

## WC/Co Hardmetals Rockwell – Vickers Hardness Comparison

**December 2004**

### Rationale

Hardness is an important property defining the scope of use for many hardmetal products. There is no unique hardness scale used by hardmetal manufacturers across the world. In some countries the Rockwell 'A' scale is popular, in other countries the Vickers hardness scale is preferred. Increasing globalisation of trade in hardmetal products demands common specification standards or validated tables through which different scales can be compared. Suitable standard reference materials are also not commercially available, although individual manufacturing companies often have in-house sets. It is understood, but not quantified, that different comparative scales may need to be used for different hardmetal products, dependent on type and composition.

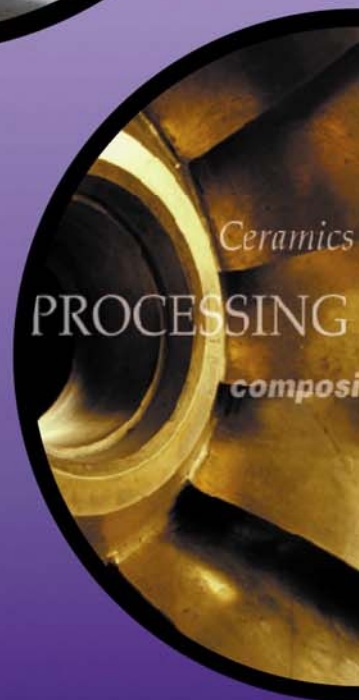
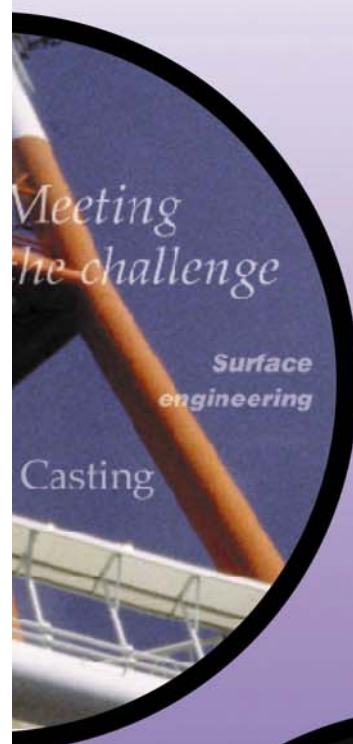
### Objectives

To conduct an intercomparison exercise between the Rockwell 'A' scale and Vickers HV30 on five representative WC/Co hardmetals; to provide information that can underpin the development of recommended conversion tables and that can also be used, especially by SME companies, to calibrate in-house hardness testing procedures. The exercise was coordinated by the Research Group of the British Hardmetal Research Association (now British Hardmetal and Engineers' Cutting Tool Association).

### Outcome

Six organisations made measurements of HRA and HV hardness which allowed a quantitative comparison between HRA and HV to be derived for standard WC/Co hardmetals and which also provided data that enabled an uncertainty associated with the measurement to be calculated.

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## Materials and Tests

Five hardmetals were manufactured by Marshalls Hard Metals Ltd to cover a reasonably wide hardness range (900-1600 HV30) representative of conventional materials (Table 1). Surfaces suitable for hardness tests were prepared by a metallographic polishing routine. Six organisations conducted Vickers and Rockwell 'A' hardness measurements on the same set of samples that were circulated in sequence to each participant.

**Table 1 Material Codes**

| Material code | Co content, wt% nominal | Coercivity kA/m | WC grain size <sup>+</sup> |
|---------------|-------------------------|-----------------|----------------------------|
| 6A/1          | 6                       | 14.2            | Fine                       |
| 11MG/1        | 11                      | 19.1            | Ultrafine                  |
| 11A/1         | 11                      | 10.4            | Fine                       |
| 11C/1         | 11                      | 6.1             | Medium                     |
| 24A/1         | 24                      | 6.1             | Fine                       |

<sup>+</sup> Categories from new ISO standard in preparation, using the linear intercept method. Values estimated from coercivity data: Ultrafine (0.2-0.5 µm); Submicron (0.5-0.8 µm); Fine (0.8-1.3 µm) Medium (1.3-2.5 µm).

## Results and Discussion

The hardness results for the five samples are given in Table 2. Orgs 1 and 3 conducted HV30 tests only. Org 4 just conducted HRA tests. Org 6 provided mean values only (not individual test results) from five indentations.

Rockwell 'A' hardness results for the five materials tested at six organisations are shown in Fig 1. Vickers hardness test results are shown in Fig 2. Figure 3 shows the means of the data set comparing HRA with HV30. A second order polynomial was fitted to the means:  $HRA = 68.39 + 0.022 (HV30) - 4.25 \times 10^{-6} (HV30)^2$ ; for  $900 > HV > 1600$ .

During the course of the work a conversion table was obtained from a USA company (Alldyne Technologies, formerly Teledyne). The data from this table for WC/Co hardmetals is also shown in Fig 3. A third order polynomial was fitted to the data.

$$HRA = 58.39 + 0.042(HV30) - 1.72 \times 10^{-5}(HV30)^2 + 2.57 \times 10^{-9}(HV30)^3$$

for  $2200 > HV30 > 1000 : 95 > HRA > 85$

The data from the current intercomparison exercise is compared with the Alldyne Technologies table in Fig 3. The agreement is good between Vickers Hardness, HV30, values of 1000-1600. There is an indication that outside this range some deviation may be present between the current exercise and the Alldyne table. Overall mean values and coefficients of variation (CV) for all tests are given in Table 3. The uncertainties (CVs) are plotted against each scale in Fig 4. It can be seen that the coefficient of variation increases slightly for both HRA and HV as the hardness decreases. Also, the CVs for the HRA tests are lower than the CVs for the HV tests. For HRA tests it increased from about 0.2 to 0.3% over the range from HRA 92 to 85 and from about 0.5 to 0.9% over the HV30 range from 1600 to 900. However, it is more important to look at the uncertainty with regard to the overall scale rather than the scale number. For the HV tests between 900 and 1600 HV30 the scale divides into about 30 discriminating intervals, assuming a typical value for 2 standard deviations (sds) is 20 pts, whereas for the HRA scale the equivalent is only 15 discriminating intervals for a typical value of 2 sds of 0.5 pts.

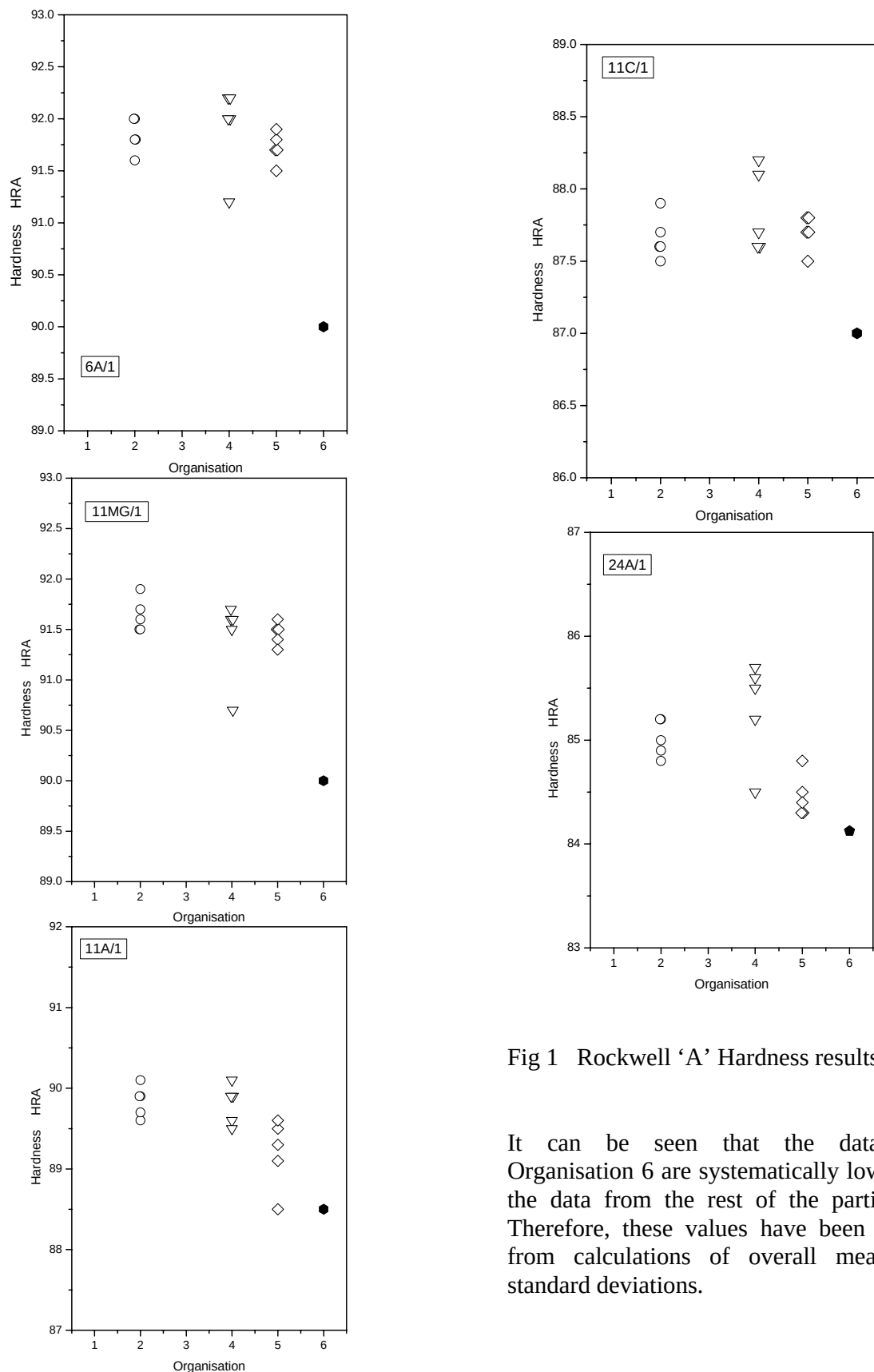


Fig 1 Rockwell 'A' Hardness results (cont).

It can be seen that the data from Organisation 6 are systematically lower than the data from the rest of the participants. Therefore, these values have been omitted from calculations of overall means and standard deviations.

Fig 1 Rockwell 'A' Hardness results.

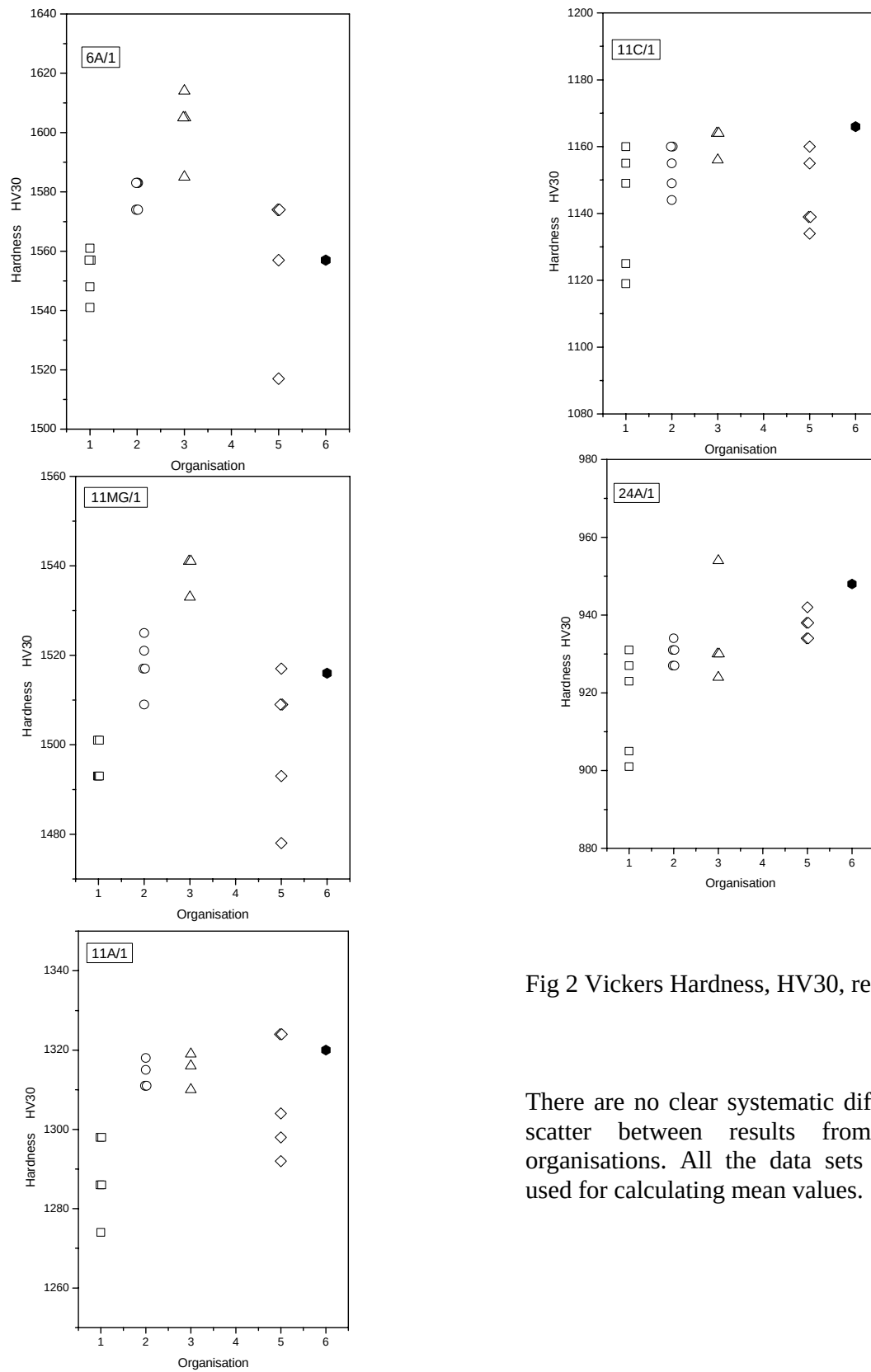


Fig 2 Vickers Hardness, HV30, results (cont)

There are no clear systematic differences in scatter between results from different organisations. All the data sets have been used for calculating mean values.

Fig 2 Vickers Hardness, HV30, results.

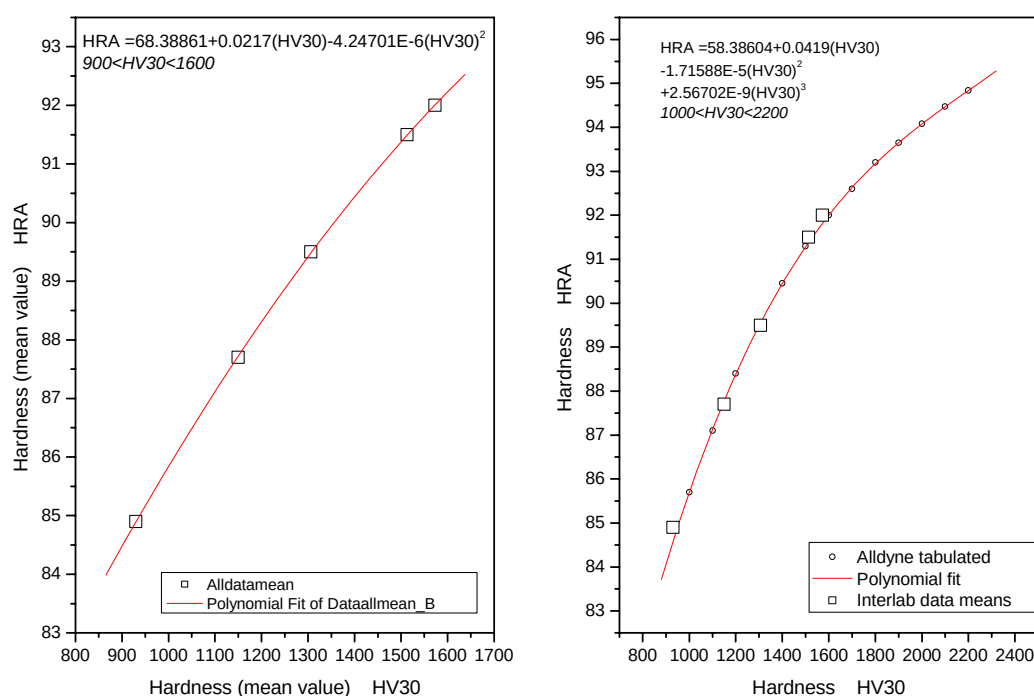


Fig 3 All organisation (excluding organisation 6) comparison of HRA and HV30 and HRA/HV30 comparative plot – USA source (Alldyne Technologies, formerly Teledyne) together with comparison with mean values from current exercise.

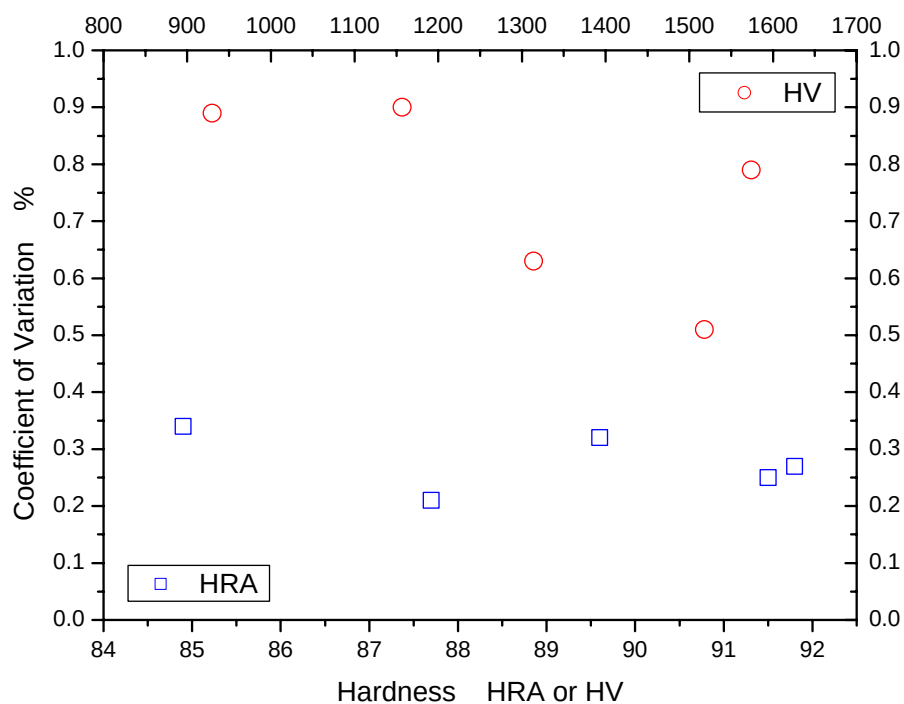


Fig 4 Coefficient of variation for HRA and HV30 measurements.

**Table 2 Hardness Results**

| <b>Sample 6A/1</b> |             |             |             |             |             |             |             |             |                   |
|--------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------------|
| Org 1              | Org 2       | Org 2       | Org 3       | Org 4       | Org 5       | Org 5       | Org 6*      | Org 6*      |                   |
| HV30               | HV30        | HRA         | HV30        | HRA         | HV30        | HRA         | HV50        | HRA         |                   |
| 1561               | 1574        | 92          | 1605        | 92          | 1517        | 91.5        |             |             |                   |
| 1557               | 1574        | 92          | 1605        | 91.2        | 1574        | 91.7        |             |             |                   |
| 1557               | 1583        | 91.8        | 1585        | 92          | 1557        | 91.7        |             |             |                   |
| 1548               | 1583        | 91.6        | 1614        | 92.2        | 1574        | 91.8        |             |             |                   |
| 1541               | 1583        | 91.8        |             | 92.2        | 1574        | 91.9        |             |             |                   |
| <b>1553</b>        | <b>1579</b> | <b>91.8</b> | <b>1602</b> | <b>91.9</b> | <b>1559</b> | <b>91.7</b> | <b>1557</b> | <b>90.0</b> | <b>Mean value</b> |

\* individual values not available

| <b>Sample 11MG/1</b> |             |             |             |             |             |             |             |             |                   |
|----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------------|
| Org 1                | Org 2       | Org 2       | Org 3       | Org 4       | Org 5       | Org 5       | Org 6*      | Org 6*      |                   |
| HV30                 | HV30        | HRA         | HV30        | HRA         | HV30        | HRA         | HV50        | HRA         |                   |
| 1493                 | 1509        | 91.9        | 1541        | 91.5        | 1478        | 91.5        |             |             |                   |
| 1501                 | 1517        | 91.5        | 1533        | 91.6        | 1509        | 91.5        |             |             |                   |
| 1493                 | 1517        | 91.7        | 1541        | 91.6        | 1517        | 91.4        |             |             |                   |
| 1501                 | 1525        | 91.6        |             | 91.7        | 1509        | 91.6        |             |             |                   |
| 1493                 | 1521        | 91.5        |             | 90.7        | 1493        | 91.3        |             |             |                   |
| <b>1496</b>          | <b>1518</b> | <b>91.6</b> | <b>1538</b> | <b>91.4</b> | <b>1501</b> | <b>91.5</b> | <b>1516</b> | <b>90.0</b> | <b>Mean value</b> |

\* individual values not available

| <b>Sample 11A/1</b> |             |             |             |             |             |             |             |             |                   |
|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------------|
| Org 1               | Org 2       | Org 2       | Org 3       | Org 4       | Org 5       | Org 5       | Org 6*      | Org 6*      |                   |
| HV30                | HV30        | HRA         | HV30        | HRA         | HV30        | HRA         | HV50        | HRA         |                   |
| 1298                | 1311        | 89.9        | 1319        | 89.6        | 1298        | 89.3        |             |             |                   |
| 1286                | 1311        | 90.1        | 1316        | 89.9        | 1324        | 88.5        |             |             |                   |
| 1286                | 1318        | 89.6        | 1310        | 89.9        | 1324        | 89.1        |             |             |                   |
| 1274                | 1311        | 89.7        |             | 89.5        | 1292        | 89.5        |             |             |                   |
| 1298                | 1315        | 89.9        |             | 90.1        | 1304        | 89.6        |             |             |                   |
| <b>1288</b>         | <b>1313</b> | <b>89.8</b> | <b>1315</b> | <b>89.8</b> | <b>1308</b> | <b>89.2</b> | <b>1320</b> | <b>88.5</b> | <b>Mean value</b> |

\* individual values not available

**Table 2 Hardness Results (cont)**

| <b>Sample 11C/1</b> |             |             |             |             |             |             |             |             |                   |
|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------------|
| Org 1               | Org 2       | Org 2       | Org 3       | Org 4       | Org 5       | Org 5       | Org 6*      | Org 6*      |                   |
| HV30                | HV30        | HRA         | HV30        | HRA         | HV30        | HRA         | HV50        | HRA         |                   |
| 1160                | 1144        | 87.6        | 1156        | 87.6        | 1139        | 87.7        |             |             |                   |
| 1155                | 1149        | 87.7        | 1164        | 87.6        | 1139        | 87.5        |             |             |                   |
| 1149                | 1155        | 87.5        | 1164        | 87.7        | 1155        | 87.8        |             |             |                   |
| 1125                | 1160        | 87.9        |             | 88.1        | 1134        | 87.8        |             |             |                   |
| 1119                | 1160        | 87.6        |             | 88.2        | 1160        | 87.7        |             |             |                   |
| <b>1142</b>         | <b>1154</b> | <b>87.7</b> | <b>1161</b> | <b>87.8</b> | <b>1145</b> | <b>87.7</b> | <b>1166</b> | <b>87.0</b> | <b>Mean value</b> |

\* individual values not available

| <b>Sample 24A/1</b> |            |           |            |             |            |             |            |             |                   |
|---------------------|------------|-----------|------------|-------------|------------|-------------|------------|-------------|-------------------|
| Org 1               | Org 2      | Org 2     | Org 3      | Org 4       | Org 5      | Org 5       | Org 6      | Org 6       |                   |
| HV30                | HV30       | HRA       | HV30       | HRA         | HV30       | HRA         | HV50       | HRA         |                   |
| 901                 | 927        | 85.2      | 930        | 85.6        | 938        | 84.3        |            |             |                   |
| 923                 | 931        | 85.2      | 954        | 85.5        | 934        | 84.3        |            |             |                   |
| 931                 | 931        | 84.9      | 924        | 85.7        | 934        | 84.5        |            |             |                   |
| 927                 | 927        | 84.8      | 930        | 84.5        | 942        | 84.4        |            |             |                   |
| 905                 | 934        | 85        |            | 85.2        | 938        | 84.8        |            |             |                   |
| <b>917</b>          | <b>930</b> | <b>85</b> | <b>934</b> | <b>85.3</b> | <b>937</b> | <b>84.5</b> | <b>948</b> | <b>84.1</b> | <b>Mean value</b> |

\* individual values not available

**Table 3 Uncertainties (Coefficient of Variation, CV, %)**

| <b>Rockwell Hardness</b> |          |       |       |       |       |       |         |
|--------------------------|----------|-------|-------|-------|-------|-------|---------|
| Sample                   | HRA mean | Org 1 | Org 2 | Org 3 | Org 4 | Org 5 | CV mean |
| 6A/1                     | 91.8     | -     | 0.19  | -     | 0.45  | 0.16  | 0.27    |
| 11MG/1                   | 91.5     | -     | 0.19  | -     | 0.45  | 0.12  | 0.25    |
| 11A/1                    | 89.6     | -     | 0.21  | -     | 0.27  | 0.49  | 0.32    |
| 11C/1                    | 87.7     | -     | 0.17  | -     | 0.33  | 0.14  | 0.21    |
| 24A/1                    | 84.9     | -     | 0.21  | -     | 0.56  | 0.25  | 0.34    |

| <b>Vickers Hardness</b> |         |       |       |       |       |       |         |
|-------------------------|---------|-------|-------|-------|-------|-------|---------|
| Sample                  | HV mean | Org 1 | Org 2 | Org 3 | Org 4 | Org 5 | CV mean |
| 6A/1                    | 1574    | 0.52  | 0.31  | 0.76  | -     | 1.58  | 0.79    |
| 11MG/1                  | 1518    | 0.29  | 0.39  | 0.30  | -     | 1.04  | 0.51    |
| 11A/1                   | 1314    | 0.78  | 0.24  | 0.35  | -     | 1.14  | 0.63    |
| 11C/1                   | 1157    | 1.61  | 0.61  | 0.40  | -     | 0.99  | 0.90    |
| 24A/1                   | 930     | 1.47  | 0.32  | 1.42  | -     | 0.36  | 0.89    |

## Summary

An intercomparison exercise between six organisations has shown that reasonable comparison exists for Vickers and Rockwell scales for conventional WC/Co hardmetals in the range 1000-1600 (HV30) : 86-92 (HRA). Further work is needed to confirm the validity of the comparison outside this range. A typical uncertainty (2 sds) associated with the measurement of hardness between different laboratories is about 20 pts for HV30 and 0.5 pts for HRA. Thus, the HV30 test is more discriminating than the HRA test within this range of hardness values.

These values can be used to underpin an estimate of confidence in discriminating between different materials or measurements at different organisations.

A set of five WC/Co hardmetals is now in place for companies to use to calibrate in-house testing procedures.

Further work should be undertaken to investigate hardness measurements on WC/Co hardmetals with HV30 > 1600 : HRA > 92 and to extend this work to hardmetals based on Ti(C,N) cermets and hardmetals that contain cubic carbides such as TiC, TaC in addition to WC.

## Acknowledgements

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