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KEY CONCEPTS IN THE U.S. MICROMETER STANDARD, ASME B89.1.13-2013

A TECHNICAL PAPER FROM THE LEADING MANUFACTURER OF METROLOGY INSTRUMENTS

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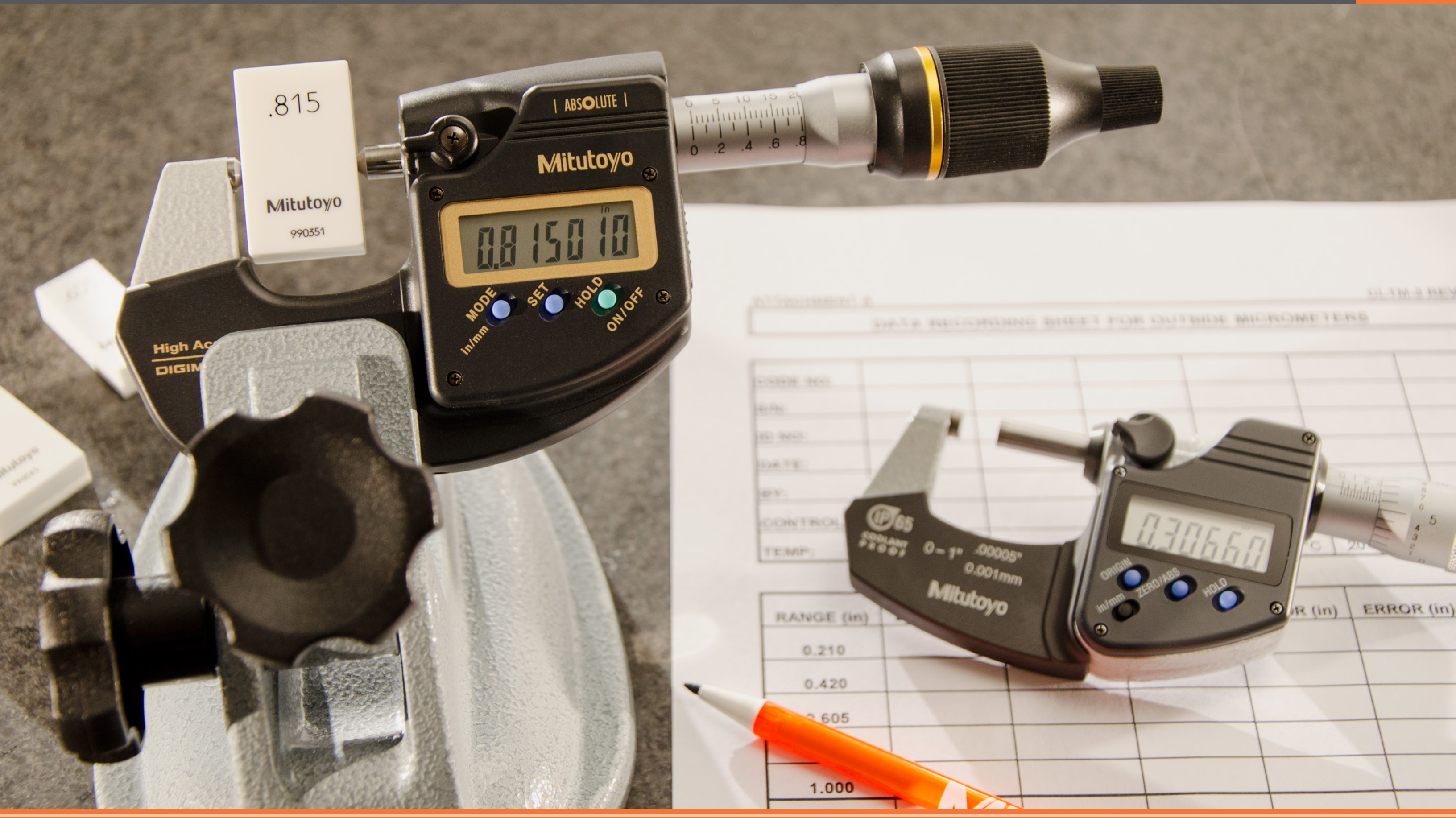

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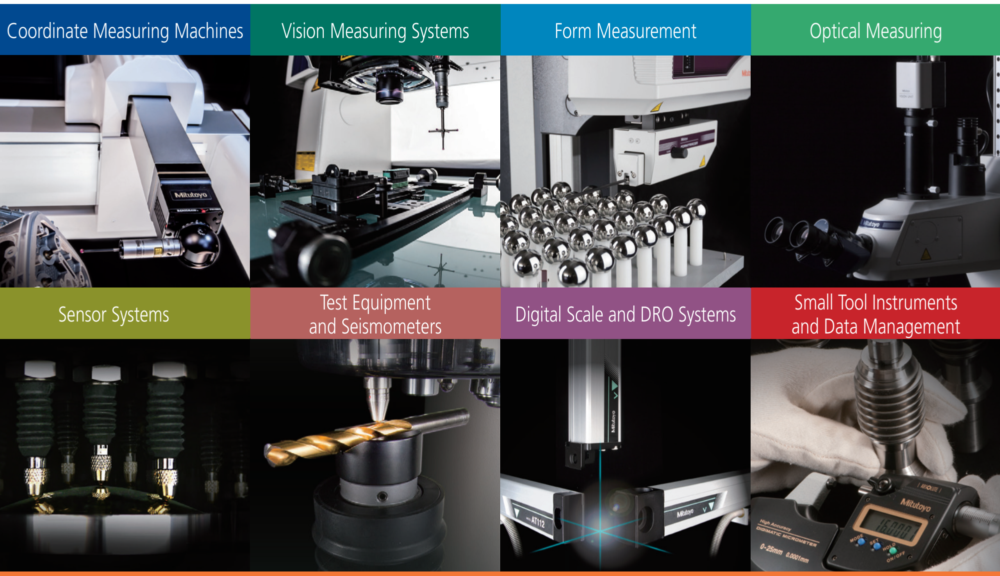
About this Presentation

In the United States, the important American national standards in dimensional metrology are the ASME B89 series of standards developed under the auspices of the American Society of Mechanical Engineers (www.asme.org). This paper discusses the revision to the American standard for micrometers, ASME B89.1.13, which was published in 2013. This standard includes many modern and novel calibration concepts that are important to understand. These concepts, while directly impacting the calibration of micrometers, also need to be understood by the larger metrology community. This paper was initially presented at the 2013 NCSL International Workshop and Symposium (www.ncsli.org).



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Important Broad-Based Metrology Concepts in the Revised U.S. Micrometer Standard

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Abstract

A revision to the U.S. standard on micrometers, ASME B89.1.13, was approved by the ASME B89 dimensional metrology standards committee in 2012, and final publication of the standard is expected in 2013. This standard includes many modern and novel calibration concepts that apply beyond the dimensional field, and the purpose of this paper is to communicate some of the highlights of this new standard to the larger metrology community. Some of the key issues include defining the measurand, traceability requirements, conformance decision rules, calibration versus verification, and measurement uncertainty. It is expected that some of the concepts in the revised ASME B89.1.13 will be controversial, for example the intentional lack of inclusion of the resolution of the unit under test in the estimation of measurement uncertainty. By presenting this new standard in completion, it is hoped that others will understand and appreciate the reasoning behind some of the novel and controversial concepts in this standard and therefore be able to apply some of the ideas not just to micrometers but to other fields of metrology as well.

Learning Objectives

- Identify the revised ASME B89.1.13 standard and explain the key new metrology concepts it contains.
- Compare the metrology concepts in ASME B89.1.13 to prior methods and analyze the differences.
- Interpret and apply the metrology concepts in ASME B89.1.13 to other metrology fields.

1 Introduction

It is expected that the completed revision to the U.S. standard on micrometers will be published in 2013. A decision was made to revise the current ASME B89.1.13-2001 [1] after the release of the new international standard on micrometers, ISO 3611:2010 [2]. The revision to the U.S. micrometer standard will most likely be known as ASME B89.1.13-2013 [3]. The purpose of this paper is not to discuss some of the micrometer-related technical issues in this standard, but rather to discuss the broader metrology issues that this standard addresses. In particular, this paper will address the following topics:

- Definition of an indication
- Default compliance decision rule
- Traceability requirement
- Sources of uncertainty
- Definition of the measurand
- Performance verification versus assignment of reference values
- Concept of a reasonably skilled operator

ASME B89 is concerned with dimensional metrology. Division 7 of ASME B89 is tasked with developing standards that support measurement uncertainty issues in dimensional metrology. Since 1999, the ASME B89.7 committee has developed a series of important standards in decision rules [4], uncertainty [5], and traceability [6]. One of the goals in the revision of ASME B89.1.13 was to utilize the concepts in these ASME B89.7 standards, and the practical implementation of these standards, as used in ASME B89.1.13-2013, will be discussed in this paper.

The author of this paper is the chair of the ASME B89.1.13 project team on micrometers and led the revision of the ASME B89.1.13 micrometer standard. The contents of this paper should not be seen as an interpretation of the standard but rather an insight into the thinking that led to some of the contents of the revision.

2 Definition of an Indication

The importance of a clearly defined measurand is well known amongst metrologists. In surveying different calibration practices for micrometers, it was noticed that the test values were often derived in many different manners. Practices ranged from averaging multiple readings to taking the best or worst from a series of readings. This is particularly problematic when the definition of an indication could change the test value and the possible outcome when comparing to specification. The ASME B89.1.13 project team recognized that in many cases associated with testing measuring instruments, across all metrology disciplines, that the definition of an indication is often not clear.

In the revised ASME B89.1.13, a micrometer indication, for use in comparing to specifications, is defined as any and all unique measurement indications made under reasonable use of the micrometer. In addition, the standard states that averaging of several test values, or other data treatment, is not permitted.

3 Default Decision Rule

In recent years, many ASME B89 standards have started including default decision rules that apply when determining conformance to specifications. The revision to ASME B89.1.13 followed the general trend in ASME B89 and adopted a simple 4:1 acceptance decision rule in accordance to ASME B89.7.3.1 [4]. By including a default decision rule in the standard, the rules for conformance are tied to the specification and not left to possibly complicated discussions between customers and suppliers. In addition, by being defined as a default rule, it is always possible for different decision rules to be defined associated with particular specifications.

4 Traceability

The revision to ASME B89.1.13 requires that all length standards used in determining conformance to specification shall have metrological traceability per ASME B89.7.5 [6]. The requirements for metrological traceability in ASME B89.7.5 are similar to the traceability requirements for ISO/IEC 17025 [7] accredited calibration labs. With so many accredited labs available these days, this requirement may not seem too significant; however, the requirement is no longer just for an accredited lab, but must be met in order to have any valid calibration of the micrometer. This requirement may have a role when disputes arise in the buying and selling of new measuring instruments.

5 Measurement Uncertainty

For most current users of the ASME B89.1.13 standard, particularly in the calibration business, the most significant change in the revision of ASME B89.1.13 is in measurement uncertainty. The uncertainty guidance in the revision is based on the “test uncertainty” concepts that were first introduced to metrology standards in ISO/TS 23165:2006 [8] for testing coordinate measuring machines. A more generalized discussion of these issues can be found in [9].

5.1 Definition of the Test Measurand

The full concepts of test uncertainty are beyond the scope of this paper; however, the most important issue is defining the measurand. In the ASME B89.1.13 revision, it is stated that the uncertainty assumes the calibration being performed is a performance verification where the measured errors are test values for comparison to specifications of the micrometer and are not assigned reference values used as correction factors in later use of the micrometer.

Many uncertainty examples in the literature and standards, including the 2001 version of ASME B89.1.13, fail to recognize the subtle difference between calibrations that result in assigned reference values and calibrations that only involve testing a measuring instrument against defined specifications. In performance verification, the measurand is the instantaneous error of indication under a particular set of allowed conditions, and the instrument errors, including any inherent repeatability, are part of what is being tested and not also included in the uncertainty.

5.2 Resolution of the Unit Under Test

For performance verifications, the resolution of the unit under test (UUT) is not a source of uncertainty. The resolution of the UUT may impact the observed errors and therefore the specifications supplied by the instrument manufacturer, but the resolution of the UUT does not create any uncertainty in the ability to perform the performance verification test. In contrast, the resolution of the reference standards used in the test should be considered in the uncertainty.

5.3 Repeatability

Repeatability is one of the most misunderstood concepts in measurement uncertainty. By definition, uncertainty characterizes dispersion, and any non-repeatability in measurement values would seem to directly lead to some type of Type A statistical test and the calculation of repeatability. But *repeatability* is not really a source of uncertainty; instead, repeatability is the property of an experimental study that is designed to evaluate the uncertainty of *something* (i.e. some influence quantity). In dimensional metrology, it is common to use repeatability studies to evaluate uncertainty associated with temperature, or fixturing, or operator influences. It is usually equally valid to use Type B estimates of uncertainty for those sources as well, and the term repeatability will not appear in the uncertainty budget.

For performance verifications, any variation of test values coming from inherent errors in the UUT are part of the purpose of the test, not also part of the test uncertainty. In the uncertainty example in the revision to ASME B89.1.13, there are no Type A sources of uncertainty and nothing called repeatability. The one issue that was debated in the development of the revision of ASME B89.1.13 was the variation coming from different operators. After some discussion, a decision was made that hand-held measuring instruments have an implicit condition associated with their specifications of a *reasonably skilled* operator. Different operators can always give different results, but as long as the operators are reasonably skilled, then the variation between operators is part of the errors of the instrument and not also part of the uncertainty. In other words, it does not require a robot making "perfect measurements" to test a micrometer, nor will the perfect robot improve the test uncertainty over any other reasonably skilled operator.

5.4 Temperature

The specifications of a micrometer are defined at 20°C. Any variation from 20°C during testing results in uncertainty. Typical sources of uncertainty are the temperature difference between the UUT and the reference standards and the uncertainty in the coefficients of thermal expansion.

5.5 Reference Standard

The uncertainty in reference standards used during testing impacts the quality of the performance verification tests, and therefore is a source of uncertainty that appears in all uncertainty budgets.

5.6 Summary of Uncertainty Sources

The revision to ASME B89.1.13 includes a worked uncertainty example for the performance verification of the length measurement error of a 0-25 mm digital outside micrometer. The sources of uncertainty included in the example are:

- Reference standard: gage block tolerance and calibration uncertainty
- Temperature: coefficients of thermal expansion and not testing at 20°C
- Temperature: difference between the UUT and reference standards

5.7 Analysis of Uncertainty

When the measurand is properly defined as performance verification, in comparison to determining reference values, a number of sources of uncertainty disappear and the resulting expanded uncertainty may dramatically drop. In this manner, at least for the micrometer case, it is usually possible to achieve the 4:1 test uncertainty ratio that is required for simple 4:1 acceptance. If 4:1 cannot be initially achieved, the solution is usually to improve the process, use a better environment, or acquire better reference standards. It is nice to see that improving the metrology does improve the uncertainty. In contrast, in current uncertainty practice, particularly for micrometer, it is common that the resolution of the UUT dominates the uncertainty and nothing can be done to improve it.

6 Conclusions

The revision to the U.S. micrometer standard, ASME B89.1.13, is expected in 2013. This revision contains many new broad metrology concepts that may have application in other metrology areas. Of particular interest is the concept of the performance verification test uncertainty adopted in the revised standard. This revision is the first time the “test uncertainty” concepts are being standardized for a metrology instrument other than a coordinate measuring machine. It is expected that this revision will create much discussion and debate on this topic. It is also expected that the implementation of this standard will solve many previously unresolved and challenging problems associated with decision rules in the micrometer calibration business.

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