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AN AMERICAN NATIONAL STANDARD

Measurement of Qualified Plain Internal Diameters for Use as Master Rings and Ring Gages

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(REVISION OF ANSI B89.1.6-1976)

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FOREWORD

(This Foreword is not part of ANSI/ASME B89.1.6M-1984.)

The American National Standards Committee B89 on Dimensional Metrology was established in February 1963 under the sponsorship of the American Society of Mechanical Engineers. The first organization meeting was held at the United Engineering Center in New York City. The scope of the Committee was defined as follows:

> Calibration and the specific conditions relating thereto. It shall encompass the inspection and the means of measuring the characteristics of the various geometrical configurations such as lengths, plane surfaces, angles, circles, cylinders, cones, and spheres.

Among the six Subcommittees originally established to carry out this mandate was B89.1 – Length, whose chairman authorized the formation of B89.1.6 to prepare a standard on the measurement of internal diameters for use as master rings and ring gages. The standard was approved by ANSI as an American National Standard on June 10, 1976.

The B89 Committee was reorganized as an ASME Standards Committee on July 8, 1981. The ASME B89 Committee then developed this revised Standard which includes specifications that extend qualifications of rings up to 21 in. (533 mm), consolidates information into tables from within the original standard and from other sources, and relates surface texture to tolerance rather than class.

This revised Standard was approved by the American National Standards Institute on June 18, 1984.

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Dimensional Metrology

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AN AMERICAN NATIONAL STANDARD

MEASUREMENT OF QUALIFIED PLAIN INTERNAL DIAMETERS FOR USE AS MASTER RINGS AND RING GAGES

1 SCOPE

This Standard is intended to provide and establish uniform practice for the measurement of master rings and ring gages to a given tolerance by means of a two-jaw internal comparator. It includes requirements for geometrical quality of master rings, quality of length standards required, the important characteristics of the comparison equipment, environmental conditions, and the means to assure that measurements are made with an acceptable level of confidence.

2 REQUIREMENTS OF MASTER RINGS AND RING GAGES

2.1 General

The capability of measuring equipment and techniques to achieve a high order of precision in the calibration of master plain cylindrical ring gages is limited to a significant degree by relevant features and conditions of the ring gages. These are grouped and discussed in the following sections:

2.2 Design
2.3 Material
2.4 Surface Texture
2.5 Geometrical Requirements
2.6 Tolerance Classes

2.2 Design

The specifications for gage blanks as to design and proportion are given in American National Standard, Gage Blanks, ANSI B47.1-1981. In addition, solid, one-piece designs must be used, irrespective of size or material.

2.3 Material

The material of which ring gage blanks are made must be free from inclusions or other imperfections which would affect surface texture. It is desirable for the material to have approximately the same coefficient of expansion as the gage blocks to be used in order to minimize the effect of small differences in temperature. It must respond to applicable hardening and stabilizing processes to permit finishing to the essential surface texture and to assure dimensional stability. Finished surfaces should have a minimum hardness equivalent to 61 on the Rockwell C Scale. Master gages must not be subjected to any quick aging or shock treatment as a check of stability. Such treatments often induce instability.

2.4 Surface Texture

The surface texture must be consistent with the accuracy of calibration desired, which in turn is related to the tolerance applicable to the gage. Table 1 lists maximum roughness values expressed in arithmetic average roughness values, also called Ra. ANSI B46.1-1978, Surface Texture, should be consulted for reference information.

2.5 Geometrical Requirements

2.5.1 General. There are several geometrical characteristics of both the finished gaging diameter and locational surfaces that must be maintained to a degree consistent with the ring tolerance. The composite variation in diameter for rings in all classes and sizes caused by variations in roundness, taper, and straightness of the gaging surface should not exceed one-half the total tolerance of the ring, determined by six diameter measurements taken as two measurements spaced approximately 90 deg. in each of three planes located $1/16$ in. (1.6 mm) from inside ends of corner radii or chamfers, and the midsection. For sizes below 0.150 in. (3.8 mm), a total of four diameter measurements should be taken in two planes within the center half of the ring. Acceptance of the ring for geometry qualifications is to be based on these measurements only. See Appendix B for additional information.

TABLE 1 SURFACE ROUGHNESS LIMITS FOR RINGS – ARITHMETIC AVERAGE (Ra)

Diameter, in. (mm)		Tolerance Class, μin. (μm) [Note (1)]			
Above	To and Including	XX	X	Y	Z
0.040 (1.02)	0.825 (20.76)	2 (.051)	4 (.10)	4 (.10)	8 (.20)
0.825 (20.96)	1.510 (38.35)	2 (.051)	4 (.10)	8 (.20)	12 (.30)
1.510 (38.35)	2.510 (63.75)	4 (.10)	8 (.20)	12 (.30)	16 (.41)
2.510 (63.75)	4.510 (114.55)	4 (.10)	8 (.20)	12 (.30)	16 (.41)
4.510 (114.55)	6.510 (165.35)	6 (.15)	12 (.30)	16 (.41)	16 (.41)
6.510 (165.35)	9.010 (228.85)	8 (.20)	16 (.41)	16 (.41)	16 (.41)
9.010 (228.85)	12.010 (305.05)	8 (.20)	16 (.41)	16 (.41)	16 (.41)
12.010 (305.05)	21.010 (533.65)	16 (.41)	16 (.41)	16 (.41)	16 (.41)

GENERAL NOTE:
Maximum peak-to-valley (Ry) measurement is not to exceed one-half total tolerance. For practical reasons, texture is expressed in terms of arithmetic average (Ra). Larger tolerances have values based on present practice.

NOTE:
(1) μin. = microinches
μm = micrometers

2.5.2 Squareness of Face. The face of the ring gage should be square to the bore within 50 times the total tolerance of the ring gage per inch. This controls first order errors that arise from imperfect alignment of the measuring contacts. When a 0.250 in. (6.3 mm) class XX ring gage having the above squareness error is checked in a comparator whose horizontal contact planes are separated by 0.001 in. (0.025 mm) above the work table, the size indicated will differ from the true diameter by 1 μin.

2.6 Tolerance Classes

2.6.1 Master rings and ring gages are graded into classes identified by "XX," "X," "Y," and "Z," which determine the applicable tolerance for a given size. Master rings are to have the total tolerance applied bilaterally (i.e., nominal size plus or minus one-half the total tolerance). Ring gages are to have the maximum ring tolerance all minus and the minimum ring tolerance all plus, unless otherwise specified. Rings marked with class identification are to conform to these tolerances as well as the other requirements in para. 2.6. Class tolerances are listed in Table 2 (see Appendix A for class XXX rings).

2.6.2 Tolerance integrity is greatly affected by uncertainty in gage block combinations (see Table 3 and Appendix C) and the quality of the calibration equipment (see Section 5).

3 REQUIREMENTS FOR REFERENCE GAGE BLOCKS[1]

3.1 Length Tolerance

It is recommended that the total uncertainty of the gage block combination selected should not exceed one-quarter of the total tolerance of the ring gage being calibrated (see Table 3).

3.2 Uncertainty

Uncertainty in the size of the gage block combination exists after applying the current calibration factors (see ANSI/ASME B89.1.9M). When uncertainties exceed these values, Appendix C provides a means to reduce the problems that arise and maintain reasonable assurance of size integrity.

3.3 Measurement of Large Rings

Block combinations for the largest class XX rings have about one-third of their uncertainty due to size and geometry, leaving about two-thirds for temperature difference between block combination and ring. This translates into approximately one-eighth of a degree Farenheit, making temperature matching between ring and blocks a major problem, and emphasizes the need to

[1] ANSI/ASME B89.1.9M, Precision Gage Blocks for Length Measurement (Through 20 in. and 500 mm).

TABLE 2 TOTAL TOLERANCES ON DIAMETER FOR DIFFERENT CLASSES AND SIZES

in. (mm)		Ring Diameter Tolerances for Different Sizes and Classes Total Tolerance, μin. (μm) [Note (1)]			
Above	To and Including	XX	X	Y	Z
0.040 (1.02)	0.825 (20.96)	20 (.51)	40 (1)	70 (1.8)	100 (2.5)
0.825 (20.96)	1.510 (38.35)	30 (.76)	60 (1.5)	90 (2.3)	120 (3)
1.510 (38.35)	2.510 (63.75)	40 (1)	80 (2)	120 (3)	160 (4.1)
2.510 (63.75)	4.510 (114.55)	50 (1.3)	100 (2.5)	150 (3.8)	200 (5.1)
4.510 (114.55)	6.510 (165.35)	65 (1.7)	130 (3.3)	190 (4.8)	250 (6.4)
6.510 (165.35)	9.010 (228.85)	80 (2)	160 (4.1)	240 (6.1)	320 (8.1)
9.010 (228.85)	12.010 (305.05)	100 (2.5)	200 (5.1)	300 (7.6)	400 (10)
12.010 (305.05)	15.010 (381.25)	150 (3.8)	300 (7.6)	450 (11)	600 (15)
15.010 (381.25)	18.010 (457.45)	200 (5.1)	400 (10)	600 (15)	800 (20)
18.010 (457.45)	21.010 (533.65)	250 (6.4)	500 (13)	750 (19)	1000 (25)

GENERAL NOTE:
References: Federal Standard H28, Screw Threads for Federal Services; ANSI/ASME B1.2-1983, Gages and Gaging for Unified Inch Screw Threads.

NOTE:
(1) μin. = microinches
μm = micrometers

TABLE 3 LIMIT OF EXPECTED UNCERTAINTY IN GAGE BLOCKS

in. (mm)		μin. (μm) [Note (1)]			
Above	To and Including	XX	X	Y	Z
0.040 (1.02)	0.825 (20.96)	±2.5 (.064)	±5 (.13)	±9 (.23)	±12 (.30)
0.825 (20.96)	1.510 (38.35)	±4 (.10)	±8 (.20)	±11 (.28)	±15 (.38)
1.510 (38.35)	2.510 (63.75)	±5 (.13)	±10 (.25)	±15 (.38)	±20 (.51)
2.510 (63.75)	4.510 (114.55)	±6 (.15)	±12 (.30)	±19 (.48)	±25 (.64)
4.510 (114.55)	6.510 (165.35)	±8 (.20)	±16 (.41)	±24 (.61)	±31 (.79)
6.510 (165.35)	9.010 (228.85)	±10 (.25)	±20 (.51)	±30 (.76)	±40 (1)
9.010 (228.85)	12.010 (305.05)	±12 (.30)	±25 (.64)	±38 (.97)	±50 (1.3)
12.010 (305.05)	15.010 (381.25)	±19 (.48)	±38 (.97)	±56 (1.4)	±75 (1.9)
15.010 (381.25)	18.010 (457.45)	±25 (.64)	±50 (1.3)	±75 (1.9)	±100 (2.5)
18.010 (457.45)	21.010 (533.65)	±31 (.79)	±62 (1.6)	±94 (2.4)	±125 (3.2)

NOTE:
(1) μin. = microinches
μm = micrometers

match the coefficient of expansion between ring and blocks, as well as the 68°F (20°C) temperature for size control.

3.4 Squareness Tolerance

If the side surfaces of the gage blocks are used to position the gage block combination on the instrument, the side surfaces shall be square to the gaging surfaces within 50 times the total tolerance of the ring to be measured per inch. This will require a squareness within 0.0015 in./in. (0.0015 mm/mm) when measuring a class XX ring below 1.510 in. (38.35 mm) diameter.

3.5 Material

It is recommended that the outside caliper jaw sections of the gage block combination be made of the same material as the ring gage in order to minimize variations due to differences in deformation by the contacts. The gage block material should have approximately the same coefficient of expansion as the ring to be measured.

4 CALIBRATION OF AN IDENTIFIED DIAMETER

4.1 General

Calibration at an identified diameter limits the effects of the taper, out-of-round, and lack of straightness on the measurement. This increased certainty extends the usefulness of the ring for some purposes and makes it easier to detect wear or secular changes in size.

4.2 Location and Marking

The location of the gaging points shall be marked on one end of the ring by a diameter line. The gaging points shall be areas diametrically opposite each other at midpoint of the length of the bore. The size of the areas shall be ±0.05 in. (1.27 mm) or one-quarter of the length of the bore from the midlength point, whichever is smaller, and ±0.05 in. (1.27 mm) or one-quarter of the length of the bore circumferentially from the marked lines, whichever is smaller.

5 CALIBRATION EQUIPMENT

5.1 General

The calibration equipment shall provide means of accurately transferring measurements from the known size of gage blocks to the master ring to be calibrated. This includes the ability to explore the size throughout the length of the ring, to adjust for assurance of measurement on a diameter, and to provide sufficient magnification and range. These specifications are intended to describe equipment capable of providing calibration with an accuracy limited primarily by the geometric qualities of the ring and the accuracy of the gage block combination used. The equipment is limited to that constructed with two measuring contacts for sensing diameter.

The equipment generally has a horizontal staging surface to support the master ring and the stack of master setting blocks. The readout device is a pointer over a scale. Other means of ring and gage block support and readout are not covered in this Standard and should be evaluated on their own merits.

5.2 Amplification

The amplification shall be adjustable so as to provide no less than five divisions for the total tolerance of the master ring. Where gaging point calibrations are to be used for increased accuracy, no less than five divisions for the expected calibration accuracy are recommended.

5.3 Precision

The precision (repeatability) of the calibration equipment should be such that the standard deviation of a number of independent readings of a gage block combination will be less than one-fifth of a least division on the indicating scale. The accuracy of the results will be in proportion to the number of readings taken and no less than 25 readings should be taken.

The standard deviation may be computed from the following formula:

$$S = \sqrt{\frac{(X_1 - X)^2 + (X_2 - X)^2 + \cdots (X_n - X)^2}{n - 1}}$$

where

S = standard deviation
$X_1, X_2 \cdots X_n$ = independent readings
X = mean value of all readings
n = number of readings

It must be understood that the value of precision obtained does not take into account systematic errors.

5.4 Accuracy

The accuracy with which the meter reading represents motion of the gaging fingers is to be within one least division on the scale when using the center of the scale as reference. Where an electrical "zero" adjustment is provided, this accuracy is to apply throughout its range. The accuracy of the calibrating device is to be within one-quarter of a least division. When the least division is 1 μin. (0.025 μm), high resolution equipment is required. One method is to use interferometric techniques. Another is to use a mechanical lever reduction device of the highest accuracy to reduce a known displacement.

5.5 Contact Geometry

The surfaces of the gaging fingers that make contact with the blocks and rings are to be spherical or spheroidal in shape. The radius in a vertical plane need not be equal to that in the horizontal plane, but if a difference exists, there must be only one way to position the contact in the gage. The heights of the centers of the contact surfaces on the two gaging fingers from the ring support surface should match within 0.001 in. (0.025 mm).

This low value allows the greatest possible tolerance on the squareness of the master ring bore to its reference face. Contact alignment in the horizontal direction is not critical; however, it is generally kept within 6 deg.

5.6 Contact Force

Contact force creates compressive deformation of the contact surfaces and bending of cantilever type fingers. Control of the bending effect for measurement is included in the precision specification (para. 5.3). It is recommended that no more than 2 oz (56.7 g) gaging force be used for a radius of 0.016 in. (0.41 mm) and no more than 4 oz (113.40 g) for a radius of 0.06 in. (1.52 mm) to avoid any permanent deformations. Differences in deformation at the contact surfaces may be significant to calibrations when the ratio of the contact radius to the master ring radius is greater than 1:4. See Appendix E for detailed information.

6 ENVIRONMENT

6.1 General

Favorable environment is essential when dealing with precise measurements and control of the essential environmental factors is desired. All environmental factors must be controlled to the degree necessary to achieve repeatability and accuracy as required in the measurement of master rings. The factors are:

(*a*) cleanliness
(*b*) temperature
(*c*) electrical interferences
(*d*) illumination
(*e*) vibration
(*f*) humidity

No attempt has been made in this Section to include specifications for other than essentials for a metrology laboratory concerned with calibration of master rings. More complete coverage of essentials recommended for metrology laboratories is included in American National Standard, Temperature and Humidity Environment for Dimensional Measurement, ANSI B89.6.2-1973 (R1979).

6.2 Cleanliness

Metrology laboratories from the least demanding to the most sophisticated should be shielded from the smoke, dust, mist, and other contaminants typical of some production areas. During calibration the instrument, master, and surface must be clean. However, it is not essential to specify the highest order of cleanliness in a metrology laboratory, but rather to select that degree which will be adequate and which will induce and reflect the quality of calibration to be achieved.

6.3 Vibration

Excessive vibration has serious detrimental effects on the accuracy attainable in precise measurements. Objectionable vibrations take two quite different forms and may be constant, periodic, or random in occurrence. These two forms are tactile and audible. Tactile vibrations (feel) are objectionable in that they may cause inconsistent and unstable contact at point of measurement, and instability in the readout of the amplifier. Audible vibrations (noise) are objectionable if they adversely affect the performance of the operator. The following are the most common methods to bring vibration levels to tolerable values.

(*a*) When locating the metrology laboratory, avoid areas adjacent to, or affected by, heavy machinery, internal or external traffic, etc.

(*b*) Insulate the areas from known potential sources of vibration and utilize insulating mountings when installing sensitive apparatus.

(*c*) Create an acceptable, low operational noise level and require strict observance of it at all times.

6.4 Temperature

68°F (20°C) is the standard temperature used internationally for linear measurement. The actual temperatures of gage, master and instrument must be known if accurate and reliable calibrations are to be achieved. When ambient temperature cannot be controlled as closely as required, ring gages and master blocks may be brought to the same temperature through the use of soaking plates and thermal shielding. Further refinement may be achieved by determining the temperature of each pertinent component and applying the necessary corrections. Metrology laboratories held within limits from ±0.1°F to ±2.0°F are being used successfully. Those laboratories with greater temperature tolerances require metrologists to take greater care in order to achieve the required level of accuracy. Significant variations in ambient temperature should be avoided. A detailed treatment will be found in ANSI B89.6.2-1973 (R1979).

6.5 Humidity

It is recommended that relative humidity be maintained between 40% and 50%. Humidity significantly beyond these limits may bring serious problems with rusting on the one hand and static electricity on the other.

6.6 Electrical Interference

It is important when selecting locations for installing electrical utilities in a metrology laboratory that the utilities leave the environment relatively free from stray electrical fields.

6.7 Illumination

There are four factors in "seeing." These are brightness, size, contrast, and time. Variations in one factor may affect one or all of the others. Increasing brightness enables the eyes to see objects small in size. However, this very brightness may lessen contrast and make it difficult or impractical to read the fine graduations of a scale. Therefore, provisions for illumination must consider and provide that which is essential for the specific tasks to be performed. From a practical viewpoint, an illumination of 100 fc at working height may well be the starting point for general work.

APPENDIX A
CLASS XXX RINGS

(This Appendix is not part of ANSI/ASME B89.1.6M-1984, and is included for information purposes only.)

Table A1 provides limits for various geometric features to provide reasonable assurance for maintaining the total tolerance specified. Surface texture is in arithmetic average units (Ra). "Roundness, etc. (See Para. 2.5.1)" refers to that paragraph in this Standard.

TABLE A1 LIMITS FOR VARIOUS GEOMETRIC FEATURES

Size, in. (mm)		μin. (μm) [Note (1)]			
Above	To and Including	Total Tolerance	Gage Block Uncertainty	Surface Texture (Ra)	Roundness, etc. (See Para. 2.5.1)
0.040 (1.02)	0.825 (20.96)	10 (.25)	±1.2 (.030)	1 (.025)	5 (.13)
0.825 (20.96)	1.510 (38.35)	15 (.38)	±1.9 (.048)	1.5 (.038)	7.5 (.19)

GENERAL NOTE:
The values shown under "Gage Block Uncertainty" and "Surface Texture (Ra)" are the maximum permitted to allow class XXX rings to be manufactured as a commercial standard.

NOTE:
(1) μin. = microinches
μm = micrometers

APPENDIX B
MEASUREMENT OF RING GEOMETRY

(This Appendix is not part of ANSI/ASME B89.1.6M-1984, and is included for information purposes only.)

B1 GENERAL

Variations due to out-of-roundness, taper, and out-of-straightness are specified as not to exceed one-half the total tolerance in combination. If they are to be measured individually, the following limits are suggested. The same condition of deviation from perfect symmetry may show up in all three measurements, but the effect would not be additive.

B2 ROUNDNESS

Deviations in roundness should be determined at three planes [two planes in sizes below 0.15 in. (3.8 mm)] normal to the nominal axis of the ring gage, utilizing a polar chart type precision spindle instrument. Out-of-roundness values are the differences between the largest and smallest radii of a measured profile measured from a nominal center. The out-of-round condition should not exceed the value shown in Table B1.

Out-of-round conditions for rings used other than as diameter masters, such as limit gages, should be evaluated by criteria more applicable to intended use in addition to diametric limitations. ANSI B89.3.1-1972 (R1979), Measurement of Out-of-Roundness, should be consulted for measurement information.

B3 TAPER

The amount of taper should be determined by measuring diameters in two planes separated by a distance equal to two-thirds of the thickness of the ring gage. The center is usually utilized in setting and is held most accurately. The difference between the two measured diameters should not exceed the values listed in Table B1.

B4 STRAIGHTNESS

Deviations from geometrical straightness should be determined by making two axial tracings approximately 90 deg. apart, utilizing a suitable instrument. The value so determined should not exceed tolerances listed in Table B1.

TABLE B1 LIMITS FOR ROUNDNESS, TAPER, OR STRAIGHTNESS FOR RING GAGES

in. (mm)		μin. (μm) [Note (1)]			
Above	To and Including	XX	X	Y	Z
0.15 (3.8)	0.825 (20.96)	7 (.18)	13 (.33)	23 (.58)	33 (.84)
0.825 (20.96)	1.510 (38.35)	10 (.25)	20 (.51)	30 (.76)	40 (1)
1.510 (38.35)	2.510 (63.75)	13 (.33)	27 (.69)	40 (1)	53 (1.4)
2.510 (63.75)	4.510 (114.55)	17 (.43)	33 (.84)	50 (1.3)	67 (1.7)
4.510 (114.55)	6.510 (165.35)	22 (.56)	43 (1.1)	63 (1.6)	83 (2.1)
6.510 (165.35)	9.010 (228.85)	27 (.69)	53 (1.3)	80 (2)	107 (2.7)
9.010 (228.85)	12.010 (305.05)	33 (.84)	67 (1.7)	100 (2.5)	133 (3.4)
12.010 (305.05)	15.010 (381.25)	50 (1.3)	100 (2.5)	150 (3.8)	200 (5.1)
15.010 (381.25)	18.010 (457.45)	67 (1.7)	133 (3.4)	200 (5.1)	267 (6.8)
18.010 (457.45)	21.010 (533.65)	83 (2.1)	167 (4.2)	250 (6.4)	333 (8.5)

GENERAL NOTE:
Any single geometrical error as outlined in Appendix B — roundness, taper, or straightness — should not exceed the listed values. The tabulated values are one-third of the total tolerance applicable for the grade of ring.

NOTE:
(1) μin. = microinches
μm = micrometers

APPENDIX C
GAGE BLOCK UNCERTAINTY

(This Appendix is not part of ANSI/ASME B89.1.6M-1984, and is included for information purposes only.)

An uncertainty greater than the values in Table 3 (see para. 3.1) may not provide reasonable assurance of size integrity. To provide this assurance it is recommended that the tolerance be modified by the amount the value in Table 3 is exceeded, and in a direction to provide reasonable assurance of size integrity and no unnecessary rejections.

Producers would reduce their tolerance by the amount their uncertainty exceeds the values in Table 3. This will provide reasonable assurance of size integrity.

Purchasers would accept within the specified tolerance plus the amount their uncertainty exceeds the values in Table 3. This avoids unnecessary rejections but does not ensure size integrity.

Examples:

(*a*) A producer with a ± 5 μin. (.13 μm) uncertainty would work to a 15 μin. (.38 μm) total tolerance on class XX rings below 0.825 in. (20.96 mm).

(*b*) A purchaser with a ± 5 μin. (.13 μm) uncertainty would accept within a 25 μin. (.64 μm) total tolerance on class XX rings below 0.825 in. (20.96 mm).

APPENDIX D
REQUIRED ACCURACY OF GAGE BLOCK COMBINATION

(This Appendix is not part of ANSI/ASME B89.1.6M-1984, and is included for information purposes only.)

D1 GENERAL

The gage block combination is used as the reference length standard for ring gage measurement. In addition to the uncertainty of the length of each gage block at the gage points, uncertainties arise due to deviation from flatness and parallelism of each gage block and end piece. Some of the methods of using gage blocks are shown in Fig. D1.

D2 PRECAUTIONS

Some methods can be used to minimize the effect of geometrical distortions. Gage block stacks and end blocks should be held together by wringing only, if at all possible, especially for class XX and class X ring gages. If clamps are used, corresponding compression corrections should be made. The current gage block calibration should be used.

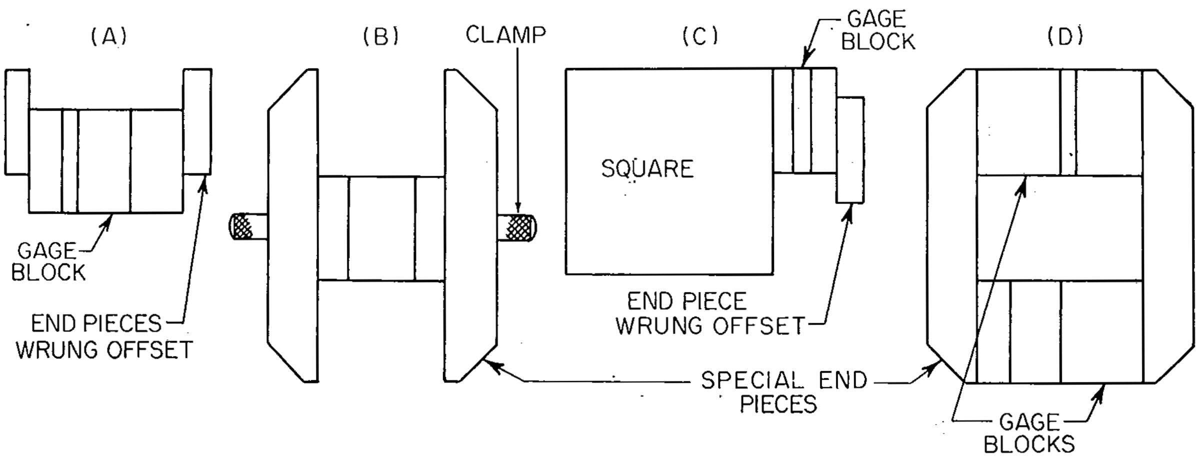

FIG. D1 EXAMPLES OF GAGE BLOCK ARRANGEMENTS IN RING GAGE CALIBRATIONS

APPENDIX E
CONTACT DEFORMATION

(This Appendix is not part of ANSI/ASME B89.1.6M-1984, and is included for information purposes only.)

When a gaging surface is touched with a spherical (or spheroidal) contact, deformation takes place in both parts. In a comparison type of measurement where the master has the same shape, material, and surface texture as the work piece, the deformations are equal and therefore cancel out as a factor in the measurement process. However, when comparing flat surfaces (such as gage blocks) and the internal surface of a master ring, there can be a significant difference as the radius of the ring approaches the radius of the contact. The graph entitled Deformation Factor in Ring Gage Measurement, Fig. E1, shows the ratio of deformation. The succeeding graphs, Figs. E2, E3, and E4, provide data on the deformation to sphere and plane for various combinations of materials.

These three graphs provide data for establishing 1 μin. as the limit of difference in deformation between the master ring and gage blocks. Any set of values selected along the curved line labeled "minimum ring dia." will have approximately 1 μin. difference in deformation between the ring and gage blocks. A set of values that is below these lines will have less difference. For example, a 0.1 in. (2.54 mm) radius with a 4 oz (113.40 g) force will give just under 1 μin. (.03 μm) difference when measuring a 1.5 in. (38.1 mm) ring.

The maximum stress lines are established for the plane surfaces of the gage block.

Example (for use of deformation graphs in measuring ring gages):

If an internal comparator with a 1/8 in. (3.2 mm) radius carbide (or diamond) stylus and a 4 oz. (113.40 g) measuring force is used to compare a 0.500 in. (12.7 mm) diameter ring gage (steel) with a gage block (steel) stack, find the deformation condition.

From the deformation graph of tungsten carbide against steel, the deformation at each contact is 8.4 μin. (.21 μm) giving 16.8 μin. (.43 μm) total deformation when in contact with the gage block stack. The maximum compressive stress is approximately 120,000 psi (82.7 MPa).

From the deformation factor graph, the deformation ratio for the radius ratio of .125 μin. (3.2 mm)/.250 μin. (6.35 mm) = 0.5 is 0.88. The total deformation with the ring is 0.88 × 16.8 = 14.8 μin. (.38 μm). The measured ring size is 16.8 - 14.8 = 2 μin. (0.43 - 0.38 = .05 μm) smaller than the actual ring size due to deformation.

The compressive stress on the ring gage will be less than that on the gage blocks due to the larger contact area.

For reduction of parallelism deviations, the closer the setting point on the combination is to the reference point of the blocks, the less the error. The technique shown in (D) of Fig. D1 also reduces the error caused by parallelism deviation.

The most common method of assuring gage block stack size is to use more than one stack to measure the same ring. Averaging such independent measurements will reduce random errors caused by geometric and other imperfections of the gage blocks. Well-controlled laboratories using this technique will generally agree within 5 μin. on ring measurements of the highest level. A more direct technique in assuring gage block stack size is to make a direct interferometric determination of length at the specific location to be used. This technique also permits a selective wringing of gage blocks to give the best geometry.

To illustrate that the gage block problem is serious, consider the use of tolerance grade 1 gage blocks. The calibrated length at the reference point is uncertain by ±2 μin. and the flatness and parallelism deviations are within 3 μin. If it is assumed that the length uncertainty is composed of a random uncertainty of ±1 μin., a three block combination where the blocks are wrung would have a systematic uncertainty of ±3 μin., and a random uncertainty of ±2 μin., giving a total uncertainty of ±5 μin. at the reference point, assuming the blocks have

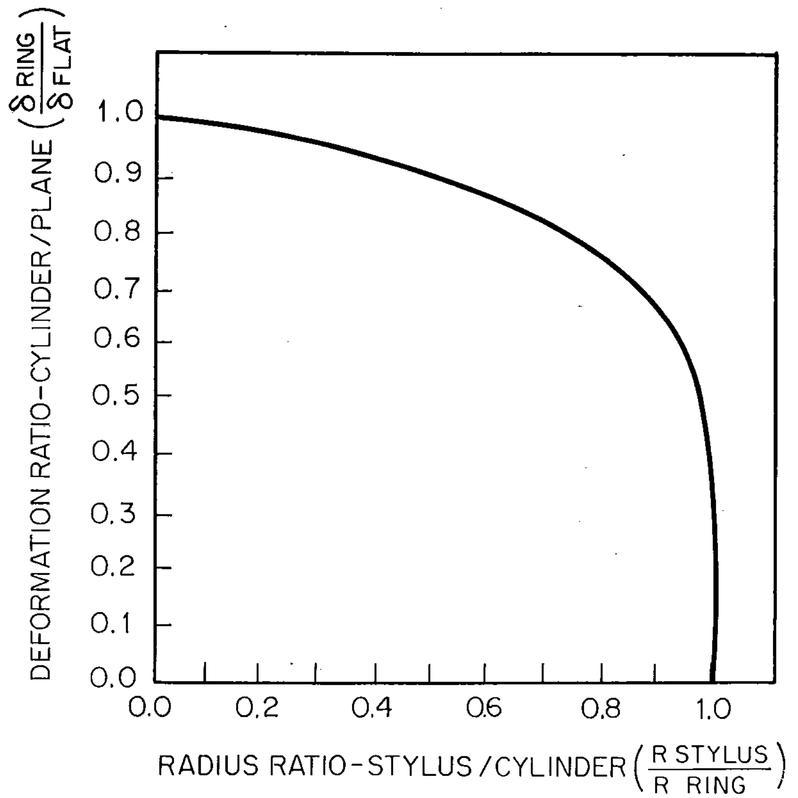

FIG. E1 DEFORMATION FACTOR IN RING GAGE MEASUREMENT

no geometrical imperfections. Most gage blocks have geometrical imperfections which will add to this uncertainty. Deviations from flatness can create thicker than normal wringing films between blocks as well as giving parallelism distortions in wrung combinations. Scratched blocks may sometimes cause larger than normal wringing film thicknesses.

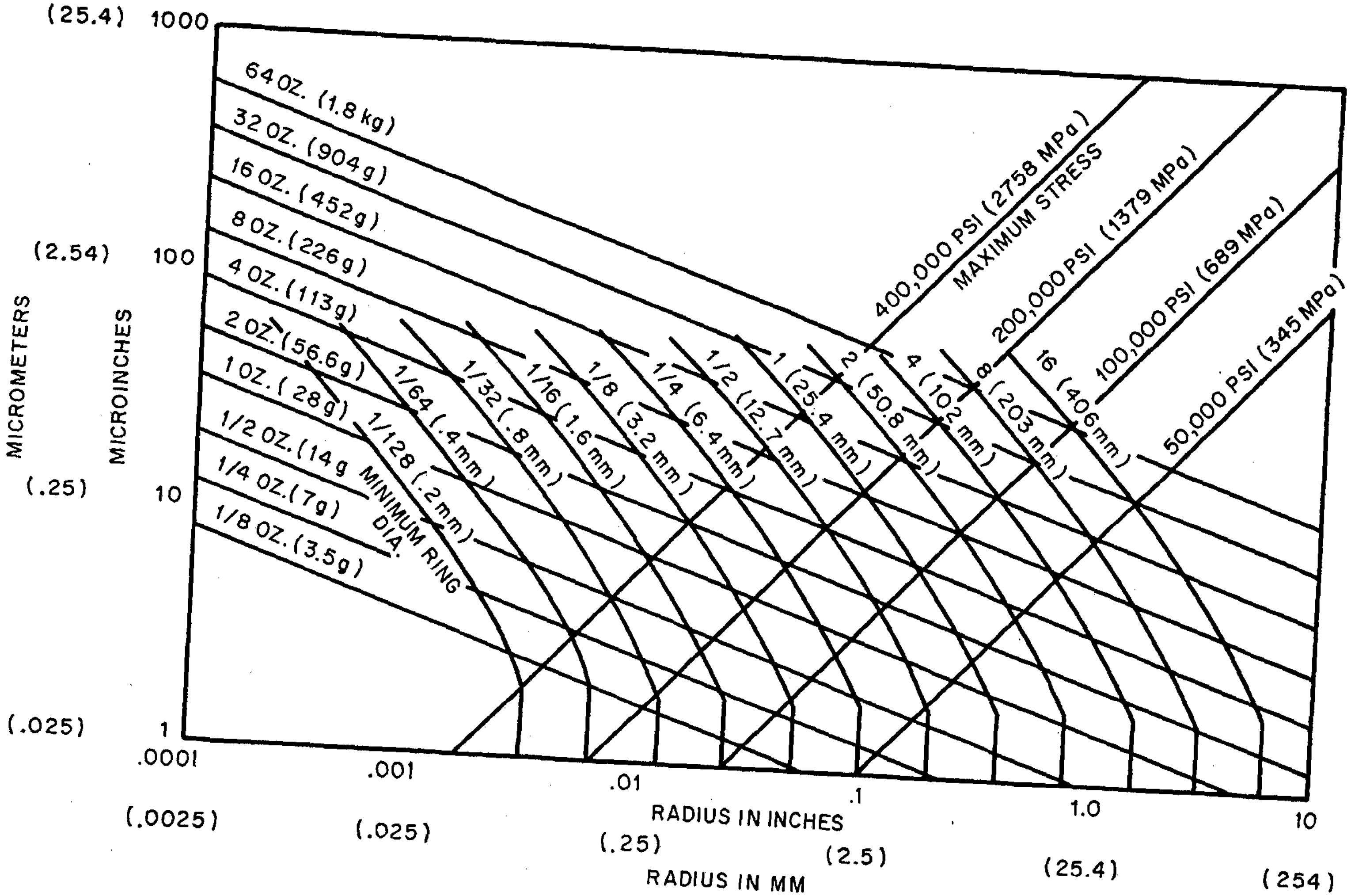

FIG. E2 SPHERE TO PLANE DEFORMATION — TUNGSTEN CARBIDE AGAINST STEEL

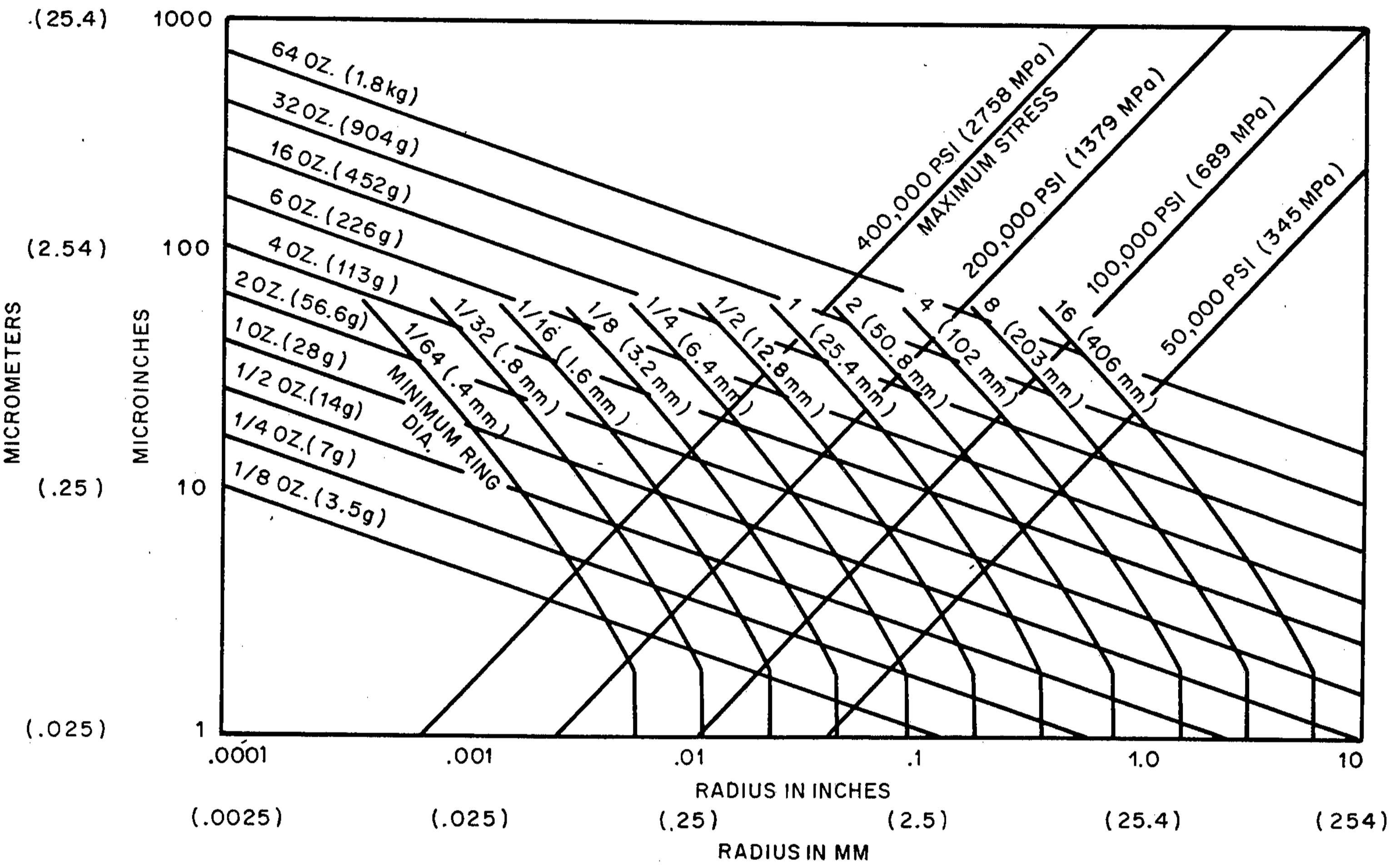

FIG. E3 SPHERE TO PLANE DEFORMATION – STEEL AGAINST STEEL

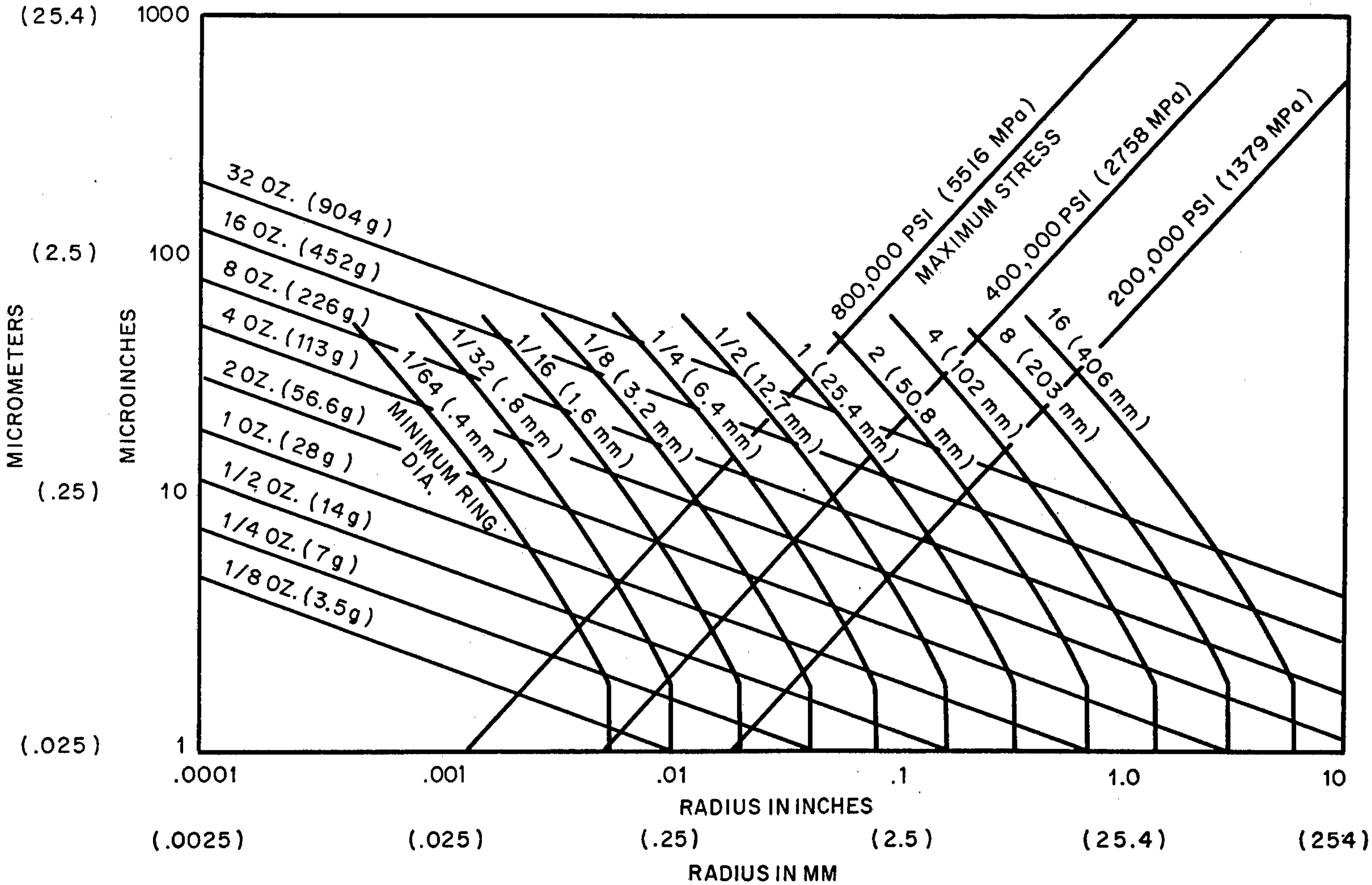

FIG. E4 SPHERE TO PLANE DEFORMATION — CARBIDE AGAINST CARBIDE

AMERICAN NATIONAL STANDARDS RELATED TO DIMENSIONAL METROLOGY

Measurement of Qualified Plain Internal Diameters for Use as Master Rings and Ring Gages B89.1.6M-1984
Precision Gage Blocks for Length Measurement (Through 20 in. and 500 mm) B89.1.9M-1984
Dial Indicators (for Linear Measurements) B89.1.10-1978
Measurement of Out-of-Roundness B89.3.1-1972 (R1979)
Temperature and Humidity Environment for Dimensional Measurement B89.6.2-1973 (R1979)
Gages and Gaging for Unified Inch Screw Threads B1.2-1983
American Gaging Practice for Metric Screw Threads B1.16-1972
Preferred Limits and Fits for Cylindrical Parts B4.1-1967 (R1979)
Surface Texture B46.1-1978

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