

REPORT NO. 1128

**Hardness Testing of Metals
Proficiency Testing Program
Round 15**

March 2019

ACKNOWLEDGMENTS

PTA wishes to gratefully acknowledge the technical assistance provided for this program by Mr S Sameem, ARL Laboratory Services Pty Ltd. Also our thanks go to ARL Laboratory Services Pty Ltd, for the supply and homogeneity testing of the samples.

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1. FOREWORD

This report summarises the results of a proficiency testing program on the hardness properties of metals. It constitutes the fifteenth 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).

Proficiency Testing Australia (PTA) conducted the testing program in December 2018 / January 2019. The aim of the program was to assess laboratories' ability to competently perform the nominated tests.

The Program Coordinator was Dr M Bunt. The Technical Adviser was Mr S Sameem, ARL Laboratory Services Pty Ltd. This report was authorised by Mrs K Cividin, PTA Quality Manager.

2. FEATURES OF THE PROGRAM

- (a) A total of 12 laboratories participated in the program, all of which returned results for inclusion in the final report. Laboratories from the following countries received samples:

7	AUSTRALIA
1	MALAYSIA
1	NEW ZEALAND
1	SAUDI ARABIA
1	TANZANIA
1	UNITED ARAB EMIRATES

To ensure confidential treatment of results, each laboratory was allocated a unique random code number. Reference to each laboratory in this report is by its code number. Please note that one laboratory reported more than one set of results and, therefore, this laboratory's code number (with letter) could appear several times in the same data set.

- (b) The results reported by participants are presented in Appendix A.
- (c) Each laboratory was provided with an aluminium sample, approximately 65 mm in diameter and approximately 40 mm thick. The sample was to be tested for Brinell, Vickers and Rockwell B hardness testing.
- (d) Laboratories were requested to perform the tests according to the *Instructions to Participants* provided and to record the results, along with an estimate of their measurement uncertainty (MU) for each result, on the accompanying *Results Sheet*, which was distributed with the samples. Copies of these documents appear in Appendix C.
- (e) Prior to distribution, the samples were tested for homogeneity by ARL Laboratory Services Pty Ltd. Based on the results of this testing, the homogeneity of the samples was established (see Appendix B).

3. FORMAT OF THE APPENDICES

- (a) Appendix A is divided into four sections (A1-A4).

Sections A1-A3 contain the analysis of results reported by laboratories for Brinell, Vickers and Rockwell B hardness. These sections contain:

- i) a table of results reported by laboratories for each test, with estimates of their MUs and calculated z-scores;
- ii) a listing of the summary statistics; and
- iii) ordered z-score charts.

Section A4 contains information on the methods used by the participants and the surface preparations they performed.

- (b) Appendix B contains details of the homogeneity testing.
- (c) Appendix C contains copies of the *Instructions to Participants* and *Results Sheet*.

4. STATISTICAL DESIGN OF THE PROGRAM

The summary statistics calculated for each test / sample consists of:

- *No. of Results*: the total number of results for that test / sample;
- *Median*: the middle value of the results;
- *Normalised IQR*: the normalised interquartile range of the results;
- *Uncertainty of the Median*: a robust estimate of the standard deviation of the *Median*;
- *Robust CV*: the robust coefficient of variation expressed as a percentage, *i.e.* $100 \times \text{Normalised IQR} / \text{Median}$;
- *Minimum*: the lowest laboratory result;
- *Maximum*: the highest laboratory result; and
- *Range*: the difference between the *Maximum* and *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:

$$\sqrt{\frac{\pi}{2}} \times \frac{\text{normIQR}}{\sqrt{n}}$$

where *normIQR* is the normalised IQR and *n* is the number of results.

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 with an absolute value less than or equal to 2.0 is considered to be satisfactory, 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 “§”. Laboratories are also encouraged to review results which have an absolute z-score value between 2.0 and 3.0 (*i.e.* $2.0 < |z\text{-score}| < 3.0$). These results are considered to be questionable results.

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

The ordered z-score charts in Appendix A are limited on the vertical axis to +3.0 and -3.0, so that outliers are clearly identifiable as those laboratories whose "bar" extends beyond the chart boundary.

For further details on the calculation and interpretation of robust z-scores and ordered z-score charts, please see the *Guide to Proficiency Testing Australia (2016)*.

5. OUTLIER RESULTS

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

Table A: Summary Statistics for All Tests

Test	Summary Statistics	Average Result
Brinell Hardness (HBW)	Number of Results	10
	Median	105.0
	Normalised IQR	2.8
	Uncertainty (Median)	1.1
Vickers Hardness (HV)	Number of Results	11
	Median	112.0
	Normalised IQR	3.3
	Uncertainty (Median)	1.3
Rockwell B Hardness (HRB)	Number of Results	9
	Median	60.50
	Normalised IQR	2.97
	Uncertainty (Median)	1.24

Table B: Summary of Statistical Outliers
(By laboratory code number)

Test	Outliers (Laboratory Code No.)
Brinell Hardness	4
Vickers Hardness	-
Rockwell B Hardness	-

Notes:

1. For each test, the results for all test methods were pooled for analysis.
2. Summary statistics and z-scores were calculated for the average hardness value reported for each test.

6. PTA AND TECHNICAL ADVISER'S COMMENTS

Consensus values (medians), derived from participants' results, are used as the assigned values in this program. These values are not metrologically traceable to an external reference.

The summary statistics, uncertainties of the assigned values and outliers, for each of the tests, are reported in Tables A and B above. Complete details of the statistical analyses appear in Appendix A.

6.1 Return rate

All of the 12 laboratories that participated in the program submitted results for inclusion in the final report. Of these 12 laboratories, six (50%) submitted results for all three tests.

The return rate for all tests is as follows:

- Brinell Hardness 10 out of 12 83%
- Vickers Hardness 10 out of 12 83%
- Rockwell B Hardness 9 out of 12 75%

6.2 Performance summary

Statistical outliers were reported by one of the 12 laboratories (8%) that returned results in this round of the program. For comparison, there were no statistical outliers reported by the participants in Round 14 of this program (see Report No. 1101 for more details).

A total of 30 results were analysed in this program. Of these results, one (3%) was an outlier result.

6.3 Brinell Hardness

A total of ten laboratories tested the sample for Brinell hardness. Of these laboratories, five tested using the AS 1816 method. Three laboratories tested using the ASTM E10 method. One laboratory tested using the ISO 6506 method. One laboratory did not specify the method they used for testing (see Appendix A4 for more details).

There were not enough results submitted for any specific method to draw reliable conclusions from analysing grouped methods on this occasion. The methods were pooled when analysing the results.

For all methods pooled, the median and its standard uncertainty for the Brinell hardness results was 105.0 ± 1.1 HBW.

The CV for the Brinell hardness results for this round was 2.6%. This compares well with the CV of 2.3%, obtained for the Brinell hardness results in Round 14 of this program (see Report No. 1101).

Laboratory code 4 reported an outlier for Brinell hardness. This laboratory's average result of 27.8 HBW, compared to the median of 105.0 HBW, suggests that this may be a typographical error. The reported test loading conditions, test methods and preparation for this laboratory seem satisfactory. However, it could be that the reporting was not done properly. It is suggested that this laboratory may need to review their testing and reporting procedures to ensure that their test results and test reports are thoroughly reviewed and approved prior to release.

Nine laboratories reported measurement uncertainties associated with their Brinell hardness test results in this round.

6.4 Vickers Hardness

Of the ten laboratories that tested the sample for Vickers hardness, seven tested using the AS 1817 method, including one laboratory that submitted two sets of results. Two laboratories tested using the ASTM E92 method. One laboratory did not specify the method they used for testing (see Appendix A4 for more details).

There were not enough results submitted for any specific method to draw reliable conclusions from analysing grouped methods on this occasion. The methods were pooled when analysing the results.

For all methods pooled, the median and its standard uncertainty for the Vickers hardness results was 112.0 ± 1.3 HV.

The CV for the Vickers hardness results for this round was 3.0%. This is higher than the CV of 2.3%, obtained for the Vickers hardness results in Round 14 of this program (see Report No. 1101).

There were no outliers reported for Vickers hardness.

Nine laboratories reported measurement uncertainties associated with their Vickers hardness test results in this round.

6.5 Rockwell B Hardness

A total of nine laboratories tested the sample for Rockwell B hardness. Of these laboratories, six tested using the AS 1815 method. One laboratory tested using the ISO 6508 method. One laboratory tested using the ASTM E18 method. One laboratory did not specify the method they used for testing (see Appendix A4 for more details).

There were not enough results submitted for any specific method to draw reliable conclusions from analysing grouped methods on this occasion. The methods were pooled when analysing the results.

For all methods pooled, the median and its standard uncertainty for the Rockwell B hardness results was 60.50 ± 1.24 HRB.

The CV for the Rockwell B hardness results for this round was 4.9%. This is higher than the CV of 1.8%, obtained for the Rockwell B hardness results in Round 14 of this program (see Report No. 1101).

There were no outliers reported for Rockwell B hardness.

Eight laboratories reported measurement uncertainties associated with their Rockwell B hardness test results in this round.

6.6 Measurement Uncertainty

The number and percentage of laboratories that reported estimates of their measurement uncertainty for each test is as follows:

- Brinell Hardness 9 out of 10 90%
- Vickers Hardness 9 out of 10 90%
- Rockwell B Hardness 8 out of 9 89%

The variation between the estimates of measurement uncertainty ranged from not reporting at all, to some reporting numerical values, while others reported percentages. One laboratory (code 6) reported an estimate of measurement uncertainty as 0.42 HRC, while their test results were in HRB.

Any laboratory that reported a measurement uncertainty less than two times the uncertainty of the median may have underestimated their measurement uncertainty.

Any laboratory that reported a measurement uncertainty greater than three times the normalised IQR may have overestimated their measurement uncertainty.

All participants are highly encouraged to report and use measurement uncertainty, so that the program analysis can provide a better outlook of the overall performance for this program.

6.7 General Comments

There was only one reported outlier for this round of the program. This was not unexpected, especially for Brinell Hardness testing. This is because hardness testing on aluminium is not generally asked for, as compared to testing on steels. Therefore, not all the participating laboratories may have had the experience to successfully test and report hardness properties of aluminium samples, especially using the Brinell Hardness test method.

One of the most important factors for any hardness test is to ensure that the indentation spacing is sufficient enough to achieve accurate results. This is especially true when there are different indenter sizes and applied loads, as in this proficiency testing program. It is also highly recommended that participants use the smaller loads first, to avoid a larger area having residual stresses, which may produce higher test results.

Since hardness tests are comparative in nature, it is very important to ensure that the area of testing is highlighted on the samples for proficiency testing purposes. This area is very important, as there may exist some variation in the hardness value from the middle section to the edges of the specimen. The samples were grooved this round to indicate the area to be tested, to help get a better understanding of the hardness results based on the sample size, shape and location.

The test report return rates of 83% for Brinell and Vickers Hardness, as well as 75% for Rockwell B hardness, suggest that the program instructions may not have been understood thoroughly. The purpose of these proficiency testing programs is to evaluate the validity of the test results reported by the participants. Irrespective of restrictions from the testing equipment, the test return rate could be improved greatly if the right techniques are applied. Using hardness conversion charts (ISO 18265 or AS 5016), the participating laboratories can verify the accuracy of the nominated hardness test results using conditions other than recommended as per the test instructions.

For the next round of this program it is suggested that the hardness tests should be taken inside the grooves on the aluminium test samples. The groove will be made at $0.50 \times \text{Radius}$.

7. REFERENCES

1. *Guide to Proficiency Testing Australia (2016)*. (This document is located on the PTA website at www.pta.asn.au under Programs / Documents).
2. *ISO/IEC 17043: 2010 Conformity assessment - General requirements for proficiency testing*.
3. *AS 1815.1: 2007 Metallic materials – Rockwell hardness test – Test method (scales A, B, C, D, E, F, G, H, K, N, T)*.
4. *AS 1816.1: 2007 Metallic materials – Brinell hardness test – Test method (ISO 6506-1: 2005, MOD)*.
5. *AS 1817.1: 2003 Metallic materials – Vickers hardness test – Test method (ISO 6507-1: 1997, MOD)*.
6. *ISO 6506-1: 2014 Metallic materials – Brinell hardness test – Part 1: Test method*.
7. *ISO 6507-1: 2018 Metallic materials – Vickers hardness test – Part 1: Test method*.
8. *ISO 6508-1: 2016 Metallic materials – Rockwell hardness test – Part 1: Test method*.
9. *ASTM E10 – Standard Test Method for Brinell Hardness of Metallic Materials*.
10. *ASTM E18 – Standard Test Methods for Rockwell Hardness of Metallic Materials*.
11. *ASTM E92 – Standard Test Method for Vickers Hardness and Knoop Hardness of Metallic Materials*.

APPENDIX A

Summary of Results

Section A1

Brinell Hardness

A1.1

Brinell Hardness (HBW) – Results and Z-Scores

Lab Code	Scale	Temp. (°C)	Test 1	Test 2	Test 3	Average	MU (±)	Z-Score
1	5/250/15	28	102	103	106	104	2.4	-0.36
2	10/3000/12	24	103	102	103	102.66	-	-0.84
3	10/3000/30	23	98	98, 101	99, 103	100	7.2	-1.80
4	5/250	28.8	27.4	28.4	27.7	27.8	3	-27.80 §
5	10/500/12	22.8	109	109	109	109	8.0	1.44
7	10/3000/22	22	99	109	116	108	2	1.08
8	10/500/15	21.4	104	104	109	106	3.76%	0.36
9	5/250/15	22	106	106	107	106	2	0.36
11	5/250	22.4	106	106	106	106	3	0.36
12B	5/125/15	24	104	103	103	103	0.58	-0.72

Summary Statistics

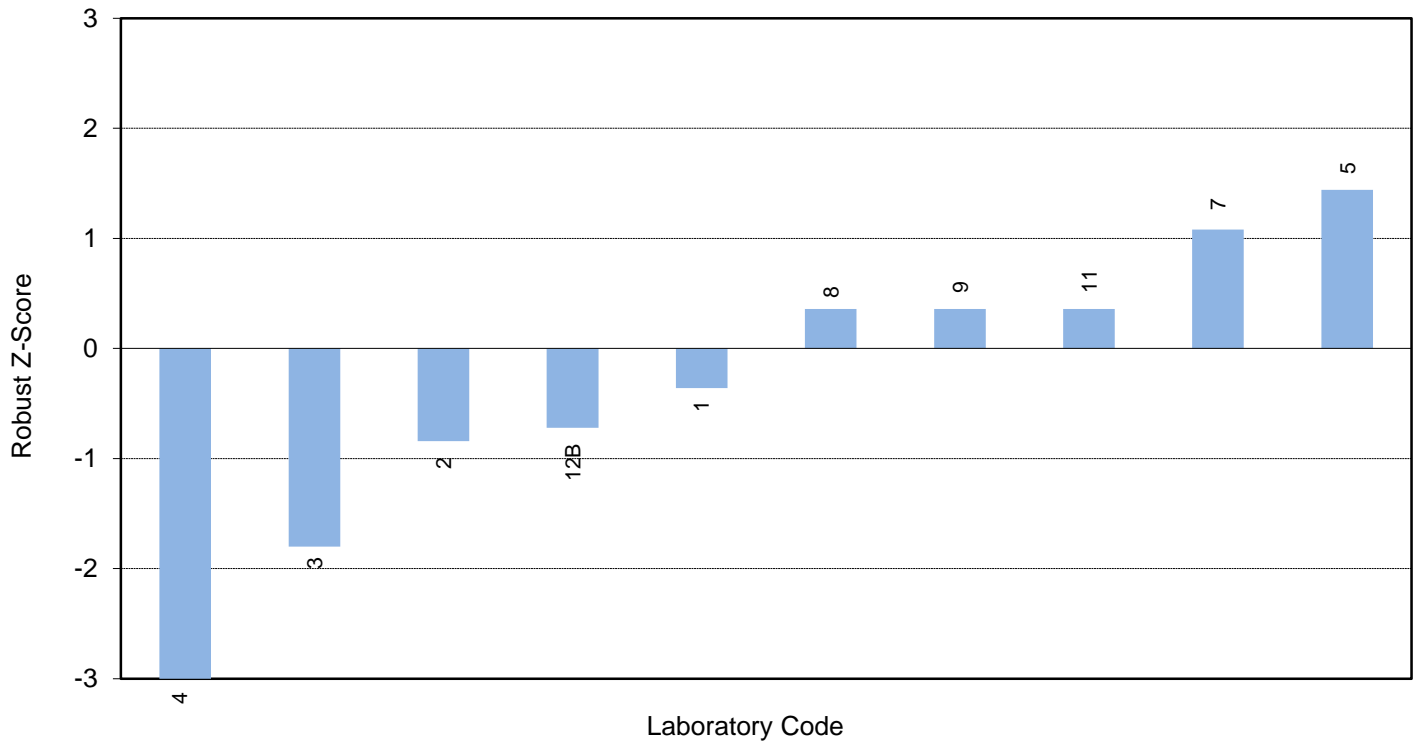
Statistic	Average Result
Number of Results	10
Median	105.0
Normalised IQR	2.8
Uncertainty (Median)	1.1
Robust CV	2.6%
Minimum	28
Maximum	109
Range	81

Notes:

1. § denotes an outlier (i.e. |z-score| ≥ 3.0).
2. The results for all test methods were pooled for analysis.
3. Summary statistics and z-scores have been calculated for the average results reported.

A1.2

Brinell Hardness (HBW)



Section A2

Vickers Hardness

A2.1

Vickers Hardness (HV) – Results and Z-Scores

Lab Code	Load	Temp. (°C)	Test 1	Test 2	Test 3	Average	MU (±)	Z-Score
1	2	28	107	109	110	109	1.8	-0.90
2	10	24	107.95	108.96	108.45	108.45	-	-1.06
3	2	23	112	113, 113	112, 112	112	3.6	0.00
6	5	26.2	113	118	113	115	1.4%	0.90
7	10	22	111	111	114	112	0.9	0.00
8	10	21.4	116	118	114	116	3.76%	1.20
9	2.5	22	112	111	111	111	3	-0.30
10	2.5	23.3	116	115	115	115.3	4.4	0.99
11	2	22.3	106	110	111	109	3	-0.90
12A	10	24	114	114	113	114	0.58	0.60
12B	20	24	114	114	114	114	0	0.60

Summary Statistics

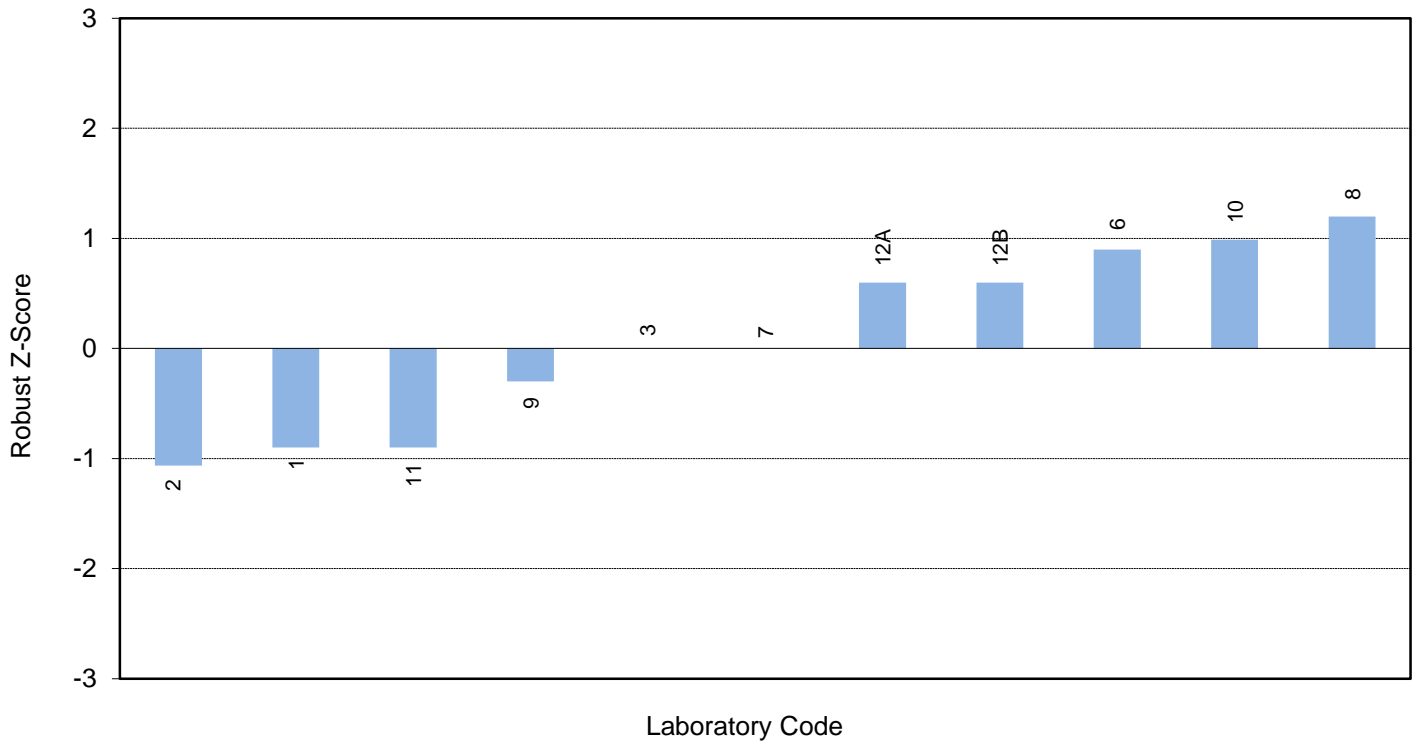
Statistic	Average Result
Number of Results	11
Median	112.0
Normalised IQR	3.3
Uncertainty (Median)	1.3
Robust CV	3.0%
Minimum	108
Maximum	116
Range	8

Notes:

1. The results for all test methods were pooled for analysis.
2. Summary statistics and z-scores have been calculated for the average results reported.

A2.2

Vickers Hardness (HV)



Section A3

Rockwell B Hardness

A3.1

Rockwell B Hardness (HRB) – Results and Z-Scores

Lab Code	Temp. (°C)	Test 1	Test 2	Test 3	Average	MU (±)	Z-Score
1	28	57.6	58.1	58.9	58.2	0.8	-0.77
2	24	60.4	59.4	60.1	59.96	-	-0.18
3	23	62.2	62.3, 62.6	62.5, 62.2	62.3	1.2	0.61
4	28.8	57.0	56.4	55.7	56.4	0.83	-1.38
6	25	58.8	58.2	59.5	58.8	0.42 HRC	-0.57
7	22	61.0	63.0	62.0	62.0	2	0.50
8	21.4	62	63	63	63	3.76%	0.84
10	23.3	62	62.5	62	62.2	0.5	0.57
11	22.3	59.4	61.0	61.1	60.5	1.5	0.00

Summary Statistics

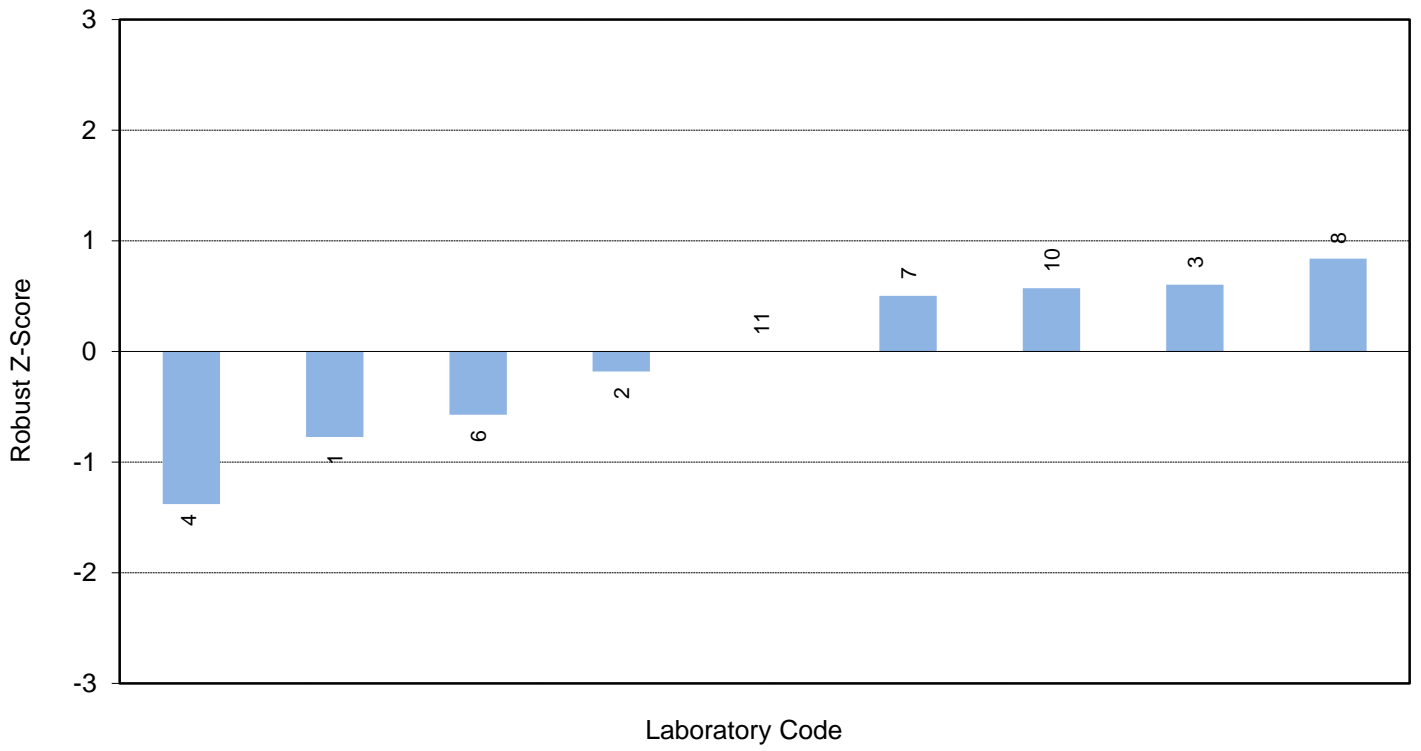
Statistic	Average Result
Number of Results	9
Median	60.50
Normalised IQR	2.97
Uncertainty (Median)	1.24
Robust CV	4.9%
Minimum	56.4
Maximum	63.0
Range	6.6

Notes:

1. The results for all test methods were pooled for analysis.
2. Summary statistics and z-scores have been calculated for the average results reported.

A3.2

Rockwell B Hardness (HRB)



Section A4

Methods Used and Surface Preparation

A4.1

Methods Used

Lab Code	Brinell Hardness	Vickers Hardness	Rockwell B Hardness
1	AS 1816.1 - 2007	AS 1817.1 - 2007	AS 1815.1 - 2007
2	ASTM E10	ASTM E92	ASTM E18
3	AS 1816.1 - 2007	AS 1817.1 - 2007	AS 1815.1 - 2007
4	ISO 6506.1	-	ISO 6508.1
5	ASTM E10-18	-	-
6	-	AS 1817.1	AS 1815.1
7	-	-	-
8	AS 1816.1	AS 1817.1	AS 1815.1
9	ASTM E10	ASTM E92	-
10	-	AS 1817.1 - 2003	AS 1815.1 - 2007
11	AS 1816.1	AS 1817.1	AS 1815.1
12A	-	AS 1817.1	-
12B	AS 1816.1	AS 1817.1	-

A4.2

Surface Preparation

Lab Code	Preparation Details
1	The surface has been polished using SiC abrasive paper (2000 grit).
2	Finish surface grinding on test surface.
3	Ground and polish finished with OPS.
4	No surface preparation performed.
5	Struer silicon carbide paper P1200 was used to remove the rough scratches (lines) on the test surface of the received sample.
6	Brinell could not be done as we do not have the correct ball size or load.
7	Polished with wet & dry to 1200 grit then polished to 3 μ m diamond paste.
8	Polished with wet/dry sandpaper (using water) 80, 320, 600, 1200 grit (all testing carried out at 1200 grit) condition.
9	The test sample was polished using 600 and 1000 grit of abrasive paper with water.
10	Wet ground sample from 240 grit down to 1200 grit, then diamond polished down to a 1 micron finish.
11	No surface preparation performed.
12A	-
12B	-

APPENDIX B

Homogeneity Testing

B1.1

HOMOGENEITY TESTING

Before the samples were distributed to participants, eight randomly selected samples were tested for homogeneity by ARL Laboratory Services Pty Ltd. Eight hardness measurements were made around the testing area, for each of the eight samples, for each hardness test. The results of the homogeneity testing are displayed below:

Homogeneity Testing Results

Brinell HBW 5/250

Sample No.	Result 1	Result 2	Result 3	Result 4	Result 5	Result 6	Result 7	Result 8	Average
4	102	103	102	104	102	102	101	103	102.4
5	102	103	103	104	102	103	101	103	102.6
11	101	102	101	102	103	104	102	101	102.0
18	101	99.5	99.5	101	102	101	101	102	100.9
21	101	103	102	101	102	101	103	101	101.8
23	103	103	102	103	102	104	103	103	102.9
31	106	104	104	99	102	104	101	104	103.0
35	99.5	98.3	101	101	98.3	103	102	102	100.6

Vickers HV 2

Sample No.	Result 1	Result 2	Result 3	Result 4	Result 5	Result 6	Result 7	Result 8	Average
4	107	112	111	114	108	112	114	113	111.4
5	115	115	112	114	113	114	109	109	112.6
11	111	112	110	108	113	109	112	110	110.6
18	111	107	109	111	109	110	112	111	110.0
21	109	112	110	109	111	110	111	110	110.3
23	112	116	112	111	114	111	113	110	112.4
31	110	110	109	109	107	111	113	111	110.0
35	110	109	109	115	113	115	113	112	112.0

B1.2

Rockwell B HRB

Sample No.	Result 1	Result 2	Result 3	Result 4	Result 5	Result 6	Result 7	Result 8	Average
4	57.5	58.0	56.0	56.4	55.5	56.0	55.5	55.5	56.30
5	54.1	54.4	55.3	56.0	56.5	55.4	56.1	55.1	55.36
11	53.5	54.2	54.5	54.0	56.2	57.6	56.7	57.0	55.46
18	56.8	56.7	56.9	56.7	56.1	56.8	58.2	56.8	56.88
21	55.6	56.3	56.2	55.2	56.5	56.5	55.6	57.2	56.14
23	54.0	57.0	55.4	55.9	55.8	56.5	56.9	55.7	55.90
31	54.5	55.3	56.0	56.0	57.3	57.2	57.7	56.5	56.31
35	54.0	48.2	55.5	55.7	55.2	55.3	49.6	54.6	53.51

Analysis of the homogeneity testing data indicated that the samples were sufficiently homogeneous for the program and, therefore, any participant results identified as outliers cannot be attributed to sample variability.

APPENDIX C

Instructions to Participants and Results Sheet

Hardness Testing Of Metals Proficiency Testing Program Round 15, December 2018

Instructions to Participants

To ensure that the results of this program can be analysed correctly, participants are asked to adhere carefully to these instructions.

- 1) The sample for this hardness testing program consists of an aluminium sample, approximately 65 mm in diameter and 40 mm thick. The sample has a number labelled on the circumference.
- 2) The sample is to be tested for Brinell, Vickers and Rockwell 'B' hardness. The samples contain two grooves. The testing area is to be between these grooves. Participants may wish to improve the surface to provide a better testing surface.
- 3) Although the hardness loading scales and conditions are at the discretion of the participating laboratories, the following loading conditions have proven to provide consistent results: HV2, HRB, and HBW 5/250.
- 4) The sample should be treated as a routine laboratory sample. All testing, recording and reporting is to be performed in accordance with your routine test methods.
- 5) Please use the attached Result Sheet to record and report your results to Proficiency Testing Australia. Please also report the method used for testing (e.g. AS 1816.1, ISO 6506.1, etc. for Brinell hardness testing, AS 1817.1, ISO 6507.1, etc. for Vickers hardness testing, AS 1815.1, ISO 6508.1, etc. for Rockwell HRB hardness testing).
- 5) Do not discard the hardness test sample until you have received the final report. You may be asked to carry out a retest or to return the sample to Proficiency Testing Australia for retesting at the laboratory that performed the homogeneity tests.
- 6) For this program, your laboratory has been allocated the code number on the attached Results Sheet. All reference to your laboratory in reports associated with this program will be via this code number, thus ensuring the confidentiality of your results.
- 7) Laboratories are also requested to calculate and report an estimate of uncertainty of measurement for each reported measurement result. All estimates of uncertainty of measurement must be given as a 95% confidence interval (coverage factor $k \approx 2$).
- 8) Return the Results Sheet, either by mail, email or facsimile, to:

Mark Bunt Proficiency Testing Australia PO Box 7507 Silverwater NSW 2128 AUSTRALIA Telephone: + 61 2 9736 8397 (1300 782 867) Fax: +61 2 9743 6664 Email: mbunt@pta.asn.au

All results should arrive at the above address by no later than **Friday 18 January 2019**. Results reported later than this date may not be analysed in the final report.

Hardness Testing Of Metals Proficiency Testing Program

Round 15, December 2018

RESULTS SHEET

Laboratory Code:

Sample I.D.	Scale	Report to nearest	Test Temp °C	Results					Standard (AS, ISO, etc.)
				Test 1	Test 2	Test 3	Average	MU (±)	
	Brinell (/ /) (mm/kg/s)	1 BHN							
	HV () Insert load used	1 HV							
	HRB	0.1 HRB							

Did you carry out surface preparation on the obverse surfaces of the samples for the hardness tests?
Yes / No

If Yes, please give details of preparation.

.....

.....

.....

.....

.....

.....

Print Name: _____

Signature: _____

Date: _____

-----End of Report-----