Capacity Building & Knowledge Transfer

Measurement traceability = Metrological traceability

Andy Henson

Director of the International Liaison and Communication Department

BIPM

Bureau International des Poids et Mesures

Why is Metrological Traceability Important?

- Metrological traceability is important because it gives you confidence and assurance that your measurement results are '*right*' - that is they agree with national standards within the statement of uncertainty in measurement.
- The results you report to your customers can be used to provide calibrations, perform tests, manufacture products, drive innovation, or make decisions which could affect health, safety, and even court proceedings.

It is important!!!

If you provide unreliable results to a manufacture that makes or services aircraft, you could be putting other people's lives at risk. Would you put your family on that plane?

Another customer of yours could be using equipment to make medical decisions that affect someone's health. What is the patient was your spouse or child?

Maybe your results will be used in court as evidence which can affect the outcome of a case. Would you be confident if you were on trial for murder?

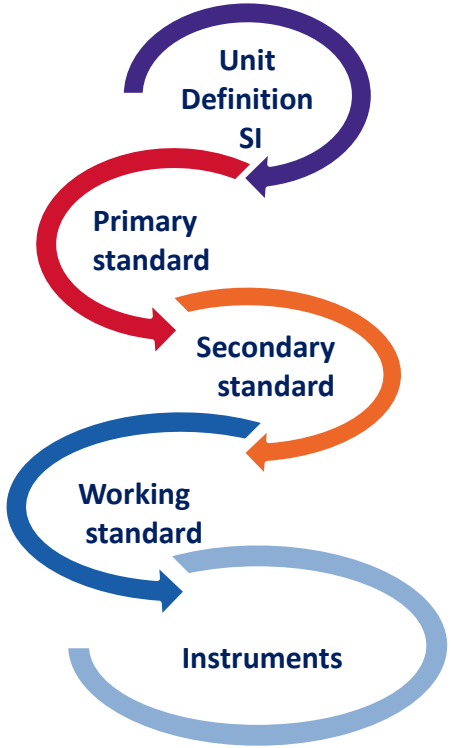
The work that you perform in the laboratory can significantly impact society.

What is Metrological Traceability?

The objectives of metrology are achieved through providing the framework for traceable measurements.

> ***"Traceability"*** *- the property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty*
>
> From the International Vocabulary of Basic and General Terms in Metrology; VIM, 3rd edition, JCGM 200:2012

Note: traceability is the property of the result of a measurement, not of an instrument or calibration report or laboratory



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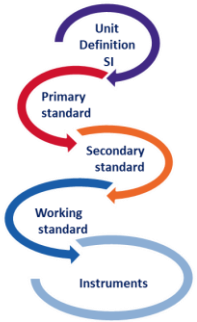


For this definition, **a 'reference' can be** a definition of a measurement unit through its **practical realization** or a **measurement standard**, or a **reference material** or **measurement procedure**

What is Metrological Traceability?

The abbreviated term "traceability" is sometimes used to mean 'metrological traceability' as well as other concepts, such as 'sample traceability' or 'document traceability' or 'instrument traceability' or 'material traceability‘ or ‘origin of goods’…

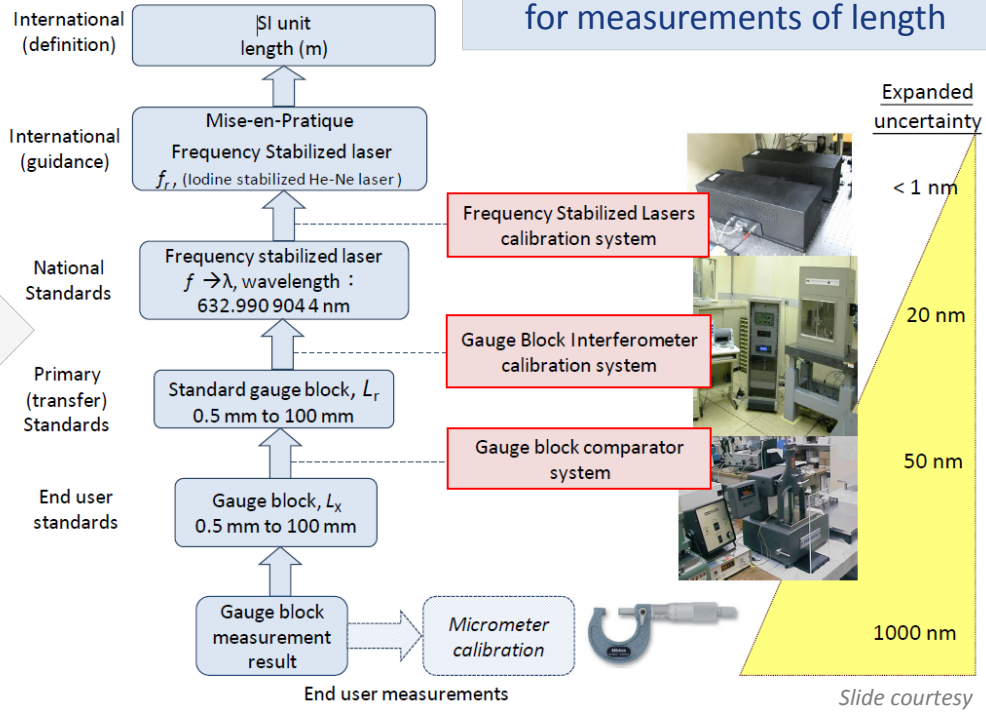
Therefore, the full term of **"metrological traceability"** is preferred if there is any risk of confusion.

Metrological traceability requires an established calibration hierarchy.

Calibration should be documented - including information on metrological traceability.

Reports can be issued as hard copies or by electronic means, provided that the requirements of this document are met.

A metrological traceability chain for measurements of length



Slide courtesy
Dr S Davidson, NPL, UK

Bureau International des Poids et Mesures

N° 77 6 November 2017

CERTIFICATE

for the study and calibration of a 100 pF capacitance standard,
Andeen-Hagerling model AH11A, serial number <s/n>, belonging to the
<NAME OF NMI> (<ACRONYM>), <City>, <Country>,
(Previous BIPM Certificate number 3, 5 February 2015)

The capacitor, enclosed in an Andeen-Hagerling frame AH1100, serial number 00200213, was received on 29 September 2017. It was measured six times during the period from 6 October to 26 October 2017. The measurements were carried out by R. Chayramy and this certificate was checked by P. Gournay and approved by M. Stock.

Study

Measurement method: comparison with a reference group of four 10 pF capacitors, using a coaxial bridge for two terminal-pair impedances. The capacitance of the reference group is known in terms of the recommended value of the von Klitzing constant, $R_{K\text{-}90} = 25\,812.807\,\Omega$, by means of a chain of impedance bridges.

Nominal ambient temperature of laboratory: 23 °C
Mean reading of the front panel meter "CHASSIS TEMP (°C)": 31.6
Mean reading of the front panel meter "DRIFT (PPM)": 0.004
Nominal voltage applied to the capacitor (root-mean-square value): 10 V
Nominal frequency of the measurements: 1592 Hz

BIPM evaluation of the voltage coefficient of capacitance: 0.4×10^{-7} pF/V, with a standard uncertainty of 2×10^{-7} pF/V.

BIPM evaluation of the relative capacitance change with frequency from 1000 Hz to 1592 Hz: $(C_{1592} - C_{1000}) / C_{1000} = -18.5\times10^{-8}$ with a standard uncertainty of 6×10^{-8}.

Results

Value of the capacitance of standard 01645 at 1592 Hz and 10 V on the mean date, 14 October 2017:

$$C = 99.999\,400\,3 \text{ pF}$$

Relative combined standard uncertainty:

$$U = 4.0\times10^{-8}$$

This uncertainty can be divided into two components: a component of 0.6×10^{-8} arising from the observed stability of the standard over the measurement period, and a component of 4×10^{-8} for the BIPM measurements and traceability.

All of the uncertainties given in this certificate are estimated standard uncertainties, without the application of a coverage factor, k; the standard uncertainty associated with the use of the recommended value $R_{K\text{-}90}$, which has a relative value of 1×10^{-7}, has not been included.

M. Stock
Director of the Physical Metrology Department

Metrological traceability routes - ISO/IEC FDIS 17025:2017

Metrological traceability to the International System of Units (SI) through:

a) calibration provided by a competent laboratory

NOTE 1 Laboratories fulfilling the requirements of ISO/IEC 17025:2017 are considered to be competent

b) certified values of certified reference materials provided by a competent producer with stated metrological traceability to the SI

NOTE 2 Reference material producers fulfilling the requirements of ISO 17034 are considered to be competent.

c) direct realization of the SI units (ensured by comparison, directly or indirectly, with national or international standards)

NOTE 3 Details of practical realization of the definitions of some important units are given in the SI brochure.

Metrological traceability routes - ISO/IEC FDIS 17025:2017

When metrological traceability to the SI units is not technically possible, the laboratory shall demonstrate metrological traceability to an appropriate reference, e.g.

a) certified values of certified reference materials provided by a competent producer

b) results of reference measurement procedures, specified methods or consensus standards that are clearly described and accepted as providing measurement results fit for their intended use and ensured by suitable comparison.

CIPM MRA specific requirements on metrological traceability

CIPM MRA Requirements on metrological traceability

All CMCs must include information on traceability of the measurements to the SI.

According to the CIPM MRA, there are two routes to establish traceability:

1. via a **primary realization** of the unit of measurement concerned, in which traceability is declared to its own demonstrable realization of the SI.
2. via another **NMI or DI having relevant CMCs** with appropriate uncertainty published **in the KCDB**, or through calibration and measurement services offered by the BIPM

CIPM MRA-D-04

In order for a primary realization or representation of the unit of measurement to be considered valid, **it requires the approval of the relevant Consultative Committee.**

The NMI or DI must make available a full assessment of the uncertainty budget and the traceability route for its measurement activity when submitting CMCs for intra- and inter-Regional review.

Traceability exceptions…

- In exceptional cases, where neither of these two routes can be strictly applied, alternative paths for establishing the traceability to recognized standards may be proposed to the CIPM through the corresponding Consultative Committee.

Any such exceptions, once approved by the CIPM, will be available in the CIPM MRA documents part of the BIPM website.

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TRACEABILITY EXCEPTION:

DELTA VALUE ISOTOPE RATIO MEASUREMENTS

Delta value isotope ratio measurements that cannot presently be made traceable to the SI should be made traceable to materials* recognised as International Standards. Since at present, values assigned to these materials are based on consensus values, these materials are not listed in the Appendix C of the BIPM Database.

* A list of certified reference materials that should be used to identify accepted references for delta value isotope ratio traceability statements is published and maintained by IUPAC:

Willi A. Brand, Tyler B. Coplen, Jochen Vogl, Martin Rosner and Thomas Prohaska
Assessment of international reference materials for isotope-ratio analysis (IUPAC Technical Report)
Pure Appl. Chem. 2014, **86**(3), 425-467

The report is available for free download:
http://www.degruyter.com/doi/10.1515/pac-2013-1023

The CIPM notes that assigned values for replacement materials should be done through a formal internationally vetted procedure that assures the continued comparability of delta value measurements.

The CIPM encourages the continuation of programmes within the NMIs to develop absolute isotope ratio measurement values for such Reference Materials and active engagement with the IUPAC community.

Traceability exception approved by the CIPM in March 2015
See Decision CIPM/104-26

Primary realization

BIPM

Approved by the CIPM in October 2007

RECOMMENDED VALUES OF STANDARD FREQUENCIES FOR APPLICATIONS INCLUDING THE PRACTICAL REALIZATION OF THE METRE AND SECONDARY REPRESENTATIONS OF THE SECOND

HELIUM NEON LASER (unstabilized) ($f \approx 474$ THz)

HeNe laser operating on the $3s_2 \rightarrow 2p_4$ transition

1. **CIPM recommended value [1] of the frequency**

$f(\mathrm{HeNe}_{\mathrm{unstabilised}}) = 473.612\,7$ THz

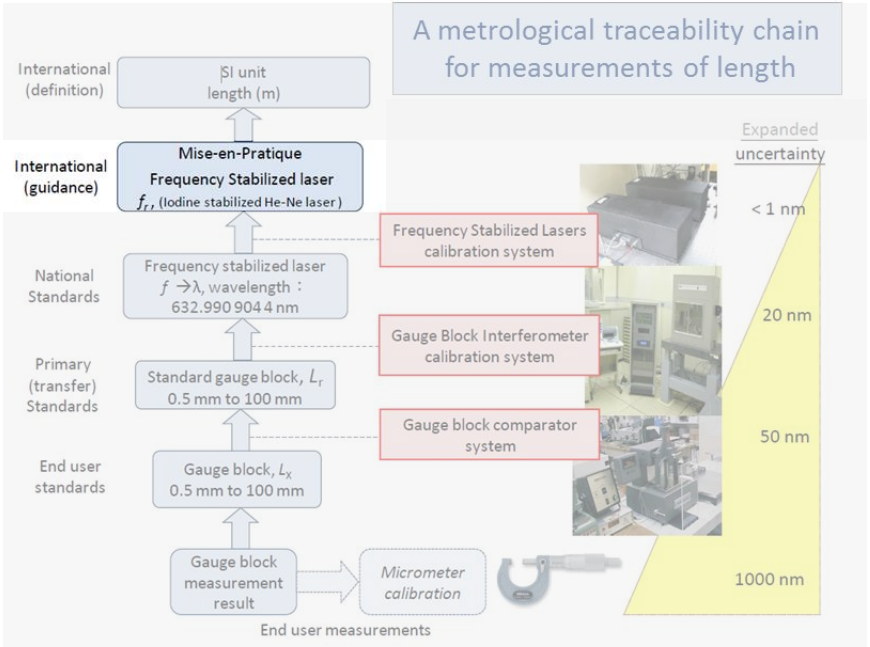
equivalent to

$\lambda(\mathrm{HeNe}_{\mathrm{unstabilised}}) = 632.990\,8$ nm

with a relative standard uncertainty of 1.5×10^{-6} applies apply to the radiation in vacuum of an unstabilized helium-neon laser operating solely on the $3s_2 \rightarrow 2p_4$ transition, independent of the isotopic mixture of the neon.

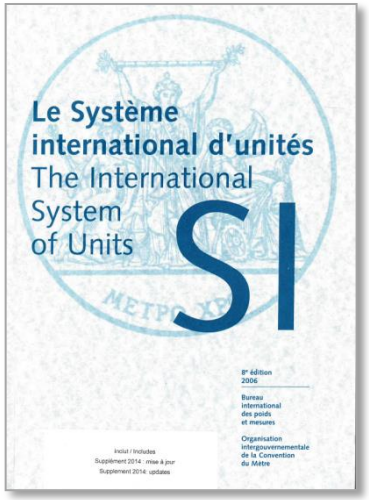
This wavelength (in vacuum) value was also recommended by CIPM 2007 as a Realization of the Definition of the Metre

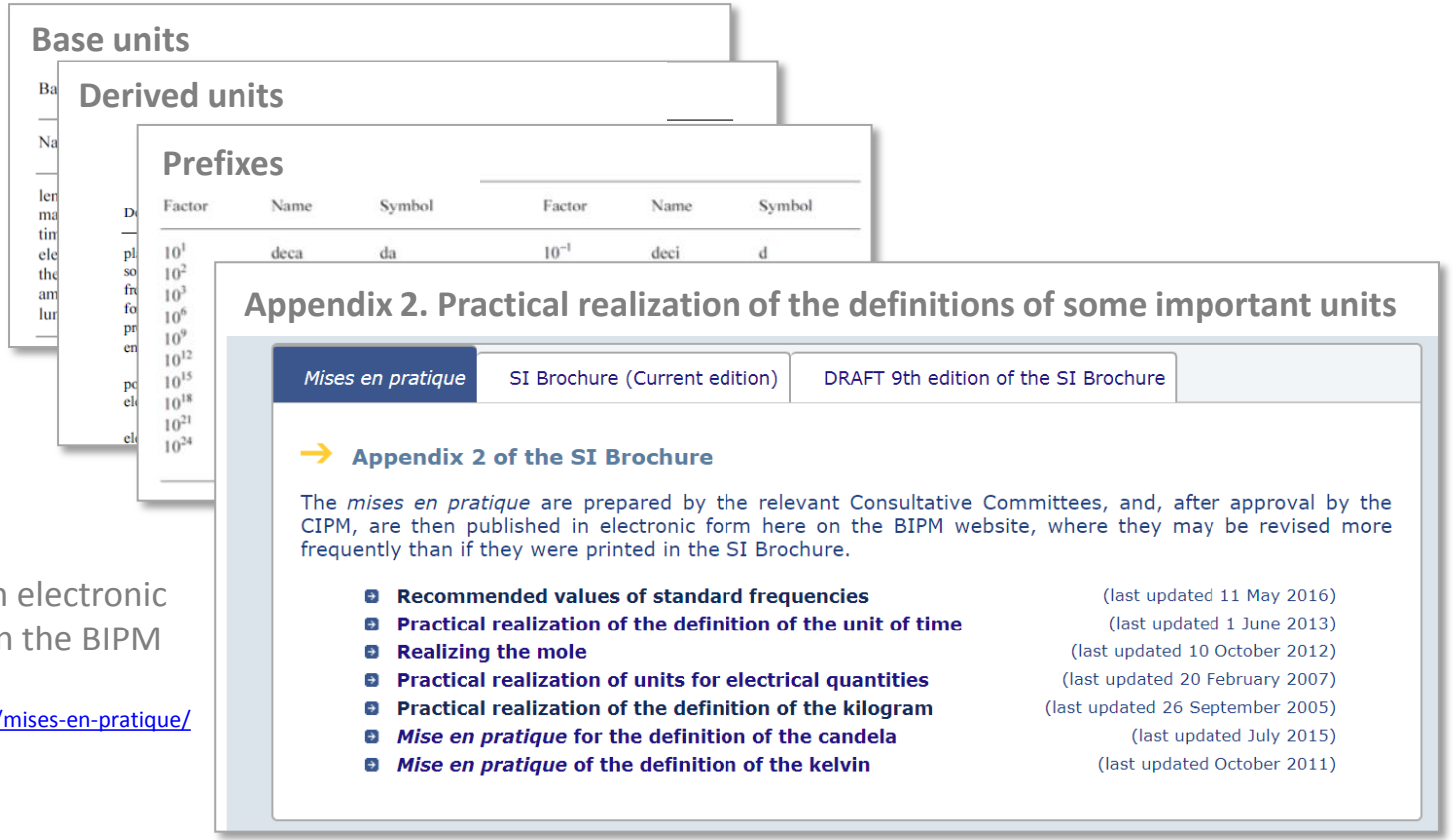
Primary realization



Real example of practical realization

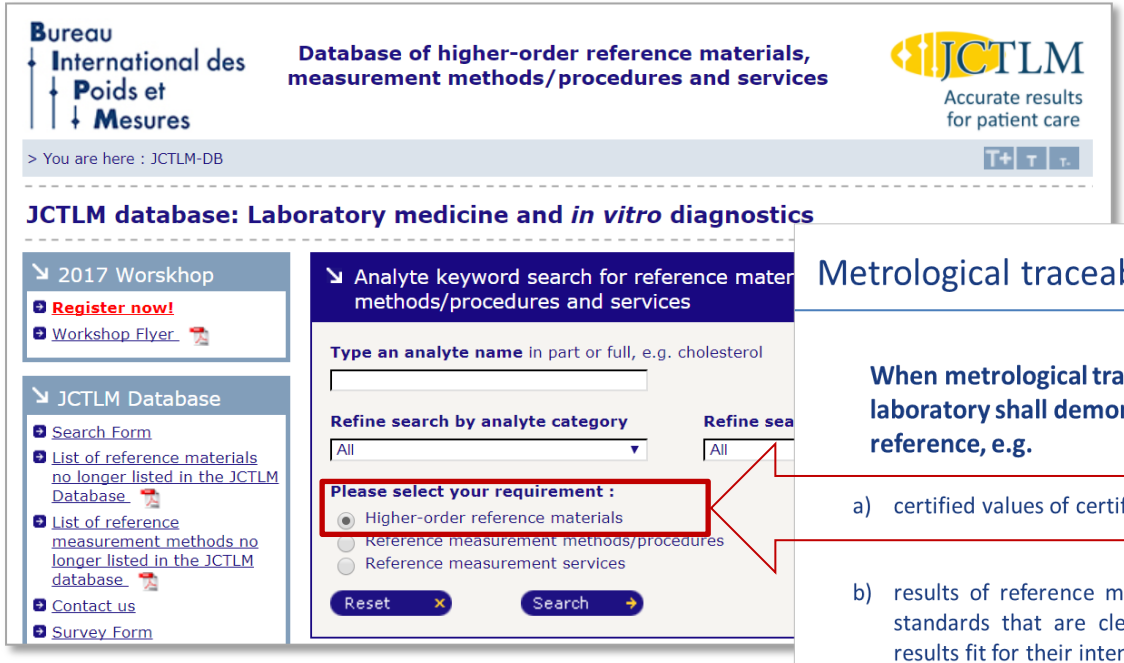
Primary realization





Appendix 2 is published in electronic form only and available on the BIPM website:
https://www.bipm.org/en/publications/mises-en-pratique/

When it is technically not possible…



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The general requirements for the competence of calibration laboratories are laid down in ISO/IEC 17025 for testing and calibration laboratories. ISO 15195:2003 refers to the specific aspects of calibration laboratories in the field of laboratory medicine where such "calibration laboratories" are usually denoted as "reference measurement laboratories"

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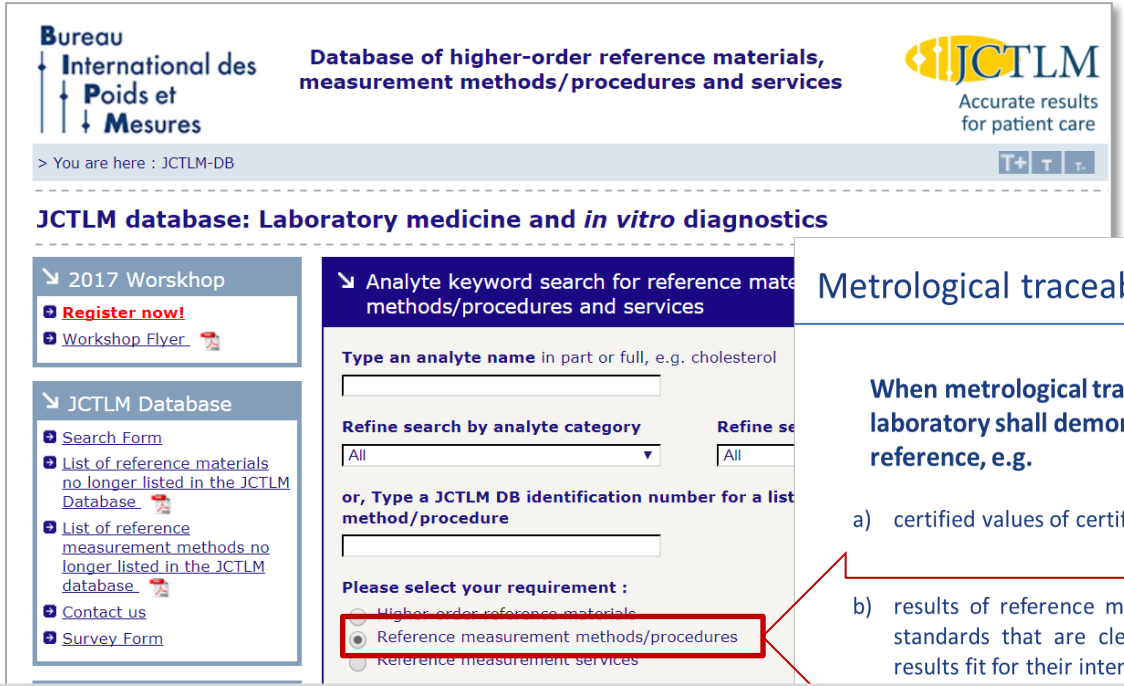

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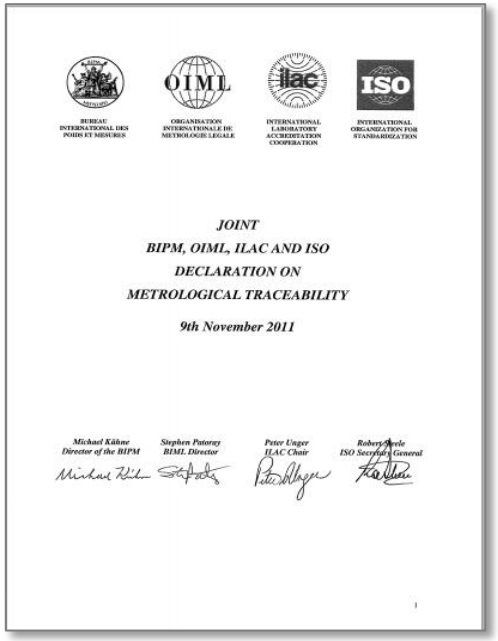
Joint BIPM, OIML, ILAC and ISO declaration on measurement traceability



BUREAU INTERNATIONAL DES POIDS ET MESURES | ORGANISATION INTERNATIONALE DE METROLOGIE LEGALE | INTERNATIONAL LABORATORY ACCREDITATION COOPERATION | INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

JOINT
BIPM, OIML, ILAC AND ISO
DECLARATION ON
METROLOGICAL TRACEABILITY

9th November 2011

Michael Kühne Director of the BIPM | *Stephen Patoray* BIML Director | *Peter Unger* ILAC Chair | *Robert Steele* ISO Secretary General

The BIPM, OIML, ILAC, and ISO endorse the following recommendations:

in order to be able to rely on their international acceptability, **calibrations should be performed**

- in **National Metrology Institutes** who should normally be signatories to the CIPM MRA and **have CMCs published in the relevant areas of the KCDB** or
- in **laboratories accredited** by accreditation bodies which are signatories to the **ILAC Arrangement**;

measurement **uncertainty should follow** the principles established in the **GUM**;

the **results of the measurements** made in accredited laboratories should be **traceable to the SI**;

NMIs providing traceability for accredited laboratories should normally be signatories to the CIPM MRA and have CMCs published in the relevant areas of the KCDB;

within the OIML's MAA, accreditation should be provided by bodies which are signatories to the ILAC Arrangement and the above policies on traceability to the SI should be followed;

The above principles should be used whenever there is a need to demonstrate metrological traceability for international acceptability.

(http://www.bipm.org/utils/common/pdf/BIPM-OIML-ILAC-ISO_joint_declaration_2011.pdf)

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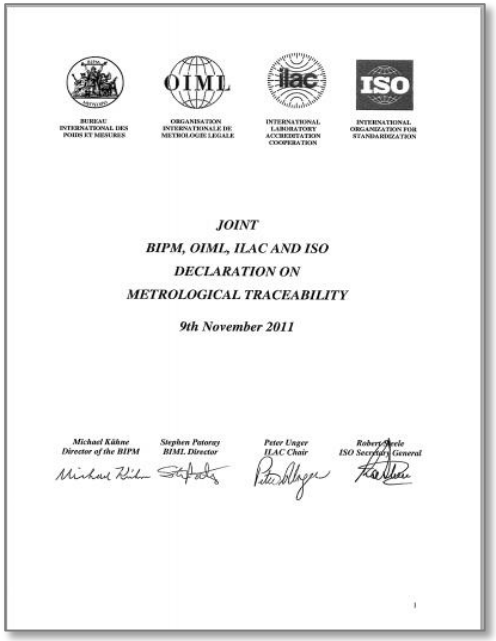

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Use of this Declaration

These principles underpin a world measurement system which provides a robust, internationally accepted framework within which users can have confidence in the validity and acceptability of measurements results. BIPM, OIML, ILAC and ISO strongly urge legislators and regulators to refer to the Arrangements described earlier in this Declaration and also to accept measurement results made within this system, thereby helping avoid technical barriers to trade. We also invite interested parties to endorse these principles and to make use of them in their own work.

BIPM, OIML, ILAC and ISO meet annually at senior level in a 'Quadripartite' informal discussion on issues of common interest

(http://www.bipm.org/utils/common/pdf/BIPM-OIML-ILAC-ISO_joint_declaration_2011.pdf)

Are you ready to submit your CMCs?

Example…

Part of your assessment will be to ensure that metrological traceability was properly addressed

Metrological traceability of the national standard	Metrological traceability of supporting measuring instruments that contribute to the measurement uncertainty	Technical evidence	Quality assurance
• *via a primary realization or* • *via another NMI or DI having relevant CMCs with appropriate uncertainty published in the KCDB,* • *or through calibration and measurement services offered by the BIPM*	• *via NMI or DI having relevant CMCs with appropriate uncertainty published in the KCDB* • *or via laboratory accredited by accreditation body participating in the ILAC MRA* *Example A: calibration of instrumentation related to the conditions under which the calibrations were made.* *Example B: dimensions of the piston/cylinder for deadweight tester*	*CMC declarations must be backed by evidence. Acceptable evidence as per CIPM MRA D-04* *Key and supplementary comparisons are the ideal supporting evidence*	*According to ISO/ IEC 17025 (ISO 17034 for CRM producers)* *Peer-Review and recognition according to the local RMO system*

Capacity Building & Knowledge Transfer

Thank you

andy.henson@bipm.org

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