TRACEABILITY CHAIN AND DISSEMINATION OF ANGLE MEASUREMENTS IN BRAZIL

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Abstract

The paper describes the metrological hierarchy established for the dissemination of angle measurements from the “Dimensional Metrology Laboratory” (LAMIN) of the “National Institute of Metrology, Standardisation and Industrial Quality” (INMETRO). It shows the traceability chain from the national standard of length to the reference system, a small angle generator, and then to angle standards and measuring equipment.

The practical benefit of the work described is the dissemination of angle measurements in Brazil, with adequate metrological confidence, from INMETRO to accredited laboratories of the Brazilian Calibration Service (RBC) and other users.

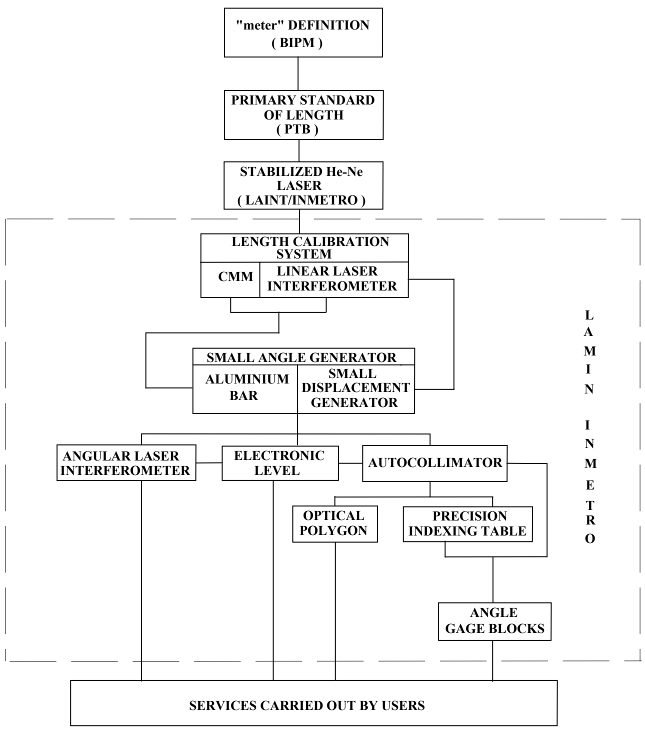
Sumaire

Introduction

Aiming at meeting users demand for calibration of angle standards and measuring instruments as well as taking into account the equipment and structure at disposal, LAMIN has developed systems and methodologies for calibration of autocollimators, optical polygons, angle gage blocks, precision indexing tables, electronic levels and angular laser interferometers.

The angle measurements carried out by the developed measuring systems are traceable to the primary standard of length and consequently linked to the length unit definition. The traceability chain adopted is described, as well as the methodologies implemented and measuring uncertainties. All the expanded measuring uncertainties, here declared, are considered for a coverage factor k=2, with a confidence level of approximately 95%.

Traceability chart for angle measurements at INMETRO.



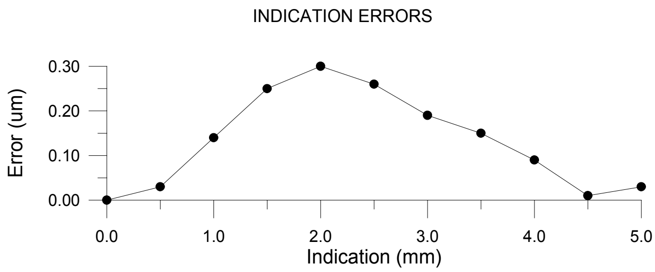
Reference Angle Measuring System

The reference for angle measurements carried out at LAMIN is a small angle generator based on a sine bar made of Aluminium, with a nominal length of 412,6mm, and a small displacement generator, with scale interval of 0,2 μm and measuring range from 0 up to 5 mm. With this system, it is possible to have angular increments of 0,1” and a measuring range up to 42’.

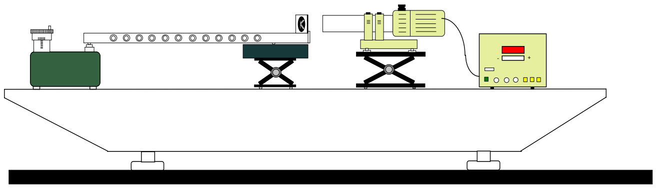
The Aluminium bar is calibrated by a linear laser interferometer adapted on a coordinate measuring machine and the small displacement generator calibrated by the linear laser interferometer itself.

The linear laser interferometer has its wavelength in vacuum calibrated by the Interferometry Laboratory (LAINT) of INMETRO. This laboratory maintains the national reference of length, a He-Ne laser of high stability, periodically calibrated by the "Physikalish Technishe Bundesanstalt" - PTB (Germany).

The calibrated length of the bar (412,5397 mm) is established by spheres fixed on it. The indication errors of the small displacement generator are plotted below and its histeresis effect is not considered because the scale is used only in one direction, from 0 to 5 mm. The deviation of the bar's length from the nominal value and the indication errors of the small displacement generator are corrected to establish the reference small angles.



This measuring system is used to calibrate autocollimators and can also be used to calibrate electronic levels and angular laser interferometers.



Small Angle Generator - Schematic view

Measuring Uncertainty The expanded measuring uncertainty obtained in the calibration of the Aluminium bar is ± 0,7 µm and in the calibration of the small displacement generator is ± 0,1 µm.

The small angles generated by the reference system are given by:

$$\alpha = arcsin(l / L)$$

where:

l = displacement by the small displacement generator.

L = length of Aluminium bar.

In accordance with the ISO [5] concepts:

$$s_l = 0,05\mu m$$

$$s_L = 0,35\mu m$$

$$u_c(\alpha) = \sqrt{\left(\frac{\partial\alpha}{\partial l}.s_l\right)^2 + \left(\frac{\partial\alpha}{\partial L}.s_L\right)^2}$$

$$u_c(\alpha) = \sqrt{\left(\frac{1}{L}.s_l\right)^2 + \left(\frac{l}{L^2}.s_L\right)^2}$$

For a coverage factor k=2, with a confidence level of approximately 95%, the expanded measuring uncertainty is given by:

$$U = 2\sqrt{1,5x10^{-14} + 4,2x10^{-18}.l}$$

for l = 1 mm, U = 0,05"

then:

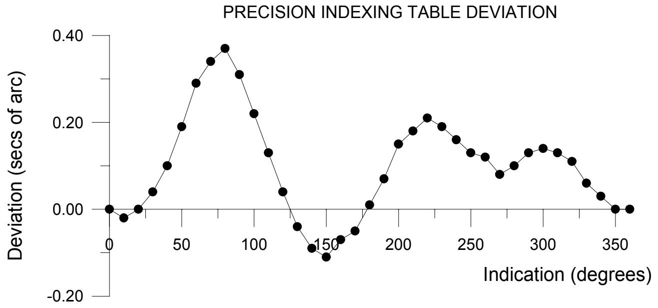
$$U = \frac{0,05''.l}{mm}\ ;\ l \text{ in mm}$$

Measuring System for Polygons Calibration

This measurement system consists of a digital autocollimator with resolution of 0,1" and a measuring range from -80" to +80" and a precision indexing table with a scale interval of 15'. An auxiliary dividing table is also used to establish different relative angle positions between the polygon and the precision indexing table. The auxiliary dividing table does not need to be calibrated.

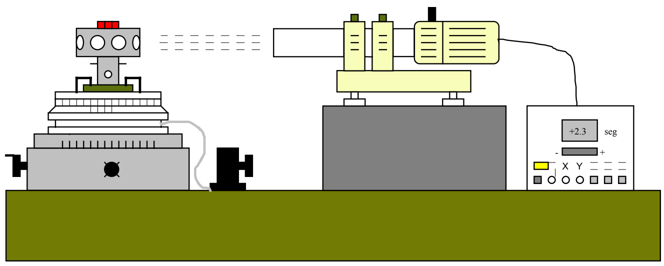
As already seen, the autocollimator is calibrated by the reference angle measuring system. The precision indexing table does not need to be calibrated, although its calibration is all the same simultaneously done on the occasion of the calibration of LAMIN's 36-face polygon.

The autocollimator errors are less than 0,1" for a measuring range from 0 up to 5", which is sufficient for detection of small angle differences obtained by the polygons calibration method used. The expanded measuring uncertainty determined for the calibration of the mentioned LAMIN's autocollimator is ± 0,1" and that for the precision indexing table, whose errors are plotted below, is ± 0,3”.



Polygons Calibration Method After analysing and comparing different methodologies for calibration of polygons and considering the available equipment at LAMIN, the results and the measuring uncertainties obtained, the method known as “multistep” was chosen.

This method consists in the comparison between the angles of an optical polygon and the angles of the precision indexing table, considering all the possible relative positions between both, the angle differences being measured by the autocollimator. The change from one relative position to another between polygon and precision indexing table is done by the auxiliary dividing table.



Polygon calibration - schematic view

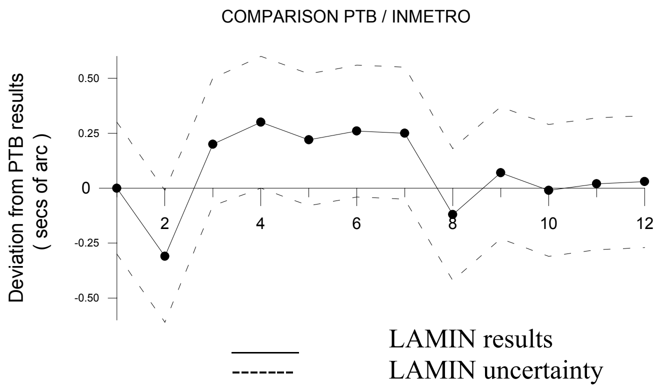
This method generates a set of n^2 measuring values, n being the number of faces of the polygon. The Least Square method is used for data processing, thus separating the errors of the polygon from those of the precision indexing table.

Measuring uncertainty The repeatability of the measuring system was determined by measuring a 4-face polygon 10 times. The maximum standard deviation obtained for the different angle positions was 0,07 μm. This value is a component used in the calculation of the measuring uncertainty of all polygons calibrated.

Other components are the standard deviation of the optical polygon error measurements, the autocollimator measuring uncertainty, as well as the flatness deviation and pyramidal errors of the optical polygon.

Taking into consideration these contributions, the expanded measuring uncertainty is ± 0,3”.

Method’s validation The validation of the calibration method, here described, was done by a measurement comparison between results obtained by the “Physikalish Technishe Bundesanstalt” (PTB) from Germany and by LAMIN.



As can be seen, the results are compatible considering that LAMIN’s measurement values, including the expanded measuring uncertainty, contain the reference values obtained by PTB, whose declared expanded measuring uncertainty is ± 0,1”.

Measuring system for calibration of angle gage blocks

This system consists of the autocollimator and the precision indexing table already mentioned. Considering some angle gage blocks, it is necessary to use another autocollimator with a bigger measuring range. In this case, an autocollimator with scale interval of 0,1”and measuring range from 0 up to 16’ is used. The final result of an angle gage block calibration is obtained taking into account the autocollimator and precision indexing table errors.

Measuring uncertainty The measuring uncertainties obtained in the autocollimator and precision indexing table calibrations, as well as the repeatability of measurements, are the main contributions to the expanded measuring uncertainty estimation in the angle gage blocks calibration, which amounts to ± 0,5”.

Conclusions

- With the methods implemented, the calibration services demanded by accredited and other laboratories from the Brazilian industrial park are being carried out with the necessary measurement accuracy.

• Some improvements can be done in the future, in order to reduce the measurement uncertainties and the time necessary to carry out calibrations. This can be done with a new autocollimator with a better resolution and a larger measuring range; with the calibration systems supported by anti-vibration tables; with the construction of a more stable and precise digital angle measuring table of better resolution, and with the automation of the polygon calibration method.

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