Report on APMP Bilateral Comparison
Measurement of long gauge blocks by comparative method

APMP.L-S6

Final Report

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1 Document control

Version Draft B.1  Issued on August 2014.

Version Draft B.2  Issued on February 2015, comments from participants taken into account.

Version Draft B.3  Issued on December 2015, comments from APMP TCL taken into account.

2 Introduction

The metrological equivalence of national measurement standards and of calibration certificates issued by national metrology institutes is established by a set of key and supplementary comparisons chosen and organized by the Consultative Committees of the CIPM or by the regional metrology organizations in collaboration with the Consultative Committees.

The procedures outlined in this document cover the technical procedure to be followed during the measurements. A goal of the APMP key comparisons for topics in dimensional metrology is to demonstrate the equivalence of routine calibration services offered by NMIs to clients, as listed in Appendix C of the Mutual Recognition Agreement (MRA). To this end, participants in this comparison agree to use the same apparatus and methods as routinely applied to client artefacts.

By their declared intention to participate in this key comparison, laboratories accept the general instructions and to strictly follow the technical protocol. The allocated time periods are not only for measurements, but also for the transportation and customs clearance.

3 Organization

3.1 Participants

Table 1. List of involved laboratories and their contacts.

<table>
<thead>
<tr>
<th>Position</th>
<th>Laboratory Code</th>
<th>Contact person, Laboratory</th>
<th>Phone, Fax, email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>NIMT</td>
<td>Mr. Pawat Phuaknoi National Institute of Metrology Thailand 3/4-5 Moo 3, Klong 5, Klong Luang, Pathumthani 12120 Thailand</td>
<td>Tel. +66 5775100 ext. 1216 Fax. +66 5775088 e-mail: <a href="mailto:pawat@nimt.or.th">pawat@nimt.or.th</a></td>
</tr>
<tr>
<td>Participant</td>
<td>KRISS</td>
<td>Dr. Tae Bong Eom Korea Research Institute of Standards and Science, 267 Gajeong-Ro, Yuseong-Gu, Daejeon 34113, Rep. of Korea</td>
<td>Tel. +82 42-868-5108 Fax +82 42-868-5608 e-mail: <a href="mailto:tbeom@kriss.re.kr">tbeom@kriss.re.kr</a></td>
</tr>
<tr>
<td>Neutral</td>
<td>NMIJ</td>
<td>Dr. Toshiyuki Takatsuji National Metrology Institute of Japan AIST 3, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, Japan</td>
<td>Tel. +81-29-861-4361 Fax +81-29-861-4152 e-mail: <a href="mailto:Toshiyuki.Takatsuji@aist.go.jp">Toshiyuki.Takatsuji@aist.go.jp</a></td>
</tr>
</tbody>
</table>
3.2 Schedule

The participating laboratories were asked to specify a preferred timetable slot for their own measurements of the gauge blocks – the timetable given in table 2 has been drawn up taking these preferences into account. Each laboratory has one month that include customs clearance, calibration and transportation to the following participant. With its confirmation to participate, the laboratory is obliged to perform the measurements in the allocated period and to allow enough time in advance for transportation so that the following participant receives them in time. In order to confirm the stability of the artefact, the start of the measurement was delayed by one month.

Table 2. Schedule of the comparison.

<table>
<thead>
<tr>
<th>APMP</th>
<th>Laboratory</th>
<th>Original Schedule</th>
<th>Actual Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>NIMT-1</td>
<td>June 2013</td>
<td>July 2013</td>
</tr>
<tr>
<td>Participant</td>
<td>KRISS</td>
<td>July 2013</td>
<td>August 2013</td>
</tr>
<tr>
<td>Pilot</td>
<td>NIMT-2</td>
<td>August 2013</td>
<td>October 2013</td>
</tr>
</tbody>
</table>

4 Artefacts

4.1 Description of artefacts

The package contains 3 gauge blocks. The gauge blocks are of rectangular cross section and comply with the calibration grade 0 of the standard ISO 3650:1998. Note: the gauge blocks were selected for good quality of the faces and small variation in length, the limit deviation $t_e$ from nominal length may not be met by some of the artefacts.

The coefficients of thermal expansion given in the following table are obtained from the manufacturer and were used as such for compensations.

Table 3. List of artefacts.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Nominal length /mm</th>
<th>Expansion coefficient /10$^6$ K$^{-1}$</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>930608</td>
<td>150</td>
<td>10.8 ± 1.0</td>
<td>Mitutoyo</td>
</tr>
<tr>
<td>930154</td>
<td>250</td>
<td>10.8 ± 1.0</td>
<td>Mitutoyo</td>
</tr>
<tr>
<td>922002</td>
<td>500</td>
<td>10.8 ± 1.0</td>
<td>Mitutoyo</td>
</tr>
</tbody>
</table>

4.2 Stability of artefacts

Steel gauge blocks occasionally show a growing or a shrinkage the rate of which is approximately linear with time. The instability of the blocks was determined in course of the comparison. For this check the measurements of the pilot laboratory are used exclusively, not that of the other participant. According to these data in Table 4, the drift was negligible compared to the measurement uncertainty and the gauge blocks are considered stable.
Table 4. Stability result of gauge blocks.

<table>
<thead>
<tr>
<th>Nominal Length mm</th>
<th>Id number</th>
<th>Jul-13 Deviation, nm</th>
<th>Uncertainty k = 2, nm</th>
<th>Oct-13 Deviation, nm</th>
<th>Uncertainty k = 2, nm</th>
<th>Drift nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>930608</td>
<td>340</td>
<td>120</td>
<td>330</td>
<td>120</td>
<td>-10</td>
</tr>
<tr>
<td>250</td>
<td>930154</td>
<td>-140</td>
<td>160</td>
<td>-160</td>
<td>160</td>
<td>-20</td>
</tr>
<tr>
<td>500</td>
<td>922002</td>
<td>-880</td>
<td>280</td>
<td>-880</td>
<td>280</td>
<td>0</td>
</tr>
</tbody>
</table>

The observed length change is significantly smaller than its uncertainty. The gauge block is considered stable and no modification to the standard evaluation procedure will be applied.

4.3 Condition of artefacts at start/end of comparison

A wooden case for the long gauge blocks is used for the transportation of the artefacts (Figure 1). Upon reception of the package, the laboratory has to check that the content is complete and that there is no apparent damage on the box or any of the standards. The reception has to be confirmed immediately to the pilot with a copy to the former participant (sender), preferably using the form as in the Appendix A of the protocol.

The organization costs were covered by the pilot laboratory, which include the standards themselves, the case and packaging, and the shipping costs to the next laboratory. The pilot laboratory has no insurance for any loss or damage of the standards during the circulation.

![Figure 1. Transporting case](image)

Once the measurements have been completed, the package shall be sent to the following participant. The steel gauge blocks need to be protected against corrosion when not being measured by means of protective oil. The sketches of the gauge block surfaces before and after comparison are illustrated in Figure 2 and 3, respectively. The “A” surface is the right hand measuring face of the gauge blocks. It should be addressed that although there are scratches on the surface of gauge blocks, the flatness quality is within their specifications and ISO 3650:1998. Also, after the bilateral comparison, there is no significant change in quality of gauge blocks’ surface. Hence, one can conclude that no damage, severe scratches or rust that may affect the measurement result, is occurred during the comparison.
5 Measuring instructions

The gauge blocks were to be measured based on the standard procedure that the laboratory regularly uses for this calibration service for its customers. The measurand is the deviation $e_c$ of the central length $l_c$ from the nominal length $l_n$ of a gauge block, $e_c = l_c - l_n$. 

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Figure 2. Sketches of the gauge blocks before comparison.

Figure 3. Sketches of the gauge blocks after comparison.
6 Results

All participants submitted their measurement report to the neutral laboratory, NMIJ, within four weeks at the latest. The measurement conditions of participants are listed in Table 5 and the numerical results are summarized in Table 6. Figure 4 illustrates the graphical representation of the results.

Table 5. Measurement conditions of participants.

<table>
<thead>
<tr>
<th>Lab</th>
<th>NIMT</th>
<th>KRISS</th>
</tr>
</thead>
</table>
| Type and model of comparator | Type: Comparator using two contacting probe  
Model: 828 CiM | Type: Comparator using two contacting probe  
Model: 130B-16 |
| Manufacturer, Tip radius and Measuring force of probe | MFR: Mahr  
Tip radius: 1 mm  
Measuring force: 1N | MFR: Mahr federal  
Tip radius: 3.2 mm  
Measuring force: Upper 1.1 N, Lower 0.6 N |
| Manufacturer, material and CTE of standard gauge blocks | MFR: Koba  
Material: Steel  
CTE: 11.5x10^-6/K, 11.0x10^-6/K | MFR: Mitutoyo  
Material: Steel  
CTE: 10.8x10^-6/K |
| Temperature range | 20.0 °C ± 0.3 °C (Room temperature)  
Temperature difference of gauge blocks is 0.03 °C | 19.88 °C - 20.10 °C |
| Measurement method and traceability | Comparative method with standard gauge blocks (grade K of the same nominal length, and the same material) | Comparative method with standard gauge blocks (grade K of the same nominal length, and the same material) |

Table 6. Deviation (x) and expanded uncertainty at k = 2 reported by the laboratories.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Deviation from nominal length / μm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150 mm (930608)</td>
</tr>
<tr>
<td>Lab</td>
<td>x</td>
</tr>
<tr>
<td>NIMT</td>
<td>0.340</td>
</tr>
<tr>
<td>KRISS</td>
<td>0.345</td>
</tr>
</tbody>
</table>
Figure 4. Reported measurement results. Error bars indicate expanded uncertainty at $k = 2$.

7 Analysis

For each laboratory’s result, the $E_n$ value is calculated. $E_n$ is defined as the absolute value of the difference in participants’ measured values, divided by the expanded uncertainty of this difference. Table 7 lists the the $E_n$ values for each gauge block.

$$E_n = \frac{|x_1 - x_2|}{\sqrt{U^2(x_1) + U^2(x_2)}}$$

Table 7. Degrees of equivalence, associated with the expanded uncertainties with $k = 2$.

<table>
<thead>
<tr>
<th>Nominal Length, mm</th>
<th>ID No.</th>
<th>$E_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>930608</td>
<td>0.037</td>
</tr>
<tr>
<td>250</td>
<td>930154</td>
<td>0.138</td>
</tr>
<tr>
<td>500</td>
<td>922002</td>
<td>0.995</td>
</tr>
</tbody>
</table>
8 Conclusion

The bilateral comparison for long gauge block calibration using comparative method was conducted. Three gauge blocks were used as artefact with length of 150 mm, 250 mm and 500 mm. The gauge blocks were examined before and after despatch and no significant damage was occurred during the measurement. The participants performed measurement according to their routine calibration procedure which is normally used to provide calibration service to the customer. All reported measurement results from the two participants agree well with $\epsilon_n < 1$.

KRISS had participated in the APMP.L-K2: Calibration of long gauge blocks and hence this comparison and the regional key comparison can be linked.

9 References


