Estimating Dose Rates and Photon Energy Spectra in Sandia's Low Intensity Cobalt Array

Nathan Hart

Sandia Nat'l Labs – 1515 Eubank Blvd NE MS1145 – Albuquerque, NM, 87123 – nhhart@sandia.gov – (505)284-3556

INTRODUCTION

The Low Intensity Cobalt Array (LICA) at Sandia National Laboratories is an underwater irradiation structure, located in the Gamma Irradiation Facility (GIF) pool, which is used for long-term cobalt-60 gamma irradiation of materials typically seen in nuclear systems. The samples can be environmentally controlled and monitored. Due to the array's position on the bottom of an 18-foot pool of water, measurements are impractical outside of TLD dosimetry, which only produces the total absorbed dose. By modeling the LICA using Monte Carlo N-Particle software (MCNP6) and comparing it to measured TLD values, the dose rates and energy spectra can be estimated for the locations within the LICA.

MODELING THE LICA

Using drawings, blueprints, and measurements of the LICA, the geometry of the structure was created using transformations of rectangular parallelepipeds (RPPs) and corresponding transformation cards. Two rows of Co-60 source pins were modeled as separate rectangular arrays with two universes designated as empty pins and source pins. The same was true for the cans (designed to hold the samples being irradiated), which currently have two universes, empty spaces and "blocking" cans. The blocking can universe can be altered to include different materials in the future. With the exception of cobalt and water, all the materials in the array are steel or an aluminum alloy. The dose rate tallies were done by modeling a CaF_2:Mn TLD at both locations and using F6 energy heating tallies. The dose rate can be time corrected easily by using the exponential decay equation. The energy spectra were obtained by taking F5 volume flux tallies in the innermost cell of the can (the actual 'inside' of the empty can) and normalizing them over the net flux in the can.

Benchmarking the Data

The absorbed dose rate for various locations within the LICA was measured using CaF_2 TLD. The data are presented in Tables I and II (in units of Gy/hr) for the LICA rows B and C at 5.2 in. from the bottom of the can and 8.6 in. from the bottom of the can, respectively. It should be noted that this data is just for benchmarking and has significant error attached to it due to materials in the cans.

LICA Dose Rates from TLD Data at 5.2"		
Row	B (Gy/h)	C (Gy/h)
11	0.54	0.56
10	1.37	1.35
9	3.1	3.03
8	7.53	7.19
7	19.1	19.0
6	55.9	57.9
5	200	211
4	375	389

Table I. TLD dose rates at 5.2"

LICA Dose Rates from TLD Data at 8.6"		
Row	B (Gy/h)	C (Gy/h)
6	48.2	54.3
5	174	134
4	328	341

Table II. TLD dose rates at 8.6"

RESULTS

The MCNP dose rate data in Tables III and IV closely mirror the data from CaF_2 TLDs. One source of error is the fact that the TLD data were from an experiment with multiple variables such as different materials and heating, not an ideal, identical environment that was modeled in MCNP. However, after correcting the dose rate data for decay, the MCNP results agree well with the measured values for the same LICA locations.

LICA Dose Rates corrected for decay at 5.2"		
Row	B (Gy/h)	C (Gy/h)
11	0.60	0.65
10	1.50	1.41
9	3.15	3.17
8	7.62	7.33
7	18.8	19.0
6	55.1	56.3
5	205	204
4	407	395

Table III. MCNP6 dose rates at 5.2"

LICA Dose Rates corrected for decay at 8.6"		
Row	B (Gy/h)	C (Gy/h)
11	0.60	0.62
10	1.37	1.28
9	2.94	2.98
8	7.26	7.10
7	17.6	17.9
6	52.0	52.6
5	183	182
4	361	350

Table IV. MCNP6 dose rates at 6.8”

The gamma energy spectra for different LICA locations are shown in Figure 1. It can be seen that as the can position moves farther from sources the fraction of uncollided gamma photons decreases and the contribution from the photons that underwent interactions (those in the 0.1-1 MeV range), steadily increases. The energy spectra also tell us that the contribution from low energy gammas (1-50 keV) is small compared to the uncollided and high energy contribution.

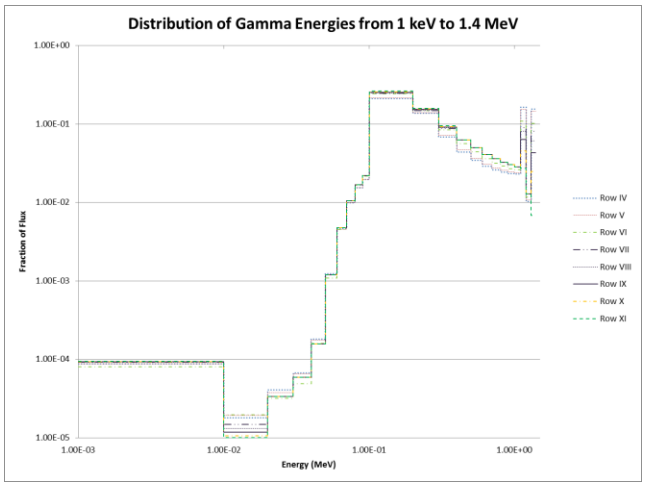

Fig. 1. Energy Spectra of Gammas in LICA

APPENDIX A: LICA PHOTO

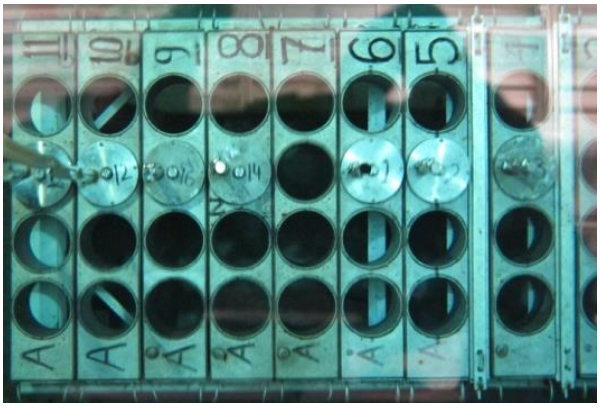

Fig. A.1. Top-down view of the LICA with cans in 11, 10, 9, 8, 6, 5, and 4C, and the rest empty

APPENDIX B: VISUAL EDITOR REPRESENTATION OF LICA MODEL

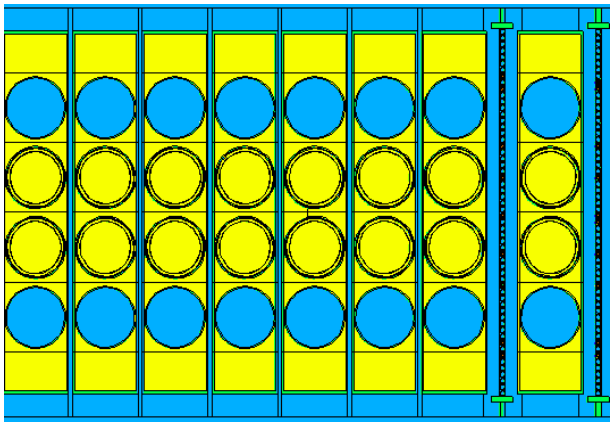

Fig. B.1. Top-down view of LICA model with blocking cans in middle rows and empty in the outside rows.

NOMENCLATURE

LICA = Low Intensity Cobalt Array
TLD = Thermoluminescent Dosimeter
MCNP = Monte Carlo N-Particle simulator
CaF_2 = Calcium fluoride
GIF = Gamma Irradiation Facility

ENDNOTES

Special thanks to everyone who helped me with this project including Maryla Wasiolek, Don Hanson, Russell Durrer, Michael Spoerner, and Nick Giron.

REFERENCES

1. R.J. MCCONN JR; ET AL. “Compendium of Material Composition Data for Radiation Transport Modeling,” PNNL-15870 Rev. 1, Pacific Northwest National Laboratory (2011).
2. K. RUSSELL DEPRIEST, “Neutron Contribution to CaF_2:Mn Thermoluminescent Dosimeter Response in Mixed (n/γ) Field Environments,” SAND2002-3778, Sandia National Laboratories (2002).
3. BARTBERGER; J. LEWIN, “Low Intensity Cobalt Array (LICA) Facility Interface Documents and Drawing List,” 14213-S44000, Sandia National Laboratories (1983).