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Twenty-Second ORNL Intercomparison of Criticality Accident Dosimetry Systems: August 12-16, 1985

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TWENTY-SECOND ORNL INTERCOMPARISON OF CRITICALITY ACCIDENT DOSIMETRY SYSTEMS: AUGUST 12-16, 1985*

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Highlights

The twenty-second in a series of criticality accident dosimetry intercomparison studies was conducted at the Oak Ridge National Laboratory's Dosimetry Applications Research Facility during August 12-16, 1985. The Health Physics Research Reactor operated in the pulse mode over Storage Pit No. 1 was used to simulate three criticality accidents with different radiation fields. Participants from nine organizations measured neutron doses between 0.36 and 3.78 Gy and gamma doses between 0.22 and 0.80 Gy at area monitoring stations and on phantoms. Approximately 68% of all neutron dose estimates based on foil activation, thermoluminescent, hair activation, and blood sodium activation methods were within ± 25% of reference values. About 44% of all gamma results measured using thermoluminescent dosimeters (TLD-700 or $CaSO_4$ phosphors) were within 20% of reference doses. The generally poor measurement accuracy exhibited in this study indicates a need for continuing ORNL accident dosimetry intercomparison and training programs.

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INTRODUCTION

The twenty-second in a series[1-7] of criticality accident dosimetry intercomparisons was conducted at the Oak Ridge National Laboratory's (ORNL) Dosimetry Applications Research (DOSAR) Facility during August 12-16, 1985. Participants measured neutron doses between 0.36 and 3.78 Gy and gamma doses between 0.22 and 0.80 Gy at area monitoring locations (air stations) and on phantoms for three simulated criticality accidents. The accidents were simulated by operating the Health Physics Research Reactor (HPRR)[8] at ORNL in the pulse mode with and without spectrum modifying shields. Results reported by individual organizations were compared with those of other participants who made similar measurements under identical conditions and to reference doses supplied by the DOSAR staff. This week-long study also included lectures, discussions, and demonstrations on subjects concerning neutron activation, biological dosimetry, accident dose conventions, medical aspects of radiation accidents, and problems associated with criticality accident monitoring at participating agencies. The program for this intercomparison is included in Appendix A of this report.

This study differed from previous ORNL accident dosimetry intercomparisons in that the HPRR was operated over Storage Pit No. 1 instead of over a concrete floor at the "experiment position". The change in reactor operating location resulted in the need for new reference dosimetry compared to that used in prior studies[9]. The new reference data was developed based on multisphere neutron measurements, discrete-ordinates transport calculations, and neutron and gamma integral dose measurements. Documentation of the revised HPRR reference dosimetry should be completed in CY 1986.

PARTICIPATION

A total of 18 people from nine different organizations participated in this study. All nine agencies reported final dose estimates. Appendix B lists individual participants, their affiliations, mailing addresses, and abbreviations used in this report to identify participating organizations.

DESCRIPTION OF EXPERIMENTS

A summary of experimental conditions for the three pulses considered in this study is given in Table 1. The three pulses had fission yields between 6.40 and 9.52 x 10^{16} fissions for the HPRR with the following shield conditions: unshielded, shielded with 20-cm of concrete, and shielded with 12-cm of Lucite. Details of the shield construction have been reported in the literature[9].

Figure 1 shows the experimental arrangement of the HPRR, a shield, and dosimeters for the concrete-shielded pulse. A typical arrangement of phantoms and dosimeters is shown in Figure 2. Accident dosimeters were mounted on ring stands or tables for area monitoring station measurements and on BOMAB[10] or Lucite block phantoms for personnel monitoring. Dosimeters at air stations and phantom centerlines were located 3 m from the reactor vertical centerline. Horizontal centerlines of the HPRR, area monitors, and personnel dosimeters were positioned about 1.4 m above the floor level. All phantoms were arranged with their fronts facing the HPRR. One BOMAB phantom was filled with a saline solution with a sodium content approximating that of human whole blood(1.9 mg/ml). The activated saline solution was made available to participants after each pulse for dose measurements based on simulated blood sodium activation analysis[11]. Another BOMAB phantom used for personnel monitoring studies was filled with tap water.

DOSIMETERS USED IN THE INTERCOMPARISON

A general description of the types of radiation dosimeters used in this study and the abbreviations used to identify them are given below. Neutron doses were measured using foil activation systems or thermoluminescent dosimeters (TLD's) at air stations and foil activation, TLD, sodium activation, or hair activation on phantoms. All gamma measurements were made using thermoluminescent dosimeters with TLD-700 (^{7}LiF) or $CaSO_4$ phosphors. Detailed descriptions of the accident dosimetry systems and evaluation methods are available in the literature[12,13].

Neutron Dosimeters

1. Foil Activation Systems (Act) - Some materials (e.g., gold, copper, indium, sulfur) become radioactive when exposed to neutrons. By measuring the activity of exposed foils, neutron fluences over differential energy ranges can be estimated for the incident spectrum. Associated neutron doses can be obtained by applying fluence-to-dose conversion factors to the estimated fluences and summing over the range of energies encompassed by the activation foils. Some activation systems also use foils made of fissionable materials (e.g., plutonium, neptunium, uranium) which have fission cross sections with thresholds at different neutron energies. These systems are called Threshold Detector Units (TDU's) and are generally used for area monitoring.

2. Thermoluminescent Dosimeters (TLD) - In some substances, metastable states are produced when these materials are irradiated and, upon heating, light is emitted in proportion to the absorbed dose. For neutron monitoring, two types of TL materials-one sensitive to gammas (^{7}LiF) and the other sensitive to neutrons and gammas (^{6}LiF)-are simultaneously exposed to the simulated nuclear accident radiation

fields. The response due to neutrons can be determined after both chips are analyzed. The thermoluminescent neutron systems considered in this study were of the direct interaction type which respond mostly to directly incident neutrons.

3. Sodium Activation (NaAct) - Samples from irradiated, saline-filled phantoms are analyzed for ^{24}Na activity by any of a variety of counting techniques. The dose received by a phantom is proportional to the activity per unit volume of solution.

4. Human Hair Activation (HAct) - Samples of human hair are analyzed for ^{32}P activity following irradiation. This method is used to determine the dose due to neutrons with energies greater than the $^{32}S(n,p)$ threshold of about 2.5 MeV. The total neutron dose can be determined if the fast neutron dose fraction is known.

Gamma Dosimeters

All gamma dosimeters used in this study were TLD's containing TLD-700 or $CaSO_4$ phosphors. These dosimeters are also used for routine gamma personnel monitoring at participating agencies.

REFERENCE DOSIMETRY

Reference neutron and gamma doses in air and on phantoms are given in Tables 2 and 3 respectively. Reference neutron doses in air (Table 2) were obtained using fission yields determined by measuring the ^{32}P beta activity in a 22 gram sulfur pellet located at a fixed position near the reactor core and applying new dose-per-fission conversion factors at 3 m from the reactor for the various HPRR spectra. Neutron doses in air are given in terms of wet tissue kerma[14] and element 57 absorbed dose[15] with the capture gamma component excluded. Element 57 refers to the central volume element of a tissue-equivalent cylindrical phantom used to calculate the average absorbed dose per unit incident neutron fluence. Neutron dose in volume element 57 is the highest for all volume elements in the phantom and represents the expected maximum measured value for each exposure in this study. Reference neutron doses at air stations varied from 0.36 to 3.78 Gy for this study. Reference gamma doses in air were obtained by dividing neutron kerma in air by the neutron-to-gamma dose ratio at 3 m from the reactor. The neutron-to-gamma dose ratio is based on measured results from the first twenty-one ORNL intercomparison studies. For this intercomparison, reference gamma doses at air stations varied from 0.22 to 0.54 Gy.

The reference neutron and gamma doses on phantoms given in Table 3 for tissue kerma were calculated by multiplying doses in air by appropriate air-to-phantom conversion factors developed from measured results of the first twenty-one NAD intercomparison studies. These factors were not applied to element 57 dose since this convention already gives the absorbed dose in a particular volume element of a tissue equivalent phantom. Reference neutron and gamma doses on phantoms ranged from 0.42 to 3.78 Gy and from 0.28 to 0.80 Gy, respectively, for this study. For comparison with measured results, reference neutron doses will are given in terms of wet tissue kerma at air stations and element 57 absorbed dose on phantoms. These conventions are commonly used to report doses in criticality accident dosimetry intercomparison studies[1,2] and are recommended by international regulatory agencies[14].

MEASUREMENT RESULTS AND ANALYSIS

Tables 4-9 summarize final results of measurements reported by participants for this intercomparison. Air station results including neutron and gamma dose estimates, and detection systems are given in Tables 4-6 for each reporting agency. Tables 7-9 summarize results of measurements made on phantoms for each organization. Data contained in these tables include neutron doses, gamma doses, and the basis for the reported dose estimates.

Table 10 summarizes results of neutron dose measurements at air stations and on phantoms based on data shown in Tables 4-9. The table gives average measured neutron doses and experimental standard deviations about the mean for each basic dosimeter type (foil activation, blood sodium, hair activation, and TL systems) and for the composite of all measurements. Reference values are also included in terms of wet tissue kerma for air station results and element 57 absorbed dose for phantom measurements.

Average measured neutron doses normalized to the reference values and associated percent standard deviations about the mean (in parenthesis) are given in Table 11 for each basic dosimeter type and for the composite of all measurements. Normalized doses indicate the accuracy of the mean of a set of measurements relative to the reference value. Standard deviation about the mean is a measure of precision and reflects agreement among individual measurements of the same dose.

Considering all dosimeter types (column labeled "All" in Table 11), average measured results were higher than reference values by an average of about 35% for air stations and 15% for phantoms. For air station and phantom measurements, results for the unshielded spectrum were more accurate (within 6% of reference) than results for the moderated spectra which were 17 to 70% higher than references. Average measured phantom doses were more accurate than corresponding results at air stations for each spectrum. Standard deviations associated with these data were lower for the unshielded pulse than for the shielded pulses for air station and phantom locations.

Neutron dose measurements at air stations were made using foil activation detectors, the most popular type of area monitor used in this study, or TLD systems. Average activation-measured neutron doses varied from 1.06 to 1.79 times reference values with the unshielded spectrum providing the most accurate results. Associated standard deviations averaged 6% of the mean for the unshielded pulse and 40% of the means for the shielded pulses. Since only one agency reported air station results based on TLD's, no detailed analysis of the data is possible. However, TLD-measured neutron doses varied from 1.C8 to 1.35 times reference values for the three pulses

With regard to phantom data, personnel accident dosimeters based on foil activation provided average neutron doses which varied from 1.03 to 1.55 times references with results for the unshielded spectrum being the most accurate. Associated standard deviations were about 20% of the means for the unshielded and concrete-shielded pulses. Normalized doses for the one agency who used TLD's to measure neutron doses on phantoms ranged from 0.96 to 1.10 times reference values (average = 1.03) for the three pulses. Average results based on blood sodium activation were also very accurate and were within 6% of references for each case. These data were also very precise in that the average standard deviation for the three pulses was only 9% of the means. These accurate results for blood sodium activation are expected since empirical correlations used in this analysis by participating agencies were obtained for the

HPRR spectra considered in this study. Hair activation data, which was reported by one agency, provided accurate results for the unshielded spectrum (1.01 times the reference dose) but poor results for the moderated spectra (0.48 and 1.76 times references). This performance is expected because of the reduced fraction of neutron fluence above sulfur threshold and the low reference doses (about 0.5 Gy) for the concrete- and Lucite-shielded spectra[16]. Of the basic systems used to estimate neutron doses to personnel, TLD's and sodium activation were the most accurate (within 10% of reference values) for all spectra and dose levels considered in this study.

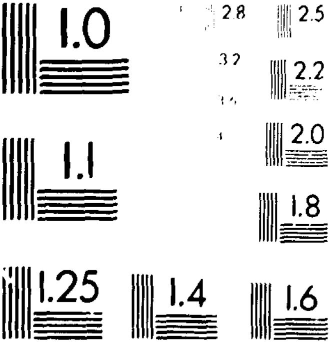
Average gamma dose measurements at air stations and on phantoms, associated experimental standard deviations about the mean, and reference doses for each pulse are summarized in Table 12. All gamma measurements were made using either TLD-700 or $CaSO_4$ phosphors. Average measured gamma doses normalized to reference values and associated percent standard deviations from the mean (in parenthesis) for air station and phantom locations are given in Table 13. Average measured results varied from 1.14 to 1.53 and from 1.11 to 1.39 times references for air stations and phantoms, respectively. No obvious correlations between gamma measurement performance characteristics (accuracy and precision) and incident spectrum is obvious from these data.

Measured and reference phantom-to-air station dose ratios are given in Table 14 for neutrons and gammas. Neutron doses measured on phantoms are higher than air station results due to neutrons reflected from the phantom. Gamma doses on phantoms are higher than at air stations because of the contribution of gamma rays from neutron capture reactions in hydrogenous phantom materials. Measured phantom-to-air dose ratios are within one experimental standard deviation of reference values

MICROCOPY RESOLUTION TEST CHART

NBS 1010a

ANSI and ISO TEST CHART No. 2



except for the Lucite-shielded pulse which produced a slightly low measured result.

DOSIMETER PERFORMANCE RELATIVE TO REGULATORY CRITERIA

Guidelines [17,18] for criticality accident dosimetry suggest accuracies of ± 25% for neutron and ±20% for gamma dose measurements. Table 15 summarizes the performance of neutron and gamma measurements made in this study relative to these criteria for air stations, phantoms, and the composite of all measurements. Data shown in the table include the number of measurements reported, the number satisfying the appropriate criterion, and the percent of results satisfying the criterion (in parenthesis).

A total of 68% of all reported neutron results was within ± 25% of reference values. Participants exhibited about the same success satisfying the neutron guidelines at air stations and on phantoms in that 64% and 70%, respectively, of the reported doses were within 25% of references. All results for the unshielded spectra met the guideline while only 50% of the results for the moderated pulses satisfied the standard. This performance is consistent with that observed in the most recent ORNL intercomparisons[1-3] which indicated about 75% of all neutron measurements within the suggested limits.

Gamma data showed that 44% of all reported results was within ± 20% of reference doses. About 60% of the air station measurements met the criterion while only 36% of the phantom measurements satisfied the standard. All gamma results for the concrete-shielded pulse were within ± 20% of references while none of the Lucite-shielded data were within this limit. This overall gamma measurement performance is consistent with that observed in recent ORNL intercomparisons[2,3].

CONCLUSIONS

Results of the Twenty-Second ORNL Criticality Accident Dosimetry Intercomparison Study indicated that about 68% of all neutron measurements and 44% of all gamma measurements made under simulated accident conditions satisfied suggested regulatory guidelines relative to reference doses. For neutron measurements at air stations or on phantoms, the most accurate results were obtained for the unshielded HPRR spectrum which also had the highest reference neutron dose (about 3.5 Gy). Poorest accuracies were exhibited for moderated spectra with reference neutron doses of approximately 0.5 Gy. On the average, neutron doses measured using TLD's or blood sodium activation methods were more accurate than results obtained using foil activation systems. Average reported gamma dose estimates based on TLD-700 or $CaSO_4$ phosphors were higher than reference values by 11 to 53% for all pulses and monitoring locations. Results obtained in this study were consistent with accident dosimeter performance characteristics observed in recent ORNL intercomparisons.

RECOMMENDATIONS

The generally poor measurement accuracy exhibited in this study indicates a need for continuing ORNL accident dosimetry testing and training programs. To fill this need, the DOSAR staff will continue to conduct criticality accident dosimetry intercomparisons every two years and accident dosimetry training courses during the years between intercomparisons.

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ORNL-PHOTO 5165-85

Figure 1. Experimental arrangement for pulse 2 (concrete-shielded) with the HPRR operated over the storage pit.

ORNL-PHOTO 5164-85

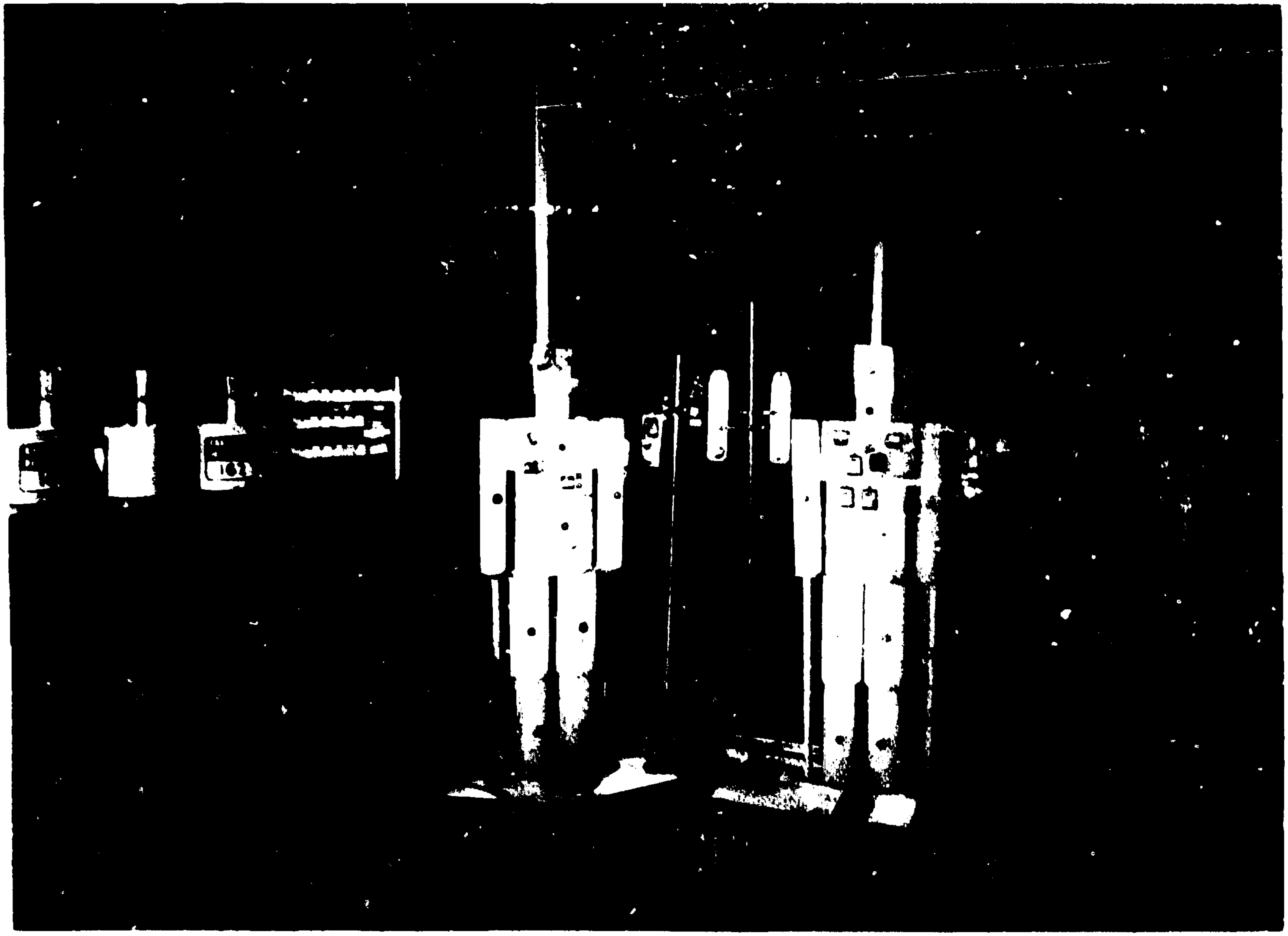

Figure 2. Typical arrangement of phantoms and dosimeters for the 22nd Criticality Accident Dosimetry Intercomparison Study.

Table 1. Summary of experimental conditions[a]

Pulse No.	Date	Eastern Daylight Time	Pulse yield, 10^{16} fissions[b]	Shield	Reactor to shield distance, m
1	8/13/85	1030	9.52	None	-
2	8/14/85	1116	7.37	20-cm concrete	1.5
3	8/15/85	1100	6.40	12-cm Lucite	2

[a]Dosimeters at area monitoring stations and on Lucite phantoms were located at 3 m from the center of the HPRR. Centerlines of BOMAB phantoms on which personnel dosimeters were exposed were 3 m from the HPRR centerline.

[b]Based on sulfur pellet activation analysis.

Table 2. Reference neutron and gamma doses at air stations

Pulse no.	Shield	Pulse yield, 10^{16} fissions	Neutron dose, 10^{-2} Gy[a] Kerma	Neutron dose, 10^{-2} Gy[a] Element 57	Neutron-to-gamma dose ratio[b]	Gamma dose 10^{-2} Gy[c]
1	None	9.52	333	378	6.2	54
2	20-cm concrete	7.37	48	54	2.2	22
3	12-cm Lucite	6.40	36	42	1.2	30

[a] Calculated dose at 3 m from the reactor centerline based on new HPRR reference dosimetry. Units are 10^{-2} Gy (1 rad).

[b] Dose ratio at 3 m from the reactor centerline based on measured results of the first twenty-one nuclear accident dosimetry intercomparison studies.

[c] Neutron kerma divided by the neutron-to-gamma dose ratio.

Table 3. Reference neutron and gamma doses on phantoms

Pulse no.	Neutron air-to-phantom conversion[a]	Neutron dose, 10^{-2}Gy Kerma[b]	Neutron dose, 10^{-2}Gy Element 57	Gamma air-to-phantom conversion[a]	Gamma dose, 10^{-2}Gy[b]
1	1.06	353	378	1.49	80
2	1.20	58	54	1.25	28
3	1.19	43	42	1.27	38

[a]Ratio of phantom-to-air dose based on measured results from the first twenty-one accident dosimetry intercomparisons.

[b]Product of conversion factor times the dose in air given in Table 2.

Table 4. Measurements at air stations for pulse no. 1

Yield: 9.52 (10^{16}) fissions

Shield: None

Group	Neutron dose, 10^{-2}Gy[a]	Gamma dose, 10^{-2}Gy	Detection system: Neutron	Detection system: Gamma
Reference	333	54	-	-
Reference	378[b]	-	-	-
DOSAR	379	-	TDU	-
PNL	360	64	TLD	TLD-700
RFP	330	-	Act	-
SRP	361	87	Act	TLD-$CaSO_4$
Y-12	340	-	Act	-

[a]Neutron doses represent wet tissue kerma unless otherwise indicated and are given in units of 10^{-2}Gy (1 rad).

[b]Element 57 dose with $H(n,\gamma)$ component excluded.

Table 5. Measurements at air stations for pulse no. 2

Yield: 7.37 (10^{16}) fissions

Shield: 20-cm concrete

Group	Neutron dose, 10^{-2}Gy[a]	Gamma dose, 10^{-2}Gy	Detection system: Neutron	Detection system: Gamma
Reference	48	22	-	-
Reference	54[b]	-	-	-
DOSAR	53	-	TDU	-
PNL	65	24	TLD	TLD-700
RFP	63	-	Act	-
SRP	114	26	Act	TLD-$CaSO_4$
Y-12	114	-	Act	-

[a]Neutron doses represent wet tissue kerma unless otherwise indicated and are given in units of 10^{-2}Gy (1 rad).

[b]Element 57 dose with H(n,γ) component excluded.

Table 6. Measurements at air stations for pulse no. 3

Yield: 6.40 (10^{16}) fissions

Shield: 12-cm Lucite

Group	Neutron dose, 10^{-2}Gy[a]	Gamma dose, 10^{-2}Gy	Detection system	
			Neutron	Gamma
Reference	36	30	-	-
Reference	42[b]	-	-	-
DOSAR	39	-	TDU	-
PNL	41	46	TLD	TLD-700
RFP	34	-	Act	-
SRP	114	26	Act	TLD-$CaSO_4$
Y-12	114	-	Act	-

[a]Neutron doses represent wet tissue kerma unless otherwise indicated and are given in units of 10^{-2}Gy (1 rad).

[b]Element 57 dose with H(n,γ) component excluded.

Table 7. Measurements on phantoms for pulse no. 1

Yield: 9.52 (10^{16}) fissions

Shield: None

Group	Neutron dose, 10^{-2}Gy[a]	Gamma dose, 10^{-2}Gy	Basis for estimates: Neutron	Basis for estimates: Gamma
Reference	378	80	–	–
DOSAR	378	–	NaAct[b]	
DOSAR	380	–	HAct[c]	–
DPC	363	98	TLD	TLD-$CaSO_4$
INEL	459	105	Act	TLD-700
NLO	411	127	Act	TLD
SRP	302	112	Act	TLD-$CaSO_4$
Y-12	335	–	NaAct	–

[a]Neutron doses given in element 57 convention unless otherwise indicated and are given in units of 10^{-2}Gy (1 rad).

[b]Blood sodium activation.

[c]Activation of sulfur in hair.

Table 8. Measurements on phantoms for pulse no. 2

Yield: 7.37 (10^{16}) fissions

Shield: 20-cm concrete

Group	Neutron dose, 10^{-2}Gy[a]	Gamma dose, 10^{-2}Gy	Basis for estimates: Neutron	Basis for estimates: Gamma
Reference	54	28	-	-
DOSAR	52	-	NaAct[b]	-
DOSAR	26	-	HAct[c]	-
DPC	55	32	TLD	TLD-$CaSO_4$
INEL	47	-	NaAct	TLD-700
INEL	72	32	Act	TLD
NLO	72	32	Act	TLD
SRP	71	28	Act	TLD-$CaSO_4$
Y-12	63	-	NaAct	-

[a]Neutron doses given in element 57 convention unless otherwise indicated and are given in units of 10^{-2}Gy (1 rad).

[b]Blood sodium activation.

[c]Activation of sulfur in hair.

Table 9. Measurements on phantoms for pulse no. 3

Yield: 6.40 (10^{16}) fissions

Shield: 12-cm Lucite

Group	Neutron dose, 10^{-2}Gy[a]	Gamma dose, 10^{-2}Gy	Basis for estimates Neutron	Basis for estimates Gamma
Reference	42	38	-	-
DOSAR	43	-	NaAct[b]	-
DOSAR	74	-	HAct[c]	-
DPC	46	53	TLD	TLD-$CaSO_4$
INEL	46	53	TLD	TLD-$CaSO_4$
INEL	40	-	NaAct	-
NLO	-	49	-	TLD

[a]Neutron doses given in element 57 convention unless otherwise indicated and are given in units of 10^{-2}Gy (1 rad).

[b]Blood sodium activation.

[c]Activation of sulfur in hair.

Table 10. Summary of results of neutron dose measurements at air stations and on phantoms

Pulse no.	Dosimeter location (spectrum)	Neutron dose, 10^{-2} Gy[a] Act[b]	TLD	NaAct[c]	HAct[d]	All[e]	Reference
1	Air (bare)	352 ±22(4)[f]	360(1)	-	-	354 ± 19(5)	333
2	Air (concrete)	86 ± 32(4)	65(1))	-	-	82 ± 30(5)	48
3	Air (Lucite)	48 ± 21(3)	41(1)	-	-	46 ± 17(4)	36
1	Phantom (bare)	391 ± 80(3)	363(1)	356 ±30(2)	380(1)	375 ± 51(7)	378
2	Phantom (concrete)	78 ± 11(3)	55(1)	53 ± 8(3)	26(1)	63 ± 14(8)	54
3	Phantom (Lucite)	65(1)	46(1)	42 ± 2(2)	74(1)	54 ± 15(5)	42

[a]Values are average doses ± one standard deviation based on data shown in Tables 4-6 (air stations) and Tables 7-9 (phantoms). Wet tissue kerma convention is used for air station results and element 57 convention used for phantom measurements.

[b]Neutron activation foils and TDU's.

[c]Blood sodium activation.

[d]Activation of sulfur in hair.

[e]Includes results for all dosimeter types.

[f]Number of measurements given in parenthesis.

Table 11. Normalized average measured neutron doses and percent standard deviations[a]

Pulse no.	Dosimeter location (spectrum)	Normalized neutron dose (percent standard deviation)[b]				
		Act[c]	TLD	NaAct[d]	HAct[e]	All[f]
1	Air (bare)	1.06 (6)	1.08[g]	-	-	1.06(5)
2	Air (concret-)	1.79 (37)	1.35[g]	-	-	1.70(36)
3	Air (Lucite)	1.33(44)	1.14[g]	-	-	1.28(37)
1	Phantom (bare)	1.03(21)	0.96[g]	0.94(8)	1.01[g]	0.99(14)
2	Phantom (concrete)	1.44(20)	1.02[g]	1.00(15)	0.48[g]	1.17(22)
3	Phantom (Lucite)	1.55[g]	1.10[g]	1.00(5)	1.76[g]	1.29(28)

[a]Based on data shown in Table 10.

[b]Average reported measured dose divided by the reference value (percent of one standard deviation about the mean).

[c]Neutron activation foils and TDU's.

[d]Blood sodium activation.

[e]Activation of sulfur in hair.

[f]Includes results for all dosimeter types.

[g]Only one measurement reported for this pulse.

Table 12. Summary of results of gamma dose measurements at air stations and on phantoms

Pulse no.	Dosimeter location(spectrum)	Gamma dose, 10^{-2} Gy[a]	
		TLD[b]	Reference
1	Air (bare)	76 ± 16(2)	54
2	Air (concrete)	25 ± 1(2)	22
3	Air (Lucite)	46 (1)	30
1	Phantom (bare)	111 ± 12(4)	80
2	Phantom (concrete)	31 ± 2(4)	28
3	Phantom (Lucite)	51 ± 2(3)	38

[a]Values are average doses based on data shown in Tables 4-6 (air) and Tables 7-9 (phantoms) ± one standard deviation about the mean (number of reported results in parenthesis).

[b]All reported gamma measurements were made with TLD-700 or $CaSO_4$ phosphors.

Table 13. Normalized average measured gamma doses and associated percent standard deviations[a]

Pulse no.	Shield	Dosimeter location	Normalized gamma dose (percent standard deviation)[b]
1	None	Air	1.41(30)
2	Concrete	Air	1.14(5)
3	Lucite	Air	1.53[c]
1	None	Phantom	1.39(15)
2	Concrete	Phantom	1.11(7)
3	Lucite	Phantom	1.34(5)

[a]Based on data shown in Table 12.

[b]Average reported measured dose divided by the reference value (percent of one standard deviation about the mean).

[c]Only one measurement reported for this pulse.

Table 14. Comparison of doses measured on phantoms with those measured at air stations

Pulse no.	Shield	Ratio of phantom dose to air station dose			
		Neutron		Gamma	
		Measured[a]	Reference[b]	Measured[c]	Reference[b]
1	None	1.06 $\pm$ 0.17[d]	1.06	1.46 $\pm$ 0.24	1.49
2	Concrete	1.41 $\pm$ 0.24[e]	1.20	1.24 $\pm$ 0.08	1.25
3	Lucite	1.17 $\pm$ 0.49	1.19	1.11 $\pm$ 0.04	1.27

[a] Based on data given in Table 10 for all reported dose measurements.

[b] Based on measured results from the first 21 intercomparisons.

[c] Based on data given in Table 12 for all reported dose measurements.

[d] Phantom dose (element 57) divided by air dose (tissue kerma) $\pm$ one standard deviation about the mean.

[e] One very low reported neutron dose on a phantom was not considered in this calculation.

Table 15. Summary of final measured results relative to regulatory criteria[a]

Pulse no.	Dosimeter location (shield)	Neutron results: Number of measurements	Neutron results: Number meeting criterion[b]	Gamma results: Number of measurements	Gamma results: Number meeting criterion[b]
1	Air (none)	5	5(100)	2	1 (50)
2	Air (concrete)	5	1 (20)	2	2 (100)
3	Air (Lucite)	4	3 (75)	1	0 (0)
1	Phantom (none)	7	7(100)	4	0 (0)
2	Phantom (concrete)	8	4 (50)	4	4 (100)
3	Phantom (Lucite)	5	3 (60)	3	0 (0)
Total		34	23 (68)	16	7 (44)

[a]Criteria presented in ANSI N13.3 which suggests accuracies of ± 25% for neutron doses and ± 20% for gamma doses.

[b]Number of measurements meeting the above mentioned criteria (percent meeting criteria).

PROGRAM

TWENTY-SECOND NUCLEAR ACCIDENT DOSIMETRY INTERCOMPARISON STUDY

August 12-16, 1985

Date	Time	Activity
August 12 (Monday)	9:30 AM	Welcome and orientation, C. S. Sims (ORNL)
	10:00	Review of the study program, R. E. Swaja (ORNL)
	10:30	Tour of DOSAR Facility and HPRR - Equipment setup
		LUNCH
	1:00 PM	Lecture: Criticality Accident Dosimetry, R. E. Swaja (ORNL)
	2:00	Lecture: Reporting Accident Doses, C. S. Sims (ORNL)
	3:00	Preparation for Pulse No. 1
August 13 (Tuesday)	8:00 AM	Final setup of dosimeters for Pulse No. 1
	9:00	Descriptions of dosimetry systems—Study participants
	10:00	Observation of HPRR pulse operation--Pulse No. 1--unshielded
	11:00	Group photograph—collect dosimeters
		LUNCH
	1:00	Dosimeter analysis and experimental analysis of quick sort system responses for unshielded spectrum
August 14 (Wednesday)	8:00 AM	Final setup of dosimeters for Pulse No. 2
	9:00-11:30	Tour of ORNL for NAD Study participants
	10:00	Pulse No. 2--concrete shield
	11:30	Collect dosimeters
		LUNCH

	1:00 PM	Dosimeter analysis and experimental analysis of quick sort system responses for concrete spectrum

August 15 (Thursday)	8:00 AM	Final setup of dosimeters for Pulse No. 3
	9:00	Progress in the Analysis of the Japanese Bomb Survivor Data, G. D. Kerr, ORNL
	10:00	Medical Aspects of Radiation Accidents, S. A. Fry (ORAU)
	10:30	Pulse No. 3—Lucite shield
	11:30	Collect dosimeters
		LUNCH
	1:00	Dosimeter analysis and experimental analysis of quick sort system responses for Lucite spectrum

August 16 (Friday)	9:30 AM	Presentation of preliminary dose estimates, discussion of quick sort experiments, and review of data reporting format
	10:30	Critique and summary
	11:00	End of study

APPENDIX A

APPENDIX B

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