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## PRELIMINARY RESULTS OF EURAMET ROCKWELL COMPARISON BETWEEN INRiM AND UME (EURAMET.M.H-S1.A.B.C)

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### Abstract:

A bilateral supplementary comparison between INRiM (National Metrology Institute of Italy) and UME (National Metrology Institute of Turkey) had been decided to be organized in the field of Hardness Metrology to determine the consistency of the national hardness standards in both countries realizing Rockwell Hardness measurements in accordance with ISO 6508-1:2016 [1] and ISO 6508-3:2015 [2] standards. In this paper the procedure and preliminary measurement results of the bilateral EURAMET supplementary comparison between the two laboratories are explained.

**Keywords:** Hardness, Rockwell, comparison, supplementary

### 1. INTRODUCTION

A bilateral supplementary comparison between INRiM (Istituto Nazionale di Ricerca Metrologica) and UME (TÜBİTAK Ulusal Metroloji Enstitüsü) was carried out in the field of Hardness Metrology to determine the consistency of the national hardness standards used in both countries realizing Rockwell Hardness measurements in accordance with the ISO 6508-1:2016 [1] and the ISO 6508-3:2015 [2] standards, including the new definition of Rockwell Hardness scales accepted by the CIPM/CCM WGH [3]. The most important and the most widely used Rockwell Hardness scales such as HRA, HRBW and HRC constitute the scope of the comparison which was piloted by INRiM.

The blocks used in the comparison as transfer standards were provided by UME. Each NMI measured five hardness levels for HRC and four hardness levels for HRA and HRBW scales on the same transfer standards, using both their own and common indenters which also were provided by UME by providing its own indenters. Measurements were carried out first by UME as the provider of the blocks, then by the pilot laboratory

(PL) INRiM, then again by UME for checking the stability of the transfer standards.

The NMIs were requested to realize the traceability of each component constituting the hardness scales on their national standards to the base SI units and constitute their uncertainty budgets before the comparison measurements.

### 2. TRANSFER STANDARDS USED IN THE COMPARISON

In the bilateral comparison a total of three sets of hardness reference blocks were used; one set for each hardness scale of HRA, HRBW and HRC, separately. Five blocks for HRC scale and four blocks for each of HRA and HRBW scales, a total of 13 hardness reference blocks were used. The blocks are placed in a wooden protective case during transportation with their anti-rusting paper and original cover provided by their producer. Some information related to the hardness reference blocks used in the comparison and their pictures are given below.

Table 1: Hardness reference blocks for HRA scale

No	Hardness Value	Serial Number	Producer
1	27 HRA	668-385	YAMAMOTO
2	46 HRA	666-752	YAMAMOTO
3	66 HRA	293-733	YAMAMOTO
4	87 HRA	284-385	YAMAMOTO

Table 2: Hardness reference blocks for HRBW scale

No	Hardness Value	Serial Number	Producer
1	32 HRBW	668-326	YAMAMOTO
2	53 HRBW	661-029	YAMAMOTO
3	73 HRBW	666-251	YAMAMOTO
4	95 HRBW	666-850	YAMAMOTO

Table 3: Hardness reference blocks for HRC scale

No	Hardness Value	Serial Number	Producer
1	25 HRC	492-096	YAMAMOTO
2	36 HRC	489-678	YAMAMOTO
3	45 HRC	369-719	YAMAMOTO
4	57 HRC	454-774	YAMAMOTO
5	67 HRC	486-336	YAMAMOTO

The pictures of the transfer standards used in the comparison with their nominal hardness values and serial numbers are given below. Their surfaces were cleaned with soft material before and after measurements when it is needed.

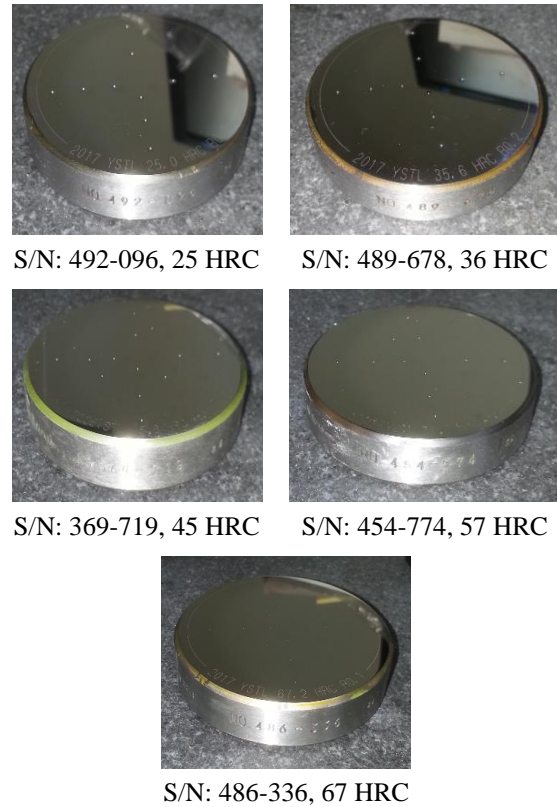


Figure 3: Transfer Standards for HRC scale

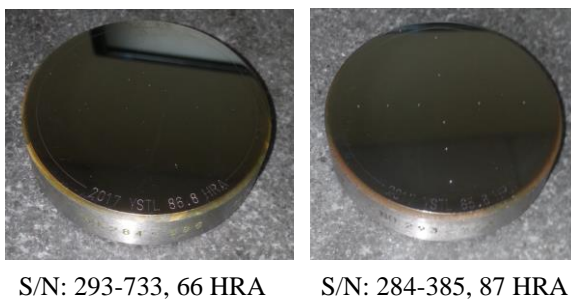
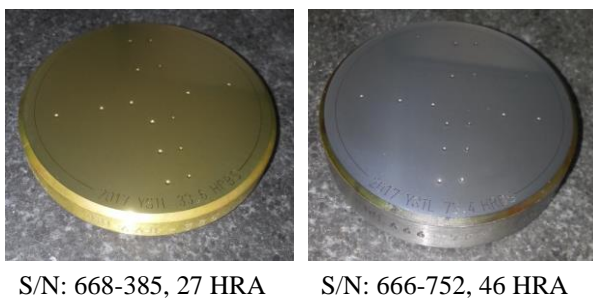


Figure 1: Transfer Standards for HRA scale

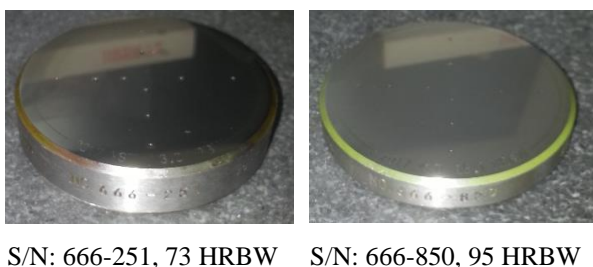
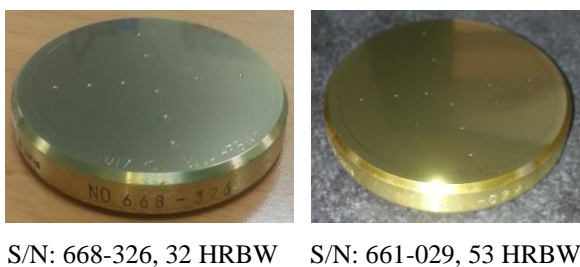


Figure 2: Transfer Standards for HRBW scale

### 3. COMPARISON PROCEDURE

It was requested that each participant shall assure that the national standards to be used in the comparison at least were in accordance with the ISO 6508-1:2016 [1] and the ISO 6508-3:2015 [2] standards. Under these circumstances the components to be calibrated/verified are as follows;

- Force (preliminary load, total load, preliminary load after removal of the additional load).
- Testing cycle (in accordance with the new definition of HRC scale accepted by the CCM WGH [3] or at least in accordance with the ISO 6508-1:2016 [1] and the ISO 6508-3:2015 [2] standards).
- Indenter geometrical parameters (in accordance with the ISO 6508-3:2015 [2] standard).
- Depth measurement system (in accordance with the ISO 6508-3:2015 [2] standard).

Beside management of calibration of the components given above, the blocks were placed in the laboratory one day before the measurements for temperature equilibrium. The measurement steps realized during the comparison measurement are as follows;

- Before starting the measurements, it was assured that the standardizing machines were working properly in accordance with their design parameters and the relevant ISO standards' requirements.



$u(x_{ref})$  : standard uncertainty of  $x_{ref}$

- The deviation from the CRV is calculated by,

$$d_i = x_i - x_{ref} \quad (3)$$

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

$$U(d_i) = k \cdot u(d_i) \quad (4)$$

Where  $u(d_i)$  is calculated by,

$$u^2(d_i) = u^2(x_i) - u^2(x_{ref}) \quad (5)$$

and  $k = 2$ .

- The coefficient  $E_n$  is the equivalence between the measurements of participating institutes, is calculated as given below,

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

where,

$$U(x_i) = k \cdot u(x_i) \quad (7)$$

$$U(x_{ref}) = k \cdot u(x_{ref}) \quad (8)$$

- The  $x_i$  is equivalent with  $x_{ref}$  (CRV) at 95% confidence level, if  $|E_n| \leq 1$ ,

where,

- $X_{INRiM}$  is INRiM measurement value,
- $U_{INRiM}$  is the expanded uncertainty value that declared by INRiM,
- $X_{UME}$  is UME measurement value,
- $U_{UME}$  is the expanded uncertainty value that declared by UME,
- $X_{ref}$  is the Comparison Reference Value (CRV),
- $U_{ref}$  is the uncertainty value of CRV,
- $d_{INRiM}$  is the deviation value of INRiM from the CRV,
- $U_{G-INRiM}$  is the uncertainty of the deviation value of INRiM from the CRV,
- $E_{n-INRiM}$  is the degree of equivalence of INRiM expressed in  $E_n$  ratio,
- $d_{UME}$  is the deviation value of UME from the CRV,
- $U_{G-UME}$  is the uncertainty of the deviation value of UME from the CRV,
- $E_{n-UME}$  is the degree of equivalence of UME expressed in  $E_n$  ratio.

## 6. COMPARISON RESULTS

In this comparison the degree of equivalence of each participant with respect to the CRV was calculated. This calculation comprises calculation the deviation of each participant from the CRV and the associated uncertainty of this deviation. Also the  $E_n$  ratios were also calculated for each hardness scale and level. The two participants declare consistent uncertainty values and measurements results are in a significant consistency with each other. Below you can see the tabular and graphical interpretation of the measurement results and calculations.

Table 5: DoE of INRiM and UME (wrt. CRV) – HRA – common indenter

$X_{UME}$	$U_{UME}$	$X_{INRiM}$	$U_{INRiM}$	$X_{ref}$	$U_{ref}$	$d_{UME}$	$U_{G-UME}$	$E_{n-UME}$	$d_{INRiM}$	$U_{G-INRiM}$	$E_{n-INRiM}$
26.68	0.29	26.35	0.30	26.52	0.21	0.16	0.21	0.77	-0.16	0.21	0.77
44.87	0.30	44.66	0.30	44.77	0.21	0.11	0.21	0.51	-0.11	0.21	0.51
65.65	0.30	65.53	0.30	65.59	0.21	0.06	0.21	0.28	-0.06	0.21	0.28
87.08	0.30	87.10	0.30	87.09	0.21	-0.01	0.21	0.05	0.01	0.21	0.05

Table 6: DoE of INRiM and UME (wrt. CRV) – HRBW – common indenter

$X_{UME}$	$U_{UME}$	$X_{INRiM}$	$U_{INRiM}$	$X_{ref}$	$U_{ref}$	$d_{UME}$	$U_{G-UME}$	$E_{n-UME}$	$d_{INRiM}$	$U_{G-INRiM}$	$E_{n-INRiM}$
31.29	0.43	30.94	0.42	31.12	0.30	0.18	0.30	0.59	-0.17	0.30	0.59
53.22	0.41	52.99	0.43	53.11	0.29	0.11	0.28	0.38	-0.12	0.31	0.38
72.62	0.39	72.74	0.42	72.68	0.29	-0.06	0.22	0.22	0.07	0.31	0.22
95.03	0.40	95.27	0.41	95.15	0.29	-0.12	0.28	0.42	0.13	0.29	0.42

Table 7: DoE of INRiM and UME (wrt. CRV) – HRC – common indenter

$X_{UME}$	$U_{UME}$	$X_{INRiM}$	$U_{INRiM}$	$X_{ref}$	$U_{ref}$	$d_{UME}$	$U_{G-UME}$	$E_{n-UME}$	$d_{INRiM}$	$U_{G-INRiM}$	$E_{n-INRiM}$
24.73	0.31	24.89	0.30	24.81	0.22	-0.08	0.22	0.38	0.08	0.21	0.38
35.10	0.28	35.25	0.30	35.17	0.20	-0.07	0.19	0.36	0.08	0.22	0.36
45.57	0.34	45.68	0.30	45.63	0.22	-0.06	0.25	0.24	0.05	0.20	0.24
55.63	0.30	55.66	0.31	55.64	0.22	-0.01	0.21	0.07	0.02	0.22	0.07
67.42	0.32	67.47	0.31	67.45	0.22	-0.03	0.23	0.12	0.03	0.22	0.12

Table 8: DoE of INRiM and UME (wrt. CRV) – HRA – own indenter

$X_{UME}$	$U_{UME}$	$X_{INRiM}$	$U_{INRiM}$	$X_{ref}$	$U_{ref}$	$d_{UME}$	$U_{G-UME}$	$E_{n-UME}$	$d_{INRiM}$	$U_{G-INRiM}$	$E_{n-INRiM}$
26.68	0.29	26.42	0.31	26.55	0.21	0.12	0.20	0.61	-0.14	0.22	0.61
44.87	0.30	44.71	0.31	44.79	0.22	0.08	0.21	0.39	-0.09	0.22	0.39
65.65	0.30	65.33	0.30	65.49	0.21	0.16	0.21	0.76	-0.16	0.21	0.76
87.08	0.30	86.96	0.30	87.02	0.21	0.06	0.21	0.28	-0.06	0.21	0.28

Table 9: DoE of INRiM and UME (wrt. CRV) – HRBW – own indenter

$X_{UME}$	$U_{UME}$	$X_{INRiM}$	$U_{INRiM}$	$X_{ref}$	$U_{ref}$	$d_{UME}$	$U_{G-UME}$	$E_{n-UME}$	$d_{INRiM}$	$U_{G-INRiM}$	$E_{n-INRiM}$
31.29	0.43	31.03	0.42	31.16	0.30	0.13	0.30	0.43	-0.13	0.30	0.43
53.22	0.41	53.32	0.43	53.26	0.29	-0.05	0.28	0.17	0.05	0.31	0.17
72.62	0.39	72.74	0.41	72.67	0.28	-0.06	0.27	0.21	0.06	0.30	0.21
95.03	0.40	95.20	0.41	95.11	0.29	-0.08	0.28	0.30	0.09	0.29	0.30

Table 10: DoE of INRiM and UME (wrt. CRV) – HRC – own indenter

$X_{UME}$	$U_{UME}$	$X_{INRiM}$	$U_{INRiM}$	$X_{ref}$	$U_{ref}$	$d_{UME}$	$U_{G-UME}$	$E_{n-UME}$	$d_{INRiM}$	$U_{G-INRiM}$	$E_{n-INRiM}$
24.73	0.31	24.46	0.31	24.60	0.22	0.13	0.22	0.61	-0.13	0.22	0.61
35.10	0.28	34.85	0.30	34.98	0.20	0.12	0.19	0.63	-0.14	0.22	0.63
45.57	0.34	45.28	0.30	45.41	0.22	0.17	0.25	0.66	-0.13	0.20	0.66
55.63	0.30	55.26	0.30	55.44	0.21	0.18	0.21	0.86	-0.18	0.21	0.86
67.42	0.32	67.17	0.30	67.29	0.22	0.13	0.23	0.56	-0.11	0.21	0.56

In regard to the calculations shown in the tables above the graphical representations are as shown below.

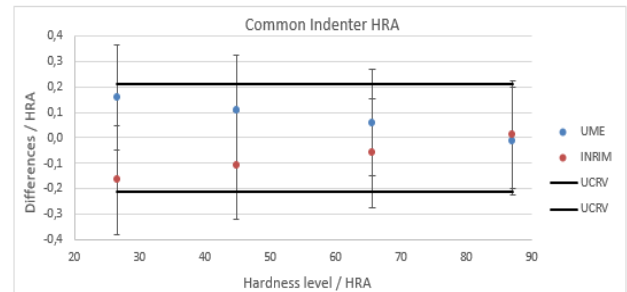


Figure 5: Deviations of INRiM and UME values from the CRV with the associated expanded uncertainty – HRA – common indenter

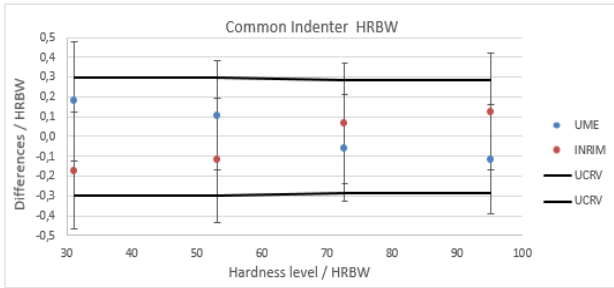


Figure 6: Deviations of INRiM and UME values from the CRV with the associated expanded uncertainty – HRBW – common indenter

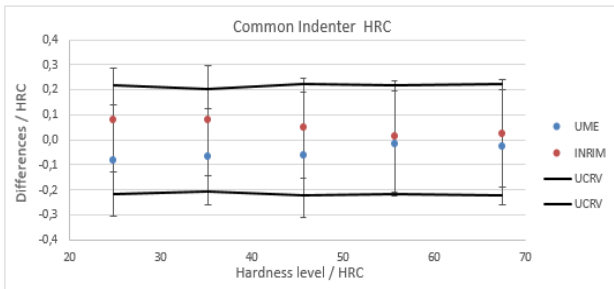


Figure 7: Deviations of INRiM and UME values from the CRV with the associated expanded uncertainty – HRC – common indenter

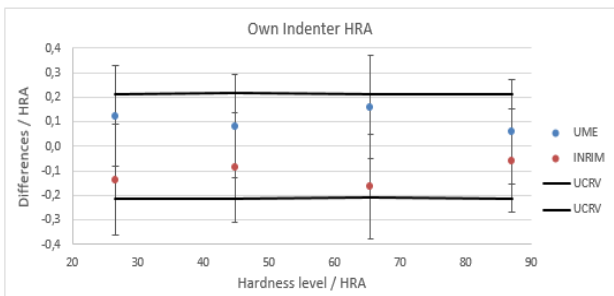


Figure 8: Deviations of INRiM and UME values from the CRV with the associated expanded uncertainty – HRA – own indenter

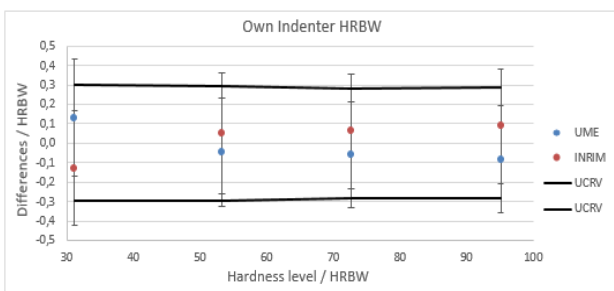


Figure 9: Deviations of INRiM and UME values from the CRV with the associated expanded uncertainty – HRBW – own indenter

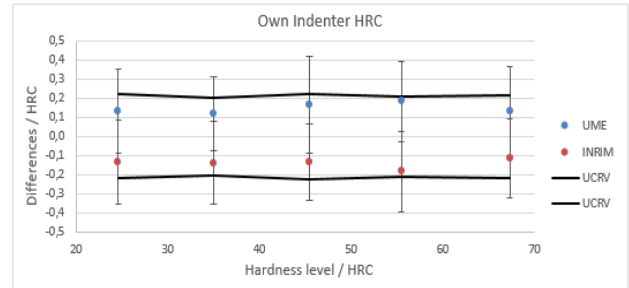


Figure 10: Deviations of INRiM and UME values from the CRV with the associated expanded uncertainty – HRC – own indenter

## 7. SUMMARY

At the end of the bilateral comparison between INRiM and UME in the most widely used Rockwell hardness scales HRA, HRBW and HRC is completed without any unexpected phenomena in any stage of it. The participating institutes declared similar uncertainty values and there was a significant consistency between the measured values of the transfer standards. The comparison reference values (CRVs), the deviation value of INRiM and UME from the CRV and their uncertainties,  $d_{\text{INRiM}}$ ,  $d_{\text{UME}}$ ,  $U_{d\text{-INRiM}}$ ,  $U_{d\text{-UME}}$ , and  $E_n$  ratios were calculated and shown in Tables 5 to 10 and Figures 5 to 10 in the *Comparison Results*. In some cases, the degrees of equivalence for the results obtained by the common indenter is greater than the degree of equivalence for the results obtained by the own indenters. This is probably because of a bias in our machine in that scale/range but still within the uncertainty declared. The degrees of equivalence show a significant consistency between INRiM and UME hardness standards in HRA, HRBW and HRC Rockwell hardness scales and this comparison is supporting the present and possible new CMC submissions.

## 8. REFERENCES

- [1] EN ISO 6508–1:2016, Metallic Materials–Rockwell Hardness Test–Part1: Test Method (scales A, B, C, D, E, F, G, H, K, N, T).
- [2] EN ISO 6508–3:2015, Metallic Materials–Rockwell Hardness Test - Part3: Calibration of Reference Blocks (scales A, B, C, D, E, F, G, H, K, N, T).
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