Asia Pacific Laboratory Accreditation Cooperation

APLAC T052 Tensile Test for Metallic Materials Proficiency Testing Program

Final Report

March 2008

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1. Introduction

This report summarizes the results of APLAC T052 Tensile Test for Metallic Materials Proficiency Testing Program involving testing laboratories for the Asia Pacific Laboratory Accreditation Cooperation (APLAC), European co-operation for Accreditation (EA) and InterAmerican Accreditation Cooperation (IAAC). The mechanical properties requested in this program were Yield Strength, Tensile Strength and Percentage elongation after Fracture.

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

2. Program Feature

(a) APLAC members, and EA and IAAC unaffiliated bodies were invited to participate. There were in total 60 laboratory participants nominated by 35 accreditation bodies (ABs) in this program. All samples were sent to the ABs and transferred to the participating laboratories. Eleven participating laboratories did not return results; hence the analysis of the results did not include those laboratories.

Table 1 Summary of Economies and Participants

Economy	No. of Participants	Economy	No. of Participants
Argentina	1	New Zealand	2
Australia	2	Philippines	3
Canada	1	Poland	3
Chile	1	Portugal	2
Croatia	1	Romania	1
Czech Republic	1	Russia	2
Germany	1	Singapore	3
Greece	1	South Korea	2
HK, SAR	1	Sri Lanka	1
India	3	Switzerland	1
Indonesia	2	Taiwan	3
Italy	1	Thailand	2
Japan	3	Turkey	1
Latvia	1	United Kingdom	1
Malaysia	2	USA	6
Mexico	2	Viet Nam	2
Mongolia	1	**Total**	**60**

(b) Participating laboratories were supplied two round bars of metallic materials. These are numbered A and B for preparing standard 12.5mm round tensile test specimens.

(c) Each participating laboratory is required to obtain the mechanical properties of Yield Strength, Tensile Strength and Percentage Elongation in sample A and sample B.

(d) Prior to distribution the samples were analyzed for homogeneity. The testing results showed that the samples were sufficiently homogeneous. Therefore any results later identified as outliers could not be attributed to any significant sample variability. (Appendix B)

(e) Laboratories were requested to perform the tests according to their copy of the Instructions to Participants and to record their results on the accompanying Results Sheet, both of which were distributed to participants with the samples. (Appendix C)

(f) Each laboratory was randomly allocated a unique code number for the program to enable confidentiality of results. Its code number makes reference to each laboratory in this report.

3. Content of Appendices

APPENDIX A contains:

(a) The results of two samples reported by laboratories and the calculated Z-Score result for each test on each sample.

(b) A table of robust statistics for each test, such as number of results, median, normalized IQR, robust CV, minimum, maximum and range.

(c) Z-Scores and ordered Z-Score charts calculated for laboratories for each test.

(d) Test methods are reported for each laboratory.

(e) Youden Plots

APPENDIX B contains the details of sample preparation and homogeneity testing.

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

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

4. Statistical design of the program

An identical statistical design was used in this program. The samples labeled A and B had the same mechanical properties.

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

For each laboratory, single robust Z-scores of between-lab and within-lab were calculated for sample A and sample B.

5. Outlier Results

The outliers of feedback results are shown as below, the detail information please refers to the Summary of Results in Appendix A.

Yield Strength		
	Between Laboratories Z score	Within Laboratories Z score
Lab Code	6, 37	---
Tensile Strength		
Lab Code	29, 37, 42, 56	16, 64

6. Technical Comments

General Comments

1. More than 15 laboratories used the same testing speed before and after yield, they did not satisfy the requirements of ASTM E8/E8M-04.
2. In the final report, it is recommended to notify the participants to choose the right specimen shape in the operation of testing software. The wrong cross section area will lead to outlier results in the yield and tensile strength.
3. The data analysis of the yield strength, tensile strength and percentage elongation from the participants shows the good sample homogeneity.
4. The information of "Use of Extensometer: ☐ Yes ☐ No" should be added prior "Class of Extensometer" in the result sheet in the future PT program of metallic materials tensile test. It will help to definitely judge whether the yield strength (determined by the offset method or extension-under-load method) is included in the statistical calculation.
5. If any part of the fracture takes place outside the gage marks, the percentage elongation shall not be included in the statistical calculation (such as Lab 64).
6. When failures happen during the test, it is recommended to ask the program organizer for more samples to re-test if the time schedule is enough.
7. Owing to requiring the data rounded to the nearest 1% and the lower percentage elongation (~10%), even some laboratories reported the data to the nearest 0.1% or 0.01%, there were more than 17 laboratories out of the Youden Plot Circle (CL=95%). The results might be unfair for the laboratories near the Circle, such as Labs. 3, 4, 10, 11, 42, and 62, so the statistical calculation result of percentage elongation should not be reported in Outlier Results. To avoid the above phenomena happening, it is recommended to report the percentage elongation to the nearest 0.1% at least in the future PT program of metallic materials tensile test.

Comments for Participants

1. The specimen dimensions of Lab 66 are much smaller than the recommended ones; it may be due to the insufficient testing machine capacity or not be aware of the recommended dimensions. For the decrease of the variation in the testing results, it is recommended that the participants should have the sufficient capacity to perform the test.
2. The yield and tensile strength of Lab 37 are abnormally low in sample A and sample B, it is due to the wrong cross section area calculation as a square specimen.
3. The fracture of sample A, Lab 64 takes place outside the gage marks, it is recommended that the percentage elongation (including sample B) shall not be included in the statistical calculation. It also have to describe the reason why not be included in the final report.
4. Lab 18, Lab 29, Lab 50 and Lab 56 did not use the extensometer to determine the yield strength (0.2% offset), the yield strength of the above 4 laboratories should be not included in the statistical calculation, but the tensile strength and percent elongation still be calculated. The above 4 laboratories still filled the yield strength data on the result sheet, it showed they had no any sense on the determination of the yield strength (0.2% offset).

Appendix A

Summary of Results

Information of Test

Table 2 Summary of Results- Yield Strength

Item 1	**Yield Strength**					
Lab Code	Result A	Result B	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded Uncertainty	
1	759	776	-0.525	0.626	N/A	N/A
2	840	786	1.647	-2.794	N/A	N/A
3	799	755	-0.072	-2.313	N/A	N/A
4	762	730	-1.552	-1.734	N/A	N/A
5	795	792	0.716	-0.337	N/A	N/A
6	829	855	3.032※	1.06	N/A	N/A
7					N/A	N/A
9					N/A	N/A
10	752	788	-0.406	1.542	N/A	N/A
11	725	725	-2.555	-0.193	N/A	N/A
14	789	775	0.167	-0.867	N/A	N/A
15	768	784	-0.119	0.578	N/A	N/A
16	827	784	1.289	-2.264	N/A	N/A
17	780	787	0.239	0.145	N/A	N/A
18					N/A	N/A
19	785	762	-0.239	-1.301	N/A	N/A
20					N/A	N/A
21	760	780	-0.406	0.771	N/A	N/A
22	775	818	0.86	1.879	N/A	N/A
23	769	773	-0.358	0	N/A	N/A
25	773	763	-0.501	-0.674	N/A	N/A
27					N/A	N/A
28	813	841	2.316	1.156	N/A	N/A
29					N/A	N/A
30	781	776	0	-0.434	N/A	N/A
31					N/A	N/A
32	746	775	-0.86	1.204	N/A	N/A
34	789	819	1.218	1.253	N/A	N/A
36	756	774	-0.645	0.674	N/A	N/A
37	582	616	-8.571※	1.445	N/A	N/A
38	763	764	-0.716	-0.145	N/A	N/A
39	749	754	-1.289	0.048	N/A	N/A
41	828	823	2.244	-0.434	N/A	N/A
42					N/A	N/A
43	785	780	0.191	-0.434	N/A	N/A
45					N/A	N/A
47	784	812	0.931	1.156	N/A	N/A

Item 1	Yield Strength					
Lab Code	Result A	Result B	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded Uncertainty	
48					N/A	N/A
49	779	782	0.096	-0.048	N/A	N/A
50					N/A	N/A
52	773	767	-0.406	-0.482	N/A	N/A
54	777	772	-0.191	-0.434	N/A	N/A
55	818	780	0.979	-2.023	N/A	N/A
56					N/A	N/A
57					N/A	N/A
58	766	807	0.382	1.783	N/A	N/A
59	780	789	0.287	0.241	N/A	N/A
60	774	778	-0.119	0	N/A	N/A
61					N/A	N/A
62	784	769	-0.096	-0.915	N/A	N/A
64	778	789	0.239	0.337	N/A	N/A
65					N/A	N/A
66	786	772	0.024	-0.867	N/A	N/A
67	755	777	-0.597	0.867	N/A	N/A
69	806	798	1.122	-0.578	N/A	N/A
70	759	769	-0.692	0.289	N/A	N/A
71	777	832	1.242	2.457	N/A	N/A
72					N/A	N/A
73	805	815	1.504	0.289	N/A	N/A
75					N/A	N/A

No. of result	43	43
Median	778	780
Normalized IQR	19.644	14.826
Robust CV (%)	2.525	1.901
Maximum	840	855
Minimum	582	616
Range	258	239

Table 3 Summary of Results- Tensile Strength

Item 2	**Tensile Strength**					
Lab Code	Result A	Result B	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded Uncertainty	
1	837	848	-0.54	0.411	N/A	N/A
2	873	852	0.809	-1.466	N/A	N/A
3	844	834	-0.776	-0.821	N/A	N/A
4	851	834	-0.54	-1.232	N/A	N/A
5	826	822	-1.787	-0.469	N/A	N/A
6	830	855	-0.54	1.232	N/A	N/A
7					N/A	N/A
9	874	838	0.371	-2.346	N/A	N/A
10	831	870	0	2.053	N/A	N/A
11	860	875	1.147	0.645	N/A	N/A
14	866	842	0.236	-1.642	N/A	N/A
15	845	849	-0.236	0	N/A	N/A
16	894	839	1.079	-3.46※	N/A	N/A
17	823	848	-1.012	1.232	N/A	N/A
18	826	854	-0.708	1.408	N/A	N/A
19	839	806	-1.889	-2.17	N/A	N/A
20					N/A	N/A
21	835	850	-0.54	0.645	N/A	N/A
22	848	856	0.101	0.235	N/A	N/A
23	840	838	-0.776	-0.352	N/A	N/A
25	901	882	2.765	-1.349	N/A	N/A
27					N/A	N/A
28	886	879	2.158	-0.645	N/A	N/A
29	895	895	3.001※	-0.235	N/A	N/A
30	851	854	0.135	-0.059	N/A	N/A
31					N/A	N/A
32	835	841	-0.843	0.117	N/A	N/A
34	828	858	-0.506	1.525	N/A	N/A
36	840	856	-0.169	0.704	N/A	N/A
37	655	688	-12.073※	1.701	N/A	N/A
38	853	859	0.371	0.117	N/A	N/A
39	820	827	-1.821	0.176	N/A	N/A
41	843	859	0.034	0.704	N/A	N/A
42	918	877	3.17※	-2.639	N/A	N/A
43	856	850	0.169	-0.587	N/A	N/A
45					N/A	N/A
47	841	862	0.067	0.997	N/A	N/A

Item 2	Tensile Strength					
Lab Code	Result A	Result B	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded Uncertainty	
48					N/A	N/A
49	847	850	-0.135	-0.059	N/A	N/A
50	830	826	-1.518	-0.469	N/A	N/A
52	858	862	0.641	0	N/A	N/A
54	847	840	-0.472	-0.645	N/A	N/A
55	884	845	0.944	-2.522	N/A	N/A
56	895	897	3.069※	-0.117	N/A	N/A
57					N/A	N/A
58	843	873	0.506	1.525	N/A	N/A
59	869	876	1.484	0.176	N/A	N/A
60	862	839	0	-1.584	N/A	N/A
61					N/A	N/A
62	838	864	0.034	1.29	N/A	N/A
64	841	917	1.922	4.223※	N/A	N/A
65					N/A	N/A
66	817	806	-2.631	-0.88	N/A	N/A
67	837	860	-0.135	1.114	N/A	N/A
69	878	875	1.754	-0.411	N/A	N/A
70	836	842	-0.776	0.117	N/A	N/A
71	844	847	-0.337	-0.059	N/A	N/A
72					N/A	N/A
73	858	870	0.911	0.469	N/A	N/A
75					N/A	N/A

No. of result	49	49
Median	844	852
Normalized IQR	19.274	17.791
Robust CV (%)	2.284	2.088
Maximum	918	917
Minimum	655	688
Range	263	229

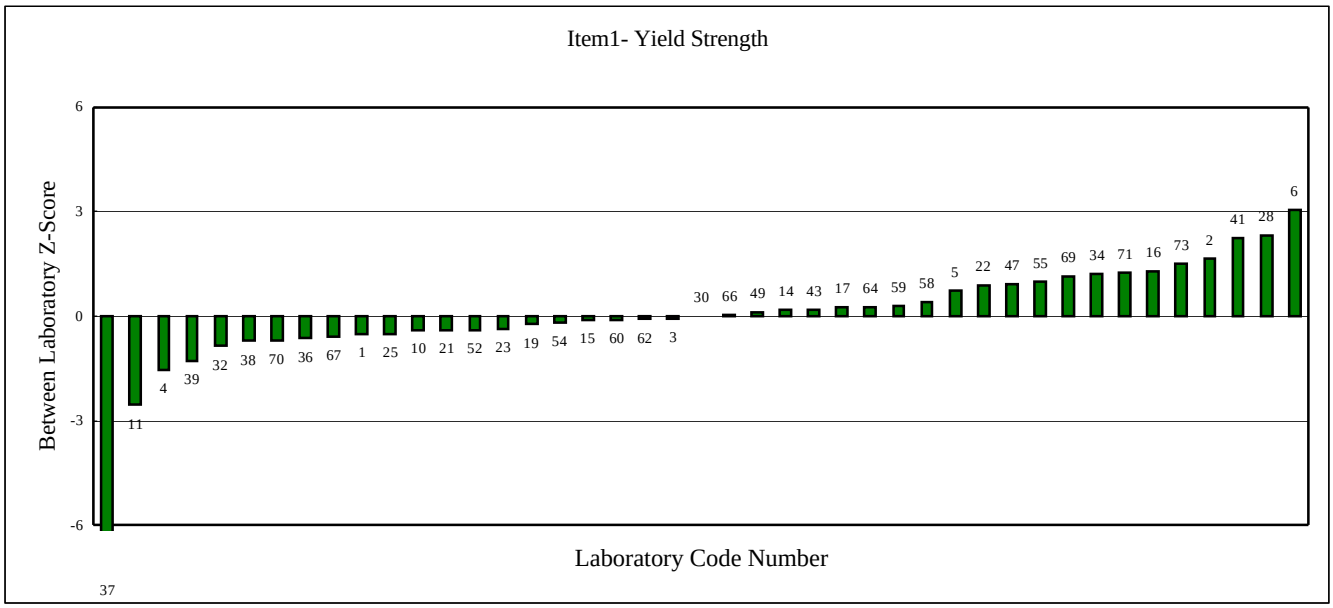
Table 4 Summary of Results- Percentage Elongation after Fracture

Item 3	**Percentage Elongation after Fracture**					
Lab Code	Result A	Result B	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded Uncertainty	
1	10	10	0	0	N/A	N/A
2	12	14	2.628	7.6※	N/A	N/A
3	9	8	-1.314	-3.8※	N/A	N/A
4	11	12	1.314	3.8※	N/A	N/A
5	10	10	0	0	N/A	N/A
6	7.84	10.84	-0.578	0	N/A	N/A
7					N/A	N/A
9	9	9	-0.876	0	N/A	N/A
10	10	11	0.438	3.8※	N/A	N/A
11	9	10	-0.438	3.8※	N/A	N/A
14	11	11	0.876	0	N/A	N/A
15	11	11	0.876	0	N/A	N/A
16	10	10	0	0	N/A	N/A
17	9	9	-0.876	0	N/A	N/A
18	9	8	-1.314	-3.8※	N/A	N/A
19	9	9	-0.876	0	N/A	N/A
20					N/A	N/A
21	9	11	0	7.6※	N/A	N/A
22	8	8	-1.752	0	N/A	N/A
23	10	10	0	0	N/A	N/A
25	9	9	-0.876	0	N/A	N/A
27					N/A	N/A
28	10	10	0	0	N/A	N/A
29	11.7	11.8	1.533	0.38	N/A	N/A
30	10	9	-0.438	-3.8※	N/A	N/A
31					N/A	N/A
32	12	12	1.752	0	N/A	N/A
34	9	10	-0.438	3.8※	N/A	N/A
36	12	12	1.752	0	N/A	N/A
37	9.79	10.58	0.162	3.002※	N/A	N/A
38	9.8	10.1	-0.044	1.14	N/A	N/A
39	10	10.4	0.175	1.52	N/A	N/A
41	10	10	0	0	N/A	N/A
42	12	11	1.314	-3.8※	N/A	N/A
43	9.62	11.42	0.456	6.84※	N/A	N/A
45					N/A	N/A

Item 3	Percentage Elongation after Fracture					
Lab Code	Result A	Result B	Between Laboratories Z-Score	Within Laboratories Z-Score	Expanded Uncertainty	
47	11.6	9	0.263	-9.88※	N/A	N/A
48					N/A	N/A
49	11.7	11.7	1.489	0	N/A	N/A
50	9.7	9.58	-0.315	-0.456	N/A	N/A
52	11	12	1.314	3.8※	N/A	N/A
54	10	10	0	0	N/A	N/A
55	8	8	-1.752	0	N/A	N/A
56	8.49	8.03	-1.524	-1.748	N/A	N/A
57					N/A	N/A
58	10	10	0	0	N/A	N/A
59	11	11	0.876	0	N/A	N/A
60	13	11	1.752	-7.6※	N/A	N/A
61					N/A	N/A
62	11	10	0.438	-3.8※	N/A	N/A
64					N/A	N/A
65					N/A	N/A
66	7	8	-2.19	3.8※	N/A	N/A
67	11	9	0	-7.6※	N/A	N/A
69	10	11	0.438	3.8※	N/A	N/A
70	11	9	0	-7.6※	N/A	N/A
71	10	8	-0.876	-7.6※	N/A	N/A
72					N/A	N/A
73	13	13	2.628	0	N/A	N/A
75					N/A	N/A

No. of result	48	48
Median	10	10
Normalized IQR	1.483	1.483
Robust CV (%)	14.826	14.826
Maximum	13	14
Minimum	7	8
Range	6	6

Figure 1 Histogram of Yield Strength



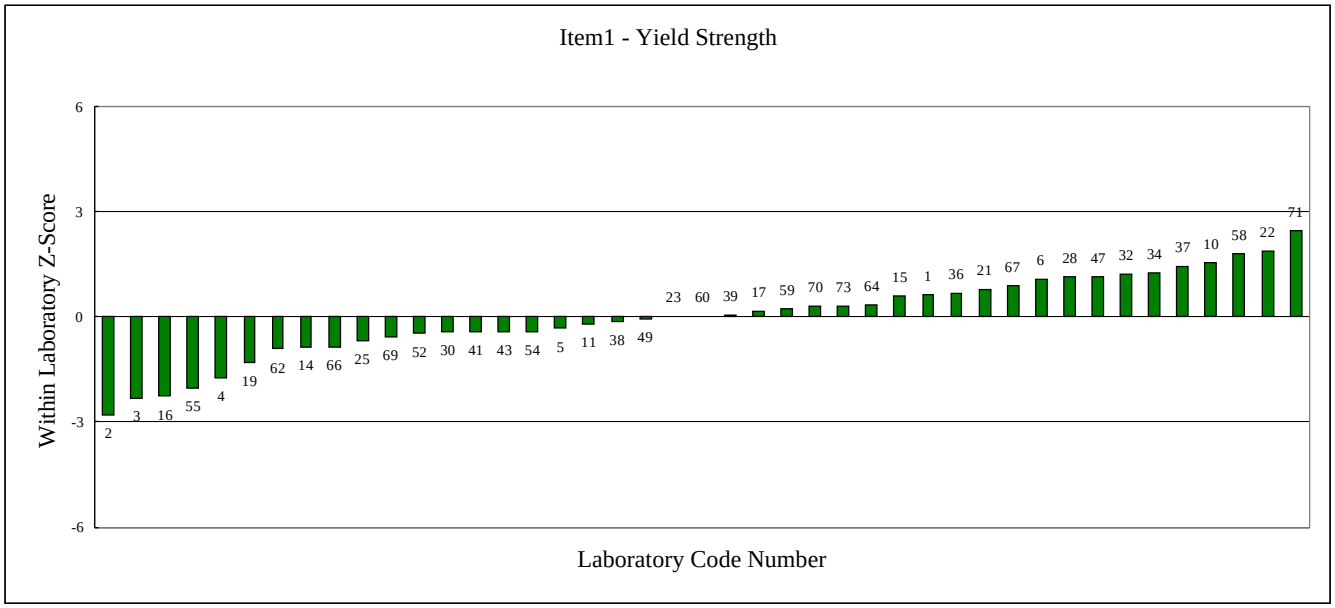
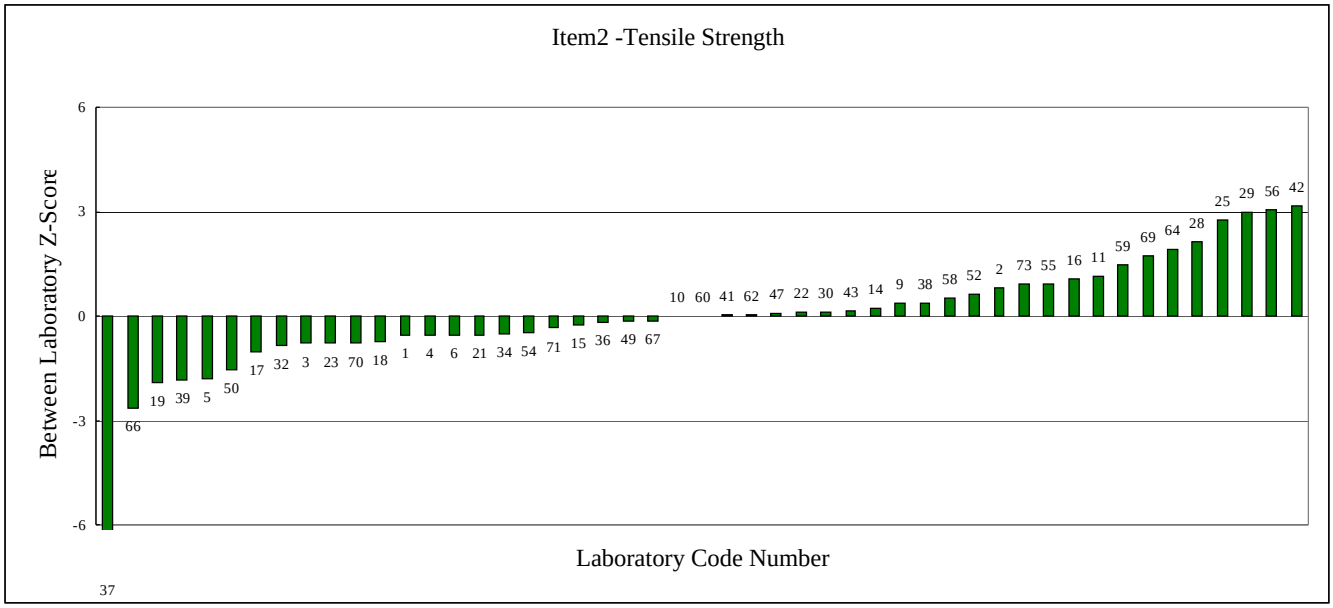


Figure 2 Histogram of Tensile Strength



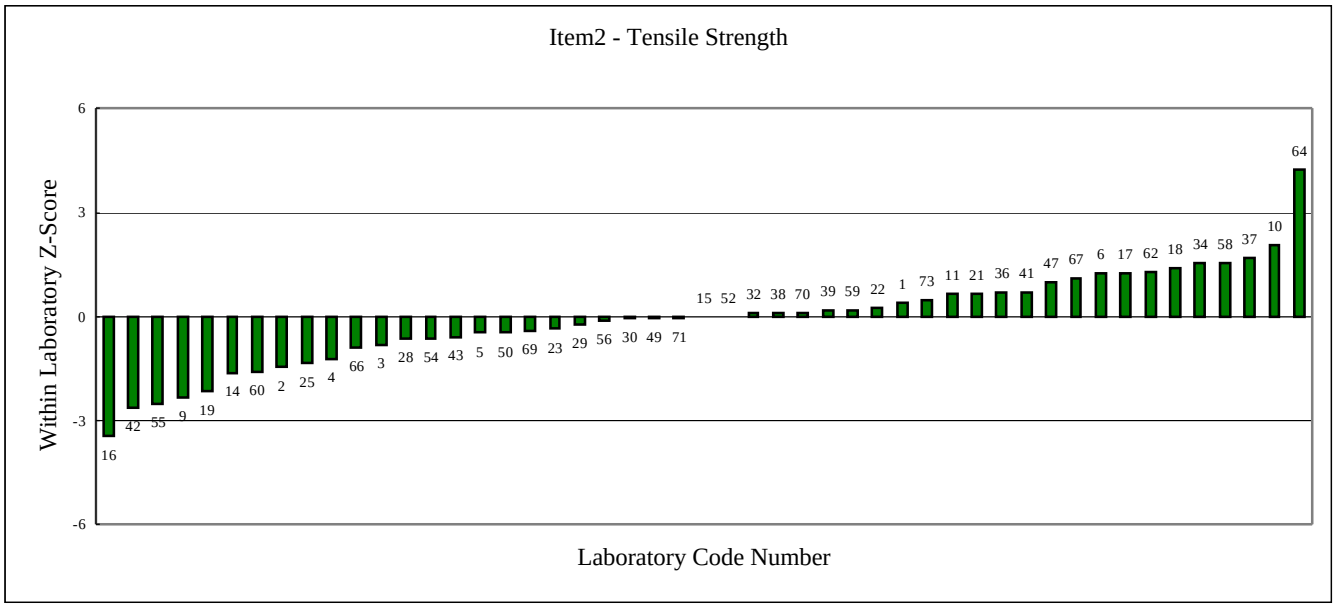
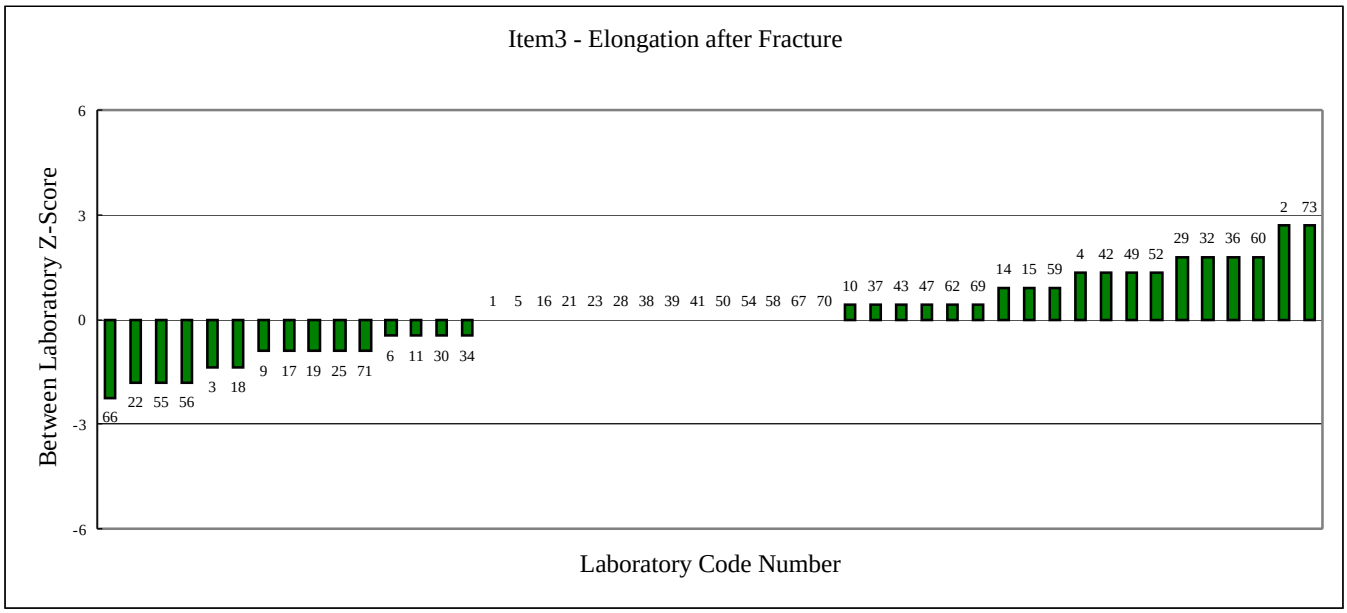


Figure 3 Histogram of Percentage Elongation after Fracture



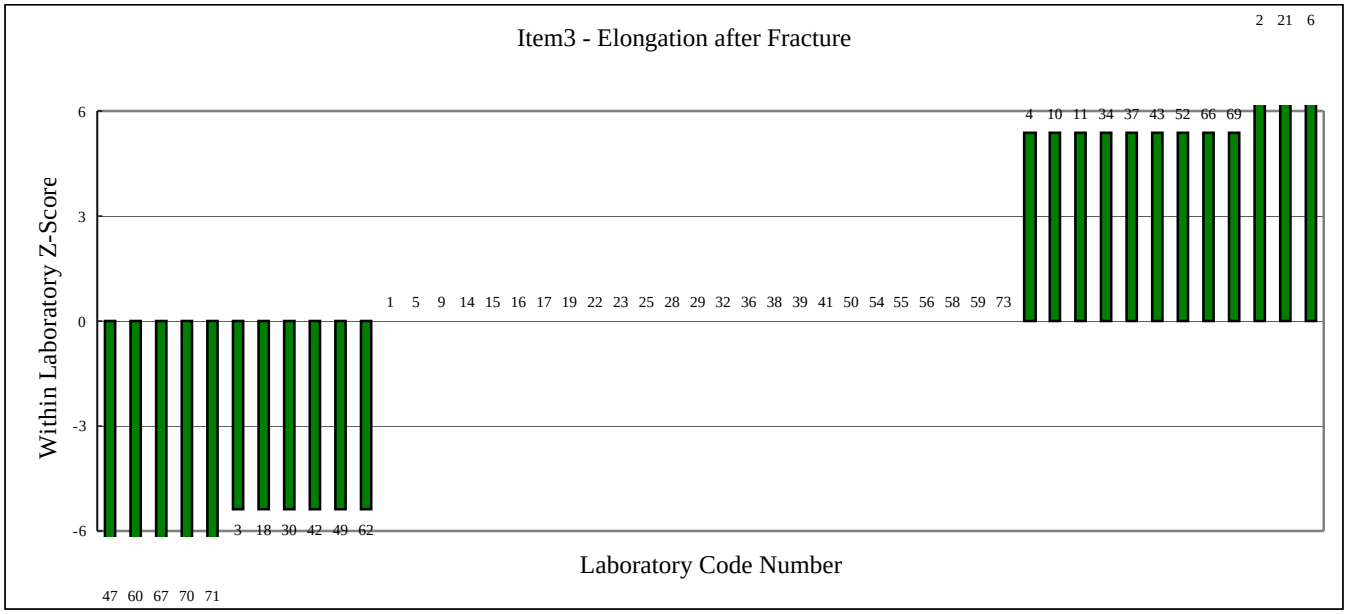


Figure 4

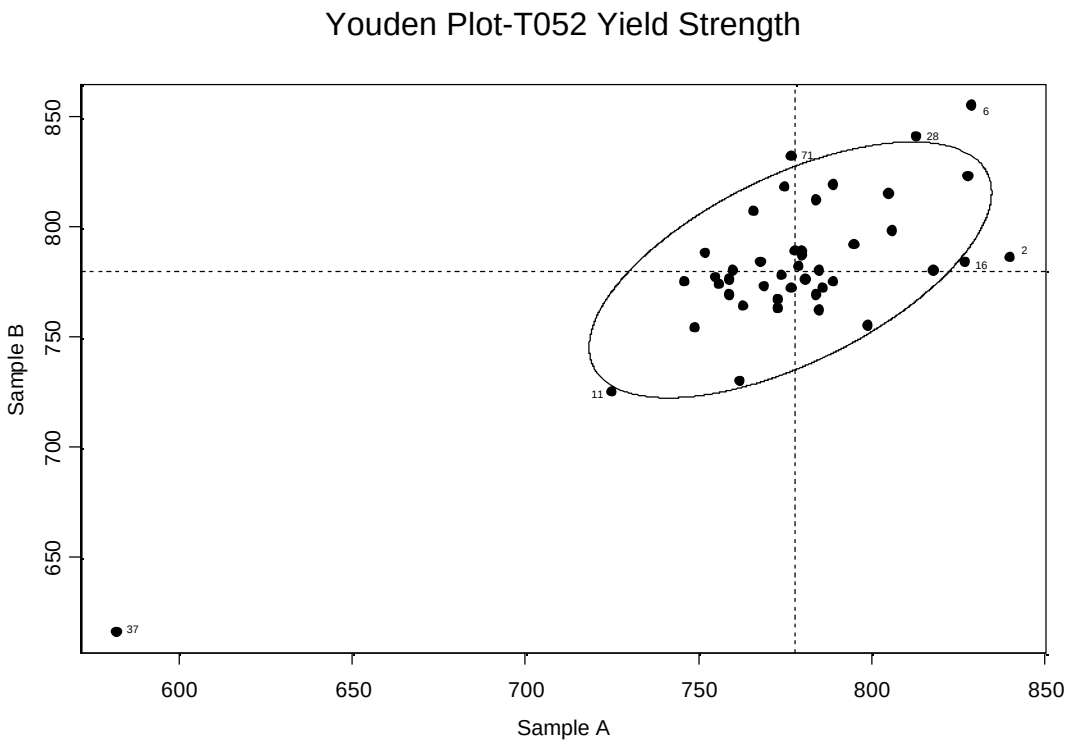


Figure 5

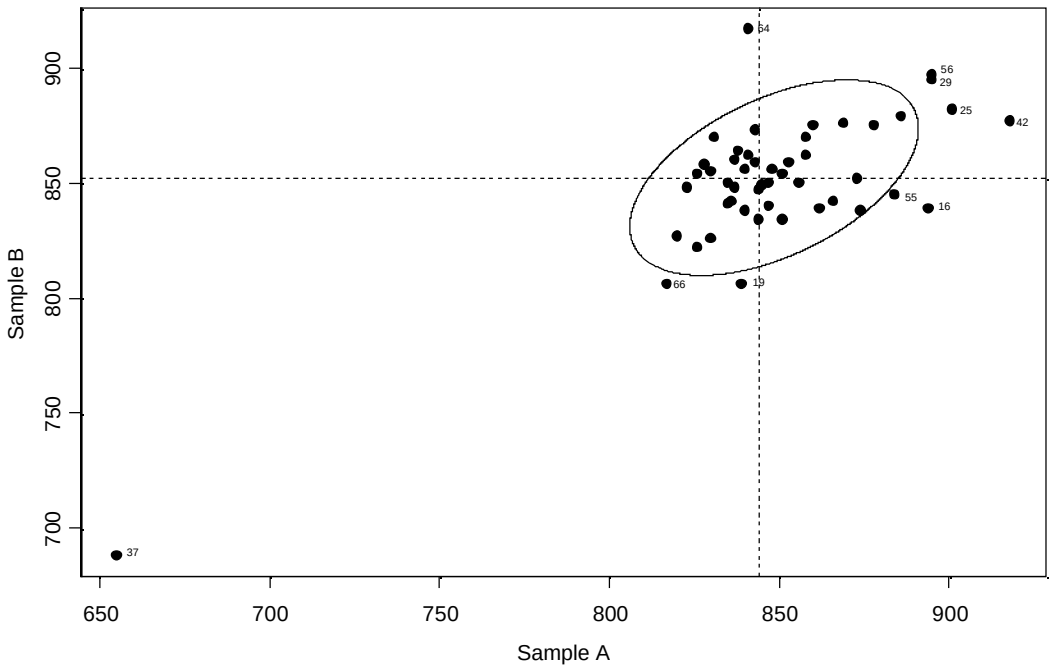


Figure 6

Youden Plot-T052 Elongation Percentage, CL=95%

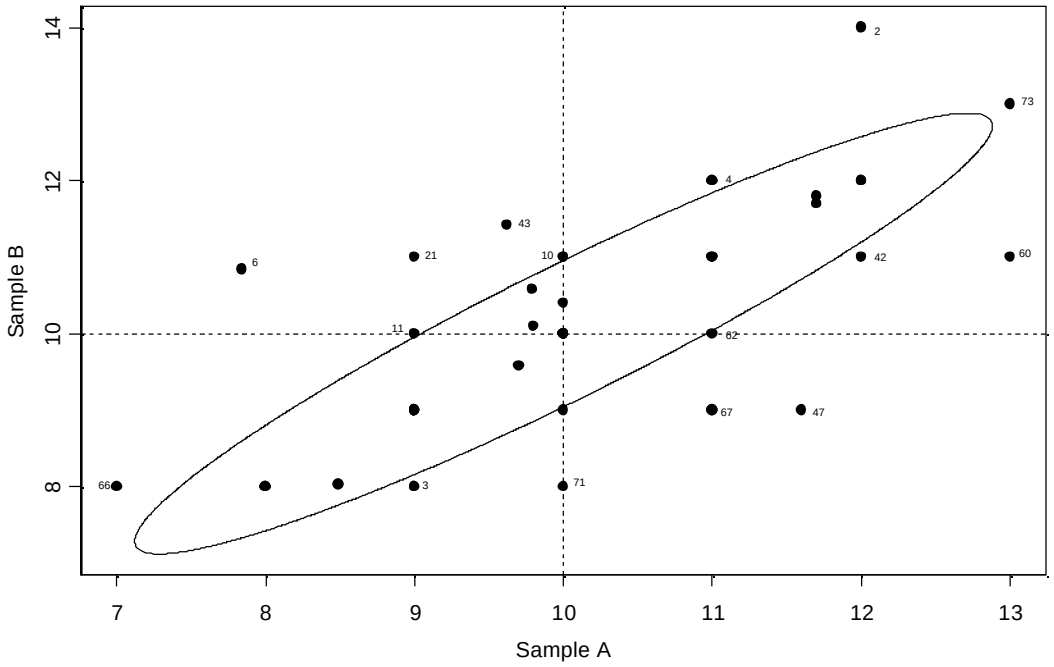


Table 5 Information of Test

Lab Code	Type of Testing Machine	Manufacture/ Model of Machine	Type of Grips	Class of Extensometer	Type of Testing Speed Control	Additional Information	Date
1	electro-mechanic	ZWICK/ ROELL/ Z1200	hydraulic	0.5	strain rate indicator	working with testxpert 12-special test program	2007/7/31
2	hydraulic	schenk trebel upm1000	V groove	1	servo control		2007/7/6
3	hydraulic	Shimadzu UH-1000KNA	V groove	B2(ASTM E83/06)	servo control		2007/7/18
4	ball screw	instron 1197	grcpping devlce for threaded-end specimens	1		crosshead control	30/07/2007
5		UIB 1000/ Ibtt-spain		Accuracy ± 0.03mm			2, August 2007
6							
7							
8							
9	hydraulic	Shimadzu/UH2000KNA	V groove	NONE	Free running rate of cross-head	Equipment does not have an extensaneter, hence, OFF-Set yield cannot be determine	2007/7/13
10	ball screw	ZWICK/ Z250/ JN5A	V groove	CLASS A	strain rate indicator	External Micrometer [Manufacture: Mitutoyo]	2007/7/13
11	hydraulic	avery/type 7110 CCJ	Threaded ends	D	strain rate indicator		24/07/2007
12							
13							
14	hydraulic	400kN Schenck RBO 40/20 with instron controller & bluetrll software	V groove	Class B1			13/07/2007
15	hydraulic	walter+Bai AG/TTM-1000	PARALLEL	Class 1	servo control		26/07/2007
16	hydraulic	Gotech Testing Machine / GT-7001-LC50	V groove		Hydraulic valve control system	Rate of stressing between 0.6 to 0.9	10/07/2007

Lab Code	Type of Testing Machine	Manufacture/ Model of Machine	Type of Grips	Class of Extensometer	Type of Testing Speed Control	Additional Information	Date
						kgf/mm²/sec through out the test	
17	hydraulic	Baldwin 120 BTE	Button-end	ASTM E83 B-1 extensometer/ system over test range, but B-2 system over full scale of extensometer	Load pacer and crosshead rate		2007/7/31
18	hydraulic	Amsler (40 tons)	V groove	None	Micrometer		
19	electro-mechanical	Zwick, Z-250	V groove	0.5	strain rate indicator		25/07/2007
20							
21	hydraulic	SATEC	V groove	B2	servo control		2007/7/27
22	electro-mechanical	Zwick/ Roell/ Z600E	ring-shaped	1	servo control		27/07/2007
23	ball screw	Shimadzu cooporation / AG25TD	V groove	Class 1	servo control		2007/7/26
24							
25	hydraulic	Dartec Limited/M1000-RF	V groove	0.10%	servo control, strain rate indieator, maximum strain rate control	Computerized control	25th July, 2007
26							
27							
28	hydraulic	Shimadzu Universal Testing Machine UH-100KN	Thread Shouldered	Class B1		Cross Head Velocity	13/07/2007
29	hydraulic	WOLPERT/TUZ.200	V groove	Has not an externsometer	maximum strain rate control	The mechanical testing laboratory has not a recorder for curre diagrams	2007/7/30

Lab Code	Type of Testing Machine	Manufacture/ Model of Machine	Type of Grips	Class of Extensometer	Type of Testing Speed Control	Additional Information	Date
30	hydraulic		V groove	0.5	servo control		2007/7/24
31							
32	ball screw	SHIMADZU UMH-50	V groove	B-2	servo control		07/31/2007
33							
34	hydraulic	KYEONG DO/KDU-50	V groove		servo control	NA	18, July, 2007
35							
36	ball screw	SHIMADZU/AG-I 250kN	V groove		servo control		7/24/2007
37	ball screw	ZWICK 250kN Type:1484	plate	B-1	strain rate indicator		
38							
39	ball screw	Zwick Z150	others	0.5	strain rate indicator		11/09/2007
40							
41	hydraulic	Shimadzu cooperation / UH-F50A	V groove	Class 2	servo control		2007/7/19
42	hydraulic	Free-Running Crosshead Speed	V groove	None	Free-Running Crosshead Speed		2007/7/14
43	hydraulic	FIE-make; UTN-40E	V groove	Class 1	strain rate indicator		18.07.2007
44							
45							
46							
47	hydraulic	Make:FIE, Maharastra; Model:UTE 40/ Sr.No:7/2005-3237	V groove	EE-2 Extensometer Manufactured as per IS 12872:1990 & ISO9513:1989 in Class I accuracy	Manual	Manual Load Rate Control	23.07.07
48							
49	ball screw	Instron 5500 R	V groove	0.5	servo control	Distance between the fracture and the nearest gauge mark=14mm	2007/7/27

Lab Code	Type of Testing Machine	Manufacture/ Model of Machine	Type of Grips	Class of Extensometer	Type of Testing Speed Control	Additional Information	Date
50	hydraulic	Shinadzu-Japan model UH-200A	flat	NONE	strain rate indicator	Software-WIN UH V3.0Q	2007/7/13
51							
52	hydraulic	shimadzu cooporation / UH-F1000KNA	V groove	Class 2	servo control		2007/7/23
53							
54	hydraulic	SATEC	plate	B1	maximum strain rate control	N/A	July 30/ 2007
55	hydraulic	Instron Satec Systems / 300HVL	shouler/threader end holders	B-2	servo control		2007/7/16
56	hydraulic	Instron/5594 (200HVL)	plate	N/A	Servo Control		2007/7/30
57							
58	hydraulic	MTS / Sintech 65G	V groove	B1	Servo Control	NIL	2007/7/11
59	hydraulic	Avery Denison Universal Testing Machine (Type:7159 RUBICON, S/N98046)	Wedge grips	Class B-1	Servo Control		2007/7/9
60	hydraulic	Avery-denison (50, 100, 250 & 500kN)	V groove	GRADE 2	others: Strain rate uncontrolled		05/07/2007
61							
62	hydraulic	INSTRON 1343-8500 plus; class 0.5	V groove	INSTRON, class 0.5	Servo Control		2007/7/30
63							
64	hydraulic	TINIUS-OLSEN Deluxe super C	Threaded	B-1	Servo Control	fracture of sample A-216 occurred outside of gauge length	2007/7/16
65							
66	hydraulic	BALDWIN	V groove	Rate of change of platen	Rate of stressing		2007/8/8

Lab Code	Type of Testing Machine	Manufacture/ Model of Machine	Type of Grips	Class of Extensometer	Type of Testing Speed Control	Additional Information	Date
67	Electromechanical with screw	Instron 300 kN Model 4208	Hydraulic side plate acting	Class 1	Pacing	The speed (strain applled, or extension) is controlled by the software installed in the computer. (series IX)	2007/7/26
68							
69	hydraulic	FIE INDIA,Model UTE100		Class I	Free running cross head speed		31.07-07
70	hydraulic	Avery, Type 7110 DCJ	V groove	Class1, ISO 9513-1989	Manual		10.07-07
71	hydraulic	Tinius Olsen Servo Super "L"120, 0001b Model 602 USA	The self-aligning holders for threaded	B	servo control		2007/7/18
72							
73	hydraulic	Baldwin / BTE 1045	V groove	Tinius Olsen 4%-50	servo control		12.07-2007
74							
75							

Appendix B

Preparation of the samples

Homogeneity testing

SAMPLE PREPARATION

The samples used in this program were originally supplied by ITRI, Taiwan. The properties A and B were slightly different but this was not made known to the participants at the time of testing. Since the purpose is to compare the performance of the laboratories, it is required that they should be supplied with homogeneous materials. It is therefore imperative that the source of supply is carefully selected and samples supplied to the laboratories are tested first for homogeneity. For this purpose steel rods from two melts are considered. 800 steel rods from melt A and 800 steel rods from melt B were used for testing homogeneity. All the steel rods were executed heat-treatment. The surface of all the steel rods were ground and polished after heat-treatment.

HOMOGENEITY TESTING

All the steel rods were executed hardness test on the round surface for homogeneity. Before the samples were distributed to participants, ten samples from melt A and melt B were selected and tested in the laboratory of the sample supplier to assess the sample variability. Results for Yield Strength, Tensile Stress and Elongation were determined for both samples A and B. The results and summary statistics for these determinations are presented below. These indicate that the samples were sufficiently homogenous so that any results identified, as extreme cannot be attributed to sample variability.

Table 6 Homogeneity Testing Results for Sample A

Sample No.	Yield Strength Rp0.2 (1Mpa)	Tensile Strength Rm (1Mpa)	Elongation A (%)
A1	773	861	10
A2	792	874	9
A3	773	866	10
A4	772	864	9
A5	782	859	9
A6	778	862	9
A7	777	866	9
A8	783	861	9
A9	785	872	10
A10	784	867	9
Median	780.1	865.3	9.4
Norm. IQR	7.1	4.0	0.4
Robust CV	0.9%	0.5%	4.4%
Mean	780.0	865.5	9.4
SD	6.3	4.8	0.4
CV	0.81%	0.55%	4.20%
Max.	792	874	10
Min.	772	859	9
Range	20	15	1

Table 7 Homogeneity Testing Results for Sample B

Sample No.	Yield Strength Rp0.2 (1Mpa)	Tensile Strength Rm (1Mpa)	Elongation A (%)
B1	772	866	9
B2	774	864	10
B3	775	867	10
B4	786	872	10
B5	777	868	9
B6	777	867	9
B7	784	871	9
B8	775	866	9
B9	780	870	10
B10	764	862	9
Median	776.2	867.3	9.4
Norm. IQR	3.6	2.5	0.2
Robust CV	0.5%	0.3%	1.6%
Mean	776.6	867.6	9.5
SD	6.1	3.0	0.3
CV	0.78%	0.35%	2.89%
Max.	786	872	10
Min.	764	862	9
Range	22	10	1

Appendix C

Instructions to Participants

Results Sheet

Asia Pacific Laboratory Accreditation Cooperation

APLAC T052 Proficiency Testing Program
Tensile Test for Metallic Materials

INSTRUCTIONS TO PARTICIPATING LABORATORIES

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

1. SAMPLE

The participating laboratory will obtain two round bars of metallic materials. These are numbered A and B for preparing standard 12.5mm round tensile test specimens. The capacity of testing machine had better over 150 kN.

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

2. TESTS TO BE PERFORMED

Sample Information: The two samples are Φ20mm × 250mm blank. Laboratory must machine tensile round specimen from the center of each blank. The standard round specimen has a 50mm gage length and 12.5mm in diameter of reduced section. Please refer to the part of Standard Specimen in ASTM E8M-04 FIG. 8.

Testing Period: Test should be finished **within one week** after receiving the samples.

Test Method: The method of tensile test at ambient temperature is according to **ASTM E8M-04**. In testing procedure, the preparation of test pieces and the speed of the testing shall also conform to **ASTM E8M-04** requirements**.**

The following mechanical properties of results must be obtained for each specimen:

1. Diameter and Gauge Length before Testing
2. Yield Strength (0.2% offset)
3. Tensile Strength
4. Percentage Elongation (%, on Gauge Length＝4 times the Diameter)

For reducing the factors of variances and easy discussing the bias of the test, we suggest that complete the test in the same time interval, and the same operator and the testing apparatus are recommended.

Where possible, uncertainties should be calculated using the method in the ISO Guide to the Expression of Uncertainty in Measurements.

3. DOCUMENTS TO BE SUBMITTED

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

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

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

4. CONFIDENTIALITY

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

5. GENERAL INFORMATION

For general queries, please contact your accreditation body.

Additional information may be obtained from:

Taiwan Accreditation Foundation (TAF)

Ms. Jean Yang

TEL： +886-3-5714848 Ext 224

FAX：+886-3-5726308

E-mail: jeanyang@taftw.org.tw

Asia Pacific Laboratory Accreditation Cooperation

APLAC T052 Proficiency Testing Program

Tensile Test for Metallic Materials

Result Sheet

Lab Code: ☐

Testing Data	Sample A No.____	Sample B No.____
Ambient Temperature (℃)		
Diameter (0.01mm) before Testing		
Gauge Length (0.01mm) before Testing		
Yield Strength (0.2% Offset, 1MPa)		
Tensile Strength (1MPa)		
Percentage Elongation after Fracture (1%)		
Speed of Testing		
Before Yield (min^{-1})		
After Yield (min^{-1})		

If other methods are used, please kindly specify.

Type of Testing Machine: ☐ hydraulic ☐ ball screw ☐ others:_____

Manufacture/Model of Machine: _____

Type of Grips: ☐ V groove ☐ plate ☐ others:_____

Class of Extensometer: _____

Type of Testing Speed Control:

☐ servo control ☐ strain rate indicator ☐ maximum strain rate control ☐ others:_____

Additional Information: _____

_____

Date: _____ Signature: _____

Measurement Uncertainty Budget

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

Date: _____ Signature: _____

INSTRUCTIONS – MEASUREMENT UNCERTAINTY

Part (1) Background information & justification for this change

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

What is uncertainty of measurement?

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

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

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

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

To assist laboratories to comply with the requirements of ISO/IEC 17025 for estimating uncertainty and to promote a uniform methodology in its estimation, information packages for APLAC PT testing program participants now include general guidance relating to estimating uncertainties for the specific testing involved, and final program reports will now include relevant worked examples. All program participants are required to report their estimates of uncertainty to their accreditation bodies along with their results unless the Technical Adviser to the program specifically waives any requirement to estimate uncertainties. The estimates of uncertainty provided by participants will be incorporated into the final program reports enabling direct comparison of uncertainty estimates across the program participants. The uncertainty estimates will not be used in the evaluation of the results on the primary samples.

How is uncertainty of measurement to be estimated?

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

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

ISO GUM methodology

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

ISO2, UKAS3 and Eurachem/CITAC4 and made available over the internet[7].

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

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

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

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

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

Here are a few important terms:

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

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

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

Sensitivity coefficient (*ci*) is the mathematical relationship between an influencing parameter and its effect on the result of a measurement. In many instances it is unity. That is, there is a one to one relationship between the value of the influence and its effect on the measurement result. For example, when weighing a sample of material, any uncertainty due to errors in the balance reading will have a one to one effect on the measurement result. On the other hand, if we are considering the influence of temperature on the length of a metal bar then the sensitivity coefficient is equal to the coefficient of linear thermal expansion for the metal bar multiplied by the length of the bar. It is important to note that a sensitivity coefficient has units. It is also important to note that the calculation methodology used by Eurachem/CITAC4 incorporates sensitivity coefficients in a manner that does not require their specific evaluation.

Combined standard uncertainty (*uc(y)*) is the final estimate of uncertainty for the test or measurement result *y* expressed as a standard deviation. It is calculated by multiplying the standard uncertainty *u(xi)* for each input component *(xi)* with its respective sensitivity coefficient *ci* to

produce *ciu(xi)* and then combining those values by taking the square root of the sum of their squares. Note that the products *ciu(xi)* must each be expressed in the same units as those required for expressing the combined estimate *uc(y).*

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

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

References

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

Appendix D

Statistical Procedures

Calculations and Formulae

STATISTICAL PROCEDURES

The procedures are based on robust statistics and use z-score to assess performance of participant. Z-score are normalized value that gives a score to each result, relative to the other numbers in the group, so a z-score value close to zero means that result agrees well with those from the other laboratories.

Robust statistics are statistics that are not highly influenced by the presence of extreme results. In a mathematical environment robustness is the ability of a statistical method center of a database, the mean (average), is not robust. A robust alternative to the mean is the median (the middle value). The difference between these two is best illustrated by the following example.

The statistical procedures use z-score to identify outlier results. An outlier will be any result(s), which has an absolute z-score value greater than three.

The calculation of the z-score depends on the statistical design of the program. In the most cases programs are designed so that pairs of results are obtained, i.e. either two related samples are distributed or (less frequently and avoided if possible) two results on one sample are requested. Related samples can be identical (uniform pair) or similar (split pair). Occasionally it may be the case that a program can only be designed to have a single result on a single sample.

Pairs of results are necessary to evaluate both sources of variation-the variability within a laboratory termed as within-laboratory variation and the variability. Between laboratories termed as between-laboratories variation. The analysis (and interpretation) of results is the same, regardless of whether a uniform or split sample design has been used.

For each pair of results, two z-scores will be calculated. The between-laboratories z-score will be based on the sum of the pair of results. The within-laboratory z-score will be calculated from the difference between the two results. These robust z-scores will use the median and normalized interquartile (IQR) in place of the mean and standard deviation. As indicated above, any pair of results which has a z-score outside the range ± 3 will be identified as an outlier. Please note that the results are presented in the table "as reported" by participants. Outliers are identified in the table by a marker (※) next to the relevant z-scores.

A very high between-laboratories z-score indicates that one or both of a laboratory's results is significantly higher than the consensus value (median). Similarly, a very low (i.e. negative) between-laboratories z-score shows that a laboratory's result(s) is lower than expected. A very high (positive) or low (negative) within-laboratory z-score indicates that the difference between the laboratory's results is too large or too small (respectively).

Summary of Statistics

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

1. The number of results for that test/sample (*No. of Results*);
2. The median of laboratory's results - i.e. the middle value (*Median*);
3. The normalized interquartile range of the results (*Normalized IQR*) – the interquartile range times 0.7413;
4. The robust coefficient of variation, expressed as a percentage (*Robust CV*) - i.e.

   100× *Normalized IQR* ÷ *Median*;
5. The minimum and maximum laboratory results; and
6. The range (*Maximum* - *Minimum*).
7. ZB denotes the between-laboratories z-score and ZW denotes the within-laboratory z-score.

Ordered Z-Score Charts

Ordered between laboratories z-score bar charts and ordered within laboratory z-score bar charts are also used to illustrate the data. Each laboratory z-score is drawn on a chart and identified by their code number. The z-score limits of ± 3 are also drawn which makes it easy to identify any bars extending past this point which would be outliers.

These charts contain solid lines at +3 and –3, so the outliers are clearly identifiable as the laboratories whose "bar" extends beyond these cut-off lines. The y-axis has been limited to range from –6 to +6, so in some cases very large or small (negative) Z-scores appear as extending beyond the limit of the chart.

Youden Plot

Youden plots are used to illustrate the data. These plots consist of a rectangular plot on which laboratory is represented by a point. The horizontal component of each point is the result of laboratory on the first sample of a pair while the vertical component is its result on the second sample. A 95% confidence ellipse for the bivariate analysis of differences (i.e. high or low results for both samples) is points outside the ellipse in either the upper right or lower left quadrant. Outliers with random error components (i.e. high results for one sample and low result for the other) are points outside the ellipse in either the upper left or lower right quadrants.

STATISTICAL CALCULATIONS AND FORMULAE

Robust Z-Scores are calculated by replacing the mean and standard deviation in the "classical" Z-Score by the median and normalized IQR, respectively - i.e. the Z-Score for a result is the result minus the median (all) divided by the normalized IQR.

$$\text{Z-Score} = \frac{\text{Result} - Median}{NormalizedIQR}$$

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

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

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