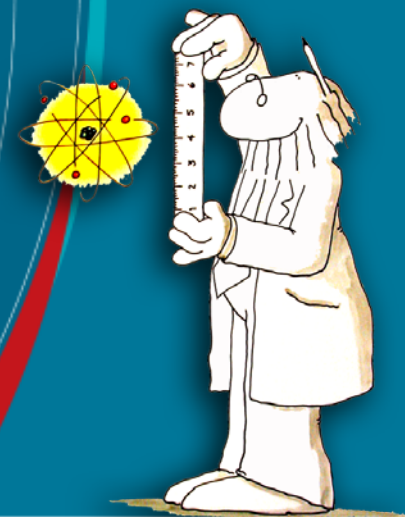


The role of Cs-137 in international ionizing radiation metrology

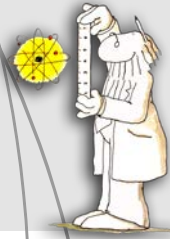
Malcolm McEwen

January 2021

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



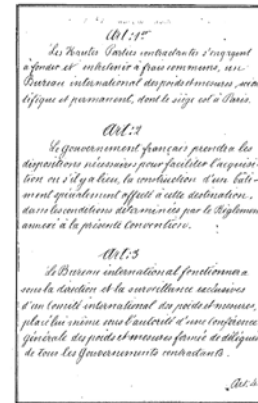
Signed in Paris in 1875 (representatives of 17 nations)

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”



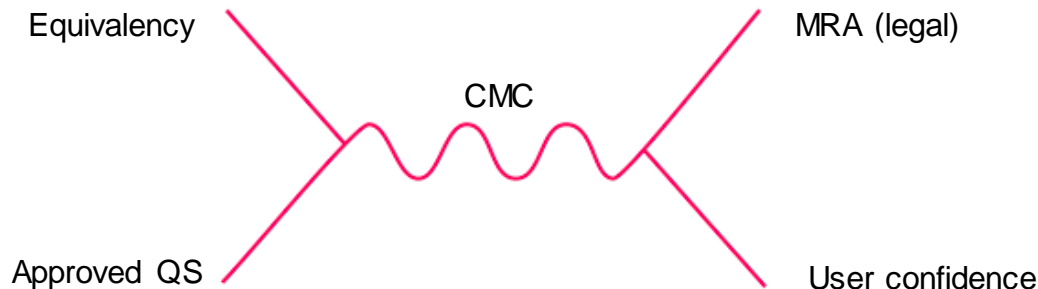
Calibration Measurement Capability



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

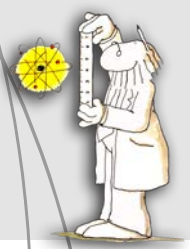
Comprises two components:

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

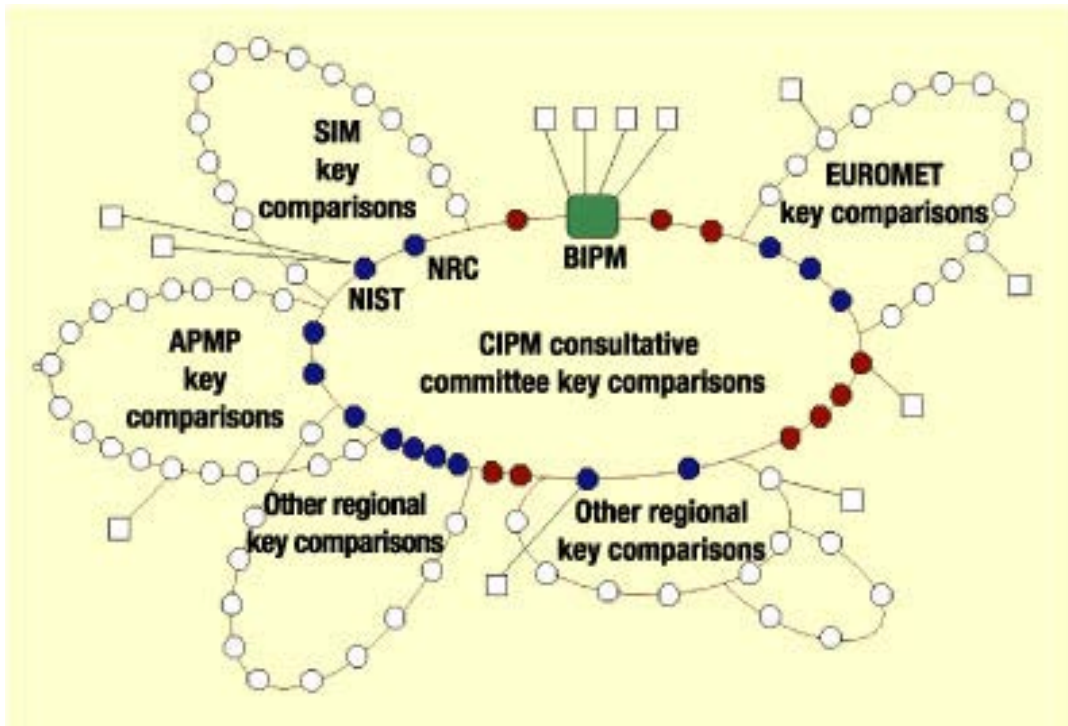
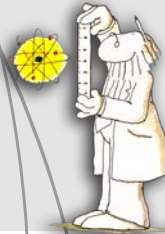
3 distinct sections – dosimetry, radioactivity, neutrons

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**

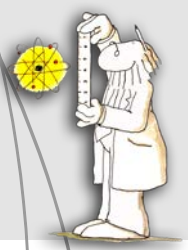


Equivalency requires a comparison



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

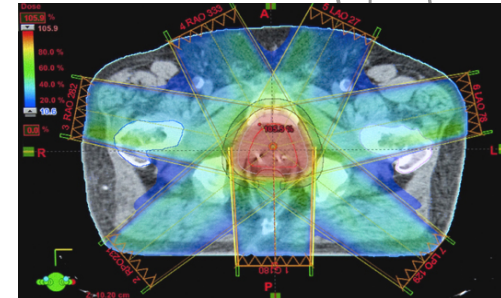
In radiation dosimetry we want to measure the energy deposited by a radiation beam in some material

**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

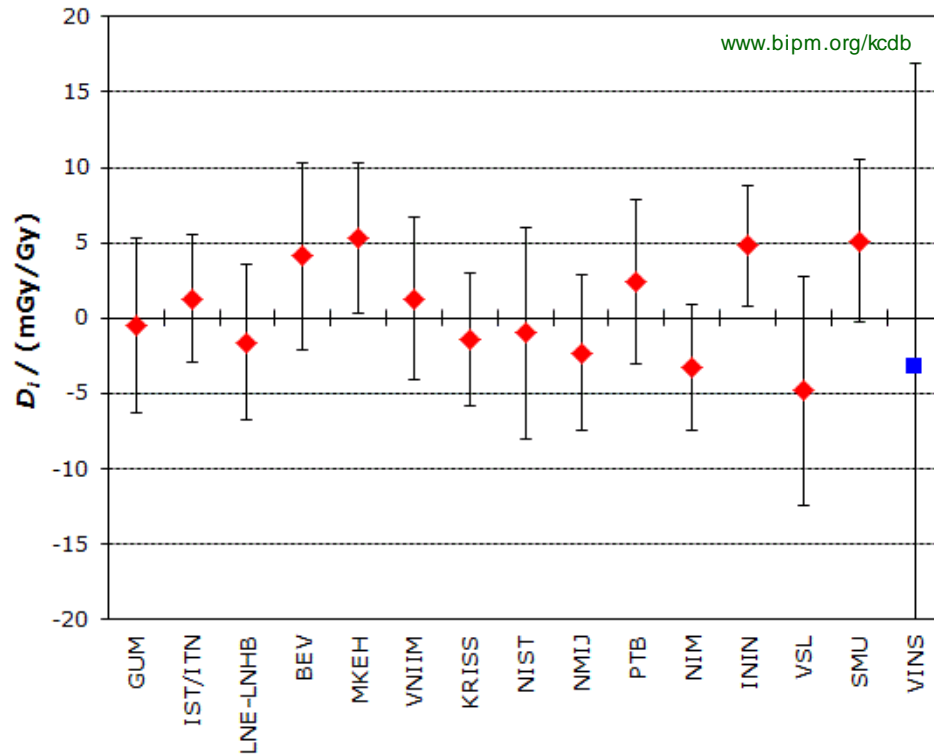
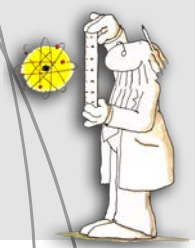
All these have been approved by the international community



Comparisons for dosimetry

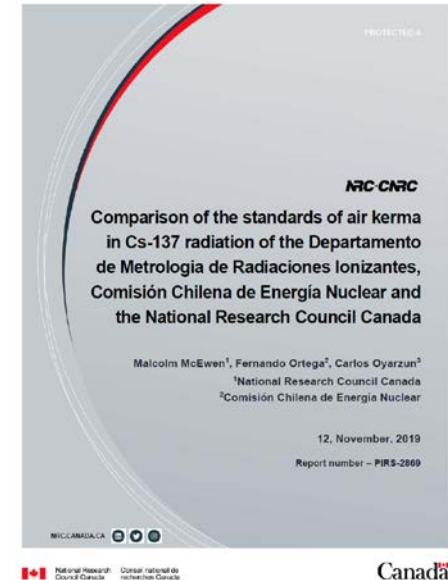
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BIPM.RI(I)-K5	Air kerma	Cs-137	Ongoing
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BIPM.RI(I)-K8	air kerma strength	Ir-192 HDR	Ongoing
BIPM.RI(I)-K9	Absorbed dose to water	50-250 keV	New

BIPM.RI(I)-K5



Laboratories from Europe,
North America, Central
America, Asia

Not the only
option for
comparisons





Why Cs-137?

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

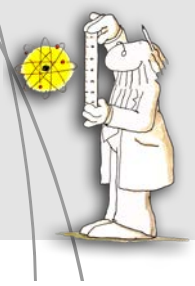
But which beams are appropriate/necessary?

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

Second edition
2019-03

Radiological protection — X and gamma reference radiation for calibrating dosimeters 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

*Radioprotection — Rayonnements X et gamma de référence pour l'étalonnage des dosimètres et des dosimètres, et pour la détermination de leur réponse en fonction de l'énergie des photons —
Partie 2: Dosimétrie pour la radioprotection dans les gammes d'énergie de 8 keV à 1,3 MeV et de 4 MeV à 9 MeV*



Reference number
ISO 4037-2:2019(EN)

© ISO 2019



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 stable 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

Suggestions for topics suitable for these Point/Counterpoint debates should be addressed to Colin G. Orton, Professor Emeritus, Monash University, Physics, Victoria Campus, 246 Clayton Rd, Clayton, Australia. Tel: 61 3 9421 2275. E-mail: ramanathan.ganesan@monash.gov.au

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

Ramanathan Ganesan, Ph.D.,
Radiation Physics, Medical Radiation Services Branch, Australian Radiation Protection
and Nuclear Safety Agency, Melbourne 3001, Victoria, Australia
Tel: 61 3 9421 2275. E-mail: ramanathan.ganesan@monash.gov.au

Colin G. Orton, Ph.D.,
Ionizing Radiation Standards, National Research Council of Canada, Ottawa, Ontario K1A 0R6, Canada
Tel: 613 993 2797 Ext 226. E-mail: colin.orton@nrc.ca

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<http://dx.doi.org/10.1111/1461-4022.12148>

OVERVIEW

Most medical linear accelerators worldwide are calibrated using ionization chambers that are themselves calibrated by a standards laboratory, or secondary standards laboratory, in a Co-60 beam. Because these chambers are actually used to calibrate high-energy x-ray beams, it has been suggested that calibration against Co-60 is outdated and should be replaced by calibration in linear accelerator beams. This is the claim advanced in this month's Point/Counterpoint.



Arguing for the Proposition is Ramanathan Ganesan, Ph.D. Dr. Ganesan earned his Ph.D. in Physics from the University of Mumbai in 2001, having previously worked for many years as Scientific Officer in the Radiation Standards Section, Radiation Safety Systems Division, BARC, Trombay, Mumbai, India. Subsequently, he spent some time working at the National Physical Laboratory, UK, and NIST, Gaithersburg, MD, USA, before he moved to his current position as Senior Radiation Scientist, Radiotherapy Section Medical Radiation Services Branch, Australian Radiation Protection and Nuclear Safety Agency, Melbourne, Victoria, Australia. His major research interests are calibration measurements of photon and electron beams, calibration of dosimeters, small field

dosimetry, development of diamond and diode detectors, and calibration of environmental radiation dosimeters.



Arguing against the Proposition is Malcolm R. McEwen, Ph.D. Dr. McEwen earned his Ph.D. in Radiation Physics from the University of Surrey, UK, in 2002, having previously worked for many years at the Centre for Imaging Radiation Metrology, National Physical Laboratory, UK. He then moved to his current position as Research Officer at the Ionizing Radiation Standards Group, National Research Council of Canada, Ottawa, Canada, where he is Director of the Ottawa Medical Physics Institute and Adjunct Professor within the Department of Physics, Carleton University. Dr. McEwen is Chairman of the Consultative Committee for Ionizing Radiation Section I of the Bureau International des Poids et Mesures and has been very active in the AAPM including having served as Chair of the Working Group to review and extend data in the AAPM TG-51 dosimetry protocol for radiotherapy, and he is the current Chair of the AAPM Calibration Laboratory Accreditation Subcommittee. His major research interests are improvements in reference dosimetry for radiation therapy, experimental and theoretical work on the performance and application of secondary dosimeters in high energy photon and electron beams, investigation of novel dosimeters/applications in dosimetry at radiotherapy dose levels, and development of



No Cs-137?

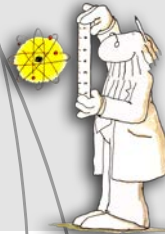
No obvious replacement as a reference radiation field for ionizing radiation metrology

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



malcolm.mcewen@nrc-cnrc.gc.ca

