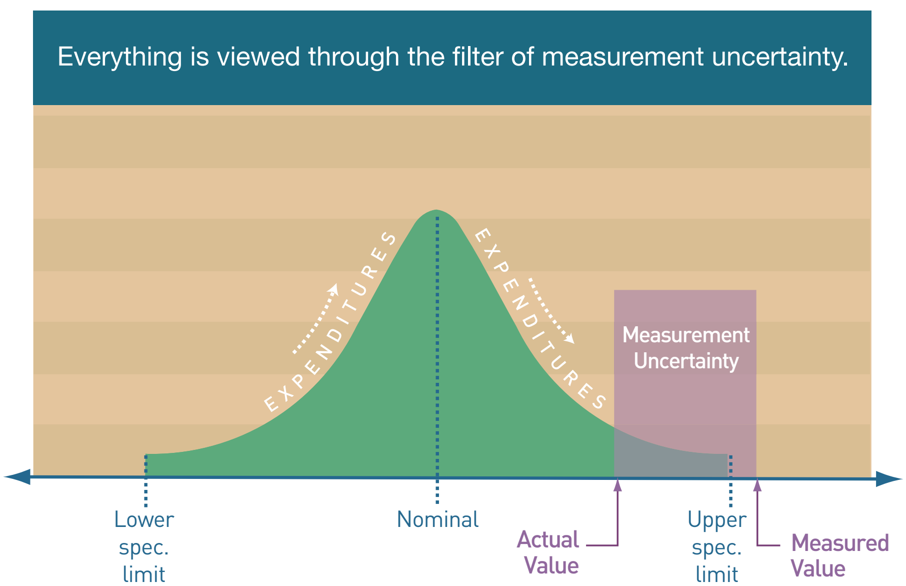
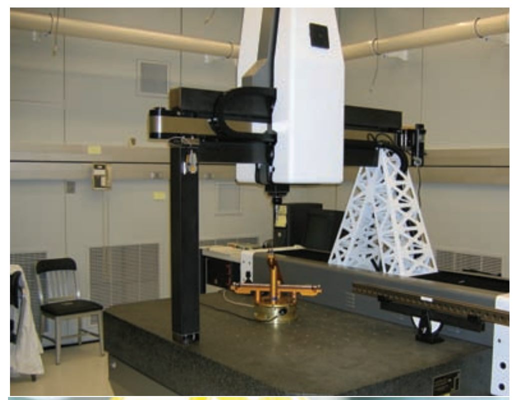
ASME B89.7
Measurement Uncertainty

Understanding and Economic Benefits





Standards and Guidelines

What is Measurement Uncertainty?

You've undertaken a measurement for a product design that has been manufactured, assembled and inspected by your supply chain.

- But what if your particular measurement might be "off" from what you would consider to be acceptable?
- How do you assess your likelihood of being "off"?
- How do you determine what is the acceptable range for being "off"?
- And how do you express this likelihood and range in quantitative terms – so that all parties in your supply chain can agree?

Clearly, the implications of such measurements are enormously significant throughout the manufacturing, assembling and inspection process, especially in such "big ticket" industries as medical, aerospace, automotive, disc-drive and energy. The potential impact on costs could range into millions of dollars. So it benefits all engineers greatly to be accurate in how they undertake, evaluate and communicate their measurements.

Image at lower right courtesy of "Productive Metrology, Adding Value to Manufacture," by H. Kunzmann, T. Pfeifer, R. Schmitt, H. Schwenke, A. Weckenmann, published in the CIRP Annual vol. 54-2, 2005.

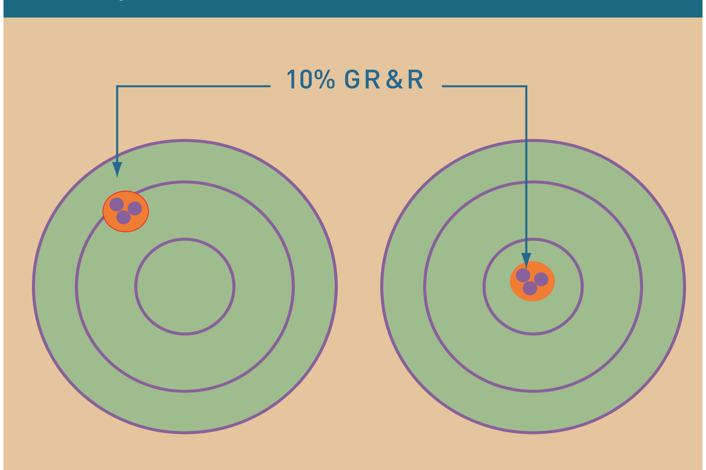
Measurement uncertainty is the quantitative evaluation of the reasonable values that are associated with a measurement result. It is a probabilistic expression of the doubt in a particular measurement value.

Whether addressing the performance tests of instruments or the calibrations of artifacts, ASME B89.7 documents provide the framework for assessing the measurement processes and quantifying the validity of the results of measurement results. Results of measurements are the numerical values produced by a measurement process.

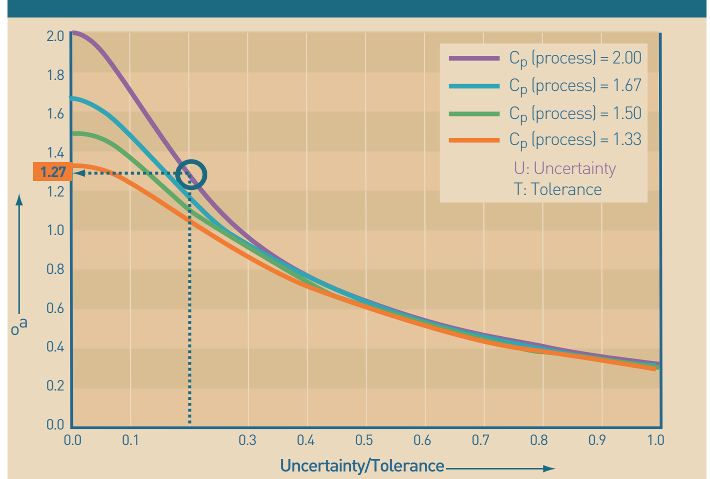
Measurement uncertainty is a number that characterizes the distribution of values that could reasonably be attributed to the realization of the measurand, or particular quantity subject to measurement. As such, measurement uncertainty is an indicator of the quality and reliability of measurement results and can be used as an effective tool to improve measurement processes.

The ASME B89 Division 7 *committee was established with the intent of developing standards in the field of measurement uncertainty and to remain abreast of the latest developments in the field. It also provides guidance to other B89 divisions. It is noteworthy that documents created under the auspices of B89 Division 7 are significantly broader in scope than traditional B89 performance-testing standards as they include all ramifications of and variations in the measuring process. It is also important to state the B89.7 Series of documents use Type A and Type B evaluations and are 100% GUM (Guide to the Expression of Uncertainty in Measurement) compliant.*

Measured results must be repeatable and reproducible but by itself can be both a technical and financial risk.



Influence of measurement uncertainty on process parameters,



What Practitioners Say About Measurement Uncertainty

The main goal for [measurement] uncertainty is to make sure the measurements taken by a certain system (gage, CMM or the like) are appropriate for the application. ***The cost of having poor measurements is multiplied as the nonconforming components move through the processes towards final assembly and on to a customer.***

—Paulo H. Pereira, Ph.D., ASQ-CQE
Global Quality
Production Center of Excellence
Caterpillar Inc.

Companies can save money with measurement uncertainty by being in a position to make better technical and business decisions.

Companies using gage repeatability and reproducibility (GR&R) as their basis for measurement systems analysis would be at high-risk. This limited method of analysis is not capable of capturing the full magnitude of measurement error and biases induced by many influencing factors. ***Measured results must be repeatable and reproducible, but by itself can be both a technical and financial risk. It is easy to have measured results that are repeatably and reproducibly incorrect,*** as uncorrected biases are easily induced that can be many times larger than the GR&R numbers initially recognized by the metrologist.

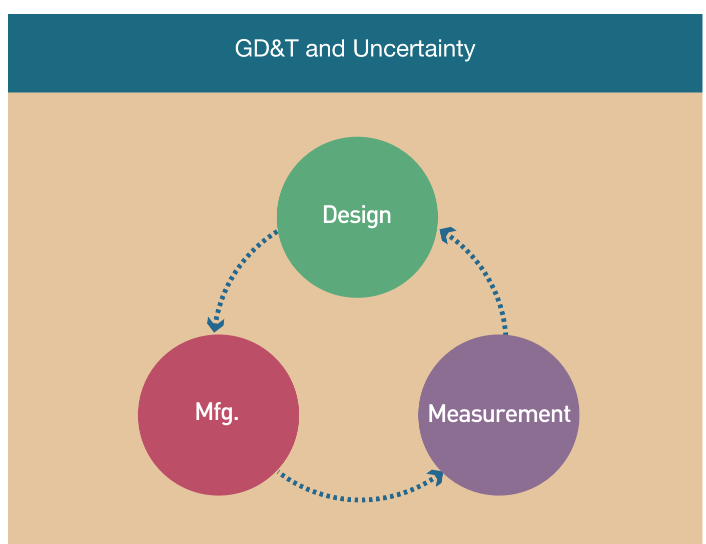
Customers and suppliers already know when this is occurring, as one of the two following situations happens: Measurement data can look good -- it complies with specification requirements, but the parts do not work or properly fit. Or measurement data can look bad -- it does not comply with specification requirements, but the parts actually do work.

—Greg Hetland, Ph.D.
Founder
International Institute of Geometric Dimensioning & Tolerancing (IIGDT)

Measurement uncertainty describes the accuracy of a measurement result; it is the quantitative evaluation of the reasonable values that are associated with a particular measurement. Whether addressing the performance test results of instruments, or the calibrations of gauges, standard methods for assessing the measurement uncertainty and quantifying the validity of the results can be used as an effective tool to improve measurement processes.

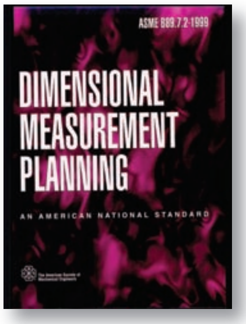
Consensus standards like those provided in the ASME B89.7 documents provide a means to achieve GUM-compliant uncertainty statements and a recognized method of establishing measurement traceability. As a result, use ***of such standards reduces ambiguity about the consequences of measurement uncertainty and allows users to benefit from the established work of expert analysis; thus avoiding potential pitfalls and reducing costs.***

—Steven D. Phillips, Ph.D.
Leader, Physicist
Large-Scale Coordinate Metrology Group
NIST – National Institute of Standards and Technology



Measurement Uncertainty Standards

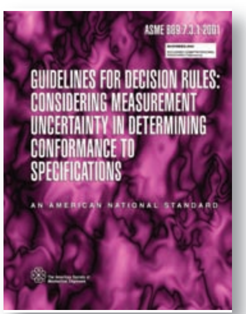
ASME B89.7 Documents



B89.7.2 – 1999

Dimensional Measurement Planning

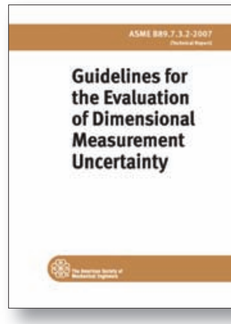
The intent of this Standard is to facilitate agreement between suppliers and customers by specifying a standard method for assessing the dimensional acceptability of workpieces. Components of the method are the preparation of an adequate dimensional measurement plan and the use of the plan in making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



B89.7.3.1 – 2001

Guidelines for Decision Rules: Considering Measurement Uncertainty, Determining Conformance to Specifications

These guidelines provide suggestions for decision rules when considering measurement uncertainty in determining conformance to specification. Applying these guidelines can assist businesses in avoiding disagreements with customers and suppliers about conformance to specifications and in managing costs associated with conformance decisions.



B89.7.3.2 – 2007

Guidelines for the Evaluation of Dimensional Measurement Uncertainty (An ASME Technical Report)

The primary purpose of this Technical Report is to provide introductory guidelines for assessing dimensional measurement uncertainty in a manner that is less complex than presented in the Guide to the Expression of Uncertainty in Measurement (GUM). These guidelines are fully consistent with the GUM methodology and philosophy. The technical simplifications include not assigning degrees of freedom to uncertainty sources, assuming uncorrelated uncertainty sources, and avoiding partial differentiation by always working with input quantities having units of the measurand. A detailed discussion is presented on measurement uncertainty concepts that should prove valuable to both the novice and experienced metrologist. Worked examples, with an emphasis on thermal issues, are provided.

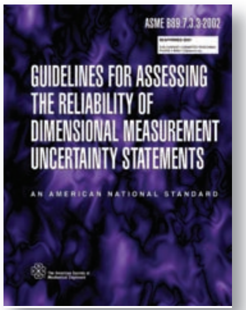
For Information:

ASME Standards & Certification
Three Park Avenue
New York, NY 10016-5990 U.S.A.

Fredric Constantino

Phone: +1.212.591.8684
Fax: +1.212.591.8501
Email: constantinof @ asme.org
Website: go.asme.org/B89.7

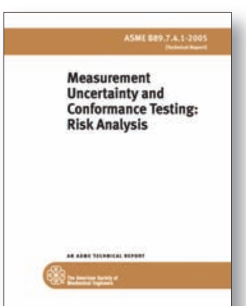
Measurement Uncertainty Standards



B89.7.3.3 – 2002

Guidelines for Assessing the Reliability of Dimensional Measurement Uncertainty Statements

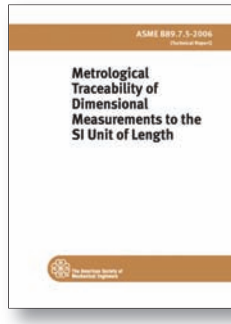
The primary purpose of this Technical Report is to provide guidelines for assessing the reliability of measurement uncertainty statements. Applying these guidelines can assist businesses in avoiding disagreements about measurement uncertainty statements and in resolving such disagreements should they occur. Disagreements over uncertainty statements involving a single measurement system and multiple measurement systems (each having their own uncertainty statement) are considered. Guidance is provided for examining uncertainty budgets as the primary method of assessing their reliability. Additionally, resolution by direct measurement of the measurand is also discussed.



B89.7.4.1 – 2005

Measurement Uncertainty and Conformance Testing: Risk Analysis (An ASME Technical Report)

This Technical Report provides guidelines for setting gauging (or test) limits in support of accept/reject decisions in workpiece inspections, instrument verifications, and general conformance tests where uncertain numerical test results are compared with specified requirements. In accepting or rejecting workpieces or instruments based on the results of inspection measurements, the presence of unavoidable measurement uncertainty introduces the risk of making erroneous decisions. By implementing a decision rule that defines a range of acceptable measurement results, one can balance the risks of rejecting conforming workpieces or instruments and accepting nonconforming ones.

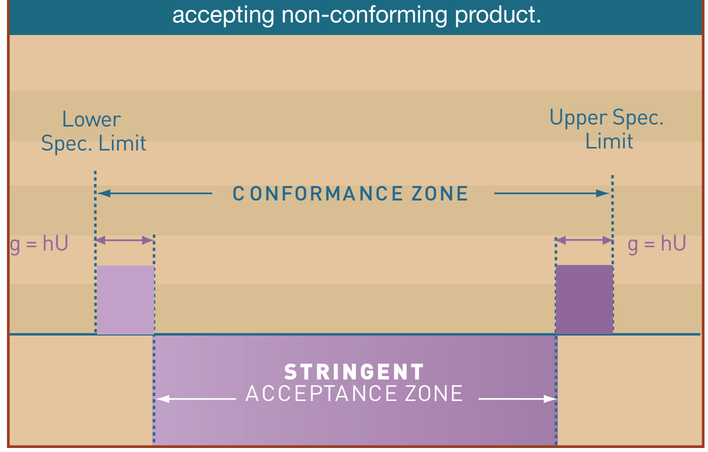


B89.7.5 – 2006

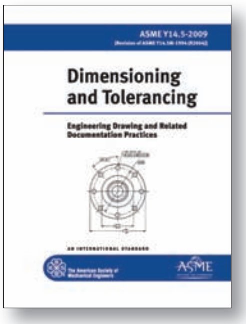
Metrological Traceability of Dimensional Measurements to the SI Unit of Length (An ASME Technical Report)

The primary purpose of this Technical Report is to provide introductory guidelines for assessing dimensional measurement uncertainty in a manner that is less complex than presented in the Guide to the Expression of Uncertainty in Measurement (GUM). These guidelines are fully consistent with the GUM methodology and philosophy. The technical simplifications include not assigning degrees of freedom to uncertainty sources, assuming uncorrelated uncertainty sources, and avoiding partial differentiation by always working with input quantities having units of the measurand. A detailed discussion is presented on measurement uncertainty concepts that should prove valuable to both the novice and experienced metrologist. Worked examples, with an emphasis on thermal issues, are provided.

B89.7.3.1 – DECISION RULES. Conformance zone must be guard banded by magnitude of measurement uncertainty to establish acceptance zone. Guard banding reduces risk of accepting non-conforming product.



ASME Related Documents

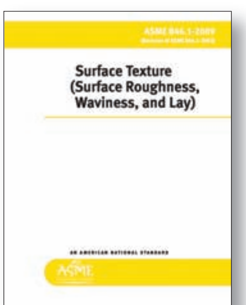


Y14.5 – 2009

Geometric Dimensioning and Tolerancing

The Y14.5 standard is considered the authoritative guideline for the design language of geometric dimensioning nd tolerancing (GD&T.) It establishes uniform practices for stating and interpreting GD&T and related requirements for use on engineering drawings and in related documents. GD&T is an essential tool for communicating design intent — that parts from technical drawings have the desired form, fit, function and interchangeability. By providing uniformity in drawing specifications and interpretation, GD&T reduces guesswork throughout the manufacturing process — improving quality, lowering costs, and shortening deliveries.

ASME also offers 12 related standards on GD&T, including: ***Y14.41 – 2003: Digital Product Definition Data Practices.*** For more offerings and info, visit: **go.asme.org/gdt.**

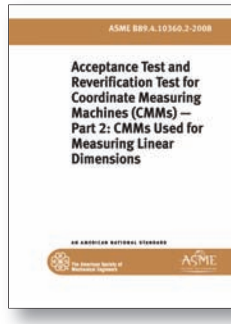


B46.1 – 2009

Surface Texture, Surface Roughness, Waviness and Lay

This Standard is concerned with the geometric irregularities of surfaces. It defines surface texture and its constituents: roughness, waviness, and lay. It also defines parameters for specifying surface texture. The terms and ratings in this Standard relate to surfaces produced by such means as abrading, casting, coating, cutting, etching, plastic deformation, sintering, wear, erosion, etc.

Look for a new 2010 ASME B46.1 edition, which will include an executive summary presenting the essential issues in measuring surface roughness. The 2010 edition will contain many additions and clarifications over the current edition, and provides in one volume an overall guide to surface roughness measurement including instrument descriptions, filtering requirement, parameter selection, and harmonization with the new ISO 3-D texture parameters. To order, visit: **go.asme.org/B46catalog.**



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)

This Technical Report establishes requirements and methods for specifying and testing the performance of coordinate measuring machines (CMMs) having three linear axes perpendicular to each other and up to one rotary axis positioned arbitrarily with respect to these linear axes. In addition to clarifying the performance evaluation of CMMs, this Technical Report seeks to facilitate performance comparisons among machines by unifying terminology, general machine classification, and the treatment of environmental effects.

This is a redesignation and update of B89.4.1-1997. It was created to harmonize the B89.4.1 standard with ISO 10360.2 by incorporating the entire 10360.2 document into it and adding additional requirements that can be found in text boxes throughout the technical report.

About ASME Codes and Standards

ASME is the leading international developer of codes and standards associated with the art, science, and practice of mechanical engineering. Starting with the first issuance of its legendary Boiler & Pressure Vessel Code in 1911, ASME's codes and standards have grown to nearly 600 offerings currently in print. These offerings cover a breadth of topics, including pressure technology, nuclear plants, elevators/escalators, construction, engineering design, standardization, and performance testing.

Developing and revising ASME codes and standards occurs year-round. More than 4,000 dedicated volunteers—engineers, scientists, government officials, and others, but not necessarily members of the Society—contribute their technical expertise to protect public safety, while reflecting best practices of industry. The results of their efforts are being used in over 100 nations; thus setting the standard for code-development worldwide.

Standards Development Process

In developing all its codes and standards, ASME employs a consensus-based process that considers the input of all relevant stakeholders. Due process for all input is assured and monitored. All codes-and-standards development is open to public review at appropriate stages, and the actions of the committee are documented and completely transparent. ASME's development process is accredited by The American National Standards Institute (ANSI), while its principles are consistent with those of the World Trade Organization's Technical Barriers to Trade Agreement.

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ASME Codes and Standards enjoys ongoing volunteer contributions from hundreds of leading companies, consultants, academics and government officials. Contributors range from department heads and the top technical experts in their fields all the way to young engineers in their early-career stages. This mix helps assure that the resulting standards are truly visionary, while also being practical and applicable for everyday end-users.

For more information on volunteering, visit:
go.asme.org/B89.7

About ASME

ASME helps the global engineering community develop solutions to real world challenges facing all people and our planet. Founded in 1880 as the American Society of Mechanical Engineers, ASME has grown to serve 120,000 professional members in 138 countries. We actively enable inspired collaboration, knowledge sharing and skill development across all engineering disciplines, all around the world, while promoting the vital role of the engineer in society.

ASME products and services include our renowned codes and standards, certification and accreditation programs, professional publications, technical conferences, risk-management tools, government/regulatory advisory, continuing education and professional development programs. These efforts, guided by ASME leadership, and powered by our volunteer networks and staff, help make the world a safer and better place, today, and for future generations.

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Three Park Avenue
New York, NY
10016-5990 U.S.A.

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