ASME B89.1.13-2001

MICROMETERS

AN AMERICAN NATIONAL STANDARD

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FOREWORD

ASME Standards Committee B89 on Dimensional Metrology, under procedures approved by the American National Standards Institute, has the responsibility of preparing standards that encompass the inspection and the means of measuring characteristics of various geometrical parameters, such as diameter, length, flatness, parallelism, concentricity, taper, and squareness. Since micrometers are widely used for the measurement and comparison of some of these features, the B89 Consensus Committee authorized formation of Project Team B89.1.13 to prepare this Standard.

As most of the micrometers used in the United States are built to inch-system specifications, the International Organization for Standardization (ISO) standards do not address all the needs of American industry. The inch-system portion of this Standard is based in part on Federal Specification GGG-C-105C, published by the General Services Administration (GSA), as well as manufacturer's current practices and technologies. The metric-system portion of this Standard is consistent with ISO efforts in support of international commerce.

This Standard was approved by the American National Standards Institute on November 30, 2001.

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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.

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MICROMETERS

1 SCOPE

This Standard is intended to provide the essential requirements for micrometers as a basis for mutual understanding between manufacturers and consumers. Outside, inside, and depth micrometers are described in the Standard.

2 DEFINITIONS

backlash: a relative movement between interacting mechanical parts, resulting from looseness [ASME B5.54M-1992 (R1998)]. In this Standard, backlash is further defined as the rotation of the spindle, in the opposite direction of the initial reading, before spindle moves in a linear direction. This condition is typically caused by looseness of fit between the lead screw and adjusting nut.

bias: systematic error of the indication of a measuring instrument (VIM).

eccentricity: the distance between the geometric center or axis of the body and its axis of rotation.

end shake: the amount of spindle movement, when an axial force is applied in the direction of the spindle alternating towards the anvil and away from the anvil, without rotating the spindle.

error (of indication) of a measuring instrument: indication of a measuring instrument minus a true value of the corresponding quantity (VIM).

NOTE: This concept applies mainly where the instrument is compared to a reference standard.

flatness: the condition of a surface having all elements in one plane (ASME Y14.5M-1994).

maximum permissible error (MPE): extreme values of an error permitted by specifications, etc., for a given measuring instrument (VIM).

parallelism: the condition of a surface or center plane, equidistant at all points from a datum plane or axis, equidistant along its length from one or more datum planes or a datum axis (ASME Y14.5M-1994).

runout: a composite tolerance used to control the functional relationship of one or more features of a part to a datum axis. The types of features controlled by runout tolerances include those surfaces constructed around a datum axis and those constructed at right angles to a datum axis (ASME Y14.5M-1994).

side shake: the amount of spindle side movement, when a force is applied perpendicularly to the measuring end of the spindle, alternating from side to side, without rotating the spindle.

tolerance: the total amount the specified dimension is permitted to vary. The tolerance is the difference between the maximum and minimum limits (ASME Y14.5M-1994).

3 REFERENCES

This Standard has been coordinated insofar as possible with the following standards.

ASME B5.54M-1992 (R1998), Methods for Performance Evaluation of Computer Numerically Controlled Machine Centers

ASME Y14.5M-1994, Dimensioning and Tolerancing

Publisher: The American Society of Mechanical Engineers (ASME International), Three Park Avenue, New York, NY 10016

IEEE/ASTM SI 10-1997, Standard for Use of the International System of Units (SI): The Modern Metric System Revision and Redesignation of ANSI/IEEE Std 268-1992 and ASTM E 380

Publisher: Institute of Electrical and Electronics Engineers (IEEE), 445 Hoes Lane, Piscataway, NJ 08854

ISO 3611, Micrometers Calipers for External Measurements, 1978

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

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4 MICROMETERS, GENERAL

4.1 Materials

The materials used for the component parts of a micrometer shall meet the minimum requirements for hardness, stability, and strength.

4.2 Resolution

Micrometers using the inch system shall read to the least count of 0.001 in., 0.0001 in., or 0.00005 in. Micrometers using the metric system shall read to 0.01 mm, 0.002 mm, or 0.001 mm.

4.3 Finish

The surface of graduated parts shall have a satin chrome or dull, nonglare finish. All other exposed parts not utilized as measuring components shall be coated to prevent corrosion. Exposed surfaces of measuring components shall have a ground finish with surface roughness not to exceed 32 μin. (0.8 μm) Ra, except where otherwise specified within this document.

4.4 Identification Marking

In addition to other markings, instruments shall be marked in a permanent and legible manner with the manufacturer's name or trademark so that the part number, range of the instrument, and the source of the manufacturer can be readily determined.

4.5 Adjustments

Each instrument shall be adjustable to compensate for wear on the measuring faces and/or wear between the screw portion of the spindle and the nut.

4.6 Micrometers Screw Spindle

The screw spindle material shall be stabilized, precision-ground, and have a hardness not less than 62 on the Rockwell C Scale. The fit between the spindle and its bearings, including the nut, shall be free-turning without perceptible backlash, end shake, or side shake.

4.7 Measuring Faces

All measuring faces shall be hardened to not less than 62 on the Rockwell C Scale.

4.8 Graduations

The graduations shall have the depth reduced below the surface of the component carrying the graduations and shall be of contrasting color. Variations in width of the graduated lines on the thimble and fiducial line on the barrel shall not exceed 0.001 in. (0.025 mm).

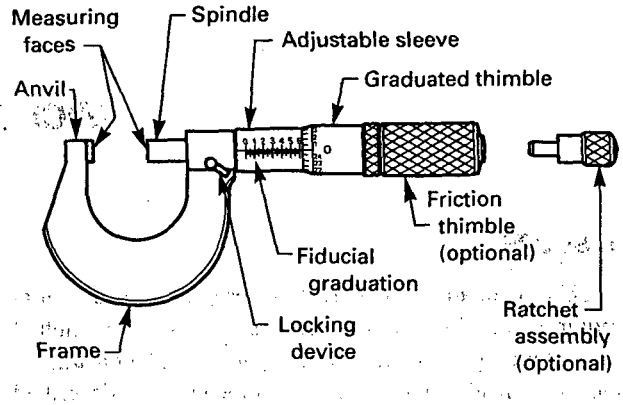


FIG. 1 TYPICAL OUTSIDE MICROMETER

5 OUTSIDE MICROMETERS (SEE FIG. 1)

5.1 Frame

The frame shall be shaped to permit the measurement of a cylinder having a diameter equal to the maximum capacity of the micrometer caliper. The cross section design and the frame material shall be such that when a force of 2 lb for inch-reading micrometers, or 10 N for metric-reading micrometers, is applied to the anvil end of the frame parallel to the spindle axis, the flexure of the frame shall not exceed the tolerances specified in Table 1 or 2.

5.2 Measuring Faces

For outside micrometers with flat measuring faces, the maximum flatness error allowable shall not exceed 40 μin. (1 μm) for each face. The maximum flatness error allowable for both faces shall not exceed the maximum parallelism error allowable for a given range as stated in Table 1 or 2. Surface finish shall not exceed 4 μin. (0.1 μm) Ra.

5.3 Maximum Permissible Error

With the micrometer set to read zero at minimum travel, the error of indication, parallelism of the spindle face to the anvil face, and misalignment between anvil and spindle shall not exceed the maximum values indicated in Table 1 or 2 at any point within the measuring range of the instrument.

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TABLE 1 MAXIMUM PERMISSIBLE ERRORS FOR OUTSIDE MICROMETERS (INCH SYSTEM)

Range, in.	Frame Flex Maximum (2 lb force), in.	Error of Indication (1), ± in.	Maximum Parallelism		Spindle-Anvil Alignment, in.
			Fixed Anvil, in.	Interchangeable Anvil, in.	
0–1	0.00010	0.00010	0.00005	0.00040	0.00200
1–2	0.00010	0.00020	0.00010	0.00040	0.00300
2–3	0.00010	0.00020	0.00020	0.00040	0.00450
3–4	0.00015	0.00020	0.00020	0.00040	0.00600
4–5	0.00015	0.00020	0.00020	0.00040	0.00800
5–6	0.00015	0.00020	0.00020	0.00040	0.01000
6–7	0.00020	0.00020	0.00020	0.00040	0.01000
7–9	0.00020	0.00020	0.00025	0.00060	0.01000
9–12	0.00030	0.00030	0.00030	0.00060	0.01000
12–18	0.00040	0.00040	0.00040	0.00080	0.01500
18–24	0.00050	0.00050	0.00050	0.00080	0.01500
24–30	0.00060	0.00060	0.00060	0.00100	0.01500
30–36	0.00070	0.00070	0.00070	0.00100	0.01500

NOTE:
(1) Independent of flatness and parallelism.

5.4 Setting Standards

The measuring surfaces of setting standards for outside micrometers shall have a hardness of not less than 60 on the Rockwell C Scale. The deviation in length from the nominal size shall not exceed the values listed in Table 3 or 4.

6 INSIDE MICROMETERS (SEE FIG. 2)

Inside micrometers may be either of fixed length or have interchangeable rods that carry the measuring faces. The measuring faces shall have a radius of curvature less than one-half of the smallest measuring range. Surface finish shall not exceed 8 μin. (0.2 μm) Ra.

6.1 Maximum Permissible Error

The maximum allowable error in the movement shall be 0.0001 in. within each inch of travel, or 0.0025 mm within each 25 mm of travel. With the screw set at the zero position, the maximum permissible error in overall length of the micrometer head shall be 0.0003 in. (0.0075 mm). When applicable, extensions, collars, or sleeves can be used to extend the range of measurement. An additional permissible error of 0.0002 in. (0.005 mm) will be allowed for each extension, collar, or sleeve, in overall length.

7 DEPTH MICROMETERS (SEE FIG. 3)

Depth micrometers shall consist of a micrometer head fixed into a base with a flat reference surface, and interchangeable rods to measure distance in relation to the flat reference surface.

7.1 Base

The reference surface of the base shall have a hardness of not less than 62 on the Rockwell C Scale, shall be flat within 0.0001 in. per inch of length (0.0025 mm per 25 mm of length), and shall have a finish not to exceed 8 μin. (0.2 μm) Ra.

7.2 Measuring Rods

The rods shall be interchangeable to measure in increments within the travel of the micrometer screw. Rods shall be provided with a means to compensate for wear. The rods shall be straight and the runout (double the eccentricity) when fully extended shall not exceed 0.003 in. per inch of extension or 0.075 mm per 25 mm of extension. Measuring faces of rods shall be flat within 0.0001 in. (0.0025 mm), and the surface finish shall not exceed 4 μin. (0.1 μm) Ra.

7.3 Maximum Permissible Error

The maximum permissible error of indication in the movement of the screw shall be 0.0001 in. within each

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TABLE 2 MAXIMUM PERMISSIBLE ERRORS FOR OUTSIDE MICROMETERS (METRIC SYSTEM)

Range, mm	Frame Flex Maximum (10 N), mm	Error of Indication (1), ± mm	Maximum Parallelism		Spindle-Anvil Alignment, mm
			Fixed Anvil, mm	Interchangeable Anvil, mm	
0–25	0.002	0.004	0.002	0.010	0.050
25–50	0.002	0.004	0.002	0.010	0.100
50–75	0.003	0.005	0.003	0.010	0.100
75–100	0.003	0.005	0.003	0.010	0.150
100–125	0.004	0.006	0.004	0.010	0.200
125–150	0.005	0.006	0.004	0.010	0.250
150–175	0.006	0.007	0.005	0.015	0.250
175–200	0.006	0.007	0.005	0.015	0.250
200–225	0.007	0.008	0.006	0.015	0.250
225–250	0.008	0.008	0.006	0.015	0.250
250–275	0.008	0.009	0.007	0.015	0.250
275–300	0.009	0.009	0.007	0.015	0.250
300–350	0.010	0.010	0.008	0.020	0.250
350–375	0.011	0.011	0.009	0.020	0.250
375–400	0.012	0.011	0.009	0.020	0.250
400–425	0.012	0.012	0.010	0.020	0.250
425–450	0.013	0.012	0.010	0.020	0.250
450–475	0.014	0.013	0.011	0.025	0.380
475–500	0.015	0.013	0.011	0.025	0.380
500–600	0.017	0.015	0.013	0.030	0.380
600–700	0.020	0.017	0.015	0.030	0.380
700–800	0.022	0.019	0.017	0.035	0.380
800–900	0.025	0.021	0.019	0.035	0.380

NOTE:
(1) Independent of flatness and parallelism.

inch of travel (0.0025 mm within each 25 mm of travel). With the head set to zero, the maximum permissible error of the rod and head together shall not exceed 0.0002 in. (0.005 mm).

8 SPECIALTY MICROMETERS

A large variety of specialty micrometers are commercially available for measuring tubing, threads, specialized measuring-face configurations for use in restricted areas, large diameter measuring faces, spherical shaped measuring faces, and conical measuring faces. These micrometers shall meet all the general requirements covered in paras. 4.1 through 4.8. They shall meet the maximum permissible error (MPE) requirements of Table 1 or 2 for interchangeable anvil micrometers when applicable.

TABLE 3 INCH-MEASURE SETTING STANDARDS

Size, in.	Maximum Permissible Error, ± in.
0–1	0.00005
2–4	0.00010
5–8	0.00015
9–11	0.00020
12–18	0.00025
19–24	0.00030
25–36	0.00035

9 MICROMETERS WITH DIGITAL READOUT

In addition to meeting all of the requirements applicable under this specification, the following shall apply to micrometers with digital readout.

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TABLE 4 METRIC-MEASURE SETTING STANDARDS

Size, mm	Maximum Permissible Error, ± mm
0–25	0.002
50–125	0.002
150–200	0.003
225–275	0.004
300–425	0.005
450–575	0.006
600–750	0.007
775–900	0.008

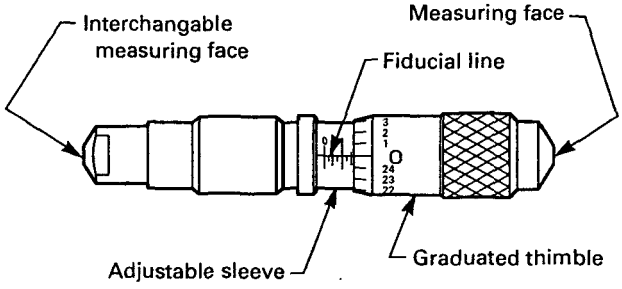


FIG. 2 TYPICAL INSIDE MICROMETER

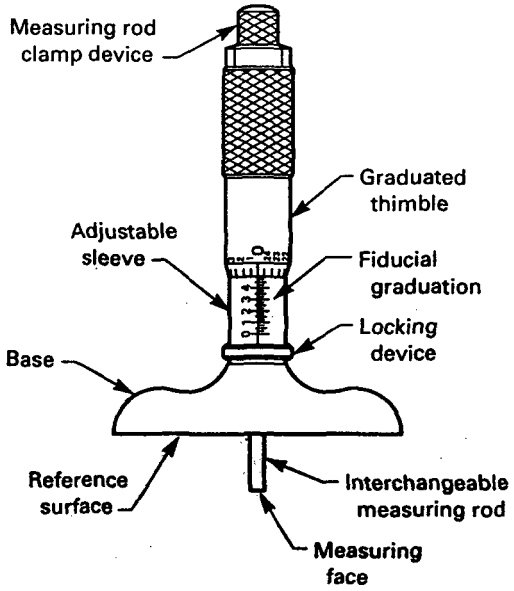


FIG. 3 TYPICAL DEPTH MICROMETER

9.1 Mechanical Digital (See Fig. 4)

The figures of the display shall have good contrast with the background, and the least-count digit shall agree with the analog reading within one digit of least count.

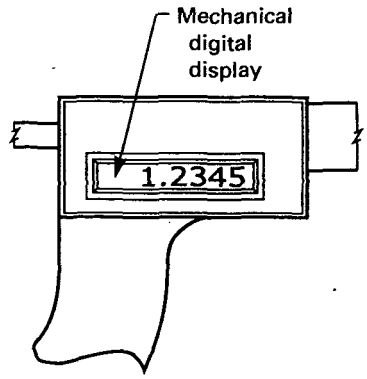


FIG. 4 MECHANICAL DIGITAL MICROMETER

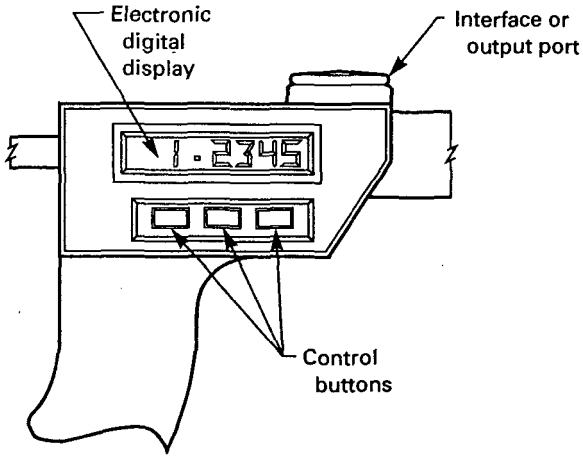


FIG. 5 ELECTRONIC DIGITAL MICROMETER

9.2 Electronic Digital (See Fig. 5)

The figures of the display shall have good contrast with the background, and the least-count digit shall agree with the analog reading within one digit, where applicable. The least count shall be correctly rounded, not simply a truncated digit. The electronics shall have the ability to retain the zero setting when in the off mode, and micrometers with greater capacity than 1 in. (25 mm) shall have preset capabilities so that a complete measurement (e.g., 5.1254) can be displayed and transmitted. If for any reason the microprocessor loses count (e.g., due to quick movement or a low battery condition), an error message shall appear on the display. Micrometers having the ability to transfer data shall have the output protocol designated by the manufacturer and described in sufficient detail to allow for interfacing with existing equipment.

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NONMANDATORY APPENDIX A
GOOD OPERATING PROCEDURE

A1 GENERAL

This Appendix is intended to provide general guidance on good operating procedures involving micrometers, specifically the outside, inside, and depth micrometers.

A2 MICROMETER, OUTSIDE

A2.1 Zero Setting, Mechanical Micrometer

Prior to taking measurements, the zero point of the micrometer must be established. Zero setting is the first step of operation with outside, inside, or depth micrometers. Clean the anvil and spindle measuring faces (1 in. or 25 mm range micrometers) by inserting lint-free paper between them and lightly closing the spindle, then slowly pulling the paper through. A lint-free cloth can be used to clean the spindle and anvil measuring faces on larger micrometers. Observe graduations and make sure the micrometer reads zero with clean measuring faces. If the micrometer does not read zero, adjust the sleeve accordingly.

A2.2 Zero Setting, Digital Micrometer

For a digital micrometer equipped with a zero-setting button, clean the faces, then close the micrometer using the friction or ratchet stop. Press the reset or zero button. If ABS (Absolute) or INC (Incremental) zero is featured, press ABS zero.

A2.3 Zero Setting, Large Micrometers

Micrometers larger than the 0–1 in. (0–25 mm) range models must be set to zero by using a setting standard or gage block. Use friction or ratchet stop whenever possible. When setting zero on micrometers larger than 12 in. (300 mm), the micrometer should be held in the position of its intended use (horizontal or vertical).

A2.4 Friction or Ratchet Stop

Friction or ratchet stops on micrometers provide a uniform force when making measurements. The accuracy and repeatability is generally better when using friction or ratchet stops.

A2.5 Micrometer Stand

While one-hand operation is a common practice, the use of the micrometer stand is recommended when more accurate measurements are required. It allows the operator to free both hands and generally lowers the uncertainty of the measurements.

A2.6 How to Read the Micrometer

A2.6.1 Micrometer, Outside, Inch, 0.001 in. Resolution. Graduations are engraved on the adjustable sleeve and graduated thimble of a micrometer. The adjustable sleeve is graduated in 40 equal parts with each line representing 0.025 in., which corresponds to one thread of the micrometer spindle. The numbers on the adjustable sleeve, 1, 2, and 3, represent 0.100 in., 0.200 in., and 0.300 in., respectively. The graduated thimble has 25 lines on its circumference, each line representing 0.001 in. The numbers on the graduated thimble, 1, 2, 3, and 5, represent 0.001 in., 0.002 in., 0.003 in., and 0.005 in., respectively.

A2.6.2 Micrometer, Outside, Metric, 0.01-mm Reading. Graduations are engraved on the adjustable sleeve and graduated thimble of a micrometer. The adjustable sleeve is graduated in 50 equal parts, with each line representing 0.5 mm, which corresponds to one thread of the micrometer spindle. The numbers on the adjustable sleeve, 5, 10, 15, represent 5 mm, 10 mm, and 15 mm, respectively. The graduated thimble has 50 lines on its circumference, with each line representing 0.01 mm. The numbers on the graduated thimble, 5, 10, 15, and 30, represent 0.05 mm, 0.10 mm, 0.15 mm, and 0.30 mm, respectively.

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A3 MICROMETER, INSIDE

A3.1 Measuring Holes

In using the inside micrometer to measure holes, one anvil should be kept stationary and the other anvil should be moved back and forth, and up and down, while the micrometer is being expanded until it no longer moves freely. It is good practice to take at least three readings to ensure that the diameter has been measured correctly.

A3.2 Measuring Large Pieces

When large objects are measured in the horizontal position using two-point contact, support the internal micrometer with vee blocks or other means of support to reduce bending. It is preferable to avoid using additional operators as this increases the transfer of heat from the operator to the gage.

A4 MICROMETER, DEPTH

A4.1 Hand Pressure

The important point to remember in using micrometer depth gages is that a comparatively light force applied to advance the thimble can raise the anvil away from the surface upon which it is resting, thereby creating an error in the reading. For this reason, the contact stem should be lowered very carefully with a light touch on the thimble, then withdrawn slightly and brought to bear on the component two or three times to make sure it has not overrun the proper reading.

A4.2 Proper Reading of Graduation

Most depth micrometers are equipped with reverse-reading shells. As the depth rod extends farther from the base reference surface, the reading will be larger. Care should be taken to not misread the graduation.

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NONMANDATORY APPENDIX B
ENVIRONMENTAL CONSIDERATIONS

B1 GENERAL

This Appendix is intended to provide general guidance and awareness regarding the environmental considerations involving the use of outside, inside, and depth micrometers.

B2 REFERENCE

ISO 1-1975, Standard Reference Temperature for Industrial Length Measurements

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

ASME B89.6.2-1973 (R1995), Temperature and Humidity Environment for Dimensional Measurement

Publisher: The American Society of Mechanical Engineers (ASME International), Three Park Avenue, New York, NY 10016

B3 TEMPERATURE

B3.1 Reference Temperature

Whenever precision measurements are made, the temperature should be kept as near to the reference temperature of 20°C (68°F) as possible. Since most standards and measuring instruments are usually made of steel, they have practically the same coefficient of expansion; therefore, the requirement that the temperature remain constant is more important than the actual temperature.

B3.2 Heat Transfer

The length of the standard or part being measured can change due to excessive handling. When making critical measurements, the operator should wear insulated gloves to avoid heating the standard or part.

B3.3 Working Temperature

When gages are used, especially in production shops, working temperatures are seldom at the reference temperature. If the gage is accurate at the reference temperature, and the coefficients of expansion of both the work part and gage are approximately the same, the effect of the deviation from 20°C (68°F) is less than if the parts were of different materials.

B3.4 Difference due to Dissimilar Materials

If parts made of aluminum or magnesium are checked by steel gages, an allowance for temperature differences, with reference to 20°C (68°F), must be made as the expansion coefficient of aluminum is approximately twice that of steel, while the coefficient of magnesium is even greater.

B3.5 Soak Time

Gages should be stored in a constant temperature room before they are inspected to ensure they are nearly the same temperature as the measurement laboratory. The amount of soak time required depends on the size of the gage and the desired accuracy.

B4 HUMIDITY

The relative humidity of the atmosphere in a gage laboratory should preferably be kept under 45% to minimize the possibility of corrosion. In general, the air conditioning system of a laboratory should remain in operation at all times. This is both because the change in humidity may cause corrosion and because there are delays while instruments and gages reach the proper temperature on the day when the laboratory is reopened.

B5 CLEANLINESS

Cleanliness is an important requirement for a good gage laboratory. Small particles of dirt may cause serious errors in precision measurements and bring about excessive wear of precision instruments.

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NONMANDATORY APPENDIX C
TEST METHODS

C1 GENERAL

This Appendix is intended to provide general guidance regarding test methods for outside, inside, and depth micrometers.

C2 MICROMETERS, OUTSIDE

C2.1 Visual Inspection

Examine the measuring surfaces of the micrometer for nicks and burrs, and check to ensure that the micrometer operates smoothly through its entire range of travel.

C2.2 Zero-Setting Check

After ensuring that the measuring faces are clean, zero the micrometer by bringing spindle and anvil together. Adjust to as near zero as possible.

C2.3 Flatness Check

Check the flatness of the measuring anvils with an optical flat and a monochromatic light source.

C2.4 Parallelism Check for Micrometers Less Than 1 in.

Check the parallelism of the measuring anvils with a pair of optical parallels and a monochromatic light source. The difference in thickness of the two parallels should be equal to one-half of the spindle revolution.

NOTE: For used gages it is acceptable to measure the combined effect of flatness and parallelism by measuring the diameter of two balls over different areas of the measuring faces. The difference in the ball diameters should be equal to one-half of the spindle revolution.

C2.5 Parallelism Check for Large Micrometers

Mount the micrometer vertically. Place the gagehead on the bottom anvil and adjust micrometer until entire anvil surface is level. Then place the gagehead on the upper anvil and measure the largest deviation.

C2.6 Micrometer Head Calibration

Check micrometer at different points around the screw. For example, a 1 in. micrometer can be checked using the following gage block stack sizes: 0.210 in., 0.420 in., 0.605 in., 0.815 in., and 1.000 in.; and a 25 mm micrometer can be checked using the following gage block sizes: 7.7 mm, 12.9 mm, 17.6 mm, 22.8 mm, and 25 mm. These sizes check the screw at approximately the 0 deg, 90 deg, 180 deg, and 270 deg positions.

C3 MICROMETERS, INSIDE

C3.1 Visual Inspection

Examine the measuring surfaces of the micrometer for nicks and burrs, and check to ensure that the micrometer operates smoothly through its entire range of travel.

C3.2 Micrometer Head Calibration

Check the micrometer head at several different places and positions around the micrometer spindle/screw. For example, a 1 in. micrometer can be checked using a measuring machine or gage blocks at these positions: 0.000 in., 0.210 in., 0.420 in., 0.605 in., 0.815 in., and 1.000 in. A 25 mm micrometer can be checked using a measuring machine or gage blocks at these positions: 0.0 mm, 7.7 mm, 12.9 mm, 17.6 mm, 22.8 mm, and 25 mm. These sizes check the screw at approximately the 0 deg, 90 deg, 180 deg, and 270 deg positions.

C3.3 Standard End-Measuring-Rod Calibration

Calibrate the end measuring rods on a standard measuring machine or a similar machine. Gage blocks can be used for rod length comparison.

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C4 MICROMETER, DEPTH

C4.1 Visual Inspection

Examine measuring surfaces of the micrometer for nicks and burrs, and check to ensure that the micrometer operates smoothly throughout its entire range of travel.

C4.2 Zero-Setting Check

Zero the micrometer by bringing both measuring faces in contact with a known flat surface (gage block face). Adjust to as near zero as possible. If the micrometer is accompanied by interchangeable rods, each rod must be inserted in the micrometer and a zero-setting check made.

C4.3 Base-Flatness Check

Set the micrometer on two gage block stacks of the same nominal dimension that are located at the outer edges of the base. These stacks should be within the range of the micrometer. Take a reading. Repeat by moving the gage block stacks to the center of the base and take a reading. Compare the readings. The difference in the readings is an indication of the base flatness.

C4.4 Micrometer Head Calibration

Check micrometer at different points around the screw. For example, a 1 in. micrometer can be checked using the following gage block stack sizes: 0.210 in., 0.420 in., 0.605 in., 0.815 in., and 1.000 in.; and a 25 mm micrometer can be checked using the following gage block sizes: 7.7 mm, 12.9 mm, 17.6 mm, 22.8 mm, and 25 mm. These sizes check the screw at approximately the 0 deg, 90 deg, 180 deg, and 270 deg positions.

C4.5 Depth Micrometer, Rod Calibration

Measure the straightness of the rods by rotating them in a vee block and measuring the runout. Rods longer than about 12 in. tend to sag; they can be measured by rotating them on a flat surface and measuring the amount of bending at the center of the rod.

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NONMANDATORY APPENDIX D
UNCERTAINTY FOR MICROMETER CALIBRATIONS

D1 INTRODUCTION

This Appendix is intended to provide general guidance and awareness regarding the determination and application of measurement uncertainty. The examples given are for guidance only. The actual uncertainties will be different for each laboratory.

D2 DEFINITIONS

error (of indication) of a measuring instrument: indication of a measuring instrument minus a true value of the corresponding quantity (VIM).

NOTE: This concept applies mainly where the instrument is compared to a reference standard.

measurement uncertainty: parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand (quantity being measured).

D3 REFERENCES

ISO, Guide to the Expression of Uncertainty in Measurement, International Organization for Standardization, Geneva, Switzerland, 1993

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

Taylor, Barry N. and Kuyatt, Chris E., Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994

Publisher: National Institute of Standards and Technology (NIST), Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402

D4 MICROMETER PARAMETERS

Specifications are given in the Standard for the surface finish, frame flexure, error of indication, parallelism of spindle faces, flatness of spindle faces, friction-thimble force, hardness, and misalignment of the spindles. A complete calibration would include all of these parameters. Except in rare cases, it is not practical, nor necessary, to measure all of the parameters in a calibration. In common practice, only the error of indication and the flatness and parallelism of the anvils are measured. The uncertainty budgets shown in this example are for the error of indication.

D5 SOURCES OF ERROR IN INSTRUMENT CALIBRATION

Common sources of error in mechanical calibrations include the uncertainty in the master, the repeatability, resolution, parallax errors, uncertainty in the temperature of the master, uncertainty in the temperature of the test item, uncertainty in the coefficient of thermal expansion, elastic deformation, cosine errors, Abbe offset, and others, depending on the type of instrument or material standards being measured. Not all of these sources contribute to the measurement uncertainty when calibrating a micrometer.

D6 SAMPLE UNCERTAINTY BUDGETS

Two sample uncertainty budgets are included, the first in metric units and the second in inch units. The dominant uncertainty source is different in the two examples.

An uncertainty budget for the measurement of the error of indication for a 0–25 mm metric micrometer is given in Table D1. The micrometer error of indication was measured using gage blocks in a temperature-controlled room maintained at 20°C ±2°C. The difference between the temperature of the micrometer and the gage blocks used in the calibration was estimated not to exceed 1°C.

D6.1 0–25 mm Vernier Micrometer

D6.1.1 Master Values. The calibrated values of the gage blocks used in the calibration were not known. It was only known that the blocks were within the tolerances for a grade 2 set. The blocks could deviate

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TABLE D1 UNCERTAINTY BUDGET FOR CALIBRATING 0–25 mm VERNIER MICROMETER

Uncertainty Source	Estimate	Type	Distribution	Divisor	Standard Uncertainty	Variance, u^2
Gage Blocks	0.14	B	Rect	1.73	0.08	0.01
Repeatability	0.45	A	Normal	1	0.45	0.20
Uncertainty of coefficient	0.08	B	Rect	1.73	0.05	0
Master/part temperature difference	0.29	B	Rect	1.73	0.17	0.03
Summation	...	...	...	...	...	0.24
Standard uncertainty, U_c	...	...	...	...	0.49	...
Expanded uncertainty, U	...	...	...	...	1.0	...

GENERAL NOTE: All values are in micrometers.

anywhere from 0 to ±0.14 μm from nominal, so a rectangular distribution is assumed.

D6.1.2 Repeatability. The repeatability of the instrument was determined by measuring a 0.75 in. gage block 30 times. The one standard deviation was 0.45 μm The standard deviation of the mean was $0.45/\sqrt{30}$, or 0.08 μm. In all subsequent measurements only one reading will be taken; therefore, the one standard deviation (0.45 μm) is used in the uncertainty budget. Once the measurement uncertainty for a process has been obtained, it can then be used for all measurements made under similar conditions.

D6.1.3 Uncertainty in Coefficient of Thermal Expansion. Because the coefficient of thermal expansion is not known any better than 10%, a component in the uncertainty budget is added for this effect. The coefficient of thermal expansion of steel was assumed to be 11.5×10^{-6}/°C. The difference in the coefficient of thermal expansion between the two materials could be as large as 1.6×10^{-6}/°C. The standard temperature for dimensional measurements is 20°C. The uncertainty in correcting the two gages to 20°C due to the uncertainty in knowing the coefficient of thermal expansion can be expressed by the equation:

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

where

L = the nominal length
T = the temperature
$\Delta\alpha$ = the uncertainty in the coefficient of thermal expansion

NOTE: The uncertainty due to the error in the thermometer of ±0.02°C is considered to be insignificant.

or

$$\Delta L = 0.025 \text{ m} \times 2°\text{C} \times 1.6 \times 10^{-6} = 0.08 \text{ μm}$$

D6.1.4 Uncertainty due to Master and Part Temperature Difference. It was determined that due to handling, the temperatures of the micrometer and the gage blocks could be as much as 1°C apart. The uncertainty caused by this temperature difference can be expressed as:

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

where

L = the nominal length
Δt = the difference in temperature between the blocks and the gage
α = the coefficient of thermal expansion

or

$$0.025 \text{ m} \times 1°\text{C} \times 11.5 \times 10^{-6}/°\text{C} = 0.29 \text{ μm}$$

D6.2 0–6 in. Digital Micrometer

An uncertainty budget for the measurement of the error of indication for a 0–6 in. micrometer is given in Table D2. The micrometer error of indication was measured using gage blocks in a temperature-controlled room maintained at 68°F ±2°F. The difference between the temperature of the micrometer and the gage blocks used in the calibration was estimated not to exceed 1°F.

D6.2.1 Master Values. The calibrated values of the gage blocks were used in the calibration process. The calibration report stated that the uncertainty for a 6 in. block was ±20 μin. at 95% confidence level (k = 2). The reported value is divided by 2 to get one standard deviation.

D6.2.2 Resolution. The resolution of the instrument is listed in Table D2. Because the repeatability was less than the resolution, the larger of the two is reported. For an instrument that rounds the last digit, the resolution is one half of the last digit. The micrometer used in this example read to the nearest 0.0005 in.

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TABLE D2 UNCERTAINTY BUDGET FOR CALIBRATING 0–6 in. DIGITAL MICROMETER

Uncertainty Source	Estimate	Type	Distribution	Divisor	Standard Uncertainty	Variance, u^2
Gage Blocks	20	B	Rect	2	10	100
Resolution	250	B	Rect	1.73	144	20,833
Uncertainty of coefficient	10.8	B	Rect	1.73	6	39
Master/part temperature difference	38	B	Rect	1.73	22	481
Summation	...	...	...	...	...	21,453
Standard uncertainty, U_c	...	...	...	...	146	...
Expanded uncertainty, U	...	...	...	...	292	...

GENERAL NOTE: All values are in microinches.

D6.2.3 Uncertainty in Coefficient of Thermal Expansion. Because the coefficient of thermal expansion is not known any better than 10%, a component in the uncertainty budget is added for this effect. The coefficient of thermal expansion of steel was assumed to be 6.4×10^{-6}/°F. The difference in the coefficient of thermal expansion between the two materials could be as large as 0.9×10^{-6}/°F. The standard temperature for dimensional measurements is 20°C (68°F). The uncertainty in correcting the two gages to 68°F due to the uncertainty in knowing the coefficient of thermal expansion can be expressed by the equation:

$$\Delta L = L(68 - T)\Delta\alpha$$

where

L = the nominal length
T = the temperature
$\Delta\alpha$ = the uncertainty in the coefficient of thermal expansion

or

$$\Delta L = 6 \text{ in.} \times 2°\text{F} \times 0.9 \times 10^{-6}/°\text{F} = 10.8 \ \mu\text{in.}$$

D6.2.4 Uncertainty due to Master and Part Temperature Difference. It was determined that due to handling, the micrometer and the gage blocks could be as much as 1°F apart. The uncertainty caused by this temperature difference can be expressed as:

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

where

L = the nominal length
Δt = the difference in temperature between the blocks and the gage
α = the coefficient of thermal expansion

or

$$6 \text{ in.} \times 1°\text{F} \times 6.4 \times 10^{-6}/°\text{F} = 38 \ \mu\text{in.}$$

NOTE: The uncertainty due to the error in the thermometer of ±0.05°F is insignificant.

D7 CONCLUSION

In both examples the standard uncertainty u_c is calculated by taking the square root of the sum of the squares of the individual standard uncertainties. The standard uncertainty u_c is then multiplied by a coverage factor k (usually 2) to get approximately a 95% confidence level.

The format for an uncertainty budget does not need to be as shown in these examples. It is only necessary to list the sources of uncertainty and the standard uncertainty, and explain how they were obtained. The table can contain two columns or as many as are needed.

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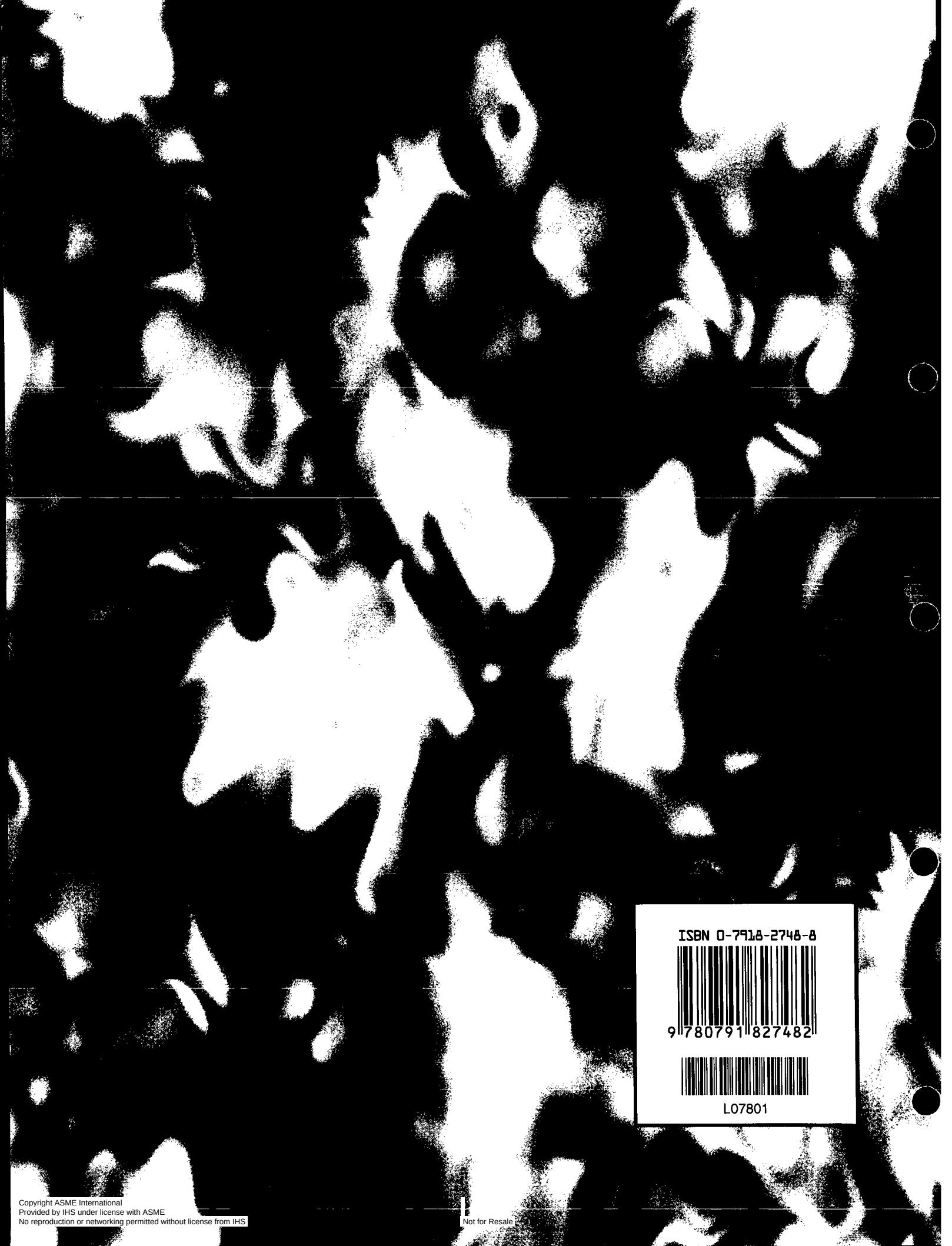
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