ISTITUTO NAZIONALE DI RICERCA METROLOGICA

EURAMET

(EURAMET Project 870)

Bilateral Comparison of measurements of precision polygons

Technical protocol

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1. Introduction

1.1 At its meeting in October 2005 the EUROMET TC group for Length has approved a proposal of a comparison of measurements of precision polygons between INRIM (formerly IMGC, Italy), IPQ (Portugal) and LNMC (Latvia), later Metrosert (Estonia) has been added to the comparison.

1.2 The standard gauges to be calibrated were chosen to be two polygons with 6 and 12 sides, INRIM acts as the pilot laboratory.

1.3 The procedures outlined in this document cover the technical procedure to be followed during measurement of the polygons. The procedures are principally intended to allow for a clear description of the required measurements, handling and transportation of the circulating standards and to complete the comparison in the time scale provided for. This technical protocol was prepared following the layout principles of the documents for previous comparisons. The allowance to use parts of this prior work wherever possible is gratefully acknowledged.

1.4 A goal of the EURAMET 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) [BIPM, 1999]. To this end, participants in this comparison agree to use the same apparatus and methods as routinely applied to client artefacts.

1.5 By their declared intention to participate in this key comparison, the laboratory accepts the general instructions and technical protocols as stated in this document and commits themselves to follow the procedures rigorously.

2. Organisation

2.1. Participants

Laboratory	Address	Contact person /tel/fax/e-mail
INRIM	Istituto Nazionale di Ricerca Metrologica Strada delle cacce, 73 IT-10135 Torino Italy	Marco Pisani +39 011 3919 961 +39 011 3919 959 m.pisani@inrim.it
IPQ	Instituto Português da Qualidade (IPQ) Laboratório Central de Metrologia Rua António Gião, 2 PT-2829-513 Caparica Portugal	Fernanda Saraiva +351 21 294 81 60 +351 21 264 81 88 fsaraiva@mail.ipq.pt
LNMC	Latvian National Metrology Centre 157, K. Valdemara Str. Riga, LV-1013 Latvia	Edite Turka +371 7 362 086 +371 7 362 805 edite.turka@lnmc.lv
Metrosert	AS Metrosert Aru 10 10317 Tallinn Estonia	Lauri Lillepea tel: +372 681 48 10 fax: +372 681 48 18 lauri.lillepea@metrosert.ee

2.2. Form of comparison

2.2.1 The comparison will be in a circular form. The gauges will be circulated within the participants then returned to the pilot laboratory.

2.2.2 All results are to be communicated directly to the pilot laboratories as soon as possible and certainly within 4 weeks of the completion of the measurements by a laboratory.

2.2.3 Timetable

Laboratory	Country	Date
INRIM	Italy	January 2008
IPQ	Portugal	February 2008
LNMC	Latvia	March 2008
Metrosert	Estonia	April 2008
INRIM	Italy	May 2008

2.2.4 Each laboratory has one month for calibration and transportation. With its confirmation to participate, each laboratory has confirmed that it is capable to perform the measurements in the time allocated to it. It guarantees that the standards arrive in the country of the next participant at the beginning of the next month.

2.2.5 If for some reason, the measurement facility is not ready or customs clearance takes too much time in a country, the laboratory has to contact the pilot laboratory immediately and - according to the arrangement made - eventually to send the standards directly to the next participant before finishing the measurements or even without doing any measurements.

2.3. Handling of artefacts

2.3.1 The artefacts should be examined immediately upon receipt. Their condition should be noted and communicated to the pilot laboratory of their group. Please use the fax form in appendix A.2.

2.3.2 The gauges should only be handled by authorized persons and stored in such a way as to prevent damage.

2.3.3 The faces should not be cleaned with mechanical or chemical means. The dust can be removed with a soft brush or a clean air jet.

2.3.4 The gauges should be examined before despatch and any change in condition during the measurement at each laboratory should be communicated to the pilot laboratory.

2.3.5 Please inform the pilot laboratory and the next laboratory via fax or e-mail when the gauges are about to be sent to the next recipient.

2.4 Transport of artefacts

2.4.1 It is of utmost importance that the artefacts be transported in a manner in which they will not be lost, damaged or handled by un-authorised persons.

2.4.2 Packaging for the artefacts has been made which will be suitably robust to protect the artefacts from being deformed or damaged during transit.

2.4.3 Transportation is each laboratory's responsibility and cost. Each participating laboratory covers the costs for its own measurements, transportation and any customs charges as well as for any damages that may have occurred within its country. The overall costs for the organisation, initial and interim measurements and the processing of results are covered by the organising pilot laboratories. The pilot laboratories have no insurance for any loss or damage of the standards during transportation.

3 Description of the standards

3.1 Artefacts

The artefacts to be calibrated are two polygons. The details are given in the table below:

Type	Model and ID number	Face size (mm)	Material
12 sides	Matrix POLST 01	12 x 12	Steel
6 sides	INRIM POLSTD 03	50 x 25	Glass Al coated

Fig. 1: Matrix 12 sided polygon. The face index is the nominal value in degrees.

Fig. 2: a) glass 6 sided polygon, b) detail of numbers indicating the measuring face indexes

3.2 Artefacts present condition

The 12 sides polygon has been used for many years, for this reason the faces shows slight scratches due to mechanical cleaning. Nevertheless no major defect is present on any face. The 6 sided polygon is relatively new and has large and clean reflecting faces (only minor scratches and dirt is present). This last is particularly delicate and mechanical contact with faces should be avoided even wearing gloves (please handle it using the upper and lower face and the central hole).

4 Measurement instructions

4.1 Definitions

4.1.1 The precision polygon has reflecting side faces which serve as measuring faces. In ideal conditions the individual measuring faces are perpendicular to the base of the polygon. In practice, the measuring faces are not perpendicular to the base by small tilts referred to as **pyramidal errors**. In any case, the **measuring plane** is defined as the plane parallel to the base of the polygon.

4.1.2 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,...,n). The deviations of the pitch angles from their nominal values of 360°/n are referred to as pitch angle deviations.

$$\Delta\ \alpha_i = \alpha_i - \frac{360°}{n} \qquad (i = 2,3,\ldots,n) \tag{1}$$

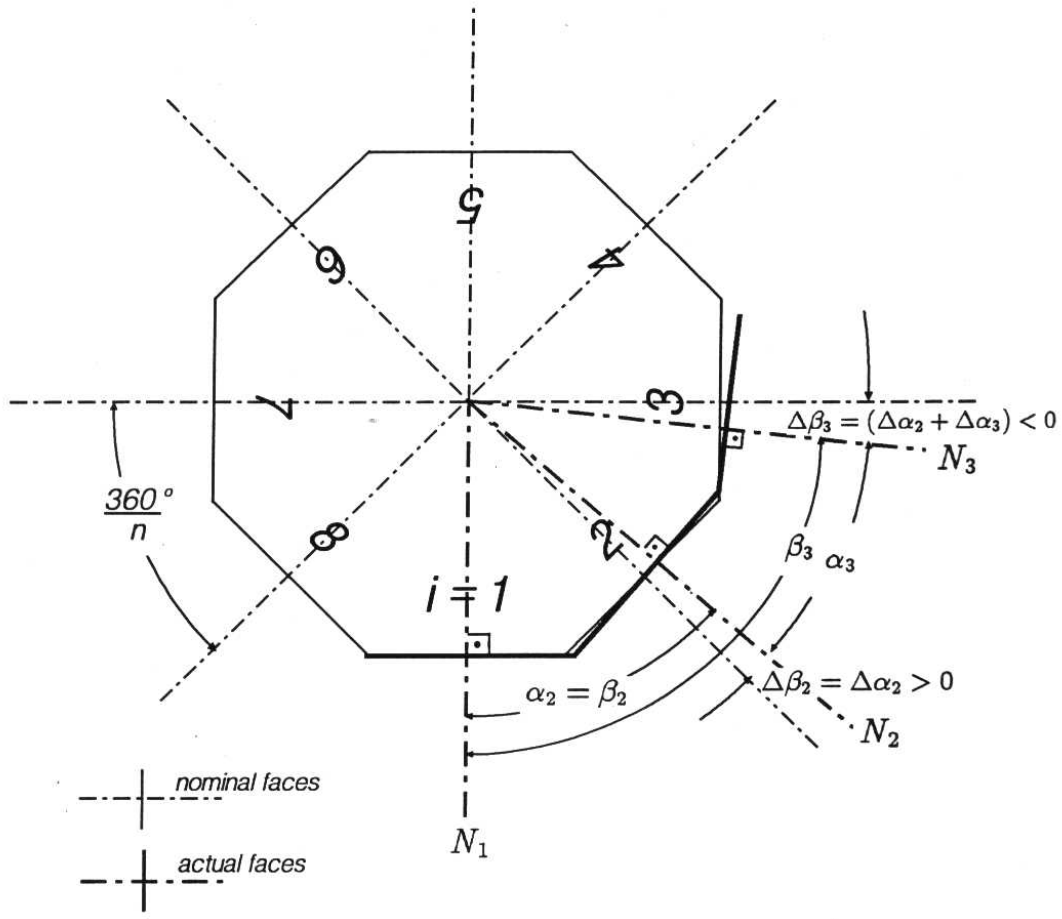

Fig. 3:

Measuring face index	$i = 1 \ldots n$
Normals to the faces	N_i
Pitch angles	α_i (angles between $N_i - 1$ and N_i)
Pitch angle deviations (measurand)	$\Delta\alpha_i = \alpha_i - \frac{360°}{n}$ (i = 2,3,…)

Note: please ignore the angles indicated in the picture as β

4.1.3 The positive count direction of the polygon angle corresponds to the count direction of the face (index *i*). **Note that in both the polygons used in this comparison the positive count direction is clockwise (opposite with respect to the example).**

4.1.4 The **measurand** is the deviation of the pitch angles from the nominal value as defined in (4.1.2) $\Delta\alpha_i$. See figure 3

4.2 Measurement method

4.2.1 The polygons are to be measured in the normal position: with the face indicated as the base downwards (please refer to Fig. 1 and 2 to see which is the upward face). The polygons must be adjusted for eccentricity: the polygons must be laterally adjusted so that the measuring faces have a minimum run-out.

4.2.2 The autocollimator must be adjusted as precisely as possible, with it's optical axis perpendicular and in true alignment to the table's axis of rotation and central to the centre of the polygon faces.

4.3 Measurement Uncertainties

4.3.1 The uncertainty for the measurements of both the polygon and angle blocks must be according to *ISO Guide for the Expression of Uncertainty in Measurement.*

4.3.2 Each laboratory will report the complete uncertainty budget used to estimate the measurement uncertainty.

4.3.3 The uncertainty must be stated as the combined standard uncertainty u and also be stated as the expanded uncertainty U_{95}.

4.4 Transmission of results

4.4.1 As soon as possible after measurements have been made, the results should be communicated to the pilot laboratory and at the latest within four weeks.

4.4.2 The measurement report forms in appendix A.1 of this document will be sent by e-mail to the co-ordinator. In any case, the signed report must also be sent in paper form by mail. In case of any differences, the paper forms are considered to be the definitive version.

4.4.3 Following receipt of the measurement reports from the participating laboratories, the pilot laboratory will analyse the results and prepare a first draft report on the comparison. This will be circulated to the participants for comments, additions and corrections. The procedure outlined in the BIPM 'Guidelines for CIPM key comparisons' and EUROMET Guide 3 will be followed.

A.1 Measurement report

12 SIDED POLYGON

I. Short description of the instrument / measurement method

II Uncertainty budget

III Results

Maximum pyramidal error (optional pyramidar error table): arc sec

Calibration table:

Faces	Pitch angle deviation $\Delta\alpha_i$ /''
0°-30°	
30°-60°	
60°-90°	
90°-120°	
120°-150°	
150°-180°	
180°-210°	
210°-240°	
240°-270°	
270°-300°	
300°-330°	
330°-360°	

Expanded uncertainty U_{95} =

6 SIDED POLYGON

I. Short description of the instrument / measurement method

II Uncertainty budget

III Results

Maximum pyramidal error (optional pyramidar error table): arc sec

Faces	Pitch angle deviation $\Delta\alpha_i$ l''
1-2	
2-3	
3-4	
4-5	
5-6	
6-1	

Expanded uncertainty U_{95} =

Laboratory:

Date:

Signature:

A.2 Receipt confirmation

FAX

To: Marco Pisani
FAX n°: +39 011 3919959

From: (participating laboratory)

We confirm having received the standards of the *EURAMET 870 comparison of measurements of precision polygons* on .....(date).

After visual inspection

- o no damage has been noticed;
- o the following damage must be reported:
  .....
  .....
  .....
  .....