Producing Traceable Irradiations for Calibration of Dosimeters or Instruments

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Overview

- United States Department of Energy (DOE) Laboratory Accreditation Program (DOELAP) for Dosimetry
  - Performance testing of DOE labs' dosimetry programs
  - Photons, betas, neutrons, and mixtures
  - Photon and beta irradiations performed at the Radiological and Environmental Sciences Laboratory (RESL) in Idaho

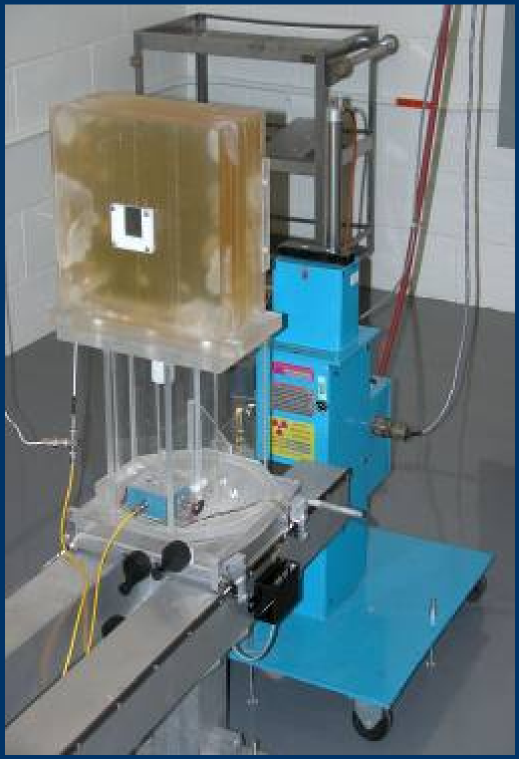
Photon Irradiations

- Isotopic photon sources
  - Am-241 (59 keV)
  - Cs-137 (662 keV)
  - Co-60 (1.2 MeV, 1.3 MeV)
- X-rays
  - National Institute of Standards and Technology (NIST) beams
  - International Organization for Standardization (ISO) beams

Traceable Irradiations

- Isn't it just a matter of using a calibrated source?
- Isn't it just a matter of using a calibrated instrument, time, and distance?
- What is "traceable?"
- From NIST: "the establishment of an unbroken chain of comparisons to stated references"

Isotopic Sources



Am-241

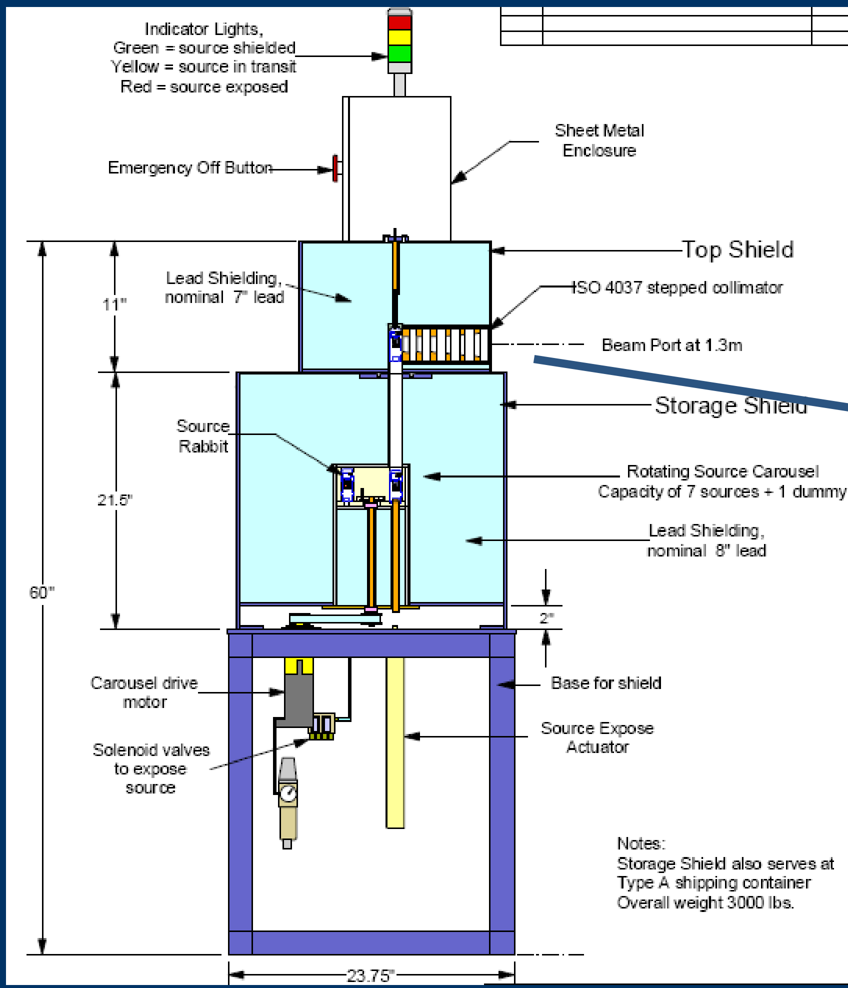
Co-60 and Cs-137

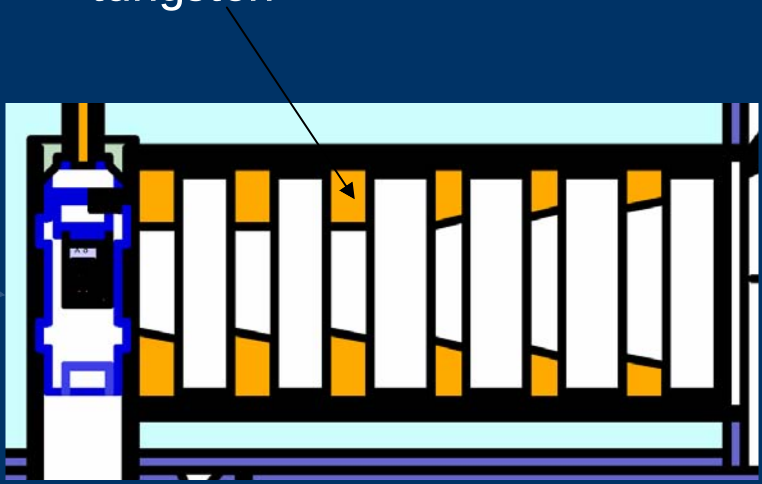
Cs-137

Isotopic Source Characterization

- Source specification
  - <1% K_a from impurities
  - Chemical form, specific activity
  - Encapsulation to reduce unwanted radiations
- Facility considerations
  - <5% K_a from scatter (inverse square test)
  - Collimator to reduce scatter from irradiator

Isotopic Source Characterization





Example of ISO Collimator

Isotopic Source Characterization

- Standard Instrument
  - “Reference” ionization chamber – stable to within ±2%
  - Calibrated, traceable
- Other considerations
  - Warmed up
  - At least four readings
  - Shutter transit time
  - Conversion coefficients
- Calibrated electrometer
- Orientation of ion chamber
- Leakage
- Location
- Beam size
- Chamber support

Isotopic Source Characterization

- Incomplete ion collection?
- Beam non-uniformity

- What are considerations for open ion chambers?
  - Temperature
  - Pressure
  - Humidity

Transfer Standard

- Ion chamber is given K_a/C value traceable to (or from) NIST or other national reference lab
- Measured current (C/s) multiplied by calibration factor yields air kerma rate
- Exposure time determines air kerma
- Dosimeters mounted on a “phantom”
- Published C_K conversion coefficients yield personal dose equivalent

Corrections to Isotopic Sources

- Decay
- Interpolation between calibration positions
- Electronic equilibrium

Electronic Equilibrium

- Required to ensure depth dose is the same regardless of geographical location
- Must create for Cs-137 and Co-60
- Depth dose measured in phantom with extrapolation chamber
- Buildup cap on ion chamber is still required

Electronic Equilibrium

Uncertainty

- Must estimate for each contributor
- Methods presented in Guide to the Expression of Uncertainty in Measurements (GUM)
  - BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML (1993)
  - ANSI/NCSL Z540-2-1997 (R2002)
  - NIST Technical Note 1297 (1994)

Elements of Uncertainty

Cs-137 Example

Source	Type A	Type B	Total
Calibration Distance	-	0.082%	0.082%
Phantom Distance	-	0.082%	0.082%
Beam Uniformity	0.29%	-	0.29%
Computer Time	0.0024%	0.0067%	0.007%
Electrometer Current	0.3%	0.12%	0.32%
Calibration of ion chamber	-	0.7%	0.7%
Pressure	-	0.04%	0.04%
Temperature	-	0.25%	0.25%
Combined Uncertainty			0.87%
Expanded Combined Uncertainty			**1.7%**

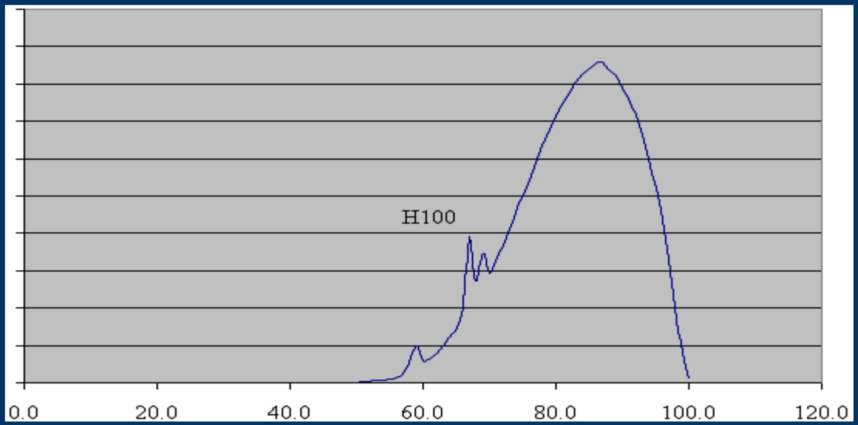
Am-241 Example

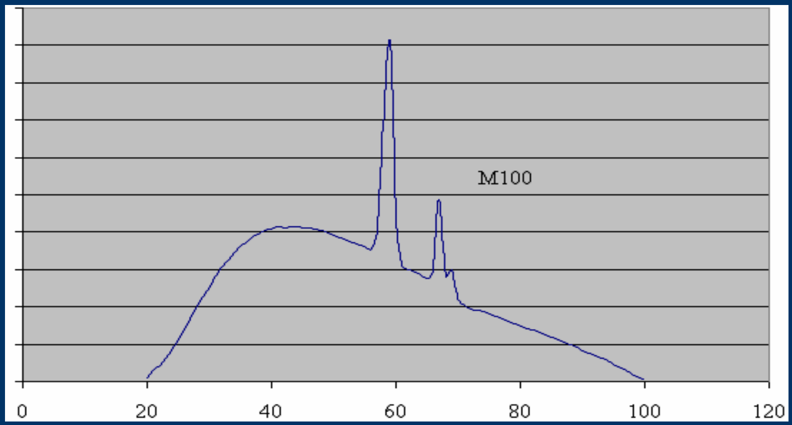
Source	Type A	Type B	Total
Calibration Distance	-	0.226%	0.226%
Phantom Distance	-	0.226%	0.226%
Beam Uniformity	1.5%	-	1.5%
Computer Time	0.0027%	0.0067%	0.007%
Electrometer Current	0.1%	0.12%	0.15%
Calibration of ion chamber	-	0.85%	0.85%
Pressure	-	0.04%	0.04%
Temperature	-	0.25%	0.25%
Combined Uncertainty			1.8%
Expanded Combined Uncertainty			**3.5%**

X-ray Source

X-ray Beam Quality

- Determined by ISO or NIST
- Function of peak energy and filtration
  - ISO: NS, WS, LK, HK
  - NIST: L, M, H, S





X-ray Beam Quality

- How is it measured?
- Half-value layer (HVL) and homogeneity coefficient (HC)
  - HVL: ±5%
  - HC: ±10%
  - HC = $[HVL_1/HVL_2] \times 100$
- No uncertainty estimation required

X-ray Beam Quality

Characteristics of NIST Photon Beam Techniques

NIST Tech.	Added Filter[a]				Half-Value Layer		Homogeneity[b] Coefficient		$\bar{E}$ (keV)	FWHM (keV)
Beam Code	Al (mm)	Cu (mm)	Sn (mm)	Pb (mm)	Al (mm)	Cu (mm)	Al	Cu		
M100	5				5.02		73		53	42
H100	4	5.2			13.5	1.14	100	94	83	23
H150	4	4	1.51		17	2.5	100	95	118	44
H200	4	0.6	4.16	0.77	19.8	4.1	100	99	162	52
H250	4	0.6	1.04	2.72	22	5.2	100	98	204	61
H300	4.1		3	5	23	6.2	99	98	251	68

X-ray Source

Free-air ion chamber (FAIC)

X-ray Source

Free-air ion chamber (FAIC)

Transfer Standard for X-rays

- X-ray source: fluctuations in current and voltage could affect results
- Calibration transferred from ion chamber to x-ray machine back to transmission chamber for active measurement

Elements of Uncertainty

X-ray Example

Source	Type A	Type B	Total
Calibration Distance	–	0.085%	0.085%
Phantom Distance	–	0.085%	0.085%
Beam Uniformity	0.81%	–	0.81%
Computer Time	–	0.007%	0.007%
Electrometer Current	0.1%	0.12%	0.15%
Calibration of ion chamber	0.3%	0.5%	0.6%
Pressure	–	0.04%	0.04%
Temperature	–	0.25%	0.25%
Combined Uncertainty			1.1%
Expanded Combined Uncertainty			**2.1%**

For Further Reading

- ISO 4037-1,2,3 *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy*, (1996-1999)
- http://ts.nist.gov/Standards/Accreditation/upload/hb150-2d.pdf *Technical Guide for Ionizing Radiation Measurements*

DOELAP Program Status

- Still using DOE standards for accreditation of whole body dosimetry
- Still using ANSI/HPS N13.32-1995 for extremity dosimetry
- Updated onsite assessment checklist to include criteria for OSL (optically stimulated luminescence) assessment

DOELAP Program Status

- DRAFT standard written updating assessment criteria to ISO 17025:2005
  - Adopts ANSI/HPS N13.11-2001
  - Leaves room to adopt N13.11-200X and N13.32-2007
- Program requirements rewritten to adopt ISO 17011:2004
- Undergone informal review
- Anticipated release for formal review this year

DOELAP Program Status

- Some program elements may be affected by new US regulation changes in 10CFR835
- Roundtable on last day of Health Physics Society meeting in Portland (July 2007) to discuss dosimetry implications

Questions?