

## Key comparison APMP.L-K1

MEASURAND : Length of gauge blocks

TRAVELLING STANDARDS : 10 steel gauge blocks

$x_i$  : average of the central length measured in two orientations by laboratory  $i$

$u_i$  : combined standard uncertainty of  $x_i$

| Nominal value<br>Lab $i$ | 0.5 mm        |               | 1.01 mm       |               | 1.1 mm        |               | 6 mm          |               | 7 mm          |               | 8 mm          |               | 15 mm         |               | 80 mm         |               |
|--------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                          | $x_i$<br>/ nm | $u_i$<br>/ nm | $x_i$<br>/ nm | $u_i$<br>/ nm | $x_i$<br>/ nm | $u_i$<br>/ nm | $x_i$<br>/ nm | $u_i$<br>/ nm | $x_i$<br>/ nm | $u_i$<br>/ nm | $x_i$<br>/ nm | $u_i$<br>/ nm | $x_i$<br>/ nm | $u_i$<br>/ nm | $x_i$<br>/ nm | $u_i$<br>/ nm |
| NMIA                     | 41.5          | 10.0          | -16.5         | 10.0          | 2.0           | 10.0          | 0.5           | 10.0          | -3.0          | 10.0          | 32.5          | 10.0          | 14.5          | 10.0          | 47.0          | 14.0          |
| NIM                      | 26.0          | 9.7           | -32.0         | 9.7           | -13.5         | 9.7           | -21.5         | 9.7           | -25.5         | 9.7           | 3.5           | 9.7           | 21.5          | 9.8           | 33.0          | 13.4          |
| SPRING Singapore         | 30.0          | 14.0          | -20.5         | 14.0          | -3.0          | 14.0          | 6.5           | 15.0          | -8.0          | 15.0          | 27.5          | 16.0          | 18.5          | 17.0          | 73.0          | 27.0          |
| NMIJ                     | 23.9          | 8.6           | -43.8         | 8.6           | -27.5         | 8.6           | -35.4         | 8.7           | -29.2         | 8.7           | -5.4          | 8.7           | 6.2           | 8.8           | 10.5          | 12.6          |
| KRISS                    | 31.5          | 14.8          | -33.0         | 15.7          | -1.5          | 16.9          | -8.0          | 14.8          | -16.5         | 14.8          | 9.0           | 14.8          | 14.0          | 14.6          | 20.0          | 19.2          |
| NML-SIRIM                | 22.0          | 15.0          | -33.5         | 15.0          | -2.0          | 15.0          | -2.5          | 15.0          | -7.0          | 15.0          | -             | -             | 13.0          | 15.0          | -             | -             |
| NIMT                     | 36.0          | 11.0          | -33.0         | 11.0          | -20.5         | 11.0          | -31.0         | 11.0          | -26.0         | 11.0          | -             | -             | -32.0         | 11.0          | -             | -             |
| VMI-STAMEQ               | 14.0          | 14.0          | -13.5         | 14.0          | 14.5          | 14.0          | 95.0          | 14.0          | 80.5          | 14.0          | -             | -             | 27.0          | 14.0          | -             | -             |
| MSL                      | 60.5          | 19.0          | -10.5         | 19.0          | 5.5           | 19.0          | 15.5          | 19.0          | 30.0          | 19.0          | -             | -             | 71.0          | 20.0          | -             | -             |
| NPLI                     | -             | -             | -30.0         | 19.3          | -             | -             | -13.0         | 21.0          | 15.5          | 21.4          | -             | -             | -4.0          | 24.1          | -             | -             |

| Nominal value<br>Lab $i$ | 90 mm         |               | 100 mm        |               | Date of measurement                |
|--------------------------|---------------|---------------|---------------|---------------|------------------------------------|
|                          | $x_i$<br>/ nm | $u_i$<br>/ nm | $x_i$<br>/ nm | $u_i$<br>/ nm |                                    |
| NMIA                     | -61.5         | 15.0          | -95.5         | 16.0          | Mar 01                             |
| NIM                      | -57.0         | 14.0          | -92.5         | 14.7          | Apr - May 01                       |
| SPRING Singapore         | -36.0         | 28.0          | -76.5         | 30.0          | Jun 01                             |
| NMIJ                     | -67.1         | 13.4          | -111.7        | 14.3          | Jan 01, Jul - Aug 01, Jul - Aug 02 |
| KRISS                    | -61.5         | 16.6          | -96.0         | 17.6          | Sep 01                             |
| NML-SIRIM                | -28.5         | 18.0          | -54.0         | 18.0          | Oct 01                             |
| NIMT                     | -126.5        | 20.0          | -180.5        | 22.0          | Nov 01                             |
| VMI-STAMEQ               | -54.0         | 21.0          | -378.5        | 22.0          | Dec 01 - Jan 02                    |
| MSL                      | -74.5         | 25.0          | -132.0        | 26.0          | Mar - Apr 02                       |
| NPLI                     | 207.0         | 49.6          | 176.5         | 53.0          | May - Jun 02                       |

CMS/ITRI was unable to participate due to instrument failure.

Two of the steel gauge blocks (8 mm and 80 mm) were damaged in the course of the comparison.

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$x_{i,1}$  : average of the central length measured in two orientations by laboratory  $i$

$u_{i,1}$  : combined standard uncertainty of  $x_{i,1}$

| Nominal value<br>Lab $i$ | 0.5 mm            |                   | 1.01 mm           |                   | 1.1 mm            |                   | 6 mm              |                   | 7 mm              |                   | 8 mm              |                   | 15 mm             |                   | 80 mm             |                   |
|--------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|                          | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm |
| MSL                      | 11.0              | 20.0              | 42.0              | 20.0              | -1.0              | 20.0              | 24.0              | 20.0              | -7.0              | 20.0              | 17.0              | 20.0              | 23.0              | 20.0              | -88.0             | 24.0              |
| NIMT                     | -1.0              | 11.0              | 27.0              | 11.0              | -24.0             | 11.0              | 17.0              | 11.0              | -39.0             | 11.0              | 5.0               | 11.0              | 21.0              | 11.0              | -67.0             | 19.0              |
| NML-SIRIM                | -12.0             | 15.0              | 25.0              | 15.0              | -25.0             | 15.0              | 6.0               | 15.0              | -38.0             | 15.0              | -9.0              | 15.0              | 10.0              | 16.0              | -92.0             | 21.0              |
| NMIJ                     | -2.0              | 8.6               | 40.0              | 8.6               | -18.0             | 8.6               | 18.0              | 8.6               | -19.0             | 8.6               | 5.0               | 8.6               | 22.0              | 8.8               | -80.0             | 12.5              |
| CMS/ITRI                 | -24.0             | 14.0              | 9.0               | 14.0              | -27.0             | 14.0              | 13.0              | 14.0              | -36.0             | 14.0              | -22.0             | 14.0              | -15.0             | 14.0              | -109.0            | 17.0              |
| VMI-STAMEQ               | 2.5               | 14.0              | 41.5              | 14.0              | 7.5               | 14.0              | 45.5              | 15.0              | -14.5             | 15.0              | -9.0              | 16.0              | 42.5              | 17.0              | -67.5             | 29.0              |
| NPLI                     | -18.0             | 15.4              | 62.0              | 15.5              | 25.0              | 15.7              | 51.0              | 17.1              | 6.0               | 17.4              | -8.0              | 17.7              | 11.0              | 19.9              | -33.0             | 40.0              |

| Nominal value<br>Lab $i$ | 90 mm             |                   | 100 mm            |                   | Date of<br>measurement |
|--------------------------|-------------------|-------------------|-------------------|-------------------|------------------------|
|                          | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm | $x_{i,1}$<br>/ nm | $u_{i,1}$<br>/ nm |                        |
| MSL                      | -62.0             | 25.0              | 66.0              | 26.0              | Jun 05                 |
| NIMT                     | -25.0             | 21.0              | 71.0              | 22.0              | Jul 05                 |
| NML-SIRIM                | -60.0             | 22.0              | 49.0              | 23.0              | Aug 05                 |
| NMIJ                     | -45.0             | 13.4              | 65.0              | 14.3              | Sep-Oct 05             |
| CMS/ITRI                 | -55.0             | 18.0              | 35.0              | 18.0              | Nov 05                 |
| VMI-STAMEQ               | 56.5              | 31.0              | 103.5             | 33.0              | Dec 05                 |
| NPLI                     | -104.0            | 43.1              | 235.0             | 46.2              | Feb-May 06             |

Measurements were also carried out at NMIJ in May 2005 (before the beginning of the comparison) and from June to August 2006 (after the end of the comparison). They are not reported here. The degrees of equivalence of NMIJ are computed using the measurement results obtained in September and October 2005.

## Key comparison APMP.L-K1

MEASURAND : Length of gauge blocks

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For each nominal value, the APMP.L-K1 reference value,  $x_R$ , is obtained as the weighted mean excluding outliers and MSL results (see Section 4 of the APMP.L-K1 Final Report). The standard uncertainty,  $u_R$ , of  $x_R$  is computed as the internal standard deviation of the weighted mean.

| Nominal value     | 0.5 mm | 1.01 mm | 1.1 mm | 6 mm  | 7 mm  | 8 mm | 15 mm | 80 mm | 90 mm | 100 mm |
|-------------------|--------|---------|--------|-------|-------|------|-------|-------|-------|--------|
| $x_R / \text{nm}$ | 28.9   | -29.9   | -10.2  | -17.2 | -17.5 | 10.4 | 14.5  | 30.6  | -55.8 | -98.1  |
| $u_R / \text{nm}$ | 4.0    | 4.0     | 4.1    | 4.2   | 4.2   | 4.9  | 4.4   | 6.9   | 6.3   | 7.5    |
| $u_A / \text{nm}$ | 3.2    | 10.4    | 8.3    | 11.8  | 4.5   | 10.1 | 2.2   | 8.2   | 12.0  | 6.6    |

For each nominal value, the degree of equivalence of each laboratory  $i$  participant in APMP.L-K1 with respect to the APMP.L-K1 reference value is given by a pair of terms:

$D_i = x_i - x_R$ , and  $U_i$ , its expanded uncertainty ( $k = 2$ ) with  $U_i = 2(u_i^2 - u_R^2 + u_A^2)^{1/2}$ ;  $u_A$  is the uncertainty linked to the artefact.

No pair-wise degrees of equivalence are calculated.

Results of key comparison APMP.L-K1 are not linked to any other key comparison results.

## Key comparison APMP.L-K1.1

MEASURAND : Length of gauge blocks

TRAVELLING STANDARDS : 10 steel gauge blocks

For each nominal value, the APMP.L-K1.1 reference value,  $x_{R,1}$ , is obtained as the weighted mean excluding outliers and CMS results (see Section 5 of the APMP.L-K1.1 Final Report). The standard uncertainty,  $u_{R,1}$ , of  $x_{R,1}$  is computed as the internal standard deviation of the weighted mean.

| Nominal value         | 0.5 mm | 1.01 mm | 1.1 mm | 6 mm | 7 mm  | 8 mm | 15 mm | 80 mm | 90 mm | 100 mm |
|-----------------------|--------|---------|--------|------|-------|------|-------|-------|-------|--------|
| $x_{R,1} / \text{nm}$ | -3.3   | 38.2    | -11.0  | 23.2 | -22.2 | 1.4  | 21.7  | -77.4 | -48.7 | 66.7   |
| $u_{R,1} / \text{nm}$ | 5.1    | 5.1     | 5.1    | 5.2  | 5.2   | 5.3  | 5.5   | 8.2   | 9.1   | 9.4    |
| $u_{A,1} / \text{nm}$ | 6.4    | 5.8     | 17.0   | 9.0  | 7.6   | 5.5  | 3.6   | 5.5   | 5.5   | 1.0    |

For each nominal value, the degree of equivalence of each laboratory  $i$  participant in APMP.L-K1.1 with respect to the APMP.L-K1.1 reference value is given by a pair of terms:

$D_{i,1} = x_{i,1} - x_{R,1}$ , and  $U_{i,1}$ , its expanded uncertainty ( $k = 2$ ) with  $U_{i,1} = 2(u_{i,1}^2 - u_{R,1}^2 + u_{A,1}^2)^{1/2}$ ;  $u_{A,1}$  is the uncertainty linked to the artefact.

The pair-wise degrees of equivalence are not calculated.

Results of key comparison APMP.L-K1.1 are not linked to any other key comparison results.

However, for each common nominal value, the APMP.L-K1 and APMP.L-K1.1 graphs of equivalence are shown side by side.

## Key comparison APMP.L-K1

MEASURAND : Length of gauge blocks

TRAVELLING STANDARDS : 10 steel gauge blocks

Degrees of equivalence relative to the APMP.L-K1 reference value

| Nominal value<br>Lab <i>i</i> ↓ | 0.5 mm        |               | 1.01 mm       |               | 1.1 mm        |               | 6 mm          |               | 7 mm          |               | 8 mm          |               | 15 mm         |               | 80 mm         |               | 90 mm         |               | 100 mm        |               |
|---------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                                 | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm | $D_i$<br>/ nm | $U_i$<br>/ nm |
| NMIA                            | 13            | 19            | 13            | 28            | 12            | 25            | 18            | 30            | 14            | 20            | 22            | 27            | 0             | 19            | 16            | 29            | -6            | 36            | 3             | 31            |
| NIM                             | -3            | 19            | -2            | 27            | -3            | 24            | -4            | 29            | -8            | 20            | -7            | 26            | 7             | 18            | 2             | 28            | -1            | 35            | 6             | 29            |
| SPRING<br>Singapore             | 1             | 28            | 9             | 34            | 7             | 31            | 24            | 37            | 9             | 30            | 17            | 37            | 4             | 33            | 42            | 55            | 20            | 60            | 22            | 60            |
| NMIJ                            | -5            | 16            | -14           | 26            | -17           | 22            | -18           | 28            | -12           | 18            | -16           | 25            | -8            | 16            | -20           | 27            | -11           | 34            | -14           | 28            |
| KRISS                           | 3             | 29            | -3            | 37            | 9             | 37            | 9             | 37            | 1             | 30            | -1            | 34            | -1            | 28            | -11           | 39            | -6            | 39            | 2             | 34            |
| NML-SIRIM                       | -7            | 30            | -4            | 36            | 8             | 33            | 15            | 37            | 10            | 30            | -             | -             | -2            | 29            | -             | -             | 27            | 41            | 44            | 35            |
| NIMT                            | 7             | 21            | -3            | 29            | -10           | 26            | -14           | 31            | -9            | 22            | -             | -             | -47           | 21            | -             | -             | -71           | 45            | -82           | 43            |
| VMI-STAMEQ                      | -15           | 28            | 16            | 34            | 25            | 31            | 112           | 36            | 98            | 28            | -             | -             | 12            | 27            | -             | -             | 2             | 47            | -280          | 43            |
| MSL                             | 32            | 38            | 19            | 43            | 16            | 41            | 33            | 44            | 47            | 38            | -             | -             | 56            | 39            | -             | -             | -19           | 54            | -34           | 52            |
| NPLI                            | -             | -             | 0             | 43            | -             | -             | 4             | 47            | 33            | 43            | -             | -             | -19           | 48            | -             | -             | 263           | 101           | 275           | 106           |

## Key comparison APMP.L-K1.1

MEASURAND : Length of gauge blocks

TRAVELLING STANDARDS : 10 steel gauge blocks

Degrees of equivalence relative to the APMP.L-K1.1 reference value

| Nominal value<br>Lab <i>i</i> ↓ | 0.5 mm            |                   | 1.01 mm           |                   | 1.1 mm            |                   | 6 mm              |                   | 7 mm              |                   | 8 mm              |                   | 15 mm             |                   | 80 mm             |                   | 90 mm             |                   | 100 mm            |                   |
|---------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|                                 | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm | $D_{i,1}$<br>/ nm | $U_{i,1}$<br>/ nm |
| MSL                             | 14                | 41                | 4                 | 40                | 10                | 51                | 1                 | 43                | 15                | 42                | 16                | 40                | 1                 | 39                | -11               | 46                | -13               | 48                | -1                | 49                |
| NIMT                            | 2                 | 23                | -11               | 23                | -13               | 39                | -6                | 26                | -17               | 25                | 4                 | 22                | -1                | 20                | 10                | 36                | 24                | 39                | 4                 | 40                |
| NML-SIRIM                       | -9                | 31                | -13               | 30                | -14               | 44                | -17               | 33                | -16               | 32                | -10               | 30                | -12               | 31                | -15               | 40                | -11               | 42                | -18               | 42                |
| NMIJ                            | 1                 | 19                | 2                 | 18                | -7                | 37                | -5                | 23                | 3                 | 20                | 4                 | 17                | 0                 | 16                | -3                | 22                | 4                 | 23                | -2                | 22                |
| CMS/ITRI                        | -21               | 29                | -29               | 28                | -16               | 43                | -10               | 32                | -14               | 30                | -23               | 28                | -37               | 27                | -32               | 32                | -6                | 33                | -32               | 31                |
| VMI-STAMEQ                      | 6                 | 29                | 3                 | 28                | 18                | 43                | 22                | 33                | 8                 | 32                | -10               | 32                | 21                | 33                | 10                | 57                | 105               | 60                | 37                | 63                |
| NPLI                            | -15               | 32                | 24                | 31                | 36                | 45                | 28                | 37                | 28                | 37                | -9                | 36                | -11               | 39                | 44                | 79                | -55               | 85                | 168               | 90                |





















