

REPORT NO. 808

**Hardness Testing of Metals
Proficiency Testing Program
Round 4**

May 2013

ACKNOWLEDGMENTS

PTA wishes to gratefully acknowledge the technical assistance provided for this program by Mr I Harrison, Amdel Limited, Whyalla Laboratory, OneSteel Site, a Division of Bureau Veritas Australia Pty Ltd. This assistance included providing input into the design of the program, technical advice and discussion of the final report, as well as supplying the samples.

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PO Box 7507 Silverwater NSW 2128 AUSTRALIA

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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 fourth round of an ongoing series of programs.

Proficiency Testing Australia conducted the testing program in March 2013. 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 I Harrison, Amdel Limited, Whyalla Laboratory, OneSteel Site, a Division of Bureau Veritas Australia Pty Ltd. This report was authorised by Mr P Briggs, PTA General Manager.

2. FEATURES OF THE PROGRAM

- (a) A total of 47 laboratories participated in the program. Two of these laboratories did not return results for inclusion in the final report. Laboratories from the following states and countries received samples:

| | |
|----|--------------|
| 10 | NSW |
| 8 | VIC |
| 6 | SA |
| 5 | WA |
| 2 | QLD |
| 1 | TAS |
| 9 | IRAN |
| 1 | BRAZIL |
| 1 | HONG KONG |
| 1 | MALAYSIA |
| 1 | SAUDI ARABIA |
| 1 | SINGAPORE |
| 1 | TAIWAN |

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 some laboratories reported more than one set of results and, therefore, these laboratories' code numbers (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 a micro-alloyed Rails steel section 65 mm x 40 mm x 11 mm, conforming to AS/NZS 3679.1. The sample was to be tested for both both Vickers and Rockwell B testing. Each sample was pre-prepared for testing but participants could improve the surface to provide a better testing surface.

- (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 Amdel Limited, Whyalla Laboratory, OneSteel Site. Based on the results of this testing, the homogeneity of the samples was established (see Appendix B).
- (f) The samples were also tested for stability by Amdel Limited, Whyalla Laboratory, OneSteel Site. The analysis of the stability testing results showed that the samples were sufficiently stable for testing for the duration of the program (see Appendix B).

3. FORMAT OF THE APPENDICES

- (a) Appendix A is divided into three sections (A1-A3).

Sections A1-A2 contain the analysis of results reported by laboratories for Vickers and Rockwell 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 A3 contains information on the methods used by the participants and the surface preparations they performed.

- (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

For each statistically analysed test, robust statistical procedures were used to generate the z-scores and summary statistics for each hardness determination - number of results, median, normalised interquartile range (IQR), uncertainty of the median, robust coefficient of variation (CV), minimum, maximum and range.

For each participant, the robust z-score calculated for each hardness result was based on the average hardness value reported for each test.

5. OUTLIER RESULTS

Robust z-scores have been used to assess each laboratory's testing performance. When calculated from single results, z-scores are used to detect excessively high or excessively low results in comparison to the consensus value (the median). Any result with an absolute z-score greater than or equal to 3.0 (*i.e.* ≤ -3.0 or ≥ 3.0) is classified as an outlier.

For further details on the calculation and interpretation of robust z-scores, please see reference [1].

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

Table A: Summary Statistics for All Tests

| Test | Summary Statistics | Average Result |
|---------------------|----------------------|----------------|
| Vickers (HV) | Number of Results | 45 |
| | Median | 330.00 |
| | Normalised IQR | 6.67 |
| | Uncertainty (Median) | 1.25 |
| Rockwell B (HRB) | Number of Results | 19 |
| | Median | 107.80 |
| | Normalised IQR | 0.74 |
| | Uncertainty (Median) | 0.21 |
| Rockwell C (HRC) | Number of Results | 17 |
| | Median | 33.70 |
| | Normalised IQR | 0.74 |
| | Uncertainty (Median) | 0.23 |

Notes:

1. For each test, the results for all test methods were pooled for analysis.
2. Summary statistics were calculated for the average hardness value reported for each test.
3. The uncertainty of the median was calculated as: $\sqrt{\frac{\pi}{2}} \times \frac{normIQR}{\sqrt{n}}$.
4. A number of participants reported the Rockwell C hardness of the sample because the hardness of the sample was above the maximum range of the Rockwell B scale.

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

| Test | Outliers |
|------------------|-----------------|
| Vickers (HV) | - |
| Rockwell B (HRB) | 7 |
| Rockwell C (HRC) | - |

6. PTA AND TECHNICAL ADVISER'S COMMENTS

Consensus values (medians), 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

Forty-five of the 47 (96%) laboratories that participated in the program returned results. Of these 45 laboratories, 33 (73%) submitted results for both tests.

The return rate for all tests is as follows:

- Vickers Hardness 43 out of 45 96%
- Rockwell Hardness 35 out of 45 78%

6.2 Performance summary

One or more statistical outliers were reported by one of the 45 laboratories (2%) that returned results in this round of the program. For comparison, 13% of the participants reported outlier results in Round 3 of this program (see Report No. 756B for more details).

A total of 81 results were analysed in this program. Of these results, one (1%) was an outlier result. For comparison, 7% of the results analysed in Round 3 of this program were outlier results (see Report No. 756B for more details).

6.3 Vickers Hardness

A total of 43 laboratories tested the sample for Vickers hardness. Of these laboratories, 28 tested using the AS 1817.1 method, including one laboratory (code 42) that reported three sets of results. Four laboratories tested using the ISO 6507-1 method. Five laboratories tested using ASTM methods. Six laboratories did not report the method they used for testing (see Appendix A3 for more details).

For the laboratories that used the AS 1817.1 method, the median and standard error of the Vickers hardness results was 330.00 ± 1.40 HV. For all methods pooled, the median and standard error of the Vickers hardness results was 330.00 ± 1.25 HV.

The methods were pooled when analysing the results.

The last round of the Hardness Testing of Metals program in which the participants tested a sample for Vickers hardness was Round 2. The CV for the Vickers hardness results for this round was 2.02%. This compares well with the CV of 2.39%, obtained for the sample tested for Vickers hardness in Round 2 of this program (see Report No. 703).

There were no outliers reported for Vickers hardness. Four other laboratories (codes 3, 20, 28 and 32) obtained $|z\text{-scores}| > 2.0$.

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

6.4 Rockwell Hardness

Laboratories were requested to test the sample they received for this program for Rockwell B hardness. Because the hardness of the sample was above the maximum range of the Rockwell B scale, three laboratories (codes 4, 34 and 36) reported that they could not report Rockwell B hardness results. Another 16 laboratories reported Rockwell C hardness results, instead of Rockwell B hardness. Eighteen laboratories reported Rockwell B hardness, while one laboratory (code 43) reported results for both Rockwell B and Rockwell C hardness. Both the Rockwell B and Rockwell C results were analysed for this round of the program.

Of the 35 laboratories that reported results for Rockwell hardness, 20 tested using the AS 1815.1 method. Four laboratories tested using the ISO 6508-1 method. One laboratory reported using both AS 1815.1 and ISO 6508-1. Four laboratories tested using ASTM methods. Six laboratories did not report the method they used for testing (see Appendix A3 for more details).

For the Rockwell B results, the median and standard error of the laboratories that used the AS 1815.1 method was 108.10 ± 0.43 HRB, while the median and standard error for all methods pooled was 107.80 ± 0.21 HRB.

For the Rockwell C results, the median and standard error of the laboratories that used the AS 1815.1 method was 33.82 ± 0.17 HRC, while the median and standard error for all methods pooled was 33.70 ± 0.23 HRC.

The methods were pooled when analysing the Rockwell B and Rockwell C results.

The CV for the Rockwell B hardness results was 0.69%. This is lower than the CV of 2.16%, obtained for the sample tested for Rockwell B hardness in Round 3 of this program (see Report No. 756B).

For Rockwell B hardness, one laboratory (code 7) reported an outlier result. One other laboratory (code 47) obtained an $|z\text{-score}| > 2.0$.

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

The last round of the Hardness Testing of Metals program in which the participants tested a sample for Rockwell C hardness was Round 2. The CV for the Rockwell C hardness results for this round was 2.20%. This is higher than the CV of 1.53%, obtained for the sample tested for Rockwell C hardness in Round 2 of this program (see Report No. 703).

There were no outliers reported for Rockwell C hardness. One other laboratory (code 19) obtained a $|z\text{-score}| > 2.0$.

Four laboratories reported measurement uncertainties associated with their Rockwell C hardness test results in this round.

6.5 General Comments

A number of participants made comments about the suitability of using the Rockwell B scale in determining the hardness of the test blocks. Technically, these comments are correct, and the Rockwell C scale would have been the better choice for testing. It is pleasing that several laboratories noted this and performed the tests in the Rockwell C scale. However, the intent for this round of the program was to simulate the provision of samples by a customer, who was seeking information. The Rockwell B scale was selected, even though the readings obtained exceeded the range expected when using Rockwell B. In this case, it would be the testing laboratories' responsibility to provide the information in the scale requested by the customer, even though the scale requested was not the most appropriate.

7. REFERENCES

1. *Guide to Proficiency Testing Australia (2012)*. (This document is located on the PTA website at www.pta.asn.au under Programs / Documents).
2. *AS 1815.1-2007 Metallic materials – Rockwell hardness test – Test method (scales A, B, C, D, E, F, G, H, K, N, T)*.
3. *AS 1817.1-2003 Metallic materials – Vickers hardness test – Test method (ISO 6507-1: 1997, MOD)*.
4. *ISO 6507-1: 2005 Metallic materials – Vickers hardness test – Part 1: Test method*.
5. *ISO 6508-1: 2005 Metallic materials – Rockwell hardness test – Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*.
6. *AS/NZS 3679.1-2010 Structural steel - Hot-rolled bars and sections*.

APPENDIX A

Summary of Results

Section A1

Vickers Hardness

A1.1

Vickers Hardness (HV) – Results and Z-Scores

| Lab Code | Temp. (°C) | Test 1 | Test 2 | Test 3 | Average | MU (±) | Z-Score |
|----------|------------|----------|----------|--------|---------|--------|---------|
| 1 | 25 | 318 | 321 | 318 | 319 | - | -1.65 |
| 2 | 25 | 334 | 334 | 334 | 334 | - | 0.60 |
| 3 | 20 | 348 | 344 | 341 | 344 | 12.5 | 2.10 |
| 4 | - | 315 | 330 | 320 | 321.67 | - | -1.25 |
| 5 | 24 | 327 | 325 | 329 | 327 | - | -0.45 |
| 6 | 22 | 325 | 322 | 325 | 324 | - | -0.90 |
| 7 | 21 | 330 | 336 | 327 | 331 | - | 0.15 |
| 8 | 23.5 | 326.9 | 325.8 | 329.4 | 327.4 | 2.9 | -0.39 |
| 10 | 21 | 333.0 | 332.0 | 340.3 | 335.4 | - | 0.81 |
| 11 | 20 | 330 | 331 | 329 | 330 | - | 0.00 |
| 12 | 21 | 322.0 | 325.0 | 325.0 | 324.0 | - | -0.90 |
| 13 | 21.7 | 325 | 331.7 | 329 | 328.6 | - | -0.21 |
| 14 | 23 | 333 | 331 | 329 | 331 | - | 0.15 |
| 15 | 21 | 335 | 334 | 333 | 334 | 5.7 | 0.60 |
| 16 | 23 ± 5 | 338 | 343 | 340 | 340.3 | - | 1.54 |
| 17 | 23.2 | 323 | 320 | 321 | 321.3 | 1.8 | -1.30 |
| 18 | 23 | 326.0 | 326.8 | 327.6 | 326.8 | 8.4 | -0.48 |
| 19 | 22 | 327 | 322 | 329 | 326 | - | -0.60 |
| 20 | 25 | 339 | 346 | 346 | 343.6 | 10% | 2.04 |
| 21 | 22 | 330 | 325 | 335 | 330 | - | 0.00 |
| 23 | 21 | 323.5 | 321.0 | 324.5 | 323.0 | - | -1.05 |
| 24 | - | 322 | 330 | 325 | 325.7 | - | -0.64 |
| 25 | 20 | 332 | 330 | 333 | 332 | - | 0.30 |
| 26 | 27 | 329.9 | 340.3 | 336.1 | 335.4 | 4.6 | 0.81 |
| 27 | 23 | 328 | 329 | 329 | 329.3 | 3.46 | -0.10 |
| 28 | 22.5 | 345.9 | 346.2 | 343.2 | 345.1 | 0.5 | 2.26 |
| 30 | 26 | 320 | 322 | 321 | 321 | - | -1.35 |
| 31 | 21 | 331 | 329 | 329 | 329 | 1.4% | -0.15 |
| 32 | 24.0 | 348.2 | 346.9 | 353.8 | 349.6 | 5.3 | 2.94 |
| 33 | 21 | 334 | 325 | 329 | 329 | 3.10 | -0.15 |
| 34 | 21 | 327 | 328 | 325 | 327 | 3.3 | -0.45 |
| 35 | 22 | 338 | 338 | 338 | 338 | - | 1.20 |
| 36 | 21 | 335 | 333 | 333 | 334 | - | 0.60 |
| 38 | - | 327 | 333 | 335 | 331.7 | - | 0.25 |
| 39 | - | 318 | 318 | 343 | 326.3 | - | -0.55 |
| 40 | 21 | 347.7 | 338.0 | 324.5 | 336.7 | 16.2 | 1.00 |
| 41 | - | 327 | 336 | 327 | 330 | 3.7 | 0.00 |
| 42A | 22 | 329, 314 | 325, 317 | 323 | 322 | - | -1.20 |

A1.2

Vickers Hardness (HV) – Results and Z-Scores

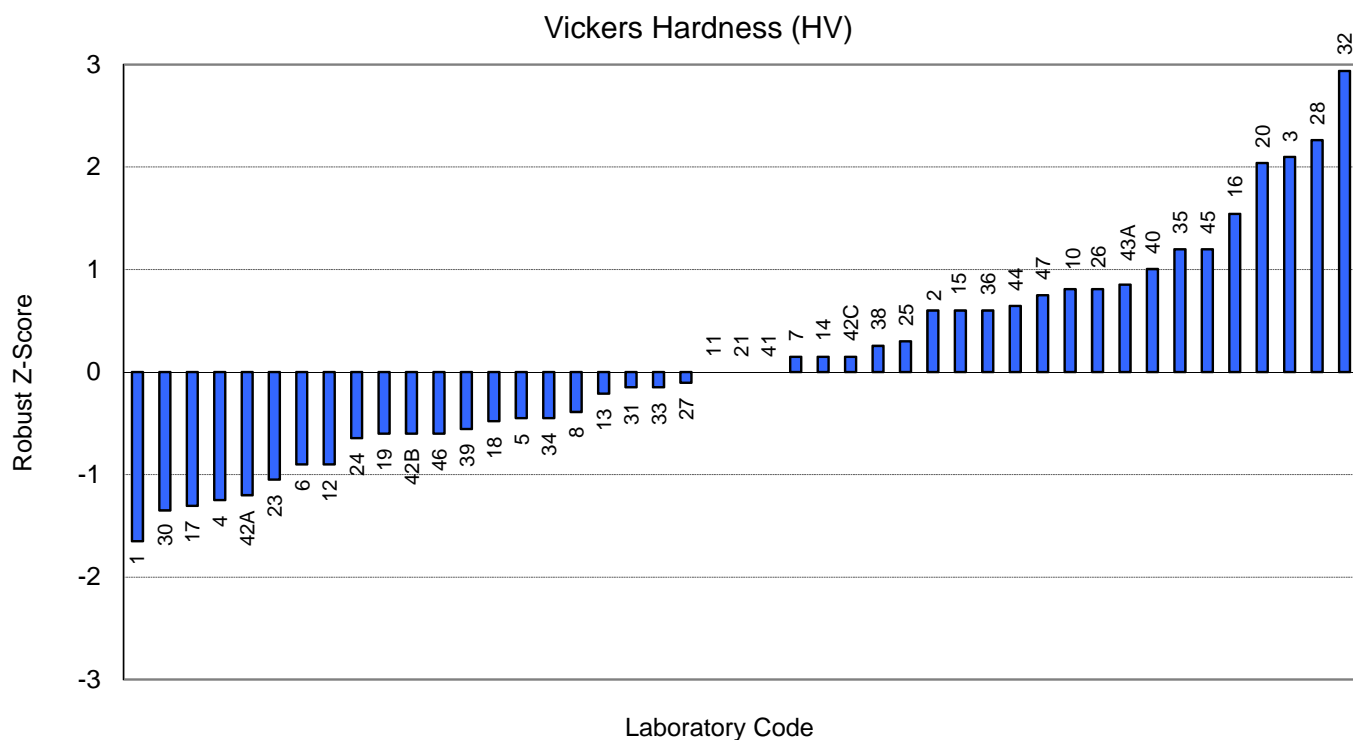
| Lab Code | Temp. (°C) | Test 1 | Test 2 | Test 3 | Average | MU (±) | Z-Score |
|----------|------------|----------|----------|--------|---------|--------|---------|
| 42B | 22 | 320, 327 | 331, 326 | 327 | 326 | - | -0.60 |
| 42C | 22 | 336, 332 | 331, 330 | 328 | 331 | - | 0.15 |
| 43A | 28 | 338 | 333 | 336 | 335.7 | 5.62 | 0.85 |
| 44 | 22.5 | 339 | 331 | 333 | 334.3 | 4.21 | 0.64 |
| 45 | 23 | 332 | 342 | 340 | 338.0 | 2.96 | 1.20 |
| 46 | 21 | 327 | 329 | 323 | 326 | - | -0.60 |
| 47 | 23 | 333 | 339 | 333 | 335.0 | 3.4 | 0.75 |

Summary Statistics

| Statistic | Average Result |
|----------------------|----------------|
| Number of Results | 45 |
| Median | 330.00 |
| Normalised IQR | 6.67 |
| Uncertainty (Median) | 1.25 |
| Robust CV | 2.02% |
| Minimum | 319.0 |
| Maximum | 349.6 |
| Range | 30.6 |

Notes:

1. Summary statistics and z-scores have been calculated for the average results reported.
2. Laboratory 42 submitted three sets of results for Vickers hardness and submitted five results, instead of three, for each set of results.



Section A2

Rockwell Hardness

A2.1

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

| Lab Code | Temp. (°C) | Test 1 | Test 2 | Test 3 | Average | MU (±) | Z-Score |
|----------|------------|--------|--------|--------|---------|--------|----------|
| 2 | 25 | 108 | 108 | 109 | 108.33 | - | 0.71 |
| 4 | - | - | - | - | - | - | - |
| 5 | 24 | 107.5 | 107.5 | 107.5 | 107.5 | - | -0.40 |
| 7 | 21 | 60 | 63 | 63 | 62 | - | -61.78 § |
| 8 | 23.5 | 107.8 | 107.7 | 107.5 | 107.6 | - | -0.27 |
| 13 | 21.4 | 106.9 | 107.1 | 107.3 | 107.1 | - | -0.94 |
| 16 | 23 ± 5 | 107.8 | 107.6 | 108.1 | 107.8 | - | 0.00 |
| 18 | 23 | 107.4 | 107.7 | 107.3 | 107.5 | 3.2 | -0.40 |
| 21 | 22 | 109 | 108 | 110 | 109 | - | 1.62 |
| 23 | - | 108.3 | 108.3 | 108.6 | 108.4 | 0.3 | 0.81 |
| 26 | 27 | 107.6 | 107.5 | 107.6 | 107.6 | 1.25 | -0.27 |
| 27 | 23 | 108 | 109 | 108 | 108 | 1.38 | 0.27 |
| 28 | 22.4 | 108.5 | 108.4 | 108.6 | 108.5 | 0.5 | 0.94 |
| 29 | 22 | 107.2 | 107.6 | 107.4 | 107.4 | 0.40 | -0.54 |
| 30 | 26 | 109 | 109 | 109 | 109 | - | 1.62 |
| 31 | 21 | 108.5 | 109 | 108.5 | 108.5 | - | 0.94 |
| 34 | - | - | - | - | - | - | - |
| 36 | 21 | - | - | - | - | - | - |
| 40 | 21 | 107.9 | 107.5 | 107.5 | 107.6 | 0.7 | -0.27 |
| 43A | 27 | 109.0 | 108.5 | 109.0 | 109.0 | 1.10 | 1.62 |
| 46 | 21 | 107 | 108 | 108 | 107.5 | - | -0.40 |
| 47 | 23 | 109.5 | 109.1 | 109.6 | 109.4 | 1.0 | 2.16 |

Summary Statistics

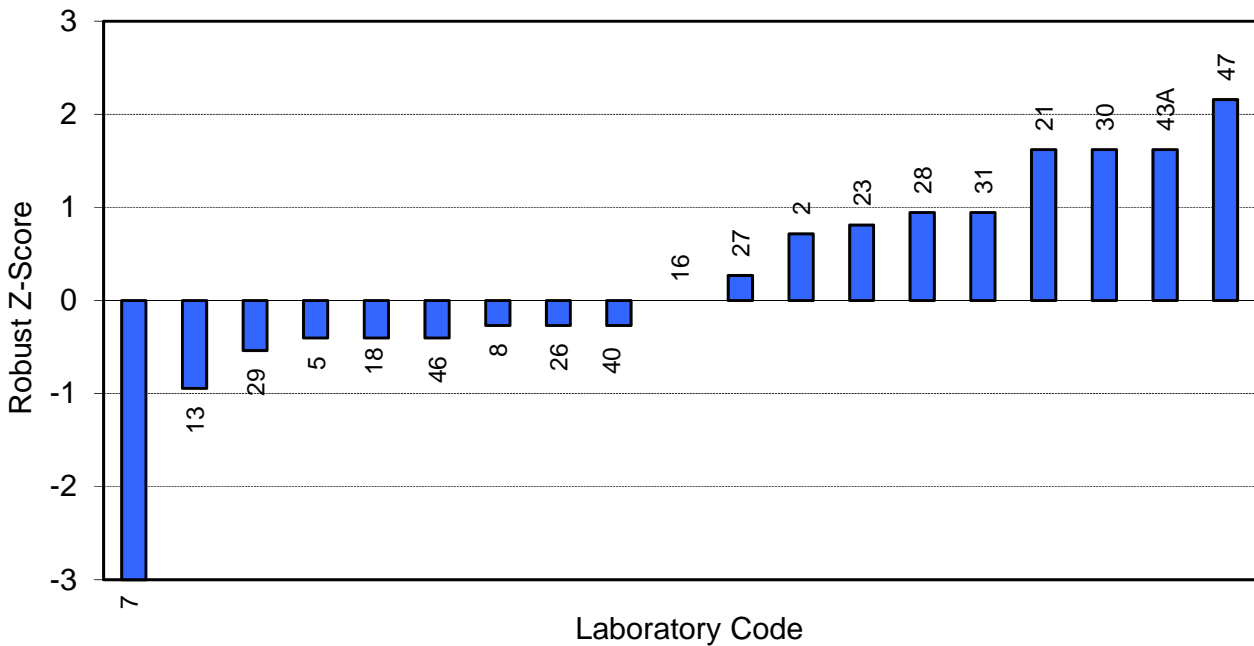
| Statistic | Average Result |
|----------------------|----------------|
| Number of Results | 19 |
| Median | 107.80 |
| Normalised IQR | 0.74 |
| Uncertainty (Median) | 0.21 |
| Robust CV | 0.69% |
| Minimum | 62.0 |
| Maximum | 109.4 |
| Range | 47.4 |

A2.2

Notes:

1. § denotes an outlier (i.e. $|z\text{-score}| \geq 3.0$).
2. Summary statistics and z-scores have been calculated for the average results reported.
3. Laboratories 4, 34 and 36 commented that they did not report Rockwell B hardness results because the hardness of the sample was above the maximum range of the Rockwell B scale.
4. Laboratory 43 reported both Rockwell B and Rockwell C hardness results. Their Rockwell B hardness results have been assigned the laboratory code 43A.

Rockwell B Hardness (HRB)



A2.3

Rockwell C Hardness (HRC) – Results and Z-Scores

| Lab Code | Temp. (°C) | Test 1 | Test 2 | Test 3 | Average | MU (±) | Z-Score |
|----------|------------|--------|--------|--------|---------|--------|---------|
| 1 | 25 | 32.7 | 32.8 | 33.2 | 32.9 | - | -1.08 |
| 6 | 22 | 34 | 34.5 | 33 | 33.83 | - | 0.18 |
| 10 | 21 | 34 | 34 | 34 | 34 | - | 0.40 |
| 11 | 20 | 34.5 | 34.5 | 35.0 | 34.7 | - | 1.35 |
| 12 | 21 | 33.0 | 33.0 | 33.5 | 33.2 | - | -0.67 |
| 15 | 21 | 34.3 | 34.0 | 33.4 | 33.9 | 0.4 | 0.27 |
| 19 | 22 | 35.8 | 36.2 | 35.0 | 35.7 | - | 2.70 |
| 22 | - | 34.4 | 34.5 | 34.8 | 34.6 | - | 1.21 |
| 24 | - | 33.8 | 33.7 | 35.0 | 34.2 | - | 0.67 |
| 25 | 20 | 32 | 34 | 34 | 33 | - | -0.94 |
| 35 | 22 | 32.9 | 33 | 33 | 32.9 | - | -1.08 |
| 38 | - | 32.5 | 32.8 | 33 | 32.8* | - | -1.26 |
| 39 | - | 32.0 | 32.0 | 34.4 | 32.8 | - | -1.21 |
| 42A | 22 | 33, 34 | 34, 34 | 34 | 33.8 | - | 0.13 |
| 43B | 27 | 33.0 | 34.0 | 33.5 | 33.5 | 1.41 | -0.27 |
| 44 | 23.3 | 32.5 | 34.9 | 33.7 | 33.7 | 0.2 | 0.00 |
| 45 | 23 | 33.6 | 33.4 | 32.4 | 33.1 | 0.37 | -0.81 |

Summary Statistics

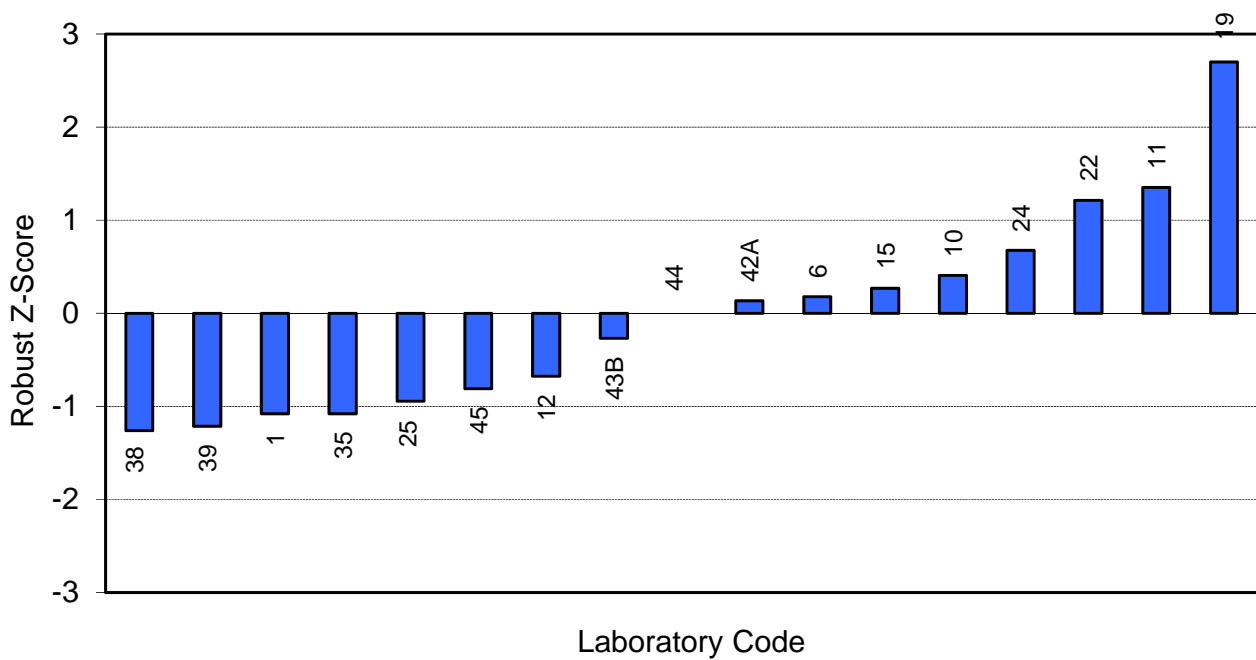
| Statistic | Average Result |
|----------------------|----------------|
| Number of Results | 17 |
| Median | 33.70 |
| Normalised IQR | 0.74 |
| Uncertainty (Median) | 0.23 |
| Robust CV | 2.20% |
| Minimum | 32.8 |
| Maximum | 35.7 |
| Range | 2.9 |

A2.4

Notes:

1. Summary statistics and z-scores have been calculated for the average results reported.
2. * Laboratory 38 did not report an average result for their Rockwell C hardness results. The result tabulated was calculated from the three test results they submitted.
3. Laboratory 42 submitted five results, instead of three, for their Rockwell C hardness results.
4. Laboratory 43 reported both Rockwell B and Rockwell C hardness results. Their Rockwell C hardness results have been assigned the laboratory code 43B.

Rockwell C Hardness (HRC)



Section A3

Methods Used and Surface Preparation

A3.1

Methods Used

| Lab Code | Vickers Hardness | Rockwell Hardness |
|----------|------------------|------------------------|
| 1 | ASTM E 92-82 | ASTM E 384-10 |
| 2 | - | - |
| 3 | AS 1817.1 | - |
| 4 | - | - |
| 5 | - | - |
| 6 | AS 1817.1 2003 | AS1815.1 2007 |
| 7 | AS 1817.1 | AS 1815 |
| 8 | ASTM E 384-11 | ASTM E 18-11 |
| 10 | AS 1817 | AS 1815 |
| 11 | AS 1817-2003 | AS 1815-2007 |
| 12 | AS | AS |
| 13 | AS 1817.1 | AS 1815.1 |
| 14 | AS | - |
| 15 | AS 1817.1-2003 | AS 1815.1-2007 |
| 16 | AS 1817.1 2003 | AS1815.1 2007 |
| 17 | AS 1817.1 | - |
| 18 | ISO 6507-1 | ISO 6508-1 |
| 19 | AS 1817.1 | AS 1815.1 |
| 20 | AS 1817.1 2003 | - |
| 21 | - | - |
| 22 | - | - |
| 23 | AS 1817.1 | AS 1815.1 |
| 24 | AS 1817 | AS 1815 |
| 25 | AS 1817.1-2003 | AS 1815.1-2003 |
| 26 | ISO 6507.1 | ISO 6508.1 |
| 27 | E 384 | E 18 |
| 28 | ISO 6507.1 | ISO 6508.1 |
| 29 | - | AS 1815.1 / ISO 6508.1 |
| 30 | AS | - |
| 31 | AS 1817.1-2003 | AS 1815.1 2007 |
| 32 | ASTM E 384 | - |
| 33 | AS 1817.1 2003 | - |
| 34 | AS 1817-2003 | - |
| 35 | AS 1817.1 | AS 1815.1 |
| 36 | AS 1817 | AS 1815 |
| 38 | - | - |
| 39 | - | - |
| 40 | ISO | ISO |

A3.2

Methods Used

| Lab Code | Vickers Hardness | Rockwell Hardness |
|----------|----------------------|----------------------|
| 41 | AS 1817.1 | - |
| 42A | AS 1817.1 | AS 1815.1 |
| 42B | AS 1817.1 | - |
| 42C | AS 1817.1 | - |
| 43A | AS1817.1 | AS 1815.1 |
| 43B | - | AS 1815.1 |
| 44 | AS 1817.1 | AS 1815.1 |
| 45 | ASTM E 384 | ASTM E 18 |
| 46 | AS 1817.1 | AS 1815.1 |
| 47 | LRTM 301 / AS 1817.1 | LRTM 302 / AS 1815.1 |

A3.3

Surface Preparation

| Lab Code | Preparation Details |
|----------|--|
| 1 | For sample preparation the following grinders have been used: 600, 800, 1000. |
| 2 | - |
| 3 | No surface preparation. |
| 4 | - |
| 5 | The surface of the sample was polished by using 350 and 600 grinders and using polish powder (600 mesh). The other side of the sample was also polished by using 600 grinder. |
| 6 | Sample was further prepared using wet & dry paper up to a finish of 800 grit. |
| 7 | Surface was cleaned and finished/polished to P1200. |
| 8 | Test surface light polished on 600 grain abrasive paper. |
| 10 | No surface preparation. |
| 11 | The sample was surface ground on both sides and polished using finer grades of silicon carbide paper to a 1200 grit finish. Indentations were randomly located towards the middle. |
| 12 | The sample was prepped on a pre-grinder down to 800 grit wet 'n' dry. |
| 13 | No surface preparation. |
| 14 | Ground/polished surface to grit size 600. |
| 15 | Sample prepared to 3 μ finish. |
| 16 | Micron metallographic polish. |
| 17 | Surface prepared to 2400 grit finish. |
| 18 | Surface grinder was used on both sides. |
| 19 | Surface grind and SiC paper grind to 1200 grit finish. |
| 20 | Polished to 1200 grit. |
| 21 | - |
| 22 | - |
| 23 | The test block was reprepared - firstly 800 grit on rotary grinding machine, then 1200 grit on rotary grinding machine (Vickers only). |
| 24 | Polished to 1200 grit. |
| 25 | Specimen was polished to 1200 grit (wet & dry). |
| 26 | Hand wet polished with 400-80-1000-1200 grit paper. Final hand polish with paste. |
| 27 | - |
| 28 | No surface preparation. |
| 29 | No surface preparation. |
| 30 | Hand polish. Grade #400, #1200. |
| 31 | Polished with 15 μ m polishing after sanding to 1500 grit finish. |
| 32 | No surface preparation. |
| 33 | Face that carried the sample ID was hand prepared on 320 grit wet and dry to produce witness over full surface. Test face was prepared on progressively finer wet and dry paper up to 1200 grit. Preparation with each finer grade continued until previous witness removed. |

A3.4

Surface Preparation

| Lab Code | Preparation Details |
|----------|--|
| 34 | Machined 0.25 mm off one surface then surface ground & polished to a P600 finish. |
| 35 | The sample was milled parallel and polished to grit P1200 before hardness testing (side opposite hard stamping). |
| 36 | Wet finishing, succession of SiC grit papers #400, #600, #800, #1000, #1200. |
| 38 | - |
| 39 | - |
| 40 | The sample is polished with grit 600 sand paper. |
| 41 | Polished to P1000. |
| 42A | Surface prepared to a 1 μ m finish. |
| 42B | Surface prepared to a 1 μ m finish. |
| 42C | Surface prepared to a 1 μ m finish. |
| 43A | Test surface was ground to grit 320 finish. |
| 43B | Test surface was ground to grit 320 finish. |
| 44 | SiC grind at 400 grit and 1200 grit and polished to 1 micron finish. |
| 45 | No surface preparation. |
| 46 | Surface grinding 0.1 mm. |
| 47 | Test side - manually ground to 1200 grade with silicon carbide paper. |
| | Base side - manually ground to 360 grade using silicon carbide paper. |

APPENDIX B

Homogeneity and Stability Testing

B1.1

HOMOGENEITY TESTING

Before the samples were distributed to participants, ten randomly selected samples were tested for homogeneity by Amdel Limited, Whyalla Laboratory, OneSteel Site. The results of the homogeneity testing are displayed below:

Homogeneity Testing Results

DPH (Vickers) VH30

| Test Piece ID | Test 1 | Test 2 | Test 3 | Average |
|---------------|--------|--------|--------|---------|
| 1 | 346 | 338 | 332 | 338.7 |
| 12 | 340 | 348 | 346 | 344.7 |
| 13 | 344 | 334 | 340 | 339.3 |
| 21 | 334 | 344 | 338 | 338.7 |
| 32 | 338 | 346 | 355 | 346.3 |
| 35 | 339 | 333 | 339 | 337.0 |
| 42 | 331 | 338 | 351 | 340.0 |
| 44 | 338 | 355 | 329 | 340.7 |
| 46 | 339 | 336 | 339 | 338.0 |
| 55 | 326 | 329 | 344 | 333.0 |

Rockwell B Hardness

| Test Piece ID | Test 1 | Test 2 | Test 3 | Average |
|---------------|--------|--------|--------|---------|
| 1 | 108.8 | 109.0 | 109.0 | 108.93 |
| 12 | 108.8 | 108.0 | 105.0 | 107.27 |
| 13 | 106.0 | 107.3 | 107.8 | 107.03 |
| 21 | 109.0 | 108.4 | 108.3 | 108.57 |
| 32 | 109.1 | 107.0 | 108.0 | 108.03 |
| 35 | 107.3 | 108.3 | 108.3 | 107.97 |
| 42 | 108.7 | 107.5 | 106.4 | 107.53 |
| 44 | 107.8 | 107.2 | 107.0 | 107.33 |
| 46 | 107.1 | 107.1 | 107.0 | 107.07 |
| 55 | 107.4 | 107.3 | 108.0 | 107.57 |

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.

B2.1

STABILITY TESTING

Three randomly selected samples were also tested for stability by Amdel Limited, Whyalla Laboratory, OneSteel Site. This testing took place at the same time as the participants tested the samples. The results of the stability testing are displayed below:

Stability Testing Results

DPH (Vickers) VH30

| Test Piece ID | Test 1 | Test 2 | Test 3 | Average |
|---------------|--------|--------|--------|---------|
| 25 | 339 | 362 | 338 | 346.3 |
| 37 | 363 | 321 | 320 | 334.7 |
| 58 | 336 | 336 | 336 | 336.0 |

Rockwell B Hardness

| Test Piece ID | Test 1 | Test 2 | Test 3 | Average |
|---------------|--------|--------|--------|---------|
| 25 | 105.4 | 108.0 | 110.0 | 107.80 |
| 37 | 106.5 | 108.0 | 109.0 | 107.83 |
| 58 | 108.7 | 109.0 | 109.3 | 109.00 |

Analysis of the stability testing results showed that the samples were sufficiently stable for testing for the duration of the program.

APPENDIX C

Instructions to Participants and Results Sheet

Hardness Testing Of Metals Proficiency Testing Program Round 4, March 2013

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 a micro-alloyed Rails steel section 65 x 40 x 11mm, conforming to AS/NZS 3679.1. It is to be used for both Vickers and Rockwell 'B' testing and has been pre-prepared for testing. Participants may wish to improve the surface to provide a better testing surface.
- 2) All testing, recording and reporting is to be performed in accordance with your routine test methods, but AS 1817.1 / ISO 6507.1 - Vickers hardness testing and AS 1815.1 / ISO 6508.1 - Rockwell HRB hardness testing are the preferred methods.
- 3) Please use the attached result sheet to record and report your results to Proficiency Testing Australia.
- 4) Do not discard the hardness test samples until you have received the final report. You may be asked to carry out a retest or to return the samples to Proficiency Testing Australia for retesting at the laboratory that performed the homogeneity tests.
- 5) 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.
- 6) 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 $k \approx 2$).
- 7) 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 **Thursday 28 March 2013**. Results reported later than this date may not be analysed in the final report.

Hardness Testing Of Metals Proficiency Testing Program

Round 4, March 2013

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 (±) | |
| | Vickers | 0.1 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.

.....

.....

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.....

.....

.....

Print Name: _____

Signature: _____

Date: _____

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