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Guidelines for the Evaluation of Uncertainty of Test Values Associated With the Verification of Dimensional Measuring Instruments to Their Performance Specifications

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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FOREWORD

JCGM 100:2008, "Evaluation of measurement data — Guide to the expression of uncertainty in measurement," known as GUM, contains the internationally accepted method of expressing measurement uncertainty. The United States has adopted GUM as a national standard. The evaluation of measurement uncertainty has been applied for some time at national measurement institutes, but more recently, issues such as measurement traceability and laboratory accreditation are resulting in its widespread use in calibration laboratories.

Given the potential impact to business practices, national and international standards committees are working to publish new standards that will facilitate the integration of the GUM approach and the consideration of measurement uncertainty. In support of this effort, the ASME B89 Committee for Dimensional Metrology has formed Division 7, Measurement Uncertainty.

Measurement uncertainty has important economic consequences for calibration and measurement activities. In calibration reports, the magnitude of the uncertainty is often taken as an indication of the quality of the laboratory, and smaller uncertainty values generally are of higher value and higher cost. ASME B89.7.1, Guidelines for Addressing Measurement Uncertainty in the Development and Application of ASME B89 Documents, provides recommendations associated with measurement uncertainty for use in the development of ASME B89 documents and in the application of the existing ASME B89.7 series of uncertainty-related documents. ASME B89.7.2, Dimensional Measurement Planning, gives a high-level outline of what to consider when making measurements and provides examples of how measurement uncertainty is addressed for workpiece acceptance decisions. ASME B89.7.3.1, Guidelines to Decision Rules in Determining Conformance to Specifications, addresses the role of measurement uncertainty when accepting or rejecting products based on a measurement result and a product specification and provides the language to communicate what decision rule is used. ASME B89.7.3.2, Guidelines for the Evaluation of Dimensional Measurement Uncertainty, provides a simplified approach (relative to GUM) to the evaluation of dimensional measurement uncertainty associated with measurement results on workpieces. ASME B89.7.3.3, Guidelines for Assessing the Reliability of Dimensional Measurement Uncertainty Statements, examines how to resolve disagreements concerning the magnitude of the measurement uncertainty statement. ASME B89.7.4.1, Measurement Uncertainty and Conformance Testing: Risk Analysis, provides guidance on evaluating the risks involved in any product acceptance/rejection decision. Finally, ASME B89.7.5, Metrological Traceability of Dimensional Measurement to the SI Unit of Length, provides one specific definition of metrological traceability and several examples demonstrating the concept.

This Standard provides guidance for the specific case of evaluating the uncertainty of test values associated with testing dimensional measuring instruments to their ASME B89 performance specifications.

ASME B89.7.6 was approved by the American National Standards Institute (ANSI) on October 31, 2019.

Acknowledgment. This work was initiated and chaired by the late Dr. Steven D. Phillips. The ASME B89 Committee recognizes his inspiring zeal, his tireless commitment, and his inestimable contribution to this Committee and to the dimensional metrology community at large.

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

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If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the B89 Standards Committee at the above address. The request for an 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 in one or two words.
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. Please provide a condensed and precise question, composed in such a way that a “yes” or “no” reply is acceptable.
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Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. 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.

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Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

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PREFACE

The primary purpose of this Standard is to provide guidance for assessing the uncertainty of test values associated with the verification of dimensional instruments to their ASME B89 performance specifications. This guidance is fully consistent with the GUM methodology and philosophy. The particular case of verifying dimensional instruments is frequently misunderstood by practitioners. This confusion arises primarily because the measurand of the verification is the instrument's measurement error when measuring the calibrated reference quantity specified in the testing protocol. The test values produced during ASME B89 testing are estimates of these measurement errors. Hence, in verification testing, the performance of the instrument is the quantity being measured. The instrument is verified as complying with its ASME B89 performance specification if the test values are within the instrument's maximum permissible error (MPE) and satisfy the decision rule stated in the testing protocol. To ensure that this verification is metrologically traceable, the uncertainty in the test values must be evaluated, i.e., the practitioner must determine how well each test value estimates the measurement error made by the instrument under verification when it is used to measure the reference quantity specified by the testing protocol. By distinguishing the instrument under verification from the measurement system performing the verification, the evaluation of the uncertainty of the test values is shown to follow the GUM procedure. ASME B89.7.6 provides both detailed discussions and worked examples to clarify this issue and should prove valuable to both novice and experienced metrologists.

Guidelines for the Evaluation of Uncertainty of Test Values Associated With the Verification of Dimensional Measuring Instruments to Their Performance Specifications

1 SCOPE

This Standard provides guidelines for evaluating the uncertainty of test values obtained when verifying dimensional measuring instruments[1] to an ASME B89 testing protocol. The scope is limited to the case in which the test measurand is the error of indication at a rated operating condition; hence, test measurands such as the "worst possible" error of indication that might occur at any operating condition (including those conditions that are not tested) are outside the scope of this Standard.

ASME B89 testing protocols are composed of many individual tests, each test yielding one test value that is an estimate of the instrument's measurement error at the particular operating condition tested, and this test value is compared against the maximum permissible error (MPE) (specified for that rated operating condition) using the protocol's decision rule. Although the MPE is specified by the instrument manufacturer for all rated operating conditions, the test value uncertainty is associated only with the test value obtained at the particular operating condition prevailing at the moment the test value was obtained (unless a correction to the indication is performed that is allowed by the test protocol).

Because each test investigates the error of indication at a particular rated operating condition, the test value uncertainty does not include the robustness or comprehensiveness of the testing protocol, i.e., it does not address the number of tests or their distribution over different rated operating conditions. This issue is addressed by the standardization committee creating the testing protocol; the committee balances the number of tests against the amount of time and effort to complete the testing protocol.

The scope of this Standard excludes issues associated with the evaluation of the uncertainty of future measurement results on workpieces and focuses solely on the test value uncertainties used to verify the instrument's performance specification. Typically, the test value uncertainty is much smaller than the associated MPE value of the verification test.

2 DEFINITIONS

The following definitions are specific to this Standard:

instrument: the measuring system that is under verification to its performance specification.

NOTE: In this Standard, the term "instrument" is equivalent to "instrument under verification."

verification system: the measuring system that is used to verify an instrument to its performance specification.

NOTE: In this Standard, the verification system includes everything necessary to execute the testing protocol. This includes the calibrated reference quantity, equipment used in the transfer process, the human operator (if one is involved), computations and any other analysis needed, environmental and other conditions required by the instrument under verification, and any input quantities required to realize the measurand of the verification test.

3 REFERENCES

The following is a list of publications referenced in this Standard:

ASME B89.1.13-2013, Micrometers
ASME B89.1.14-2018, Calipers
ASME B89.4.10360.2-2008, Acceptance Test and Reverification Test for Coordinate Measuring Machines (CMMs) — Part 2: CMMs Used for Measuring Linear Dimensions (Technical Report)

[1] In this Standard, the term "instrument" is exclusively used to refer to the device under verification to its performance specification; hence the term "instrument" always means "instrument under the verification test." In contrast, the measuring system providing the calibrated reference value used in the verification test is referred to as a "verification system."