

Benchmark Evaluation of one Dimensional Array of HEU Moderated and Reflected by Lucite

Igor Lengar¹, Domen Kotnik^{1,2}, Luka Snoj^{1,2}, Jesson Hutchinson³,
Rene Sanchez³, Travis Grove³

¹ “Jožef Stefan” Institute, Jamova 39, Ljubljana, Slovenia

² Faculty of mathematics and physics, University of Ljubljana, Jadranska 19, Ljubljana, Slovenia

³ Los Alamos National Laboratory, Los Alamos, NM 87545, United States

igor.lengar@ijs.si

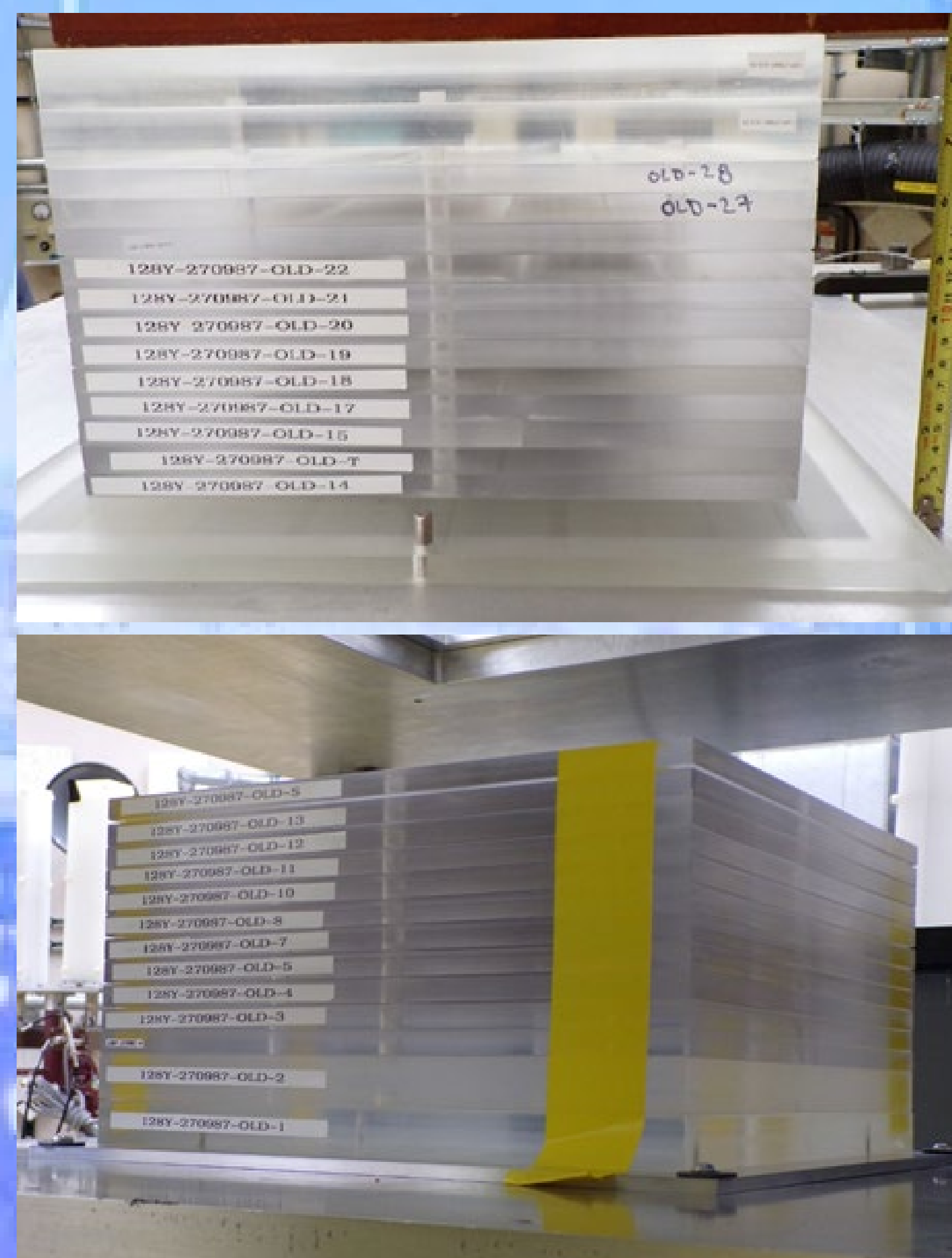
ABSTRACT

Two critical experiments with HEU-Lucite were performed using the Planet Universal Critical Assembly Machine at Los Alamos National Laboratory in 2019. HEU foils were interleaved with Lucite in a column stack for moderation and reflection from the square Lucite plates. The evaluation of the experiments is presented. A Monte-Carlo (MCNP6) calculation model was developed for the determination of uncertainties and their effect on the multiplication factor. Experimental uncertainties were found to be low with the overall uncertainty in k_{eff} approximately 240 pcm. The comparison of calculations with experimental data is presented.

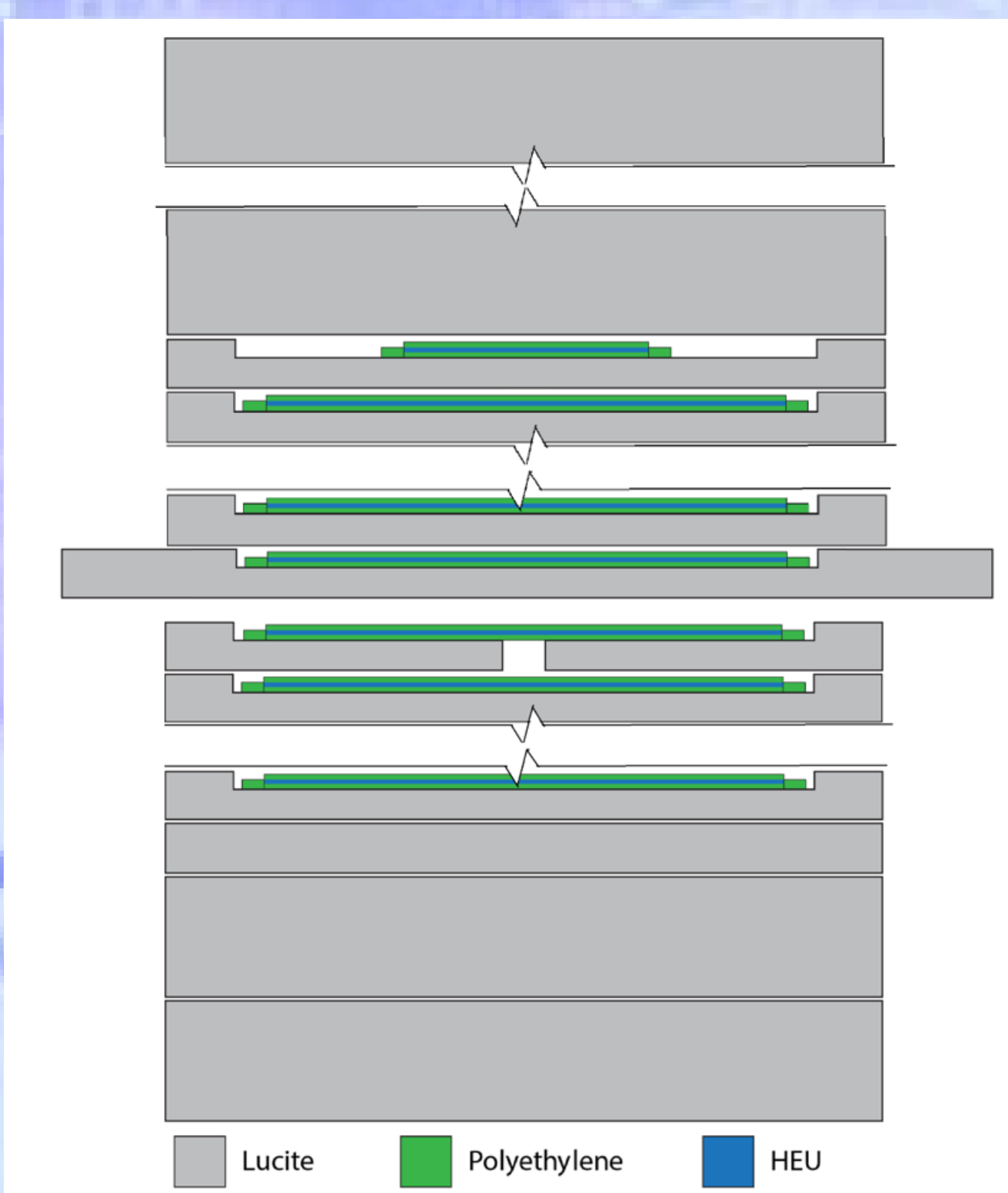
INTRODUCTION

Comparison of calculational results with integral experimental data is necessary for validation of nuclear data and analytical methods and criticality safety analysis. Two HEU-Lucite (polymethyl methacrylate) experiments were performed and included into the Handbook of the International Criticality Safety Benchmark Evaluation Project (ICSBEP). The present experiments are unique in using Lucite as moderator/reflector.

Evaluation of experimental uncertainties with MCNP6 calculations is performed in the present work.



Upper and lower stack of Lucite plates, interleaved with HEU foils. The lower stack is lifted to achieve criticality.



Schematic of HEU-Lucite Experiment, for clarity one reflector and several moderator plates were excluded from the figure. Drawing not to scale.

EXPERIMENTAL SET-UP

The stack for each experiment is divided into two parts. The lower stack is lifted to achieve criticality by closing the gap between the top and bottom portions. Two critical experiments were performed with a difference in dimension of the uppermost HEU foil. Both experiments were composed of 23 moderator plates holding HEU foils and three upper and three lower reflector plates. HEU foils had 93.23 wt% of ²³⁵U (total U mass approximately 1.55 kg), dimensions 9 by 9 inches square and a thickness of 0.003 inch. The measured reactivity was 40.45 cents and 19.13 cents.

Benchmark Measurement Uncertainties in k_{eff}

Source of Uncertainty	Standard Uncertainty (1 σ) in Parameter		Standard Uncertainty (1 σ) in k_{eff}	
	Configuration 1	Configuration 2	Configuration 1	Configuration 2
Material Mass and Isotopic Content and Impurities				
Total HEU mass	3.394 g	3.394 g	0.0004	0.0003
Total Lucite mass	11.15 g	11.15 g	0.0001	0.0001
Total Polyethylene mass	4.8 g	4.8 g	0.0002	0.0002
Uranium 235 isotopic	0.02 % / 2	0.02 % / 2	0.0000	0.0000
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Dimensions and Assembly				
HEU foil width	0.05% / $\bar{O}3$	0.05% / $\bar{O}3$	0.0000	0.0000
Lucite plate width	2.54 mm / $\bar{O}3$	2.54 mm / $\bar{O}3$	0.0004	0.0004
Lucite plate thickness	0.254 mm / $\bar{O}3$	0.254 mm / $\bar{O}3$	0.0002	0.0002
Random gap variation			0.0002	0.0002
Stack height	1 mm, each stack	1 mm, each stack	0.0023	0.0022
Horizontal HEU foil position	0.5 mm	0.5 mm	0.0000	0.0000
Surrounding Structures				
Room, Planet machine, ...			0.0002	0.0002
Impurities				
Lucite impurities	chemical analyses	chemical analyses	0.0000	0.0000
Polyethylene impurities	chemical analyses	chemical analyses	0.0001	0.0001
HEU impurities	as per reference	as per reference	0.0001	0.0001
Aluminium composition	max., min. elemental content	max., min. elemental content	0.0000	0.0000
k_{eff}				
k_{eff} measurement	40.45 ϵ 0.00156/2/ $\bar{O}3$	19.13 ϵ 0.00156/2/ $\bar{O}3$	0.0002	0.0001
Combined Uncertainty in k_{eff}			0.0024	0.0023

UNCERTAINTY OF THE EXPERIMENT

The uncertainty in the overall height of the stack was dominating and consequence of gaps between individual Lucite plates, indicating on plate wrapping. It amounted to 225 pcm. The sensitivity calculations were performed using MCNP 6.2 with the ENDF/B-VIII.0 library. Total uncertainty of the benchmark was derived from individual effects, combined using the sum of squares. The overall uncertainty is small, consequence of a well prepared and documented experiment and the fact that it was prepared recently with aim of being included into the ICSBEP database.

Model	MCNP 6.2, ENDF/B-VIII.0	MCNP 6.2, ENDF/B-VII.0
Configuration 1	1.01893 \pm 0.00002	1.01759 \pm 0.00002
Configuration 2	1.01538 \pm 0.00002	1.01404 \pm 0.00002

Sample Calculation Results

C/E-1 and (C/E-1)/ σ , ENDF/B-VIII.0 library. σ is the combined benchmark uncertainty in k_{eff}

	C/E-1 [%]	(C/E-1)/ σ	C-E [pcm]
Configuration 1	1.65	6.9	1653
Configuration 2	1.45	6.3	1448

EXPERIMENT vs. CALCULATION

The Lucite material was used in the experiments, enabling evaluation of the scattering kernel $S(\alpha, \beta)$ for Lucite, which became available in the ENDF/B VIII library. Calculations (C) show a higher value of k_{eff} with respect to the benchmark model k_{eff} or the experimental k_{eff} (E). This is to some degree in line with sample calculations from other evaluations within the same experimental series.

ACKNOWLEDGMENTS

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