Setup and Characterization of a Cesium-137 Dosimetry Calibration Source in a Space-Constrained Environment

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Abstract

Proper characterization of Cesium-137 sources used for dosimeter calibration and performance testing is crucial for accurate and precise knowledge of Air Kerma rate and delivered dose. A 270 GBq Cesium-137 source was relocated to a new facility, which had a footprint of approximately 2.8 m x 3.6 m and a 3.4 m high ceiling. A small room size, such as in the new facility, may significantly increase backscatter from the walls, or room return. Due to the limited source strength, a relatively close irradiation position of 1 m from the source was selected to decrease required exposure times. Proximity to the small but cylindrical source has the potential to alter the one-over-r^2 relationship of air kerma rate with distance associated with point sources. Practical tutorials concerning dosimetry irradiation facilities are largely absent from the archival literature. For those reasons, standard characterization experiments were repeated multiple times, great care was taken with positioning, several experiments were added to the standard ones, an ion chamber was used rather than film or dosimeters for greater accuracy and precision, and practical details of the process were recorded. The impacts of room size and finite source dimensions were quantified and mitigated by the efforts reported here. Recommendations for simple but thorough facility characterization, beam calibration and quality control resulted.

Introduction:

- Cs-137 is commonly used for performance testing of personal dosimetry such as thermoluminescent dosimeters (TLDs) and optically stimulated luminescence dosimeters (OSLDs).
- It is important that the source used for such testing is well characterized and the behavior understood as completely as possible.
- A polymethyl methacrylate (PMMA) phantom designed to meet personnel dosimetry performance testing standards (ANSI, DOE, and CNSC) was used for calibration and experimentation.
- An Cs-137 irradiation source was relocated and experiments were performed to characterize it in its new environment.

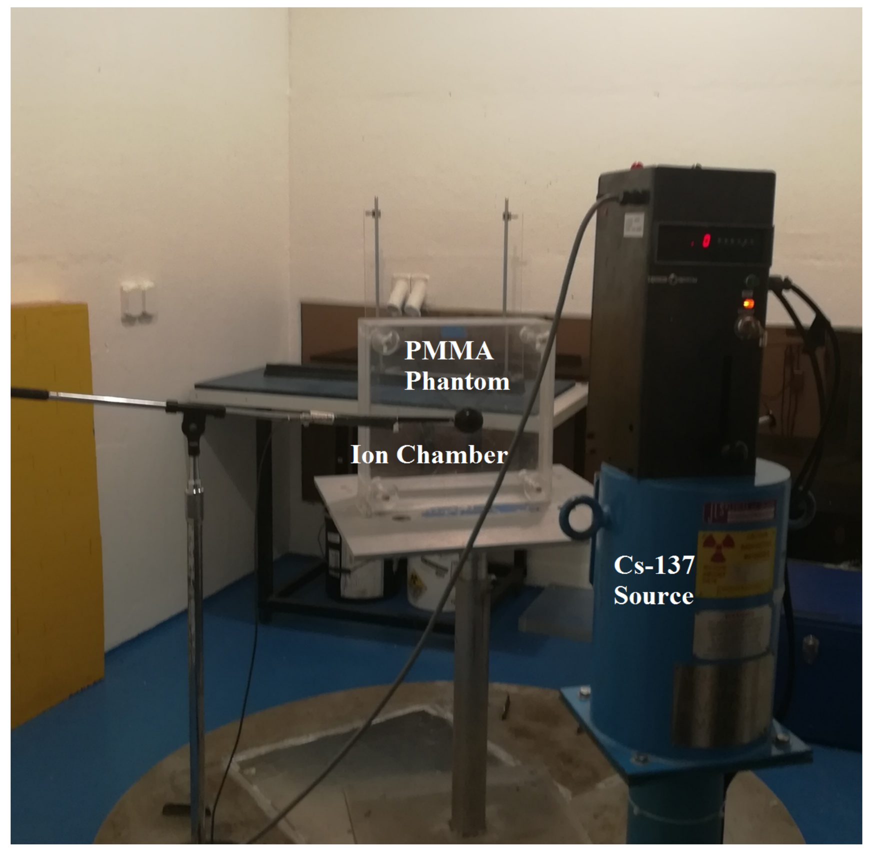
Methods:

The Cs-137 facility was tested for:

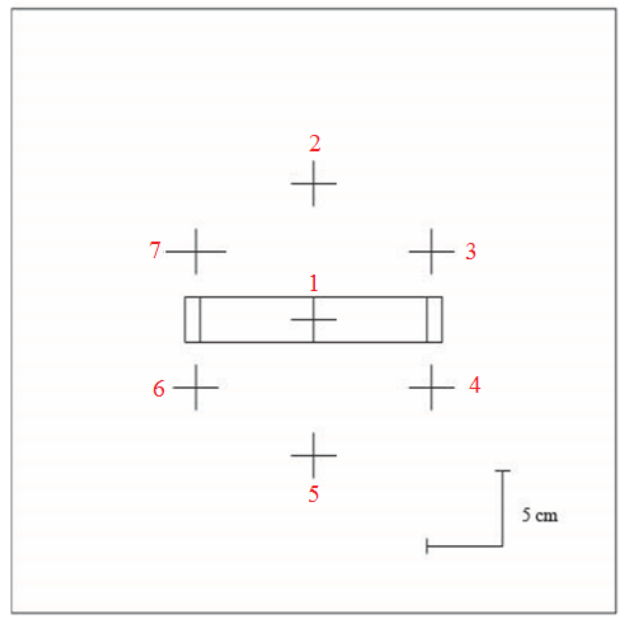
- Phantom alignment
- Behavior across phantom face: 100 measurements at 100 equally-spaced positions
- Consistency of dose rate
- Half value layer (for Pb)
- Inverse square behavior
- Backscatter/room return

Measurements were taken using an NIST traceable ion chamber in charge collection mode.

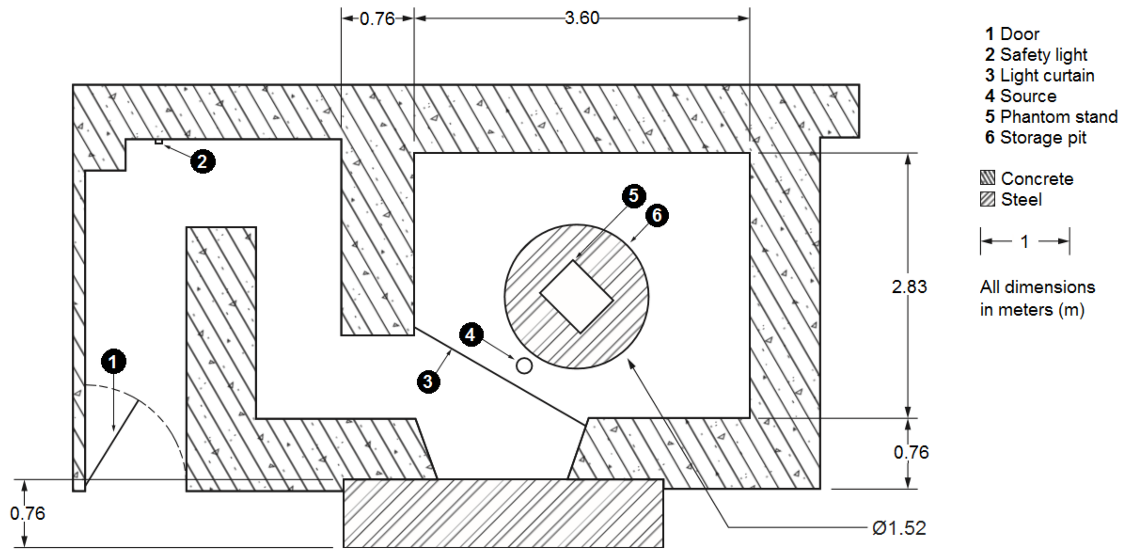
Setup for taking Cs-137 measurements



Isodose Ring Positions on Face of Phantom



Cs-137 Facility Floor Plan



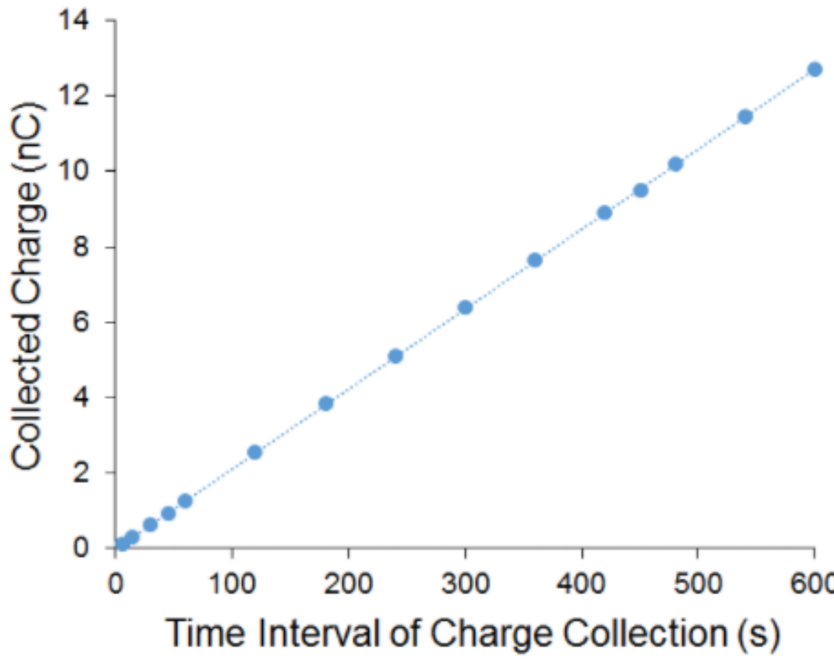
Result 1

Position	Average Air Kerma Rate (mGy h^{-1})	Standard Deviation	% CV
1	24.85	0.51	2.07
2	23.85	0.73	3.06
3	24.39	0.39	1.60
4	24.47	0.07	0.31
5	23.90	0.71	2.96
6	24.30	0.03	0.13
7	24.46	0.42	1.73

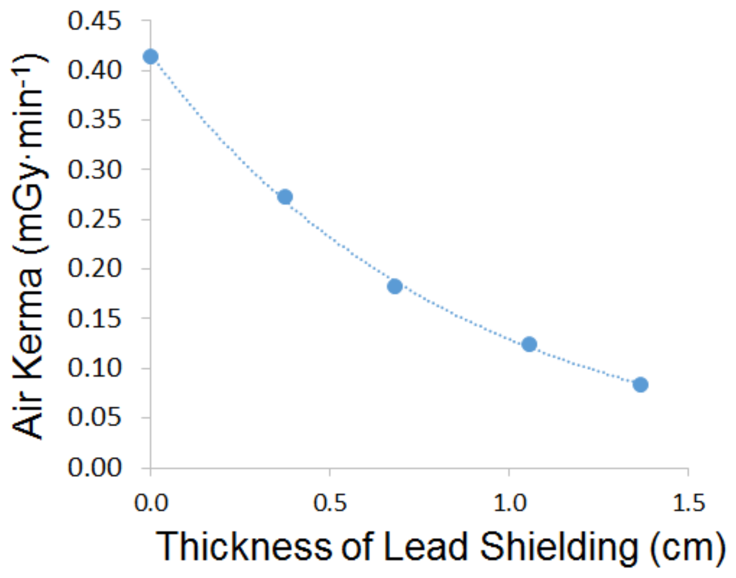
Result 2

11.6	15.4	19.9	21.6	24.5	24.5	21.6	19.9	15.4	11.6
15.4	12.4	5.7	7.2	5.4	5.4	7.2	5.7	12.4	15.4
19.9	5.7	5.4	2.4	2.6	2.6	2.4	5.4	5.7	19.9
21.6	7.2	2.4	1.0	0.6	0.6	1.0	2.4	7.2	21.6
24.5	5.4	2.6	0.6	0.1	0.1	0.6	2.6	5.4	24.5
24.5	5.4	2.6	0.6	0.1	0.1	0.6	2.6	5.4	24.5
21.6	7.2	2.4	1.0	0.6	0.6	1.0	2.4	7.2	21.6
19.9	5.7	5.4	2.4	2.6	2.6	2.4	5.4	5.7	19.9
15.4	12.4	5.7	7.2	5.4	5.4	7.2	5.7	12.4	15.4
6.7	3.0	2.9	2.4	0.3	0.3	2.4	2.9	3.0	6.7

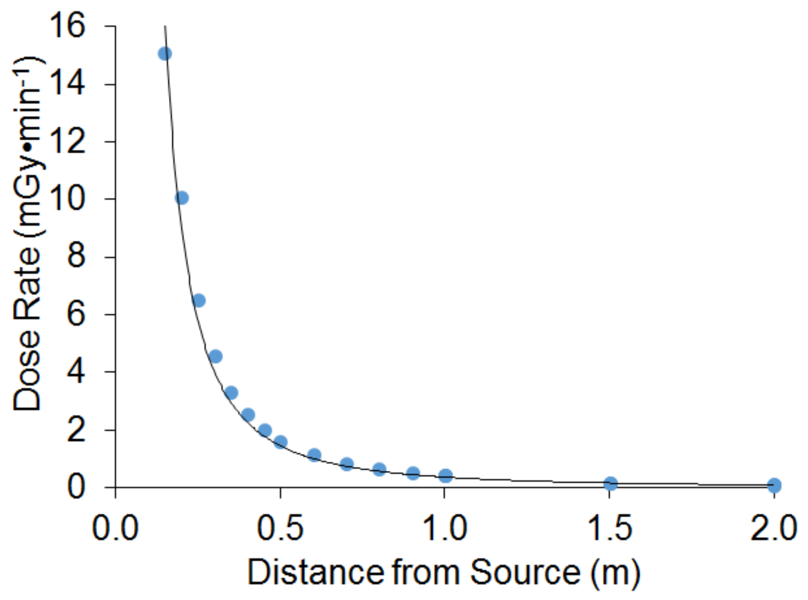
Result 3



Result 4



Result 5



Key Results:

1. Measurements taken around the 9 cm radius isodose ring over a period of five separate days resulted in an average 1.65% coefficient of variance between measurements taken. As seen in the table, positions 2 and 5 had the highest standard deviations.
2. Grid measurements taken within the 20 x 20 cm area used for OSL calibration resulted in a dose rate coefficients of variance below 3.5%.
3. The relationship between charge collection and time of irradiation demonstrates linearity with a R^2 value of 0.99997.
4. Based on the exponential fit, the thickness of lead shielding necessary to reduce the exposure at the face of the phantom by a factor of 2 was found to be 0.597 cm.
5. The relationship between the distance of the irradiator to the distance of the ion chamber fit an inverse square model, with measurements taken as close as 15 cm.
6. Backscatter from the PMMA phantom accounts for 6.5% of the overall measurements taken with the phantom in place.

Conclusions:

- The linear fit of the relationship between time of irradiation and charge collected at small time intervals suggests that the time for the source to rise and fall is negligible.
- The Cs-137 source behaves like a point source at distances of at least 15 cm.
- Scattering from the tissue equivalent phantom accounts for a significant portion, 6.5%, of the overall exposure rate at the front of the phantom. It is important to adjust for this for experiments conducted without a phantom present.
- Measurements taken along the 100 grid confirmed the expected edge effects from the set isodose range on the phantom face.
- The standard deviation in the exposure rate between equidistant points in the center of the phantom differ no more than 1.0% in the center sixteen 4 x 4 cm squares.

Acknowledgements

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References

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