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Lawrence Livermore National Laboratory

IER-602 CED-4a Report: Updated Results of the Nuclear Accident Dosimetry Intercomparison at the Armed Forces Radiobiology Research Institute's TRIGA Reactor

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Introduction

The IER-602 3b document (Angus, et al. 2024) reported the initial, 24-hour results of the international nuclear accident intercomparison, which took place at the Armed Forces Radiobiological Research Institute during June 24-28, 2024. This report provides updated results and further analysis of the intercomparison.

Target Value Comparison

The initial results were compared to target values not yet adjusted by the AFRRI reactor operations staff. Dose results are adjusted for inter-irradiation variations between the setup and experiment run, as well as the leading dose (i.e. dose during the ramp-up to target power level) and post-scam dose (i.e. dose from delayed fissions and core retreat) as recorded by the fixed ion chambers located in the irradiation room. Details of this process were discussed in the IER-484 3b report (Tamashrio, et al. 2024). Table 1 reports the ion chamber results for the intercomparison. MC2 and MC4 are the ceiling mounted ion chambers. As seen by the "Target Deviation" column, all irradiations were within 5% of the target value, which is within the uncertainty presented in the IER-602 3b report.

Table 1: Irradiation Ion Chamber Results

Irradiation Info		Total Dose [cGy]				Target	Average Dose Rate [cGy/min]		
Exposure	Target [cGy]	MC2	MC4	Avg	Diff	Deviation	MC2	MC4	Average
Tuesday BOMAB	350	351.99	347.28	349.64	-1.35%	-0.10%	60.25	59.48	59.86
Tuesday FIA	350	351.04	351.13	351.09	0.03%	0.31%	59.89	59.95	59.92
Wednesday BOMAB	220	220.16	218.37	219.27	-0.81%	-0.33%	59.87	59.45	59.66
Wednesday FIA	220	221.44	221.46	221.45	0.01%	0.66%	59.29	59.64	59.47
Thursday BOMAB	350	352.57	322.42	337.49	-8.94%	-3.57%	60.88	55.7	58.29

30 Day Reported Doses

Labs were provided an additional 30 days after the conclusion of the exercise to provide updated dose values, including gamma doses if not previously reported, for the BOMAB irradiations. Updated results are reported in Table 2 and Table 3. For these tables, red text indicates the average value outside of the target criteria; a blue highlight indicates the value was low, while red indicates the value was high.

Table 2: 30 Day Results for Tuesday BOMAB Irradiation

	Neutron [Gy]			Gamma [Gy]			Total Dose [Gy]		
Lab Number	BOMAB 1	BOMAB 2	BOMAB 3	BOMAB 1	BOMAB 2	BOMAB 3	BOMAB 1	BOMAB 2	BOMAB 3
1	3.50	2.14	1.50	5.60	3.40	2.40	9.10	5.54	3.90
2	2.96	2.02	1.56	4.73	3.22	2.50	7.69	5.24	4.06
3	2.90	2.11	1.34	5.44	2.60	1.53	8.34	4.71	2.87
4	4.41	2.25	1.75	*	*	*	*	*	*
5	3.09	3.15	1.51	3.81	2.03	1.53	6.90	5.18	3.04
6	2.30	1.05	0.68	4.50	2.31	1.53	6.80	3.36	2.21
7	3.02	2.40	0.64	*	*	*	*	*	*
8	2.27	1.23	0.68	4.21	2.54	1.88	6.48	3.77	2.56
9	2.65	1.42	0.86	3.45	1.71	1.16	6.10	3.13	2.02
10	6.30	3.32	1.71	*	*	*	*	*	*
Average	3.34	2.11	1.22	4.53	2.54	1.79	7.34	4.42	2.95
Standard Deviation	1.21	0.75	0.45	0.80	0.61	0.50	1.08	0.98	0.79
Target	3.68	1.93	1.21	5.53	3.15	2.17	9.21	5.07	3.38
Uncertainty	0.36	0.20	0.18	0.42	0.24	0.20	0.55	0.31	0.27
Upper Test Criteria	4.67	2.45	1.56	6.98	3.97	2.74	11.58	6.38	4.26
Lower Test Criteria	2.69	1.40	0.86	4.09	2.32	1.59	6.84	3.77	2.49
% Meeting Criteria	60%	60%	50%	71%	57%	43%	57%	57%	71%

*: excluded from “% Meeting Criteria calculation”

Table 3: 30 Day Results for Wednesday BOMAB Irradiation

	Neutron [Gy]			Gamma [Gy]			Total Dose [Gy]		
Lab Number	BOMAB 1	BOMAB 2	BOMAB 3	BOMAB 1	BOMAB 2	BOMAB 3	BOMAB 1	BOMAB 2	BOMAB 3
1	1.20	1.00	2.24	1.96	1.79	3.36	3.16	2.79	5.60
2	1.22	0.68	2.86	2.28	1.62	3.51	3.50	2.30	6.37
3	1.34	2.26	2.15	1.20	1.11	2.93	2.54	3.37	5.08
4	1.10	0.78	2.19	*	*	*	*	*	*
5	1.18	0.70	1.78	1.49	0.98	2.59	2.67	1.68	4.37
6	1.52	0.99	2.64	1.97	1.34	3.67	3.49	2.33	6.31
7	1.48	2.98	2.33	1.21	0.67	2.93	2.69	3.65	5.26
8	0.93	0.67	1.90	1.40	1.13	2.83	2.33	1.80	4.73
9	0.96	0.72	1.76	1.16	0.78	1.97	2.12	1.50	3.73
10	1.08	1.26	2.02	1.95	1.53	3.65	3.03	2.79	5.67
Average	1.20	1.20	2.19	1.62	1.22	3.05	2.84	2.47	5.24
Standard Deviation	0.20	0.79	0.36	0.42	0.38	0.56	0.49	0.75	0.87
Target	1.29	0.67	2.70	2.10	1.36	3.71	3.39	2.03	6.41
Uncertainty	0.20	0.20	0.77	0.18	0.16	0.49	0.27	0.25	0.91
Upper Test Criteria	1.68	0.93	3.72	2.65	1.73	4.76	4.28	2.59	8.25
Lower Test Criteria	0.91	0.41	1.68	1.54	0.98	2.66	2.50	1.46	4.57
% Meeting Criteria	100%	50%	100%	44%	56%	78%	78%	56%	78%

*: excluded from “% Meeting Criteria calculation”

For the Tuesday, unblinded irradiation, 42% of the 24 hour results were within the ANSI/HPS N13.3 “Dosimetry for Criticality Accidents” (R2019) bias criteria; this improved to 56% upon revision. 61% met the total dose target for the 30 day results.

For the Wednesday, blinded irradiation, 83% met the neutron dose bias criteria at 30 days, compared to 80% upon initial reporting. 70% of results met the total dose criteria.

While not included in the results analysis of the exercise, Uniformed Services University of Health Services (USUHS) deployed Mirion IM-276A/PD field electronic dosimeters during for the irradiations. Their results for the Tuesday and Wednesday BOMAB irradiations are provided in Table 4.

Table 4: USUHS Electronic Dosimeter Results

Tuesday Irradiation			
	Neutron Dose [Gy]	Gamma Dose [Gy]	Total Dose [Gy]
BOMAB 1	1.78	4.25	6.03
BOMAB 2	0.87	2.47	3.34
BOMAB 3	0.54	1.53	2.07
Wednesday Irradiation			
	Neutron Dose [Gy]	Gamma Dose [Gy]	Total Dose [Gy]
BOMAB 1	0.53	1.47	2.00
BOMAB 2*	0.55	0.10	0.65
BOMAB 3	1.09	2.33	3.42

*: not corrected for phantom rotation

Activation of non-dosimetric items

As described in the CED-3b report, multiple labs tested the activation potential on non-dosimetric items during the optional third experimental run. Two labs, Y-12 and LLNL, reported results for activated personal items.

Table 5 contains the data raw counts-per-minute (CPM) reported from a handheld survey instrument for the items deployed by Y-12.

Table 5: Activation of personal items

Item	**Gross CPM**
Watch (face up)	14752
Watch (face down)	96274
Soda can	18971
Belt	12782
Bracelet (face up)	54319
Bracelet (face down)	117844
Battery	207756
8 coins	100013
Silver Dime	15923
Glasses	19469

Additionally, they provided spectra from their AEGIS HPGe detector, which are only qualitatively useful due to geometric and material uncertainties. A sample spectrum of the metal watch is provided in Figure 1.

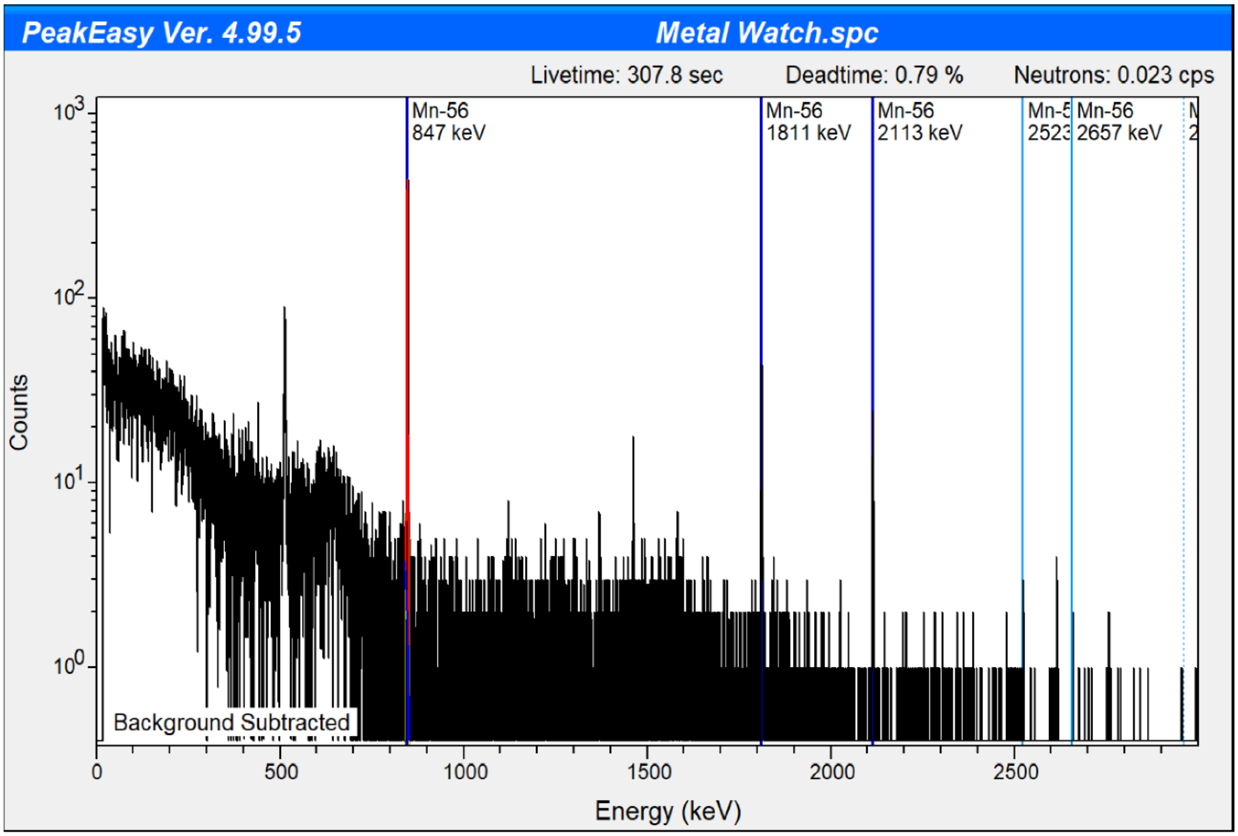

Figure 1: Sample gamma spectrum of activated watch, provided by Y-12.

LLNL sewed 12 metal clothing rivets onto the lab coat placed on the BOMAB: four on the front, one on each side under the arm, and six on the back. The rivets were procured from a clothing supply store and are made of an unknown metal alloy. However, they exhibited a strong 0.511 MeV gamma ray signal from positron decay, which is assumed to be from activated copper (^{64}Cu) present within the rivets. Each set of rivets was counted for the same amount of time using a high-purity germanium detector, and the total counts were normalized by the number of rivets present at each location. Uncertainty of the reported data is less than 10%. The data for the counts is reported in Table 6.

Table 6: Gamma Counts of Activated Rivet

Location	0.511 MeV Counts per rivet
Front	9275
Back	1197
Right	4366
Left	4374

As seen above, the front rivets produced the highest activation signal as they were facing the source. The two side rivets (left and right) were less activated than the front set because they were partially shielded by the arms of the BOMAB. The left and right had consistent results, which is confirmatory of the "head on" exposure geometry. The back rivets reported the lowest activated, which is expected due to shielding. These results suggest that adding small clothing rivets to standard lab coats or other required personal protective equipment for work within a fissile material facility, may be a low-cost method of determining personal orientation were a criticality excursion to occur.

Comparison to Past Results

Nuclear accident dosimetry intercomparisons have taken place since 1965, with varied spectrum, sources, participants, and regulatory requirements. Broadly, there have been three eras of intercomparisons:

1) Testing at the Health Physics Research Reactor (HPRR) at Oak Ridge National Laboratory (ORNL); 1965-1985 (Sims 1989).
2) Testing at the Silene and Calibran reactors at CEA Valduc, France; 2009-2014 (Hickman, et al. 2011) (Hickman, et al. 2010) (Hickman, et al. 2010) (Lobaugh, et al. 2015) (Hill and Conrady 2010).
3) NNSA/DOE funded testing in the United States under the Nuclear Criticality Safety Program (NCSP) portfolio, multiple locations; 2016-present (Heinrichs, et al. 2014)(Stone 2022) (Hickman, Wilson and Trompier 2018) (Hickman, Wilson and Trompier 2018).

Formal intercomparisons were not performed between 1985 and 2009.

The professional consensus standard for nuclear accident dosimetry, ANSI/HPS N13.3 was first issued in 2013 and reaffirmed by the HPS in 2019. This timeframe corresponds to the revitalization of intercomparisons and increased participation within United States. As such, and due to the limited availability of data from all participants, comparison to past results will be limited to the modern NCSP period, focusing on the initial (24 hour) neutron results. Due to blinded nature of the reports, performance of individual labs cannot be reported.

For the analyzed intercomparisons (IER 148 at Godiva, 2016; IER 253 at Flattop, 2018, IER 538 at Godiva, 2022; and IER 602 at AFRRI, 2024), distance from the radiation sources was 1-3 m, and neutron doses between 0.5 Gy and 5.5 Gy. Typically, the first irradiation for each exercise was unblinded, where the participants were told some information about the irradiation, such as dose targets or phantom locations, prior to reporting results. The second irradiation was blinded in some manner, where information about phantom distance and orientation was withheld from participants. The average passing performance, on a participant basis, is reported in with "passing" defined as meeting the bias accuracy specified in the ANSI/HPS standard. For the first three intercomparisons, performance on the first, unblinded irradiation had a higher percentage of reported values meeting the passing criteria than on the blinded case. However, for the AFRRI exercise, the trend was reversed. A possible explanation for this effect is the use of a different neutron field. The leakage neutrons from TRIGA reactor at AFRRI must pass through a portion of the water jacket prior to entering the exposure room. This results in additional moderation and is therefore a softer neutron energy spectra compared to the "in air" configurations of Flattop or the Godiva assembly. Additional studies with other neutron energy spectra should be performed to determine effects on participant accuracy.

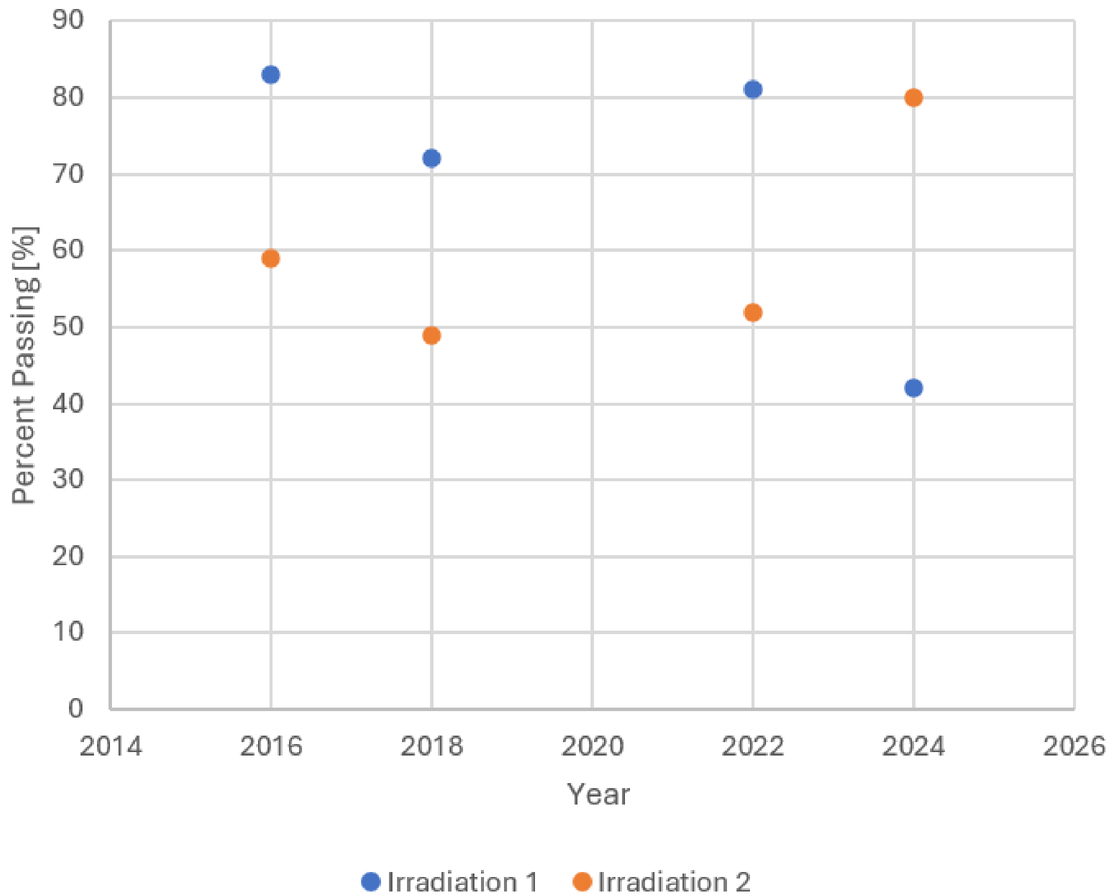

Figure 2: Cohort performance at intercomparisons

The ANSI/HPS standard uses three different bias criteria, depending on total dose: ±50 for doses between 0.1-1 Gy and ±25% for doses between 1 Gy and 10 Gy. The third bias criterion, positive indication of doses greater than 10 Gy, was not tested.

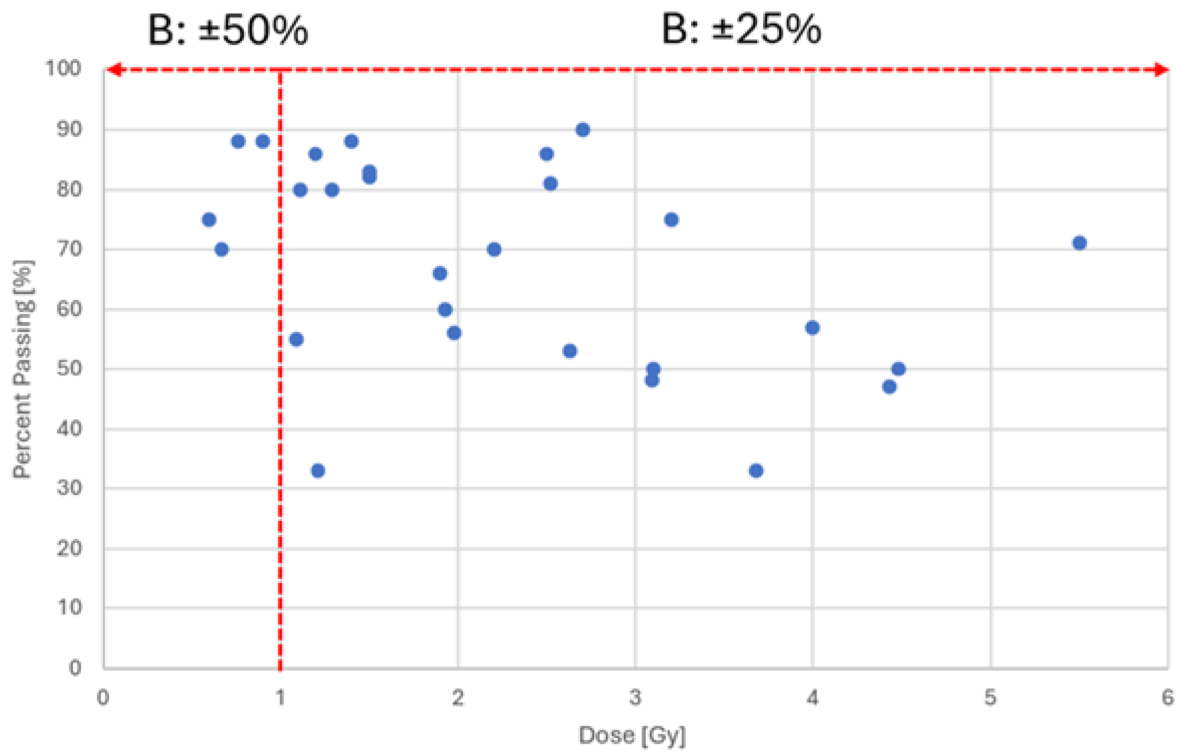

Figure 3: Cohort performance broken out by dose. The bias performance criteria (B) are show for <1 Gy and ≥1 Gy

Under about 3 Gy, there were no strong performance trends. Above 3 Gy, there appears to be a degradation in the cohort meeting the performance criteria. For future intercomparisons, an expanded range of doses should be tested, with a focus on high doses where performance decreases.

Effects of Shadowing

Coincident with the personal items irradiation, the effect of shadowing was measured by arranging the three BOMAB phantoms in a line so the downstream phantoms are shadowed by the ones nearer to the reactor core.

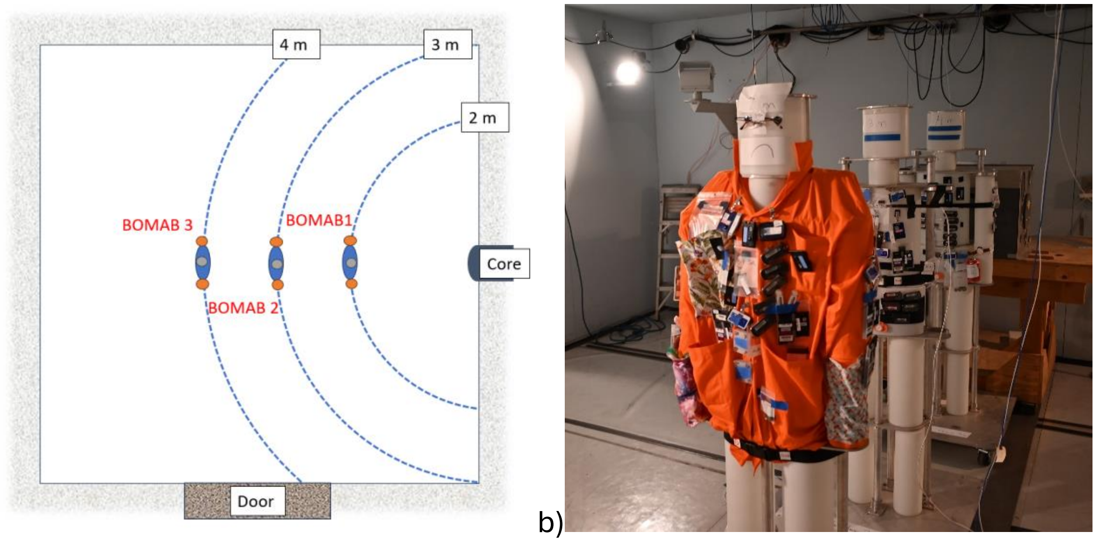

Figure 4: Setup for shadowed irradiation; a) irradiation schematic b) picture of setup looking from the core towards the BOMABS

Only neutron results were considered in this analysis. To determine the expected effect of shielding, neutron dose for individual phantoms was estimated using data from the IER-484 CED 3b report. The expected dose to the centerline phantom for each configuration was scaled to the irradiation target for this run, 3.5 Gy at 2 m. Doses for the shadowed configuration could not be estimated using the avaiable data or the IER-484 characterization.

Distance from Core [m]	Estimated Dose [Gy] (unshadowed)	Measured Dose [Gy] (shadowed)
2	2.43 ± 0.24	3.12 ± 0.33
3	1.00 ± 0.23	0.98 ± 0.33
4	0.60 ± 0.12	0.74 ± 0.43

Additionally, the expected dose and effect of shadowing was calcuated using the COG High Fidelity Multi-Particle Transport Code (https://cog.llnl.gov/). The three phatoms, depicted in Figure 5, were modeled using the BOMAB specifications while neglecting the aluminium frame. All parts were modeled as water instead of water encased in high density polyethylene. The radiation source was a 20 cm x 20 cm plane source emitting neutrons with a Watt fission energy spectrum and penetrating 4 cm of water to approximate the spectrum presented in (Eisenhauer 1991). The phantoms were placed in a 6 m x 6 m x 4 m air box. Bounding the box was 30 cm of wood covered in 0.001 cm Gd_2O_3 paint on the interior surface as discussed in (Virbinski and Cassapakis 1981). This is an approximate, albiet simplified model, of the previously measured data. A sample COG input deck is included in Appendix A. Neutron fluence was tallied at the boundary of the chest phantoms using the energy bins in ANSI/HPS N13.3 Dosimetry for Criticality Accidents Table B1. This table provides fluence-to-dose conversion factors that were used to calulate the total dose for each phantom. $1x10^9$ source neutrons were transported for each simulation; this resulted in a maximum simulation uncertainty of 1.3% (range 0.12%-1.3%, average 0.34%) for dose to the an individual phantom.

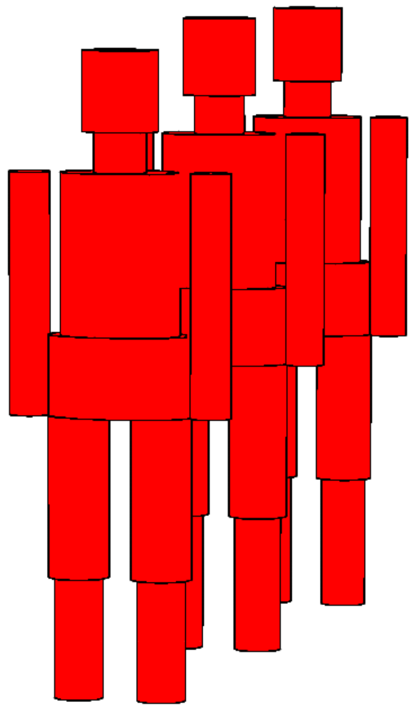

Figure 5: Simplified model of the irradiation geometry, using the same perspective as Figure 4.

All results were normalized to the dose at the 2 m phantom for each condition.

Table 7: Effects of Shielding

Distance [m]	Estimated (unshadowed)	Measured (shadowed)	COG Calculation (unshadowed)	COG Calculation (shadowed)
2 m	100%	100%	100%	100%
3 m	41%	31%	49%	9.5%
4 m	25%	24%	30%	5.5%

The estimated and calculated doses for the unshielded cases were consistent to within 10%. However, for the measured shadowed case, the only significant reduction of dose occurred at the 3 m position, and only by 10% (relative to 2 m). The 4 m doses was not significantly altered compared to the estimated, unshadowed case. These results are disparate from the simplified simulation, which predicted a significantly reduced dose at the two downstream locations. Possible improvements include a more realistic model of the neutron source, such as a full simulation of the TRIGA reactor, or the inclusion of other scatter bodies within the room, for example the wooden table holding a lead shield that's visible behind the phantoms in Figure 4.

Conclusion

The IER-602 CED-4a report provides updated results and further analysis from the nuclear accident dosimetry intercomparison conducted at the Armed Forces Radiobiology Research Institute's TRIGA reactor in June 2024. The findings highlight several key outcomes and opportunities for improvement in nuclear accident dosimetry practices.

The updated 30-day results demonstrate significant improvement in dosimetry performance compared to the initial 24-hour results. Compared to previous intercomparisons, overall accuracy remained consistent. Future intercomparisons should test higher neutron doses (greater than 3 Gy) where there is indication of decreased performance.

The activation of non-dosimetric items, such as personal items and clothing rivets, provided valuable insights into potential low-cost methods for assessing personal orientation or involvement during a criticality excursion.

The shadowing experiments revealed discrepancies between measured and simulated neutron doses, particularly in the downstream phantoms. While the simplified COG simulations predicted significant dose reductions due to shadowing, the measured data showed only modest reductions. This highlights the need for more refined modeling approaches and further experimental validation to better understand the effects of shielding and shadowing in complex irradiation scenarios. Consideration should be given to future shadowed exposures, or partial body irradiations.

Overall, this intercomparison exercise demonstrates continued progress in nuclear accident dosimetry, with improvements in accuracy, expanded participation, and innovative approaches to dosimetry assessment.

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Appendix A

```
3 bomabs in a line in exposure room
BASIC
        neutron delayedn photon
SURFACES
        1 box 8 100 200 tr -205 0 0 $ water plane shielding fission source to mimic reactor
        10 ec 9.5 7 60 80 tr 0 0 0 0 0 1 0 1 0 $ head
        11 c 6.5 50 60 tr 0 0 0 0 0 1 0 1 0 $ neck
        121 ec 15 10 10 50 tr 0 0 0 0 0 1 0 1 0 $ chest
        122 ec 15 10 10 50 tr 0 0 0 0 0 1 0 1 0 $ chest
        123 ec 15 10 10 50 tr 0 0 0 0 0 1 0 1 0 $ chest
        13 ec 18 10 -10 10 tr 0 0 0 0 0 1 0 1 0 $ pelvis, center
        14 c 5 -10 50 tr 0 23 0  0 23 1  0 24 0 $ arm, left
        15 c 5 -10 50 tr 0 -23 0  0 -23 1  0 -22 0 $ arm, right
        16 c 7.5 -50 -10 tr 0 10.5 0  0 10.5 1  0 11.5 0 $ thigh, left
        17 c 7.5 -50 -10 tr 0 -10.5 0  0 -10.5 1  0 -9.5 0 $ thigh, right
        18 c 6 -90 -50 tr 0 10.5 0  0 10.5 1  0 11.5 0 $ calf, left
        19 c 6 -90 -50 tr 0 -10.5 0  0 -10.5 1  0 -9.5 0 $ calf, right
        101 box 20 60 170 tr 0 0 5 $ bounding box for phantom 1
        102 box 20 60 170 tr 100 0 5 $ bounding box for phantom 2
        103 box 20 60 170 tr 200 0 5 $ bounding box for phantom 3
        200 box 600 600 400 tr 80 0 0 $ air box
        201 box 600.001 600.001 400.001 tr 80 0 0 $ gd2o3 paint
        202 box 630 630 430 tr 80 0 0 $ wood

GEOMETRY
        use unit 2 irradiationScene -200
        sector 201 gadox -201 +200
        sector 202 wood -202 +201
        boundary vacuum +202

define unit 2 $ general box
        use unit 1 phantom1 -101
        use unit 3 phantom2 -102 tru 100 0 5
        use unit 4 phantom3 -103 tru 200 0 5
        sector 1 waterBox -1
        fill 2

define unit 1 $ phantom at 1 m
        sector 10 head1 -10
        sector 11 neck1 -11
        sector 121 chest1 -121
        sector 13 pelvis2 -13
        sector 14 armL1 -14
        sector 15 armR1 -15
```

```
        sector 16 thighL1 -16
        sector 17 thighR1 -17
        sector 18 calfL1 -18
        sector 19 calfR1 -19
        fill 2

define unit 3 $ phantom at 2 m
        sector 10 head1 -10
        sector 11 neck1 -11
        sector 122 chest1 -122
        sector 13 pelvis2 -13
        sector 14 armL1 -14
        sector 15 armR1 -15
        sector 16 thighL1 -16
        sector 17 thighR1 -17
        sector 18 calfL1 -18
        sector 19 calfR1 -19
        fill 2

define unit 4 $ phantom at 3 m
        sector 10 head1 -10
        sector 11 neck1 -11
        sector 123 chest1 -123
        sector 13 pelvis2 -13
        sector 14 armL1 -14
        sector 15 armR1 -15
        sector 16 thighL1 -16
        sector 17 thighR1 -17
        sector 18 calfL1 -18
        sector 19 calfR1 -19
        fill 2


        picture cs s color xy 0 -20 20 -30 30
        picture cs s color xy 0 -220 300 -30 30
        picture cs s color xz 0 -20 20 -100 100
        picture cs s color yz 0 -30 30 -100 100
        picture cs s color xy 0 -400 400 -400 400
        picture p m color 0 0 0 400 1000 15 15 1
MIX
        nlib=ENDFB8R0
        mat=1 water 1
        mat=2 air 0.00129
        mat=3   bunches
                c 1.43-2 $ wood
```

```
                h 2.40-2
                o 1.19-2
        mat=4   bunches $ gadox paint
                gd 4.09-2
                o 6.13-2
ASSIGN-M
        1 1
        10 1
        11 1
        121 1
        122 1
        123 1
        13 1
        14 1
        15 1
        16 1
        17 1
        18 1
        19 1
        201 4
        202 3
SOURCE
        npart 1000000000
        DEFINE POSITION 1
        SS-PAR  -210 10 -10
                -210 -10 -10
                -210 -10 10
        DEFINE ENERGY 1 NEUTRON
                WATT 1 2
        DEFINE ANGLE 1
                1 0 0
                ISOTROPIC
                IMPORTANCE
                        -1 0.0 0 0 1 1
        INC 1 E 1 P 1 A 1

DETECTOR
        NUMBER = phantom1
        TITLE="Phantom 1 neutron flux"
        BOUNDARY 2 121 33000
        BIN ENERGY NEUTRON
                1.00E-9
                2.15E-9
                4.64E-9
                1.00E-8
```

2.15E-8
4.64E-8
1.00E-7
2.15E-7
4.64E-7
1.00E-6
2.15E-6
4.64E-6
1.00E-5
2.15E-5
4.64E-5
1.00E-4
2.15E-4
4.64E-4
1.00E-3
2.15E-3
4.64E-3
1.00E-2
1.25E-2
1.58E-2
1.99E-2
2.51E-2
3.16E-2
3.98E-2
5.01E-2
6.30E-2
7.94E-2
1.00E-1
1.25E-1
1.58E-1
1.99E-1
2.51E-1
3.16E-1
3.98E-1
5.01E-1
6.30E-1
7.94E-1
1.00
1.25
1.58
1.99
2.51
3.16
3.98
5.01

6.30
7.94
1.00E+1
1.58E+1

NUMBER = phantom2
TITLE="Phantom 2 neutron flux"
BOUNDARY 2 122 33000
BIN ENERGY NEUTRON
1.00E-09
2.15E-09
4.64E-09
1.00E-08
2.15E-08
4.64E-08
1.00E-07
2.15E-07
4.64E-07
1.00E-06
2.15E-06
4.64E-06
1.00E-05
2.15E-05
4.64E-05
1.00E-04
2.15E-04
4.64E-04
1.00E-03
2.15E-03
4.64E-03
1.00E-02
1.25E-02
1.58E-02
1.99E-02
2.51E-02
3.16E-02
3.98E-02
5.01E-02
6.30E-02
7.94E-02
1.00E-01
1.25E-01
1.58E-01
1.99E-01
2.51E-01

3.16E-01
3.98E-01
5.01E-01
6.30E-01
7.94E-01
1.00E+00
1.25E+00
1.58E+00
1.99E+00
2.51E+00
3.16E+00
3.98E+00
5.01E+00
6.30E+00
7.94E+00
1.00E+01
1.58E+01

NUMBER = phantom3
TITLE="Phantom 3 neutron flux"
BOUNDARY 2 123 33000
BIN ENERGY NEUTRON
1.00E-09
2.15E-09
4.64E-09
1.00E-08
2.15E-08
4.64E-08
1.00E-07
2.15E-07
4.64E-07
1.00E-06
2.15E-06
4.64E-06
1.00E-05
2.15E-05
4.64E-05
1.00E-04
2.15E-04
4.64E-04
1.00E-03
2.15E-03
4.64E-03
1.00E-02

1.25E-02
1.58E-02
1.99E-02
2.51E-02
3.16E-02
3.98E-02
5.01E-02
6.30E-02
7.94E-02
1.00E-01
1.25E-01
1.58E-01
1.99E-01
2.51E-01
3.16E-01
3.98E-01
5.01E-01
6.30E-01
7.94E-01
1.00E+00
1.25E+00
1.58E+00
1.99E+00
2.51E+00
3.16E+00
3.98E+00
5.01E+00
6.30E+00
7.94E+00
1.00E+01
1.58E+01

END