L8 Metrological Traceability
Objectives

In this lecture we will:

➢ Define traceability of measurements
➢ Identify unbroken chains of traceability to primary standards
➢ Apply traceability concepts to measurement examples from dosimetry applications and
➢ Establish traceability through sample calibration procedures
6.5 Metrological traceability

6.5.1 Establish and maintain metrological traceability of measurement results by means of a documented unbroken chain of calibrations.

6.5.2 To ensure calibration and measurement made by the laboratory are traceable to the international system of units (SI) through:

a. calibration provided by a competent (ISO/IEC 17025 accredited) laboratory

b. certified values of certified reference materials provided by a competent producer (ISO 17034) to the SI

c. direct realization of the SI units ensured by comparison, directly or indirectly, with national or international standards.
6.5 Metrological traceability

6.5.3 Establish traceability to appropriate measurement standard (where calibration or metrological traceability is not as per SI units) as follows;

➢ The use of certified reference materials

➢ The use of results of reference measurement procedures, specified methods or consensus standards that are clearly described and accepted as providing measurement results fit for the intended use
VIM definition – Calibration

- **Calibration**: operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication.
  - **NOTE 1** A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.
  - **NOTE 2** Calibration should not be confused with adjustment of a measuring system, often mistakenly called “self-calibration”, nor with verification of calibration.
  - **NOTE 3** Often, the first step alone in the above definition is perceived as being calibration.
**Calibration hierarchy**: sequence of calibrations from a reference to the final measuring system, where the outcome of each calibration depends on the outcome of the previous calibration

- **NOTE 1** Measurement uncertainty necessarily increases along the sequence of calibrations.
- **NOTE 2** The elements of a calibration hierarchy are one or more measurement standards and measuring systems operated according to measurement procedures.
- **NOTE 3** For this definition, the ‘reference’ can be a definition of a measurement unit through its practical realization, or a measurement procedure, or a measurement standard.
- **NOTE 4** A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the quantity value and measurement uncertainty attributed to one of the measurement standards.
Metrological traceability: 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

- NOTE 1 For this definition, a ‘reference’ can be a definition of a measurement unit through its practical realization, or a measurement procedure including the measurement unit for a non-ordinal quantity, or a measurement standard.
- NOTE 2 Metrological traceability requires an established calibration hierarchy.
- NOTE 3 Specification of the reference must include the time at which this reference was used in establishing the calibration hierarchy, along with any other relevant metrological information about the reference, such as when the first calibration in the calibration hierarchy was performed.
- NOTE 4 For measurements with more than one input quantity in the measurement model, each of the input quantity values should itself be metrologically traceable and the calibration hierarchy involved may form a branched structure or a network. The effort involved in establishing metrological traceability for each input quantity value should be commensurate with its relative contribution to the measurement result.
VIM definition – Metrological traceability chain

• **Metrological traceability chain**: traceability chain sequence of measurement standards and calibrations that is used to relate a measurement result to a reference
  • NOTE 1 A metrological traceability chain is defined through a calibration hierarchy.
  • NOTE 2 A metrological traceability chain is used to establish metrological traceability of a measurement result.
  • NOTE 3 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the quantity value and measurement uncertainty attributed to one of the measurement standards.
Unbroken chain of calibration

A prerequisite to metrological traceability is a previously established calibration hierarchy:

- Primary standards laboratory
- (Secondary standards laboratories)
- Calibration services
- Measurement laboratory
Unbroken Chain

• An unbroken chain for traceability to a primary standard exists if any measurement devices and instruments by any laboratory other than the primary standards laboratory are calibrated by reference material directly linked or compared to primary standards laboratory measurements and by this to the International System of Units (SI).
Figure 1 Metrology act regulates the seven SI units, the three IR units, and their dissemination.
Figure 2 Governmental regulations: on one side the metrology and dissemination of units and on the other side the regulations about the use of radiation by the radiation protection legislation.
Recognized traceability to national standards of other countries
E.g Weighing
Unbroken Chain (Example)

➢ Primary standard laboratory produces reference material for use by calibration services
➢ Calibration services calibrate their measurement devices by reference material by primary standard laboratory
Calibration service produces reference material, certifies it by measurements on calibrated devices

Measurement service uses reference material by calibration service to calibrate measurement devices

Measurement service provides measurement results to customers
Reference Material

Information on reference materials necessary for calibration and measurement services:

➢ Standard reference date
➢ Reference data including reference value and associated uncertainties
➢ Certificate of traceability of reference material to primary standard through direct calibration or comparison
Traceability Recommendations

➢ Archiving and organisation of all calibrations standard data
➢ Archiving of all calibration procedures, calibration outcomes and calibration certificates
➢ Scheduling of periodic calibrations
➢ Retention of calibrated spare parts for important devices (reduces down-time in case of malfunction)
Metrological Traceability

[Diagram showing a network of institutions including IAEA, BIPM, PSDLs, SSDLs, and Users]
6.5 Metrological traceability

CERTIFICATE OF CALIBRATION

S.E. INTERNATIONAL, INC.
435 Farm Road P.O. Box 38 Summersown, TN. 38069
Ph: 921-624-3001 Fax: 921-624-3005
www.saint.com | radiationinfo@saint.com

Certificate Number: 17-2181
CAL DATE: 10/28/2017
CAL DUE DATE: 10/26/2018

Customer Information:

Minerology
Tim Flanagan
2860 W. Live Oak Dr.
Prescott, AZ 86305 USA

Instrument Information:

Instrument: Radiation Alert
Type: GM Survey Meter
Model: Inspector EXP
Serial: 23554-03622
Make: LND
Tube Model: 7317
Detector: External
Input Sens: 2 VDC
Input Voltage test: 50V/DC

Inspector EXP O/N# 23554-03622

Contamination Check: ☑
Alarm Check: ☑
Audio Check: ☑
Received: Out of Spec:
Mechanical Check:
Battery Check: 9.23VDC
Tolerance: ± 10% ± 20% Out of Spec

Calibration Data:

S.E. International, Inc. Certifies the above described instrument was calibrated in a known radiation field using a Ca^{137}(MnO_4^-) source of activity. The transfer Instrument was checked in a radiation field using a source of activity. The results are tabulated below. Measurements were made in accordance with the applicable standards and procedures. (See TENNESSEE LICENSE P-5100-21)

Precision/Conformance Check performed with Ca^{137} Source s/n 211891 [Precision: ± 10% ± 20%]

Consistency Check: 1 mCi of Ca^{137} indicates 34.11 mR/hr when placed against the center of the GM tube opposite the end window. This reading does at the Cal factor in which the unit was calibrated.

Reading 1: 34.29 mR/hr
Reading 2: 34.10 mR/hr
Reading 3: 33.93 mR/hr
Mean: 34.11 mR/hr
Temperature: 19.6 °C
Humidity: 42.1 %

Notes: Cal Factor is set at Cal 102. For more on the Cal Factor... see owners manual. 220v to bal... replaced.

<table>
<thead>
<tr>
<th>Decade Range</th>
<th>Reference Point</th>
<th>Instrument Meter Reading after Calibration</th>
<th>Correction Factors for &gt; +/- 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mR/hr - 100 mR/hr</td>
<td>50 mR/hr</td>
<td>5.03 mR/hr</td>
<td>None</td>
</tr>
<tr>
<td>1 mR/hr - 10 mR/hr</td>
<td>5.10 mR/hr</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>0.1 mR/hr - 1 mR/hr</td>
<td>0.49 mR/hr</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>0.1 mR/hr - 0.1 mR/hr</td>
<td>0.05 mR/hr</td>
<td>0.05 mR/hr</td>
<td></td>
</tr>
</tbody>
</table>

* Range addresses 2 (two) meter standards for instrument evaluation /+/-5% tolerance average.

Ca^{137} Gamma 6010 Capsule SN A-655 and Model 28-54 Calibrator SN 10261 calibrated monthly for decay
Multi-meter SN 0500300591 Cal Date: 15 Nov. 2016 Cal Due: 15 Nov. 2017

Calibrated by: Robert Russell
Metrological Traceability

- The dosimetry system should be designed and operated so that calibration and measurements are *traceable* to the quantities required such as the relevant operational quantities for individual monitoring of external radiation: dose equivalent $Hp(10)$, $Hp(0.07)$ and $Hp(3)$.

- Traceable calibrations/irradiations, together with reliable estimated uncertainties are provided by **NMI or accredited SSDL’s**. Typically, the calibration procedures and data used in these standard dosimetry laboratories follow the ISO standards for calibration of radiation protection instruments [ISO 4037, …]. So, it is very unlikely that you can produce your own metrological traceable calibration.

- Traceable calibration, that is those carried out by a standards laboratory, should be performed at regular intervals as part of the quality system. Recommendation: **at least every two years**.
Thermoluminescent Dosimeter

- Primary standards laboratory:
  - Establishes instrumentation to measure physical quantities (air kerma) by use of reference radiation fields (well characterised source activity – units in Bq).
  - Uses established conversion factors to relate physical quantities to operational radiation protection quantities (dose).
Thermoluminescent Dosimeter

- Measurement Laboratory:
  - Sends sample dosimeters to reference laboratory for irradiation under standard conditions (reference dose rate and dose, reference field parameters, ICRU slab phantom).
  - Uses irradiated dosimeters for direct comparison with measurements.
Calibration and Verification

- Reproducibility of the calibration should be controlled e.g. monthly by verification (quality control QC) of the calibration. The verification can be done under simplified conditions. For example, the verification is done using dosemeters irradiated free-in-air, instead of on a phantom, with a $^{137}$Cs source. This can be done using your own irradiator that does not have to be accredited.

- The metrological traceability of calibration cannot be achieved through this verification, but it can be used for QC purposes to verify the reproducibility of calibration or the reader. The verification of calibration can follow for example a QA-procedure, where the action limits for the stability/reproducibility of the calibration factors are stated, based on expertise, statistical data and experience of the laboratory.

- See separate lecture
Gamma Spectrometry

- Primary standard laboratory:
  - Calibration of reference material /sources with well defined activity of certain nuclides (units in Bq or Bq/mL).
  - For whole body counters:
    Calibration of a “physical phantom”, simulating the human body, with well defined activity.
Gamma Spectrometry

• Measurement laboratory:
  ➢ Calibration of gamma spectrometers by calibration reference material
  ➢ Gamma spectrometric measurements
  ➢ Possibly: removal of bias contributions by correction factors (e.g., cascade summing corrections, …)
Liquid Scintillation Counting

- Primary standard laboratory: Calibration by reference beta standard with well defined activity of certain nuclides (units in Bq or Bq/mL)
**Alpha Spectrometry**

- **Primary standard laboratory:**
  - Calibration of reference material with well defined activity of certain nuclides (units in Bq or Bq/mL).

- **Measurement laboratory:**
  - Calibration of alpha spectrometers by reference material or tracer