



LAS-Q002

TTLABS POLICY ON MEASUREMENT TRACEABILITY

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Scope and Field of Application¹

The quality of products and services is becoming increasingly dependent on reliable measurements. The importance attached to measurements is reflected in relevant standards by the requirement that measurements must be “traceable” to national or international standards of measurement. Different definitions and explanations of the term “traceability” exist in standards and various literature, giving rise to differing interpretations and misinterpretations.

This policy document is intended to explain the concept of measurement traceability, how it can be achieved, and how it can be demonstrated. TTLABS requirements pertaining to measurement traceability are described. This document is intended for all TTLABS-accredited and enrolled calibration and testing laboratories.

Specific requirements found in this Policy are in *italic* type and numbered as in “(TI)”.

Introduction- the Concept of “Traceability”

Traceability is the property of a measurement result whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons, each step in the chain having stated uncertainties². The purpose of requiring traceability is to ensure that measurements are accurate representations of the specific quantity subject to measurement, within the uncertainty of the measurement.

Traceability is characterized by six essential elements³:

1. *An unbroken chain of comparison*: Traceability begins with an unbroken chain of comparisons originating at national, international or intrinsic standards of measurement and ending with the working reference standards of a given metrology laboratory;
2. *Measurement uncertainty*: The measurement uncertainty for each step in the traceability chain must be calculated according to defined methods and must be stated at each step of the chain so that an overall uncertainty for the whole chain can be calculated;
3. *Documentation*: Each step in the chain must be performed according to documented and generally acknowledged procedures and the results must be documented, i.e., in a calibration or test report;
4. *Competence*: The laboratories or bodies performing one or more steps in the chain must

¹ See, for example, EA-4/07, *Traceability of Measuring and Test Equipment to National Standards*.

² ILAC-G2:1994, *Traceability of Measurements*.

³ *ibid.*

- supply evidence of technical competence, e.g., by demonstrating that they are accredited by a recognized accreditation body;
5. *Reference to SI units*: Where possible, the primary national, international or intrinsic standards must be primary standards for realization of the SI units;
 6. *Recalibrations*: Calibrations must be repeated at appropriate intervals in such a manner that traceability of the standard is preserved.

(T1) TTLABS requires that all calibrations and verifications of measuring and test equipment, reference standards, and reference materials be conducted by accredited calibration laboratories (in some instances an accredited testing laboratory may also be able to satisfy traceability requirements) or by a recognized national metrology institute. (T2) These calibrations or verifications must be documented in a calibration certificate or report endorsed by the accreditation body's symbol, or otherwise makes reference to accredited status.

(T3) All laboratories must define their policy for achieving measurement traceability and also for achieving traceability for reference materials if applicable. The policy must be in compliance with this policy document.

The Distinction between Calibration and Testing and Achieving Traceability through Dimensional Testing Laboratories

Calibration is defined as the “set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, or values represented by a material measure, and the corresponding known values of a measurand”⁴. A test is defined as “a technical operation that consists of the determination of one or more characteristics or performance of a given product, material, organism, physical phenomenon, process or service according to a specified procedure.”⁵

In short, “calibration” means determining and documenting the deviation of the indication of a measuring instrument (or the stated value of a material measure) from the conventional “true” value of the measurand. The term “traceability” means a process whereby the indication of a measuring instrument (or a material measure) can be compared, in one or more stages, with a national or international standard for the measurand in question.

Traceability is typically achieved through calibration services. However, in some instances, traceability can be achieved through test results. For example, since TTLABS enforces the same requirements on dimensional inspection laboratories (including traceability requirements and requirements pertaining to the calculation and reporting of measurement uncertainty) as it does for dimensional calibration laboratories, the distinction between calibration and testing can be lost.

Therefore, a dimensional testing laboratory that issues an accredited test report containing appropriate statements of measurement results, measurement uncertainty, and traceability can be considered as having produced a “calibration” report for the dimensional artifact in question regardless of the title of the document. This can be particularly useful for complex dimensional artifacts that most dimensional calibration laboratories will not be accredited to calibrate.

⁴ VIM, *International vocabulary of basic and general terms in metrology*

⁵ ISO/IEC Guide 2, Definition 13.1.

Similar situations could arise in other fields of testing as well.

Scopes of Accreditation

Scopes of accreditation are documents that define specifically the measurements a laboratory is accredited to make. In addition, the scope defines the ranges of the accredited measurand along with the associated best measurement capability expressed as an uncertainty for each measurand and range.

Before placing work with an accredited laboratory, it is important that the customer request a copy of the laboratory's scope so that the customer can ensure that the laboratory is accredited to perform the needed measurements. In addition, customers must ensure that the laboratory's measurement uncertainties are suitable for their needs.

Accredited Calibration and Test Reports

For the purpose of demonstrating measurement traceability, calibration certificates should, wherever applicable, indicate the traceability to national or international standards of measurement and should provide the measurement result and associated uncertainty of measurement.

Wherever applicable, and when suitable for customer requirements, a statement of compliance with an identified metrological specification can be accepted instead of measurement results and associated uncertainties.

Only calibration certificates or reports endorsed by a recognized accreditation body's symbol, or which otherwise makes reference to accredited status, are considered to satisfy traceability requirements. By definition, such an endorsed certificate or report will contain an appropriate statement of measurement results and/or a statement of compliance with an identified metrological specification accompanied by an appropriately defined uncertainty statement and a suitable statement of traceability.

Determination and Statement of Uncertainty

A crucial element of the concept of measurement traceability is measurement uncertainty. ***(T4) Where uncertainty calculations are applicable, TTLABS requires that testing and calibration laboratories calculate measurement uncertainty in accordance with the ISO "Guide to the Expression of Uncertainty in Measurement." These uncertainties must be supported by uncertainty budgets, and they will be represented as expanded uncertainties typically using a coverage factor of $k=2$ to approximate the 95% confidence level.***

(T5) If a calibration certificate or report contains a statement of the measurement result and the associated uncertainty, then the uncertainty statement must be accompanied by an explanation of the meaning of the uncertainty statement. An example of such an explanation might be the statement "Reported uncertainties represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor of $k=2$ ". Statements of uncertainty which do not specify at least the coverage factor and the confidence level are incomplete and they are inadequate for the purpose of demonstrating that measurement traceability has been achieved.

It is often the case that a calibration certificate will contain the statement “in tolerance”, or words to that effect, along with a statement to the effect that the measurement uncertainty does not exceed a certain fraction of the tolerance. Such fractions are often called “accuracy ratios” or “uncertainty ratios”, or TARs and TURs for short. Uncertainty statements phrased in terms of TURs can be adequate for the purpose of demonstrating measurement traceability since they are implicit statements of the uncertainty: knowing the tolerance and the accuracy ratio allows one to determine the largest possible value of the measurement uncertainty. However, ***(T6) TURs must be calculated using the expanded uncertainty of the measurement, not the “collective uncertainty of the measurement standards”.***

(T7) Implicit uncertainty statements must be accompanied by words to the effect that the accuracy ratio was calculated using the expanded measurement uncertainty. In addition the coverage factor and confidence level must be stated.

Statements of Traceability

(T8) In addition to the information required in the above sections, calibration reports and certificates must contain a traceability statement. This statement will affirm that the calibration reported was conducted using standards whose values are traceable to an appropriate national, international, intrinsic, or mutual consent standard. For example, if the traceability chain for a given laboratory originates at NIST, then the statement will affirm that “This calibration was conducted using standards traceable to NIST”, or words to that effect.

Calibration certificates and reports which do not contain equivalent statements of traceability, or which only refer to NIST report of test numbers as evidence of traceability (see below) are insufficient to demonstrate measurement traceability.

In-house Calibrations

An in-house calibration system ensures that all measuring and test equipment used in a company is calibrated regularly against its own reference standards. The in-house calibration system shall ensure traceability of measurement by having its reference standards calibrated at an accredited calibration laboratory or a national metrology institute.

The nature and scope of the metrological control of in-house calibration is at the discretion of the parent organization. They must be adapted to the particular applications so that the results obtained with the measuring and test equipment are sufficiently accurate and reliable. Accreditation of organizations performing in-house calibrations is not always necessary to satisfy the requirements of ISO/IEC 17025. However, in light of the definition of measurement traceability, ***(T9) all in-house calibrations must be supported by the following minimal set of elements:***

- 1) The in-house laboratory must maintain documented procedures for the in-house calibrations and the in-house calibrations must be evidenced by a calibration report, certificate, or sticker, or other suitable method, and calibration records must be retained for an appropriate, prescribed time;***
- 2) The in-house laboratory must maintain training records for calibration personnel and these records must demonstrate the technical competence of the personnel performing the calibrations: evidence of competence includes, for example, documented training***

- and the results of measurement audits;*
- 3) *The in-house laboratory must be able to demonstrate traceability to national or international standards of measurement by procuring calibration services from accredited calibration labs or a national metrology institute;*
 - 4) *The in-house laboratory must have and apply procedures for evaluating measurement uncertainty. Measurement uncertainty must be taken into account when statements of compliance with specifications are made;*
 - 5) *Reference standards must be recalibrated at appropriate intervals to ensure that the reference value is reliable. Policy and procedures for establishing and changing calibration intervals must be based on the historical behavior of the reference standard.*

It is not always easy to define the precise circumstances under which a given calibration should be considered to be an in-house calibration that is not subject to accreditation requirements. However at least two cases can be distinguished:

- 1) If the calibration service is performed within the same physical location as the customer⁶, and if the calibrations are performed in a permanent calibration laboratory (i.e., customer equipment to be calibrated is transported to the calibration laboratory), then the calibration should be considered to be an in-house calibration not subject to accreditation requirements;
- 2) If the calibration service is performed at a location other than a permanent calibration laboratory (i.e., if reference standards are being transported to the customer equipment to be calibrated), then such a calibration service should be accredited.

Acceptable Accreditors of Calibration and Testing Providers

Globally, there is a system of Multi-Lateral Mutual Recognition Agreements or Arrangements (MLAs or MRAs) with numerous accreditation bodies throughout the world. The importance of these agreements is that the signatories promote the recognition and acceptance of certificates and reports issued by organizations accredited by accreditation bodies that have signed the MRA. Through the vehicle of the MRA, a uniform level of competence of the accredited bodies involved is assured and the need for multiple assessments is diminished or eliminated. This means that a supplier should only need one certificate or report to satisfy the markets and governments represented by MRA signatories.

Currently, the global multi-lateral recognition agreement amongst accrediting bodies is the International Laboratory Accreditation Cooperation (ILAC) Arrangement. TTLABS recognizes and accepts the accreditations granted by ILAC Arrangement signatories and signatories to the Inter-American Accreditation Cooperation (IAAC) MLA.

Accredited test and calibration results, reported by laboratories that are accredited by any of these bodies, and reported in a test or calibration report endorsed by the accrediting body's symbol, or which otherwise refers to its accredited status, are recognized by TTLABS as satisfying the requirements pertaining to measurement traceability.

⁶ "Customer" refers to the recipient of the in-house calibration service.

Use of NMI Test Report Numbers as Evidence of Traceability

National Metrology Institutes (NMIs), such as TTBS or NIST of the United States usually issue report numbers with its calibrations. Although the NMI can verify the authenticity of its report numbers, having an authentic number does not provide assurance or evidence that the measurement value provided by another organization is traceable. Not only should there be an unbroken chain of comparisons, each measurement should be accompanied by a statement of uncertainty associated with the farthest link in the chain from the NMI, that is, the last facility providing the measurement value. NMIs do not have that information; only the facilities that provided the measurement values to the customer can provide the associated uncertainties and describe the traceability chain.

To establish an audit trail for traceability, a proper calibration result should include: the assigned value, a stated uncertainty, identification of the standards used in the calibration and the specification of any environmental conditions of the calibration where correction factors should be applied, if the standard or equipment were to be used under different environmental conditions.

Report numbers should not be used nor required as proof of the adequacy or traceability of a test or measurement.

It should also be noted that nationally and internationally recognized standards dealing with test and measurement quality requirements such as ISO/IEC 17025 do not require the use or reporting of NMI report numbers to establish traceability.

Consequently, TTLABS neither requires nor accepts the presence of NMI report numbers on calibration reports as sufficient evidence of the traceability of a measurement result.

Summary of Specific Requirements

(T1) All calibrations and verifications of measuring and test equipment, reference standards, and reference materials shall be conducted by accredited calibration laboratories (in some instances an accredited testing laboratory may also be able to satisfy traceability requirements) or by a recognized national metrology institute.

(T2) Calibrations or verifications must be documented in a calibration certificate or report endorsed by a recognized accreditation body's symbol, or otherwise makes reference to accredited status.

(T3) Laboratories shall define their policy for achieving measurement traceability. This policy shall be in compliance with this policy document.

(T4) Where uncertainty calculations are applicable, testing and calibration laboratories shall calculate measurement uncertainty in accordance with the ISO "Guide to the Expression of Uncertainty in Measurement." These uncertainties shall be supported by uncertainty budgets, and they shall be represented as expanded uncertainties typically using a coverage factor of $k=2$ to approximate the 95% confidence level.

(T5) If a calibration certificate or report contains a statement of the measurement result and the associated uncertainty, then the uncertainty statement shall be accompanied by an explanation of the meaning of the uncertainty statement. (For example, "This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of $k=2$.)

(T6) TURs shall be calculated using the expanded uncertainty of the measurement, not the “collective uncertainty of the measurement standards”.

(T7) Implicit uncertainty statements (generally expressed in terms of a TUR) shall be accompanied by words to the effect that the uncertainty ratio was calculated using the expanded measurement uncertainty. In addition the coverage factor and confidence level shall be stated.

(T8) Calibration reports and certificates issued by TTLABS-accredited calibration laboratories shall contain a traceability statement.

(T9) All in-house calibrations shall be supported by the following minimal set of elements:

- a) The in-house laboratory shall maintain documented procedures for the in-house calibrations and the in-house calibrations shall be evidenced by a calibration report, certificate, or sticker, or other suitable method, and calibration records shall be retained for an appropriate, prescribed time;
- b) The in-house laboratory shall maintain training records for calibration personnel and these records shall demonstrate the technical competence of the personnel performing the calibrations;
- c) The in-house laboratory shall be able to demonstrate traceability to national or international standards of measurement by procuring calibration services from accredited calibration labs or a national metrology institute;
- d) The in-house laboratory shall have and apply procedures for evaluating measurement uncertainty. Measurement uncertainty shall be taken into account when statements of compliance with specifications are made;
- e) Reference standards shall be recalibrated at appropriate intervals to ensure that the reference value is reliable. Policy and procedures for establishing and changing calibration intervals shall be based on the historical behavior of the reference standard.