Granite Surface Plates

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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ASME B89.3.7-2013

Granite Surface Plates

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

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

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FOREWORD

This ASME Standard is a revision of the 1973 Federal Specification GGG-P-463c which has been used extensively in American industry since its publication. Although the measurement methods for surface plates had already been in use some decades prior to the Federal Specification, it did serve to document these methods. In addition, it provided common language and terms of classification for surface plate manufacturing and commerce. While little has changed with regard to measurement methods and the flatness tolerances of the various plate grades are still relevant today, ASME B89 Division 3 decided an effort was justified to modernize the document. Most notably, a more complete glossary was added with currently accepted definitions, metric units were added where appropriate, and a new format was used that should be more familiar to current users of the Standard. This Committee also recognized the need for updates to a surface plate specification to incorporate modern concepts, such as traceability and measurement uncertainty, that have undergone considerable development since 1973. This new document under ASME B89 ownership will provide the platform for these and other updates periodically through the revision process.

This edition of B89.3.7 was approved by ANSI on April 12, 2013.

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Dimensional Metrology

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Secretary, B89 Standards Committee
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http://go.asme.org/Inquiry

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

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

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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 the topic of the inquiry.

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. The inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in 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 that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

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Introduction

One primary purpose of specifying values for surface plate parameters such as flatness, or for measuring these parameters, is to predict or estimate the level of accuracy that may be accomplished in measurements when the surface plate serves as a reference for those measurements, i.e., the measurement errors will tend to be smaller when a flatter (higher grade) surface plate is used as a reference, and measurement errors will generally be larger when a lower grade surface plate is used. Although, in general, it is difficult to quantitatively relate surface plate flatness to measurement errors, for specific applications, a certain flatness parameter may correlate very well with measurement errors, e.g., a measurement task involving a height stand with support spacing the same as that of a repeat reading gage may have measurement errors that are close to the repeat readings from the gage. It is safe to say, in general, the correlation will be useful but qualitative. The definitions and procedures in this Standard can also allow fair comparisons between surface plates, and they can help to identify and quantify changes in a given surface plate that occur over time, either from use or from changes in the environment.

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GRANITE SURFACE PLATES

1 GENERAL

1.1 Scope

This Standard covers igneous rock (granite) plates for use in high accuracy locating, layout, and inspection work. It encompasses new certification, recertification in the field, and recertification after resurfacing. In general, the standard covers any size granite surface plate. Information for the sizes in common use is presented in tabular form.

1.2 Classification: Styles and Grades

Surface plates shall be of the following styles and grades:

(a) *Styles (shapes)*
- Rectangular, no ledge (see Fig. 2)
- Rectangular, 2 ledge, either direction (see Fig. 3)
- Rectangular, 4 ledge (see Fig. 4)
- Round, no ledge (see Fig. 5)

(b) *Grades*
- AA
- A
- B

2 DEFINITIONS

bow: the condition of a surface plate where the middle of the plate is higher or lower than the two ends.

F.I.M.: Full Indicator Movement.

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

grade: the classification of a surface plate according to the flatness and repeat reading tolerance of the work surface. (This Standard covers three grades: AA, A, and B.)

inserts: typically made of metal (usually stainless steel, to prevent rusting) and are "plugs," usually predrilled and tapped to various thread diameters and pitches, and are epoxied into a granite surface plate. They can also be furnished as a "solid" insert — no predrilling or tapping. Threaded inserts allow for hold-down capabilities and fixturing on a granite surface plate.

ledge: an undercut made along the sides or across the ends (or both) of a surface plate.

repeat reading: a measure of flatness over localized areas of a surface plate. This measure is usually obtained using a repeat reading gage (see following definition) that measures height variation of the surface plate from a reference established by the base of the repeat reading gage. The range of readings taken with a repeat reading gage represents local deviation from flatness over the area sampled.

repeat reading gage: a gage used to obtain repeat readings (see Fig. I-3). This instrument estimates the ability to reproduce a measurement of a fixed height at any place on the surface plate. The repeat reading gage is sensitive to short wavelength variations in flatness when readings are taken over small intervals of movement of its base.

twist: the condition of a surface plate where the plate takes on the shape of a surface whose ends have been turned in opposite directions (e.g., like the shape of a propeller). The four corners of plates having this condition do not lie within the same plane. The lines characterizing opposite ends of a surface plate that exhibits twist have some relative angle between them (see Fig. 1).

3 REFERENCES

3.1 Normative References

ASME B46.1, Surface Texture, Surface Roughness, Waviness and Lay

ASME B89.6.2, Temperature and Humidity Environment for Dimensional Measurement

ASME B89.7.3.1, Guidelines For Decision Rules: Considering Measurement Uncertainty in Determining Conformance to Specifications

ASME Y14.5M, Dimensioning and Tolerancing

Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900 (www.asme.org)

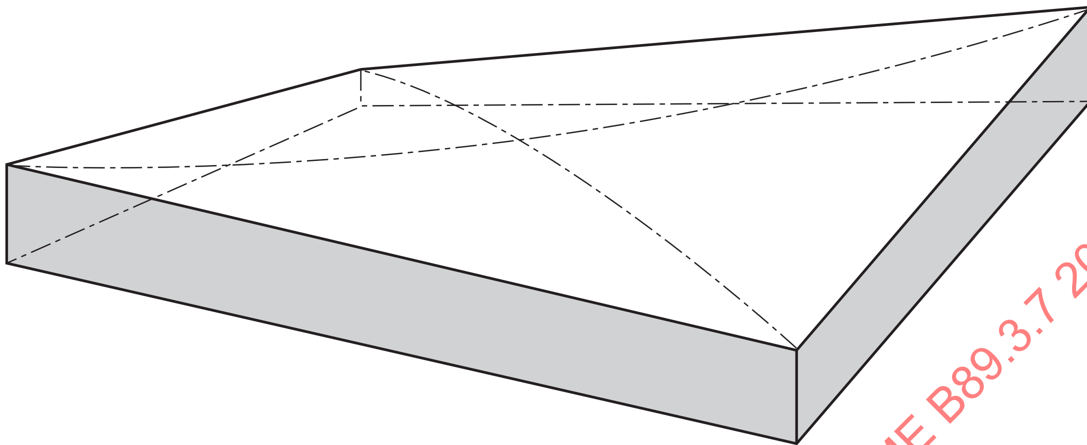
ASTM C119-99b, Terminology Relating to Dimension Stone

ASTM C615-99, Standard Specification for Granite Dimension Stone

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

Research Paper 1320, Physical, Mineralogical, and Durability Studies on the Building and Monumental Granites of the United States, Journal of Research of

Fig. 1 Exaggerated View of a Surface Plate With Twist



the National Bureau of Standards, Vol. 25, August 1940, pp. 161-205.
Publisher: National Institute of Standards and Technology (NIST), 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899 (www.nist.gov)

Moody, J.C. (1955, October). The Moody Method. The Tool Engineer

3.2 Additional References

ISO 17025:2005, General requirements for the competence of testing and calibration laboratories
Publisher: International Organization for Standardization (ISO), Central Secretariat, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Genève 20, Switzerland/Suisse (www.iso.org)

JCGM 100:2008, Evaluation of measurement data — Guide to the expression of uncertainty in measurement (GUM). Available at http://www.bipm.org/en/publications/guides/gum.html
JCGM 200:2012, International Vocabulary of Metrology — Basic and General Concepts and Associated Terms (VIM), Third Edition, http://www.bipm.org/en/publications/guides/vim.html
Publisher: Bureau International des Poids et Mesures (BIPM), Pavillon de Breteuil, F-92312 Sèvres Cedex, France (www.bipm.org)

4 GENERAL REQUIREMENTS

4.1 Materials

Surface plates covered by this Standard shall be made from fine or medium grained igneous rock, e.g., material such as biotite granite, biotite hornblende, diabase, hypersthene gabbro, muscovite-biotite, and muscovite biotite/granite-gneiss, etc. The material shall be free of cracks or other defects that may affect the serviceability of the surface plate. Other granites are acceptable provided they meet the requirements of this Standard. Refer to Table A-1 for material properties.

4.2 Cracks and Color Streaks

Cracks are cause for rejection. Color streaks have no effect on the serviceability of the granite and are acceptable.

4.2.1 Style. Surface plates covered by this Standard shall be of the four styles illustrated in Figs. 2 through 5.

4.2.2 Size. Surface plates covered by this Standard shall be any size. The most common sizes are listed in Table 1.

4.2.3 Thickness and Stiffness. The surface plate shall have a thickness capable of supporting a total normal load equal to 240 kg/m^2 (50 lb/ft^2) of surface plate area, loaded in the center of the plate, without deflecting the plate along a diagonal or diameter more than one-half the flatness tolerance (see Nonmandatory Appendix B).

4.2.4 Clamping Ledges. See Fig. 3.

4.2.4.1 Clamping ledges on surface plates under 150 mm (6 in.) thick shall not be less than 40% of the surface plate thickness, in thickness, X, and the overhang, Y, shall be approximately one-fourth of the surface plate thickness.

4.2.4.2 Clamping ledges on surface plates 150 mm (6 in.) thick or over shall not be less than 80 mm (3 in.) in thickness, X, and the overhang, Y, shall be not more than 50 mm (2 in.).

4.2.4.3 Ledge clamping surfaces shall be parallel with the working surface within 5 mm/m (0.06 in./ft).

4.2.5 Supports. Unless otherwise specified, support of the surface plate shall be by three fixed feet, located

Fig. 2 Surface Plate, Style 1, No Ledge, Rectangular or Square

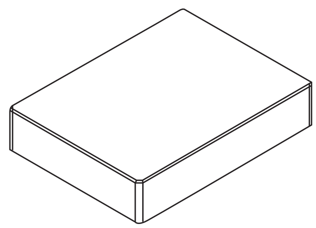


Fig. 3 Surface Plate, Style 2, Two-Ledge, Either Direction, Rectangular or Square

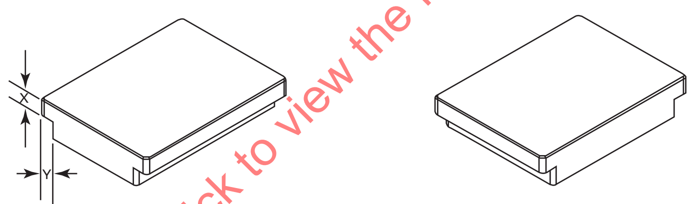


Fig. 4 Surface Plate, Style 3, Four-Ledge, Rectangular or Square

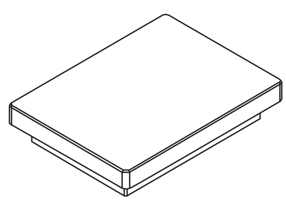


Fig. 5 Surface Plate, Style 4, No Ledge, Round

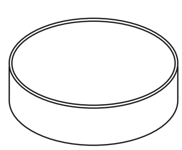


Table 1 Common Sizes and Flatness Tolerances

Common Sizes: Rectangular Surface Plates — U.S. Customary Size, in. — Width	Length	Metric Size, mm — Width	Length	Tolerance — Grade AA — Local Variation in Flatness (Using Repeat Reading Gage) — U.S. Size, µin.	Metric Size, µm	Grade AA — Overall Flatness — U.S. Size, µin.	Metric Size, µm	Grade A — Local Variation in Flatness (Using Repeat Reading Gage) — U.S. Size, µin.	Metric Size, µm	Grade A — Overall Flatness — U.S. Size, µin.	Metric Size, µm	Grade B — Local Variation in Flatness (Using Repeat Reading Gage) — U.S. Size, µin.	Metric Size, µm	Grade B — Overall Flatness — U.S. Size, µin.	Metric Size, µm
12	12	300	300	35	0.9	50	1.3	60	1.5	100	2.5	110	2.8	200	5
12	18	300	450	35	0.9	50	1.3	60	1.5	100	2.5	110	2.8	200	5
18	18	450	450	35	0.9	50	1.3	60	1.5	100	2.5	110	2.8	200	5
18	24	450	600	35	0.9	80	2.0	60	1.5	160	4.0	110	2.8	320	8
24	24	600	600	45	1.2	80	2.0	70	1.8	160	4.0	120	3.0	320	8
24	36	600	900	45	1.2	100	2.5	70	1.8	200	5.0	120	3.0	400	10
24	48	600	1 200	45	1.2	150	4.0	70	1.8	300	8.0	120	3.0	600	16
30	48	750	1 200	45	1.2	180	4.5	70	1.8	360	9.0	120	3.0	720	18
36	36	900	900	45	1.2	150	4.0	70	1.8	300	8.0	120	3.0	600	16
36	48	900	1 200	45	1.2	200	5.0	70	1.8	400	10.0	120	3.0	800	20
36	60	900	1 500	60	1.5	250	6.5	80	2.0	500	13.0	160	4.0	1,000	26
36	72	900	1 800	60	1.5	300	7.5	80	2.0	600	15.0	160	4.0	1,200	30
48	48	1 200	1 200	60	1.5	200	5.0	80	2.0	400	10.0	160	4.0	800	20
48	60	1 200	1 500	60	1.5	300	7.5	80	2.0	600	15.0	160	4.0	1,200	30
48	72	1 200	1 800	60	1.5	350	9.0	80	2.0	700	18.0	160	4.0	1,400	36
48	96	1 200	2 400	75	1.9	500	13.0	100	2.5	1,000	26.0	200	5.0	2,000	52
48	120	1 200	3 000	90	2.3	700	18.0	120	3.0	1,400	36.0	240	6.0	2,800	72
60	120	1 500	3 000	90	2.3	750	19.0	120	3.0	1,500	38.0	240	6.0	3,000	76
72	96	1 800	2 400	90	2.3	600	15.0	120	3.0	1,200	30.0	240	6.0	2,400	60
72	144	1 800	3 600	100	2.5	1,100	28.0	140	3.5	2,200	56.0	280	7.0	4,400	112

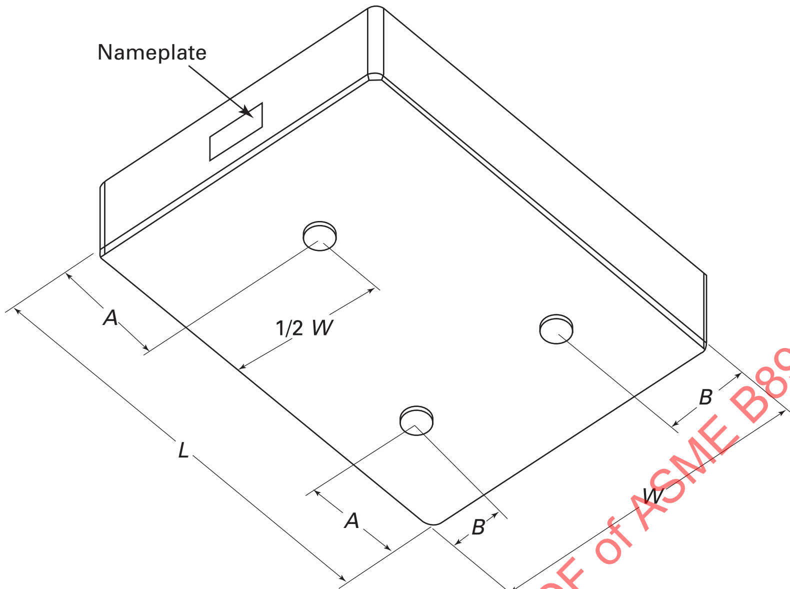
Round Surface Plates Diameter — U.S. Customary Size, in.	Metric Size, mm	Grade AA — Round Surface Plates Local Variation in Flatness (Using Repeat Reading Gage) — U.S. Size, µin.	Metric Size, µm	Grade AA — Overall Flatness — U.S. Size, µin.	Metric Size, µm	Grade A — Round Surface Plates Local Variation in Flatness (Using Repeat Reading Gage) — U.S. Size, µin.	Metric Size, µm	Grade A — Overall Flatness — U.S. Size, µin.	Metric Size, µm	Grade B — Round Surface Plates Local Variation in Flatness (Using Repeat Reading Gage) — U.S. Size, µin.	Metric Size, µm	Grade B — Overall Flatness — U.S. Size, µin.	Metric Size, µm
12	300	35	0.9	50	1.3	60	1.5	100	2.5	110	2.8	200	5
18	450	35	0.9	50	1.3	60	1.5	100	2.5	110	2.8	200	5
24	600	35	0.9	80	2.0	60	1.5	160	4.0	110	2.8	320	8
36	900	45	1.2	100	2.5	70	1.8	200	5.0	120	3.0	400	10
48	1 200	45	1.2	120	3.0	70	1.8	240	6.0	120	3.0	500	12

GENERAL NOTES:

(a) Dimensions of length and width for common sizes are nominal dimensions only. The tolerances in this Table apply to sizes within ±5% of the nominal sizes listed. For guidance on recommended tolerances on sizes outside the listed common sizes, see para. 4.3.4.1. For flatness tolerances on surface plates not covered explicitly by this Standard, it is recommended that the manufacturer and buyer agree on the expected tolerance before a contract is concluded.

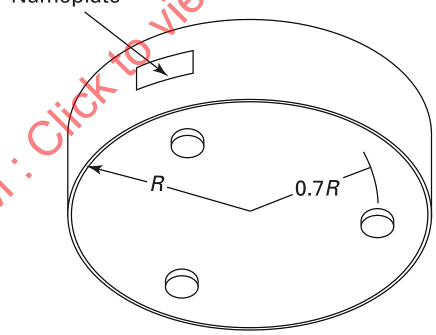
(b) For granite reference flats smaller than the sizes listed above (commonly known as "toolmakers' flats"), consult the manufacturer for tolerances supplied.

Fig. 6 Support Layout for Rectangular Surface Plate



GENERAL NOTE: $A = \frac{1}{5}$ to $\frac{1}{4}$ of L; $B = \frac{1}{5}$ to $\frac{1}{4}$ of W

Fig. 7 Support Layout for Round Surface Plate



according to Figs. 6 and 7 to support the work surface properly, and to minimize deflection. When the three fixed supports have special requirements due to their location, load, and/or vibration conditions, the supports and their locations shall be clearly specified (see Nonmandatory Appendix C).

4.2.5.1 Rectangular Plates. The support pads shall be located no less than one-fifth, and no more than one-fourth, of the length and width in from the ends and sides, respectively, with the exception that the single pad at one end shall be located in the center (see Fig. 6). Calculating the thickness for rectangular plates when the plate is supported on three supports at $\frac{1}{5}L$ positions, it is recommended to refer to Nonmandatory Appendix B.

4.2.5.2 Round Plates. The support pads shall be located at three equally spaced positions on a circle with a radius of approximately 0.7 radius of the plate, measured from the center of the base surface (see Fig. 7).

4.2.6 Holes, Slots, and Inserts. Holes, slots, and inserts, when required, shall not deform or stress the work surface.

4.3 Work Surface

4.3.1 Workmanship of Work Surface. The work surface shall be lapped, free from rough lapping marks.

4.3.2 Surface Texture. Using a cutoff of 0.8 mm (0.03 in.), the surface roughness shall not exceed 0.8 μm (32 μin.) average roughness (Ra) for grades AA and A

Table 2 Tolerances for Local Variations in Flatness Using a Repeat Reading Gage
Full Indicator Movement (FIM)

Diagonal or Diameter Range, mm (in.)	Grade AA, μm (μin.)	Grade A, μm (μin.)	Grade B, μm (μin.)
≤800 (30)	0.9 (35)	1.5 (60)	2.8 (110)
>800 (30) – 1 500 (60)	1.2 (45)	1.8 (70)	3.0 (120)
>1 500 (60) – 2 200 (90)	1.5 (60)	2.0 (80)	4.0 (160)
>2 200 (90) – 3 000 (120)	1.9 (75)	2.5 (100)	5.0 (200)
>3 000 (120) – 3 800 (150)	2.3 (90)	3.0 (120)	6.0 (240)
>3 800 (150)	2.5 (100)	3.5 (140)	7.0 (280)

GENERAL NOTE: It may be possible to achieve better FIM results than the above tolerances, but any requirement of enhanced FIM results should be negotiated between the buyer and seller for a specific surface plate, as it is beyond the scope of this Standard.

plates and shall not exceed 1.6 μm (63 μin.) average roughness (Ra) for grade B plates. This shall be determined by the average of five readings taken at points distributed across the working surface of the surface plate. Please refer to ASME B46.1, Surface Texture (Surface Roughness, Waviness and Lay) for more information.

4.3.3 Tolerances on Repeat Reading Measurement (Local Variations). Tolerances on local variations are given in Table 2. (See Mandatory Appendix I-4.2 for test procedure.)

4.3.4 Flatness Tolerance (Entire Work Surface). All points of the work surface shall be contained between two parallel planes, the base plane and the roof plane, separated by a distance no greater than that specified for the respective grades (see Fig. I-5). The work surface flatness tolerance for the three grades of plates is given in Table 1. (See Mandatory Appendix I for testing methods.) The tolerances on grades A and B plates are 2 and 4 times, respectively, those of grade AA.

Flatness tolerance for surface plates, whose sizes are not listed in Table 1, is obtained from the following formula:

$$\text{Overall flatness tolerance } (\mu\text{m}) = 1 + 1.6D^2$$

$$\text{Overall flatness tolerance } (\mu\text{in.}) = 40 + D^2/25$$

where

D = diagonal or diameter of the plate

The calculated flatness tolerance for grade AA is rounded up to the nearest 0.5-μm or 25-μin. increment. The tolerance of grades A and B plates are 2 and 4 times, respectively, those for grade AA.

4.3.4.1 Twist. The four corners of the working surface of the plate shall lie within two parallel planes, separated by a maximum of 25% of the flatness tolerance.

4.3.4.2 Working Surface Area. The tolerance (both overall flatness and repeat readings) and twist shall apply to the entire surface except for the edge of each plate as specified in Table 3.

Table 3 Restrictions on Surface Area for Flatness and Twist

Diameter or Diagonal of Plate, mm	Diameter or Diagonal of Plate, in.	Distance in From Edges (All Grades), mm	Distance in From Edges (All Grades), in.
300 – 1 200	12 – 48	25	1.0
>1 200	>48	38	1.5

4.3.5 Decision Rules. When determining if a surface plate meets the grade requirements expressed in Table 1, the guidelines of ASME B89.7.3.1 apply. Unless otherwise specified, a simple acceptance with a ratio of 4:1 applies for grades A and B. A simple acceptance with a ratio of 2:1 is acceptable for grade AA evaluations, as achieving a 4:1 ratio between the grade tolerance and measurement uncertainty may not be economically feasible.

4.4 General Workmanship

4.4.1 Edges and Corners. All edges and corners shall be smoothly rounded to minimize chance of chipping.

4.4.2 Sides Adjacent to Work Surface, Ledge Surfaces, and Squareness. The four sides adjacent to work surface and all ledge surfaces shall have a surface texture such as is commercially produced by a wire saw-cutting operation, or better, and shall be square with each other within 5 mm/m (0.06 in./ft).

4.4.3 Bottom Surface. Bottom surface may have a surface texture as rough as is commercially produced by a gang saw, or better.

4.5 Nameplate

4.5.1 Durability. The nameplate shall be permanent and shall be impervious to commercially available cleaning solutions designed for use on surface plates.

4.5.2 Location

4.5.2.1 Rectangular Plates. The nameplate shall be located on the side nearest to the single support pad (see Fig. 6).

4.5.2.2 Round Plates. The nameplate shall be located on the side nearest any support pad (see Fig. 7).

4.5.3 Manufacturer Nameplate. Unless otherwise specified, the following information shall be permanently and legibly marked:

- manufacturer's name
- manufacturer's serial number

4.6 Certificate of Conformance

All surface plates shall be furnished with a certificate of conformance that states that the plate meets the requirements of this Standard.

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MANDATORY APPENDIX I
TESTING

The following material provides guidance for testing surface plates for stiffness, roughness, repeat reading, and flatness. The tests described reflect current industry practice. Other test methods may be used so long as they correctly assess the parameter being tested and do not cause damage to the surface plate.

I-1 VERTICAL SPATIAL THERMAL GRADIENTS

Vertical spatial temperature gradients that occur in the plate can create significant distortion by bowing the surface plate (see Nonmandatory Appendix D). This distortion is reflected in the calibration for flatness. Therefore, if the current calibration is to be compared with previous calibrations, the effects due to thermal distortion must be considered.

If these vertical spatial thermal differences are kept within the limits expressed in Table I-1, the flatness distortion will not exceed one-half of the tolerance given in Table 1. If the surface plate is being calibrated at a location different from where it will be located when in use, it is important to match the anticipated spatial thermal gradients of the air at the position the plate is to occupy when it is in use.

Local thermal gradients can be reduced by refraining from placing calibration instruments with built-in heat sources on the surface plate during calibrations.

After the thermal soaking time has passed (see Nonmandatory Appendix D) and just before calibration starts, the vertical spatial thermal gradient in the plate shall not exceed the value given in Table I-1.

I-2 STIFFNESS TEST

A thick circular steel plate, with a minimum thickness the larger of 13 mm (0.5 in.) or 0.005 mm times the load in kilograms (0.0005 in. times the load in pounds) and a diameter approximately equal to one-sixth the diameter or diagonal of the surface plate, is placed on the center of the plate. The surface plate shall be supported on three support pads as specified in paras. 4.2.5.1 and 4.2.5.2. A rigid beam is supported on feet located at the extremes of the plate diameter or diagonal, and an indicator with sufficient range and sensitivity is positioned halfway between the feet on this beam (see Fig. I-1). A cage for transmitting the load to the surface plate straddles the beam and rests on the circular plate. The indicator point contacts the circular plate. The difference in indicator readings before and after loading the

Table I-1 Maximum Allowable Vertical Spatial Thermal Gradient for Calibration

Grade	°C/mm of Plate Thickness	°F/in. of Plate Thickness
AA	0.001	0.05
A	0.002	0.10
B	0.004	0.20

cage at 240 kg/m^2 (50 lb/ft^2) of surface plate area shall not exceed one-half the flatness tolerance. The rigid beam for deflection measurements on round plates shall be located to pass over one support pad. Other methods for measuring the deflection may be used as long as the results are comparable.

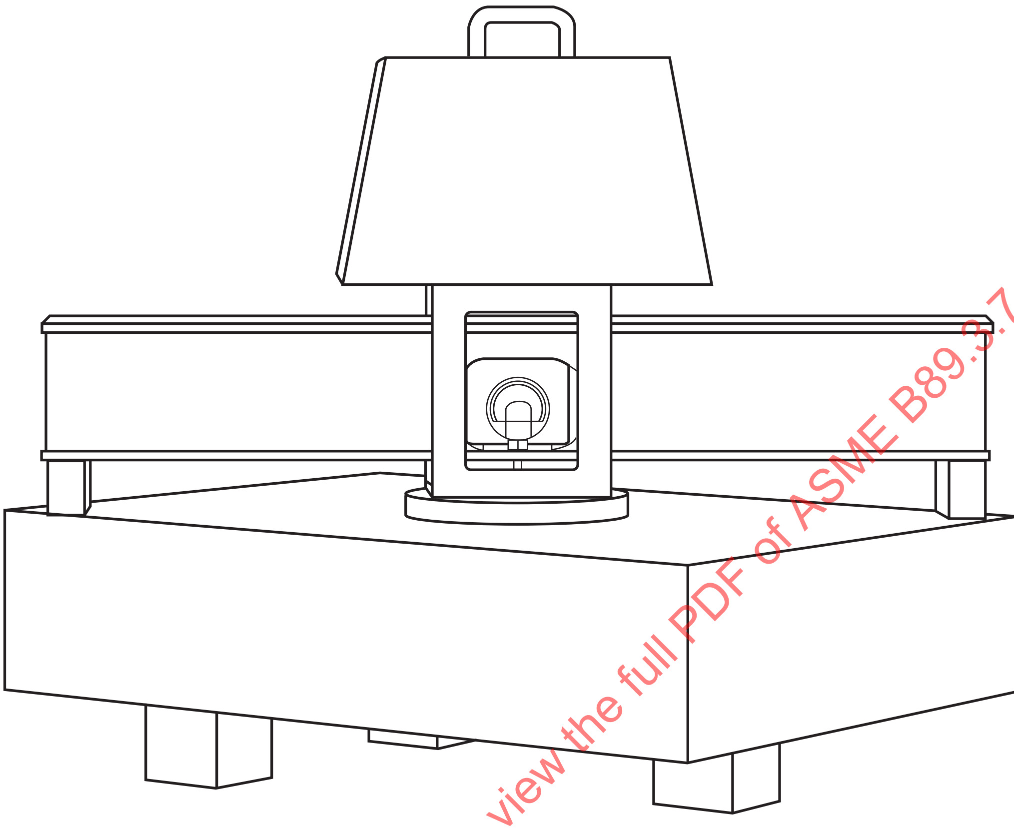
I-3 SURFACE TEXTURE

The average roughness, Ra, shall be assessed with a surface profile-measuring instrument using 0.8-mm (0.03-in.) cut-off, which meets the requirements of the current issue of ASME B46.1. The surface plate shall be sampled near the center and at four random positions away from the center. See para. 4.3.2 for allowable average roughness, Ra, values.

I-4 FLATNESS EVALUATION

Evaluating a surface plate for usefulness can involve evaluations in several different wavelength regimes. In the short wavelength world, where the concern is related to how a measuring device may be affected by local variations in the flatness of the reference surface provided by the surface plate, a method should be used which is sensitive to wavelengths of approximately the same size as the measuring instrument. Common usage in this wavelength regime is to test using a repeat reading gage. These tests may typically show local problems in the flatness of the surface plate due to wear, damage, or contamination. This type of test may not reflect flatness issues on the surface plate where the wavelengths contributing to the out-of-flatness are long, relative to the instruments being used, e.g., height and transfer stands, etc. Evaluation of these longer wavelength contributors is commonly performed using angle measurement tools, such as autocollimators, electronic levels,

Fig. I-1 Stiffness Test Example



spirit levels, or laser interferometers, using tools with reference lengths of approximately 100 mm (4 in.). Wavelengths essentially of the same size as the surface plate (e.g., conditions characterized in the list of definitions as bow and twist) are commonly evaluated by test processes and instruments, such as the in-line flatness gage or tram gage illustrated below, where the length of the gage is approximately the same as the length of the sides of the surface plate diagonal. Other methodologies are entirely appropriate but should be evaluated according to what wavelengths they are sensitive to.

I-4.1 Instrumentation

Instrumentation for calibrating surface plate flatness include autocollimator, electronic level, high accuracy spirit levels, laser interferometer, master straight edge with a traveling indicator or with a beam gage, alignment lasers, and in-line flatness gages.

I-4.1.1 In-line Flatness Gage (Tram). The in-line flatness gage consists of a beam with two fixed feet at one end and one fixed foot at the other end (see Fig. I-2). An indicator with floating contact is in the center, equidistant from the feet. Interchangeable fixed feet or different length beams provide flatness data for accommodating different sizes of surface plates. The distance between these feet determine the wavelength sensitivity of this instrument.

This instrument is used with a master on which to set the indicator and produces data to establish flatness where the wavelength is no longer than twice the distance between the feet of the in-line flatness gage.

I-4.2 Tests for Local Variation in Flatness

A repeat reading gage in general conformance with Fig. I-3 shall be used to indicate measurements of local out-of-flatness caused by local variations in flatness. Place the repeat reading gage in the center of the surface plate on the longest centerline, and zero the indicator. For plates with diagonals or diameters under 460 mm (18 in.), the scanning pattern of the gage is random. For larger plates, scan the eight-line pattern shown in Fig. I-4 and additional equally spaced coordinate lines such that no spacing between scanned lines exceeds 150 mm (6 in.). The FIM shall not exceed the values given in Table 2. The least graduation of the meter or dial shall not exceed 0.2 μm (10 μin.) or one-fifth of the allowed FIM value, whichever is larger.

Fig. I-2 Tram Gage

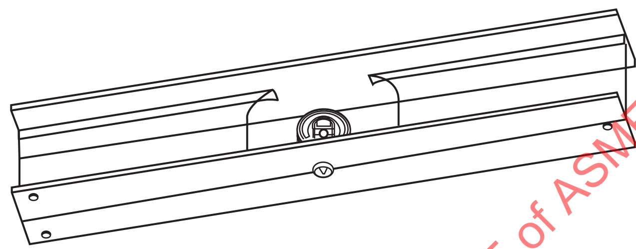
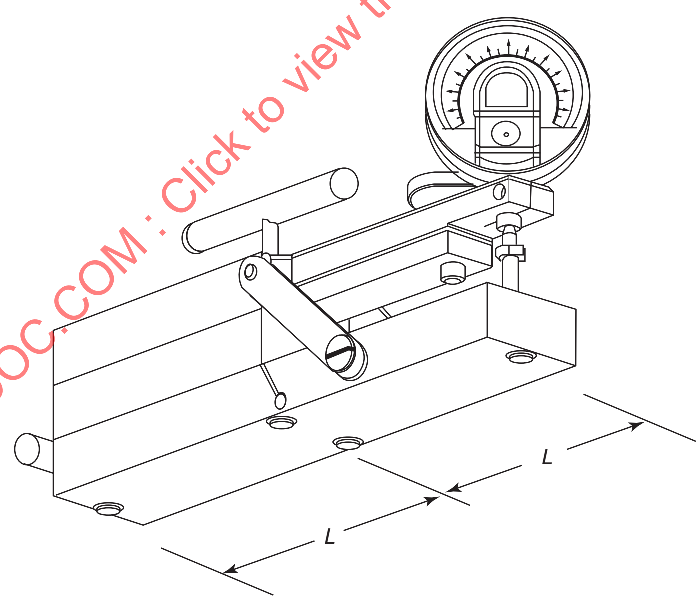


Fig. I-3 Repeat Readings Gage



GENERAL NOTES:
(a) The four contact points are 9.5 mm (0.38 in.) in diameter.
(b) L = 125 mm (5 in.).

Fig. I-4 Eight-line Calibration Pattern for Rectangular and Round Surface Plates

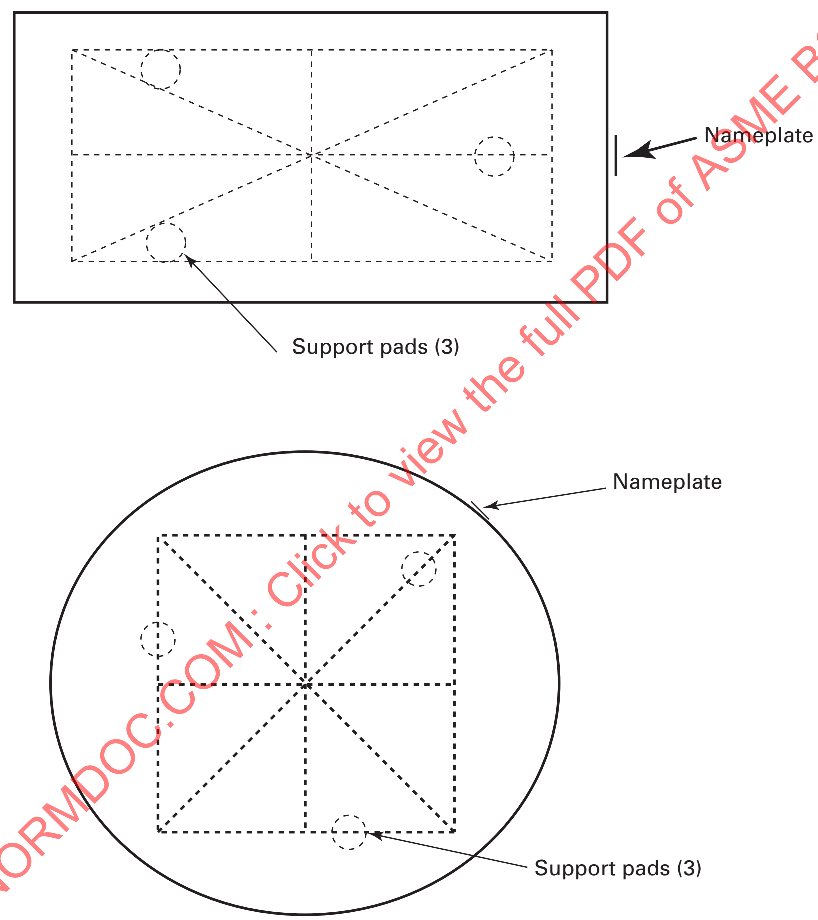
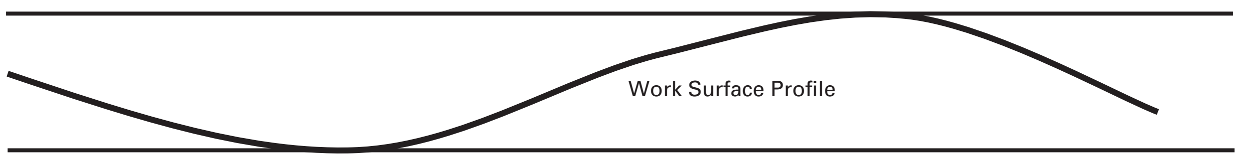


Fig. I-5 Plane Identification



I-4.3 Testing for Flatness Tolerance (Entire Work Surface)

In addition to the test for local variations in flatness outlined in para. I-4.2, a test that evaluates the out-of-flatness of the entire work surface shall be conducted. At least one of the tests outlined in paras. I-4.3.1 through I-4.3.3 shall be conducted.

I-4.3.1 Acceptance Test. A simple check for acceptance of the overall flatness of a surface plate consists of analyzing three flatness profiles taken using equipment sensitive to the longer wavelength contributors, as described in para. I-4. This test produces results on a sample of the surface, which usually will correctly estimate the actual condition of the overall surface. The three profile lines to be evaluated are the two principal diagonals for rectangular surface plates or two orthogonal diameters for round plates, plus the additional profile line passing through both the intersection of these two lines and through the point of maximum departure found by scanning the work surface with a repeat reading gage. A minimum of six steps per profile line is required, and the maximum step spacing is 300 mm (12 in.).

Each of these three profile lines shall be adjusted to eliminate any slope in the lines by setting each line's endpoints to be equal. The value at the intersection point, which is common to all three lines, shall be set to zero. The value of the maximum point minus the minimum point, taking all three lines into account, shall be less than the overall-flatness tolerance from Table 1. The surface plate must also meet the requirements of para. I-4.2.

If the results from this acceptance test are challenged, a referee test, such as the one described in para. I-4.3.2, shall be carried out.

I-4.3.2 Flatness Calibration and Referee Test. Any valid referee test will generate data that correctly represents the flatness of the whole surface and is consistent with the definition of flatness given in section 2 and para. 4.3.4 (see Fig. I-5) of this Standard. One widely used referee test method is known as "The Moody Method" (see para. 3.1).

Most instruments do not work satisfactorily close to the edge as specified in Table 4, but the edge profile shall be tied to the pattern by other instrumentation, such as master straight edge with indicator or in-line flatness gage.

I-4.3.3 Small Surface Plates. Alternative methods may be used for assessing the flatness of surface plates too small to be checked using the above instruments and methods. Alternative methods may include

(a) using a small in-line flatness gage with a master flat or straight edge for zero-setting the indicator.

(b) sliding a small plate over a flatness gage made by mounting a sensing probe in the center of a larger calibrated surface.

(c) setting a small plate on a larger, calibrated plate and precisely leveling the smaller plate parallel to the larger surface. It can then be checked using a transfer stand that references from the larger surface. Care must be taken to account for the length of the over-hanging arm, which may amplify any errors in the reference surface.

(d) if the surface of the small plate is small enough and reflective enough, it may be possible to check its flatness using an optical flat with monochromatic light.

(e) using a coordinate-measuring machine (CMM).

NONMANDATORY APPENDIX A
MINERALOGICAL AND PHYSICAL PROPERTIES

Table A-1 gives some of the mineralogical properties of rock types used in the production of granite surface plates.

For more information, refer to Research Paper RP 1320, Part of Journal of Research of the National Bureau of Standards, Volume 25, August 1940: "Physical, Mineralogical, and Durability Studies on the Building and Monumental Granites of the United States."

Table A-1 Granite Rock Types, Physical Properties, and Mineral Components

Rock Type	Natural Color	Texture	Mineral Constituents in Descending Order of Abundance	Modulus of Elasticity Range	
				10^9 N/m^2	10^6 psi
Biotite granite	Bluish gray	Fine-grained	Orthoclase, smoky quartz [Note (1)], oligoclase, albite, biotite, muscovite, magnetite, and zircon	24 – 48	3.5 – 7.0
Biotite granite	Light gray	Medium-grained	Oligoclase, orthoclase and microcline, quartz, biotite, apatite, and zircon	25 – 48	3.5 – 7.0
Biotite granite	Pink	Medium-grained	Orthoclase with a small amount of microcline, plagioclase, quartz [Note (1)], biotite, magnetite, and garnet	34 – 62	5.0 – 9.0
Biotite hornblende granite	Reddish brown	Fine-grained	Orthoclase and microcline, quartz [Note (1)], hornblende, biotite, plagioclase, and magnetite	41 – 62	6.0 – 9.0
Biotite-muscovite	Light gray	Medium to fine-grained	Microcline, quartz, plagioclase, biotite, muscovite, and magnetite	34 – 48	5.0 – 7.0
Diabase	Dark gray	Fine-grained	Plagioclase, pyroxene, and magnetite	62 – 83	9.0 – 12.0
Hypersthene gabbro	Dark gray	Fine-grained	Plagioclase, pyroxene, hornblende, magnetite, and biotite	69 – 83	10.0 – 12.0
Muscovite-biotite granite-gneiss	Light gray	Medium-grained	Microcline and orthoclase, oligoclase, quartz, rutile, muscovite, biotite, and apatite	25 – 55	3.5 – 8.0

NOTE:
(1) 28% to 32% quartz by volume. Under certain conditions, high quartz content tends to increase wear life.

NONMANDATORY APPENDIX B
THICKNESS

The following information is only useful in calculating the thickness for rectangular plates when the plate is supported on three supports at $\frac{1}{5}L$ positions as shown in Fig. 6. Metric units are in meters and newtons (one kilogram = 9.8 N); U.S. Customary units are in inches and pounds.

$$t = \left[WL^2 f\left(\frac{L}{w}\right) / Ed \right]^{1/3}$$

where

d = total deflection, center below extreme corners, m (in.)

E = modulus of elasticity, N/m^2 ($lb/in.^2$)

L = length of plate, m (in.)

$f\left(\frac{L}{w}\right)$ = values derived by Research Institute of the University of Dayton dated 1965 as given in Table B-1

t = thickness of plate, m (in.)

W = concentrated load at center, N (lb)

w = width of plate, m (in.)

Recommended minimum thicknesses for rectangular granite plates for deflection equal to or slightly less than one-half of the flatness tolerance for three values of modulus of elasticity and for concentrated center loading of 240 kg/m^2 (50 lb/ft^2) and 480 kg/m^2 (100 lb/ft^2) of work surface area are tabulated in Tables B-2M, B-2, B-3M, and B-3.

There is no empirical equation available for calculating the thickness of circular granite surface plates. The present practice is to make the thickness the same as that of a square plate whose side is the same as the diameter of the circular plate.

EXAMPLE (Metric): A normally loaded Grade A surface plate 900 mm x 1 200 mm has an overall-flatness tolerance of 10 μm. From the values in Tables B-2M and B-3M, assuming $E = 38 \times 10^9$ N/m^2, the formula above gives

$$\begin{aligned} t^3 &= (273 \text{ kg} \times 9.8 \text{ N/kg} \times 1.2^2 \text{ m}^2 \times 0.13)/ \\ &\quad (38 \times 10^9 \text{ N/m}^2 \times {}^1/_2 \times 10 \times 10^{-6} \text{ m}) \\ &= (500.83 \text{ N m}^{2)}/(190 \times 10^3 \text{ N/m}) \\ &= 2.64 \times 10^{-3} \text{ m}^3 \end{aligned}$$

$$t = 138 \text{ mm}$$

Tables B-2M and B-3M show a value of 150 mm that is consistent with Note (2) below.

EXAMPLE (U.S. Customary): A normally loaded Grade A surface plate 36 in. × 48 in. has an overall-flatness tolerance of 400 μin. From the values in Tables B-2 and B-3, assuming $E = 5.5 \times 10^6$ psi, the formula above gives

$$\begin{aligned} t^3 &= (600 \text{ lb} \times 48^2 \text{ in.}^2 \times 0.13)/(5.5 \times 10^6 \text{ psi} \times {}^1/_2 \\ &\quad \times 400 \times 10^{-6} \text{ in.}) \\ &= (179{,}712 \text{ lb in.}^2)/1{,}100 \text{ lb/in.}) \\ &= 163.38 \text{ in.}^3 \end{aligned}$$

$$t = 5.5 \text{ in.}$$

Tables B-2 and B-3 show a value of 6 in. that is consistent with Note (2) below.

NOTES:

(1) Because granite materials have a range of values for the modulus of elasticity, Tables B-2M, B-2, B-3M, and B-3 show tabulated calculations for several representative values of E, covering the range of commonly used granites.

Column "a" is based on $E = 62 \times 10^9$ N/m^2 (9.0×10^6 psi)

Column "b" is based on $E = 38 \times 10^9$ N/m^2 (5.5×10^6 psi)

Column "c" is based on $E = 21 \times 10^9$ N/m^2 (3.0×10^6 psi)

(2) The minimum thickness recommendations in Tables B-2M, B-2, B-3M, and B-3 are consistent with present manufacturing practice. Therefore, some thicknesses are greater than the values calculated with the equation given in this Nonmandatory Appendix.

Table B-1 Values of $f\left(\frac{L}{w}\right)$ for Various Surface Plate Geometries

L/w	$f\left(\frac{L}{w}\right)$
1.0	0.12
1.5	0.14
2.0	0.18
2.5	0.22
3.0	0.26
4.0	0.34
6.0	0.55

Table B-2M Recommended Minimum Thickness for Normal Loading (240 kg/m^2 on Rectangular Granite Surface Plates on Three Supports)

Size				Total Load, *W*	Granite Thickness, mm [Note (1)]								
					Grade								
					AA			A			B		
Width, *w*	Length, *L*	Diagonal	Area, m^2	(kg)	a	b	c	a	b	c	a	b	c
250	250	295	0.063	15	50	50	50	50	50	50	50	50	50
300	300	425	0.090	22	50	50	75	50	50	50	50	50	50
300	400	500	0.120	29	50	75	75	50	50	75	50	50	50
300	450	541	0.135	33	75	75	100	75	75	75	50	50	50
400	400	565	0.160	39	50	75	75	50	75	75	50	50	50
400	630	746	0.252	61	100	100	125	75	75	100	75	75	100
630	630	890	0.397	97	100	100	125	75	75	100	75	75	75
630	1 000	1 182	0.630	154	130	150	200	100	125	150	75	100	150
800	1 200	1 342	0.720	176	150	180	230	125	150	180	100	125	150
1 000	1 000	1 414	1.000	244	130	150	200	100	125	175	75	100	150
1 000	1 500	1 803	1.500	366	175	225	275	150	175	200	125	150	175
1 000	2 000	2 236	2.000	488	125	125	150	100	100	125	75	75	100
1 500	2 000	2 500	3.000	732	125	125	150	100	100	125	75	75	100
1 500	3 000	3 354	4.500	1 098	330	380	455	255	305	355	205	230	280
1 500	3 500	3 808	5.250	1 231	350	400	500	275	320	400	225	250	325
1 500	4 000	4 272	6.000	1 464	400	450	550	300	350	450	250	300	350

GENERAL NOTE:
Column "a" is based on $E = 62 \times 10^9$ N/m^2
Column "b" is based on $E = 38 \times 10^9$ N/m^2
Column "c" is based on $E = 21 \times 10^9$ N/m^2
where E is Young's modulus of elasticity

NOTE:
(1) These minimum thickness recommendations are in line with present manufacturing practice. Therefore, some thicknesses are greater than the values calculated with the equation given in this Nonmandatory Appendix.

Table B-2 Recommended Minimum Thickness for Normal Loading
($50\ lb/ft^2$ on Rectangular Granite Surface Plates on Three Supports)

Size					Granite Thickness, in. [Note (1)]								
					Grade								
					AA			A			B		
Width, *w*	Length, *L*	Diagonal	Area, ft^2	Total Load, *W* (lb)	a	b	c	a	b	c	a	b	c
12	12	17.0	1	50	2	2	2	2	2	2	2	2	2
12	18	21.6	1.5	75	3	3	4	3	3	3	2	2	2
18	18	25.5	2.25	112	3	4	4	3	3	3	2	2	2
18	24	30.0	3	150	4	4	5	3	3	4	2	3	3
24	24	33.9	4	200	4	4	5	3	3	4	3	3	4
24	36	43.3	6	300	5	6	7	4	6	6	3	4	5
24	48	53.7	8	400	6	7	9	5	6	7	4	5	6
36	36	50.9	9	450	5	6	7	4	5	6	3	4	4
36	48	60.0	12	600	6	7	9	5	6	7	4	5	6
36	60	70.0	15	750	7	9	11	6	7	8	5	6	7
36	72	80.5	18	900	9	10	13	7	8	10	6	7	8
48	48	67.9	16	800	7	8	9	5	6	8	4	5	6
48	60	76.9	20	1,000	7	9	10	6	7	8	5	5	7
48	72	86.5	24	1,200	8	10	12	7	8	10	5	6	8
48	96	107.3	32	1,600	11	13	15	9	10	12	7	8	9
48	120	129.2	40	2,000	13	15	18	10	12	14	8	9	11
60	120	134.2	50	2,500	13	15	18	10	12	14	8	9	11
72	96	120.0	48	2,400	10	12	15	8	10	12	6	7	9
72	144	161.0	72	3,600	14	17	20	11	13	16	9	10	12

GENERAL NOTE:
Column "a" is based on $E = 9.0 \times 10^6$ psi
Column "b" is based on $E = 5.5 \times 10^6$ psi
Column "c" is based on $E = 3.0 \times 10^6$ psi
where *E* is Young's modulus of elasticity

NOTE:
(1) These minimum thickness recommendations are in line with present manufacturing practice. Therefore, some thicknesses are greater than the values calculated with the equation given in this Nonmandatory Appendix.

Table B-3M Recommended Minimum Thickness for Heavy Loading
(480 kg/m^2 on Rectangular Granite Surface Plates on Three Supports)

Size			Area, (m^2)	Total Load, *W* (kg)	Granite Thickness, mm [Note (1)]								
					Grade								
					AA			A			B		
Width, *w*	Length, *L*	Diagonal			a	b	c	a	b	c	a	b	c
250	250	295	0.063	30	75	75	75	75	75	75	75	75	75
300	300	425	0.090	44	75	75	100	75	75	75	75	75	75
300	400	500	0.120	58	75	100	100	75	75	100	75	75	75
300	450	541	0.135	66	100	100	125	100	100	100	75	75	75
400	400	565	0.160	78	75	100	100	75	100	100	75	75	75
400	630	746	0.252	122	125	125	150	100	100	125	100	100	125
630	630	890	0.397	194	125	125	150	100	100	125	100	100	100
630	1 000	1 182	0.630	308	175	200	250	125	150	225	125	150	200
800	1 200	1 342	0.720	352	200	225	300	150	200	225	125	150	200
1 000	1 000	1 414	1.000	488	175	200	250	125	150	225	100	125	200
1 000	1 500	1 803	1.500	732	225	275	350	200	225	250	150	200	225
1 000	2 000	2 236	2.000	976	150	150	200	125	125	150	100	100	125
1 500	2 000	2 500	3.000	1 464	150	150	200	125	125	150	100	100	125
1 500	3 000	3 354	4.500	2 196	415	475	575	320	385	450	260	290	350
1 500	3 500	3 808	5.250	2 462	440	510	625	350	400	500	285	315	410
1 500	4 000	4 272	6.000	2 928	500	565	700	375	440	565	315	375	440

GENERAL NOTE:
Column “a” is based on $E = 62.05 \times 10^9$ N/m^2
Column “b” is based on $E = 37.92 \times 10^9$ N/m^2
Column “c” is based on $E = 20.68 \times 10^9$ N/m^2
where E is Young’s modulus of elasticity

NOTE:
(1) These minimum thickness recommendations are in line with present manufacturing practice. Therefore, some thicknesses are greater than the values calculated with the equation given in this Nonmandatory Appendix.

Table B-3 Recommended Minimum Thickness for Heavy Loading
(100 lb/ft^2 on Rectangular Granite Surface Plates on Three Supports)

Size					Granite Thickness, in. [Note (1)]								
					Grade								
					AA			A			B		
Width, *w*	Length, *L*	Diagonal	Area, ft^2	Total Load, *W* (lb)	a	b	c	a	b	c	a	b	c
12	12	17.0	1	100	3	3	3	3	3	3	3	3	3
12	18	21.6	1.5	150	4	4	5	4	4	4	4	4	3
18	18	25.5	2.25	225	4	4	5	4	4	4	3	4	3
18	24	30.0	3	300	4	5	6	4	4	5	4	4	4
24	24	33.9	4	400	5	6	6	4	5	5	3	4	4
24	36	43.3	6	600	6	7	9	5	6	7	4	5	6
24	48	53.7	8	800	8	9	12	6	8	9	5	6	7
36	36	50.9	9	900	6	7	9	5	6	7	5	5	6
36	48	60.0	12	1,200	8	9	11	6	7	9	6	6	7
36	60	70.0	15	1,500	10	11	13	8	9	11	6	7	8
36	72	80.5	18	1,800	12	13	16	10	10	13	8	8	10
48	48	67.9	16	1,600	8	10	12	6	8	10	6	6	8
48	60	76.9	20	2,000	10	11	13	8	9	10	6	7	8
48	72	86.5	24	2,400	12	12	15	10	10	12	8	8	9
48	96	107.3	32	3,200	14	16	19	12	13	15	10	10	12
48	120	129.2	40	4,000	16	18	23	14	15	18	12	12	14
60	120	134.2	50	5,000	16	18	23	14	15	18	12	12	14
72	96	120.0	48	4,800	14	15	19	12	12	15	10	10	12
72	144	161.0	72	7,200	18	21	25	16	17	20	14	14	16

GENERAL NOTE:
Column "a" is based on $E = 9.0 \times 10^6$ psi
Column "b" is based on $E = 5.5 \times 10^6$ psi
Column "c" is based on $E = 3.0 \times 10^6$ psi
where E is Young's modulus of elasticity

NOTE:
(1) These minimum thickness recommendations are in line with present manufacturing practice. Therefore, some thicknesses are greater than the values calculated with the equation given in this Nonmandatory Appendix.

NONMANDATORY APPENDIX C
SUPPORTS

C-1 NONSTANDARD SUPPORTS

There are working and loading conditions where more than the standard three point supports are desirable. These cases should be individually engineered. The foundation should be engineered for minimum deflection under load since any movement will affect the surface of the surface plate. Even changes in the moisture content of a supporting concrete foundation may cause a change in the surface as the foundation shifts. When four or more supports are used, shims or adjusting screws are necessary to make all supports receive their share of the load. If a plate is used for a particularly heavy load, adjustable supports, which indicate the lift they are applying, may be considered. The supports could be spotted under the loading points and set to approximately equal the loading. Sometimes the work surface flatness can be improved by shifting support positions. Fulcrum, air, and hydraulic supports are available. Whenever nonstandard supports are used, the surface plate should be calibrated at the site for compliance to the flatness tolerance. When supports at their permanent location are not attached to the plate, a diagram should be supplied showing the proper location of supporting points for calibration purposes.

When using wedges and a torque wrench, the spacing of each support should be such that each one supports an equal volume of granite. Wedges should be placed under each support point. Before the granite is placed on the wedges, each wedge should be in a "down" or retracted position.

The next step is the most important: The tops of the wedges should be surveyed, so that the top of each antifriction plate is in the same level plane within 0.8 mm (0.031 in.). If shimming is required, put the shims between the bottom of the wedge and the foundation. This is necessary, as the wedges generally only have 6.4 mm (0.25 in.) total adjustment, and all possible adjustment should be conserved for leveling and final tolerance.

The next operation is to lower the granite plate on the wedges, keeping the projection on all four sides as per the layout print supplied by the manufacturer.

Precise leveling is not important. However, if checking involves checking the part with an optical level mounted on the floor, then the leveling must be more accurate.

The first step in leveling is accomplished with the four corner wedges only. It is very important to use a torque wrench for this operation and to have each of the four corner wedges to exactly the same torque at the point of level. This prevents any possibility of twist or strain in the plate that would interfere with final tolerance.

The next step is to bring the other wedges up to final torque. This should be done by moving from one to the other, raising each wedge only about 7 N·m (5 ft-lb) of torque at a time until all are equal.

C-2 RESILIENT SUPPORTS

Resilient supports may be used on surface plates. They are necessary where there is excessive vibration present in the area. The use of resilient supports (an isolation system) reduces the effects of vibrations in the floor. The percentage of the reduction will be a function of the vibration frequency and the natural frequency of the isolation system, i.e., the lower the natural frequency, the greater the isolation.

NONMANDATORY APPENDIX D
FACTORS DISTORTING THE WORK SURFACE

D-1 HOLES, SLOTS, AND INSERTS

Holes, slots, or inserts are not recommended on the work surface of grade AA surface plates because their use may cause the surface contour to change. They may be used on grades A and B plates with caution.

D-2 TORQUE ON THREADED INSERTS

Do not exceed the maximum torque values given in Table D-1. Use a torque wrench to limit distorting the work surface and pulling the insert.

D-3 CLAMPING LEDGES ON GRADE AA SURFACE PLATES

There is danger of distorting the work surface flatness beyond tolerance when a heavy item rests on the ledge or an item is clamped to the edge.

D-4 SPATIAL THERMAL GRADIENTS

Changes in thermal gradients between the top and bottom surfaces of a granite plate will cause changes in the work surface. If the temperature at the top of the granite plate is hotter, the work surface moves toward convex, and if it is colder, the work surface moves toward concave.

Table D-1 Permissible Torque on Threaded Inserts

Thread Size, mm	Torque, N·m
M6 × 1	10
M8 × 1	20
M10 × 1.25	27
M12 × 1.25	34
M16 × 1.50	41
Thread Size, in.	**Torque, ft-lb**
0.2500	7
0.3125	15
0.3750	20
0.5000	25
0.6250	30
0.7500	35

The values of the deformation (bow) are calculated from a simple model that assumes that the material properties are uniform through the plate and that the plate bends uniformly. The following equation is used:

$$\text{bow} = L^2 \alpha \Delta T / 8H$$

where

H = the thickness of the surface plate

L = the length of the diagonal of the working surface of the plate

ΔT = the temperature difference between the top and bottom of the plate

α = the coefficient of thermal expansion of the granite

In metric units [length units in millimeters and temperature units in degrees Celsius (°C)], the units of bow are in millimeters. In U.S. Customary units [length units in inches and temperature units in degrees Fahrenheit (°F)], the units of bow are in inches.

The value for the coefficient of thermal expansion of granites varies with the exact granite composition. Values from 4.7 to 8.0 × 10^{-6} mm/mm/°C (2.6 to 4.4 × 10^{-6} in./in./°F) are found. Users are recommended to contact the manufacturer of the particular surface plate to determine the particular value that applies to their own surface plate. The value of 6.3 × 10^{-6} mm/mm/°C (3.5 × 10^{-6} in./in./°F) is used in the following examples.

EXAMPLE (Metric): Grade A granite plate size 600 mm × 900 mm × 150 mm with temperature gradient of 1°C and with work surface at the higher temperature. Its diagonal is 1 082 mm. The work surface diagonal is 1 082 – (2 × 25) = 1 032 mm (see Table 3). Substituting these values into the equation gives

$$(1\,032 \text{ mm} \times 1\,032 \text{ mm}) \times 6.3 \times 10^{-6} \text{ mm/mm/°C} \times 1\text{°C})/(8 \times 150 \text{ mm}) = 0.0056 \text{ mm} = 5.6\ \mu\text{m}$$

EXAMPLE (U.S. Customary): Grade A granite plate size 2 ft × 3 ft × 6 in. with temperature gradient of 2°F and with work surface at the higher temperature. Its diagonal is 43.3 in. The work surface diagonal is 43.3 – (2 × 1.0) – 41.3 in. (see Table 3). Substituting these values into the equation gives

$$(41.3 \text{ in.} \times 41.3 \text{ in.}) \times 3.5 \times 10^{-6} \text{ in./in./°F} \times 2\text{°F})/(8 \times 6 \text{ in.}) = 0.000249 \text{ in.} = 249\ \mu\text{in.}$$

Temperature gradients can be caused by heat due to lighting; using cleaning agents that evaporate, chilling the surface; air currents (drafts) in the room, both hot or cold; radiant heat affecting one surface more than the others; stratification of temperature, particularly during the winter due to heated air rising and cool air sinking to the floor; and insufficient space between the bottom of the plate and its supporting table, which restricts air flow to the bottom of the plate, causing ambient temperature changes to affect the top more than the bottom.

D-5 TEMPERATURE SOAKING TIME

Before granite surface plates are used or calibrated, the granite should remain in the calibration area until it has reached room temperature. Large plates require more soak-out time than smaller ones. The following will help in estimating the soak-out time.

Soak-out time $= K[C_1/(1/L + 1/w + 1/H)]$ hr for rectangular plates

$K\,[C_2/(1/2H + 1/D)]$ hr for round plates

where

D = diameter of surface plate
H = height of surface plate
L = length of surface plate
w = width of surface plate

and K is a multiplier determined as follows:

C_1 = 16.2 if the plate dimensions are in feet and 53.1 if the plate dimensions are in meters
C_2 = 8.1 if the plate dimensions are in feet and 26.6 if the plate dimensions are in meters
$K = -\ln(RTO/\Delta T)$

given

RTO = Residual Temperature Offset or required closeness to final temperature
T_1 = temperature of granite before soak-out time
T_2 = temperature of granite at time of measurement
$\Delta T = T_2 - T_1$ = temperature change of environment

Calculate $RTO/\Delta T$, and then calculate K, or read it from the chart in Fig. D-1.

NOTE: As $RTO/\Delta T$ is a dimensionless ratio, temperature can be in either degrees Fahrenheit (°F) or degrees Celsius (°C).

EXAMPLE (Metric): Given a surface plate that is subjected to a change in environmental temperature of 10°C, how much time must elapse before inspection can proceed if the temperature of the plate is to be within 1°C of the final temperature?

The dimensions of the plate are 600 mm × 900 mm × 150 mm.

Solution:

H = 0.15 m
L = 0.6 m
RTO = 1°C
$RTO/\Delta T$ = 0.1
w = 0.9 m
ΔT = 10°C

From Fig. D-1, K = 2.3

Estimated soak-out time = 2.3 [53.1/(1/0.6 + 1/0.9 + 1/0.15)] = 12.9 h

EXAMPLE (U.S. Customary): Given a surface plate that is subjected to a change in environmental temperature of 50°F, how much time must elapse before inspection can proceed if the temperature of the plate is to be within 1°F of the final temperature?

The dimensions of the plate are 18 in. × 18 in. × 4 in.

Solution:

H = 13 ft
L = 32 ft
RTO = 1°F
$RTO/\Delta T$ = 0.02
w = 32 ft
ΔT = 50°F

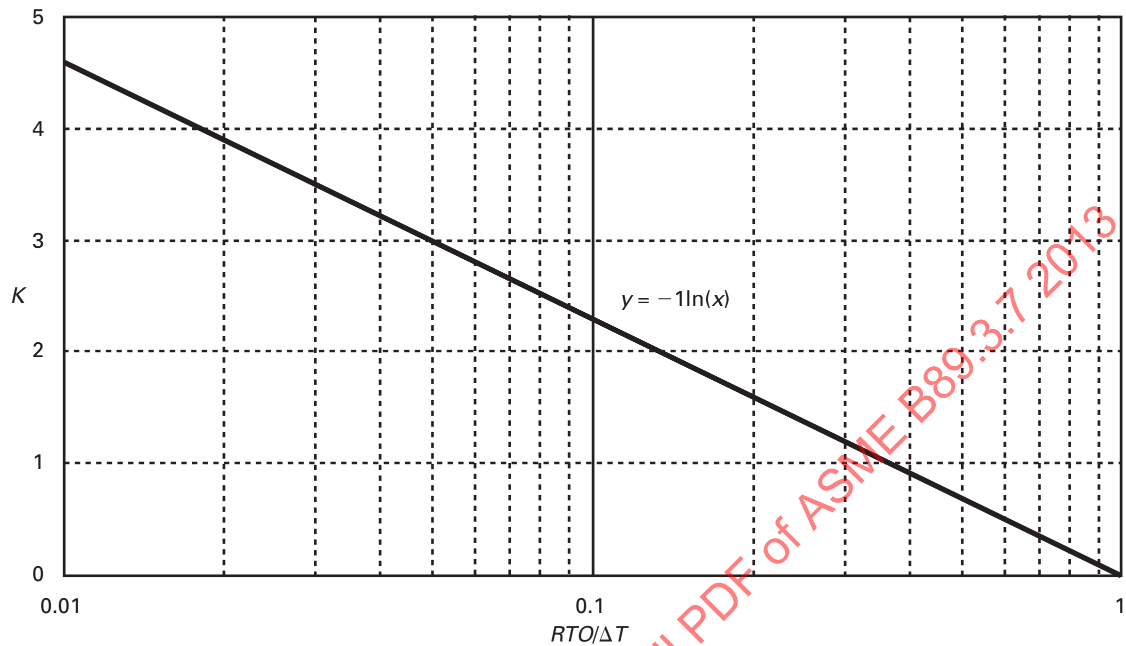
From Fig. D-1, K = 3.8

Estimated soak-out time = 3.8 [16.2/(2/3 + 2/3 + 3)] = 14.2 hr

D-6 SUPPORTS

Plates supported at more than three points or other than as specified by the manufacturer will cause distortion.

Fig. D-1 Residual Temperature Offset Over Temperature Change



NONMANDATORY APPENDIX E
CARE OF GRANITE SURFACE PLATES

E-1 CLEANING AND MOISTURE

Plates should be cleaned thoroughly and given adequate time to dry and stabilize before being used or calibrated. (This time can be included in the temperature soak-out time.) Water-based cleaners that have not dried out will make iron parts rust if left in contact on the surface overnight.

E-2 SCRATCHES AND NICKS

Whenever scratches and nicks appear on granite plates, the resulting burrs should be removed with a flat silicon carbide stone or a diamond impregnated cast iron block. Any bump that shatters the surface raises fractured material at the rim of the crater.

E-3 WEAR DISTRIBUTION

When a specific work area receives hard usage, it is suggested that the plate be rotated 180 deg on a periodic basis to increase wear life, or at least use different areas. The production of a contour map during calibration is particularly helpful in locating the parts of the plate that should be given most use.

E-4 PERIODIC RECALIBRATION

Periodic recalibration of granite surface plates is recommended to determine resurfacing or replacement needs. The interval between calibrations will vary with the grade of the plate, wear resistance, and conditions and frequency of use. Surface plates used in manufacturing departments might be recalibrated every 6 mo, whereas plates used in the laboratory may be recalibrated every year. Frequent monitoring of the work surface by scanning it with the repeat reading gage is desirable. When these results differ significantly from those recorded at the previous calibration, one should recalibrate the plate. For more information, ILAC-G24 or NCSLI RP-1 address methods for determining appropriate recalibration intervals.

E-5 DOWNGRADING, RESURFACING, OR REPLACEMENT LEVELS

At recalibration period, it is suggested that surface plates that deviate from the work surface flatness tolerance, which show repeat readings that exceed in-house requirements or which have objectionable scratches and nicks in the work area, shall be downgraded, resurfaced, or replaced.

E-6 REFERENCES

ILAC-G24:2007/OIML D 10:2007, Guidelines for the determination of calibration intervals of measuring instruments

Publisher: International Laboratory Accreditation Cooperation (ILAC), P.O. Box 7507, Silverwater, NSW 2128, Australia (www.ilac.org)

NCSLI RP-1 — 2010, Establishment and Adjustment of Calibration Intervals

Publisher: The National Conference of Standards Laboratories (NCSL International), 2995 Wilderness Place, Suite 107, Boulder, CO 80301 (www.ncsli.org)

NONMANDATORY APPENDIX F
GUIDANCE TO ESTIMATING UNCERTAINTY IN SURFACE PLATE MEASUREMENT

F-1 GENERAL

This Nonmandatory Appendix provides guidance for estimating measurement uncertainty by listing and discussing the factors that should be considered. Examples are provided for reference. The underlying assumptions for the example analyses should be carefully considered as these may not apply to individual circumstances. The acceptable analysis procedures are well documented and are assumed to be well known by the user of this Standard [1, 2].

F-2 REPEAT READING TEST

The result of this test is the range of indicator readings, or full indicator movement (FIM). The uncertainty budget for this parameter should consider the following:

(a) Measurement Resolution. The resolution may be determined by the specified least graduation of the meter or dial, any electrical noise if applicable, vibration, analog-to-digital conversion resolution if applicable, etc.

(b) Accuracy. The accuracy may be determined as the deviation compared with known standards of length within the measuring range used in the repeat reading test.

(c) Repeatability/Reproducibility. A well-designed and -executed study might of repeatability/reproducibility include the effects of resolution, as well as environmental factors and operator influences. As such, the results may encompass a large percentage of the measurement uncertainty for this test.

The uncertainty analysis for the repeat reading is therefore relatively simple as long as the measurand is clearly stated as the FIM value. If the results were stated as an estimate of flatness, then many other uncertainty terms would be necessary. This is not in the scope of this Nonmandatory Appendix.

EXAMPLE: A repeat reading gage is used to measure the FIM repeat reading parameter according to the test described in Mandatory Appendix I. The measurand for purposes of the uncertainty estimate is defined as the total range of surface deviations that a perfectly rigid and stable repeat reading gage having perfect accuracy and infinite resolution would measure along the lines specified for the test in the absence of any deflections, thermal effects, dirt, etc. The measurement procedure results in an estimate of this measurand, the FIM parameter, which is the difference between maximum and minimum readings from the actual gage. The uncertainty in this measurement may be estimated as follows.

F-2.1 Examples

F-2.1.1 Metric Units. The displacement transducer of the repeat reading gage is calibrated and certified to have a 5:1 accuracy ratio to the requirements of any grade A or less surface plate, i.e., 1.5 μm/5 = 0.3 μm.

A test for repeatability of the gage was conducted. Two nest positions were created on a Grade B 24-in. × 24-in. surface plate diagonally opposed and with maximum practical separation distance. The repeatability test consisted of the initial step of zeroing the displacement transducer at an arbitrary position near the center of the plate, and the following steps were repeated 25 times:

(a) sliding the gage into nest 1

(b) recording reading (1,i)

(c) sliding the gage into nest 2

(d) recording reading (2,i)

The operator was instructed to read the dial indicator by estimating to the closest 0.1 μm, which is one-fifth the 0.5-μm graduation of the gage dial. In normal use of the gage, the instructions require the operator to read to the nearest graduation. Therefore, in this analysis, the resolution is not considered to be included in the repeatability test results.

The resulting 50 readings were analyzed by statistical means with the result of a standard deviation for repeatability of 0.21 μm.

For a point reading, the standard uncertainty is estimated as the combination of resolution, accuracy, and repeatability.

Standard uncertainty due to resolution, $u(res)$, is estimated using Type B evaluation with the assumption of a uniform distribution with bounds equal to ±0.5 resolution.

$$u(res) = \frac{\frac{0.5\ \mu\text{m}}{2}}{\sqrt{3}} = 0.14\ \mu\text{m}$$

Standard uncertainty due to accuracy, $u(acc)$, is estimated using Type B evaluation with the assumption of a uniform distribution with bounds equal to the certified accuracy. To this is added in quadrature the standard uncertainty of the calibration.