ASME B89.7.2-2014

[Revision of ASME B89.7.2-1999 (R2004)]

Dimensional Measurement Planning

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

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FOREWORD

The intent of this Standard is to facilitate agreement between suppliers and customers by specifying a standard method for assessing the dimensional acceptability of workpieces. Components of the method are the preparation of an adequate dimensional measurement plan and the use of the plan in making measurements. Major inputs to the method are dimensional specifications developed, for example, in compliance with ASME Y14.5-2009, Dimensioning and Tolerancing [1].

The first publication of ASME Y14.5 was a significant step forward in manufacturing because it defined methods for the unambiguous expression of design intent on workpiece drawings. ASME Y14.5 specifies design intent in terms of workpiece features (e.g., cylinders, planes, spheres, etc.). A feature is dimensioned and toleranced by specifying boundaries within which the infinite number of points on the feature surface must lie (for surface geometries) or by specifying a boundary within which the axes must lie (axes control). Any adequate assessment of whether a manufactured feature complies with an ASME Y14.5 drawing specification must consider this infinite number of points.

In the early days of ASME Y14.5, serious attempts to determine compliance of workpiece features with drawing specifications were based on gaging by attributes, e.g., by means of ring gages, plug gages, and functional gages. Such gages dealt with the infinite number of points by means of gaging surfaces, which were intended as the ideal counterparts of the surfaces to be measured. Uncertainty due to gage imperfections was minimized by specifying gages whose probable errors were tightly controlled when compared with the tolerances of the workpieces to be measured. Gage dimensions were biased to ensure that no nonconforming workpieces were accepted, even though such biasing resulted in the rejection of some conforming workpieces.

In 1994, a supporting standard was released that explicitly defined the mathematical expression of ASME Y14.5, which was ASME Y14.5.1M-1994, Mathematical Definition of Dimensioning and Tolerancing Principles [7]. This Standard presents a mathematical definition of geometrical dimensioning and tolerancing consistent with the principles and practices of ASME Y14.5M-1994, enabling determination of actual values.

Since the capability of a typical manufacturing process has improved more rapidly than the measurement capability associated with gaging by attributes, the old methods have led to expensive increases in the rejection of conforming workpieces. Statistical analysis capabilities and cost effectiveness have led to the proliferation of coordinate-measuring machines (CMMs) that cannot directly verify dimensional acceptability using an infinite number of points in a workpiece feature surface but account for this in the associated measurement uncertainty statement. In some instances, the algorithms used to associate substitute geometrical elements according to drawing specifications result in significant measurement uncertainty. ASME Working Group B89.3.2 (now B89.7.2) was formed to address these and related issues.

One of these issues is the criterion for acceptable dimensional measurement practice. A measurement process should be designed to balance measurement quality and cost, including costs associated with decision outcomes resulting in rejecting conforming products or accepting nonconforming products due to the measurement uncertainty. While the analysis of costs is workpiece-specific and outside the scope of this dimensional measurement Standard, the measurement process should be designed to provide the required metrological data for the risk analysis needed to formulate a decision rule.

Measurement quality is characterized in terms of measurement uncertainty. Previous practice has been to assume that gage quality was controlled to a level where the contribution to measurement uncertainty due to gaging error was negligible. This assumption was applied both to measurement by attributes, as described above, and to measurement by variables using simple bench tools such as micrometers and height gages. Gage repeatability and reproducibility (GR&R) studies provide useful information relating to uncertainty but they cannot, in themselves, completely determine measurement uncertainty values.

The Guide to the Expression of Uncertainty in Measurement (GUM) [2] and the equivalent U.S. standard, ANSI/NCSL Z540.2-1997 [4], are considered to be the authoritative documents on the evaluation of measurement uncertainty. A recent supplement to the GUM, JCGM 101:2008 [5], describes the use of Monte Carlo methods for uncertainty evaluation.

The ASME B89.7 Subcommittee has developed a series of standards and technical reports pertaining to the evaluation of measurement uncertainty, decision rules and conformity assessment, and metrological traceability considerations. These documents include

- B89.7.3.1, Guidelines for Decision Rules: Considering Measurement Uncertainty in Determining Conformance to Specifications
- B89.7.3.2, Guidelines for the Evaluation of Dimensional Measurement Uncertainty

- B89.7.3.3, Guidelines for Assessing the Reliability of Dimensional Measurement Uncertainty Statements
- B89.7.4.1, Measurement Uncertainty and Conformance Testing: Risk Analysis
- B89.7.5, Metrological Traceability of Dimensional Measurements to the SI Unit of Length

The ASME B89.7.2 Standard makes use of the methods of the foregoing documents for the evaluation of measurement uncertainty, formulation of decision rules, calculation of the risks of mistaken decisions, and, when desired, demonstration of metrological traceability to the SI unit of length, the meter.

In considering its assignment, the ASME B89.7.2 Working Group determined that a single "cookbook" standard covering all valid methods for measuring all possible workpiece features for all possible purposes under all possible conditions would be impractical. Among the problems are the difficulty of writing and maintaining such an extensive document, lack of documentation for some types of measurements, and rapidly changing technology.

The approach of the current Standard is to identify the principles applicable to all dimensional measurements, and to cite detailed standards for specific classes of measurements as they become available. Two strategies are used. The first is to ensure the validity of dimensional measurements by specifying requirements for preparation, approval, and use of dimensional measurement plans. The second is to provide appendices that discuss methods and resources for developing such plans.

The ASME B89.7.2 Standard considers that a measurement method is acceptable if it results in an acceptable measurement uncertainty. Thus, for example, a gage producing a limited point data set (e.g., a CMM) may be used to determine compliance with ASME Y14.5 if the uncertainty component due to the limited data can be reasonably evaluated and if the resultant combined standard uncertainty is acceptable according to the decision rule and the target uncertainty. The decision rule and target uncertainty is determined by management and is an appropriate balance between measurement quality and cost. For example, if a manufacturing process produces few nonconforming workpieces, and the impact of an out-of-tolerance workpiece is low, then a low-accuracy measurement method may be adequate. For workpieces where an out-of-tolerance condition could cause serious injury and the cost of rejecting a conforming workpiece is high, the measurement requirement might be stringent and the acceptable measurement uncertainty small. Such considerations may be embodied in contracts or company policies.

The body of this Standard delineates requirements and recommendations for dimensional measurement planning. Actions required for compliance with the Standard are identified by use of the word "shall." Compliance with other identified actions is strongly recommended to ensure quality in measurement. The appendices provide examples of how to develop a plan, how to select gaging, and how to evaluate various components of measurement uncertainty. Means are presented for determining the probabilities of decision outcomes in workpiece acceptance or rejection. Such probabilities are useful in evaluating plan acceptability. A reference section is also included. The Standard provides the user with means for meeting the requirements of ANSI/ASQC E2, Guide to Inspection Planning [6].

It is anticipated that future work of the ASME B89.7.2 Working Group will be in the area of updating and revising this second edition of the Standard in response to further study, public comments, and other standards developments.

The first edition of this Standard was approved by the American National Standards Institute (ANSI) on October 26, 1999. This 2014 edition of ASME B89.7.2 was approved by ANSI as an American National Standard on July 17, 2014.

ASME B89 COMMITTEE
Dimensional Metrology

CORRESPONDENCE WITH THE B89 COMMITTEE

General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a Case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, B89 Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
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.

When appropriate, proposals should be submitted using the B89 Project Initiation Request Form.

Proposing a Case. Cases may be issued for the purpose of providing alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee Web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the B89 Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the B89 Standards Committee at go.asme.org/Inquiry.

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.
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.

Attending Committee Meetings. The B89 Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the B89 Standards Committee. Future Committee meeting dates and locations can be found on the Committee Page at go.asme.org/B89committee.

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DIMENSIONAL MEASUREMENT PLANNING

1 SCOPE

1.1 Objective

The objective of this Standard is to ensure correctness and acceptability of dimensional measurements.

1.2 Requirements

This Standard specifies requirements for preparation and approval of dimensional measurement plans and for the use of approved plans in making dimensional measurements.

1.3 Applicability

This Standard considers that a dimensional measurement method is acceptable if its associated measurement uncertainty per the Guide to the Expression of Uncertainty in Measurement (GUM) [2] meets business needs, e.g., cost of measurements, consequences of pass and fail errors, liability, specific policies, and customer requirements. In assessing the acceptability of a stated measuring procedure, management should take into account the importance and difficulty of evaluating measurement uncertainty in such a way as to quantitatively capture the effects of all significant sources of measurement error.

1.4 Purpose

This Standard is intended for use by process and quality engineers or personnel performing a similar function in planning dimensional measurements.

2 DEFINITIONS

accept-reject measurement: measurement made for the purpose of accepting or rejecting a workpiece or workpiece feature or property.

attribute gage: gage that verifies conformance of a workpiece property with a specified requirement without yielding a measured value.

conforming: having a true value lying within or on the boundary of a stated tolerance interval.

NOTE: The issue of conformance/nonconformance involves where the true value of the measurand lies with respect to the tolerance zone; the issue of acceptance/rejection involves where a measured value lies with respect to the acceptance zone.

consumer's risk: probability of a pass error.

dimensional measurement: measurement of a geometrical property of a workpiece.

dimensional measurement plan: plan detailing equipment, environment, and procedure for measuring one or more geometrical properties of a workpiece or for measuring the properties of a process.

dimensional measurement planner (DMP): person who prepares a dimensional measurement plan.

fail error: rejection, as a result of measurement uncertainty, of a conforming property of a process or a workpiece.

NOTE: A fail error is also known as false rejection or a Type 1 error.

failure mode and effects analysis (FMEA): for a system, the steps of listing failure modes and determining effects of failure on the system in each mode.

feature: general term applied to physical portion of a workpiece, such as a surface, hole, or slot.

gaging limits: specified limits of a measured value of a workpiece property.

NOTE: Gaging limits are also known as acceptance limits.

geometric characteristic: dimensional description of a feature.

manufacturing plan: plan detailing organization, equipment, environment, personnel, and procedures for manufacturing a workpiece.

measurand: quantity intended to be measured.

nonconforming: having the true value lying outside the boundaries of a stated tolerance interval.