ASME B89.1.9-2023

[Revision of ASME B89.1.9-2002 (R2012)]

Gage Blocks

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AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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FOREWORD

The U.S. gage block standard has not changed substantively since Federal Specification GGG-G-15C of 1975. During the intervening years, there have been several very important shifts in the use of gage blocks, a large growth of internationalization in design and manufacture of parts, and even changes to basic concepts like uncertainty and traceability. With all of these factors in mind, the ASME B89.1.9 Committee began to consider a total rewrite of ASME B89.1.9 in the early 1990s. The basic criteria were to adhere as closely as possible to the International Standard ISO 3650 while making necessary additions to adapt ISO 3650 to measuring practice in the United States.

ASME B89.1.9 includes specifications for inch system gage blocks as well as metric system gage blocks. The International Standard defines only rectangular gage blocks, yet the United States also has a significant number of square hoke-style blocks. Since the grades in this Standard have some of the same designations as the GGG-G-15C standard, the prefix "AS" (American Standard) was added to the names of Grades 1 and 2 to prevent misidentification. A Grade 00 was also added with tolerances near those of the Grade 1 per GGG-G-15C. While the committee basically agreed with the logic behind the ISO 3650 grade tolerances, it was also recognized that the use of graded sets is deeply embedded in some industries, and the loss of the high-accuracy grade would be a hardship for some users.

ASME B89.1.9 includes nine Nonmandatory Appendices. Most of these appendices have information that is not in the current ISO 3650 but was in GGG-G-15C or previous editions of ASME B89.1.9. The most important of these is Nonmandatory Appendix A, which describes the differences between this Standard and its predecessors.

ASME B89.1.9-2023 significantly revises ASME B89.1.9-2002 (R2012). Discussion of gage block accessories has been moved from an appendix to the body of the Standard. As with other ASME B89 standards, the default decision rule has been implemented, and the measurement uncertainty discussion has been updated to include additional sources of error to provide a more complete example. Additionally, this Standard contains a new Nonmandatory Appendix H covering the contact measuring instrument. The addition of Nonmandatory Appendix H eliminates the reliance of this Standard on ASME B89.1.2M, as all necessary information is now contained in this Standard.

The committee would like to acknowledge the many people who, while not members of the committee, were kind enough to attend an occasional meeting or send comments on the early drafts of this Standard. These interactions increased the committee's knowledge of actual gage block use in industry and were very important in drafting the changes made to ISO 3650 to correspond to U.S. practice.

This Standard was approved by the American National Standards Institute (ANSI) on February 23, 2023.

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Gage Blocks

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(2) to provide alternative requirements

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GAGE BLOCKS

1 INTRODUCTION

Gage blocks are length standards representing specific lengths, traceable to the meter, of the International System of Units (SI). Depending on the kind of application and the required quality, gage blocks are offered in several grades. The calibration of gage blocks includes the measurement of the length value at a specified point of the measuring face and the evaluation of the measurement uncertainty.

2 SCOPE

This Standard specifies the most important design and metrological characteristics of gage blocks with a rectangular or square cross section and a nominal length, l_n, ranging from 0.1 mm to 1 000 mm for metric sizes and 0.004 in. to 40 in. for inch sizes. It is not the intent of this Standard to preclude the use, by contractual agreement, of gage blocks of other shapes, grades, or materials.

Limit deviations and tolerances are stated for the calibration Grade K and the Grades 00, 0, AS-1, and AS-2 for various measuring purposes.

NOTE: The characteristics of Grades K, 0, AS-1, and AS-2 are identical to those of the same name in ISO 3650:1998, with the exception that in this Standard, the length of the block is defined when measured in the vertical orientation.

3 NORMATIVE REFERENCES

The following standards contain provisions that, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. The American National Standards Institute (ANSI) maintains registers of currently valid International Standards and U.S. National Standards.

ASME B46.1. Surface Texture (Surface Roughness, Waviness, and Lay). The American Society of Mechanical Engineers.

ASME B89.7.1. Guidelines for Addressing Measurement Uncertainty in the Development and Application of ASME B89 Standards. The American Society of Mechanical Engineers.

ASME B89.7.3.1. Guidelines for Decision Rules: Considering Measurement Uncertainty in Determining Conformance to Specifications. The American Society of Mechanical Engineers.

ASME B89.7.3.2. Guidelines for the Evaluation of Dimensional Measurement Uncertainty. The American Society of Mechanical Engineers.

ASME B89.7.4.1. Measurement Uncertainty and Conformance Testing: Risk Analysis. The American Society of Mechanical Engineers.

ASME B89.7.5. Metrological Traceability of Dimensional Measurements to the SI Unit of Length. The American Society of Mechanical Engineers.

ASME Y14.5. Dimensioning and Tolerancing. The American Society of Mechanical Engineers.

ASTM E18-20. Standard Test Methods for Rockwell Hardness of Metallic Materials. The American Society for Testing and Materials.

ASTM E140-12b(2019)e1. Standard Hardness Conversion Tables for Metals. The American Society for Testing and Materials.

Engineering Metrology Toolbox (2023). National Institute of Standards and Technology. https://emtoolbox.nist.gov

ISO 1. Standard reference temperature for industrial length measurements. International Organization for Standardization.

ISO 3650:1998. Gauge Blocks. International Organization for Standardization.

ISO 6507-1. Metallic materials — Vickers hardness test — Part 1: Test method. International Organization for Standardization.

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ISO/IEC 17025. General Requirements for the Competence of Testing and Calibration Laboratories. International Organization for Standardization.
JCGM 100:2008. Evaluation of measurement data — Guide to the expression of uncertainty in measurement. Joint Committee for Guides in Metrology.
JCGM 200:2012. International Vocabulary of Metrology — Basic and general concepts and associated terms. Joint Committee for Guides in Metrology.
Resolution 1 of the 17th General Conference of Weights and Measures (1983). International Bureau of Weights and Measures. https://www.bipm.org/en/committees/cg/cgpm/17-1983/resolution-1

4 DEFINITIONS

4.1 Gage Block

A gage block is a block of rectangular or square section, made of wear-resistant material, with one pair of planar, mutually parallel measuring faces. The measuring faces shall have surfaces that can be wrung (see para. 4.7) to the measuring faces of other gage blocks to make composite assemblies or to similarly textured surfaces of auxiliary plates for length measurements.

4.2 Length of a Gage Block, l

The length of a gage block at a particular point of the measuring face is the perpendicular distance between this point and the planar surface of an auxiliary plate of the same material and surface texture on which the other measuring face has been wrung (see para. 4.4 and Figures 4.2-1 and 4.2-2).

The length of a gage block, l, includes the effect of one face wringing (see para. 9.3.1).

NOTE: The length, l, is a physical quantity consisting of a numerical value and a length unit (e.g., meter, inch). If only the numerical value is treated (e.g., in tables), the units should be stated explicitly.

4.3 Gage Length of a Gage Block, l_g

4.3.1 Gage Length of a Rectangular Gage Block. The gage length, l_g, of a rectangular gage block is the length of a gage block taken at the reference point. For rectangular gage blocks, the reference point is taken at the center of the free measuring face (see Figure 4.2-1).

NOTE: Gage length, l_g, is a special instance of length, l.

4.3.2 Gage Length of a Square Gage Block. The gage length, l_g, of a square gage block is the length of a gage block taken at the reference point, midway between the hole or outer edge of the countersink and the edge of the block nearest to the size marking. If the size marking is on the side of the block, the top of the block is either above or to the right of the marking, depending on the orientation of the writing. If the block is marked on the top gaging surface, the reference point is located midway between the hole and the edge of the block to the right of the size marking (see Figure 4.2-2).

4.4 Deviation of the Length at Any Point From Nominal Length, e

The deviation of the length, e, at any point from the nominal length, l_n, is the algebraic difference $l - l_n$.

4.5 Deviation From Flatness, f_d

The deviation from flatness, f_d, is the minimum distance between two parallel planes between which all points of the measuring face lie (see Figure 4.5-1).

4.6 Variation in Length, v

The variation in length, v, is the difference between the maximum length, l_{max}, and the minimum length, l_{min}. It is equal to the sum of the deviations f_0 and f_u from the gage length, l_g (see Figure 4.6-1).

4.7 Wringing

Wringing is the property of the measuring faces of gage blocks to adhere to other measuring faces or to faces with similar surface texture as a result of molecular forces (see Nonmandatory Appendix E, section E-5).

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Figure 4.2-1
Gage Length, l_g, and Another Example for Length, l, at Any Point of a Gage Block Wrung to the Plane Surface of an Auxiliary Plate

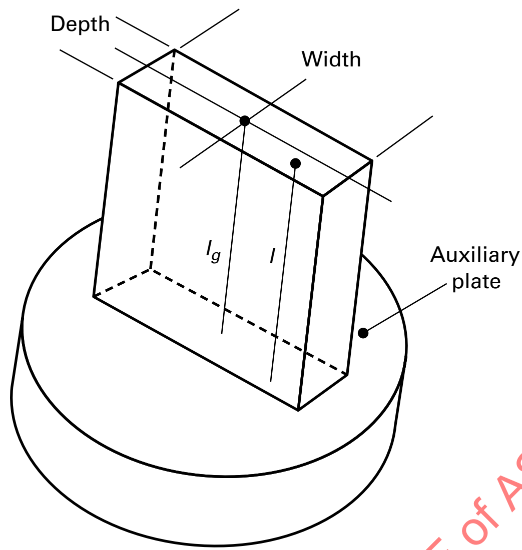

Figure 4.2-2
Reference Points of Square Gage Blocks

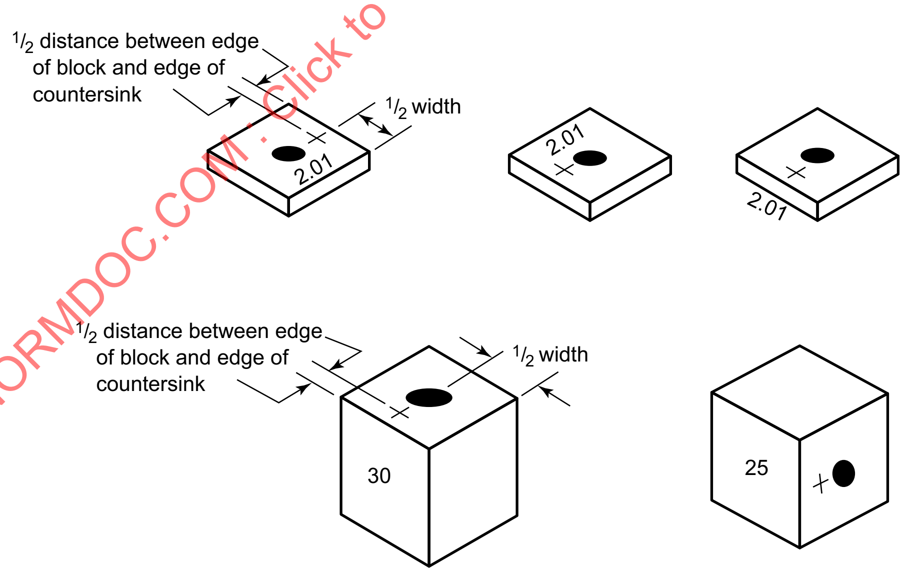

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Figure 4.5-1
Deviation From Flatness, f_d

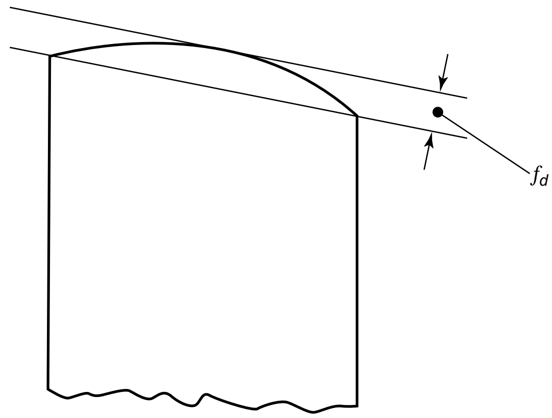
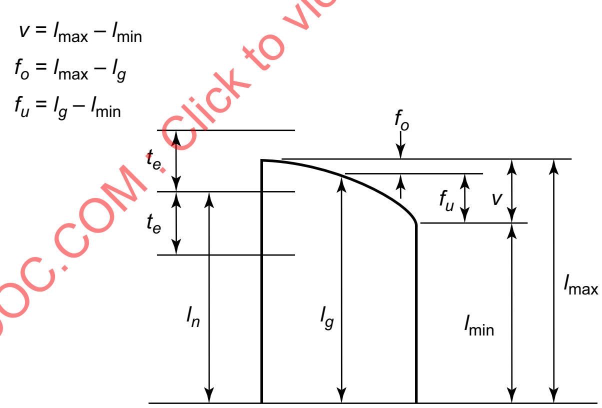


Figure 4.6-1
Nominal Length, l_n; Gage Length, l_g; Variation, v, With f_o and f_u; and Limit Deviations, t_e, for Length at Any Point, Proceeding From the Nominal Length



GENERAL NOTE: See para. 8.1 and Tables 7.1-1 and 7.1-2.

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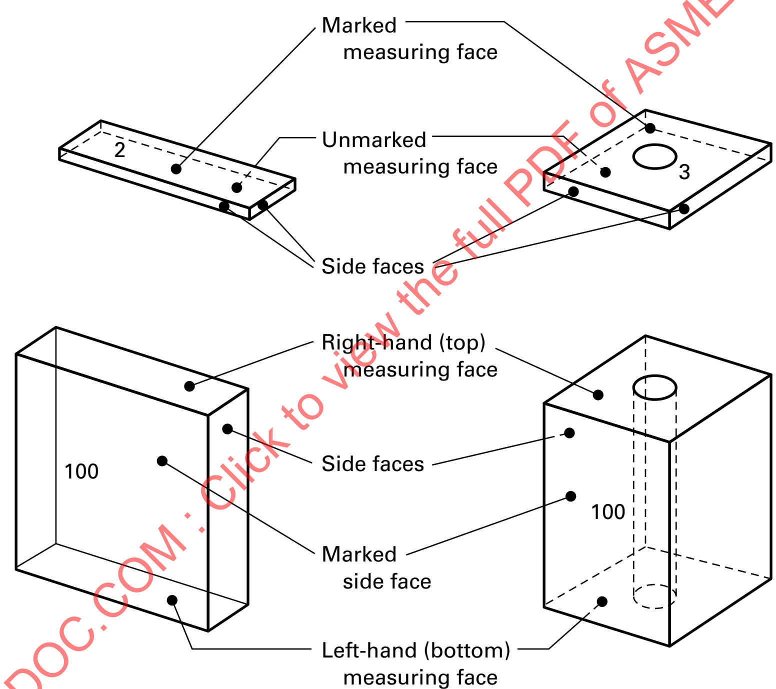
5 NOMENCLATURE OF FACES

See Figure 5-1 for rectangular and square gage blocks.

Figure 5-1
Nomenclature of Gage Block Faces



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6 BASIS OF MEASUREMENT, TRACEABILITY, AND REFERENCE CONDITION

6.1 Units of Length (Meter, Inch)

The meter is defined as the distance traveled by light in a vacuum in $\frac{1}{299\,792\,458}$ of a second (Resolution 1 of the 17th General Conference of Weights and Measures, 1983). The definition is realized by working wavelength standards recommended by the International Committee of Weights and Measures. One inch is 25.4 mm exactly.

6.2 Metrological Traceability

All the length standards used in the calibration of a gage block shall exhibit metrological traceability per ASME B89.7.5.

6.3 Reference Temperature and Standard Pressure

The nominal length and measured lengths of a gage block apply at the reference temperature of 20°C (68°F) (see ISO 1) and the standard air pressure 101.325 kPa (14.700 psi).

NOTE: The effect on the length of a gage block caused by deviations from the standard pressure may be ignored under normal atmospheric conditions.

6.4 Reference Position of Gage Blocks

The defined length of a gage block refers to the vertical position, with the measuring faces horizontal. Blocks can be measured in any orientation if corrections for deformation are made (see Nonmandatory Appendix G). The orientation of blocks over 100 mm (~4 in.) in length should be recorded in the calibration report.

7 GENERAL DIMENSIONS, MATERIAL PROPERTIES, AND MARKING

7.1 General Dimensions

The nominal dimensions of the cross section and their limit deviations are given in Tables 7.1-1 and 7.1-2.

If rectangular gage blocks with nominal length over 100 mm are provided with coupling holes, the dimensions and location of holes shall be as shown in Figure 7.1-1. Rectangular gage blocks of Grade K shall not be combined with coupling devices.

Table 7.1-1
Dimensions in Millimeters

Cross Section	Nominal Length, l_n	Width, a		Depth, b	
		Nominal	Tolerance	Nominal	Tolerance
Square	0.5 to 1 000	24.1	±0.2	24.1	±0.2
Rectangle	0.1 to 10	30	+0.0/−0.3	9	−0.05/−0.20
	Over 10 to 1 000	35	+0.0/−0.3	9	−0.05/−0.20

GENERAL NOTE: Square gage blocks have a center hole of 6.7 mm ± 0.1 mm. The hole is countersunk on both sides 70 deg to 84 deg for blocks 5 mm and longer. Blocks under 5 mm are not countersunk.

Table 7.1-2
Dimensions in Inches

Cross Section	Nominal Length, l_n	Width, a		Depth, b	
		Nominal	Tolerance	Nominal	Tolerance
Square	0.01 to 40	0.95	±0.01	0.95	±0.01
Rectangle	0.004 to 0.2	1.181	+0.074/−0.084	0.355	+0.020/−0.010
	Over 0.2 to 40	1.378	+0.010/−0.0207	0.355	+0.020/−0.010

GENERAL NOTE: Square gage blocks have a center hole of 0.265 in. ± 0.010 in. The hole is countersunk on both sides 70 deg to 84 deg for blocks 0.2 in. and longer. Blocks under 0.2 in. are not countersunk.

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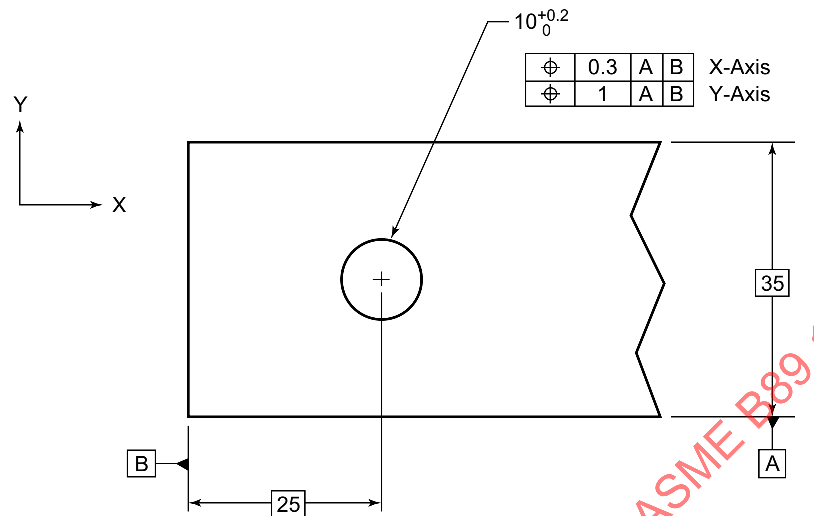
Figure 7.1-1
Dimensions of Coupling Holes



GENERAL NOTE: Dimensions are in millimeters.

Table 7.2.1-1
Dimensional Stability

Grade	Maximum Permissible Change in Nominal Length, l_n, per Year, m
K, 00, 0	± (0.02 µm + 0.25 × 10^{-6} l_n)
AS-1, AS-2	± (0.05 µm + 0.5 × 10^{-6} l_n)

7.2 Material Properties

7.2.1 Material. Gage blocks shall be made of high-grade steel or of other wear-resistant materials, such as chromium carbide, tungsten carbide, and ceramic (partially stabilized zirconia), capable of being finished with surfaces that will wring readily and that will be stable for length within the tolerance in Table 7.2.1-1.

7.2.2 Coefficient of Thermal Expansion. The coefficient of thermal expansion of gage blocks in the temperature range 10°C to 30°C (50°F to 86°F) shall be known to within ±1.0 × 10^{-6}/°C (±1.0 × 10^{-6}/°F). The coefficient of expansion with its uncertainty of determination shall be supplied with all grades.

7.2.3 Hardness. The measuring faces of steel gage blocks shall have a Vickers hardness of not less than 800 HV 0.5 (see ISO 6507-1) or Rockwell C62 [see ASTM E18-20 and ASTM E140-12b(2019)e1].

7.2.4 Dimensional Stability. The maximum permissible changes in length per year of gage blocks are stated in Table 7.2.1-1. They apply when the gage blocks are not exposed to exceptional temperatures, vibrations, shocks, magnetic fields, or mechanical forces.

7.3 Marking

Gage blocks shall be permanently marked with the nominal length and the name or trademark of the manufacturer in characters not less than 1.5 mm (0.06 in.) high. Rectangular gage blocks smaller than 6 mm (0.24 in.) nominal length may be marked on a measuring face, but an area of 9 mm × 12 mm (0.35 in. × 0.47 in.) at the center of the measuring face and an area of 2.5 mm × 2.5 mm (0.1 in. × 0.1 in.) in each of the four corners shall be left clear of any marking. Square gage blocks may be marked on the measuring face, but the quadrant of the face where the measurements are made shall be left clear of any marking.

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Gage blocks for which a calibration certificate is issued shall be marked with an identification number. It is recommended that all other gage blocks, especially gage blocks of Grades K, 00, and 0, should likewise be identifiable.

If the grades are indicated on the gage block, the following markings shall be used:

Gage Block Grade	Marking
K	K
00	00
0	0
AS-1	–
AS-2	+

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8 METROLOGICAL REQUIREMENTS

8.1 General

Each gage block shall conform to the requirements of its grade (see Tables 8.1-1 and 8.1-2).

The requirements of Tables 8.1-1, 8.1-2, and 8.2.1-1 apply to the measuring faces of the gage block omitting a border zone with a maximum width of 0.8 mm (0.03 in.) as measured from the plane of the side faces. In this border zone, the surface shall not lie above the plane of the measuring face.

Grade K gage blocks are intended for calibrating other gage blocks and shall always be used in connection with a calibration certificate.

8.2 Deviation From Flatness Tolerance, t_f

8.2.1 Gage Blocks With Nominal Length Exceeding 2.5 mm (0.1 in.). The deviation from flatness, f_d, of each measuring face of a gage block of nominal length greater than 2.5 mm (0.1 in.) shall not exceed the appropriate tolerance in Table 8.2.1-1, whether the gage block is wrung to an auxiliary plate or is in the unwrung state.

8.2.2 Gage Blocks With Nominal Length up to 2.5 mm (0.1 in.). The deviation from flatness, f_d, of each measuring face of a gage block of nominal length up to 2.5 mm (0.1 in.) shall not exceed the appropriate tolerance in Table 8.2.1-1 when the gage block is wrung to an auxiliary plate (see para. 9.3.2) with a thickness of not less than 11 mm (0.43 in.).

With the gage block in the unwrung state, each measuring face shall be flat to within 4 µm (160 µin.).

8.3 Measuring Faces

The measuring faces of all gage blocks shall wring readily. Fine scratches without burrs may be accepted when they do not impair the wringing property. The edges of the measuring faces shall be rounded to a radius not exceeding 0.3 mm (0.012 in.) or provided with a chamfer not exceeding 0.3 mm (0.012 in.). The transition between the chamfer and measuring face shall be such that the wringing property of the measuring faces is not impaired.

8.4 Side Faces

8.4.1 Side Face Flatness. The deviation from flatness of the side faces shall not exceed 40 µm for nominal length up to 100 mm (4 in.). For nominal length over 100 mm (4 in.), the tolerances shall be given by 40 µm + 40 × 10^{-6} l_n.

8.4.2 Side Face Parallelism. The deviation from parallelism (including form deviations) of a side face with the opposing side face as a datum shall not exceed 80 µm (0.003 in.) for nominal lengths up to 100 mm (4 in.). For nominal lengths over 100 mm (4 in.) up to 1 000 mm (40 in.), the tolerances shall be given by 80 µm + 80 × 10^{-6} l_n.

8.4.3 Side Face Perpendicularity. The deviation from perpendicularity of a side face with a measuring face shall not exceed the values given in Table 8.4.3-1 (see Figure 8.4.3-1).

8.4.4 Side Face Edges. All edges between the side faces shall have a radius or chamfer of not more than 0.3 mm (0.012 in.).

8.5 Conformance Test (Application of Decision Rule)

The default decision rule when determining the conformance of a gage block to specifications stated in this Standard depends on the gage block grade as shown in Table 8.5-1. The decision rules stated in Table 8.5-1 are in accordance with ASME B89.7.3.1. For new gage blocks, the default decision rule applies unless otherwise agreed upon by both the customer

Table 8.1-1
Maximum Permitted Deviations of the Length at Any Point and Tolerance on Variation in Length for Gage Blocks (Metric)

Range of Nominal Length, l_n, mm	Calibration Grade K: Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µm	Calibration Grade K: Tolerance for the Variation in Length, t_v, µm	Grade 00: Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µm	Grade 00: Tolerance for the Variation in Length, t_v, µm	Grade 0: Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µm	Grade 0: Tolerance for the Variation in Length, t_v, µm	Grade AS-1: Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µm	Grade AS-1: Tolerance for the Variation in Length, t_v, µm	Grade AS-2: Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µm	Grade AS-2: Tolerance for the Variation in Length, t_v, µm
$l_n \le 0.5$	0.30	0.05	0.10	0.05	0.14	0.10	0.30	0.16	0.60	0.30
$0.5 < l_n \le 10$	0.20	0.05	0.07	0.05	0.12	0.10	0.20	0.16	0.45	0.30
$10 < l_n \le 25$	0.30	0.05	0.07	0.05	0.14	0.10	0.30	0.16	0.60	0.30
$25 < l_n \le 50$	0.40	0.06	0.10	0.06	0.20	0.10	0.40	0.18	0.80	0.30
$50 < l_n \le 75$	0.50	0.06	0.12	0.07	0.25	0.12	0.50	0.18	1.00	0.35
$75 < l_n \le 100$	0.60	0.07	0.15	0.07	0.30	0.12	0.60	0.20	1.20	0.35
$100 < l_n \le 150$	0.80	0.08	0.20	0.08	0.40	0.14	0.80	0.20	1.60	0.40
$150 < l_n \le 200$	1.00	0.09	0.25	0.09	0.50	0.16	1.00	0.25	2.00	0.40
$200 < l_n \le 250$	1.20	0.10	0.30	0.10	0.60	0.16	1.20	0.25	2.40	0.45
$250 < l_n \le 300$	1.40	0.10	0.35	0.10	0.70	0.18	1.40	0.25	2.80	0.50
$300 < l_n \le 400$	1.80	0.12	0.45	0.12	0.90	0.20	1.80	0.30	3.60	0.50
$400 < l_n \le 500$	2.20	0.14	0.50	0.14	1.10	0.25	2.20	0.35	4.40	0.60
$500 < l_n \le 600$	2.60	0.16	0.65	0.16	1.30	0.25	2.60	0.40	5.00	0.70
$600 < l_n \le 700$	3.00	0.18	0.75	0.18	1.50	0.30	3.00	0.45	6.00	0.70
$700 < l_n \le 800$	3.40	0.20	0.85	0.20	1.70	0.30	3.40	0.50	6.50	0.80
$800 < l_n \le 900$	3.80	0.20	0.95	0.20	1.90	0.35	3.80	0.50	7.50	0.90
$900 < l_n \le 1\,000$	4.20	0.25	1.00	0.25	2.00	0.40	4.20	0.60	8.00	1.00

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Table 8.1-2
Maximum Permitted Deviations of the Length at Any Point and Tolerance on Variation in Length for Gage Blocks (U.S. Customary)

	Calibration Grade K		Grade 00		Grade 0		Grade AS-1		Grade AS-2	
Range of Nominal Length, l_n, in.	Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µin.	Tolerance for the Variation in Length, t_v, µin.	Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µin.	Tolerance for the Variation in Length, t_v, µin.	Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µin.	Tolerance for the Variation in Length, t_v, µin.	Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µin.	Tolerance for the Variation in Length, t_v, µin.	Limit Deviations of Length at Any Point From Nominal Length, $\pm t_e$, µin.	Tolerance for the Variation in Length, t_v, µin.
$l_n \le 0.05$	12	2	4	2	6	4	12	6	24	12
$0.05 < l_n \le 0.4$	10	2	3	2	5	4	8	6	18	12
$0.45 < l_n \le 1$	12	2	3	2	6	4	12	6	24	12
$1 < l_n \le 2$	16	2	4	2	8	4	16	6	32	12
$2 < l_n \le 3$	20	2	5	3	10	4	20	6	40	14
$3 < l_n \le 4$	24	3	6	3	12	5	24	8	48	14
$4 < l_n \le 5$	32	3	8	3	16	5	32	8	64	16
$5 < l_n \le 6$	32	3	8	3	16	5	32	8	64	16
$6 < l_n \le 7$	40	4	10	4	20	6	40	10	80	16
$7 < l_n \le 8$	40	4	10	4	20	6	40	10	80	16
$8 < l_n \le 10$	48	4	12	4	24	6	48	10	104	18
$10 < l_n \le 12$	56	4	14	4	28	7	56	10	112	20
$12 < l_n \le 16$	72	5	18	5	36	8	72	12	144	20
$16 < l_n \le 20$	88	6	20	6	44	10	88	14	176	24
$20 < l_n \le 24$	104	6	25	6	52	10	104	16	200	28
$24 < l_n \le 28$	120	7	30	7	60	12	120	18	240	28
$28 < l_n \le 32$	136	8	34	8	68	12	136	20	260	32
$32 < l_n \le 36$	152	8	38	8	76	14	152	20	300	36
$36 < l_n \le 40$	160	10	40	10	80	16	168	24	320	40

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Table 8.2.1-1
Deviation From Flatness Tolerance, t_f

Range for Nominal Length l_n, mm (in.)	Deviation From Flatness Tolerance, t_f, µm (µin.)					
	K All Styles	00 Rectangular	00 Square	0 All Styles	AS-1 All Styles	AS-2 All Styles
0.1 to 50 (0.004 to 2)	0.05 (2.0)	0.05 (2.0)	0.05 (2.0)	0.1 (4.0)	0.15 (6.0)	0.25 (10.0)
Over 50 to 150 (over 2 to 6)	0.05 (2.0)	0.05 (2.0)	0.07 (2.0)	0.1 (4.0)	0.15 (6.0)	0.25 (10.0)
Over 150 to 500 (over 6 to 20)	0.1 (4.0)	0.1 (4.0)	0.1 (4.0)	0.15 (6.0)	0.18 (7.0)	0.25 (10.0)
Over 500 to 1 000 (over 20 to 40)	0.15 (6.0)	0.15 (6.0)	0.15 (6.0)	0.18 (7.0)	0.20 (8.0)	0.25 (10.0)

Table 8.4.3-1
Perpendicularity Tolerance

Nominal Length, mm (in.)	Perpendicularity Tolerance, mm (in.)
From 10 to 25 (from 0.1 to 1)	0.050 (0.002)
From 25 to 60 (from 1 to 2)	0.070 (0.003)
From 60 to 150 (from 2 to 6)	0.100 (0.004)
From 150 to 400 (from 6 to 16)	0.140 (0.006)
From 400 to 1 000 (from 16 to 40)	0.180 (0.007)

Figure 8.4.3-1
Perpendicularity of a Side Face With the Measuring Face

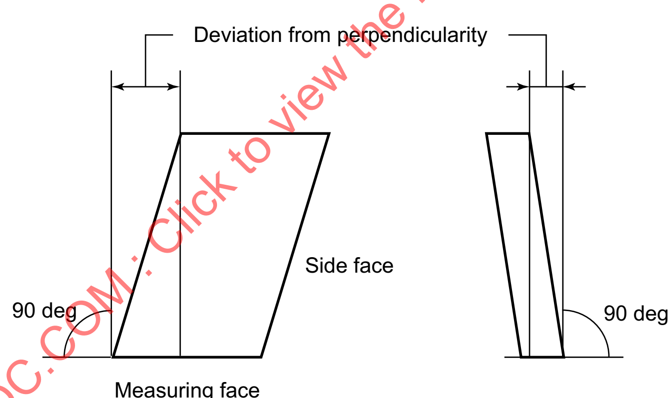

Table 8.5-1
Default Decision Rule When Determining Conformance of Gage Blocks

Gage Block Grade	Default Decision Rule
K	Simple 2:1 acceptance
00	Simple 1:1 acceptance
0	Simple 1.5:1 acceptance
AS-1	Simple 2:1 acceptance
AS-2	Simple 3:1 acceptance

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and supplier. For used gage blocks, the default decision rule applies unless the user states an alternative decision rule. This decision rule shall be used in the calibration of the gage blocks.

When using a simple acceptance decision rule, a simple 4:1 acceptance decision rule is preferable. The decision rules shown in Table 8.5-1 are due to the practical and economic limitations in achieving lower measurement uncertainties in the calibration of gage blocks using technology available at the time of the publication of this Standard.

Users should consider the implications of the measurement uncertainty associated with the decision rule used (see Nonmandatory Appendix J).

9 CALIBRATION OF GAGE BLOCKS

9.1 General

Measurement of gage blocks is outlined in paras. 6.1 and 6.2 as a sequence starting from the basic definition of the unit of length and proceeding through the stage of interferometry for high-grade (preferably Grade K) gage blocks. One or several further stages of measurement by comparison may follow for measurement of other grade gages. More details of the stages are given in paras. 9.3 and 9.4, respectively. The measurement result of length and the associated uncertainty shall be supplied in a calibration certificate.

9.2 Wringing Test

The wringing property of measuring faces of the gage block is tested using an optical flat that shall satisfy a deviation from flatness tolerance of 0.1 µm.

The wrung measuring face shall be observed through the optical flat and shall be clear of interference bands, color, and bright spots.

For gage blocks of Grades K, 00, and 0, no bright spots or shades should be visible. For gage blocks of Grades AS-1 and AS-2, bright spots or shades of a minor extent (less than a quarter of the total area) are permitted.

9.3 Measurement by Interferometry

9.3.1 Measured Length. The length of a gage block as shown in Figures 4.2-1 and 4.2-2 (Grade K is recommended) should be measured at the reference point of the measuring face using the method of interferometry. The block shall be positioned with the bottom (see Figure 5-1) wrung to a reference surface of the same material and surface texture (see para. 4.2). If the measurement deviates from these conditions, the calibration report shall describe the differences and any corrections necessitated by the changes.

Measurement of the deviations f_0 and f_u from the gage length (see para. 4.6) shall be made at the points of maximum length, l_{max}, and minimum length, l_{min}, of the gage block (see Figure 4.6-1).

9.3.2 Auxiliary Plate. The auxiliary plate on which the gage block is wrung during the measurement shall meet the requirements of para. 7.2 (i.e., it should consist of the same material as the gage block and have a wringing surface of the same surface texture as the measuring faces of the gage block). If auxiliary plates of some other material, such as fused quartz or fused silica, are used, then the corrections made necessary by the different physical material properties need to be taken into account (see para. 9.3.3). The auxiliary plate shall be not less than 11 mm (0.43 in.) thick, and it shall have a wringing face with flatness deviations of less than 0.025 µm (1 µin.) over a diameter of 40 mm (1.5 in.).

9.3.3 Corrections to Measurements by Interferometry. Corrections shall be made to the calculations for significant influences, including the following:

(a) temperature, atmospheric pressure, and atmospheric humidity on the wavelength of light
(b) deviation of the gage block temperature from 20°C (68°F)
(c) wringing action on the length of the gage block when the gage block and auxiliary plate are of different materials
(d) surface texture and optical phase changes on the reflection of the light wave
(e) the aperture of the interferometer (diaphragm size and focal length) on the position of the interference fringes
(f) deformation of the gage block when measured in horizontal orientation

9.3.4 Calibration Certificate. The calibration certificate shall contain the measurement results, in particular the gage length, l_g, or the deviation of the gage length from nominal, $l_g - l_n$; the $k = 2$ expanded uncertainty (see JCGM 100); the simple N:1 acceptance decision rule used (see para. 8.5); and a statement of traceability with reference to the wavelength standards used. The certificate shall state which measuring face of the gage block was wrung during the measurement and the coefficient of thermal expansion used to adjust the results to length at 20°C (68°F) (see para. 9.3.3). The calibration certificate shall be issued in compliance with ISO/IEC 17025.

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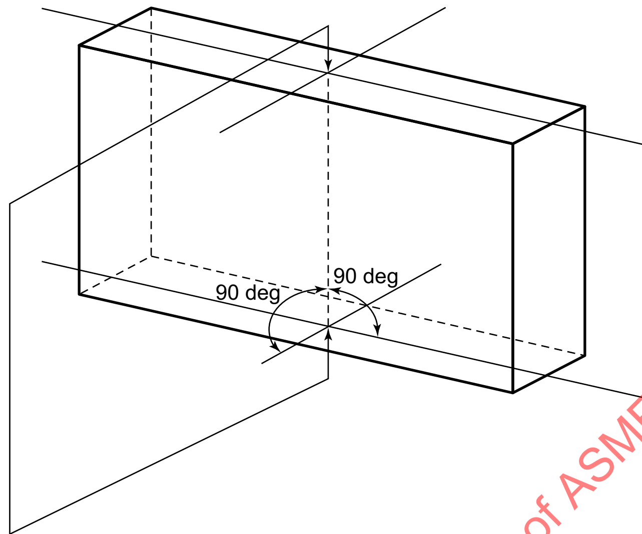
Figure 9.4.1-1
Measurement of Gage Length by Comparison Taking the Perpendicular Distance From the Reference Point of a Measuring Face to the Opposite Face



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9.4 Measurement by Comparison

9.4.1 Principle of Measurement. To determine the length of a gage block by comparison, the difference of its gage length from that of a reference standard gage block is measured and applied algebraically to the length of the reference standard. For the probing, the measuring faces of each gage are touched from opposite directions in the manner shown in Figure 9.4.1-1, and the length difference is measured by a high-resolution length indicator.

9.4.2 Gage Length. A measurement by comparison transfers the gage length of a reference standard gage block to a gage block under test. The reference standard gage block may be either directly measured by interferometry or related through one or several stages by comparison to a standard measured by interferometry.

NOTE: The effect of one wringing, which is included in the length of the reference standard gage block measured by interferometry, is transferred by the comparison measurement.

9.4.3 Method of Determining Length by Comparison. The relatively small difference in gage length between a reference standard gage block of known gage length and another gage of the same nominal length but unknown gage length is measured by a high-resolution length indicator.

9.4.4 Variation in Length. The measurement by comparison may be used to explore the variation in length. The variations between readings at the reference point and four corners of the measuring face, approximately 1.5 mm (0.060 in.) from the side faces, could be regarded as representative for determining the variation in length. If representative points other than near the corners of the measuring face are used for the determination of the variation in length, their position shall be described.

9.4.5 Corrections. Corrections for the following effects should be made when calculating the result of comparison for the length of gage blocks concerned (see para. 9.4.2):

(a) bias of the measuring device (see JCGM 200)

(b) influence of temperature differing from 20°C (68°F) and different coefficients of thermal expansions of the two gage blocks under comparison

(c) influence of different deformations at the contacts of the anvils with the measuring faces of the two gage blocks made of different materials

9.4.6 Calibration Certificate. The calibration certificate shall contain the measurement results, in particular the gage length, l_g, or the deviation of the gage length from the nominal length, $l_g - l_n$; the $k = 2$ expanded uncertainties; the simple N:1 acceptance decision rule used (see para. 8.5); and a statement of traceability. The calibration certificate shall also contain the coefficient of thermal expansion of the gage blocks used for making the correction according to para. 9.4.5. The calibration certificate shall be issued in compliance with ISO/IEC 17025.

10 GAGE BLOCK ACCESSORIES

10.1 General

The use of gage blocks may be expanded by using gage block accessories. For example, extension jaws when used with gage blocks may form an internal or external stepped-measurement standard that could be used in the calibration of calipers or height gages.

10.2 Scope

This Standard covers the following types of gage block accessories:
(a) half-round jaws
(b) internal extension jaws
(c) straight measuring jaws
(d) base blocks

Scribers and center points are not specifically covered other than they shall be compatible for use in style and material with gage blocks and shall have wringing surfaces, as applicable, of similar wringing quality as gage blocks. Tolerances for scribers and center points are usually far greater than for gage blocks and the accessories listed above.

Manufacturers may provide items such as clamps, tie rods, or screws to hold gage blocks and accessories together during use. This Standard does not cover these items. Users should consult the manufacturer for specific details for accessory items not covered.

10.3 Material

Material properties shall conform to para. 7.2.1.

10.4 Tolerance Requirements

Tolerance requirements shall apply to wringing surfaces of gage block accessories, omitting a border zone with a maximum width of 0.8 mm (0.03 in.) as measured from the plane of the side faces. Surfaces in this border zone shall not be above the plane of the wringing surface and shall conform to para. 8.1. The squareness of side faces shall conform to para. 8.4.

10.5 Half-Round Jaws

10.5.1 Length *l* of a Half-Round Jaw. The length (size) of a half-round jaw is the maximum perpendicular distance from the wringing surface to the top of the radius (see Figures 10.5.1-1 and 10.5.1-2).

10.5.2 Length Tolerance. The deviation of the measured length from the nominal size shall not exceed ±0.8 µm (±32 µin.) at any point along the radius.

If half-round jaws are sold new in pairs, the sum of the deviations of the lengths (size) from nominal at the two reference points shall not exceed ±1.0 µm (±40 µin.). This paired tolerance shall not apply to used half-round jaws.

10.5.3 Variation in Length. The variation in length at any point on the radius with respect to the wringing surface shall not exceed 0.3 µm (12 µin.). Variation in length shall be tested by measuring the length at two auxiliary points, one close to the start and the other close to the end of the radius. The distance of these auxiliary points from the end or start of the radius shall not exceed 0.8 mm (0.03 in.). The variation in length is the maximum length minus the minimum length at these auxiliary points.

10.5.4 Flatness of Wringing Surface. The deviation from flatness of the wringing surface shall not exceed 0.3 µm (12 µin.).

10.5.5 Design

10.5.5.1 Radius. The center point of the radius shall be on or above the wringing surface (see Figure 10.5.5.1-1). The radius need not be a full radius as only a line contact is usually made between the jaw and an object to be measured. However, the radius shall be wide enough to provide support during use. If an abbreviated arc is used, the sides of the jaw containing the radius shall provide clearance for use and shall remain inside the extended radius (see Figure 10.5.5.1-2).

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10.5.5.2 Minimum Width. The minimum width of the body of the half-round jaw, excluding the radius portion, shall be

(a) 34 mm (1.34 in.) for rectangular-style jaws
(b) 24 mm (0.94 in.) for square-style jaws

10.5.5.3 Relief. A relief shall be placed between the body and radius portion of the jaw. If an abbreviated radius is used on the jaw, then only surfaces that might be outside the extended radius need to be relieved. This relief is to provide clearance during use (see para. 10.5.1).

10.5.6 Marking. Half-round jaws shall be permanently marked with the nominal length and the name or trademark of the manufacturer on a side face in characters not less than 1.5 mm (0.06 in.) high.

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Figure 10.5.1-1
Half-Round Jaw

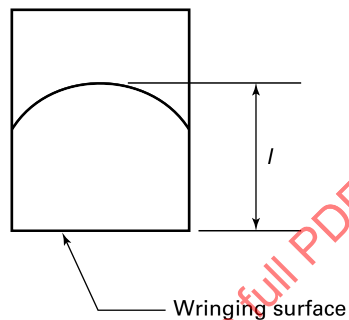


Figure 10.5.1-2
Side View of Half-Round Jaw

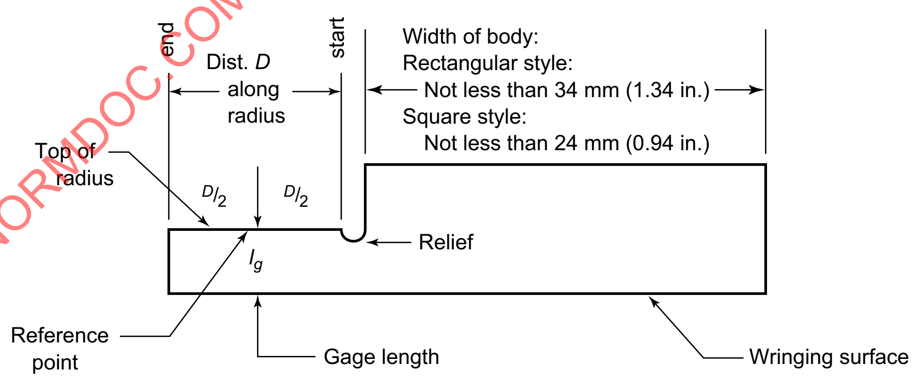


Figure 10.5.5.1-1
Center Point of Radius, *R*, of Half-Round Jaw

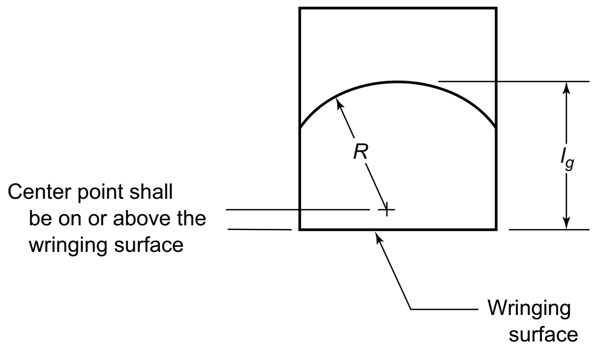
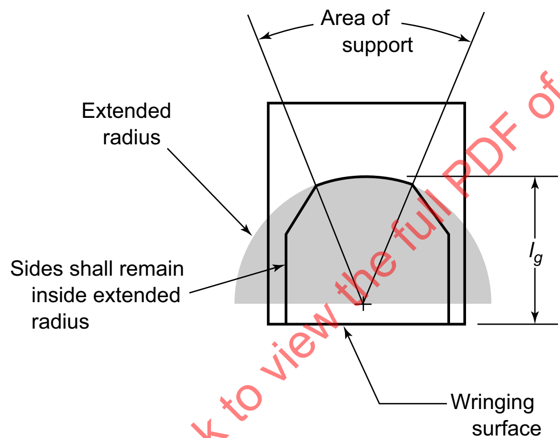


Figure 10.5.5.1-2
Abbreviated Arc of Half-Round Jaw



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10.6 Internal Extension Jaws

10.6.1 Design. Internal extension jaws have no nominal size and have only one wringing surface. Their purpose is to extend the measuring surface of gage blocks to create a known internal dimension (see Figure 10.6.1-1). They should be robust or thick enough to resist deflection or deformation during use.

10.6.2 Flatness. The deviation from flatness of the wringing surface shall not exceed 0.3 µm (12 µin.).

10.7 Straight Measuring Jaws

10.7.1 Design. Straight measuring jaws are finished to a length (size) like a gage block and have two parallel measuring (gaging) surfaces that define the gage length. These jaws have a greater width than gage blocks so the gaging surfaces may extend beyond a gage block to create internal or external dimensions.

10.7.2 Length of a Straight Measuring Jaw. The length of a straight measuring jaw is defined as a gage block in para. 4.3.

10.7.3 Length Tolerance. The length at any point on a measuring surface shall not exceed ±0.6 µm (±24 µin.). If straight measuring jaws are sold new in pairs, the sum of the deviations of the lengths (size) from nominal at the two reference points shall not exceed ±0.8 µm (±32 µin.). This paired tolerance shall not apply to used straight measuring jaws.

10.7.4 Variation in Length. The variation in length of a straight measuring jaw is defined in para. 4.6 and shall not exceed 0.3 µm (12 µin.). Variation in length shall be tested per para. 8.4.4, with the exception as shown in Figure 10.7.4-1.

If representative points other than those shown in Figure 10.7.4-1 are used for the determination of variation in length, their position shall be described.

Figure 10.6.1-1
Extension Jaws to Make Internal Dimension Using Gage Blocks

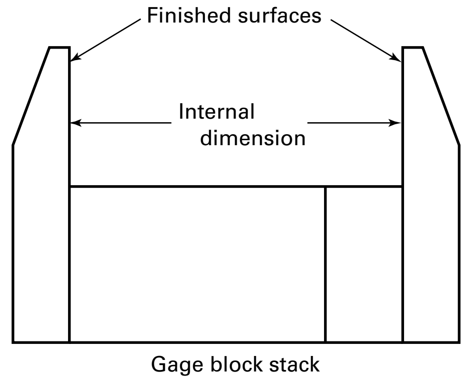
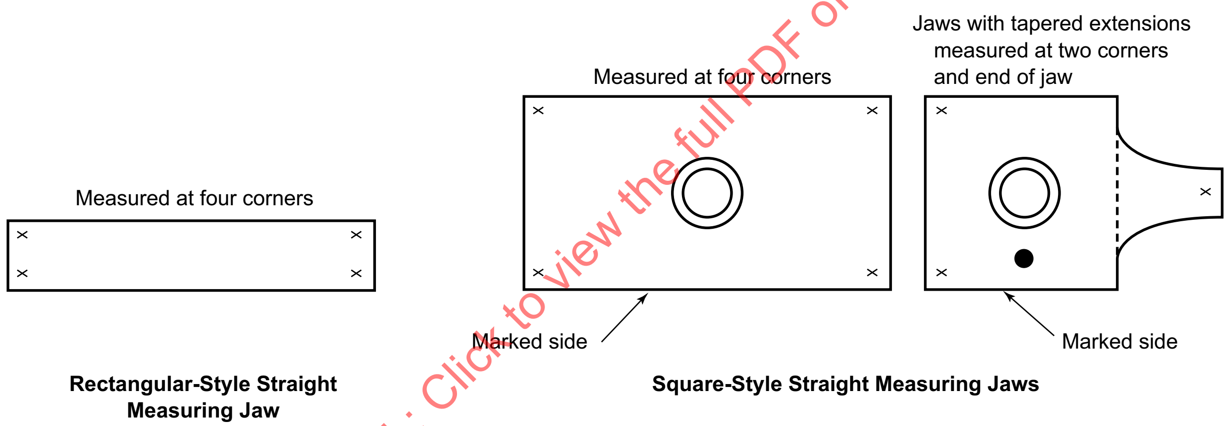


Figure 10.7.4-1
Reference Points for Variation in Length Measurement



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10.7.5 Flatness of Gaging Surfaces. The deviation from flatness of the gaging surfaces shall not exceed 0.3 μm (12 μin.).

10.7.6 Marking. Straight measuring jaws shall be permanently marked with the nominal length and the name or trademark of the manufacturer on a side face in characters not less than 1.5 mm (0.06 in.) high.

10.8 Base Blocks

10.8.1 Introduction. Base blocks are used in combination, wrung to gage blocks to provide a nominal dimension perpendicular to a supporting surface such as a surface plate. The base block is in contact with the supporting surface and should be capable of supporting a wrung stack of gage blocks at least 300 mm (11.8 in.) high in a stable manner. Base blocks shall have a method of securing or attaching the wrung gage blocks to the base block.

10.8.2 Design. Base block designs other than those described in this section may be suitable for use.

10.8.2.1 Rectangular-Style Base Block. The rectangular base block usually consists of a riser block with a top wringing surface mounted on a supporting base. The riser has the same depth as a rectangular gage block and has clearance around and below it for the use of external clamps (see Figures 10.8.2.1-1 and 10.8.2.1-2).

10.8.2.2 Square-Style Base Block. The square-style base block is usually a single flat piece with two parallel surfaces, finished to a length (size), and with a countersunk through hole to accept screw heads and tie rods for assembling combinations with square gage blocks. An area on the top wringing surface around the hole, not less than 24.1 mm × 24.1 mm (0.95 in. × 0.95 in.), shall be suitable for wringing (see Figures 10.8.2.2-1 and 10.8.2.2-2).

10.8.3 Length of a Base Block. The length (size) of a base block at any point of the top wringing surface is the perpendicular distance from that point to the supporting surface.

10.8.4 Length Tolerance. The deviation of the length shall not exceed ±0.6 μm (±24 μin.) from the nominal length at any point on the top wringing surface.

10.8.5 Variation in Length. The variation in length shall not exceed 0.3 μm (12 μin.). The top wringing surface should be checked for length at four auxiliary points in the area where gage blocks would normally be wrung. The variation in length is the maximum length minus the minimum length at these auxiliary points and the reference point.

10.8.5.1 Rectangular Style. The width of the top wringing surface shall be at least 35 mm (1.38 in.). If representative points other than those shown in Figure 10.8.5.1-1 are used for the determination of the variation in length, their positions shall be described.

10.8.5.2 Square Style. If representative points other than a point in each corner are used for the determination of variation in length, their position shall be described.

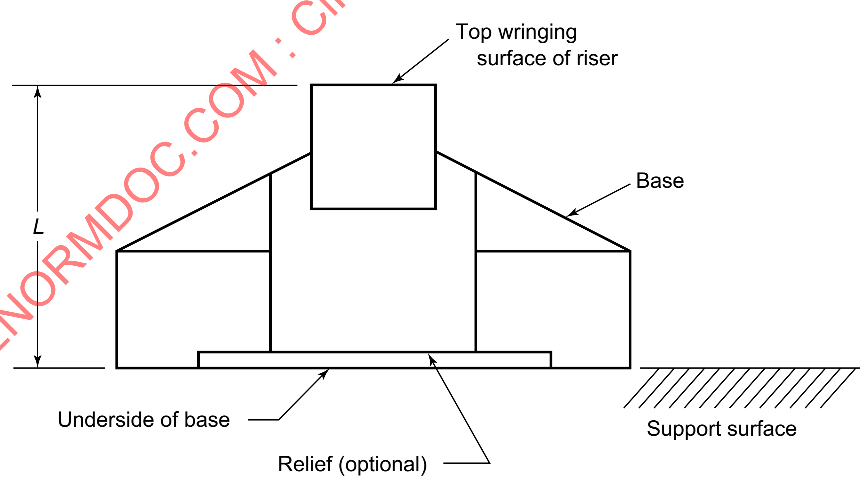
10.8.6 Flatness

10.8.6.1 Top Wringing Surface. The top wringing surface shall have deviation from flatness not greater than 0.3 μm (12 μin.).

10.8.6.2 Underside. The underside of the base block shall have deviation from flatness not greater than 1.0 μm (40 μin.) and shall not rock on a surface plate. The underside surface of the base block may be relieved.

10.8.7 Marking. Base blocks shall be permanently marked with the nominal length and the name or trademark of the manufacturer on a side face in characters not less than 1.5 mm (0.06 in.) high.

Figure 10.8.2.1-1
Rectangular Base Block



Front View of Rectangular Base Block

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Figure 10.8.2.1-2
Reference Point for Rectangular Base Block

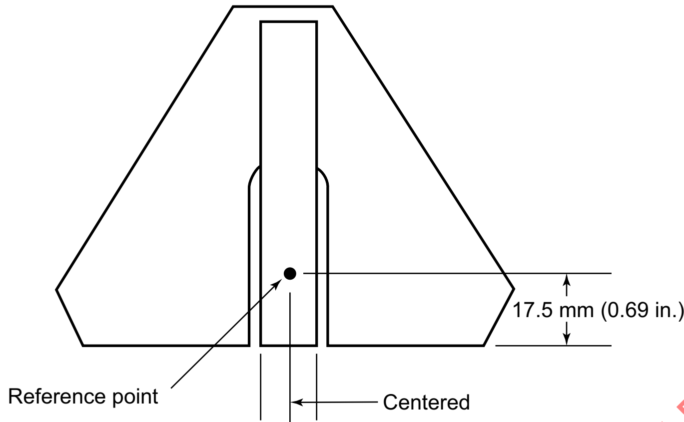

Figure 10.8.2.2-1
Square Base Block

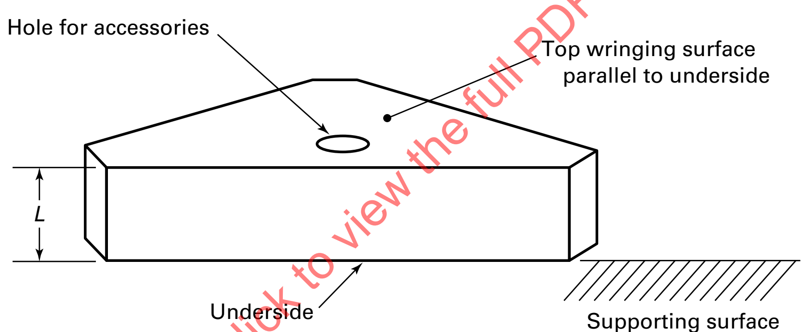

Figure 10.8.2.2-2
Reference Point for Square Base Block

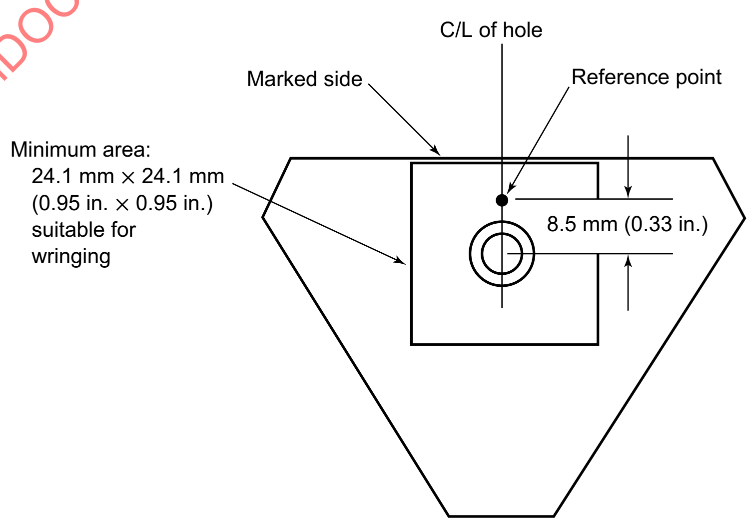

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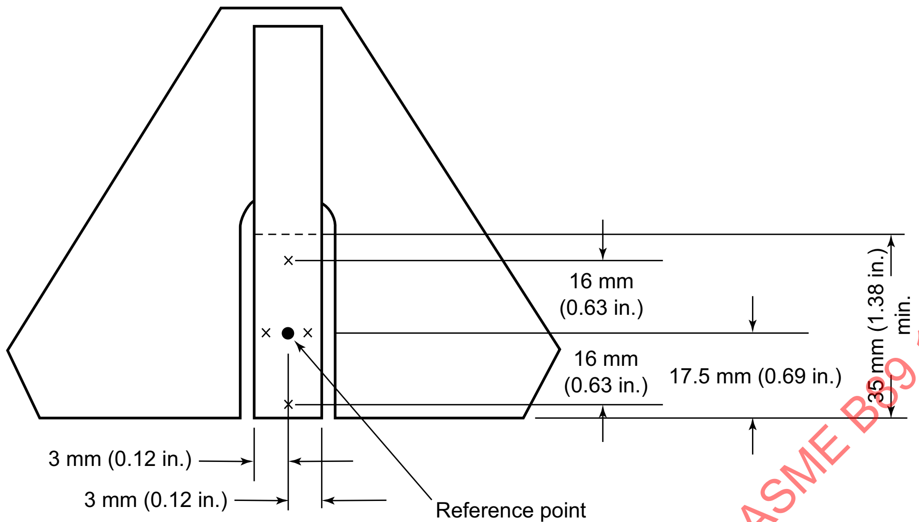
Figure 10.8.5.1-1
Reference Points for Variation in Length of Rectangular Base Block



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NONMANDATORY APPENDIX A DIFFERENCES BETWEEN FORMER GGG-G-15C, ASME B89.1.9-2002 (R2012), AND THIS STANDARD

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A-1 INTRODUCTION

This Appendix acts as a guide to highlight the major differences between Federal Specification GGG-G-15C, ASME B89.1.9-2002 (R2012), and this edition of this Standard. An earlier edition of this Standard, ANSI/ASME B89.1.9-1984 (R1997), is nearly identical in content to GGG-G-15C.

NOTE: Federal Specification GGG-G-15C (1970), Gage Blocks and Accessories (Inch and Metric), was canceled in 1999.

A-2 BILATERAL TOLERANCING

The tolerances in this Standard are all bilateral and symmetric about zero. In GGG-G-15C, some of the tolerances were weighted on the plus side to allow for wear (see Table A-2-1).

A-3 POINTS ON GAGING SURFACE WITHIN TOLERANCE BAND

All the points on the gaging surface shall be within the stated tolerance in this Standard. Under GGG-G-15C, the length (size) tolerance applied only to the reference or measuring point. Points near the corners or edges could exceed the length tolerance due to variation in length (parallelism) of the block (see Figure A-3-1).

A-4 PARALLELISM

The term *parallelism* as used in GGG-G-15C is replaced in this Standard by *variation in length* (see para. 4.6).

A-5 LENGTH TOLERANCES

A-5.1 Suggested Replacements for Former Federal Grades

While not exact, the grades in Table A-5.1-1 are listed as a guide to users when ordering replacement blocks for sets with former Federal Grades.

Close comparison of the length tolerances of the suggested grades in Table A-5.1-1 to those of the former Federal Grades may reveal that the suggested grades of this Standard are slightly larger. This is partly due to the expansion of the tolerance to include all the points of the gaging surface (see section A-3) and partly due to the bilateral tolerancing. The suggested replacements in Table A-5.1-1 are not exact.

A-6 ACCESSORIES

Specification for accessories are in this Standard.

A-7 ACCEPTANCE/REJECTION OF GAGE BLOCKS (OUT-OF-TOLERANCE CONDITION)

A-7.1 Used Gage Blocks: Customer Specification for Acceptance/Rejection

There is no special rule for used gage blocks in this Standard. For used gage blocks, users may specify other replacement tolerances according to their needs. The calibration/testing laboratory should note and implement these customer-specified replacement tolerances as part of the laboratory's contract review procedures.

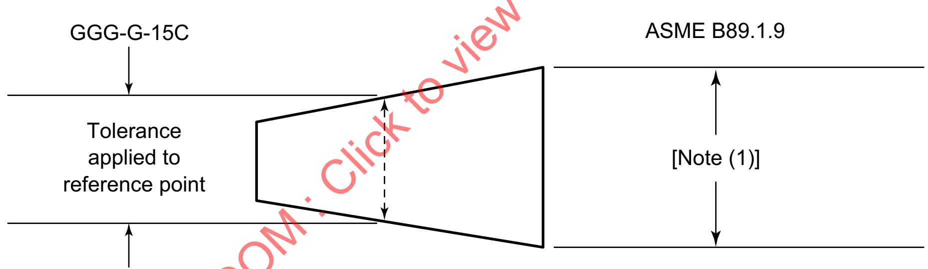
A-8 APPENDICES

The listing of some gage block sets, packaging, and testing/inspection methods has been moved to the appendices. Other appendices regarding possible sources of measurement uncertainty, gravity, atmospheric effects on gage blocks, and the use and care of gage blocks have been added for informational purposes to the user.

Table A-2-1
Length Tolerance Comparison

Size	Length Tolerance: GGG-G-15C	Length Tolerance: ASME B89.1.9
SI Units		
1 mm	Grade 1, ±0.5 μm	Grade 00, ±0.07 μm
	Grade 2, +0.10/−0.05 μm	Grade 0, ±0.12 μm
75 mm	Grade 3, +0.45/−0.22 μm	Grade AS-1, ±0.50 μm
U.S. Customary Units		
0.1 in.	Grade 1, ±2 μin.	Grade 00, ±3 μin.
	Grade 2, +4/−2 μin.	Grade 0, ±5 μin.
2.0 in.	Grade 3, +16/−8 μin.	Grade AS-1, ±16 μin.

Figure A-3-1
Change in Definition for Tolerance Band in Length



NOTE: (1) All points on gaging surface shall be within stated tolerance.

Table A-5.1-1
Suggested Replacement Grades

Former Federal Grade (Reference GGG-G-15C)	ASME B89.1.9 Grades
1	00
2	0
3	AS-1
...	AS-2

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NONMANDATORY APPENDIX B
POSSIBLE SOURCES OF MEASUREMENT UNCERTAINTY

B-1 INTRODUCTION

The calculation of uncertainty for a measurement is an effort to convey an idea of the reasonableness of the result according to standardized rules. There are many "standard" methods of estimating and combining components of uncertainty. An international effort to standardize uncertainty statements has resulted in an ISO report, Guide to the Expression of Uncertainty in Measurement (see JCGM 100). This method is used by the National Institute of Standards and Technology and is recommended for all laboratories. There are a number of published discussions of gage block measurement uncertainty that may be consulted for further guidance.

Uncertainty sources are classified according to the estimation method used. Type A uncertainties are estimated statistically. The data used for these calculations can be from repetitive measurements of the workpiece, measurements of check standards, or a combination of the two. Uncertainties estimated by any other method are called Type B. For dimensional calibrations, the major sources of Type B uncertainties are thermometer calibrations, thermal expansion coefficients of gages, deformation corrections, index of refraction corrections, and apparatus specific sources.

B-2 UNCERTAINTY SOURCES

This Appendix presents some of the typical sources of uncertainty for gage block calibrations made by mechanical comparison. They are

(a) master gage calibration
(b) long-term reproducibility
(c) thermal expansion
  (1) thermometer calibration
  (2) thermal expansion coefficient
  (3) thermal gradients (gage–gage, gage–scale)
(d) elastic deformation
  (1) probe contact deformation
  (2) compression of artifacts under their own weight
(e) scale calibration
  (1) stability, drift
  (2) sensor calibration: artifact standards, linearity, fit routine
  (3) effects of environmental variation: scale thermal expansion
(f) instrument geometry
  (1) abbe offset and instrument geometry errors
  (2) scale and gage alignment (cosine errors)
  (3) gage support geometry (anvil flatness, block flatness, etc.)
(g) artifact geometry

B-2.1 Master Gage Calibration

The uncertainty associated with the master gage is the reported uncertainty from the higher echelon laboratory that calibrated the master block. It is the responsibility of the laboratory to understand the uncertainty statements reported by their calibration source and convert them to the standard uncertainty form specified in JCGM 100.

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B-2.2 Long-Term Reproducibility

It might be possible to list the causes of measurement variability, such as operator variation, thermal history of the artifact, and electronic noise in the detector, but to assign accurate quantitative estimates to these causes is difficult. The best method to determine reproducibility is to compare repeated measurements of the same artifact from either customer measurement histories or laboratory-owned check standards.

For example, if a check standard is measured weekly over a period of years, the block measurement history includes variations from different operators, instruments, environmental conditions, and thermometer and barometer calibrations. The history data then reflect these sources in a realistic and statistically significant way. The history data are fit to a straight line, and the deviations from the best fit line are used to calculate the standard deviation σ.

If a number of check standards are used that reasonably span the range of lengths and materials usually calibrated by the laboratory, the laboratory will have a realistic and well-documented measure of the calibration reproducibility.

B-2.3 Thermal Expansion

For the mechanical comparison, there are three primary thermal-related uncertainty contributions. These include the uncertainties associated with the material (block) temperature reading, the thermal expansion coefficients of both the master and client block, and the potential temperature gradient between the master and client block. The uncertainties are stated in the form

$$u_i(l) = |c_i|\, u(x_i)$$

where c_i is the sensitivity coefficient.

The uncertainty for each component is the relative standard length uncertainty, whereas the standard uncertainty components in the equations are in their appropriate units.

Symbols that appear on the right-hand side of equations in paras. B-2.3.1 through B-2.3.4 are the following:

α_c = thermal expansion coefficient of the client block
α_s = thermal expansion coefficient of the master block
L = nominal length
T_c = temperature of the client block
T_{ref} = reference temperature of 20°C
T_s = temperature of the master block
$u(a_s)$, $u(a_c)$ = standard uncertainty of the thermal expansion coefficients for the master and client blocks, respectively, ppm/°C
$u(T_c - T_s)$ = standard uncertainty of the temperature gradient, °C

B-2.3.1 Material Temperature Uncertainty, u_T

$$u_T = |L(\alpha_s - \alpha_c)|\, u(\theta_s)$$

where $u(\theta_s)$ is typically a combined standard uncertainty itself, composed of the calibration uncertainty of the temperature indicator, potential drift behavior from manufacturer specifications or calibration history analysis, and reading repeatability.

B-2.3.2 Thermal Expansion Coefficient Uncertainty of the Master Block, u_{Tm}

$$u_{Tm} = |L(T_s - 20)|\, u(\alpha_s)$$

B-2.3.3 Thermal Expansion Coefficient Uncertainty of the Client Block, u_{Tc}

$$u_{Tc} = |L(T_c - 20)|\, u(\alpha_c)$$

B-2.3.4 Thermal Gradient Between the Master and Client Block, u_{Tmc}

$$u_{Tmc} = |L\alpha|\, u(T_c - T_s)$$

For simplicity, the list provided in this Appendix does not include the higher order correlated terms. In most cases, in their absence, this abbreviated guidance should still provide a reasonable estimate to within 10%.

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B-2.4 Mechanical Deformation

All mechanical measurements involve contact of surfaces, and all surfaces in contact are deformed. For gage blocks, a correction is needed whenever the master block and test block are made of different materials. If the blocks are of similar material, the elastic properties themselves determine how much the material deforms when measured with a contact system. The amount of deformation depends on the spherical radii of the measuring and reference contact tips, measuring forces of the contact tips, and material of the gage block being measured.

Since the first two factors may vary from one instrument to another, the deformation values for the different materials should be determined using values that apply to the specific comparator being used in the calibration procedure.

Instead of deriving the equations for this particular condition from Hertzian theory, Puttock and Thwaite from the National Standards Laboratory of Australia published Technical Paper No. 25, Elastic Compression of Spheres and Cylinders at Point and Line Contact, in 1969 that has the formulas already derived for almost all contact geometries found in dimensional metrology. To make the task even simpler, the National Institute of Standards and Technology (NIST) in Gaithersburg, MD, with the permission of the National Standards Laboratory of Australia has automated the calculations. This elastic deformation calculator can be found at the NIST Engineering Metrology Toolbox: https://emtoolbox.nist.gov.

B-3 EXAMPLE UNCERTAINTY BUDGET

B-3.1 Calibration of Gage Block by Mechanical Comparison

A typical calibration laboratory calibrates steel gage blocks of lengths from 0.1 mm to 100 mm in an environment of (20°C ± 1°C), and the master and customer blocks are always within ±0.1°C of each other. An uncertainty statement for the length of the gage block with validity conditions to be those specified by the measurand-defining conditions is required. This is a multiple measurement scenario since the uncertainty statement will be applied to many future gage block measurement results.

B-3.2 Measurand

The measurand is the length of the gage block as defined in this Standard. This definition is based on an interferometric length measurement at 20°C. National measurement institutes also provide gage block calibrations based on mechanical comparison so the transfer of the interferometrically based definition to a mechanical (point-to-point) length is already included in the calibration report of the master blocks.

B-3.3 Uncertainty Validity Conditions

Measured length	25 mm
Reproducibility	0.030 μm
Temperature range	20°C ± 1°C
Temperature difference between blocks	0.1°C
Temperature indicator reading uncertainty (k = 2)	0.07°C
Customer gage block CTE	$(11.5 \pm 1.0) \times 10^{-6}$/°C
Master gage block CTE	$(10.8 \pm 0.5) \times 10^{-6}$/°C
Master gage block calibration uncertainty (k = 2)	0.050 μm
Comparator Specifications:	
Dual 6.4-mm-diameter diamond or tungsten carbide (6% Co) spherical contacts	
Upper contact force	0.83 N
Lower contact force	0.28 N

B-3.4 Measurement Method and Environment

The measurement method will be by mechanical comparison to a master gage block in an environment of 20°C ± 1°C (over all measurements) and is essentially homogeneous in the measuring volume. The calibration includes comparison of customer gage block to a "Master" that is steel. The "Masters" are calibrated by a higher echelon calibration laboratory. Since the master and customer's blocks are all steel, it is assumed that they have similar CTEs and elastic properties (Young's modulus and Poisson's ratio).

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B-3.5 Temperature Correction

Gage bocks are typically calibrated in laboratories where the average temperature is approximately 20°C with some known limits of thermal variation. In common practice, no temperature correction is made. However, some laboratories may perform temperature correction. If temperature correction is performed, that statement will be added to the calibration certificate and the associated uncertainty evaluated and included.

B-3.6 Input Quantities

Choosing input quantities is guided by the availability of data and the description of the measurement process.

B-3.6.1 Reproducibility (Type A). Creating an input quantity called reproducibility, based on the check standard data, is advantageous as it includes the effects of many (nuisance) influence quantities, including cleanliness/contamination, multiple operator effects, block geometry effects, comparator's transfer ability, and scale calibration because the check standard data include several scale recalibrations. (In this example, it is assumed the comparator is routinely recalibrated.) One standard deviation due to reproducibility was 0.030 µm, which is the standard uncertainty, u_{rep}.

$$u_{\mathrm{rep}} = 0.030\ \mu\mathrm{m}$$

B-3.6.2 Master Block Calibration (Type B). From the certificate, the expanded uncertainty, U, with a coverage factor of k = 2, is 0.050 µm. The standard uncertainty, u_{master}, is the following:

$$u_{\mathrm{master}} = \frac{0.050\ \mu\mathrm{m}}{2} = 0.025\ \mu\mathrm{m}$$

B-3.6.3 Thermal Effects (Type B). The standard reference temperature for length of a gage block is 20°C.

B-3.6.3.1 Material Temperature Uncertainty. For this example, the comparison is between two steel gage blocks (similar materials); therefore, no correction is being made to 20°C as the nominal thermal expansion coefficients of both blocks is assumed to be the same. The temperature-indicating device uncertainty is simply divided by 2 to get the standard uncertainty in temperature. Therefore, the standard uncertainty in length due to the temperature-indicating device, u_t, is negligible.

$$\begin{aligned} u_T &= |L(\alpha_s - \alpha_c)|\, u(\theta_s) \\ &= |\,0.025\ \mathrm{m}\,(10.8 - 11.5)/°\mathrm{C}|(0.035°\mathrm{C}) \\ &= 0.001\ \mu\mathrm{m} \end{aligned}$$

B-3.6.3.2 Thermal Expansion Coefficient Uncertainty, Master Block. The manufacturer's specifications are given for the CTE values for the master block and the distribution is unknown, so to convert to standard uncertainty form, a rectangular distribution is assumed.

$$u(\alpha_s) = \frac{0.5/°\mathrm{C}}{\sqrt{3}} = 0.29/°\mathrm{C}$$

The standard uncertainty in length is obtained by substituting this result into the appropriate equation from para. B-2.3.2.

$$\begin{aligned} u_{Tm} &= |L(T_s - 20)|\, u(\alpha_s) \\ &= |(0.025\ \mathrm{m}\,(21°\mathrm{C} - 20°\mathrm{C})|(0.29/°\mathrm{C}) \\ &= 0.008\ \mu\mathrm{m} \end{aligned}$$

B-3.6.3.3 Thermal Expansion Coefficient Uncertainty, Client Block. The manufacturer's specifications are given for the CTE values for the client block and the distribution is unknown, so to convert to standard uncertainty form, a rectangular distribution is assumed.

$$u(\alpha_s) = \frac{1.0/°\mathrm{C}}{\sqrt{3}} = 0.58/°\mathrm{C}$$

The standard uncertainty in length is obtained by substituting this result into the appropriate equation from para. B-2.3.3.

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$$
\begin{aligned}
u_{Tc} &= |L(T_c - 20)|\, u(\alpha_c) \\
&= |0.025\,\text{m}\,(21°\text{C} - 20°\text{C})|(0.58/°\text{C}) \\
&= 0.015\,\mu\text{m}
\end{aligned}
$$

B-3.6.3.4 Thermal Gradient Between the Master and Client Blocks. The maximum temperature gradient (difference) between the master and client blocks was given as 0.1°C, which is interpreted as the full width of a rectangular distribution in the conversion to standard uncertainty in temperature form.

$$
u(T_c - T_s) = \frac{0.1/°\text{C}}{2\sqrt{3}} = 0.03/°\text{C}
$$

The standard uncertainty in length is obtained by substituting this result into the appropriate equation from para. B-2.3.4. The higher of the two thermal expansion values was used so that the calculation was conservative.

$$
\begin{aligned}
u_{Tmc} &= |L\alpha|\, u(T_c - T_s) \\
&= |(0.025\,\text{m})(11.5/°\text{C})|(0.03°\text{C}) \\
&= 0.009\,\mu\text{m}
\end{aligned}
$$

B-3.6.4 Deformation (Type B). Although we have like materials, in that both blocks are a mild or carbon steel, such as AISI 52100 Steel or Grade D2 Steel, there is uncertainty in the elastic properties that determines how much the material deforms when measured with a contact system. Before declaring that the contribution is negligible, this must be shown to be the case, even for nominally like materials. The simplest approach is to determine what the variability in the elastic modulus and Poisson's ratio could be, then using the appropriate Puttock and Thwaite formula (Engineering Metrology Toolbox, 2023) for sphere-to-plane deformation, calculate the potential deformation errors, and convert that error into the standard uncertainty form.

Using the forces and tip material and diameter in the appropriate formula, along with the range of values published for AISI 52100 steel, the extremes and maximum potential error can be determined. Values for the elastic modulus of AISI 52100 vary from 190 GPa to 210 GPa, and Poisson's ratio varies from 0.27 to 0.30. Applying the formula varying only Poisson's ratio within the given range, the results show this variability has no real effect on the deformation results. However, varying the elastic modulus between the extremes results in a potential deformation difference of 0.012 µm.

	Deformation, µm	
Applied Force, N	***E* = 190 GPa**	***E* = 210 GPa**
0.83 (top force)	0.162	0.154
0.28 (bottom force)	0.079	0.075
Total deformation	0.241	0.229
Deformation difference	0.012	

The potential deformation error is converted to standard uncertainty form by assuming the error to be the full width of a rectangular distribution.

$$
u_{\text{def}} = \frac{0.012\,\mu\text{m}}{2\sqrt{3}} = 0.004\,\mu\text{m}
$$

B-3.7 Combined and Expanded Uncertainty

Using the values determined in para. B-3.6, the associated standard uncertainty is estimated as shown in Table B-3.7-1. The combined uncertainty, u_c, is then calculated as

$$
\begin{aligned}
u_c &= \sqrt{(u_{\text{rep}})^2 + (u_{\text{master}})^2 + (u_T)^2 + (u_{Tm})^2 + (u_{Tc})^2 + (u_{Tmc})^2 + (u_{\text{def}})^2} \\
&= \sqrt{(0.030)^2 + (0.025)^2 + (0.001)^2 + (0.008)^2 + (0.015)^2 + (0.009)^2 + (0.004)^2} \\
&= 0.044\,\mu\text{m}
\end{aligned}
$$

The temperature measurement uncertainty and deformation uncertainty (third and seventh terms, respectively) will not have an impact on the result, due to the comparison of like materials and the dominance of the master uncertainty and reproducibility terms.

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

$$U = 2u_c = 2(0.044\ \mu\text{m}) = 0.088\ \mu\text{m}$$

B-3.8 References

Decker, J. E., Ulrich, A., and Pekelsky, J. R. (2008). "Uncertainty of Gauge Block Calibration by Mechanical Comparison: A Worked Example for Like Materials." NCSLI Measure, 3(4), 30–42.

Doiron, T., and Beers, J. (1995). The Gage Block Handbook (NIST Monograph 180). National Institute of Standards and Technology.

Doiron, T., and Stoup, J. (1997). "Uncertainty and Dimensional Calibrations." Journal of Research of the National Institute of Standards and Technology, 102(6), 647–676.

Puttock, J., and Thwaite, E. G. (1969). Elastic Compression of Spheres and Cylinders at Point and Line Contact (National Standards Laboratory Technical Paper No. 25). Commonwealth Scientific and Industrial Research Organization.

Table B-3.7-1
Uncertainty Budget for the Length Measurement of a 25-mm Steel Gage Block

Uncertainty Source	Standard Uncertainty, μm
Reproducibility of mechanical comparison from check standard	0.030
Calibration of master block	0.025
Temperature indicator	0.001
Thermal expansion coefficient of master block	0.008
Thermal expansion coefficient of client block	0.015
Thermal gradient between master and client block	0.009
Deformation error due to uncertainty in elastic properties for both master and client blocks	0.004

GENERAL NOTE: The expanded (k = 2) uncertainty is equal to 0.088 μm.

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NONMANDATORY APPENDIX C TESTING METHODS

C-1 SIZE MEASUREMENT

C-1.1 Measurement by Interferometry

To comply with the requirement of para. 4.4, the length l_g is measured at the gage points defined in Figures 4.2-1 and 4.2-2. To fulfill the requirements of para. 4.3, the plane surface (auxiliary plate) to which the measuring face is wrung must be of the same material and surface texture as the measuring face to which the interferometric measurements are being made, or phase shift corrections must be applied.

NOTE: The phase shift associated with a block or auxiliary plate may change if relapped and should be remeasured.

The auxiliary plate providing the measuring reference surface should have a thickness of at least 11 mm (0.43 in.), and the surface should be flat to within 0.025 µm (1.0 µin.) over any 40-mm (1.57-in.) diameter area and should not be concave. When the gage block is measured in the horizontal position and the auxiliary plate is wrung to one measuring face, compensation shall be made for the mass of the auxiliary plate.

The results of a length measurement by interferometry should be corrected for possible departure from ideal conditions of measurement. For example

(a) effects of temperature, barometric pressure, and humidity on wavelengths of light in air

(b) effects of temperature, barometric pressure, and optical phase shift on the length

NOTE: Standard atmospheric pressure is 101.325 kPa (14.7 psi).

(c) geometric effects such as obliquity and slit corrections

The report of an interferometric measurement should state which of the two measuring faces of the gage block was wrung to the measuring reference surface during measurement. If not otherwise specified, the left-hand measuring face, or the unmarked face in the case of marking on one of the measuring faces, should serve as the reference plane. (It may be noted that this face often has the superior wringing quality.)

If required, a mean may be taken of two measurements with each face wrung to the auxiliary plate surface in turn. If this procedure has been followed, it should be stated in the report.

C-1.2 Measurement by Comparison

The length of a gage block, as measured by comparison with a reference standard (master gage block), is the distance from one point of a measuring face to the point of the opposite measuring face measured perpendicular to the plane of one of the measuring faces (see Figure 9.4.1-1). Measurement by comparison entails the use of a measuring device that usually has mechanically operated anvils contacting the two measuring faces of the gage block.

The master gage block used to set the measuring device should be of a superior geometry (deviation from flatness and variation in length) to the gage block being measured. The calibrated lengths of the master blocks should be used for all calibrations. A more accurate result of measurement will be achieved by this method if the master gage block and the block to be measured are made of the same material.

When using a method of comparison by contact, the effect of the measuring force applied by the measuring device should be taken into account, particularly if the blocks have nominal lengths less than 1.5 mm (0.06 in.). In the case of gage blocks of different materials, any differences in their thermal properties (coefficient of thermal expansion) or elastic properties (contact deformation) will also have to be taken into account.

C-2 VARIATION IN LENGTH

The variation in length measurement of gage blocks shall be the maximum variation in length between the gaging faces, excluding 0.8 mm (0.03 in.) at the edges of the faces, and shall meet the requirements of Tables 7.1-1 and 7.1-2 and para. 8.4.4. Using a point-to-point mechanical comparator, five points should be measured: the reference point and four points near the corners or the midpoints along the block edges. Points should be made 1.5 mm (0.06 in.) from the edges. The

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positions of the measurement points should be stated in the report if the variation in length is reported or the grade tolerance verified.

C-3 FLATNESS OF GAGING SURFACE

For tolerance Grades K and 00, the deviation from flatness of the gaging surfaces on blocks 2.5 mm (0.1 in.) and longer shall be measured unwrung in a flatness interferometer using monochromatic light of known wavelength and viewed within 2 deg of normal incidence. The deviation from flatness in any direction over the gaging surface, excluding 0.8 mm (0.03 in.) on the edges, shall not exceed the tolerances given in Table 7.2.1-1. [Blocks of tolerance Grades K and 00 under 2.5 mm (0.1 in.) shall be measured for deviation from flatness when they are wrung to an optical flat.]

For tolerance Grades 0, AS-1, and AS-2, the deviation from flatness of gaging surfaces on blocks 2.5 mm (0.1 in.) and longer shall be measured either in a flatness interferometer or in a light box. If the light box method is used, the deviations shall be measured with a master optical flat and monochromatic light of known wavelength. The interference fringe shall be viewed at an angle within 10 deg of normal incidence. The deviation from flatness in any direction over the gaging surface, excluding 0.8 mm (0.03 in.) on the edges, shall not exceed the tolerances given in Table 8.2.1-1. Since the majority of tolerance Grades 0, AS-1, and AS-2 under 2.5 mm (0.1 in.) in length are not precisely flat in their free state, the test for variation in length (see paras. 4.7 and 8.4.4) is considered sufficient.

C-4 SURFACE TEXTURE ON GAGING SURFACES

The gaging surfaces, after thorough cleaning, should be visually examined. Those appearing to have the rougher surface texture should be compared visually with samples known to have good wringing characteristics. Those blocks that appear to be questionable should be subject to the guidelines and test for wringing quality in section C-5.

The quality of the gaging surface texture plays an important part in the firmness of adherence when wrung, but the relationship between surface texture and wring quality has not been fully established. As a practical guide, a maximum value of 0.025 μm Ra, measured in accordance with ANSI B46.1-2019, should not be exceeded.

C-5 WRINGING QUALITY TEST

Only those blocks that are questionable on the visual surface texture test in section C-4 should be tested for wringing quality (where agreed upon with the customer). The wringing property of measuring faces of the gage blocks is tested using an optical flat. The test should satisfy a deviation from flatness tolerance of 0.1 μm (3.94 μin.) on both gaging surfaces of the gage block. The wrung measuring face should be observed through an optical flat and should be clear of interference bands, color, and bright spots. For gage blocks of Grades K, 00, and 0, no bright spots or shades should be visible. For gage blocks of Grades AS-1 and AS-2, minor bright spots or shades should be permitted.

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NONMANDATORY APPENDIX D
THIN GAGE BLOCKS [LESS THAN 1.0 mm (0.040 in.)]

D-1 INTRODUCTION

Thin gage blocks are harder to calibrate and use than other gage blocks (see Figures D-1-1 and D-1-2). The purpose of this Appendix is to illustrate the difficulties in using this group of gage blocks and to emphasize that extra care and thought should be taken when using them to keep uncertainties as low as expected.

D-2 OUT-OF-FLAT CONDITION

Gage blocks up through 2.5 mm (0.100 in.) are not usually within the flatness tolerance if unwrung. The deviation from flatness of these gages in their free state (unwrung) may be up to 4 µm (157.5 µin.) (see para. 7.2.2). Generally, however, the greater the length (size), the flatter the block will be in its free state. A 2-mm (0.080-in.) block is usually flatter than a 1-mm (0.040-in.) block that is usually flatter than a 0.5-mm (0.020-in.) block. This out of flatness in the free state is usually only a problem for blocks under 1 mm (0.040 in.).

D-3 INCREASED UNCERTAINTY

This lack of flatness in the free state may cause increased uncertainty during use or calibration.

D-3.1 Combination of Gage Blocks

Because it is not usually possible to view the wring of a gage block unless wrung to an optical flat, a thin block may not entirely wring out flat during use. This can lead to errors when used in combinations with other gage blocks. If thin blocks are used in a combination, it would be good practice to check the wrung combination for final flatness before use.

D-3.2 Thin Blocks Used Alone

Even when used alone, measuring system geometry may introduce errors. The specifications in this paragraph should only be used if blocks meet the free state flatness specification.

When using a vertical comparator with dual opposed aligned upper and lower gage heads (see also Nonmandatory Appendix H for comparator types) for measurement, the block should be measured with the top of the block pointing up. In this scenario, the measured deviation is the true value, as the process eliminates any concave or convex (bent) condition inherent in the block.

Whereas using a vertical comparator with single lower gage head or vertical comparator with single upper gage head (see also Nonmandatory Appendix H for comparator types) for measurement, the block should be measured twice: first, with the top of the block pointing up, and second, rotated 180 deg in the horizontal plane and measured with the top of the block pointing down. The smallest of the two deviation results should be reported, thus eliminating any effect due to concave or convex (bend) condition inherent in the block.

When a comparator is used, the contact geometry radius to radius (ball tips), will create deformation and will affect the measured deviation. Therefore, it is necessary to apply deformation corrections depending on the force and tip radius (Engineering Metrology Toolbox, 2023) and then report the undeformed deviation.

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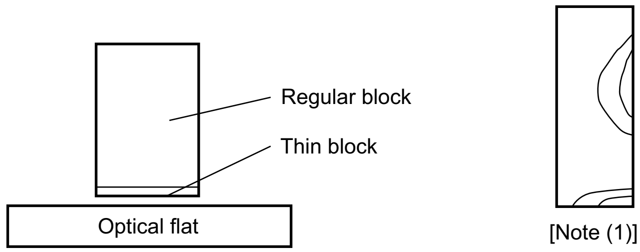
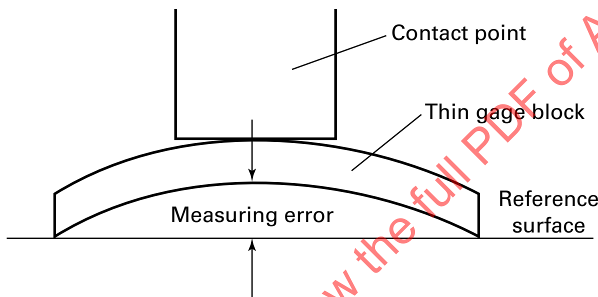
Figure D-1-1
Errors in Wringing of Thin Blocks



NOTE: (1) This band pattern was viewed after wringing a 0.5-mm (0.020-in.) gage block. The block had a flatness of approximately 2.5 µm (100 µin.) in its free state.

Figure D-1-2
Curvature of Thin Blocks Can Cause Measurement Errors



GENERAL NOTE: The method shown is not recommended for measuring gage blocks.

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NONMANDATORY APPENDIX E
USE AND CARE OF GAGE BLOCKS

E-1 INTRODUCTION

The correct use and care of gage blocks is of the utmost importance when attempting to perform close tolerance measurements. This Appendix will explain the extra care required to maintain and correctly use gage blocks to maintain the accuracy and integrity of their use.

E-2 CLEANING GAGE BLOCKS

This cleaning procedure is used for both rectangular and square gage blocks. Cleaning gage blocks properly and thoroughly is extremely important. A gage block with even a thin film covering of grease and grime will never be accurate and will only serve to damage the block when used in this manner. Gage blocks should be cleaned in a nonchlorinated organic solvent such as mineral spirits. Although used in the past, solvents such as trichloroethylene and benzene should not be used because of their severe health risks. Place the gage blocks in a tank or bath that is large enough to completely submerge the blocks in the cleaning solvent. A rubber mat should be placed on the bottom of the tank to reduce the risk of scratching or burring the gage blocks. Soak the gage blocks for a short period of time. Use a clean, soft, lint-free cloth or soft bristle brush dampened with solvent to loosen solidified contaminants. Wipe the blocks dry with a lint-free cloth or towel.

Special attention should be given to the center hole for square gage blocks. While cleaning the blocks, as described above, run a long, small diameter, medium bristle brush through the center bore to dislodge any contaminants. Then dry with a small, soft cloth tied to the end of a weighted string. Weighted end first, pull the string and cloth through the hole. This process may have to be repeated two to three times. Check for dryness prior to using the gage block.

Blocks with only a very thin oil coating may be cleaned effectively with a water-free alcohol, such as ethanol or propanol. This cleaning is often used even after cleaning with solvents such as mineral spirits to remove small traces of oil that remain after the solvent is removed.

Extreme caution should be exercised in handling all gage blocks.

E-3 DEMAGNETIZATION

Demagnetize steel blocks that retain a magnetic field prior to use for measurement or calibration. Good quality electronic demagnetizers and gauss gages (meters) are available through several industrial catalogs.

E-4 STONING AND DEBURRING GAGE BLOCKS

Nicked or badly scratched measuring faces of gage blocks will never permit a good "wring" and may also give incorrect readings. A gage block requires good overall geometry to measure properly.

For removing small nicks and scratches on gage blocks, there are three different, optically flat deburring stones available. All types of stones are used in the same manner but are used on different materials. Black granite and natural Arkansas stones are used on steel blocks to remove burrs and nicks caused by normal use. The sintered aluminum oxide stone, with a serrated top face, will work well on all blocks (including tungsten and chromium carbide) to aggressively remove severe nicks and gouges that may be above the measuring surfaces.

If done correctly, this stoning or deburring process will not lessen the quality or integrity of the gage block. Using a carrier of natural mineral spirits on the stone during the deburring process is preferred by some. It does not show a negative effect or increased wear factor on the gage block. Placing the clean gage block on the deburring stone, and with a very light force of approximately 0.8 N (3 oz), move the burred measuring face of the gage block in a figure eight pattern on the deburring stone. Excess pressure applied to the block may reduce the length or change the geometry of the block.

After a short time (approximately 5 s or less), stop and clean the gage block thoroughly. Check the measuring face of the gage block by wringing it to a glass or quartz auxiliary plate (see para. 9.3.2). View the wrung face through the optical flat looking for bands or light areas. It is usually helpful to use a monochromatic light source when viewing the wrung face. In most cases, depending on the required gage block grade tolerance, a "smudge" (one light band spread over a large area)

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should appear. Repeat the deburring procedure as necessary until the block wrings successfully to the optical flat (see section C-5).

WARNING: Never use an abrasive to remove burrs from gage blocks.

Abrasives used on any deburring stone or lap, or even excess pressure applied to serrated aluminum oxide stone, will remove enough material from the gaging surface to change the measured length of the block.

E-5 WRINGING GAGE BLOCKS

Wringing gage blocks together properly is essential to achieve an accurate gage block setup. The phenomenon of wringing gage blocks together seems to occur for a number of reasons, including adhesive action from the surface tension of an ultra-thin film of oil or moisture held between two blocks and some type of molecular attraction or bond between materials. The better the geometry of the blocks, the better the wring can be.

E-5.1 How to Wring Gage Blocks

This wringing process is used quite frequently and will result in an effective bond of the gage blocks without any measurable wear to their measuring surfaces. The items one will need are a clean, soft, absorbent, lint-free cloth; a small bottle of mineral spirits for use as a cleaner; a pad of clean white "dust-free" paper; and a small container of good quality light instrument oil. First, clean the blocks well by applying a small amount of mineral spirits to the cloth, paying close attention not to scratch the measuring faces. Rub gently until clean. Lay a piece of clean paper on a flat, nonabsorbent clean surface, and place a couple of drops of oil on one area of the paper. Then take one of the previously cleaned gage blocks, and place it with the measuring face down on the paper, sliding it gently in the oiled area. Pick up the gage block, and wipe it with a figure eight motion on a clean nonoiled area of the paper to clean off the excess oil. When cleaned correctly, the oil should only be visible as a slight discoloration to the measuring surface of the block. Quickly, and with light pressure, slide it onto the cleaned surface of the other gage block. With a circular motion, carefully slide the block half out of engagement and then back into a matched position. A good wring will give strong resistance when sliding the blocks into their final position.

E-6 STORAGE

It is important to clean and remove any fingerprints from steel gage blocks prior to storage as oils contained in the fingerprints may contain acids that will corrode and stain the blocks.

Gage blocks that are not in use should be stored in a closed container supplied by the manufacturer. Steel blocks that are not in constant use, or that are stored in an area where the relative humidity exceeds 50%, should be coated with a preservative oil recommended by the gage block manufacturer. Gage blocks should be oiled individually by spraying or dampening a clean, soft, lint-free cloth with the preservative oil and then wiping the cloth over the entire surface of each gage block. Do this for each block.

NOTE: When oiling gage blocks, never spray a preservative oil directly into the gage block case hoping to get the whole set at one time. This oil will collect in the case and, over time, will combine with dust and grime to damage the blocks.

E-7 PACKAGING GAGE BLOCKS FOR SHIPMENT

When shipping gage blocks, take every precaution possible to ensure safe travel. Steel blocks should be oiled (see section E-6). All blocks should be packaged in a case specifically designed for transport, available from the gage block manufacturer. The proper case should not allow the blocks to shake during transit. Some cases will require added cushioning. A thin piece of foam or bubble wrap should remedy the situation. Place a piece of wax paper between the oiled gages and the cushioning to prevent the padding from absorbing any oil off the gage blocks.

NOTE: Too much extra padding is not a good idea, especially if the blocks are thin. The added pressure could warp the blocks or damage the case.

Once all blocks are packaged in the case correctly, the case itself should be locked, if possible, with the key taped securely to the outside top of the case. Then wrap the case in a heavy brown packaging paper, and strap the paper around the case in at least two or three places with a good, strong tape, such as an industrial-grade fiberglass tape. When these steps are completed, package the case in a heavy-duty box for shipping. Make sure the shipping box is large enough to allow for at least 75 mm (3 in.) of solid packing material on all sides and corners of the wrapped gage block case. If the gage blocks are to be returned, request the sender to repackage the blocks in the same manner received.

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E-8 TIE RODS

There are a number of mechanical devices to clamp gage blocks together, intended to ensure the safe transport of wrung gage block stacks. Long rectangle blocks have a hole (see Figure 7.1-1) set at each end for this purpose.

There are also rods with internal threads at the ends that fit into the hole in square blocks. Blocks are clamped together using screws that have heads that match the countersink angle of the holes so they can screw into the rod and lie completely below the gaging surface of the block.

Serious misuses of tie rods that should be avoided are the following:

(a) Tie rods should be loosened before using the stack as a length standard. Even small pressure from the tie rod can have a serious effect on the length of the gage block stack.

(b) A tie rod is not a substitute for wringing the blocks together. If the blocks are merely stacked and connected with the tie rod, the length of the stack is completely disconnected from their calibrations and should not be used as a length standard.

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