# ASIA PACIFIC METROLOGY PROGRAM

# INTERCOMPARISON OF HIGH PRECISION ROUNDNESS MEASUREMENT APMP.L-S4

## 2012-2013

Pilot institute: National Institute of Metrology (Thailand), NIMT

Contact: Jariya Buajarern; jariya@nimt.or.th

Coordinating institute: National Metrology Institute of Japan, NMIJ

Contact: Kazuya Naoi; naoi.k@aist.go.jp

# PROTOCOL
# Version 03

**Prepared by**
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**National Institute of Metrology (Thailand)**

**Issued February 2012**

## 1. Introduction

The broad objective of the Asia Pacific Metrology Program (APMP) is to improve the measurement capabilities in the Asia Pacific region by sharing facilities and experience in metrology. Comparison of calibrations by different laboratories on given artifacts adds confidence in the measurement of standards and leads to international acceptance of the measurements carried out by these laboratories. This intercomparison concerns the calibration of glass hemisphere and roundness assessment of the softgauge.

Standards circulated to all laboratories consist of:

- Two (2) glass hemispheres
- Two (2) softgauges

Measurement conditions for each standard are described in the appropriate section of this document. If the ISO guidelines cannot be followed an approximation may be made with detailed description of how the measurement conditions have varied.

On completion of measurements, the results of the intercomparison will be circulated for comment and a final report presented to the APMP.

## 2. Pilot and Coordinating Laboratory

The project will be piloted by:

Dr Jariya Buajarern
Dimensional Metrology Department
National Institute of Metrology (Thailand)
3/4-5 Moo 3, Klong 5, Klong Luang,
Pathumthani 12120 Thailand
Telephone: +66 2 577 5100 ext 1206
Fax: +66 2 577 5088
Email: jariya@nimt.or.th

The pilot laboratory will be responsible for

- Preparing the protocol
- Planning the program and organizing the schedule
- Maintaining a list of participants' information
- Liaising with participants
- Collecting and assessing results by accepted statistical methods
- Preparing the draft report
- Distributing the draft report for comment
- Reviewing comments and completing the final report

And the project will be coordinated by:

Dr Kazuya Naoi
National Institute of Advanced Industrial Science and Technology (AIST)
Tsukuba Central 3, 1-1-1 Umezono, Tsukuba,
Ibaraki 305-8563, Japan
Telephone: +81 29 861 4041
Fax: +81 29 861 4041
Email: naoi.k@aist.go.jp

The program coordinator will be responsible for

- Reviewing the protocol
- Preparing the artifacts
- Declaring the value of the artifacts
- Making initial and final measurements
- Reviewing comments and completing the final report

## 3. Participating Laboratories

Cooperation of all participants is essential for a successful intercomparison.

Participants are listed in Table 1. They are expected to:

- Provide correct and up to date contact and address details to the pilot laboratory.
- Have all resources and instrumentation ready by the scheduled month of measurement and commit to carry out measurements according to the schedule (Table 2).
- Ensure funds are available for onward transport of the artifacts.
- Select a suitable agent for forwarding the artifacts to the next participant and organize smooth movement through customs using appropriate documents.
- On receipt of the artifacts, inform the program pilot (by email) of receipt, any damage to the standards or the box or of any other problems or delays (Appendix C).
- Follow the instructions of measurement for each standard or specify any variation.
- Calculate a mean result and associated uncertainty.
- On completion of measurements, re-examine the condition of each standard and notify the coordination of any change (Appendix C).
- Repack the artifacts and make transport arrangements. Ensure that the set of documents are enclosed. Inform the next participant in advance. ATA Carnet will be supplied for those countries that participate in this scheme. The schedule has been set to make efficient use of the Carnet scheme.
- Supply all results including coordinate value of the roundness measurements in **.xls** or **.txt** or **.ascii** format, calibration reports, uncertainty calculations and Appendix D summary to the pilot laboratory within 6 weeks of receipt of the artifacts.
- Agree not to discuss any measurement results prior to distribution of the draft report (after completion of all measurements).

Refer to Appendix B for a more detailed checklist of actions required.

**Table 1: Participants and contacts**

| No. | Country | Laboratory / Address | Transportation address | Contact name and email | Phone |
|---|---|---|---|---|---|
| 1 | **Thailand** (Pilot) | National Institute of Metrology (Thailand), **NIMT** 3/4-5 Moo 3, Klong 5, Klong Luang, Pathumthani 12120, Thailand | Same | **Dr Jariya Buajarern** jariya@nimt.or.th | +66 25775100 ext 1216 |
| 2 | **Japan** (Coordinator) | National Metrology Institute of Japan, **NMIJ** National Institute of Advanced Industrial Science and Technology (AIST) Tsukuba Central 3, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, Japan | Same | **Dr Kazuya Naoi** naoi.k@aist.go.jp | +81 298614041 |
| 3 | **Australia** | National Metrology Institute, **NMIA** Department of Industry, Innovation, Science, Research and Tertiary Education Unit 1 - 153 Bertie Street, Port Melbourne, Vic 3207 | Same | **Mr Andrew Baker** andrew.baker@measurement.gov.au | +61 396444902 |
| 4 | **China** | National Institute of Metrology, **NIM** Beisanhuandonglu 18, Beijing 100013, China | Same | **Dr Xue Zi** xuez@nim.ac.cn | +86 1064524915 |
| 5 | **Chinese Taipei** | Center for Measurement Standards / Industrial Technology Research Institute (**CMS/ITRI**) 321 Kuang Fu Rd., Sec. 2, Bldg. 16 30042 Hsinchu, Taiwan | Same | **Mr Chin-Lung Tsai** walter_tsai@itri.org.tw | +886 35743764 |
| 6 | **Republic of Korea** | Korea Research Institute of Standards and Science, **KRISS** 267 Gajeong-Ro, Yuseong-Gu, Daejeon 305-340, Rep. of Korea | Same | **Dr Tae Bong Eom** tbeom@kriss.re.kr | +82 8685100 |
| 7 | **Singapore** | National Metrology Centre/Agency for Science, Technology and Research , **NMC**, A*STAR 1 Science Park Drive, Singapore 118221 | Same | **Ms Tan Siew Leng** tan_siew_leng@nmc.a-star.edu.sg | +65 62791938 |
| 8 | **South Africa** | National Metrology Institue of South Africa, **NMISA** Private Bag X34, Lynnwood Ridge, Pretoria, 0040, South Africa | National Metrology Institute of South Africa Bld 5, CSIR campus, Meiring Naude Road, Brumeria, Pretoria | **Mr Oelof Kruger** oakruger@nmisa.org | +27 128414340 |

## 4. Scheduling, Packaging and Customs

The program is to commence in 2012 with measurement at the coordinating laboratory. The order for measurement is listed in Table 2. Each laboratory is expected to make all required measurement in a two week period and allow a further two week period for transferring the artifacts to the next listed laboratory. Those scheduled for December or January are allowed four weeks for measurement due to expected public holidays and a further two week period for transfer. The coordinating laboratory will make repeat measurements at the end of the schedule to check the stability of the artifacts.

**Table 2: Measurement schedule**

| No. | Date | Country | Lab | Carnet |
|---|---|---|---|---|
| 1 | March 2012 | Japan | NMIJ | Yes |
| 2 | April 2012 | Thailand | NIMT | Yes |
| 3 | May 2012 | Australia | NMIA | Yes |
| 4 | June 2012 | South Africa | NMISA | Yes |
| 5 | July 2012 | Singapore | NMC | Yes |
| 6 | September 2012 | Korea | KRISS | Yes |
| 7 | October 2012 | Thailand | NIMT | Yes |
| 8 | November 2012 | Japan | NMIJ | Yes |
| 9 | December 2012 | Chinese Taipei | ITRI | No |
| 10 | January 2013 | China | NIM | No |
| 11 | February 2013 | Japan | NMIJ | Yes |

Only the first measurement results from the coordinating laboratory will be included and analyzed.

The ATA Carnet system is to be used to cover customs formalities whenever possible. Not all participating countries recognize the Carnet system. A Carnet is valid for twelve months from the date of issue. Each country has to ensure that supplied documents are sufficient for the required customs clearance according to the agreed schedule.

It is the responsibility of the coordinating laboratory to arrange for appropriate packing and handling details and to organize appropriate documentation. It is expected that each participating country will have arranged for customs clearance and will have all resources required for measurement ready in advance. Each participant is responsible for re-packing and shipping the artifacts to the next participant and bearing the cost associated with forwarding the artifacts.

The artifacts are transported inside a protective aluminum box. A strong envelope is taped to the outside of the box with a copy of all documents and a second copy inside the box.
The documents consist of:

1. Custom Declaration (Appendix A)
2. This protocol
3. ATA Carnet (if applicable)

If any documents are lost or missing, please contact the pilot and coordinating laboratory immediately for replacement.

The following items are inside the packing box:

1. Copy of documents package (see above)
2. Metal box with two artifacts inside and 1 memory stick inside

Two glass hemispheres are made of glass. Carefully clean the standards with lint free tissues or cloth and small quantities or residue free solvents (such as ethanol). Please handle all standards with care.

Perform a visual inspection (Appendix C) and take digital photographs of all standards (if necessary) upon delivery and again at the end of the measurement before passing on to the next participant. Forward the inspection forms (Appendix C) or digital photos to jariya@nimt.or.th upon delivery and after passing on.

**Important!** When repacking the box, put a copy of the documents in a strong envelope on the outside of the box as well as a copy inside to help with customs inspections.

## 5. Equipment

Each laboratory may choose the most appropriate equipment. Follow to the measurement instructions in section 7 and 8.

**Table 3: Expected measurement instruments**

| Country | Lab | Equipment | Traceability |
|---|---|---|---|
| Japan | NMIJ | Talyrond 73 | Laser interferometer |
| Australia | NMIA | Talyrond 73 | Flick standard, Laser interferometer |
| Thailand | NIMT | Talyrond 73 | Flick standard, NMIA |
| Singapore | NMC | Talyrond 395 | NPL |
| South Africa | NMISA | Talyrond 73 | Laser interferometer |
| Korea | KRISS | Talyrond 395 | Laser interferometer |
| Chinese Taipei | ITRI | Talyrond 73 | Laser interferometer |
| China | NIM | Talyrond 73 | Gauge blocks |

## 6. Artifacts

The artifacts to be circulated for assessment of roundness are:

**Table 4: Artifacts details**

| Type | Manufacturer | Serial No. |
|---|---|---|
| Glass Hemisphere | Taylor Hobson | 8726 |
| | Taylor Hobson | 6767 |
| Softgauge I | - | SoftgaugeI |
| Softgauge II | - | SoftgaugeII |

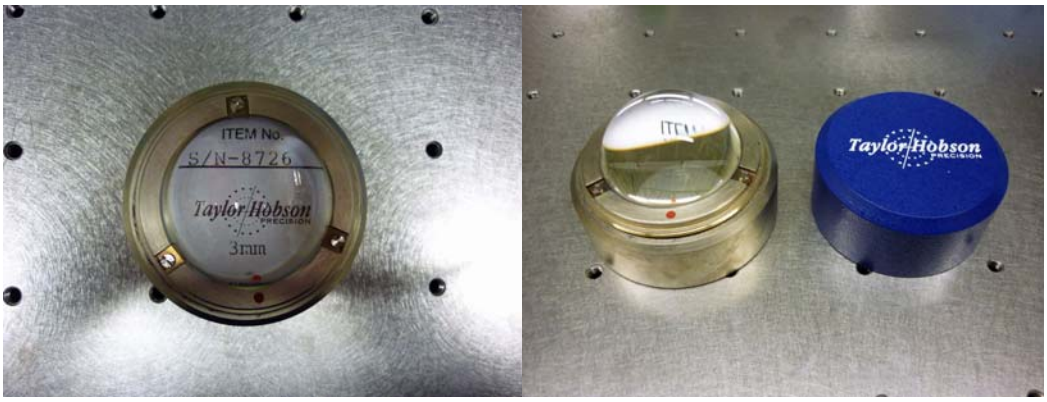


**Figure 1: Glass Hemisphere (8726)**


**Figure 2: Glass Hemisphere (6767)**

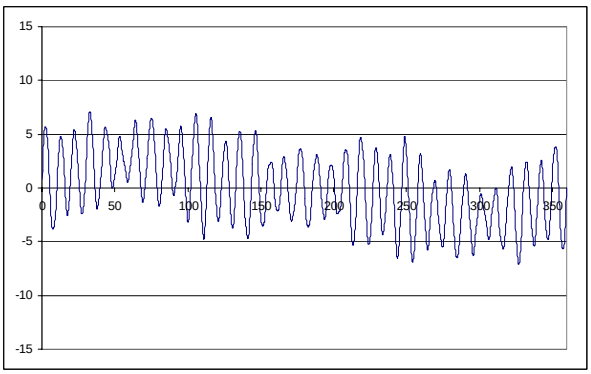


**Figure 3: SoftgaugeI**

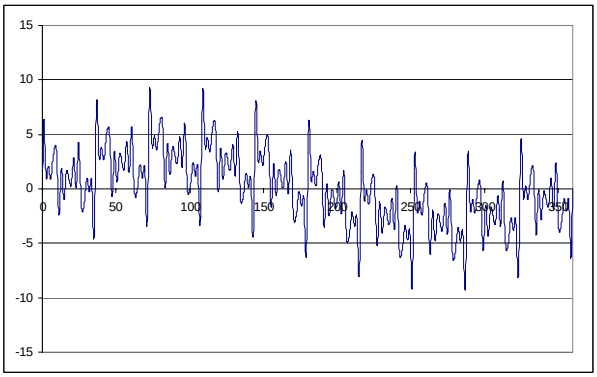


**Figure 4: SoftgaugeII**

To ensure the best possible comparison, measurement are to be performed according to the conditions listed in sections 7 and 8 which are obtained from ISO/TS 12181-1 [1] and ISO/TS 12181-2 [2] year 2003.The laboratory should make every attempt to comply with these conditions for measurement. If any condition cannot be met, the nearest option available should be used and this variation must be specified in the report and Appendix D summary.

Measurement should be made with the equipment that will achieve the smallest uncertainty, however the choice of instrument is at the discretion of the laboratory.

## 7. Instruction for measurement

All measurements must be performed at the speed of traverse not more than 10 revolutions/minute. Probing force must be specified and should not exceed 0.25 N. Stylus tip radius must be specified. Direction of measurement should be perpendicular to the spherical surface. A repeatability test (three or more measurements) should be provided. The workpiece is to be taken off the instrument between measurements.

Each laboratory shall use an error separation technique to remove the contribution of the spindle error.

### 7.1 Glass Hemisphere

The reference mark (red dot on the mount) should be aligned with the 270° reference position of the rotating element. The plane of measurement is 3 mm above the top of the mount as shown in Figure 5.

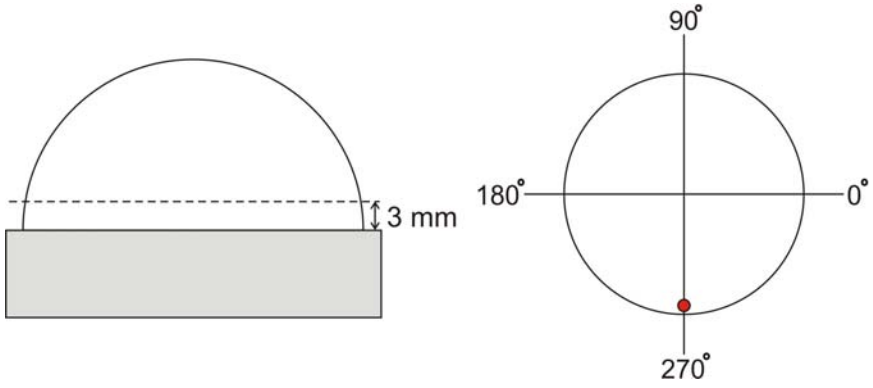


**Figure 5: Measurement plane and alignment of the glass hemisphere**

### 7.2 Softgauges

Softgauges are computer data files. Two profiles are supplied on memory stick in .txt format. Each laboratory will have to determine which format is suitable. If assistance is necessary, please contact the pilot laboratory. Roundness must be assessed in accordance with the ISO/TS 12181-2:2003 at given transmission listed in Table 5.

**Table 5: Measurement conditions.**

| Softgauge No. | 1-15 UPR | 1-50 UPR |
|---|---|---|
| I | √ | √ |
| II | √ | √ |

## 8. Instruction for Roundness Assessments

Where possible, a **Gaussian filter** should be used in preference to a 2-RC filter. Type of filter used must be specified.

### 8.1 Glass hemisphere

Roundness deviation of glass hemisphere shall be evaluated with reference to the Least Square Circle (LSC) in accordance with the ISO/TS 12181-1:2003. Measurement is to be made with a filter transmission of 1-50 UPR.

### 8.2 Softgauges

Roundness deviation of the softgauges shall be evaluated with reference to the Least Square Circle (LSC) in accordance with the ISO/TS 12181-2:2003. Measurement results are to be made with a filter transmission of 1-15 UPR and 1-50 UPR.

## 9. Results of Measurement and Uncertainty from Each Laboratory

Each participant shall produce a written report to be submitted to the pilot laboratory within six weeks after receipt of the artifacts.

All laboratories shall report peak-to-valley departure from roundness of all artifacts at each filtering condition, in relation to the center of the least squares circle. Each measurement shall be accompanied by its relevant plot (1-50 UPR).

In order to summarize the measuring set-up and conditions, each laboratory is asked to fill in the following list:

- Rotating workpiece or rotating probe
- Rotation speed (rpm)
- Direction of rotation (CW or CCW)
- Number of measured values per revolution
- Filtering conditions (filter type, homemade/commercial software, etc.)
- Plotting magnification
- Error separation technique (Multistep/otherwise), details (Number of step, etc.)
- Stylus: lever type or plunger type, dimensions
- Stylus static force (gauging force)
- Ball tip: material, diameter
- Transducer type

The report must also include:

- List and identification of the instruments
- Description of measurement methods
- Traceability to primary standards (calibration devices and procedures)
- Date of measurements
- Ambient temperature and its variation during measurements
- Number of replications for each measurement
- Statement of the uncertainty of all results (with an analysis of individual contribution), following BIPM recommendations, with $k = 2$.
- Any additional results concerning optional measurements
- Any additional detail, comment or suggestion useful for the interpretation of results
- Roundness profile of all artifacts in **.txt** , **.xls** or **.ascii** format sent to the pilot laboratory, NIMT, where name is the laboratory identifier and serial number of the artifacts. For example, for NIMT measurement result of glass hemisphere, s/n XXXX "**NIMT-XXXX.txt**".

Participants should estimate as best as possible the contributing components of their specific system. In each calculation the laboratory must also list the source of each component value. Possible uncertainty components for a roundness measuring instrument may include (but not limited to):

- Calibration of a reference
- Variation in measurement of reference and test pieces
- Drift
- Linearity
- Temperature effect

Participants should include the calculated uncertainty of measurement for each artifact sent to the pilot laboratory, NIMT, as an Excel spreadsheet: **name Uncertainty.xls** where "**name**" is the laboratory identifier such as NIMT.

## 10. Withdrawal from Intercomparison

Laboratory may withdraw any or all of its results from the intercomparison at any stage prior to the submission of its results to the pilot laboratory. Reasons should be discussed with the pilot laboratory. Once the pilot laboratory receives the submission of results, it is assumed that the laboratory is happy with the results and regards them as appropriate to contribute to the calculation of reference value. The pilot will then proceed with the following analysis which will statistically determine which results are included.

## 11. Intercomparison Analysis

When all measurements are completed, the arithmetic mean and the weighted mean of the values $x_i$ from each individual laboratory will be calculated. To avoid bias, only the first set of measurements from the coordinating laboratory was included in reference value determination.

Arithmetic mean: $$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i \quad (1)$$

Weighted mean: $$\bar{x}_w = \left[ \sum_{i=1}^{n} x_i \Big/ u^2(x_i) \right] \Big/ \left[ \sum_{i=1}^{n} 1 \Big/ u^2(x_i) \right] \quad (2)$$

**Note: The two methods will be calculated for comparison only. The weighted mean will be used for the reference values.**

The standard uncertainty of the reference value $u(x_{ref})$, willl be calculated by combining the uncertainties of the laboratories with an estimate of the unstability of the artifact $u(x_{art})$. The combined uncertainty $u(x_{LAB})$ of the laboratories is

$$u(x_{LAB}) = \frac{1}{\sqrt{n}} \cdot \sqrt{\sum_{i=1}^{n} u(x_i)} \quad (3)$$

where $u(x_i)$ is the reported uncertainty at $k$ =1.

The unstability of the artifact will be determined from variation in roundness value obtained from the pre-measurement and post-measurement carried out by the coordinator. The standard uncertainty of the reference value $u(x_{ref})$ will be calculated using

$$u(x_{ref}) = \sqrt{u(x_{LAB})^2 + u(x_{art})^2} \quad (4)$$

Assessment of each laboratory result will be made with the degree of equivalence ratio ($E$n).

$$En = \frac{x_i - x_{ref}}{\sqrt{u^2(x_i) + u^2(x_{ref})}} \quad (5)$$

Any result with an $En > 1$ with respect to the reference value will be excluded and the reference value and En ratio will be recalculated. In the $En$ formula (5) the minus sign "-" should be used in the denominator for values contributing to the reference value but a plus sign "+" for values not contributing to the reference value.

Birge ratio will be calculated in order to check the statistical consistency of a comparison. If the measurements being compared come from the same population, the propagated uncertainty (internal) $u_I(\bar{x}_w)$ should agree with that calculated from the standard deviation of the weighted mean (external uncertainty) $u_E(\bar{x}_w)$.

$$u_I^2(\bar{x}_w) = \left[ \sum_{i=1}^{N} 1 \Big/ u^2(x_i) \right]^{-1} \quad (6)$$

$$u_E^2(\bar{x}_w) = \left[ \sum_{i=1}^{n} (x_i - \bar{x}_w)^2 \Big/ u^2(x_i) \right] \Big/ \left[ (N-1) \sum_{i=1}^{n} 1 \Big/ u^2(x_i) \right] \quad (7)$$

The Birge ratio, $R_B$ is defined as

$$R_B = \frac{u_E(\bar{x}_w)}{u_I(\bar{x}_w)} \quad (8)$$

The Birge ratio has an expectation value of $R_B$ = 1, when considering standard uncertainties. For a coverage factor of $k$ = 2, the expectation value is increased and the data in a comparison are consistent when

$$R_B < \sqrt{1+\sqrt{\frac{8}{N-1}}} \tag{9}$$

## 12. Draft and Final Report

It is anticipated that the draft report will be sent to all participants within one month of the final measurement. Participants are expected to correct any mistakes in the draft with respect to their own submissions and review and comment on analysis and conclusions. After all discussions are complete, the final report will then be submitted to the APMP for publication following recommended international guidelines.

## 13. References

[1] ISO/TS 12181-1 *Geometrical Product Specifications (GPS) – Roundness – Part 1: Vocabulary and parameters of roundness*, International Organization for Standardization, Geneva, Switzerland, 2003.

[2] ISO/TS 12181-2 *Geometrical Product Specifications (GPS) – Roundness – Part 2: Specification operators*, International Organization for Standardization, Geneva, Switzerland, 2003.

[3] ISO 4291 *Methods for the assessment of departure from roundness – Measurement of variations in radius*, International Organization for Standardization, Geneva, Switzerland, 1985.

[4] *Evaluation of measurement data - Guide to the expression of uncertainty in measurement (GUM), JCGM 100.2008 GUM 1995 with minor corrections, International Organization for Standardization, Geneva, Switzerland, 2008.*

[5] ISO/IEC 17043 *Conformity assessment – General requirements for proficiency testing*, International Organization for Standardization, Geneva, Switzerland, 2010.

[6] M.G. Cox, "*The Evaluation of Key Comparison Data*", Metrologia, 2002, 39, 589-595.

[7] H. Haitjema, H. Bosse, M. Frennberg, A. Sacconi, R. Thalmann, "International comparison of roundness profiles with nanometric accuracy", Metrologia, 1996, 33, 67-73.

[8] H. Bosse, F. Lüdicke, H. Reimann, "An intercomparison on roundness and form measurement", Measurement, 1994, 13, 107-117.

[9] M. Frennberg, A. Sacconi, "International comparison of high-accuracy roundness measurements", Metrologia, 1996, 33, 539-544.

[10] EUROMET, "High precision roundness", Project 533, Final report (Mittatekniikan Keskus, Helsinki, 2001)

## Appendix A: CUSTOM DECLARATIION

## TO WHOM IT MAY CONCERN

**APMP Regional Comparison**

The Asia Pacific Metrology Program (APMP) is an organization representing the National Measurement / Standards Laboratories of a large number of countries / territories in the Asia-Pacific region. Its broad objective is to improve the measurement capabilities in the Asia-Pacific region by sharing facilities and experience in metrology.

One very successful method used by the APMP is the comparison of calibrations performed by different laboratories on given artifacts. Successful completion of these intercomparisons adds confidence to the laboratories in the carrying out of standards measurements and leads to international acceptance of the measurements carried out by these laboratories.

As part of a major intercomparisons program, the APMP is conducting an intercomparisons on roundness involving the highest level measurement laboratories of the following countries:

**Japan, Thailand, Australia, South Africa, Singapore, Republic of Korea, Thailand, Japan, Chinese Taipei, Japan, China, Japan (return)**

This program is coordinated by the National Institute of Metrology (Thailand) and the National Metrology Institute of Japan.

The following artifacts are circulated among the participants for calibration:
**Two (2) glass hemispheres**
**One (1) memory stick containing two (2) data files of various formats**

The purchase / manufacturing cost of the artifacts is approximately **US$6,000**; however they have no commercial value (not for sale). They are meant solely for the calibration of national standards and will be exported immediately after the calibration is completed. Refer to the schedule on page 5 of this document.

We request that the artifacts are not handled or removed from the container / package. If a Customs inspection is required, please contact the relevant person listed on page 4 of this document. So that he / she can be present and help you unpack.

Comparison pilot

Dr Jariya Buajarern
Dimensional Metrology Department
National Institute of Metrology (Thailand)

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Pathumthani 12120 Thailand
Telephone: +66 2 577 5100 ext 1206
Fax: +66 2 577 5088
Email: jariya@nimt.or.th

Signature

Dr.Kazuya Naoi
Dimensional Standards Section
Lengths and Dimensions Division
National Metrology Institute of Japan
AIST Tsukuba Central 3, Umezono
1-1-1, Tsukuba, Ibaraki, 305-8563, Japan
Telephone: +81-29-861-4041
Fax: +81-29-861-4041
Email: naoi.k@aist.go.jp

Signature

## Appendix B: CHECKLIST OF INSTRUCTIONS

Participants are expected to perform the following actions in approximate order:

1. Prepare equipment ready for your scheduled date of measurement (Table 2).
2. Unpack the standards from the box. If there is a problem with the box itself, contact the pilot laboratory immediately.
3. Confirm the documents are in order (ATA Carnet, customs and protocol).
4. Clean the standards with soft lint-free tissue and solvent.
5. Examine the standards and note any damage including scratches in the form in Appendix C. Take digital photographs if necessary.
6. Notify the pilot laboratory by email that the standards have been received and any damage to the standards or the box.
7. Measure the standards as described in section 7 using the recommended measurement conditions where possible.
8. Calculate the uncertainty of measurement according to section 8.
9. Prepare one or more typical calibration reports.
10. Reassess each standard after measurements are completed for any changes to surface condition. Inform the pilot laboratory by email of any significant damage to the standards.
11. Complete the summary of results form in Appendix D.
12. Repack the standards, memory stick, one set of documents inside the aluminium box and the other documents set outside the aluminium box. The ATA Carnet must be outside the aluminium box.
13. Prepare and arrange the freight service with appropriate documentation for delivery to the next laboratory on the schedule.
14. Inform the pilot laboratory and the next contact of the transfer by email.
15. Send the conditions of standards form (Appendix C), summary of results (Appendix D), uncertainty spreadsheets, calibration reports, printed roundness profile and roundness data file saved in CD as .txt or .xls or .ascii format to the pilot laboratory within 6 weeks of receipt of the artifacts.

**Note: Roundness data file, uncertainty spreadsheet and digital photo of the artifacts can be sent to the pilot laboratory by email at jariya@nimt.or.th.**

**Appendix C: RECEIPT OF STANDARD FOR APMP.L-S4 COMPARISON**

**For Laboratory: …… Date: ……**

**Note:** The clips with clamping screws retain the standards. If three clamping screws release, there is a possibility that standard has broken. Please check red marks on the glass part. They shall be in the same position as in picture.

We confirm having received a complete set of standards on _____ (date).

After visual inspection,

☐ No damage has been noticed

☐ The damage(s) occured

**Appendix D: CONDITION OF STANDARDS REPORT**

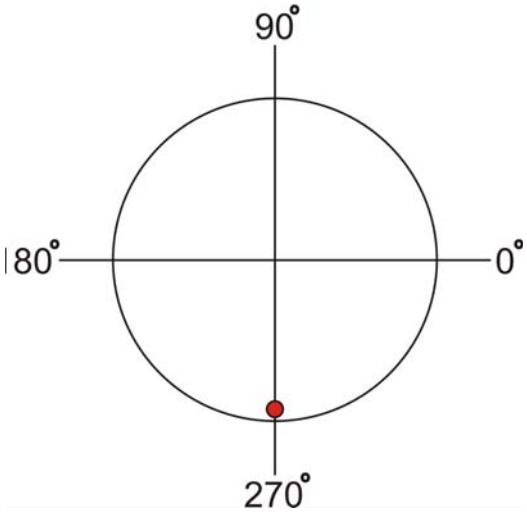
**For Laboratory: …… Date: ……**

**Condition of standards BEFORE and AFTER measurement.**

Print this page twice, once for before and once for after measurement.
If there are no changes you may write “no changes after” on the initial page for each standard.
Take photographs of any significant damage and email them to the pilot laboratory.

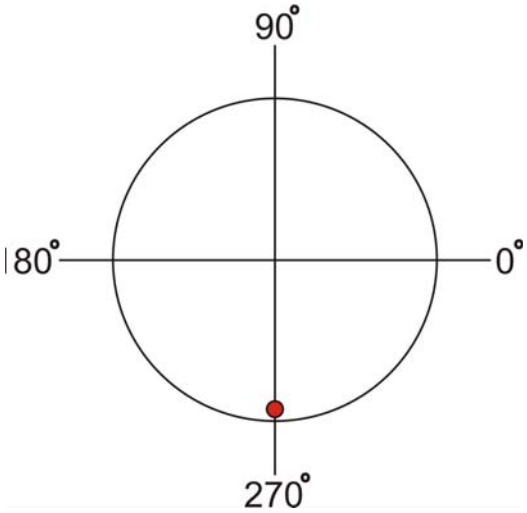
1. Glass hemisphere (SN 8726)

……
……
……




2. Glass hemisphere (SN 6767)

……
……
……



## Appendix E: MEASUREMENT RESULTS

**For Laboratory: …… Date: ……**

Please fill in all results and ensure results are clear and comments are in English.

**Description of the measurement methods and instruments**

……
……
……
……
……
……
……
……
……
……
……
……

**Table E1**: Measurement condition

| Set-up | Detail |
|---|---|
| **Rotating workpiece or probe** | |
| **Rotation speed (rpm)** | |
| **Number of measured values per revolution** | |
| **Filtering conditions (UPR)** | |
| **Plotting magnification (nm)** | |
| **Error separation technique** | |
| **Stylus: Type and dimensions** | |
| **Stylus static force (mN)** | |
| **Ball tip: material and diameter (mm)** | |
| **Transducer type** | |

## Appendix E: MEASUREMENT RESULTS

**For Laboratory: …… Date: ……**

### Measurement results

**Table E2**: Results and uncertainties of glass hemisphere (SN 8726)

| Filtering | LSC |
|---|---|
| 1-15 UPR | ± |
| 1-50 UPR | ± |

**Table E3**: Results and uncertainties of glass hemisphere (SN 6767)

| Filtering | LSC |
|---|---|
| 1-15 UPR | ± |
| 1-50 UPR | ± |

**Table E4**: Results of softgauges

Software name and version: ……
Number of points: ……

| Filtering | SoftgageI | SoftgageII |
|---|---|---|
| 1-15 UPR | | |
| 1-50 UPR | | |

**END OF PROTOCOL.**