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Calibration of Gauge Block Comparators

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Calibration Guide

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Purpose

This document has been produced to improve harmonisation in gauge block calibration. It gives advice to calibration laboratories to establish practical procedures.

Authorship

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1 Introduction

1.1 The purpose of this technical guideline is to improve harmonisation for gauge block calibration. It gives advice to calibration laboratories to establish practical procedures. The guideline is based on a national calibration guideline [ref. 1] and on the International Standard ISO 3650 [ref. 2]. In the first part (sections 2, 3 and 4), the general definitions and the minimum technical requirements for the calibration of gauge block comparators are given. The second part of this guideline is of procedural nature and gives practical advice to calibration laboratories. In sections 5 and 6 an example of a typical calibration procedure is presented. It is noted that laboratories working according to ISO/IEC 17025 shall validate their calibration procedures. This may lead to modification of the principles and examples given in this document.

2 Scope and field of application

2.1 This guideline refers to instruments used to calibrate gauge blocks up to 100 mm nominal length by the comparison method (cf. ISO 3650, clause 7.4), where the length of a standard gauge block is transferred to the gauge block under test by mechanical probing. The calibration shall be carried out with the aid of gauge blocks. The guideline is intended only for instruments probing the measurement faces of the gauge block with two length indicators from opposite sides.

2.2 **Components:** The gauge block comparator comprises the measurement pedestal, the measurement table with the gauge block positioning device, two length indicators connected to an electronic measuring instrument with numerical display and a digital interface, if necessary.

2.3 **Site of calibration:** The comparator shall be calibrated at the place of use, so that all the ambient conditions which will influence the instrument in service, are taken into consideration.

3 Terminology

3.1 The definitions used in this guideline are in compliance with the International Standard ISO 3650 [ref. 2].

l_n nominal length of the gauge block

l_c central length of the gauge block

$f_o = l_{max} - l_c$ difference between maximum length and central length

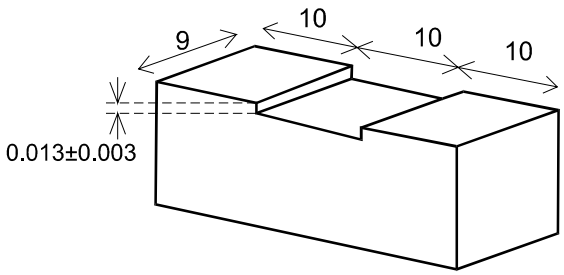
$f_u = l_c - l_{min}$ difference between central length and minimum length

The variation of length measured at the centre and the four corners of the gauge block can be regarded as representative for f_o and f_u (ISO 3650, clause 7.4.4).

4 Reference standards

4.1 The gauge block comparator shall be calibrated by means of gauge blocks, preferably using 6 pairs of typically the following lengths:

Pair No.	Nominal length / mm	
	A	B
1	0.5	0.5
2	1.0	1.005
3	1.0	1.01
4	4.0	4.0
5	100.0	100.0
6	6.0	6.0*



* bridge-shaped gauge block

4.2 The gauge blocks shall all be of the same material, marked with an identification number and satisfy with respect to the quality of the measurement faces (flatness and variation in length) the tolerances of the calibration grade K (ISO 3650). Gauge block B of pair No. 6 is a special block designed as a bridge. It allows the sensitivity of the lower length indicator to be compared with the sensitivity of the upper indicator. One of its measuring faces is flat whereas the opposite face is divided into three sections of almost equal size (9 mm x 10 mm). The centre section has a nominal length of 6 mm, the two outer sections are (13±3) µm longer. The plane measuring face of the gauge block must have wringing quality. The variation in length should not exceed 0.05 µm in the central area (7 mm in diameter) and 0.2 µm on the protruding sections. Such bridge-shaped gauge blocks are commercially available from several manufacturers.

4.3 The difference between the central lengths l_c of gauge blocks A and B forming pairs 1 to 5, and the deviations f_o and f_u from the central length of gauge blocks B of pairs 2 and 3 shall be calibrated with an expanded uncertainty of measurement (k = 2) preferably smaller than or equal to 0.02 µm. The gauge blocks of pair No. 6 need not be calibrated.

5 Example of a calibration procedure

5.1 Preparation for calibration

5.1.1 Before calibration, check that the gauge block comparator operates correctly as described in the manufacturer's operating instructions. In addition, the following properties shall be checked:

(a) The surface of the measurement table must be impeccable, i.e. without scratches and wear.

(b) The measuring faces of the anvils must be undamaged and spherical. Their vertices must be correctly aligned with respect to each other.

(c) The measuring force of the upper and lower length indicators must be in compliance with the manufacturer's specifications.

(d) The correct sequence for the retraction of the two anvils. The measuring face of the lower anvil must be retracted below the surface of the measurement table.

(e) In the non-lowered position, the measuring face of the lower anvil shall protrude from the measurement table's surface by 20 µm to 100 µm.

5.2 Comparison measurement of central length

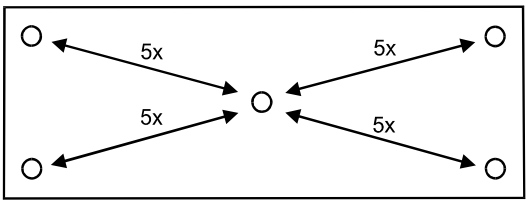
5.2.1 With each of the gauge block pairs Nos. 1 to 5, five comparison measurements shall be carried out. The measurements shall be repeated after the positions of gauge blocks A and B have been interchanged in the gauge block positioning device. The mean values and the standard deviations shall be calculated for each measurement series of a pair of gauge blocks (10 measurement values).

5.3 Comparison measurement with the bridge shaped gauge block

5.3.1 Two measurement series, each comprising 10 measurements, shall be carried out for pair No. 6. In the first series, the bridge shaped gauge block shall be placed with the plane measuring face on the measuring table, whereas for the second series it is turned upside down. The mean values and the standard deviations shall be calculated for both measurement series (10 measurement values each) as well as the difference between the two mean values.

5.4 Deviations f_o and f_u from the central length

5.4.1 To determine the deviations f_0 and f_u from the central length, each of the four corners of the measuring face of one of the gauge blocks 1.005 mm or 1.01 mm shall be probed five times in succession, starting at the centre of the measuring face.



The four measurement series shall be repeated after the gauge block being rotated by 180° in the horizontal plane. The mean values and the standard deviations shall be calculated for each of the eight measurement series. The deviations f_0 and f_u from the central length result from the largest and the smallest value of the eight mean values.

6 Evaluation of results

6.1 General consideration

6.1.1 In principle, the measurement results and the calibration values of the standards can be used to determine corrections for the calibrated comparator and to estimate the uncertainty. In practice, however, the indicated values of the comparator are used without correction to simplify the measurement procedure. This is justifiable, as the measured length differences are small and the corrections can be ignored in general. Their influence shall be taken into account as a contribution to the uncertainty. In cases, where the deviations of the indicated values exceed acceptable limits, the comparator and its electronics should be readjusted.

6.1.2 In the following, criteria for acceptance of the gauge block comparator are given and the uncertainty based on these criteria is stated. These criteria are recommended to be applied for high accuracy calibrations of grade 0 gauge blocks, where a target expanded measurement uncertainty of typically

$0.05\ \mu m + 0.5 \times 10^{-6} \times l_n$ ($k = 2$)

is aimed at. If these criteria are not met or if higher uncertainties are tolerable, the criteria may be modified and the associated uncertainty has to be evaluated.

6.2 Acceptance criteria

6.2.1 The standard deviations determined according to paragraphs 5.2, 5.3 and 5.4 shall not exceed the value of 0.015 µm. The maximum permissible deviation of the mean values according to paragraph 5.2, and the maximum permissible deviation of the values f_0 and f_u according to paragraph 5.4 from the values according to the calibration certificate of the standards amount to ±0.03 µm. The difference between the mean values according to paragraph 5.3 shall not exceed ±0.03 µm.

7 Measurement uncertainty

7.1 Based on the above acceptance criteria, the measurement uncertainty of the gauge block comparator has been evaluated. Taking into account the random contribution for an average of at least five single measurements, the digital resolution of the electronic indicator (0.01 µm), a residual difference in the sensitivity of the two length indicators, the quality of the measuring table and the uncertainty of calibration of the length indicators, one obtains an expanded uncertainty of $U = 0.03\ \mu m + 0.002 \times D$, if the indicated length difference D does not exceed 10 µm. The stated uncertainty corresponds to the combined standard uncertainty multiplied by the coverage factor $k = 2$, in accordance with the GUM [ref. 3].

7.2 The uncertainty of the gauge block comparator has to be taken into account, when the uncertainty of gauge block calibration is evaluated. It does not contain the influence of temperature and the quality of the measuring faces of the gauge blocks to be compared.

8 Calibration certificate

8.1 The certificate of calibration shall contain the following information:

(a) The place of calibration and of use of the instrument.

(b) The identification of the standards used together with their values according to the calibration certificate.

(c) The manufacturer, type and serial number of the components of the gauge block comparator.

(d) The settings of the control elements of the electronic length measuring instrument during calibration (measuring range, digital resolution of the display etc.).

(e) The ambient temperature range during the calibration.

(f) The measurement results should be presented in tabular form (see Appendix).

9 References

1. DKD - R4 - 1: 1994. *Auswahl und Kalibrierung von Endmaßmeßgeräten zur Verwendung als Normalgeräte in Kalibrierlaboratorien.*

2. ISO 3650:1998. *Geometrical Product Specifications (GPS) – Length standards - Gauge blocks.*

3. ISO Guide to the expression of Uncertainty in Measurement, first edition 1995, ISO (Geneva)

Appendix A

Example of tables to present the calibration results of a gauge block comparator

A1 Differences of central length l_c

Pair No	Nominal length		Ident. No. of gauge blocks	Value from calibration certificate	Measured mean value	Difference	Measured standard deviation
	A	*B*		*C*	*M*	*C* - *M*	
	mm	mm		(*B* – *A*) / µm	(*B* – *A*) / µm	µm	(*B* – *A*) / µm
1	0.5	0.5					
2	1.0	1.005					
3		1.010					
4	4	4					
5	100	100					

A2 Difference of central length of pair No. 6

Pair	Nominal length		Ident. No. of gauge blocks	Measured mean value		Difference of mean	Measured standard deviation	
No	*A*	*B*		Gauge block B flat side down (Pos. *d*)	Gauge block B flat side up (Pos. *u*)	Pos. *d* – Pos. *u*	Pos. *d*	Pos. *u*
	mm	mm		(*B* – *A*) / µm	(*B* – *A*) / µm	µm	(*B* – *A*) / µm	(*B* – *A*) / µm
6	6	6						

A3 Deviations f_o *and* f_u *from the central length*

Nominal length	Ident. No.	Value from calibration certificate		Measured mean value		Difference		Measured standard deviation
		C		*M*		*C* – *M*		max. value from 8 series
mm		f_o µm	f_u	f_o µm	f_u	f_o µm	f_u	µm