



SIM.L-K3.2019
Key Comparison
Calibration of Angle Standards

Technical Protocol
(Final_2 – December 2019)

INSTITUTO NACIONAL DE TECNOLOGÍA INDUSTRIAL
ARGENTINA

NATIONAL RESEARCH COUNCIL CANADA
CANADA

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1. Document control

Version Draft A1	Issued on September 2019.
Version Draft A2	Issued on October 2019.
Version Final	Issued on November 2019
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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.

At its meeting in June 2019, the SIM TC for Length, decided upon a key comparison on angle standard, named SIM.L-K3.2019, with INTI as the pilot laboratory, and NRC as the co-pilot laboratory. The SIM comparison will be registered by October 2019; artefacts measurement shall start in November 2019.

The procedures outlined in this document cover the technical procedure to be followed during the measurements. A goal of the SIM 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 of this document. Participants should keep in mind that the allocated time period is not only for measurements, but transportation and customs clearance as well. Once the protocol and list of participants has been agreed, no change to the protocol or list of participants may be made without prior agreement of all participants.

3. Organization

3.1 Participants

Laboratory Code	Contact person, laboratory	Phone, email
INTI	Bruno Gastaldi INTI Av. Vélez Sarsfield 1561 Córdoba X5000JJC, Argentina	Tel: 54 0351 4684835 e-mail: gastaldi@inti.gob.ar
INMETRO	Luiz H. B. Vieira INMETRO Av. N. Sra. das Graças, 50 Xerém - D. Caxias - RJ 20250-020, Brazil	Tel: 55 212679 9020 / 9045 e-mail: lhvieira@inmetro.gov.br
CENAM	Miguel Viliesid CENAM Apartado Postal 1-100 – Centro Queretaro Mexico	Tel: 52 42 11 0574 e-mail: mviliesi@cenam.mx
NIST	Bryon Faust NIST 100 Bureau Drive Gaithersburg, MD 20899 Maryland United States	Tel: 301-975-2000 e-mail: bryon.faust@nist.gov
NRC	Brian Eves NRC 1200 Montreal Road, Bldg M36, Rm134 Ottawa K1A 0R6, Canada	Tel: 1 613 993 7578 e-mail: Brian.Eves@nrc-cnrc.gc.ca

Table 1

3.2 Time Schedule

The comparison will commence with INTI, as the pilot laboratory, followed by all the participants and will terminate with INTI for verification of either drift or damage to the artefacts.

Each laboratory will have one month (4 weeks) to perform the calibration and a further 2 weeks to pass it on to the next laboratory. Should a laboratory experience problems, be it in the measurements of the artefacts or with the customs of a country, the allocated time must be adhered to, even if it means not completing the measurements. Otherwise, the time schedule

starts to run behind and it is very difficult to get back on track, which is unfair to the remaining laboratories.

Region	Laboratory	Start Date
SIM	INTI (pilot lab)	4 November 2019
SIM	NIST	6 January 2020
SIM	NRC	17 February 2020
SIM	CENAM	30 March 2020
SIM	INMETRO	11 May 2020
SIM	INTI (pilot lab)	22 June 2020

Table 2

3.3 Handling of artefacts

The gauges should be examined immediately upon receipt. The condition of the gauges should be noted and communicated to the pilot laboratory. Please use the return form; Appendix A.4.

No re-lapping or re-furbishing of the artefacts should be attempted. Laboratories should attempt to measure all gauges/artefacts, unless in doing so would result in damage to their equipment.

The gauges should be inspected before being dispatched and any change in their condition during the measurements at the laboratory should be communicated to the pilot laboratory.

The laboratory must also inform the next laboratory via e-mail when the artefacts are to be sent to them.

After the measurements, the artefacts must be packed in the original packaging before shipment to the next laboratory.

3.4 Transportation of artefacts

It is very important that the artefacts be packed and transported in the best possible manner, thus eliminating either damage, being lost or handled by unauthorized persons.

The artefacts should be accompanied by documentation uniquely identifying the items. The packaging should be easily opened to enable inspection by custom officials.

Each laboratory must cover the cost of its own measurements; transportation to the next laboratory and any custom's charges incurred. The laboratory is also responsible for any damages

which may occur within the country during the measurements and transportation. The pilot laboratory has no insurance for any loss or damage to the artefacts during transportation.



Figure 1_a – Individual boxes of the artefacts



Figure 1_b – Transporting case of the gauges

4. Description of artefacts

The artefacts to be measured consist of a 9 sided polygon and 6 angle blocks.

The polygon, serial number 7.7780P12, is manufactured by Starrett, made of the material CROBLOX, with 9 measuring faces of 20 mm x 15 mm each. The polygon has a center hole of 25,4 mm for mounting purposes and a thickness of 17,5 mm.

Six angle blocks, 5"; 30"; 3', 5', 5° and 15° will be used to test the calibration capabilities of the laboratory. The angle blocks will be of the manufacturer Starrett, made of the material CROBLOX and all of them have the serial number 926. The angle blocks have measuring faces of 25 mm x 50 mm.

Drawing:

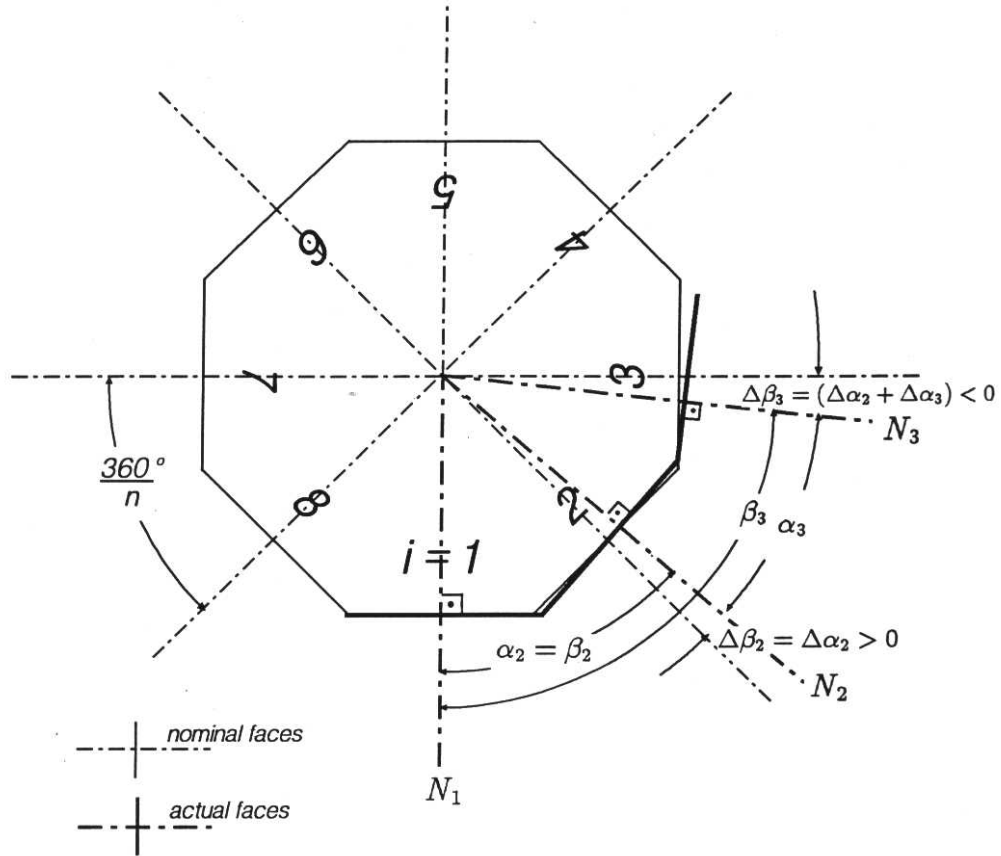


Figure 2 – Polygon definitions

Measuring face index	$i = 1 \dots n$
Normal to the faces	N_i
Pitch angles	α_i (angles between N_{i-1} and N_i)
Pitch angle deviations	$\Delta\alpha_i = \alpha_i - \frac{360^\circ}{n}$ ($i = 2, 3, \dots$)

5. Measurement Instructions

5.1 Definitions

The precision polygon has reflecting side faces which serve as measuring faces. In ideal conditions, the individual measuring faces are perpendicular to the measuring plane. In practice, the measuring faces are not perpendicular to the measuring plane by small tilts referred to as pyramidal errors. In that case, the measuring plane is defined as the plane for which the sum of the squares of the pyramidal errors of all measuring faces is a minimum.

The pitch angles α_i are the angles between the projections of two adjacent normals N_{i-1} and N_i in the measuring plane with the counting index ($i = 1, 2, \dots, n$). The deviations of the pitch angles from their nominal values of $360^\circ/n$ are referred to as pitch angle deviations.

$$\Delta\alpha_i = \alpha_i - \frac{360^\circ}{n} \quad (i = 2, 3, \dots, n) \quad (1)$$

The positive count direction of the polygon angle corresponds to the count direction of the face (index i) indicated on the polygon.

Note that with the polygon in the normal and the inverted position the count directions are opposite.

The angle blocks used are basically a polygon but with only two faces. These blocks, like polygons, also have pyramidal errors.

The goal of this Regional Comparison is to demonstrate the equivalence of routine calibration service for angle measurements offered by NMIs to clients, as listed or as intended to be listed by them in Appendix C of the BIPM Mutual Recognition Arrangement (MRA). To this end, participants in this comparison agree to use the same apparatus and methods as routinely applied when calibrating artefacts for clients. Participants are free to tune and operate their systems to best-measurement performance and to take any extra measurements needed to produce a best measurement result, provided that these extra efforts would also be available to a client if requested.

5.2 Measurement methods

The polygon and angle blocks are to be measured in both the normal and inverted positions. Normal position for the polygon is with the identification faces numbers looking upwards. Normal position for the angle blocks is shown in Figure 3.

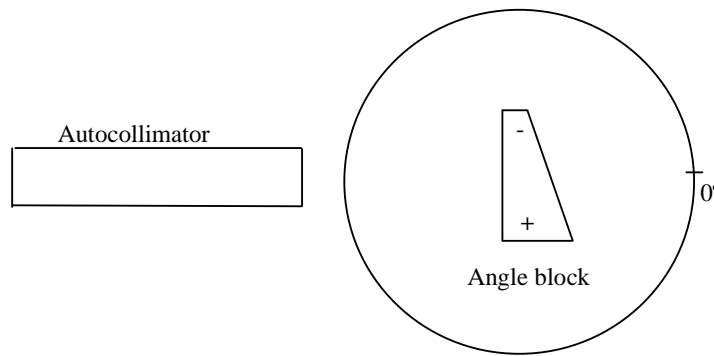


Figure 3 – Angle block in normal position

The polygon and angle blocks must be adjusted for eccentricity. The polygon/angle block must be laterally adjusted so that the measuring faces have a minimum run-out.

The following methods can be used but are not prescribed;

- a) The use of an autocollimator and an index table or angle measuring table.
- b) The method of comparison with the fixed pitch angle formed by two autocollimators.
- c) Where the autocollimator in method **a)** is replaced by an interferometer (phase shifting). The interferometer then measures the difference in angle from the index table.

Any alternative method can be used but only non-contact methods should be used. **No probing of the surfaces is allowed.**

The autocollimator (or interferometer) must be adjusted as precisely as possible, with its optical axis perpendicular and in true alignment to the table's axis of rotation and centered with the center of the polygon/angle block faces.

The polygon/angle blocks must be adjusted with the aid of an autocollimator (or interferometer) in the plane perpendicular to the table's axis of rotation (measuring plane) in such a way that the pyramidal errors of all measuring faces are at a minimum. The measuring axis of the autocollimator (or interferometer); the x-axis, must be adjusted parallel to the measuring plane of the angle blocks/polygon.

It is recommend for the polygon mounting to follow the Starrett recommendation to clamp down it using only the center screw with thin washer on underside and the 3 point bushing on top so that the polygon is clamped at center. Any other clamping may damage the polygon.
Figure 4



Figure 4 - Accessories for the polygon mounting

6. Measurement uncertainties

The uncertainty of measurement shall be estimated according to the ISO Guide to the Expression of Uncertainty in Measurement. The participating laboratories are encouraged to use their usual model for the uncertainty calculation.

All measurement uncertainties shall be stated as standard uncertainties, and the individual components of uncertainty itemized on separate sheets (Appendix A.3) for each artefact or artefact type for submission. The corresponding effective degree of freedom for each component should be stated by the participants. If none is given, ∞ is assumed

7. Reporting of results

The deviation from the nominal angle must be reported (positive deviation indicates a measured angle bigger than the nominal angle) for all artifacts. Both the polygon and the angle blocks must be reported in arc seconds and the value to be reported is the average of the normal and inverted positions.

The results and description of the measuring system must be sent to the pilot laboratory within 1 month of the completion of the measurements. (Appendix A.1 and Appendix A.2)

The reference value to be used in this comparison has still to be decided yet. It is however proposed that a weighted average of the results, with weighting factors as normally derived from the stated uncertainties of the results be used as the reference value.

A.1 Measurement results

9 sided polygon

Laboratory:

Method of measurement (as per 4.2):

Maximum pyramidal error: arc sec

Faces	Pitch angle deviation [arc sec]	u (k = 1) [arc sec]	Effective degrees of freedom ν_i
1-2			
2-3			
3-4			
4-5			
5-6			
6-7			
7-8			
8-9			
9-1			

Date:.....

Signature:.....

Angle blocks

Laboratory:

Method of measurement (as per 4.2):

Maximum pyramidal error (LS plane): arc sec

Angle block	Angle deviation [arc sec]	u (k = 1) [arc sec]	Effective degrees of freedom ν_i
5''			
30''			
3'			
5'			
5°			
15°			

Date:.....

Signature:.....

A.2 Description of the measuring system/set-up

Make and type of instrument(s)

.....

.....

.....

.....

Traceability path:

.....

.....

.....

.....

Description of measuring technique

.....

.....

.....

.....

A.3 Uncertainty of measurement

Uncertainty Component Description x_i	Standard Uncertainty $u(x_i)$	Sensitivity Coefficient $ c_i \equiv \partial/\partial x_i$	Combined Standard Uncertainty $u_i \equiv c_i u(x_i)$

COMBINED STANDARD UNCERTAINTY ($k = 1$)

A.4 Return form

Attention: Bruno Gastaldi

INTI

gastaldi@inti.gob.ar

We confirm having received the artefacts for the SIM Regional Comparison on angle standards on..... (Date)

After visual inspection:

No damage has been observed

Damage has been observed (detailed comments)

.....

.....

.....

Laboratory: