

Report No. 1118

**Metal Alloys Proficiency Testing
Program**

Round 35

Stainless Steel

January 2019

Acknowledgments

PTA wishes to gratefully acknowledge the technical assistance provided for this program by Mr W Ting from Universal Scientific Laboratory Pty Ltd, along with the supply of the samples.

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1. FOREWORD

This report summarises the results of a proficiency testing program on the chemical analysis of metal alloys. It constitutes the thirty fifth round of an ongoing series of programs. This program is accredited to ISO/IEC 17043:2010 “Conformity assessment - General requirements for proficiency testing” by International Accreditation New Zealand (IANZ).

The program was conducted in October 2018 by Proficiency Testing Australia (PTA). The aim of the program was to assess laboratories’ abilities to competently perform the prescribed analyses.

The Program Coordinator was Mrs K Cividin and the Technical Adviser was Mr W Ting from Universal Scientific Laboratory. This report was authorised by Mr P Briggs, PTA General Manager.

2. FEATURES OF THE PROGRAM

(a) Participants were provided with one stainless steel disc sample.

(b) A total of 11 laboratories received samples, comprising:

- 7 Australian participants; and

- 4 overseas participants, including:

- Egypt, Ethiopia and Qatar

Of these 11 laboratories, 9 submitted their results by the due date.

(c) Laboratories were provided with the *Instructions to Participants* and *Results Sheet* (see Appendix C). Laboratories were requested to perform the tests according to their routine methods and to record their results on the *Results Sheet*.

(d) Prior to sample distribution, eight randomly selected samples were analysed for homogeneity. Based on the results of this testing (see Appendix B), the homogeneity of the samples was established.

(e) Each laboratory was randomly allocated a unique code number for the program to ensure confidentiality of results. Reference to each laboratory in this report is by code number only. Please note that one laboratory reported more than one set of results and, therefore, their code number (with letter) may appear several times in the same data set.

(f) Results (as reported by participants) with corresponding summary statistics (i.e. number of results, median, uncertainty of the median, normalised interquartile range, robust coefficient of variation, minimum, maximum and range) are presented in Appendix A. Measurement Uncertainty (MU) is also

presented where supplied by participants. Where this was not reported, “nr” will appear in that column. Please note that this information is presented for information purposes only and has not been used for the formal evaluation of results.

- (g) A robust statistical approach, using z-scores, was utilised to assess laboratories’ testing performance (see Section 4). Robust z-scores and z-score charts relevant to each test are presented in Appendix A.
- (h) The document entitled *Guide to Proficiency Testing Australia, 2016* (reference [1]) defines the statistical terms and details the statistical procedures referred to in this report.
- (i) A tabulated listing of laboratories (by code number) identified as having outlier results can be found on page 7.

3. FORMAT OF THE APPENDICES

- (a) Appendix A contains the analysis of results reported by laboratories for the sample by all methods pooled. This section contains the following for each determinant, where appropriate:
 - a table of results and calculated z-scores;
 - a list of summary statistics; and
 - ordered z-score charts.
- (b) Appendix B contains details of the homogeneity and stability testing.
- (c) Appendix C contains copies of the *Instructions to Participants and Results Sheet*.

4. STATISTICAL DESIGN OF THE PROGRAM

- (a) Outlier Results and Z-scores

In order to assess laboratories’ testing performance, a robust statistical approach, using z-scores, was utilised. Z-scores give a measure of how far a result is from the consensus value (i.e. the median), and gives a "score" to each result relative to the other results in the group.

A z-score close to zero indicates that the result agrees well with those from other laboratories, whereas a z-score with an absolute value greater than or equal to 3.0 is considered to be an outlier and is marked by the symbol “§”.

The table on page 7 summarises the outlier results detected.

(b) Results Tables and Summary Statistics

Each of these tables contains the results returned by each laboratory, including the code number for the technique used, and the robust z-score calculated for each result, where applicable.

Results have been entered exactly as reported by participants. That is, laboratories which did not report results to the precision (i.e. number of decimal places) requested on the Results Sheet have not been rounded to the requested precision before being included in the statistical analysis.

Where a statistical analysis has been conducted, a list of summary statistics appears at the bottom of the table of results and consists of:

- the number of results for that test/sample (*No. of Results*);
- the median of these results, i.e. the middle value (*Median*);
- the uncertainty of the median; a robust estimate of the standard deviation of the *Median*;
- the normalised interquartile range of the results (*Normalised IQR*);
- the robust coefficient of variation, expressed as a percentage (*Robust CV*) - i.e. $100 \times \text{Normalised IQR} / \text{Median}$;
- the minimum and maximum laboratory results; and
- the range (*Maximum - Minimum*).

The median is a measure of the centre of the data.

The normalised IQR is a measure of the spread of the results. It is calculated by multiplying the interquartile range (IQR) by a correction factor which converts the IQR to an estimate of the standard deviation. The IQR is the difference between the upper and lower quartiles (i.e. the values above and below which a quarter of the results lie, respectively).

For normally distributed data, the uncertainty of the median is approximated by:

$$\sqrt{\frac{\pi}{2}} \times \frac{\text{normIQR}}{\sqrt{n}} \quad n = \text{number of results}$$

Please see reference [1] for further details on these robust summary statistics.

(c) Ordered Z-Score Charts

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

These charts contain solid lines at +3.0 and -3.0, so that outliers are clearly identifiable as those laboratories whose "bar" extends beyond these "cut-off" lines. The y-axis of these charts has been limited, so very large z-scores appear to extend beyond the chart boundary.

The following table summarises the results submitted by participants for the program using all methods.

TABLE A: SUMMARY STATISTICS

Test	No. of Results	Median	Normalised IQR
Carbon	14	0.0475	0.0031
Manganese	14	1.5845	0.0172
Phosphorus	14	0.0295	0.0014
Sulfur	14	0.0269	0.0019
Silicon	14	0.2803	0.0095
Copper	14	0.3688	0.0147
Nickel	14	10.0595	0.0984
Chromium	14	16.9593	0.0817
Molybdenum	14	2.0275	0.0180
Vanadium	14	0.0813	0.0032
Cobalt	14	0.1590	0.0044

5. PTA AND TECHNICAL ADVISER'S COMMENTS

The alloy tested was a 316 stainless steel, which is in wide use globally, therefore, accredited laboratories should be competent in the analysis of this material. For the AES arc/spark method, which most laboratories used, there should have been no inter-element effects arising from this material and the accuracy of the result should have depended on the calibration of the instrument and the cleanliness of the sample. At the low level of carbon in this alloy, calibration of the instrument and verification of the result are critical, as it is important to be able to differentiate between Grade 316 and Grade 316L, the latter having maximum specified carbon of 0.03%. For major constituents such as chromium, nickel and molybdenum, verification of the instruments or method is vital. All laboratories should be in the possession of certified reference materials with which they can verify the calibration status of their instruments before generating and reporting results. Laboratories which have participated in previous programs should be in possession of previously analysed discs which are effectively Certified Reference Materials (CRMs).

Carbon

Overall the results were good. The deletion of the outliers gives remarkable consistency between laboratories for this element. The outliers suggest calibration errors at this low level of carbon.

Manganese

In general these results were very good.

Nickel

Overall the results were good. The minimum nickel specified is 10.0% and steel manufacturers will try to avoid adding more nickel than is necessary. The results for laboratory code 10 would be acceptable with MU.

Chromium

The results were very good at this level of chromium. It appears that laboratory code 5 determined chromium volumetrically.

Molybdenum

Because of the cost of this element, manufacturers tend to aim for just above the minimum specified, which is 2.00%. The results for this test were satisfactory.

Phosphorus

With the exception of the outliers these results were satisfactory. Accurate analysis of "tramp" elements is necessary when trying to differentiate between two or more heats (batches) of steel.

Sulfur

The results for this test were very good. The comments regarding accuracy for phosphorus are equally applicable to sulfur.

Silicon

In general these were satisfactory.

Copper

These results were acceptable. This element would often be a determining factor when identifying a particular heat of steel.

Cobalt

These results were satisfactory. Like copper, this element would not normally be added in the manufacturing process but test results would be used to identify a particular heat of steel.

Vanadium

These results were very good. Even the outlier borders on being considered acceptable.

Variations within and between laboratories

Most results were generated by AES arc/spark. Replicates within laboratories were very good.

Variation between methods

Most laboratories reported results generated by atomic emission spectroscopy. One laboratory used LECO (C & S) for Phosphorus and Silicon, and atomic absorption spectrometry for the remainder.

Possible sources of error

When using AES arc/spark it is vital the calibration status of the instrument is checked before analysing unknowns, and adjusted if necessary. A certified reference material should be run in parallel with all analyses, regardless of the technique employed. As mentioned, participating laboratories can use this sample and previous discs for calibration and verification.

Measurement Uncertainties

The measurement uncertainties reported were unexceptionable.

This is a common alloy and becomes a worthwhile addition to laboratories' 'libraries' of certified reference materials. It can be used to confirm the calibration status of instruments and the accuracy of reported results.

The ability of a laboratory to accurately analyse this material is critical as there is a tendency on the part of manufacturers to aim close to the minimum for nickel, chromium and molybdenum.

Analysis of this alloy should be within the scope of laboratories accredited in the field of Metals and alloys - iron and steel. It is still important that results, particularly for the salient elements, but also for the residual elements, are as accurate as possible. This is necessary when a particular heat (batch) of steel has to be identified,

therefore, confidence in the calibration status of instruments is vital, as is confidence in non-instrumental techniques (gravimetric and volumetric).

Metrological Traceability and Measurement Uncertainty of Assigned Values

Consensus values (median) derived from participants' results are used in this program. These values are not metrologically traceable to an external reference

As the assigned value for this program is the median of the results submitted by the participants, the uncertainty of the median has been calculated and is presented as part of the summary statistics for each element.

Analysis of Results by Method Groups

Grouped analysis was performed for methods appearing at least 11 times in each test. The results are tabulated below.

TABLE B: ANALYSIS OF GROUPED METHODS

Test 0.000%	Grouped Method Technique	No. of Results	Median	Uncertainty of the Median
Carbon	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	0.0475	0.0010
Manganese	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	1.5865	0.0055
Phosphorus	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	0.0295	0.0005
Sulfur	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	0.0267	0.0008
Silicon	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	0.2810	0.0035
Copper	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	0.3695	0.0052
Nickel	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	10.0540	0.0375
Chromium	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	16.9735	0.0301
Molybdenum	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	13	2.0280	0.0075
Cobalt	AES - Arc/Spark (Atomic Emission Spectroscopy - Arc\Spark)	12	0.1590	0.0017

The above table does not include results for Vanadium as all participants reported using the same method.

6. OUTLIER RESULTS

Laboratories reporting outlier results by pooled methods analysis are listed in the following table:

TABLE C: SUMMARY OF STATISTICAL OUTLIERS

Test	Laboratory Code No.
Carbon	1, 4, 10
Manganese	-
Phosphorus	4, 10
Sulfur	10
Silicon	-
Copper	-
Nickel	-
Chromium	-
Molybdenum	4, 10
Vanadium	7
Cobalt	7

7. REFERENCES

- [1] *Guide to Proficiency Testing Australia*, 2016 (This document can be found on the PTA website, www.pta.asn.au)
- [2] *AS1442-2007 Carbon steels and carbon-manganese steels-Hot rolled bars and semifinished products.*

APPENDIX A

Results and Data Analysis

Carbon.....	A1
Manganese.....	A2
Phosphorus.....	A3
Sulfur.....	A4
Silicon.....	A5
Copper.....	A6
Nickel.....	A7
Chromium.....	A8
Molybdenum.....	A9
Vanadium.....	A10
Cobalt.....	A11

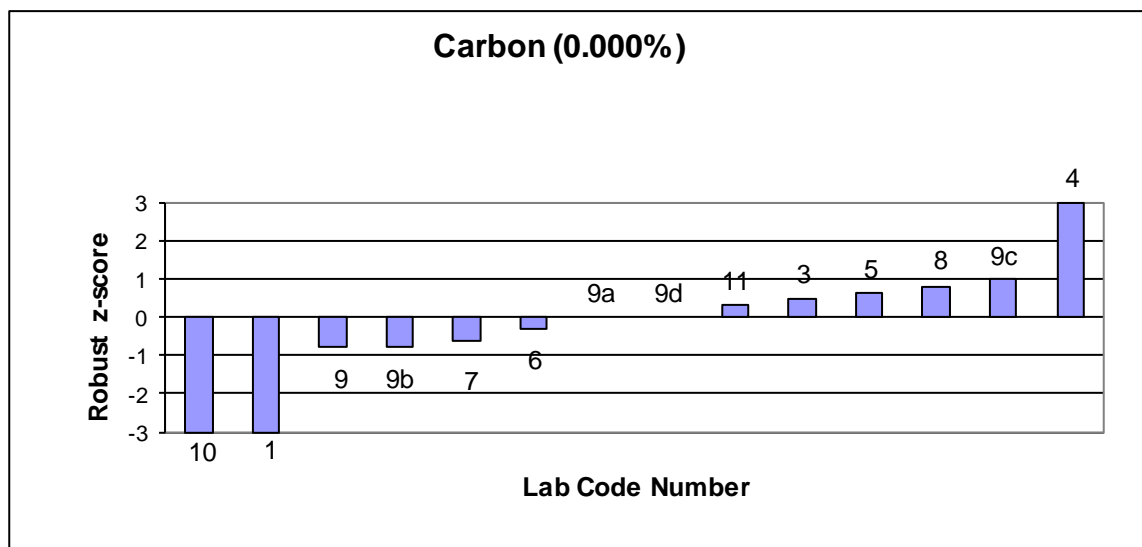
Carbon (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	0.035	0.036	0.0359	0.003	-3.75	§ 1
3	0.049	0.049	0.0490	0.003	0.48	1
4	0.060	0.058	0.0590	0.004	3.72	§ 1
5	0.049	0.050	0.0494	0.002	0.61	6
6	0.046	0.047	0.0465	0.005	-0.32	1
7	0.045	0.046	0.0455	0.001	-0.65	1
8	0.050	0.050	0.0500	0.008	0.81	1
9	0.045	0.045	0.0450	nr	-0.81	1
9a	0.047	0.048	0.0475	nr	0.00	1
9b	0.045	0.045	0.0450	nr	-0.81	1
9c	0.050	0.051	0.0505	nr	0.97	1
9d	0.048	0.047	0.0475	nr	0.00	1
10	0.033	0.037	0.0350	0.001	-4.04	§ 1
11	0.049	0.048	0.0485	0.006	0.32	1

§ = an outlier result i.e |z-score| ≥ 3.0

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
6 LECO/OES

No. of Results	14
Median	0.0475
Norm IQR	0.0031
Uncertainty of the Median	0.0010
Robust CV	6.5%
Min	0.035
Max	0.059
Range	0.024



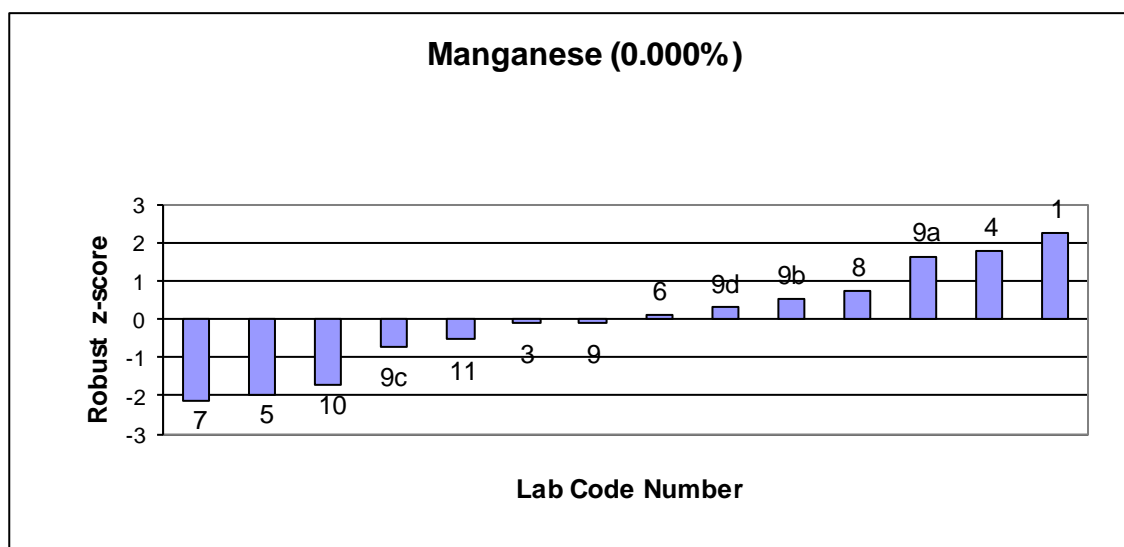
Manganese (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	1.627	1.619	1.6230	0.04	2.23	1
3	1.585	1.580	1.5825	0.019	-0.12	1
4	1.610	1.620	1.6150	0.015	1.77	1
5	1.540	1.560	1.5500	0.05	-2.00	3
6	1.585	1.588	1.5865	0.04	0.12	1
7	1.550	1.546	1.5480	0.006	-2.12	1
8	1.599	1.595	1.5970	0.048	0.73	1
9	1.584	1.581	1.5825	nr	-0.12	1
9a	1.617	1.607	1.6120	nr	1.60	1
9b	1.592	1.595	1.5935	nr	0.52	1
9c	1.576	1.568	1.5720	nr	-0.73	1
9d	1.585	1.594	1.5895	nr	0.29	1
10	1.550	1.560	1.5550	0.012	-1.71	1
11	1.575	1.576	1.5755	0.016	-0.52	1

§ = an outlier result i.e $|z\text{-score}| \geq 3.0$

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
3 AAS (Atomic Absorption Spectrometry)

No. of Results	14
Median	1.5845
Norm IQR	0.0172
Uncertainty of the Median	0.0058
Robust CV	1.1%
Min	1.548
Max	1.623
Range	0.075

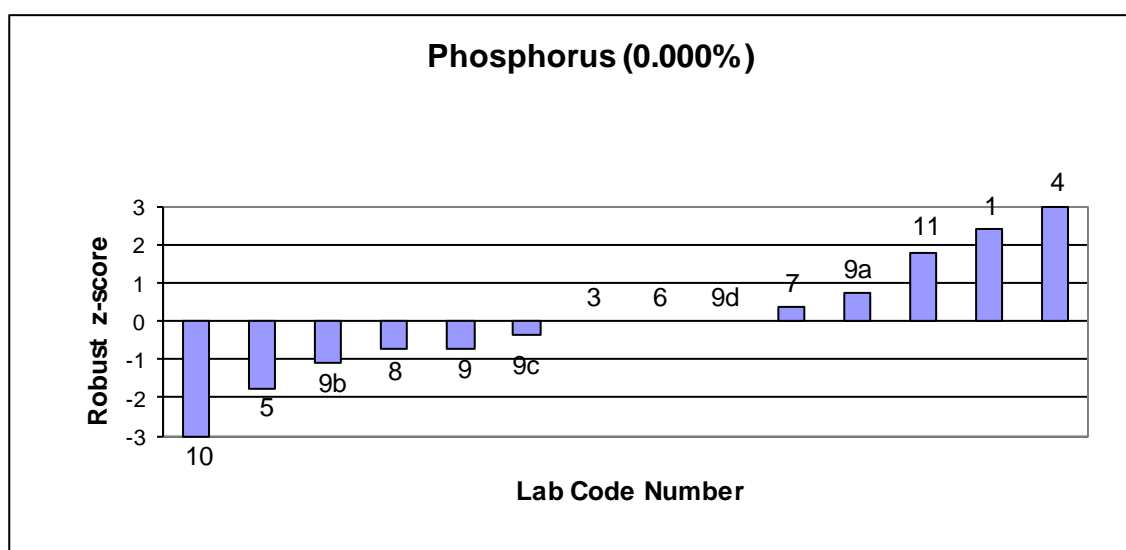


Phosphorus (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	0.0331	0.0325	0.0328	0.003	2.37	1
3	0.029	0.03	0.0295	0.003	0.00	1
4	0.039	0.038	0.0385	0.003	6.48	1
5	0.027	0.0271	0.0271	0.005	-1.76	5
6	0.029	0.03	0.0295	0.006	0.00	1
7	0.03	0.03	0.0300	0	0.36	1
8	0.028	0.029	0.0285	0.003	-0.72	1
9	0.029	0.028	0.0285	nr	-0.72	1
9a	0.03	0.031	0.0305	nr	0.72	1
9b	0.028	0.028	0.0280	nr	-1.08	1
9c	0.029	0.029	0.0290	nr	-0.36	1
9d	0.029	0.03	0.0295	nr	0.00	1
10	0.022	0.022	0.0220	0.0012	-5.40	1
11	0.032	0.032	0.0320	0.006	1.80	1

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
5 Photometric

No. of Results	14
Median	0.0295
Norm IQR	0.0014
Uncertainty of the Median	0.0005
Robust CV	4.7%
Min	0.022
Max	0.039
Range	0.017



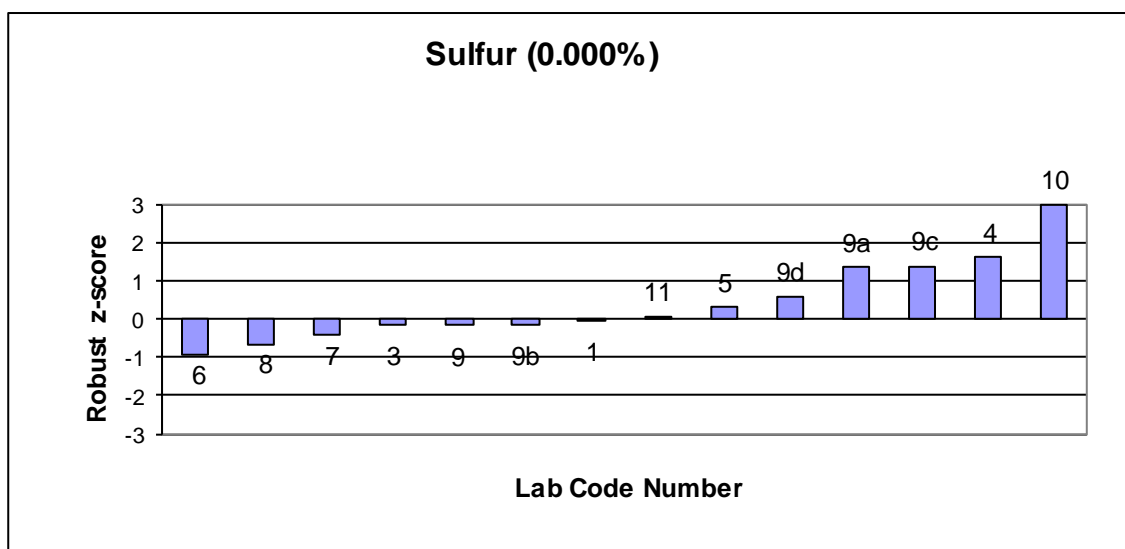
Sulfur (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	0.027	0.0264	0.0267	0.008	-0.08	1
3	0.026	0.027	0.0265	0.005	-0.18	1
4	0.031	0.029	0.0300	0.003	1.62	1
5	0.0272	0.0277	0.0275	0.002	0.31	6
6	0.025	0.025	0.0250	0.005	-0.95	1
7	0.026	0.026	0.0260	0	-0.44	1
8	0.025	0.026	0.0255	0.003	-0.69	1
9	0.027	0.026	0.0265	nr	-0.18	1
9a	0.029	0.03	0.0295	nr	1.36	1
9b	0.026	0.027	0.0265	nr	-0.18	1
9c	0.029	0.03	0.0295	nr	1.36	1
9d	0.028	0.028	0.0280	nr	0.59	1
10	0.038	0.038	0.0380	0.0012	5.73 §	1
11	0.026	0.028	0.0270	0.003	0.08	1

§ = an outlier result i.e $|z\text{-score}| \geq 3.0$

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
6 LECO/OES

No. of Results	14
Median	0.0269
Norm IQR	0.0019
Uncertainty of the Median	0.0007
Robust CV	7.2%
Min	0.025
Max	0.038
Range	0.013

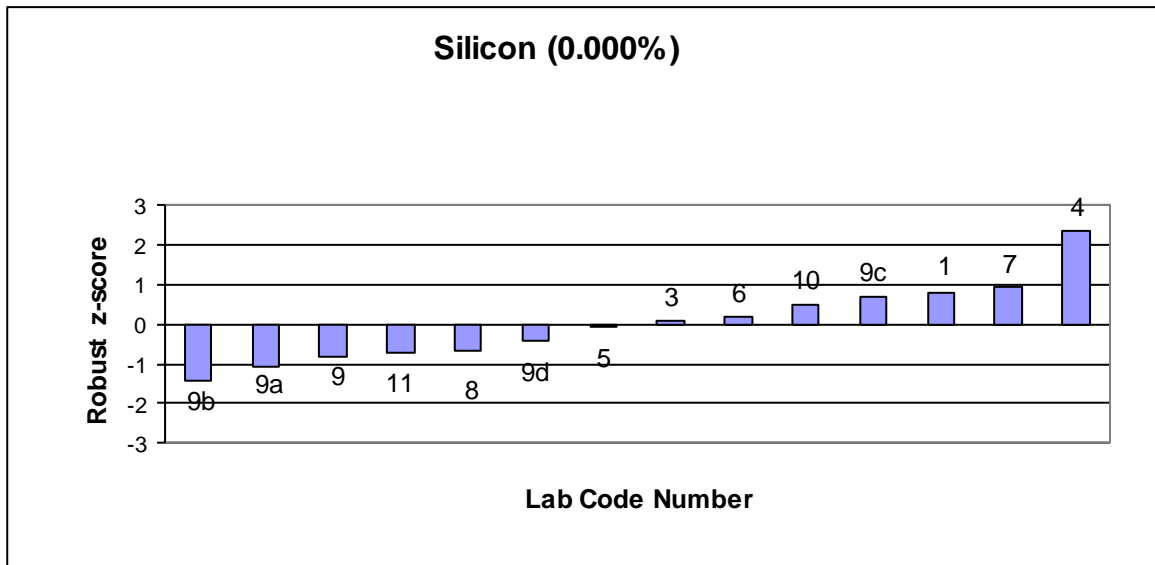


Silicon (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	0.289	0.287	0.2880	0.01	0.81	1
3	0.281	0.281	0.2810	0.015	0.08	1
4	0.308	0.297	0.3025	0.012	2.33	1
5	0.279	0.28	0.2795	0.01	-0.08	5
6	0.279	0.285	0.2820	0.03	0.18	1
7	0.291	0.287	0.2890	0.006	0.92	1
8	0.275	0.273	0.2740	0.014	-0.65	1
9	0.272	0.273	0.2725	nr	-0.81	1
9a	0.27	0.27	0.2700	nr	-1.07	1
9b	0.265	0.268	0.2665	nr	-1.44	1
9c	0.287	0.287	0.2870	nr	0.71	1
9d	0.276	0.276	0.2760	nr	-0.45	1
10	0.28	0.29	0.2850	0.007	0.50	1
11	0.273	0.274	0.2735	0.036	-0.71	1

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
 5 Photometric

No. of Results	14
Median	0.2803
Norm IQR	0.0095
Uncertainty of the Median	0.0032
Robust CV	3.4%
Min	0.267
Max	0.303
Range	0.036



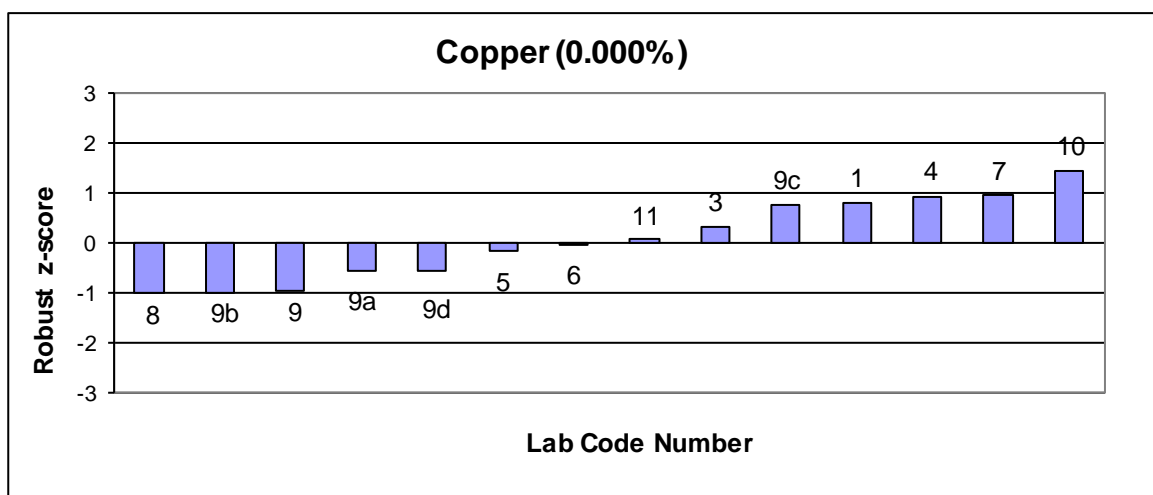
Copper (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	0.38	0.381	0.3805	0.02	0.80	1
3	0.373	0.374	0.3735	0.008	0.32	1
4	0.38	0.384	0.3820	0.006	0.90	1
5	0.364	0.368	0.3660	0.01	-0.19	3
6	0.372	0.364	0.3680	0.025	-0.05	1
7	0.382	0.383	0.3825	0.001	0.93	1
8	0.359	0.348	0.3535	0.018	-1.04	1
9	0.355	0.354	0.3545	nr	-0.97	1
9a	0.36	0.361	0.3605	nr	-0.56	1
9b	0.355	0.352	0.3535	nr	-1.04	1
9c	0.38	0.38	0.3800	nr	0.76	1
9d	0.363	0.358	0.3605	nr	-0.56	1
10	0.39	0.39	0.3900	0.004	1.44	1
11	0.369	0.37	0.3695	0.008	0.05	1

n/a = not applicable

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
3 AAS (Atomic Absorption Spectrometry)

No. of Results	14
Median	0.3688
Norm IQR	0.0147
Uncertainty of the Median	0.0049
Robust CV	4.0%
Min	0.354
Max	0.390
Range	0.037



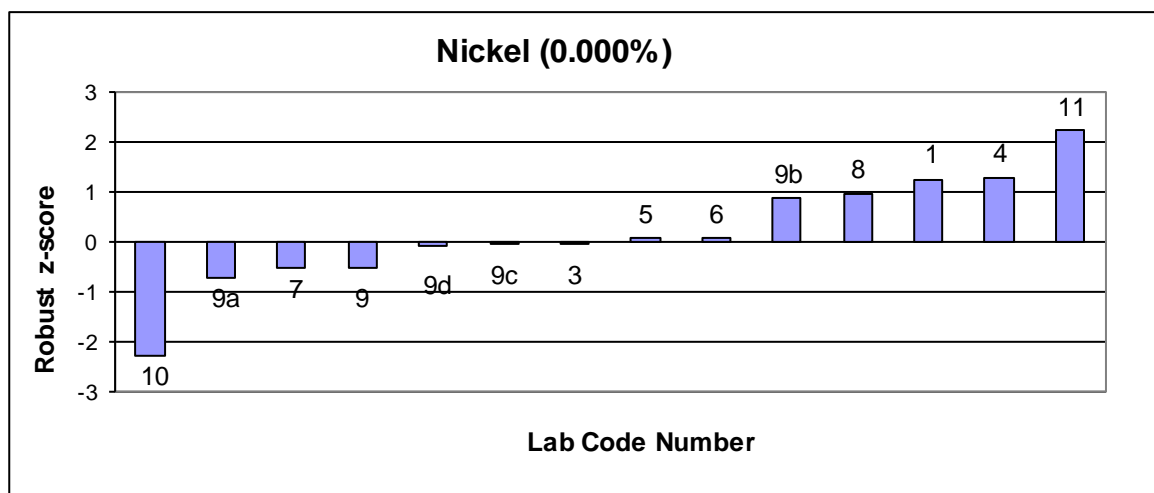
Nickel (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	10.18	10.18	10.1800	0.050	1.22	1
3	10.049	10.059	10.0540	0.108	-0.06	1
4	10.16	10.21	10.1850	0.058	1.28	1
5	10.05	10.08	10.0650	0.100	0.06	4
6	10.054	10.078	10.0660	0.250	0.07	1
7	10.042	9.974	10.0080	0.096	-0.52	1
8	10.132	10.176	10.1540	0.139	0.96	1
9	9.988	10.029	10.0085	nr	-0.52	1
9a	9.945	10.026	9.9855	nr	-0.75	1
9b	10.165	10.123	10.1440	nr	0.86	1
9c	10.089	10.016	10.0525	nr	-0.07	1
9d	10.085	10.014	10.0495	nr	-0.10	1
10	9.89	9.78	9.8350	0.040	-2.28	1
11	10.266	10.288	10.2770	0.157	2.21	1

n/a = not applicable

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
4 Gravimetric

No. of Results	14
Median	10.0595
Norm IQR	0.0984
Uncertainty of the Median	0.0330
Robust CV	1.0%
Min	9.835
Max	10.277
Range	0.442

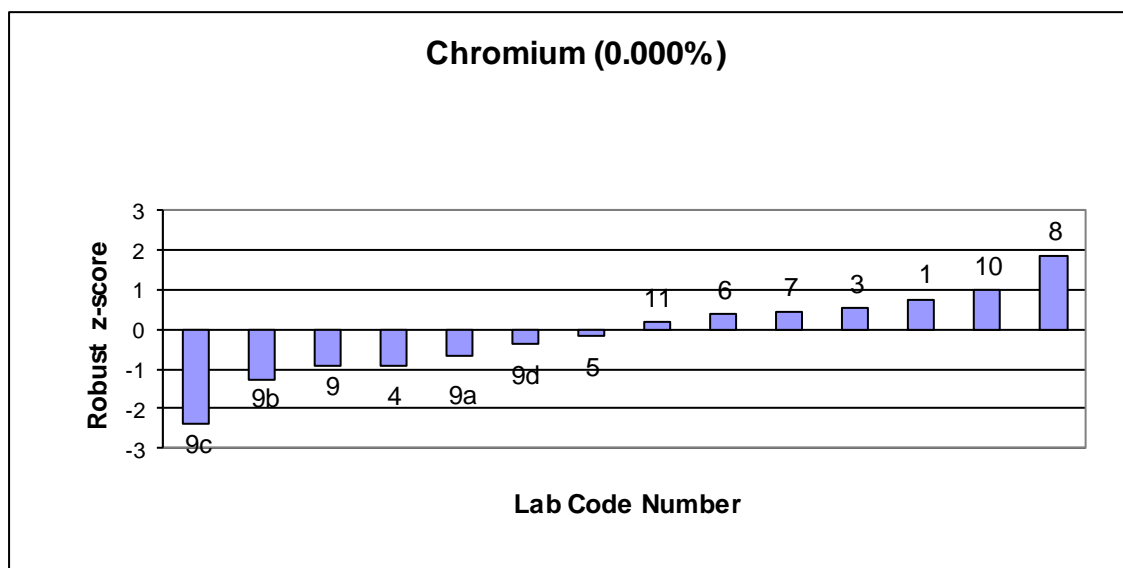


Chromium (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	17.000	17.040	17.0200	0.05	0.74	1
3	16.988	17.016	17.0020	0.142	0.52	1
4	16.910	16.860	16.8850	0.084	-0.91	1
5	16.950	16.940	16.9450	0.1	-0.17	6
6	17.021	16.960	16.9905	0.3	0.38	1
7	16.984	17.007	16.9955	0.033	0.44	1
8	17.089	17.135	17.1120	0.232	1.87	1
9	16.888	16.878	16.8830	nr	-0.93	1
9a	16.892	16.919	16.9055	nr	-0.66	1
9b	16.876	16.833	16.8545	nr	-1.28	1
9c	16.794	16.735	16.7645	nr	-2.38	1
9d	16.928	16.928	16.9280	nr	-0.38	1
10	17.030	17.050	17.0400	0.06	0.99	1
11	16.959	16.988	16.9735	0.24	0.17	1

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
6 LECO/OES

No. of Results	14
Median	16.9593
Norm IQR	0.0817
Uncertainty of the Median	0.0274
Robust CV	0.5%
Min	16.765
Max	17.112
Range	0.348

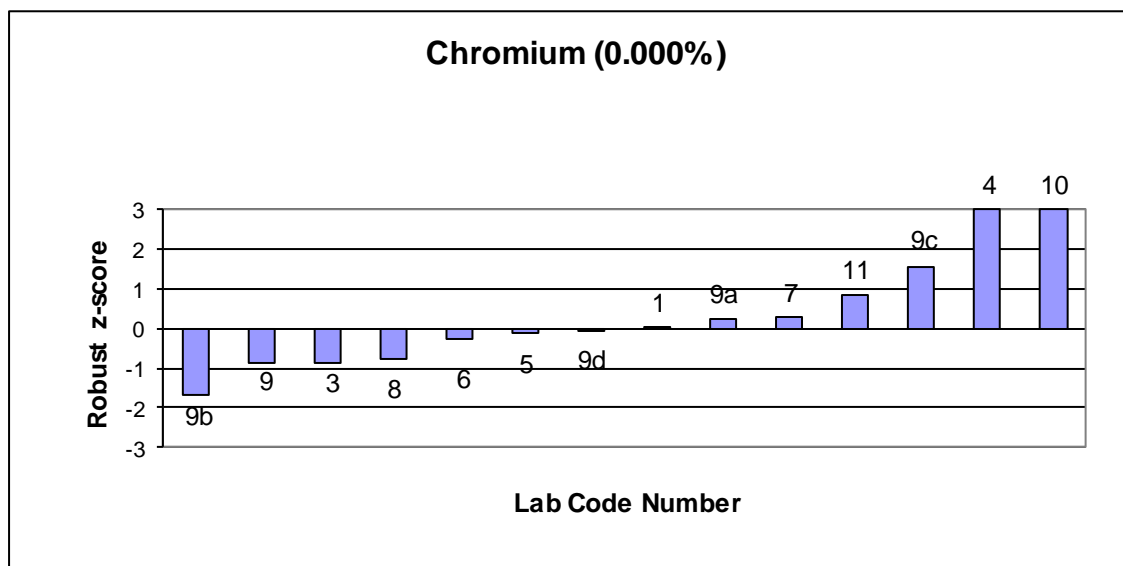


Molybdenum (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	2.029	2.027	2.0280	0.04	0.03	1
3	2.016	2.008	2.0120	0.033	-0.86	1
4	2.11	2.09	2.1000	0.02	4.03 §	1
5	2.03	2.02	2.0250	0.05	-0.14	3
6	2.033	2.012	2.0225	0.052	-0.28	1
7	2.039	2.026	2.0325	0.018	0.28	1
8	2.015	2.013	2.0140	0.041	-0.75	1
9	2.009	2.014	2.0115	nr	-0.89	1
9a	2.029	2.035	2.0320	nr	0.25	1
9b	1.996	1.998	1.9970	nr	-1.70	1
9c	2.054	2.057	2.0555	nr	1.56	1
9d	2.024	2.03	2.0270	nr	-0.03	1
10	2.16	2.13	2.1450	0.003	6.54 §	1
11	2.043	2.043	2.0430	0.073	0.86	1

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
3 AAS (Atomic Absorption Spectrometry)

No. of Results	14
Median	2.0275
Norm IQR	0.0180
Uncertainty of the Median	0.0060
Robust CV	0.9%
Min	1.997
Max	2.145
Range	0.148



Vanadium (0.000%)

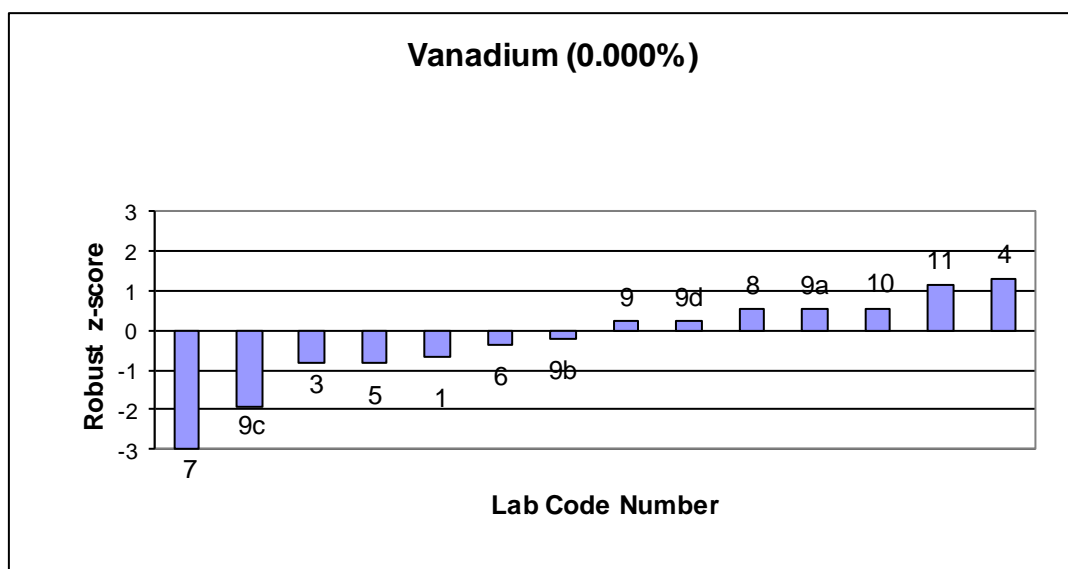
Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	0.079	0.079	0.0790	0.008	-0.69	1
3	0.079	0.078	0.0785	0.002	-0.85	1
4	0.086	0.085	0.0855	0.001	1.31	1
5	0.079	0.078	0.0785	0.005	-0.85	3
6	0.082	0.078	0.0800	0.01	-0.39	1
7	0.067	0.068	0.0675	0.001	-4.24	§
8	0.083	0.083	0.0830	0.004	0.54	1
9	0.082	0.082	0.0820	nr	0.23	1
9a	0.083	0.083	0.0830	nr	0.54	1
9b	0.080	0.081	0.0805	nr	-0.23	1
9c	0.075	0.075	0.0750	nr	-1.93	1
9d	0.083	0.081	0.0820	nr	0.23	1
10	0.083	0.083	0.0830	0.003	0.54	1
11	0.085	0.085	0.0850	0.001	1.16	1

nr = not reported

n/a = not applicable

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
3 AAS (Atomic Absorption Spectrometry)

No. of Results	14
Median	0.0813
Norm IQR	0.0032
Uncertainty of the Median	0.0011
Robust CV	4.0%
Min	0.068
Max	0.086
Range	0.018



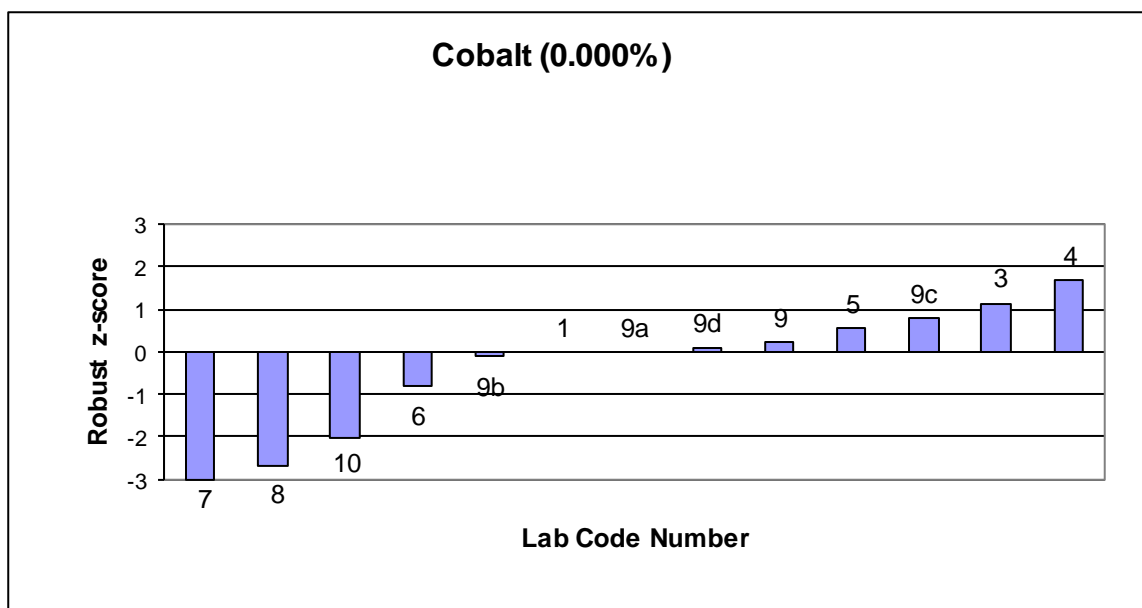
Cobalt (0.000%)

Lab Code	Result 1	Result 2	Average	MU	Robust Z-score	Technique
1	0.159	0.159	0.1590	0.01	0.00	1
3	0.164	0.164	0.1640	0.003	1.12	1
4	0.166	0.167	0.1665	0.002	1.69	1
5	0.162	0.161	0.1615	0.005	0.56	3
6	0.156	0.155	0.1555	0.02	-0.79	1
7	0.131	0.13	0.1305	0.001	-6.41 §	1
8	0.146	0.148	0.1470	0.007	-2.70	1
9	0.160	0.16	0.1600	nr	0.22	1
9a	0.159	0.159	0.1590	nr	0.00	1
9b	0.159	0.158	0.1585	nr	-0.11	1
9c	0.163	0.162	0.1625	nr	0.79	1
9d	0.160	0.159	0.1595	nr	0.11	1
10	0.150	0.15	0.1500	0.003	-2.02	1

§ = an outlier result i.e $|z\text{-score}| \geq 3.0$

Technique: 1 AES - Arc/spark (Atomic Emission Spectroscopy - Arc/Spark)
3 AAS (Atomic Absorption Spectrometry)

No. of Results	13
Median	0.1590
Norm IQR	0.0044
Uncertainty of the Median	0.0015
Robust CV	2.8%
Min	0.131
Max	0.167
Range	0.036



APPENDIX B

Homogeneity and Stability Testing

Sample Preparation and Homogeneity Testing.....	B1
Stability Testing.....	B1

Sample Preparation and Homogeneity

The stainless steel samples were supplied by Universal Scientific Laboratory Pty Ltd.

Eight discs were selected and tested for each element and the results are shown in the following tables:

Sample	Carbon	Sulphur	Phosphorus	Silicon	Manganese	Chromium
1	0.04999	0.0283	0.0269	0.267	1.560	16.94
2	0.04817	0.0286	0.0270	0.279	1.601	16.96
3	0.04812	0.0287	0.0271	0.283	1.567	16.99
4	0.04926	0.0284	0.0270	0.281	1.566	17.00
5	0.04989	0.0272	0.0300	0.279	1.558	16.95
6	0.04955	0.0260	0.0270	0.284	1.539	17.00
7	0.04790	0.0264	0.0263	0.281	1.534	16.83
8	0.05000	0.0262	0.0264	0.263	1.531	16.83
Average	0.04911	0.027475	0.027213	0.277125	1.557	16.9375
SD	0.000904	0.001155	0.001166	0.007754	0.022854	0.070051
CV	1.84%	4.20%	4.28%	2.80%	1.47%	0.41%

Sample	Nickel	Copper	Molybdenum	Vanadium	Titanium	Cobalt
1	10.03	0.374	2.0100	0.080	0.0038	0.161
2	10.02	0.371	1.9970	0.079	0.0045	0.163
3	10.10	0.375	2.0040	0.0799	0.0044	0.159
4	10.07	0.364	2.0120	0.0782	0.0043	0.156
5	10.06	0.370	2.0650	0.0786	0.0044	0.161
6	10.09	0.365	2.0490	0.0797	0.0044	0.1625
7	10.08	0.361	2.0390	0.0790	0.0043	0.1617
8	10.10	0.358	2.0500	0.0771	0.0050	0.162
Average	10.06875	0.36725	2.028025	0.078938	0.004388	0.160775
SD	0.030443	0.006182	0.025615	0.000977	0.000327	0.002278
CV	0.30%	1.68%	1.26%	1.24%	7.45%	1.42%

Analysis of this data indicated that the samples were sufficiently homogeneous and, therefore, any results later identified as outliers could not be attributed to sample variability.

Stability Testing

Due to the nature of the samples it was not considered necessary to perform stability testing.

APPENDIX C

Documentation

Instructions to Participants	C1
Results Sheet	C2



**Proficiency Testing Program
Metal Alloys (Round 35) – October 2018**

INSTRUCTIONS TO PARTICIPANTS

Please read instructions carefully **BEFORE** commencing testing.

1. For this round each participant will be supplied with one steel disc.
2. Participants are asked to test the percentage composition (in duplicate) for each sample for the following elements:

Carbon, Manganese, Phosphorus, Sulfur, Silicon, Copper, Nickel, Chromium, Molybdenum, Cobalt and Vanadium. If the analysis of any element is not possible, please note this on the results sheet.

Please be advised that the initial measurement recorded is to be noted as “Result 1” and the following measurement is to be recorded as “Result 2” on the results sheet.

3. These tests are to be conducted by the methods used routinely in your laboratory. The sample should be treated as a routine sample.
4. Results are to be reported as a % to three decimal places. **Do not report any values as “<”**. The method used for each test should also be noted.
5. For each test note the appropriate technique code no. on the Results Sheet:
 1. AES – Arc/Spark (Atomic Emission Spectroscopy – Arc\Spark)
 2. AES – ICP (Atomic Emission spectroscopy – Inductively Coupled Plasma)
 3. AAS (Atomic Absorption Spectrometry)
 4. Gravimetric
 5. Photometric
 6. Other (please specify)
6. Laboratories are also requested to calculate and report an estimate of measurement uncertainty (MU) for each reported measurement result. All estimates of measurement uncertainty must be given as a 95% confidence interval (coverage factor $k \approx 2$)
7. Testing may commence as soon as samples are received. All laboratories are asked to return their results by **Friday 2nd November 2018** to:

Karen Cividin
Proficiency Testing Australia
PO Box 7507
Silverwater NSW 2128
AUSTRALIA
Phone: +61 2 9736 8295

Fax: +61 2 9743 6664

8. To allow for the confidential treatment of your results in the final report, you have been allocated a code number which appears on your results sheet.



Proficiency Testing Program
Metal Alloys (Round 35) – October 2018

RESULTS SHEET

Date sample was received: _____

Lab Code:

TEST (report % to three decimal places)	SAMPLE		MU (±)	Technique Code No.
	Result 1	Result 2		
Carbon				
Sulfur				
Phosphorus				
Silicon				
Manganese				
Chromium				
Nickel				
Copper				
Molybdenum				
Vanadium				
Cobalt				

Signed: _____

Date: _____

Please return no later than
Friday 2nd November 2018, to:

Karen Cividin, Proficiency Testing Australia
 PO Box 7507, Silverwater NSW 2128
 phone: +61 2 9736 8295, fax: +61 9743 6664

- End of Report -