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The role of Cs-137 in international ionizing radiation metrology

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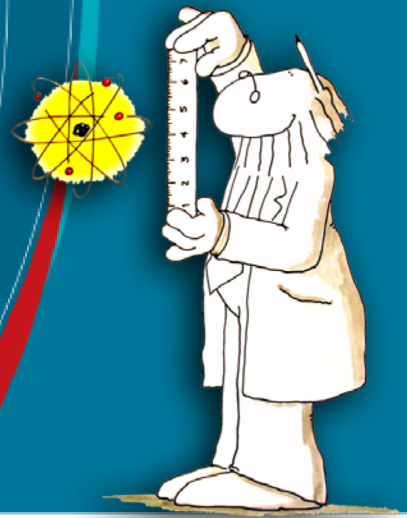
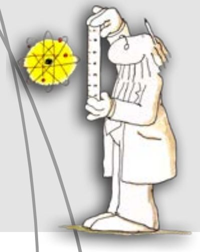
Chair, CIPM Consultative Committee on Ionising Radiation

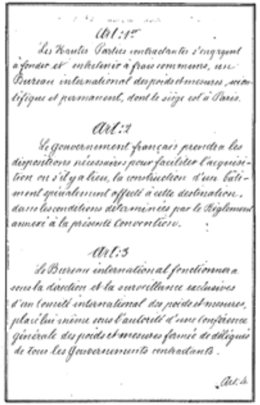


Outline



- Introduction to international metrology
- The need for demonstrating equivalence
- The role of Cs-137 as a reference radiation field
- Alternatives

Convention du Mètre



Art: 1er

Les Hautes Parties contractantes s'engagent à fonder et entretenir à frais communs, un Bureau international des poids et mesures, scientifique et permanent, dont le siège est à Paris.

Art: 2

Le Gouvernement français prendra les dispositions nécessaires pour faciliter l'acquisition ou s'il y a lieu, la construction d'un bâtiment spécialement affecté à cette destination, dans les conditions déterminées par le Règlement annexé à la présente Convention.

Art: 3

Le Bureau international fonctionnera sous la direction et la surveillance exclusives d'un Comité international des poids et mesures, placé lui-même sous l'autorité d'une Conférence générale des poids et mesures formée de délégués de tous les Gouvernements contractants.

Art: 4

Signed in Paris in 1875 (representatives of 17 nations)

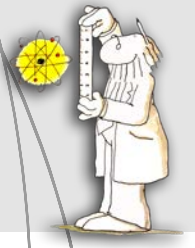
Established a permanent organizational structure for members on all matters relating to units of measurement

Created the BIPM – Bureau International des Poids et Mesures

- Intergovernmental organization (now 62 Member States)
- Under supervision of the International Committee for Weights and Measures (CIPM)
- Acts in matters of world metrology (demands for increasing accuracy, range and diversity)

Remains the basis of international agreement on units of measurement

CIPM MRA – the next step



Mutual Recognition Arrangement

Paris: 14th October 1999

40 entities originally, now 106 (plus 152 designated organizations)

Mutual recognition of

- ✓ National measurement standards
- ✓ Calibration and measurement certificates

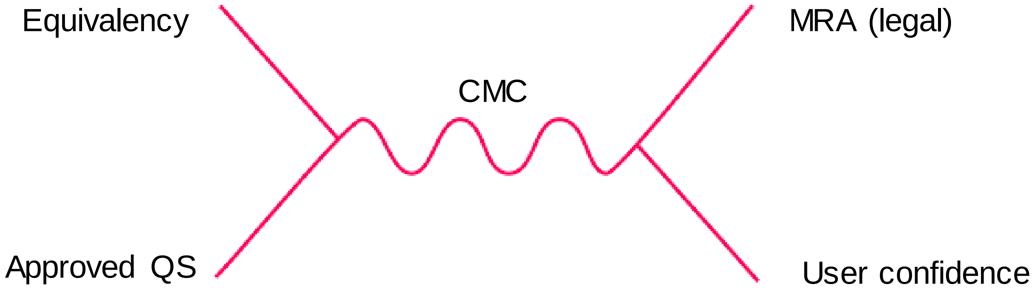
A legal framework that can be summarized by:
“Demonstrate science, Enable trade”

Calibration Measurement Capability

A CMC is the formal 'proof' that a laboratory can carry out a particular measurement

Comprises two components:

1. Demonstration of equivalency of a measurement standard with one or more other national standards
2. Demonstration of an internationally recognized quality system for the dissemination of the standard



CCRI
Consultative Committee on Ionizing Radiation

Consultative committees are the primary forum for discussing progress on primary standards and determining future directions (for NMIs and BIPM)

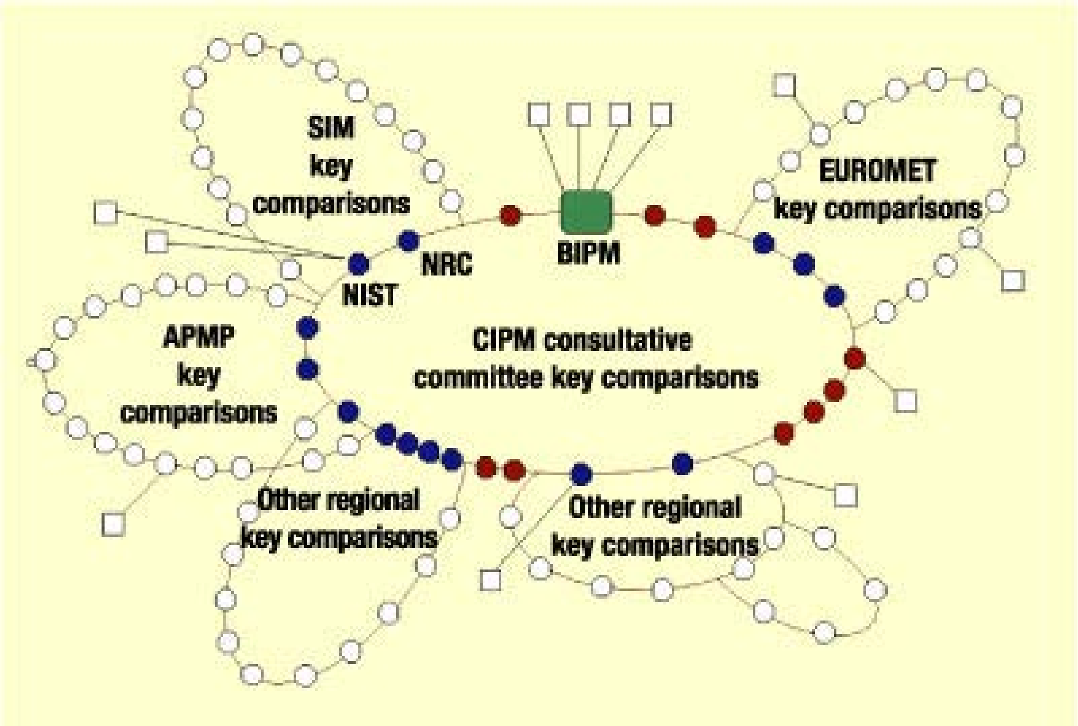
CCRI established 1958

3 distinct sections – dosimetry, radioactivity, neutrons

Activities

- Definitions of quantities and units
- Standards for x-ray, γ-ray, charged particle and neutron dosimetry
- Radioactivity measurements
- Advice to CIPM regarding IR standards and BIPM activities
- **Approves comparisons of specific quantities**

Equivalency requires a comparison

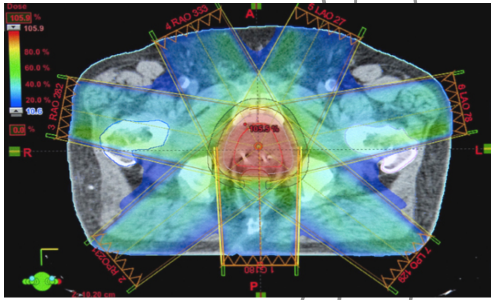


There are various ways to compare and demonstrate equivalency

For all Ionizing Radiation comparisons a **radiation field** is required

Now we get to the physics

In radiation dosimetry we want to measure the energy deposited by a radiation beam in some material



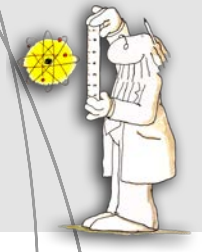
Most often that material is the human body (radiation therapy, radiation protection)

Ideally, a radiation detector for this purpose (a dosimeter) would have a response that was energy independent

> i.e., it would only respond to the energy deposited, not the type of beam interacting with matter

Practical detectors are not ideal!

Applications



An added challenge is that we also need to consider beam intensity:

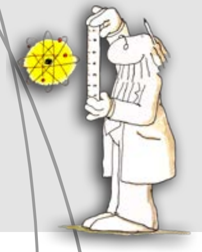
- A detector appropriate for radiation therapy will not have the sensitivity for radiation protection measurements (> factor 1000 difference in intensity)

Geometry is also important:

- Radiation therapy uses a directed beam, radiation protection assumes a more uniform distribution

To demonstrate equivalence we need the right kind of detector in the right kind of radiation beam

Comparisons for dosimetry



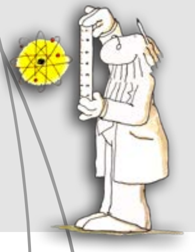
Comparison	Quantity	Energy	Year
BIPM.RI(I)-K1	Air kerma	Co-60	Ongoing
BIPM.RI(I)-K2	Air kerma	10-50 keV	Ongoing
BIPM.RI(I)-K3	Air kerma	50-250 keV	Ongoing
BIPM.RI(I)-K4	Absorbed dose to water	Co-60	Ongoing
BIPM.RI(I)-K5	Air kerma	Cs-137	Ongoing
BIPM.RI(I)-K6	Absorbed dose to water	4-25 MV (linac photons)	Ongoing
BIPM.RI(I)-K7	Air kerma	mammography	Ongoing
BIPM.RI(I)-K8	air kerma strength	Ir-192 HDR	Ongoing
BIPM.RI(I)-K9	Absorbed dose to water	50-250 keV	New

Need a different radiation field for each application

May also need a different radiation field for different beam intensities

All these have been approved by the international community

Comparisons for dosimetry



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BIPM.RI(I)-K5	**Air kerma**	**Cs-137**	**Ongoing**
BIPM.RI(I)-K6	Absorbed dose to water	4-25 MV (linac photons)	Ongoing
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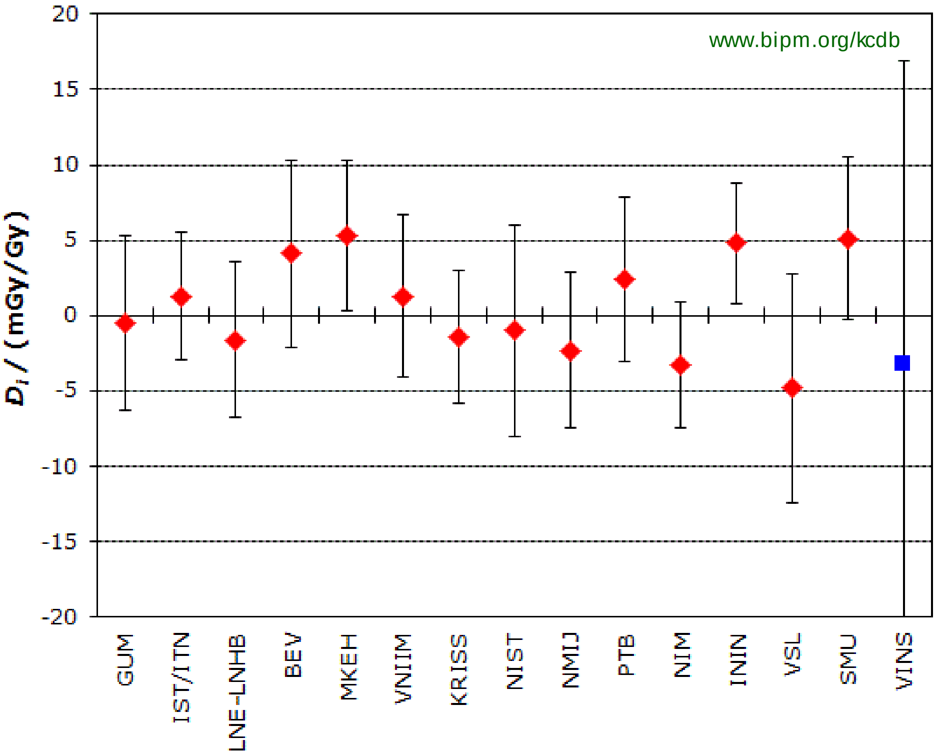
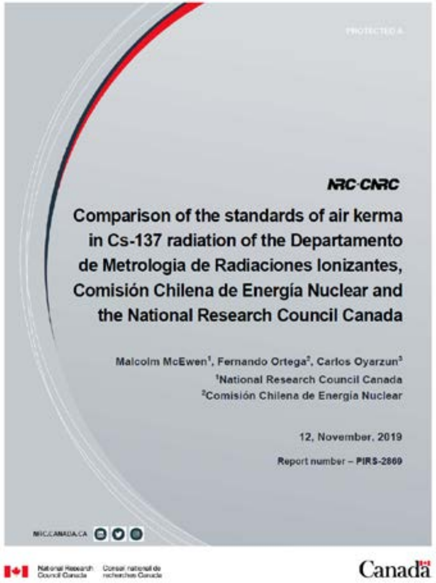
BIPM.RI(I)-K5



Laboratories from Europe, North America, Central America, Asia

Not the only option for comparisons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Comparison of the standards of air kerma in Cs-137 radiation of the Departamento de Metrologia de Radiaciones Ionizantes, Comisión Chilena de Energía Nuclear and the National Research Council Canada

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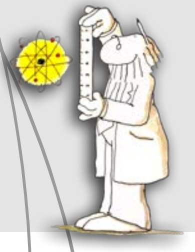
Canada

Why Cs-137?



We’ve established we need comparisons and comparisons require radiation fields

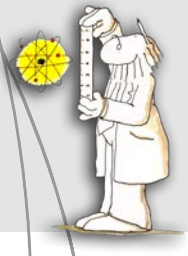
But which beams are appropriate/necessary?

Need to cover from ~ 10 keV to ~ 10 MeV

Cs-137 provides a photon energy in the region between x-ray tubes and Co-60 and linear accelerators

(Half-life and availability in suitable intensity and form also relevant)

Implications of international standardization on Cs-137



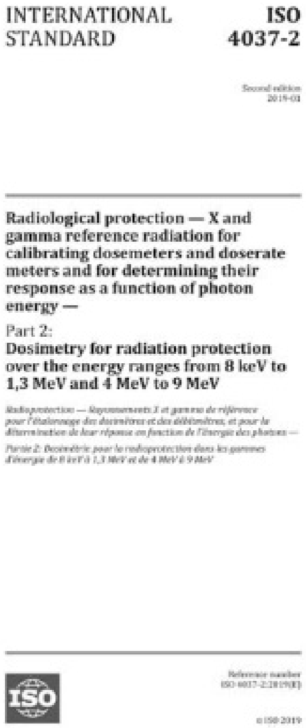
International standardization means:

1. Cs-137 is one of the agreed beams in which detectors are compared

2. Cs-137 becomes a beam that is required for detector characterization and performance specification

3. Significant knowledge and procedures built upon the assumption of the availability of Cs-137 radiation fields

Infrastructure, specifications, procedures



INTERNATIONAL STANDARD

ISO 4037-2

Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy —

Part 2:
Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV

Reference number
ISO 4037-2:2019(E)

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Why radiation sources in metrology at all?

A National Measurement Institute needs stable references to maintain its measurement capabilities

Electrically generated radiation fields are inherently less table than isotope-based radiation fields

Radioactive sources have only two ‘free’ parameters:

- Half-life
- Geometrical precision (positioning)

Makes them very hard to replace

POINT/COUNTERPOINT

Calibration of radiotherapy ionization chambers using Co-60 is outdated and should be replaced by direct calibration in linear accelerator beams

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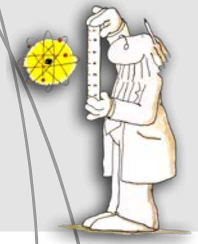
OVERVIEW

No Cs-137?



No obvious replacement as a reference radiation field for ionizing radiation metrology

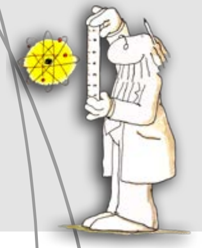
Limited number of other gamma-emitting sources, very limited when filtered for suitable line spectrum, half-life and cost

Electrically generated sources are currently either too low in energy (DC kV x-ray tubes) or not sufficiently stable (linear accelerators)

Just accepting a gap in the photon spectrum means higher uncertainties

Capabilities of NMIs are compromised – users affected

Summary



International metrology demonstrates the equivalence of measurements in different countries and enables trade

In ionizing radiation, Cs-137 is used in one of the Key Comparisons organized by the BIPM

Decades of comparison data are dependent on the ongoing availability of Cs-137 beams

There is no simple alternative to Cs-137 without negatively impacting both NMI accuracy and dissemination to users

THANK YOU

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