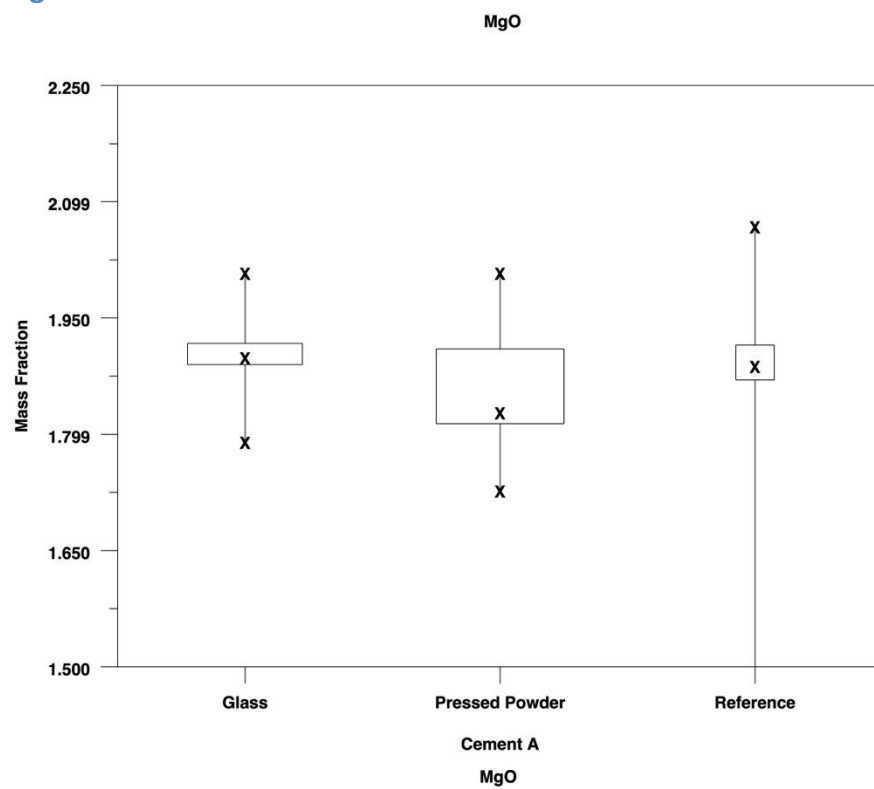


Figure 15 Box plots for MgO XRF glass and powder, and reference methods.

MgO XRF, Cements A B, Glass, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	1.8828	0.0081	-0.0225	-0.81	0.56
2	1.8715	0.0422	-0.0338	-1.22	2.90
3	1.9067	0.0046	0.0013	0.05	0.32
4	1.8983	0.0041	-0.0070	-0.25	0.28
5	1.9037	0.0084	-0.0017	-0.06	0.57
6	1.9050	0.0084	-0.0003	-0.01	0.57
7	1.9867	0.0103	0.0813	2.93	0.71
8	1.9320	0.0049	0.0267	0.96	0.34
9	1.8667	0.0163	-0.0387	-1.39	1.12
10	1.8833	0.0103	-0.0220	-0.79	0.71
11	1.9217	0.0172	0.0163	0.59	1.18
12	1.9317	0.0117	0.0263	0.95	0.80
13	1.8953	0.0173	-0.0100	-0.36	1.19
14	1.8983	0.0075	-0.0070	-0.25	0.52
15	1.8933	0.0137	-0.0120	-0.43	0.94
16	1.9135	0.0044	0.0081	0.29	0.30
17	1.9000	0.0089	-0.0053	-0.19	0.61

Average of cell averages = 1.90532
 Standard Deviation of cell averages = 0.02779
 Repeatability Standard Deviation = 0.01457
 Reproducibility Standard Deviation = 0.03081
 h, k Critical Values = 2.51000, 1.78000

MgO XRF, Cements A B, Glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	1.0490	0.0055	-0.0163	-0.75	0.57
2	1.0372	0.0218	-0.0282	-1.30	2.26
3	1.0603	0.0048	-0.0050	-0.23	0.50
4	1.0683	0.0075	0.0030	0.14	0.78
5	1.0662	0.0035	0.0008	0.04	0.36
6	1.0650	0.0055	-0.0003	-0.02	0.57
7	1.1050	0.0105	0.0397	1.83	1.09
8	1.0785	0.0054	0.0132	0.61	0.56
9	1.1050	0.0105	0.0397	1.83	1.09
10	1.0483	0.0041	-0.0170	-0.78	0.42
11	1.1017	0.0117	0.0363	1.67	1.21
12	1.0583	0.0117	-0.0070	-0.32	1.21
13	1.0445	0.0144	-0.0208	-0.96	1.50
14	1.0417	0.0041	-0.0237	-1.09	0.42
15	1.0750	0.0084	0.0097	0.45	0.87
16	1.0600	0.0031	-0.0053	-0.25	0.32
17	1.0467	0.0103	-0.0187	-0.86	1.07

Average of cell averages = 1.06533
 Standard Deviation of cell averages = 0.02171
 Repeatability Standard Deviation = 0.00962
 Reproducibility Standard Deviation = 0.02342
 h, k Critical Values = 2.51000, 1.78000

MgO XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	1.8907	0.0167	-0.0164	-0.60	1.10
2	1.8750	0.0421	-0.0321	-1.18	2.78
3	1.9087	0.0029	0.0016	0.06	0.19
4	1.8917	0.0075	-0.0154	-0.57	0.50
5	1.9037	0.0072	-0.0034	-0.12	0.47
6	1.9117	0.0117	0.0046	0.17	0.77
7	1.9900	0.0141	0.0829	3.04	0.93
8	1.9298	0.0053	0.0228	0.84	0.35
9	1.8767	0.0163	-0.0304	-1.12	1.08
10	1.8800	0.0063	-0.0271	-0.99	0.42
11	1.9167	0.0121	0.0096	0.35	0.80
12	1.9350	0.0055	0.0279	1.03	0.36
13	1.9130	0.0224	0.0059	0.22	1.48
14	1.9000	0.0155	-0.0071	-0.26	1.02
15	1.8967	0.0082	-0.0104	-0.38	0.54
16	1.9076	0.0048	0.0005	0.02	0.32
17	1.8933	0.0082	-0.0137	-0.50	0.54

Average of cell averages = 1.90706
 Standard Deviation of cell averages = 0.02725
 Repeatability Standard Deviation = 0.01517
 Reproducibility Standard Deviation = 0.03056
 h, k Critical Values = 2.51000, 1.78000

MgO XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	1.0452	0.0040	-0.0196	-1.22	0.46
2	1.0435	0.0229	-0.0213	-1.32	2.62
3	1.0598	0.0050	-0.0050	-0.31	0.58
4	1.0667	0.0103	0.0019	0.12	1.19
5	1.0648	0.0025	0.0000	0.00	0.29
6	1.0667	0.0052	0.0019	0.12	0.59
7	1.0967	0.0052	0.0319	1.98	0.59
8	1.0738	0.0065	0.0090	0.56	0.75
9	1.0933	0.0103	0.0285	1.77	1.19
10	1.0483	0.0041	-0.0165	-1.02	0.47
11	1.0850	0.0084	0.0202	1.25	0.96
12	1.0683	0.0075	0.0035	0.22	0.86
13	1.0585	0.0118	-0.0063	-0.39	1.36
14	1.0500	0.0063	-0.0148	-0.92	0.73
15	1.0750	0.0055	0.0102	0.63	0.63
16	1.0574	0.0011	-0.0074	-0.46	0.13
17	1.0483	0.0075	-0.0165	-1.02	0.86

Average of cell averages = 1.06479
Standard Deviation of cell averages = 0.01613
Repeatability Standard Deviation = 0.00871
Reproducibility Standard Deviation = 0.01798
h, k Critical Values = 2.51000, 1.78000

MgO XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	1.9733	0.0137	0.1191	1.82	1.14
2	1.8267	0.0082	-0.0275	-0.42	0.68
3	1.7952	0.0147	-0.0590	-0.90	1.23
4	1.7403	0.0065	-0.1139	-1.74	0.54
5	1.9083	0.0183	0.0541	0.83	1.54
6	1.8450	0.0138	-0.0092	-0.14	1.16
7	1.8383	0.0133	-0.0159	-0.24	1.11
8	1.9317	0.0041	0.0775	1.18	0.34
9	1.8450	0.0084	-0.0092	-0.14	0.70
10	1.9933	0.0151	0.1391	2.12	1.26
12	1.9183	0.0133	0.0641	0.98	1.11
13	1.9121	0.0041	0.0579	0.88	0.34
14	1.8062	0.0118	-0.0480	-0.73	0.99
17	1.8163	0.0102	-0.0379	-0.58	0.85
18	1.7733	0.0207	-0.0809	-1.23	1.73
19	1.8317	0.0041	-0.0225	-0.34	0.34
20	1.9050	0.0138	0.0508	0.78	1.16
21	1.8161	0.0093	-0.0381	-0.58	0.78
23	1.8183	0.0098	-0.0359	-0.55	0.82
25	1.8235	0.0072	-0.0307	-0.47	0.60
26	1.8200	0.0126	-0.0342	-0.52	1.06

Average of cell averages = 1.85419
 Standard Deviation of cell averages = 0.06550
 Repeatability Standard Deviation = 0.01193
 Reproducibility Standard Deviation = 0.06640
 h, k Critical Values = 2.57000, 1.79000

MgO XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	1.1483	0.0147	0.0467	0.75	1.36
2	1.1200	0.0110	0.0184	0.29	1.01
3	1.1423	0.0105	0.0407	0.65	0.97
4	1.0102	0.0204	-0.0915	-1.46	1.89
5	1.0833	0.0121	-0.0183	-0.29	1.12
6	1.0900	0.0089	-0.0116	-0.19	0.83
7	1.0600	0.0110	-0.0416	-0.66	1.01
8	1.1300	0.0089	0.0284	0.45	0.83
9	1.1050	0.0055	0.0034	0.05	0.51
10	1.2583	0.0041	0.1567	2.50	0.38
12	1.1867	0.0137	0.0850	1.36	1.26
13	1.1969	0.0065	0.0952	1.52	0.60
14	1.1198	0.0124	0.0182	0.29	1.15
17	1.0717	0.0049	-0.0300	-0.48	0.45
18	1.0500	0.0179	-0.0516	-0.82	1.65
19	1.0583	0.0075	-0.0433	-0.69	0.70
20	1.1383	0.0117	0.0367	0.59	1.08
21	1.0504	0.0093	-0.0513	-0.82	0.86
23	1.0417	0.0075	-0.0600	-0.96	0.70
25	1.0245	0.0019	-0.0771	-1.23	0.18
26	1.0483	0.0075	-0.0533	-0.85	0.70

Average of cell averages = 1.10162
 Standard Deviation of cell averages = 0.06267
 Repeatability Standard Deviation = 0.01082
 Reproducibility Standard Deviation = 0.06344
 h, k Critical Values = 2.57000, 1.79000

MgO XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	1.9717	0.0299	0.1176	1.77	2.33
2	1.8267	0.0103	-0.0274	-0.41	0.80
3	1.7955	0.0124	-0.0586	-0.88	0.97
4	1.7405	0.0071	-0.1136	-1.71	0.55
5	1.9133	0.0137	0.0592	0.89	1.06
6	1.8433	0.0052	-0.0108	-0.16	0.40
7	1.8417	0.0194	-0.0124	-0.19	1.51
8	1.9300	0.0089	0.0759	1.15	0.70
9	1.8467	0.0082	-0.0074	-0.11	0.64
10	1.9933	0.0151	0.1392	2.10	1.17
12	1.9233	0.0052	0.0692	1.04	0.40
13	1.9139	0.0046	0.0598	0.90	0.36
14	1.7990	0.0170	-0.0551	-0.83	1.32
17	1.8163	0.0116	-0.0378	-0.57	0.90
18	1.7667	0.0197	-0.0874	-1.32	1.53
19	1.8333	0.0052	-0.0208	-0.31	0.40
20	1.9017	0.0117	0.0476	0.72	0.91
21	1.8145	0.0087	-0.0397	-0.60	0.67
23	1.8233	0.0121	-0.0308	-0.46	0.94
25	1.8184	0.0051	-0.0357	-0.54	0.40
26	1.8233	0.0052	-0.0308	-0.46	0.40

Average of cell averages = 1.85412
 Standard Deviation of cell averages = 0.06626
 Repeatability Standard Deviation = 0.01285
 Reproducibility Standard Deviation = 0.06729
 h, k Critical Values = 2.57000, 1.79000

MgO XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	1.1333	0.0151	0.0334	0.53	1.42
2	1.1317	0.0098	0.0317	0.51	0.92
3	1.1433	0.0069	0.0434	0.69	0.65
4	1.0103	0.0200	-0.0896	-1.43	1.88
5	1.0700	0.0210	-0.0299	-0.48	1.97
6	1.0900	0.0063	-0.0099	-0.16	0.59
7	1.0550	0.0122	-0.0449	-0.72	1.15
8	1.1317	0.0075	0.0317	0.51	0.71
9	1.1050	0.0055	0.0051	0.08	0.52
10	1.2533	0.0052	0.1534	2.45	0.49
12	1.1883	0.0147	0.0884	1.41	1.38
13	1.1979	0.0032	0.0980	1.57	0.30
14	1.1070	0.0061	0.0071	0.11	0.58
17	1.0725	0.0034	-0.0274	-0.44	0.32
18	1.0367	0.0121	-0.0633	-1.01	1.14
19	1.0617	0.0075	-0.0383	-0.61	0.71
20	1.1383	0.0147	0.0384	0.61	1.38
21	1.0493	0.0085	-0.0506	-0.81	0.80
23	1.0467	0.0052	-0.0533	-0.85	0.49
25	1.0246	0.0029	-0.0753	-1.20	0.27
26	1.0517	0.0075	-0.0483	-0.77	0.71

Average of cell averages = 1.09992
 Standard Deviation of cell averages = 0.06252
 Repeatability Standard Deviation = 0.01063
 Reproducibility Standard Deviation = 0.06327
 h, k Critical Values = 2.57000, 1.79000

Table 7 Precision Statistics CaO by XRF glass and powder preparations for replicates 1 and 2

MgO, Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	1.9053	0.0278	0.0146	0.0308	0.04	0.09
2	1.0653	0.0217	0.0096	0.0234	0.03	0.07

MgO, Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	1.9071	0.0272	0.0152	0.0306	0.04	0.09
2	1.0648	0.0161	0.0087	0.0180	0.02	0.05

MgO, Powder, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	1.8542	0.0655	0.0119	0.0664	0.03	0.19
2	1.1016	0.0627	0.0108	0.0634	0.03	0.18

MgO, Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	1.8541	0.0663	0.0128	0.0673	0.04	0.19
2	1.0999	0.0625	0.0106	0.0633	0.03	0.18

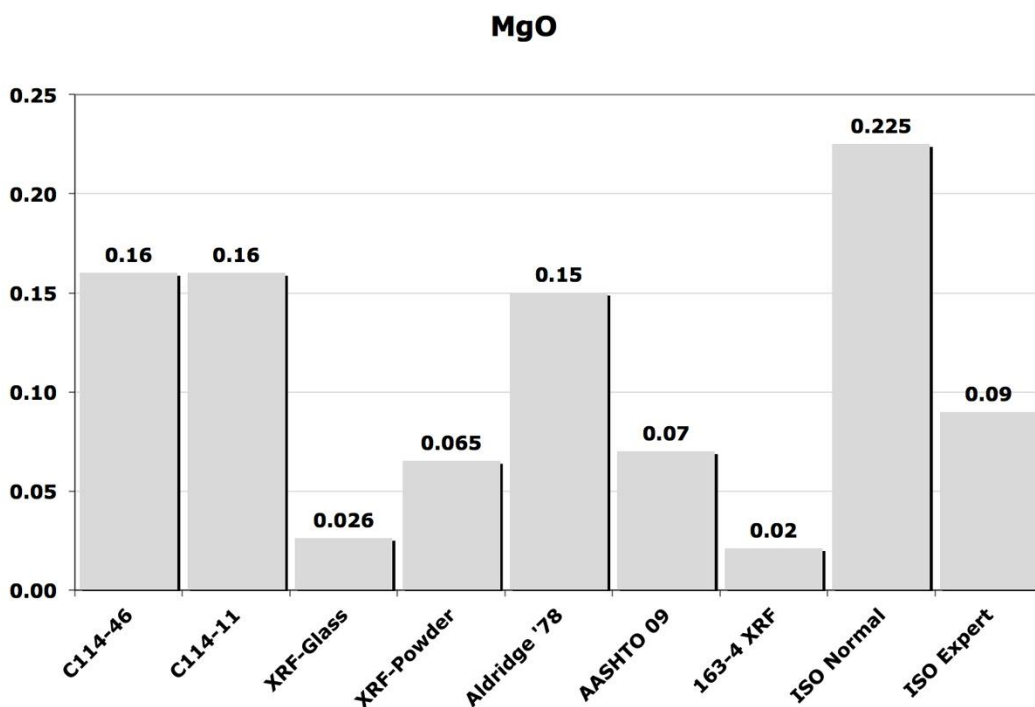


Figure 16 MgO precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

SO₃

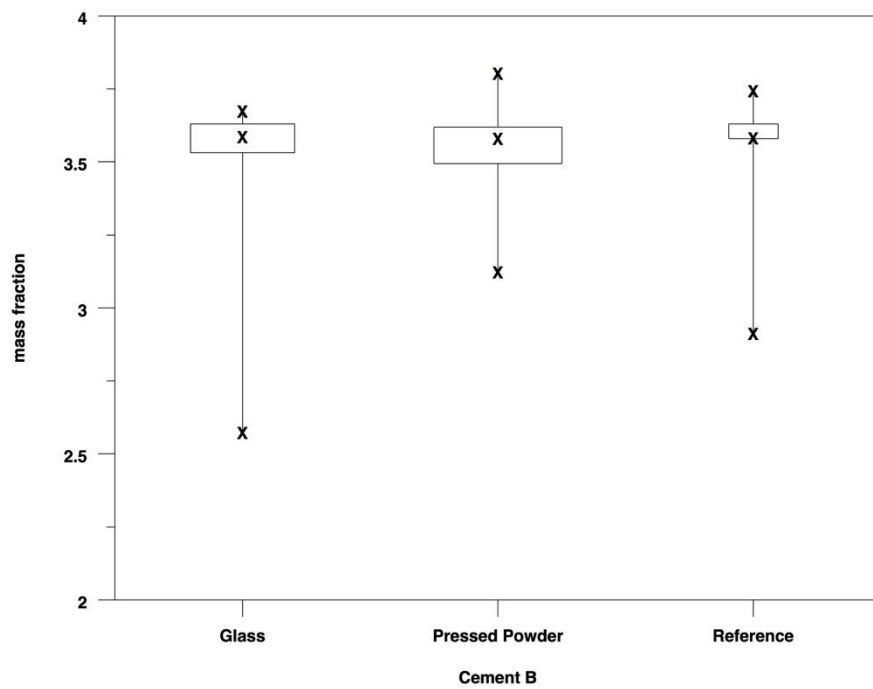
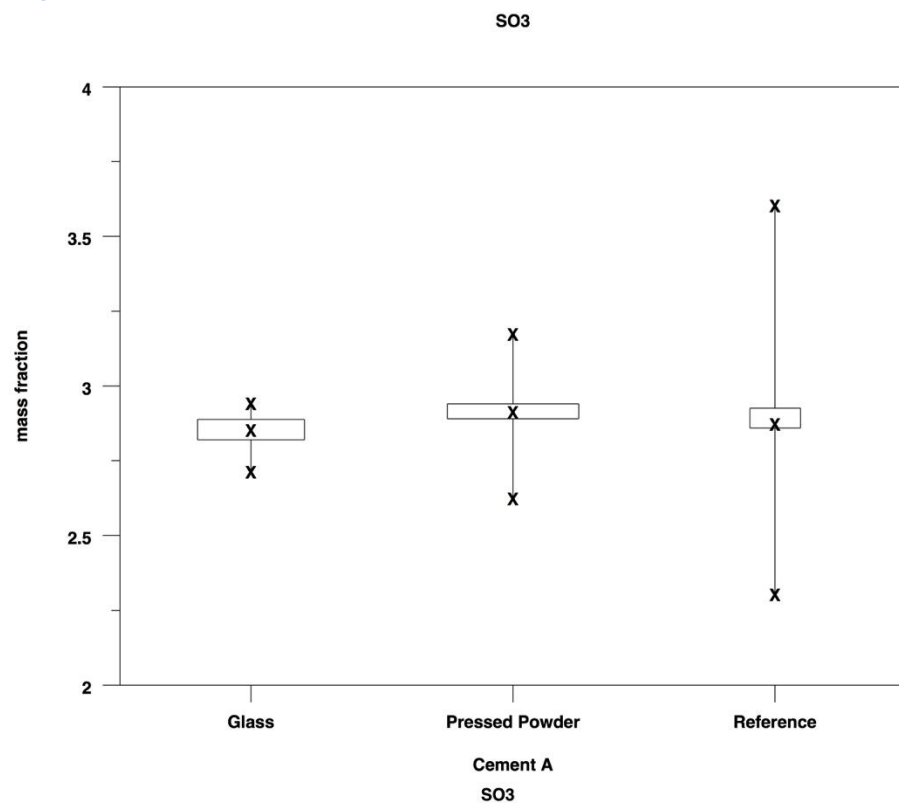


Figure 17 Box plots for SO₃ XRF glass and powder, and reference methods.

SO₃ XRF, Cements A B, Glass, Replicate, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	2.8783	0.0223	0.0270	0.56	0.93
2	2.8483	0.0223	-0.0030	-0.06	0.93
3	2.7650	0.0315	-0.0863	-1.80	1.31
4	2.8285	0.0244	-0.0228	-0.48	1.02
5	2.8458	0.0637	-0.0055	-0.11	2.66
6	2.8382	0.0185	-0.0132	-0.27	0.77
7	2.9002	0.0141	0.0488	1.02	0.59
8	2.8733	0.0103	0.0220	0.46	0.43
9	2.8038	0.0238	-0.0475	-0.99	0.99
10	2.7815	0.0191	-0.0698	-1.46	0.80
11	2.9433	0.0034	0.0920	1.92	0.14
12	2.8883	0.0248	0.0370	0.77	1.04
13	2.8667	0.0121	0.0153	0.32	0.51
14	2.9133	0.0052	0.0620	1.29	0.22
15	2.8150	0.0084	-0.0363	-0.76	0.35
16	2.8317	0.0098	-0.0197	-0.41	0.41

Average of cell averages = 2.85133
 Standard Deviation of cell averages = 0.04798
 Repeatability Standard Deviation = 0.02396
 Reproducibility Standard Deviation = 0.05274
 h, k Critical Values = 2.49000, 1.77000

SO₃ XRF, Cements A B, Glass, Replicate, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	3.6217	0.0133	0.0491	0.64	0.53
2	3.5783	0.0279	0.0057	0.07	1.11
3	3.3883	0.0172	-0.1843	-2.40	0.69
4	3.5190	0.0125	-0.0536	-0.70	0.50
5	3.5933	0.0426	0.0207	0.27	1.70
6	3.5367	0.0140	-0.0359	-0.47	0.56
7	3.6270	0.0406	0.0544	0.71	1.62
8	3.6483	0.0204	0.0757	0.99	0.81
9	3.6090	0.0210	0.0364	0.47	0.84
10	3.4330	0.0477	-0.1396	-1.82	1.90
11	3.6722	0.0099	0.0996	1.30	0.40
12	3.5700	0.0297	-0.0026	-0.03	1.18
13	3.6200	0.0190	0.0474	0.62	0.76
14	3.6350	0.0055	0.0624	0.81	0.22
15	3.5283	0.0098	-0.0443	-0.58	0.39
16	3.5817	0.0194	0.0091	0.12	0.77

Average of cell averages = 3.57261
 Standard Deviation of cell averages = 0.07685
 Repeatability Standard Deviation = 0.02505
 Reproducibility Standard Deviation = 0.08018
 h, k Critical Values = 2.49000, 1.77000

SO₃ XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	2.8767	0.0151	0.0251	0.52	0.66
2	2.8500	0.0179	-0.0015	-0.03	0.78
3	2.7633	0.0403	-0.0882	-1.83	1.77
4	2.8262	0.0211	-0.0254	-0.53	0.93
5	2.8500	0.0605	-0.0015	-0.03	2.65
6	2.8417	0.0238	-0.0099	-0.20	1.04
7	2.9003	0.0123	0.0488	1.01	0.54
8	2.8783	0.0133	0.0268	0.56	0.58
9	2.8000	0.0116	-0.0515	-1.07	0.51
10	2.7828	0.0156	-0.0687	-1.43	0.69
11	2.9417	0.0047	0.0901	1.87	0.21
12	2.8867	0.0151	0.0351	0.73	0.66
13	2.8633	0.0163	0.0118	0.25	0.72
14	2.9150	0.0055	0.0635	1.32	0.24
15	2.8150	0.0105	-0.0365	-0.76	0.46
16	2.8333	0.0103	-0.0182	-0.38	0.45

Average of cell averages = 2.85152
 Standard Deviation of cell averages = 0.04818
 Repeatability Standard Deviation = 0.02279
 Reproducibility Standard Deviation = 0.05248
 h, k Critical Values = 2.49000, 1.77000

SO₃ XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	3.6333	0.0339	0.0695	0.80	0.32
2	3.5883	0.0299	0.0245	0.28	0.29
3	3.3917	0.0133	-0.1722	-1.97	0.13
4	3.5223	0.0205	-0.0415	-0.48	0.20
5	3.5815	0.0448	0.0176	0.20	0.43
6	3.5513	0.0150	-0.0125	-0.14	0.14
7	3.6283	0.0442	0.0645	0.74	0.42
8	3.6483	0.0075	0.0845	0.97	0.07
9	3.6107	0.0275	0.0468	0.54	0.26
10	3.4338	0.0450	-0.1300	-1.49	0.43
11	3.6688	0.0101	0.1050	1.20	0.10
12	3.4050	0.4048	-0.1589	-1.82	3.88
13	3.6183	0.0194	0.0545	0.62	0.19
14	3.6367	0.0082	0.0728	0.83	0.08
15	3.5217	0.0147	-0.0422	-0.48	0.14
16	3.5817	0.0133	0.0178	0.20	0.13

Average of cell averages = 3.56386
 Standard Deviation of cell averages = 0.08729
 Repeatability Standard Deviation = 0.10441
 Reproducibility Standard Deviation = 0.12924
 h, k Critical Values = 2.49000, 1.77000

SO3 XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	2.8200	0.0179	-0.0865	-0.95	0.81
2	2.7333	0.0103	-0.1731	-1.90	0.47
3	2.8917	0.0098	-0.0148	-0.16	0.44
4	2.9000	0.0155	-0.0065	-0.07	0.70
5	2.9260	0.0345	0.0195	0.21	1.56
6	2.9267	0.0082	0.0202	0.22	0.37
7	2.9432	0.0473	0.0367	0.40	2.13
8	2.9767	0.0151	0.0702	0.77	0.68
9	2.7558	0.0070	-0.1507	-1.65	0.31
10	2.9350	0.0187	0.0285	0.31	0.84
11	2.9853	0.0281	0.0789	0.86	1.26
12	2.9065	0.0088	0.0000	0.00	0.40
13	2.9167	0.0242	0.0102	0.11	1.09
14	2.9510	0.0397	0.0445	0.49	1.79
15	2.9083	0.0172	0.0019	0.02	0.78
16	2.8983	0.0117	-0.0081	-0.09	0.53
17	2.9117	0.0117	0.0052	0.06	0.53
18	2.9149	0.0235	0.0085	0.09	1.06
19	3.1517	0.0232	0.2452	2.69	1.04
20	2.9133	0.0121	0.0069	0.08	0.55
21	2.9259	0.0121	0.0194	0.21	0.54
22	2.9517	0.0183	0.0452	0.50	0.83
23	2.9317	0.0223	0.0252	0.28	1.00
24	2.6800	0.0335	-0.2265	-2.48	1.51

Average of cell averages = 2.90647
 Standard Deviation of cell averages = 0.09120
 Repeatability Standard Deviation = 0.02219
 Reproducibility Standard Deviation = 0.09342
 h, k Critical Values = 2.6000, 1.79000

Initial Preparation of Test Result Data for Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	3.4583	0.0133	-0.0925	-0.66	0.50
2	3.3850	0.0084	-0.1658	-1.19	0.31
3	3.5733	0.0121	0.0225	0.16	0.45
4	3.5833	0.0137	0.0325	0.23	0.51
5	3.6122	0.0229	0.0614	0.44	0.86
6	3.5333	0.0250	-0.0175	-0.13	0.94
7	3.6287	0.0414	0.0779	0.56	1.56
8	3.7317	0.0264	0.1809	1.30	0.99
9	3.3085	0.0140	-0.2423	-1.74	0.53
10	3.6217	0.0183	0.0709	0.51	0.69
11	3.7017	0.0380	0.1509	1.08	1.43
12	3.6087	0.0085	0.0579	0.42	0.32
13	3.4567	0.0327	-0.0941	-0.68	1.23
14	3.5835	0.0240	0.0327	0.23	0.90
15	3.6217	0.0232	0.0709	0.51	0.87
16	3.6167	0.0121	0.0659	0.47	0.45
17	3.1650	0.0259	-0.3858	-2.77	0.97
18	3.6148	0.0393	0.0640	0.46	1.48
19	3.7883	0.0147	0.2375	1.71	0.55
20	3.6050	0.0295	0.0542	0.39	1.11
21	3.5445	0.0123	-0.0063	-0.05	0.46
22	3.5450	0.0235	-0.0058	-0.04	0.88
23	3.5883	0.0382	0.0375	0.27	1.43
24	3.3433	0.0550	-0.2075	-1.49	2.07

Average of cell averages = 3.55080
 Standard Deviation of cell averages = 0.13932
 Repeatability Standard Deviation = 0.02662
 Reproducibility Standard Deviation = 0.14142
 h, k Critical Values = 2.6000, 1.79000

SO₃ XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	2.8217	0.0194	-0.0848	-0.92	0.89
2	2.7467	0.0082	-0.1598	-1.74	0.38
3	2.8983	0.0117	-0.0082	-0.09	0.54
4	2.9067	0.0151	0.0002	0.00	0.69
5	2.9267	0.0342	0.0202	0.22	1.57
6	2.9267	0.0052	0.0202	0.22	0.24
7	2.9443	0.0487	0.0378	0.41	2.24
8	2.9800	0.0167	0.0735	0.80	0.77
9	2.7500	0.0069	-0.1565	-1.70	0.32
10	2.9350	0.0105	0.0285	0.31	0.48
11	2.9782	0.0261	0.0717	0.78	1.20
12	2.9080	0.0060	0.0015	0.02	0.27
13	2.9217	0.0223	0.0152	0.17	1.02
14	2.9507	0.0420	0.0442	0.48	1.93
15	2.9067	0.0294	0.0002	0.00	1.35
16	2.9017	0.0075	-0.0048	-0.05	0.35
17	2.9150	0.0084	0.0085	0.09	0.38
18	2.9170	0.0254	0.0105	0.11	1.17
19	3.1517	0.0223	0.2452	2.67	1.02
20	2.9100	0.0126	0.0035	0.04	0.58
21	2.9260	0.0123	0.0195	0.21	0.57
22	2.9550	0.0187	0.0485	0.53	0.86
23	2.9133	0.0103	0.0068	0.07	0.47
24	2.6650	0.0259	-0.2415	-2.63	1.19

Average of cell averages = 2.90649
 Standard Deviation of cell averages = 0.09196
 Repeatability Standard Deviation = 0.02176
 Reproducibility Standard Deviation = 0.09408
 h, k Critical Values = 2.60000, 1.79000

SO₃ XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	3.4600	0.0155	-0.0921	-0.67	0.64
2	3.3983	0.0098	-0.1538	-1.11	0.40
3	3.5750	0.0176	0.0229	0.17	0.73
4	3.5900	0.0110	0.0379	0.27	0.45
5	3.6128	0.0217	0.0607	0.44	0.89
6	3.5450	0.0308	-0.0071	-0.05	1.27
7	3.6270	0.0390	0.0749	0.54	1.60
8	3.7317	0.0264	0.1795	1.30	1.09
9	3.3030	0.0164	-0.2491	-1.80	0.68
10	3.6200	0.0155	0.0679	0.49	0.64
11	3.7005	0.0367	0.1484	1.07	1.51
12	3.6133	0.0061	0.0612	0.44	0.25
13	3.4583	0.0319	-0.0938	-0.68	1.31
14	3.5858	0.0236	0.0337	0.24	0.97
15	3.6100	0.0141	0.0579	0.42	0.58
16	3.6183	0.0133	0.0662	0.48	0.55
17	3.1617	0.0299	-0.3905	-2.83	1.23
18	3.6172	0.0382	0.0650	0.47	1.57
19	3.7883	0.0147	0.2362	1.71	0.61
20	3.6050	0.0243	0.0529	0.38	1.00
21	3.5466	0.0137	-0.0055	-0.04	0.57
22	3.5417	0.0194	-0.0105	-0.08	0.80
23	3.5800	0.0283	0.0279	0.20	1.16
24	3.3617	0.0371	-0.1905	-1.38	1.53

Average of cell averages = 3.55214
 Standard Deviation of cell averages = 0.13804
 Repeatability Standard Deviation = 0.02428
 Reproducibility Standard Deviation = 0.13980
 h, k Critical Values = 2.60000, 1.79000

Table 8 Precision Statistics SO₃ by XRF glass and powder preparations for replicates 1 and 2.

SO₃ Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	2.8513	0.0480	0.0240	0.0527	0.07	0.15
2	3.5726	0.0769	0.0250	0.0802	0.07	0.22

SO₃ Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	2.8515	0.0482	0.0228	0.0525	0.06	0.15
2	3.5639	0.0873	0.1044	0.1292	0.29	0.36

SO₃ Powder, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	2.9065	0.0912	0.0222	0.0934	0.06	0.26
2	3.5508	0.1393	0.0266	0.1414	0.07	0.40

SO₃ Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	2.9065	0.0920	0.0218	0.0941	0.06	0.26
2	3.5521	0.1380	0.0243	0.1398	0.07	0.39

SO₃

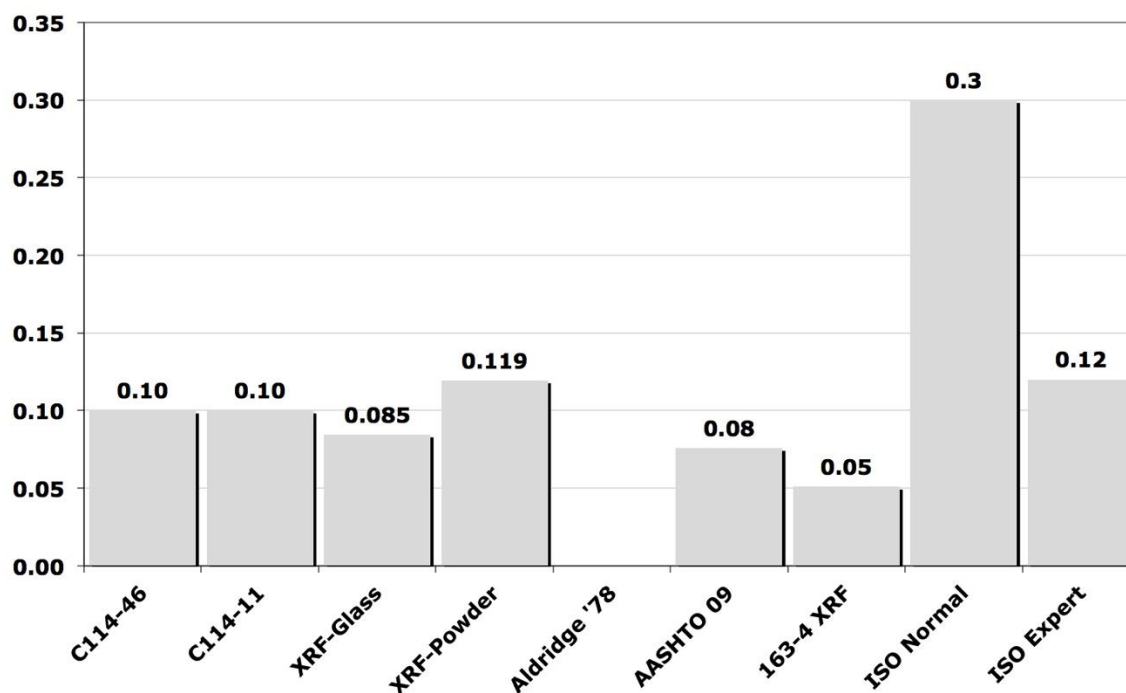


Figure 18 SO₃ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

Na₂O

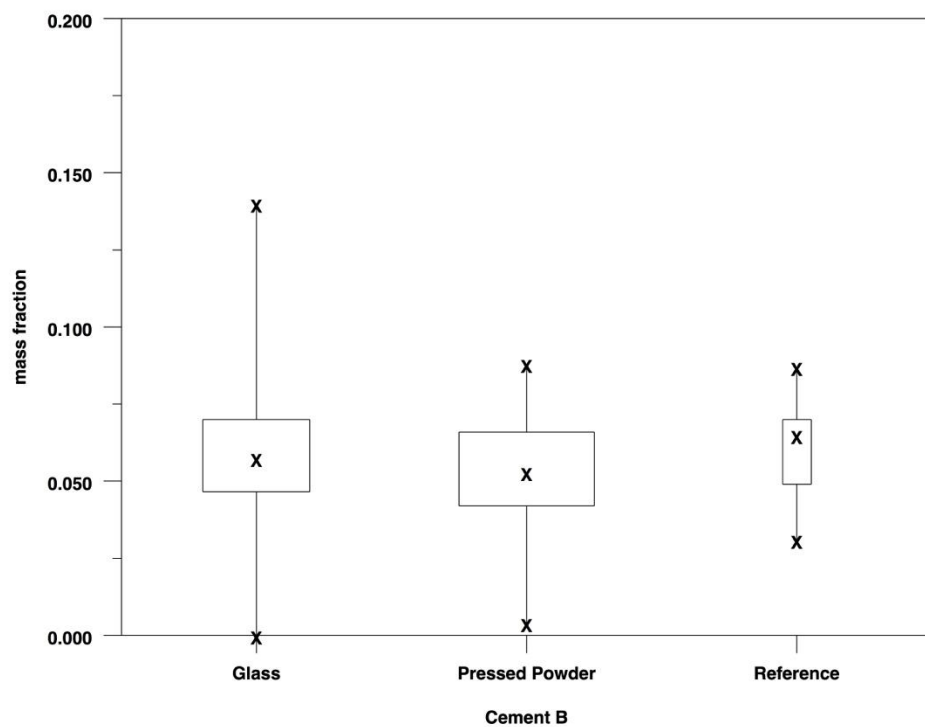
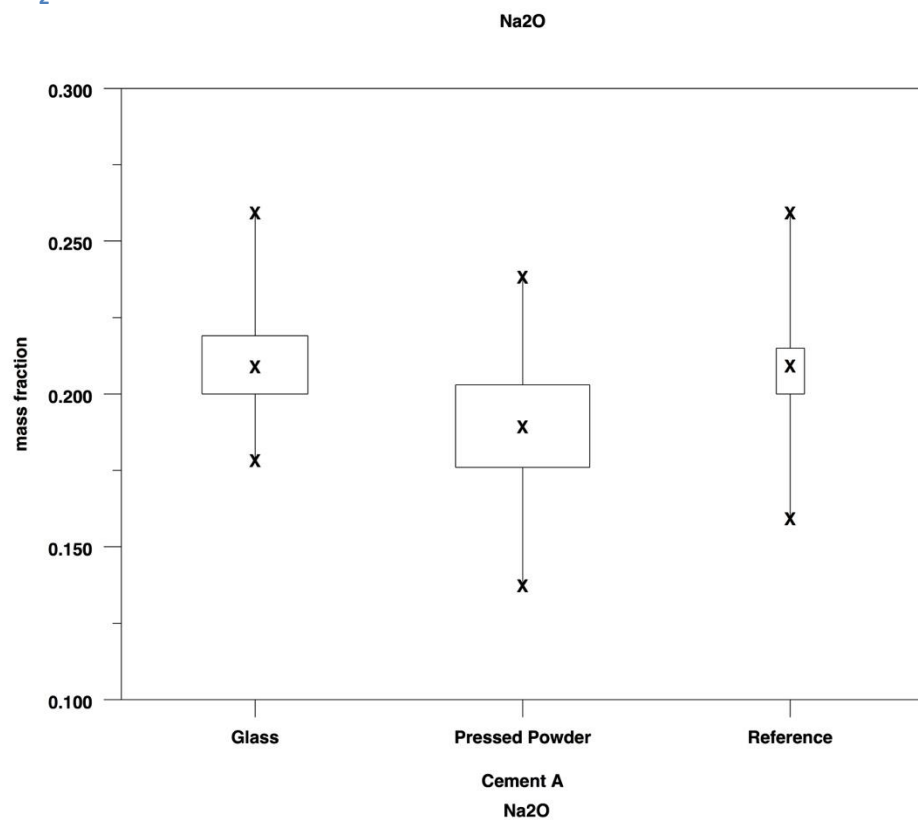


Figure 19 Box plots for Na₂O XRF glass and powder, and reference methods.

Na₂O XRF, Cements A B, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.1950	0.0055	-0.0148	-1.06	0.61
2	0.1983	0.0041	-0.0115	-0.82	0.46
3	0.2350	0.0138	0.0252	1.80	1.55
4	0.2083	0.0098	-0.0015	-0.10	1.10
5	0.2023	0.0057	-0.0075	-0.53	0.64
6	0.2105	0.0005	0.0007	0.05	0.05
7	0.1867	0.0082	-0.0231	-1.65	0.92
8	0.2182	0.0065	0.0084	0.60	0.73
9	0.2300	0.0141	0.0202	1.44	1.59
10	0.2056	0.0036	-0.0042	-0.30	0.41
11	0.2097	0.0051	-0.0001	-0.01	0.57
12	0.2133	0.0082	0.0035	0.25	0.92
13	0.2293	0.0181	0.0195	1.39	2.03
14	0.2115	0.0052	0.0017	0.12	0.58
15	0.1932	0.0076	-0.0166	-1.19	0.85

Average of cell averages = 0.20979
 Standard Deviation of cell averages = 0.01401
 Repeatability Standard Deviation = 0.00892
 Reproducibility Standard Deviation = 0.01620
 h, k Critical Values = 2.47000, 1.77000

Na₂O XRF, Cements A B, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0417	0.0117	-0.0153	-0.67	1.51
2	0.0617	0.0075	0.0047	0.21	0.97
3	0.0967	0.0103	0.0397	1.75	1.34
4	0.0450	0.0055	-0.0119	-0.53	0.71
5	0.0587	0.0028	0.0017	0.08	0.36
6	0.0556	0.0003	-0.0013	-0.06	0.04
7	0.0000	0.0000	-0.0569	-2.51	0.00
8	0.0710	0.0022	0.0141	0.62	0.28
9	0.0900	0.0110	0.0331	1.46	1.42
10	0.0456	0.0041	-0.0114	-0.50	0.52
11	0.0418	0.0073	-0.0151	-0.66	0.94
12	0.0633	0.0052	0.0064	0.28	0.67
13	0.0697	0.0156	0.0127	0.56	2.02
14	0.0650	0.0035	0.0081	0.36	0.45
15	0.0482	0.0091	-0.0088	-0.39	1.17

Average of cell averages = 0.05692
 Standard Deviation of cell averages = 0.02270
 Repeatability Standard Deviation = 0.00773
 Reproducibility Standard Deviation = 0.02378
 h, k Critical Values = 2.47000, 1.77000

Na₂O XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.1950	0.0105	-0.0148	-1.18	1.26
2	0.2000	0.0063	-0.0098	-0.78	0.76
3	0.2350	0.0138	0.0252	2.02	1.66
4	0.2100	0.0063	0.0002	0.02	0.76
5	0.2023	0.0023	-0.0074	-0.59	0.28
6	0.2102	0.0009	0.0004	0.03	0.11
7	0.1900	0.0126	-0.0198	-1.58	1.52
8	0.2190	0.0085	0.0092	0.74	1.02
9	0.2283	0.0117	0.0186	1.49	1.41
10	0.2120	0.0035	0.0022	0.18	0.43
11	0.2057	0.0057	-0.0041	-0.33	0.68
12	0.2083	0.0075	-0.0014	-0.11	0.91
13	0.2223	0.0107	0.0126	1.01	1.29
14	0.2115	0.0036	0.0017	0.14	0.43
15	0.1967	0.0073	-0.0131	-1.05	0.88

Average of cell averages = 0.20975
 Standard Deviation of cell averages = 0.01249
 Repeatability Standard Deviation = 0.00831
 Reproducibility Standard Deviation = 0.01461
 h, k Critical Values = 2.47000, 1.77000

Na₂O XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0450	0.0084	-0.0179	-0.64	0.19
2	0.0583	0.0075	-0.0046	-0.16	0.18
3	0.1067	0.0175	0.0437	1.56	0.41
4	0.0467	0.0103	-0.0163	-0.58	0.24
5	0.0570	0.0025	-0.0059	-0.21	0.06
6	0.0557	0.0007	-0.0072	-0.26	0.02
7	0.0000	0.0000	-0.0629	-2.25	0.00
8	0.0700	0.0027	0.0071	0.25	0.06
9	0.0933	0.0052	0.0304	1.09	0.12
10	0.1141	0.1626	0.0511	1.83	3.78
11	0.0447	0.0080	-0.0183	-0.65	0.19
12	0.0633	0.0052	0.0004	0.01	0.12
13	0.0777	0.0202	0.0147	0.53	0.47
14	0.0643	0.0028	0.0014	0.05	0.07
15	0.0472	0.0129	-0.0158	-0.56	0.30

Average of cell averages = 0.06293
 Standard Deviation of cell averages = 0.02798
 Repeatability Standard Deviation = 0.04297
 Reproducibility Standard Deviation = 0.04818
 h, k Critical Values = 2.47000, 1.77000

Na₂O XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.2000	0.0000	0.0138	0.71	0.00
2	0.1817	0.0041	-0.0045	-0.23	0.82
3	0.1773	0.0022	-0.0088	-0.46	0.43
4	0.1817	0.0117	-0.0045	-0.23	2.34
5	0.2027	0.0063	0.0165	0.85	1.26
6	0.2000	0.0000	0.0138	0.71	0.00
7	0.1517	0.0041	-0.0345	-1.78	0.82
8	0.2100	0.0000	0.0238	1.23	0.00
9	0.1883	0.0041	0.0022	0.11	0.82
10	0.2000	0.0063	0.0138	0.71	1.26
11	0.2083	0.0041	0.0222	1.14	0.82
12	0.2055	0.0015	0.0193	1.00	0.30
13	0.2055	0.0024	0.0193	1.00	0.49
14	0.1769	0.0010	-0.0093	-0.48	0.20
15	0.1475	0.0049	-0.0387	-2.00	0.98
16	0.1817	0.0041	-0.0045	-0.23	0.82
17	0.1548	0.0069	-0.0313	-1.62	1.37
18	0.1758	0.0035	-0.0103	-0.53	0.70
19	0.2102	0.0071	0.0240	1.24	1.42
20	0.1683	0.0098	-0.0178	-0.92	1.96
21	0.1877	0.0049	0.0015	0.08	0.98
22	0.2105	0.0019	0.0243	1.26	0.37
23	0.1684	0.0015	-0.0177	-0.91	0.29
24	0.1733	0.0052	-0.0128	-0.66	1.03

Average of cell averages = 0.18616
 Standard Deviation of cell averages = 0.01936
 Repeatability Standard Deviation = 0.00500
 Reproducibility Standard Deviation = 0.01990
 h, k Critical Values = 2.60000, 1.79000

Na₂O XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0550	0.0055	0.0024	0.13	0.92
2	0.0517	0.0041	-0.0010	-0.05	0.69
3	0.0583	0.0052	0.0057	0.31	0.87
4	0.0650	0.0055	0.0124	0.68	0.92
5	0.0687	0.0053	0.0161	0.88	0.89
6	0.0700	0.0000	0.0174	0.95	0.00
7	0.0150	0.0055	-0.0376	-2.07	0.92
8	0.0600	0.0000	0.0074	0.40	0.00
9	0.0450	0.0055	-0.0076	-0.42	0.92
10	0.0517	0.0041	-0.0010	-0.05	0.69
11	0.0750	0.0055	0.0224	1.23	0.92
12	0.0668	0.0015	0.0142	0.78	0.25
13	0.0843	0.0023	0.0317	1.74	0.39
14	0.0457	0.0003	-0.0070	-0.38	0.05
15	0.0088	0.0038	-0.0438	-2.41	0.64
16	0.0250	0.0084	-0.0276	-1.52	1.41
17	0.0482	0.0199	-0.0045	-0.25	3.34
18	0.0413	0.0023	-0.0113	-0.62	0.39
19	0.0580	0.0073	0.0054	0.29	1.23
20	0.0467	0.0052	-0.0060	-0.33	0.87
21	0.0725	0.0047	0.0199	1.09	0.79
22	0.0627	0.0031	0.0100	0.55	0.52
23	0.0479	0.0028	-0.0048	-0.26	0.47
24	0.0400	0.0000	-0.0126	-0.69	0.00

Average of cell averages = 0.05264
 Standard Deviation of cell averages = 0.01819
 Repeatability Standard Deviation = 0.00595
 Reproducibility Standard Deviation = 0.01898
 h, k Critical Values = 2.60000, 1.79000

Na₂O XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.2000	0.0000	0.0132	0.68	0.00
2	0.1833	0.0052	-0.0035	-0.18	0.98
3	0.1783	0.0027	-0.0085	-0.44	0.52
4	0.1867	0.0052	-0.0002	-0.01	0.98
5	0.2033	0.0064	0.0165	0.85	1.21
6	0.2000	0.0000	0.0132	0.68	0.00
7	0.1517	0.0041	-0.0352	-1.81	0.77
8	0.2100	0.0000	0.0232	1.19	0.00
9	0.1900	0.0000	0.0032	0.16	0.00
10	0.2000	0.0063	0.0132	0.68	1.20
11	0.2050	0.0055	0.0182	0.94	1.04
12	0.2058	0.0013	0.0190	0.98	0.25
13	0.2073	0.0023	0.0205	1.06	0.44
14	0.1767	0.0003	-0.0102	-0.52	0.05
15	0.1490	0.0020	-0.0378	-1.95	0.38
16	0.1850	0.0055	-0.0018	-0.10	1.04
17	0.1528	0.0087	-0.0340	-1.75	1.64
18	0.1757	0.0039	-0.0112	-0.58	0.74
19	0.2143	0.0132	0.0275	1.42	2.49
20	0.1700	0.0089	-0.0168	-0.87	1.69
21	0.1870	0.0064	0.0002	0.01	1.22
22	0.2092	0.0031	0.0223	1.15	0.58
23	0.1665	0.0042	-0.0203	-1.05	0.80
24	0.1767	0.0052	-0.0102	-0.53	0.98

Average of cell averages = 0.18685
 Standard Deviation of cell averages = 0.01938
 Repeatability Standard Deviation = 0.00528
 Reproducibility Standard Deviation = 0.01997
 h, k Critical Values = 2.60000, 1.79000

Na₂O XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0550	0.0055	0.0029	0.16	1.08
2	0.0533	0.0052	0.0013	0.07	1.02
3	0.0603	0.0059	0.0083	0.46	1.16
4	0.0633	0.0052	0.0113	0.62	1.02
5	0.0685	0.0066	0.0165	0.91	1.29
6	0.0700	0.0000	0.0179	0.99	0.00
7	0.0150	0.0055	-0.0371	-2.05	1.08
8	0.0600	0.0000	0.0079	0.44	0.00
9	0.0450	0.0055	-0.0071	-0.39	1.08
10	0.0517	0.0041	-0.0004	-0.02	0.81
11	0.0750	0.0055	0.0229	1.27	1.08
12	0.0658	0.0013	0.0138	0.76	0.26
13	0.0835	0.0008	0.0314	1.74	0.17
14	0.0456	0.0002	-0.0065	-0.36	0.03
15	0.0140	0.0017	-0.0381	-2.11	0.33
16	0.0250	0.0084	-0.0271	-1.50	1.65
17	0.0322	0.0137	-0.0199	-1.10	2.70
18	0.0435	0.0029	-0.0086	-0.47	0.58
19	0.0590	0.0034	0.0069	0.38	0.67
20	0.0417	0.0041	-0.0104	-0.58	0.81
21	0.0717	0.0058	0.0196	1.08	1.15
22	0.0632	0.0027	0.0111	0.61	0.54
23	0.0475	0.0026	-0.0045	-0.25	0.52
24	0.0400	0.0000	-0.0121	-0.67	0.00

Average of cell averages = 0.05208
 Standard Deviation of cell averages = 0.01807
 Repeatability Standard Deviation = 0.00506
 Reproducibility Standard Deviation = 0.01865
 h, k Critical Values = 2.60000, 1.79000

Table 9 Precision Statistics Na₂O by XRF glass and powder preparations for replicates 1 and 2.

Na₂O Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	0.2098	0.0140	0.0089	0.0162	0.02	0.05
2	0.0569	0.0227	0.0077	0.0238	0.02	0.07

Na₂O Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	0.2098	0.0125	0.0083	0.0146	0.02	0.04
2	0.0629	0.0280	0.0430	0.0482	0.12	0.13

Na₂O Powder, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	0.1862	0.0194	0.0050	0.0199	0.01	0.06
2	0.0526	0.0182	0.0060	0.0190	0.02	0.05

Na₂O Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	0.1868	0.0194	0.0053	0.0200	0.01	0.06
2	0.0521	0.0181	0.0051	0.0187	0.01	0.05

Na₂O

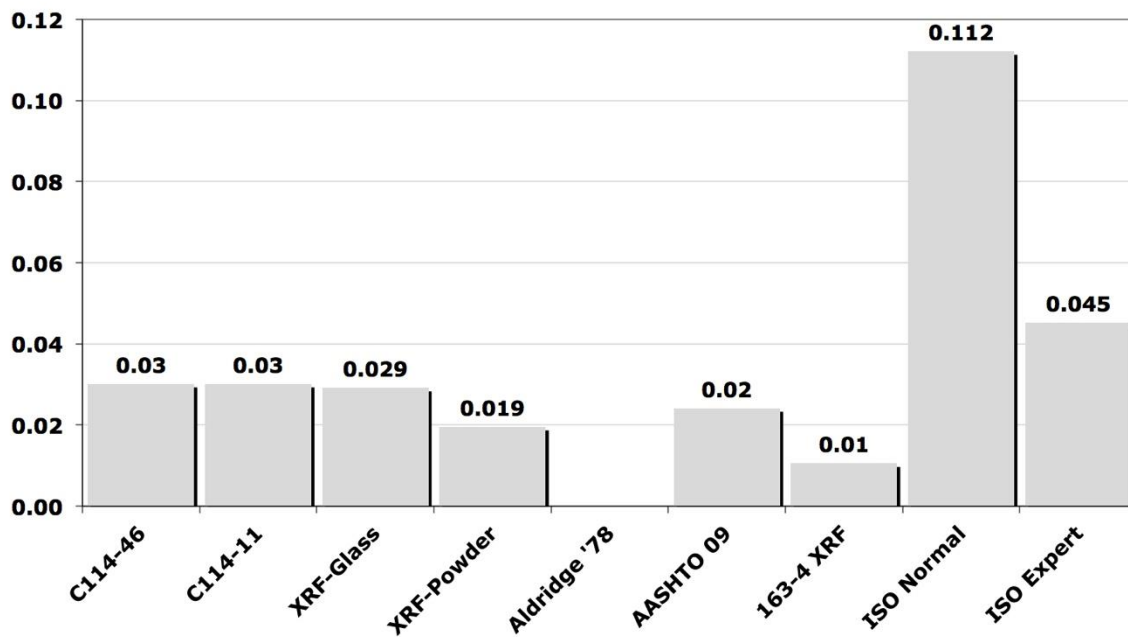


Figure 20 Na₂O precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

K₂O

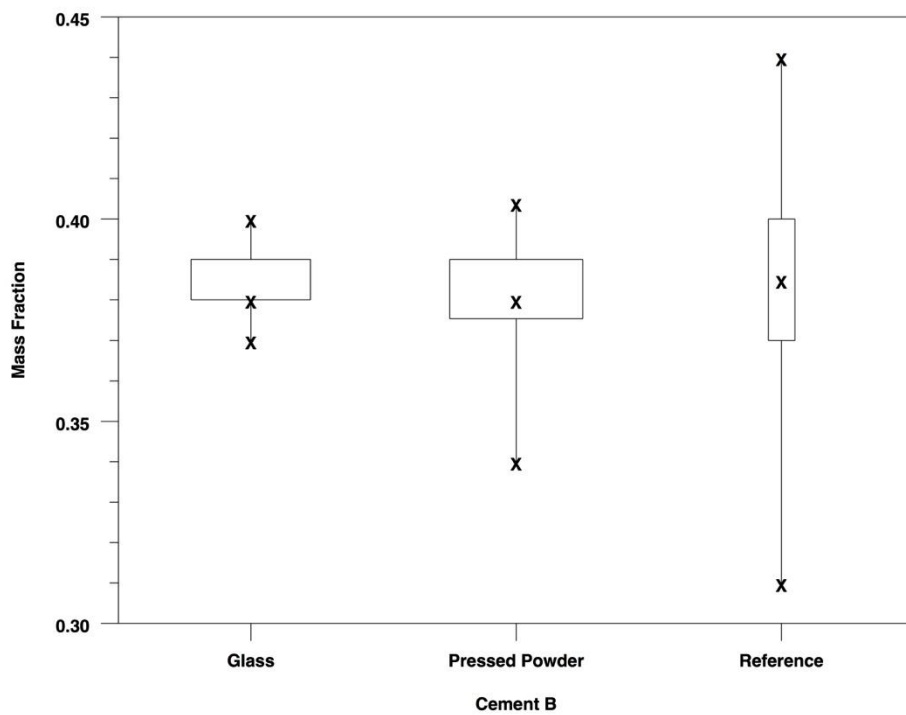
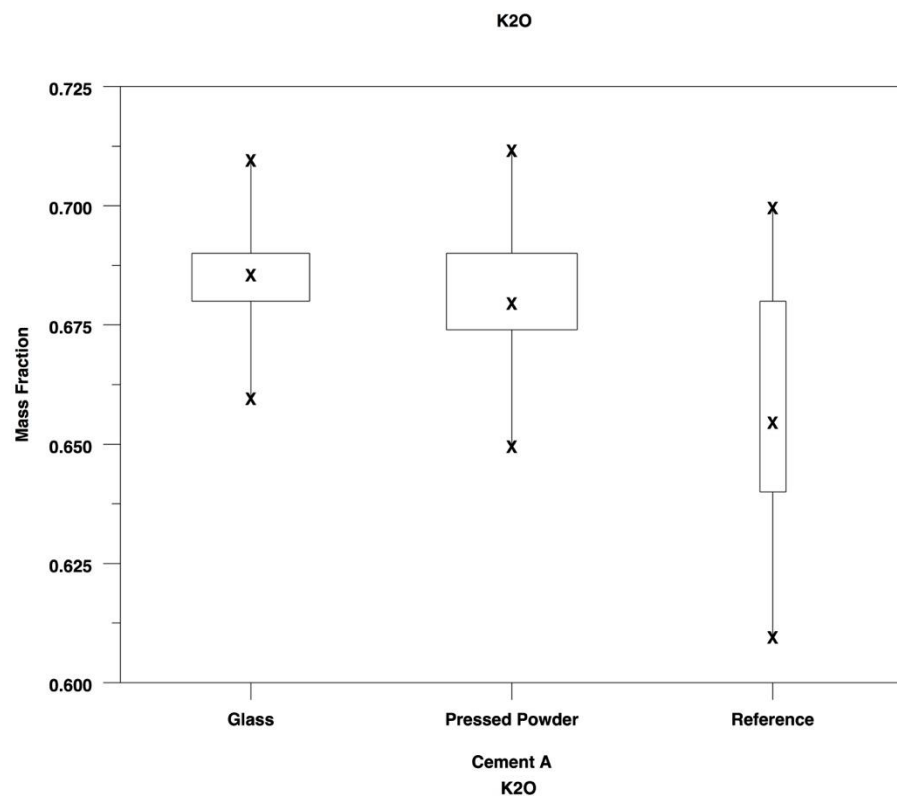


Figure 21 Box plots for K₂O XRF glass and powder, and reference methods.

K₂O XRF, Cements A B, Glass, Replicate 1, Material 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.6800	0.0000	-0.0064	-0.67	0.00
2	0.6800	0.0000	-0.0064	-0.67	0.00
3	0.6878	0.0042	0.0014	0.14	0.97
4	0.7067	0.0052	0.0202	2.09	1.21
5	0.6917	0.0041	0.0052	0.54	0.95
6	0.6817	0.0075	-0.0048	-0.49	1.76
7	0.6985	0.0020	0.0121	1.25	0.47
8	0.6767	0.0028	-0.0098	-1.01	0.65
9	0.7050	0.0055	0.0186	1.92	1.28
10	0.6742	0.0060	-0.0123	-1.27	1.40
11	0.6850	0.0055	-0.0014	-0.15	1.28
12	0.6834	0.0019	-0.0031	-0.32	0.44
13	0.6897	0.0015	0.0032	0.33	0.35
14	0.6883	0.0041	0.0019	0.20	0.95
15	0.6843	0.0033	-0.0021	-0.22	0.76
16	0.6733	0.0052	-0.0131	-1.36	1.21
17	0.6833	0.0052	-0.0031	-0.32	1.21

Average of cell averages = 0.68645
 Standard Deviation of cell averages = 0.00966
 Repeatability Standard Deviation = 0.00428
 Reproducibility Standard Deviation = 0.01042
 h, k Critical Values = 2.51000, 1.78000

K₂O XRF, Cements A B, Glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3817	0.0041	-0.0017	-0.33	1.16
2	0.3800	0.0000	-0.0034	-0.66	0.00
3	0.3890	0.0022	0.0056	1.10	0.62
4	0.3850	0.0055	0.0016	0.32	1.56
5	0.3917	0.0041	0.0083	1.62	1.16
6	0.3800	0.0000	-0.0034	-0.66	0.00
7	0.3932	0.0013	0.0098	1.92	0.36
8	0.3808	0.0017	-0.0025	-0.49	0.49
9	0.3850	0.0055	0.0016	0.32	1.56
10	0.3828	0.0044	-0.0005	-0.10	1.24
11	0.3817	0.0041	-0.0017	-0.33	1.16
12	0.3782	0.0014	-0.0052	-1.02	0.41
13	0.3862	0.0017	0.0028	0.55	0.49
14	0.3883	0.0041	0.0050	0.97	1.16
15	0.3803	0.0048	-0.0030	-0.59	1.37
16	0.3733	0.0052	-0.0100	-1.96	1.47
17	0.3800	0.0000	-0.0034	-0.66	0.00

Average of cell averages = 0.38336
 Standard Deviation of cell averages = 0.00511
 Repeatability Standard Deviation = 0.00351
 Reproducibility Standard Deviation = 0.00604
 h, k Critical Values = 2.51000, 1.78000

K₂O XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.6733	0.0082	-0.0130	-1.29	1.70
2	0.6800	0.0000	-0.0064	-0.63	0.00
3	0.6900	0.0037	0.0036	0.36	0.78
4	0.7067	0.0052	0.0203	2.00	1.07
5	0.6933	0.0052	0.0070	0.69	1.07
6	0.6833	0.0052	-0.0030	-0.30	1.07
7	0.6976	0.0023	0.0112	1.10	0.49
8	0.6755	0.0052	-0.0109	-1.07	1.08
9	0.7050	0.0055	0.0186	1.84	1.14
10	0.6757	0.0067	-0.0107	-1.06	1.39
11	0.6850	0.0055	-0.0014	-0.14	1.14
12	0.6835	0.0016	-0.0029	-0.28	0.34
13	0.6900	0.0021	0.0036	0.36	0.44
14	0.6867	0.0052	0.0003	0.03	1.07
15	0.6845	0.0042	-0.0019	-0.19	0.87
16	0.6717	0.0041	-0.0147	-1.45	0.85
17	0.6867	0.0052	0.0003	0.03	1.07

Average of cell averages = 0.68638
Standard Deviation of cell averages = 0.01013
Repeatability Standard Deviation = 0.00480
Reproducibility Standard Deviation = 0.01104
h, k Critical Values = 2.51000, 1.78000

K₂O XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3800	0.0000	-0.0030	-0.58	0.00
2	0.3800	0.0000	-0.0030	-0.58	0.00
3	0.3882	0.0022	0.0052	1.00	0.65
4	0.3883	0.0041	0.0053	1.03	1.18
5	0.3900	0.0000	0.0070	1.35	0.00
6	0.3800	0.0000	-0.0030	-0.58	0.00
7	0.3930	0.0010	0.0100	1.94	0.28
8	0.3800	0.0017	-0.0030	-0.58	0.49
9	0.3850	0.0055	0.0020	0.38	1.59
10	0.3812	0.0056	-0.0018	-0.36	1.63
11	0.3800	0.0063	-0.0030	-0.58	1.83
12	0.3785	0.0016	-0.0045	-0.86	0.46
13	0.3858	0.0017	0.0028	0.54	0.50
14	0.3883	0.0041	0.0053	1.03	1.18
15	0.3795	0.0051	-0.0035	-0.68	1.49
16	0.3733	0.0052	-0.0097	-1.87	1.50
17	0.3800	0.0000	-0.0030	-0.58	0.00

Average of cell averages = 0.38301
 Standard Deviation of cell averages = 0.00517
 Repeatability Standard Deviation = 0.00345
 Reproducibility Standard Deviation = 0.00606
 h, k Critical Values = 2.51000, 1.78000

K₂O XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.6732	0.0008	-0.0092	-0.75	0.16
2	0.6617	0.0041	-0.0207	-1.69	0.86
3	0.7022	0.0033	0.0198	1.61	0.69
4	0.6800	0.0000	-0.0024	-0.19	0.00
5	0.6767	0.0052	-0.0057	-0.47	1.09
6	0.6767	0.0052	-0.0057	-0.47	1.09
7	0.6900	0.0063	0.0076	0.62	1.34
8	0.6900	0.0063	0.0076	0.62	1.34
9	0.6833	0.0052	0.0009	0.08	1.09
10	0.6833	0.0052	0.0009	0.08	1.09
11	0.6800	0.0000	-0.0024	-0.19	0.00
12	0.6733	0.0052	-0.0091	-0.74	1.09
13	0.6824	0.0059	0.0000	0.00	1.26
14	0.7083	0.0041	0.0259	2.11	0.86
15	0.6562	0.0010	-0.0262	-2.13	0.21
16	0.6972	0.0078	0.0148	1.20	1.65
17	0.6883	0.0075	0.0059	0.48	1.59
18	0.6738	0.0021	-0.0086	-0.70	0.45
19	0.6750	0.0055	-0.0074	-0.60	1.16
20	0.6901	0.0024	0.0077	0.63	0.51
21	0.6883	0.0041	0.0059	0.48	0.86

Average of cell averages = 0.68238
Standard Deviation of cell averages = 0.01228
Repeatability Standard Deviation = 0.00473
Reproducibility Standard Deviation = 0.01302
h, k Critical Values = 2.57000, 1.79000

K₂O XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3782	0.0030	-0.0019	-0.18	0.78
2	0.3800	0.0000	-0.0001	-0.01	0.00
3	0.3935	0.0012	0.0134	1.28	0.32
4	0.3800	0.0000	-0.0001	-0.01	0.00
5	0.3483	0.0041	-0.0317	-3.03	1.06
6	0.3700	0.0000	-0.0101	-0.96	0.00
7	0.3717	0.0041	-0.0084	-0.80	1.06
8	0.3833	0.0052	0.0033	0.31	1.35
9	0.3817	0.0075	0.0016	0.15	1.96
10	0.3833	0.0052	0.0033	0.31	1.35
11	0.3700	0.0000	-0.0101	-0.96	0.00
12	0.3883	0.0041	0.0083	0.79	1.06
13	0.3737	0.0015	-0.0064	-0.61	0.39
14	0.3933	0.0052	0.0133	1.26	1.35
15	0.3761	0.0008	-0.0040	-0.38	0.21
16	0.3955	0.0057	0.0154	1.47	1.48
17	0.3883	0.0041	0.0083	0.79	1.06
18	0.3825	0.0032	0.0024	0.23	0.84
19	0.3883	0.0041	0.0083	0.79	1.06
20	0.3805	0.0018	0.0005	0.04	0.48
21	0.3750	0.0055	-0.0051	-0.48	1.43

Average of cell averages = 0.38008
 Standard Deviation of cell averages = 0.01048
 Repeatability Standard Deviation = 0.00384
 Reproducibility Standard Deviation = 0.01105
 h, k Critical Values = 2.57000, 1.79000

K₂O XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.6728	0.0010	-0.0095	-0.76	0.21
2	0.6583	0.0041	-0.0240	-1.92	0.87
3	0.7022	0.0029	0.0198	1.58	0.62
4	0.6800	0.0000	-0.0023	-0.19	0.00
5	0.6767	0.0052	-0.0057	-0.45	1.10
6	0.6783	0.0041	-0.0040	-0.32	0.87
7	0.6900	0.0063	0.0077	0.61	1.34
8	0.6883	0.0041	0.0060	0.48	0.87
9	0.6833	0.0082	0.0010	0.08	1.73
10	0.6867	0.0052	0.0043	0.35	1.10
11	0.6800	0.0000	-0.0023	-0.19	0.00
12	0.6750	0.0055	-0.0073	-0.59	1.16
13	0.6823	0.0064	0.0000	0.00	1.36
14	0.7083	0.0041	0.0260	2.08	0.87
15	0.6552	0.0006	-0.0271	-2.17	0.13
16	0.6975	0.0072	0.0152	1.21	1.54
17	0.6900	0.0063	0.0077	0.61	1.34
18	0.6743	0.0026	-0.0080	-0.64	0.55
19	0.6767	0.0052	-0.0057	-0.45	1.10
20	0.6896	0.0023	0.0073	0.58	0.49
21	0.6833	0.0052	0.0010	0.08	1.10

Average of cell averages = 0.68233
 Standard Deviation of cell averages = 0.01252
 Repeatability Standard Deviation = 0.00471
 Reproducibility Standard Deviation = 0.01324
 h, k Critical Values = 2.57000, 1.79000

K₂O XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3782	0.0026	-0.0019	-0.19	0.74
2	0.3783	0.0041	-0.0017	-0.17	1.14
3	0.3937	0.0012	0.0136	1.32	0.34
4	0.3800	0.0000	-0.0001	-0.01	0.00
5	0.3483	0.0041	-0.0317	-3.08	1.14
6	0.3700	0.0000	-0.0101	-0.98	0.00
7	0.3717	0.0041	-0.0084	-0.82	1.14
8	0.3833	0.0052	0.0033	0.32	1.45
9	0.3817	0.0041	0.0016	0.15	1.14
10	0.3833	0.0052	0.0033	0.32	1.45
11	0.3700	0.0000	-0.0101	-0.98	0.00
12	0.3867	0.0052	0.0066	0.64	1.45
13	0.3735	0.0020	-0.0066	-0.64	0.56
14	0.3933	0.0052	0.0133	1.29	1.45
15	0.3760	0.0007	-0.0041	-0.40	0.20
16	0.3952	0.0056	0.0151	1.46	1.56
17	0.3867	0.0052	0.0066	0.64	1.45
18	0.3832	0.0022	0.0031	0.30	0.62
19	0.3883	0.0041	0.0083	0.80	1.14
20	0.3803	0.0016	0.0002	0.02	0.45
21	0.3800	0.0000	-0.0001	-0.01	0.00

Average of cell averages = 0.38008
 Standard Deviation of cell averages = 0.01031
 Repeatability Standard Deviation = 0.00357
 Reproducibility Standard Deviation = 0.01081
 h, k Critical Values = 2.57000, 1.79000

Table 10 Precision Statistics K₂O by XRF glass and powder preparations for replicates 1 and 2.

K₂O Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	0.6864	0.0097	0.0043	0.0104	0.01	0.03
2	0.3834	0.0051	0.0035	0.0060	0.01	0.02

K₂O Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	0.6864	0.0101	0.0048	0.0110	0.01	0.03
2	0.3830	0.0052	0.0034	0.0061	0.01	0.02

K₂O Powder, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	0.6824	0.0123	0.0047	0.0130	0.01	0.04
2	0.3801	0.0105	0.0038	0.0110	0.01	0.03

K₂O Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	0.6823	0.0125	0.0047	0.0132	0.01	0.04
2	0.3801	0.0103	0.0036	0.0108	0.01	0.03

K₂O

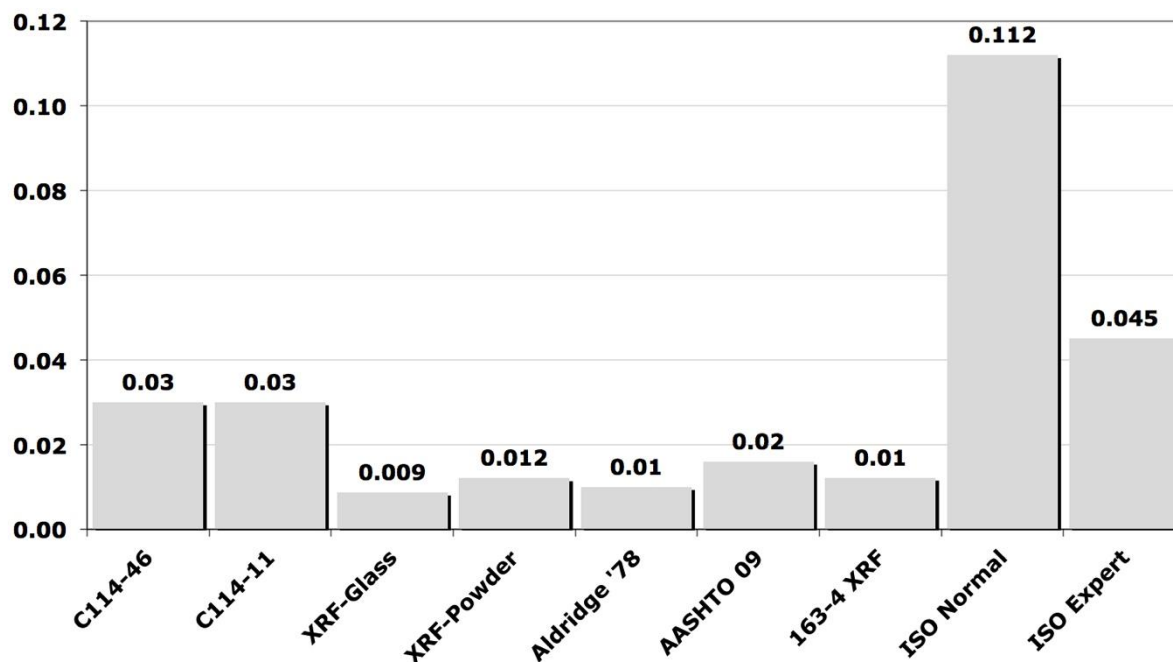


Figure 22 K₂O precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

TiO₂

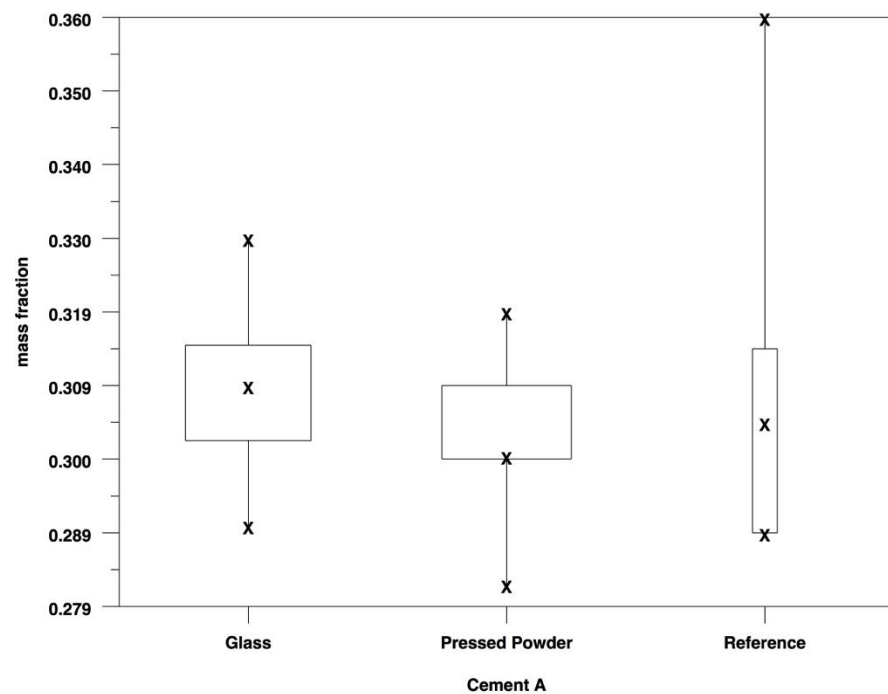
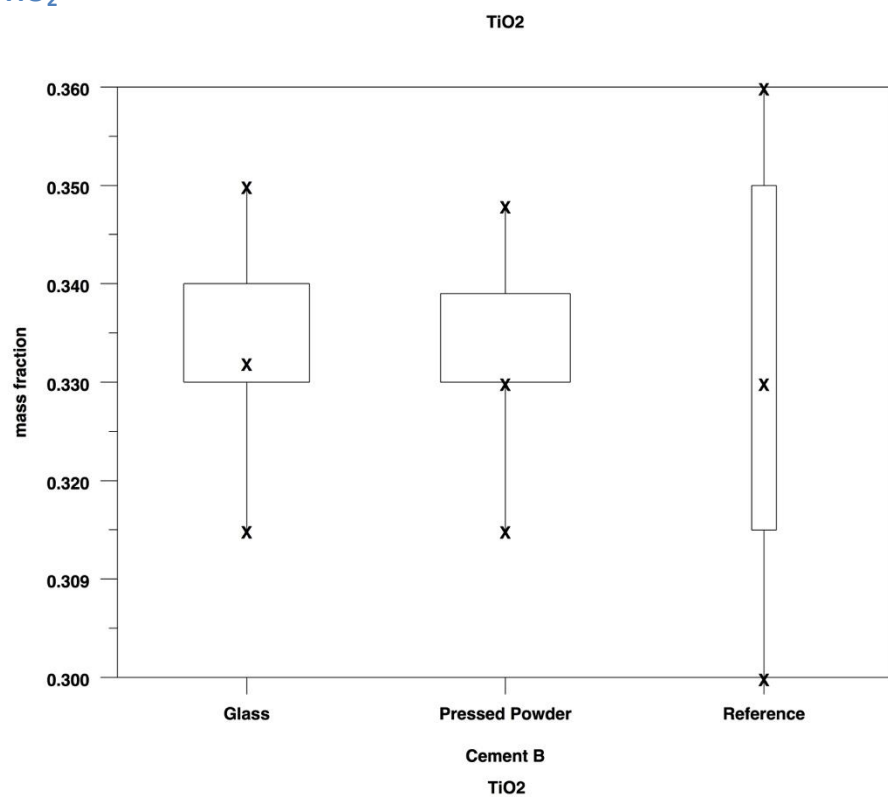


Figure 23 Box plots for TiO₂ XRF glass and powder, and reference methods

TiO₂ XRF, Cements A B, Glass, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3200	0.0000	0.0105	1.58	0.00
2	0.3097	0.0042	0.0002	0.03	1.05
3	0.3083	0.0041	-0.0011	-0.17	1.02
4	0.3083	0.0018	-0.0011	-0.17	0.44
5	0.3200	0.0000	0.0105	1.58	0.00
6	0.3023	0.0068	-0.0071	-1.07	1.70
7	0.3185	0.0029	0.0090	1.36	0.72
8	0.3050	0.0055	-0.0045	-0.67	1.36
9	0.3120	0.0010	0.0026	0.39	0.25
10	0.3167	0.0052	0.0072	1.08	1.28
11	0.3055	0.0016	-0.0040	-0.59	0.41
12	0.3067	0.0052	-0.0028	-0.42	1.28
13	0.3160	0.0033	0.0065	0.98	0.82
14	0.3033	0.0052	-0.0061	-0.92	1.28
15	0.2983	0.0021	-0.0111	-1.67	0.51
16	0.3033	0.0052	-0.0061	-0.92	1.28
17	0.3067	0.0052	-0.0028	-0.42	1.28

Average of cell averages = 0.30945
 Standard Deviation of cell averages = 0.00666
 Repeatability Standard Deviation = 0.00402
 Reproducibility Standard Deviation = 0.00760
 h, k Critical Values = 2.51000, 1.78000

TiO₂ XRF, Cements A B, Glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3433	0.0052	0.0094	1.43	1.16
2	0.3353	0.0033	0.0014	0.21	0.74
3	0.3350	0.0055	0.0010	0.16	1.23
4	0.3330	0.0014	-0.0010	-0.15	0.32
5	0.3433	0.0052	0.0094	1.43	1.16
6	0.3278	0.0038	-0.0061	-0.94	0.86
7	0.3413	0.0041	0.0074	1.12	0.93
8	0.3267	0.0052	-0.0073	-1.12	1.16
9	0.3422	0.0006	0.0082	1.25	0.13
10	0.3400	0.0000	0.0060	0.92	0.00
11	0.3312	0.0013	-0.0028	-0.43	0.30
12	0.3333	0.0052	-0.0006	-0.10	1.16
13	0.3382	0.0046	0.0042	0.64	1.03
14	0.3283	0.0041	-0.0056	-0.86	0.92
15	0.3237	0.0067	-0.0103	-1.57	1.50
16	0.3250	0.0055	-0.0090	-1.37	1.23
17	0.3300	0.0063	-0.0040	-0.61	1.42

Average of cell averages = 0.33398
 Standard Deviation of cell averages = 0.00656
 Repeatability Standard Deviation = 0.00444
 Reproducibility Standard Deviation = 0.00771
 h, k Critical Values = 2.51000, 1.78000

TiO₂ XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3200	0.0000	0.0106	1.59	0.00
2	0.3097	0.0066	0.0003	0.04	1.53
3	0.3083	0.0041	-0.0010	-0.16	0.94
4	0.3070	0.0009	-0.0024	-0.35	0.21
5	0.3217	0.0041	0.0123	1.84	0.94
6	0.3033	0.0066	-0.0060	-0.90	1.52
7	0.3190	0.0049	0.0096	1.44	1.12
8	0.3000	0.0000	-0.0094	-1.40	0.00
9	0.3120	0.0014	0.0026	0.39	0.32
10	0.3133	0.0052	0.0040	0.59	1.19
11	0.3048	0.0012	-0.0045	-0.68	0.27
12	0.3050	0.0055	-0.0044	-0.65	1.27
13	0.3168	0.0025	0.0075	1.12	0.57
14	0.3033	0.0052	-0.0060	-0.90	1.19
15	0.3033	0.0061	-0.0060	-0.90	1.41
16	0.3033	0.0052	-0.0060	-0.90	1.19
17	0.3083	0.0041	-0.0010	-0.16	0.94

Average of cell averages = 0.30937
 Standard Deviation of cell averages = 0.00669
 Repeatability Standard Deviation = 0.00432
 Reproducibility Standard Deviation = 0.00777
 h, k Critical Values = 2.51000, 1.78000

TiO₂ XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3433	0.0052	0.0101	1.42	1.18
2	0.3350	0.0053	0.0017	0.25	1.22
3	0.3333	0.0052	0.0001	0.01	1.18
4	0.3323	0.0018	-0.0009	-0.13	0.40
5	0.3433	0.0052	0.0101	1.42	1.18
6	0.3263	0.0055	-0.0069	-0.98	1.26
7	0.3427	0.0040	0.0094	1.33	0.92
8	0.3283	0.0041	-0.0049	-0.70	0.94
9	0.3430	0.0005	0.0097	1.37	0.12
10	0.3400	0.0000	0.0067	0.95	0.00
11	0.3305	0.0019	-0.0028	-0.39	0.43
12	0.3267	0.0052	-0.0066	-0.93	1.18
13	0.3365	0.0038	0.0032	0.46	0.87
14	0.3283	0.0041	-0.0049	-0.70	0.94
15	0.3225	0.0064	-0.0108	-1.52	1.46
16	0.3250	0.0055	-0.0083	-1.17	1.26
17	0.3283	0.0041	-0.0049	-0.70	0.94

Average of cell averages = 0.33326
 Standard Deviation of cell averages = 0.00708
 Repeatability Standard Deviation = 0.00436
 Reproducibility Standard Deviation = 0.00812
 h, k Critical Values = 2.51000, 1.78000

TiO₂ XRF, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.2907	0.0014	-0.0112	-1.59	0.47
2	0.3025	0.0019	0.0006	0.09	0.65
3	0.3000	0.0000	-0.0019	-0.26	0.00
4	0.3127	0.0024	0.0108	1.53	0.84
5	0.3022	0.0036	0.0003	0.04	1.25
6	0.3000	0.0000	-0.0019	-0.26	0.00
7	0.2873	0.0041	-0.0145	-2.06	1.43
8	0.2933	0.0052	-0.0085	-1.21	1.79
9	0.3059	0.0010	0.0040	0.57	0.35
10	0.3067	0.0041	0.0048	0.68	1.42
11	0.2963	0.0035	-0.0056	-0.79	1.20
12	0.2983	0.0041	-0.0035	-0.50	1.42
13	0.3100	0.0000	0.0081	1.15	0.00
14	0.3000	0.0000	-0.0019	-0.26	0.00
15	0.3115	0.0022	0.0096	1.36	0.75
16	0.3033	0.0052	0.0015	0.21	1.79
17	0.3100	0.0000	0.0081	1.15	0.00
18	0.3030	0.0020	0.0011	0.16	0.68

Average of cell averages = 0.30187
 Standard Deviation of cell averages = 0.00706
 Repeatability Standard Deviation = 0.00288
 Reproducibility Standard Deviation = 0.00754
 h, k Critical Values = 2.51000, 1.78000

TiO₂ XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3210	0.0029	-0.0112	-1.67	1.01
2	0.3347	0.0008	0.0025	0.37	0.28
3	0.3300	0.0000	-0.0022	-0.32	0.00
4	0.3417	0.0029	0.0095	1.42	1.03
5	0.3370	0.0040	0.0048	0.72	1.39
6	0.3317	0.0041	-0.0005	-0.08	1.42
7	0.3317	0.0018	-0.0005	-0.08	0.61
8	0.3217	0.0041	-0.0105	-1.57	1.42
9	0.3414	0.0004	0.0092	1.38	0.14
10	0.3388	0.0012	0.0067	1.00	0.41
11	0.3222	0.0023	-0.0100	-1.49	0.79
12	0.3250	0.0055	-0.0072	-1.07	1.91
13	0.3383	0.0041	0.0062	0.92	1.42
14	0.3317	0.0041	-0.0005	-0.08	1.42
15	0.3407	0.0019	0.0085	1.27	0.65
16	0.3300	0.0000	-0.0022	-0.32	0.00
17	0.3300	0.0000	-0.0022	-0.32	0.00
18	0.3316	0.0022	-0.0005	-0.08	0.76

Average of cell averages = 0.33217
 Standard Deviation of cell averages = 0.00669
 Repeatability Standard Deviation = 0.00287
 Reproducibility Standard Deviation = 0.00718
 h, k Critical Values = 2.51000, 1.78000

TiO₂ XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.2908	0.0026	-0.0117	-1.70	0.77
2	0.3030	0.0011	0.0005	0.07	0.33
3	0.3000	0.0000	-0.0025	-0.37	0.00
4	0.3117	0.0022	0.0091	1.33	0.65
5	0.3053	0.0027	0.0028	0.41	0.82
6	0.3000	0.0000	-0.0025	-0.37	0.00
7	0.2893	0.0027	-0.0132	-1.92	0.82
8	0.2950	0.0055	-0.0075	-1.10	1.65
9	0.3053	0.0006	0.0028	0.41	0.17
10	0.3087	0.0039	0.0061	0.89	1.17
11	0.2973	0.0018	-0.0052	-0.76	0.54
12	0.2983	0.0075	-0.0042	-0.61	2.27
13	0.3117	0.0041	0.0091	1.33	1.23
14	0.3033	0.0052	0.0008	0.11	1.55
15	0.3125	0.0014	0.0100	1.45	0.42
16	0.3017	0.0041	-0.0009	-0.13	1.23
17	0.3100	0.0000	0.0075	1.09	0.00
18	0.3018	0.0020	-0.0008	-0.11	0.61

Average of cell averages = 0.30254
 Standard Deviation of cell averages = 0.00687
 Repeatability Standard Deviation = 0.00332
 Reproducibility Standard Deviation = 0.00751
 h, k Critical Values = 2.53000, 1.78000

TiO₂ XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.3202	0.0029	-0.0121	-1.70	0.87
2	0.3332	0.0024	0.0009	0.12	0.73
3	0.3300	0.0000	-0.0023	-0.32	0.00
4	0.3413	0.0050	0.0091	1.27	1.52
5	0.3378	0.0043	0.0056	0.78	1.30
6	0.3283	0.0041	-0.0039	-0.55	1.25
7	0.3305	0.0028	-0.0018	-0.25	0.86
8	0.3250	0.0055	-0.0073	-1.02	1.67
9	0.3413	0.0005	0.0091	1.27	0.16
10	0.3405	0.0023	0.0082	1.15	0.69
11	0.3223	0.0025	-0.0100	-1.40	0.75
12	0.3250	0.0055	-0.0073	-1.02	1.67
13	0.3400	0.0000	0.0077	1.08	0.00
14	0.3317	0.0041	-0.0006	-0.09	1.25
15	0.3442	0.0016	0.0119	1.67	0.49
16	0.3300	0.0000	-0.0023	-0.32	0.00
17	0.3283	0.0041	-0.0039	-0.55	1.25
18	0.3313	0.0021	-0.0009	-0.13	0.64

Average of cell averages = 0.33228
 Standard Deviation of cell averages = 0.00712
 Repeatability Standard Deviation = 0.00328
 Reproducibility Standard Deviation = 0.00773
 h, k Critical Values = 2.53000, 1.78000

Table 11 Precision Statistics TiO₂ by XRF glass and powder preparations for replicates 1 and 2.

TiO₂ Glass, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	0.3095	0.0067	0.0040	0.0076	0.01	0.02
2	0.3340	0.0066	0.0044	0.0077	0.01	0.02

TiO₂ Glass, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	0.3094	0.0067	0.0043	0.0078	0.01	0.02
2	0.3333	0.0071	0.0044	0.0081	0.01	0.02

TiO₂ Powder, Replicate 1

Material	Xbar	s_x	s_r	s_R	r	R
1	0.3019	0.0071	0.0029	0.0075	0.01	0.02
2	0.3322	0.0067	0.0029	0.0072	0.01	0.02

TiO₂ Powder, Replicate 2

Material	Xbar	s_x	s_r	s_R	r	R
1	0.3025	0.0069	0.0033	0.0075	0.01	0.02
2	0.3323	0.0071	0.0033	0.0077	0.01	0.02

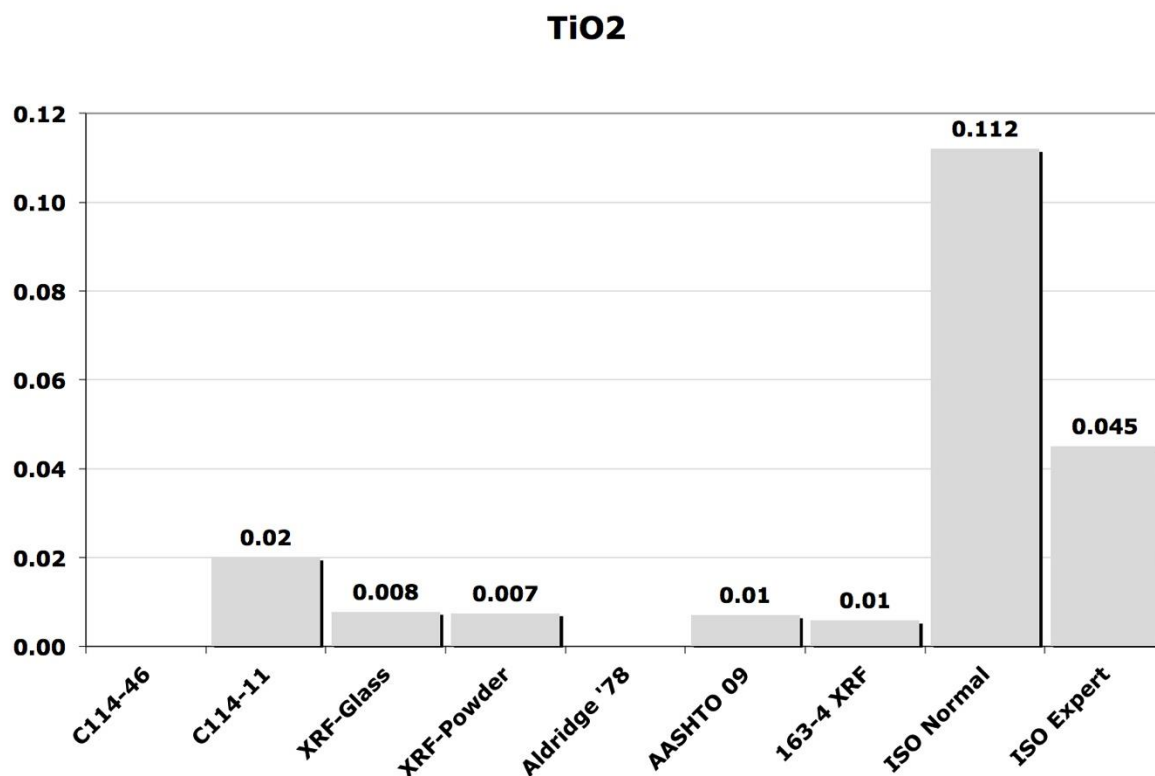


Figure 24 TiO₂ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

P_2O_5

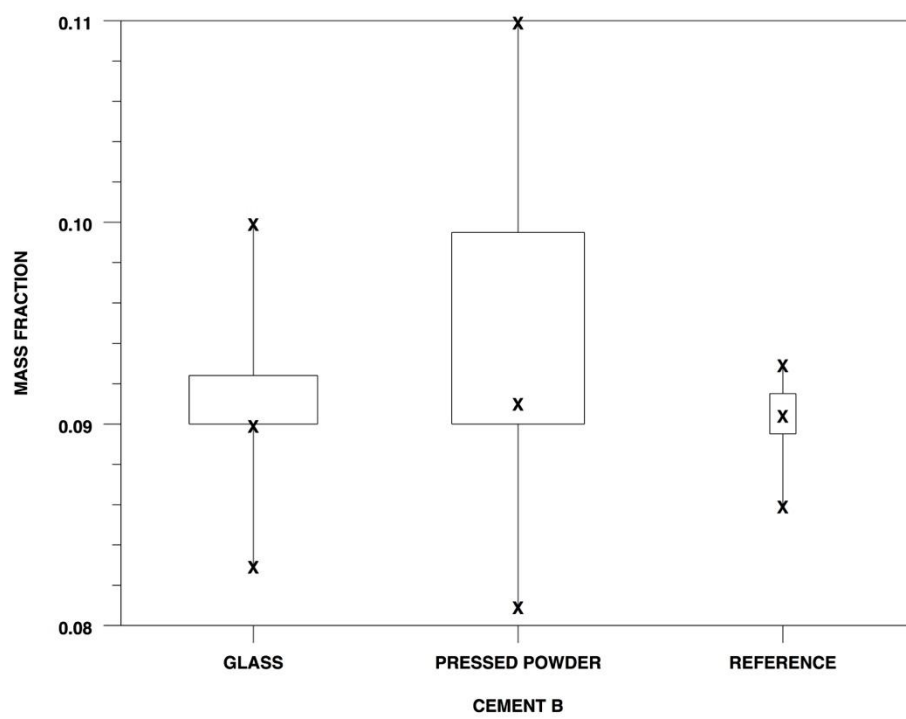
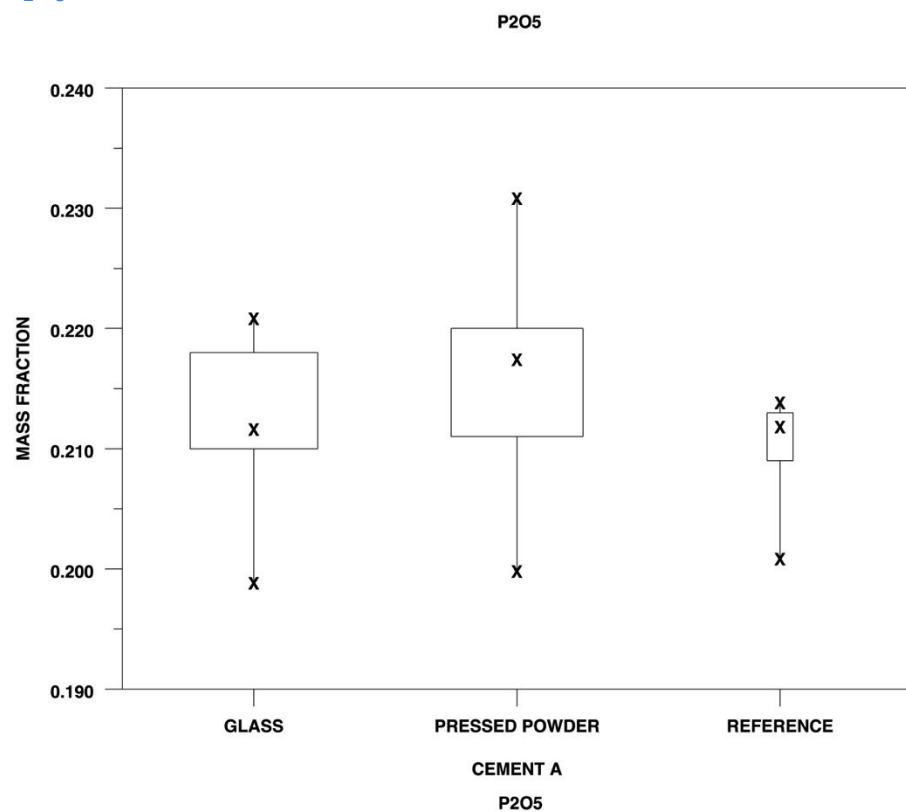


Figure 25 Box plots for P_2O_5 XRF glass and powder, and reference methods.

P₂O₅ XRF, Cements A B, Glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.2058	0.0083	-0.0068	-1.65	2.04
2	0.2108	0.0007	-0.0018	-0.44	0.18
3	0.2183	0.0041	0.0057	1.38	1.00
4	0.2160	0.0019	0.0034	0.81	0.46
5	0.2175	0.0026	0.0049	1.18	0.63
6	0.2117	0.0041	-0.0010	-0.24	1.00
7	0.2133	0.0022	0.0007	0.17	0.53
8	0.2150	0.0055	0.0024	0.57	1.34
9	0.2093	0.0014	-0.0033	-0.80	0.33
10	0.2083	0.0075	-0.0043	-1.05	1.84
11	0.2200	0.0000	0.0074	1.79	0.00
12	0.2132	0.0050	0.0005	0.13	1.23
13	0.2067	0.0052	-0.0060	-1.45	1.26
14	0.2145	0.0002	0.0019	0.45	0.05
15	0.2100	0.0000	-0.0026	-0.64	0.00
16	0.2118	0.0029	-0.0008	-0.20	0.72

Average of cell averages = 0.21265
Standard Deviation of cell averages = 0.00412
Repeatability Standard Deviation = 0.00409
Reproducibility Standard Deviation = 0.00556
h, k Critical Values = 2.49000, 1.77000

P₂O₅ XRF, Cements A B, Glass, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0930	0.0037	0.0018	1.36	1.46
2	0.0923	0.0011	0.0012	0.86	0.42
3	0.0900	0.0000	-0.0012	-0.86	0.00
4	0.0920	0.0017	0.0008	0.62	0.66
5	0.0930	0.0020	0.0018	1.36	0.79
6	0.0900	0.0000	-0.0012	-0.86	0.00
7	0.0925	0.0015	0.0013	0.99	0.60
8	0.0900	0.0000	-0.0012	-0.86	0.00
9	0.0900	0.0006	-0.0012	-0.86	0.25
10	0.0900	0.0000	-0.0012	-0.86	0.00
11	0.0917	0.0041	0.0005	0.37	1.62
12	0.0918	0.0049	0.0007	0.50	1.95
13	0.0917	0.0041	0.0005	0.37	1.62
14	0.0921	0.0002	0.0009	0.67	0.08
15	0.0900	0.0000	-0.0012	-0.86	0.00
16	0.0885	0.0045	-0.0027	-1.96	1.77

Average of cell averages = 0.09116
Standard Deviation of cell averages = 0.00136
Repeatability Standard Deviation = 0.00252
Reproducibility Standard Deviation = 0.00267
h, k Critical Values = 2.49000, 1.77000

P₂O₅ XRF, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.2120	0.0024	-0.0010	-0.23	0.65
2	0.2110	0.0006	-0.0020	-0.44	0.16
3	0.2167	0.0052	0.0036	0.78	1.43
4	0.2143	0.0023	0.0013	0.28	0.65
5	0.2173	0.0020	0.0043	0.93	0.54
6	0.2117	0.0041	-0.0014	-0.30	1.13
7	0.2142	0.0023	0.0011	0.24	0.64
8	0.2183	0.0041	0.0053	1.14	1.13
9	0.2095	0.0016	-0.0035	-0.77	0.45
10	0.2067	0.0052	-0.0064	-1.38	1.43
11	0.2200	0.0000	0.0070	1.50	0.00
12	0.2168	0.0040	0.0038	0.82	1.11
13	0.2017	0.0041	-0.0114	-2.46	1.13
14	0.2144	0.0004	0.0013	0.28	0.11
15	0.2133	0.0052	0.0003	0.06	1.43
16	0.2108	0.0063	-0.0022	-0.48	1.75

Average of cell averages = 0.21304
Standard Deviation of cell averages = 0.00463
Repeatability Standard Deviation = 0.00362
Reproducibility Standard Deviation = 0.00569
h, k Critical Values = 2.49000, 1.77000

P₂O₅ XRF, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0947	0.0027	0.0029	1.86	1.08
2	0.0928	0.0009	0.0011	0.68	0.35
3	0.0900	0.0000	-0.0018	-1.12	0.00
4	0.0913	0.0016	-0.0004	-0.27	0.65
5	0.0925	0.0015	0.0007	0.47	0.60
6	0.0900	0.0000	-0.0018	-1.12	0.00
7	0.0933	0.0023	0.0016	1.01	0.93
8	0.0900	0.0000	-0.0018	-1.12	0.00
9	0.0903	0.0005	-0.0014	-0.91	0.20
10	0.0900	0.0000	-0.0018	-1.12	0.00
11	0.0933	0.0052	0.0016	1.01	2.05
12	0.0937	0.0043	0.0019	1.22	1.69
13	0.0917	0.0041	-0.0001	-0.06	1.62
14	0.0923	0.0001	0.0005	0.34	0.05
15	0.0900	0.0000	-0.0018	-1.12	0.00
16	0.0922	0.0046	0.0004	0.26	1.83

Average of cell averages = 0.09176
 Standard Deviation of cell averages = 0.00157
 Repeatability Standard Deviation = 0.00252
 Reproducibility Standard Deviation = 0.00279
 h, k Critical Values = 2.49000, 1.77000

P₂O₅ XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.2200	0.0000	0.0037	0.66	0.00
2	0.2300	0.0000	0.0137	2.42	0.00
3	0.2168	0.0012	0.0006	0.10	0.35
4	0.2107	0.0018	-0.0056	-0.99	0.52
5	0.2200	0.0000	0.0037	0.66	0.00
6	0.2200	0.0000	0.0037	0.66	0.00
7	0.2190	0.0021	0.0027	0.48	0.62
8	0.2183	0.0041	0.0021	0.36	1.21
9	0.2102	0.0015	-0.0061	-1.08	0.44
10	0.2130	0.0009	-0.0033	-0.58	0.26
11	0.2067	0.0052	-0.0096	-1.70	1.53
12	0.2144	0.0017	-0.0019	-0.34	0.50
13	0.2083	0.0041	-0.0079	-1.40	1.21
14	0.2199	0.0005	0.0036	0.64	0.14
15	0.2200	0.0000	0.0037	0.66	0.00
16	0.2152	0.0037	-0.0011	-0.20	1.08
17	0.2143	0.0103	-0.0019	-0.34	3.05

Average of cell averages = 0.21628
 Standard Deviation of cell averages = 0.00566
 Repeatability Standard Deviation = 0.00338
 Reproducibility Standard Deviation = 0.00645
 h, k Critical Values = 2.51000, 1.78000

P₂O₅ XRF, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0917	0.0041	-0.0031	-0.38	0.33
2	0.1050	0.0055	0.0103	1.26	0.45
3	0.0895	0.0019	-0.0052	-0.65	0.15
4	0.0870	0.0019	-0.0077	-0.95	0.16
5	0.1000	0.0000	0.0053	0.65	0.00
6	0.0900	0.0000	-0.0047	-0.58	0.00
7	0.0903	0.0012	-0.0044	-0.54	0.10
8	0.1017	0.0041	0.0069	0.85	0.33
9	0.0917	0.0016	-0.0031	-0.38	0.13
10	0.0910	0.0011	-0.0037	-0.46	0.09
11	0.0900	0.0000	-0.0047	-0.58	0.00
12	0.0945	0.0009	-0.0002	-0.03	0.08
13	0.0900	0.0000	-0.0047	-0.58	0.00
14	0.0913	0.0002	-0.0035	-0.43	0.02
15	0.1200	0.0490	0.0253	3.11	4.01
16	0.0960	0.0037	0.0013	0.16	0.31
17	0.0910	0.0073	-0.0037	-0.46	0.59

Average of cell averages = 0.09474
 Standard Deviation of cell averages = 0.00811
 Repeatability Standard Deviation = 0.01223
 Reproducibility Standard Deviation = 0.01380
 h, k Critical Values = 2.51000, 1.78000

P₂O₅ XRF, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.2200	0.0000	0.0038	0.70	0.00
2	0.2283	0.0041	0.0121	2.24	1.30
3	0.2167	0.0015	0.0005	0.09	0.48
4	0.2117	0.0022	-0.0045	-0.84	0.69
5	0.2200	0.0000	0.0038	0.70	0.00
6	0.2200	0.0000	0.0038	0.70	0.00
7	0.2190	0.0009	0.0028	0.52	0.29
8	0.2183	0.0041	0.0021	0.39	1.30
9	0.2103	0.0016	-0.0059	-1.08	0.52
10	0.2125	0.0016	-0.0037	-0.68	0.53
11	0.2050	0.0055	-0.0112	-2.07	1.75
12	0.2143	0.0022	-0.0019	-0.34	0.69
13	0.2100	0.0000	-0.0062	-1.14	0.00
14	0.2197	0.0004	0.0035	0.64	0.13
15	0.2200	0.0000	0.0038	0.70	0.00
16	0.2152	0.0041	-0.0010	-0.19	1.30
17	0.2143	0.0083	-0.0019	-0.34	2.65

Average of cell averages = 0.21620
 Standard Deviation of cell averages = 0.00542
 Repeatability Standard Deviation = 0.00313
 Reproducibility Standard Deviation = 0.00613
 h, k Critical Values = 2.51000, 1.78000

P₂O₅ XRF, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0933	0.0052	0.0000	0.01	1.83
2	0.0983	0.0041	0.0050	1.16	1.44
3	0.0895	0.0016	-0.0038	-0.88	0.58
4	0.0870	0.0018	-0.0063	-1.45	0.63
5	0.1000	0.0000	0.0067	1.55	0.00
6	0.0900	0.0000	-0.0033	-0.76	0.00
7	0.0915	0.0008	-0.0018	-0.42	0.30
8	0.1017	0.0041	0.0084	1.93	1.44
9	0.0923	0.0021	-0.0010	-0.22	0.73
10	0.0905	0.0015	-0.0028	-0.65	0.54
11	0.0900	0.0000	-0.0033	-0.76	0.00
12	0.0945	0.0006	0.0012	0.28	0.22
13	0.0905	0.0012	-0.0028	-0.65	0.43
14	0.0911	0.0002	-0.0022	-0.50	0.08
15	0.1000	0.0000	0.0067	1.55	0.00
16	0.0955	0.0039	0.0022	0.51	1.39
17	0.0903	0.0067	-0.0030	-0.68	2.38

Average of cell averages = 0.09330
Standard Deviation of cell averages = 0.00433
Repeatability Standard Deviation = 0.00283
Reproducibility Standard Deviation = 0.00505
h, k Critical Values = 2.51000, 1.78000

Table 12 Precision Statistics P₂O₅ by XRF glass and powder preparations for replicates 1 and 2.

P₂O₅ Glass, Rep. 1

Material	Xbar	s_x	s_r	s_R	r	R
1	0.2126	0.0041	0.0041	0.0056	0.01	0.02
2	0.0912	0.0014	0.0025	0.0027	0.01	0.01

P₂O₅ Glass, rep. 2

Material	Xbar	s_x	s_r	s_R	r	R
1	0.2130	0.0046	0.0036	0.0057	0.01	0.02
2	0.0918	0.0016	0.0025	0.0028	0.01	0.01

P₂O₅ Powder, rep. 1

Material	Xbar	s_x	s_r	s_R	r	R
1	0.2163	0.0057	0.0034	0.0064	0.01	0.02
2	0.0947	0.0081	0.0122	0.0138	0.03	0.04

P₂O₅ Powder, rep. 2

Material	Xbar	s_x	s_r	s_R	r	R
1	0.2162	0.0054	0.0031	0.0061	0.01	0.02
2	0.0933	0.0043	0.0028	0.0050	0.01	0.01

P2O5

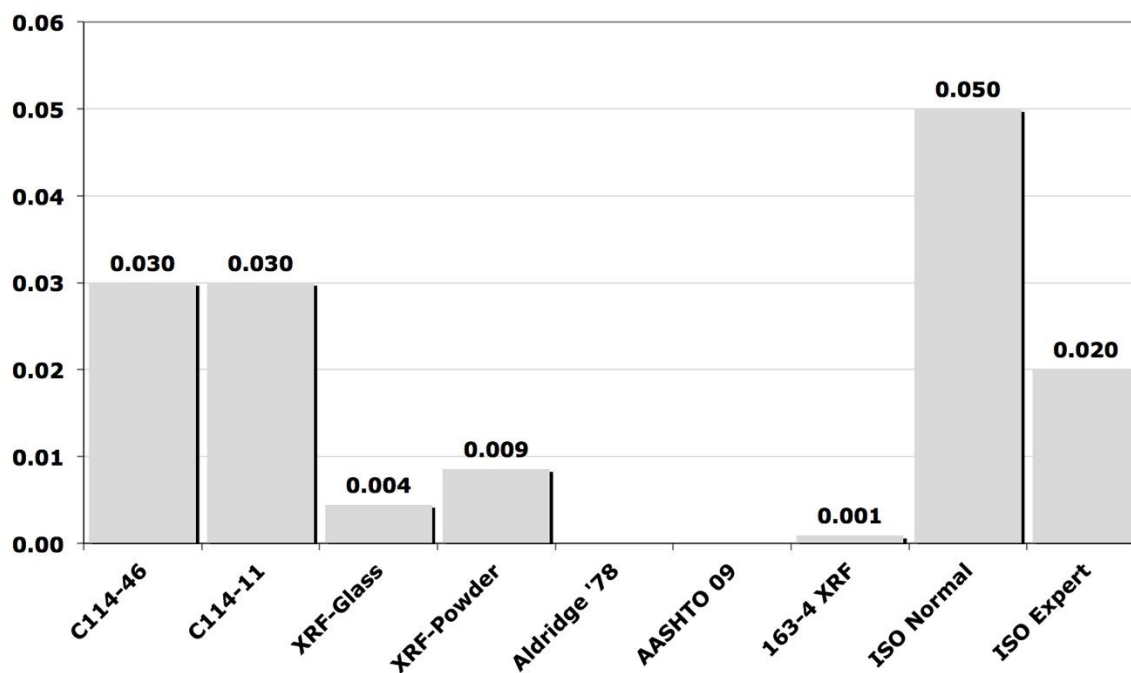


Figure 26 P₂O₅ precision statistics by method with bar chart comparing results to current and past ASTM C114 limits and previous studies on chemical analysis precision as 1-sigma, between lab (s_R).

Cl

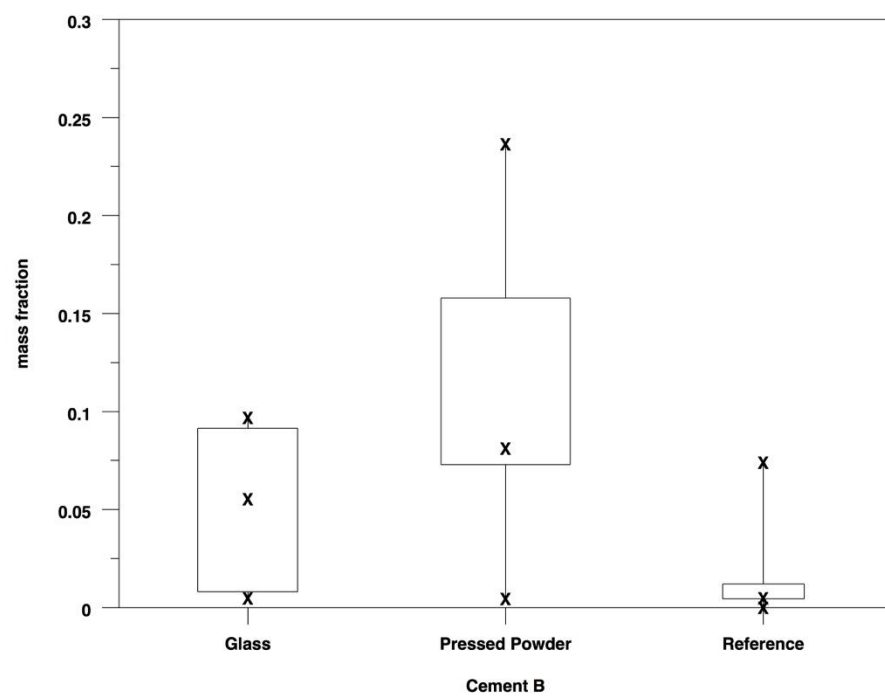
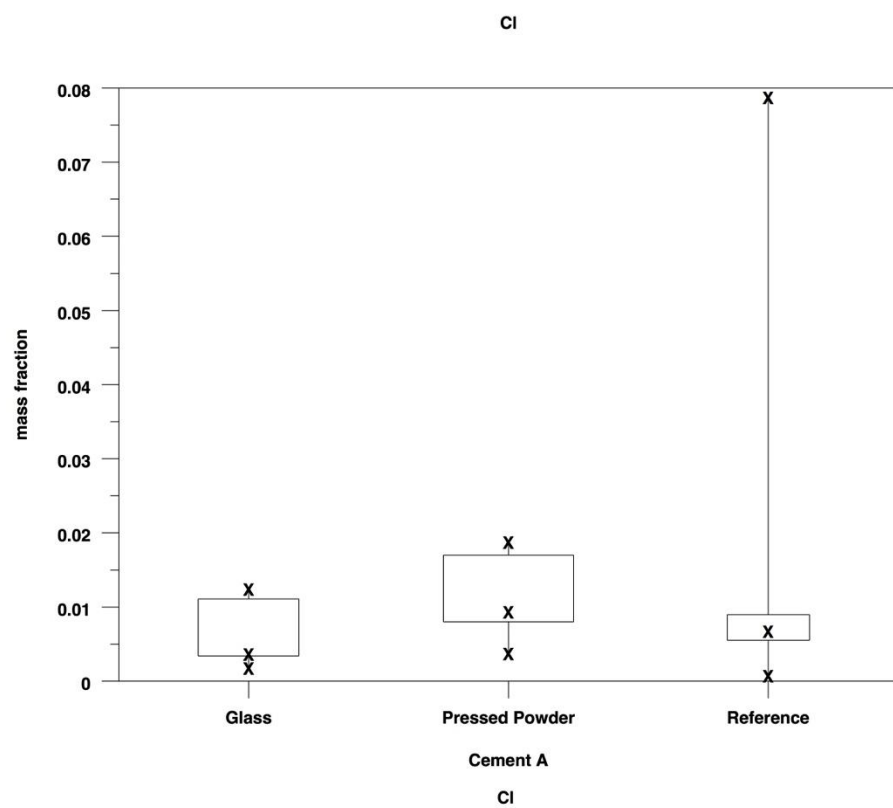


Figure 27 Box plots for Cl XRF glass and powder, and reference methods.

XRF Cl, Cements A B, Glass, Replicate 1, Material: 1*

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0180	0.0030	0.0088	1.24	1.83
2	0.0035	0.0010	-0.0057	-0.81	0.65
3	0.0119	0.0007	0.0027	0.38	0.45
4	0.0035	0.0002	-0.0057	-0.81	0.15

Average of cell averages = 0.00923
 Standard Deviation of cell averages = 0.00705
 Repeatability Standard Deviation = 0.00162
 Reproducibility Standard Deviation = 0.00721
 h, k Critical Values = 1.49000, 1.60000

XRF Cl, Cements A B, Glass, Replicate 1, Material: 2*

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.1222	0.0030	0.0523	1.07	0.77
2	0.0578	0.0047	-0.0120	-0.24	1.21
3	0.0917	0.0053	0.0219	0.45	1.36
4	0.0076	0.0011	-0.0622	-1.27	0.29

Average of cell averages = 0.06983
 Standard Deviation of cell averages = 0.04910
 Repeatability Standard Deviation = 0.00388
 Reproducibility Standard Deviation = 0.04922
 h, k Critical Values = 1.49000, 1.60000

* n = 4 is less than recommended number of laboratories. These data are presented individually (glass and powder preparations) and collectively.

XRF Cl, Cements A B, Glass, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0162	0.0032	0.0073	1.19	1.81
2	0.0042	0.0012	-0.0047	-0.77	0.66
3	0.0118	0.0009	0.0029	0.47	0.54
4	0.0035	0.0002	-0.0054	-0.88	0.10

Average of cell averages = 0.00891
 Standard Deviation of cell averages = 0.00612
 Repeatability Standard Deviation = 0.00177
 Reproducibility Standard Deviation = 0.00633
 h, k Critical Values = 1.49000, 1.60000

XRF Cl, Cements A B, Glass, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.1215	0.0015	0.0516	1.06	0.39
2	0.0582	0.0052	-0.0118	-0.24	1.34
3	0.0920	0.0055	0.0221	0.45	1.41
4	0.0080	0.0009	-0.0619	-1.27	0.24

Average of cell averages = 0.06993
 Standard Deviation of cell averages = 0.04871
 Repeatability Standard Deviation = 0.00387
 Reproducibility Standard Deviation = 0.04883
 h, k Critical Values = 1.49000, 1.60000

XRF Cl, Cements A B, Powder, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0173	0.0008	0.0066	1.37	0.77
2	0.0083	0.0007	-0.0024	-0.50	0.66
3	0.0100	0.0000	-0.0007	-0.15	0.00
4	0.0152	0.0023	0.0045	0.92	2.20
5	0.0040	0.0000	-0.0067	-1.39	0.00
6	0.0095	0.0004	-0.0012	-0.25	0.37

Average of cell averages = 0.01072
 Standard Deviation of cell averages = 0.00483
 Repeatability Standard Deviation = 0.00106
 Reproducibility Standard Deviation = 0.00493
 h, k Critical Values = 1.92000, 1.68000

XRF Cl, Cements A B, Powder, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.1568	0.0017	0.0452	0.62	0.16
2	0.0825	0.0019	-0.0291	-0.40	0.17
3	0.1400	0.0000	0.0283	0.39	0.00
4	0.2117	0.0266	0.1000	1.38	2.44
5	0.0055	0.0000	-0.1062	-1.46	0.00
6	0.0734	0.0007	-0.0383	-0.53	0.06

Average of cell averages = 0.11166
 Standard Deviation of cell averages = 0.07270
 Repeatability Standard Deviation = 0.01090
 Reproducibility Standard Deviation = 0.07338
 h, k Critical Values = 1.92000, 1.68000

XRF Cl, Cements A B, Powder, Replicate 2, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0178	0.0012	0.0068	1.34	0.81
2	0.0088	0.0008	-0.0023	-0.46	0.53
3	0.0100	0.0000	-0.0011	-0.21	0.00
4	0.0159	0.0032	0.0048	0.96	2.22
5	0.0040	0.0000	-0.0071	-1.40	0.00
6	0.0099	0.0005	-0.0011	-0.23	0.35

Average of cell averages = 0.01107
 Standard Deviation of cell averages = 0.00504
 Repeatability Standard Deviation = 0.00145
 Reproducibility Standard Deviation = 0.00521
 h, k Critical Values = 1.92000, 1.68000

XRF Cl, Cements A B, Powder, Replicate 2, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.1578	0.0016	0.0457	0.63	0.14
2	0.0837	0.0019	-0.0284	-0.39	0.17
3	0.1400	0.0000	0.0278	0.38	0.00
4	0.2117	0.0269	0.0996	1.37	2.44
5	0.0055	0.0000	-0.1067	-1.47	0.00
6	0.0742	0.0008	-0.0380	-0.52	0.07

Average of cell averages = 0.11216
 Standard Deviation of cell averages = 0.07267
 Repeatability Standard Deviation = 0.01105
 Reproducibility Standard Deviation = 0.07337
 h, k Critical Values = 1.92000, 1.68000

XRF Cl, Cements A B, Combined Methods, Replicate 1, Material: 1

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0035	0.0010	-0.0057	-1.05	1.02
2	0.0119	0.0007	0.0027	0.51	0.71
3	0.0035	0.0002	-0.0056	-1.05	0.24
4	0.0173	0.0008	0.0082	1.52	0.79
6	0.0083	0.0007	-0.0009	-0.16	0.68
7	0.0152	0.0023	0.0060	1.12	2.27
8	0.0040	0.0000	-0.0052	-0.96	0.00
9	0.0095	0.0004	0.0004	0.07	0.38

Average of cell averages = 0.00916
 Standard Deviation of cell averages = 0.00537
 Repeatability Standard Deviation = 0.00103
 Reproducibility Standard Deviation = 0.00545
 h, k Critical Values = 2.15000, 1.72000

XRF Cl, Cements A B, Combined Methods, Replicate 1, Material: 2

Laboratory Number	Cell Mean	Cell SD	<i>d</i>	<i>h</i>	<i>k</i>
1	0.0578	0.0047	-0.0280	-0.40	0.48
2	0.0917	0.0053	0.0058	0.08	0.54
3	0.0076	0.0011	-0.0783	-1.12	0.12
4	0.1568	0.0017	0.0710	1.01	0.18
6	0.0825	0.0019	-0.0033	-0.05	0.19
7	0.2117	0.0266	0.1258	1.79	2.72
8	0.0055	0.0000	-0.0804	-1.15	0.00
9	0.0734	0.0007	-0.0125	-0.18	0.07

Average of cell averages = 0.08588
 Standard Deviation of cell averages = 0.07013
 Repeatability Standard Deviation = 0.00978
 Reproducibility Standard Deviation = 0.07070
 h, k Critical Values = 2.15000, 1.72000

Cl Glass, Replicate 1: n = 4

Material	Xbar	s_x	s_r	s_R	r	R
1	0.0092	0.0071	0.0016	0.0072	0.00	0.02
2	0.0698	0.0491	0.0039	0.0492	0.01	0.14

Cl Glass, Replicate 2: n = 4

Material	Xbar	s_x	s_r	s_R	r	R
1	0.0089	0.0061	0.0018	0.0063	0.00	0.02
2	0.0699	0.0487	0.0039	0.0488	0.01	0.14

Cl Powder, Replicate 1: n = 6

Material	Xbar	s_x	s_r	s_R	r	R
1	0.0107	0.0048	0.0011	0.0049	0.00	0.01
2	0.1117	0.0727	0.0109	0.0734	0.03	0.21

Cl Powder, Replicate 2: n = 6

Material	Xbar	s_x	s_r	s_R	r	R
1	0.0111	0.0050	0.0014	0.0052	0.00	0.01
2	0.1122	0.0727	0.0110	0.0734	0.03	0.21

Cl Combined Methods, Replicate 1: n=9

Material	Xbar	s_x	s_r	s_R	r	R
1	0.0092	0.0054	0.0010	0.0054	0.00	0.02
2	0.0859	0.0701	0.0098	0.0707	0.03	0.20

Cl Combined Methods, Replicate 2: n=9

Material	Xbar	s_x	s_r	s_R	r	R
1	0.0102	0.0053	0.0016	0.0055	0.00	0.02
2	0.0953	0.0648	0.0089	0.0653	0.02	0.18

Appendix B. Request for Participants Letter.

ASTM Round Robin for C01.23.03 Task Force Group

Instructions

The ASTM C01.23.03 task force group wishes to thank you for agreeing to be a part of the Round Robin (RR) which will define the precision and, hopefully, the bias of the X-ray fluorescence spectrometric (XRF) elemental analysis of hydraulic cements. Many versions of an XRF analytical procedure exist as set up and used by cement producers, cement users, commercial laboratories and general users. Generally, all parties are interested in producing a high quality, accurate analysis for industrial use. The Cement and Concrete Laboratory (CCRL) in cooperation with the ASTM Inter-Laboratory Study (ILS) has agreed to provide samples of Portland cement (meeting ASTM C150 guidelines) and various other mixtures of Portland cement and other compounds for the XRF analysis in this RR. Statistical analysis of the returned data will be compiled for the task force by NIST statisticians.

Method

The “10th Preliminary Draft” of “Standard Test Method for the Major and Minor Elements in Cement by X-Ray Fluorescence” produced by the task force group is available by downloading from a special web-based program set up by CCRL for the specific purpose of this RR. The method is specifically, a generalized approach to the XRF analysis of hydraulic cements, and is subject to revision when data is collected to show any confusion, indecision, or conflicts in the “10th Preliminary Draft.” There have already been “lots” of “discussions” and changes to the method, and there may be more changes. Some have already been suggested by task force members and other interested parties that may be implemented when actual data begins to roll in.

In the interest of collecting data from the RR before I go to a nursing home, we should start to collect now. Again the method is a generalized approach to XRF analysis of hydraulic cements, and the individual Standard Operating Procedures (SOP) used in your individual laboratory should fit in the generalized guidelines. Please follow the method as closely as possible so that your specific laboratory data can be utilized for comparison to all the other data.

The method actually has two preparation schemes for presentation to the XRF, fused disk and pressed powder. If your laboratory has the capability to do both preparation methods, please, please, do so.

In Part 4.2.2 of the “10th Preliminary Draft,” it specifically states “*Part 2 of the method is not generally applicable to the analysis of blended cements, including those blended with silica fume, limestone, pozzolans, fly ash, slag, and any combination thereof higher than the amounts of additions found in Portland cements meeting Specification C 150.*” **For the purposes of this RR data collection only, ignore this statement and run pressed**

pellets, if you have the capability, for comparison with the fused disk preparation.

We need to establish the precision and truth of this statement and a comparison will determine if this statement is correct and help establish precision data on the pressed pellet mixtures by XRF.

Data Return

The data return for this RR is by accessing the CCRL web site for examination and determining what needs to be reported. It will be much easier if you report data on-line in a similar fashion as CCRL data is now reported; the statistician will love you. If you are unable to report data on-line, fill out the data and send to me (by FAX) and I'll key punch it in for your data return. By making a request to CCRL, on this RR you can obtain more sample, if you are going to do samples by pressed powder. Ask for three vials of about 30 grams on each of the RR samples for powder prep and one sample vial if sample prep is fused disk only.

If you have the capability, we ask you to run powder prep and fused pellet on the two samples being mailed from CCRL. So for instance, there will be Sample A fused pellet data return and Sample A pressed pellet data return; then Sample B fused pellet data return and Sample B pressed pellet data return. There will be potentially 4 data return sheets for each sample in the mailing from CCRL. The first two samples mailed from CCRL are guaranteed to be C150 Portland Cements. The next two to four mailings of sample pairs will be mixtures.

If you can't do fused pellets, please participate in the pressed pellet RR, and conversely if you can't do pressed pellets, do fused pellets. All data will be used and gratefully appreciated by the task force group and task group chairman. We estimate that this RR study will take a minimum of 1½ years to 2½ years, a mere moment in the large ASTM scheme of things, but the data will hopefully live forever.

1. The section at the top should be filled out for company and individual returning the data, but, in general, no data will be identified with the lab unless you wish it to be. This ID is in case we have to contact you to clear up some misunderstanding or finger trouble with the data entry.
2. Please give as much data on the Fusion Bead preparation as possible. Flux composition, Non-wetting agent, etc. For the Pressed Pellet, as much info as possible, Binder composition, Grinding aid and etc.
3. Look at the return data sheet, what is intended here is to make on Day 1, three pellets: fusion and/or pressed pellets, and analyze each pellet twice, then report on the properly identified data sheets. Day 2 of your choosing, make three pellets: fusion and/or pressed pellets, and run each one twice, and report results on the proper data return sheets.
4. If possible (and only if possible) on your instrument, give the raw element intensities and/or raw background intensities before calculations and applied corrections. In the case

of each element you only need to answer the Calibration/correction model question once, not every time on each prep.

5. LOI should be run and reported each sample prep day. Insoluble Residue and Free Lime need only to be run once, each prep day and only if the sufficient data is returned for the XRF data. The RR is primarily an XRF RR; the other data at the end of the CCRL data return will be used if needed.
6. Data should be reported to the CCRL web site with one more significant digit than the smallest uncertainty (or standard deviation) value of your best standard elemental value for the element being reported back to CCRL. Report determined values no later than three (3) months after receipt of samples in your laboratory. (i. e., SRM 1880a has a certified value for CaO of 63.83% +/- 0.46, report to three decimals for CaO unless you have lower values on reference materials that were used. ZnO is certified at 0.005% +/- 0.001, so report to four decimals in weight percent, unless you have used reference standards which have a lower +/- values.)

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Appendix C. XRF Glass Summary by Material and Replicate.

Analyte	Material	Xbar	s_x	s_r	s_R	r	R	n
CaO	1	63.8787	0.3498	0.1061	0.363	0.3	1.02	17
	2	63.5162	0.3384	0.1261	0.3574	0.35	1	
	1	63.872	0.3628	0.1056	0.3754	0.3	1.05	
	2	63.5022	0.3719	0.1344	0.3916	0.38	1.1	
SiO ₂	1	20.535	0.075	0.0493	0.0875	0.14	0.25	18
	2	20.2389	0.11	0.0574	0.1218	0.16	0.34	
	1	20.5316	0.0818	0.0467	0.0922	0.13	0.26	
	2	20.2336	0.1028	0.0607	0.1168	0.17	0.33	
Al ₂ O ₃	1	5.0078	0.0495	0.0216	0.0532	0.06	0.15	17
	2	5.13	0.0569	0.0223	0.0604	0.06	0.17	
	1	5.0085	0.0498	0.0188	0.0526	0.05	0.15	
	2	5.133	0.0581	0.0207	0.0611	0.06	0.17	
Fe ₂ O ₃	1	2.7363	0.0283	0.0138	0.031	0.04	0.09	15
	2	4.2401	0.0291	0.0108	0.0308	0.03	0.09	
	1	2.7371	0.0287	0.0109	0.0303	0.03	0.08	
	2	4.2399	0.0309	0.0173	0.0347	0.05	0.1	
SO ₃	1	2.8513	0.048	0.024	0.0527	0.07	0.15	16
	2	3.5726	0.0769	0.025	0.0802	0.07	0.22	
	1	2.8515	0.0482	0.0228	0.0525	0.06	0.15	
	2	3.5639	0.0873	0.1044	0.1292	0.29	0.36	
MgO	1	1.9053	0.0278	0.0146	0.0308	0.04	0.09	17
	2	1.0653	0.0217	0.0096	0.0234	0.03	0.07	
	1	1.9071	0.0272	0.0152	0.0306	0.04	0.09	
	2	1.0648	0.0161	0.0087	0.018	0.02	0.05	
Na ₂ O	1	0.2098	0.014	0.0089	0.0162	0.02	0.05	15
	2	0.0569	0.0227	0.0077	0.0238	0.02	0.07	
	1	0.2098	0.0125	0.0083	0.0146	0.02	0.04	
	2	0.0629	0.028	0.043	0.0482	0.12	0.13	
K ₂ O	1	0.6864	0.0097	0.0043	0.0104	0.01	0.03	17
	2	0.3834	0.0051	0.0035	0.006	0.01	0.02	
	1	0.6864	0.0101	0.0048	0.011	0.01	0.03	
	2	0.383	0.0052	0.0034	0.0061	0.01	0.02	
TiO ₂	1	0.3095	0.0067	0.004	0.0076	0.01	0.02	17
	2	0.334	0.0066	0.0044	0.0077	0.01	0.02	
	1	0.3094	0.0067	0.0043	0.0078	0.01	0.02	
	2	0.3333	0.0071	0.0044	0.0081	0.01	0.02	

continued								
Analyte	Material	Xbar	s_x	s_r	s_R	r	R	n
P ₂ O ₅	1	0.2126	0.0041	0.0041	0.0056	0.01	0.02	16
	2	0.0912	0.0014	0.0025	0.0027	0.01	0.01	
	1	0.213	0.0046	0.0036	0.0057	0.01	0.02	
	2	0.0918	0.0016	0.0025	0.0028	0.01	0.01	
Cl	1	0.0092	0.0054	0.001	0.0054	0	0.02	9
(glass+powder)	2	0.0859	0.0701	0.0098	0.0707	0.03	0.2	

Appendix D. XRF Powder Summary by Material and Replicate.

Analyte	Material	Xbar	s_x	s_r	s_R	r	R	n
CaO	1	64.0931	0.3603	0.1207	0.3767	0.34	1.05	23
	2	63.6979	0.281	0.1025	0.2962	0.29	0.83	
	1	64.118	0.3618	0.1133	0.3763	0.32	1.05	
	2	63.7197	0.2747	0.0961	0.2884	0.27	0.81	
SiO ₂	1	20.67	0.1258	0.0561	0.1358	0.16	0.38	22
	2	20.117	0.176	0.0538	0.1827	0.15	0.51	
	1	20.6776	0.1255	0.0584	0.1363	0.16	0.38	
	2	20.1218	0.1756	0.0542	0.1824	0.15	0.51	
Al ₂ O ₃	1	4.8213	0.0773	0.0239	0.0803	0.07	0.22	22
	2	5.1292	0.1103	0.0196	0.1118	0.05	0.31	
	1	4.8267	0.0763	0.0244	0.0795	0.07	0.22	
	2	5.1321	0.1066	0.0203	0.1082	0.06	0.3	
Fe ₂ O ₃	1	2.7444	0.044	0.0127	0.0455	0.04	0.13	24
	2	4.2488	0.0422	0.0187	0.0456	0.05	0.13	
	1	2.7442	0.0448	0.014	0.0466	0.04	0.13	
	2	4.2475	0.0433	0.0181	0.0464	0.05	0.13	
SO ₃	1	2.9065	0.0912	0.0222	0.0934	0.06	0.26	24
	2	3.5508	0.1393	0.0266	0.1414	0.07	0.4	
	1	2.9065	0.092	0.0218	0.0941	0.06	0.26	
	2	3.5521	0.138	0.0243	0.1398	0.07	0.39	
MgO	1	1.8542	0.0655	0.0119	0.0664	0.03	0.19	26
	2	1.1016	0.0627	0.0108	0.0634	0.03	0.18	
	1	1.8541	0.0663	0.0128	0.0673	0.04	0.19	
	2	1.0999	0.0625	0.0106	0.0633	0.03	0.18	
Na ₂ O	1	0.1862	0.0194	0.005	0.0199	0.01	0.06	24
	2	0.0526	0.0182	0.006	0.019	0.02	0.05	
	1	0.1868	0.0194	0.0053	0.02	0.01	0.06	
	2	0.0521	0.0181	0.0051	0.0187	0.01	0.05	
K ₂ O	1	0.6824	0.0123	0.0047	0.013	0.01	0.04	21
	2	0.3801	0.0105	0.0038	0.011	0.01	0.03	
	1	0.6823	0.0125	0.0047	0.0132	0.01	0.04	
	2	0.3801	0.0103	0.0036	0.0108	0.01	0.03	
TiO ₂	1	0.3019	0.0071	0.0029	0.0075	0.01	0.02	18
	2	0.3322	0.0067	0.0029	0.0072	0.01	0.02	
	1	0.3025	0.0069	0.0033	0.0075	0.01	0.02	
	2	0.3323	0.0071	0.0033	0.0077	0.01	0.02	

continued Analyte	Material	Xbar	s_x	s_r	s_R	r	R	n
P ₂ O ₅	1	0.2163	0.0057	0.0034	0.0064	0.01	0.02	17
	2	0.0947	0.0081	0.0122	0.0138	0.03	0.04	
	1	0.2162	0.0054	0.0031	0.0061	0.01	0.02	
	2	0.0933	0.0043	0.0028	0.005	0.01	0.01	
Cl (glass+powder)	1	0.0095	0.0055	0.0014	0.0056	0	0.02	9
	2	0.0864	0.0702	0.0099	0.0708	0.03	0.2	

Appendix E. Raw Data by Analyte.

Data by oxide after initial outlier removal for SiO₂, Al₂O₃, Fe₂O₃, CaO, MgO, SO₃, Na₂O, K₂O, TiO₂, and Cl. Data are organized with the XRF-glass results to the left and XRF-powder to the right. A lab identifier is provided in the first column of each preparation method. The six replicate measurements for that lab and analyte for duplicate 1 and then duplicate two are provided in columns 2 and 3 of each preparation method. Duplicate measurements represent a repeat measurement on the same specimen. The final column labeled cement indicates cement A (1) or cement B (2). Since outliers were evaluated on an analyte-by-analyte basis, a specific lab designation may not be the same lab across all analytes. For example, if lab 1 had a high between-lab precision for Al₂O₃, its data were removed and the labs reordered so no gap in the numbering existed.

SiO₂

SiO ₂ : Glass Preparation				SiO ₂ : Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	20.418	20.414	1	1	20.650	20.680	1
1	20.380	20.403	1	1	20.800	20.800	1
1	20.287	20.270	1	1	20.760	20.780	1
1	20.330	20.460	1	1	20.570	20.630	1
1	20.484	20.347	1	1	20.630	20.730	1
1	20.480	20.393	1	1	20.730	20.730	1
2	20.522	20.462	1	2	20.542	20.575	1
2	20.362	20.308	1	2	20.580	20.580	1
2	20.348	20.328	1	2	20.569	20.581	1
2	20.317	20.246	1	2	20.636	20.654	1
2	20.321	20.394	1	2	20.684	20.645	1
2	20.431	20.408	1	2	20.645	20.370	1
3	20.519	20.524	1	3	20.565	20.572	1
3	20.518	20.524	1	3	20.726	20.715	1
3	20.524	20.545	1	3	20.595	20.619	1
3	20.565	20.561	1	3	20.634	20.628	1
3	20.536	20.536	1	3	20.647	20.669	1
3	20.518	20.552	1	3	20.635	20.636	1
4	20.540	20.510	1	4	20.640	20.660	1
4	20.510	20.570	1	4	20.640	20.630	1
4	20.510	20.510	1	4	20.600	20.590	1
4	20.550	20.520	1	4	20.700	20.720	1
4	20.530	20.510	1	4	20.550	20.540	1
4	20.520	20.520	1	4	20.640	20.630	1
5	20.596	20.591	1	5	20.590	20.640	1
5	20.541	20.560	1	5	20.690	20.760	1
5	20.595	20.580	1	5	20.760	20.790	1
5	20.655	20.673	1	5	20.570	20.580	1
5	20.582	20.585	1	5	20.690	20.630	1
5	20.634	20.633	1	5	20.670	20.660	1
6	20.530	20.570	1	6	20.940	20.930	1

6	20.560	20.560	1	6	20.950	20.940	1
6	20.560	20.580	1	6	20.900	20.910	1
6	20.550	20.520	1	6	20.950	20.940	1
6	20.470	20.440	1	6	20.920	20.910	1
6	20.500	20.440	1	6	20.940	20.930	1
7	20.660	20.670	1	7	20.760	20.780	1
7	20.740	20.720	1	7	20.800	20.820	1
7	20.590	20.590	1	7	20.760	20.780	1
7	20.590	20.580	1	7	20.830	20.840	1
7	20.760	20.740	1	7	20.760	20.770	1
7	20.640	20.640	1	7	20.720	20.750	1
8	20.552	20.552	1	8	20.740	20.750	1
8	20.508	20.554	1	8	20.740	20.760	1
8	20.499	20.475	1	8	20.790	20.750	1
8	20.469	20.441	1	8	20.760	20.760	1
8	20.472	20.455	1	8	20.740	20.710	1
8	20.512	20.501	1	8	20.730	20.740	1
9	20.500	20.490	1	9	20.420	20.440	1
9	20.550	20.450	1	9	20.420	20.440	1
9	20.560	20.500	1	9	20.410	20.440	1
9	20.490	20.480	1	9	20.520	20.540	1
9	20.510	20.530	1	9	20.430	20.450	1
9	20.490	20.450	1	9	20.430	20.460	1
10	20.560	20.470	1	10	20.766	20.751	1
10	20.470	20.490	1	10	20.751	20.750	1
10	20.460	20.500	1	10	20.768	20.769	1
10	20.560	20.550	1	10	20.750	20.747	1
10	20.570	20.570	1	10	20.695	20.692	1
10	20.610	20.500	1	10	20.777	20.766	1
11	20.430	20.460	1	11	20.527	20.529	1
11	20.420	20.450	1	11	20.509	20.511	1
11	20.500	20.520	1	11	20.538	20.503	1
11	20.530	20.520	1	11	20.556	20.600	1
11	20.480	20.460	1	11	20.603	20.593	1
11	20.430	20.470	1	11	20.575	20.552	1
12	20.550	20.550	1	12	20.560	20.570	1
12	20.570	20.570	1	12	20.620	20.640	1
12	20.540	20.480	1	12	20.690	20.650	1
12	20.610	20.620	1	12	20.800	20.800	1
12	20.620	20.580	1	12	20.730	20.780	1
12	20.600	20.540	1	12	20.690	20.730	1
13	20.496	20.542	1	13	20.556	20.592	1
13	20.507	20.583	1	13	20.574	20.619	1
13	20.516	20.609	1	13	20.550	20.608	1
13	20.617	20.608	1	13	20.614	20.658	1
13	20.627	20.646	1	13	20.629	20.647	1
13	20.633	20.682	1	13	20.564	20.604	1
14	20.480	20.520	1	14	20.510	20.532	1
14	20.510	20.520	1	14	20.690	20.706	1

14	20.500	20.490	1	14	20.624	20.639	1
14	20.570	20.450	1	14	20.678	20.709	1
14	20.570	20.500	1	14	20.560	20.577	1
14	20.510	20.540	1	14	20.601	20.605	1
15	20.550	20.570	1	15	20.590	20.610	1
15	20.510	20.520	1	15	20.680	20.690	1
15	20.430	20.480	1	15	20.740	20.740	1
15	20.530	20.540	1	15	20.580	20.550	1
15	20.630	20.630	1	15	20.640	20.710	1
15	20.620	20.630	1	15	20.650	20.600	1
16	20.640	20.640	1	16	20.530	20.560	1
16	20.710	20.670	1	16	20.510	20.470	1
16	20.680	20.660	1	16	20.510	20.560	1
16	20.630	20.700	1	16	20.450	20.530	1
16	20.670	20.650	1	16	20.480	20.500	1
16	20.650	20.600	1	16	20.470	20.500	1
17	20.489	20.479	1	17	20.650	20.630	1
17	20.537	20.532	1	17	20.500	20.490	1
17	20.446	20.511	1	17	20.600	20.600	1
17	20.490	20.528	1	17	20.570	20.560	1
17	20.514	20.474	1	17	20.420	20.420	1
17	20.495	20.494	1	17	20.560	20.510	1
18	20.600	20.610	1	18	20.502	20.536	1
18	20.600	20.660	1	18	20.578	20.603	1
18	20.600	20.630	1	18	20.614	20.613	1
18	20.570	20.580	1	18	20.463	20.463	1
18	20.610	20.670	1	18	20.531	20.518	1
18	20.650	20.600	1	18	20.571	20.610	1
1	20.236	20.296	2	19	20.710	20.770	1
1	20.254	20.121	2	19	20.780	20.820	1
1	20.079	20.093	2	19	20.780	20.770	1
1	20.267	20.168	2	19	20.870	20.870	1
1	20.304	20.118	2	19	20.880	20.910	1
1	20.279	20.108	2	19	20.890	20.940	1
2	20.319	20.198	2	20	20.880	20.820	1
2	20.325	20.325	2	20	20.870	20.850	1
2	20.126	20.237	2	20	20.720	20.780	1
2	20.240	20.151	2	20	20.790	20.810	1
2	20.172	20.063	2	20	20.830	20.850	1
2	20.144	20.029	2	20	20.680	20.720	1
3	20.163	20.168	2	21	20.714	20.653	1
3	20.168	20.184	2	21	20.777	20.782	1
3	20.188	20.195	2	21	20.669	20.679	1
3	20.139	20.137	2	21	20.665	20.660	1
3	20.148	20.145	2	21	20.706	20.653	1
3	20.161	20.146	2	21	20.702	20.683	1
4	20.250	20.250	2	22	20.840	20.880	1
4	20.290	20.300	2	22	20.860	20.870	1
4	20.300	20.290	2	22	20.910	20.870	1

4	20.300	20.340	2	22	20.890	20.930	1
4	20.280	20.280	2	22	20.960	20.970	1
4	20.350	20.310	2	22	20.920	20.940	1
5	20.307	20.297	2	1	20.100	20.140	2
5	20.315	20.273	2	1	20.150	20.180	2
5	20.321	20.308	2	1	20.150	20.130	2
5	20.356	20.352	2	1	20.120	20.150	2
5	20.376	20.394	2	1	20.140	20.120	2
5	20.357	20.387	2	1	20.200	20.160	2
6	20.390	20.270	2	2	19.691	19.722	2
6	20.360	20.290	2	2	19.678	19.722	2
6	20.340	20.410	2	2	19.737	19.728	2
6	20.220	20.200	2	2	19.740	19.742	2
6	20.260	20.200	2	2	19.712	19.752	2
6	20.220	20.240	2	2	19.808	19.820	2
7	20.240	20.240	2	3	20.108	20.130	2
7	20.350	20.360	2	3	20.113	20.128	2
7	20.440	20.440	2	3	19.923	19.938	2
7	20.310	20.360	2	3	20.128	20.109	2
7	20.450	20.450	2	3	20.013	20.025	2
7	20.320	20.320	2	3	20.118	20.144	2
8	20.231	20.214	2	4	20.240	20.260	2
8	20.272	20.243	2	4	20.280	20.250	2
8	20.234	20.270	2	4	20.290	20.290	2
8	20.227	20.219	2	4	20.230	20.200	2
8	20.228	20.223	2	4	20.300	20.280	2
8	20.276	20.257	2	4	20.250	20.240	2
9	20.200	20.200	2	5	20.360	20.350	2
9	20.200	20.190	2	5	20.270	20.270	2
9	20.160	20.170	2	5	20.240	20.310	2
9	20.210	20.270	2	5	20.300	20.310	2
9	20.190	20.300	2	5	20.320	20.290	2
9	20.170	20.200	2	5	20.350	20.280	2
10	20.230	20.140	2	6	20.400	20.410	2
10	20.180	20.250	2	6	20.350	20.330	2
10	20.160	20.160	2	6	20.450	20.440	2
10	20.240	20.220	2	6	20.300	20.310	2
10	20.240	20.300	2	6	20.340	20.320	2
10	20.120	20.120	2	6	20.410	20.420	2
11	19.970	19.970	2	7	20.480	20.500	2
11	19.970	19.960	2	7	20.530	20.560	2
11	20.050	19.850	2	7	20.480	20.510	2
11	19.890	20.090	2	7	20.510	20.520	2
11	19.880	20.020	2	7	20.590	20.590	2
11	19.960	19.990	2	7	20.540	20.550	2
12	20.250	20.200	2	8	20.060	20.040	2
12	20.260	20.210	2	8	20.060	20.040	2
12	20.260	20.200	2	8	20.000	19.970	2
12	20.310	20.270	2	8	20.100	20.080	2

12	20.300	20.220	2	8	20.100	20.080	2
12	20.310	20.240	2	8	19.950	19.970	2
13	20.009	20.224	2	9	19.940	19.970	2
13	20.073	20.160	2	9	19.900	19.910	2
13	20.066	20.189	2	9	19.830	19.850	2
13	20.173	20.182	2	9	19.940	19.950	2
13	20.162	20.195	2	9	19.890	19.890	2
13	20.193	20.115	2	9	19.880	19.900	2
14	20.300	20.300	2	10	20.394	20.403	2
14	20.290	20.300	2	10	20.438	20.435	2
14	20.310	20.320	2	10	20.423	20.432	2
14	20.210	20.290	2	10	20.309	20.308	2
14	20.290	20.260	2	10	20.418	20.430	2
14	20.260	20.250	2	10	20.431	20.430	2
15	20.220	20.200	2	11	20.013	20.013	2
15	20.180	20.170	2	11	19.939	19.935	2
15	20.120	20.130	2	11	19.995	19.982	2
15	20.310	20.280	2	11	19.981	19.963	2
15	20.430	20.430	2	11	19.995	19.997	2
15	20.340	20.340	2	11	20.021	20.035	2
16	20.460	20.430	2	12	19.980	20.060	2
16	20.460	20.430	2	12	20.130	20.170	2
16	20.540	20.490	2	12	20.200	20.220	2
16	20.420	20.400	2	12	20.050	19.990	2
16	20.430	20.450	2	12	20.040	20.060	2
16	20.400	20.440	2	12	20.100	20.090	2
17	20.134	20.143	2	13	20.113	20.154	2
17	20.134	20.143	2	13	20.080	20.099	2
17	20.105	20.123	2	13	20.082	20.108	2
17	20.102	20.135	2	13	20.041	20.079	2
17	20.102	20.135	2	13	20.064	20.102	2
17	20.146	20.101	2	13	20.037	20.070	2
18	20.280	20.300	2	14	19.936	19.968	2
18	20.300	20.250	2	14	19.925	19.928	2
18	20.290	20.310	2	14	19.927	19.946	2
18	20.310	20.350	2	14	20.026	20.056	2
18	20.320	20.340	2	14	19.947	19.966	2
18	20.340	20.310	2	14	20.101	20.101	2
				15	20.160	20.130	2
				15	20.100	20.030	2
				15	20.090	20.050	2
				15	20.030	20.020	2
				15	20.080	20.010	2
				15	20.050	19.960	2
				16	20.090	20.110	2
				16	20.130	20.150	2
				16	20.160	20.150	2
				16	20.050	20.050	2
				16	20.060	20.090	2

16	20.060	20.040	2
17	20.040	20.000	2
17	20.040	20.010	2
17	20.090	20.110	2
17	19.900	19.900	2
17	19.900	19.900	2
17	19.910	19.910	2
18	20.058	20.080	2
18	20.056	20.057	2
18	20.000	19.955	2
18	20.037	20.054	2
18	20.135	20.123	2
18	20.176	20.179	2
19	20.090	20.180	2
19	20.140	20.180	2
19	20.190	20.150	2
19	20.150	20.220	2
19	20.200	20.220	2
19	20.200	20.260	2
20	19.980	19.970	2
20	20.040	20.030	2
20	20.020	20.090	2
20	20.080	20.060	2
20	20.130	20.140	2
20	20.030	20.020	2
21	20.015	20.008	2
21	20.015	20.008	2
21	20.093	20.075	2
21	20.121	20.152	2
21	20.121	20.152	2
21	20.157	20.130	2
22	20.110	20.130	2
22	20.180	20.200	2
22	20.210	20.230	2
22	20.160	20.190	2
22	20.160	20.180	2
22	20.230	20.230	2

Al₂O₃

Al ₂ O ₃ : Glass Preparation				Al ₂ O ₃ : Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	2.7050	2.7210	1	1	2.6600	2.6600	1
1	2.7270	2.7210	1	1	2.6600	2.6600	1
1	2.7170	2.7210	1	1	2.6500	2.6400	1
1	2.7340	2.7240	1	1	2.6600	2.6600	1
1	2.7510	2.7270	1	1	2.6700	2.6500	1
1	2.7340	2.7360	1	1	2.6600	2.6500	1
2	2.6650	2.6670	1	2	2.6800	2.6800	1
2	2.7350	2.7360	1	2	2.7100	2.7000	1
2	2.7430	2.7400	1	2	2.7400	2.7400	1
2	2.7350	2.7460	1	2	2.7000	2.6700	1
2	2.7590	2.7550	1	2	2.7100	2.7200	1
2	2.7510	2.7560	1	2	2.7100	2.6500	1
3	2.7230	2.7260	1	4	2.7040	2.7060	1
3	2.7260	2.7270	1	4	2.6910	2.6910	1
3	2.7300	2.7280	1	4	2.7170	2.7190	1
3	2.7310	2.7320	1	4	2.7390	2.7430	1
3	2.7310	2.7320	1	4	2.7400	2.7410	1
3	2.7310	2.7320	1	4	2.7400	2.7370	1
4	2.7300	2.7300	1	5	2.7400	2.7400	1
4	2.7300	2.7300	1	5	2.7400	2.7400	1
4	2.7300	2.7300	1	5	2.7400	2.7400	1
4	2.7300	2.7300	1	5	2.7400	2.7500	1
4	2.7300	2.7300	1	5	2.7400	2.7400	1
4	2.7400	2.7400	1	5	2.7300	2.7300	1
5	2.7280	2.7280	1	6	2.7500	2.7600	1
5	2.7260	2.7300	1	6	2.7500	2.7500	1
5	2.7310	2.7310	1	6	2.7600	2.7300	1
5	2.7320	2.7320	1	6	2.7500	2.7400	1
5	2.7280	2.7330	1	6	2.7500	2.7500	1
5	2.7320	2.7340	1	6	2.7400	2.7500	1
6	2.7400	2.7300	1	7	2.7200	2.7500	1
6	2.7300	2.7300	1	7	2.7200	2.7400	1
6	2.7300	2.7400	1	7	2.7300	2.7200	1
6	2.7300	2.7400	1	7	2.7200	2.7400	1
6	2.7300	2.7400	1	7	2.7200	2.7300	1
6	2.7400	2.7400	1	7	2.7300	2.7300	1
7	2.6800	2.6800	1	8	2.8500	2.8600	1
7	2.6800	2.6900	1	8	2.8300	2.8300	1
7	2.6900	2.6900	1	8	2.8400	2.8300	1
7	2.6900	2.6900	1	8	2.8300	2.8300	1
7	2.7000	2.7000	1	8	2.8300	2.8300	1
7	2.7000	2.7000	1	8	2.8100	2.8100	1
8	2.7340	2.7370	1	9	2.8200	2.8100	1
8	2.7410	2.7370	1	9	2.7700	2.7700	1
8	2.7420	2.7430	1	9	2.7600	2.7700	1
8	2.7290	2.7440	1	9	2.8300	2.8100	1

8	2.7470	2.7460	1	9	2.7600	2.7500	1
8	2.7410	2.7470	1	9	2.7600	2.7400	1
9	2.7800	2.7800	1	10	2.8100	2.8100	1
9	2.7800	2.7800	1	10	2.8200	2.8200	1
9	2.7900	2.7800	1	10	2.8100	2.8100	1
9	2.7900	2.7900	1	10	2.8000	2.8000	1
9	2.7900	2.7900	1	10	2.8000	2.8000	1
9	2.7800	2.7900	1	10	2.8000	2.8000	1
10	2.6800	2.6800	1	11	2.7971	2.8050	1
10	2.6800	2.6800	1	11	2.7821	2.7904	1
10	2.6800	2.6800	1	11	2.7969	2.8003	1
10	2.6700	2.6900	1	11	2.7950	2.8052	1
10	2.7500	2.6900	1	11	2.7789	2.7808	1
10	2.6800	2.7000	1	11	2.7819	2.7852	1
11	2.7300	2.7200	1	12	2.6880	2.6780	1
11	2.7400	2.7300	1	12	2.6750	2.6710	1
11	2.7400	2.7300	1	12	2.6730	2.6810	1
11	2.7300	2.7400	1	12	2.6630	2.6860	1
11	2.7400	2.7500	1	12	2.6880	2.6810	1
11	2.7500	2.7500	1	12	2.6720	2.6760	1
12	2.7610	2.7630	1	13	2.7400	2.7370	1
12	2.7610	2.7740	1	13	2.7270	2.7350	1
12	2.7730	2.7780	1	13	2.7230	2.7220	1
12	2.7840	2.7820	1	13	2.7350	2.7340	1
12	2.7770	2.7880	1	13	2.7240	2.7150	1
12	2.7940	2.7890	1	13	2.7130	2.7120	1
13	2.7200	2.7200	1	14	2.7490	2.7500	1
13	2.7200	2.7200	1	14	2.7920	2.7940	1
13	2.7200	2.7300	1	14	2.7740	2.7720	1
13	2.7400	2.7300	1	14	2.7800	2.7850	1
13	2.7400	2.7400	1	14	2.7540	2.7610	1
13	2.7300	2.7400	1	14	2.7620	2.7610	1
14	2.7900	2.7800	1	15	2.7100	2.7200	1
14	2.7800	2.7800	1	15	2.7200	2.7200	1
14	2.7900	2.7900	1	15	2.7300	2.7300	1
14	2.7900	2.7900	1	15	2.7200	2.7300	1
14	2.7900	2.7900	1	15	2.7200	2.7200	1
14	2.7900	2.7900	1	15	2.7200	2.7100	1
15	2.7200	2.7200	1	16	2.7900	2.7900	1
15	2.7300	2.7300	1	16	2.7800	2.7900	1
15	2.7300	2.7300	1	16	2.7800	2.7900	1
15	2.7300	2.7300	1	16	2.7800	2.7700	1
15	2.7300	2.7400	1	16	2.7800	2.7800	1
1	4.2120	4.2050	2	17	2.7385	2.7390	1
1	4.2230	4.2110	2	17	2.6974	2.6996	1
1	4.2350	4.2150	2	17	2.6932	2.6922	1
1	4.2220	4.2190	2	17	2.7116	2.7109	1
1	4.2160	4.2210	2	17	2.6964	2.6942	1

1	4.2270	4.2330	2	17	2.7027	2.7028	1
2	4.1860	4.1690	2	18	2.7350	2.7360	1
2	4.2580	4.2340	2	18	2.7460	2.7470	1
2	4.2420	4.2360	2	18	2.7370	2.7410	1
2	4.2510	4.2380	2	18	2.7620	2.7610	1
2	4.2460	4.2390	2	18	2.7460	2.7450	1
2	4.2350	4.2450	2	18	2.7550	2.7580	1
3	4.2460	4.2390	2	19	2.7000	2.7000	1
3	4.2420	4.2430	2	19	2.7000	2.7000	1
3	4.2440	4.2440	2	19	2.7000	2.7000	1
3	4.2460	4.2460	2	19	2.7400	2.7400	1
3	4.2450	4.2470	2	19	2.7200	2.7200	1
3	4.2530	4.2500	2	19	2.7100	2.7100	1
4	4.2100	4.2000	2	20	2.7900	2.7900	1
4	4.2100	4.2100	2	20	2.7900	2.7900	1
4	4.2200	4.2200	2	20	2.8000	2.8000	1
4	4.2200	4.2200	2	20	2.8000	2.8000	1
4	4.2100	4.2200	2	20	2.8000	2.8000	1
4	4.2300	4.2200	2	20	2.8000	2.7900	1
5	4.2310	4.2370	2	21	2.7553	2.7423	1
5	4.2400	4.2380	2	21	2.7504	2.7442	1
5	4.2400	4.2380	2	21	2.7499	2.7481	1
5	4.2440	4.2380	2	21	2.7396	2.7409	1
5	4.2380	4.2400	2	21	2.7565	2.7515	1
5	4.2460	4.2400	2	21	2.7564	2.7522	1
6	4.2500	4.2400	2	22	2.7200	2.7200	1
6	4.2500	4.2400	2	22	2.7100	2.7100	1
6	4.2600	4.2500	2	22	2.7100	2.7100	1
6	4.2500	4.2500	2	22	2.7100	2.7100	1
6	4.2400	4.2500	2	22	2.7100	2.7100	1
6	4.2600	4.2600	2	22	2.7100	2.7100	1
7	4.1500	4.1500	2	23	2.7100	2.7100	1
7	4.1600	4.1500	2	23	2.7200	2.7200	1
7	4.1700	4.1700	2	23	2.7100	2.7200	1
7	4.1800	4.1700	2	23	2.7000	2.7100	1
7	4.1700	4.1700	2	23	2.7100	2.7200	1
7	4.1800	4.1900	2	23	2.7100	2.7100	1
8	4.2390	4.2350	2	24	2.8000	2.8000	1
8	4.2460	4.2410	2	24	2.7900	2.8000	1
8	4.2350	4.2420	2	24	2.8000	2.8000	1
8	4.2490	4.2490	2	24	2.8100	2.8100	1
8	4.2430	4.2500	2	24	2.8100	2.8100	1
8	4.2330	4.2530	2	24	2.7900	2.7900	1
9	4.3000	4.2900	2	1	4.2400	4.2300	2
9	4.3000	4.2900	2	1	4.2700	4.2700	2
9	4.3000	4.3000	2	1	4.2600	4.2700	2
9	4.3100	4.3000	2	1	4.2400	4.2500	2
9	4.2900	4.3000	2	1	4.2700	4.2700	2
9	4.3000	4.3100	2	1	4.2600	4.2700	2

10	4.2400	4.2400	2	2	4.3100	4.3300	2
10	4.2600	4.2400	2	2	4.1700	4.1800	2
10	4.2500	4.2400	2	2	4.3000	4.3000	2
10	4.2400	4.2500	2	2	4.3000	4.2600	2
10	4.2700	4.2800	2	2	4.2400	4.2700	2
10	4.2900	4.3700	2	2	4.2600	4.2700	2
11	4.2400	4.2100	2	4	4.2030	4.2050	2
11	4.2200	4.2300	2	4	4.2090	4.2090	2
11	4.2300	4.2300	2	4	4.2250	4.2190	2
11	4.2300	4.2300	2	4	4.2130	4.2160	2
11	4.2300	4.2400	2	4	4.2290	4.2270	2
11	4.2300	4.2500	2	4	4.2710	4.2600	2
12	4.2650	4.2490	2	5	4.2300	4.2300	2
12	4.2360	4.2530	2	5	4.2300	4.2400	2
12	4.2550	4.2600	2	5	4.2400	4.2300	2
12	4.2530	4.2630	2	5	4.2200	4.2200	2
12	4.2520	4.2680	2	5	4.2500	4.2500	2
12	4.2560	4.2690	2	5	4.2300	4.2300	2
13	4.2200	4.2200	2	6	4.2400	4.2400	2
13	4.2300	4.2200	2	6	4.2500	4.2500	2
13	4.2200	4.2200	2	6	4.2400	4.2500	2
13	4.2300	4.2300	2	6	4.2500	4.2400	2
13	4.2400	4.2400	2	6	4.2400	4.2600	2
13	4.2400	4.2400	2	6	4.2500	4.2500	2
14	4.2800	4.2700	2	7	4.2600	4.2500	2
14	4.2800	4.2800	2	7	4.2500	4.2500	2
14	4.2800	4.2800	2	7	4.2500	4.2400	2
14	4.2800	4.2800	2	7	4.2400	4.2300	2
14	4.2700	4.2800	2	7	4.2600	4.2400	2
14	4.2700	4.2800	2	7	4.2400	4.2500	2
15	4.2300	4.2100	2	8	4.3300	4.3300	2
15	4.2300	4.2200	2	8	4.3400	4.3400	2
15	4.2300	4.2300	2	8	4.3400	4.3400	2
15	4.2300	4.2300	2	8	4.3200	4.3300	2
15	4.2300	4.2400	2	8	4.3300	4.3300	2
15	4.2400	4.2400	2	8	4.3400	4.3400	2
				9	4.2700	4.2300	2
				9	4.2600	4.2100	2
				9	4.2600	4.2200	2
				9	4.2200	4.1700	2
				9	4.2600	4.1900	2
				9	4.2500	4.1900	2
			10		4.2800	4.2900	2
			10		4.3000	4.2900	2
			10		4.3000	4.3000	2
			10		4.2900	4.2900	2
			10		4.2900	4.3000	2
			10		4.2900	4.3000	2
			11		4.3218	4.3349	2

11	4.3297	4.3191	2
11	4.3137	4.3218	2
11	4.2969	4.3006	2
11	4.3187	4.3126	2
11	4.3149	4.3175	2
12	4.1990	4.2140	2
12	4.1950	4.1900	2
12	4.2070	4.2070	2
12	4.1980	4.1840	2
12	4.1880	4.1990	2
12	4.2000	4.2100	2
13	4.2010	4.2180	2
13	4.2140	4.2210	2
13	4.2240	4.2170	2
13	4.1860	4.1860	2
13	4.2130	4.2170	2
13	4.1950	4.2130	2
14	4.1950	4.1930	2
14	4.1880	4.1830	2
14	4.1960	4.1960	2
14	4.1920	4.2000	2
14	4.2060	4.2010	2
14	4.2150	4.2270	2
15	4.2300	4.2200	2
15	4.2700	4.2500	2
15	4.2800	4.2700	2
15	4.2300	4.2300	2
15	4.2800	4.2600	2
15	4.2700	4.2600	2
16	4.2800	4.2900	2
16	4.2800	4.2800	2
16	4.2900	4.3000	2
16	4.2500	4.2600	2
16	4.2700	4.2700	2
16	4.2600	4.2700	2
17	4.2259	4.2277	2
17	4.1953	4.1967	2
17	4.1866	4.1860	2
17	4.2004	4.2102	2
17	4.2093	4.2066	2
17	4.2099	4.2101	2
18	4.3000	4.3130	2
18	4.2970	4.3040	2
18	4.3900	4.3910	2
18	4.3910	4.3870	2
18	4.3590	4.3520	2
18	4.3050	4.2920	2
19	4.2000	4.2000	2
19	4.2100	4.2100	2

19	4.2000	4.2000	2
19	4.2100	4.2100	2
19	4.2100	4.2100	2
19	4.2100	4.2200	2
20	4.2700	4.2700	2
20	4.2600	4.2600	2
20	4.2700	4.2700	2
20	4.2700	4.2700	2
20	4.2700	4.2700	2
20	4.2700	4.2700	2
21	4.2652	4.2689	2
21	4.2652	4.2689	2
21	4.2692	4.2667	2
21	4.2654	4.2678	2
21	4.2654	4.2678	2
21	4.2600	4.2580	2
22	4.2200	4.2100	2
22	4.2100	4.2200	2
22	4.2100	4.2200	2
22	4.2100	4.2100	2
22	4.2100	4.2200	2
22	4.2000	4.2100	2
23	4.2200	4.2100	2
23	4.2200	4.2200	2
23	4.1900	4.2000	2
23	4.2000	4.2000	2
23	4.2100	4.2100	2
23	4.2000	4.2000	2
24	4.2100	4.2300	2
24	4.2400	4.2200	2
24	4.2100	4.2100	2
24	4.2200	4.2200	2
24	4.2100	4.2100	2
24	4.2200	4.2100	2

Fe₂O₃

Fe ₂ O ₃ : Glass Preparation				Fe ₂ O ₃ : Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	4.913	4.916	1	1	4.720	4.780	1
1	4.895	4.922	1	1	4.820	4.810	1
1	4.944	4.924	1	1	4.790	4.790	1
1	4.921	4.918	1	1	4.680	4.740	1
1	4.953	4.987	1	1	4.770	4.760	1
1	4.953	4.932	1	1	4.720	4.680	1
2	5.030	5.026	1	2	4.730	4.750	1
2	5.016	5.009	1	2	4.740	4.750	1
2	5.013	5.012	1	2	4.750	4.750	1
2	5.041	5.023	1	2	4.720	4.730	1
2	5.036	5.026	1	2	4.750	4.720	1
2	5.020	5.016	1	2	4.700	4.700	1
3	4.980	4.980	1	3	4.735	4.764	1
3	4.960	4.980	1	3	4.731	4.732	1
3	4.970	4.970	1	3	4.705	4.723	1
3	4.960	4.970	1	3	4.749	4.754	1
3	4.980	4.980	1	3	4.741	4.734	1
3	4.960	4.980	1	3	4.667	4.647	1
4	4.973	4.967	1	4	4.803	4.797	1
4	4.957	4.955	1	4	4.899	4.908	1
4	4.977	4.979	1	4	4.862	4.867	1
4	4.996	4.968	1	4	4.820	4.829	1
4	4.971	4.969	1	4	4.873	4.885	1
4	4.992	4.986	1	4	4.827	4.831	1
5	4.970	4.950	1	5	4.960	4.950	1
5	4.960	4.950	1	5	4.940	4.940	1
5	4.940	4.980	1	5	4.930	4.930	1
5	5.020	4.990	1	5	4.960	4.960	1
5	4.980	5.000	1	5	4.940	4.940	1
5	4.970	4.980	1	5	4.960	4.960	1
6	5.130	5.140	1	6	4.850	4.860	1
6	5.150	5.150	1	6	4.830	4.860	1
6	5.140	5.120	1	6	4.840	4.850	1
6	5.130	5.120	1	6	4.800	4.820	1
6	5.140	5.150	1	6	4.810	4.810	1
6	5.130	5.130	1	6	4.830	4.810	1
7	5.002	4.979	1	7	4.790	4.800	1
7	5.032	5.027	1	7	4.790	4.800	1
7	5.017	5.006	1	7	4.780	4.790	1
7	4.979	4.986	1	7	4.810	4.800	1
7	4.973	4.973	1	7	4.780	4.780	1
7	4.998	5.000	1	7	4.800	4.790	1
8	5.020	5.010	1	8	4.990	4.980	1
8	5.030	4.980	1	8	5.000	5.000	1
8	5.010	5.020	1	8	4.990	5.000	1
8	4.990	5.010	1	8	4.990	4.970	1

8	5.030	5.000	1	8	4.960	4.980	1
8	5.000	5.010	1	8	4.980	5.000	1
9	4.990	4.980	1	9	4.820	4.830	1
9	5.000	4.980	1	9	4.830	4.840	1
9	4.950	4.940	1	9	4.820	4.820	1
9	4.940	4.930	1	9	4.840	4.840	1
9	4.990	4.960	1	9	4.820	4.830	1
9	4.940	4.950	1	9	4.830	4.840	1
10	4.930	4.970	1	10	4.830	4.840	1
10	4.940	4.910	1	10	4.860	4.860	1
10	4.980	4.940	1	10	4.820	4.830	1
10	4.980	4.970	1	10	4.830	4.840	1
10	4.920	4.970	1	10	4.860	4.880	1
10	4.920	4.930	1	10	4.840	4.830	1
11	4.990	5.000	1	11	4.884	4.887	1
11	5.000	4.990	1	11	4.880	4.888	1
11	5.000	4.980	1	11	4.892	4.890	1
11	5.050	5.050	1	11	4.895	4.903	1
11	5.010	5.050	1	11	4.881	4.877	1
11	5.020	5.000	1	11	4.880	4.882	1
12	5.019	5.043	1	13	4.748	4.789	1
12	5.044	5.080	1	13	4.751	4.763	1
12	5.036	5.088	1	13	4.761	4.752	1
12	5.059	5.088	1	13	4.768	4.769	1
12	5.122	5.105	1	13	4.769	4.770	1
12	5.103	5.079	1	13	4.791	4.754	1
13	4.950	5.000	1	14	4.740	4.750	1
13	4.980	5.020	1	14	4.780	4.760	1
13	5.010	5.000	1	14	4.800	4.770	1
13	4.990	5.010	1	14	4.810	4.800	1
13	4.980	5.020	1	14	4.790	4.800	1
13	5.020	5.030	1	14	4.800	4.790	1
14	5.030	5.030	1	15	4.743	4.798	1
14	5.020	5.020	1	15	4.743	4.791	1
14	5.010	5.000	1	15	4.767	4.794	1
14	5.000	5.000	1	15	4.729	4.800	1
14	5.010	5.030	1	15	4.770	4.776	1
14	5.020	5.040	1	15	4.764	4.791	1
15	5.100	5.100	1	16	4.906	4.913	1
15	5.050	5.040	1	16	4.960	4.963	1
15	5.040	5.040	1	16	4.931	4.940	1
15	5.040	5.040	1	16	5.027	5.031	1
15	5.030	5.040	1	16	4.956	4.960	1
15	5.010	5.020	1	16	4.953	4.948	1
16	5.048	5.026	1	17	4.810	4.820	1
16	5.044	5.039	1	17	4.800	4.780	1
16	5.048	5.052	1	17	4.780	4.780	1
16	5.058	5.043	1	17	4.760	4.800	1
16	5.048	5.039	1	17	4.760	4.760	1

16	5.049	5.027	1	17	4.760	4.790	1
17	5.010	5.020	1	18	4.830	4.850	1
17	5.020	5.010	1	18	4.820	4.820	1
17	5.030	5.010	1	18	4.840	4.840	1
17	5.020	5.010	1	18	4.830	4.830	1
17	5.030	5.040	1	18	4.830	4.830	1
17	5.020	5.030	1	18	4.820	4.830	1
1	5.047	5.030	2	19	4.880	4.885	1
1	5.046	5.049	2	19	4.809	4.829	1
1	5.025	5.056	2	19	4.822	4.825	1
1	5.064	5.070	2	19	4.821	4.816	1
1	5.035	5.038	2	19	4.813	4.809	1
1	5.068	5.074	2	19	4.823	4.824	1
2	5.145	5.126	2	20	4.840	4.840	1
2	5.132	5.143	2	20	4.800	4.830	1
2	5.126	5.132	2	20	4.770	4.780	1
2	5.149	5.146	2	20	4.850	4.870	1
2	5.143	5.128	2	20	4.800	4.820	1
2	5.132	5.139	2	20	4.790	4.800	1
3	5.120	5.110	2	21	4.900	4.890	1
3	5.120	5.130	2	21	4.890	4.900	1
3	5.110	5.120	2	21	4.860	4.850	1
3	5.120	5.120	2	21	4.910	4.910	1
3	5.100	5.100	2	21	4.880	4.890	1
3	5.120	5.110	2	21	4.880	4.880	1
4	5.091	5.095	2	22	4.710	4.705	1
4	5.096	5.087	2	22	4.714	4.710	1
4	5.088	5.087	2	22	4.710	4.709	1
4	5.109	5.102	2	22	4.684	4.683	1
4	5.118	5.125	2	22	4.700	4.689	1
4	5.107	5.127	2	22	4.702	4.694	1
5	5.080	5.070	2	1	4.970	4.900	2
5	5.120	5.100	2	1	4.930	4.950	2
5	5.080	5.090	2	1	4.960	4.950	2
5	5.150	5.140	2	1	4.910	4.970	2
5	5.140	5.120	2	1	4.930	4.980	2
5	5.110	5.140	2	1	4.960	4.940	2
6	5.250	5.240	2	2	5.240	5.220	2
6	5.280	5.260	2	2	5.220	5.180	2
6	5.270	5.300	2	2	5.220	5.220	2
6	5.230	5.270	2	2	5.230	5.220	2
6	5.260	5.300	2	2	5.220	5.230	2
6	5.260	5.260	2	2	5.220	5.200	2
7	5.141	5.123	2	3	5.293	5.306	2
7	5.137	5.156	2	3	5.278	5.282	2
7	5.133	5.166	2	3	5.301	5.290	2
7	5.138	5.145	2	3	5.309	5.337	2
7	5.182	5.150	2	3	5.335	5.356	2
7	5.149	5.151	2	3	5.324	5.323	2

8	5.130	5.130	2	4	5.118	5.117	2
8	5.150	5.110	2	4	5.127	5.121	2
8	5.140	5.140	2	4	5.093	5.099	2
8	5.110	5.110	2	4	5.154	5.166	2
8	5.110	5.140	2	4	5.119	5.120	2
8	5.100	5.120	2	4	5.118	5.125	2
9	5.080	5.080	2	5	5.280	5.270	2
9	5.070	5.080	2	5	5.280	5.270	2
9	5.130	5.090	2	5	5.290	5.290	2
9	5.090	5.060	2	5	5.240	5.260	2
9	5.060	5.060	2	5	5.280	5.280	2
9	5.130	5.070	2	5	5.270	5.270	2
10	5.050	5.010	2	6	5.060	5.060	2
10	5.020	5.020	2	6	5.060	5.070	2
10	5.000	5.000	2	6	5.050	5.060	2
10	4.940	5.040	2	6	5.070	5.060	2
10	5.010	5.070	2	6	5.070	5.090	2
10	5.050	5.040	2	6	5.080	5.050	2
11	5.100	5.120	2	7	5.020	5.030	2
11	5.140	5.120	2	7	5.020	5.030	2
11	5.130	5.100	2	7	5.040	5.020	2
11	5.120	5.130	2	7	5.020	5.010	2
11	5.130	5.140	2	7	5.020	5.020	2
11	5.150	5.110	2	7	5.040	5.040	2
12	5.162	5.180	2	8	5.290	5.260	2
12	5.135	5.203	2	8	5.270	5.280	2
12	5.191	5.245	2	8	5.290	5.290	2
12	5.200	5.163	2	8	5.260	5.270	2
12	5.175	5.183	2	8	5.310	5.300	2
12	5.185	5.197	2	8	5.280	5.270	2
13	5.090	5.070	2	9	5.160	5.150	2
13	5.120	5.110	2	9	5.130	5.150	2
13	5.120	5.150	2	9	5.120	5.120	2
13	5.020	5.060	2	9	5.140	5.140	2
13	5.080	5.090	2	9	5.130	5.140	2
13	5.120	5.150	2	9	5.140	5.140	2
14	5.140	5.150	2	10	5.220	5.210	2
14	5.130	5.150	2	10	5.170	5.170	2
14	5.120	5.120	2	10	5.220	5.220	2
14	5.140	5.140	2	10	5.170	5.160	2
14	5.180	5.210	2	10	5.210	5.220	2
14	5.150	5.160	2	10	5.140	5.140	2
15	5.200	5.210	2	11	5.099	5.087	2
15	5.240	5.230	2	11	5.088	5.095	2
15	5.220	5.210	2	11	5.082	5.078	2
15	5.190	5.210	2	11	5.020	5.036	2
15	5.190	5.180	2	11	5.063	5.066	2
15	5.200	5.210	2	11	5.085	5.068	2
16	5.169	5.164	2	13	5.292	5.303	2

16	5.169	5.164	2	13	5.327	5.314	2
16	5.166	5.162	2	13	5.320	5.285	2
16	5.172	5.165	2	13	5.311	5.310	2
16	5.172	5.165	2	13	5.319	5.318	2
16	5.173	5.161	2	13	5.305	5.301	2
17	5.140	5.130	2	14	5.020	5.030	2
17	5.120	5.130	2	14	5.050	5.050	2
17	5.140	5.150	2	14	5.070	5.070	2
17	5.160	5.170	2	14	5.030	5.010	2
17	5.160	5.160	2	14	5.020	5.030	2
17	5.160	5.150	2	14	5.040	5.030	2
				15	4.969	5.008	2
				15	4.976	5.029	2
				15	5.010	5.039	2
				15	4.947	5.040	2
				15	5.011	5.056	2
				15	5.005	5.018	2
				16	5.210	5.203	2
				16	5.197	5.211	2
				16	5.217	5.217	2
				16	5.221	5.211	2
				16	5.204	5.200	2
				16	5.233	5.231	2
				17	5.160	5.130	2
				17	5.150	5.160	2
				17	5.140	5.140	2
				17	5.120	5.120	2
				17	5.140	5.110	2
				17	5.110	5.140	2
				18	5.050	5.040	2
				18	5.060	5.050	2
				18	5.060	5.060	2
				18	5.010	5.020	2
				18	5.020	5.010	2
				18	5.030	5.020	2
				19	5.097	5.114	2
				19	5.047	5.046	2
				19	5.096	5.137	2
				19	5.081	5.089	2
				19	5.070	5.064	2
				19	5.071	5.076	2
				20	5.060	5.100	2
				20	5.070	5.100	2
				20	5.070	5.110	2
				20	5.070	5.090	2
				20	5.100	5.110	2
				20	5.070	5.100	2
				21	5.170	5.170	2
				21	5.180	5.190	2

21	5.180	5.190	2
21	5.200	5.200	2
21	5.240	5.240	2
21	5.160	5.160	2
22	4.991	4.982	2
22	4.991	4.982	2
22	5.018	5.019	2
22	5.011	5.002	2
22	5.011	5.002	2
22	5.011	5.010	2

CaO

CaO: Glass Preparation				CaO: Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	64.180	64.190	1	1	63.877	63.818	1
1	64.160	64.250	1	1	63.903	63.923	1
1	64.230	64.290	1	1	63.814	63.789	1
1	64.050	64.200	1	1	64.052	63.994	1
1	64.120	64.000	1	1	64.061	64.155	1
1	64.100	64.020	1	1	63.871	63.883	1
2	64.140	64.180	1	2	63.384	63.391	1
2	64.370	64.300	1	2	63.764	63.777	1
2	64.010	64.040	1	2	63.680	63.692	1
2	64.050	64.000	1	2	63.659	63.654	1
2	64.360	64.350	1	2	63.410	63.374	1
2	64.070	64.100	1	2	63.526	63.514	1
3	63.840	63.740	1	3	63.910	64.120	1
3	63.720	63.800	1	3	64.190	64.230	1
3	63.820	63.730	1	3	64.260	64.350	1
3	64.030	63.640	1	3	64.070	64.090	1
3	64.010	63.790	1	3	64.220	64.170	1
3	63.860	63.930	1	3	64.230	64.290	1
4	63.207	63.194	1	4	64.210	64.230	1
4	63.139	63.227	1	4	64.140	64.140	1
4	63.264	63.147	1	4	64.120	64.160	1
4	63.287	63.224	1	4	64.250	64.230	1
4	63.486	63.322	1	4	63.990	64.030	1
4	63.207	63.274	1	4	63.700	63.940	1
5	63.627	63.652	1	5	63.880	63.960	1
5	63.679	63.665	1	5	63.900	63.960	1
5	63.597	63.701	1	5	63.910	63.980	1
5	63.801	63.720	1	5	63.920	63.930	1
5	63.711	63.668	1	5	63.790	63.820	1
5	63.772	63.772	1	5	63.900	63.950	1
6	64.250	64.300	1	6	64.150	64.230	1
6	64.020	64.030	1	6	64.180	64.270	1
6	63.940	63.950	1	6	64.190	64.270	1
6	63.830	63.910	1	6	64.360	64.420	1
6	64.200	64.240	1	6	64.190	64.300	1
6	64.180	64.340	1	6	64.250	64.310	1
7	63.510	63.580	1	7	63.550	63.950	1
7	63.540	63.600	1	7	63.880	63.910	1
7	63.630	63.640	1	7	63.810	64.020	1
7	63.680	63.660	1	7	63.640	63.710	1
7	63.740	63.670	1	7	63.840	63.810	1
7	63.620	63.750	1	7	63.780	63.980	1
8	64.280	64.300	1	8	63.850	64.040	1
8	64.350	64.400	1	8	63.930	64.000	1

8	64.350	64.310	1	8	63.990	64.010	1
8	64.310	64.310	1	8	64.040	64.140	1
8	64.230	64.250	1	8	64.130	64.240	1
8	64.280	64.260	1	8	64.240	64.250	1
9	63.610	63.605	1	9	63.920	63.930	1
9	63.753	63.494	1	9	64.200	64.130	1
9	63.706	63.441	1	9	64.040	64.100	1
9	63.704	63.682	1	9	64.030	64.050	1
9	63.487	63.498	1	9	64.010	64.090	1
9	63.517	63.462	1	9	64.070	64.130	1
10	63.970	63.790	1	10	63.650	63.640	1
10	64.040	64.020	1	10	64.010	63.840	1
10	63.900	63.950	1	10	64.020	64.110	1
10	64.040	64.070	1	10	63.810	63.780	1
10	63.980	63.990	1	10	63.850	63.840	1
10	63.990	64.080	1	10	63.810	63.800	1
11	63.430	63.398	1	11	64.800	64.800	1
11	63.436	63.454	1	11	64.710	64.700	1
11	63.188	63.441	1	11	64.720	64.740	1
11	63.288	63.407	1	11	64.640	64.730	1
11	63.413	63.388	1	11	64.680	64.650	1
11	63.483	63.243	1	11	64.660	64.680	1
12	64.180	64.210	1	12	64.820	64.700	1
12	64.250	64.300	1	12	64.790	64.790	1
12	64.240	64.240	1	12	64.770	64.640	1
12	63.900	63.930	1	12	64.720	64.790	1
12	64.080	64.150	1	12	64.790	64.920	1
12	64.050	64.060	1	12	64.410	64.570	1
13	63.872	63.855	1	13	63.890	63.850	1
13	63.861	63.843	1	13	64.100	64.110	1
13	63.906	63.881	1	13	64.090	64.110	1
13	63.846	63.841	1	13	63.940	63.970	1
13	63.871	63.875	1	13	64.040	64.070	1
13	63.912	63.893	1	13	64.070	64.100	1
14	64.330	64.290	1	14	63.396	63.384	1
14	64.280	64.230	1	14	63.597	63.611	1
14	64.190	64.250	1	14	63.684	63.697	1
14	64.200	64.290	1	14	63.395	63.358	1
14	64.200	64.310	1	14	63.523	63.561	1
14	64.410	64.290	1	14	63.822	63.828	1
15	63.119	63.143	1	15	64.220	64.210	1
15	63.316	63.317	1	15	64.290	64.270	1
15	63.301	63.319	1	15	64.270	64.250	1
15	63.519	63.563	1	15	64.250	64.260	1
15	63.212	63.132	1	15	64.270	64.340	1
15	63.197	63.162	1	15	64.060	64.160	1
16	64.240	64.240	1	16	64.096	63.987	1
16	64.190	64.200	1	16	64.188	63.992	1
16	64.310	64.240	1	16	64.104	64.076	1

16	64.450	64.450	1	16	63.851	63.896	1
16	64.350	64.370	1	16	64.239	64.046	1
16	64.510	64.560	1	16	64.084	64.079	1
17	63.920	63.860	1	17	64.110	64.200	1
17	63.930	63.900	1	17	64.170	64.190	1
17	63.960	64.020	1	17	64.200	64.200	1
17	63.950	63.930	1	17	64.170	64.190	1
17	63.840	63.810	1	17	64.210	64.150	1
17	63.960	63.960	1	17	64.220	64.240	1
1	63.930	63.940	2	18	63.269	63.302	1
1	63.850	63.840	2	18	63.576	63.604	1
1	63.700	63.700	2	18	63.373	63.376	1
1	63.530	63.440	2	18	63.460	63.483	1
1	63.620	63.500	2	18	63.608	63.623	1
1	63.650	63.620	2	18	63.511	63.523	1
2	63.440	63.400	2	19	63.800	63.790	1
2	63.680	63.680	2	19	63.910	63.930	1
2	63.970	63.980	2	19	64.010	64.080	1
2	63.610	63.620	2	19	64.030	64.090	1
2	63.990	63.960	2	19	64.100	64.110	1
2	63.510	63.550	2	19	64.030	64.090	1
3	63.490	63.520	2	20	64.765	64.798	1
3	63.410	63.470	2	20	64.742	64.766	1
3	63.580	63.600	2	20	64.688	64.725	1
3	63.760	63.920	2	20	64.815	64.902	1
3	63.710	63.540	2	20	64.852	64.893	1
3	63.670	63.620	2	20	64.394	64.409	1
4	62.908	62.915	2	21	64.760	64.760	1
4	62.974	62.619	2	21	64.780	64.710	1
4	62.712	62.735	2	21	64.630	64.580	1
4	62.886	62.942	2	21	64.570	64.670	1
4	62.812	62.870	2	21	64.770	64.870	1
4	63.051	63.056	2	21	64.900	64.850	1
5	63.367	63.351	2	22	64.294	64.281	1
5	63.279	63.416	2	22	64.260	64.266	1
5	63.491	63.408	2	22	64.330	64.350	1
5	63.498	63.484	2	22	64.349	64.355	1
5	63.565	63.483	2	22	64.123	64.122	1
5	63.477	63.498	2	22	64.311	64.372	1
6	63.630	63.620	2	23	64.010	63.990	1
6	63.670	63.660	2	23	63.880	63.920	1
6	63.540	63.550	2	23	63.880	63.880	1
6	63.700	63.730	2	23	64.070	64.070	1
6	63.960	63.990	2	23	63.930	63.870	1
6	63.970	63.880	2	23	64.000	63.930	1
7	63.020	63.040	2	1	63.729	63.755	2
7	63.070	62.970	2	1	63.499	63.554	2
7	63.110	63.010	2	1	63.538	63.588	2
7	63.120	62.980	2	1	63.633	63.561	2

7	63.030	63.030	2	1	63.540	63.541	2
7	63.020	62.950	2	1	63.398	63.619	2
8	63.820	63.820	2	2	63.405	63.406	2
8	63.850	63.770	2	2	63.320	63.361	2
8	63.760	63.800	2	2	63.407	63.423	2
8	63.860	63.920	2	2	63.446	63.460	2
8	63.870	63.800	2	2	63.494	63.460	2
8	63.810	63.810	2	2	63.663	63.685	2
9	63.033	62.694	2	3	63.830	63.810	2
9	62.984	62.694	2	3	63.720	63.730	2
9	62.957	62.636	2	3	63.660	63.740	2
9	62.738	62.771	2	3	63.760	63.910	2
9	62.747	62.756	2	3	63.900	64.000	2
9	62.741	62.803	2	3	63.870	63.840	2
10	63.730	63.740	2	4	63.590	63.640	2
10	63.670	63.610	2	4	63.580	63.590	2
10	63.870	63.840	2	4	63.660	63.690	2
10	63.870	63.980	2	4	63.600	63.640	2
10	63.860	63.900	2	4	63.690	63.690	2
10	63.830	63.900	2	4	63.760	63.770	2
11	63.061	62.968	2	5	64.070	64.020	2
11	63.061	62.968	2	5	64.010	63.910	2
11	63.004	63.012	2	5	64.090	64.060	2
11	63.020	63.071	2	5	64.080	64.010	2
11	63.020	63.071	2	5	64.080	64.070	2
11	63.069	62.934	2	5	63.870	63.940	2
12	63.790	63.700	2	6	63.740	63.780	2
12	63.750	63.610	2	6	63.750	63.800	2
12	63.750	63.790	2	6	63.610	63.680	2
12	63.690	63.770	2	6	63.740	63.820	2
12	63.700	63.730	2	6	63.660	63.740	2
12	63.630	63.640	2	6	63.750	63.850	2
13	63.615	63.613	2	7	63.120	63.300	2
13	63.692	63.664	2	7	63.360	63.490	2
13	63.676	63.654	2	7	63.230	63.260	2
13	63.586	63.575	2	7	63.340	63.380	2
13	63.616	63.615	2	7	63.240	63.430	2
13	63.583	63.601	2	7	63.320	63.400	2
14	63.700	63.740	2	8	63.440	63.520	2
14	63.670	63.760	2	8	63.450	63.520	2
14	63.740	63.850	2	8	63.500	63.510	2
14	63.820	63.930	2	8	63.610	63.590	2
14	63.900	63.940	2	8	63.700	63.710	2
14	63.810	63.830	2	8	63.670	63.660	2
15	63.369	63.331	2	9	63.750	63.750	2
15	63.334	63.333	2	9	63.780	63.690	2
15	63.162	63.185	2	9	63.660	63.700	2
15	63.473	63.485	2	9	63.690	63.660	2
15	63.812	63.830	2	9	63.700	63.740	2

15	63.292	63.264	2	9	63.840	63.920	2
16	63.750	63.770	2	10	63.600	63.660	2
16	63.650	63.700	2	10	63.590	63.500	2
16	63.700	63.680	2	10	63.580	63.680	2
16	63.890	63.880	2	10	63.650	63.560	2
16	63.990	64.060	2	10	63.570	63.600	2
16	63.570	63.490	2	10	63.600	63.650	2
17	63.730	63.740	2	11	64.170	64.340	2
17	63.800	63.770	2	11	64.260	64.230	2
17	63.790	63.780	2	11	64.340	64.220	2
17	63.830	63.830	2	11	64.060	64.160	2
17	63.820	63.880	2	11	64.130	64.170	2
17	63.780	63.850	2	11	64.150	64.130	2
				12	64.050	64.140	2
				12	64.050	64.140	2
				12	64.230	64.340	2
				12	64.250	64.290	2
				12	64.250	64.290	2
				12	64.260	64.250	2
				13	63.390	63.390	2
				13	63.390	63.390	2
				13	63.480	63.590	2
				13	63.440	63.450	2
				13	63.440	63.450	2
				13	63.510	63.530	2
				14	63.348	63.392	2
				14	63.380	63.382	2
				14	63.185	63.156	2
				14	63.148	63.340	2
				14	63.635	63.639	2
				14	63.668	63.703	2
				15	63.730	63.730	2
				15	63.730	63.760	2
				15	63.870	63.820	2
				15	63.820	63.800	2
				15	63.760	63.780	2
				15	63.810	63.840	2
				16	63.463	63.471	2
				16	63.463	63.471	2
				16	63.536	63.498	2
				16	63.589	63.553	2
				16	63.589	63.553	2
				16	63.542	63.445	2
				17	63.440	63.480	2
				17	63.580	63.540	2
				17	63.640	63.610	2
				17	63.620	63.680	2
				17	63.690	63.720	2
				17	63.610	63.670	2

18	63.418	63.439	2
18	63.479	63.494	2
18	63.200	63.226	2
18	63.467	63.483	2
18	63.397	63.405	2
18	63.464	63.470	2
19	63.260	63.390	2
19	63.440	63.430	2
19	63.550	63.450	2
19	63.460	63.460	2
19	63.390	63.470	2
19	63.520	63.570	2
20	63.836	63.931	2
20	63.989	64.006	2
20	64.013	64.045	2
20	63.997	64.035	2
20	64.125	64.160	2
20	64.158	64.178	2
21	64.230	64.210	2
21	64.230	64.130	2
21	64.170	64.130	2
21	64.140	64.220	2
21	64.370	64.350	2
21	64.500	64.470	2
22	63.909	63.914	2
22	63.936	63.929	2
22	63.934	63.945	2
22	63.584	63.568	2
22	63.968	63.972	2
22	63.992	64.003	2
23	63.510	63.520	2
23	63.540	63.500	2
23	63.620	63.600	2
23	63.500	63.480	2
23	63.660	63.670	2
23	63.520	63.510	2

MgO

MgO: Glass Preparation				MgO: Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	1.8770	1.8770	1	1	1.9700	1.9700	1
1	1.8840	1.8680	1	1	1.9700	1.9700	1
1	1.8750	1.8890	1	1	1.9600	1.9200	1
1	1.8970	1.8940	1	1	1.9600	1.9700	1
1	1.8780	1.9140	1	1	1.9900	1.9900	1
1	1.8860	1.9020	1	1	1.9900	2.0100	1
2	1.8880	1.8930	1	2	1.8200	1.8300	1
2	1.9120	1.8990	1	2	1.8200	1.8200	1
2	1.8740	1.9140	1	2	1.8400	1.8400	1
2	1.8660	1.8520	1	2	1.8200	1.8300	1
2	1.8970	1.8920	1	2	1.8300	1.8300	1
2	1.7920	1.8000	1	2	1.8300	1.8100	1
3	1.8660	1.8580	1	3	1.7700	1.7740	1
3	1.8610	1.8570	1	3	1.7860	1.8000	1
3	1.8720	1.8550	1	3	1.8070	1.7990	1
3	2.2730	2.2390	1	3	1.7980	1.8050	1
3	2.2420	2.2570	1	3	1.8080	1.8070	1
3	2.2730	2.2680	1	3	1.8020	1.7880	1
4	1.9070	1.9080	1	4	1.7420	1.7460	1
4	1.9040	1.9120	1	4	1.7490	1.7460	1
4	1.9150	1.9060	1	4	1.7370	1.7350	1
4	1.9080	1.9090	1	4	1.7300	1.7290	1
4	1.9030	1.9120	1	4	1.7400	1.7410	1
4	1.9030	1.9050	1	4	1.7440	1.7460	1
5	1.9000	1.8900	1	5	1.9000	1.9300	1
5	1.9000	1.8900	1	5	1.8900	1.9100	1
5	1.9000	1.8900	1	5	1.9100	1.9100	1
5	1.9000	1.9000	1	5	1.9300	1.9200	1
5	1.9000	1.8800	1	5	1.8900	1.8900	1
5	1.8900	1.9000	1	5	1.9300	1.9200	1
6	1.8980	1.8970	1	6	1.8500	1.8500	1
6	1.8940	1.8990	1	6	1.8400	1.8400	1
6	1.8990	1.8980	1	6	1.8400	1.8400	1
6	1.9170	1.9110	1	6	1.8700	1.8500	1
6	1.9080	1.9030	1	6	1.8300	1.8400	1
6	1.9060	1.9140	1	6	1.8400	1.8400	1
7	1.9100	1.9300	1	7	1.8600	1.8700	1
7	1.9000	1.9100	1	7	1.8300	1.8400	1
7	1.9200	1.9200	1	7	1.8300	1.8300	1
7	1.9000	1.9100	1	7	1.8500	1.8600	1
7	1.9000	1.9000	1	7	1.8300	1.8300	1
7	1.9000	1.9000	1	7	1.8300	1.8200	1
8	1.9800	1.9900	1	8	1.9400	1.9400	1
8	2.0000	2.0100	1	8	1.9300	1.9300	1
8	1.9800	1.9900	1	8	1.9300	1.9200	1
8	1.9800	1.9700	1	8	1.9300	1.9400	1

8	1.9800	2.0000	1	8	1.9300	1.9300	1
8	2.0000	1.9800	1	8	1.9300	1.9200	1
9	1.9280	1.9350	1	9	1.8400	1.8400	1
9	1.9380	1.9250	1	9	1.8500	1.8500	1
9	1.9340	1.9280	1	9	1.8400	1.8400	1
9	1.9370	1.9300	1	9	1.8600	1.8600	1
9	1.9280	1.9240	1	9	1.8400	1.8500	1
9	1.9270	1.9370	1	9	1.8400	1.8400	1
10	1.8900	1.8600	1	10	1.9800	1.9800	1
10	1.8800	1.8600	1	10	2.0000	2.0000	1
10	1.8700	1.8900	1	10	2.0000	2.0100	1
10	1.8600	1.9000	1	10	1.9700	1.9700	1
10	1.8500	1.8700	1	10	2.0000	2.0000	1
10	1.8500	1.8800	1	10	2.0100	2.0000	1
11	1.8900	1.8800	1	11	1.9700	1.9700	1
11	1.9000	1.8900	1	11	1.8800	1.8800	1
11	1.8800	1.8800	1	11	1.8700	1.8700	1
11	1.8700	1.8700	1	11	1.9000	1.8900	1
11	1.8800	1.8800	1	11	1.8700	1.8700	1
11	1.8800	1.8800	1	11	1.8600	1.8800	1
12	1.9000	1.9300	1	12	1.9200	1.9200	1
12	1.9300	1.9200	1	12	1.9400	1.9300	1
12	1.9100	1.9000	1	12	1.9200	1.9200	1
12	1.9400	1.9300	1	12	1.9000	1.9200	1
12	1.9400	1.9100	1	12	1.9200	1.9300	1
12	1.9100	1.9100	1	12	1.9100	1.9200	1
13	1.9300	1.9300	1	13	1.9123	1.9123	1
13	1.9500	1.9300	1	13	1.9128	1.9106	1
13	1.9300	1.9400	1	13	1.9157	1.9200	1
13	1.9400	1.9400	1	13	1.9094	1.9113	1
13	1.9200	1.9300	1	13	1.9057	1.9098	1
13	1.9200	1.9400	1	13	1.9168	1.9195	1
14	1.9110	1.9340	1	14	1.7890	1.8010	1
14	1.8870	1.9270	1	14	1.8160	1.7740	1
14	1.8790	1.9350	1	14	1.8100	1.7910	1
14	1.8740	1.8800	1	14	1.8110	1.8110	1
14	1.9110	1.9030	1	14	1.8170	1.8230	1
14	1.9100	1.8990	1	14	1.7940	1.7940	1
15	2.0000	2.0100	1	15	2.0100	2.0200	1
15	2.0000	2.0000	1	15	1.8700	1.8700	1
15	2.0000	2.0100	1	15	1.9000	1.9000	1
15	2.0000	2.0200	1	15	1.8500	1.8700	1
15	2.0200	2.0000	1	15	1.8400	1.8700	1
15	2.0200	2.0000	1	15	1.8700	1.8700	1
16	1.9000	1.9100	1	16	1.8140	1.8170	1
16	1.9000	1.9200	1	16	1.8120	1.8170	1
16	1.9100	1.8900	1	16	1.8170	1.8220	1
16	1.8900	1.8800	1	16	1.0824	1.8280	1
16	1.9000	1.9100	1	16	1.8280	1.8310	1

16	1.8900	1.8900	1	16	1.8230	1.8160	1
17	1.9100	1.9000	1	17	1.8150	1.8080	1
17	1.8900	1.9100	1	17	1.8350	1.8360	1
17	1.9100	1.8900	1	17	1.8150	1.8240	1
17	1.8900	1.8900	1	17	1.8160	1.8130	1
17	1.8800	1.8900	1	17	1.8040	1.8050	1
17	1.8800	1.9000	1	17	1.8130	1.8120	1
18	1.9096	1.9079	1	18	1.7600	1.7400	1
18	1.9196	1.9159	1	18	1.7800	1.7700	1
18	1.9109	1.9035	1	18	1.8000	1.8000	1
18	1.9135	1.9040	1	18	1.7400	1.7600	1
18	1.9179	1.9043	1	18	1.7800	1.7600	1
18	1.9092	1.9098	1	18	1.7800	1.7700	1
19	1.9000	1.9000	1	19	1.8400	1.8400	1
19	1.9100	1.9000	1	19	1.8300	1.8300	1
19	1.9100	1.8900	1	19	1.8300	1.8300	1
19	1.8900	1.9000	1	19	1.8300	1.8400	1
19	1.8900	1.8800	1	19	1.8300	1.8300	1
19	1.9000	1.8900	1	19	1.8300	1.8300	1
1	1.0500	1.0500	2	20	1.9100	1.9200	1
1	1.0390	1.0410	2	20	1.8800	1.8900	1
1	1.0470	1.0420	2	20	1.9200	1.9000	1
1	1.0510	1.0430	2	20	1.9100	1.9100	1
1	1.0530	1.0500	2	20	1.9000	1.8900	1
1	1.0540	1.0450	2	20	1.9100	1.9000	1
2	1.0480	1.0710	2	21	1.8082	1.8069	1
2	1.0540	1.0420	2	21	1.8221	1.8186	1
2	1.0380	1.0620	2	21	1.8259	1.8208	1
2	0.9970	1.0050	2	21	1.8047	1.8008	1
2	1.0310	1.0380	2	21	1.8107	1.8168	1
2	1.0550	1.0430	2	21	1.8250	1.8228	1
3	1.0280	1.0600	2	22	1.6300	1.6390	1
3	1.0150	1.0240	2	22	1.6220	1.6160	1
3	1.0450	1.0060	2	22	1.6440	1.6480	1
3	1.4310	1.4380	2	22	1.6220	1.6270	1
3	1.4350	1.4480	2	22	1.6290	1.6270	1
3	1.4260	1.4410	2	22	1.4950	1.4870	1
4	1.0560	1.0520	2	23	1.8200	1.8100	1
4	1.0580	1.0620	2	23	1.8200	1.8300	1
4	1.0600	1.0570	2	23	1.8000	1.8100	1
4	1.0640	1.0670	2	23	1.8300	1.8300	1
4	1.0560	1.0600	2	23	1.8200	1.8200	1
4	1.0680	1.0610	2	23	1.8200	1.8400	1
5	1.0800	1.0700	2	24	1.8400	1.8400	1
5	1.0700	1.0800	2	24	1.8400	1.8400	1
5	1.0700	1.0700	2	24	1.8200	1.8200	1
5	1.0700	1.0700	2	24	1.8300	1.8300	1
5	1.0600	1.0500	2	24	1.8300	1.8300	1
5	1.0600	1.0600	2	24	1.8300	1.8300	1

6	1.0650	1.0630	2	25	1.8321	1.8231	1
6	1.0630	1.0680	2	25	1.8293	1.8193	1
6	1.0660	1.0670	2	25	1.8236	1.8186	1
6	1.0730	1.0620	2	25	1.8116	1.8084	1
6	1.0650	1.0660	2	25	1.8206	1.8212	1
6	1.0650	1.0630	2	25	1.8239	1.8197	1
7	1.0700	1.0700	2	26	1.8200	1.8200	1
7	1.0600	1.0700	2	26	1.8200	1.8200	1
7	1.0700	1.0700	2	26	1.8000	1.8300	1
7	1.0700	1.0600	2	26	1.8200	1.8300	1
7	1.0600	1.0700	2	26	1.8400	1.8200	1
7	1.0600	1.0600	2	26	1.8200	1.8200	1
8	1.1100	1.0900	2	1	1.1600	1.1400	2
8	1.0900	1.1000	2	1	1.1500	1.1300	2
8	1.1100	1.1000	2	1	1.1200	1.1200	2
8	1.1000	1.0900	2	1	1.1600	1.1600	2
8	1.1200	1.1000	2	1	1.1500	1.1300	2
8	1.1000	1.1000	2	1	1.1500	1.1200	2
9	1.0710	1.0740	2	2	1.1400	1.1400	2
9	1.0760	1.0670	2	2	1.1200	1.1200	2
9	1.0810	1.0660	2	2	1.1200	1.1400	2
9	1.0750	1.0810	2	2	1.1200	1.1300	2
9	1.0850	1.0810	2	2	1.1100	1.1400	2
9	1.0830	1.0740	2	2	1.1100	1.1200	2
10	1.1100	1.0800	2	3	1.1360	1.1450	2
10	1.1200	1.1000	2	3	1.1460	1.1500	2
10	1.1000	1.1000	2	3	1.1320	1.1350	2
10	1.1000	1.0800	2	3	1.1610	1.1520	2
10	1.0900	1.1000	2	3	1.1430	1.1370	2
10	1.1100	1.1000	2	3	1.1360	1.1410	2
11	1.0500	1.0500	2	4	1.0140	1.0140	2
11	1.0500	1.0500	2	4	1.0480	1.0480	2
11	1.0500	1.0500	2	4	0.9970	0.9990	2
11	1.0400	1.0500	2	4	1.0120	1.0090	2
11	1.0500	1.0400	2	4	0.9960	0.9990	2
11	1.0500	1.0500	2	4	0.9940	0.9930	2
12	1.1000	1.0900	2	5	1.1000	1.0900	2
12	1.1200	1.0900	2	5	1.0800	1.0500	2
12	1.1000	1.0700	2	5	1.0700	1.0600	2
12	1.1100	1.0800	2	5	1.0700	1.0700	2
12	1.0900	1.0900	2	5	1.0900	1.1000	2
12	1.0900	1.0900	2	5	1.0900	1.0500	2
13	1.0800	1.0800	2	6	1.1000	1.0900	2
13	1.0600	1.0700	2	6	1.0900	1.0900	2
13	1.0600	1.0700	2	6	1.0800	1.0900	2
13	1.0500	1.0700	2	6	1.1000	1.1000	2
13	1.0500	1.0600	2	6	1.0900	1.0900	2
13	1.0500	1.0600	2	6	1.0800	1.0800	2
14	1.0330	1.0650	2	7	1.0800	1.0700	2

14	1.0350	1.0620	2	7	1.0500	1.0500	2
14	1.0270	1.0770	2	7	1.0500	1.0500	2
14	1.0600	1.0490	2	7	1.0600	1.0700	2
14	1.0570	1.0450	2	7	1.0600	1.0500	2
14	1.0550	1.0530	2	7	1.0600	1.0400	2
15	1.2200	1.2300	2	8	1.1400	1.1400	2
15	1.2300	1.2300	2	8	1.1400	1.1300	2
15	1.2300	1.2300	2	8	1.1200	1.1200	2
15	1.2200	1.2300	2	8	1.1200	1.1300	2
15	1.2300	1.2300	2	8	1.1300	1.1300	2
15	1.2300	1.2300	2	8	1.1300	1.1400	2
16	1.0400	1.0500	2	9	1.1100	1.1100	2
16	1.0500	1.0500	2	9	1.1000	1.1000	2
16	1.0400	1.0400	2	9	1.1000	1.1000	2
16	1.0400	1.0500	2	9	1.1100	1.1100	2
16	1.0400	1.0600	2	9	1.1000	1.1000	2
16	1.0400	1.0500	2	9	1.1100	1.1100	2
17	1.0700	1.0800	2	10	1.2600	1.2600	2
17	1.0700	1.0700	2	10	1.2600	1.2500	2
17	1.0900	1.0800	2	10	1.2600	1.2500	2
17	1.0800	1.0700	2	10	1.2600	1.2600	2
17	1.0700	1.0800	2	10	1.2500	1.2500	2
17	1.0700	1.0700	2	10	1.2600	1.2500	2
18	1.0623	1.0584	2	11	1.1100	1.1100	2
18	1.0623	1.0584	2	11	1.1700	1.1700	2
18	1.0581	1.0572	2	11	1.0900	1.1000	2
18	1.0568	1.0575	2	11	1.0900	1.0900	2
18	1.0568	1.0575	2	11	1.0800	1.0900	2
18	1.0637	1.0554	2	11	1.0800	1.0900	2
19	1.0600	1.0500	2	12	1.2000	1.2000	2
19	1.0500	1.0600	2	12	1.1900	1.1900	2
19	1.0500	1.0500	2	12	1.1900	1.2000	2
19	1.0300	1.0500	2	12	1.1900	1.1900	2
19	1.0400	1.0400	2	12	1.1900	1.1900	2
19	1.0500	1.0400	2	12	1.1600	1.1600	2
				13	1.2061	1.2014	2
				13	1.1979	1.2023	2
				13	1.2025	1.1960	2
				13	1.1904	1.1960	2
				13	1.1936	1.1976	2
				13	1.1906	1.1943	2
				14	1.1330	1.1000	2
				14	1.1290	1.1000	2
				14	1.1260	1.1150	2
				14	1.1210	1.1110	2
				14	1.1090	1.1100	2
				14	1.1010	1.1060	2
				15	1.1700	1.1800	2
				15	1.1100	1.1100	2

15	1.1200	1.1100	2
15	1.1800	1.1800	2
15	1.1400	1.1500	2
15	1.1100	1.1200	2
16	1.0660	1.0670	2
16	1.0460	1.0560	2
16	1.0500	1.0460	2
16	1.0690	1.0670	2
16	1.0600	1.0580	2
16	1.0570	1.0600	2
17	1.0750	1.0740	2
17	1.0660	1.0680	2
17	1.0670	1.0690	2
17	1.0770	1.0740	2
17	1.0760	1.0770	2
17	1.0690	1.0730	2
18	1.0800	1.0600	2
18	1.0300	1.0300	2
18	1.0400	1.0300	2
18	1.0600	1.0400	2
18	1.0500	1.0300	2
18	1.0400	1.0300	2
19	1.0700	1.0700	2
19	1.0600	1.0600	2
19	1.0600	1.0600	2
19	1.0600	1.0700	2
19	1.0500	1.0600	2
19	1.0500	1.0500	2
20	1.1500	1.1600	2
20	1.1300	1.1300	2
20	1.1500	1.1500	2
20	1.1400	1.1300	2
20	1.1400	1.1400	2
20	1.1200	1.1200	2
21	1.0574	1.0501	2
21	1.0398	1.0397	2
21	1.0372	1.0378	2
21	1.0557	1.0565	2
21	1.0555	1.0554	2
21	1.0566	1.0563	2
22	0.9490	0.9470	2
22	0.9520	0.9520	2
22	0.9370	0.9340	2
22	0.9370	0.9390	2
22	0.9340	0.9300	2
22	0.9300	0.9290	2
23	1.0400	1.0500	2
23	1.0500	1.0400	2
23	1.0300	1.0500	2

23	1.0500	1.0400	2
23	1.0400	1.0500	2
23	1.0400	1.0500	2
24	1.0800	1.0800	2
24	1.0800	1.0800	2
24	1.0800	1.0900	2
24	1.0900	1.0900	2
24	1.0900	1.1000	2
24	1.0800	1.0800	2
25	1.0235	1.0222	2
25	1.0235	1.0222	2
25	1.0277	1.0299	2
25	1.0251	1.0251	2
25	1.0251	1.0251	2
25	1.0221	1.0230	2
26	1.0500	1.0600	2
26	1.0600	1.0500	2
26	1.0400	1.0500	2
26	1.0500	1.0500	2
26	1.0400	1.0600	2
26	1.0500	1.0400	2

SO₃

SO3: Glass Preparation				SO3: Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	2.8600	2.8700	1	1	2.7900	2.7900	1
1	2.9000	2.9000	1	1	2.8200	2.8300	1
1	2.9100	2.8900	1	1	2.8300	2.8400	1
1	2.8600	2.8600	1	1	2.8100	2.8100	1
1	2.8800	2.8700	1	1	2.8300	2.8200	1
1	2.8600	2.8700	1	1	2.8400	2.8400	1
2	2.8700	2.8600	1	2	2.7300	2.7500	1
2	2.8800	2.8800	1	2	2.7300	2.7500	1
2	2.8300	2.8400	1	2	2.7500	2.7500	1
2	2.8300	2.8300	1	2	2.7400	2.7500	1
2	2.8500	2.8500	1	2	2.7200	2.7300	1
2	2.8300	2.8400	1	2	2.7300	2.7500	1
3	2.7900	2.8000	1	3	2.8800	2.8800	1
3	2.8000	2.8000	1	3	2.8800	2.8900	1
3	2.7900	2.8000	1	3	2.9000	2.9100	1
3	2.7400	2.7200	1	3	2.8900	2.9000	1
3	2.7400	2.7300	1	3	2.9000	2.9000	1
3	2.7300	2.7300	1	3	2.9000	2.9100	1
4	2.8260	2.8200	1	4	2.9000	2.9100	1
4	2.7900	2.7960	1	4	2.9000	2.9000	1
4	2.8670	2.8620	1	4	2.8700	2.8800	1
4	2.8290	2.8270	1	4	2.9100	2.9100	1
4	2.8290	2.8250	1	4	2.9100	2.9200	1
4	2.8300	2.8270	1	4	2.9100	2.9200	1
5	2.8910	2.8770	1	5	2.9090	2.9080	1
5	2.8930	2.8840	1	5	2.9020	2.9030	1
5	2.8900	2.8890	1	5	2.9880	2.9880	1
5	2.8320	2.8630	1	5	2.9340	2.9350	1
5	2.8410	2.8580	1	5	2.8920	2.8940	1
5	2.7280	2.7290	1	5	2.9310	2.9320	1
6	2.8300	2.8140	1	6	2.9300	2.9300	1
6	2.8320	2.8510	1	6	2.9300	2.9300	1
6	2.8220	2.8680	1	6	2.9200	2.9200	1
6	2.8690	2.8680	1	6	2.9200	2.9300	1
6	2.8240	2.8250	1	6	2.9400	2.9300	1
6	2.8520	2.8240	1	6	2.9200	2.9200	1
7	2.9110	2.9100	1	7	2.8770	2.8770	1
7	2.8810	2.8820	1	7	2.8940	2.8980	1
7	2.8870	2.8890	1	7	2.9970	3.0030	1
7	2.9170	2.9120	1	7	2.9580	2.9410	1
7	2.8980	2.9010	1	7	2.9570	2.9700	1
7	2.9070	2.9080	1	7	2.9760	2.9770	1
8	2.8800	2.8800	1	8	2.9800	2.9800	1
8	2.8700	2.8800	1	8	2.9900	2.9900	1
8	2.8700	2.8800	1	8	2.9800	2.9800	1
8	2.8700	2.8600	1	8	2.9700	2.9800	1

8	2.8900	2.9000	1	8	2.9500	2.9500	1
8	2.8600	2.8700	1	8	2.9900	3.0000	1
9	2.8160	2.7940	1	9	2.7597	2.7489	1
9	2.7880	2.7980	1	9	2.7569	2.7507	1
9	2.8370	2.7970	1	9	2.7548	2.7480	1
9	2.7680	2.7880	1	9	2.7475	2.7449	1
9	2.8110	2.8220	1	9	2.7665	2.7632	1
9	2.8030	2.8010	1	9	2.7494	2.7444	1
10	2.7900	2.7910	1	10	2.9300	2.9400	1
10	2.7580	2.7610	1	10	2.9500	2.9500	1
10	2.7600	2.7670	1	10	2.9600	2.9400	1
10	2.7820	2.7860	1	10	2.9400	2.9300	1
10	2.8060	2.8020	1	10	2.9200	2.9300	1
10	2.7930	2.7900	1	10	2.9100	2.9200	1
11	2.9480	2.9470	1	11	2.9570	2.9590	1
11	2.9380	2.9360	1	11	2.9620	2.9740	1
11	2.9420	2.9370	1	11	2.9820	2.9470	1
11	2.9430	2.9400	1	11	2.9870	2.9820	1
11	2.9460	2.9440	1	11	2.9880	2.9840	1
11	2.9430	2.9460	1	11	3.0360	3.0230	1
12	2.8600	2.9000	1	12	2.9110	2.9120	1
12	2.9000	2.8800	1	12	2.9030	2.9080	1
12	2.9300	2.9100	1	12	2.9100	2.9070	1
12	2.8700	2.8700	1	12	2.8900	2.8970	1
12	2.8900	2.8800	1	12	2.9130	2.9140	1
12	2.8800	2.8800	1	12	2.9120	2.9100	1
13	2.8700	2.8800	1	13	2.9200	2.9300	1
13	2.8600	2.8600	1	13	2.9000	2.9000	1
13	2.8600	2.8400	1	13	2.9200	2.9200	1
13	2.8500	2.8500	1	13	2.8900	2.9000	1
13	2.8800	2.8700	1	13	2.9100	2.9200	1
13	2.8800	2.8800	1	13	2.9600	2.9600	1
14	2.9200	2.9200	1	14	2.9200	2.9160	1
14	2.9100	2.9200	1	14	2.8850	2.8820	1
14	2.9200	2.9200	1	14	2.9850	2.9860	1
14	2.9100	2.9100	1	14	2.9690	2.9700	1
14	2.9100	2.9100	1	14	2.9790	2.9820	1
14	2.9100	2.9100	1	14	2.9680	2.9680	1
15	2.8200	2.8300	1	15	2.9000	2.8800	1
15	2.8200	2.8200	1	15	2.9200	2.9300	1
15	2.8200	2.8200	1	15	2.9300	2.9200	1
15	2.8200	2.8100	1	15	2.8800	2.8600	1
15	2.8000	2.8100	1	15	2.9100	2.9200	1
15	2.8100	2.8000	1	15	2.9100	2.9300	1
16	2.8200	2.8300	1	16	2.9000	2.9000	1
16	2.8300	2.8300	1	16	2.9100	2.9100	1
16	2.8400	2.8500	1	16	2.8900	2.9000	1
16	2.8400	2.8400	1	16	2.8800	2.8900	1
16	2.8200	2.8200	1	16	2.9000	2.9100	1

16	2.8400	2.8300	1	16	2.9100	2.9000	1
1	3.6100	3.6100	2	17	2.8900	2.9000	1
1	3.6400	3.6700	2	17	2.9100	2.9200	1
1	3.6100	3.6600	2	17	2.9200	2.9200	1
1	3.6300	3.6300	2	17	2.9200	2.9200	1
1	3.6100	3.5800	2	17	2.9100	2.9100	1
1	3.6300	3.6500	2	17	2.9200	2.9200	1
2	3.5900	3.6000	2	18	2.8789	2.8814	1
2	3.5800	3.5700	2	18	2.9255	2.9284	1
2	3.6100	3.6300	2	18	2.9338	2.9351	1
2	3.5400	3.5500	2	18	2.8918	2.8878	1
2	3.6000	3.6100	2	18	2.9271	2.9307	1
2	3.5500	3.5700	2	18	2.9326	2.9384	1
3	3.3800	3.3900	2	19	3.1300	3.1300	1
3	3.3900	3.3900	2	19	3.1600	3.1600	1
3	3.3900	3.4000	2	19	3.1500	3.1600	1
3	3.3800	3.3900	2	19	3.1800	3.1800	1
3	3.3700	3.3700	2	19	3.1700	3.1600	1
3	3.4200	3.4100	2	19	3.1200	3.1200	1
4	3.5230	3.5140	2	20	2.9200	2.9200	1
4	3.5010	3.4950	2	20	2.9000	2.8900	1
4	3.5380	3.5560	2	20	2.9100	2.9100	1
4	3.5160	3.5170	2	20	2.9000	2.9000	1
4	3.5120	3.5190	2	20	2.9200	2.9200	1
4	3.5240	3.5330	2	20	2.9300	2.9200	1
5	3.6090	3.5940	2	21	2.9361	2.9412	1
5	3.6340	3.6270	2	21	2.9403	2.9359	1
5	3.6030	3.5960	2	21	2.9161	2.9142	1
5	3.5110	3.4950	2	21	2.9321	2.9334	1
5	3.5920	3.5840	2	21	2.9098	2.9126	1
5	3.6110	3.5930	2	21	2.9211	2.9187	1
6	3.5410	3.5410	2	22	2.9300	2.9300	1
6	3.5180	3.5430	2	22	2.9300	2.9400	1
6	3.5420	3.5400	2	22	2.9700	2.9700	1
6	3.5210	3.5520	2	22	2.9700	2.9800	1
6	3.5450	3.5520	2	22	2.9500	2.9500	1
6	3.5530	3.5800	2	22	2.9600	2.9600	1
7	3.6480	3.6570	2	23	2.9600	2.9300	1
7	3.5740	3.5680	2	23	2.9200	2.9000	1
7	3.5760	3.5750	2	23	2.9500	2.9100	1
7	3.6520	3.6560	2	23	2.9400	2.9100	1
7	3.6500	3.6520	2	23	2.9200	2.9200	1
7	3.6620	3.6620	2	23	2.9000	2.9100	1
8	3.6700	3.6500	2	24	2.7300	2.6900	1
8	3.6700	3.6400	2	24	2.6700	2.6600	1
8	3.6500	3.6600	2	24	2.6300	2.6300	1
8	3.6200	3.6400	2	24	2.6700	2.6600	1
8	3.6300	3.6500	2	24	2.7000	2.7000	1
8	3.6500	3.6500	2	24	2.6800	2.6700	1

9	3.6100	3.6390	2	1	3.4500	3.4500	2
9	3.6480	3.6450	2	1	3.4500	3.4500	2
9	3.6020	3.5750	2	1	3.4700	3.4800	2
9	3.6110	3.5970	2	1	3.4400	3.4400	2
9	3.5890	3.6150	2	1	3.4700	3.4700	2
9	3.5940	3.5930	2	1	3.4700	3.4700	2
10	3.4670	3.4650	2	2	3.3800	3.3900	2
10	3.4670	3.4650	2	2	3.3900	3.4100	2
10	3.4750	3.4740	2	2	3.3900	3.4100	2
10	3.3730	3.3770	2	2	3.3700	3.3900	2
10	3.3730	3.3770	2	2	3.3900	3.4000	2
10	3.4430	3.4450	2	2	3.3900	3.3900	2
11	3.6580	3.6690	2	3	3.5700	3.5800	2
11	3.6620	3.6520	2	3	3.5600	3.5600	2
11	3.6730	3.6630	2	3	3.5600	3.5500	2
11	3.6800	3.6760	2	3	3.5900	3.5800	2
11	3.6810	3.6730	2	3	3.5800	3.6000	2
11	3.6790	3.6800	2	3	3.5800	3.5800	2
12	3.5700	2.5800	2	4	3.5600	3.5800	2
12	3.5400	3.5400	2	4	3.5800	3.5800	2
12	3.5400	3.5800	2	4	3.5900	3.5900	2
12	3.6100	3.6000	2	4	3.5800	3.5900	2
12	3.6000	3.5500	2	4	3.6000	3.6100	2
12	3.5600	3.5800	2	4	3.5900	3.5900	2
13	3.6000	3.6000	2	5	3.5810	3.5870	2
13	3.6000	3.6000	2	5	3.6290	3.6210	2
13	3.6200	3.6200	2	5	3.6280	3.6340	2
13	3.6300	3.6100	2	5	3.5900	3.5890	2
13	3.6500	3.6500	2	5	3.6370	3.6370	2
13	3.6200	3.6300	2	5	3.6080	3.6090	2
14	3.6400	3.6400	2	6	3.4900	3.4900	2
14	3.6400	3.6500	2	6	3.5500	3.5600	2
14	3.6300	3.6300	2	6	3.5400	3.5700	2
14	3.6400	3.6300	2	6	3.5200	3.5300	2
14	3.6300	3.6400	2	6	3.5600	3.5500	2
14	3.6300	3.6300	2	6	3.5400	3.5700	2
15	3.5300	3.5300	2	7	3.5830	3.5880	2
15	3.5400	3.5400	2	7	3.6060	3.6160	2
15	3.5300	3.5200	2	7	3.6180	3.6110	2
15	3.5300	3.5300	2	7	3.6840	3.6790	2
15	3.5100	3.5000	2	7	3.6760	3.6720	2
15	3.5300	3.5100	2	7	3.6050	3.5960	2
16	3.6000	3.5800	2	8	3.7500	3.7500	2
16	3.6000	3.6000	2	8	3.7000	3.7000	2
16	3.5900	3.5900	2	8	3.7300	3.7300	2
16	3.5700	3.5800	2	8	3.7600	3.7600	2
16	3.5500	3.5600	2	8	3.7000	3.7000	2
16	3.5800	3.5800	2	8	3.7500	3.7500	2
				9	3.3060	3.2990	2

9	3.3060	3.2990	2
9	3.3350	3.3350	2
9	3.2970	3.2910	2
9	3.2970	3.2910	2
9	3.3100	3.3030	2
10	3.6100	3.6000	2
10	3.6300	3.6100	2
10	3.6100	3.6300	2
10	3.6000	3.6100	2
10	3.6500	3.6400	2
10	3.6300	3.6300	2
11	3.6690	3.6550	2
11	3.7550	3.7510	2
11	3.6560	3.6670	2
11	3.7360	3.7320	2
11	3.6980	3.7000	2
11	3.6960	3.6980	2
12	3.6010	3.6120	2
12	3.5990	3.6030	2
12	3.6050	3.6150	2
12	3.6150	3.6140	2
12	3.6210	3.6140	2
12	3.6110	3.6220	2
13	3.4300	3.4300	2
13	3.5000	3.5000	2
13	3.4600	3.4600	2
13	3.4600	3.4500	2
13	3.4800	3.4900	2
13	3.4100	3.4200	2
14	3.5900	3.5960	2
14	3.6090	3.6130	2
14	3.6060	3.6050	2
14	3.5440	3.5490	2
14	3.5750	3.5720	2
14	3.5770	3.5800	2
15	3.6100	3.6100	2
15	3.6200	3.6000	2
15	3.6300	3.6200	2
15	3.5900	3.5900	2
15	3.6200	3.6100	2
15	3.6600	3.6300	2
16	3.6100	3.6000	2
16	3.6300	3.6300	2
16	3.6300	3.6300	2
16	3.6000	3.6100	2
16	3.6100	3.6300	2
16	3.6200	3.6100	2
17	3.1700	3.1700	2
17	3.1700	3.1700	2

17	3.1400	3.1300	2
17	3.1600	3.1600	2
17	3.2100	3.2100	2
17	3.1400	3.1300	2
18	3.5657	3.5690	2
18	3.6025	3.6051	2
18	3.6097	3.6157	2
18	3.5876	3.5892	2
18	3.6617	3.6620	2
18	3.6617	3.6621	2
19	3.7800	3.7800	2
19	3.7700	3.7700	2
19	3.7800	3.7900	2
19	3.8100	3.8100	2
19	3.8000	3.8000	2
19	3.7900	3.7800	2
20	3.5700	3.5700	2
20	3.6300	3.6200	2
20	3.5700	3.5800	2
20	3.6000	3.6100	2
20	3.6300	3.6300	2
20	3.6300	3.6200	2
21	3.5468	3.5474	2
21	3.5463	3.5475	2
21	3.5569	3.5597	2
21	3.5234	3.5215	2
21	3.5385	3.5453	2
21	3.5551	3.5583	2
22	3.5200	3.5200	2
22	3.5500	3.5500	2
22	3.5200	3.5200	2
22	3.5600	3.5500	2
22	3.5800	3.5700	2
22	3.5400	3.5400	2
23	3.6000	3.5800	2
23	3.5800	3.5700	2
23	3.6500	3.6100	2
23	3.5600	3.5900	2
23	3.5400	3.5300	2
23	3.6000	3.6000	2
24	3.2700	3.3400	2
24	3.3800	3.3800	2
24	3.4000	3.4000	2
24	3.3900	3.3900	2
24	3.2900	3.3000	2
24	3.3300	3.3600	2

Na₂O

Na ₂ O: Glass Preparation				Na ₂ O: Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	0.2000	0.1900	1	1	0.2000	0.2000	1
1	0.2000	0.2000	1	1	0.2000	0.2000	1
1	0.1900	0.2000	1	1	0.2000	0.2000	1
1	0.2000	0.1800	1	1	0.2000	0.2000	1
1	0.1900	0.1900	1	1	0.2000	0.2000	1
1	0.1900	0.2100	1	1	0.2000	0.2000	1
2	0.2000	0.1900	1	2	0.1900	0.1900	1
2	0.2000	0.2000	1	2	0.1800	0.1800	1
2	0.2000	0.2000	1	2	0.1800	0.1800	1
2	0.2000	0.2100	1	2	0.1800	0.1900	1
2	0.1900	0.2000	1	2	0.1800	0.1800	1
2	0.2000	0.2000	1	2	0.1800	0.1800	1
3	0.2400	0.2300	1	3	0.1760	0.1740	1
3	0.2500	0.2600	1	3	0.1740	0.1790	1
3	0.2200	0.2400	1	3	0.1770	0.1780	1
3	0.2500	0.2200	1	3	0.1800	0.1800	1
3	0.2200	0.2300	1	3	0.1780	0.1770	1
3	0.2300	0.2300	1	3	0.1790	0.1820	1
4	0.2000	0.2200	1	4	0.1600	0.1800	1
4	0.2200	0.2100	1	4	0.1900	0.1900	1
4	0.2200	0.2100	1	4	0.1900	0.1900	1
4	0.2000	0.2100	1	4	0.1800	0.1900	1
4	0.2000	0.2000	1	4	0.1800	0.1800	1
4	0.2100	0.2100	1	4	0.1900	0.1900	1
5	0.2090	0.2040	1	5	0.1989	0.2009	1
5	0.1980	0.2020	1	5	0.2029	0.2001	1
5	0.2100	0.1980	1	5	0.1984	0.2008	1
5	0.2010	0.2040	1	5	0.1969	0.1982	1
5	0.1970	0.2040	1	5	0.2140	0.2157	1
5	0.1990	0.2020	1	5	0.2051	0.2042	1
6	0.2102	0.2093	1	6	0.2000	0.2000	1
6	0.2103	0.2106	1	6	0.2000	0.2000	1
6	0.2103	0.2093	1	6	0.2000	0.2000	1
6	0.2099	0.2111	1	6	0.2000	0.2000	1
6	0.2107	0.2095	1	6	0.2000	0.2000	1
6	0.2113	0.2112	1	6	0.2000	0.2000	1
7	0.1800	0.2000	1	7	0.1600	0.1500	1
7	0.1900	0.1800	1	7	0.1500	0.1500	1
7	0.2000	0.1800	1	7	0.1500	0.1600	1
7	0.1900	0.2100	1	7	0.1500	0.1500	1
7	0.1800	0.1900	1	7	0.1500	0.1500	1
7	0.1800	0.1800	1	7	0.1500	0.1500	1
8	0.2150	0.2200	1	8	0.2100	0.2100	1
8	0.2180	0.2270	1	8	0.2100	0.2100	1
8	0.2270	0.2280	1	8	0.2100	0.2100	1
8	0.2250	0.2110	1	8	0.2100	0.2100	1

8	0.2130	0.2210	1	8	0.2100	0.2100	1
8	0.2110	0.2070	1	8	0.2100	0.2100	1
9	0.2200	0.2300	1	9	0.1900	0.1900	1
9	0.2400	0.2300	1	9	0.1800	0.1900	1
9	0.2300	0.2100	1	9	0.1900	0.1900	1
9	0.2100	0.2200	1	9	0.1900	0.1900	1
9	0.2300	0.2400	1	9	0.1900	0.1900	1
9	0.2500	0.2400	1	9	0.1900	0.1900	1
10	0.2073	0.2181	1	10	0.2000	0.2000	1
10	0.2075	0.2116	1	10	0.1900	0.1900	1
10	0.2086	0.2123	1	10	0.2000	0.2000	1
10	0.1985	0.2127	1	10	0.2100	0.2100	1
10	0.2064	0.2090	1	10	0.2000	0.2000	1
10	0.2054	0.2080	1	10	0.2000	0.2000	1
11	0.2120	0.2060	1	11	0.2000	0.2000	1
11	0.2150	0.2070	1	11	0.2100	0.2000	1
11	0.2150	0.2020	1	11	0.2100	0.2000	1
11	0.2040	0.2160	1	11	0.2100	0.2100	1
11	0.2080	0.2030	1	11	0.2100	0.2100	1
11	0.2040	0.2000	1	11	0.2100	0.2100	1
12	0.2100	0.2200	1	12	0.2030	0.2040	1
12	0.2100	0.2000	1	12	0.2050	0.2050	1
12	0.2200	0.2100	1	12	0.2050	0.2060	1
12	0.2200	0.2000	1	12	0.2060	0.2080	1
12	0.2200	0.2100	1	12	0.2070	0.2060	1
12	0.2000	0.2100	1	12	0.2070	0.2060	1
13	0.2550	0.2360	1	13	0.2030	0.2040	1
13	0.2430	0.2230	1	13	0.2070	0.2080	1
13	0.2140	0.2040	1	13	0.2080	0.2110	1
13	0.2080	0.2220	1	13	0.2070	0.2060	1
13	0.2350	0.2200	1	13	0.2020	0.2070	1
13	0.2210	0.2290	1	13	0.2060	0.2080	1
14	0.2200	0.2170	1	14	0.1764	0.1771	1
14	0.2080	0.2140	1	14	0.1767	0.1768	1
14	0.2140	0.2120	1	14	0.1765	0.1766	1
14	0.2070	0.2080	1	14	0.1766	0.1763	1
14	0.2070	0.2100	1	14	0.1789	0.1768	1
14	0.2130	0.2080	1	14	0.1762	0.1765	1
15	0.1920	0.2020	1	15	0.1480	0.1480	1
15	0.1950	0.2070	1	15	0.1470	0.1470	1
15	0.2000	0.1900	1	15	0.1380	0.1500	1
15	0.1990	0.1900	1	15	0.1510	0.1500	1
15	0.1940	0.1910	1	15	0.1500	0.1470	1
15	0.1790	0.2000	1	15	0.1510	0.1520	1
1	0.0400	0.0400	2	16	0.1800	0.1800	1
1	0.0600	0.0600	2	16	0.1800	0.1900	1
1	0.0400	0.0400	2	16	0.1900	0.1900	1
1	0.0300	0.0400	2	16	0.1800	0.1800	1
1	0.0300	0.0500	2	16	0.1800	0.1800	1

1	0.0500	0.0400	2	16	0.1800	0.1900	1
2	0.0700	0.0500	2	17	0.1550	0.1680	1
2	0.0600	0.0600	2	17	0.1640	0.1460	1
2	0.0600	0.0700	2	17	0.1600	0.1540	1
2	0.0500	0.0600	2	17	0.1560	0.1520	1
2	0.0600	0.0500	2	17	0.1470	0.1540	1
2	0.0700	0.0600	2	17	0.1470	0.1430	1
3	0.0900	0.0900	2	18	0.1770	0.1760	1
3	0.0900	0.1400	2	18	0.1730	0.1730	1
3	0.1100	0.1100	2	18	0.1800	0.1780	1
3	0.1100	0.1000	2	18	0.1710	0.1710	1
3	0.0900	0.1000	2	18	0.1790	0.1820	1
3	0.0900	0.1000	2	18	0.1750	0.1740	1
4	0.0500	0.0500	2	19	0.2240	0.2390	1
4	0.0500	0.0500	2	19	0.2060	0.2030	1
4	0.0500	0.0600	2	19	0.2090	0.2120	1
4	0.0400	0.0300	2	19	0.2100	0.2170	1
4	0.0400	0.0500	2	19	0.2040	0.2040	1
4	0.0400	0.0400	2	19	0.2080	0.2110	1
5	0.0580	0.0560	2	20	0.1800	0.1800	1
5	0.0590	0.0550	2	20	0.1700	0.1700	1
5	0.0620	0.0600	2	20	0.1800	0.1800	1
5	0.0580	0.0600	2	20	0.1600	0.1600	1
5	0.0610	0.0570	2	20	0.1600	0.1600	1
5	0.0540	0.0540	2	20	0.1600	0.1700	1
6	0.0560	0.0565	2	21	0.1860	0.1760	1
6	0.0560	0.0565	2	21	0.1900	0.1850	1
6	0.0557	0.0556	2	21	0.1850	0.1920	1
6	0.0553	0.0553	2	21	0.1930	0.1930	1
6	0.0553	0.0553	2	21	0.1920	0.1910	1
6	0.0555	0.0549	2	21	0.1800	0.1850	1
7	0.0000	0.0000	2	22	0.2090	0.2080	1
7	0.0000	0.0000	2	22	0.2130	0.2130	1
7	0.0000	0.0000	2	22	0.2080	0.2050	1
7	0.0000	0.0000	2	22	0.2110	0.2070	1
7	0.0000	0.0000	2	22	0.2120	0.2100	1
7	0.0000	0.0000	2	22	0.2100	0.2120	1
8	0.0750	0.0750	2	23	0.1694	0.1635	1
8	0.0700	0.0690	2	23	0.1669	0.1600	1
8	0.0700	0.0680	2	23	0.1695	0.1664	1
8	0.0690	0.0680	2	23	0.1702	0.1695	1
8	0.0700	0.0710	2	23	0.1667	0.1682	1
8	0.0720	0.0690	2	23	0.1680	0.1717	1
9	0.0900	0.0900	2	24	0.1800	0.1800	1
9	0.1000	0.0900	2	24	0.1700	0.1800	1
9	0.0700	0.0900	2	24	0.1700	0.1800	1
9	0.0900	0.1000	2	24	0.1800	0.1800	1
9	0.0900	0.0900	2	24	0.1700	0.1700	1
9	0.1000	0.1000	2	24	0.1700	0.1700	1

10	0.0465	0.0448	2	1	0.0500	0.0500	2
10	0.0452	0.0446	2	1	0.0500	0.0500	2
10	0.0510	0.0467	2	1	0.0500	0.0500	2
10	0.0407	0.0502	2	1	0.0600	0.0600	2
10	0.0487	0.0485	2	1	0.0600	0.0600	2
10	0.0413	0.0482	2	1	0.0600	0.0600	2
11	0.0410	0.0450	2	2	0.0500	0.0500	2
11	0.0450	0.0330	2	2	0.0500	0.0500	2
11	0.0480	0.0570	2	2	0.0500	0.0500	2
11	0.0280	0.0490	2	2	0.0500	0.0600	2
11	0.0470	0.0420	2	2	0.0600	0.0600	2
11	0.0420	0.0420	2	2	0.0500	0.0500	2
12	0.0600	0.0600	2	3	0.0540	0.0550	2
12	0.0600	0.0600	2	3	0.0530	0.0560	2
12	0.0600	0.0600	2	3	0.0550	0.0540	2
12	0.0600	0.0600	2	3	0.0590	0.0650	2
12	0.0700	0.0700	2	3	0.0650	0.0660	2
12	0.0700	0.0700	2	3	0.0640	0.0660	2
13	0.0490	0.0770	2	4	0.0700	0.0700	2
13	0.0530	0.0580	2	4	0.0700	0.0600	2
13	0.0700	0.0530	2	4	0.0600	0.0600	2
13	0.0840	0.0780	2	4	0.0700	0.0700	2
13	0.0760	0.1050	2	4	0.0600	0.0600	2
13	0.0860	0.0950	2	4	0.0600	0.0600	2
14	0.0650	0.0650	2	5	0.0656	0.0657	2
14	0.0680	0.0670	2	5	0.0627	0.0604	2
14	0.0610	0.0630	2	5	0.0639	0.0624	2
14	0.0620	0.0610	2	5	0.0750	0.0759	2
14	0.0640	0.0620	2	5	0.0730	0.0731	2
14	0.0700	0.0680	2	5	0.0722	0.0738	2
15	0.0490	0.0550	2	6	0.0700	0.0700	2
15	0.0500	0.0500	2	6	0.0700	0.0700	2
15	0.0640	0.0670	2	6	0.0700	0.0700	2
15	0.0460	0.0350	2	6	0.0700	0.0700	2
15	0.0430	0.0330	2	6	0.0700	0.0700	2
15	0.0370	0.0430	2	6	0.0700	0.0700	2
				7	0.0200	0.0200	2
				7	0.0200	0.0200	2
				7	0.0200	0.0200	2
				7	0.0100	0.0100	2
				7	0.0100	0.0100	2
				7	0.0100	0.0100	2
				8	0.0600	0.0600	2
				8	0.0600	0.0600	2
				8	0.0600	0.0600	2
				8	0.0600	0.0600	2
				8	0.0600	0.0600	2
				8	0.0600	0.0600	2
				9	0.0400	0.0500	2

9	0.0500	0.0400	2
9	0.0400	0.0500	2
9	0.0500	0.0500	2
9	0.0400	0.0400	2
9	0.0500	0.0400	2
10	0.0500	0.0500	2
10	0.0500	0.0500	2
10	0.0500	0.0500	2
10	0.0600	0.0600	2
10	0.0500	0.0500	2
10	0.0500	0.0500	2
11	0.0800	0.0800	2
11	0.0800	0.0800	2
11	0.0700	0.0700	2
11	0.0800	0.0800	2
11	0.0700	0.0700	2
11	0.0700	0.0700	2
12	0.0690	0.0670	2
12	0.0680	0.0680	2
12	0.0660	0.0650	2
12	0.0660	0.0650	2
12	0.0670	0.0650	2
12	0.0650	0.0650	2
13	0.0810	0.0840	2
13	0.0830	0.0830	2
13	0.0840	0.0840	2
13	0.0850	0.0840	2
13	0.0880	0.0840	2
13	0.0850	0.0820	2
14	0.0455	0.0457	2
14	0.0455	0.0457	2
14	0.0455	0.0457	2
14	0.0461	0.0455	2
14	0.0461	0.0455	2
14	0.0454	0.0453	2
15	0.0130	0.0140	2
15	0.0090	0.0160	2
15	0.0090	0.0130	2
15	0.0050	0.0130	2
15	0.0040	0.0120	2
15	0.0130	0.0160	2
16	0.0300	0.0300	2
16	0.0300	0.0300	2
16	0.0200	0.0300	2
16	0.0300	0.0300	2
16	0.0300	0.0200	2
16	0.0100	0.0100	2
17	0.0540	0.0430	2
17	0.0660	0.0490	2

17	0.0750	0.0380	2
17	0.0360	0.0240	2
17	0.0320	0.0270	2
17	0.0260	0.0120	2
18	0.0420	0.0480	2
18	0.0420	0.0440	2
18	0.0440	0.0440	2
18	0.0430	0.0440	2
18	0.0380	0.0420	2
18	0.0390	0.0390	2
19	0.0620	0.0570	2
19	0.0690	0.0650	2
19	0.0480	0.0580	2
19	0.0530	0.0560	2
19	0.0560	0.0570	2
19	0.0600	0.0610	2
20	0.0500	0.0500	2
20	0.0400	0.0400	2
20	0.0400	0.0400	2
20	0.0500	0.0400	2
20	0.0500	0.0400	2
20	0.0500	0.0400	2
20	0.0500	0.0400	2
21	0.0740	0.0720	2
21	0.0740	0.0750	2
21	0.0640	0.0630	2
21	0.0780	0.0800	2
21	0.0710	0.0680	2
21	0.0740	0.0720	2
22	0.0640	0.0660	2
22	0.0580	0.0620	2
22	0.0630	0.0600	2
22	0.0600	0.0620	2
22	0.0650	0.0620	2
22	0.0660	0.0670	2
23	0.0461	0.0471	2
23	0.0461	0.0444	2
23	0.0443	0.0449	2
23	0.0512	0.0490	2
23	0.0507	0.0513	2
23	0.0488	0.0485	2
24	0.0400	0.0400	2
24	0.0400	0.0400	2
24	0.0400	0.0400	2
24	0.0400	0.0400	2
24	0.0400	0.0400	2
24	0.0400	0.0400	2

K₂O

K2O: Glass Preparation				K2O: Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	0.6800	0.6700	1	1	0.6360	0.6360	1
1	0.6800	0.6800	1	1	0.6380	0.6370	1
1	0.6800	0.6600	1	1	0.6380	0.6390	1
1	0.6800	0.6800	1	1	0.6450	0.6440	1
1	0.6800	0.6700	1	1	0.6400	0.6390	1
1	0.6800	0.6800	1	1	0.6480	0.6470	1
2	0.6800	0.6800	1	2	0.6740	0.6730	1
2	0.6800	0.6800	1	2	0.6740	0.6730	1
2	0.6800	0.6800	1	2	0.6730	0.6730	1
2	0.6800	0.6800	1	2	0.6730	0.6710	1
2	0.6800	0.6800	1	2	0.6720	0.6740	1
2	0.6800	0.6800	1	2	0.6730	0.6730	1
3	0.6920	0.6900	1	3	0.6600	0.6600	1
3	0.6870	0.6940	1	3	0.6600	0.6500	1
3	0.6890	0.6950	1	3	0.6600	0.6600	1
3	0.6810	0.6860	1	3	0.6700	0.6600	1
3	0.6860	0.6870	1	3	0.6600	0.6600	1
3	0.6920	0.6880	1	3	0.6600	0.6600	1
4	0.7000	0.7100	1	4	0.6980	0.6980	1
4	0.7100	0.7100	1	4	0.7040	0.7040	1
4	0.7100	0.7100	1	4	0.7060	0.7050	1
4	0.7100	0.7000	1	4	0.7050	0.7050	1
4	0.7100	0.7000	1	4	0.7000	0.7000	1
4	0.7000	0.7100	1	4	0.7000	0.7010	1
5	0.6900	0.6900	1	5	0.6800	0.6800	1
5	0.7000	0.6900	1	5	0.6900	0.6700	1
5	0.6900	0.7000	1	5	0.6700	0.6800	1
5	0.6900	0.7000	1	5	0.6700	0.6700	1
5	0.6900	0.6900	1	5	0.6700	0.6700	1
5	0.6900	0.6900	1	5	0.6800	0.6800	1
6	0.6800	0.6800	1	6	0.6800	0.6800	1
6	0.6800	0.6800	1	6	0.6800	0.6800	1
6	0.6700	0.6800	1	6	0.6800	0.6800	1
6	0.6800	0.6900	1	6	0.6800	0.6800	1
6	0.6900	0.6900	1	6	0.6800	0.6800	1
6	0.6900	0.6800	1	6	0.6800	0.6800	1
7	0.7000	0.7000	1	7	0.6800	0.6800	1
7	0.7000	0.7000	1	7	0.6700	0.6700	1
7	0.7000	0.7000	1	7	0.6800	0.6800	1
7	0.7000	0.7000	1	7	0.6800	0.6800	1
7	0.7000	0.7000	1	7	0.6700	0.6700	1
7	0.7000	0.7000	1	7	0.6800	0.6800	1
8	0.7000	0.6980	1	8	0.6800	0.6800	1
8	0.6980	0.7000	1	8	0.6700	0.6800	1
8	0.7000	0.7000	1	8	0.6700	0.6700	1

8	0.6948	0.6968	1	8	0.6800	0.6800	1
8	0.6997	0.6938	1	8	0.6800	0.6800	1
8	0.6987	0.6968	1	8	0.6800	0.6800	1
9	0.6720	0.6700	1	9	0.7000	0.7000	1
9	0.6760	0.6720	1	9	0.6900	0.6900	1
9	0.6800	0.6770	1	9	0.6900	0.6900	1
9	0.6760	0.6720	1	9	0.6800	0.6800	1
9	0.6790	0.6780	1	9	0.6900	0.6900	1
9	0.6770	0.6840	1	9	0.6900	0.6900	1
10	0.7000	0.7000	1	10	0.7000	0.6900	1
10	0.7000	0.7000	1	10	0.6900	0.6900	1
10	0.7000	0.7000	1	10	0.6900	0.6900	1
10	0.7100	0.7100	1	10	0.6800	0.6800	1
10	0.7100	0.7100	1	10	0.6900	0.6900	1
10	0.7100	0.7100	1	10	0.6900	0.6900	1
11	0.6690	0.6680	1	11	0.6300	0.6500	1
11	0.6750	0.6780	1	11	0.3400	0.6400	1
11	0.6810	0.6870	1	11	0.6500	0.6500	1
11	0.6650	0.6710	1	11	0.6400	0.6300	1
11	0.6770	0.6730	1	11	0.6400	0.6500	1
11	0.6780	0.6770	1	11	0.6300	0.6500	1
12	0.6890	0.6890	1	12	0.6800	0.6700	1
12	0.6870	0.6810	1	12	0.6900	0.6900	1
12	0.6810	0.6970	1	12	0.6800	0.6800	1
12	0.6760	0.6750	1	12	0.6800	0.6800	1
12	0.6880	0.6880	1	12	0.6800	0.6800	1
12	0.6750	0.6940	1	12	0.6800	0.6800	1
13	0.6900	0.6900	1	13	0.6900	0.6800	1
13	0.6900	0.6900	1	13	0.6800	0.6800	1
13	0.6900	0.6900	1	13	0.6800	0.7000	1
13	0.6800	0.6800	1	13	0.6800	0.6800	1
13	0.6800	0.6800	1	13	0.6800	0.6800	1
13	0.6800	0.6800	1	13	0.6900	0.6800	1
14	0.6836	0.6833	1	14	0.6800	0.6900	1
14	0.6806	0.6823	1	14	0.6900	0.6900	1
14	0.6821	0.6819	1	14	0.6900	0.6900	1
14	0.6832	0.6826	1	14	0.6800	0.6800	1
14	0.6855	0.6851	1	14	0.6800	0.6800	1
14	0.6853	0.6859	1	14	0.6800	0.6900	1
15	0.6920	0.6930	1	15	0.6800	0.6800	1
15	0.6880	0.6870	1	15	0.6800	0.6800	1
15	0.6880	0.6890	1	15	0.6800	0.6800	1
15	0.6900	0.6910	1	15	0.6800	0.6800	1
15	0.6900	0.6890	1	15	0.6800	0.6800	1
15	0.6900	0.6910	1	15	0.6800	0.6800	1
16	0.6900	0.6900	1	16	0.6700	0.6700	1
16	0.6900	0.6800	1	16	0.6800	0.6800	1
16	0.6800	0.6900	1	16	0.6700	0.6800	1
16	0.6900	0.6900	1	16	0.6800	0.6800	1

16	0.6900	0.6800	1	16	0.6700	0.6700	1
16	0.6900	0.6900	1	16	0.6700	0.6700	1
17	0.6900	0.6820	1	17	0.6740	0.6733	1
17	0.6860	0.6900	1	17	0.6847	0.6848	1
17	0.6810	0.6860	1	17	0.6870	0.6876	1
17	0.6820	0.6870	1	17	0.6758	0.6751	1
17	0.6840	0.6780	1	17	0.6850	0.6856	1
17	0.6830	0.6840	1	17	0.6878	0.6876	1
18	0.6800	0.6800	1	18	0.7100	0.7100	1
18	0.6700	0.6700	1	18	0.7100	0.7100	1
18	0.6700	0.6700	1	18	0.7100	0.7100	1
18	0.6700	0.6700	1	18	0.7100	0.7100	1
18	0.6800	0.6700	1	18	0.7100	0.7100	1
18	0.6700	0.6700	1	18	0.7000	0.7000	1
19	0.6800	0.6900	1	19	0.6577	0.6545	1
19	0.6800	0.6800	1	19	0.6560	0.6552	1
19	0.6800	0.6900	1	19	0.6570	0.6557	1
19	0.6800	0.6800	1	19	0.6557	0.6556	1
19	0.6900	0.6900	1	19	0.6548	0.6558	1
19	0.6900	0.6900	1	19	0.6562	0.6545	1
1	0.3800	0.3800	2	20	0.6780	0.6770	1
1	0.3800	0.3800	2	20	0.6820	0.6820	1
1	0.3900	0.3800	2	20	0.6850	0.6840	1
1	0.3800	0.3800	2	20	0.6870	0.6870	1
1	0.3800	0.3800	2	20	0.6810	0.6830	1
1	0.3800	0.3800	2	20	0.6740	0.6750	1
2	0.3800	0.3800	2	21	0.6900	0.6900	1
2	0.3800	0.3800	2	21	0.6980	0.6980	1
2	0.3800	0.3800	2	21	0.7120	0.7110	1
2	0.3800	0.3800	2	21	0.6920	0.6930	1
2	0.3800	0.3800	2	21	0.6950	0.6960	1
2	0.3800	0.3800	2	21	0.6960	0.6970	1
3	0.3870	0.3900	2	22	0.7000	0.7000	1
3	0.3930	0.3880	2	22	0.6900	0.6900	1
3	0.3880	0.3860	2	22	0.6900	0.6900	1
3	0.3880	0.3900	2	22	0.6800	0.6800	1
3	0.3880	0.3850	2	22	0.6900	0.6900	1
3	0.3900	0.3900	2	22	0.6800	0.6900	1
4	0.3900	0.3800	2	23	0.6720	0.6720	1
4	0.3800	0.3900	2	23	0.6710	0.6710	1
4	0.3800	0.3900	2	23	0.6770	0.6780	1
4	0.3900	0.3900	2	23	0.6750	0.6750	1
4	0.3900	0.3900	2	23	0.6740	0.6760	1
4	0.3800	0.3900	2	23	0.6740	0.6740	1
5	0.3900	0.3900	2	24	0.6800	0.6800	1
5	0.3900	0.3900	2	24	0.6700	0.6700	1
5	0.4000	0.3900	2	24	0.6700	0.6700	1
5	0.3900	0.3900	2	24	0.6800	0.6800	1
5	0.3900	0.3900	2	24	0.6700	0.6800	1

5	0.3900	0.3900	2	24	0.6800	0.6800	1
6	0.3800	0.3800	2	25	0.6940	0.6936	1
6	0.3800	0.3800	2	25	0.6897	0.6898	1
6	0.3800	0.3800	2	25	0.6887	0.6879	1
6	0.3800	0.3800	2	25	0.6910	0.6898	1
6	0.3800	0.3800	2	25	0.6868	0.6869	1
6	0.3800	0.3800	2	25	0.6906	0.6896	1
7	0.4100	0.4100	2	26	0.6900	0.6800	1
7	0.4100	0.4100	2	26	0.6800	0.6800	1
7	0.4100	0.4100	2	26	0.6900	0.6900	1
7	0.4100	0.4100	2	26	0.6900	0.6900	1
7	0.4100	0.4100	2	26	0.6900	0.6800	1
7	0.4100	0.4100	2	26	0.6900	0.6800	1
8	0.3919	0.3919	2	1	0.3350	0.3350	2
8	0.3929	0.3919	2	1	0.3390	0.3400	2
8	0.3919	0.3939	2	1	0.3340	0.3360	2
8	0.3951	0.3932	2	1	0.3410	0.3400	2
8	0.3942	0.3932	2	1	0.3400	0.3390	2
8	0.3932	0.3941	2	1	0.3330	0.3340	2
9	0.3810	0.3790	2	2	0.3820	0.3820	2
9	0.3800	0.3810	2	2	0.3760	0.3760	2
9	0.3830	0.3790	2	2	0.3770	0.3770	2
9	0.3780	0.3790	2	2	0.3820	0.3810	2
9	0.3810	0.3790	2	2	0.3760	0.3760	2
9	0.3820	0.3830	2	2	0.3760	0.3770	2
10	0.3900	0.3900	2	3	0.3800	0.3800	2
10	0.3900	0.3900	2	3	0.3800	0.3800	2
10	0.3900	0.3900	2	3	0.3800	0.3800	2
10	0.3800	0.3800	2	3	0.3800	0.3800	2
10	0.3800	0.3800	2	3	0.3800	0.3800	2
10	0.3800	0.3800	2	3	0.3800	0.3700	2
11	0.3810	0.3730	2	4	0.3930	0.3940	2
11	0.3790	0.3810	2	4	0.3920	0.3920	2
11	0.3790	0.3900	2	4	0.3930	0.3930	2
11	0.3820	0.3790	2	4	0.3950	0.3950	2
11	0.3860	0.3840	2	4	0.3950	0.3950	2
11	0.3900	0.3800	2	4	0.3930	0.3930	2
12	0.3710	0.3720	2	5	0.3700	0.3700	2
12	0.3720	0.3740	2	5	0.3700	0.3600	2
12	0.3730	0.3860	2	5	0.3600	0.3600	2
12	0.3860	0.3860	2	5	0.3700	0.3800	2
12	0.3750	0.3740	2	5	0.3700	0.3600	2
12	0.3840	0.3840	2	5	0.3600	0.3700	2
13	0.3900	0.3900	2	6	0.3800	0.3800	2
13	0.3800	0.3800	2	6	0.3800	0.3800	2
13	0.3800	0.3800	2	6	0.3800	0.3800	2
13	0.3800	0.3700	2	6	0.3800	0.3800	2
13	0.3800	0.3800	2	6	0.3800	0.3800	2
13	0.3800	0.3800	2	6	0.3800	0.3800	2

14	0.3795	0.3795	2	7	0.3500	0.3500	2
14	0.3795	0.3795	2	7	0.3500	0.3500	2
14	0.3792	0.3796	2	7	0.3500	0.3500	2
14	0.3765	0.3765	2	7	0.3500	0.3500	2
14	0.3765	0.3765	2	7	0.3500	0.3500	2
14	0.3778	0.3797	2	7	0.3400	0.3400	2
15	0.3860	0.3860	2	8	0.3700	0.3700	2
15	0.3880	0.3880	2	8	0.3700	0.3700	2
15	0.3830	0.3830	2	8	0.3700	0.3700	2
15	0.3870	0.3870	2	8	0.3700	0.3700	2
15	0.3860	0.3850	2	8	0.3700	0.3700	2
15	0.3870	0.3860	2	8	0.3700	0.3700	2
16	0.3800	0.3900	2	9	0.3800	0.3800	2
16	0.3900	0.3900	2	9	0.3700	0.3700	2
16	0.3900	0.3900	2	9	0.3700	0.3700	2
16	0.3900	0.3900	2	9	0.3700	0.3700	2
16	0.3900	0.3900	2	9	0.3700	0.3700	2
16	0.3900	0.3800	2	9	0.3700	0.3700	2
17	0.3780	0.3790	2	10	0.3900	0.3900	2
17	0.3890	0.3890	2	10	0.3900	0.3900	2
17	0.3810	0.3760	2	10	0.3800	0.3800	2
17	0.3780	0.3810	2	10	0.3800	0.3800	2
17	0.3810	0.3750	2	10	0.3800	0.3800	2
17	0.3750	0.3770	2	10	0.3800	0.3800	2
18	0.3700	0.3700	2	11	0.3500	0.3400	2
18	0.3800	0.3800	2	11	0.3400	0.3400	2
18	0.3700	0.3700	2	11	0.3400	0.3400	2
18	0.3800	0.3800	2	11	0.3500	0.3500	2
18	0.3700	0.3700	2	11	0.3500	0.3400	2
18	0.3700	0.3700	2	11	0.3400	0.3400	2
19	0.3800	0.3800	2	12	0.3800	0.3800	2
19	0.3800	0.3800	2	12	0.3800	0.3800	2
19	0.3800	0.3800	2	12	0.3800	0.3800	2
19	0.3800	0.3800	2	12	0.3800	0.3800	2
19	0.3800	0.3800	2	12	0.3500	0.3800	2
19	0.3800	0.3800	2	12	0.3800	0.3800	2
				13	0.3900	0.3900	2
				13	0.3800	0.3800	2
				13	0.3800	0.3800	2
				13	0.3900	0.3800	2
				13	0.3800	0.3800	2
				13	0.3700	0.3800	2
				14	0.3900	0.3900	2
				14	0.3800	0.3800	2
				14	0.3800	0.3800	2
				14	0.3900	0.3900	2
				14	0.3800	0.3800	2
				14	0.3800	0.3800	2
				15	0.3700	0.3700	2

15	0.3700	0.3700	2
15	0.3700	0.3700	2
15	0.3700	0.3700	2
15	0.3700	0.3700	2
15	0.3700	0.3700	2
16	0.3900	0.3900	2
16	0.3900	0.3800	2
16	0.3900	0.3900	2
16	0.3900	0.3900	2
16	0.3900	0.3900	2
16	0.3800	0.3800	2
17	0.3725	0.3728	2
17	0.3747	0.3736	2
17	0.3729	0.3702	2
17	0.3718	0.3735	2
17	0.3750	0.3759	2
17	0.3754	0.3751	2
18	0.3900	0.3900	2
18	0.3900	0.3900	2
18	0.3900	0.3900	2
18	0.4000	0.4000	2
18	0.4000	0.4000	2
18	0.3900	0.3900	2
19	0.3755	0.3753	2
19	0.3755	0.3753	2
19	0.3776	0.3773	2
19	0.3762	0.3760	2
19	0.3762	0.3760	2
19	0.3756	0.3761	2
20	0.3840	0.3820	2
20	0.3830	0.3830	2
20	0.3570	0.3570	2
20	0.3600	0.3630	2
20	0.3830	0.3830	2
20	0.3850	0.3890	2
21	0.3930	0.3930	2
21	0.4040	0.4040	2
21	0.3900	0.3900	2
21	0.4010	0.4000	2
21	0.3940	0.3930	2
21	0.3910	0.3910	2
22	0.3900	0.3900	2
22	0.3900	0.3800	2
22	0.3800	0.3800	2
22	0.3900	0.3900	2
22	0.3900	0.3900	2
22	0.3900	0.3900	2
22	0.3900	0.3900	2
23	0.3810	0.3820	2
23	0.3850	0.3860	2

23	0.3810	0.3820	2
23	0.3870	0.3850	2
23	0.3830	0.3840	2
23	0.3780	0.3800	2
24	0.3900	0.3900	2
24	0.3900	0.3900	2
24	0.3800	0.3800	2
24	0.3900	0.3900	2
24	0.3900	0.3900	2
24	0.3900	0.3900	2
25	0.3825	0.3822	2
25	0.3814	0.3808	2
25	0.3809	0.3806	2
25	0.3771	0.3773	2
25	0.3811	0.3806	2
25	0.3803	0.3802	2
26	0.3700	0.3800	2
26	0.3800	0.3800	2
26	0.3700	0.3800	2
26	0.3800	0.3800	2
26	0.3800	0.3800	2
26	0.3700	0.3800	2

TiO₂

TiO ₂ : Glass Preparation				TiO ₂ : Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	0.3200	0.3200	1	1	0.2900	0.2910	1
1	0.3200	0.3200	1	1	0.2910	0.2940	1
1	0.3200	0.3200	1	1	0.2930	0.2870	1
1	0.3200	0.3200	1	1	0.2900	0.2910	1
1	0.3200	0.3200	1	1	0.2910	0.2890	1
1	0.3200	0.3200	1	1	0.2890	0.2930	1
2	0.3120	0.3060	1	2	0.3030	0.3020	1
2	0.3080	0.3080	1	2	0.3050	0.3030	1
2	0.3070	0.3200	1	2	0.3040	0.3030	1
2	0.3110	0.3070	1	2	0.3010	0.3030	1
2	0.3160	0.3150	1	2	0.3020	0.3050	1
2	0.3040	0.3020	1	2	0.3000	0.3020	1
3	0.3100	0.3100	1	3	0.2600	0.2500	1
3	0.3100	0.3100	1	3	0.2600	0.2700	1
3	0.3100	0.3100	1	3	0.2400	0.2600	1
3	0.3000	0.3100	1	3	0.2600	0.2800	1
3	0.3100	0.3000	1	3	0.2800	0.2800	1
3	0.3100	0.3100	1	3	0.2600	0.2600	1
4	0.3090	0.3060	1	4	0.3000	0.3000	1
4	0.3100	0.3080	1	4	0.3000	0.3000	1
4	0.3050	0.3070	1	4	0.3000	0.3000	1
4	0.3090	0.3070	1	4	0.3000	0.3000	1
4	0.3090	0.3080	1	4	0.3000	0.3000	1
4	0.3080	0.3060	1	4	0.3000	0.3000	1
5	0.3200	0.3200	1	5	0.3160	0.3140	1
5	0.3200	0.3200	1	5	0.3110	0.3130	1
5	0.3200	0.3200	1	5	0.3150	0.3110	1
5	0.3200	0.3200	1	5	0.3110	0.3110	1
5	0.3200	0.3300	1	5	0.3130	0.3130	1
5	0.3200	0.3200	1	5	0.3100	0.3080	1
6	0.3130	0.3020	1	6	0.3020	0.3100	1
6	0.2980	0.3080	1	6	0.3000	0.3030	1
6	0.3080	0.3040	1	6	0.2980	0.3030	1
6	0.2960	0.3090	1	6	0.3000	0.3050	1
6	0.3020	0.3060	1	6	0.3070	0.3040	1
6	0.2970	0.2910	1	6	0.3060	0.3070	1
7	0.3170	0.3170	1	7	0.3000	0.3000	1
7	0.3210	0.3230	1	7	0.3000	0.3000	1
7	0.3220	0.3120	1	7	0.3000	0.3000	1
7	0.3150	0.3250	1	7	0.3000	0.3000	1
7	0.3160	0.3160	1	7	0.3000	0.3000	1
7	0.3200	0.3210	1	7	0.3000	0.3000	1
8	0.3000	0.3000	1	8	0.2880	0.2910	1
8	0.3000	0.3000	1	8	0.2860	0.2900	1
8	0.3100	0.3000	1	8	0.2950	0.2840	1
8	0.3100	0.3000	1	8	0.2830	0.2910	1

8	0.3100	0.3000	1	8	0.2850	0.2890	1
8	0.3000	0.3000	1	8	0.2870	0.2910	1
9	0.3128	0.3145	1	9	0.3200	0.3100	1
9	0.3108	0.3111	1	9	0.3100	0.3200	1
9	0.3116	0.3123	1	9	0.3200	0.3100	1
9	0.3111	0.3106	1	9	0.3200	0.3100	1
9	0.3134	0.3122	1	9	0.3200	0.3200	1
9	0.3125	0.3112	1	9	0.3200	0.3100	1
10	0.3200	0.3100	1	10	0.2900	0.3000	1
10	0.3100	0.3200	1	10	0.2900	0.3000	1
10	0.3200	0.3100	1	10	0.2900	0.2900	1
10	0.3100	0.3100	1	10	0.3000	0.3000	1
10	0.3200	0.3200	1	10	0.2900	0.2900	1
10	0.3200	0.3100	1	10	0.3000	0.2900	1
11	0.3060	0.3040	1	11	0.3063	0.3062	1
11	0.3050	0.3060	1	11	0.3067	0.3053	1
11	0.3030	0.3050	1	11	0.3061	0.3049	1
11	0.3050	0.3030	1	11	0.3047	0.3046	1
11	0.3080	0.3050	1	11	0.3069	0.3055	1
11	0.3060	0.3060	1	11	0.3046	0.3055	1
12	0.3100	0.3000	1	12	0.3070	0.3060	1
12	0.3000	0.3000	1	12	0.3110	0.3030	1
12	0.3000	0.3000	1	12	0.3070	0.3080	1
12	0.3100	0.3100	1	12	0.3010	0.3110	1
12	0.3100	0.3100	1	12	0.3110	0.3100	1
12	0.3100	0.3100	1	12	0.3030	0.3140	1
13	0.3160	0.3160	1	13	0.3001	0.2967	1
13	0.3200	0.3210	1	13	0.2904	0.2955	1
13	0.3170	0.3150	1	13	0.2990	0.3000	1
13	0.3100	0.3140	1	13	0.2966	0.2985	1
13	0.3160	0.3180	1	13	0.2947	0.2955	1
13	0.3170	0.3170	1	13	0.2970	0.2978	1
14	0.3000	0.3100	1	14	0.3000	0.2900	1
14	0.3000	0.3000	1	14	0.3000	0.3100	1
14	0.3000	0.3000	1	14	0.3000	0.3000	1
14	0.3100	0.3000	1	14	0.3000	0.3000	1
14	0.3000	0.3100	1	14	0.3000	0.3000	1
14	0.3100	0.3000	1	14	0.2900	0.2900	1
15	0.2970	0.2970	1	15	0.3100	0.3100	1
15	0.2960	0.3070	1	15	0.3100	0.3100	1
15	0.2980	0.3000	1	15	0.3100	0.3100	1
15	0.2980	0.2970	1	15	0.3100	0.3200	1
15	0.2990	0.3080	1	15	0.3100	0.3100	1
15	0.3020	0.3110	1	15	0.3100	0.3100	1
16	0.3000	0.3000	1	16	0.3000	0.3100	1
16	0.3000	0.3000	1	16	0.3000	0.3100	1
16	0.3000	0.3000	1	16	0.3000	0.3000	1
16	0.3000	0.3000	1	16	0.3000	0.3000	1
16	0.3100	0.3100	1	16	0.3000	0.3000	1

16	0.3100	0.3100	1	16	0.3000	0.3000	1
17	0.3000	0.3100	1	17	0.3100	0.3120	1
17	0.3100	0.3100	1	17	0.3090	0.3100	1
17	0.3000	0.3100	1	17	0.3140	0.3130	1
17	0.3100	0.3100	1	17	0.3140	0.3140	1
17	0.3100	0.3100	1	17	0.3100	0.3130	1
17	0.3100	0.3000	1	17	0.3120	0.3130	1
1	0.3500	0.3500	2	18	0.3000	0.3100	1
1	0.3400	0.3400	2	18	0.3100	0.3000	1
1	0.3500	0.3400	2	18	0.3100	0.3000	1
1	0.3400	0.3400	2	18	0.3000	0.3000	1
1	0.3400	0.3500	2	18	0.3000	0.3000	1
1	0.3400	0.3400	2	18	0.3000	0.3000	1
2	0.3400	0.3350	2	19	0.3100	0.3100	1
2	0.3350	0.3310	2	19	0.3100	0.3100	1
2	0.3350	0.3270	2	19	0.3100	0.3100	1
2	0.3330	0.3370	2	19	0.3100	0.3100	1
2	0.3310	0.3420	2	19	0.3100	0.3100	1
2	0.3380	0.3380	2	19	0.3100	0.3100	1
3	0.3400	0.3300	2	20	0.3020	0.2998	1
3	0.3300	0.3400	2	20	0.3028	0.3012	1
3	0.3300	0.3400	2	20	0.3063	0.3035	1
3	0.3400	0.3300	2	20	0.3008	0.3000	1
3	0.3300	0.3300	2	20	0.3019	0.3013	1
3	0.3400	0.3300	2	20	0.3042	0.3049	1
4	0.3330	0.3330	2	1	0.3190	0.3190	2
4	0.3320	0.3300	2	1	0.3230	0.3210	2
4	0.3310	0.3310	2	1	0.3200	0.3220	2
4	0.3350	0.3330	2	1	0.3170	0.3150	2
4	0.3340	0.3320	2	1	0.3220	0.3230	2
4	0.3330	0.3350	2	1	0.3250	0.3210	2
5	0.3400	0.3400	2	2	0.3340	0.3360	2
5	0.3400	0.3500	2	2	0.3360	0.3340	2
5	0.3400	0.3400	2	2	0.3350	0.3340	2
5	0.3500	0.3400	2	2	0.3340	0.3340	2
5	0.3500	0.3500	2	2	0.3350	0.3290	2
5	0.3400	0.3400	2	2	0.3340	0.3320	2
6	0.3260	0.3280	2	3	0.3000	0.2900	2
6	0.3290	0.3210	2	3	0.2900	0.3000	2
6	0.3290	0.3230	2	3	0.3300	0.2800	2
6	0.3210	0.3210	2	3	0.2900	0.3100	2
6	0.3310	0.3310	2	3	0.3000	0.2900	2
6	0.3310	0.3340	2	3	0.3000	0.3000	2
7	0.3360	0.3490	2	4	0.3300	0.3300	2
7	0.3460	0.3370	2	4	0.3300	0.3300	2
7	0.3370	0.3420	2	4	0.3300	0.3300	2
7	0.3410	0.3410	2	4	0.3300	0.3300	2
7	0.3430	0.3420	2	4	0.3300	0.3300	2
7	0.3450	0.3450	2	4	0.3300	0.3300	2

8	0.3300	0.3200	2	5	0.3410	0.3390	2
8	0.3200	0.3300	2	5	0.3400	0.3380	2
8	0.3300	0.3300	2	5	0.3440	0.3460	2
8	0.3300	0.3300	2	5	0.3450	0.3480	2
8	0.3300	0.3300	2	5	0.3430	0.3420	2
8	0.3200	0.3300	2	5	0.3370	0.3350	2
9	0.3415	0.3428	2	6	0.3350	0.3400	2
9	0.3415	0.3428	2	6	0.3330	0.3350	2
9	0.3424	0.3440	2	6	0.3420	0.3380	2
9	0.3424	0.3426	2	6	0.3360	0.3330	2
9	0.3424	0.3426	2	6	0.3420	0.3450	2
9	0.3429	0.3429	2	6	0.3340	0.3360	2
10	0.3400	0.3400	2	7	0.3300	0.3300	2
10	0.3400	0.3400	2	7	0.3300	0.3200	2
10	0.3400	0.3400	2	7	0.3300	0.3300	2
10	0.3400	0.3400	2	7	0.3300	0.3300	2
10	0.3400	0.3400	2	7	0.3300	0.3300	2
10	0.3400	0.3400	2	7	0.3400	0.3300	2
11	0.3320	0.3280	2	8	0.3340	0.3280	2
11	0.3290	0.3290	2	8	0.3330	0.3330	2
11	0.3310	0.3300	2	8	0.3310	0.3290	2
11	0.3310	0.3310	2	8	0.3290	0.3290	2
11	0.3310	0.3330	2	8	0.3310	0.3350	2
11	0.3330	0.3320	2	8	0.3320	0.3290	2
12	0.3300	0.3300	2	9	0.3600	0.3600	2
12	0.3300	0.3200	2	9	0.3600	0.3600	2
12	0.3300	0.3200	2	9	0.3600	0.3600	2
12	0.3400	0.3300	2	9	0.3700	0.3600	2
12	0.3400	0.3300	2	9	0.3600	0.3600	2
12	0.3300	0.3300	2	9	0.3600	0.3600	2
13	0.3340	0.3350	2	10	0.3200	0.3200	2
13	0.3390	0.3350	2	10	0.3200	0.3300	2
13	0.3400	0.3430	2	10	0.3200	0.3200	2
13	0.3360	0.3330	2	10	0.3300	0.3300	2
13	0.3460	0.3390	2	10	0.3200	0.3200	2
13	0.3340	0.3340	2	10	0.3200	0.3300	2
14	0.3300	0.3300	2	11	0.3409	0.3409	2
14	0.3300	0.3200	2	11	0.3409	0.3409	2
14	0.3300	0.3300	2	11	0.3416	0.3422	2
14	0.3300	0.3300	2	11	0.3416	0.3412	2
14	0.3200	0.3300	2	11	0.3416	0.3412	2
14	0.3300	0.3300	2	11	0.3418	0.3417	2
15	0.3240	0.3340	2	12	0.3390	0.3390	2
15	0.3150	0.3260	2	12	0.3400	0.3410	2
15	0.3160	0.3180	2	12	0.3400	0.3390	2
15	0.3300	0.3200	2	12	0.3390	0.3440	2
15	0.3290	0.3190	2	12	0.3370	0.3420	2
15	0.3280	0.3180	2	12	0.3380	0.3380	2
16	0.3200	0.3200	2	13	0.3203	0.3223	2

16	0.3200	0.3200	2	13	0.3228	0.3198	2
16	0.3200	0.3200	2	13	0.3245	0.3225	2
16	0.3300	0.3300	2	13	0.3186	0.3204	2
16	0.3300	0.3300	2	13	0.3234	0.3220	2
16	0.3300	0.3300	2	13	0.3236	0.3268	2
17	0.3300	0.3300	2	14	0.3300	0.3300	2
17	0.3300	0.3300	2	14	0.3200	0.3300	2
17	0.3300	0.3300	2	14	0.3300	0.3200	2
17	0.3200	0.3300	2	14	0.3300	0.3300	2
17	0.3400	0.3200	2	14	0.3200	0.3200	2
17	0.3300	0.3300	2	14	0.3200	0.3200	2
				15	0.3300	0.3400	2
				15	0.3400	0.3400	2
				15	0.3400	0.3400	2
				15	0.3400	0.3400	2
				15	0.3400	0.3400	2
				15	0.3400	0.3400	2
				15	0.3400	0.3400	2
				16	0.3300	0.3300	2
				16	0.3300	0.3300	2
				16	0.3300	0.3400	2
				16	0.3300	0.3300	2
				16	0.3400	0.3300	2
				16	0.3300	0.3300	2
				17	0.3410	0.3430	2
				17	0.3400	0.3450	2
				17	0.3390	0.3430	2
				17	0.3390	0.3440	2
				17	0.3410	0.3430	2
				17	0.3440	0.3470	2
				18	0.3300	0.3300	2
				18	0.3300	0.3300	2
				18	0.3300	0.3300	2
				18	0.3300	0.3300	2
				18	0.3300	0.3300	2
				18	0.3300	0.3300	2
				18	0.3300	0.3300	2
				19	0.3300	0.3300	2
				19	0.3300	0.3300	2
				19	0.3300	0.3300	2
				19	0.3300	0.3200	2
				19	0.3300	0.3300	2
				19	0.3300	0.3300	2
				20	0.3334	0.3345	2
				20	0.3320	0.3318	2
				20	0.3293	0.3279	2
				20	0.3285	0.3310	2
				20	0.3332	0.3312	2
				20	0.3334	0.3317	2

P₂O₅

P2O5: Glass Preparation				P2O5: Powder Preparation			
Lab	Duplicate 1	Duplicate 2	Cement	Lab	Duplicate 1	Duplicate 2	Cement
1	0.2070	0.2130	1	1	0.2200	0.2200	1
1	0.2000	0.2090	1	1	0.2200	0.2200	1
1	0.2200	0.2110	1	1	0.2200	0.2200	1
1	0.2100	0.2160	1	1	0.2200	0.2200	1
1	0.1990	0.2110	1	1	0.2200	0.2200	1
1	0.1990	0.2120	1	1	0.2200	0.2200	1
2	0.2114	0.2114	1	2	0.2740	0.2760	1
2	0.2114	0.2104	1	2	0.2750	0.2790	1
2	0.2114	0.2104	1	2	0.2740	0.2770	1
2	0.2096	0.2116	1	2	0.2750	0.2790	1
2	0.2106	0.2116	1	2	0.2770	0.0275	1
2	0.2106	0.2106	1	2	0.2730	0.2740	1
3	0.2200	0.2200	1	3	0.2300	0.2300	1
3	0.2200	0.2200	1	3	0.2300	0.2300	1
3	0.2200	0.2100	1	3	0.2300	0.2300	1
3	0.2100	0.2200	1	3	0.2300	0.2300	1
3	0.2200	0.2100	1	3	0.2300	0.2300	1
3	0.2200	0.2200	1	3	0.2300	0.2200	1
4	0.2160	0.2150	1	4	0.2160	0.2180	1
4	0.2170	0.2180	1	4	0.2170	0.2160	1
4	0.2140	0.2130	1	4	0.2160	0.2190	1
4	0.2140	0.2150	1	4	0.2170	0.2150	1
4	0.2190	0.2140	1	4	0.2160	0.2160	1
4	0.2160	0.2110	1	4	0.2190	0.2160	1
5	0.2100	0.2200	1	5	0.2110	0.2100	1
5	0.2200	0.2100	1	5	0.2120	0.2130	1
5	0.2200	0.2100	1	5	0.2080	0.2120	1
5	0.2100	0.2100	1	5	0.2130	0.2090	1
5	0.2200	0.2000	1	5	0.2100	0.2150	1
5	0.2100	0.2100	1	5	0.2100	0.2110	1
6	0.2190	0.2140	1	6	0.2200	0.2200	1
6	0.2140	0.2180	1	6	0.2200	0.2200	1
6	0.2150	0.2160	1	6	0.2200	0.2200	1
6	0.2170	0.2190	1	6	0.2200	0.2200	1
6	0.2200	0.2190	1	6	0.2200	0.2200	1
6	0.2200	0.2180	1	6	0.2200	0.2200	1
7	0.2100	0.2100	1	7	0.2200	0.2200	1
7	0.2100	0.2200	1	7	0.2200	0.2200	1
7	0.2100	0.2100	1	7	0.2200	0.2200	1
7	0.2100	0.2100	1	7	0.2200	0.2200	1
7	0.2200	0.2100	1	7	0.2200	0.2200	1
8	0.1978	0.1916	1	8	0.2170	0.2180	1
8	0.1970	0.1955	1	8	0.2160	0.2200	1
8	0.1952	0.1928	1	8	0.2190	0.2190	1
8	0.1928	0.2011	1	8	0.2210	0.2190	1

8	0.1943	0.2003	1	8	0.2200	0.2180	1
8	0.1839	0.1874	1	8	0.2210	0.2200	1
9	0.2140	0.2150	1	9	0.2100	0.2100	1
9	0.2100	0.2120	1	9	0.2200	0.2200	1
9	0.2150	0.2170	1	9	0.2200	0.2200	1
9	0.2120	0.2110	1	9	0.2200	0.2200	1
9	0.2130	0.2140	1	9	0.2200	0.2200	1
9	0.2160	0.2160	1	9	0.2200	0.2200	1
10	0.2200	0.2100	1	10	0.2090	0.2090	1
10	0.2200	0.2200	1	10	0.2080	0.2100	1
10	0.2100	0.2200	1	10	0.2100	0.2080	1
10	0.2100	0.2200	1	10	0.2110	0.2120	1
10	0.2200	0.2200	1	10	0.2120	0.2120	1
10	0.2100	0.2200	1	10	0.2110	0.2110	1
11	0.2100	0.2110	1	11	0.2120	0.2130	1
11	0.2090	0.2080	1	11	0.2140	0.2130	1
11	0.2070	0.2070	1	11	0.2140	0.2140	1
11	0.2100	0.2110	1	11	0.2130	0.2110	1
11	0.2110	0.2100	1	11	0.2120	0.2140	1
11	0.2090	0.2100	1	11	0.2130	0.2100	1
12	0.2100	0.2100	1	12	0.1160	0.1200	1
12	0.2000	0.2000	1	12	0.1190	0.1190	1
12	0.2100	0.2100	1	12	0.1190	0.1190	1
12	0.2100	0.2100	1	12	0.1180	0.1220	1
12	0.2200	0.2000	1	12	0.1180	0.1190	1
12	0.2000	0.2100	1	12	0.1210	0.1220	1
13	0.2200	0.2200	1	13	0.2100	0.2100	1
13	0.2200	0.2200	1	13	0.2100	0.2100	1
13	0.2200	0.2200	1	13	0.2000	0.2000	1
13	0.2200	0.2200	1	13	0.2100	0.2000	1
13	0.2200	0.2200	1	13	0.2100	0.2000	1
13	0.2200	0.2200	1	13	0.2000	0.2100	1
14	0.2170	0.2200	1	14	0.2210	0.2210	1
14	0.2030	0.2370	1	14	0.2200	0.2200	1
14	0.2530	0.2460	1	14	0.2210	0.2200	1
14	0.2290	0.2230	1	14	0.2200	0.2200	1
14	0.2210	0.2080	1	14	0.2200	0.2200	1
14	0.2200	0.2260	1	14	0.2190	0.2220	1
15	0.2200	0.2200	1	15	0.2220	0.2180	1
15	0.2190	0.2210	1	15	0.2150	0.2130	1
15	0.2110	0.2130	1	15	0.2150	0.2140	1
15	0.2110	0.2110	1	15	0.2890	0.2860	1
15	0.2080	0.2170	1	15	0.2860	0.2860	1
15	0.2100	0.2190	1	15	0.2760	0.2760	1
16	0.2000	0.2000	1	16	0.2134	0.2135	1
16	0.2100	0.2000	1	16	0.2148	0.2146	1
16	0.2100	0.2000	1	16	0.2156	0.2157	1
16	0.2100	0.2100	1	16	0.2115	0.2108	1
16	0.2000	0.2000	1	16	0.2147	0.2142	1

16	0.2100	0.2000	1	16	0.2162	0.2172	1
17	0.2146	0.2148	1	17	0.2100	0.2100	1
17	0.2146	0.2138	1	17	0.2100	0.2100	1
17	0.2144	0.2146	1	17	0.2100	0.2100	1
17	0.2141	0.2145	1	17	0.2100	0.2100	1
17	0.2146	0.2145	1	17	0.2000	0.2100	1
17	0.2147	0.2139	1	17	0.2100	0.2100	1
18	0.2100	0.2200	1	18	0.2200	0.2195	1
18	0.2100	0.2200	1	18	0.2208	0.2205	1
18	0.2100	0.2100	1	18	0.2199	0.2196	1
18	0.2100	0.2100	1	18	0.2194	0.2195	1
18	0.2100	0.2100	1	18	0.2196	0.2193	1
18	0.2100	0.2100	1	18	0.2197	0.2197	1
19	0.2100	0.2170	1	19	0.2200	0.2200	1
19	0.2110	0.2140	1	19	0.2200	0.2200	1
19	0.2090	0.2040	1	19	0.2200	0.2200	1
19	0.2100	0.2020	1	19	0.2200	0.2200	1
19	0.2160	0.2160	1	19	0.2200	0.2200	1
19	0.2150	0.2120	1	19	0.2200	0.2200	1
1	0.0880	0.0940	2	20	0.2150	0.2170	1
1	0.0920	0.0910	2	20	0.2180	0.2160	1
1	0.0990	0.0970	2	20	0.2160	0.2170	1
1	0.0920	0.0970	2	20	0.2170	0.2180	1
1	0.0950	0.0920	2	20	0.2170	0.2160	1
1	0.0920	0.0970	2	20	0.2080	0.2070	1
2	0.0918	0.0928	2	21	0.2020	0.2040	1
2	0.0908	0.0918	2	21	0.2190	0.2190	1
2	0.0928	0.0918	2	21	0.2100	0.2090	1
2	0.0938	0.0929	2	21	0.2310	0.2260	1
2	0.0929	0.0938	2	21	0.2070	0.2090	1
2	0.0919	0.0938	2	21	0.2170	0.2190	1
3	0.0900	0.0900	2	1	0.0900	0.0900	2
3	0.0900	0.0900	2	1	0.0900	0.0900	2
3	0.0900	0.0900	2	1	0.0900	0.0900	2
3	0.0900	0.0900	2	1	0.1000	0.1000	2
3	0.0900	0.0900	2	1	0.0900	0.1000	2
3	0.0900	0.0900	2	1	0.0900	0.0900	2
4	0.0890	0.0920	2	2	0.1230	0.1250	2
4	0.0940	0.0930	2	2	0.1280	0.1240	2
4	0.0930	0.0930	2	2	0.1250	0.1280	2
4	0.0920	0.0890	2	2	0.1230	0.1240	2
4	0.0920	0.0910	2	2	0.1280	0.1250	2
4	0.0920	0.0900	2	2	0.1190	0.1250	2
5	0.1000	0.1010	2	3	0.1100	0.1000	2
5	0.0990	0.1010	2	3	0.1000	0.1000	2
5	0.0980	0.1010	2	3	0.1000	0.0900	2
5	0.0890	0.0950	2	3	0.1100	0.1000	2
5	0.1010	0.1010	2	3	0.1100	0.1000	2
5	0.1000	0.1000	2	3	0.1000	0.1000	2

6	0.0910	0.0950	2	4	0.0910	0.0900	2
6	0.0960	0.0910	2	4	0.0920	0.0920	2
6	0.0910	0.0930	2	4	0.0870	0.0870	2
6	0.0940	0.0920	2	4	0.0890	0.0890	2
6	0.0920	0.0910	2	4	0.0900	0.0890	2
6	0.0940	0.0930	2	4	0.0880	0.0900	2
7	0.0900	0.0900	2	5	0.0890	0.0880	2
7	0.0900	0.0900	2	5	0.0850	0.0860	2
7	0.0900	0.0900	2	5	0.0850	0.0860	2
7	0.0900	0.0900	2	5	0.0890	0.0870	2
7	0.0900	0.0900	2	5	0.0880	0.0900	2
7	0.0900	0.0900	2	5	0.0860	0.0850	2
8	0.0918	0.0912	2	6	0.1000	0.1000	2
8	0.0924	0.0976	2	6	0.1000	0.1000	2
8	0.0930	0.0928	2	6	0.1000	0.1000	2
8	0.0898	0.0927	2	6	0.1000	0.1000	2
8	0.0957	0.0947	2	6	0.1000	0.1000	2
8	0.0949	0.0912	2	6	0.1000	0.1000	2
9	0.0910	0.0950	2	7	0.0900	0.0900	2
9	0.0950	0.0900	2	7	0.0900	0.0900	2
9	0.0930	0.0920	2	7	0.0900	0.0900	2
9	0.0930	0.0920	2	7	0.0900	0.0900	2
9	0.0920	0.0950	2	7	0.0900	0.0900	2
9	0.0910	0.0960	2	7	0.0900	0.0900	2
10	0.0900	0.0900	2	8	0.0890	0.0920	2
10	0.0900	0.0900	2	8	0.0910	0.0920	2
10	0.0900	0.0900	2	8	0.0910	0.0920	2
10	0.0900	0.0900	2	8	0.0890	0.0900	2
10	0.0900	0.0900	2	8	0.0920	0.0920	2
10	0.0900	0.0900	2	8	0.0900	0.0910	2
11	0.0910	0.0910	2	9	0.1000	0.1000	2
11	0.0900	0.0900	2	9	0.1100	0.1000	2
11	0.0900	0.0900	2	9	0.1000	0.1100	2
11	0.0900	0.0900	2	9	0.1000	0.1000	2
11	0.0900	0.0910	2	9	0.1000	0.1000	2
11	0.0890	0.0900	2	9	0.1000	0.1000	2
12	0.0900	0.0900	2	10	0.0910	0.0920	2
12	0.0900	0.0900	2	10	0.0900	0.0900	2
12	0.0900	0.0900	2	10	0.0900	0.0900	2
12	0.0900	0.0900	2	10	0.0940	0.0950	2
12	0.0900	0.0900	2	10	0.0930	0.0940	2
12	0.0900	0.0900	2	10	0.0920	0.0930	2
13	0.1000	0.0900	2	11	0.0930	0.0920	2
13	0.0900	0.0900	2	11	0.0910	0.0920	2
13	0.0900	0.0900	2	11	0.0900	0.0900	2
13	0.0900	0.1000	2	11	0.0900	0.0880	2
13	0.0900	0.1000	2	11	0.0910	0.0910	2
13	0.0900	0.0900	2	11	0.0910	0.0900	2
14	0.0960	0.0820	2	12	0.0700	0.0690	2

14	0.1280	0.1040	2	12	0.0700	0.0680	2
14	0.1040	0.0920	2	12	0.0690	0.0700	2
14	0.0890	0.0770	2	12	0.0690	0.0700	2
14	0.1020	0.0920	2	12	0.0700	0.0720	2
14	0.1070	0.1020	2	12	0.0690	0.0710	2
15	0.0950	0.0950	2	13	0.0900	0.0900	2
15	0.0950	0.0960	2	13	0.0900	0.0900	2
15	0.0860	0.0960	2	13	0.0900	0.0900	2
15	0.0950	0.0950	2	13	0.0900	0.0900	2
15	0.0850	0.0850	2	13	0.0900	0.0900	2
15	0.0950	0.0950	2	13	0.0900	0.0900	2
16	0.0900	0.0900	2	14	0.0940	0.0940	2
16	0.0900	0.0900	2	14	0.0930	0.0940	2
16	0.0900	0.0900	2	14	0.0940	0.0940	2
16	0.0900	0.0900	2	14	0.2210	0.2210	2
16	0.0900	0.0900	2	14	0.2250	0.2250	2
16	0.1000	0.1000	2	14	0.2260	0.2260	2
17	0.0920	0.0924	2	15	0.1120	0.1070	2
17	0.0920	0.0924	2	15	0.1050	0.1010	2
17	0.0924	0.0921	2	15	0.1000	0.0960	2
17	0.0921	0.0923	2	15	0.1720	0.1730	2
17	0.0921	0.0923	2	15	0.1680	0.1710	2
17	0.0918	0.0922	2	15	0.1640	0.1630	2
18	0.0900	0.0900	2	16	0.0938	0.0941	2
18	0.0900	0.0900	2	16	0.0937	0.0939	2
18	0.0900	0.0900	2	16	0.0936	0.0938	2
18	0.0900	0.0900	2	16	0.0959	0.0951	2
18	0.0900	0.0900	2	16	0.0949	0.0950	2
18	0.0900	0.0900	2	16	0.0951	0.0951	2
19	0.0840	0.0970	2	17	0.0900	0.0900	2
19	0.0890	0.0840	2	17	0.0900	0.0900	2
19	0.0830	0.0910	2	17	0.0900	0.0932	2
19	0.0950	0.0960	2	17	0.0900	0.0900	2
19	0.0890	0.0930	2	17	0.0900	0.0900	2
19	0.0910	0.0920	2	17	0.0900	0.0900	2
				18	0.0911	0.0909	2
				18	0.0911	0.0909	2
				18	0.0911	0.0911	2
				18	0.0916	0.0914	2
				18	0.0916	0.0914	2
				18	0.0912	0.0911	2
				19	0.1000	0.1000	2
				19	0.1000	0.1000	2
				19	0.1000	0.1000	2
				19	0.2200	0.1000	2
				19	0.1000	0.1000	2
				19	0.1000	0.1000	2
				20	0.0990	0.0980	2
				20	0.1000	0.0990	2

20	0.0910	0.0900	2
20	0.0920	0.0910	2
20	0.0960	0.0970	2
20	0.0980	0.0980	2
21	0.0820	0.0810	2
21	0.0940	0.0860	2
21	0.0960	0.0930	2
21	0.0990	0.0970	2
21	0.0930	0.0980	2
21	0.0820	0.0870	2

Cl

Lab	Method	Duplicate 1	Duplicate 2	Cement
1	glass	0.005	0.006	1
1	glass	0.003	0.005	1
1	glass	0.004	0.004	1
1	glass	0.004	0.003	1
1	glass	0.002	0.003	1
1	glass	0.003	0.004	1
1	glass	0.056	0.059	2
1	glass	0.067	0.067	2
1	glass	0.055	0.054	2
1	glass	0.054	0.052	2
1	glass	0.057	0.059	2
1	glass	0.058	0.058	2
2	glass	0.0123	0.0136	1
2	glass	0.0117	0.0117	1
2	glass	0.0111	0.0114	1
2	glass	0.011	0.0117	1
2	glass	0.0127	0.0108	1
2	glass	0.0125	0.0115	1
2	glass	0.098	0.0976	2
2	glass	0.0924	0.0914	2
2	glass	0.094	0.0951	2
2	glass	0.0922	0.0943	2
2	glass	0.082	0.0819	2
2	glass	0.0915	0.0918	2
3	glass	0.0037	0.0038	1
3	glass	0.0035	0.0037	1
3	glass	0.0039	0.0034	1
3	glass	0.0035	0.0034	1
3	glass	0.0034	0.0034	1
3	glass	0.0032	0.0034	1
3	glass	0.0067	0.0076	2
3	glass	0.0092	0.0089	2
3	glass	0.008	0.0084	2
3	glass	0.0077	0.0082	2
3	glass	0.0081	0.0087	2
3	glass	0.006	0.0064	2
4	powder	0.017	0.018	1
4	powder	0.017	0.017	1
4	powder	0.017	0.017	1
4	powder	0.019	0.02	1
4	powder	0.017	0.017	1
4	powder	0.017	0.018	1
4	powder	0.157	0.157	2
4	powder	0.158	0.159	2
4	powder	0.159	0.159	2
4	powder	0.154	0.155	2
4	powder	0.156	0.159	2

4	powder	0.157	0.158	2
6	powder	0.0073	0.0079	1
6	powder	0.008	0.0083	1
6	powder	0.0081	0.0082	1
6	powder	0.0082	0.0088	1
6	powder	0.0091	0.0099	1
6	powder	0.0091	0.0094	1
6	powder	0.0854	0.0852	2
6	powder	0.0804	0.0813	2
6	powder	0.0812	0.082	2
6	powder	0.0831	0.0853	2
6	powder	0.0837	0.0857	2
6	powder	0.0815	0.0828	2
7	powder	0.0173	0.0176	1
7	powder	0.0174	0.0181	1
7	powder	0.0172	0.0204	1
7	powder	0.0126	0.0127	1
7	powder	0.0132	0.0131	1
7	powder	0.0134	0.0135	1
7	powder	0.2331	0.233	2
7	powder	0.237	0.238	2
7	powder	0.2375	0.2378	2
7	powder	0.1861	0.1869	2
7	powder	0.1867	0.188	2
7	powder	0.1896	0.1867	2
8	powder	0.004	0.004	1
8	powder	0.004	0.004	1
8	powder	0.004	0.004	1
8	powder	0.004	0.004	1
8	powder	0.004	0.004	1
8	powder	0.004	0.004	1
8	powder	0.0055	0.0055	2
8	powder	0.0055	0.0055	2
8	powder	0.0055	0.0055	2
8	powder	0.0055	0.0055	2
8	powder	0.0055	0.0055	2
8	powder	0.0055	0.0055	2
8	powder	0.0055	0.0055	2
9	powder	0.0093	0.0109	1
9	powder	0.0099	0.0096	1
9	powder	0.0089	0.0095	1
9	powder	0.0095	0.0099	1
9	powder	0.0097	0.0097	1
9	powder	0.0099	0.0099	1
9	powder	0.0723	0.0727	2
9	powder	0.0734	0.0742	2
9	powder	0.0743	0.0746	2
9	powder	0.0738	0.0744	2
9	powder	0.073	0.0741	2
9	powder	0.0735	0.0749	2

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References

- ¹ Data Considered by Committee C-1 of the American Society for Testing Materials in Preparing the Standard Specifications and Tests for Portland Cement (serial Designation C 9-17), Committee C-1, American Society for Testing Materials, Philadelphia, PA, July 1919.
- ² C114-11b, "Standard Test Method for Chemical Analysis of Hydraulic Cement," Annual Book of ASTM Standards, Vol. 4.01, ASTM International, West Conshohocken, PA.
- ³ J.A. Forrester, T.P. Lees, and A.E. Moore, "The Precision of Standard Cement Analysis and its Effect on the Calculated Compound Composition," S.C.I. Monograph No. 18, The Analysis of Calcareous Materials, 447-451 (1964)
- ⁴ H.G. Midgley, "Compound calculation in the phases in Portland cement clinker," Cement Technology, Vol. 1, No. 3, 1970, pp. 1-5.
- ⁵ A.M. Harrison, H.F.W. Taylor and N.B. Winter, "Electron-Optical Analysis of the Phases in a Portland Cement Clinker, with some Observations on the Calculation of Quantitative Phase Composition", Cement and Concrete Research, Vol. 15, pp. 775-780, 1985.
- ⁶ L.P. Aldridge and R.P. Eardley, "Effects of analytical errors on the Bogue calculation of compound composition," Cement Technology, 4, 1973, pp. 177-182.
- ⁷ L.P. Aldridge, "Errors in the analysis of cement," Cement Technology, 7, 1976, pp. 8-11
- ⁸ P.E. Stutzman, and D.S. Lane, "Effects of Analytical Precision on Bogue Calculations of Potential Portland Cement Composition," Journal of ASTM International, Vol. 7, No. 6, paper ID JAI102697
- ⁹ EN 196-2, Methods of Testing Cement – Part 2: Chemical analysis of cement,
- ¹⁰ NCHRP 139, "Precision Estimates for AASHTO Test Method T 105, Determined Using CCRL Proficiency Sample Data". NCHRP Project 09-26A, June 2009, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w139.pdf
- ¹¹ R. Haupt, personal communication
- ¹² ASTM E 691 "Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method," Annual Book of ASTM Standards, Vol. 14.02, ASTM International, West Conshohocken, PA.
- ¹³ G.J. Hahn and W.Q. Meeker, *Statistical Intervals: A Guide for Practitioners*, John Wiley and Sons, New York, 1991.