REPORT NO. 1139

Tensile Testing of Metals

Proficiency Testing Program

Round 12

June 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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CONTENTS

1. FOREWORD

This report summarises the results of a proficiency testing program on the tensile properties of metals. It constitutes the twelfth 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 April / May 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 33 laboratories participated in the program, two of which did not return results for inclusion in the final report. Laboratories from the following countries received samples:

16	AUSTRALIA
7	NEW ZEALAND
2	SAUDI ARABIA
1	BAHRAIN
1	BOTSWANA
1	COLOMBIA
1	EGYPT
1	ETHIOPIA
1	MALAYSIA
1	PERU
1	UNITED KINGDOM

To ensure confidential treatment of results, each laboratory was allocated a unique code number. All reference to participants in this report is by allocated code numbers. Please note that the code numbers of some laboratories (with appended letters) could appear several times in the same data set.

(b) The results reported by participants are presented in Appendix A.

(c) Laboratories were provided with two identical carbon steel flat bar samples. Both samples were approximately 400 mm in length, 40 mm in width and 6 mm in thickness. One laboratory tested flat bar samples that were approximately 500 mm in length, 60 mm in width and 6 mm in thickness. For one of the samples provided to laboratories, a proportional gauge length was to be used, while a non-proportional gauge length was to be used for the other sample.

(d) Laboratories were asked to perform tests for:

- 0.2% Proof Stress (non-proportional elongation) ($R_{p0.2}$), if applicable;
- Lower and Upper Yield Strength (ReL and ReH), if applicable;
- Tensile Strength (Rm); and
- Percentage Elongation after Fracture (A%).

(e) All testing, recording and reporting was to be performed in accordance with the laboratory's routine test methods, but testing in accordance with AS 1391 or ISO 6892-1 were the preferred test methods.

(f) 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.

(g) 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 six sections (A1-A6).

Sections A1-A5 contain the analysis of results reported by laboratories for 0.2% Proof Stress (non-proportional elongation) ($R_{p0.2}$), Lower Yield (ReL), Upper Yield (ReH), Tensile Strength (Rm) and Percentage Elongation after Fracture (A%). These sections contain, where appropriate:

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;
iii) ordered z-score charts; and
iv) a Youden diagram.

Section A6 contains information on the methods used by laboratories and the results reported by laboratories for Tensile Specimen Thickness, Tensile Specimen Gauge Width, Tensile Specimen Gauge Length, Elastic Stress or Strain Rate and Plastic Strain Rate.

(b) Appendix B contains details of the homogeneity testing.

(c) Appendix C contains copies of the *Instructions to Participants* and *Results Sheet*.

4. DESIGN OF THE PROGRAM

The summary statistics calculated for each test / sample consist 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 x *Normalised IQR* / *Median*;
- *Minimum*: the lowest laboratory result;
- *Maximum*: the highest laboratory result; and
- *Range*: the difference between the *Maximum* and *Minimum*.

Summary Statistics

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:

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

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

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 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-score| < 3.0). These results are considered to be questionable results.

Ordered Z-Score Charts

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.

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 (*i.e.* Sample 2 versus Sample 1) and 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 criteria ($|z\text{-score}| \geq 3.0$) has a confidence level of approximately 99%, whereas the ellipse is an approximate 95% confidence region.

The points outside the ellipse on the Youden diagram roughly correspond to those with z-scores greater than 2.0 or less than -2.0. Laboratories which are outside the ellipse but have not been identified as outliers (*i.e.* have $2.0 < |z\text{-score}| < 3.0$) are encouraged to review their results.

As a guide to the interpretation of these diagrams:

(i) Laboratories with significant systematic error components (*i.e.* between-laboratory variation) will usually have results outside the ellipse in either the upper right hand quadrant (as formed by the median lines) or the lower left hand quadrant (*i.e.* unusually high or low results for both samples); and

(ii) Laboratories with significant random error components (*i.e.* within-laboratory variation) will have returned results that are substantially more variable than other participants, and these results will usually lie outside the ellipse in either the upper left or lower right hand quadrants (*i.e.* an unusually high result for one sample and low for the other).

For further details on the calculation and interpretation of robust z-scores and ordered z-score charts and the construction and interpretation of Youden diagrams, 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	Sample 1	Sample 2
0.2% Proof Stress (non-proportional elongation) ($R_{p0.2}$) (MPa)	Number of Results	25	27
	Median	462.0	459.0
	Normalised IQR	18.5	15.6
	Uncertainty (Median)	4.6	3.8
Lower Yield (ReL) (MPa)	Number of Results	23	25
	Median	454.0	452.0
	Normalised IQR	18.2	12.6
	Uncertainty (Median)	4.7	3.2
Upper Yield (ReH) (MPa)	Number of Results	24	26
	Median	479.0	469.0
	Normalised IQR	15.0	16.7
	Uncertainty (Median)	3.8	4.1
Tensile Strength (Rm) (MPa)	Number of Results	30	32
	Median	543.0	543.5
	Normalised IQR	10.2	10.0
	Uncertainty (Median)	2.3	2.2
Percentage Elongation after Fracture (A%) 400 mm × 40 mm × 6 mm Samples	Number of Results	29	31
	Median	26.0	26.0
	Normalised IQR	2.7	2.7
	Uncertainty (Median)	0.6	0.6
Percentage Elongation after Fracture (A%) 500 mm × 60 mm × 6 mm Samples	Number of Results	7	7
	Median	25.0	27.0
	Normalised IQR	0.5	1.5
	Uncertainty (Median)	0.2	0.7

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

Test	Sample 1	Sample 2
0.2% Proof Stress	8	-
Lower Yield	8	8
Upper Yield	8	-
Tensile Strength	8, 30	8
Percentage Elongation after Fracture (400 mm × 40 mm × 6 mm)	-	-
Percentage Elongation after Fracture (500 mm × 60 mm × 6 mm)	-	-

Notes:

1. For each test, the results for all test methods were pooled for analysis.

2. Summary statistics and z-scores for Percentage Elongation after Fracture were calculated by converting the results to a proportional gauge length.

3. The summary statistics and z-scores for Percentage Elongation after Fracture were calculated separately for the samples that were 400 mm × 40 mm × 6 mm and the samples that were 500 mm × 60 mm × 6 mm.

4. A target CV of 5.4% was used to calculate the robust z-scores for Percentage Elongation after Fracture, for Sample 1, for the samples that were 500 mm × 60 mm × 6 mm.

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 on the previous pages. Complete details of the statistical analyses appear in Appendix A.

6.1 Return rate

Thirty-one of the 33 laboratories (94%) that participated in the program returned results. Of the 31 laboratories that submitted results for the program, the return rate for all tests is as follows:

• 0.2% Proof Stress	27 out of 31	87%
• Lower Yield	24 out of 31	77%
• Upper Yield	25 out of 31	81%
• Tensile Strength	31 out of 31	100%
• Percentage Elongation after Fracture	31 out of 31	100%

6.2 Performance summary

One or more statistical outliers were reported by two of the 31 laboratories (6%) that returned results for this round of the program. The last round of the Tensile Testing of Metals program where participants tested two steel flat bar samples was Round 10. For comparison, 33% of the participants reported outlier results in Round 10 of the Tensile Testing of Metals program (see Report No. 1028 for more details).

A total of 274 results were analysed in this round of the program. Of these results, seven (3%) were outliers. For comparison, 9% of the results analysed in Round 10 of the Tensile Testing of Metals program were outliers (see Report No. 1028 for more details).

6.3 0.2% Proof Stress

Of the 27 laboratories that tested the samples for 0.2% Proof Stress, 16 laboratories tested using AS 1391. Seven laboratories tested using ISO 6892-1. One laboratory used the ASTM E8 / E8M-16a method. One laboratory used both AS 1391 and ISO 6892-1. One laboratory used both ISO 6892-1 and the ASTM A370 method. One laboratory did not specify the method that they used for testing (see Appendix A6 for more details).

For the laboratories that used the AS 1391 method for Sample 1, the median and standard error of the 0.2% Proof Stress results was 461.0 ± 5.8 MPa. For all methods pooled, the median and standard error of the 0.2% Proof Stress results for Sample 1 was 462.0 ± 4.6 MPa.

For the laboratories that used the AS 1391 method for Sample 2, the median and standard error of the 0.2% Proof Stress results was 459.0 ± 3.8 MPa. For all methods pooled, the median and standard error of the 0.2% Proof Stress results for Sample 2 was 459.0 ± 3.8 MPa.

The methods were pooled when analysing the results for both samples.

One laboratory (code 8) reported an outlier for Sample 1. There were no outlier results reported for Sample 2. One laboratory (code 8) obtained an absolute z-score between 2.0 and 3.0 for Sample 2.

The robust CVs for the 0.2% Proof Stress results were 4.0% and 3.4% for Sample 1 and Sample 2, respectively. The last round of this program where the 0.2% Proof Stress results for flat bar samples were analysed was Round 10. In Round 10 of this program, the robust CVs obtained were 4.1% and 4.2% for Sample 1 and Sample 2, respectively. The robust CV values obtained in this round of the program compare well with the robust CV values obtained in Round 10 of the program (see Report No. 1028 for more details).

Twenty-three laboratories reported measurement uncertainties associated with their 0.2% Proof Stress test results in this round.

6.4 Lower Yield

Of the 24 laboratories that tested the samples for Lower Yield, 15 laboratories tested using AS 1391, including one laboratory that submitted two sets of results. Five laboratories tested using ISO 6892-1. One laboratory used the ASTM E8 / E8M-16a method. One laboratory used the ASTM A370 method. One laboratory used both AS 1391 and ISO 6892-1. One laboratory did not specify the method that they used for testing (see Appendix A6 for more details).

For the laboratories that used the AS 1391 method for Sample 1, the median and standard error of the Lower Yield results was 450.0 ± 4.8 MPa. For all methods pooled, the median and standard error of the Lower Yield results for Sample 1 was 454.0 ± 4.7 MPa.

For the laboratories that used the AS 1391 method for Sample 2, the median and standard error of the Lower Yield results was 452.0 ± 2.5 MPa. For all methods pooled, the median and standard error of the Lower Yield results for Sample 2 was 452.0 ± 3.2 MPa.

The methods were pooled when analysing the results for both samples.

One laboratory (code 8) reported outlier results for both samples. One laboratory (code 5) obtained an absolute z-score between 2.0 and 3.0 for Sample 2.

The robust CVs for the Lower Yield results were 4.0% and 2.8% for Sample 1 and Sample 2, respectively. The last round of this program where the Lower Yield results for a flat bar sample were analysed was Round 8, where only one sample was tested for Lower Yield. The robust CV obtained for the sample tested in Round 8 was 3.0%, which compares well with the robust CV values obtained in this round of the program (see Report No. 926 for more details).

Twenty-one laboratories reported measurement uncertainties associated with their Lower Yield test results in this round.

6.5 Upper Yield

Of the 25 laboratories that tested the samples for Upper Yield, 16 laboratories tested using AS 1391, including one laboratory that submitted two sets of results. Five laboratories tested using ISO 6892-1. One laboratory used the ASTM E8 / E8M-16a method. One laboratory used the ASTM A370 method. One laboratory used both AS 1391 and ISO 6892-1. One laboratory did not specify the method that they used for testing (see Appendix A6 for more details).

For the laboratories that used the AS 1391 method for Sample 1, the median and standard error of the Upper Yield results was 478.5 ± 4.1 MPa. For all methods pooled, the median and standard error of the Upper Yield results for Sample 1 was 479.0 ± 3.8 MPa.

For the laboratories that used the AS 1391 method for Sample 2, the median and standard error of the Upper Yield results was 472.0 ± 4.8 MPa. For all methods pooled, the median and standard error of the Upper Yield results for Sample 2 was 469.0 ± 4.1 MPa.

The methods were pooled when analysing the results for both samples.

One laboratory (code 8) reported an outlier for Sample 1. There were no outlier results reported for Sample 2. Two laboratories (codes 8 and 18B) obtained absolute z-scores between 2.0 and 3.0 for Sample 2.

The robust CVs for the Upper Yield results were 3.1% and 3.6% for Sample 1 and Sample 2, respectively. The last round of this program where the Upper Yield results for a flat bar sample were analysed was Round 8, where only one sample was tested for Upper Yield. The robust CV obtained for the sample tested in Round 8 was 7.6%, which is higher than the robust CV values obtained in this round of the program (see Report No. 926 for more details).

Twenty-two laboratories reported measurement uncertainties associated with their Upper Yield test results in this round.

6.6 Tensile Strength

A total of 31 laboratories tested the samples for Tensile Strength. Of these laboratories, nineteen tested using AS 1391, including one laboratory that submitted two sets of results. Seven laboratories tested using ISO 6892-1. One laboratory used the ASTM E8 / E8M-16a method. One laboratory used the ASTM A370 method. One laboratory used both AS 1391 and ISO 6892-1. One laboratory used both ISO 6892-1 and the ASTM A370 method. One laboratory did not specify the method that they used for testing (see Appendix A6 for more details).

For the laboratories that used the AS 1391 method for Sample 1, the median and standard error of the Tensile Strength results was 543.0 ± 2.8 MPa. For all methods pooled, the median and standard error of the Tensile Strength results for Sample 1 was 543.0 ± 2.3 MPa.

For the laboratories that used the AS 1391 method for Sample 2, the median and standard error of the Tensile Strength results was 544.0 ± 3.4 MPa. For all methods pooled, the median and standard error of the Tensile Strength results for Sample 2 was 543.5 ± 2.2 MPa.

The methods were pooled when analysing the results for both samples.

One laboratory (code 8) reported outlier results for both samples. One laboratory (code 30) reported an outlier result for Sample 1. One laboratory (code 10) obtained an absolute z-score between 2.0 and 3.0 for Sample 1. Three laboratories (codes 5, 20 and 30) obtained absolute z-scores between 2.0 and 3.0 for Sample 2.

The reported Tensile Strength results for laboratory code 8 (as well as the 0.2% Proof Stress and Lower and Upper Yield results reported by this laboratory) are the highest of all the participants in this round. Although correct techniques, dimensions and loading rates have been reported, the reason for such outlier results could be that the testing machine is due for calibration or regular maintenance. This can be seen from their reported elongation results, which fall within the statistically acceptable limits. This indicates that, although the machine is testing correctly, the load cell could need attention. Another reason for higher strength results could be that the tests were conducted without zeroing / resetting the reader. The results of this program will greatly assist this laboratory to re-evaluate the management of their test machine and address this appropriately.

One possible reason that the Tensile Strength result reported by laboratory code 30 for Sample 1 is an outlier is that the loading rate could have increased past ‘yielding’ (beyond the recommended loading rates). Although the test standards do allow this change in load rates, under some circumstances, it is very important to ensure increasing or decreasing the loading rates are carried out slowly and at small intervals.

All the participating laboratories whose reported Tensile Strength results have obtained an absolute z-score of more than 2.0 are highly encouraged to use this program to evaluate their testing methods, loading conditions, preparation procedures, equipment management and training details. It is expected of each participant to analyse their own proficiency testing results and evaluate any trends.

The robust CVs for the Tensile Strength results were 1.9% and 1.8% for Sample 1 and Sample 2, respectively. The last round of this program where the Tensile Strength results for flat bar samples were analysed was Round 10. In Round 10 of this program, the robust CVs obtained were 2.1% and 1.5% for Sample 1 and Sample 2, respectively. The robust CV values obtained in this round of the program compare well with the robust CV values obtained in Round 10 of the program (see Report No. 1028 for more details).

Twenty-seven laboratories reported measurement uncertainties associated with their Tensile Strength test results in this round.

6.7 Percentage Elongation after Fracture

A total of 31 laboratories tested the samples for Percentage Elongation after Fracture. Of these laboratories, nineteen tested using AS 1391, including one laboratory that submitted two sets of results. Seven laboratories tested using ISO 6892-1. One laboratory used the ASTM E8 / E8M-16a method. One laboratory used the ASTM A370 method. One laboratory used both AS 1391 and ISO 6892-1. One laboratory used both ISO 6892-1 and the ASTM A370 method. One laboratory did not specify the method that they used for testing (see Appendix A6 for more details).

Because the participants employed different width specimens and different gauge lengths for their tensile testing in this program, it was necessary to convert the Percentage Elongation after Fracture results submitted by the participants to a proportional gauge length of $5.65 \sqrt{S_0}$ (5.65 times the square root of the original cross-sectional area). The results were converted to a proportional gauge length using the formula of ISO 2566-1. These results are displayed in Appendix A5. The exact formula used to convert the results is given on page A5.4 of Appendix A5.

One of the participants in this round of the program (laboratory code 13) tested samples that were approximately 500 mm in length, 60 mm in width and 6 mm in thickness. While the homogeneity testing, performed by ARL Laboratory Services Pty Ltd, did not indicate any significant differences between the 400 mm × 40 mm × 6 mm samples and the 500 mm × 60 mm × 6 mm samples for any of the other tests performed in this program, there was a significant difference found between the two different sets samples for Percentage Elongation after Fracture. Therefore, the Percentage Elongation after Fracture results were analysed separately for the different sets of samples. The results submitted by laboratory code 13 for Percentage Elongation after Fracture were compared to the homogeneity testing results in order to calculate their z-scores for the 500 mm × 60 mm × 6 mm samples (please see Appendix B for more details).

For the 400 mm × 40 mm × 6 mm samples, for the laboratories that used the AS 1391 method for Sample 1, the median and standard error of the Percentage Elongation after Fracture results (converted to a proportional gauge length) was 25.4 ± 0.9%. For all methods pooled, the median and standard error of the Percentage Elongation after Fracture results (converted to a proportional gauge length) for Sample 1 was 26.0 ± 0.6%.

For the 400 mm × 40 mm × 6 mm samples, for the laboratories that used the AS 1391 method for Sample 2, the median and standard error of the Percentage Elongation after Fracture results (converted to a proportional gauge length) was 25.8 ± 0.8%. For all methods pooled, the median and standard error of the Percentage Elongation after Fracture results (converted to a proportional gauge length) for Sample 2 was 26.0 ± 0.6%.

The methods were pooled when analysing the results for both samples.

For the 400 mm × 40 mm × 6 mm samples, there were no outliers reported for either sample. One laboratory (code 7) obtained an absolute z-score between 2.0 and 3.0 for Sample 1.

The robust CVs for the Percentage Elongation after Fracture results for the 400 mm × 40 mm × 6 mm samples were 10.5% and 10.4% for Sample 1 and Sample 2, respectively. The last round of this program where the Percentage Elongation after Fracture results for flat bar samples were analysed was Round 10. In Round 10 of this program, the robust CVs obtained were 11.0% and 14.8% for Sample 1 and Sample 2, respectively. The robust CV values obtained in this round of the program are lower than the robust CV values obtained in Round 10 of the program (see Report No. 1028 for more details).

For the 500 mm × 60 mm × 6 mm samples, there were no outlier results reported for either sample.

The robust CV values for the Percentage Elongation after Fracture results for the 500 mm × 60 mm × 6 mm samples were 1.8% and 5.4% for Sample 1 and Sample 2, respectively. The robust CV value of 1.8% for Sample 1 was considered to be inappropriate to evaluate the performance of laboratory code 13 in this round, so a target CV was used to calculate the z-scores for Sample 1. The target CV chosen was 5.4%, which was the same robust CV value as that obtained for Sample 2.

Twenty-six laboratories reported measurement uncertainties associated with their Percentage Elongation after Fracture test results in this round.

6.8 Measurement Uncertainty

The majority of participants in this round (84% – 88%) reported estimates of the measurement uncertainty associated with their results. The number and percentage of laboratories that reported estimates of their measurement uncertainty for each test is as follows:

• 0.2% Proof Stress	23 out of 27	85%
• Lower Yield	21 out of 24	88%
• Upper Yield	22 out of 25	88%
• Tensile Strength	27 out of 31	87%
• Percentage Elongation after Fracture	26 out of 31	84%

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

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

All the 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. An approach, such as that described in AS 1391 Appendix H, “An Error Budget”, to the estimation of the measurement uncertainty in tensile testing is an example of an approach that could be followed.

6.9 Other Reported Results

In addition to reporting results for 0.2% Proof Stress, Lower Yield, Upper Yield, Tensile Strength and Percentage Elongation after Fracture, participants were also asked to report the Tensile Specimen Thickness, Tensile Specimen Gauge Width, Tensile Specimen Gauge Length, Elastic Stress or Strain Rate and Plastic Strain Rate. The details reported by each of the participants are displayed in Appendix A6.

It is highly recommended that all of the participants report all of this necessary information, in order to better analyse the test results. The Tensile Specimen Thickness, Tensile Specimen Gauge Width and Tensile Specimen Gauge Length are required in order to convert the Percentage Elongation after Fracture results to a proportional gauge length, while the loading rates (both stress and strain rates) can be reviewed for any abnormal test results. The loading rates are particularly important when comparing test results for elongation and yield strength, as the loading rates can affect these properties.

6.10 General Comments

The aim of this round of the program was to determine the capabilities and proficiency of the participating laboratories in comparing and understanding the role of specimen geometry on the tensile properties of the materials.

Apart from the outlier results reported by laboratory codes 8 and 30, the overall performance of the participating laboratories for this round of the program is exemplary and indicates the effectiveness of these proficiency testing programs. Participating in proficiency testing programs is very important for laboratories, as it can assist them tremendously in identifying any weaknesses in their systems that may be present and it allows them to improve their overall technical competency and proficiency.

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 1391 (2007) – *Metallic materials – Tensile testing at ambient temperature.*

4. ISO 6892-1 (2016) – *Metallic materials – Tensile testing – Part 1: Method of test at room temperature.*

5. *ISO 2566-1 (1984) – Steel – Conversion of elongation values – Part 1: Carbon and low alloy steels.*

6. ASTM A370 – *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*.

7. ASTM E8 / E8M-16a – *Standard Test Methods for Tension Testing of Metallic Materials.*

APPENDIX A

Summary of Results

Section A1

0.2% Proof Stress

0.2% Proof Stress (non-proportional elongation) ($R_{p0.2}$) (MPa) – Results and Z-Scores

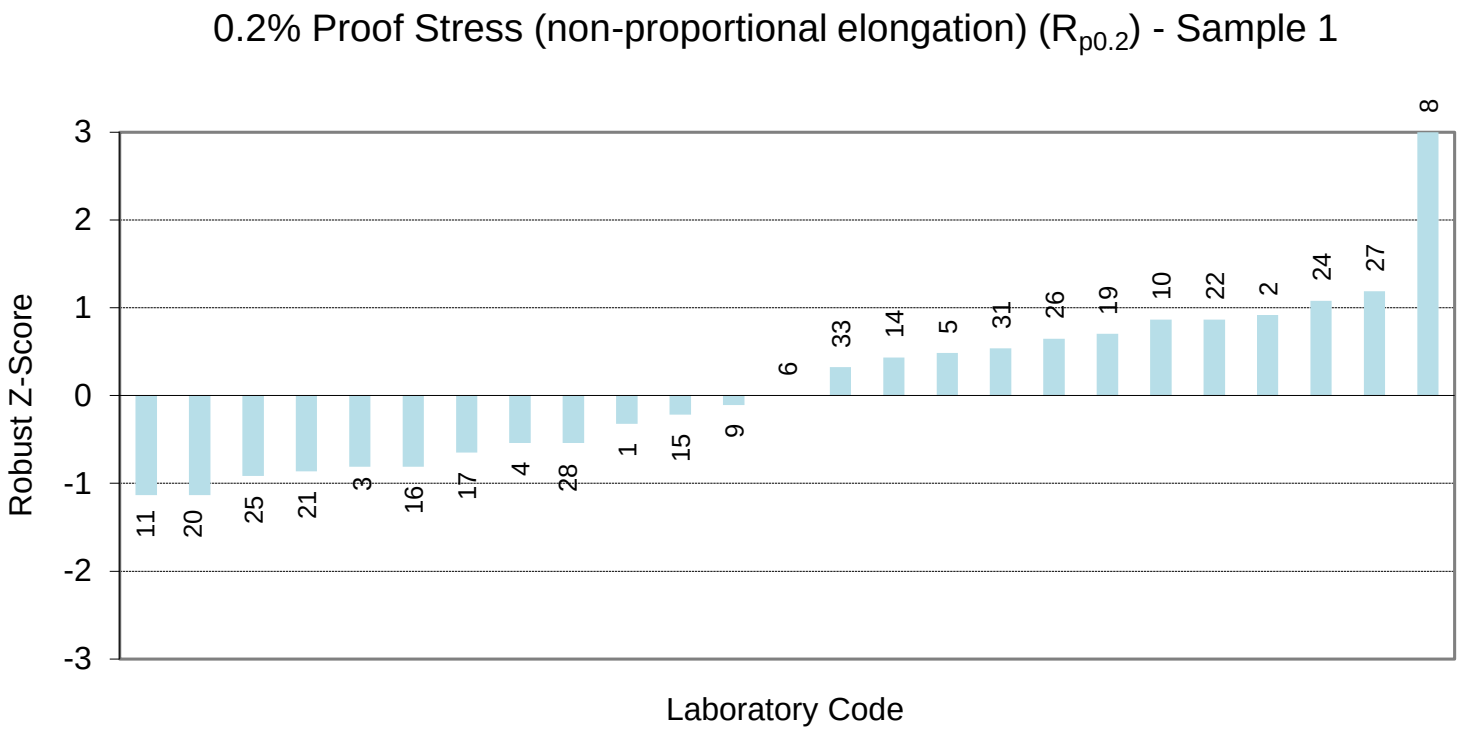
Lab Code	Sample 1			Sample 2		
	Result	MU (±)	Z-Score	Result	MU (±)	Z-Score
1	456	0.29	-0.32	461	0.29	0.13
2	479	2%	0.92	459	2%	0.00
3	447	8.1	-0.81	458	8.1	-0.06
4	452	4.5	-0.54	428	4	-1.99
5	471	5.5%	0.49	488	5.5%	1.86
6	462	13	0.00	462	13	0.19
8	533	-	3.83 **§**	502	-	2.76
9	460	15	-0.11	473	16	0.90
10	478	4	0.86	475	4	1.03
11	441	5	-1.13	447	5	-0.77
13	-	-	-	456	-	-0.19
14	470	6.35	0.43	471	6.35	0.77
15	458	2.5	-0.22	443	2.2	-1.03
16	447	9	-0.81	450	9	-0.58
17	450	5	-0.65	445	5	-0.90
19	475	-	0.70	476	-	1.09
20	441	19	-1.13	434	19	-1.61
21	446	95%	-0.86	452	95%	-0.45
22	478	2%	0.86	459	2%	0.00
24	482	-	1.08	475	-	1.03
25	445	4.50	-0.92	455	4.10	-0.26
26	474	0.17%	0.65	469	0.17%	0.64
27	484	6	1.19	457	6	-0.13
28	452	10	-0.54	438	10	-1.35
30	-	-	-	489	8	1.93
31	472	3.6%	0.54	461	3.6%	0.13
33	468	0.25%	0.32	454	0.25%	-0.32

Summary Statistics

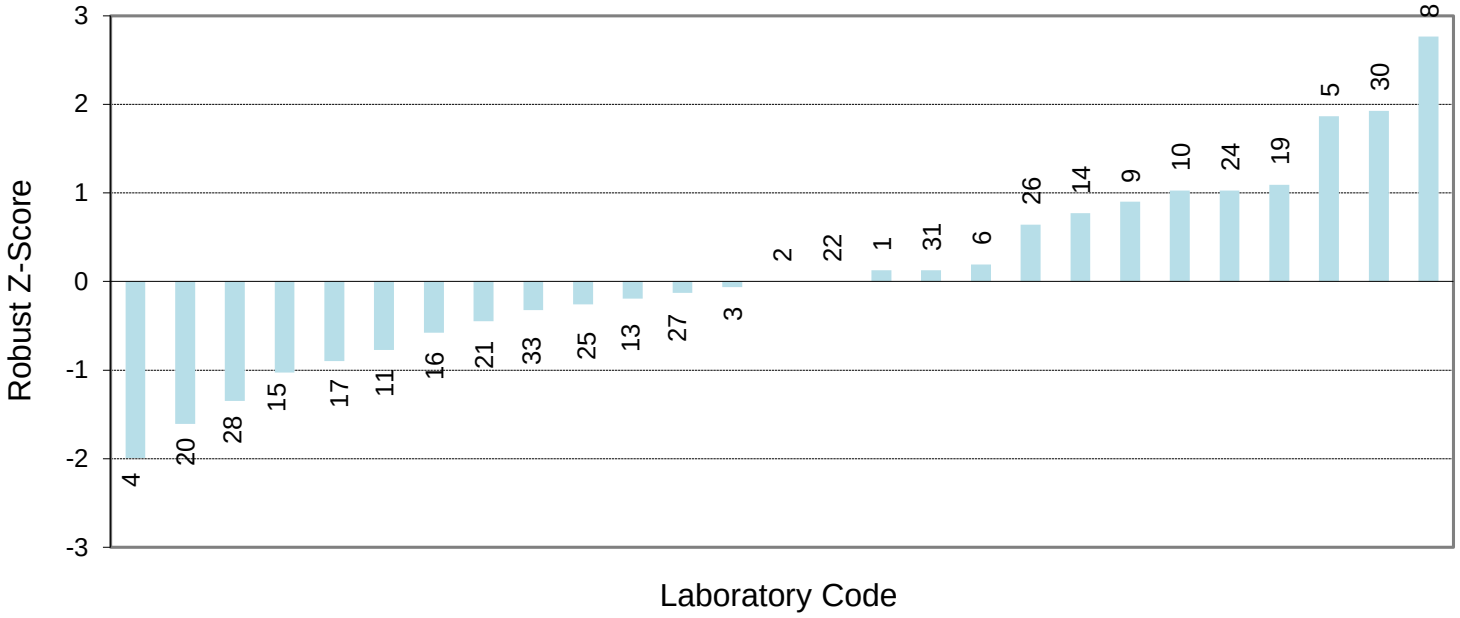
Statistic	Sample 1	Sample 2
Number of Results	25	27
Median	462.0	459.0
Normalised IQR	18.5	15.6
Uncertainty (Median)	4.6	3.8
Robust CV	4.0%	3.4%
Minimum	441	428
Maximum	533	502
Range	92	74

Notes:

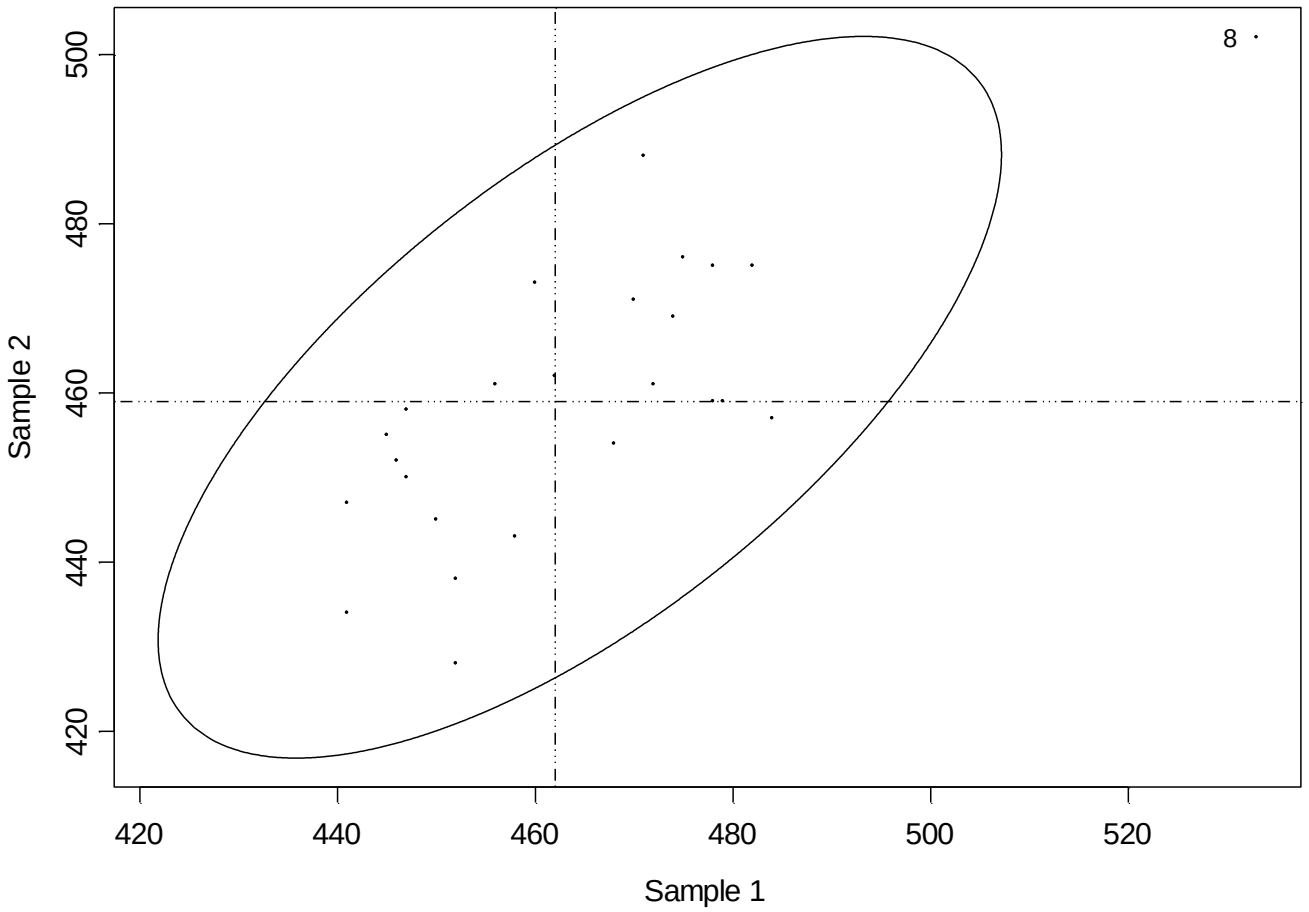
1. **§** denotes an outlier (*i.e.* |z-score| ≥ 3.0).
2. The samples for laboratory code 9 were machined by another laboratory.
3. Laboratory code 13 tested samples that were approximately 500 mm in length, 60 mm in width and 6 mm in thickness. These results have been pooled for analysis with the results reported by the other participants that tested the samples that were approximately 400 mm in length, 40 mm in width and 6 mm in thickness (see Appendix B for more details).
4. The Youden diagram on the following page is provided for information only.
5. The results reported by laboratory codes 13 and 30 are not included in the Youden diagram, as these were not a pair of results (for Sample 1 and Sample 2).



0.2% Proof Stress (non-proportional elongation) ($R_{p0.2}$) - Sample 2



0.2% Proof Stress (MPa)



Section A2

Lower Yield

Lower Yield (ReL) (MPa) – Results and Z-Scores

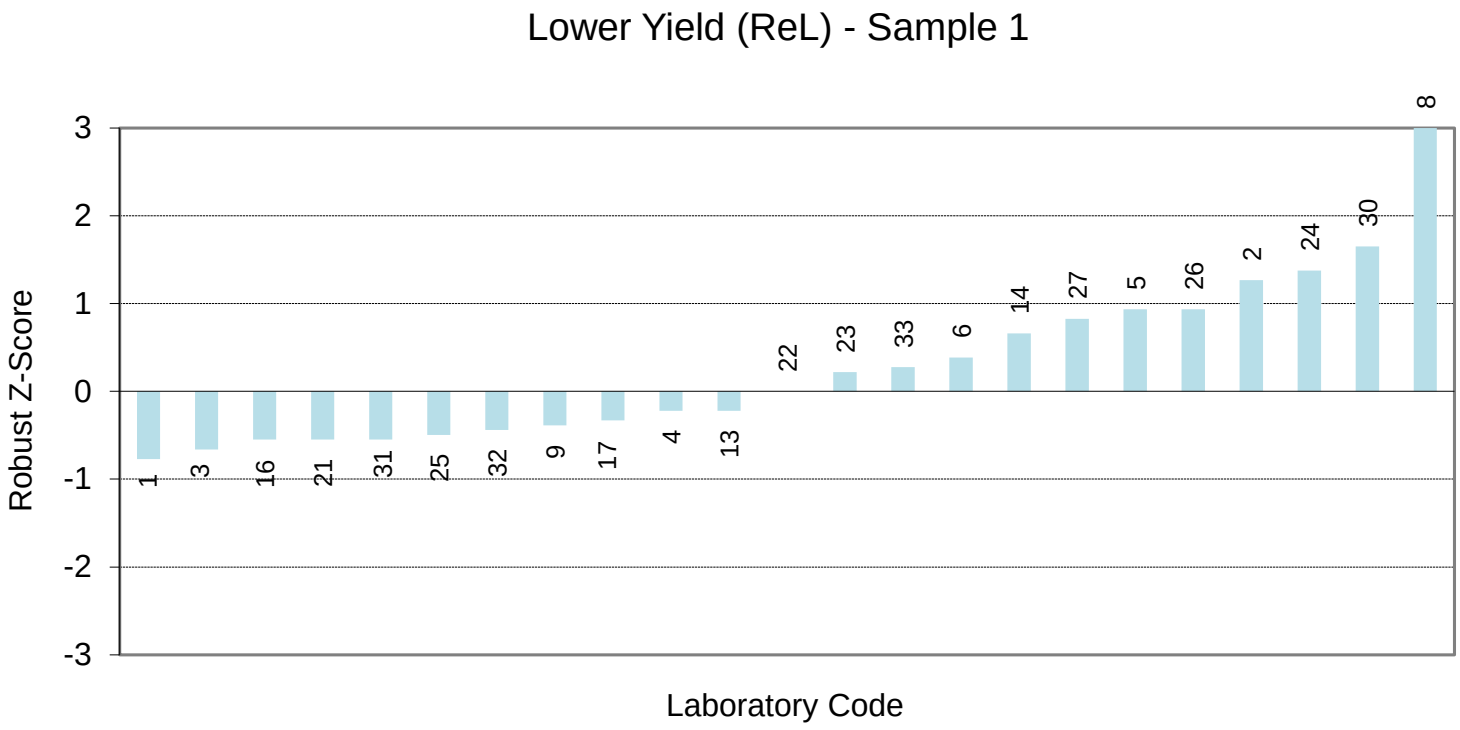
Lab Code	Sample 1			Sample 2		
	Result	MU (±)	Z-Score	Result	MU (±)	Z-Score
1	440	0.29	-0.77	447	0.29	-0.40
2	477	2%	1.27	448	2%	-0.32
3	442	8.1	-0.66	458	8.1	0.48
4	450	4.5	-0.22	427	4	-1.98
5	471	5.5%	0.94	488	5.5%	2.86
6	461	13	0.39	459	13	0.56
8	515	-	3.36 **§**	497	-	3.57 **§**
9	447	15	-0.39	473	16	1.67
13	450	0.23%	-0.22	450	0.23%	-0.16
14	466	6.35	0.66	468	6.35	1.27
16	444	9	-0.55	448	9	-0.32
17	448	2.5	-0.33	434	2.5	-1.43
18A	-	-	-	450	-	-0.16
18B	-	-	-	430	-	-1.75
21	444	95%	-0.55	452	95%	0.00
22	454	2%	0.00	451	2%	-0.08
23	458	6	0.22	457	6	0.40
24	479	14	1.38	465	14	1.03
25	445	4.10	-0.50	455	4.50	0.24
26	471	0.17%	0.94	468	0.17%	1.27
27	469	6	0.83	455	6	0.24
30	484	8	1.65	475	8	1.83
31	444	0.6%	-0.55	438	0.6%	-1.11
32	446.01	-	-0.44	449.75	-	-0.18
33	459	0.25%	0.28	450	0.25%	-0.16

Summary Statistics

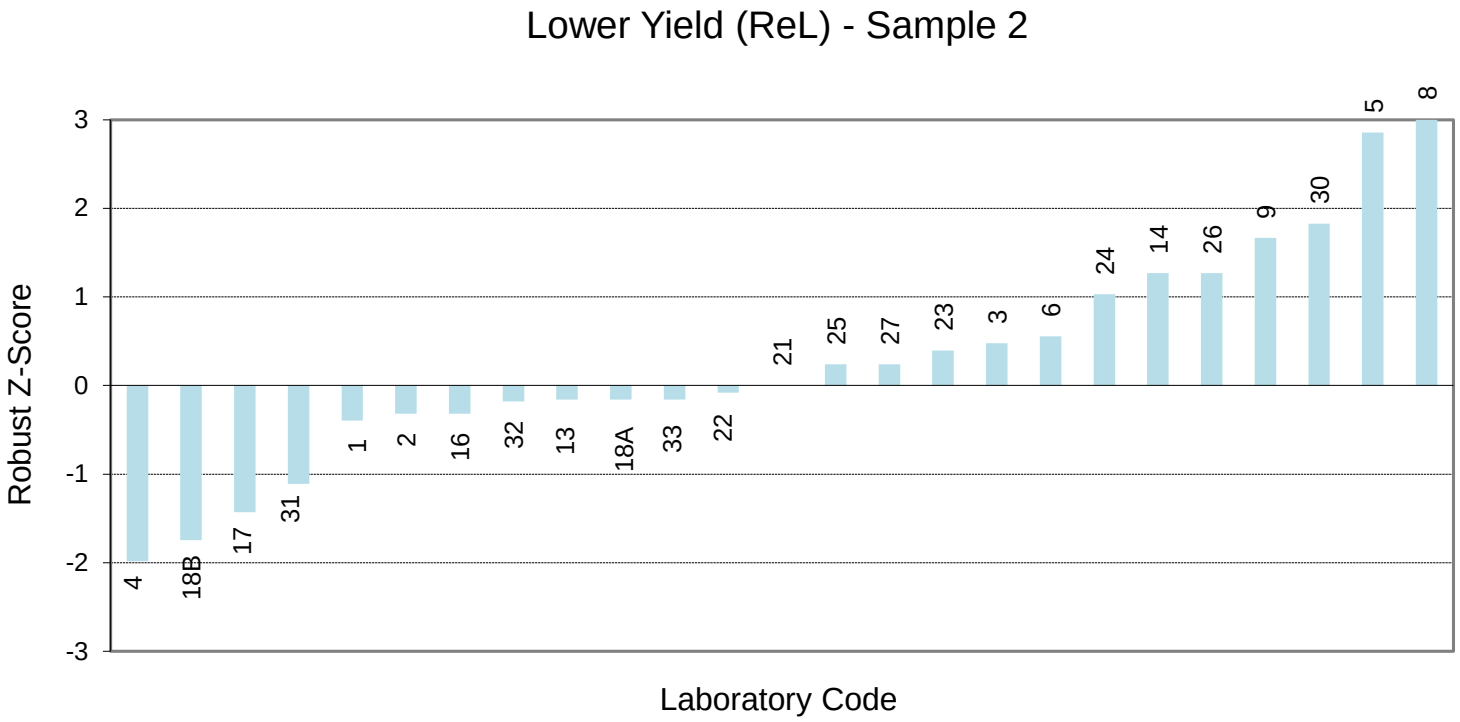
Statistic	Sample 1	Sample 2
Number of Results	23	25
Median	454.0	452.0
Normalised IQR	18.2	12.6
Uncertainty (Median)	4.7	3.2
Robust CV	4.0%	2.8%
Minimum	440	427
Maximum	515	497
Range	75	70

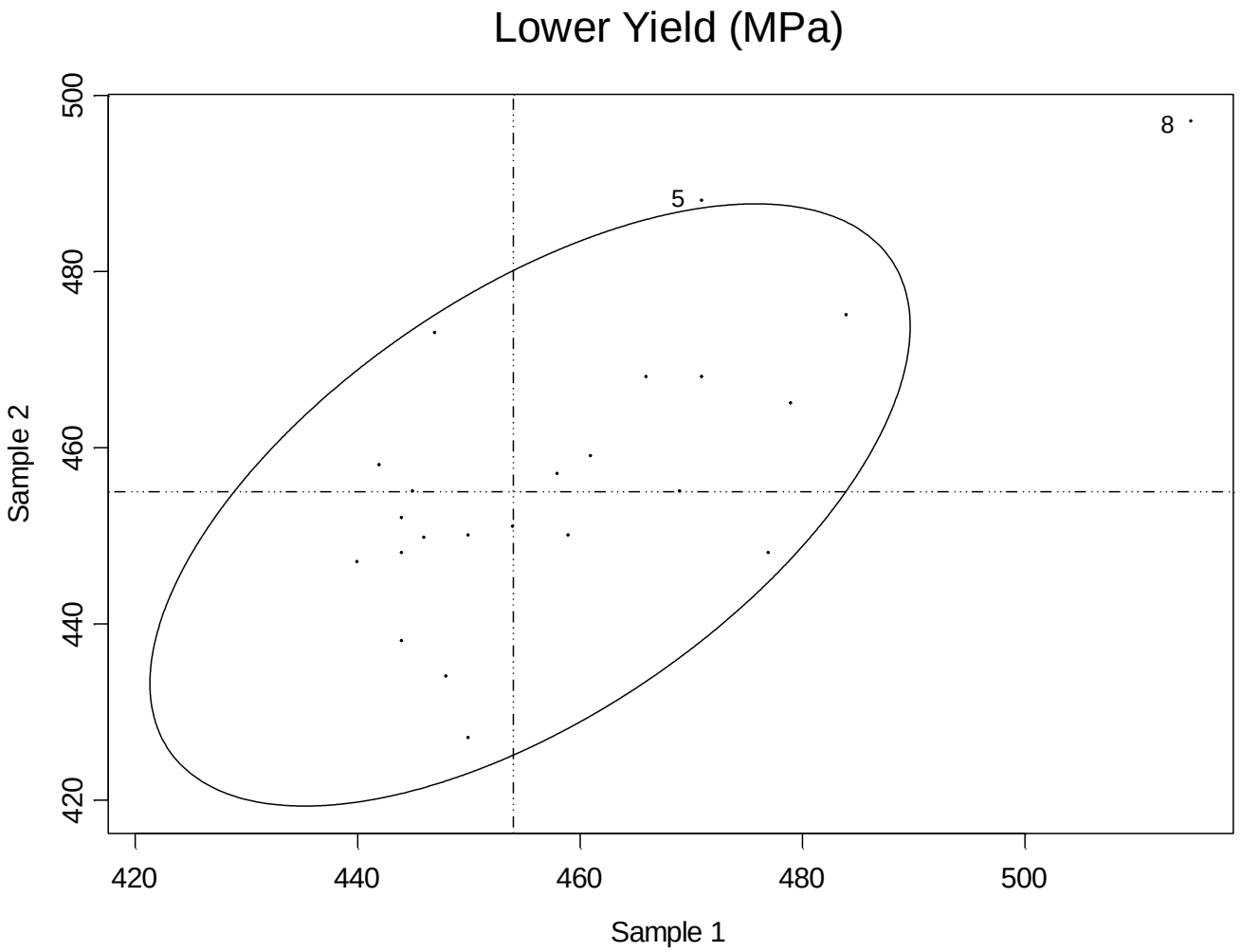
Notes:

1. **§** denotes an outlier (*i.e.* |z-score| ≥ 3.0).
2. The samples for laboratory code 9 were machined by another laboratory.
3. Laboratory code 13 tested samples that were approximately 500 mm in length, 60 mm in width and 6 mm in thickness. These results have been pooled for analysis with the results reported by the other participants that tested the samples that were approximately 400 mm in length, 40 mm in width and 6 mm in thickness (see Appendix B for more details).
4. Laboratory code 18 does not perform proportional testing on flat bar samples.
5. The Youden diagram on the following page is provided for information only.
6. The results reported by laboratory code 18 (18A and 18B) are not included in the Youden diagram, as these were not a pair of results (for Sample 1 and Sample 2).



A2.3


Lower Yield (ReL) - Sample 2
Robust Z-Score
3
2
1
0
-1
-2
-3
4
18B
17
31
1
2
16
32
13
18A
33
22
21
25
27
23
3
6
24
14
26
9
30
5
8
Laboratory Code


Lower Yield (MPa)
Sample 2
500
480
460
440
420
8
5
420
440
460
480
500
Sample 1

Section A3

Upper Yield

Upper Yield (ReH) (MPa) – Results and Z-Scores

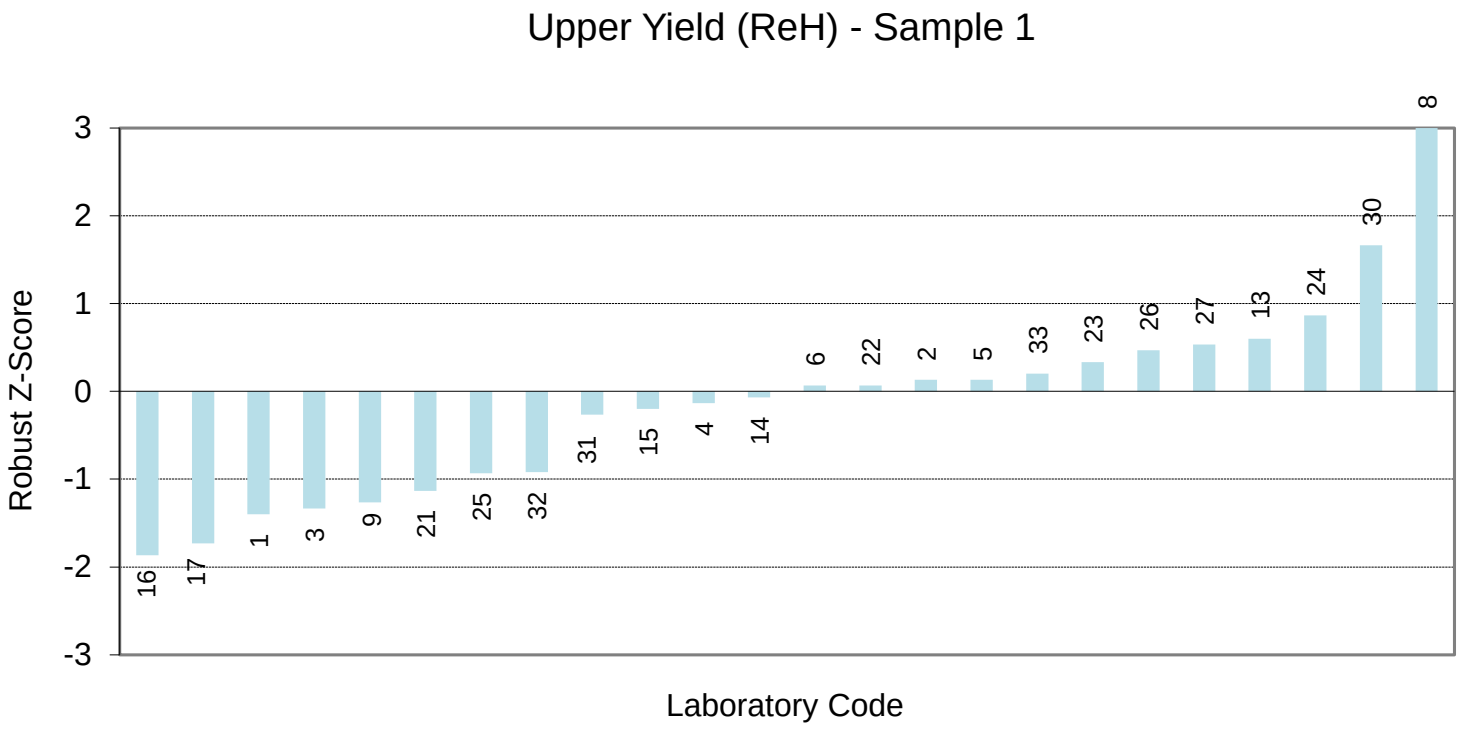
Lab Code	Sample 1			Sample 2		
	Result	MU (±)	Z-Score	Result	MU (±)	Z-Score
1	458	0.29	-1.40	464	0.29	-0.30
2	481	2%	0.13	461	2%	-0.48
3	459	8.1	-1.33	475	8.1	0.36
4	477	5	-0.13	440	4	-1.74
5	481	5.5%	0.13	495	5.5%	1.56
6	480	13	0.07	483	13	0.84
8	554	-	5.00 **§**	510	-	2.46
9	460	15	-1.27	473	16	0.24
13	488	0.23%	0.60	487	0.23%	1.08
14	478	6.35	-0.07	481	6.35	0.72
15	476	2.6	-0.20	458	2.3	-0.66
16	451	9	-1.87	458	9	-0.66
17	453	2.5	-1.73	447	2.5	-1.32
18A	-	-	-	465	-	-0.24
18B	-	-	-	435	-	-2.04
21	462	95%	-1.13	471	95%	0.12
22	480	2%	0.07	466	2%	-0.18
23	484	8	0.33	484	8	0.90
24	492	14	0.87	487	14	1.08
25	465	4.40	-0.93	475	4.20	0.36
26	486	0.17%	0.47	491	0.17%	1.32
27	487	6	0.53	467	6	-0.12
30	504	8	1.67	492	8	1.38
31	475	0.6%	-0.27	467	0.6%	-0.12
32	465.17	-	-0.92	462.01	-	-0.42
33	482	0.25%	0.20	458	0.25%	-0.66

Summary Statistics

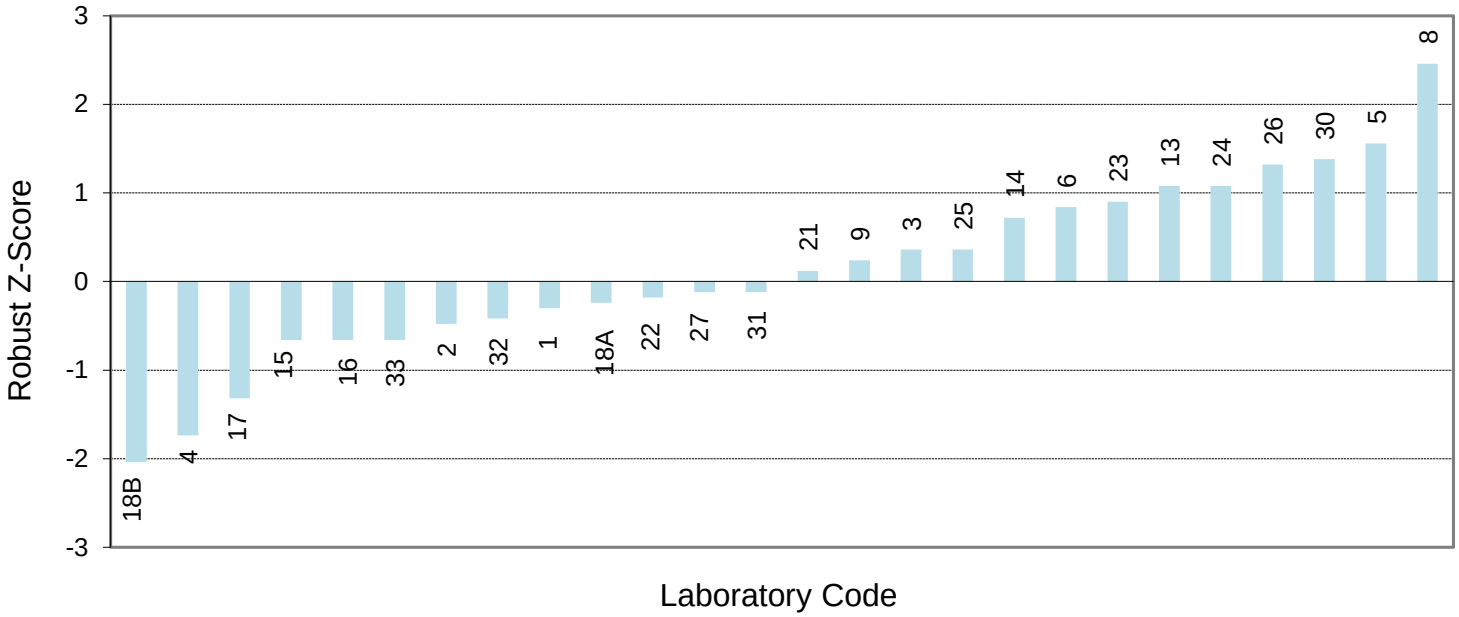
Statistic	Sample 1	Sample 2
Number of Results	24	26
Median	479.0	469.0
Normalised IQR	15.0	16.7
Uncertainty (Median)	3.8	4.1
Robust CV	3.1%	3.6%
Minimum	451	435
Maximum	554	510
Range	103	75

Notes:

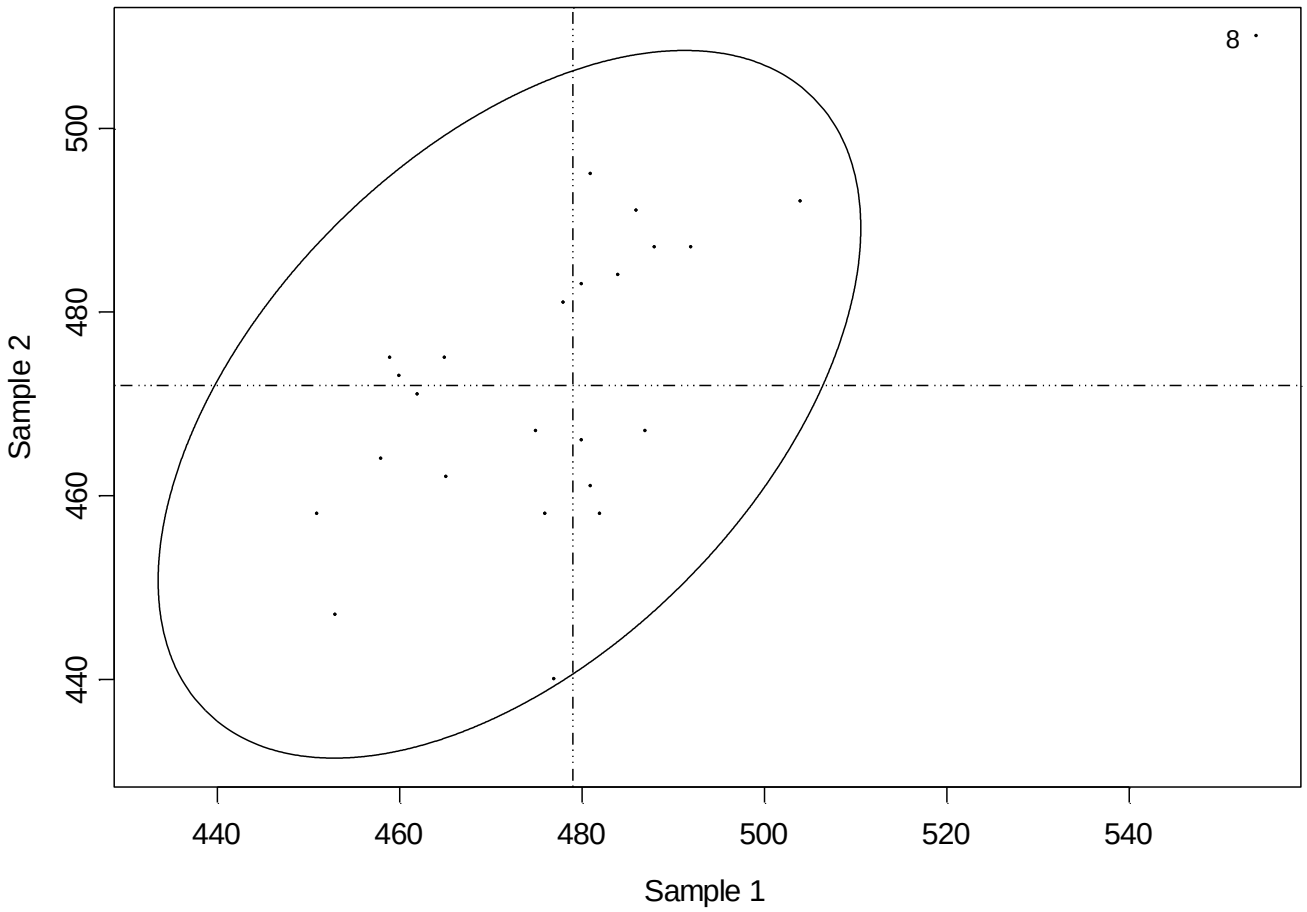
1. **§** denotes an outlier (*i.e.* |z-score| ≥ 3.0).
2. The samples for laboratory code 9 were machined by another laboratory.
3. Laboratory code 13 tested samples that were approximately 500 mm in length, 60 mm in width and 6 mm in thickness. These results have been pooled for analysis with the results reported by the other participants that tested the samples that were approximately 400 mm in length, 40 mm in width and 6 mm in thickness (see Appendix B for more details).
4. Laboratory code 18 does not perform proportional testing on flat bar samples.
5. The Youden diagram on the following page is provided for information only.
6. The results reported by laboratory code 18 (18A and 18B) are not included in the Youden diagram, as these were not a pair of results (for Sample 1 and Sample 2).



Upper Yield (ReH) - Sample 2



Upper Yield (MPa)



Section A4

Tensile Strength

Tensile Strength (Rm) (MPa) – Results and Z-Scores

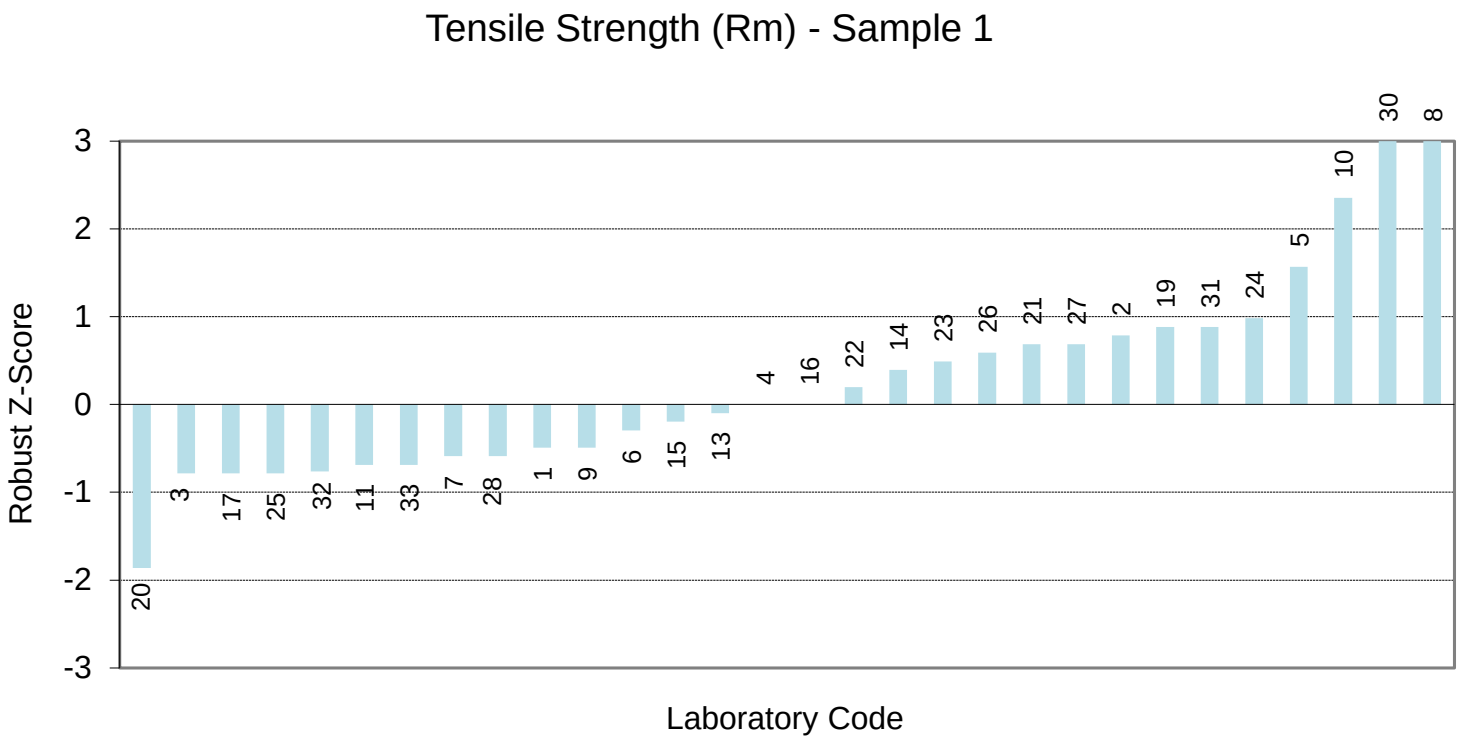
Lab Code	Sample 1			Sample 2		
	Result	MU (±)	Z-Score	Result	MU (±)	Z-Score
1	538	0.29	-0.49	543	0.29	-0.05
2	551	2%	0.78	538	2%	-0.55
3	535	9.7	-0.78	539	9.7	-0.45
4	543	5	0.00	527	5	-1.65
5	559	2.4%	1.57	569	2.4%	2.55
6	540	11	-0.29	542	11	-0.15
7	537	1.66	-0.59	532	2.84	-1.15
8	619	-	7.46 **§**	585	-	4.15 **§**
9	538	17	-0.49	555	17	1.15
10	567	5	2.35	563	5	1.95
11	536	4	-0.69	537	4	-0.65
13	542	0.21%	-0.10	544	0.21%	0.05
14	547	5.09	0.39	556	5.09	1.25
15	541	2.9	-0.20	533	2.7	-1.05
16	543	10	0.00	535	9	-0.85
17	535	3	-0.78	532	3	-1.15
18A	-	-	-	550	-	0.65
18B	-	-	-	530	-	-1.35
19	552	-	0.88	554	-	1.05
20	524	15	-1.86	514	15	-2.95
21	550	95%	0.69	544	95%	0.05
22	545	2%	0.20	544	2%	0.05
23	548	2	0.49	547	2	0.35
24	553	17	0.98	540	16	-0.35
25	535	3.80	-0.78	540	4.60	-0.35
26	549	0.17%	0.59	551	0.17%	0.75
27	550	7	0.69	549	7	0.55
28	537	9	-0.59	545	9	0.15
30	582	0.14	3.83 **§**	567	0.14	2.35
31	552	0.6%	0.88	546	0.6%	0.25
32	535.21	-	-0.76	537.35	-	-0.61
33	536	0.25%	-0.69	536	0.25%	-0.75

Summary Statistics

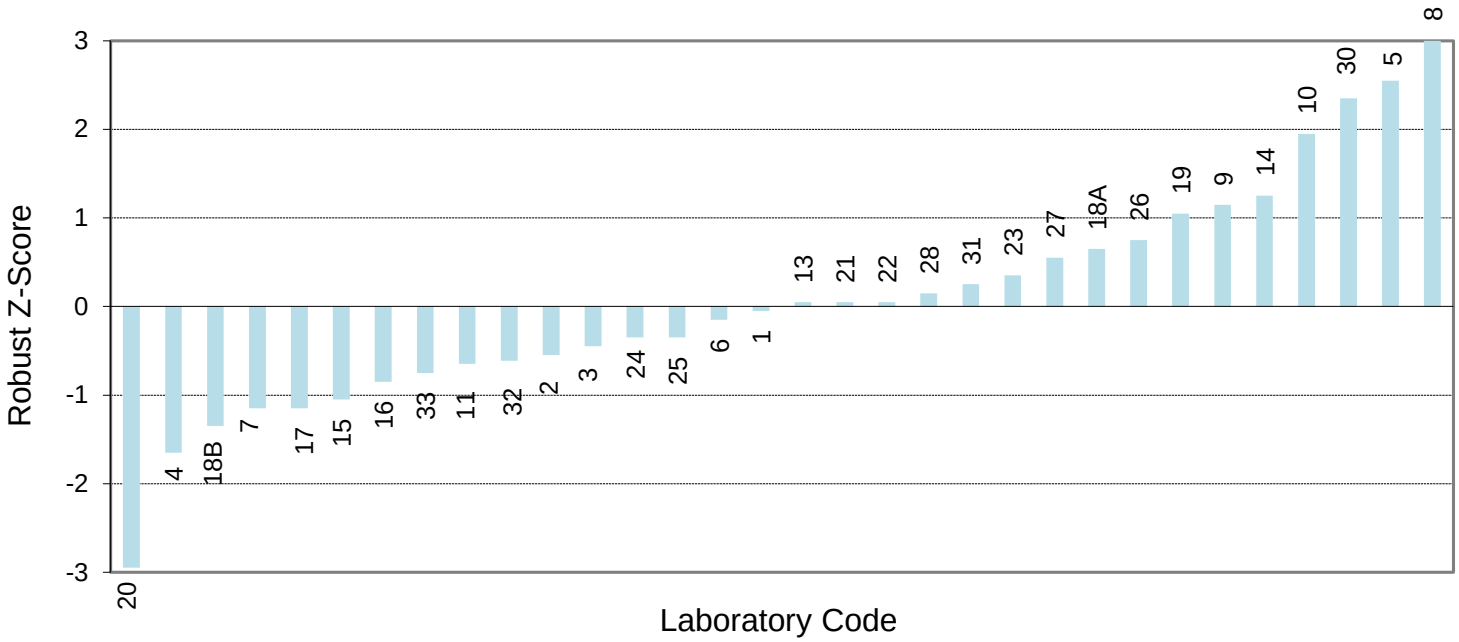
Statistic	Sample 1	Sample 2
Number of Results	30	32
Median	543.0	543.5
Normalised IQR	10.2	10.0
Uncertainty (Median)	2.3	2.2
Robust CV	1.9%	1.8%
Minimum	524	514
Maximum	619	585
Range	95	71

Notes:

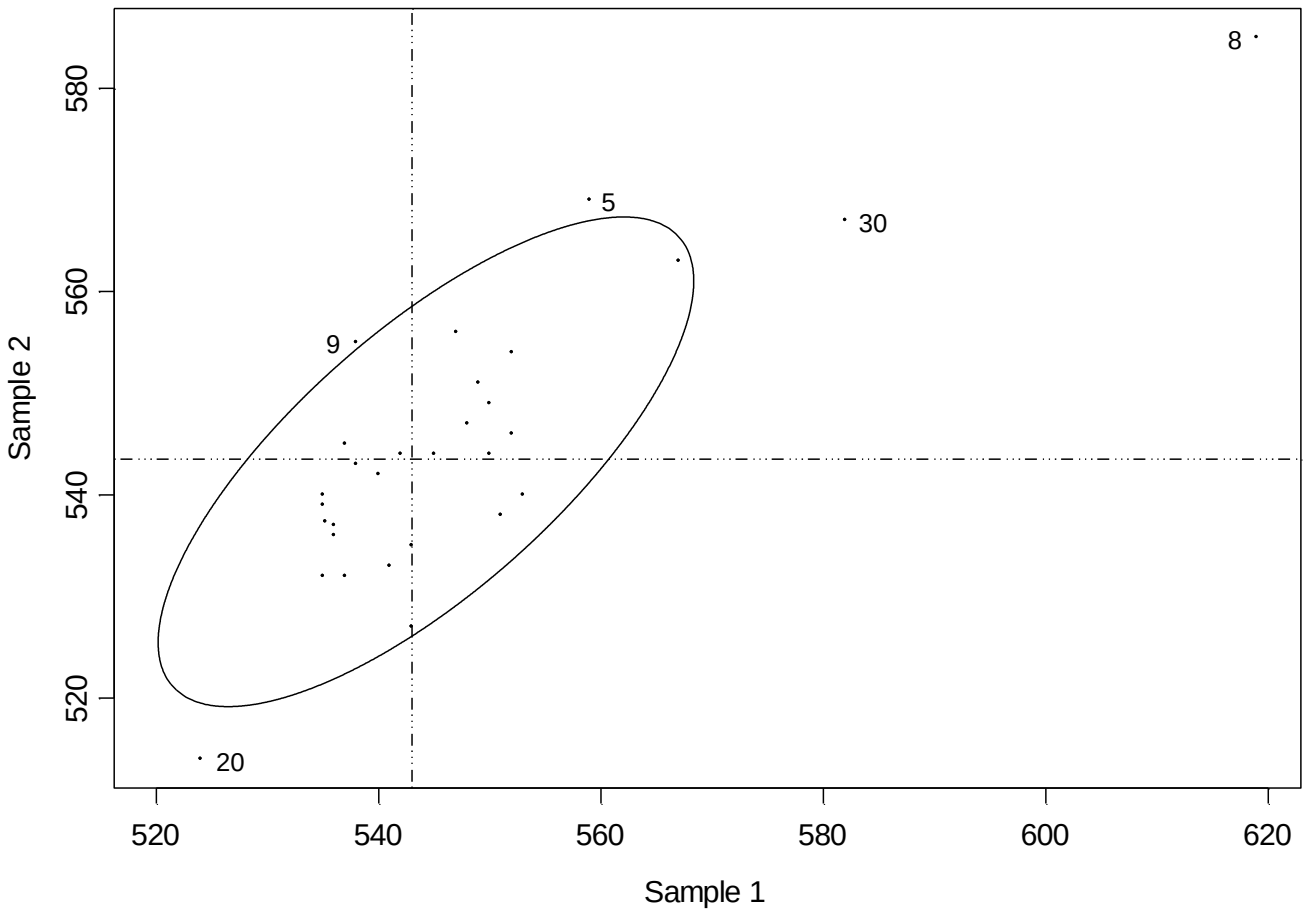
1. **§** denotes an outlier (*i.e.* |z-score| ≥ 3.0).
2. The samples for laboratory code 9 were machined by another laboratory.
3. Laboratory code 13 tested samples that were approximately 500 mm in length, 60 mm in width and 6 mm in thickness. These results have been pooled for analysis with the results reported by the other participants that tested the samples that were approximately 400 mm in length, 40 mm in width and 6 mm in thickness (see Appendix B for more details).
4. Laboratory code 18 does not perform proportional testing on flat bar samples.
5. The Youden diagram on the following page is provided for information only.
6. The results reported by laboratory code 18 (18A and 18B) are not included in the Youden diagram, as these were not a pair of results (for Sample 1 and Sample 2).



Tensile Strength (Rm) - Sample 2



Tensile Strength (MPa)



Section A5

Percentage Elongation after Fracture

Percentage Elongation after Fracture (A%) – Results and Proportional Gauge Length (PGL) Results

Lab Code	Sample 1			Sample 2		
	Result	MU (±)	PGL Result	Result	MU (±)	PGL Result
1	27	1.4	27	24	1.4	26
2	24	2%	24	22	2%	24
3	29	1.4	29	21	1.4	23
4	27	1	28	23	1	25
5	23	0.05	23	28	0.05	28
6	24	1	24	21	1	26
7	18.5	0.29	19	18.5	0.29	30
8	22	-	22	22	-	25
9	23	1.3	23	20	1.3	22
10	23	2%	23	22	2%	25
11	25	1	31	35	1	29
13	26	-	26	32	-	26
14	26.0	1.70	26	25.2	1.70	22
15	30	0.23	30	27	0.31	27
16	28	2	28	23	2	26
17	24	1	24	21	1	23
18A	-	-	-	27	-	27
18B	-	-	-	26	-	26
19	23	-	26	26	-	26
20	26	1	26	19	1	22
21	27	95%	27	27	95%	26
22	28	2%	28	25	2%	28
23	30	1%	28	26	1%	29
24	27	1	27	26	1	29
25	23	0.80	23	20	0.60	22
26	25	0.02 mm	25	21	0.02 mm	21
27	27	1	26	22	1	27
28	22.0	0.5	22	28	0.5	28
30	27.1	1	27	26.3	1	29
31	26	1%	26	27	1%	28
32	25.45	-	25	30.47	-	29
33	26	1%	26	23	1%	26

Percentage Elongation after Fracture (A%) –
400 mm × 40 mm × 6 mm Samples
Proportional Gauge Length (PGL) Results and Z-Scores

Lab Code	Sample 1		Sample 2	
	PGL Result	Z-Score	PGL Result	Z-Score
1	27	0.36	26	0.00
2	24	-0.83	24	-0.60
3	29	1.06	23	-0.98
4	28	0.55	25	-0.20
5	23	-1.08	28	0.88
6	24	-0.67	26	-0.18
7	19	-2.74	30	1.51
8	22	-1.32	25	-0.29
9	23	-1.10	22	-1.44
10	23	-1.00	25	-0.52
11	31	1.69	29	0.98
14	26	-0.01	22	-1.38
15	30	1.42	27	0.45
16	28	0.90	26	-0.10
17	24	-0.64	23	-1.02
18A	-	-	27	0.36
18B	-	-	26	-0.01
19	26	-0.18	26	0.05
20	26	0.00	22	-1.50
21	27	0.35	26	0.15
22	28	0.68	28	0.70
23	28	0.71	29	1.09
24	27	0.33	29	1.11
25	23	-1.07	22	-1.40
26	25	-0.26	21	-1.78
27	26	0.00	27	0.36
28	22	-1.45	28	0.89
30	27	0.52	29	1.23
31	26	0.02	28	0.59
32	25	-0.21	29	0.96
33	26	0.00	26	-0.15

Summary Statistics
400 mm × 40 mm × 6 mm Samples

Statistic	Sample 1	Sample 2
Number of Results	29	31
Median	26.0	26.0
Normalised IQR	2.7	2.7
Uncertainty (Median)	0.6	0.6
Robust CV	10.5%	10.4%
Minimum	19	21
Maximum	31	30
Range	12	9

Percentage Elongation after Fracture (A%) –
500 mm × 60 mm × 6 mm Samples
Proportional Gauge Length (PGL) Results and Z-Scores

Lab Code	Sample 1		Sample 2	
	PGL Result	Z-Score	PGL Result	Z-Score
13	26	0.85	26	-0.85

Summary Statistics
500 mm × 60 mm × 6 mm Samples

Statistic	Sample 1	Sample 2
Number of Results	7	7
Median	25.0	27.0
Normalised IQR	0.5	1.5
Uncertainty (Median)	0.2	0.7
Robust CV	1.8%	5.4%
Target SD	1.4	n/a
Target CV	5.4%	n/a
Minimum	24	25
Maximum	26	27
Range	2	2

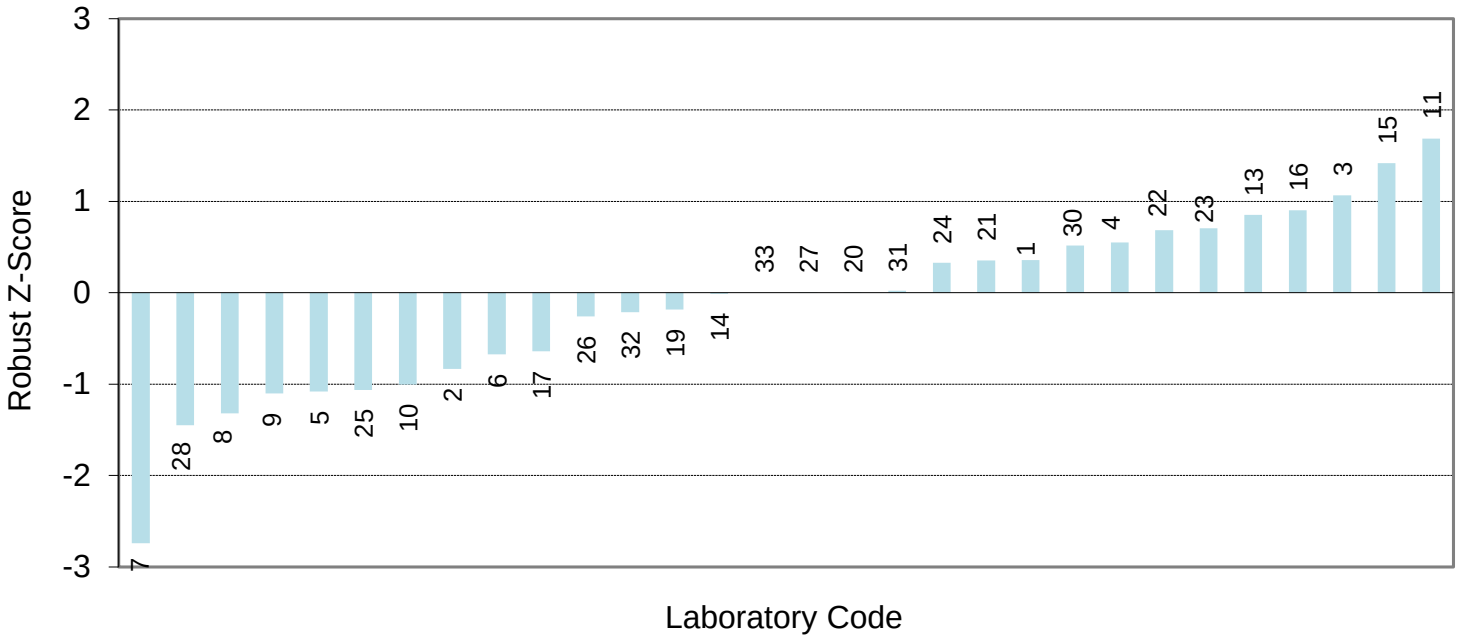
Notes:

1. To analyse the Percentage Elongation after Fracture results, the results submitted by participants were converted to a proportional gauge length (PGL) using the following formula:

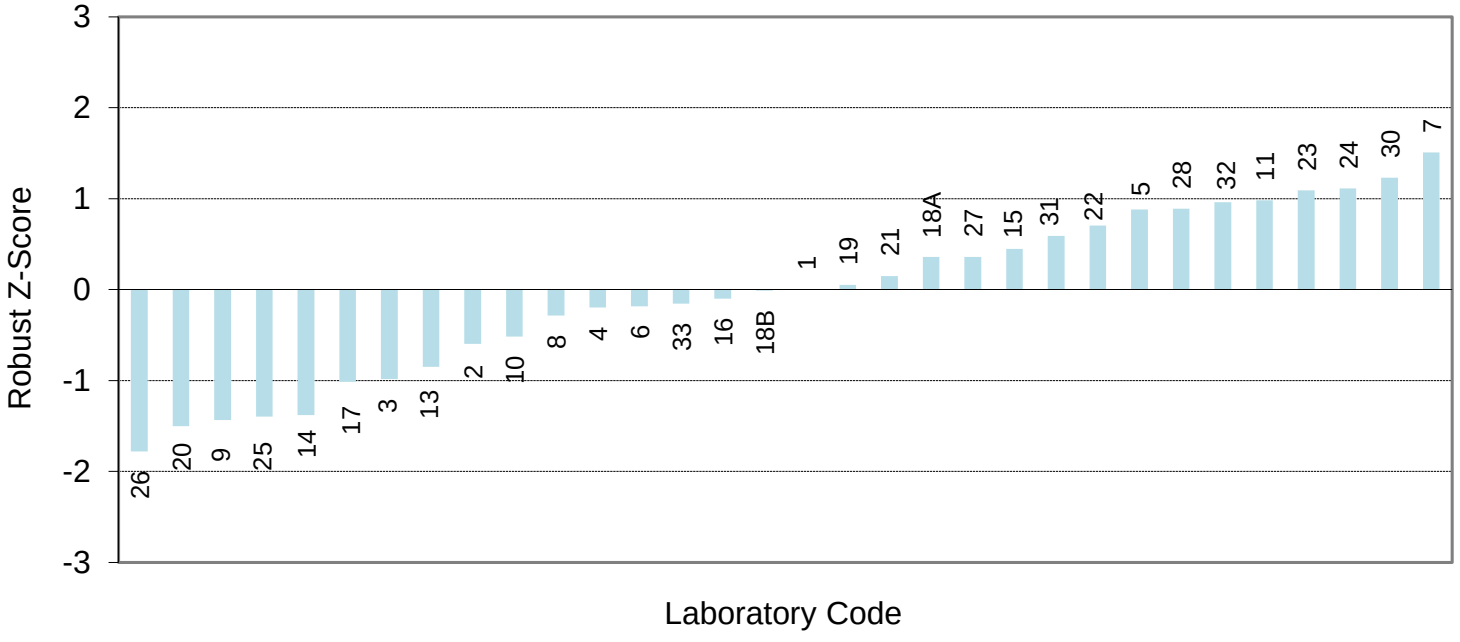
$$\text{PGL Result} = \frac{\text{Result}}{2} \times \left(\frac{\text{Tensile Specimen Gauge Length}}{\sqrt{\text{Thickness} \times \text{Tensile Specimen Width}}} \right)^{0.4}.$$

2. The samples for laboratory code 9 were machined by another laboratory.
3. Laboratory code 13 tested samples that were approximately 500 mm in length, 60 mm in width and 6 mm in thickness. The summary statistics and z-scores for their Percentage Elongation after Fracture results were calculated by including results that were obtained from testing by ARL Laboratory Services Pty Ltd for samples that were 500 mm in length, 60 mm in width and 6 mm in thickness (see Appendix B for more details).
4. A target CV was used to calculate the robust z-scores for the Percentage Elongation after Fracture results for laboratory code 13, for Sample 1. The target CV chosen was 5.4%.
5. The target SD (standard deviation) for the 500 mm × 60 mm × 6 mm samples was obtained by multiplying the target CV by the median. This target SD was used to calculate the z-scores for laboratory code 13 for Sample 1. For more information on the use of target CVs to calculate z-scores, please see the Guide to Proficiency Testing Australia (2016).
6. Laboratory code 18 does not perform proportional testing on flat bar samples. The Percentage Elongation after Fracture results reported by laboratory code 18 for Sample 2 were already converted to a proportional gauge length. Therefore, the formula, above, was not applied to these results.
7. Separate Youden diagrams for the 400 mm × 40 mm × 6 mm samples and the 500 mm × 60 mm × 6 mm samples have been generated and are displayed on the following pages. The Youden diagram for the 500 mm × 60 mm × 6 mm samples includes the results obtained from the testing by ARL Laboratory Services Pty Ltd (see Appendix B). These diagrams are provided for information only.
8. The results reported by laboratory code 18 (18A and 18B) are not included in the Youden diagram for the 400 mm × 40 mm × 6 mm samples, as these were not a pair of results (for Sample 1 and Sample 2).

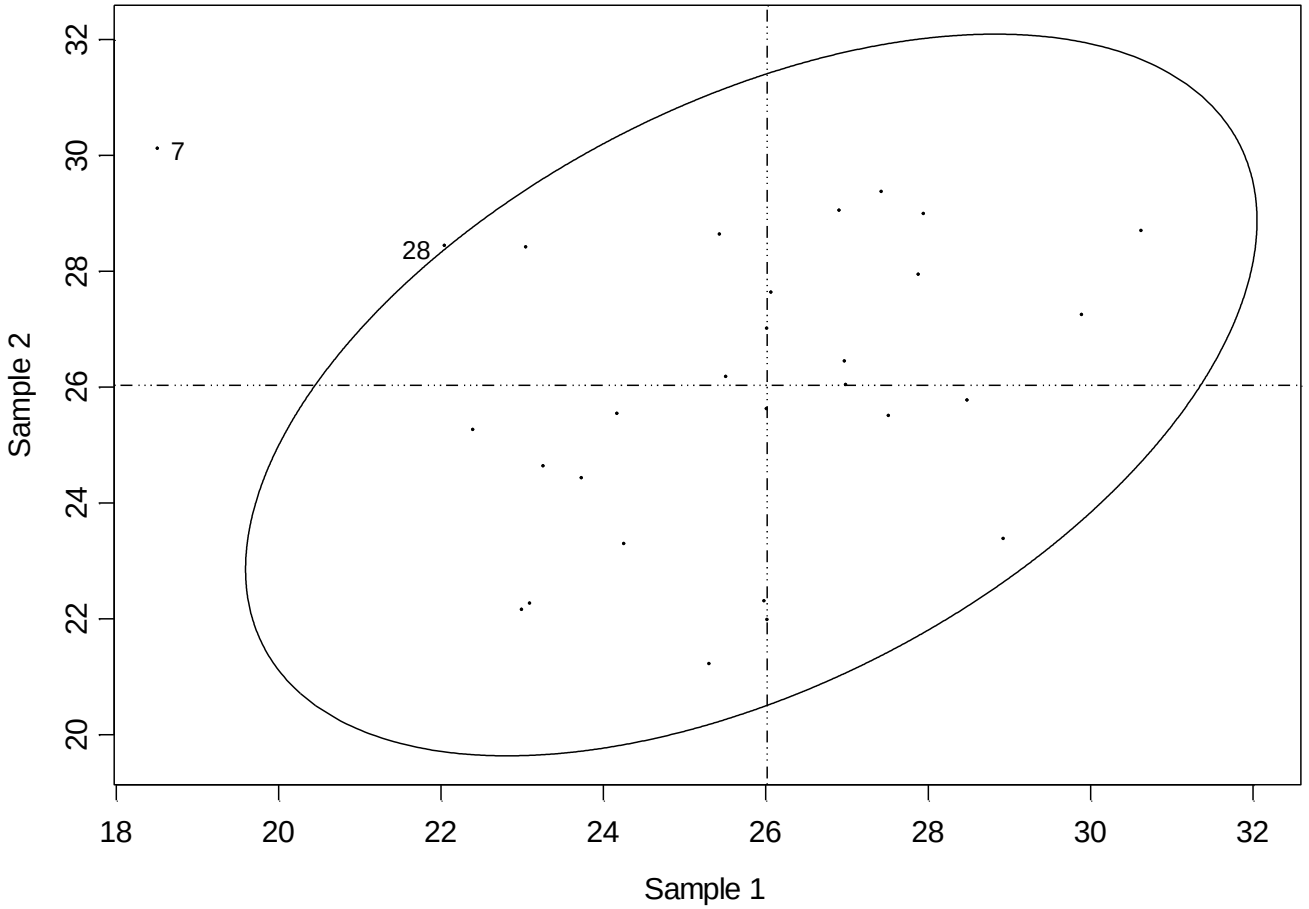
Percentage Elongation after Fracture (A%) - Sample 1



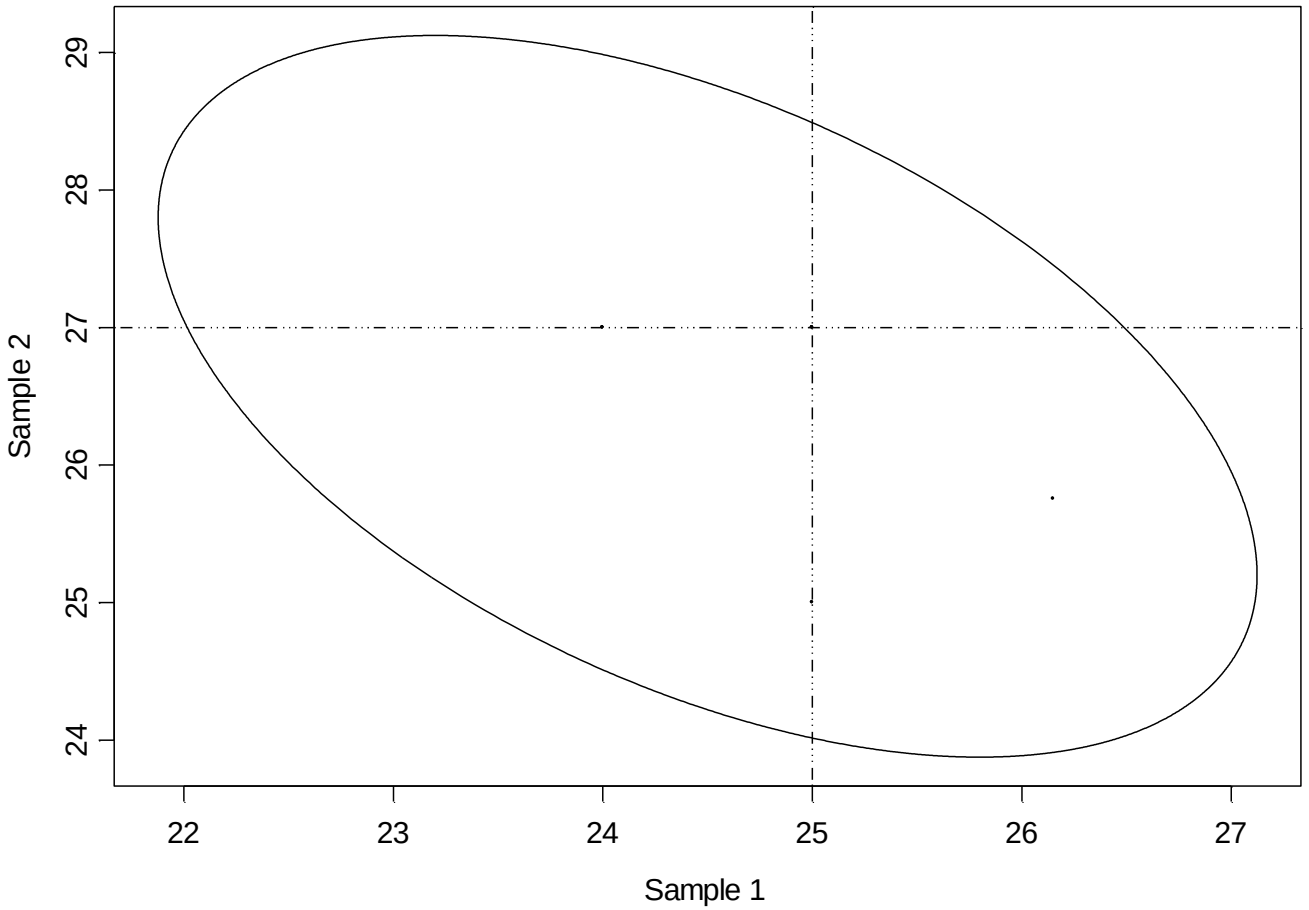
Percentage Elongation after Fracture (A%) - Sample 2



Percentage Elongation after Fracture (400 mm x 40 mm x 6 mm)



Percentage Elongation after Fracture (500 mm x 60 mm x 6 mm)



Section A6

Method Information and Other Reported Results

Method Information

Lab Code	0.2% Proof Stress	Lower Yield	Upper Yield
1	ISO 6892-1	ISO 6892-1	ISO 6892-1
2	AS 1391	AS 1391	AS 1391
3	AS 1391, ISO 6892-1	AS 1391, ISO 6892-1	AS 1391, ISO 6892-1
4	AS 1391 - 2007	AS 1391 - 2007	AS 1391 - 2007
5	AS 1391 - 2007	AS 1391 - 2007	AS 1391 - 2007
6	AS 1391	AS 1391	AS 1391
8	AS 1391	AS 1391	AS 1391
9	AS 1391 - 2007	AS 1391 - 2007	AS 1391 - 2007
10	ISO 6892-1	-	-
11	ISO 6892-1 A2, ASTM A370	-	-
13	AS 1391	AS 1391	AS 1391
14	ISO 6892-1	ISO 6892-1	ISO 6892-1
15	AS 1391	-	AS 1391
16	ASTM E8 / E8M-16a	ASTM E8 / E8M-16a	ASTM E8 / E8M-16a
17	AS 1391	AS 1391	AS 1391
18A	-	AS 1391	AS 1391
18B	-	AS 1391	AS 1391
19	AS 1391	-	-
20	AS 1391	-	-
21	AS 1391	AS 1391	AS 1391
22	AS 1391	AS 1391	AS 1391
23	-	AS 1391	AS 1391
24	BS-EN ISO 6892-1: 2016	BS-EN ISO 6892-1: 2016	BS-EN ISO 6892-1: 2016
25	AS 1391 - 2007	AS 1391 - 2007	AS 1391 - 2007
26	AS 1391	AS 1391	AS 1391
27	-	-	-
28	ISO 6892-1 A224	-	-
30	ISO 6892-1: 2016	ISO 6892-1: 2016	ISO 6892-1: 2016
31	AS 1391 - 2007	AS 1391 - 2007	AS 1391 - 2007
32	-	ASTM A370	ASTM A370
33	ISO 6892-1	ISO 6892-1	ISO 6892-1

Method Information

Lab Code	Tensile Strength	Percentage Elongation after Fracture
1	ISO 6892-1	ISO 6892-1
2	AS 1391	AS 1391
3	AS 1391, ISO 6892-1	AS 1391, ISO 6892-1
4	AS 1391 - 2007	AS 1391 - 2007
5	AS 1391 - 2007	AS 1391 - 2007
6	AS 1391	AS 1391
7	AS 1391	AS 1391
8	AS 1391	AS 1391
9	AS 1391 - 2007	AS 1391 - 2007
10	ISO 6892-1	ISO 6892-1
11	ISO 6892-1 A2, ASTM A370	ISO 6892-1 A2, ASTM A370
13	AS 1391	AS 1391
14	ISO 6892-1	ISO 6892-1
15	AS 1391	AS 1391
16	ASTM E8 / E8M-16a	ASTM E8 / E8M-16a
17	AS 1391	AS 1391
18A	AS 1391	AS 1391
18B	AS 1391	AS 1391
19	AS 1391	AS 1391
20	AS 1391	AS 1391
21	AS 1391	AS 1391
22	AS 1391	AS 1391
23	AS 1391	AS 1391
24	BS-EN ISO 6892-1: 2016	BS-EN ISO 6892-1: 2016
25	AS 1391 - 2007	AS 1391 - 2007
26	AS 1391	AS 1391
27	-	-
28	ISO 6892-1 A224	ISO 6892-1 A224
30	ISO 6892-1: 2016	ISO 6892-1: 2016
31	AS 1391 - 2007	AS 1391 - 2007
32	ASTM A370	ASTM A370
33	ISO 6892-1	ISO 6892-1

Tensile Specimen Thickness and Tensile Specimen Gauge Width

Lab Code	Tensile Specimen Thickness (mm)				Tensile Specimen Gauge Width (mm)			
	Sample 1		Sample 2		Sample 1		Sample 2	
	Result	MU (±)	Result	MU (±)	Result	MU (±)	Result	MU (±)
1	5.78	0.00349	5.78	0.00349	24.30	0.00349	23.05	0.00349
2	5.98	1%	5.96	1%	19.88	1%	19.92	1%
3	5.97	0.014	5.83	0.014	12.46	0.014	20.09	0.014
4	5.67	0.1	5.96	0.1	12.53	0.1	20.06	0.1
5	5.68	0.02	5.83	0.02	12.53	0.02	12.47	0.02
6	5.96	0.002	5.96	0.002	12.64	0.019	12.63	0.019
7	6.06	0.023	6.05	0.023	20.05	0.023	18.10	0.023
8	5.70	-	5.90	-	12.52	-	14.95	-
9	6.0	0.01	6.0	0.01	22	0.01	20	0.01
10	5.91	0.01	5.71	0.01	12.48	0.04	19.93	0.02
11	5.82	-	5.83	-	28.01	-	36.22	-
13	5.79	0.002	5.76	0.002	40.15	0.002	40.17	0.002
14	5.69	0.001	5.74	0.001	20.08	0.01	25.08	0.01
15	5.75	0.002	5.98	0.002	19.90	0.014	12.50	0.014
16	5.74	0.002	5.91	0.002	12.49	0.004	29.99	0.004
17	6.00	0.005	6.01	0.005	12.34	0.01	19.85	0.01
18A	-	-	5.78	-	-	-	39.91	-
18B	-	-	6.05	-	-	-	40.34	-
19	5.98	-	5.98	-	19.90	-	24.80	-
20	5.98	0.01	5.96	0.01	25.48	0.02	25.34	0.02
21	5.74	95%	5.99	95%	13.67	95%	14.50	95%
22	5.71	1%	5.72	1%	20.10	1%	20.09	1%
23	5.76	0.4%	5.93	0.4%	19.32	0.5%	19.61	0.5%
24	5.7	-	5.74	-	20.07	-	20.05	-
25	5.90	0.013	5.80	0.013	21.90	0.013	20.20	0.013
26	5.63	0.02	5.96	0.02	13.05	0.02	12.46	0.02
27	5.68	0.06	5.80	0.06	10.59	0.06	12.38	0.06
28	5.94	0.10	5.77	0.10	12.48	0.01	12.55	0.01
30	5.68	0.01	5.70	0.01	25.38	0.01	20.24	0.01
31	5.75	0.2%	5.60	0.2%	13.40	0.2%	12.45	0.2%
32	5.97	-	5.78	-	25.35	-	19.06	-
33	5.70	0.5%	5.75	0.5%	25.27	0.5%	20.31	0.5%

Tensile Specimen Gauge Length (mm)

Lab Code	Sample 1		Sample 2	
	Result	MU (±)	Result	MU (±)
1	67	0.00349	80	0.00349
2	60	1%	80	1%
3	48.50	0.25	80.00	0.25
4	50	0.1	80	0.1
5	48	0.02	50	0.02
6	50	0.019	80	0.019
7	62.50	0.5	200	0.5
8	50.0	-	75.0	-
9	65	0.01	80	0.01
10	50	0.1	80	0.1
11	120	-	50	-
13	87.5	0.015	50	-
14	60.4	0.01	50	0.01
15	60	0.30	50	0.30
16	50	0.003	100	0.003
17	50	0.3	80	0.5
18A	-	-	200	-
18B	-	-	200	-
19	80	-	70	-
20	70	0.02	100	0.02
21	50	95%	50	95%
22	60	1%	80	1%
23	50	0.8%	80	0.8%
24	60	-	80	-
25	65	1.0	80	1.0
26	50	0.02	50	0.02
27	40	1	80	1
28	49.00	0.01	50.00	0.01
30	70.0	0.6	80.0	0.6
31	50	0.2%	50	0.2%
32	69.51	-	50.8	-
33	68	1%	80	1%

Elastic Stress or Strain Rate (number / sec)

Lab Code	Sample 1		Sample 2	
	Result	MU (±)	Result	MU (±)
1	458	0.29	464	0.29
2	0.0003	5%	0.0005	5%
3	0.0001	-	0.0015	-
4	0.0025	-	0.0025	-
5	0.00025	-	0.00025	-
6	0.0001	-	0.0001	-
7	-	-	-	-
8	0.0009	-	0.0009	-
9	12 MPa/s	-	12 MPa/s	-
10	12 MPa/s	1 MPa/s	12 MPa/s	1 MPa/s
11	4	-	7	-
13	0.0008	-	0.0008	-
14	0.0008	-	0.0008	-
15	0.00025	0.25%	0.00025	0.25%
16	0.7 kgf/mm^2/s	-	0.7 kgf/mm^2/s	-
17	15 MPa/sec	-	15 MPa/sec	-
18A	-	-	-	-
18B	-	-	-	-
19	-	-	-	-
20	0.0007	-	0.0008	-
21	0.00025	95%	0.00025	95%
22	0.0007	1%	0.0022	1%
23	0.00027	0.05%	0.00027	0.05%
24	0.25	-	0.25	-
25	-	-	-	-
26	6 MPa/s	-	6 MPa/s	-
27	0.01 kN/mm^{2}s	0.001 kN/mm^{2}s	0.01 kN/mm^{2}s	0.001 kN/mm^{2}s
28	0.00025	-	0.00025	-
30	-	-	-	-
31	0.001	-	0.001	-
32	-	-	-	-
33	0.25 mm/s	-	0.25 mm/s	-

Plastic Strain Rate (number / sec)

Lab Code	Sample 1		Sample 2	
	Result	MU (±)	Result	MU (±)
1	538	0.29	543	0.29
2	0.003	5%	0.002	5%
3	0.0002	-	0.0015	-
4	0.008	-	0.008	-
5	0.001	-	0.001	-
6	0.0021	-	0.0021	-
7	-	-	-	-
8	30	-	30	-
9	12 MPa/s	-	12 MPa/s	-
10	-	-	-	-
11	58	-	65	-
13	0.005	-	0.005	-
14	0.0075	-	0.0075	-
15	0.0025	0.25%	0.0025	0.25%
16	14 mm/min	-	14 mm/min	-
17	0.0044	-	0.0037	-
18A	-	-	-	-
18B	-	-	-	-
19	-	-	-	-
20	0.0414	-	0.0033	-
21	0.0067	95%	0.0067	95%
22	0.0003	1%	0.0021	1%
23	0.0067	0.05%	0.0067	0.05%
24	0.25	-	0.25	-
25	-	-	-	-
26	0.0025	-	0.0025	-
27	-	-	-	-
28	0.0067	-	0.0067	-
30	-	-	-	-
31	0.003	-	0.003	-
32	-	-	-	-
33	0.25 mm/s	-	0.25 mm/s	-

APPENDIX B

Homogeneity Testing

HOMOGENEITY TESTING

Before the test pieces were distributed to participants, eight specimens from each 400 mm × 40 mm × 6 mm sample were selected at random and tested by ARL Laboratory Services Pty Ltd. This was done to assess the variability of the samples to be used in the program. The results of this testing appear in the following tables.

Homogeneity Testing Results (400 mm × 40 mm × 6 mm Samples)

Sample 1 – Proportional Sample

Sample Number	Cross-sectional Area (mm^2)	Tensile Strength (MPa)	0.2% Proof Stress (MPa)	Original Gauge Length (mm)	% Elongation on $5.65\sqrt{S_0}$
1-1	126.3	535	455	65	23
1-3	125.7	535	450	65	23
1-11	123.3	530	445	65	23
1-21	126.8	530	445	65	24
1-30	123.3	530	445	65	24
1-33	121.5	530	450	65	22
1-34	118.0	530	440	65	23
1-40	122.4	540	440	65	24

Homogeneity Testing Results (400 mm × 40 mm × 6 mm Samples)

Sample 2 – Non-Proportional Sample

Sample Number	Cross-sectional Area (mm^2)	Tensile Strength (MPa)	0.2% Proof Stress (MPa)	Original Gauge Length (mm)	% Elongation on $5.65\sqrt{S_0}$
2-4	116.8	530	445	80	22
2-10	119.4	535	455	80	21
2-12	116.2	530	445	80	23
2-18	109.2	535	445	80	22
2-21	121.2	535	465	80	22
2-24	124.8	545	475	80	22
2-28	117.4	535	455	80	22
2-40	118.8	530	455	80	21

Analysis of this testing data indicated that the 400 mm × 40 mm × 6 mm samples were sufficiently homogeneous for the program and, therefore, any participant results identified as outliers cannot be attributed to sample variability.

Since one of the participants in this round of the program requested samples that were approximately 500 mm in length, 60 mm in width and 6 mm in thickness for testing, ARL Laboratory Services Pty Ltd tested six samples with these dimensions for homogeneity. The results of this testing appear in the following table.

Homogeneity Testing Results (500 mm × 60 mm × 6 mm Samples)

Sample 1 – Proportional Sample

Sample Number	Cross-sectional Area (mm^2)	Tensile Strength (MPa)	0.2% Proof Stress (MPa)	Original Gauge Length (mm)	% Elongation on $5.65\sqrt{S_0}$
1	292.9	530	450	100	25
2	292.3	535	455	100	24
3	292.3	530	445	100	25
4	292.6	525	450	100	25
5	292.7	530	445	100	24
6	292.1	530	450	100	25

Homogeneity Testing Results (500 mm × 60 mm × 6 mm Samples)

Sample 2 – Non-Proportional Sample

Sample Number	Cross-sectional Area (mm^2)	Tensile Strength (MPa)	0.2% Proof Stress (MPa)	Original Gauge Length (mm)	% Elongation on $5.65\sqrt{S_0}$
1	233.2	530	450	200	27
2	232.0	535	455	200	27
3	232.0	535	455	200	25
4	232.0	535	450	200	25
5	233.0	535	455	200	27
6	232.0	530	450	200	27

Analysis of this testing data indicated that the 500 mm × 60 mm × 6 mm samples were sufficiently homogeneous for the program and, therefore, any participant results identified as outliers cannot be attributed to sample variability.

Comparing the homogeneity results for the 400 mm × 40 mm × 6 mm samples to the homogeneity results for the 500 mm × 60 mm × 6 mm samples showed that their were no significant differences between the results for the two different sets of samples, except for Percentage Elongation after Fracture. This was to be expected, since Percentage Elongation after Fracture is the most sensitive of all the tensile properties tested for in this program. As a consequence of this analysis, the results submitted by the participant that tested the 500 mm × 60 mm × 6 mm samples were pooled for analysis with the other participants' results for all tests except Percentage Elongation after Fracture. For Percentage Elongation after Fracture, the results submitted by the participant that tested the 500 mm × 60 mm × 6 mm samples were compared to the homogeneity testing results obtained by ARL Laboratory Services Pty Ltd (shown in the tables above).

APPENDIX C

Instructions to Participants

and

Results Sheet

PROFICIENCY TESTING AUSTRALIA

Tensile Testing Of Metals Proficiency Testing Program
Round 12, April 2019

Instructions To Participants

To ensure that the results of this program can be analysed correctly, participants are asked to note carefully:

1) The samples for this tensile testing program comprise of two identical carbon steel flat bar samples. The samples are labelled 1-x for Sample 1 and 2-x for Sample 2.

2) Both of the samples are to be machined. A different Tensile Specimen Gauge Length and Tensile Specimen Gauge Width should be used when machining each sample. For Sample 1 a proportional gauge length should be used, while a non-proportional gauge length should be used for Sample 2.

3) The tests to be performed in this program are:

   - 0.2% Proof Stress (non-proportional elongation) ($R_{p0.2}$), if applicable;
   - Lower and Upper Yield Strength (ReL and ReH), if applicable;
   - Tensile Strength (Rm); and
   - Percentage Elongation after Fracture (A%).

4) Tests may commence as soon as samples are received. The samples are to be treated in the same manner as routinely tested samples.

5) All testing, recording and reporting is to be performed in accordance with your routine test methods, but testing in accordance with AS 1391 – *Metallic materials – Tensile testing at ambient temperature* (2007) or ISO 6892-1 – *Metallic materials – Tensile testing – Part 1: Method of test at room temperature* (2016) are the preferred test methods.

6) Report only one result per sample, based on the determination for each property. For each determination, results are to be reported to the accuracy and in the units indicated on the Results Sheet.

7) The method of testing used should also be reported on the Results Sheet (*e.g.* AS 1391, ISO 6892-1, etc.)

8) The Percentage Elongation after Fracture (A%) results will be converted by Proficiency Testing Australia to a proportional gauge length before analysis. Participants should therefore report the Tensile Specimen Gauge Width, Tensile Specimen Gauge Length and Tensile Specimen Thickness.

9) Participants 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 $k \approx 2$).

10) 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, ensuring the confidentiality of your results.

11) 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 **Monday 29 April 2019**. Results reported later than this date may not be analysed in the final report.

PROFICIENCY TESTING AUSTRALIA

Tensile Testing Of Metals Proficiency Testing Program Round 12, April 2019

RESULTS SHEET

Laboratory Code: _____

Test	Report results to nearest	Sample 1 Proportional		Sample 2 Non-Proportional		Method
		Result	MU (±)	Result	MU (±)	
0.2% Proof Stress (non-proportional elongation) ($R_{p0.2}$)	1 MPa					
Lower Yield Strength (ReL)	1 MPa					
Upper Yield Strength (ReH)	1 MPa					
Tensile Strength (Rm)	1 MPa					
Percentage Elongation after Fracture (A%)	1%					

Where possible, please also report the values for the following:

Test	Report results to nearest	Sample 1 Proportional		Sample 2 Non-Proportional	
		Result	MU (±)	Result	MU (±)
Tensile Specimen Thickness	0.01 mm				
Tensile Specimen Gauge Width	0.01 mm				
Tensile Specimen Gauge Length	1 mm				
Elastic Stress or Strain Rate	number / sec				
Plastic Strain Rate	number / sec				

All estimates of measurement uncertainty (MU) must be given as a 95% confidence interval (coverage factor k ≈ 2).

Print Name: _____ Signature & Date: _____

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