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Final Report
Bilateral Comparison Report on Hardness Measurement Rockwell scale A and B Between PTB and NIMT

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Abstract

This bilateral comparison hardness measurement Rockwell scale A and B was arranged by National Institute of Metrology (Thailand), NIMT as a pilot laboratory comparing with Physikalisch-Technische Bundesanstalt (PTB). The objective of the comparison is to confirm the calibration and measurement capabilities of NIMT in hardness measurement. The period was between March to August 2009. There are two sets of artifacts: scale A artifact set and scale B artifact set. The scale A artifact consists of 7 hardness blocks; 35 HRA, 40 HRA, 55 HRA, 60 HRA, 70 HRA, 80 HRA, 85 HRA. The artifact for scale B consists of 9 hardness blocks; 25 HRB, 30 HRB, 40 HRB, 50 HRB, 60 HRB, 70 HRB, 80 HRB, 90 HRB, 100 HRB. Laboratory must ensure that the primary Rockwell hardness machine pass the verification according to ISO 6508-3. Then, participants measure hardness value by making 10 indentations in the designated area for each artifact block. Hardness measurement result and uncertainty budget are then reported to pilot laboratory and are used to compute the degree of equivalence in terms of Comparison Reference Value (CRV) and En ratio.

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Content

1. Introduction

The National Institute of Metrology (Thailand), NIMT established the hardness national measurement standard on hardness scale HRA and HRB since 2006. NIMT would like to participate in an inter-laboratory comparison with a well-known national metrology institute to confirm the calibration and measurement capabilities (CMCs) of NIMT in hardness. Physikalisch-Technische Bundesanstalt (PTB) is one of the NMI's that have well supported NIMT. Also this time, the bilateral comparison on HRA and HRB, piloted by NIMT, has been arranged with Physikalisch-Technische Bundesanstalt (PTB).

2. Participating Institutes

- National Institute of Metrology (Thailand), NIMT
- Physikalisch-Technische Bundesanstalt, PTB

3. Artifacts

The artifacts are Rockwell hardness scale A and scale B reference block manufactured by Asahi Giken Co.,Ltd. Japan. Each scale consists of hardness block with serial number as in the table 1. The dimensions of the blocks are 65 mm in diameter and thickness of each block as in the table 1.

Table 1

HRA Set	S/N	Thickness	HRB Set	S/N	Thickness
35 HRA	A32208	11.50 mm	25 HRB	A30431	11.50 mm
40 HRA	A34095	11.50 mm	30 HRB	A30591	11.50 mm
55 HRA	24282	15 mm	40 HRB	A31146	11.50 mm
60 HRA	A12603	15 mm	50 HRB	A32205	11.50 mm
70 HRA	B15027	15 mm	60 HRB	A33301	11.50 mm
80 HRA	44010	15 mm	70 HRB	A34092	11.50 mm
85 HRA	A22039	15 mm	80 HRB	A35202	11.50 mm
			90 HRB	24280	15 mm
			100 HRB	30734	15 mm

The surface of each artifact block was engraved with divided segments for indicating the indentation positions (Figure 1). Each segment is used for single indentation in the comparison. There are 10 areas of measurement on each block. The rest of the segments on the block surface are reserved as alternative places for trial and error measurements

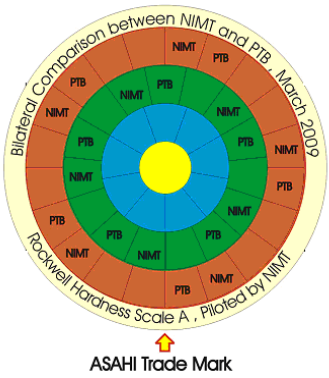

Figure 1

The plastic sheet indicating the indentation position of each participant will be enclosed with the artifact sets. It shall be placed on the artifact block in order to ensure the indentation position before making the indentation.

The two set of artifacts, a set for scale A and a set for scale B will be transferred between participants according to a timetable in which the date of measurement has been agreed between participants.

Institute/Country	Time of measurement
NIMT, Thailand	March, 2009
PTB, Germany	May 2009

4. Measurement of Artifacts

The primary Rockwell hardness machines used for the comparison must be passed the verification according to ISO 6508-3 [1]. Before making the indentation on each block, the testing cycle must be adjusted to comply with ISO 6508-3. Then start to measure the hardness value of artifact blocks by making 10 indentations each block on the designated area on the indentation-positioning sheet.

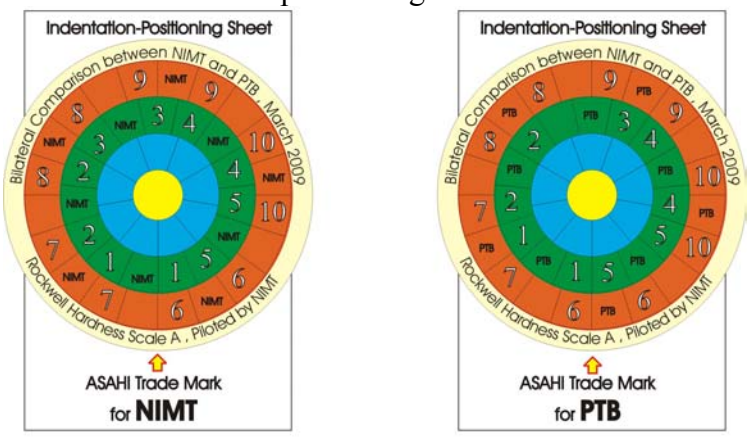

Figure 2

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5. Measurement Data

Table 2 NIMT HRA Measurement Result

	Measured value						
Hardness Block Number	A32208	A34095	24282	A12603	B15027	44010	A22039
Nominal Value (HRA)	35	40	55	60	70	80	85
Section 1	34.09	44.13	54.99	60.58	70.65	81.53	86.74
Section 2	34.08	44.30	54.95	60.57	70.67	81.55	86.74
Section 3	34.15	44.29	54.93	60.60	70.66	81.52	86.73
Section 4	33.97	44.17	55.01	60.70	70.70	81.49	86.71
Section 5	34.10	44.23	55.07	60.52	70.66	81.50	86.72
Section 6	34.02	44.27	55.07	60.47	70.66	81.53	86.58
Section 7	34.12	44.19	54.94	60.51	70.67	81.53	86.65
Section 8	34.05	44.22	54.99	60.50	70.70	81.57	86.62
Section 9	33.96	44.30	54.98	60.63	70.72	81.55	86.62
Section 10	34.11	44.29	55.01	60.57	70.76	81.53	86.63
Average Value	34.07	44.24	54.99	60.57	70.69	81.53	86.67
Correction Value	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corrected Value	34.07	44.24	54.99	60.57	70.69	81.53	86.67

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Table 3 PTB HRA Measurement Result

	Measured value						
Hardness Block Number	A32208	A34095	24282	A12603	B15027	44010	A22039
Nominal Value (HRA)	35	40	55	60	70	80	85
Section 1	33.78	44.02	55.23	60.77	70.97	81.64	86.80
Section 2	33.90	44.20	55.22	60.80	70.98	81.66	86.78
Section 3	33.76	44.16	55.32	60.91	70.98	81.63	86.71
Section 4	33.80	44.16	55.29	60.85	70.93	81.60	86.67
Section 5	34.07	43.99	55.30	60.80	70.95	81.59	86.74
Section 6	33.75	43.95	55.25	60.73	70.93	81.58	86.60
Section 7	33.91	44.20	55.26	60.78	70.95	81.60	86.57
Section 8	33.89	43.40	55.15	60.87	70.97	81.71	86.61
Section 9	33.79	44.06	55.22	60.89	71.01	81.62	86.56
Section 10	33.91	44.12	55.28	60.78	70.97	81.64	86.58
Average Value	33.86	44.03	55.25	60.82	70.96	81.63	86.66
Correction Value	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Corrected Value	33.96	44.13	55.35	60.92	71.06	81.73	86.76

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Table 4 NIMT HRB Measurement Result

	Measured value								
Hardness Block Number	A30431	A30591	A33146	A32205	A33301	A34092	A35202	24280	30734
Nominal Value (HRB)	25	30	40	50	60	70	80	90	100
Section 1	26.01	31.11	41.16	49.28	60.46	70.23	78.45	90.59	100.38
Section 2	26.10	31.19	40.83	49.28	60.60	70.09	78.58	90.48	100.41
Section 3	25.95	31.17	40.78	49.35	60.53	70.20	78.62	90.56	100.39
Section 4	25.92	31.24	40.61	49.38	60.46	70.16	78.49	90.41	100.42
Section 5	25.92	31.26	40.91	49.38	60.49	70.15	78.48	90.50	100.46
Section 6	25.77	30.88	40.47	49.19	60.46	70.13	78.41	90.51	100.48
Section 7	26.12	30.83	40.50	49.06	60.48	70.12	78.53	90.54	100.39
Section 8	25.99	30.75	40.69	49.16	60.37	70.16	78.32	90.48	100.28
Section 9	25.20	31.30	40.46	49.36	60.21	70.21	78.53	90.51	100.38
Section 10	25.16	31.32	40.22	49.24	60.27	70.04	78.52	90.57	100.46
Average Value	25.81	31.11	40.66	49.27	60.43	70.15	78.49	90.52	100.41
Correction Value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corrected Value	25.81	31.11	40.66	49.27	60.43	70.15	78.49	90.52	100.41

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Table 5 PTB HRB Measurement Result

	Measured value								
Hardness Block Number	A30431	A30591	A33146	A32205	A33301	A34092	A35202	24280	30734
Nominal Value (HRB)	25	30	40	50	60	70	80	90	100
Section 1	25.90	30.56	40.49	48.69	60.49	70.04	78.56	90.24	99.99
Section 2	25.43	30.64	40.61	48.77	60.51	70.16	78.49	90.27	100.10
Section 3	24.91	30.84	40.18	48.77	60.51	70.20	78.48	90.24	100.16
Section 4	25.01	31.30	40.22	48.78	60.50	70.17	78.31	90.27	100.16
Section 5	25.31	30.84	40.30	48.81	60.63	70.09	78.27	90.27	100.05
Section 6	25.41	30.28	40.36	48.67	60.55	70.15	78.39	90.17	100.06
Section 7	25.82	30.71	40.14	48.76	60.43	70.32	78.47	90.14	99.96
Section 8	25.22	30.92	40.39	48.83	60.38	70.19	78.57	90.13	99.99
Section 9	24.91	31.09	40.18	48.72	60.35	70.16	78.53	90.13	100.05
Section 10	24.84	30.91	40.15	48.84	60.58	70.03	78.41	90.21	100.10
Average Value	25.28	30.81	40.30	48.76	60.49	70.15	78.45	90.21	100.06
Correction Value	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Corrected Value	25.43	30.96	40.45	48.91	60.64	70.30	78.60	90.36	100.21

6. Analyzing Method of Comparison Results

The measurement results are used to compute the degree of equivalence in Comparison Reference Value (CRV) and En ratio. The calculation is shown in following formulas:

-Calculation of Comparison Reference Value (CRV)

Pilot laboratory determined *CRV* by calculating the weighted mean of measurements of all participants (x_{ref}).

$$x_{ref} = \frac{x_1/u^2(x_1) + x_2/u^2(x_2) + ... + x_n/u^2(x_n)}{1/u^2(x_1) + 1/u^2(x_2) + ... + 1/u^2(x_n)} \quad \textbf{Eq. 1}$$

-The uncertainty of the *CRV* was calculated by following expression:

$$\frac{1}{u^2(x_{ref})} = \frac{1}{u^2(x_1)} + \frac{1}{u^2(x_2)} + ... + \frac{1}{u^2(x_n)} \quad \textbf{Eq. 2}$$

Where:

x_i = The measured value of participating institute i (i=1,2,…,n)

$u(x_i)$ = The standard uncertainty of x_i

-Its deviation from *CRV*

$$d_i = x_i - x_{ref} \quad \textbf{Eq. 3}$$

-The uncertainty of this deviation at a 95% level of confidence

$$U(d_i) = k \cdot u(d_i) \quad \textbf{Eq. 4}$$

Where $u(d_i)$ was given by

$$u^2(d_i) = u^2(x_i) + u^2(x_{ref}) \quad \textbf{Eq. 5}$$

And k = 2

-Evaluation of Coefficient E_n

The equivalence between the measurements of participating institutes was expressed by coefficient E_n as well.

$$E_n = \frac{x_i - x_{ref}}{\sqrt{U^2(x_i) + U^2(x_{ref})}} \quad \textbf{Eq. 6}$$

Where:

$$U(x_i) = k \cdot u(x_i)$$

$$U(x_{ref}) = k \cdot u(x_{ref}) \qquad \textbf{Eq. 7}$$

The x_i was equivalent with CRV x_{ref} at 95% confidence level, if $|E_n| \leq 1$.

Where

CRV	is comparison Reference Value
U(CRV)	is uncertainty of CRV
D_PTB	is deviation value of PTB from CRV
U(D_PTB)	is uncertainty of deviation value of PTB from CRV
En ratio PTB	is degree of equivalence of PTB's result expressed in En ratio
D_NIMT	is deviation value of NIMT from CRV
U(D_NIMT)	is uncertainty of deviation value of NIMT from CRV
En ratio NIMT	is degree of equivalence of NIMT's result expressed in En ratio
Ue	is expanded uncertainty that evaluated by each NMIs

7. Comparison Results

The HRA comparison results, comparison reference value (CRV), the deviation value of PTB and NIMT from CRV and their uncertainty (D_PTB, D_NIMT,U(D_PTB),U(D_NIMT)) and En ratio, were calculated and shown in Table 6. Figure 3 shows

Table 6 Conclusion of comparison evaluation on Rockwell hardness scale A

PTB	PTB Comparison Result (HRA)						
No.	A32208	A34095	24282	A12603	B15027	44010	A22039
Nominal value	35	40	55	60	70	80	85
Measured value	33.96	44.13	55.35	60.92	71.06	81.73	86.76
Ue	0.25	0.49	0.16	0.17	0.13	0.14	0.22

NIMT	NIMT Comparison Result (HRA)						
No.	A32208	A34095	24282	A12603	B15027	44010	A22039
Nominal value	35	40	55	60	70	80	85
Measured value	34.07	44.24	54.99	60.57	70.69	81.53	86.67
Ue	0.40	0.40	0.39	0.40	0.39	0.38	0.40

	Comparison evaluation						
Norminal (HRA)	35	40	55	60	70	80	85
CRV	33.99	44.19	55.30	60.87	71.03	81.71	86.74
U(CRV)	0.21	0.31	0.15	0.16	0.12	0.13	0.19
D_PTB	-0.03	-0.07	0.05	0.05	0.04	0.02	0.02
U(D_PTB)	0.33	0.58	0.22	0.23	0.17	0.19	0.29
En ratio PTB	-0.09	-0.12	0.23	0.23	0.21	0.12	0.07
D_NIMT	0.08	0.04	-0.31	-0.30	-0.34	-0.18	-0.07
U(D_NIMT)	0.46	0.51	0.42	0.43	0.41	0.41	0.44
En ratio NIMT	0.17	0.09	-0.73	-0.69	-0.85	-0.43	-0.16

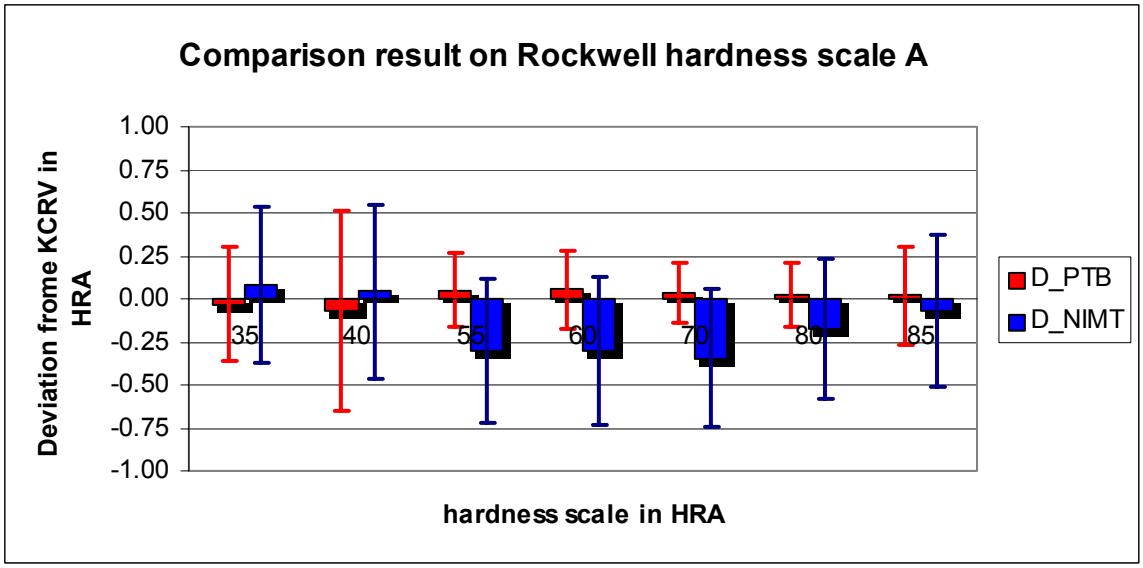

Figure 3

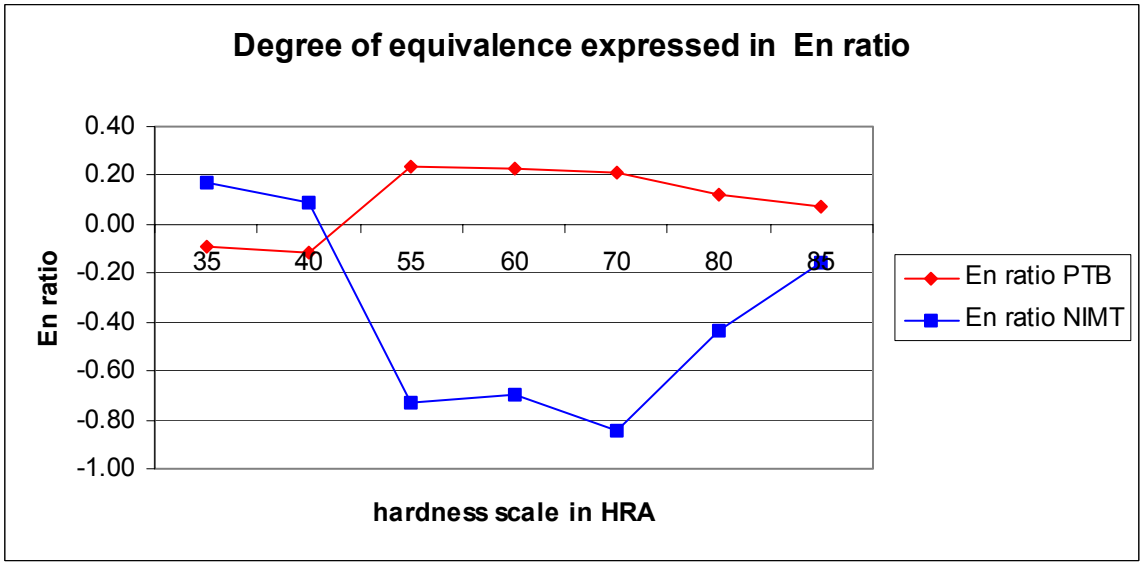

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Table 7 Conclusion of comparison evaluation on Rockwell hardness scale B

PTB	Measure value (HRB)								
No.	A30431	A30591	A31146	A32205	A33301	A34092	A35202	24280	30734
Nominal value	25	30	40	50	60	70	80	90	100
Measured value	25.43	30.96	40.45	48.91	60.64	70.30	78.60	90.36	100.21
Ue	0.76	0.58	0.34	0.17	0.21	0.21	0.23	0.15	0.16

NIMT	Measure value (HRB)								
No.	A30431	A30591	A31146	A32205	A33301	A34092	A35202	24280	30734
Nominal value	25	30	40	50	60	70	80	90	100
Measured value	25.81	31.11	40.66	49.27	60.43	70.15	78.49	90.52	100.41
Ue	0.78	0.54	0.64	0.41	0.42	0.37	0.39	0.37	0.37

	Comparison evaluation								
Norminal (HRA)	25	30	40	50	60	70	80	90	100
CRV	25.62	31.04	40.50	48.96	60.60	70.27	78.57	90.38	100.24
U(CRV)	0.55	0.40	0.30	0.16	0.19	0.18	0.20	0.14	0.15
D_PTB	-0.19	-0.08	-0.05	-0.05	0.04	0.04	0.03	-0.02	-0.03
U(D_PTB)	0.94	0.71	0.46	0.23	0.29	0.27	0.31	0.21	0.22
En ratio PTB	-0.20	-0.11	-0.10	-0.22	0.15	0.13	0.09	-0.11	-0.14
D_NIMT	0.20	0.07	0.16	0.30	-0.17	-0.12	-0.08	0.13	0.16
U(D_NIMT)	0.95	0.67	0.71	0.44	0.46	0.41	0.44	0.39	0.40
En ratio NIMT	0.21	0.10	0.23	0.69	-0.36	-0.28	-0.18	0.34	0.41

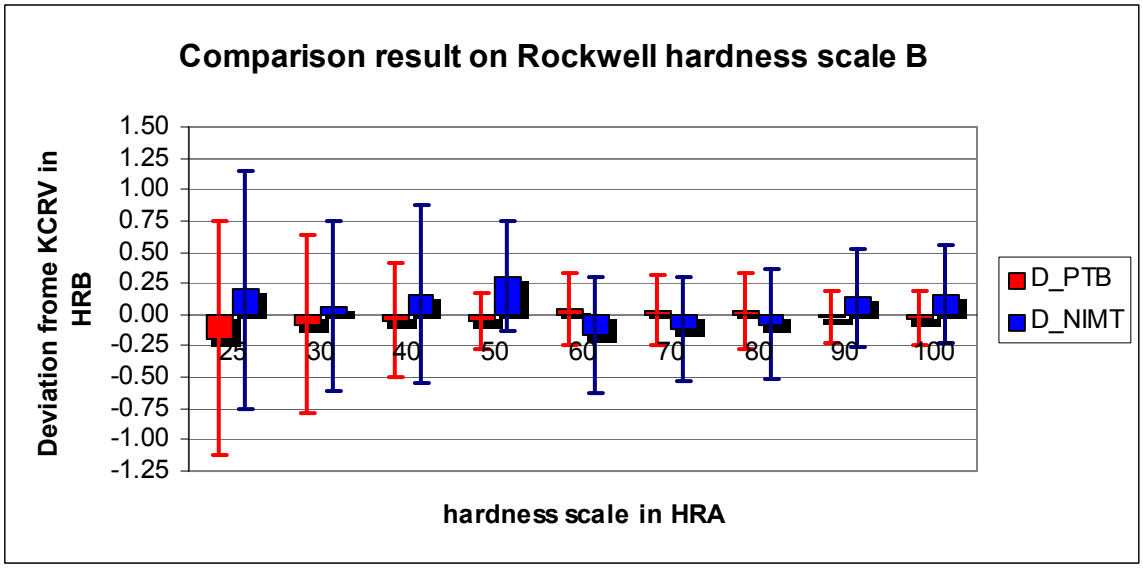

Figure 5

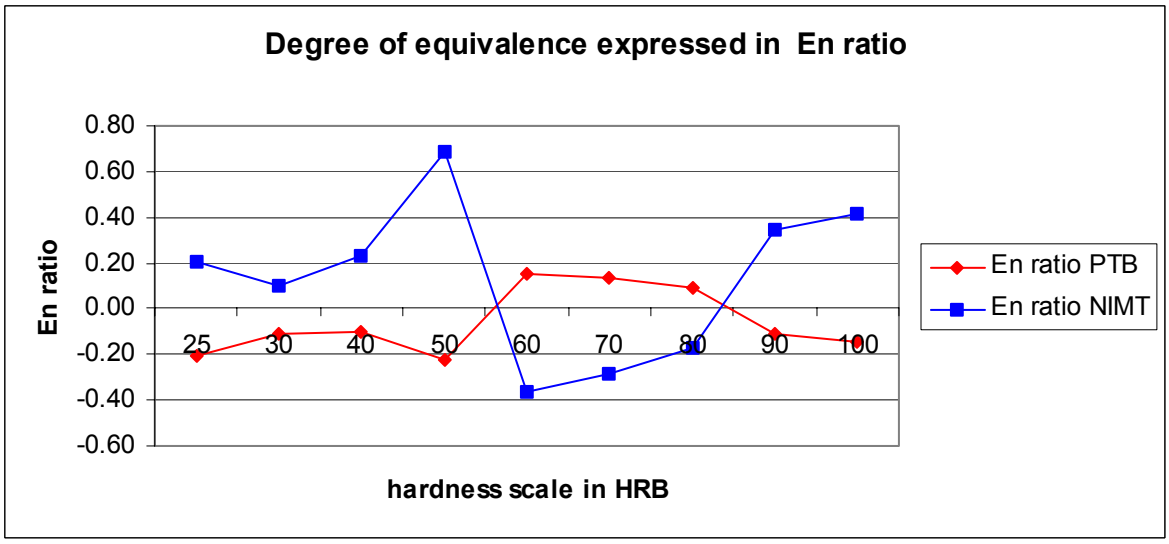

Figure 6

8. Discussion and Conclusion

This comparison used the deviation from CRV and the uncertainty of this deviation of a 95% level of confidence as the degree of equivalence. The E_n numbers were also calculated to express the equivalence between measurements of the participants. Comparison result of Rockwell hardness scale A measurement is shown in figure 3 and 4. The range of the deviation from CRV is between –0.34 HRA to 0.08 HRA. The E_n numbers ranges from –0.85 to +0.23. Figure 5 and 6 shows the comparison result of Rockwell hardness scale B measurement. The range of the deviation from CRV is between –0.17 HRB to 0.30 HRB. The E_n numbers ranges from –0.36 to +0.69. It has been shown that the NIMT and the PTB hardness machines compare well. Both laboratories show the ability of measurement in hardness scale of 35 HRA to 85 HRA and 25 HRB to 100 HRB.

9. References

[1] ISO 6508-3: Metallic materials-Rockwell hardness test-Part 3: Calibration of reference blocks (scales A, B, C, D, E, F, G, H, K, N, T)