Automated Calibration Software Guardbanding

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ABSTRACT

- The ISO 17025 standard (“General Requirements for the Competence of Testing and Calibration Laboratories”) requires that measurement uncertainty be taken into account when statements of compliance are made.
- In other words, when a calibration laboratory calibrates an instrument and produces a calibration certificate indicating that the calibration verification procedure “passed” or “failed”, it is important that, for each test point, the measurement uncertainty be first calculated and then used in the determination of the test result.

ABSTRACT (continued)

- Guardbanding is a primary technique for assuring compliance with this 17025 requirement. Considerations of efficiency and productivity in calibration laboratories require full automation whenever possible. It is therefore desirable for automated calibration software to include guardbanding capability.
- This paper describes a flexible, configurable implementation of guardbanding in an automated calibration software system. A number of techniques are discussed, including both table-based and formula-based methods. Facilities for customization of the guardbanding algorithm are presented. A description of generated result data is included.

Introduction

- Overview
- Motivation for Guarbanding
- Guardbanding Strategies
- Automation of Guardbanding
- Comments & Questions

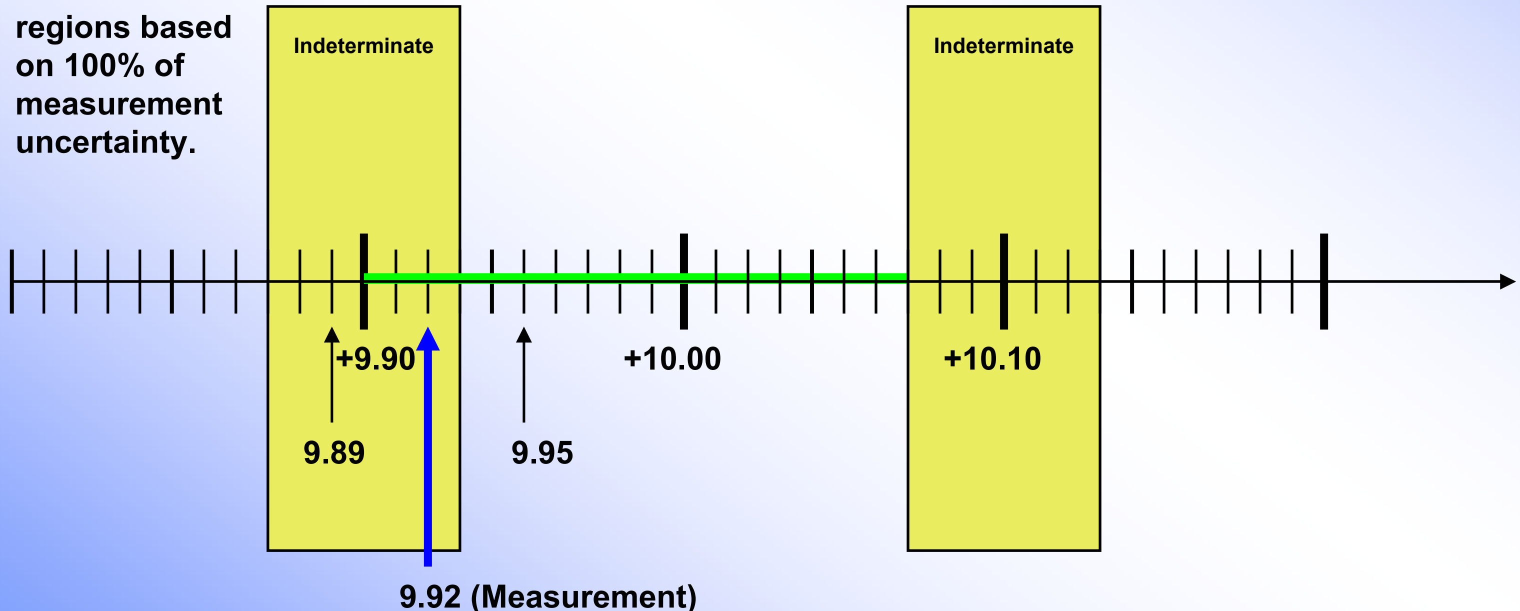
What is Guardbanding?

- The fundamental concept is to restrict the pass/fail limits applied to a calibration test based on some criterion.
- The purpose of the restriction is to control the risk of accepting an out-of-tolerance unit, or rejecting an in-tolerance unit.
- Example:
  - Test Point = 10 V
  - Test Specification = 1%
  - Test Limits are 9.9 V and 10.1 V
  - Measurement Uncertainty = 0.03 V
  - UUT Reading = 9.92 V
  - The reading is within the test limits, but if the uncertainty is considered, the true value is 9.92 +/- 0.03 V. The true value may be as low as 9.89 V, which is below the lower test limit.

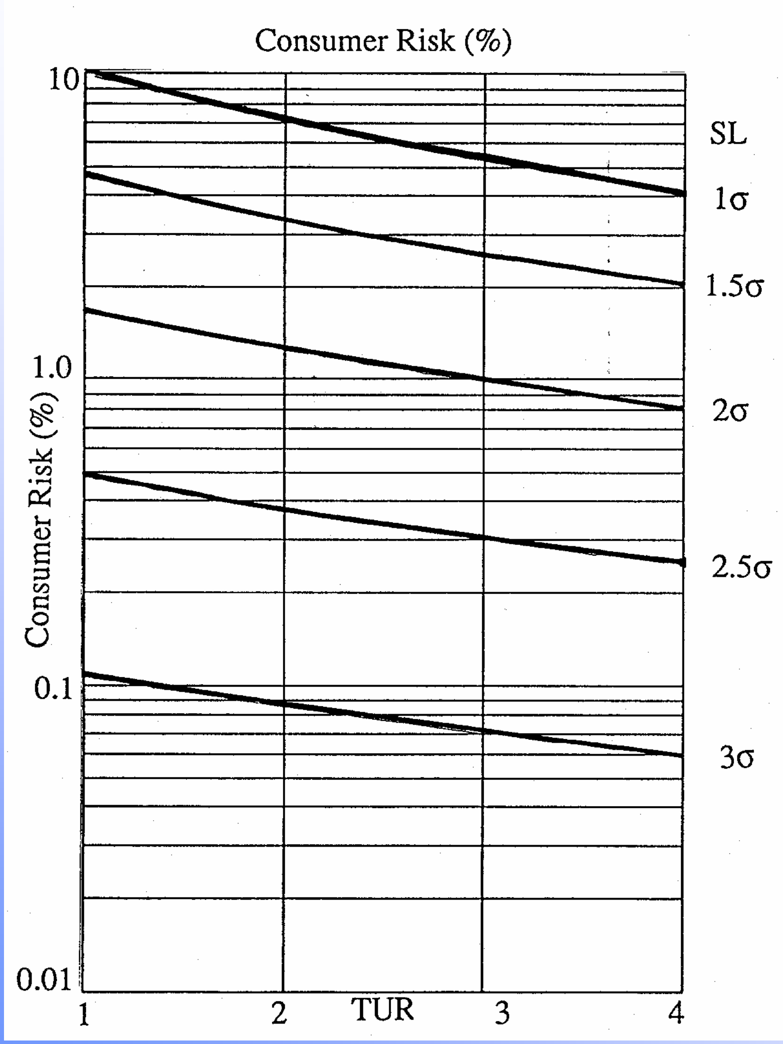
Guardbanding Example

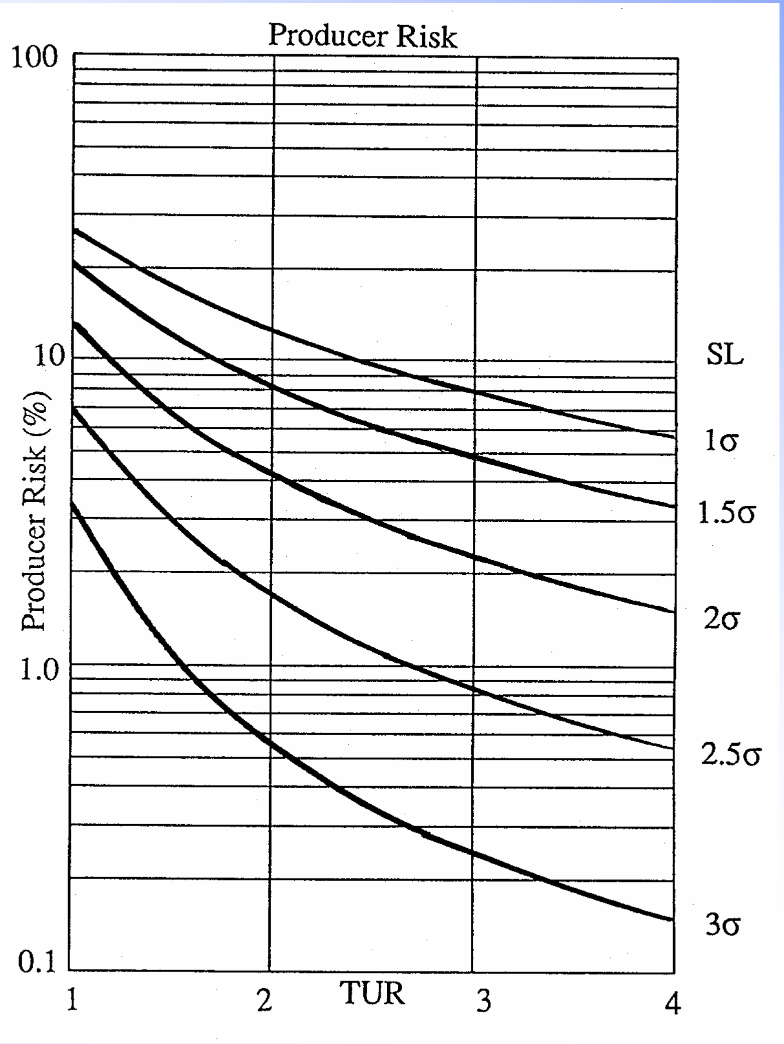
Measurement Uncertainty = 0.03

Indeterminate regions based on 100% of measurement uncertainty.



Consumer Risk and Producer Risk as a function of TUR





Guardbanding Motivation

- ISO 17025 Section 5.10.4.2
  - "When statements of compliance are made, the uncertainty of the measurement shall be taken into account."
  - The current statement is open to some debate. If one simply reports the measurement uncertainty, leaving it to the customer's discretion to interpret the value, has the uncertainty been "taken into account"?
- Other Standards
  - An organization may be subject to or claim compliance with standards other than ISO/IEC 17025:
    - * ISO 14253-1 "Geometrical Product Specifications (GPS) -- Inspection by measurement of workpieces and measuring equipment -- Part 1: Decision rules for proving conformance or non-conformance with specifications.
    - * ILAC-G8:1996 "Guidelines on Assessment and Reporting of Compliance with Specification
  - An organization may apply internal quality control standards which required guardbanding, or where guardbanding assists in meeting quality criteria.
  - Guardbanding affects the result of a calibration test!
  - Setting different test limits influences the risk of accepting defective units or rejecting conforming units

Automated Software - Guardbanding Strategies

- Strategies range from conservative to not-so-conservative.
- Most conservative is to tighten the specification limits by the full amount of the measurement uncertainty.
  - Must be able to calculate the uncertainty. Calibration software which calculates uncertainty is a pre-requisite for full automation.
- Least conservative is to do nothing. Specification limits are used "as is". This is traditional, but takes no account of the measurement uncertainty.
  - MIL STD 45662A, which requires a 4:1 TSR, follows this approach.
    - the point was found "not to be out of tolerance" rather than "within specified tolerances". This takes into account that any parameters which are accepted under this criteria which are actually out of tolerance, are not likely to be very far out of tolerance.
    - If reference specification are 3σ there's a 0.06% consumer risk
    - TSRs between 1.5:1 and 4:1, parameters with measured values which are less than 80% of the specification limits may be declared in tolerance

Guardbanding Strategies (continued)

- What are the input parameters?
  - Measurement uncertainty
  - Test uncertainty ratio (TUR)
  - Test specification ratio (TSR)
  - Acceptable risk.
  - Historical data for references and UUT
    - * Requires access to database containing extended calibration data.
    - * Access to historical data may be impractical for 3rd-party cal labs.
  - Population data for references and UUT
    - * It may be difficult to obtain data, except perhaps for manufacturer.
    - * Population data for the UUT may be used to evaluate the likely success of a particular guardbanding strategy.

Manual Guardbanding

- Automated calibration software is not used.
- Guardbanded test limits must be calculated prior to the calibration. Software packages like Excel may be used to assist in the calculation of the guardbanded limits.
- The calibration procedure is performed manually, and results are recorded on paper.
- Operator to determine each test to be *Pass*, *Fail* or *Indeterminate*

Semi-Automated Guardbanding

- Adjust Test Tolerances
  - Example:
    - * Change "DMM 10mV 1%" to "DMM 10mV 0.8%"
  - Once written, procedure may be re-used.
- May be possible to use software facilities not explicitly designed for guardbanding:
  - Marginal Pass indication.
  - Significantly Out of Tolerance indication.
- Requires significant effort to update procedure
  - Static, e.g. guardbanding factor difficult to vary based upon expanded measurement uncertainty
  - Reporting system may not be able to easily distinguish between a cal performed with or without guardbanding

Software Requirements

- An ideal automated guardbanding solution would:
  - Automate the calculation of the guardbanded test limits.
  - Support a number of “canned” methods.
  - Allow the procedure writer to enable or disable guardbanding.
  - Save result data to satisfy an auditor’s requirements.
  - Require little extra work on the part of the procedure writer.
- Flexibility
  - Customizable -- configurable on a per-test, per-procedure, per-workstation, or per-site basis.
  - It should be possible to override built-in defaults for all parameterized values.
- Compatibility
  - It should be possible to use existing automated calibration procedures with little or no modification.

TSR-Based Methods

- Method 1:
  - Recall that TSR = (Test Specification) / (Reference Specification)
    - * Nomenclature has been inconsistent. Often called TAR, sometimes TUR.
  - If TSR between 1.5 and 4, use 80% of specification limits
  - If TSR > 4, use 100% of specification limits (i.e., no guardbanding)
  - If the TSR is less than 1.5, the validity of the test may be called into question. One may, however, wish to define a guardbanding factor (less than 80%) for such tests.
  - This method is easy to describe, and relatively easy to implement.
    - * Does not require that the software have the ability to compute the measurement uncertainty

TSR-Based Methods (continued)

- The first generalization is to parameterize this method and make all parameters software-settable:
  - Make the TSR thresholds (4 and 1.5) settable by the procedure writer.
  - Make the guardbanding factor (80%) settable by the procedure writer.

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TSR-Based Methods (continued)

- Further generalize to allow a user-specified table of TSR ranges with a corresponding guardbanding factor for each range.
  - Supports an arbitrary number of points in the table.
- Provide a software-settable option to either:
  - Linearly interpolate between the points in the table, or
  - Interpret the table as a step function, choosing the more conservative guardband factor for values which fall between points in the table.

TUR-Based Strategies

- Method 2: Same flexibility as TSR-based, but uses the TUR rather than the TSR.
  - TUR = (Test Specification) / (Measurement Uncertainty)
  - Software must be able to calculate the measurement uncertainty in order to use the TUR as an input parameter to the guardbanding algorithm.

Normalized TUR-Based Strategies

- Method 3: Same as TUR-Based, but normalize the numerator and the denominator to 1 sigma:
  - Normalized TUR = (1-sigma test specification) / (standard uncertainty)
  - The software package must allow the procedure writer to specify the confidence associated with the test specification.
  - Default confidence value is 2 sigma.

Uncertainty-Based Strategies

- Method 4: Use the measurement uncertainty directly:
  - Guardbanded Upper Limit =

    Specification Upper Limit - (GBF * Measurement Uncertainty)
  - Guardbanded Lower Limit =

    Specification Lower Limit + (GBF * Measurement Uncertainty)
  - where GBF is the guardbanding factor, specifiable by the procedure writer.
  - If GBF is set to 1, this implements the Guide 25 Draft 5 recommendation.
  - Setting GBF to a value less than 1 requires justification by a metrologist.

Result Data

- Specification Test Limits
- Guardbanding Flag
- Guardbanding Method
- Guardbanded Test Limits
- Guardband Factor
- Overall Result for Each Test
  - Pass
  - Fail
  - Indeterminate
- Overall Result of Calibration Procedure

Calibration Procedure Result

- What is the overall result of the procedure (pass, fail, or indeterminate)?
- Configurable:
  - Method A: Indeterminate equivalent to Pass
  - Method B: Indeterminate equivalent to Fail
  - Method C: Indeterminate remains “Indeterminate
- Example
  - Suppose 10 tests, with 6 PASS and 4 INDETERMINATE
  - Method A: Overall result is PASS
  - Method B: Overall result is FAIL
  - Method C: Overall result is INDETERMINATE

Software Review

- Guardbanding Control
  - Enable or disable guardbanding.
  - Specify the guardbanding method.
  - Specify a table of parameter thresholds with associated guardband factors.
  - Choose whether or not to interpolate table values.
  - Supports asymmetrical tolerance specifications.
  - Specify how indeterminate test results are handled.
  - Call external programs to provide data on GBFs & other parameters.
  - Change guardbanding parameters on a per-site, per-workstation, per-procedure, or per-test basis.
  - Report results in a SQL database, for easy access by report generators or other software tools.

Conclusion

- **Guardbanding now implemented in MET/CAL**
  - Built-In Calculations & Default Values (adequate in Most Cases)
    - Use Existing Procedures without Modification
  - Flexible Implementation
    - Support for Different Guardbanding Strategies
    - Customizable by the User
  - Opportunities for improvements
    - The table-based method described here, where the independent parameter is determined by the user, and an associated guardband factor is specified for each row in the table, could be made more general by allowing a mathematical expression to determine the guardband factor on each row of the table.
    - More work should be done on guardbanding methods that directly maintain a constant risk of accepting an out-of-tolerance UUT.

RESULT	COLOUR
Pass	Green
Indeterminate Pass	Light Green
Indeterminate Fail	Light Red
Fail	Red
RSLT & Brace Text	Cyan

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Any Questions ?