

ASME B89.1.13-2013
[Revision of ASME B89.1.13-2001 (R2006)]

Micrometers

AN AMERICAN NATIONAL STANDARD



**The American Society of
Mechanical Engineers**

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Two Park Avenue • New York, NY • 10016 USA

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FOREWORD

ASME Standards Committee B89 on Dimensional Metrology, under procedures approved by the American National Standards Institute (ANSI), has the responsibility of preparing standards that encompass the inspection and the means of measuring characteristics of various geometrical parameters, such as diameter, length, flatness, parallelism, concentricity, taper, and squareness. Since micrometers are widely used for the measurement and comparison of some of these features, the B89 Consensus Committee authorized formation of Project Team B89.1.13 to prepare this Standard.

This Standard is a revision of the first edition, ASME B89.1.13-2001. The 2001 edition was based in part on Federal Specification GGG-C-105C, published by the General Services Administration (GSA), as well as manufacturer's current practices and technologies. In 2010, the International Organization for Standardization (ISO) published a revision of ISO 3611, the ISO standard for outside micrometers. The goal of this revision to ASME B89.1.13 is to bring some harmonization between these ISO and ASME standards while not changing the fundamental concepts of ASME B89.1.13-2001. In particular, the terminology and definitions associated with specifications and testing methods have been harmonized. In addition, this revision has been updated with many of the concepts developed and standardized by the ASME B89.7 subcommittee.

This Standard was approved by the American National Standards Institute on February 20, 2013.

ASME B89 COMMITTEE

Dimensional Metrology

(The following is the roster of the Committee at the time of approval of this Standard.)

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New York, NY 10016
<http://go.asme.org/Inquiry>

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible: citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued for the purpose of providing alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee Web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard, the paragraph, figure or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the B89 Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the B89 Standards Committee.

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and provide a concise description.
Edition:	Cite the applicable edition of the standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation.

Requests that are not in this format may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information which might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The B89 Standards Committee regularly holds meetings that are open to the public. Persons wishing to attend any meeting should contact the Secretary of the B89 Standards Committee.

MICROMETERS

1 SCOPE

This Standard is intended to provide the essential requirements for micrometers as a basis for mutual understanding between manufacturers and consumers. Outside, inside, and depth micrometers are described in the Standard.

2 DEFINITIONS

backlash: a relative movement between interacting mechanical parts, resulting from looseness. (ASME B5.54-2005) In this Standard, backlash is further defined as the rotation of the spindle, in the opposite direction of the initial reading, before spindle moves in a linear direction. This condition is typically caused by looseness of fit between the lead screw and adjusting nut.

end shake: the amount of spindle movement when an axial force is applied in the direction of the spindle, alternating towards the anvil and away from the anvil, without rotating the spindle.

error of indication: for a measuring instrument, difference between an instrument indication and the quantity being measured.

NOTE: The error of indication can be written as $E = R - R_0$, where R is the indication and R_0 denotes the indication of an ideal measuring instrument measuring the same measurand. In the testing and verification of a measuring instrument, the error of indication is typically evaluated by measuring a calibrated reference standard. (Adapted from JCGM 106:2012)

flatness: the condition of a surface or derived median plane having all elements in one plane.

NOTE: A flatness tolerance specifies a tolerance zone defined by two parallel planes within which the surface or derived median plane must lie. (ASME Y14.5M-2009)

full measuring face contact: contact between the full area of the measuring face and a feature of a workpiece. (ISO 3611:2010)

maximum permissible error (of indication) (MPE): for a measuring instrument, maximum difference, permitted by specifications or regulations, between the instrument indication and the quantity being measured. (JCGM 106:2012)

partial measuring face contact: contact between a partial area of the measuring face and a feature of a workpiece. (ISO 3611:2010)

side shake: the amount of spindle side movement when a force is applied perpendicularly to the measuring end

of the spindle, alternating from side to side, without rotating the spindle.

tolerance limit: specified upper or lower bound of permissible values of a property. (JCGM 106:2012)

3 REFERENCES

- ASME B5.54-2005, Methods for Performance Evaluation of Computer Numerically Controlled Machining Centers
- ASME B46.1-2009, Surface Texture (Surface Roughness, Waviness, and Lay)
- ASME B89.1.9-2002, Gage Blocks
- ASME B89.6.2-1973 (R2012), Temperature and Humidity Environment for Dimensional Measurement
- ASME B89.7.3.1-2001, Guidelines for Decision Rules: Considering Measurement Uncertainty in Determining Conformance to Specifications
- ASME B89.7.3.2-2007, Guidelines for the Evaluation of Dimensional Measurement Uncertainty
- ASME B89.7.5-2006, Metrological Traceability of Dimensional Measurements to the SI Unit of Length
- ASME Y14.5-2009, Dimensioning and Tolerancing
 Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900 (www.asme.org)
- ASTM E18-08, Standard Test Methods for Rockwell Hardness of Metallic Materials
- IEEE/ASTM SI 10-2010, American National Standard for Metric Practice
 Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)
- ISO 1:2002, Geometrical Product Specifications (GPS) — Standard reference temperature for geometrical product specification and verification
- ISO 3611:2010, Geometrical product specifications (GPS) — Dimensional measuring equipment: Micrometers for external measurements — Design and metrological characteristics
 Publisher: International Organization for Standardization (ISO) Central Secretariat, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Genève 20, Switzerland/Suisse (www.iso.org)
- JCGM 100:2008, Evaluation of measurement data — Guide to the expression of uncertainty in measurement (GUM)

JCGM 106:2012, Evaluation of measurement data — The role of measurement uncertainty in conformity assessment

JCGM 200:2008, International vocabulary of metrology — Basic and general concepts and associated terms (VIM)

Publisher: Joint Committee for Guides in Metrology, Bureau International des Poids et Mesures (BIPM), Pavillon de Breteuil, 92312 Sèvres CEDEX, France (<http://www.bipm.org/en/committees/jc/jcgm/>)

4 MICROMETERS — GENERAL

4.1 General Design

The general design and workmanship of micrometers shall be such to ensure compliance with the requirements of this Standard under all operational orientations, unless otherwise specified by the manufacturer.

4.2 Resolution

Micrometers using the metric system shall read to the least count of 0.01 mm, 0.002 mm, or 0.001 mm. Micrometers using the inch system shall read to the least count of 0.001 in., 0.0001 in., or 0.00005 in. Smaller values may be specified by the micrometer manufacturer.

4.3 Finish

The surface of graduated parts shall have a satin chrome or dull, nonglare finish. All other exposed parts not used as measuring components shall be coated to prevent corrosion. Exposed surfaces of measuring components shall have a ground finish with surface roughness not to exceed 0.8 μm (32 $\mu\text{in.}$) R_a , except where otherwise specified within this Standard.

4.4 Identification Marking

In addition to other markings, instruments shall be marked in a permanent and legible manner with the manufacturer's name or trademark so that the part number, range of the instrument, and the source of the manufacturer can be readily determined.

4.5 Adjustments

Each micrometer shall have a means for the user to set the instrument to zero or to the reference point. Each instrument shall be adjustable to compensate for wear on the measuring faces and/or wear between the screw portion of the spindle and the nut.

4.6 Micrometers Screw Spindle

The screw spindle material shall be stabilized, precision ground, and have a hardness not less than 60 HRC. The fit between the spindle and its bearings, including the nut, shall be free turning without perceptible backlash, end shake, or side shake.

4.7 Measuring Faces

All measuring faces shall have a hardness not less than 60 HRC.

4.8 Graduations

The graduations shall have the depth reduced below the surface of the component carrying the graduations and shall be of contrasting color. Variations in width of the graduated lines on the thimble and fiducial line on the barrel shall not exceed 0.030 mm (0.0012 in.).

4.9 Effect of Spindle Locking Device

For micrometers equipped with a spindle locking device, when the spindle is locked, the micrometer indication shall not change by more than 0.002 mm for a metric-reading micrometer and 0.0001 in. for an inch-reading micrometer.

4.10 Definition of an Indication

The specified maximum permissible errors (the MPE values) apply to any and all unique measurement indications made under reasonable use of the micrometer. Averaging of several test values, or other data treatment, is not permitted when determining conformance to specifications.

4.11 Temperature

All specifications are to be evaluated in accordance with ISO 1:2002 (20°C) unless another temperature is specified.

Unless otherwise stated by the manufacturer, the effective coefficient of thermal expansion (CTE) of a micrometer in the temperature range 10°C to 30°C shall be $(11.5 \pm 1.0) \times 10^{-6}/^\circ\text{C}$. If not, then the effective CTE with its uncertainty shall be supplied by the manufacturer.

NOTE: Corrections for linear thermal expansion should be considered when calibrating or using a micrometer.

4.12 Decision Rules

Unless otherwise stated, the default decision rule when determining the conformance of a micrometer to specifications is simple 4:1 acceptance in accordance with ASME B89.7.3.1.

NOTE: An example of determining conformance to specification is shown in Nonmandatory Appendix D, para. D-6.7.

4.13 Traceability

All the length standards, e.g., gage blocks, used in determining the conformance of a micrometer to specifications must have metrological traceability per ASME B89.7.5.

4.14 Specifications

The micrometer manufacturer or user may specify smaller tolerance limits and maximum permissible errors than shown in this Standard. Specifications for larger size micrometers and setting standards may also be stated in accordance with this Standard. To conform to this Standard, the same terms, definitions, and symbols shall apply and be employed. Any and all differences must be stated in completeness.

5 OUTSIDE MICROMETERS (SEE FIG. 5-1)

5.1 Frame

The frame shall be shaped to permit the measurement of a cylinder having a diameter equal to the maximum capacity of the micrometer caliper. The cross section design and the frame material shall be such that when a force of 10 N for metric-reading micrometers or 2 lb for inch-reading micrometers is applied to the anvil contact face parallel to the spindle axis, the flexure of the frame shall not exceed the tolerance limits specified in Table 5.1-1 or 5.1-2. The frame may be insulated to prevent the transmission of body heat.

5.2 Measuring Faces

For outside micrometers with flat measuring faces, the maximum flatness error allowable shall not exceed $1\ \mu\text{m}$ ($40\ \mu\text{in.}$) for each face. Surface finish shall not exceed $0.1\ \mu\text{m}$ ($4\ \mu\text{in.}$) R_a .

5.3 Spindle–Anvil Alignment

The misalignment between the anvil and spindle shall not exceed the maximum values indicated in Table 5.1-1 or 5.1-2 at any point within the measuring range of the micrometer.

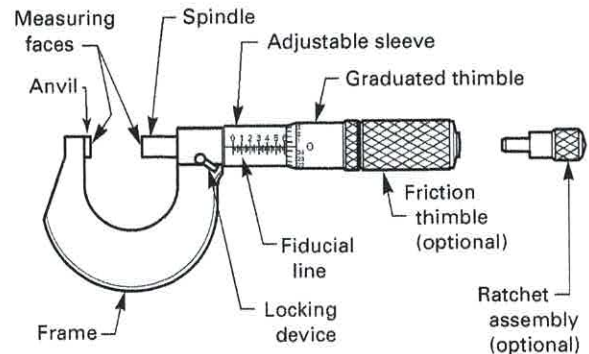
5.4 Maximum Permissible Errors (MPE)

5.4.1 Length Measurement Error. With the micrometer set to read zero at minimum travel, the length measurement error of indication, when using full measuring face contact, shall not exceed the maximum values indicated in Table 5.1-1 or 5.1-2 at any point within the measuring range of the instrument. Length measurement error is calculated as the difference between a micrometer indication and the reference value of the measurement standard.

5.4.2 Parallelism Error. The parallelism error of indication is the maximum difference in successive measurements using partial measuring face contact at any position on the measuring faces, but at the same nominal point in the measuring range of the micrometer. The parallelism error shall not exceed the maximum values indicated in Table 5.1-1 or 5.1-2 at any point within the measuring range of the micrometer.

5.4.3 Repeatability. In ISO 3611:2010, repeatability is defined as the error of indication when full measuring face contact is employed on successive measurements of the same measurand, carried out under the same conditions of measurement. This definition of repeatability is a refinement of the length measurement error and does not control any new source of measurement error in the micrometer. As such, in this Standard, the specification of repeatability is optional. If specified, the manufacturer shall express the manner in which the repeatability is assessed and reported.

Fig. 5-1 Typical Outside Micrometer



5.5 Interchangeable Anvils

The requirements in Tables 5.1-1 and 5.1-2 apply to outside micrometers with interchangeable anvils as shown. The measuring faces on the interchangeable anvils shall have a hardness not less than 60 HRC. For interchangeable anvils with flat measuring faces, the maximum flatness error allowable shall not exceed $1\ \mu\text{m}$ ($40\ \mu\text{in.}$), and the surface finish shall not exceed $0.1\ \mu\text{m}$ ($4\ \mu\text{in.}$) R_a .

5.6 Setting Standards

The measuring surfaces of setting standards for outside micrometers shall have a hardness not less than 60 HRC. The deviation in length from the nominal size shall not exceed the values listed in Table 5.6-1 or 5.6-2. For setting standards with flat faces, the parallelism between the faces shall not exceed $2\ \mu\text{m}$ ($80\ \mu\text{in.}$).

5.7 Specialty Micrometers

A large variety of specialty outside micrometers are commercially available for measuring tubing, threads, specialized measuring-face configurations for use in restricted areas, large diameter measuring faces, spherical shaped measuring faces, and conical measuring faces. These micrometers shall meet the general requirements covered in section 4 of this Standard. Specifications for specialty micrometers shall conform to the terms, definitions, and symbols employed in this Standard.

6 INSIDE MICROMETERS (SEE FIG. 6-1)

Inside micrometers may be either of fixed length or have interchangeable rods that carry the measuring faces. The measuring faces shall have a radius of curvature less than one-half of the smallest measuring range. The measuring faces shall have a hardness not less than 60 HRC, and the surface finish shall not exceed $0.2\ \mu\text{m}$ ($8\ \mu\text{in.}$) R_a .

6.1 Maximum Permissible Errors (MPE)

With the micrometer set to read zero at minimum travel, the length measurement error of indication when

Table 5.1-1 Maximum Permissible Errors of Outside Micrometers (Metric System)

Range, mm	Frame Flex Maximum (10 N), mm	Length Measurement Error, \pm mm	Parallelism Error		Spindle–Anvil Alignment, mm
			Fixed Anvil, mm	Interchangeable Anvil, mm	
0 to 25	0.002	0.004	0.002	0.010	0.06
25 to 50	0.002	0.004	0.002	0.010	0.25
50 to 75	0.003	0.005	0.003	0.010	0.30
75 to 100	0.004	0.005	0.003	0.010	0.30
100 to 125	0.005	0.006	0.004	0.010	0.50
125 to 150	0.006	0.006	0.004	0.010	0.50
150 to 175	0.006	0.007	0.005	0.015	0.50
175 to 200	0.007	0.007	0.005	0.015	0.50
200 to 225	0.008	0.008	0.006	0.015	0.70
225 to 250	0.008	0.008	0.006	0.015	0.70
250 to 275	0.009	0.009	0.007	0.015	0.70
275 to 300	0.010	0.009	0.007	0.015	0.70
300 to 350	0.011	0.010	0.008	0.020	1.00
350 to 375	0.012	0.011	0.009	0.020	1.00
375 to 400	0.012	0.011	0.009	0.020	1.00
400 to 425	0.012	0.012	0.010	0.020	1.50
425 to 450	0.013	0.012	0.010	0.020	1.50
450 to 475	0.014	0.013	0.011	0.025	1.50
475 to 500	0.015	0.013	0.011	0.025	1.50
500 to 600	0.017	0.015	0.013	0.030	2.70
600 to 700	0.020	0.017	0.015	0.030	2.70
700 to 800	0.022	0.019	0.017	0.035	2.70
800 to 900	0.025	0.021	0.019	0.035	2.70

Table 5.1-2 Maximum Permissible Errors of Outside Micrometers (Inch System)

Range, in.	Frame Flex Maximum (2 lbf), in.	Length Measurement Error, \pm in.	Parallelism Error		Spindle–Anvil Alignment, in.
			Fixed Anvil, in.	Interchangeable Anvil, in.	
0 to 1	0.00010	0.00010	0.00010	0.00040	0.003
1 to 2	0.00010	0.00020	0.00020	0.00040	0.010
2 to 3	0.00010	0.00020	0.00020	0.00040	0.012
3 to 4	0.00015	0.00020	0.00020	0.00040	0.012
4 to 5	0.00015	0.00020	0.00020	0.00040	0.020
5 to 6	0.00015	0.00020	0.00020	0.00040	0.020
6 to 7	0.00020	0.00020	0.00020	0.00040	0.020
7 to 9	0.00020	0.00020	0.00020	0.00060	0.028
9 to 12	0.00030	0.00030	0.00030	0.00060	0.028
12 to 18	0.00040	0.00040	0.00040	0.00080	0.060
18 to 24	0.00050	0.00050	0.00050	0.00080	0.110
24 to 30	0.00060	0.00060	0.00060	0.00100	0.110
30 to 36	0.00070	0.00070	0.00070	0.00100	0.110

Table 5.6-1 Metric-Measure Setting Standards

Nominal Size, mm	Size Tolerance Limits, ±mm
0 to 25	0.002
50 to 125	0.002
150 to 200	0.003
225 to 275	0.004
300 to 425	0.005
450 to 575	0.006
600 to 750	0.007
775 to 900	0.008

Table 5.6-2 Inch-Measure Setting Standards

Nominal Size, in.	Size Tolerance Limits, ±in.
0 to 1	0.00005
2 to 4	0.00010
5 to 8	0.00015
9 to 11	0.00020
12 to 18	0.00025
19 to 24	0.00030
25 to 36	0.00035

Fig. 6-1 Typical Inside Micrometer

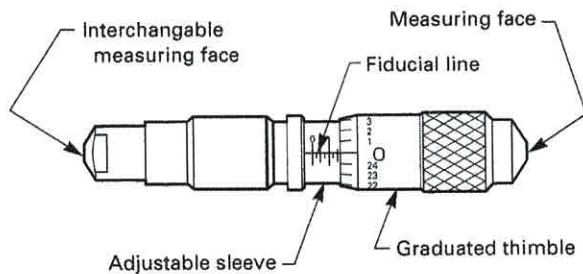


Table 6.1-1 Maximum Permissible Errors of Inside Micrometers (Metric System)

Range, mm	Length Measurement Error, ±mm
0 to 100	0.007
100 to 300	0.010
300 to 500	0.014
500 to 750	0.020
750 to 1 000	0.026

using full measuring face contact shall not exceed the maximum values indicated in Table 6.1-1 or 6.1-2 at any point within the measuring range of the instrument. Length measurement error is calculated as the difference between a micrometer indication and the reference value of the measurement standard.

Table 6.1-2 Maximum Permissible Errors of Inside Micrometers (Inch System)

Range, in.	Length Measurement Error, ±in.
0 to 4	0.00030
4 to 12	0.00050
12 to 20	0.00080
20 to 30	0.00100
30 to 40	0.00140

When applicable, extensions, collars, or sleeves can be used to extend the range of measurement. An additional permissible error of 0.005 mm (0.0002 in.) will be allowed for each extension, collar, or sleeve, in overall length.

7 DEPTH MICROMETERS (SEE FIG. 7-1)

Depth micrometers shall consist of a micrometer head fixed into a base with a flat reference surface, and interchangeable or fixed measuring rods to measure distance in relation to the flat reference surface.

7.1 Base

The reference surface of the base shall have a hardness not less than 60 HRC, shall be flat within 0.0025 mm per 25 mm of length (0.0001 in. per inch of length), and shall have a finish not to exceed 0.2 μm (8 μin.) *R_a*.

7.2 Measuring Rods

For depth micrometers with interchangeable measuring rods, the rods shall be interchangeable to measure in increments within the travel of the micrometer screw. All measuring rods shall be provided with a means to compensate for wear. Measuring faces of rods shall be flat within 0.0025 mm (0.0001 in.), and the surface finish shall not exceed 0.1 μm (4 μin.) *R_a*. The measuring faces shall have a hardness not less than 60 HRC.

7.3 Maximum Permissible Errors (MPE)

7.3.1 Length Measurement Error. With the micrometer set to read zero at minimum travel, the length measurement error of indication when using full measuring face contact shall not exceed the maximum values indicated in Table 7.3.1-1 or 7.3.1-2 at any point within the measuring range of the instrument. Length measurement error is calculated as the difference between a micrometer indication and the reference value of the measurement standard.

7.3.2 Parallelism Error. The parallelism error of indication is the maximum difference in successive measurements using partial measuring face contact at any position on the measuring face, but at the same nominal point in the measuring range of the micrometer. The parallelism error shall not exceed the maximum values indicated in Table 7.3.1-1 or 7.3.1-2 at any point within the measuring range of the micrometer.

Fig. 7-1 Typical Depth Micrometer

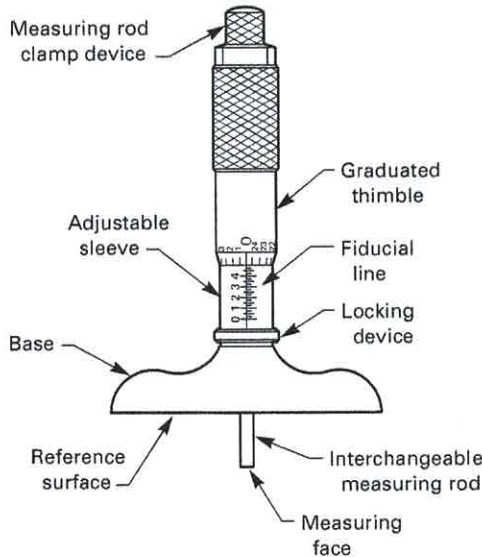


Table 7.3.1-1 Maximum Permissible Errors of Depth Micrometers (Metric System)

Range, mm	Length Measurement Error, \pm mm	Parallelism Error, mm
0 to 50	0.008	0.008
50 to 100	0.009	0.009
100 to 150	0.010	0.010
150 to 200	0.011	0.011
200 to 250	0.013	0.013
250 to 300	0.015	0.015

Table 7.3.1-2 Maximum Permissible Errors of Depth Micrometers (Inch System)

Range, in.	Length Measurement Error, \pm in.	Parallelism Error, in.
0 to 2	0.00030	0.00030
2 to 4	0.00035	0.00035
4 to 6	0.00040	0.00040
6 to 8	0.00045	0.00045
8 to 10	0.00050	0.00050
10 to 12	0.00060	0.00060

8 MICROMETERS WITH DIGITAL READOUT

In addition to meeting all of the requirements applicable under this specification, the requirements in paras. 8.1 and 8.2 shall apply to micrometers with digital readout.

8.1 Mechanical Digital (See Fig. 8.1-1)

The figures of the display shall have good contrast with the background, and the least-count digit shall

Fig. 8.1-1 Mechanical Digital Micrometer

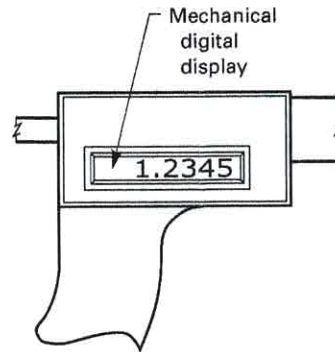
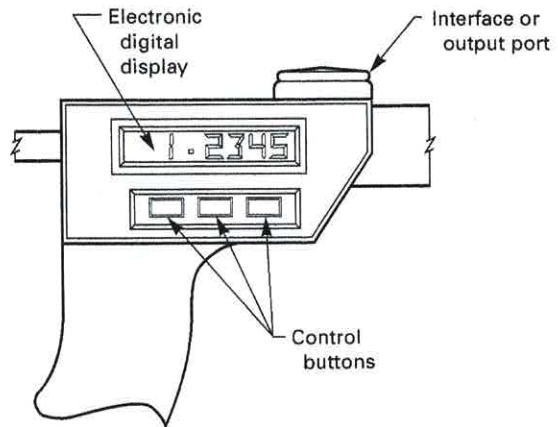


Fig. 8.2-1 Electronic Digital Micrometer



agree with the analog reading within one digit of least count.

8.2 Electronic Digital (See Fig. 8.2-1)

The figures of the display shall have good contrast with the background, and the least-count digit shall agree with the analog reading within one digit, where applicable. The least count shall not simply be a truncated digit, but shall be rounded in accordance with IEEE/ASTM SI 10-2010 or as specified by the manufacturer. The electronics shall have the ability to retain the zero setting when in the off mode, and micrometers with greater capacity than 25 mm (1 in.) shall have preset capabilities so that a complete measurement (e.g., 5.1254) can be displayed and transmitted. If for any reason the microprocessor loses count (e.g., due to quick movement or a low battery condition), an error message shall appear on the display. Micrometers having the ability to transfer data shall have the output protocol designated by the manufacturer and described in sufficient detail to allow for interfacing with existing equipment.

NONMANDATORY APPENDIX A

GOOD OPERATING PROCEDURE

A-1 GENERAL

This Nonmandatory Appendix is intended to provide general guidance on good operating procedures involving micrometers, specifically the outside, inside, and depth micrometers.

A-2 MICROMETER, OUTSIDE

A-2.1 Zero Setting, Mechanical Micrometer

Prior to taking measurements, the zero point of the micrometer must be established. Zero setting is the first step of operation with outside, inside, or depth micrometers. Clean the anvil and spindle measuring faces (0 mm to 25 mm or 0 in. to 1 in. range micrometers) by inserting lint-free paper between them and lightly closing the spindle, then slowly pulling the paper through. A lint-free cloth can be used to clean the spindle and anvil measuring faces on larger micrometers. Observe graduations and make sure the micrometer reads zero with clean measuring faces. If the micrometer does not read zero, adjust the sleeve accordingly.

A-2.2 Zero Setting, Digital Micrometer

For a digital micrometer equipped with a zero-setting button, clean the faces, then close the micrometer using the friction or ratchet stop. Press the reset or zero button. If ABS (absolute) or INC (incremental) zero is featured, press ABS zero.

A-2.3 Zero Setting, Large Micrometers

Micrometers larger than the 0 mm to 25 mm (0 in. to 1 in.) range models must be set to zero by using a setting standard or gage block. Use friction or ratchet stop whenever possible. When setting zero on micrometers larger than 300 mm (12 in.), the micrometer should be held in the position of its intended use (horizontal or vertical).

A-2.4 Friction or Ratchet Stop

Friction or ratchet stops on micrometers provide a uniform force when making measurements. The accuracy and repeatability is generally better when using friction or ratchet stops.

A-2.5 Micrometer Stand

While one-hand operation is a common practice, the use of the micrometer stand is recommended when more

accurate measurements are required. It allows the operator to free both hands and generally lowers the uncertainty of the measurements.

A-2.6 How to Read the Micrometer

A-2.6.1 Micrometer, Outside, Metric, 0.01 mm Resolution. Graduations are engraved on the adjustable sleeve and graduated thimble of a micrometer. The adjustable sleeve is graduated in 50 equal parts, with each line representing 0.5 mm, which represents the pitch of one thread of the micrometer spindle. The numbers 5, 10, and 15 on the adjustable sleeve represent 5 mm, 10 mm, and 15 mm, respectively. The graduated thimble has 50 lines on its circumference, with each line representing 0.01 mm. The numbers 5, 10, 15, and 30 on the graduated thimble represent 0.05 mm, 0.10 mm, 0.15 mm, and 0.30 mm, respectively.

A-2.6.2 Micrometer, Outside, Inch, 0.001 in. Resolution. Graduations are engraved on the adjustable sleeve and graduated thimble of a micrometer. The adjustable sleeve is graduated in 40 equal parts, with each line representing 0.025 in., which represents the pitch of one thread of the micrometer spindle. The numbers 1, 2, and 3 on the adjustable sleeve represent 0.100 in., 0.200 in., and 0.300 in., respectively. The graduated thimble has 25 lines on its circumference, with each line representing 0.001 in. The numbers 1, 2, 3, and 5 on the graduated thimble represent 0.001 in., 0.002 in., 0.003 in., and 0.005 in., respectively.

A-3 MICROMETER, INSIDE

A-3.1 Measuring Holes

In using the inside micrometer to measure holes, one anvil should be kept stationary and the other anvil should be moved back and forth, and up and down, while the micrometer is being expanded until it no longer moves freely. It is often useful to take multiple readings to expose issues with operator technique or workpiece form impacting the measurements.

A-3.2 Measuring Large Pieces

When large objects are measured in the horizontal position using two-point contact, support the internal micrometer with vee blocks or other means of support to reduce bending. It is preferable to avoid using additional operators, as this increases the transfer of heat from the operator to the gage.

A-4 MICROMETER, DEPTH

A-4.1 Hand Pressure

The important point to remember in using micrometer depth gages is that a comparatively light force applied to advance the thimble can raise the anvil away from the surface upon which it is resting, thereby creating an error in the reading. For this reason, the contact stem should be lowered very carefully with a light touch on

the thimble, then withdrawn slightly and brought to bear on the component two or three times to make sure it has not overrun the proper reading.

A-4.2 Proper Reading of Graduation

Most depth micrometers are equipped with reverse reading shells. As the depth rod extends farther from the base reference surface, the reading will be larger. Care should be taken to not misread the graduation.

NONMANDATORY APPENDIX B ENVIRONMENTAL CONSIDERATIONS

B-1 GENERAL

This Nonmandatory Appendix is intended to provide general guidance and awareness regarding the environmental considerations involving the use of outside, inside, and depth micrometers.

B-2 TEMPERATURE

B-2.1 Reference Temperature

Whenever precision measurements are made, the temperature should be kept as near to the standard reference temperature of 20°C (68°F) as possible. Since most standards and measuring instruments are usually made of steel, they have practically the same coefficient of expansion; therefore, the requirement that the temperature remain constant is more important than the actual temperature.

B-2.2 Heat Transfer

The length of the standard or part being measured can change due to excessive handling. When making critical measurements, the operator should wear insulated gloves to avoid heating the standard or part.

B-2.3 Working Temperature

When gages are used, especially in production shops, working temperatures are seldom at the standard reference temperature. If the gage is accurate at the standard reference temperature, and the coefficients of expansion of both the work part and gage are approximately the same, the effect of the deviation from 20°C (68°F) is less than if the part and gage were of different materials.

B-2.4 Difference Due to Dissimilar Materials

If measured parts are made of a material other than that used for the micrometer (typically steel), an allowance for temperature differences, with reference to 20°C (68°F), must be made.

B-2.5 Soak Time

Gages should be stored in a constant-temperature room before they are inspected to ensure they are nearly the same temperature as the measurement laboratory. The amount of soak time required depends on the size of the gage and the desired accuracy. See ASME B89.6.2 for further information and examples of estimating soak-out time.

B-3 HUMIDITY

The relative humidity of the atmosphere in a gage laboratory should preferably be kept under 45% to minimize the possibility of corrosion. In general, the air conditioning system of a laboratory should remain in operation at all times. This is both because the change in humidity may cause corrosion and because there are delays while instruments and gages reach the proper temperature on the day when the laboratory is reopened.

B-4 CLEANLINESS

Cleanliness is an important requirement for a good gage laboratory. Small particles of dirt may cause serious errors in precision measurements and bring about excessive wear of precision instruments.

NONMANDATORY APPENDIX C TEST METHODS

C-1 GENERAL

This Nonmandatory Appendix is intended to provide general guidance regarding test methods for outside, inside, and depth micrometers.

C-1.1 Zero-Setting Check

For all micrometers with adjustable zero setting, when testing a used instrument in the as-received condition, the zero point(s) should be checked prior to the adjustments and tests described in this Nonmandatory Appendix.

C-2 MICROMETERS, OUTSIDE

C-2.1 Visual Inspection

Examine the measuring surfaces of the micrometer for nicks and burrs, and check to ensure that the micrometer operates smoothly through its entire range of travel. Clean the micrometer measuring faces prior to any tests.

C-2.2 Flatness Check

Check the flatness of the measuring anvils with an optical flat and a monochromatic light source.

C-2.3 Length Measurement Error Test

Zero the micrometer at the minimum travel. Using full measuring face contact, check the micrometer at different points around the screw and across the measuring range of the micrometer. For example, a 25 mm micrometer can be checked using the 7.7 mm, 12.9 mm, 17.6 mm, 22.8 mm, and 25 mm gage block sizes; and a 1 in. micrometer can be checked using the 0.210 in., 0.420 in., 0.605 in., 0.815 in., and 1.000 in. gage block sizes. These sizes check the screw at approximately the 0 deg, 72 deg, 144 deg, 216 deg, and 288 deg positions.

C-2.4 Parallelism Error Test for Micrometers 25 mm (1 in.) or Less

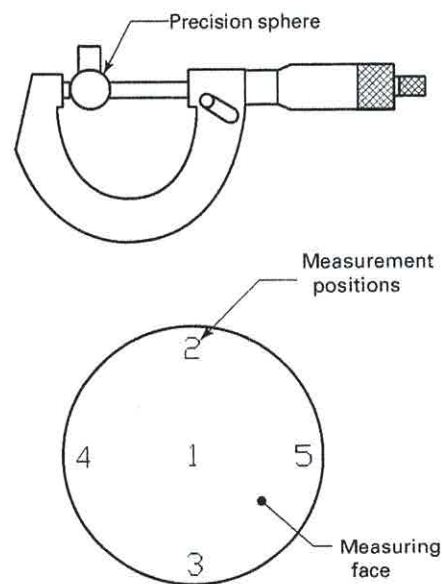
Measure a small precision sphere at different areas of the measuring faces and report the maximum difference in the measured diameters. The five measurement locations shown in Fig. C-2.4-1 could be used.

NOTE: A ball plug gage, tooling ball, or a coordinate-measuring machine (CMM) ball stylus may be useful for this test.

C-2.5 Parallelism Error Test for Large Micrometers

Measure the edge of a gage block (or gage block stack) at different locations on the measuring faces and report

Fig. C-2.4-1 Parallelism Error Test on Small Outside Micrometer



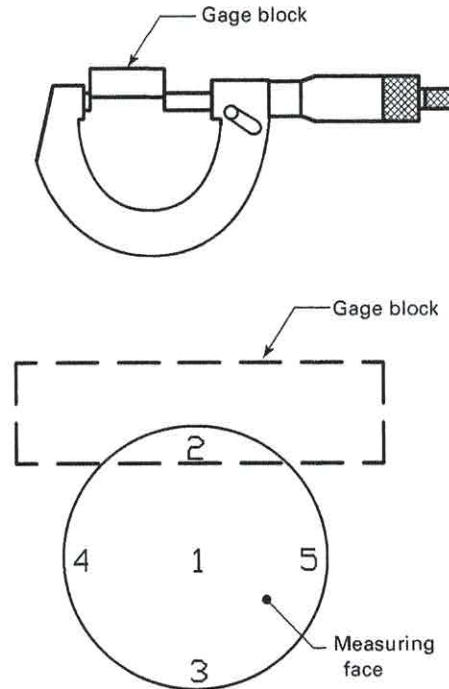
the maximum difference in the measured lengths. The five measurement locations shown in Fig. C-2.5-1 could be used. For micrometers over 175 mm (7 in.), a gage block stack can be used with one gage block centered on the anvil measuring face and the other gage block moved to the positions shown in Fig. C-2.5-1 on the spindle measuring face.

C-2.6 Parallelism Error Test Using Optical Parallels

The parallelism of the measuring anvils can be checked with a pair of optical parallels and a monochromatic light source. The difference in thickness of the two parallels should be equal to one-half of the spindle revolution. For larger micrometers, a combination of optical parallels and gage blocks may be used.

C-2.7 Setting Standards Calibration

Calibrate the setting standards on a standard measuring machine or a similar machine. Gage blocks can be used for length comparison.

Fig. C-2.5-1 Parallelism Error Test on Large Outside Micrometer**C-3 MICROMETERS, INSIDE****C-3.1 Visual Inspection**

Examine the measuring surfaces of the micrometer for nicks and burrs, and check to ensure that the micrometer operates smoothly through its entire range of travel. Examine the measuring surfaces to ensure the curved faces have no flat spots. Clean the micrometer measuring faces prior to any tests.

C-3.2 Length Measurement Error Test

C-3.2.1 Fixed Length Inside Micrometer. Zero the micrometer at the minimum travel. Using full measuring face contact, check the micrometer at several different places and positions around the micrometer spindle/screw. For example, a 100 mm to 125 mm inside micrometer can be checked using a measuring machine or gage blocks at the 100.0 mm, 107.7 mm, 112.9 mm, 117.6 mm, 122.8 mm, and 125 mm positions. A 4 in. to 5 in. inside micrometer can be checked using a measuring machine or gage blocks at the 4.000 in., 4.210 in., 4.420 in., 4.605 in., 4.815 in., and 5.000 in. positions. These sizes check the screw at approximately the 0 deg, 72 deg, 144 deg, 216 deg, and 288 deg positions.

C-3.2.2 Inside Micrometer With Interchangeable Rods. The test described in para. C-3.2.1 is first completed on the inside micrometer head. Using each of the

extension rods separately, the assembled inside micrometer is set to zero at the minimum travel and then checked at one point near the maximum travel.

C-4 MICROMETER, DEPTH**C-4.1 Visual Inspection**

Examine measuring surfaces of the micrometer for nicks and burrs, and check to ensure that the micrometer operates smoothly throughout its entire range of travel. Clean the micrometer measuring faces prior to any tests.

C-4.2 Base Flatness Check

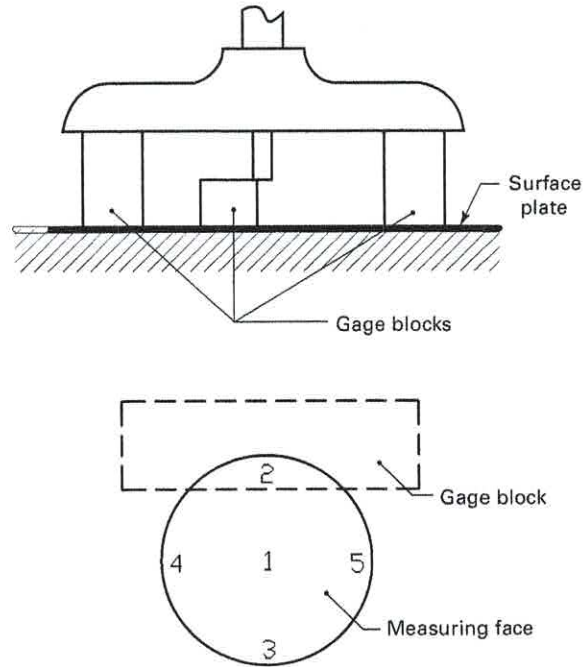
Set the micrometer on two gage block stacks of the same nominal dimension that are located at the outer edges of the base. These stacks should be within the range of the micrometer. Take a reading. Repeat by moving the gage block stacks to the center of the base and take a reading. Compare the readings. The difference in the readings is an indication of the base flatness.

NOTE: Base flatness can also be checked with an optical flat and a monochromatic light source.

C-4.3 Length Measurement Error Test

Zero the micrometer at the minimum travel. Using full measuring face contact, check the micrometer at

Fig. C-4.4-1 Parallelism Error Test on Depth Micrometer



different points around the screw and across the measuring range of the micrometer. For example, a 25 mm micrometer can be checked using the 7.7 mm, 12.9 mm, 17.6 mm, 22.8 mm, and 25 mm gage block stack sizes; and a 1 in. micrometer can be checked using the 0.210 in., 0.420 in., 0.605 in., 0.815 in., and 1.000 in. gage block stack sizes. These sizes check the screw at approximately the 0 deg, 72 deg, 144 deg, 216 deg, and 288 deg positions.

C-4.4 Parallelism Error Test

Measure the edge of a gage block (or gage block stack) at different locations on the measuring face and

report the maximum difference in the measured lengths. The five measurement locations shown in Fig. C-4.4-1 could be used.

C-4.5 Interchangeable Rods

For depth micrometers with interchangeable rods, the length measurement error test described in para. C-4.3 is completed using any one rod. The depth micrometer is then separately assembled with each of the remaining rods, set to zero at the minimum travel, and then checked at one point near the maximum travel. In addition, the parallelism error test described in para. C-4.4 should be completed using each rod separately.

NONMANDATORY APPENDIX D

UNCERTAINTY FOR MICROMETER CALIBRATIONS

D-1 INTRODUCTION

This Nonmandatory Appendix is intended to provide general guidance and awareness regarding the determination and application of measurement uncertainty when calibrating a micrometer. The examples given are for guidance only. The actual uncertainties will be different for each laboratory. The measurement uncertainty when using a micrometer, e.g., to measure manufactured workpieces, is not within the scope of this Standard but is discussed in ASME B89.7.3.2.

D-2 INFORMATIVE REFERENCES

ISO/TS 23165:2006, Geometrical product specifications (GPS) — Guidelines for the evaluation of coordinate measuring machine (CMM) test uncertainty

Publisher: International Organization for Standardization (ISO) Central Secretariat, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Genève 20, Switzerland/Suisse (www.iso.org)

Salsbury, J. G. and E. P. Morse. "Measurement uncertainty in the performance verification of indicating measuring instruments." *Precision Engineering* 36 (2012): 218–222.

D-3 MICROMETER PARAMETERS

Specifications are given in this Standard for the surface finish, frame flexure, maximum permissible errors of indication, flatness of measuring faces, friction-thimble force, hardness, and misalignment of the spindles. A complete calibration would include all of these parameters. Except in rare cases, it is not practical, or necessary, to measure all of the parameters in a calibration. In common practice, only length measurement errors, parallelism errors, and the flatness of measuring faces are tested. The uncertainty budgets shown in these examples are for the performance verification of the length measurement error.

D-4 SOURCES OF ERROR

Common sources of error in mechanical calibrations include the uncertainty in the master, the repeatability, resolution, parallax errors, uncertainty in the temperature of the master, uncertainty in the temperature of the test item, uncertainty in the coefficient of thermal

expansion, elastic deformation, cosine errors, Abbe offset, and others, depending on the type of instrument or material standards being measured. Not all of these sources contribute to the uncertainty when calibrating a micrometer.

D-5 COMMON PRACTICES

D-5.1 General

The uncertainty budgets presented in this Nonmandatory Appendix are based on common practices used in the calibration of micrometers. Other approaches may result in different uncertainty contributors and values.

D-5.2 Performance Verification

These uncertainty budgets are based on performance verifications, where the measured errors are compared to the specification of the micrometer and are not assigned values used as correction factors in later use of the micrometer. In performance verification, the measurand is an observed error of indication and the instrument errors, including any inherent repeatability, are part of what is being tested and not also included in the uncertainty. For these examples, it is also assumed that a reasonably trained and skilled operator is performing the calibration and therefore no uncertainty contributor from the operator is included; this assumption may not be valid in all cases.

D-5.3 Gage Block Size

In these examples, the calibrated value of the gage blocks is not used, but instead the nominal size marked on the gage blocks is used as the reference value. The gage blocks are assumed to be calibrated and within their tolerance grade.

D-5.4 Temperature Correction

Micrometers are often calibrated in laboratories with average temperatures of approximately 20°C (68°F) and with some known approximate limits of thermal variation. In common practice, no correction for temperature is made.

D-6 EXAMPLE UNCERTAINTY BUDGET

D-6.1 0 mm to 25 mm Digital Outside Micrometer

An uncertainty budget for the performance verification of the length measurement error for a 0 mm to

Table D-6.1-1 Uncertainty Budget for Performance Verification of the Length Measurement Error for a 0 mm to 25 mm Digital Outside Micrometer

Uncertainty Source	Estimated Limit, μm	Evaluation Method	Distribution	Divisor	Standard Uncertainty, μm
Gage block tolerance	0.140	B	Rectangular	1.73	0.081
Calibration uncertainty	0.060	B	Normal	2	0.030
Uncertainty in CTE	0.056	B	Normal	2	0.028
Nominal CTE difference	0.110	B	Normal	2	0.055
Temperature difference	0.130	B	Normal	2	0.065

GENERAL NOTE: The expanded ($k = 2$) uncertainty is equal to 0.25 μm .

25 mm digital micrometer is given in Table D-6.1-1. The micrometer error of indication was measured using Grade 0 ceramic gage blocks in a temperature-controlled room maintained at $20^\circ\text{C} \pm 2^\circ\text{C}$. The temperatures of the micrometer and gage blocks are assumed to be within these limits during the calibration, and the temperature variation is assumed to be normally distributed. The difference between the temperature of the micrometer and the gage blocks used in the calibration was estimated not to exceed 0.5°C . The uncertainty is estimated for a measured length of 25 mm.

D-6.2 Uncertainty Validity Conditions

Measured length	25 mm
Temperature range	$20^\circ\text{C} \pm 2^\circ\text{C}$
Temperature difference	0.5°C
Micrometer CTE	$(11.5 \pm 1.0) \times 10^{-6}/^\circ\text{C}$
Gage block CTE	$(9.3 \pm 0.5) \times 10^{-6}/^\circ\text{C}$
Gage block tolerance	Grade 0 ($\pm 0.14 \mu\text{m}$)
Gage block calibration uncertainty ($k = 2$)	$0.06 \mu\text{m}$

D-6.3 Reference Standard

D-6.3.1 Gage Block Tolerance. The calibrated values of the gage blocks used in the calibration were not known. It was only known that the blocks were within the tolerance limits for a Grade 0 set. The blocks could deviate anywhere from $0 \mu\text{m}$ to $\pm 0.14 \mu\text{m}$ from nominal, so a rectangular distribution is assumed.

D-6.3.2 Calibration Uncertainty Assuming a simple acceptance decision rule was used for the calibration of the gage blocks, the uncertainty in the gage block calibration is an additional uncertainty contributor in the micrometer calibration.

D-6.3.3 Independency. The likelihood that the gage block is within tolerance is assumed in this example to be independent of the uncertainty when calibrating the gage block. This assumption may not always be correct, which would result in an overestimate of uncertainty due to some double counting. In most practical cases, the increase in the uncertainty is negligible.

D-6.4 Deviation From Reference Temperature

D-6.4.1 General Equation. The standard reference temperature for length of a gage block is 20°C . The

calibration of a micrometer can never be done at exactly 20°C , and if temperature correction is not being done, then the uncertainty associated with the micrometer and gage blocks not being at 20°C can be estimated with the equation

$$\Delta L = L\Delta\alpha(20 - T)$$

where

- L = the nominal length
- T = the temperature
- $\Delta\alpha$ = the difference in the CTE between the gage blocks and the micrometer

The difference in the CTE of the gage blocks and micrometer is a combination of the nominal difference and the associated uncertainties.

D-6.4.2 Uncertainty in Nominal CTE. There is always some uncertainty in the CTE of any material. In this example, the values shown in para. D-6.2 are assumed to be normally distributed such that

$$\Delta\alpha = [U(\alpha_M)^2 + U(\alpha_{GB})^2]^{1/2}$$

where

- $U(\alpha_{GB})$ = the expanded uncertainty ($k = 2$) in the gage block CTE
- $U(\alpha_M)$ = the expanded uncertainty ($k = 2$) in the micrometer CTE

Based on the values in para. D-6.2

$$\Delta\alpha = (1^2 + 0.5^2)^{1/2} = 1.12 \times 10^{-6}/^\circ\text{C}$$

and

$$\Delta L = (0.025 \text{ m})(1.12 \times 10^{-6}/^\circ\text{C})(2^\circ\text{C}) = 0.056 \mu\text{m}$$

D-6.4.3 Nominal CTE Difference. If the nominal CTE of the gage blocks and micrometer are different, as in this example, then the following equation is applicable:

$$\Delta\alpha = |\alpha_M - \alpha_{GB}|$$

where

- α_{GB} = the nominal CTE of the gage block
- α_M = the nominal CTE of the micrometer

Based on the values in para. D-6.2

$$\Delta\alpha = |11.5 - 9.3| = 2.2 \times 10^{-6}/^{\circ}\text{C}$$

and

$$\Delta L = (0.025 \text{ m})(2.2 \times 10^{-6}/^{\circ}\text{C})(2^{\circ}\text{C}) = 0.11 \mu\text{m}$$

D-6.5 Temperature Difference

It was determined that due to handling, the temperatures of the micrometer and the gage blocks could be as much as 0.5°C apart. It is further assumed, for this example, that data is available that supports the use of a normal distribution. If temperature correction is not being used, then the uncertainty caused by this temperature difference can be expressed as

$$\Delta L = L\alpha\Delta t$$

where

L = the nominal length

α = the average CTE of the gage blocks and micrometer

Δt = the difference in temperature between the gage blocks and the micrometer

Based on the values in para. D-6.2

$$\Delta L = (0.025 \text{ m})(10.4 \times 10^{-6}/^{\circ}\text{C})(0.5^{\circ}\text{C}) = 0.13 \mu\text{m}$$

D-6.6 Combined and Expanded Uncertainty

Using the values determined in paras. D-6.3 through D-6.5, the associated standard uncertainties are estimated as shown in Table D-6.1-1. The combined uncertainty, u_c , is then calculated as

$$u_c = (0.081^2 + 0.03^2 + 0.028^2 + 0.055^2 + 0.065^2)^{1/2} = 0.124 \mu\text{m}$$

The expanded uncertainty, U , using a coverage factor, $k = 2$, is calculated as

$$U = 2u_c = 0.25 \mu\text{m}$$

D-6.7 Conformance Test (Application of Decision Rule)

The maximum permissible length measurement error listed in Table 5.1-2 for a 0 mm to 25 mm outside micrometer is $4 \mu\text{m}$. If the default decision rule of simple 4:1 acceptance in accordance with ASME B89.7.3.1 is being employed, then the expanded uncertainty, U , must be less than one-fourth (or 25%) of the MPE value. In this case, the uncertainty of $0.25 \mu\text{m}$ is only 6.3% of the MPE value and therefore a conformance decision can be made. If the largest observed error does not exceed the MPE, and the decision rule is satisfied, then acceptance can be stated, e.g., in tolerance. If the largest observed error exceeds the MPE, and the decision rule is satisfied, then rejection can be stated, e.g., out of tolerance.

D-7 LARGER MICROMETER EXAMPLE

D-7.1 75 mm to 100 mm Digital Outside Micrometer

An uncertainty budget for the performance verification of the length measurement error for a 75 mm to 100 mm digital micrometer is given in Table D-7.1-1. The micrometer error of indication was measured in the same environment and using the same gage blocks discussed in para. D-6.1 wrung to a 75 mm Grade 0 steel gage block that was also used to set zero. The thermal drift after setting zero, including the change in the average temperature of the micrometer and gage block and also the change in the temperature difference between the micrometer and gage block, was estimated not to exceed 0.5°C . The uncertainty is estimated for a measured length of 100 mm.

D-7.2 Uncertainty Validity Conditions

Measured length	100 mm (using a 75 mm and 25 mm gage block)
Wringing uncertainty	$0.1 \mu\text{m}$
Thermal drift	0.5°C
Gage block CTE	$(10.8 \pm 0.5) \times 10^{-6}/^{\circ}\text{C}$
Gage block tolerance	Grade 0 ($\pm 0.25 \mu\text{m}$)
Gage block calibration uncertainty ($k = 2$)	$0.1 \mu\text{m}$

The gage block information above applies to the 75 mm gage block used to zero and test the micrometer. These validity conditions are in addition to those in para. D-6.2.

D-7.3 Short Gage Block Use

In this example, the calibration of the larger micrometer is done using the same technique as the calibration of the smaller micrometer discussed in section D-6. The only difference is the use of the 75 mm gage block to set zero. All the uncertainty contributors shown in Table D-6.1-1 are therefore applicable to the larger micrometer case.

D-7.4 Change in Average Temperature

D-7.4.1 General Equation. Any change in the average temperature after setting zero introduces uncertainty in a manner similar to that discussed in para. D-6.4. The uncertainty associated with the thermal drift of the average temperature can be estimated with the equation

$$\Delta L = L\Delta\alpha\Delta t_a$$

where

L = the nominal length

Δt_a = the change in the average temperature after setting zero

$\Delta\alpha$ = the difference in the CTE between the gage blocks and the micrometer

Table D-7.1-1 Uncertainty Budget for Performance Verification of the Length Measurement Error for a 75 mm to 100 mm Digital Outside Micrometer

Uncertainty Source	Estimated Limit, μm	Evaluation Method	Distribution	Divisor	Standard Uncertainty, μm
Use of 25 mm block (from Table D-6.1-1)	0.250	B	Normal	2	0.125
Uncertainty in CTE (drift)	0.042	B	Normal	2	0.021
Nominal CTE difference (drift)	0.026	B	Normal	2	0.013
Temperature difference (drift)	0.418	B	Normal	2	0.209
Wringing	0.100	B	Normal	2	0.050

GENERAL NOTE: The expanded ($k = 2$) uncertainty is equal to 0.5 μm .

The difference in the CTE of the gage blocks and micrometer is a combination of the nominal difference and the associated uncertainties.

D-7.4.2 Uncertainty in Nominal CTE. Following the same discussion as in para. D-6.4.2

$$\Delta\alpha = [U(\alpha_M)^2 + U(\alpha_{GB})^2]^{1/2}$$

where

$U(\alpha_{GB})$ = the expanded uncertainty ($k = 2$) in the 75 mm gage block CTE

$U(\alpha_M)$ = the expanded uncertainty ($k = 2$) in the micrometer CTE

Based on the values in para. D-6.2 and D-7.2

$$\Delta\alpha = (1^2 + 0.5^2)^{1/2} = 1.12 \times 10^{-6}/^\circ\text{C}$$

and

$$\Delta L = (0.075 \text{ m})(1.12 \times 10^{-6}/^\circ\text{C})(0.5^\circ\text{C}) = 0.042 \mu\text{m}$$

D-7.4.3 Nominal CTE Difference. Following the same discussion as in para. D-6.4.3

$$\Delta\alpha = |\alpha_M - \alpha_{GB}|$$

where

α_{GB} = the nominal CTE of the 75 mm gage block

α_M = the nominal CTE of the micrometer

Based on the values in para. D-6.2 and D-7.2

$$\Delta\alpha = |11.5 - 10.8| = 0.7 \times 10^{-6}/^\circ\text{C}$$

and

$$\Delta L = (0.075 \text{ m})(0.7 \times 10^{-6}/^\circ\text{C})(0.5^\circ\text{C}) = 0.026 \mu\text{m}$$

D-7.5 Change in Temperature Difference

It was determined that due to handling, the temperature difference between the micrometer and the 75 mm gage block could drift by as much as 0.5 $^\circ\text{C}$ after setting zero. It is further assumed, for this example, that data is available that supports the use of a normal distribution. If temperature correction is not being used, then

the uncertainty caused by this temperature difference can be expressed as

$$\Delta L = L\alpha\Delta t_d$$

where

L = the nominal length

α = the average CTE of the gage block and micrometer

Δt_d = the change in the difference in temperature between the 75 mm gage block and the micrometer

Based on the values in para. D-6.2 and D-7.2

$$\Delta L = (0.075 \text{ m})(11.15 \times 10^{-6}/^\circ\text{C})(0.5^\circ\text{C}) = 0.418 \mu\text{m}$$

D-7.6 Wringing

For this example, it is assumed that experimental studies were done to test the gage block wringing skills of the operators performing micrometer calibrations. Based on those results, the limit for the error associated with wringing is estimated at 0.1 μm . It is further assumed that the experimental data shows a normal distribution is an acceptable assumption.

D-7.7 Combined and Expanded Uncertainty

Using the values determined in paras. D-7.3 through D-7.6, the associated standard uncertainties are estimated as shown in Table D-7.1-1. The combined uncertainty, u_c , is then calculated as

$$u_c = (0.125^2 + 0.021^2 + 0.013^2 + 0.209^2 + 0.05^2)^{1/2} = 0.25 \mu\text{m}$$

The expanded uncertainty, U , using a coverage factor, $k = 2$, is calculated as

$$U = 2u_c = 0.5 \mu\text{m}$$

D-8 CONCLUSION

The format for an uncertainty budget does not need to be as shown in these examples. It is only necessary to list the sources of uncertainty and the standard uncertainty, and explain how they were obtained. The table can contain two columns or as many as are needed.

NONMANDATORY APPENDIX E COMPARISON WITH ISO 3611:2010

This Standard includes many of the same concepts found in the International Standard on micrometers, ISO 3611:2010. Some differences do exist, and to assist users of either this Standard or ISO 3611:2010, Tables E-1 and E-2 show some of the similarities and differences between the two standards.

Table E-1 Comparison of Specifications Between This Standard and ISO 3611

Specification	ASME B89.1.13-2013	ISO 3611:2010	Comments
Full surface measurement	Length measurement error	Full surface contact error, f	Same definition
Partial surface measurement	Parallelism error	Partial surface contact error, E	ISO definition ambiguous
Repeatability	Optional	Repeatability, R	ISO definition ambiguous
Flatness of measuring faces	Yes	No	Partially covered by parallelism
Spindle-anvil alignment	Yes	No	...
Effect of locking device	Yes	Yes	Same specification
Measuring force	No	Yes	...

Table E-2 Comparison of General Concepts Between This Standard and ISO 3611

Concept	ASME B89.1.13-2013	ISO 3611:2010	Comments
Default specification values	Yes	No	...
Conformance decision rule	Simple 4:1 acceptance	ISO 14253-1 default rule	...
Definition of an indication	Yes	No	...
Example test methods	Yes	Yes	Similar methods
Example uncertainty budget	Yes	No	...
Requirements for setting standards	Yes	No	...
Scope of standard	Outside, inside, and depth micrometers	Outside micrometers	...

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