ASME B89.1.14-2018

REAFFIRMED 2023

Calipers

AN AMERICAN NATIONAL STANDARD

The American Society of
Mechanical Engineers

Calipers

AN AMERICAN NATIONAL STANDARD

The American Society of
Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: May 31, 2018

This Standard will be revised when the Society approves the issuance of a new edition.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. Interpretations are published on the Committee web page and under http://go.asme.org/InterpsDatabase. Periodically certain actions of the ASME B89 Committee may be published as Cases. Cases are published on the ASME website under the B89 Committee Page at http://go.asme.org/B89committee as they are issued.

Errata to codes and standards may be posted on the ASME website under the Committee Pages to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in codes and standards. Such errata shall be used on the date posted.

The B89 Committee Page can be found at http://go.asme.org/B89committee. There is an option available to automatically receive an e-mail notification when errata are posted to a particular code or standard. This option can be found on the appropriate Committee Page after selecting "Errata" in the "Publication Information" section.

ASME is the registered trademark of The American Society of Mechanical Engineers.

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

ASME does not "approve," "rate," or "endorse" any item, construction, proprietary device, or activity.

ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable letters patent, nor assume any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which precludes the issuance of interpretations by individuals.

No part of this document may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.

The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

Copyright © 2018 by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
All rights reserved
Printed in U.S.A.

Licensed to norziah. Last opened 1/26/24. Single user license only. Copying and networking prohibited.

CONTENTS

Foreword iv

Committee Roster v

Correspondence With the B89 Committee vi

1 **Scope** 1

2 **Definitions** 1

3 **References** 1

4 **Caliper Design** 1

5 **Maximum Permissible Errors** 1

Nonmandatory Appendices

A Good Operating Procedures 7

B Environmental Considerations 9

C Measurement Uncertainty 10

Figures

5.10.4-1 Testing Partial Surface Contact Error — Example Test Points on Two Calipers Showing Different Lengths and Different Distances From the Beam 5

5.10.6-1 Testing Line Contact Error 5

5.10.7-1 Testing Scale Shift Error — Inside Measurement 6

5.10.7-2 Testing Scale Shift Error — Depth Measurement 6

5.10.7-3 Testing Scale Shift Error — Step Measurement 6

5.10.8-1 Effect of Crossed Knife-Edge Internal Measuring Faces 6

5.10.8-2 Testing Scale Shift Error — Internal Measurement With Crossed Knife-Edge 6

Tables

5.8-1 Maximum Permissible Errors of Calipers With Measuring Range Up to 1 000 mm (40 in.) 3

5.10.4-1 Number of Test Points for E_{MPE} 4

C-4.1-1 Uncertainty Budget for Performance Verification of the Partial Surface Contact Error for a 0-mm to 150-mm Digital Caliper 12

FOREWORD

ASME B89 Standards Committee on Dimensional Metrology, under procedures approved by the American National Standards Institute, 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 calipers are widely used for the measurement and comparison of some of these features, the B89 Consensus Committee authorized formation of Project Team B89.1.14 to prepare this Standard.

The International Organization for Standardization (ISO) also develops standards in dimensional metrology. ISO standards are applicable in the United States but may not address all the needs of American industry, such as the use of both the U.S. Customary and SI systems. This Standard has been developed to be consistent with ISO 13385-1:2011, which addresses the design and metrological characteristics of calipers. This Standard has also been developed to complement ISO 13385-1:2011 by providing additional information useful in the specification, verification, and calibration of calipers. This Standard is not intended to contradict ISO 13385-1:2011 but does include additional technical information and requirements that exceed ISO 13385-1:2011.

This Standard adopted some material from the obsolete Federal Specification GGG-C-111C, published by General Services Administration (GSA), as well as manufacturer's current practices and technologies. In addition, this Standard includes many of the uncertainty and traceability concepts developed and standardized by the ASME B89.7 Subcommittee.

This Standard was approved by the American National Standards Institute on February 27, 2018.

ASME B89 COMMITTEE
Dimensional Metrology

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

STANDARDS COMMITTEE OFFICERS

T. C. Charlton, Jr., *Chair*
S. D. Phillips, *Vice Chair*
R. Richmond, *Secretary*

STANDARDS COMMITTEE PERSONNEL

T. C. Charlton, Jr., Charlton Associates
B. Crowe, CDI Engineering Solutions
J. D. Drescher, UTC — Pratt & Whitney
M. L. Fink, The Boeing Co.
G. A. Hetland, International Institute of Geometric Dimensioning and Tolerancing
M. Liebers, Professional Instruments Co.
R. L. Long, ANSI-ASQ National Accreditation Board
E. Morse, UNC Charlotte
B. Parry, Consultant
P. Pereira, Caterpillar, Inc.
S. D. Phillips, National Institute of Standards and Technology
B. S. Pippenger, Rolls-Royce
R. Richmond, The American Society of Mechanical Engineers
J. G. Salsbury, Mitutoyo America Corp.
D. Sawyer, National Institute of Standards and Technology
J. R. Schmidt, Optical Gaging Products, Inc.
C. Shakarji, National Institute of Standards and Technology
R. L. Thompson, U.S. Air Force
E. R. Yaris, Lowell, Inc.
K. L. Skinner, *Alternate*, Air Force Metrology and Calibration
D. E. Beutel, *Honorary Member*, Caterpillar, Inc.
T. E. Carpenter, *Honorary Member*, U.S. Air Force
D. J. Christy, *Honorary Member*, Mahr Federal, Inc.
R. J. Hocken, *Honorary Member*, Center for Precision Metrology
M. P. Krystek, *Honorary Member*, Physikalisch-Technische Bundesanstalt
B. R. Taylor, *Honorary Member*, Renishaw PLC

SUBCOMMITTEE 1 — LENGTH

J. G. Salsbury, *Chair*, Mitutoyo America Corp.
D. Sawyer, *Vice Chair*, National Institute of Standards and Technology
D. J. Carlson, The L. S. Starrett Co.
B. Crowe, CDI Engineering Solutions
D. Everett, National Institute of Standards and Technology
M. L. Fink, The Boeing Co.
D. T. Harris, Glastonbury Southern Gage
K. Kokal, Micro Laboratories, Inc.
A. Kumar, Mitutoyo America Corp.
W. D. Lehmus, Consultant
R. L. Long, ANSI-ASQ National Accreditation Board
E. Morse, UNC Charlotte
B. Parry, Consultant
P. Pereira, Caterpillar, Inc.
C. Shakarji, National Institute of Standards and Technology
K. L. Skinner, Air Force Metrology and Calibration
E. S. Stanfield, National Institute of Standards and Technology
R. L. Thompson, U.S. Air Force
B. T. Miller, *Alternate*, The Boeing Co.

WORKING GROUP B89.1.14 — CALIPERS

K. L. Skinner, *Chair*, Air Force Metrology and Calibration
B. Crowe, CDI Engineering Solutions
J. C. Davies, Honeywell Federal Manufacturing and Technologies
A. Kumar, Mitutoyo America Corp.
W. C. Lehmus, Consultant
R. L. Long, ANSI-ASQ National Accreditation Board
B. Parry, Consultant
J. G. Salsbury, Mitutoyo America Corp.
D. Sawyer, National Institute of Standards and Technology
C. Shakarji, National Institute of Standards and Technology
H. Tran, Sandia National Laboratories

CORRESPONDENCE WITH THE B89 COMMITTEE

General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, B89 Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
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 to provide 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 and 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 Standards 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.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the B89 Standards Committee at the above address. The request for an 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 the topic of the inquiry in one or two words.
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. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

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

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

ASME procedures provide for reconsideration of any interpretation when or if additional information that 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 and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the B89 Standards Committee. Future Committee meeting dates and locations can be found on the Committee Page at http://go.asme.org/B89committee.

INTENTIONALLY LEFT BLANK

CALIPERS

1 SCOPE

This Standard provides the essential requirements for the specification, verification, and calibration of calipers, including vernier, dial, electronic digital, and specialty calipers. ISO 13385-1 provides for the international definition of the design and metrological characteristics of calipers important in the specification, manufacture, and purchase of calipers; however, ISO 13385-1 does not provide specification values, detailed test methods, or sufficient discussion of traceability and measurement uncertainty to ensure consistent practice in the calibration of calipers. This Standard is intended to complement, not contradict, ISO 13385-1. For the verification or calibration of calipers, this Standard provides sufficient detail such that the user does not require access to ISO 13385-1.

2 DEFINITIONS

The definitions in ASME B89.7.1, ISO 13385-1:2011, and JCGM 200 apply in the use of this Standard.

3 REFERENCES

ASME B89.6.2-1973 (R2003), Temperature and Humidity Environment for Dimensional Measurement
ASME B89.7.1-2016, Guidelines for Addressing Measurement Uncertainty in the Development and Application of ASME B89 Standards (Technical Report)
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
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ISO 1:2016, Geometrical product specifications (GPS) — Standard reference temperature for the specification of geometrical and dimensional properties
ISO 13385-1:2011, Geometrical product specifications (GPS) — Dimensional measuring equipment — Part 1: Callipers; Design and metrological characteristics
ISO 14253-5:2015, Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 5: Uncertainty in verification testing of indicating measuring instruments
Publisher: International Organization for Standardization (ISO), Central Secretariat, Chemin de Blandonnet 8, Case Postale 401, 1214 Vernier, Geneva, Switzerland (www.iso.org)

JCGM 100:2008, Evaluation of measurement data — Guide to the expression of uncertainty in measurement (GUM)
JCGM 200:2008, International vocabulary of metrology — Basic and general concepts and associated terms (VIM, third edition)
Publisher: Joint Committee for Guides in Metrology, Bureau International des Poids et Mesures (BIPM), Pavillon de Breteuil, F-92312 Sèvres Cedex, France (www.bipm.org)

4 CALIPER DESIGN

4.1 General

As defined in ISO 13385-1, calipers shall incorporate the use of a movable slider with a measuring jaw that moves along a frame or beam with a stationary jaw to provide outside, inside, and when designed, step and/or depth measurements. The general design and workmanship of calipers shall be such to ensure compliance with the requirements of this Standard and ISO 13385-1 across the measuring range of the caliper and in any orientation, unless otherwise specified by the manufacturer.

4.2 Least Count

(a) Vernier calipers using SI units shall provide readings to a least count of 0.05 mm or 0.02 mm. Dial calipers using SI units shall provide readings to a least count of 0.05 mm, 0.02 mm, or 0.01 mm. Electronic digital calipers using SI units shall provide readings to a least count of 0.01 mm.

(b) Vernier or dial calipers using U.S. Customary units shall provide readings to a least count of 0.001 in. Electronic digital calipers using U.S. Customary units shall provide readings to a least count of 0.001 in. or 0.0005 in.

5 MAXIMUM PERMISSIBLE ERRORS

5.1 General

The maximum permissible errors (MPE) are specified limit values for errors that apply to all measurements permitted for use of the caliper as defined by the manufacturer and following proper operation and zero setting with the outside measuring faces. For general guidance on good operating procedures involving calipers, see Nonmandatory Appendices A and B.

5.2 Operator

Calipers are manually operated indicating measuring instruments and as such the measurement results are dependent on the skill of the operator. All specifications apply when a reasonably skilled operator uses the caliper in a manner consistent with normal operation of the caliper and in accordance with the manufacturer's recommendations.

5.3 Zero Setting

Most calipers are equipped with the ability to adjust the zero point. For calipers with adjustable zero points, the metrological characteristics described in this Standard (see para. 5.10) apply when the outside measuring faces are properly brought into contact with each other for zero setting. For calipers without an adjustable zero, e.g., some vernier calipers, there may be a nonzero error when the outside measuring faces are brought together. This error shall be included in the evaluation of the metrological characteristics without correction.

5.4 Indication

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

5.5 Temperature

All specifications apply at a rated operating condition of 20°C (68°F) unless otherwise specified. The effective nominal coefficient of thermal expansion (CTE) of a caliper in the temperature range 10°C to 30°C shall be $(11.5 \pm 1.0) \times 10^{-6}/°\mathrm{C}$. If not, then the effective nominal CTE with its uncertainty shall be supplied by the manufacturer.

Caliper specifications have a rated operating condition of 20°C (68°F); therefore, the test values observed in a verification test shall be corrected to 20°C (68°F) to obtain the error of indication that the caliper would have produced had the test been performed at 20°C (68°F). If temperature correction to 20°C (68°F) is not performed, this Standard allows the consequences to be included in the evaluation of the measurement uncertainty (see Nonmandatory Appendix C).

5.6 Measurement Uncertainty and Decision Rules

Unless otherwise stated, the default decision rule when determining the conformance of a caliper to specifications is simple 4:1 acceptance in accordance with ASME B89.7.3.1. The measurement uncertainty shall be evaluated in accordance with JCGM 100 (GUM) and ISO 14253-5. An example of determining conformance to specification is shown in Nonmandatory Appendix C, para. C-4.6.

5.7 Traceability

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

5.8 Specifications

Table 5.8-1 lists default MPE values for calipers with a measuring range up to 1 000 mm (40 in.). The MPE values in Table 5.8-1 apply when no specifications are otherwise stated. The caliper manufacturer shall state the MPE values for larger calipers. The caliper manufacturer may also specify different MPE values than shown in this Standard. MPE values stated by the caliper manufacturer shall conform to the terms, definitions, and symbols in this Standard.

Table 5.8-1 includes specifications in both U.S. Customary and SI units. Due to the analog scale interval or digital resolution of a caliper, the conversion between units is not exact. Test values and MPE values shall not be mathematically converted between units when determining conformance to a specification.

5.9 Specialty Calipers

A large variety of specialty calipers are commercially available for measuring items such as tubing, threads, specialized measuring face configurations for use in restricted areas, large diameter measuring faces, spherical shaped measuring faces, and conical measuring faces that allow contact with surfaces that may not be flat or parallel. Specifications for specialty calipers shall be stated by the manufacturer and conform to the terms, definitions, and symbols employed in this Standard and ISO 13385-1.

5.10 Metrological Characteristics

5.10.1 General. ISO 13385-1 describes the important metrological characteristics for calipers. This Standard recognizes the following metrological characteristics as defined in ISO 13385-1:

(a) partial surface contact error, E
(b) repeatability of partial surface contact error, R
(c) line contact error, L
(d) scale shift error, S
(e) error due to crossed knife-edge distance, K

Further description and default test methods for these metrological characteristics are in paras. 5.10.4 through 5.10.8. These test methods provide sufficient testing to demonstrate conformance to specification and do not change the requirements. As such, the test measurands are a finite set of possible errors of indication, and the value of each measurand is estimated by a single test value.

5.10.2 MPE Specifications. Manufacturers of calipers shall state MPE values for the metrological characteristics in para. 5.10.1, and calipers shall conform to the stated

Table 5.8-1 Maximum Permissible Errors of Calipers With Measuring Range Up to 1 000 mm (40 in.)

Measured Length, L		Analog Scale Interval or Electronic Digital Resolution									
		0.0005 in.		0.001 in.		0.01 mm		0.02 mm		0.05 mm	
mm	in.	E_{MPE}, in.	S_{MPE}, in.	E_{MPE}, in.	S_{MPE}, in.	E_{MPE}, mm	S_{MPE}, mm	E_{MPE}, mm	S_{MPE}, mm	E_{MPE}, mm	S_{MPE}, mm
$0 \leq L \leq 50$	$0 \leq L \leq 2$	±0.0010	±0.0010	±0.001	±0.001	±0.02	±0.03	±0.02	±0.04	±0.05	±0.05
$50 < L \leq 100$	$2 < L \leq 4$	±0.0010	±0.0020	±0.001	±0.002	±0.03	±0.05	±0.04	±0.06	±0.05	±0.10
$100 < L \leq 150$	$4 < L \leq 6$	±0.0010	±0.0020	±0.001	±0.002	±0.03	±0.05	±0.04	±0.06	±0.10	±0.10
$150 < L \leq 200$	$6 < L \leq 8$	±0.0015	±0.0020	±0.002	±0.003	±0.03	±0.05	±0.04	±0.06	±0.10	±0.10
$200 < L \leq 300$	$8 < L \leq 12$	±0.0015	±0.0025	±0.002	±0.003	±0.04	±0.06	±0.04	±0.06	±0.10	±0.10
$300 < L \leq 400$	$12 < L \leq 16$	±0.0020	±0.0025	±0.002	±0.003	±0.04	±0.06	±0.04	±0.06	±0.10	±0.10
$400 < L \leq 500$	$16 < L \leq 20$	±0.0020	±0.0030	±0.002	±0.003	±0.05	±0.07	±0.06	±0.08	±0.10	±0.10
$500 < L \leq 600$	$20 < L \leq 24$	±0.0020	±0.0030	±0.002	±0.003	±0.05	±0.07	±0.06	±0.08	±0.15	±0.15
$600 < L \leq 700$	$24 < L \leq 28$	±0.0025	±0.0035	±0.003	±0.004	±0.06	±0.08	±0.06	±0.08	±0.15	±0.15
$700 < L \leq 800$	$28 < L \leq 32$	±0.0025	±0.0035	±0.003	±0.004	±0.06	±0.08	±0.06	±0.08	±0.15	±0.15
$800 < L \leq 1\,000$	$32 < L \leq 40$	±0.0030	±0.0040	±0.003	±0.004	±0.07	±0.09	±0.08	±0.10	±0.15	±0.15

GENERAL NOTE: As discussed in paras. 5.10.4 through 5.10.8, by default, E_{MPE} is the limit value for errors E, R, and L, and S_{MPE} is the limit value for errors S and K.

MPE values. Default MPE values are shown in Table 5.8-1.

The default MPE values in Table 5.8-1 are for calipers with a measuring range up to 1 000 mm (40 in.). These MPE values are a function of the measured length and not the measuring range of the caliper. For larger calipers, the MPE values will increase as the measured length increases. For simplicity in practical use, the MPE values increase in a stepwise manner. During conformance testing, the measured length is considered nominal when determining the MPE values, and the smaller MPE value always applies for test points that are nominally at the transition between the MPE values. For example, if a gage block used for testing is nominally 200 mm, but the calibrated value is 200.01 mm, the MPE for 200 mm still applies.

5.10.3 Test Points. When testing for conformance to the MPE values of the caliper, sufficient test points shall be used to establish confidence in the results. Requirements for test points are found in paras. 5.10.4 through 5.10.8. The user is free to choose the test points within the limits of the requirements.

When considering test points, appropriate consideration shall be given to the caliper design and operating conditions that may indicate the presence of short-length cyclic or local errors. For dial calipers, test points shall be chosen that orient the pointer at various angles within the dial, e.g., the 0-, 90-, 180-, and 270-deg positions.

5.10.4 Partial Surface Contact Error, *E*. The partial surface contact error, E, is the length error of indication when measuring a length standard with small faces, e.g., a gage block, at any position on the outside measuring faces, and at any position within the measuring range of the caliper. This error is calculated as the difference between the caliper indication and the reference value of the measurement standard. By default, the errors shall be compared to the E_{MPE} limit values in Table 5.8-1 when determining conformance.

When testing for conformance to specification, the test points shall be approximately equally distributed across the measuring range of the caliper with a minimum number of test points in accordance with Table 5.10.4-1. At least one test point shall be at a minimum of 90% of the measuring range.

The test points shall be located on the measuring faces of the caliper at different distances from the beam. See Figure 5.10.4-1. The partial surface contact errors intentionally detect a combination of the caliper scale errors as well as the parallelism and flatness of the outside measuring faces.

5.10.5 Repeatability of Partial Surface Contact Error, *R*. The repeatability of the partial surface contact error, R, is the closeness of agreement between the results of successive measurements of the partial surface contact error at any one position on the outside measuring faces under the same conditions of measurement. The repeatability is calculated as the maximum difference (range) between three repeat readings observed at any one of the test points, including the same nominal test point and same nominal location on the measuring faces.

Since the specified MPE values of a caliper apply to any and all reasonable measured indications, repeatability issues are included in the test for the partial surface contact error using the outside measuring faces. There may be times where a specific assessment of the repeatability is useful. This is particularly the case where an issue with repeatability is observed during testing of the partial surface contact error.

Table 5.10.4-1 Number of Test Points for E_{MPE}

Measuring Range, M		Minimum Number of Test Points
mm	in.	
$0 \le M \le 150$	$0 \le M \le 6$	3
$150 < M \le 300$	$6 < M \le 12$	4
$300 < M \le 1\,000$	$12 < M \le 40$	5

GENERAL NOTE: For example, test points of 100, 200, 300, 400, and 550 mm would satisfy the test point requirements for a caliper with a measuring range of 600 mm.

If not otherwise stated, the limit value for repeatability error, *R*, shall be equal to the range of the stated E_{MPE} limit values, e.g., if $E_{MPE} = \pm 0.03$ mm, then the MPE for *R* is 0.06 mm. By default, repeatability error, *R*, shall be compared to the range of the E_{MPE} limit values in Table 5.8-1 when determining conformance.

5.10.6 Line Contact Error, *L*. The line contact error, *L*, is the error of indication when measuring a small cylindrical measurement standard, e.g., a pin gage, at any position across the outside measuring faces. This error is calculated as the maximum difference (range) between the line contact errors observed at any position on the outside measuring faces and at the same nominal position in the measuring range of the caliper.

If not otherwise stated, the limit value for line contact error, *L*, shall be equal to the range of the stated E_{MPE} limit values, e.g., if $E_{MPE} = \pm 0.02$ mm, then the MPE for *L* is 0.04 mm. By default, line contact error, *L*, shall be compared to the range of the E_{MPE} limit values in Table 5.8-1 when determining conformance.

The line contact error detects the effects of the parallelism of the outside measuring faces as well as any flatness error or localized wear. When testing for conformance to specification, the line contact error shall be tested at one position in the measuring range of the caliper. This is done by placing a small cylindrical measurement standard between the jaws as near as possible to the caliper's beam, and then slowly moving the measurement standard towards the opposite end of the jaws while carefully observing the caliper readings. See Figure 5.10.6-1. The range of the readings is the line contact error.

Prior to testing for line contact error, assessment of the possibility of wear or parallelism issues by bringing the outside measuring faces together and observing any light gap between the two measuring faces is recommended. If wear or parallelism is not suspected, then additional testing of the line contact error with the cylindrical measurement standard may not be necessary.

5.10.7 Scale Shift Error, *S*. The scale shift error, *S*, is the error of indication when using measuring faces other than the outside measuring faces. After following proper operation and zero setting with the outside measuring faces, this error is calculated as the difference between the caliper indication and the reference value of a measurement standard when using any of the other available measuring faces, e.g., inside, step, and depth measurement. By default, the errors are compared to the S_{MPE} limit values in Table 5.8-1 when determining conformance.

After testing the partial surface contact errors, *E*, using the outside measuring faces, the scale shift error, *S*, shall be tested for conformance to specification for any other measuring faces, e.g., inside, step, or depth measurement, with at least one test point.

The scale shift error for inside measurement is defined for measured lengths over 20 mm (0.75 in.) and shall be tested using an appropriate inside measurement standard, e.g., a ring gage, a specially designed caliper checker, or a gage block stack with appropriate jaws. See Figure 5.10.7-1. By default, the test point shall be between 20 mm and 50 mm (0.75 in. and 2 in.).

The scale shift error using the depth or step measurement functions shall be tested using an appropriate length standard located on a reference surface, e.g., a gage block on a surface plate. See Figures 5.10.7-2 and 5.10.7-3. By default, the test point shall be less than 50 mm (2 in.).

5.10.8 Effect Due to Crossed Knife-Edge Distance, *K*. An additional error of indication may occur when small cylindrical holes are measured on a caliper that has crossed knife-edge internal measuring faces. See Figure 5.10.8-1. This error, *K*, is treated as another type of scale shift error that applies when measuring an internal cylindrical measurement standard, e.g., a ring gage.

If not otherwise stated, for calipers with a measuring range up to and including 300 mm (12 in.), the limit value for the error due to the crossed knife-edge distance, *K*, shall be equal to the stated S_{MPE} limit values for measured lengths (diameters) from 5 mm to 300 mm (0.2 in. to 12 in.). By default, the values for *K* shall be compared to the S_{MPE} limit values in Table 5.8-1 when determining conformance.

When testing for conformance to specification, a single test point is required. The default test point shall be at nominally 5 mm (0.2 in.) in diameter. See Figure 5.10.8-2.

In this Standard, calipers with measuring ranges over 300 mm (12 in.) and crossed knife-edge internal measuring faces are not rated for the measurement of internal diameters smaller than 20 mm (0.75 in.).

Figure 5.10.4-1 Testing Partial Surface Contact Error — Example Test Points on Two Calipers Showing Different Lengths and Different Distances From the Beam

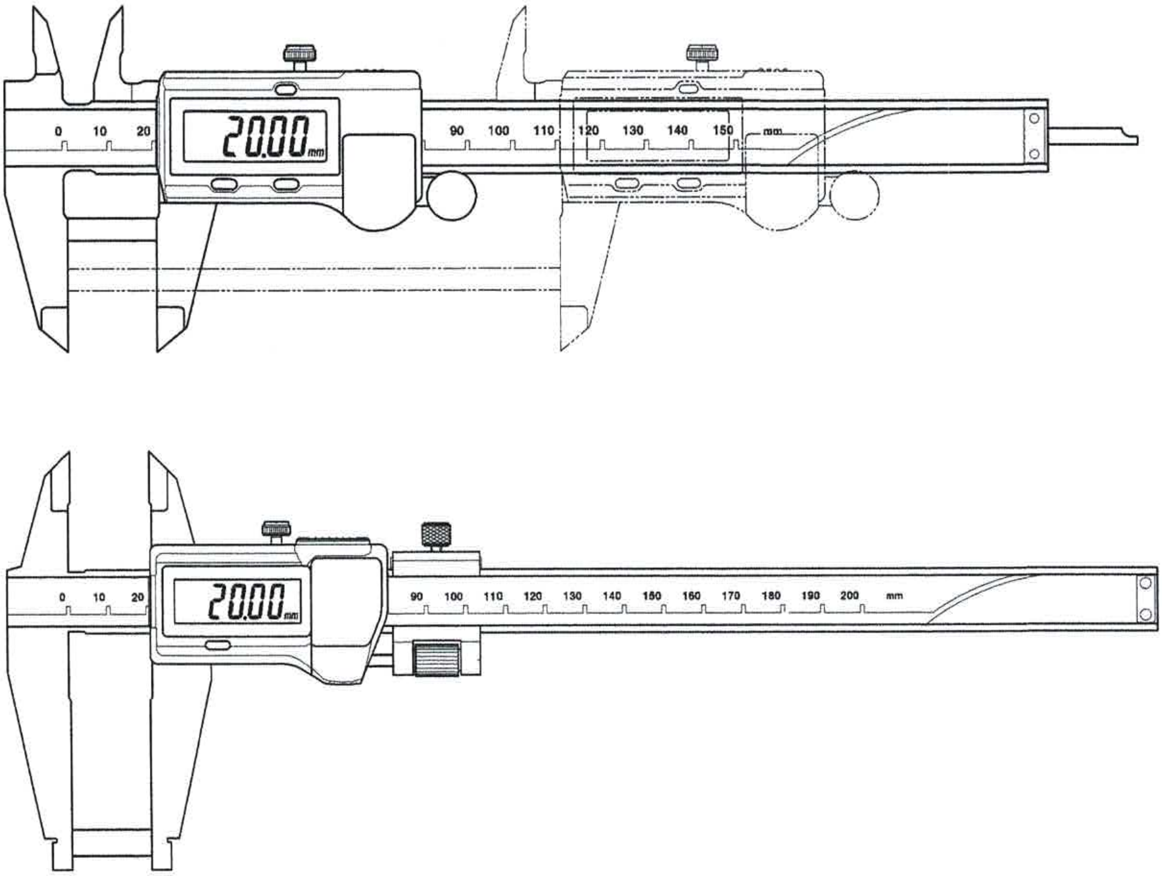


Figure 5.10.6-1 Testing Line Contact Error

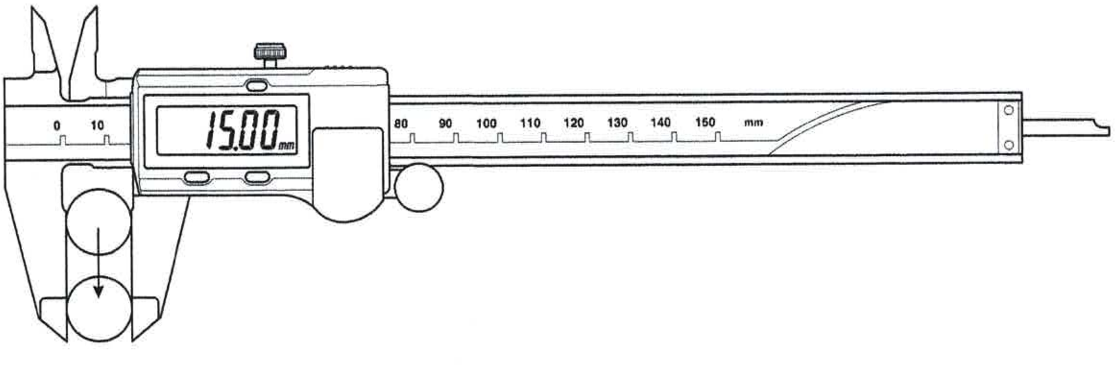


Figure 5.10.7-1 Testing Scale Shift Error — Inside Measurement

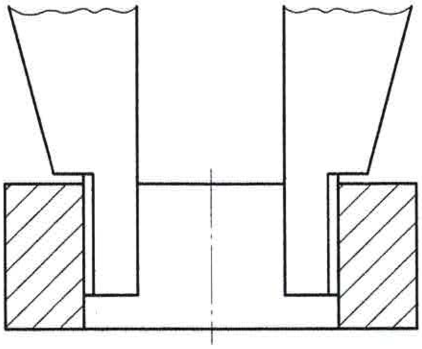


Figure 5.10.7-2 Testing Scale Shift Error — Depth Measurement

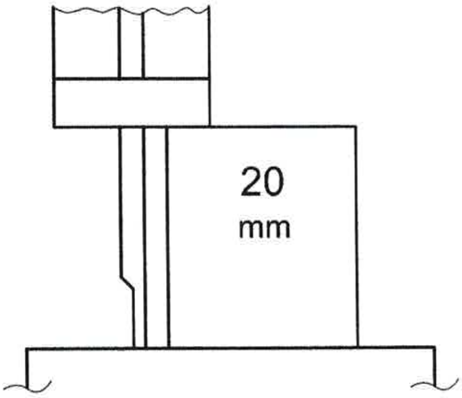


Figure 5.10.7-3 Testing Scale Shift Error — Step Measurement

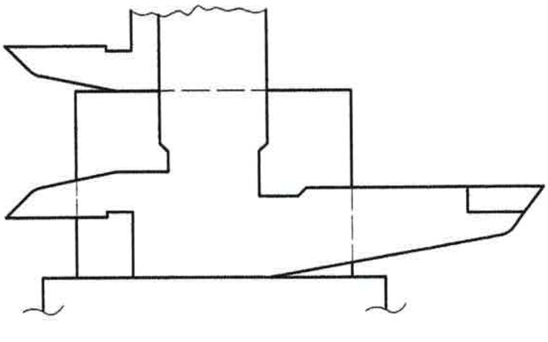


Figure 5.10.8-1 Effect of Crossed Knife-Edge Internal Measuring Faces

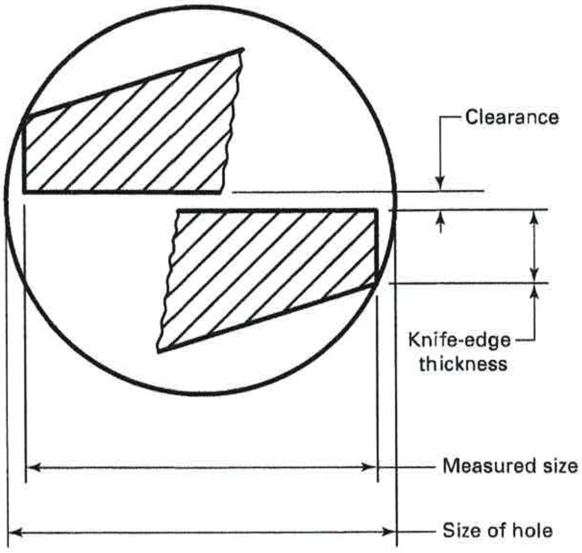
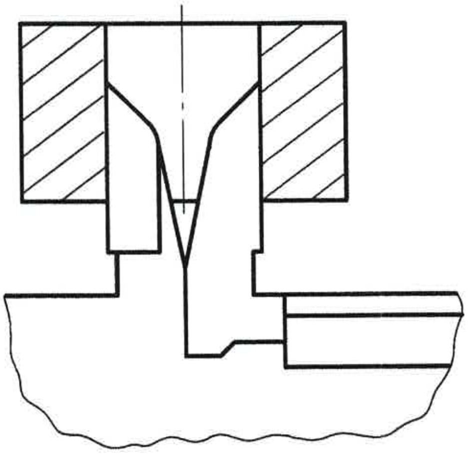


Figure 5.10.8-2 Testing Scale Shift Error — Internal Measurement With Crossed Knife-Edge



NONMANDATORY APPENDIX A
GOOD OPERATING PROCEDURES

A-1 GENERAL

This Appendix provides general guidance on good operating procedures involving calipers.

A-1.1 Preparation

The measuring faces should be inspected for any damage or excessive wear and thoroughly cleaned. Verify smooth movement of the slide along the bar. The zero reading of the measuring faces should be checked.

A-1.2 Cleaning

Prior to use, and again after use and prior to storage, measuring instruments should be cleaned to remove contaminants. Clean the measuring faces by inserting lint-free paper between them, lightly close, and pull the paper through. Calipers can be cleaned by using a soft brush or clean cloth and solvent. Care should be taken to prevent trapping of solvent in holes or crevices. Avoid spraying solvent directly on the dial or electronic digital display.

A-1.3 Preservation

For storage, shipment between facilities, or shipment from a facility to a calibration laboratory, measuring instruments should be coated with a corrosion preventative as soon as possible after cleaning operations. The corrosion preventative to be used will depend on the type of measuring instrument being stored or shipped. An approved rust-preventative (light, medium, or heavy) should be used. Close-tolerance gauging surfaces should be coated with an approved light preservative. Store the caliper with a gap between the outside measuring faces.

A-1.4 Fine Adjustment

Seat the measured part on the reference face, centralizing the part between the measuring faces. Apply minimum, consistent force at the thumb roller or fine adjustment nut. Better accuracy and repeatability can be obtained when the thumb roller or fine adjustment is used properly.

A-1.5 Locking Device

When proper reading of the instrument is hindered, the locking device should be used to preserve the reading until the tool can be read under better conditions.

A-1.6 Optional Support

When using larger calipers and more accurate measurements are required, the use of a supporting stand is recommended. This allows the operator to have both hands free and generally increases the accuracy and repeatability of measurements.

A-2 VERNIER CALIPER

A-2.1 Zero Setting

Prior to taking measurements, the zero point of the caliper must be established. Clean the measuring faces and close them by applying minimum, consistent force at the thumb roller or fine adjustment nut. Observe the graduations, and make sure the vernier plate zero lines are matched to the bar's graduation. If not, the vernier plate may be adjusted to read zero. Usually, the vernier plate does not have to be reset after the initial setting.

A-2.2 How to Read a Vernier Caliper

The following process should be used to correctly read a vernier caliper:

Step 1: From the zero (0) line on the vernier plate, read the whole units of measure from the main scale, on the bar, to the left of the zero (0) line.

Step 2: Add the partial units of measure, if any, from the last whole unit on the main scale, on the bar, to the left of the zero (0) line of the vernier plate.

Step 3: Add the value of the units from the vernier plate line that corresponds to the vernier line that best aligns (coincident) to any line on the adjacent main scale, on the bar.

Step 4: Add the values from Steps 1, 2, and 3 for the total value of the measurement.

A-3 DIAL CALIPER

A-3.1 Zero Setting

Prior to taking measurements, the zero point of the caliper must be established. Clean the measuring faces and close them by applying minimum, consistent force at the thumb roller or fine adjustment nut. Observe the dial graduations, and make sure the hand lines up with the zero graduation. If not, the dial and bezel can be rotated to align zero by hand. The zero can be reset by adjusting the bezel to a preset position or to a standard, so the dial will read the deviation from this position.

A-3.2 How to Read a Dial Caliper

The following process should be used to correctly read a dial caliper:

Step 1: Read the whole units of measure from the main scale bar to the left of the movable slide reference point.

Step 2: Add the value of units from the dial scale line that lines up best with the dial hand or pointer.

Step 3: Add the values from Steps 1 and 2 for the total value of measurement.

A-4 ELECTRONIC DIGITAL CALIPER

A-4.1 Zero Setting

Prior to taking measurements, the zero point of the caliper must be established. Clean the measuring faces and close them by applying minimum, consistent force at the thumb roller or fine adjustment nut. Observe the digital display and confirm zero set or reset zero for the appropriate measurement mode as determined by the instrument design. The tool may have an absolute (ABS) mode for direct measurement, which requires a fixed origin, zero setting at the jaws-closed position. The incremental (INC) mode allows a floating zero to be set at any position along the range for comparison measurement.

A-4.2 How to Read an Electronic Digital Caliper

Read the display directly in units of measure, observing the mode of the tool's readout.

NONMANDATORY APPENDIX B
ENVIRONMENTAL CONSIDERATIONS

B-1 GENERAL

This Appendix provides general guidance and awareness regarding the environmental considerations involving the use of vernier, dial, and electronic digital calipers.

B-2 TEMPERATURE

B-2.1 Reference Temperature

Whenever precision measurements are made, the temperature should be as close to the standard reference temperature of 20°C (68°F) as possible. Since standards and measuring instruments usually are made of steel, they have the same nominal coefficient of expansion. For caliper measurements, control of thermal gradients and temperature stability are often the most important considerations for reliable measurement. Measurement applications should consider a reasonable operating policy for maximum deviation from standard temperature and maximum temperature gradient.

B-2.2 Heat Transfer

The amount of heat transfer due to the operator handling measuring instruments or measured parts should always be considered. The longer the operator handles items, the greater the potential for temperature differences. The amount of heat transferred can be minimized by using gloves, stands to isolate the measuring instruments, a normalizing plate, air circulation, or other means to thermally stabilize the measured part or the measuring instrument from the operator.

B-2.3 Working Temperature

When measuring instruments are used in production shops, working temperatures are seldom at the standard reference temperature. If the measuring instrument is accurate at the standard reference temperature, and if the coefficients of thermal expansion of both the measured part and measuring instrument are approximately the same, the effect of the deviation from 20°C (68°F) is less than if the measured part and measuring instrument 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 caliper (typically steel), an allowance for temperature differences, with reference to 20°C (68°F), must be considered and applied if necessary.

B-2.5 Soak Time

Measuring instruments should be stored in a constant temperature room before they are calibrated to ensure they are nearly the same temperature as the measurement laboratory. The amount of soak time required depends on the size, shape, and mass of the measuring instrument along with the conditions of measurement and the desired accuracy. See ASME B89.6.2 for further information and example of estimating soak-out time.

B-3 HUMIDITY

The relative humidity of the atmosphere in a calibration laboratory should preferably be kept at a level that would minimize the possibility of corrosion. In general, the air-conditioning system of a laboratory should remain in operation at all times because elevated humidity causes corrosion and delays occur while measuring instruments reach thermal equilibrium with the laboratory that is reopened.

B-4 CLEANLINESS

Cleanliness is an important requirement for a good calibration laboratory. Contamination and spurious particles cause serious errors in precision measurements, bring about excessive wear of precision instruments, and degrade instrument performance.

NONMANDATORY APPENDIX C
MEASUREMENT UNCERTAINTY

C-1 GENERAL

This Appendix provides general guidance and awareness regarding the determination and application of measurement uncertainty when verifying the conformance of a caliper to stated specifications. The example given is for guidance only. The actual uncertainties will be different for each laboratory. The measurement uncertainty when using a caliper, e.g., to measure manufactured workpieces, is not within the scope of this Standard but is discussed in ASME B89.7.3.2.

C-2 SOURCES OF ERROR

Common sources of error in mechanical calibrations include the uncorrected error and uncertainty in the master, repeatability, resolution, reproducibility, 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 measurement uncertainty in the calibration or verification of a caliper.

C-3 COMMON PRACTICES

C-3.1 General

The uncertainty budget presented in this Appendix is based on common practices used in the calibration of calipers. Other approaches may result in different uncertainty contributors and values.

C-3.2 Performance Verification

This uncertainty budget is based on performance verifications, where the measured errors are compared to the specification of the caliper and are not assigned values used as correction factors in later use of the caliper. In performance verification, each test value is an estimate of a different measurand that is the observed error of indication of the caliper at the moment of testing, obtained at, or corrected to, the rated operating condition of 20°C (68°F). The measurement uncertainty addresses the uncertainty in the test value and does not address the comprehensiveness of the test. In this manner, the instrument errors including any inherent repeatability are part of what is being tested and not included in the uncertainty.

For this example, it is assumed that a reasonably skilled operator is performing the verification test (this assumption may not be valid in all cases), and therefore no uncertainty contribution from the operator is included in the performance verification uncertainty statement because operator effects appear (hence are accounted for) in the observed error of indication.

C-3.3 Gage Block Size

In this example, 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.

C-3.4 Temperature Correction

Calipers are often tested 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, which must be addressed in the uncertainty, as shown in the example in section C-4.

C-4 EXAMPLE UNCERTAINTY BUDGET

C-4.1 Digital Caliper

An example uncertainty budget for the performance verification of the partial surface contact error, E_{MPE}, on a 0-mm to 150-mm digital caliper is shown in Table C-4.1-1. In this example, the error of indication of the caliper is measured using calibrated gage blocks. The following assumptions and conditions apply:

(a) measured length: 150 mm
(b) caliper resolution: 0.01 mm
(c) temperature range: 20°C ± 2°C
(d) temperature difference: 0.5°C
(e) caliper CTE: 11.5×10^{-6}/°C ± 10%
(f) gage block CTE: 10.2×10^{-6}/°C ± 5%
(g) gage block tolerance: Grade 0 (±0.4 μm)

The temperatures of the caliper and gage block are assumed to be within the above temperature range during the verification test. The difference between the temperatures of the caliper and gage block is assumed to not exceed the above limit for the temperature difference.

C-4.2 Reference Standard

The calibrated values of the gage blocks are not used, and it is assumed that the blocks are within the tolerances for a Grade 0 set. A rectangular distribution is assumed with a limit of 0.4 µm.

C-4.3 Deviation from Reference Temperature

C-4.3.1 General Equation. The standard reference temperature for dimensional measurements is 20°C (68°F). The uncertainty in correcting the caliper and gage blocks to 20°C (68°F) due to the uncertainty in knowing the coefficient of thermal expansion can be expressed by the following equation:

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

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

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

C-4.3.2 Uncertainty in Nominal CTE. There is some uncertainty in the CTE of any material. For this example, the gage blocks and caliper are made from different types of steel. The caliper has a CTE of 11.5×10^{-6}/°C, which is assumed to be within ±10%. The gage blocks have a CTE of 10.2×10^{-6}/°C, which is stated by the manufacturer to be within ±5%.

(a) Applying the equation in para. C-4.3.1 for the caliper CTE:

$$\Delta L = (150\text{ mm})(2°\text{C})(1.15 \times 10^{-6}/°\text{C}) = 0.35\ \mu\text{m}$$

(b) Applying the equation in para. C-4.3.1 for the gage block CTE:

$$\Delta L = (150\text{ mm})(2°\text{C})(0.51 \times 10^{-6}/°\text{C}) = 0.15\ \mu\text{m}$$

The distributions are assumed to be rectangular for the purposes of this example.

C-4.3.3 Nominal CTE Difference. If the nominal CTEs of the caliper and gage blocks are different, as in this example, then the following equation is applicable:

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

where
α_C = nominal CTE of the caliper
α_{GB} = nominal CTE of the gage block

Based on the values in para. C-4.1,

$$\Delta\alpha = \left|11.5 - 10.2\right| = 1.3 \times 10^{-6}/°\text{C}$$

and applying this to the equation in para. C-4.3.1,

$$\Delta L = (150\text{ mm})(2°\text{C})(1.3 \times 10^{-6}/°\text{C}) = 0.39\ \mu\text{m}$$

The distribution is assumed to be rectangular for the purposes of this example.

C-4.4 Temperature Difference

It is determined that due to handling, the temperatures of the caliper and the gage blocks could be as much as 0.5°C apart. The uncertainty caused by this temperature difference can be expressed as:

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

where
L = nominal length
α = average CTE of the gage blocks and caliper
Δt = difference in temperature between the gage blocks and caliper

Based on the values in para. C-4.1,

$$\Delta L = (150\text{ mm})(0.5°\text{C})(10.85 \times 10^{-6}/°\text{C}) = 0.81\ \mu\text{m}$$

The distribution is assumed to be rectangular for the purposes of this example.

C-4.5 Combined and Expanded Uncertainty

Using the values determined in paras. C-4.2, C-4.3.2, C-4.3.3, and C-4.4, the associated standard uncertainties are estimated as shown in Table C-4.1-1. The combined uncertainty, u_c, is then calculated as follows:

$$\begin{aligned} u_c &= \left(0.23^2 + 0.20^2 + 0.09^2 + 0.23^2 + 0.47^2\right)^{1/2} \\ &= 0.61\ \mu\text{m} \end{aligned}$$

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

$$U = 2u_c = 1.2\ \mu\text{m}$$

C-4.6 Conformance Test (Application of Decision Rule)

The maximum permissible partial surface contact error listed in Table 5.8-1 for a 150-mm measured length is 0.030 mm. 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 25% of the MPE value. In this case, the uncertainty of 1.2 µm is only 4% 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

Table C-4.1-1 Uncertainty Budget for Performance Verification of the Partial Surface Contact Error for a 0-mm to 150-mm Digital Caliper

Uncertainty Source	Estimated Limit, μm	Type	Distribution	Divisor	Standard Uncertainty, μm
Gage block tolerance	0.40	B	Rectangular	1.73	0.23
Uncertainty in caliper CTE	0.35	B	Rectangular	1.73	0.20
Uncertainty in gage block CTE	0.15	B	Rectangular	1.73	0.09
Nominal CTE difference	0.39	B	Rectangular	1.73	0.23
Temperature difference	0.81	B	Rectangular	1.73	0.47

GENERAL NOTE: The expanded (k = 2) uncertainty is equal to 1.2 μm.

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.

C-5 CONCLUSION

The format for an uncertainty budget does not need to be as shown in Table C-4.1-1. It is only necessary to list the sources of uncertainty and the standard uncertainties, and explain how they were obtained. The table may contain two columns or as many as are needed.

B89 AMERICAN NATIONAL STANDARDS FOR DIMENSIONAL METROLOGY AND CALIBRATION OF INSTRUMENTS

B89-1990	Space Plate Test Recommendations for Coordinate Measuring Machines (Technical Paper)
B89 Report-1990	Parametric Calibration of Coordinate Measuring Machines (Technical Paper)
B89.1.2M-1991	Calibration of Gage Blocks by Contact Comparison Methods (Through 20 in. and 500 mm)
B89.1.5-1998 (R2014)	Measurement of Plain External Diameters for Use as Master Discs or Cylindrical Plug Gages
B89.1.6-2002 (R2017)	Measurement of Plain Internal Diameters for Use as Master Rings or Ring Gages
B89.1.7-2009 (R2014)	Performance Standard for Steel Measuring Tapes
B89.1.8-2011 (R2016)	Performance Evaluation of Displacement-Measuring Laser Interferometers
B89.1.9-2002 (R2012)	Gage Blocks
B89.1.10M-2001 (R2016)	Dial Indicators (for Linear Measurements)
B89.1.13-2013	Micrometers
B89.1.14-2018	Calipers
B89.1.17-2001 (R2017)	Measurement of Thread Measuring Wires
B89.3.1-1972 (R2003)	Measurement of Out-of-Roundness
B89.3.4-2010 (R2015)	Axes of Rotation: Methods for Specifying and Testing
B89.3.7-2013	Granite Surface Plates
B89.4.1-1997	Methods for Performance Evaluation of Coordinate Measuring Machines
B89.4.10-2000 (R2011)	Methods for Performance Evaluation of Coordinate Measuring System Software
B89.4.19-2006 (R2015)	Performance Evaluation of Laser-Based Spherical Coordinate Measurement Systems
B89.4.22-2004 (R2014)	Methods for Performance Evaluation of Articulated Arm Coordinate Measuring Machines
B89.4.10360.2-2008 (R2012)	Acceptance Test and Reverification Test for Coordinate Measuring Machines (CMMs) – Part 2: CMMs Used for Measuring Linear Dimensions
B89.6.2-1973 (2017)	Temperature and Humidity Environment for Dimensional Measurement
B89.7.1-2016	Guidelines for Addressing Measurement Uncertainty in the Development and Application of ASME B89 Standards (Technical Report)
B89.7.2-2014	Dimensional Measurement Planning
B89.7.3.1-2001 (R2011)	Guidelines for Decision Rules: Considering Measurement Uncertainty in Determining Conformance to Specifications
B89.7.3.2-2007 (R2016)	Guidelines for the Evaluation of Dimensional Measurement Uncertainty (Technical Report)
B89.7.3.3-2002 (R2017)	Guidelines for Assessing the Reliability of Dimensional Measurement Uncertainty Statements
B89.7.4.1-2005 (R2016)	Measurement Uncertainty and Conformance Testing: Risk Analysis (Technical Report)
B89.7.5-2006 (R2016)	Metrological Traceability of Dimensional Measurements to the SI Unit of Length (Technical Report)

The ASME Publications Catalog shows a complete list of all the Standards published by the Society. For a complimentary catalog, or the latest information about our publications, call 1-800-THE-ASME (1-800-843-2763).

ASME Services

ASME is committed to developing and delivering technical information. At ASME's Customer Care, we make every effort to answer your questions and expedite your orders. Our representatives are ready to assist you in the following areas:

- ASME Press
- *Codes & Standards*
- Credit Card Orders
- IMechE Publications
- Meetings & Conferences
- Member Dues Status
- Member Services & Benefits
- Other ASME Programs
- Payment Inquiries
- Professional Development Short Courses
- Publications
- Public Information
- Self-Study Courses
- Shipping Information
- Subscriptions/Journals/Magazines
- Symposia Volumes
- Technical Papers

How can you reach us? It's easier than ever!

There are four options for making inquiries* or placing orders. Simply mail, phone, fax, or E-mail us and a Customer Care representative will handle your request.

Mail
ASME
150 Clove Road, 6th Floor
Little Falls, New Jersey
07424-2139

Call Toll Free
US & Canada: 800-THE-ASME
(800-843-2763)
Mexico: 95-800-THE-ASME
(95-800-843-2763)

Fax—24 hours
973-882-1717
973-882-5155

E-Mail—24 hours
customercare@asme.org

---

*Customer Care staff are not permitted to answer inquiries about the technical content of this code or standard. Information as to whether or not technical inquiries are issued to this code or standard is shown on the copyright page. All technical inquiries must be submitted in writing to the staff secretary. Additional procedures for inquiries may be listed within.

ASME B89.1.14-2018

ISBN 978-0-7918-7206-2

9 780791 872062

L 0 9 1 1 Q