ASME B89.1.9-2002

[Revision of ANSI/ASME B89.1.9-1984 (R1997)]

GAGE BLOCKS

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Errata
to
ASME B89.1.9-2002
Gage Blocks

The errata corrections listed below apply to ASME B89.1.9-2002. Corrected figures and tables follow.

Page	*Location*	*Change*
3	Fig. 1B	Dimensions revised; reference point added to second and last drawings
4	Table 1a	Entries in last three columns revised
5	Table 1b	Entries in last three columns revised
	Fig. 5	(1) ϕ deleted from top callout (2) *0.02* and *0.03* revised to read *0.2* and *0.3*, respectively
14	Table B1	∀ replaced by ± in four places
	Table B3	∀ replaced by ± in six places
26	Table G1	(1) In last column, 18th through 29th entries revised (2) In last row, first five entries revised

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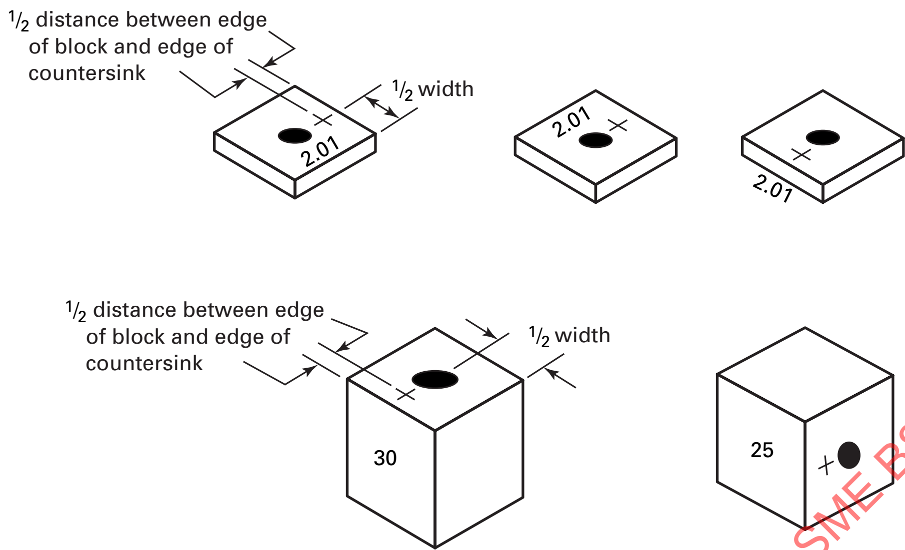

FIG. 1B REFERENCE POINTS OF SQUARE GAGE BLOCKS

TABLE 1a
DIMENSIONS IN MILLIMETERS

		a (width)		*b* (depth)	
Cross Section	**Nominal length, l_n**	**Nominal**	**Tolerance**	**Nominal**	**Tolerance**
Square	0 to 1000	24.1	±0.2	24.1	±0.2
Rectangle	0.5 up to 10	30	+0.0/−0.3	9	−0.05/−0.20
	Over 10 up to 1000	35	+0.0/−0.3	9	−0.05/−0.20

GENERAL NOTE: Square gage blocks have a 6.7 mm ±0.1 mm center hole. 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 1b
DIMENSIONS IN INCHES

		a (width)		*b* (depth)	
Cross Section	**Nominal Length, l_n**	**Nominal**	**Tolerance**	**Nominal**	**Tolerance**
Square	0 to 40	0.95	± 0.01	0.95	± 0.01
Rectangle	0.01 to 0.2	1.181	+ 0.074 − 0.084	0.355	+ 0.020 − 0.010
	Over 0.2 up to 40	1.378	+ 0.010 − 0.207	0.355	+ 0.020 − 0.010

GENERAL NOTE: Square gage blocks have a 0.265 ±0.010 in. center hole. 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.

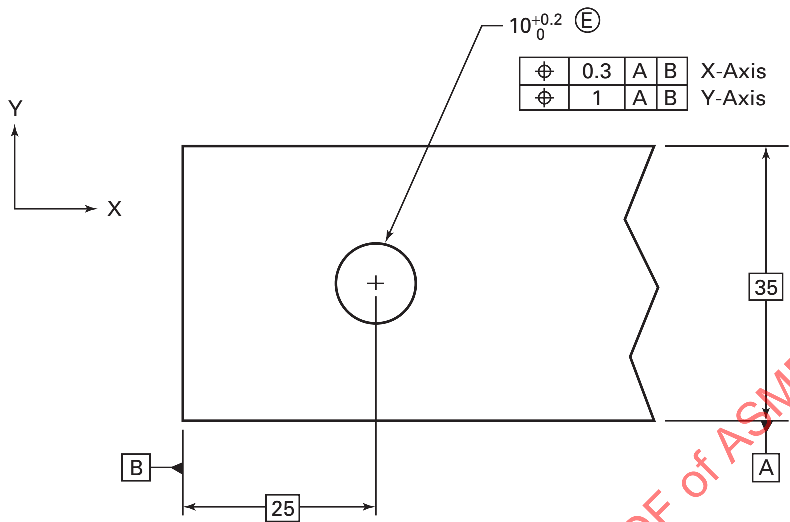

FIG. 5 DIMENSIONS OF COUPLING HOLES (mm)

TABLE B1 EXAMPLE OF TOLERANCE CHANGES

Size	GGG-G-15C	This Standard
1 mm	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
0.1 in.	Grade 2, +4/−2 μin.	Grade 0, ±5 μin.
2.0 in.	Grade 3, +16/−8 μin.	Grade AS-1, ±16 μin.

TABLE B3 LENGTH TOLERANCE COMPARISON

Size	GGG-G-15C	This Standard
1 mm	Grade 1, ± 0.05 μm	Grade AS-1, ±0.20 μm
75 mm	Grade 2, + 0.25/−0.12 μm	Grade AS-2, ±1.00 μm
0.1 in.	Grade 1, ± 2 μin.	Grade AS-1, ±8 μin.
1.0 in.	Grade 2, +4/−2 μin.	Grade AS-2, ±24 μin.

TABLE G1 INCH GAGE BLOCK SIZES (IN INCHES)

0.0055	0.0202	0.052	0.1007	0.130	0.20008
0.006	0.0203	0.053	0.1008	0.131	0.20009
0.0065	0.0204	0.054	0.1009	0.132	0.250
0.007	0.0205	0.055	0.101	0.133	0.300
0.0075	0.0206	0.056	0.102	0.134	0.350
0.008	0.0207	0.057	0.103	0.135	0.400
0.0085	0.0208	0.058	0.104	0.136	0.450
0.009	0.0209	0.059	0.105	0.137	0.500
0.0095	0.021	0.060	0.106	0.138	0.550
0.010	0.022	0.0625	0.107	0.139	0.600
0.01005	0.023	0.070	0.108	0.140	0.650
0.0101	0.024	0.078125	0.109	0.141	0.700
0.0102	0.025	0.080	0.109375	0.142	0.750
0.0103	0.026	0.090	0.110	0.143	0.800
0.0104	0.027	0.09375	0.111	0.144	0.850
0.0105	0.028	0.100	0.112	0.145	0.900
0.0106	0.029	0.10001	0.113	0.146	0.950
0.0107	0.030	0.10002	0.114	0.147	1.000
0.0108	0.03125	0.100025	0.115	0.148	2.000
0.0109	0.040	0.10003	0.116	0.149	3.000
0.011	0.046875	0.10004	0.117	0.150	4.000
0.012	0.050	0.10005	0.118	0.160	5.000
0.013	0.05005	0.10006	0.119	0.170	6.000
0.014	0.0501	0.10007	0.120	0.180	7.000
0.015	0.0502	0.100075	0.121	0.190	8.000
0.015625	0.0503	0.10008	0.122	0.200	10.000
0.016	0.0504	0.10009	0.123	0.20001	12.000
0.017	0.0505	0.1001	0.124	0.20002	16.000
0.018	0.0506	0.1002	0.125	0.20003	20.000
0.019	0.0507	0.1003	0.126	0.20004	...
0.020	0.0508	0.1004	0.127	0.20005	...
0.02005	0.0509	0.1005	0.128	0.20006	...
0.0201	0.051	0.1006	0.129	0.20007	...

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GAGE BLOCKS

ASME B89.1.9-2002

[Revision of ANSI/ASME B89.1.9-1984 (R1997)]

Date of Issuance: July 12, 2002

The next edition of this Standard is scheduled for publication in 2007. There will be no addenda or written interpretations of the requirements of this Standard issued to this edition.

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.

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Nonmandatory Appendices

FOREWORD

The United States gage block standard has not changed substantively since GGG-G-15B of 1970. During the intervening years there have been a number of 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 B89.1.9 Committee began to consider a total rewrite of the standard in the early 1990s. Our basic criteria were to adhere to the International Standard ISO 3650 as closely as possible, while making necessary additions to adapt the standard to measuring practice in the United States.

The most obvious additions were specifications for inch system gage blocks. We have avoided the more traditional term "English" system because the metric system is the legal system of units in England. The International Standard also only defines rectangular gage blocks, the United States being perhaps the only country to have square "Hoke" style blocks in significant numbers. Since the new grades have some of the same designations as the old standard we have added prefix "AS" to the names of Grades 1 and 2 to prevent misidentification. We have also added a Grade 00 with tolerances near those of the current U.S. Grade 1. While the committee basically agreed with the logic behind the ISO 3650 grade tolerances, we also recognized that the use of graded sets is deeply imbedded in some industries, and the loss of the high accuracy grade would be a hardship for some users.

There are a large number of appendixes to the standard. Most of these appendixes have information that is not in the current ISO 3650, but was in GGG-G-15C or previous editions of B89.1.9. The two largest and most important of these describe the differences between this Standard and its predecessors in Nonmandatory Appendix B, and the definition and tolerances on gage block accessories in Nonmandatory Appendix H.

The committee would also like to acknowledge the large number of people who, while not members of the committee, were kind enough to attend an occasional meeting or send comments on the early drafts of the 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 as an American National Standard on January 14, 2002.

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Dimensional Metrology

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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.

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

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

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

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

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

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

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GAGE BLOCKS

0 INTRODUCTION

Gage blocks are length standards representing specific fractions of the unit of length, 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.

1 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 0.5 mm to 1 000 mm for metric sizes and 0.010 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 for the Grades 00, 0, AS-1, and AS-2 for various measuring purposes.

NOTE: To avoid confusing Grades 1 and 2 with previous definitions, the prefix "AS" for "American Standard" should be used for all sets using the grade tolerances in this Standard.

NOTE: The characteristics of Grades K, 0, AS-1, and AS-2 are identical to those of the same name in ISO 3650: Gage Blocks, with the exception that in this Standard the length of the block is defined when measured in the vertical orientation. Grade 00 has been added to conform more closely to the current U.S. Standard (see section A1).

2 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. ANSI maintains registers of currently valid International Standards and U.S. National Standards.

ASME Y14.5-1994, Dimensioning and Tolerancing

Publisher: The American Society of Mechanical Engineers (ASME International), Three Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

ASTM E 18-94, Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

ASTM E 140-95, Standard Hardness Conversion Tables for Metals

Publisher: The American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ISO 1: 1975: Standard reference temperature for industrial length measurements

ISO 6507-1: 1997, Metallic materials - Vickers hardness test - Part 1: Test method

ISO 3650: 1998, Gauge Blocks

ISO, International Vocabulary of Basic and General Terms in Metrology (VIM), 1993

ISO, Guide to the expression of uncertainty in measurement: 1993, corrected and reprinted in 1995 (GUM)

Publisher: International Organization for Standardization (ISO), 1 rue de Varembé, Case Postale 56, CH-1121, Genève 20, Switzerland, Suisse

3 DEFINITIONS

3.1 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. 3.7) to the measuring faces of other gage blocks to make composite assemblies, or to similarly textured surfaces of auxiliary plates for length measurements.

3.2 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 upon which

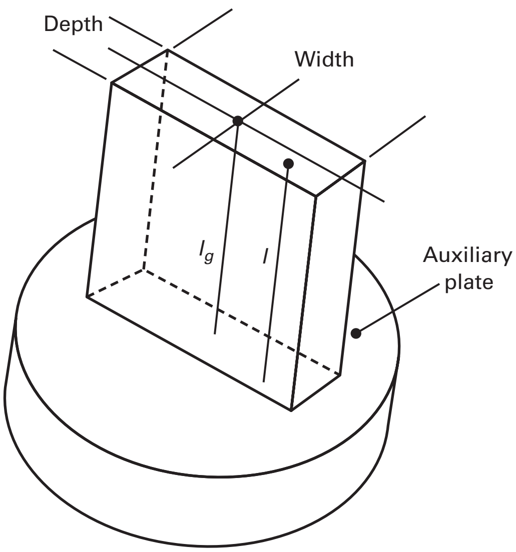

FIG. 1A GAGE LENGTH l_g AND ANOTHER EXAMPLE FOR LENGTH l AT ANY POINT OF A GAGE BLOCK WRUNG TO THE PLANE SURFACE OF AN AUXILIARY PLATE

the other measuring face has been wrung (see para. 3.4 and Figs. 1a and 1b)

The length of a gage block l includes the effect of one face wringing (see para. 8.3.1).

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.

3.3 Gage Length l_g of a Gage Block

3.3.1 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 Fig. 1a).

NOTE: l_g is a special instance of length l.

3.3.2 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 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 Fig. 1b).

3.4 Deviation of the Length at any Point From Nominal Length e

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

3.5 Deviation From Flatness f_d

The deviation f_d from flatness is the minimum distance between two parallel planes between which all points of the measuring face lie (see Fig. 2).

3.6 Variation in Length v

The variation v in length 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 Fig. 3).

3.7 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 F, section F5).

4 NOMENCLATURE OF FACES

Rectangular and square gage blocks (see Fig. 4).

5 BASIS OF MEASUREMENT, TRACEABILITY, AND REFERENCE CONDITION

5.1 Units of Length (Meter, Inch)

The meter is defined as the distance traveled by light in vacuum in 1/299 792 458 of a second (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 (CIPM). One inch is 25.4 mm, exactly.

5.2 Traceability

The measured length of a gage block is traceable to national or international standards of length, if the measurement result can be related by an unbroken chain of comparison measurements each with documented uncertainties to a gage block that has been calibrated by interferometry using appropriate wavelength standards.

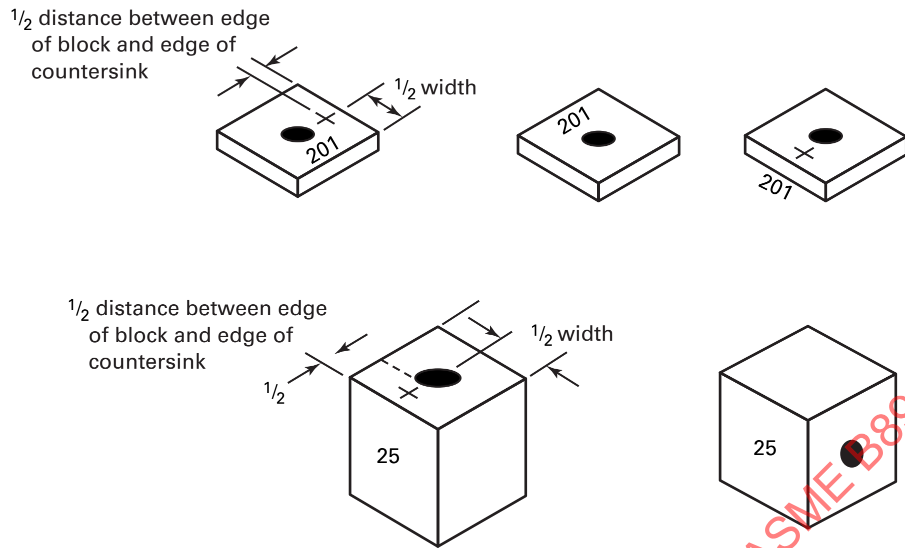

FIG. 1B REFERENCE POINTS OF SQUARE GAGE BLOCKS

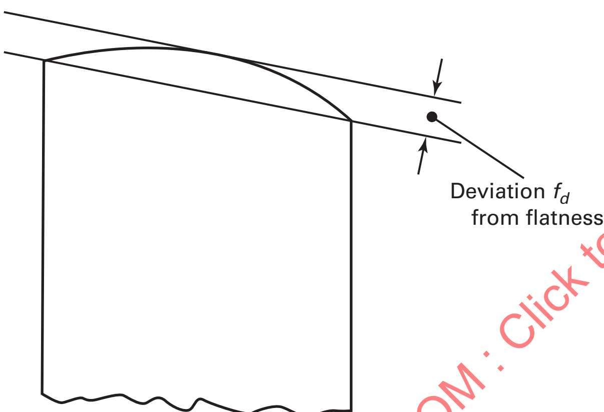

FIG. 2 DEVIATION FROM FLATNESS f_d

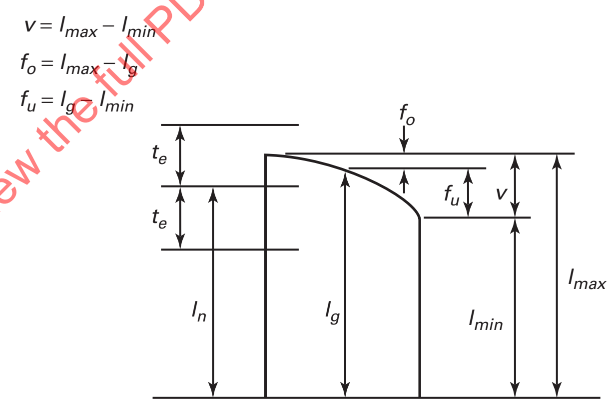

FIG. 3 NOMINAL LENGTH, l_n; GAGE LENGTH, l_g; VARIATION, v WITH f_o and f_u; LIMIT DEVIATIONS, t_e, FOR LENGTH AT ANY POINT, PROCEEDING FROM THE NOMINAL LENGTH (See Para. 7.1 and Tables 4a and 4b)

5.3 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 (760 mm Hg).

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

5.4 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 Appendices D and I). The orientation of blocks over 100 mm (4 in.) in length should be recorded in the calibration report.

6 GENERAL DIMENSIONS, MATERIAL PROPERTIES, AND MARKING

6.1 General Dimensions

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

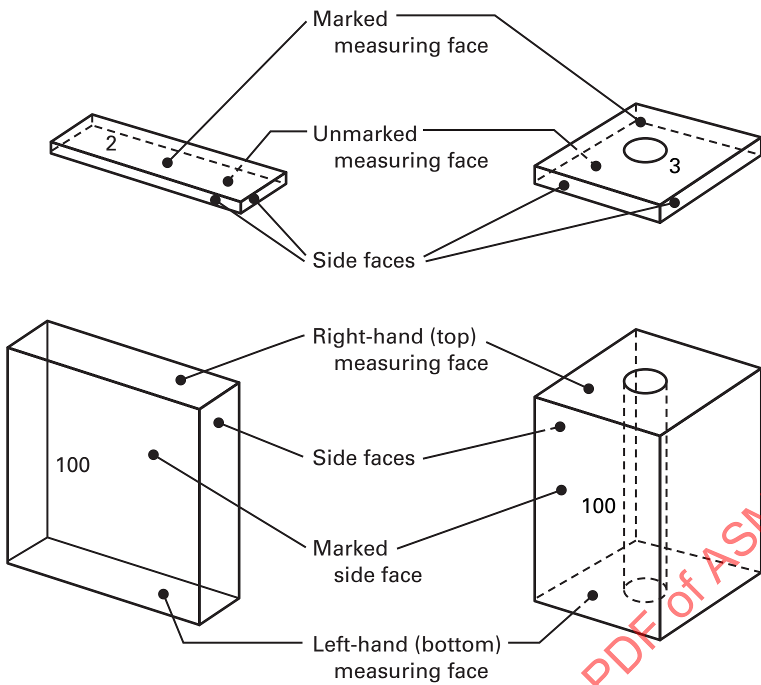

FIG. 4 NOMENCLATURE OF FACES OF GAGE BLOCKS

TABLE 1a
DIMENSIONS IN MILLIMETERS

Cross Section	Nominal length, l_n	a (width) Nominal	a (width) Tolerance	b (depth) Nominal	b (depth) Tolerance
Square	0 to 1000	24.1	±0.2	24.1	±0.2
Rectangle	0.5 up to 10	30	0	. . .	−0.05
	Over 10 up to 1000	35	−0.3	9	−0.20

GENERAL NOTE: Square gage blocks have a 6.7 mm ±0.1 mm center hole. 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.

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 Fig. 5. Rectangular gage blocks of Grade K shall not be combined with coupling devices.

6.2 Material Properties

6.2.1 Material. Gage blocks shall be made of high grade steel or of other wear-resistant materials capable of being finished with surfaces that will wring readily, and that will be stable for length within the tolerance in Table 2.

6.2.2 Coefficient of Thermal Expansion. The coefficient of thermal expansion of steel gage blocks in the temperature range 10°C to 30°C shall be $(11.5 \pm 1.0) \times 10^{-6}$ / °C.

The coefficient of expansion with its uncertainty of determination shall be supplied with steel Grade K and Grade 00 gage blocks, also with all grades made with materials other than hardened steel.

6.2.3 Hardness. The measuring faces of steel gage blocks shall have a Vickers hardness of not less than 800 HV 0.5 (see ISO 6507-2) or Rockwell C62 (see ASTM E 18-94 and ASTM E 140-95).

TABLE 1b
DIMENSIONS IN INCHES

Cross Section	Nominal Length, l_n	*a* (width) Nominal	*a* (width) Tolerance	*b* (depth) Nominal	*b* (depth) Tolerance
Square	0 to 40	0.95	±0.01	0.95	±0.01
Rectangle	0.01 to 0.2	1.181	+0.074		
			−0.084	0.355	+0.020
	Over 0.2 up to 40	1.378	+0.010		−0.010
			−0.0207		

GENERAL NOTE: Square gage blocks have a 0.265 ±0.010 in. center hole. 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.

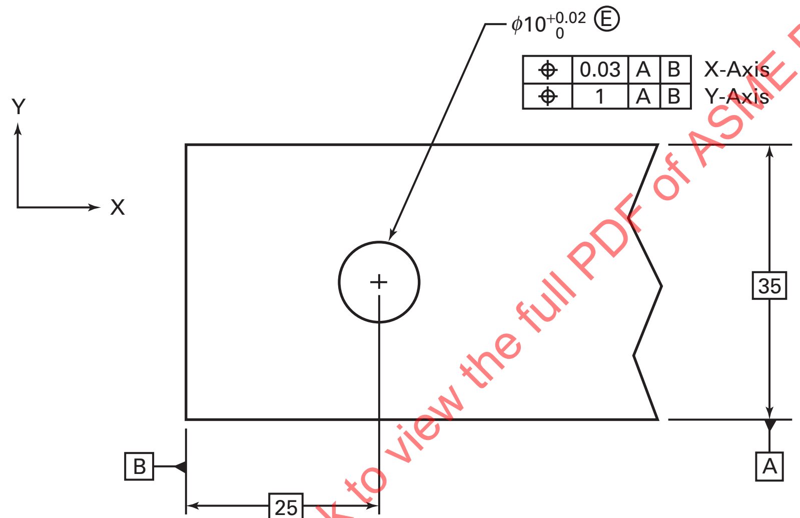

FIG. 5 DIMENSIONS OF COUPLING HOLES (mm)

TABLE 2 DIMENSIONAL STABILITY

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

6.2.4 Dimensional Stability. The maximum permissible changes in length per year of gage blocks are stated in Table 2. They apply when the gage blocks are not exposed to exceptional temperatures, vibrations, shocks, magnetic fields or mechanical forces.

6.3 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 high. Rectangular gage blocks smaller than 6 mm nominal length may be marked on a measuring face, but an area of 9 mm × 12 mm at the center of the measuring face and an area of 2.5 mm × 2.5 mm 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.

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:

Calibration Grade = K:K
Grade = 00: 00
Grade = 0: 0
Grade = AS-1: −
Grade = AS-2: =

TABLE 3 DEVIATION FROM FLATNESS TOLERANCE t_f

	Deviation from flatness tolerance t_f in μm (μin.)					
	Style and Grade					
Nominal Length Range for l_n	K All Styles	00 Rectangular	00 Square	0 All Styles	AS-1 All Styles	AS-2 All Styles
0.5 mm up to 50 mm	0.05	0.05	0.05	0.1	0.15	0.25
0.010 in. up to 2 in.	(2)	(2)	(2)	(4)	(6)	(10)
50 mm up to 150 mm	0.05	0.05	0.07	0.1	0.15	0.25
2 in. up to 6 in.	(2)	(2)	(3)	(4)	(6)	(10)
Over 150 mm up to 500 mm	0.1	0.1	0.1	0.15	0.18	0.25
Over 6 in. up to 20 in.	(4)	(4)	(4)	(6)	(7)	(10)
Over 500 mm up to 1 000 mm	0.15	0.15	0.15	0.18	0.20	0.25
Over 20 in. up to 40 in.	(6)	(6)	(6)	(7)	(8)	(10)

7 METROLOGICAL REQUIREMENTS

7.1 General

Each gage block shall conform to the requirements of its grade (see Tables 4a and 4b), as indicated below.

NOTE: In previous editions, the quantity "parallelism of the gaging faces" was specified in place of variation in length.

The requirements of Tables 3, 4a, and 4b apply to the measuring faces of the gage block omitting a border zone with a maximum width of 0.8 mm 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.

7.2 Deviation From Flatness Tolerance t_f

7.2.1 Gage Blocks With Nominal Length Exceeding 2.5 mm (0.1 in.). The deviation f_d from flatness 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 3, whether the gage block is wrung to an auxiliary plate or is in the unwrung state.

7.2.2 Gage Blocks With Nominal Length up to 2.5 mm (0.1 in.). The deviation f_d from flatness 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 3 when the gage block is wrung to an auxiliary plate (see para. 8.3.2) with a thickness of not less than 11 mm.

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

7.3 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 or provided with a chamfer not exceeding 0.3 mm. The transition between the chamfer and the measuring face shall be such that the wringing property of the measuring faces is not impaired.

7.4 Side Faces

7.4.1 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.

7.4.2 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 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.

7.4.3 Side Face Perpendicularity. The deviation from perpendicularity of a side face with a measuring face shall not exceed the values given in Table 5 (see Fig. 6).

7.4.4 Side Face Edges. All edges between the side faces shall have a radius or chamfer of not more than 0.3 mm (0.013 in.).

TABLE 4a MAXIMUM PERMITTED DEVIATIONS OF THE LENGTH AT ANY POINT AND TOLERANCE ON VARIATION IN LENGTH FOR METRIC GAGE BLOCKS

Nominal Length Range	Calibration Grade K		Grade 00		Grade 0		Grade AS-1		Grade AS-2	
l_n in mm	Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µm	Tolerance for the Variation In Length t_v µm	Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µm	Tolerance for the Variation In Length t_v µm	Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µm	Tolerance for the Variation in Length t_v µm	Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µm	Tolerance for the Variation in Length t_v µm	Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µm	Tolerance for the Variation in Length t_v µm
$l_n \leq 0.5$	0.30	0.05	0.10	0.05	0.14	0.10	0.30	0.16	0.60	0.30
$0.5 < l_n \leq 10$	0.20	0.05	0.07	0.05	0.12	0.10	0.20	0.16	0.45	0.30
$10 < l_n \leq 25$	0.30	0.05	0.07	0.05	0.14	0.10	0.30	0.16	0.60	0.30
$25 < l_n \leq 50$	0.40	0.06	0.10	0.06	0.20	0.10	0.40	0.18	0.80	0.30
$50 < l_n \leq 75$	0.50	0.06	0.12	0.07	0.25	0.12	0.50	0.18	1.00	0.35
$75 < l_n \leq 100$	0.60	0.07	0.15	0.07	0.30	0.12	0.60	0.20	1.20	0.35
$100 < l_n \leq 150$	0.80	0.08	0.20	0.08	0.40	0.14	0.80	0.20	1.60	0.40
$150 < l_n \leq 200$	1.00	0.09	0.25	0.09	0.50	0.16	1.00	0.25	2.00	0.40
$200 < l_n \leq 250$	1.20	0.10	0.30	0.10	0.60	0.16	1.20	0.25	2.40	0.45
$250 < l_n \leq 300$	1.40	0.10	0.35	0.10	0.70	0.18	1.40	0.25	2.80	0.50
$300 < l_n \leq 400$	1.80	0.12	0.45	0.12	0.90	0.20	1.80	0.30	3.60	0.50
$400 < l_n \leq 500$	2.20	0.14	0.50	0.14	1.10	0.25	2.20	0.35	4.40	0.60
$500 < l_n \leq 600$	2.60	0.16	0.65	0.16	1.30	0.25	2.60	0.40	5.00	0.70
$600 < l_n \leq 700$	3.00	0.18	0.75	0.18	1.50	0.30	3.00	0.45	6.00	0.70
$700 < l_n \leq 800$	3.40	0.20	0.85	0.20	1.70	0.30	3.40	0.50	6.50	0.80
$800 < l_n \leq 900$	3.80	0.20	0.95	0.20	1.90	0.35	3.80	0.50	7.50	0.90
$900 < l_n \leq 1000$	4.20	0.25	1.00	0.25	2.00	0.40	4.20	0.60	8.00	1.00

TABLE 4b MAXIMUM PERMITTED DEVIATIONS OF THE LENGTH AT ANY POINT AND TOLERANCE ON VARIATION IN LENGTH FOR INCH GAGE BLOCKS

Nominal Length Range	Calibration Grade K		Grade 00		Grade 0		Grade AS-1		Grade AS-2	
l_n in inches	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 Llength $\pm t_e$ 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.
$l_n \leq 0.05$	12	2	4	2	6	4	12	6	24	12
$0.05 < l_n \leq 0.4$	10	2	3	2	5	4	8	6	18	12
$0.45 < l_n \leq 1$	12	2	3	2	6	4	12	6	24	12
$1 < l_n \leq 2$	16	2	4	2	8	4	16	6	32	12
$2 < l_n \leq 3$	20	2	5	3	10	4	20	6	40	14
$3 < l_n \leq 4$	24	3	6	3	12	5	24	8	48	14
$4 < l_n \leq 5$	32	3	8	3	16	5	32	8	64	16
$5 < l_n \leq 6$	32	3	8	3	16	5	32	8	64	16
$6 < l_n \leq 7$	40	4	10	4	20	6	40	10	80	16
$7 < l_n \leq 8$	40	4	10	4	20	6	40	10	80	16
$8 < l_n \leq 10$	48	4	12	4	24	6	48	10	104	18
$10 < l_n \leq 12$	56	4	14	4	28	7	56	10	112	20
$12 < l_n \leq 16$	72	5	18	5	36	8	72	12	144	20
$16 < l_n \leq 20$	88	6	20	6	44	10	88	14	176	24
$20 < l_n \leq 24$	104	6	25	6	52	10	104	16	200	28
$24 < l_n \leq 28$	120	7	30	7	60	12	120	18	240	28
$28 < l_n \leq 32$	136	8	34	8	68	12	136	20	260	32
$32 < l_n \leq 36$	152	8	38	8	76	14	152	20	300	36
$36 < l_n \leq 40$	160	10	40	10	80	16	168	24	320	40

TABLE 5 PERPENDICULARITY TOLERANCE

Nominal Length	Perpendicularity Tolerance µm (in.)
From 10 mm up to 25 mm From 0.1 in. up to 1 in.	50 (0.002)
From 25 mm up to 60 mm From 1 in. up to 2 in.	70 (0.003)
From 60 mm up to 150 mm From 2 in. up to 6 in.	100 (0.004)
From 150 mm up to 400 mm From 6 in. up to 16 in.	140 (0.005)
From 400 mm up to 1 000 mm From 16 in. up to 40 in.	180 (0.006)

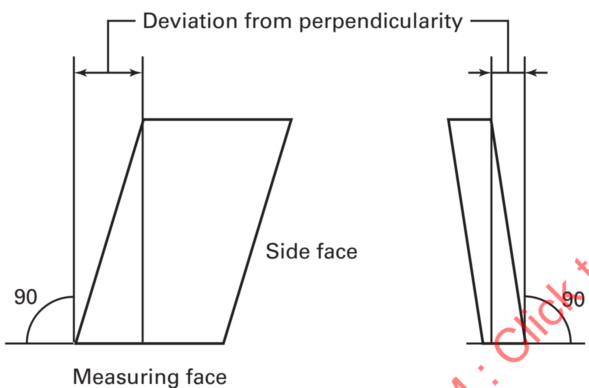

FIG. 6 PERPENDICULARITY OF A SIDE FACE WITH A MEASURING FACE

8 CALIBRATION OF GAGE BLOCKS

8.1 General

Measurement of gage blocks is outlined in paras. 5.1 and 5.2 as a sequence starting from the basic definition of the unit of length and proceeding through the stage of interferometry for high grade (preferably K grade) 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. 8.3 and 8.4, respectively. The measurement result of length and the associated uncertainty shall be supplied in a calibration certificate.

8.2 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 grade AS-1 and AS-2 bright spots or shades of a minor extent (less than $\frac{1}{4}$ of total area) are permitted.

8.3 Measurement by Interferometry

8.3.1 Measured Length. The length of a gage block as shown in Figs. 1a and 1b (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 Fig. 4) wrung to a reference surface of the same material and surface texture (see para. 3.2). 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. 3.6) shall be made at the points of maximum length l_{max} and minimum length l_{min} of the gage block (see Fig. 3).

8.3.2 Auxiliary Plate. The auxiliary plate upon which the gage block is wrung during the measurement shall meet the requirements of para. 6.2 (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. 8.3.3). The auxiliary plate shall be not less than 11 mm thick and it shall have a wringing face with flatness deviations of less than 0.025 µm over a diameter of 40 mm.

8.3.3 Corrections to Measurements by Interferometry. Corrections shall be made to the calculations for significant influences, e.g.:

(a) temperature, atmospheric pressure and atmospheric humidity on the wavelength of light;

(b) deviation of temperature of the gage block from 20°C (68°F);

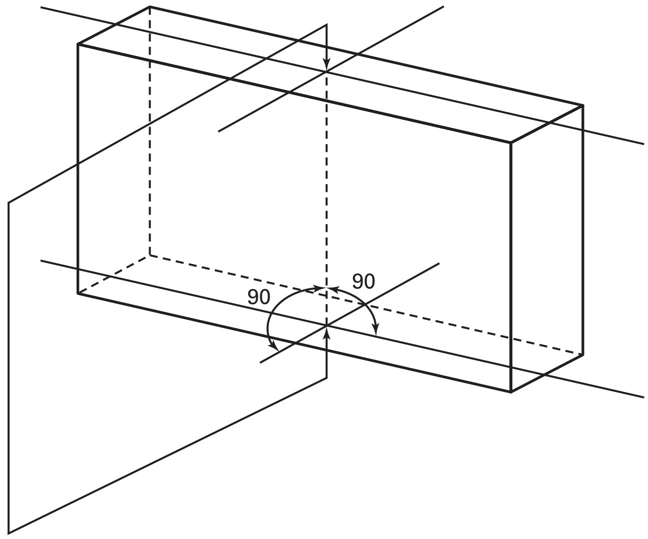

FIG. 7 MEASUREMENT OF GAGE LENGTH BY COMPARISON TAKING THE PERPENDICULAR DISTANCE FROM THE REFERENCE POINT OF A MEASURING FACE TO THE OPPOSITE FACE

(c) wringing action on the length of the gage block when the gage block and the 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.

8.3.4 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 GUM), 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 (see para. 8.3.3).

8.4 Measurement by Comparison

8.4.1 Principle of Measurement. In order 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 Fig. 7, and the length difference is measured by a high-resolution length indicator.

8.4.2 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 either directly be 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.

8.4.3 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.

8.4.4 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 at the 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.

8.4.5 Corrections. Corrections for the following effects should be made when calculating the result of comparison for the length of gage blocks concerned (see para. 8.4.2):

(a) bias of the measuring device (see VIM 5.25);

(b) influence of temperature differing from 20°C 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.

8.4.6 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 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. 8.4.5.

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NONMANDATORY APPENDIX A
GRADE 00

A1 INTRODUCTION

Gage Blocks were invented to provide a way to make accurate length standards for a very wide range of lengths with only a few gages. The gages are combined in different combinations by wringing to provide the needed length. A few well-characterized gages were not adequate because of the limited range of existing high accuracy indicators. One of the reasons for the development of gage block grades was to allow the user to make gage block stacks of known worst case deviation from nominal. If this worst case uncertainty was acceptable for use, the user did not have to consult the calibration report and calculate the length of each stack from the reported deviations of the individual blocks.

Current gaging practice is in a transition from these traditional short-range indicators to longer range indicators such as laser interferometers and linear gratings. These long-range indicators can be calibrated using a very small set of artifacts, and for a small set of gages the use of the calibrated corrections is very simple. Thus, the need for wringing stacks of gage blocks and the associated calculations is unnecessary. The length tolerance in Tables 4a and 4b reflect this change in use of gage blocks. Since the transition to long range indicators is not complete, this appendix describes an alternative grade for gage blocks to be used in addition to the grades in the main body of the standard.

A2 GENERAL

The geometry requirements (deviation from flatness and variation in length) for Grade 00 are the same as those of Grade K in this Standard. The length tolerances are generally $^1/_4$ of those for Grade K, and are given in Tables 4a and 4b.

NONMANDATORY APPENDIX B
DIFFERENCES BETWEEN FORMER GGG-G-15C AND THIS STANDARD

TABLE B1 EXAMPLE OF TOLERANCE CHANGES

Size	GGG-G-15C	This Standard
1 mm	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
0.1 in.	Grade 2, +4/–2 μin.	Grade 0, ∀ 5 μin.
2.0 in.	Grade 3, +16/–8 μin.	Grade AS-1, ∀ 16 μin.

B1 INTRODUCTION

This appendix is intended to be a guide in highlighting the major differences between Federal Specification GGG-G-15C and this Standard. The earlier edition of this Standard, ANSI/ASME B89.1.9-1984 (R1997), is nearly identical in content to GGG-G-15C (1971).

B2 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.

B3 POINTS ON GAGING SURFACE WITHIN TOLERANCE BAND

All the points on the gaging surface must 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.

TABLE B2 SUGGESTED REPLACEMENT GRADES

Former Federal Grade (Reference GGG-G-15C)	Grades (This Standard)
1	00
2	0
3	AS-1
. . .	AS-2

TABLE B3 LENGTH TOLERANCE COMPARISON

Size	GGG-G-15C	This Standard
1 mm	Grade 1, ∀ 0.05 μm	Grade AS-1, ∀ 0.20 μm
75 mm	Grade 2, + 0.25/–0.12 μm	Grade AS-2, ∀ 1.00 μm
0.1 in.	Grade 1, ∀ 2 μin.	Grade AS-1, ∀ 8 μin.
1.0 in.	Grade 2, +4/–2 μin.	Grade AS-2, ∀ 24 μin.

B4 PARALLELISM

The term *parallelism* as used in GGG-G-15C is replaced in this Standard by *variation in length* (see para. 3.6).

B5 LENGTH TOLERANCES

B5.1 Suggested Replacements for Former Federal Grades

While not exact, the grades in Table B2 are listed as a guide to users when ordering replacement blocks for sets with former Federal Grades:

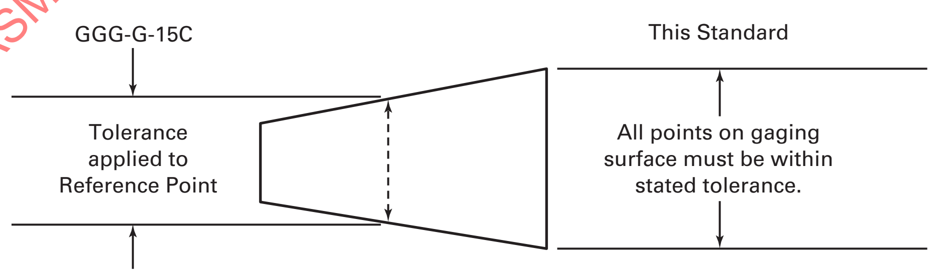


FIG. B1 CHANGE IN DEFINITION OF TOLERANCE BAND FOR LENGTH

Close comparison of the length tolerances of the suggested grades in Table B2 to those of the former Federal Grades, may reveal that the suggested grades of the 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 B3), and partly due to the bilateral tolerancing. The suggested replacements in Table B2 are not exact.

B5.2 Grade K

A Grade K has been introduced in this Standard that has no analogous former Federal Grade. The intended use of this grade is as a comparison standard for calibration. These blocks have tighter tolerances for variation in length and deviation from flatness than most blocks, but have a fairly large length tolerance. As comparison masters, they must be used with corrections for their calibrated lengths.

B5.2.1 Grade K vs. Grade 00. The tolerance for variation in length and deviation from flatness for Grade 00 are comparable to Grade K in this Standard (see Nonmandatory Appendix A and Tables 4a and 4b). Grade 00 has tighter length tolerances than Grade K. Therefore, Grade 00 blocks may be used as Grade K blocks, but Grade K blocks cannot be used as Grade 00.

B5.3 Grade AS-2

A Grade AS-2 has been introduced into this Standard with tolerances approximately double those of any former Federal Grade. This grade is intended for use in applications where extreme accuracy is not required. It is also recommended that corrections for their calibrated length be made during use.

B5.4 Different Tolerances for Grades AS-1 and AS-2

Grade AS-1 and Grade AS-2 block tolerances of this Standard should not be confused with tolerances of former Federal Grades 1 and 2. These tolerances are very different. The length tolerances can be four times or more greater than the former Federal tolerances. The tolerances for deviation from flatness and variation in length are also very different.

B5.5 Former Federal Grade 0.5

Former Federal Grade 0.5 or an equivalent is not listed in this Standard.

B6 TOLERANCING IN THE METRIC SYSTEM

Tolerances in this Standard are given primarily in the metric system, except where specifically applicable to the length (size) of an inch system block.

B7 ACCEPTANCE/REJECTION OF GAGE BLOCKS (i.e., OUT OF TOLERANCE CONDITION)

B7.1 Acceptance/Rejection: Former Federal Specification GGG-G-15C

Federal Specification GGG-G-15C contained a table for the Allowance of Measurement Uncertainty. For new gages, the tolerances used for acceptance/rejection were increased both plus and minus by the amount given in the table that depended on the grade and length of the block. For used gage blocks, it was recommended that blocks that exceeded twice the length, variation in length, or deviation from flatness tolerances for new gages be replaced.

B7.2 Acceptance/Rejection: This Standard

This Standard does not recommend any particular criteria for making in/out of grade decisions. Gage block manufacturers and suppliers should specify in their literature or catalog the acceptance criteria used to assign grades. The buyer may, of course, either accept these criteria or specify different criteria when buying new blocks.

B7.3 Used Gage Blocks: Customer Specification for Acceptance/Rejection

There is no special rule for used gage blocks in the new 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.

B8 APPENDICES

Specification for accessories, the listing of some gage blocks sets, packaging, and testing/inspection methods have 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.

NONMANDATORY APPENDIX C
TESTING METHODS

C1 SIZE MEASUREMENT

C1.1 Measurement by Interferometry

To comply with the requirement of para. 3.4, the length l_g is measured at the gage points defined in Figs. 1a and 1b. To fulfill the requirements of para. 3.3, 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 shall have a thickness of at least 11 mm and the surface shall be flat to within 0.025 μm over any 40 mm diameter area and shall not be concave. When the gage block is measured in the horizontal position and the auxiliary plate is wrung to one measuring face, compensation must be made for the mass of the auxiliary plate.

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

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

(b) effects of temperature, barometric pressure, and optical phase shift on the length
(Note that standard atmospheric pressure is 101.325 kPa);

(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 rigid plane 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 plane surface in turn. If this procedure has been followed, it should be stated in the report.

C1.2 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 Fig. 7). 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 may have to be taken into account, particularly if the blocks have nominal lengths less than 1.5 mm. 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.

C2 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 at the edges of the faces, and shall meet the requirements of Tables 4a and 4b, and para. 7.4.4. 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 from the edges. The positions of the measurement points should be stated in the report if the variation in length is reported or the grade tolerance verified.

C3 FLATNESS OF GAGING SURFACE

For tolerance Grades K and 00, the deviation from flatness of the gaging surfaces on blocks 2.5 mm 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 on the edges, shall not exceed the tolerances given in Table 3. (Blocks of tolerance Grades K and 00 under 2.5 mm 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 and longer shall be measured either in a flatness interferometer or 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 on the edges, shall not exceed the tolerances given in Table 3. Since the majority of tolerance Grades 0, AS-1, and AS-2 under 2.5 mm in length are not precisely flat in their free state, the test for variation in length (see paras. 3.7 and 7.4.4) is considered sufficient.

C4 SURFACE TEXTURE ON GAGING SURFACES

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

The quality of the texture of the gaging surfaces 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 B46.1-1996, shall not be exceeded.

C5 WRINGING QUALITY

Only those blocks that are questionable on the visual surface texture test above shall be tested for wringing quality. The wringing property of measuring faces of the gage blocks 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 Grade AS-0, AS-1, and AS-2, minor bright spots or shades shall be permitted.

NONMANDATORY APPENDIX D
POSSIBLE SOURCES OF MEASUREMENT UNCERTAINTY

D1 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 GUM). 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 (1-3).

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.

D2 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

D2.1 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, if necessary, to the form specified in the GUM.

D2.2 Long Term Reproducibility

It might be possible to list the causes of measurement variability, such as operator variation, thermal history of the artifact, 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, thermometer and barometer calibrations. The history data then reflects 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.

D2.3 Thermal Expansion

There are three major sources of error. First, the thermometer used to measure the temperature has some uncertainty. If the master gage block and the calibrated block are of the same material and nominal size this uncertainty source is negligible.

Secondly, if the measurement was not made at exactly 20°C, thermal expansion correction must be made using an assumed thermal expansion coefficient. If the master and calibrated blocks are the same material, this source of uncertainty is minimized. However, even in this case, blocks of the same material may have slightly different coefficients of thermal expansion (CTE). As a general rule, an estimate of ±10% is reasonable unless the CTE of both blocks have been measured.

Finally, there can be a temperature gradient between the master block and the test block.

Mathematically, the thermal expansion correction can be expressed as:

$$\Delta L_i = \alpha(20 - T_i)\, L_i$$

L_i = the artifact length
ΔL_i = the length correction
α = the thermal expansion coeffecient
T_i = the artifact temperature

Note that under the more typical shop environments where the temperature is over 20°C, the correction is negative; that is, the block is longer than its calibration by ΔL.

The uncertainty in the length difference between the two blocks of the same material has three components: one from the temperature uncertainty δT, one from the thermal expansion coefficient uncertainty δT, and one from possible gradients between the blocks $(T_1 - T_2)$.

$$\delta L_{12} = \alpha L(\delta T) + L\,(20 - T)\,(\delta\alpha) + \alpha L\,(T_1 - T_2)$$

For two blocks of different materials, this equation becomes more complex because the thermal expansion coefficients are no longer the same.

D2.4 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. These deformations can be calculated from standard formulas, or obtained from nomographs in reference 4 of para. 2.8. If the radius of curvature is measured, the uncertainty in the deformation corrections is negligible. If the correction is measured, the uncertainty in that measurement must be analyzed and an uncertainty budget prepared.

D2.5 Scale Calibration

The electronic or mechanical transducers generally have a very short range and are calibrated using gage blocks calibrated by interferometry or by a higher echelon of mechanical comparison. The uncertainty of the sensor calibration depends on the uncertainty in the artifacts and the reproducibility of the sensor system. Several artifacts are used to provide calibration points throughout the sensor range and a least squares fit is used to determine linear calibration coefficients. The standard deviation of the slope can be used to find the uncertainty for typical calibrations. If most of the laboratory calibrations span a range of L and the standard deviation of the slope is δS, then the standard uncertainty might be estimated as $(L \times \delta S)$.

D2.6 Instrument Geometry

Each instrument has a characteristic geometry that, if not perfect, will lead to errors. The specific uncertainty depends on the instrument, but for gage block comparators the major source is the probe alignment and reference surface geometry.

Reference surface geometry for gage block comparisons includes the roundness of the contacts (two-contact comparator) or one contact and the anvil that supports the block (one-contact comparator). For one-contact comparators, the geometry of the support combined with the flatness of the gage block face may cause a bias in the measurement.

The alignment error is the angle difference and offset of the measurement scale from the actual measurement line. Examples are the alignment of the two opposing heads of a two probe the gage block comparator and the squareness of the probe to the support anvil in one probe comparators.

D2.7 Artifact Geometry

Perhaps the most difficult source of uncertainty to estimate is the effects of the test gage geometry on the calibration. In para. 3.3 of the standard a note points out that each mechanical comparison assigns the wringing layer length of a block measured by interferometry to each block traceable to it by mechanical comparisons. Thus, if the bottom of a test block is much less flat than the master block (a common situation for all but K and 00 blocks) a bias is introduced into the measurement.

A related uncertainty is introduced if blocks are wrung together. The calibrated length of each block is the point-to-point length plus the wringing film assigned from the original interferometrically measured master block. Since both blocks are not perfectly flat, when the two faces are wrung together the distance between the two gage points may not be the same as the wringing film length assigned from the master block.

D2.8 References

Uncertainty evaluation for the measurement of gauge blocks by optical interferometry, 34, 779-493 (1997)

Publisher: Sociedade Brasileira de Metrologia, Avenida Beira Mar, 262/5?andar, Castelo – Rio de Janeiro – RJ – Brasil CEP. 20021-060

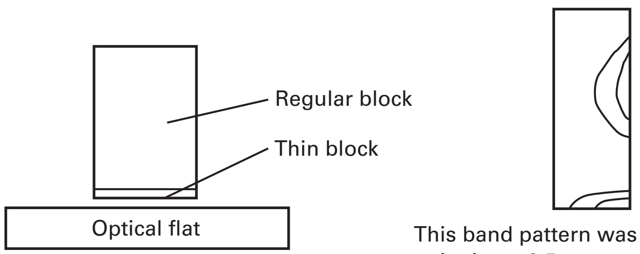
Gage Block Handbook NIST Monograph 180, 1995

Uncertainty and Dimensional Calibrations, Journal of Research of the National Institute of Standards and Technology, Vol. 102, No. 6, pp. 647-676, 1997

Contact Deformation in Gage Block Comparisons, NBS Technical Note 962, 1978

National Institute of Standards and Technology (NIST), 100 Bureau Drive, Stop 3460, Gaithersburg, MD 20089

NONMANDATORY APPENDIX E
THIN GAGE BLOCKS (LESS THAN 1.0 mm or 0.040 in.)



This band pattern was viewed after wringing a 0.5 mm gage block. The block had a flatness of approximately 2.5 μm or 100 μin. in its free state.

FIG. E1 ERRORS IN WRINGING OF THIN BLOCKS

E1 INTRODUCTION

Thin gage blocks are harder to calibrate and harder to use than other gage blocks. 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.

E2 OUT OF FLAT CONDITION

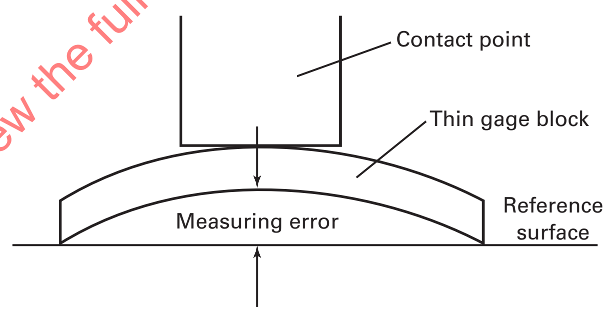
Gage blocks up through 2.5 mm (0.100 in.) are not usually within the flatness tolerance if unwrung. The deviation from flatness of these gages in their free state (unwrung) may be up to 4 μm (see para. 6.2.2). Generally however, the greater the length (size), the flatter the block will be in its free state. A 2 mm block is usually flatter than a 1 mm block that is usually flatter than a 0.5 mm block. This out of flatness in the free state is usually only a problem for blocks under 1 mm (0.040 in.).

E3 INCREASED UNCERTAINTY

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

E3.1 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.



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

FIG. E2 CURVATURE OF THIN BLOCKS CAN CAUSE MEASUREMENT ERRORS

E3.2 Thin Blocks Used Alone

Even when used alone, measuring system geometry may introduce errors.

It is recommended that a comparator with top and bottom point contacts be used for the calibration of thin gage blocks. Blocks should be measured and then turned over and measured again. The smallest result should be reported.

NONMANDATORY APPENDIX F
USE AND CARE OF GAGE BLOCKS

F1 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.

F2 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 non-chlorinated 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 must 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 the 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.

F3 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.

F4 STONING AND DEBURRING GAGE BLOCKS

Nicked or badly scratched measuring faces of gage blocks will never permit a good “wring” and may also give inaccurate 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 upon 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 five seconds 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. 8.3.2). 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 upon the required gage block grade tolerance, a "smudge" (one light band spread over a large area) should appear. Repeat the deburring procedure as necessary until the block wrings successfully to the optical flat (see section C5).

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.

F5 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.

F5.1 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 you 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, non-absorbent clean surface and place a couple of drops of oil on one area of the paper. Now, 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 non-oiled area of the paper to clean off the excess oil. Note, 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.

F6 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.

F7 PACKAGING GAGE BLOCKS FOR SHIPMENT

When shipping gage blocks, take every precaution possible to ensure safe travel. Steel blocks should be oiled (see section F6). 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. Now, 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 re-package the blocks in the same manner received.

F8 TIE RODS

There 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 Fig. 5) 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.

There are two serious misuses of tie rods that must be avoided.

(a) Tie rods must 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.

NONMANDATORY APPENDIX G
GAGE BLOCK SIZES AND SETS

G1 GAGE BLOCK SIZES

The following table lists the most common size gage blocks manufactured. The list is not complete because special sizes are always being made. Listed sizes are not necessarily standard with all gage block manufacturers.

G2 GAGE BLOCK SETS

Many compositions of gage block sets are available in both inch and metric sizes. The compositions and numbers of gage blocks in sets may vary somewhat as offered by different gage block manufacturers. For that reason, only a few of the more common sets are described in this appendix. For the selection of set composition best suited to the user's requirements, reference to manufacturer's catalogs is recommended.

TABLE G1 INCH GAGE BLOCK SIZES (IN INCHES)

0.0055	0.0202	0.052	0.1007	0.130	0.20008
0.006	0.0203	0.053	0.1008	0.131	0.20009
0.0065	0.0204	0.054	0.1009	0.132	0.250
0.007	0.0205	0.055	0.101	0.133	0.300
0.0075	0.0206	0.056	0.102	0.134	0.350
0.008	0.0207	0.057	0.103	0.135	0.400
0.0085	0.0208	0.058	0.104	0.136	0.450
0.009	0.0209	0.059	0.105	0.137	0.500
0.0095	0.021	0.060	0.106	0.138	0.550
0.010	0.022	0.0625	0.107	0.139	0.600
0.01005	0.023	0.070	0.108	0.140	0.650
0.0101	0.024	0.078125	0.109	0.141	0.700
0.0102	0.025	0.080	0.109375	0.142	0.750
0.0103	0.026	0.090	0.110	0.143	0.800
0.0104	0.027	0.09375	0.111	0.144	0.850
0.0105	0.028	0.100	0.112	0.145	0.900
0.0106	0.029	0.10001	0.113	0.146	0.950
0.0107	0.030	0.10002	0.114	0.147	10.000
0.0108	0.03125	0.100025	0.115	0.148	20.000
0.0109	0.040	0.10003	0.116	0.149	30.000
0.011	0.046875	0.10004	0.117	0.150	40.000
0.012	0.050	0.10005	0.118	0.160	50.000
0.013	0.05005	0.10006	0.119	0.170	60.000
0.014	0.0501	0.10007	0.120	0.180	70.000
0.015	0.0502	0.100075	0.121	0.190	80.000
0.015625	0.0503	0.10008	0.122	0.200	100.000
0.016	0.0504	0.10009	0.123	0.20001	120.000
0.017	0.0505	0.1001	0.124	0.20002	160.000
0.018	0.0506	0.1002	0.125	0.20003	200.00
0.019	0.0507	0.1003	0.126	0.20004	. . .
0.020	0.0508	0.1004	0.127	0.20005	. . .
0.02005	0.0509	0.1005	0.128	0.20006	. . .
0.020	0.05	0.100	0.12	0.2000	. . .

TABLE G2 METRIC GAGE BLOCK SIZES (IN MILLIMETERS)

0.20	1.06	1.41	2.11	2.46	16.0
0.25	1.07	1.42	2.12	2.47	16.5
0.30	1.08	1.43	2.13	2.48	17.0
0.40	1.09	1.44	2.14	2.49	17.5
0.405	1.10	1.45	2.15	2.5	18.0
0.41	1.11	1.46	2.16	2.6	18.5
0.42	1.12	1.47	2.17	2.7	19.0
0.43	1.13	1.48	2.18	2.8	19.5
0.44	1.14	1.49	2.19	2.9	20.0
0.45	1.15	1.5	2.20	3.0	20.5
0.46	1.16	1.6	2.21	3.5	21.0
0.47	1.17	1.7	2.22	4.0	21.5
0.48	1.18	1.8	2.23	4.5	22.0
0.49	1.19	1.9	2.24	5.0	22.5
0.50	1.20	2.0	2.25	5.5	23.0
					23.5
0.60	1.21	2.0005	2.26	6.0	
0.70	1.22	2.001	2.27	6.5	24.0
0.80	1.23	2.002	2.28	7.0	24.5
0.90	1.24	2.003	2.29	7.5	25.0
1.0	1.25	2.004	2.30	8.0	30.0
1.0005	1.26	2.005	2.31	8.5	40.0
1.001	1.27	2.006	2.32	9.0	50.0
1.002	1.28	2.007	2.33	9.5	60.0
1.003	1.29	2.008	2.34	10.0	70.0
1.004	1.30	2.009	2.35	10.5	75.0
					80.0
1.005	1.31	2.01	2.36	11.0	
1.006	1.32	2.02	2.37	11.5	90.0
1.007	1.33	2.03	2.38	12.0	100.0
1.008	1.34	2.04	2.39	12.5	125.0
1.009	1.35	2.05	2.40	13.0	150.0
1.01	1.36	2.06	2.41	13.5	175.0
1.02	1.37	2.07	2.42	14.0	200.0
1.03	1.38	2.08	2.43	14.5	300.0
1.04	1.39	2.09	2.44	15.0	400.0
1.05	1.40	2.10	2.45	15.5	500.0

TABLE G3 81 PIECE INCH GAGE BLOCK SET (ALL SIZES IN INCHES)

Range	Blocks Included In Set
	9 blocks 0.1001 thru 0.1009 in steps of 0.0001
0.100 thru 12.000 in steps of 0.001	49 blocks 0.101 thru 0.1490 in steps of 0.001
0.200 thru 12.000 in steps of 0.0001	19 blocks 0.050 thru 0.950 in steps of 0.050
	4 blocks 1.000 thru 4.000 in steps of 1.000

TABLE G4 88 PIECE INCH GAGE BLOCK SET (ALL SIZES IN INCHES)

Range	Blocks Included In Set
	9 blocks 0.1001 thru 0.1009 in steps of 0.0001
0.100 thru 12.000 in steps of 0.001	49 blocks 0.101 thru 0.149 in steps of 0.001
0.200 thru 12.000 in steps of 0.0001	19 blocks 0.050 thru 0.950 in steps of 0.050
0.300 thru 12.000 in steps of 0.000025	4 blocks 1.000 thru 4.000 in steps of 1.000
$^1/_{16}$ thru 12.000 in steps of $^1/_{64}$	3 blocks 0.100025, 0.10005, 0.100075
	4 blocks $^1/_{16}$, $^5/_{64}$, $^3/_{32}$, $^7/_{64}$

TABLE G5 36 PIECE INCH GAGE BLOCK SET (ALL SIZES IN INCHES)

Range	Blocks Included In Set
	1 block 0.050
	9 blocks 0.1001 thru 0.1009 in steps of 0.0001
0.200 thru 8.000 in steps of 0.001	9 blocks 0.101 thru 0.109 in steps of 0.0010
0.300 thru 8.000 in steps of 0.0001	9 blocks 0.110 thru 0.190 in steps of 0.0100
	5 blocks 0.100 thru 0.500 in steps of 0.1000
	3 blocks 1.000, 2.000, 4.000

TABLE G6 8 PIECE INCH LONG GAGE BLOCK SET (ALL SIZES IN INCHES)

Blocks Included In Set			
5.000	7.000	10.000	16.000
6.000	8.000	12.000	20.000

TABLE G7 28 PIECE INCH THIN GAGE BLOCK SET (ALL SIZES IN INCHES)

Range	Blocks Included In Set
0.020 thru 0.240 in steps of 0.001	1 block 0.02005
0.040 thru 0.240 in steps of 0.0001	9 blocks 0.0201 thru 0.0209 in steps of 0.0001
0.060 thru 0.240 in steps of 0.00005	9 blocks 0.021 thru 0.029 in steps of 0.001
	9 blocks 0.010 thru 0.090 in steps of 0.010

TABLE G8 45 PIECE METRIC GAGE BLOCK SET (ALL SIZES IN MILLIMETERS)

Range	Blocks Included In Set
	9 blocks 1.001 thru 1.009 in steps of 0.001
1.0 thru 450 in steps of 0.1	9 blocks 1.010 thru 1.090 in steps of 0.010
2.0 thru 450 in steps of 0.01	9 blocks 1.100 thru 1.900 in steps of 0.100
3.0 thru 450 in steps of 0.110	9 blocks 1.000 thru 9.000 in steps of 1.000
	9 blocks 10.000 thru 90.000 in steps of 10.00

TABLE G9 88 PIECE METRIC GAGE BLOCK SET (ALL SIZES IN MILLIMETERS)

Range	Blocks Included In Set
	1 block 0.5
1.0 thru 450 in steps of 0.100	1 block 1.0005
1.0 thru 450 in steps of 0.010	9 blocks 1.001 thru 1.090 in steps of 0.001
2.0 thru 450 in steps of 0.001	49 blocks 1.10 thru 1.490 in steps of 0.010
3.0 thru 450 in steps of 0.0005	18 blocks 1.00 thru 9.500 in steps of 0.50
	10 blocks 10.0 thru 100.0 in steps of 10.0

TABLE G10 112 PIECE METRIC GAGE BLOCK SET (ALL SIZES IN MILLIMETERS)

Range	Blocks Included In Set
	1 block 0.5
1.0 thru 250 in steps of 0.100	1 block 1.0005
1.0 thru 250 in steps of 0.010	9 blocks 1.001 thru 1.090 in steps of 0.001
2.0 thru 250 in steps of 0.001	49 blocks 1.100 thru 1.490 in steps of 0.010
3.0 thru 250 in steps of 0.0005	48 blocks 1.000 thru 24.500 in steps of 0.500
	4 blocks 25.000 thru 100.000 in steps of 25.000

TABLE G11 8 PIECE METRIC LONG GAGE BLOCK SET (ALL SIZES IN MILLIMETERS)

Blocks Included In Set			
125.000	175.000	250.000	400.000
150.000	200.000	300.000	500.000