



APLAC T020

Proficiency Testing Program of Portland Cement Testing

February 2006

ACKNOWLEDGEMENTS

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1. **FOREWORD**

This report summarises the results of APLAC T020 Proficiency Testing Program of Portland Cement Testing involving testing laboratories for the Asia Pacific Laboratory Accreditation Cooperation (APLAC). This program covered chemical composition of Portland Cement.

The exercise was conducted by the CNLA/ TAF(Taiwan Accreditation Foundation). The aim of the program was to assess laboratories' ability to competently perform the tests examined.

2. **FEATURES OF THE PROGRAM**

- a) APLAC, IAAC and EA members were invited to participate. There are in total 82 laboratory participants nominated by 33 accreditation bodies (ABs) in this program. A total of 8 laboratories did not send the samples due to the delivery problems. Twelve participating laboratories did not return results in time; hence the results from those laboratories were excluded from the analysis.

Economy	No. of Labs	Economy	No. of Labs
Argentina	1	Australia	4
Brazil	6	Brunei Darussalam	3
Belgium	1	Bulgaria	2
Czech Republic	2	Ecuador	1
Guatemala	1	Hong Kong	2
Hungary	1	India	4
Italy	2	Korea	2
Lithuania	2	Malaysia	4
Trinidad and Tobago	2	New Zealand	3
Philippines	4	Portugal	4
Chile	2	Singapore	1
Slovakia	4	Spain	4
Sweden	2	Taiwan	4
Thailand	5	Uruguay	1
USA	2	Vietnam	4
Mongolia	2		

- b) Participating laboratories were supplied two 35g bottles of Portland cement samples labelled APT20A, and APT20B, each sample were identical.
- c) The following tests were performed on each sample in duplicate:
 Silicone Dioxide (SiO_2)
 Aluminium Oxide (Al_2O_3)
 Ferric Oxide (Fe_2O_3)
 Calcium Oxide (CaO)
 Magnesium Oxide (MgO)
 Sulfur Trioxide (SO_3)
- d) Prior to distribution the samples were analysed for homogeneity. The testing results showed that the samples were sufficiently homogeneous. Therefore any results later identified as outliers could not be attributed to any significant sample variability. (Appendix B)

- e) Laboratories were requested to perform the tests according to their copy of the "Instructions to Participants" and to record their results on the accompanying "Results Sheet", both of which were distributed to participants with the sample. (Appendix C)
- f) Each laboratory was randomly allocated a unique code number for the program to enable confidentiality of results. Reference to each laboratory in this report is made by its code number.

3. CONTENT OF APPENDICIES

APPENDIX A contains:

- (i) The duplicate results reported by laboratories and the calculated average result for each test on each sample.
- (ii) A table of robust statistics for each test - number of results, median, normalised IQR, robust CV, minimum, maximum and range.
- (iii) Z-scores and z-score charts calculated for between laboratories and within laboratory for each test.
- (iv) A Youden diagram for each test.
- (v) Test methods and testing equipment reported for each lab.

APPENDIX B contains details of sample preparation and stability testing data.

APPENDIX C contains a copy of the "Instructions to participants" and the "Results Sheet", as supplied to participants.

APPENDIX D contains details of statistical procedures, calculations and formulae.

4. STATISTICAL DESIGN OF THE PROGRAM

A uniform level statistical design was used in this program. The samples labelled APT20A, and APT20B (sample pair) were the same.

Robust statistical procedures were used to generate the z-scores and summary statistics for the sample - number of results, median, normalised interquartile range, minimum, maximum and range.

For each laboratory, the between-laboratories z-score was calculated for the sample pair. This was based on the (standardised) sum of the calculated mean of the duplicate results reported for each sample. The within laboratory z-score was based on the (standardised) difference between the mean of the duplicate results reported for each sample.

TABLE A - SUMMARY STATISTICS

Test	Summary Statistic	APLAC Sample A	APLAC Sample B
Silicone Dioxide (SiO₂) (%)	No. of Results	63	63
	Median	21.185	21.165
	Normalized IQR	0.202	0.211
Aluminium Oxide (Al₂O₃) (%)	No. of Results	61	61
	Median	4.185	4.185
	Normalized IQR	0.263	0.289
Ferric Oxide (Fe₂O₃) (%)	No. of Results	63	63
	Median	3.945	3.950
	Normalized IQR	0.107	0.113
Calcium Oxide (CaO) (%)	No. of Results	63	63
	Median	64.345	64.395
	Normalized IQR	0.428	0.430
Magnesium Oxide (MgO) (%)	No. of Results	64	64
	Median	1.848	1.833
	Normalized IQR	0.122	0.094
Sulfur Trioxide (SO₃) (%)	No. of Results	66	66
	Median	2.250	2.245
	Normalized IQR	0.058	0.063

5. **OUTLIER RESULTS**

In order to achieve the program's aim of assessing laboratories' testing performance, a robust statistical approach, which uses z-scores to assess participants performance has been utilised. The z-score is a measure of how far the result(s) is from the consensus value - a normalized value which gives a "score" to each result relative to the other results in the group. Therefore a z-score close to zero means that the result agrees well with those from other laboratories. An outlier will be any result(s) which has an absolute z-score value greater than three.

Appendix D given details on the calculation of z-scores and modes.

TABLE B
OUTLIER RESULTS
(Between-Laboratories and Within-Laboratory)

Test	Between – Laboratories Z-Score	Within-Laboratory Z-Score
Silicone Dioxide (SiO₂) (%)	19, 68, 55, 14, 40, 56	33, 19, 55, 68, 15, 42, 56, 11
Aluminium Oxide (Al₂O₃) (%)	10, 57, 56, 71, 80	39, 25, 10, 75, 55, 77
Ferric Oxide (Fe₂O₃) (%)	19, 71, 14, 10	40, 68, 23, 11, 10
Calcium Oxide (CaO) (%)	19, 10, 14, 11	10, 23, 52, 29, 25, 19
Magnesium Oxide (MgO) (%)	45, 10, 12, 42, 20, 40, 77, 11, 15, 3	45, 39, 68, 15, 23, 73, 80, 74, 56, 11
Sulfur Trioxide (SO₃) (%)	19, 30	19, 56, 74

Of the 66 participating laboratories, the total of 28 laboratories has been identified as having reported one or more extreme results. Out of the 380 results returned, the total of 72 results has been identified as extreme results (18.9%).

The following parameters in Table C are used to calculate the z-score values.

TABLE C: Z-Score Values

Test	Standardised Sum		Standardised difference	
	Median	Norm IQR	Median	Norm IQR
Silicone Dioxide (SiO₂) (%)	29.925	0.271	-0.000	0.052
Aluminium Oxide (Al₂O₃) (%)	5.933	0.367	-0.007	0.042
Ferric Oxide (Fe₂O₃) (%)	5.590	0.151	-0.004	0.028
Calcium Oxide (CaO) (%)	91.02	0.55	0.000	0.09
Magnesium Oxide (MgO) (%)	2.620	0.161	0.000	0.032
Sulfur Trioxide (SO₃) (%)	3.175	0.083	0.002	0.021

Refer to Appendix D for calculation of standardised sum and standardised difference.

6. TECHNICAL COMMENTS

- a) The test results agree well, especially in the condition of the large number of countries and testing methods. This could be shown apparently from the summary statistic table. The laboratories have been marked as outliers where special cause errors have been occurred. Diagnostics of the outliers are provided by z-scores for between-laboratories and within-laboratory variation (& Youden plot main axis excursions)
- b) Most of the outlier results appear to be associated with systematic error compared to random error. The outliers are mainly from between-laboratory measures, refer to z-score diagram & Youden plot for the six test items.
- c) One laboratory (Lab code 19) reported lower test results for 4 test items (SiO_2 , Fe_2O_3 , CaO 及 SO_3) from the supplied sample A & B. Recheck the recovery of the control and reference standards to correct the systematic error are strongly recommended.
- d) For aluminium oxide, Lab code 80 reported almost 2 times test results of the median for both sample A & B, but reported normal for the other 5 test items. It seems very possibly result from misuse of some parameter in the operation of calculation process.
- e) For Magnesium Oxide, 23 outliers were reported in the recovered 62 laboratories data. Only 2 outlier lab used XRF method, the other 21 used titration method. This main reason was the misjudgement of the titration end point. Enforced training for the reading of end point is recommended.
- f) As a general rule from the analytic results of Z-score, the related Laboratories with a Z-score outside the range $-2 \sim +2$ are suggested to check the factors of uncertainties of their measurement system; the related Laboratories with a Z-score outside the range $-3 \sim +3$ are encouraged to review the factors of uncertainties and even investigate “Quality Management” and “Technical Requirements” of their whole system.

APPENDIX A

Summary of Results

Item 1

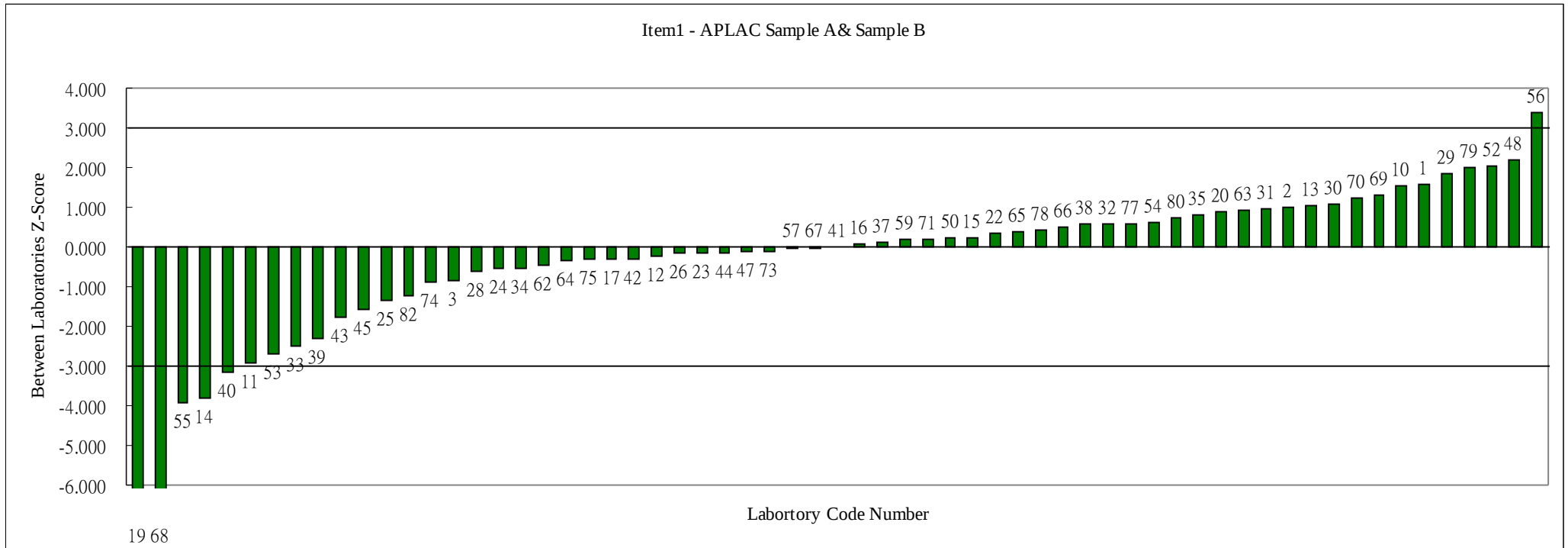
Item	Test									
	SiO ₂									
1	Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty Sample A Sample B
1		21.46	21.43	21.445	21.48	21.49	21.485	1.59	-0.54	±0.14 ±0.14
2		21.26	21.36	21.310	21.42	21.37	21.395	1.00	-1.15	N/A N/A
3		20.96	21.00	20.980	21.00	21.04	21.020	-0.83	-0.54	N/A N/A
4		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
5		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
6		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
7		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
8		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
9		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
10		21.33	21.49	21.410	21.55	21.46	21.505	1.55	-1.28	N/A N/A
11		20.45	20.43	20.440	20.73	20.80	20.765	-2.91	-4.38※	N/A N/A
12		21.12	21.15	21.135	21.06	21.13	21.095	-0.24	0.54	±0.04% ±0.07%
13		21.40	21.34	21.370	21.32	21.37	21.345	1.03	0.34	±0.10% ±0.10%
14		20.38	20.32	20.350	20.48	20.55	20.515	-3.79※	-2.23	N/A N/A
15		20.71	20.96	20.835	21.76	21.39	21.575	0.24	-9.98※	±0.80% ±0.80%
16		21.18	21.19	21.185	21.17	21.16	21.165	0.08	0.27	±0.26% ±0.26%
17		21.10	21.10	21.100	21.10	21.10	21.100	-0.31	0.00	±0.55% ±0.55%
18		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
19		19.71	19.78	19.745	19.11	19.18	19.145	-8.94※	8.09※	N/A N/A
20		21.29	21.41	21.350	21.32	21.29	21.305	0.87	0.61	±0.11% ±0.11%
21		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
22		21.30	21.26	21.280	21.32	21.02	21.170	0.34	1.48	N/A N/A
23		21.12	21.20	21.160	21.06	21.15	21.105	-0.14	0.74	±0.15% ±0.06%
24		21.12	21.10	21.110	21.03	20.99	21.010	-0.52	1.35	N/A N/A
25		20.86	20.89	20.875	20.94	20.91	20.925	-1.36	-0.67	N/A N/A
26		21.16	21.21	21.185	21.08	21.07	21.075	-0.16	1.48	±0.9% ±0.9%
27		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A
28		21.02	21.06	21.040	21.06	21.02	21.040	-0.63	0.00	N/A N/A
29		21.58	21.57	21.575	21.46	21.46	21.460	1.86	1.55	N/A N/A
30		21.42	21.38	21.400	21.36	21.32	21.340	1.10	0.81	N/A N/A
31		21.35	21.31	21.330	21.34	21.38	21.360	0.96	-0.41	N/A N/A
32		21.26	21.27	21.265	21.25	21.31	21.280	0.59	-0.20	±0.104% ±0.104%
33		20.80	21.10	20.950	20.24	20.57	20.405	-2.52	7.35※	±0.05474% ±0.05474%
34		21.04	21.00	21.020	21.08	21.12	21.100	-0.52	-1.08	±0.13% ±0.13%

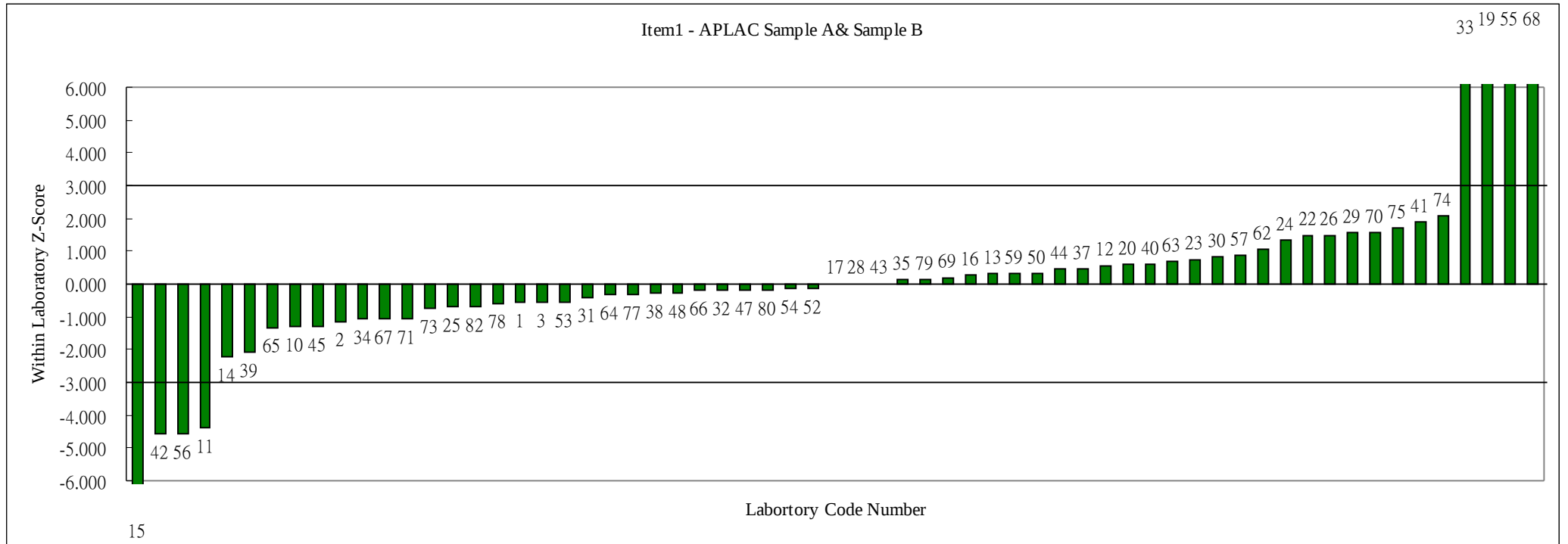
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1	SiO ₂									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
73	21.08	21.14	21.110	21.18	21.15	21.165	-0.12	-0.74	±0.05%	±0.05%
74	21.08	21.06	21.070	20.91	20.92	20.915	-0.87	2.09	N/A	N/A
75	21.12	21.20	21.160	21.00	21.07	21.035	-0.33	1.69	±0.528725%	±0.528725%
76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
77	21.25	21.27	21.260	21.26	21.31	21.285	0.59	-0.34	±0.30%	±0.30%
78	21.20	21.24	21.220	21.26	21.27	21.265	0.43	-0.61	N/A	N/A
79	21.55	21.55	21.550	21.54	21.54	21.540	2.01	0.14	N/A	N/A
80	21.27	21.32	21.295	21.30	21.32	21.310	0.74	-0.20	N/A	N/A
81	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
82	21.00	20.80	20.900	21.02	20.88	20.950	-1.23	-0.67	±0.087%	±0.087%
83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

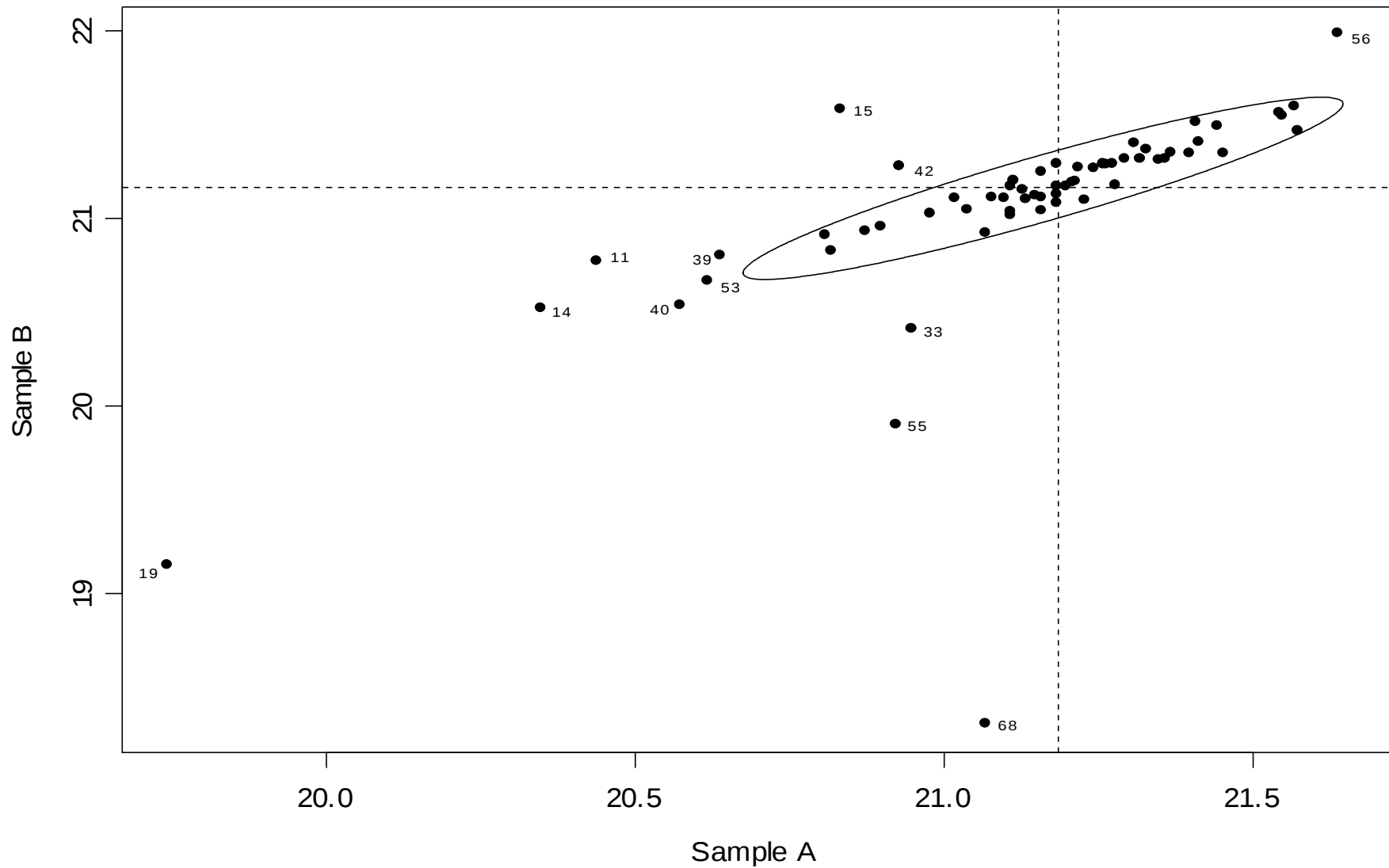
No. of result	63	63
Median	21.185	21.165
Normalized IQR	0.202	0.211
Robust CV(%)	0.954	0.998
Maximum	21.64	21.98
Minimum	19.745	18.3
Range	1.895	3.68

NOTE : ※ denotes an outlier (i.e. |z-score| ≥ 3)

Item 1 – APLAC Sample A & Sample B



Y ouden Plot-T020 Portland Cement



Item 2

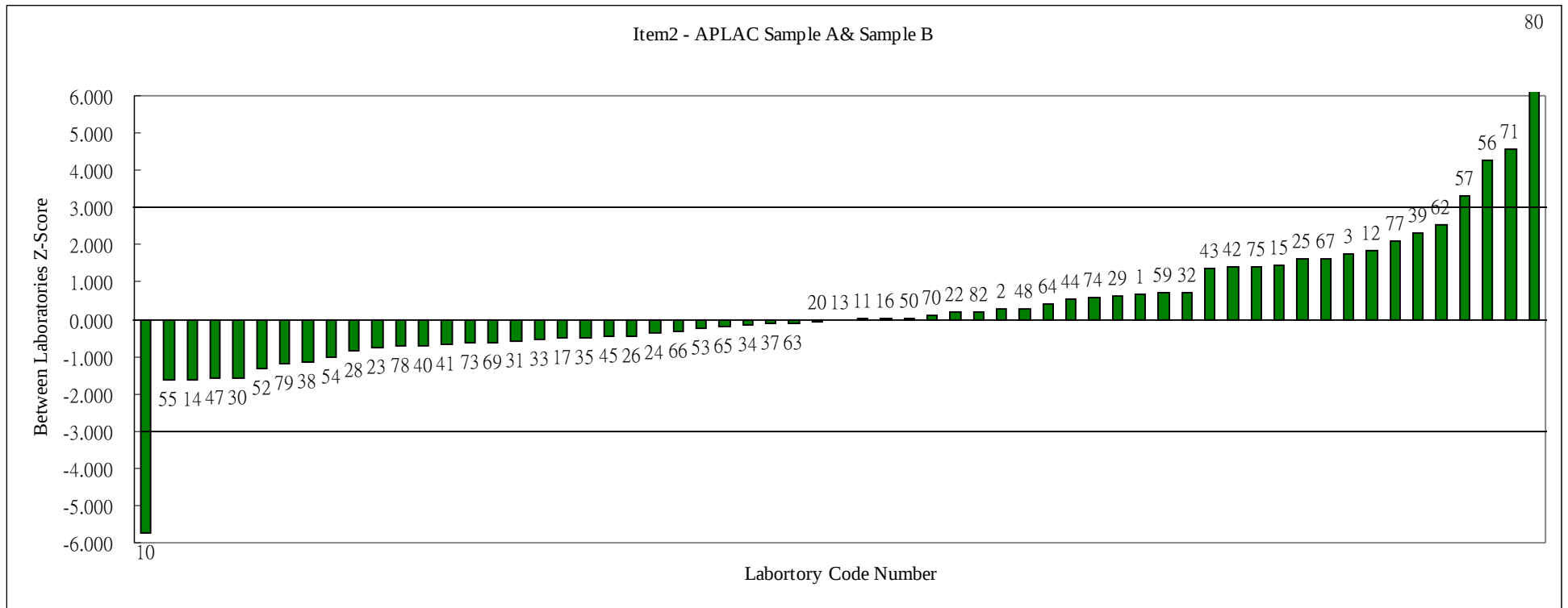
Item	Test									
2	Al ₂ O ₃									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
1	4.34	4.37	4.355	4.38	4.37	4.375	0.66	0.51	±0.21	±0.21
2	4.25	4.32	4.285	4.29	4.20	4.245	0.27	-0.51	N/A	N/A
3	4.64	4.64	4.640	4.65	4.65	4.650	1.73	0.34	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	2.91	2.89	2.900	2.53	2.51	2.520	-5.73※	-6.24※	N/A	N/A
11	4.27	4.30	4.285	4.06	4.16	4.110	0.01	-2.78	N/A	N/A
12	4.74	4.62	4.680	4.63	4.69	4.660	1.83	-0.17	±0.17%	±0.06%
13	4.19	4.18	4.185	4.20	4.21	4.205	0.00	0.51	±0.04%	±0.04%
14	3.77	3.81	3.790	3.73	3.78	3.755	-1.63	-0.42	N/A	N/A
15	4.50	4.57	4.535	4.56	4.67	4.615	1.47	1.52	±0.13%	±0.13%
16	4.21	4.19	4.200	4.21	4.18	4.195	0.01	0.08	±0.06%	±0.06%
17	4.06	4.06	4.060	4.07	4.07	4.070	-0.50	0.34	±0.29%	±0.29%
18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20	4.15	4.18	4.165	4.23	4.15	4.190	-0.07	0.59	±0.03%	±0.03%
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	4.30	4.26	4.280	4.24	4.18	4.210	0.19	-1.01	N/A	N/A
23	4.00	4.05	4.025	3.91	4.02	3.965	-0.77	-0.84	±0.09%	±0.07%
24	4.10	4.12	4.110	4.09	4.08	4.085	-0.38	-0.25	N/A	N/A
25	4.82	4.82	4.820	4.45	4.38	4.415	1.63	-6.66※	N/A	N/A
26	4.08	4.09	4.085	4.07	4.09	4.080	-0.43	0.08	±0.3%	±0.3%
27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	3.92	4.02	3.970	4.00	3.98	3.990	-0.83	0.51	N/A	N/A
29	4.33	4.28	4.305	4.46	4.37	4.415	0.64	2.02	N/A	N/A
30	3.81	3.80	3.803	3.78	3.77	3.777	-1.56	-0.27	N/A	N/A
31	4.00	4.04	4.020	4.04	4.11	4.075	-0.57	1.10	N/A	N/A
32	4.41	4.40	4.405	4.36	4.36	4.360	0.72	-0.59	±0.23%	±0.23%
33	4.08	4.10	4.090	3.98	4.07	4.025	-0.53	-0.93	±0.05420%	±0.05420%

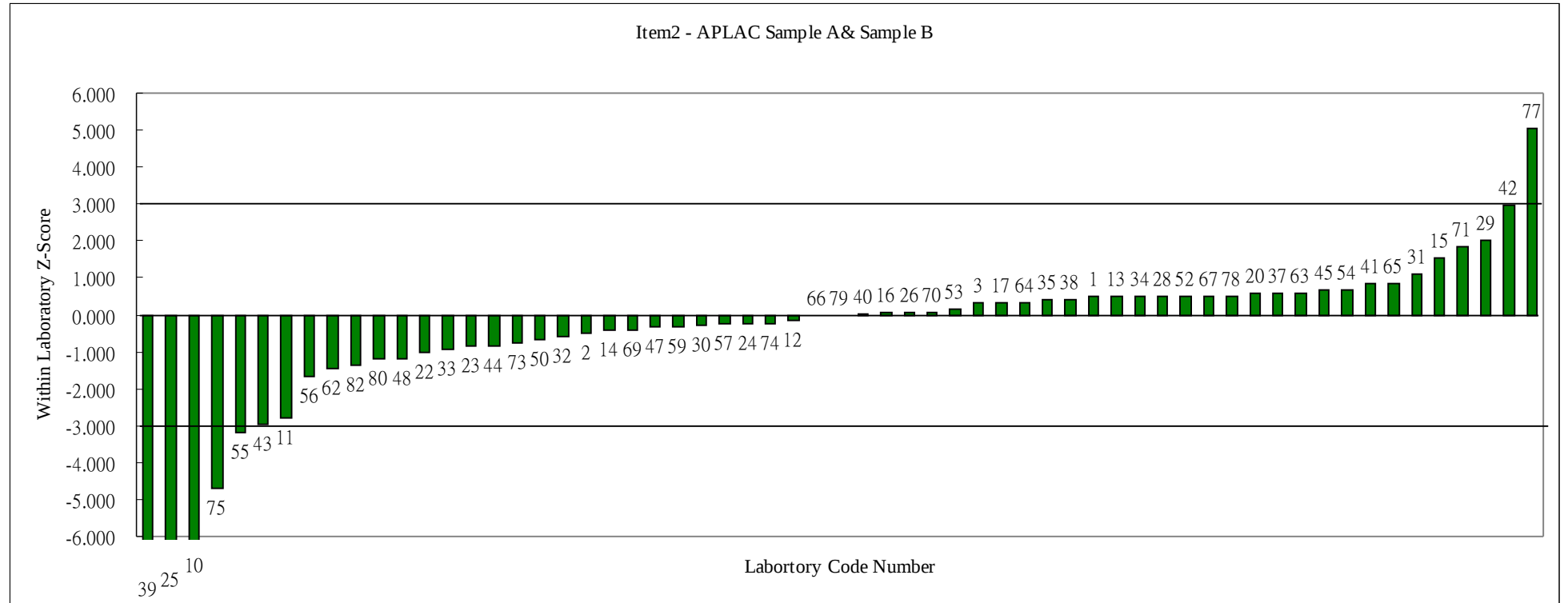
2	Al ₂ O ₃									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
34	4.14	4.16	4.150	4.18	4.16	4.170	-0.14	0.51	±0.07%	±0.07%
35	4.06	4.06	4.060	4.09	4.06	4.075	-0.49	0.42	±0.01370%	±0.01370%
36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37	4.17	4.15	4.160	4.20	4.17	4.185	-0.09	0.59	±0.19%	±0.19%
38	3.87	3.90	3.885	3.89	3.91	3.900	-1.17	0.42	±0.06%	±0.05%
39	5.04	5.04	5.040	4.53	4.56	4.545	2.30	-8.18※	±0.40%	±0.40%
40	3.98	4.06	4.020	4.01	4.01	4.010	-0.69	0.00	±0.10%	±0.10%
41	4.00	4.00	4.000	4.04	4.04	4.040	-0.67	0.84	N/A	N/A
42	4.60	4.36	4.480	4.61	4.68	4.645	1.42	2.95	±0.139317%	±0.139317%
43	4.74	4.55	4.645	4.54	4.38	4.460	1.38	-2.95	N/A	N/A
44	4.38	4.36	4.370	4.29	4.33	4.310	0.56	-0.84	±0.11%	±0.11%
45	4.03	4.09	4.060	4.11	4.07	4.090	-0.46	0.67	±0.11%	±0.11%
46	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
47	3.77	3.82	3.795	3.77	3.76	3.765	-1.60	-0.34	±0.0428%	±0.0428%
48	4.36	4.26	4.310	4.18	4.28	4.230	0.29	-1.18	±0.01%	±0.01%
49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
50	4.19	4.27	4.230	4.18	4.18	4.180	0.04	-0.67	N/A	N/A
51	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
52	3.84	3.84	3.840	3.83	3.89	3.860	-1.33	0.51	±0.09%	±0.09%
53	4.10	4.16	4.130	4.11	4.15	4.130	-0.25	0.17	N/A	N/A
54	3.92	3.91	3.915	3.95	3.94	3.945	-1.02	0.67	0.23	0.23
55	3.86	3.88	3.870	3.67	3.67	3.670	-1.64	-3.20※	N/A	N/A
56	5.30	5.42	5.360	5.16	5.34	5.250	4.28※	-1.69	N/A	N/A
57	5.08	5.06	5.070	5.01	5.08	5.045	3.32※	-0.25	±0.47%	±0.47%
58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
59	4.37	4.42	4.395	4.33	4.40	4.365	0.71	-0.34	±0.30%	±0.30%
60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
62	4.88	4.91	4.895	4.82	4.78	4.800	2.52	-1.43	N/A	N/A
63	4.17	4.15	4.160	4.18	4.19	4.185	-0.09	0.59	N/A	N/A
64	4.33	4.27	4.300	4.30	4.32	4.310	0.42	0.34	N/A	N/A
65	4.10	4.16	4.130	4.09	4.25	4.170	-0.17	0.84	±0.20%	±0.20%
66	4.13	4.11	4.120	4.10	4.12	4.110	-0.31	0.00	±0.075%	±0.075%
67	4.62	4.60	4.610	4.58	4.68	4.630	1.64	0.51	±0.12%	±0.12%
68	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
69	4.06	4.04	4.050	4.01	4.02	4.015	-0.63	-0.42	±0.12%	±0.12%
70	4.24	4.21	4.225	4.21	4.23	4.220	0.11	0.08	N/A	N/A
71	5.39	5.27	5.330	5.53	5.33	5.430	4.57※	1.86	N/A	N/A

2	Al_2O_3									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
72	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
73	4.07	4.04	4.055	3.97	4.03	4.000	-0.65	-0.76	$\pm 0.05\%$	$\pm 0.05\%$
74	4.37	4.35	4.360	4.37	4.30	4.335	0.59	-0.25	N/A	N/A
75	4.80	4.62	4.710	4.52	4.32	4.420	1.43	-4.72※	$\pm 4.625927\%$	$\pm 4.625927\%$
76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
77	4.55	4.64	4.595	4.85	4.92	4.885	2.10	5.06※	$\pm 0.12\%$	$\pm 0.12\%$
78	4.00	3.99	3.995	4.03	4.00	4.015	-0.73	0.51	N/A	N/A
79	3.89	3.89	3.890	3.88	3.88	3.880	-1.20	0.00	N/A	N/A
80	8.51	8.66	8.585	8.43	8.58	8.505	16.77※	-1.18	N/A	N/A
81	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
82	4.32	4.26	4.290	4.20	4.20	4.200	0.19	-1.35	$\pm 0.028\%$	$\pm 0.028\%$
83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

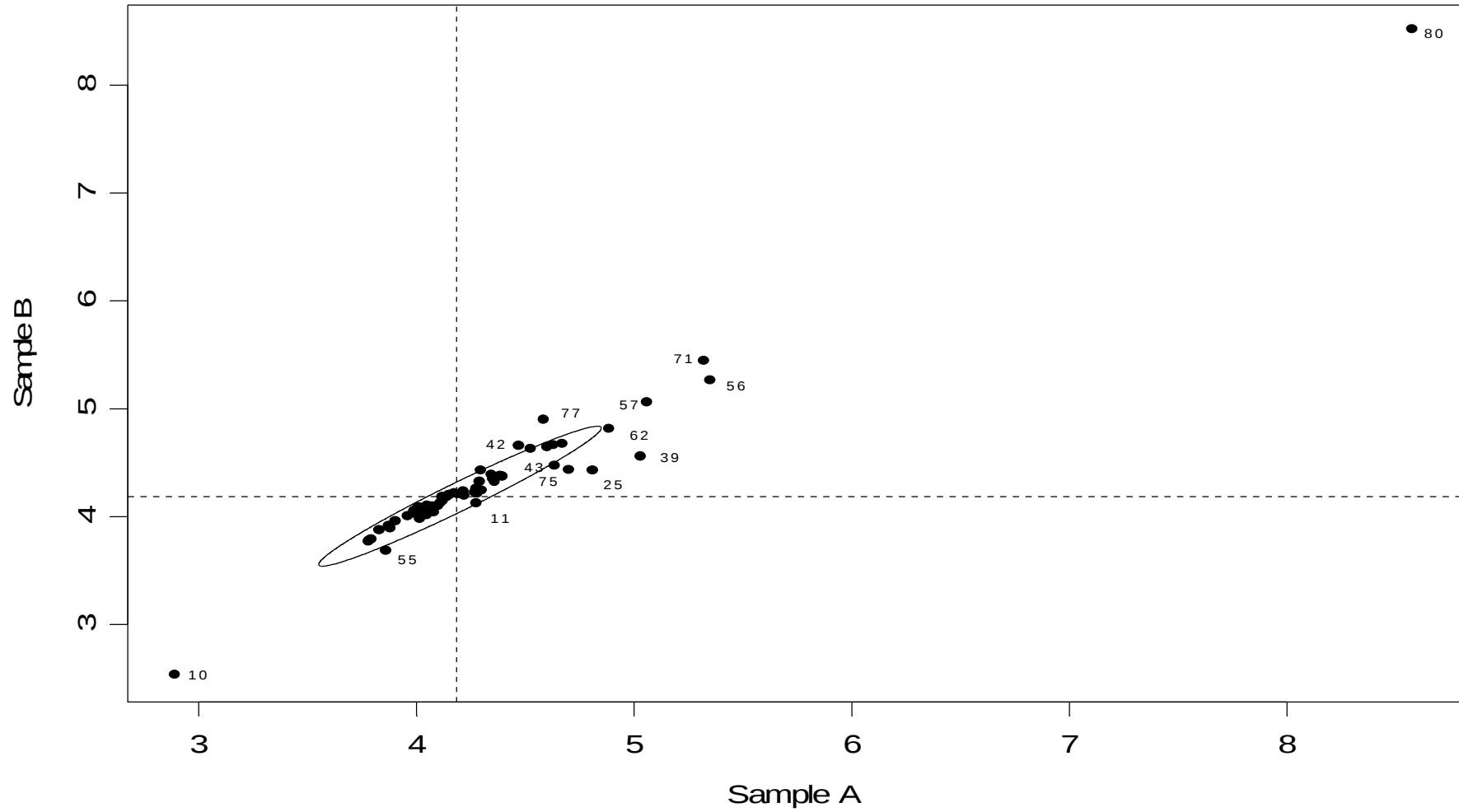
No. of result	61	61
Median	4.185	4.185
Normalized IQR	0.263	0.289
Robust CV(%)	6.288	6.908
Maximum	8.585	8.505
Minimum	2.9	2.52
Range	5.685	5.985

NOTE : ※ denotes an outlier (i.e. $|z\text{-score}| \geq 3$)

Item 2 – APLAC Sample A & Sample B



Youden Plot-T020 Portland Cement



Item 3

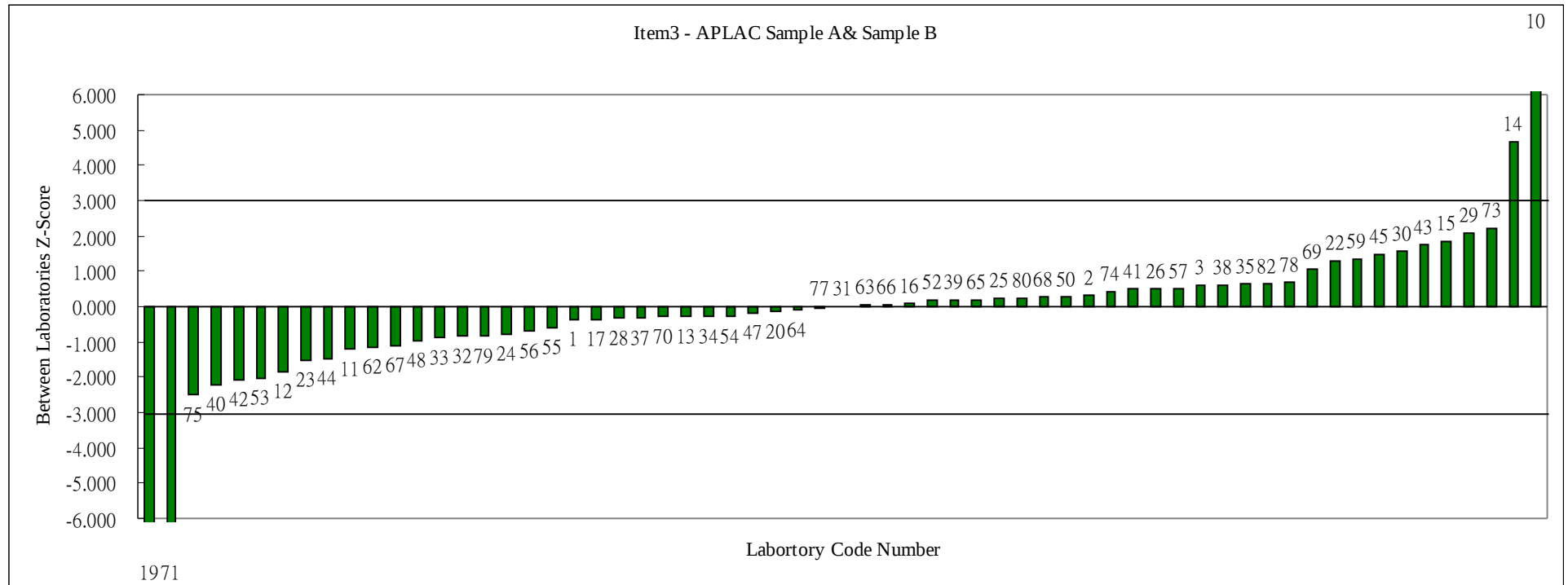
Item	Test									
3	Fe ₂ O ₃									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
1	3.90	3.92	3.910	3.91	3.92	3.915	-0.38	0.26	±0.07	±0.07
2	4.00	3.98	3.990	4.00	3.96	3.980	0.31	-0.13	N/A	N/A
3	4.03	4.03	4.030	4.00	4.00	4.000	0.59	-0.64	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	5.20	5.26	5.230	5.16	5.70	5.430	12.93※	5.27※	N/A	N/A
11	3.74	3.72	3.730	3.95	3.89	3.920	-1.20	5.01※	N/A	N/A
12	3.78	3.82	3.800	3.72	3.70	3.710	-1.85	-2.18	±0.06%	±0.02%
13	3.94	3.92	3.930	3.93	3.91	3.920	-0.26	-0.13	±0.02%	±0.02%
14	4.49	4.46	4.475	4.40	4.44	4.420	4.65※	-1.29	N/A	N/A
15	4.07	4.12	4.095	4.12	4.29	4.205	1.85	2.96	±0.16%	±0.16%
16	3.97	3.96	3.965	3.94	3.97	3.955	0.07	-0.13	±0.09%	±0.09%
17	3.91	3.91	3.910	3.92	3.92	3.920	-0.35	0.39	±0.16%	±0.16%
18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
19	2.51	2.55	2.530	2.42	2.45	2.435	-13.80※	-2.31	N/A	N/A
20	3.93	3.95	3.940	3.94	3.93	3.935	-0.14	0.00	±0.03%	±0.03%
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	4.12	4.08	4.100	4.08	4.08	4.080	1.29	-0.39	N/A	N/A
23	3.74	3.72	3.730	3.85	3.86	3.855	-1.50	3.34※	±0.04%	±0.05%
24	3.87	3.88	3.875	3.86	3.87	3.865	-0.77	-0.13	N/A	N/A
25	3.96	3.98	3.970	3.96	4.00	3.980	0.21	0.39	N/A	N/A
26	4.01	4.01	4.010	3.99	4.02	4.005	0.52	0.00	±0.1%	±0.1%
27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	3.96	3.92	3.940	3.90	3.90	3.900	-0.31	-0.90	N/A	N/A
29	4.17	4.15	4.160	4.18	4.20	4.190	2.09	0.90	N/A	N/A
30	4.11	4.12	4.115	4.11	4.14	4.125	1.57	0.39	N/A	N/A
31	3.99	3.94	3.965	3.94	3.94	3.940	0.00	-0.51	N/A	N/A
32	3.90	3.84	3.870	3.89	3.82	3.855	-0.85	-0.26	±0.23%	±0.23%
33	3.87	3.88	3.875	3.82	3.87	3.845	-0.87	-0.64	±0.07541%	±0.07541%

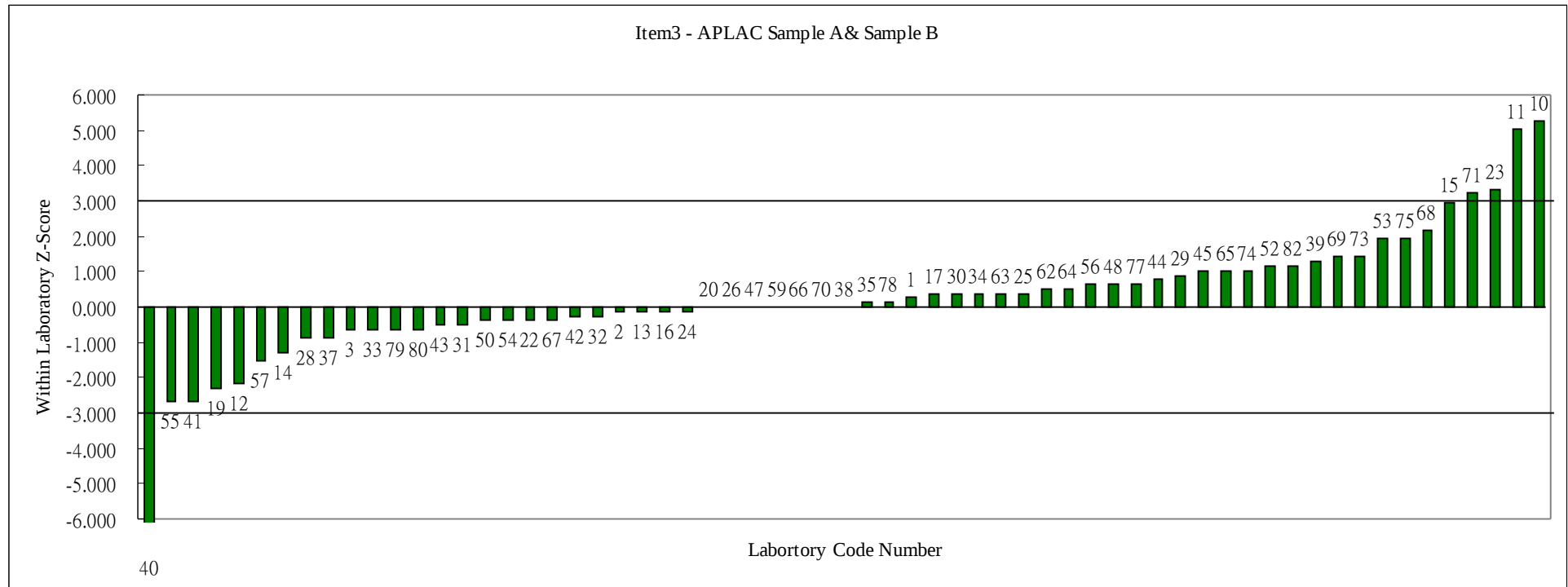
3	Fe ₂ O ₃									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
34	3.90	3.94	3.920	3.94	3.92	3.930	-0.26	0.39	±0.04%	±0.04%
35	4.02	4.02	4.020	4.02	4.02	4.020	0.63	0.13	±0.02057%	±0.02057%
36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37	3.94	3.94	3.940	3.90	3.90	3.900	-0.31	-0.90	±0.12%	±0.12%
38	4.01	4.03	4.020	4.03	4.00	4.015	0.61	0.00	±0.07%	±0.08%
39	3.96	3.94	3.950	4.02	3.97	3.995	0.19	1.29	±0.60%	±0.60%
40	3.85	3.85	3.850	3.73	3.43	3.580	-2.23	-6.81※	±0.10%	±0.10%
41	4.06	4.06	4.060	3.95	3.95	3.950	0.49	-2.70	N/A	N/A
42	3.80	3.68	3.740	3.69	3.76	3.725	-2.07	-0.26	±0.082146%	±0.082146%
43	4.14	4.16	4.150	4.11	4.14	4.125	1.74	-0.51	N/A	N/A
44	3.79	3.78	3.785	3.82	3.80	3.810	-1.46	0.77	±0.04%	±0.04%
45	4.11	4.07	4.090	4.12	4.13	4.125	1.46	1.03	±0.09%	±0.09%
46	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
47	3.94	3.93	3.935	3.93	3.93	3.930	-0.19	0.00	±0.0386%	±0.0386%
48	3.84	3.84	3.840	3.88	3.84	3.860	-0.96	0.64	±0.01%	±0.01%
49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
50	4.00	3.98	3.990	3.95	3.99	3.970	0.26	-0.39	N/A	N/A
51	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
52	3.94	3.96	3.950	3.98	4.00	3.990	0.16	1.16	±0.09%	±0.09%
53	3.71	3.69	3.700	3.78	3.76	3.770	-2.04	1.93	N/A	N/A
54	3.93	3.94	3.935	3.91	3.92	3.915	-0.26	-0.39	±0.09%	±0.09%
55	3.93	3.96	3.945	3.84	3.83	3.835	-0.59	-2.70	N/A	N/A
56	3.86	3.88	3.870	3.88	3.90	3.890	-0.68	0.64	N/A	N/A
57	4.04	4.04	4.040	4.04	3.91	3.975	0.52	-1.54	±0.47%	±0.48%
58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
59	4.10	4.10	4.100	4.10	4.09	4.095	1.36	0.00	±0.25%	±0.25%
60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
62	3.81	3.83	3.820	3.84	3.83	3.835	-1.17	0.51	N/A	N/A
63	3.96	3.94	3.950	3.95	3.97	3.960	0.02	0.39	N/A	N/A
64	3.92	3.95	3.935	3.94	3.96	3.950	-0.09	0.51	N/A	N/A
65	3.90	4.01	3.955	3.97	4.01	3.990	0.19	1.03	±0.11%	±0.11%
66	3.95	3.97	3.960	3.95	3.96	3.955	0.05	0.00	±0.0085%	±0.30%
67	3.85	3.84	3.845	3.84	3.81	3.825	-1.10	-0.39	±0.09%	±0.09%
68	3.89	3.99	3.940	4.00	4.04	4.020	0.26	2.18	N/A	N/A
69	4.03	4.05	4.040	4.10	4.08	4.090	1.06	1.41	±0.02%	±0.02%
70	3.92	3.93	3.925	3.92	3.92	3.920	-0.28	0.00	N/A	N/A
71	2.94	2.98	2.960	3.06	3.10	3.080	-8.75※	3.21※	N/A	N/A

3	Fe ₂ O ₃									
Lab Code	APT20A	APT20A	Average	APT20B	APT20B	Average	Between	Within	Expanded uncertainty	
	Result1	Result2		Result1	Result2		Laboratories	Laboratories	Sample A	Sample B
	(%)	(%)	(%)	(%)	(%)	(%)	Z-Score	Z-Score		
72	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
73	4.15	4.18	4.165	4.23	4.20	4.215	2.23	1.41	±0.05%	±0.05%
74	3.99	3.97	3.980	4.03	4.00	4.015	0.42	1.03	N/A	N/A
75	3.64	3.66	3.650	3.68	3.76	3.720	-2.51	1.93	±0.010062%	±0.010062%
76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
77	3.94	3.94	3.940	3.96	3.96	3.960	-0.02	0.64	±0.14%	±0.14%
78	4.02	4.03	4.025	4.03	4.02	4.025	0.68	0.13	N/A	N/A
79	3.88	3.88	3.880	3.85	3.85	3.850	-0.82	-0.64	N/A	N/A
80	3.96	4.02	3.990	3.96	3.96	3.960	0.21	-0.64	N/A	N/A
81	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
82	4.00	4.00	4.000	4.00	4.08	4.040	0.63	1.16	±0.028%	±0.028%
83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

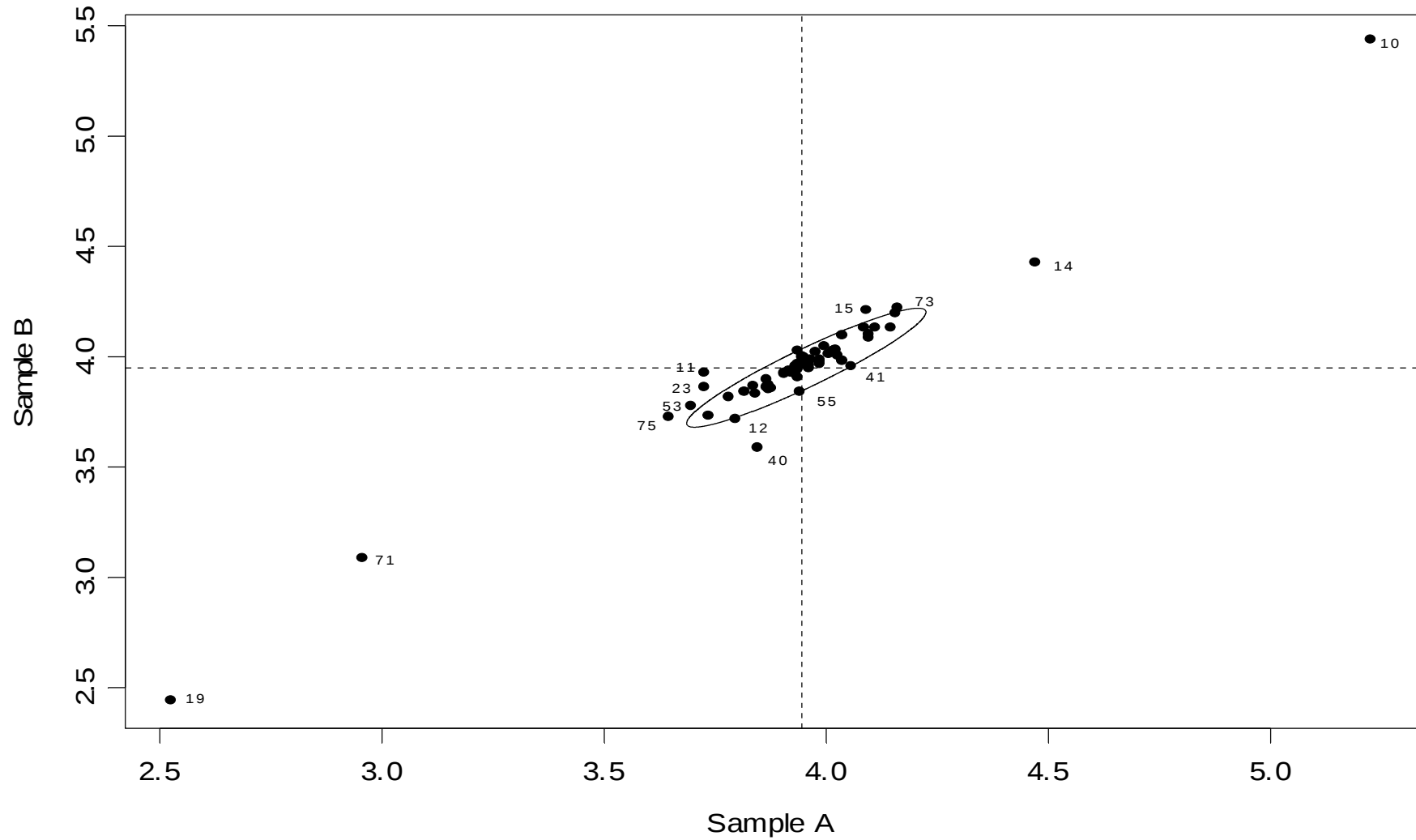
No. of result	63	63
Median	3.945	3.95
Normalized IQR	0.107	0.113
Robust CV(%)	2.725	2.862
Maximum	5.23	5.43
Minimum	2.53	2.435
Range	2.7	2.995

NOTE : ※ denotes an outlier (i.e. |z-score| ≥ 3)

Item 3 – APLAC Sample A & Sample B



Youden Plot-T020 Portland Cement



Item 4

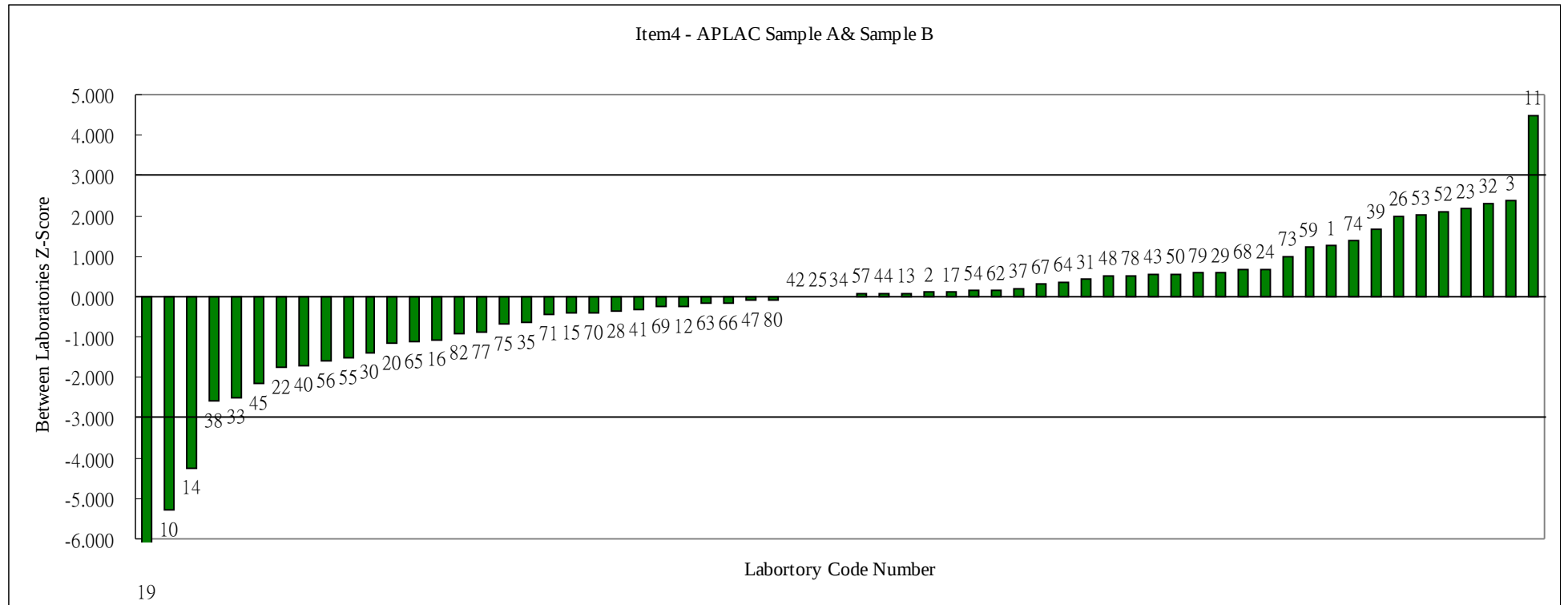
Item	Test									
4	CaO									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
1	64.90	64.87	64.885	64.80	64.84	64.820	1.27	-0.55	±0.40	±0.40
2	64.41	64.15	64.280	64.55	64.47	64.510	0.10	1.94	N/A	N/A
3	65.14	65.14	65.140	65.43	65.43	65.430	2.38	2.45	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	62.61	62.41	62.510	62.21	61.96	62.085	-5.29✖	-3.58✖	N/A	N/A
11	66.16	66.24	66.200	65.95	66.04	65.995	4.47✖	-1.73	N/A	N/A
12	64.36	64.34	64.350	64.20	64.16	64.180	-0.24	-1.43	±0.03%	±0.04%
13	64.44	64.28	64.360	64.50	64.35	64.425	0.09	0.55	±0.26%	±0.26%
14	62.70	62.84	62.770	62.84	62.40	62.620	-4.27✖	-1.27	N/A	N/A
15	64.34	64.27	64.305	64.15	64.05	64.100	-0.40	-1.73	±0.50%	±0.50%
16	63.87	63.97	63.920	63.92	63.98	63.950	-1.09	0.25	±0.57%	±0.57%
17	64.40	64.40	64.400	64.40	64.40	64.400	0.11	0.00	±1.1%	±1.1%
18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
19	54.72	54.81	54.765	56.32	56.18	56.250	-22.74✖	12.52✖	N/A	N/A
20	63.79	64.10	63.945	63.88	63.86	63.870	-1.16	-0.63	±0.13%	±0.13%
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	63.80	63.50	63.650	63.70	63.70	63.700	-1.75	0.42	N/A	N/A
23	65.44	65.36	65.400	65.08	64.96	65.020	2.19	-3.20✖	±0.16%	±0.14%
24	64.69	64.70	64.695	64.56	64.55	64.555	0.69	-1.18	N/A	N/A
25	63.92	64.01	63.965	64.79	64.69	64.740	-0.01	6.53✖	N/A	N/A
26	65.02	65.24	65.130	64.97	65.27	65.120	1.97	-0.08	±0.9%	±0.9%
27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	64.27	64.17	64.220	64.17	64.27	64.220	-0.35	0.00	N/A	N/A
29	64.34	64.38	64.360	64.88	64.76	64.820	0.60	3.88✖	N/A	N/A
30	63.75	63.80	63.775	63.87	63.83	63.850	-1.40	0.63	N/A	N/A
31	64.40	64.56	64.480	64.56	64.56	64.560	0.42	0.67	N/A	N/A
32	65.25	65.20	65.225	65.33	65.23	65.280	2.30	0.46	±0.14%	±0.14%

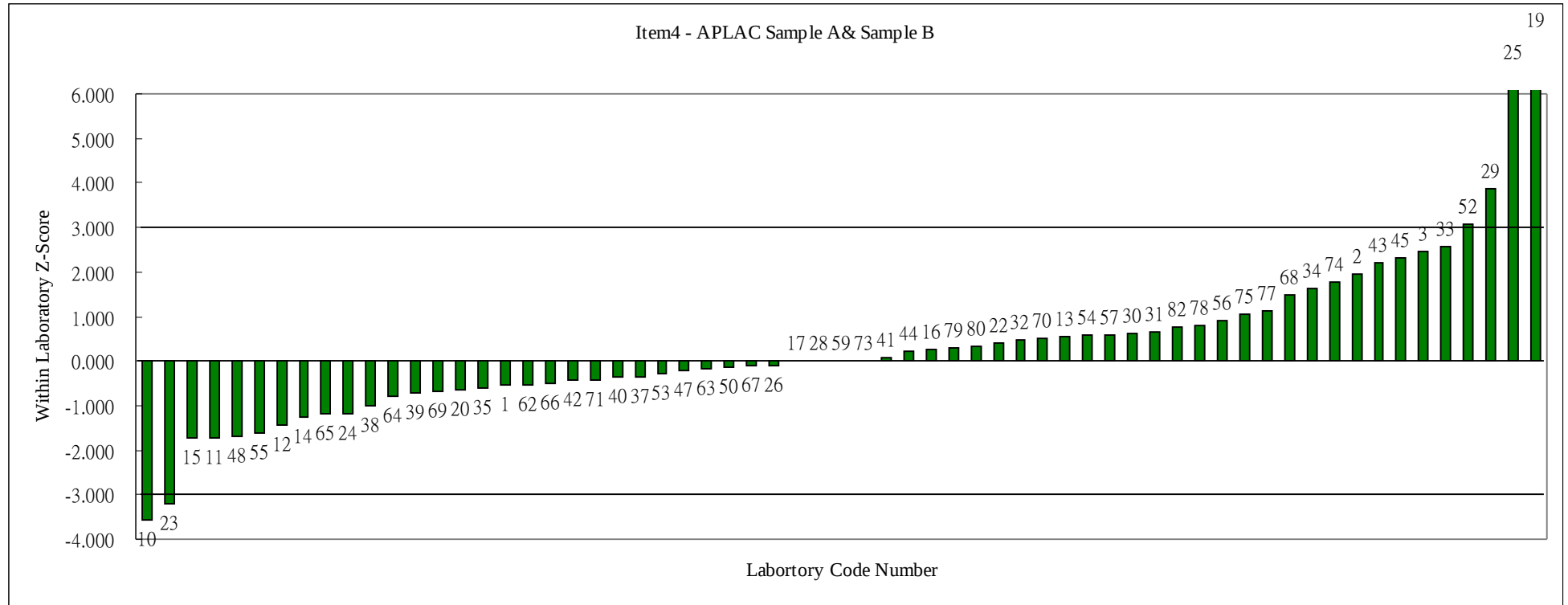
4	CaO									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
33	63.04	63.41	63.225	63.54	63.52	63.530	-2.52	2.57	±0.5062%	±0.5062%
34	64.31	64.21	64.260	64.41	64.50	64.455	0.00	1.64	±0.12%	±0.12%
35	64.14	64.14	64.140	64.00	64.14	64.070	-0.65	-0.59	±0.00259%	±0.00259%
36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37	64.46	64.46	64.460	64.43	64.41	64.420	0.21	-0.34	±0.26%	±0.26%
38	63.43	63.40	63.415	63.33	63.26	63.295	-2.58	-1.01	±0.24%	±0.25%
39	65.09	65.02	65.055	65.00	64.94	64.970	1.68	-0.72	±0.86%	±0.86%
40	63.71	63.71	63.710	63.67	63.67	63.670	-1.72	-0.34	±0.10%	±0.10%
41	64.23	64.23	64.230	64.24	64.24	64.240	-0.32	0.08	N/A	N/A
42	64.45	64.30	64.375	64.30	64.35	64.325	-0.02	-0.42	±0.082010%	±0.082010%
43	64.40	64.49	64.445	64.89	64.52	64.705	0.56	2.19	N/A	N/A
44	64.38	64.36	64.370	64.37	64.42	64.395	0.06	0.21	±0.22%	±0.22%
45	63.30	63.46	63.380	63.70	63.61	63.655	-2.16	2.32	±0.64%	±0.64%
46	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
47	64.32	64.34	64.330	64.33	64.28	64.305	-0.10	-0.21	±0.0077%	±0.0077%
48	64.70	64.60	64.650	64.50	64.40	64.450	0.50	-1.69	±0.01%	±0.01%
49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
50	64.51	64.66	64.585	64.49	64.65	64.570	0.57	-0.13	N/A	N/A
51	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
52	64.96	65.03	64.995	65.15	65.57	65.360	2.11	3.08※	±0.57%	±0.59%
53	65.19	65.13	65.160	65.15	65.10	65.125	2.02	-0.30	N/A	N/A
54	64.37	64.40	64.385	64.33	64.58	64.455	0.16	0.59	0.43	0.43
55	63.65	64.09	63.870	63.61	63.75	63.680	-1.50	-1.60	N/A	N/A
56	63.64	63.74	63.690	63.79	63.81	63.800	-1.57	0.93	N/A	N/A
57	64.22	64.47	64.345	64.33	64.50	64.415	0.06	0.59	±0.30%	±0.34%
58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
59	64.84	64.84	64.840	64.84	64.84	64.840	1.24	0.00	±0.89%	±0.89%
60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
62	64.47	64.44	64.455	64.37	64.41	64.390	0.17	-0.55	N/A	N/A
63	64.31	64.31	64.310	64.28	64.30	64.290	-0.15	-0.17	N/A	N/A
64	64.49	64.61	64.550	64.58	64.33	64.455	0.37	-0.80	N/A	N/A
65	63.90	64.10	64.000	63.50	64.22	63.860	-1.10	-1.18	±1.20%	±1.20%
66	64.34	64.32	64.330	64.28	64.26	64.270	-0.15	-0.51	±0.075%	±0.075%
67	64.42	64.54	64.480	64.40	64.54	64.470	0.30	-0.08	±0.11%	±0.11%
68	64.51	64.56	64.535	64.69	64.73	64.710	0.68	1.48	N/A	N/A
69	64.31	64.29	64.300	64.21	64.23	64.220	-0.25	-0.67	±0.144%	±0.144%
70	64.11	64.24	64.175	64.15	64.32	64.235	-0.39	0.51	N/A	N/A

4	CaO									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
71	64.20	64.23	64.215	64.22	64.11	64.165	-0.43	-0.42	N/A	N/A
72	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
73	64.68	64.82	64.750	64.82	64.68	64.750	1.01	0.00	±0.05%	±0.05%
74	64.89	64.68	64.785	65.10	64.89	64.995	1.37	1.77	N/A	N/A
75	63.97	64.10	64.035	64.22	64.10	64.160	-0.67	1.05	±1.049331%	±1.049331%
76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
77	63.88	64.02	63.950	64.02	64.15	64.085	-0.87	1.14	±0.72%	±0.72%
78	64.52	64.51	64.515	64.58	64.64	64.610	0.53	0.80	N/A	N/A
79	64.57	64.57	64.570	64.31	64.90	64.605	0.59	0.30	N/A	N/A
80	64.31	64.31	64.310	64.30	64.40	64.350	-0.07	0.34	N/A	N/A
81	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
82	63.96	63.96	63.960	64.14	63.96	64.050	-0.91	0.76	±0.031%	±0.031%
83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

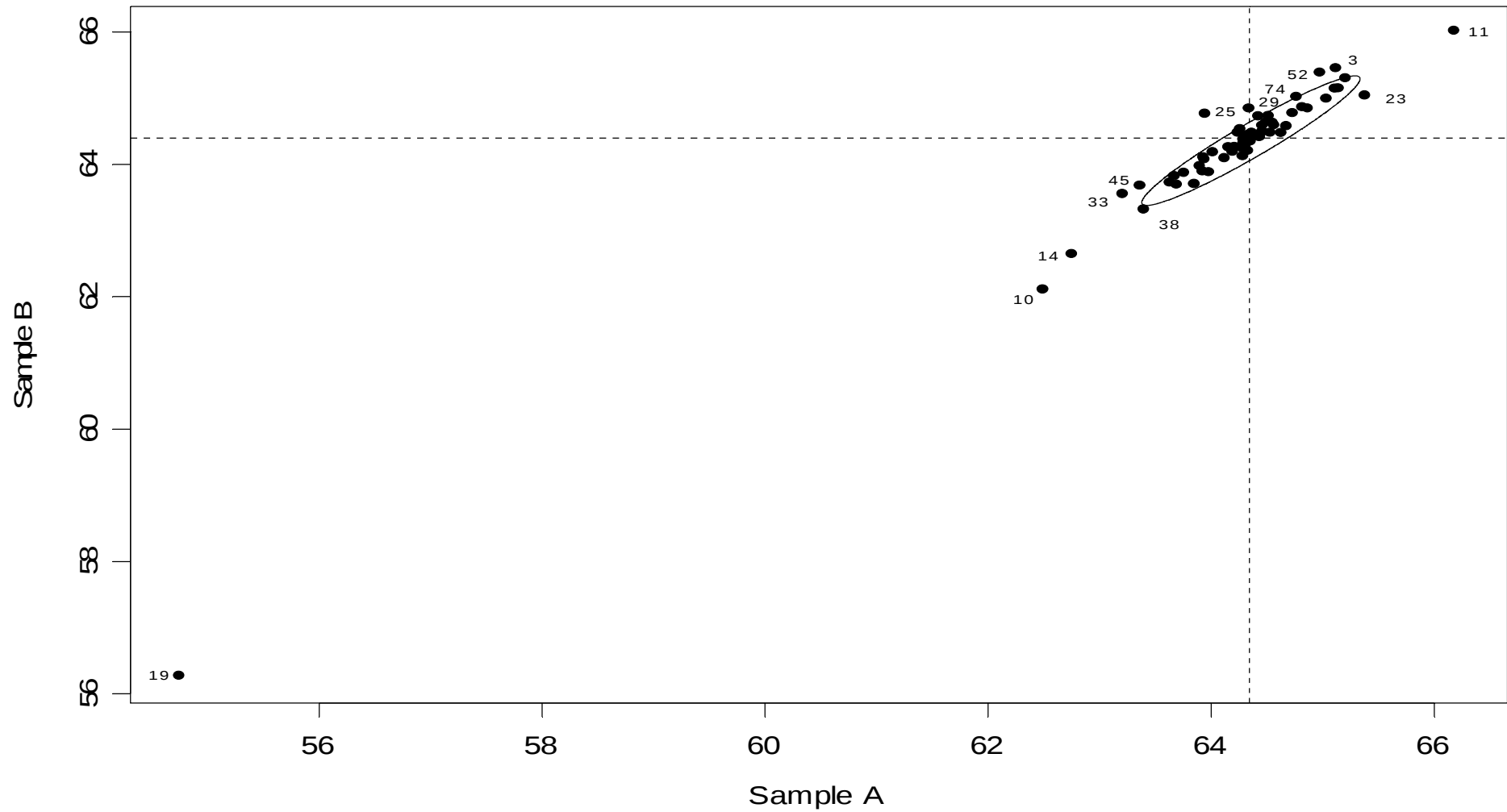
No. of result	63	63
Median	64.345	64.395
Normalized IQR	0.428	0.43
Robust CV(%)	0.665	0.668
Maximum	66.2	65.995
Minimum	54.765	56.25
Range	11.435	9.745

NOTE : ※ denotes an outlier (i.e. |z-score| ≥ 3)

Item 4 – APLAC Sample A & Sample B



Y ouden Plot-T020 Portland Cement



Item 5

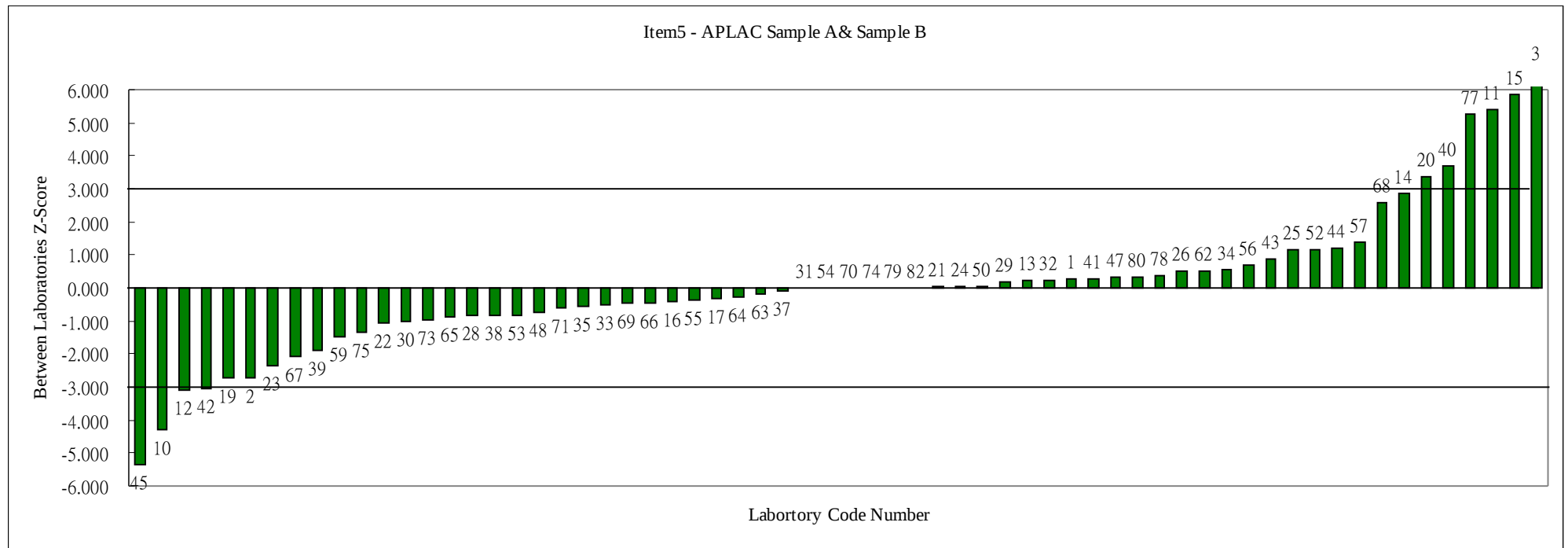
Item	Test									
	MgO									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
1	1.87	1.91	1.890	1.89	1.86	1.875	0.26	0.33	±0.05	±0.05
2	1.48	1.61	1.545	1.61	1.48	1.545	-2.71	0.00	N/A	N/A
3	2.65	2.65	2.650	2.55	2.55	2.550	6.59※	2.20	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	1.31	1.30	1.305	1.43	1.42	1.425	-4.30※	-2.64	N/A	N/A
11	2.68	2.74	2.710	2.26	2.18	2.220	5.40※	10.79※	N/A	N/A
12	1.47	1.41	1.440	1.59	1.53	1.560	-3.11※	-2.64	±0.08%	±0.06%
13	1.88	1.88	1.880	1.89	1.87	1.880	0.24	0.00	±0.04%	±0.04%
14	2.10	2.18	2.140	2.18	2.24	2.210	2.84	-1.54	N/A	N/A
15	2.37	2.40	2.385	2.74	2.56	2.650	5.86※	-5.84※	±0.28%	±0.28%
16	1.80	1.79	1.795	1.83	1.81	1.820	-0.40	-0.55	±0.08%	±0.08%
17	N/A	1.83	1.830	N/A	1.80	1.800	-0.33	0.66	±0.16%	±0.16%
18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
19	1.51	1.52	1.515	1.59	1.55	1.570	-2.73	-1.21	N/A	N/A
20	2.22	2.26	2.240	2.25	2.20	2.225	3.35※	0.33	±0.04%	±0.04%
21	1.87	1.85	1.860	1.85	1.86	1.855	0.04	0.11	±0.21%	±0.21%
22	1.77	1.73	1.750	1.73	1.70	1.715	-1.06	0.77	N/A	N/A
23	1.54	1.45	1.495	1.63	1.72	1.675	-2.36	-3.96※	±0.08%	±0.07%
24	1.87	1.85	1.860	1.86	1.85	1.855	0.04	0.11	N/A	N/A
25	1.98	1.98	1.980	1.99	1.99	1.990	1.17	-0.22	N/A	N/A
26	1.94	1.89	1.915	1.92	1.90	1.910	0.53	0.11	±0.2%	±0.2%
27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	1.78	1.79	1.785	1.74	1.72	1.730	-0.84	1.21	N/A	N/A
29	1.87	1.86	1.865	1.89	1.88	1.885	0.20	-0.44	N/A	N/A
30	1.75	1.74	1.745	1.73	1.73	1.730	-1.01	0.33	N/A	N/A
31	1.83	1.87	1.850	1.85	1.85	1.850	-0.02	0.00	N/A	N/A
32	1.88	1.85	1.865	1.90	1.89	1.895	0.24	-0.66	±0.12%	±0.12%

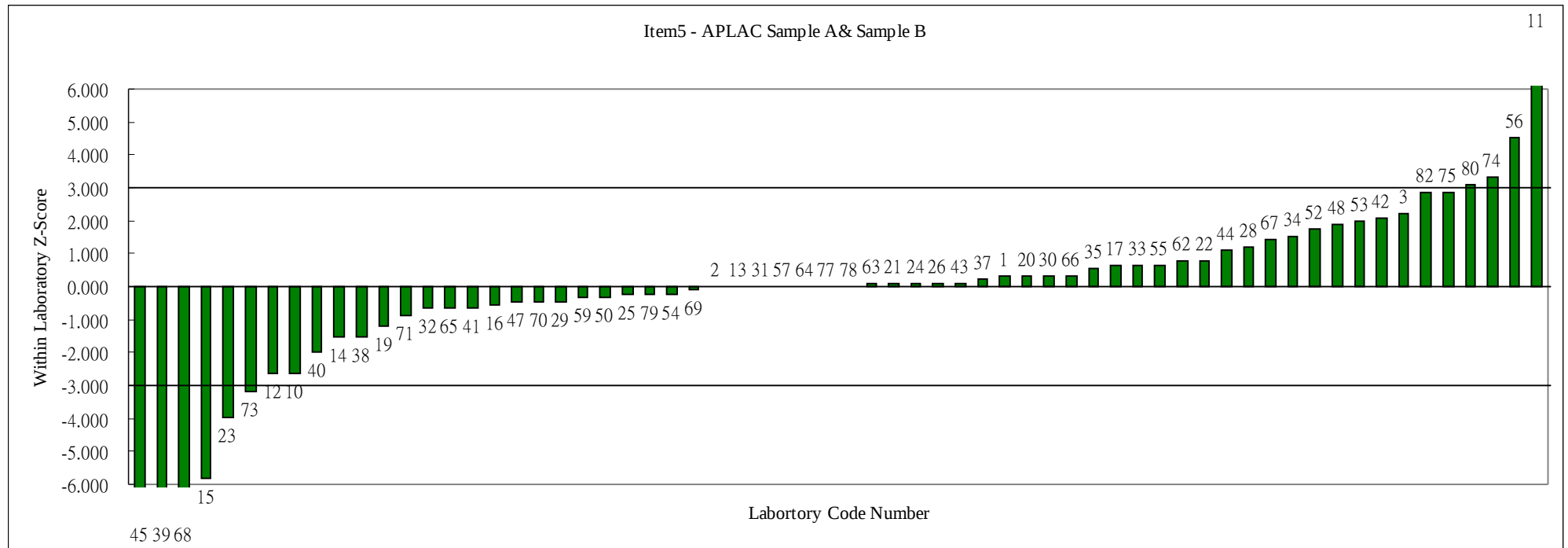
5	MgO									
Lab	APT20A	APT20A	Average	APT20B	APT20B	Average	Between	Within	Expanded uncertainty	
Code	Result1	Result2		Result1	Result2		Laboratories	Laboratories	Sample A	Sample B
	(%)	(%)	(%)	(%)	(%)	(%)	Z-Score	Z-Score		
33	1.81	1.81	1.810	1.75	1.81	1.780	-0.51	0.66	±0.20902%	±0.20902%
34	1.97	1.93	1.950	1.86	1.90	1.880	0.55	1.54	±0.06%	±0.06%
35	1.80	1.80	1.800	1.75	1.80	1.775	-0.57	0.55	±0.00266%	±0.00266%
36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37	1.83	1.86	1.845	1.82	1.85	1.835	-0.11	0.22	±0.19%	±0.19%
38	1.70	1.75	1.725	1.77	1.82	1.795	-0.82	-1.54	±0.18%	±0.18%
39	1.44	1.32	1.380	1.89	1.91	1.900	-1.87	-11.45※	±0.50%	±0.50%
40	2.22	2.23	2.225	2.33	2.30	2.315	3.68※	-1.98	±0.10%	±0.10%
41	1.87	1.87	1.870	1.90	1.90	1.900	0.29	-0.66	N/A	N/A
42	1.56	1.55	1.555	1.46	1.46	1.460	-3.04※	2.09	±0.027888%	±0.027888%
43	1.95	1.96	1.955	1.95	1.95	1.950	0.88	0.11	N/A	N/A
44	1.99	2.04	2.015	1.95	1.98	1.965	1.21	1.10	±0.08%	±0.08%
45	0.86	0.80	0.830	1.70	1.62	1.660	-5.35※	-18.28※	±0.07%	±0.07%
46	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
47	1.90	1.86	1.880	1.91	1.89	1.900	0.33	-0.44	±0.1353%	±0.1353%
48	1.81	1.81	1.810	1.72	1.73	1.725	-0.75	1.87	±0.02%	±0.02%
49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
50	1.88	1.82	1.850	1.83	1.90	1.865	0.04	-0.33	N/A	N/A
51	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
52	2.13	1.92	2.025	1.91	1.98	1.945	1.17	1.76	±0.06%	±0.06%
53	1.80	1.81	1.805	1.71	1.72	1.715	-0.82	1.98	N/A	N/A
54	1.85	1.84	1.845	1.86	1.85	1.855	-0.02	-0.22	±0.07%	±0.07%
55	1.82	1.83	1.825	1.79	1.80	1.795	-0.37	0.66	N/A	N/A
56	1.89	2.18	2.035	1.86	1.80	1.830	0.71	4.52※	N/A	N/A
57	2.02	2.00	2.010	2.04	1.98	2.010	1.39	0.00	±0.054%	±0.074%
58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
59	1.65	1.70	1.675	1.68	1.70	1.690	-1.50	-0.33	±0.10%	±0.10%
60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
62	1.91	1.95	1.930	1.90	1.89	1.895	0.53	0.77	N/A	N/A
63	1.83	1.84	1.835	1.83	1.83	1.830	-0.18	0.11	N/A	N/A
64	1.84	1.80	1.820	1.81	1.83	1.820	-0.29	0.00	N/A	N/A
65	1.71	1.77	1.740	1.74	1.80	1.770	-0.86	-0.66	±0.08%	±0.08%
66	1.82	1.80	1.810	1.79	1.80	1.795	-0.44	0.33	±0.02%	±0.02%
67	1.69	1.61	1.650	1.59	1.58	1.585	-2.07	1.43	±0.07%	±0.07%
68	1.89	1.93	1.910	2.37	2.40	2.385	2.60	-10.46※	N/A	N/A
69	1.80	1.79	1.795	1.83	1.77	1.800	-0.49	-0.11	±0.060%	±0.060%
70	1.86	1.83	1.845	1.87	1.86	1.865	0.02	-0.44	N/A	N/A

5	MgO									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
71	1.86	1.67	1.765	1.85	1.76	1.805	-0.60	-0.88	N/A	N/A
72	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
73	1.67	1.67	1.670	1.86	1.77	1.815	-0.97	-3.19※	±0.05%	±0.05%
74	1.93	1.93	1.930	1.78	1.78	1.780	0.02	3.30※	N/A	N/A
75	1.74	1.79	1.765	1.57	1.70	1.635	-1.34	2.86	±0.536441%	±0.536441%
76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
77	2.40	2.50	2.450	2.50	2.40	2.450	5.26※	0.00	±0.036%	±0.036%
78	1.91	1.88	1.895	1.88	1.91	1.895	0.37	0.00	N/A	N/A
79	1.85	1.85	1.850	1.86	1.86	1.860	0.02	-0.22	N/A	N/A
80	1.93	1.99	1.960	1.82	1.82	1.820	0.33	3.08※	N/A	N/A
81	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
82	1.88	1.96	1.920	1.77	1.81	1.790	0.02	2.86	±0.018%	±0.018%
83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

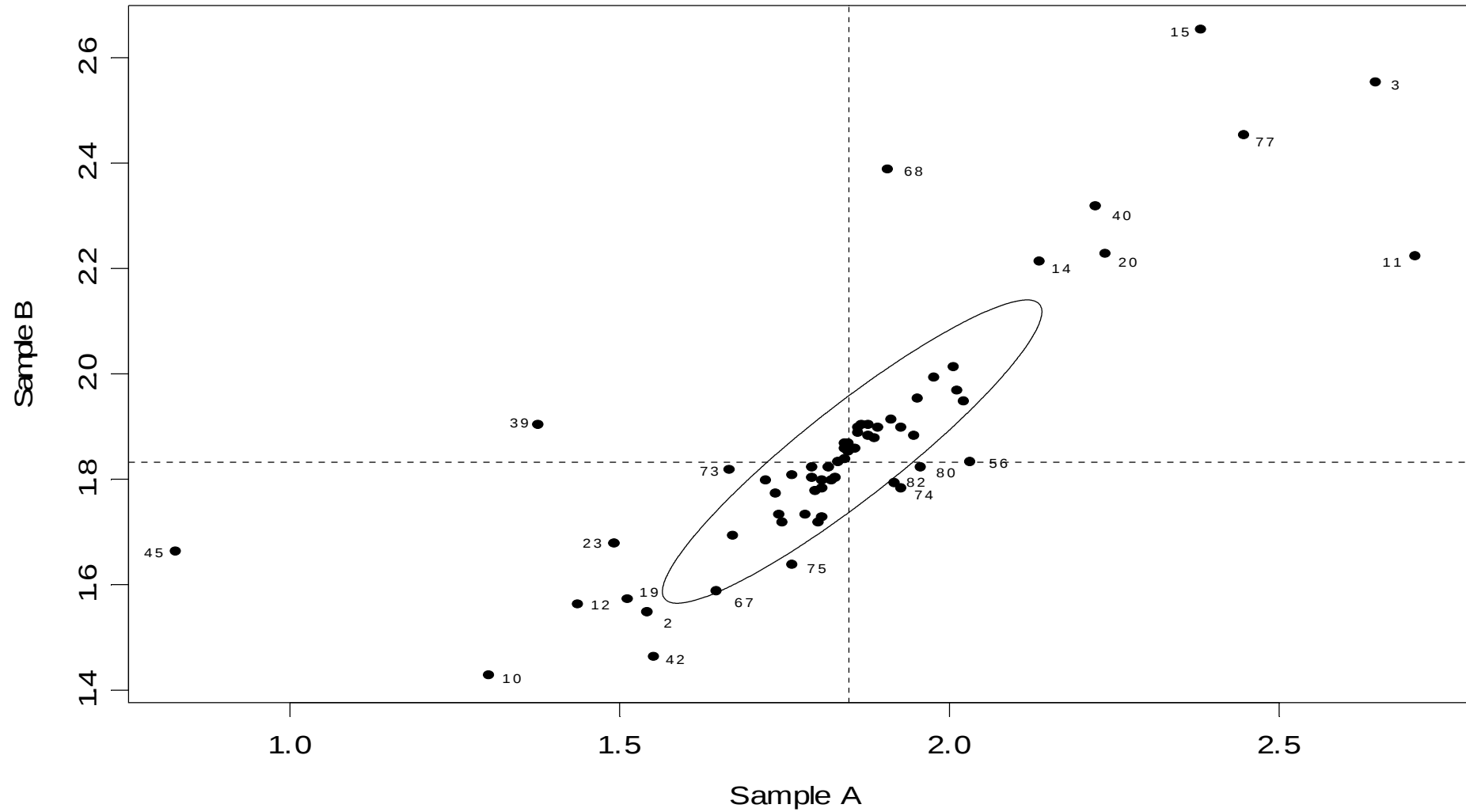
No. of result	64	64
Median	1.848	1.833
Normalized IQR	0.122	0.094
Robust CV(%)	6.621	5.107
Maximum	2.71	2.65
Minimum	0.83	1.425
Range	1.88	1.225

NOTE : ※ denotes an outlier (i.e. |z-score| ≥ 3)

Item 5 – APLAC Sample A & Sample B



Youden Plot-T020 Portland Cement



Item 6

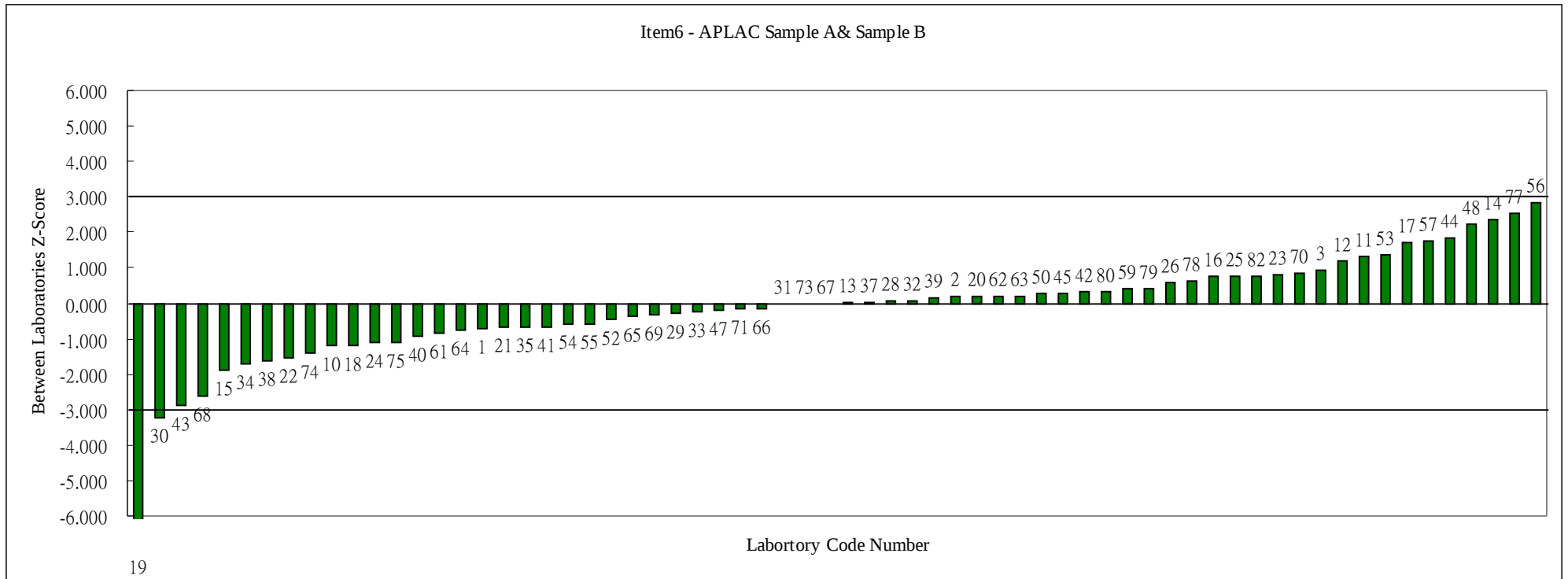
Item	Test									
6	SO ₃									
Lab Code	APT20A Result1 (%)	APT20A Result2 (%)	Average (%)	APT20B Result1 (%)	APT20B Result2 (%)	Average (%)	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded uncertainty	
									Sample A	Sample B
1	2.21	2.19	2.200	2.22	2.19	2.205	-0.73	-0.25	±0.05	±0.05
2	2.25	2.25	2.250	2.26	2.27	2.265	0.21	-0.59	N/A	N/A
3	2.28	2.28	2.280	2.32	2.32	2.320	0.94	-1.43	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	2.14	2.15	2.145	2.20	2.21	2.205	-1.20	-2.11	N/A	N/A
11	2.35	2.31	2.330	2.34	2.29	2.315	1.33	0.42	N/A	N/A
12	2.35	2.31	2.330	2.30	2.30	2.300	1.20	0.93	±0.06%	±0.00%
13	2.27	2.24	2.255	2.25	2.23	2.240	0.04	0.42	±0.02%	±0.02%
14	2.38	2.36	2.370	2.37	2.42	2.395	2.36	-0.93	N/A	N/A
15	2.10	2.14	2.120	2.13	2.17	2.150	-1.88	-1.10	N/A	N/A
16	2.31	2.29	2.300	2.28	2.28	2.280	0.77	0.59	±0.14%	±0.14%
17	2.35	2.35	2.350	2.35	2.33	2.340	1.71	0.25	±0.12%	±0.12%
18	2.15	2.22	2.185	2.19	2.14	2.165	-1.20	0.59	±0.004%	±0.004%
19	0.89	0.94	0.915	1.77	1.72	1.745	-15.67※	-28.08※	N/A	N/A
20	2.26	2.27	2.265	2.24	2.26	2.250	0.21	0.42	±0.01%	±0.01%
21	2.21	2.22	2.215	2.19	2.20	2.195	-0.69	0.59	±0.03%	±0.03%
22	2.18	2.19	2.185	2.11	2.14	2.125	-1.54	1.94	N/A	N/A
23	2.29	2.26	2.275	2.36	2.26	2.310	0.81	-1.27	±0.06%	±0.06%
24	2.19	2.19	2.190	2.17	2.17	2.170	-1.11	0.59	N/A	N/A
25	2.30	2.29	2.295	2.28	2.29	2.285	0.77	0.25	N/A	N/A
26	2.32	2.27	2.295	2.25	2.28	2.265	0.60	0.93	±7.0%	±7.0%
27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	2.26	2.25	2.255	2.24	2.25	2.245	0.09	0.25	N/A	N/A
29	2.21	2.26	2.235	2.22	2.22	2.220	-0.30	0.42	N/A	N/A
30	2.06	2.06	2.060	2.06	2.05	2.055	-3.21※	0.08	N/A	N/A
31	2.26	2.26	2.260	2.21	2.24	2.225	-0.04	1.10	N/A	N/A
32	2.24	2.26	2.250	2.24	2.26	2.250	0.09	-0.08	±0.09%	±0.09%

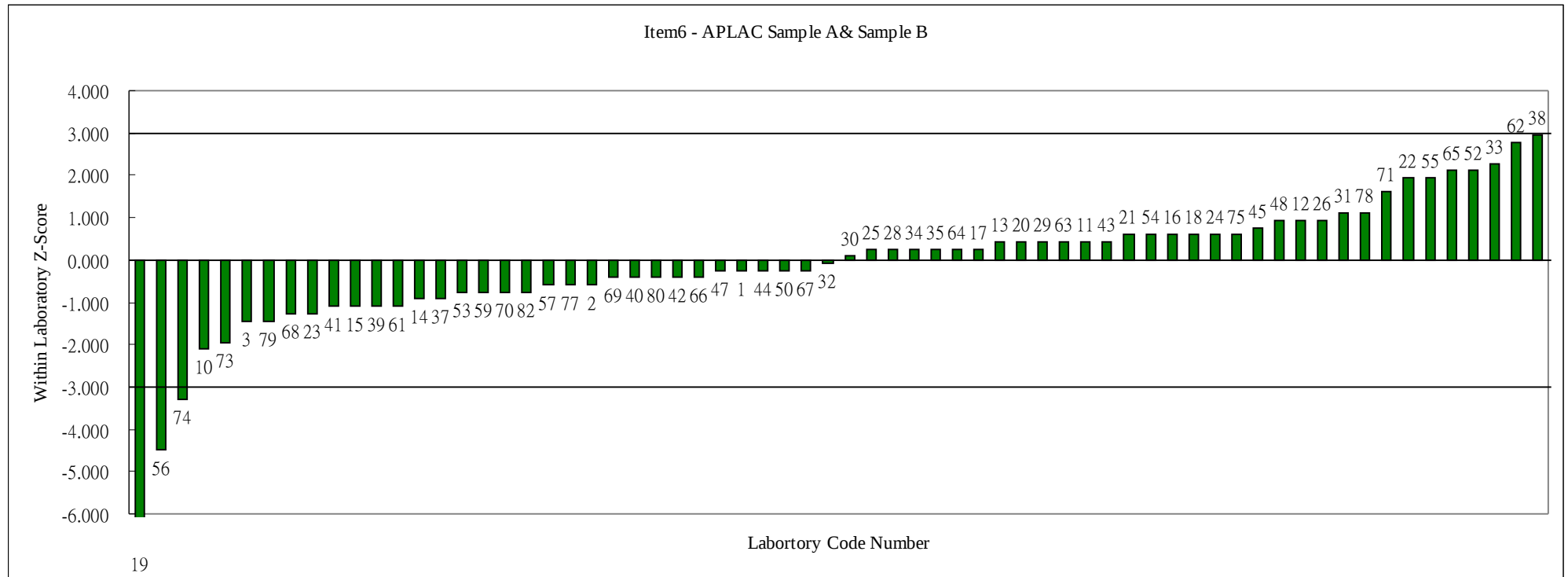
6	SO ₃									
Lab	APT20A	APT20A	Average	APT20B	APT20B	Average	Between	Within	Expanded uncertainty	
Code	Result1	Result2		Result1	Result2		Laboratories	Laboratories	Sample A	Sample B
	(%)	(%)	(%)	(%)	(%)	(%)	Z-Score	Z-Score		
33	2.25	2.28	2.265	2.13	2.26	2.195	-0.26	2.28	±0.07409%	±0.07409%
34	2.13	2.17	2.150	2.12	2.16	2.140	-1.71	0.25	±0.02%	±0.02%
35	2.20	2.22	2.210	2.21	2.19	2.200	-0.69	0.25	±0.00183%	±0.00183%
36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37	2.24	2.23	2.235	2.26	2.26	2.260	0.04	-0.93	±0.12%	±0.12%
38	2.17	2.22	2.195	2.09	2.12	2.105	-1.63	2.95	±0.36%	±0.23%
39	2.21	2.27	2.240	2.29	2.25	2.270	0.17	-1.10	±0.16%	±0.16%
40	2.16	2.21	2.185	2.21	2.18	2.195	-0.94	-0.42	±0.10%	±0.10%
41	2.19	2.19	2.190	2.22	2.22	2.220	-0.69	-1.10	N/A	N/A
42	2.26	2.26	2.260	2.28	2.26	2.270	0.34	-0.42	±0.032442%	±0.032442%
43	2.02	2.15	2.085	2.13	2.01	2.070	-2.87	0.42	N/A	N/A
44	2.33	2.37	2.350	2.38	2.33	2.355	1.84	-0.25	±0.04%	±0.04%
45	2.30	2.25	2.275	2.23	2.27	2.250	0.30	0.76	±0.09%	±0.09%
46	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
47	2.23	2.23	2.230	2.24	2.23	2.235	-0.21	-0.25	±0.0304%	±0.0304%
48	2.36	2.42	2.390	2.38	2.34	2.360	2.23	0.93	±0.01%	±0.01%
49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
50	2.25	2.27	2.260	2.27	2.26	2.265	0.30	-0.25	N/A	N/A
51	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
52	2.20	2.30	2.250	2.19	2.18	2.185	-0.47	2.11	±0.18%	±0.17%
53	2.31	2.32	2.315	2.33	2.34	2.335	1.37	-0.76	N/A	N/A
54	2.23	2.21	2.220	2.21	2.19	2.200	-0.60	0.59	±0.07%	±0.07%
55	2.22	2.26	2.240	2.18	2.18	2.180	-0.60	1.94	N/A	N/A
56	2.33	2.36	2.345	2.56	2.39	2.475	2.83	-4.47※	N/A	N/A
57	2.36	2.32	2.340	2.36	2.35	2.355	1.76	-0.59	±0.0343%	±0.017%
58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
59	2.25	2.27	2.260	2.28	2.28	2.280	0.43	-0.76	±0.12%	±0.12%
60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
61	2.18	2.18	2.180	2.22	2.20	2.210	-0.86	-1.10	N/A	N/A
62	2.29	2.31	2.300	2.23	2.20	2.215	0.21	2.78	N/A	N/A
63	2.25	2.28	2.265	2.25	2.25	2.250	0.21	0.42	N/A	N/A
64	2.20	2.21	2.205	2.19	2.20	2.195	-0.77	0.25	N/A	N/A
65	2.25	2.26	2.255	2.18	2.20	2.190	-0.39	2.11	±0.08%	±0.08%
66	2.24	2.22	2.230	2.25	2.23	2.240	-0.17	-0.42	±0.015%	±0.015%
67	2.24	2.24	2.240	2.25	2.24	2.245	-0.04	-0.25	±0.01%	±0.01%
68	2.07	2.08	2.075	2.10	2.12	2.110	-2.61	-1.27	N/A	N/A
69	2.21	2.23	2.220	2.22	2.24	2.230	-0.34	-0.42	±0.03%	±0.03%
70	2.28	2.29	2.285	2.30	2.31	2.305	0.86	-0.76	N/A	N/A

6	SO ₃									
Lab Code	APT20A	APT20A	Average	APT20B	APT20B	Average	Between Laboratories	Within Laboratories	Expanded uncertainty	
	Result1 (%)	Result2 (%)	(%)	Result1 (%)	Result2 (%)	(%)	Z-Score	Z-Score	Sample A	Sample B
71	2.30	2.22	2.260	2.16	2.26	2.210	-0.17	1.60	N/A	N/A
72	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
73	2.27	2.16	2.215	2.24	2.30	2.270	-0.04	-1.94	±0.05%	±0.05%
74	2.12	2.11	2.115	2.22	2.20	2.210	-1.41	-3.29※	N/A	N/A
75	2.18	2.20	2.190	2.21	2.13	2.170	-1.11	0.59	±0.032993%	±0.032993%
76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
77	2.35	2.42	2.385	2.38	2.42	2.400	2.53	-0.59	±0.048%	±0.048%
78	2.30	2.30	2.300	2.26	2.27	2.265	0.64	1.10	N/A	N/A
79	2.24	2.26	2.250	2.30	2.28	2.290	0.43	-1.43	N/A	N/A
80	2.25	2.27	2.260	2.27	2.27	2.270	0.34	-0.42	N/A	N/A
81	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
82	2.29	2.27	2.280	2.29	2.31	2.300	0.77	-0.76	±0.014%	±0.014%
83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

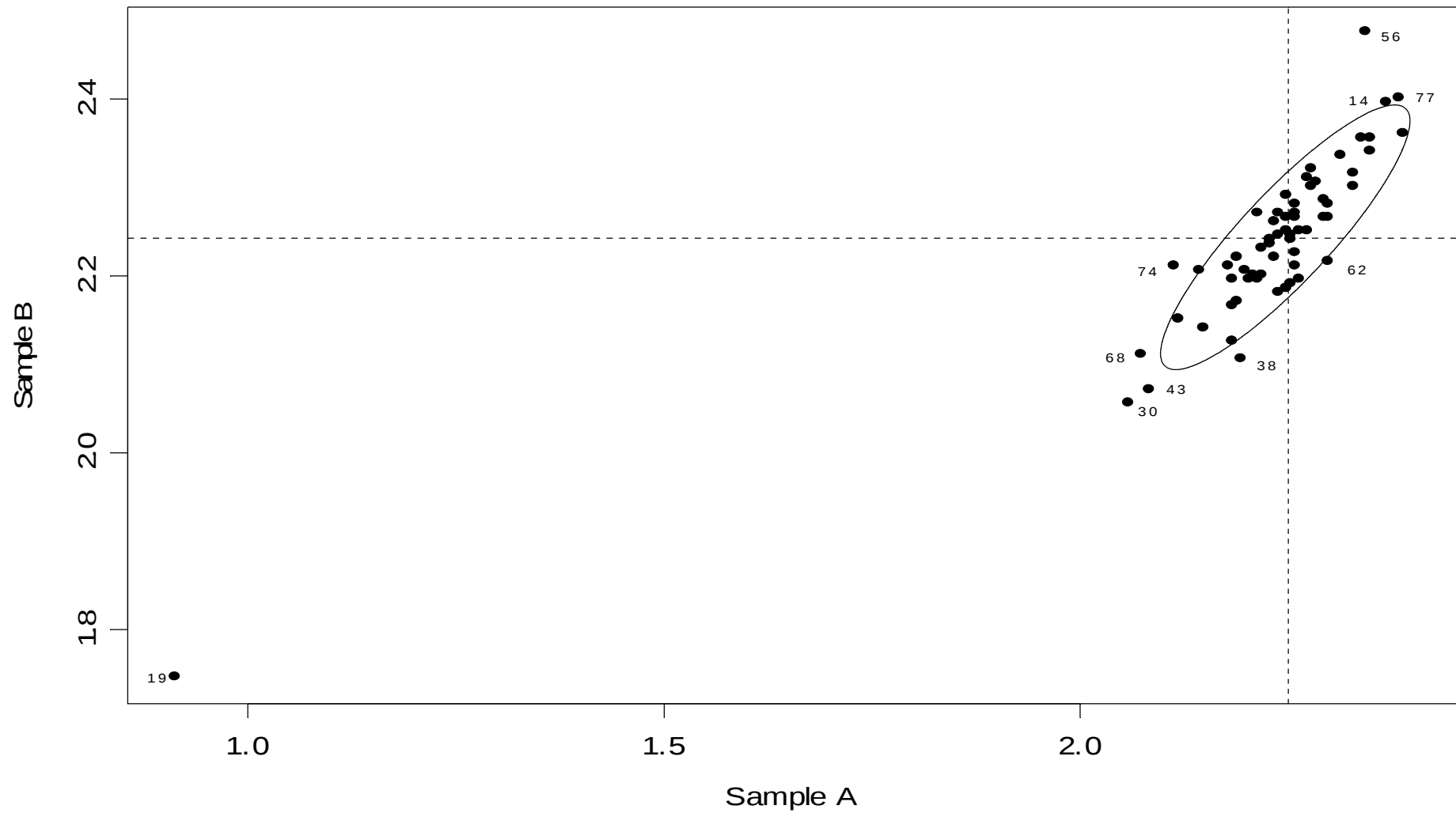
No. of result	66	66
Median	2.25	2.243
Normalized IQR	0.058	0.063
Robust CV(%)	2.595	2.81
Maximum	2.39	2.475
Minimum	0.915	1.745
Range	1.475	0.73

NOTE : ※ denotes an outlier (i.e. |z-score| ≥ 3)

Item 6 – APLAC Sample A & Sample B



Youden Plot-T020 Portland Cement



Test methods

Lab Code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃
1	ASTM C 114 - 04a	ASTM C 114 - 04a	ASTM C 114 - 04a	ASTM C 114 - 04a	ASTM C 114 - 04a	ASTM C 114 - 04a
2	EN 196-2	EN 196-2	EN 196-2	EN 196-2	EN 196-2	EN 196-2
3	CSN EN 196-2	CSN 72 0109-1	CSN 72 0110-2	CSN 72 0113	CSN 72 0114	CSN EN 196-2
4	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A
10	BSEN 196-2/SS397-2	BSEN 196-2/SS397-2	BSEN 196-2/SS397-2	BSEN 196-2/SS397-2	BSEN 196-2/SS397-2	BSEN 196-2/SS397-2
11	ASTM C114-2003	ASTM C114-2003	ASTM C114-2003	ASTM C114-2003	ASTM C114-2003	ASTM C114-2003
12	ASTM C114-88	ASTM C114-88	ASTM C114-88	ASTM C114-88	ASTM C114-88	ASTM C114-88
13	ASTM C114	ASTM C114	ASTM C114	ASTM C114	ASTM C114	ASTM C114
14	ASTM C-114-85 S.N. 6	N/A	ASTM C-114-85 S.N. 8	IS: 4032-85 CI:4.8.2	IS: 4032-845 CI 4.8.2	IS: 4032-85 CI 4.9
15	IS 4032:1985	IS 4032:1985	IS 4032:1985	IS 4032:1985	IS 4032:1985	IS 4032:1985
16	XRF	XRF	XRF	XRF	XRF	XRF
17	ER9214	ER9214	ER9214	ER9214	ER9214	ER9214
18	N/A	N/A	N/A	N/A	N/A	EN 196-2
19	EN 196-2:1996	N/A	EN 196-2:1996	EN 196-2:1996	EN 196-2:1996	EN 196-2:1996
20	AS2350.2	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	NM21*	NM16*

Lab Code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃
22	NBR NM 21/04	NBR NM 21/04	NBR NM 21/04	NBR NM 21/04	NBR NM 21/04	NBR NM 16/04
23	EN 196-2	EN 196-2	EN 196-2	EN 196-2	EN 196-2	EN 196-2
24	XRF	XRF	XRF	XRF	XRF	XRF
25	IRAM 1504	IRAM 1504	IRAM 1591-1	IRAM 1591-1	IRAM 1692	IRAM 1504
26	X-Ray Fluorescence	X-Ray Fluorescence	X-Ray Fluorescence	X-Ray Fluorescence	X-Ray Fluorescence	Leybold CS-analyzer 2003
27	N/A	N/A	N/A	N/A	N/A	N/A
28	ASTM C114	ASTM C114	ASTM C114	ASTM C114	ASTM C114	ASTM C114
29	Gravimetric method	ICP/AES	ICP/AES	Volumetric method	ICP/AES	Gravimetric method
30	XRF	XRF	XRF	XRF	XRF	XRF
31	UNI EN 196/2	UNI EN 196/2	UNI EN 196/2	UNI EN 196/2	UNI EN 196/2	UNI EN 196/2
32	ASTM C114	ASTM C114	ASTM C114	ASTM C114	ASTM C114	ASTM C114
33	XRF	XRF	XRF	XRF	XRF	XRF
34	ASTM C114-04	ASTM C114-04	ASTM C114-04	ASTM C114-04	ASTM C114-04	ASTM C114-04
35	TCVN 141:1998	TCVN 141:1998	TCVN 141:1998	TCVN 141:1998	TCVN 141:1998	TCVN 141:1998
36	N/A	N/A	N/A	N/A	N/A	N/A
37	ASTM C114-88E1	ASTM C114-88E1	ASTM C114-88E1	ASTM C114-88E1	ASTM C114-88E1	ASTM C114-88E1
38	ASTM C114-04	ASTM C114-04	ASTM C114-04	ASTM C114-04	ASTM C114-04	ASTM C114-04
39	CSN EN 196-2	CSN 72 0109, cast 3	CSN 72 0110, cast 3	CSN EN 196-2	CSN EN 196-2	CSN EN 196-2
40	N/A	N/A	N/A	N/A	N/A	N/A
41	EN 196-2, Clause 7	EN 196-2, Clause 13.11	EN 196-2, Clause 13.10	EN 196-2, Clause 13.12	EN 196-2, Clause 13.13	EN 196-2, Clause 8
42	CNS 1078	CNS 1078	CNS 1078	CNS 1078	CNS 1078	CNS 1078
43	EN-196-2:1996	EN-196-2:1996	EN-196-2:1996	EN-196-2:1996	EN-196-2:1996	EN-196-2:1996

A7.3

Lab Code	SiO2	Al2O3	Fe2O3	CaO	MgO	SO3
44	ASTM C114-86	ASTM C114-86	ASTM C114-86	ASTM C114-86	ASTM C114-86	ASTM C114-86
45	UNE-EN 196-2	UNE-EN 196-2	UNE-EN 196-2	UNE-EN 196-2	UNE-EN 196-2	UNE-EN 196-2
46	N/A	N/A	N/A	N/A	N/A	N/A
47	BS4550:Part 2:1970 C1.4	BS4550:Part 2:1970 C1.7	BS4550:Part 2:1970 C1.8	BS4550:Part 2:1970 C1.6	BS4550:Part 2:1970 C1.9	BS4550:Part 2:1970 C1.12
48	ASTM C114-99	ASTM C114-99	ASTM C114-99	ASTM C114-99	ASTM C114-99	ASTM C114-99
49	N/A	N/A	N/A	N/A	N/A	N/A
50	XRF	XRF	XRF	XRF	XRF	XRF
51	N/A	N/A	N/A	N/A	N/A	N/A
52	XRF Fused Bead	XRF Fused Bead	XRF Fused Bead	XRF Fused Bead	XRF Fused Bead	XRF Fused Bead
53	CNS 1078	CNS 1078	CNS 1078	CNS 1078	CNS 1078	CNS 1078
54	UNE-EN 196-2	PE. CM-MA-05-E	UNE-EN 196-2	UNE-EN 196-2	UNE-EN 196-2	UNE-EN 196-2
55	XRF Fused Bead	XRF Fused Bead	N/A	N/A	XRF Fused Bead	XRF Fused Bead
56	NM21	NM14	NM14	NM21	Internal Procedure C-0839	NM21
57	IS 4032: 1985	IS 4032: 1985	IS 4032: 1985	IS 4032: 1985	IS 4032: 1985	IS 4032: 1985
58	N/A	N/A	N/A	N/A	N/A	N/A
59	ASTM C114	N/A	ASTM C114	ASTM C114	ASTM C114	ASTM C114
60	N/A	N/A	N/A	N/A	N/A	N/A
61	N/A	N/A	N/A	N/A	N/A	141:1998
62	N/A	N/A	N/A	N/A	N/A	N/A
63	XRF	XRF	XRF	XRF	XRF	XRF
64	XRF	XRF	XRF	XRF	XRF	IR Sulfur Analyzer
65	BDS EN 196-2	BDS EN 196-2	BDS EN 196-2	BDS EN 196-2	BDS EN 196-2	BDS EN 196-2

Lab Code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃
66	CNS 1078	CNS 1078	CNS 1078	CNS 1078	CNS 1078	CNS 1078
67	TIS 15 Part 18- 2519(1976)	N/A	N/A	N/A	N/A	N/A
68	EN 196-2	EN 196-2	EN 196-2	EN 196-2	EN 196-2	EN 196-2
69	CNS 1078	CNS 1078	CNS 1078	CNS 1078	CNS 1078	CNS 1078
70	XRF	XRFF	XRFF	XRFF	XRFF	XRFF
71	EN 196-2:1996	ASTM C 114-04	EN 196-2:1996	ASTM C 114-04	EN 196-2:1996	EN 196-2:1996
72	N/A	N/A	N/A	N/A	N/A	N/A
73	MS522 : Part 3 1989 clause 5	MS522 : Part 3 1989 clause 10	MS522 : Part 3 1989 clause 9	MS522 : Part 3 1989 clause 14	MS522 : Part 3 1989 clause 15	MS522 : Part 3 1989 clause 13
74	Clause 16 : MS 522 : Part3	Clause 10 : MS 522 : Part3	Clause 10 : MS 522 : Part3	Clause 10 : MS 522 : Part3	Clause 15 : MS 522 : Part3	Clause 15 : MS 522 : Part3
75	Clause 5 of MS 522 : Part3	Clause 10 of MS 522 : Part3	Clause 9 of MS 522 : Part3	Clause 7 of MS 522 : Part3	Clause 8 of MS 522 : Part3	Clause 13 of MS 522 : Part3
76	N/A	N/A	N/A	N/A	N/A	N/A
77	MS522 Part 3 1989 clause 5	MS522 Part 3 1989	MS522 Part 3 1989	MS522 Part 3 1989	MS522 Part 3 1989	MS522 Part 3 1989
78	FRX	FRX	FRX	FRX	FRX	FRX
79	ASTM C114	ASTM C114	ASTM C114	ASTM C114	ASTM C114	ASTM C114
80	EN 196-2 section 13.5	EN 196-2	EN 196-2	EN 196-2 section 13.14	EN 196-2 section 13.14	EN 196-2
81	N/A	N/A	N/A	N/A	N/A	N/A
82	NCh 147	NCh 147	NCh 147	NCh 147	NCh 147	NCh 147
83	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX B

Preparation of the Samples

and

Homogeneity Testing

PREPARATION OF THE SAMPLES

The test samples, Portland cement , are provided by Taiwan Cement Corporation as the specimens for the 2005 APLAC T020 Proficiency Testing Program of Portland Cement Testing. After the homogeneity testing by the Chemistry testing laboratory of the Bureau of Standards, Metrology and Inspection, Ministry of Economic Affairs, R.O.C., it was confirmed that the product properties are uniform enough to meet the requirements of ASTM E826-85 (Reapproved 1996) “ standard practice for testing of materials for development of reference materials”.

HOMOGENEITY TESTING

The following homogeneity confirmation was carried out on two Portland cement sample sets by Bureau of Standards, Metrology and Inspection, Ministry of Economic Affairs, R.O.C, which tested according to ASTM E826-85 (Reapproved 1996) “ standard practice for testing of materials for development of reference materials”.

Each set consist 125 specimens which 15 specimens were tested according to the random sample selection scheme. A measurement is made on each of the 15 specimens. The measurements are repeated 4 times, taking care to choose the specimens in random order each time. Compute all the parameters described in ASTM E826 Appendixes X1.6.to see whether the maximum difference between any of the mean $\bar{t}$ values exceed the w computed value or not. There is evidence at the 95% confidence level that the test specimens are homogeneous in case of the $\bar{t}$ values does not exceed w value, the s homogeneity test results are detailed in the table below.

The homogeneity test results prior to [dispatching](#) the test samples to the participating laboratories.

Sample A

Test item	Tested specimens	Repeated test times	Uniformity Test Result					
			Average (%)	MAX	MIN	W	t'	Result
SiO₂	15	4	21.652	21.675	21.625	0.1792	0.05	Uniform
Al₂O₃	15	4	3.8047	3.8175	3.8000	0.0352	0.0175	Uniform
Fe₂O₃	15	4	3.8968	3.9025	3.8925	0.0382	0.01	Uniform
MgO	15	4	1.996	2.0025	1.99	0.0294	0.0125	Uniform
SO₃	15	4	2.2998	2.31	2.295	0.0323	0.015	Uniform
Ti₂O₂	15	4	0.181	0.1825	0.18	0.0134	0.0025	Uniform
P₂O₅	15	4	0.09	0.0903	0.0898	0.0026	0.0005	Uniform
CaO	15	4	65.352	65.425	65.3	0.29541	0.125	Uniform

Sample B

Test Item	Tested specimens	Repeated test times	Uniformity Test Result					
			Average (%)	MAX	MIN	W	t'	Result
SiO₂	15	4	21.658	21.7	21.6	0.2219	0.1	Uniform
Al₂O₃	15	4	3.8075	3.8225	3.8000	0.0586	0.0225	Uniform
Fe₂O₃	15	4	3.8943	3.9125	3.8825	0.0407	0.03	Uniform
MgO	15	4	1.9957	2	1.99	0.0318	0.01	Uniform
SO₃	15	4	2.2975	2.3025	2.2925	0.0364	0.01	Uniform
Ti₂O₂	15	4	0.1818	0.185	0.18	0.0143	0.005	Uniform
P₂O₅	15	4	0.0899	0.0905	0.0895	0.0033	0.001	Uniform
CaO	15	4	65.39	65.45	65.325	0.2507	0.125	Uniform

APPENDIX C

Instructions to Participants

Results Sheet



APLAC T020 Proficiency Testing Program of Portland Cement Testing

INSTRUCTIONS TO PARTICIPATING LABORATORIES

To ensure that results from this program can be analyzed properly, participants are asked to adhere carefully to the following instructions.

1. SAMPLE

Two 35g bags of samples labeled APT20A, APT20B, and the documents "Instructions To Participating Laboratories and Results Sheet" have been supplied to each laboratory. **The lab. code is identified on the Results Sheet.**

Upon receipt, unpack the artifacts and inspect them for any defects. Please contact your accreditation body if there is damage.

2. TESTS TO BE PERFORMED

The following Tests are to be performed on each sample in duplicate to the reporting units and accuracy stated on the results sheet, Testing should be finished within two weeks after receiving the samples

- SiO_2
- Al_2O_3 (include Ti_2O_2 、 P_2O_5)
- Fe_2O_3
- CaO
- MgO
- SO_3

The testing is to be performed in accordance with **ASTM C114 - 04 or method for which accreditation is held and record the method on the results sheet.**

3. DOCUMENTS TO BE SUBMITTED

Within one week of the completion of the tests, participating laboratories are required to send to their accreditation body:

No other documents are required. Laboratories should make a copy of all documents and worksheets for their own records and keep these on file for an adequate period of time (at least until a final report has been issued).

A final report will be issued at the end of the program with each laboratory only identified by a **confidential** code number.

4. CONFIDENTIALITY

For this program your laboratory has been allocated the code number shown on the results sheet. All reference to your laboratory in reports associated with this program will be with this code number, thus ensuring confidentiality of results.

5. GENERAL INFORMATION

For general queries, please contact your accreditation body.

Additional information may be obtained from:

Ms. Chan Yu-Ying

TAF/ Department of Laboratory Accreditation

TEL : +886-3-5714848 ext 203

FAX : +886-3-5726308

E-mail: yuyingchan@taftw.org.tw



APLAC T020 Proficiency Testing Program of Portland Cement Testing RESULTS SHEET

Laboratory C

ode:

Please complete this results sheet and return it to your national accreditation body and TAF/
Department of Laboratory Accreditation.

Testing Laboratory : _____ Date of test : _____

Summary of Test Results

Test	APT20A		APT20B		Method
	Result 1	Result2	Result1	Result2	
SiO ₂					
Al ₂ O ₃ (include Ti ₂ O ₂ 、 P ₂ O ₅)					
Fe ₂ O ₃					
CaO					
MgO					
SO ₃					

REPORT ALL TEST TO 2 DECIMAL PLACES

Signature : _____ **Date :** _____

Measurement Uncertainty Budget

Items	Factors of Uncertainty x_i	Type A / Type B	Probability Distribution	Standard Uncertainty $u(x_i)$	Coverage Factor(κF)
Combined Standard Uncertainty $u_c(Y)$:					
Expanded Uncertainty (95% confidence interval) $U_{exp}=\kappa=\kappa_c(y)$:					

Note : Please participating laboratories provide test original data (curve diagrams) e-mail or fax to CNLA.

Signature : _____ **Date :** _____

INSTRUCTIONS – MEASUREMENT UNCERTAINTY

Part (1) Background information & justification for this change

ISO/IEC 17025 requires that, except under specified conditions, the uncertainty of measurement associated with the results of tests and measurements must be estimated.

What is uncertainty of measurement?

Uncertainty of measurement is defined as a “parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand” (the measurand is the particular quantity subject to measurement).

The result of a test or measurement is our best estimate of the true value of the measurand. The result is imperfect. The true value of the measurand is contained within a range of values about the measurement result and the “uncertainty of measurement” is an estimate of the magnitude of that range expressed at a given level of confidence (confidence interval). Uncertainty of measurement is usually given as a 95% confidence interval and would normally be expressed in the appropriate SI units (ie. mm, °C, g/l, MPa etc).

For example, the result of a measurement might be 5.1 mg/l with an uncertainty of ± 0.2 mg/l at a 95% level of confidence. This means that there is an estimated 95% probability that the true value is in the range 4.9 mg/l to 5.3 mg/l. The 95% probability means that there is an estimated one in twenty chance that the true value is outside that range.

Uncertainty of measurement may also be expressed as a percentage where appropriate.

To assist laboratories to comply with the requirements of ISO/IEC 17025 for estimating uncertainty and to promote a uniform methodology in its estimation, information packages for APLAC PT testing program participants now include general guidance relating to estimating uncertainties for the specific testing involved, and final program reports will now include relevant worked examples. All program participants are required to report their estimates of uncertainty to their accreditation bodies along with their results unless the Technical Adviser to the program specifically waives any requirement to estimate uncertainties. The estimates of uncertainty provided by participants will be incorporated into the final program

reports enabling direct comparison of uncertainty estimates across the program participants. The uncertainty estimates will not be used in the evaluation of the results on the primary samples.

How is uncertainty of measurement to be estimated?

APLAC expects that program participants' uncertainties of measurement would be estimated in accordance with the requirements of the respective member accreditation bodies. There are different approaches and methodologies available. Worked examples provided in APLAC PT program reports will generally be based on ISO GUM but will recognise other methodologies in accordance with 5.4.6.3 NOTE 3 in ISO 17025.

Estimates of uncertainty of measurement provided by program participants are required to be given at the 95% level of confidence.

ISO GUM methodology

An estimate of uncertainty of measurement would usually be based on the combination of a number of influencing parameters (components of uncertainty) such as errors in reference values, instrument errors, repeatability, thermal effects, weighing errors, inhomogeneity etc. ISO GUM methodology requires that the influence of each component of uncertainty on the measurement result be quantified and expressed numerically as a standard deviation. These values are then combined according to the rules of the propagation of uncertainty to produce a combined standard deviation (combined standard uncertainty) and the combined standard uncertainty is multiplied by a coverage factor to produce an expanded uncertainty at the required level of confidence. Detailed descriptions and information on the implementation of this methodology have been published by ISO², UKAS³ and Eurachem/CITAC⁴ and made available over the internet⁷.

Uncertainty of measurement is best estimated within the individual laboratory environment. All factors which will have a significant influence on the test or measurement result must be included in the estimation process. There must be suitable programs utilising reference standards, instruments and materials to ensure on-going and adequate quality control and repeatability and reproducibility of methods and equipment over time. In many instances, it will be possible to utilise quality control data in assessing uncertainty components such as precision. Where these data are not available, it may be necessary to carry out precision studies or to rely on published information about the method or portions of it until the laboratory can obtain its own estimates.

APLAC is aware of the general need for better estimates of uncertainty, and estimates that are obtained under similar conditions in all laboratories. PT programs are useful mechanisms for spreading awareness of uncertainty of measurement and the effects of different ways of estimating it. We anticipate that the information made available through PT programs will help focus discussions on uncertainty of measurement.

APLAC Technical Committees will interpret the information and report on current practices. They will also make recommendations for improving the collection of uncertainty data, the estimation of uncertainties and incorporating data and information on uncertainty of measurement into PT program reports. Therefore we anticipate an evolution in the mechanisms for collecting and reporting uncertainty data and associated information over the next few years.

Participation in APLAC PT programs should assist laboratories to develop appropriate estimates of uncertainty, help to guide accreditation bodies to adopting common and consistent approaches leading to enhanced understanding and international comparability of measurements among the member nations.

APLAC will consider the use of estimates of uncertainty of measurement in the evaluation of its PT testing program results after it is satisfied that participating laboratories are estimating uncertainties of measurement in an appropriate and consistent manner.

Here are a few important terms:

Standard uncertainty ($u(x_i)$) is an input component of uncertainty x_i expressed as a standard deviation. It should be expressed in the units of the influencing parameter, but may be expressed as a percentage where convenient.

Type A evaluation estimates of standard uncertainty are evaluated by applying statistical techniques to a series of repeatability or curve fitting data. For example, a standard uncertainty estimated from the repeatability of measurements on replicate samples is a Type A evaluation.

Type B evaluation estimates of standard uncertainty are based on assumed probability distributions, experience, laboratory records, or other information. For example, a standard uncertainty estimated using data provided on a calibration certificate is a Type B evaluation.

Sensitivity coefficient (c_i) is the mathematical relationship between an influencing parameter and its effect on the result of a measurement. In many instances it is unity. That is, there is a one to one relationship between the value of the influence and its effect on the measurement result. For example, when weighing a sample of material, any uncertainty due to errors in the balance reading will have a one to one effect on

the measurement result. On the other hand, if we are considering the influence of temperature on the length of a metal bar then the sensitivity coefficient is equal to the coefficient of linear thermal expansion for the metal bar multiplied by the length of the bar. It is important to note that a sensitivity coefficient has units. It is also important to note that the calculation methodology used by Eurachem/CITAC4 incorporates sensitivity coefficients in a manner which does not require their specific evaluation.

Combined standard uncertainty ($uc(y)$) is the final estimate of uncertainty for the test or measurement result y expressed as a standard deviation. It is calculated by multiplying the standard uncertainty $u(xi)$ for each input component (xi) with its respective sensitivity coefficient ci to produce $ciu(xi)$ and then combining those values by taking the square root of the sum of their squares. Note that the products $ciu(xi)$ must each be expressed in the same units as those required for expressing the combined estimate $uc(y)$.

Expanded uncertainty (U) is the final result of our estimate of uncertainty expressed as a confidence interval. It is calculated by multiplying the combined standard uncertainty by a coverage factor to produce the desired level of confidence (usually 95%).

Coverage factor (k) is a multiplier used to expand the combined standard uncertainty $uc(y)$ to an interval that is estimated to contain the true value of the measurand at a given level of confidence ($U = k.uc(y)$). The coverage factor then represents the number of standard deviations in the expanded uncertainty and is determined according to the Student-t distribution. A coverage factor of 2 is commonly used to approximate the expanded uncertainty to the 95% confidence level.

References

1. ISO-IEC 17025:1999. General requirements for the competence of testing and calibration laboratories. ISO, Geneva (1999)
2. Guide to the Expression of Uncertainty in Measurement. ISO, Geneva (1993)
3. UKAS LAB 12: The Expression of Uncertainty in Testing. UKAS, London(2000)
4. Eurachem / CITAC Guide QUAM:2000.P1. Quantifying Uncertainty in Analytical Measurement, 2nd Edition (2000)
5. ISO/DTS 21748:2002 Guide for the use of repeatability, reproducibility, and trueness estimates in measurement uncertainty estimation.
6. APLAC TC 005, Interpretation and Guidance on the Estimation of Uncertainty of Measurement in Testing
7. Websites: www.A2LA.org/ (for A2LA policies, links to guidance documents, including the UKAS Guide, and the Eurachem/CITAC Guide, at no cost)
www.measurementuncertainty.org/ (Eurachem/CITAC Guide) www.fasor.com/iso25/ (general information, links, and discussion of ISO-IEC 17025)

APPENDIX D

Statistical Procedures, Calculations and Formulae

STATISTICAL PROCEDURES

For each statistically analysed test, the following information is given :

- (a) a table of results and calculated z-scores;
- (b) a list of summary statistics;
- (c) ordered z-score charts; and
- (d) a youden diagram

(a) Table of Results and Robust Z-Scores

These tables contain the results returned by each laboratory, and the z-scores calculated for each pair of results.

Please note that the results are presented in the table “as reported” by participants. Outliers are identified in the table by a marker (※) next to the relevant z-scores

(b) Summary Statistics

The list of summary statistics appears at the bottom of the table of results and consists of:

- (i) the number of results for that test/sample (*No. of Results*);
- (ii) the median of laboratory’s results - i.e. the middle value (*Median*);
- (iii) the normalised interquartile range of the results (*Normalised IQR*) – the interquartile range times 0.7413;
- (iv) the robust coefficient of variation, expressed as a percentage (*Robust CV*) - i.e.

$$100 \times \text{Normalised IQR} \div \text{Median};$$
- (v) the minimum and maximum laboratory results; and
- (vi) the range (*Maximum - Minimum*).

(c) Ordered Z-Score Charts

On these charts each laboratory’s z-score is shown, in order of magnitude, and is marked with its code number. From these each laboratory can readily compare its performance relative to the other laboratories.

For sample pair A & B, the first chart in each section is of the between-laboratories zscores for the sample pair and the second is of the within-laboratory z-scores (if applicable).

These charts contain solid lines at +3 and –3, so the outliers are clearly identifiable as the laboratories whose “bar” extends beyond these “cutoff” lines. The y-axis has been limited to range from –5 to +5, so in some cases very large or small (negative) z-scores appear as extending beyond the limit of the chart.

(d) Youden Diagrams

Youden two-sample diagrams are presented to highlight laboratory systematic differences. They are based on a plot of each laboratory's pair of results, sample two versus sample one, represented by a black spot •.

These diagrams also feature an approximate 95% confidence ellipse for the bivariate analysis of the results, and dashed lines which mark the median value for each of the samples.

All points which lie outside the ellipse are labelled with the laboratory's code number. Note however that these points may not correspond with those identified as outliers. This is because the outlier criterion ($|z\text{-score}| > 3$) has a confidence level of approximately 99%, whereas the ellipse is an approximate 95% confidence region.

So, the points outside the ellipse on the Youden diagram will roughly correspond to those with z-scores greater than 2 or less than -2. The laboratories which are outside the ellipse but have not been identified as extreme (those which have $2 < |z\text{-score}| < 3$) are encouraged to investigate their results.

- (i) laboratories with significant systematic error components (i.e. between-laboratories variation) will be outside the ellipse in either the upper right hand quadrant (as formed by the median lines) or the lower left hand quadrant, i.e. inordinately high or low results for both samples.
- (ii) laboratories with random error components (i.e. within-laboratory variation) significantly greater than other participants will be outside the ellipse and (usually) in either the upper left or lower right quadrants, i.e. an inordinately high result for one sample and low for the other.

It is important to note however that Youden diagrams are an illustration of the data only, and are *not* used to assess the results (this is done by the z-scores).

STATISTICAL CALCULATIONS AND FORMULAE

Suppose we have pairs of results (for related samples) from a number of laboratories. Let A_i be the result for the first sample (A) from laboratory i . Similarly, B_i is the result from laboratory i for the second sample (B). The number of (pairs of) results is denoted by N .

The median is the middle value of the group, i.e. half of the results are higher than it and half are lower. It is calculated from the sorted values (from lowest to highest). If N is an odd number, the median is the singular central value. If N is even, it is the average of the two central values.

The interquartile range (IQR) is the difference between the lower and upper quartiles. The lower quartile ($Q1$) is the value *below* which a quarter of the results lie. Similarly, the upper quartile ($Q3$) is the value *above* which a quarter of the results lie. The quartiles are calculated analogously to the median and $IQR = Q3 - Q1$. The "Normalised IQR " equals $IQR \times 0.7413$. The factor 0.7413 comes from the standard normal distribution, which has a mean of zero and a standard deviation equal to one. The width of the interquartile range of such a distribution is 1.34898 and $1/1.34898 = 0.7413$.

Multiplying the IQR by this factor makes it comparable to a standard deviation. The "Robust CV" is a coefficient of variation and is equal to the normalised IQR divided by the median, expressed as a percentage (i.e. multiplied by 100). The minimum, maximum and range are the lowest value, the highest value and the difference between them (respectively).

Robust z-scores are calculated by replacing the mean and standard deviation in the "classical" z-score by the median and normalised IQR, respectively - i.e. the z-score for a result is the result minus the median (all) divided by the normalised IQR. As indicated above, the between-laboratories and within-laboratory z-scores are based on the (standardised) sum and difference of the pair of results.

Let S_i be the standardised sum of laboratory's results. Also, D_i is the standardised difference between the two results from laboratory i . Now

$$S_i = \frac{(A_i + B_i)}{\sqrt{2}}$$

$$D_i = \frac{(A_i - B_i)}{\sqrt{2}} \quad \text{if } \text{median}(A_i) > \text{median}(B_i),$$

or

$$D_i = \frac{(B_i - A_i)}{\sqrt{2}} \quad \text{if } \text{median}(A_i) < \text{median}(B_i).$$

So, the between-laboratories z-score for laboratory i (denoted ZB_i) is the robust z-score of its S_i and their within-laboratory z-score (ZW_i) is the robust z-score of its D_i - i.e.

$$ZB_i = \frac{S_i - \text{median}(S_i)}{IQR(S_i) \times 0.7413}$$

and

$$ZW_i = \frac{D_i - \text{median}(D_i)}{IQR(D_i) \times 0.7413}$$