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Fourteenth Nuclear Accident Dosimetry Intercomparison Study: July 13–22, 1977

C. S. Sims

HEALTH AND SAFETY RESEARCH DIVISION
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FOURTEENTH NUCLEAR ACCIDENT DOSIMETRY INTERCOMPARISON STUDY: JULY 13-22, 1977

C. S. Sims

Date Published: June 1979

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Fourteenth Nuclear Accident Dosimetry Intercomparison Study: July 13-22, 1977

C. S. Sims

HIGHLIGHTS

The fourteenth in the continuing series of Nuclear Accident Dosimetry Intercomparison Studies was held July 13-22, 1977, at the Oak Ridge National Laboratory. The Health Physics Research Reactor, operated in the pulse mode, served as the radiation source. Four different shielding configurations (unshielded, 12-cm Lucite, 20-cm concrete, and 5-cm steel/15-cm concrete) helped simulate various nuclear criticality accident situations. Participants from eleven different organizations, seven domestic and four foreign, performed nuclear accident dose measurements during the study. Dosimeters used as area monitors as well as dosimeters on phantoms were intercompared under identical experimental conditions. Reported values of neutron dose were within ±38% of the mean for all pulses while gamma ray doses were within ±25% of the mean at one standard deviation. As a whole, these results fail to meet established guidelines of ±20% (gamma) and ±25% (neutron). Participants, in general, still need to demonstrate that they can consistently perform accurate dose measurements for a variety of neutron and gamma spectra.

INTRODUCTION

The fourteenth in the series[1-3] of nuclear accident dosimeter intercomparison studies was conducted at Oak Ridge National Laboratory's (ORNL) Dosimetry Applications Research (DOSAR) facility during the period July 13-22, 1977. Participants measured neutron and gamma radiation doses resulting

from simulated nuclear accident conditions provided by the Health Physics Research Reactor (HPRR)[4] operating in the pulse mode. Participants compared their results with those of other participants who made similar measurements under identical conditions. In addition to the experimental work, the study included lecture and discussion sessions on various relevant subjects such as development of albedo dosimeters, criticality alarm systems, medical aspects of nuclear accidents, and international activity in nuclear accident dosimetry. The program for the entire study is Appendix I of this report.

PARTICIPATION

Eleven different organizations, seven domestic and four foreign, participated (i.e., exposed dosimeters) in the fourteenth nuclear accident dosimetry intercomparison study. A list of participant organizations and the abbreviations by which they are commonly identified is given in Appendix II. In addition to the experiment participants and the lecturers (see Appendix I), many observers attended the intercomparison study.

DESCRIPTION OF THE EXPERIMENTS

The HPRR was operated in the pulse mode to simulate nuclear accidents. Four different pulses were performed: one with dosimeters behind a 5-cm steel/15 cm concrete shield, one unshielded, one using a 20-cm concrete shield, and (by special request) one using a 12-cm Lucite shield. The various shields resulted in the experimental dosimeters being exposed to a wide range of neutron energy spectra[5] and neutron-to-gamma ratios. Participants mounted dosimeters at area monitoring stations (also called air stations) and on Bomab[6] phantoms.

Table 1 is a summary of the relevant experimental conditions for each of the four pulses. Figures 1, 2, and 3 clearly show the experimental arrangement for the first three pulses. The arrangement for pulse number 4 was not photographed. It was similar to the others with two exceptions: the shield and the dosimeters were one meter further away from the HPRR and only one phantom (phantom C) was used.

Two of the three phantoms used in the experiments were filled with a saline solution (the third was water-filled) such that the sodium concentrations approximated that in human blood. Concentrations of sodium in the phantoms are presented in Table 2. When irradiated by neutrons, the sodium becomes activated; the activity is proportional to the neutron dose.[6,7] Samples of the irradiated solutions were made available to participants shortly after each of the first three pulses.

DOSIMETERS USED IN THE INTERCOMPARISON

The general types of radiation dosimetry systems used by the participants in this intercomparison study are briefly described below. Detailed descriptions of these and similar systems are available elsewhere.[1-3, 8-10]

Gamma Dosimeters

1. Radiophotoluminescent Glass Dosimeter (RPL) — When speically prepared glass is exposed to radiation, its luminescent properties are changed. The magnitude of these changes is proportional to the dose.

2. Thermoluminescent Dosimeter (TLD) — Irradiation of TLD material produces metastable centers which, upon heating, emit light in proportion to the dose received by the material.

Neutron Dosimeters

1. Foil Activation (ACT) — Foils (e.g., gold, copper, indium) exposed to neutrons become radioactive. The radioactivity is measured and the dose obtained from knowledge of the incident spectrum and weighted dose per unit fluence.

2. Sodium Activation (Na ACT) — Saline solution samples from irradiated phantoms are analyzed for induced ^{24}Na activity by any of a variety of counting techniques. The dose received by a phantom is proportional to the specific activity of the solution.

3. Threshold Detector Unit (TDU) — Gram quantities of fissionable material (e.g., plutonium, neptunium, uranium) having fission cross sections with thresholds at different neutron energies are enclosed in a boron shield. The TDU's also generally contain activation foils such as gold and sulfur for additional spectral definition. Neutron fluence within certain energy ranges is determined by counting fission product gammas. Dose is obtained using predetermined dose per unit fluence values.

4. Track Damage Dosimeter (TRACK) — A fissionable material (e.g., ^{232}Th) called a radiator is placed in a dosimeter unit adjacent to a plastic foil. When bombarded by neutrons, the radiator undergoes fission. The fission fragments cause damage in the plastic. The damage, appropriately described as tracks (of fission fragments), is visible under a microscope. The density of tracks in the plastic is a measure of the neutron dose. Nonvisual techniques for track determination are also in common use.

MEASUREMENT RESULTS

Tables 3 through 6 contain reported results of measurements made at air stations for pulse numbers 1 through 4, respectively. Tables 7 through 10 contain results of phantom-related measurements for the same four pulses. Presentation in this tabular form allows intercomparison of results among participants.

Table 11 is a summary of all the dose measurements. The standard deviation from the mean measured gamma dose varied from 11 to 25%; for neutrons, it varied from 25 to 38%.

The dose measured on phantoms is compared with that measured at air stations in Table 12. For all except the Lucite-shielded case, the measured phantom dose was larger than the air station dose by 10 to 20% for neutrons and 60 to 70% for gammas. The neutron dose is enhanced due to neutrons reflected into the dosimeters from the phantom. The gamma dose is enhanced due to the $^{1}H(n, \gamma)^{2}H$ reactions in the water inside the phantoms. The single Lucite-shielded phantom dose to air station dose ratio reported is not sufficient to determine a definite trend. Based on previous experiments with the Lucite shield at DOSAR, this ratio was expected to be about 1.0 for neutrons and 1.4 for gammas.

The measured dose for various shielding configurations normalized to a given number of fissions (e.g., 10^{16} fissions is convenient) is of interest to the HPRR operating staff and allow comparison of measurements from year to year. This information is available from the intercomparison study and is included in Table 13.

The neutron dose-to-gamma dose ratio (i.e., n/γ) is an important parameter in dosimetry experiments since many dosimeters have a different sensitivity for neutrons than they have for gammas. These ratios for the various shield configurations were determined for the study measurements and are reported in Table 14.

CONCLUSIONS

From analysis of the basic data reported by the participants, it is seen that the neutron dose was measured with a precision (at one standard

deviation) of 25 to 38% and the gamma dose was measured with a precision of 11 to 25%. Imprecise results are inaccurate results. It is, therefore, implied that the measured results *as a whole* do not fall within the recognized ±25% (neutron) and ±20% (gamma) accuracy guidelines.[11,12] It should, however, be emphasized that the majority of participants reported results within ±20% of the mean for most measurements. One to three outlying data points (i.e., neutron measurements varying from the mean by 40 to 70% and gamma measurements varying from the mean by 25 to 40%) per pulse contributed heavily to the overall group lack of precision. Some participants still need to demonstrate that they can consistently perform accurate dose (particularly neutron) measurements over a wide variety of shielding configurations.

REFERENCES

1. C. S. Sims, *Fifteenth Nuclear Accident Dosimetry Intercomparison Study: August 14-22, 1978*, ORNL/TM-6554, 1979.
2. H. W. Dickson, F. F. Haywood, and K. Becker, *Tenth Dosimetry Intercomparison Study August 27-September 7, 1973*, ORNL/TM-4566, March 1975.
3. J. W. Poston and F. F. Haywood, *1972 Intercomparison of Nuclear Accident Dosimetry Systems at the Oak Ridge National Laboratory*, ORNL/TM-4387, July 1972.
4. J. A. Auxier, "The Health Physics Research Reactor," *Health Phys.* 11, 89-93, (1965).
5. H. W. Dickson and L. W. Gilley, "Personnel Dosimetry Intercomparison Studies at the ORNL Health Physics Research Reactor," *Proceedings of Symposium on National and International Standardization in Radiation Dosimetry, December 5-19, 1977, Atlanta, Georgia.*
6. F. W. Sanders and J. A. Auxier, "Neutron Activation of Sodium in Anthropomorphous Phantoms," *Health Phys.* 8, 371-379 (1962).
7. D. R. Davy, L. H. Peshori, and J. W. Poston, "Sodium-24 Production in Saline-Filled Phantoms under Neutron Irradiations," *Health Phys.* 12, 1353-1356 (1966).
8. C. N. Wright, J. E. Hoy, and W. F. Splichael, Jr., *Savannah River Plant Criticality Dosimeter System*, DP-1006, Savannah River Laboratory, Aiken, South Carolina (1965).
9. J. C. Bailey, *A New Neutron Dosimeter and Neutron-Spectrum Model for Nuclear Accident Dosimetry*, K-1763, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee (1969).

10. H. Ing and W. G. Cross, "A Criticality Neutron Dosimeter Using the $^{103}Rh(n,n')^{103m}Rh$ Reaction," *Health Phys.* 25, 291 (1973).

11. American National Standards Institute, ANSI N13.3-1969, "Dosimetry for Criticality Accidents," 1969.

12. *U.S. Atomic Energy Commission Manual,* AEC 0545, "Nuclear Accident Dosimetry Program," Reprinted May 2, 1974.

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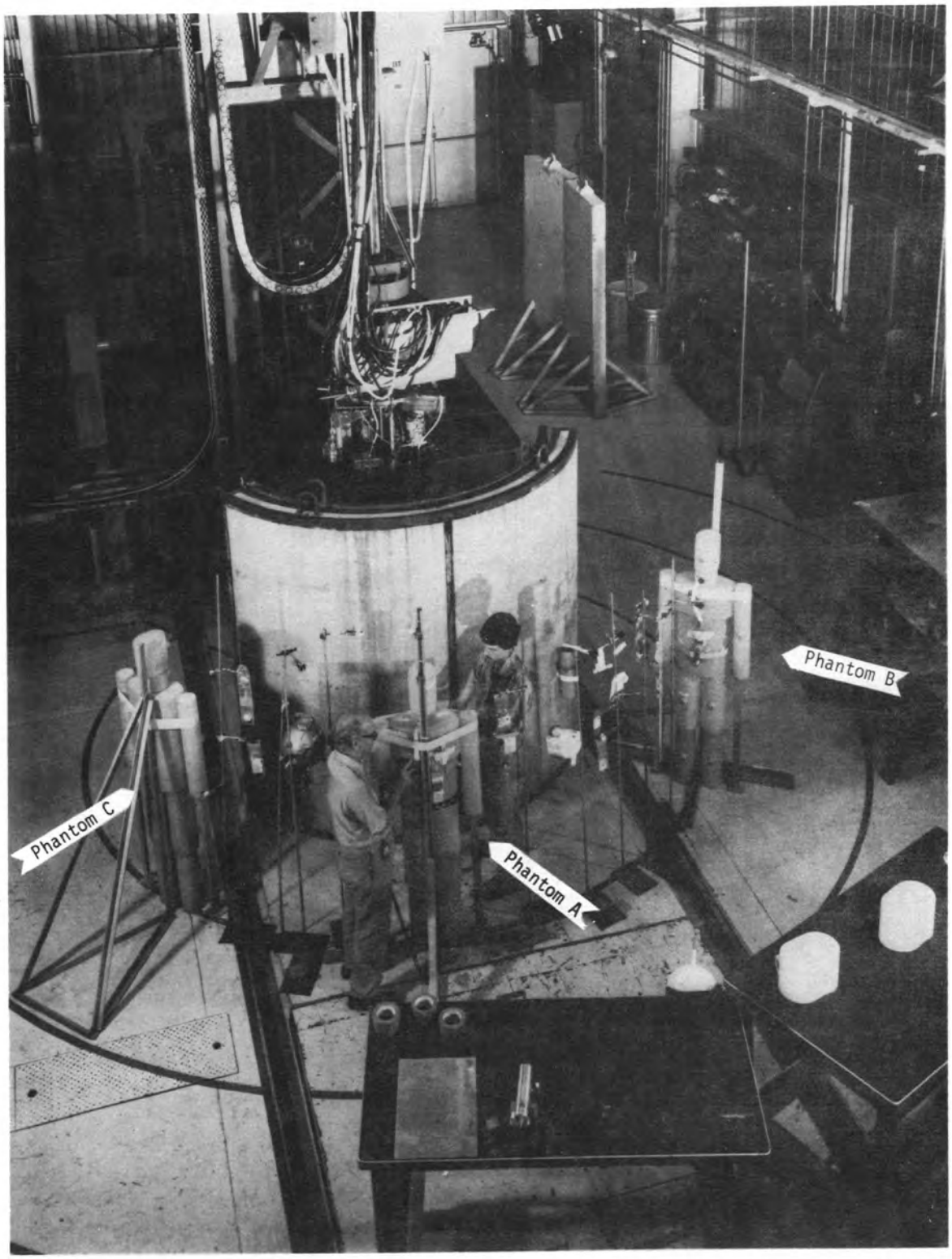

Fig. 1. Experimental arrangement for Pulse No. 1 (shield is 5-cm steel/ 15-cm concrete).

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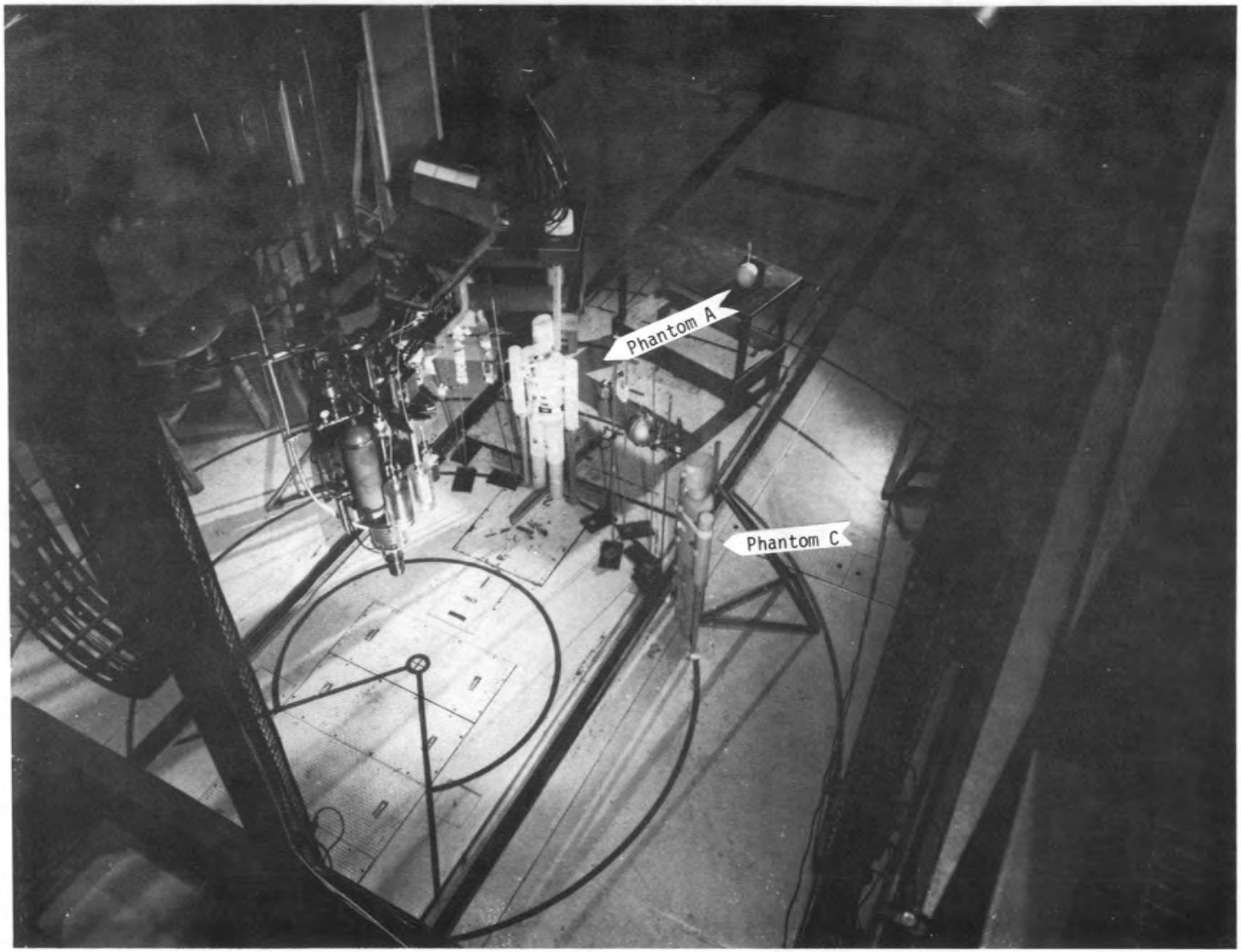

Fig. 2. Experimental arrangement for Pulse No. 2 (unshielded).

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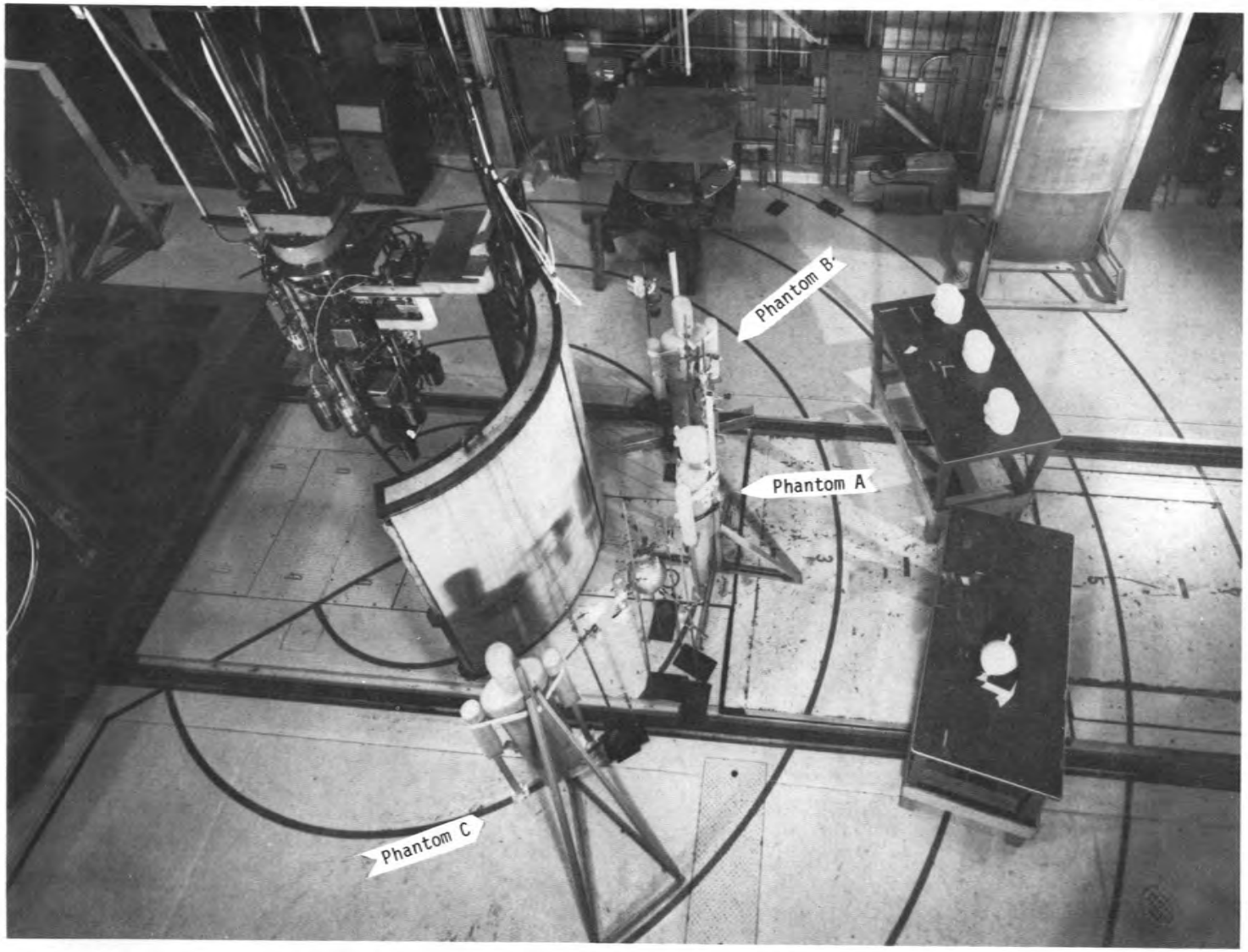

Fig. 3. Experimental arrangement for Pulse No. 3 (shield is 20-cm concrete).

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Table 1. Summary of experimental conditions during the Fourteenth Nuclear Accident Dosimetry Intercomparison Study

Pulse	Date	Eastern daylight time	Pulse yield, 10^{16} fissions	Shield	Reactor to shield distance, meters	Reactor to dosimeter distance,[a] meters
1	7/14/77	1025	6.60	5 cm steel + 15 cm concrete	1	2
2	7/18/77	1016	8.51	None		2
3	7/20/77	0959	5.39	20 cm concrete	1	2
4	7/21/77	1006	6.94	12 cm Lucite	2	3

[a]Area monitoring stations and the fronts of phantoms on which dosimeters were exposed were at the same distance from the HPRR.

ORNL/DWG 79-9435

Table 2. Sodium concentrations in saline solution-filled Bomab phantoms[a] irradiated during the Fourteenth Nuclear Accident Dosimetry Intercomparison Study

	Sodium concentration, mg/ml		
Pulse	Phantom A	Phantom B	Phantom C
1	1.62	1.52	Tap water[b]
2	1.62	1.51	Tap water
3	1.56	1.49	Tap water
4	Not used	Not used	Tap water

[a]See Fig. 1 for location and orientation of phantoms A, B, and C.

[b]The sodium chloride solutions in phantoms A and B were prepared with distilled water.

ORNL/DWG 79-9437

Table 3. ORNL Fourteenth Intercomparison of Nuclear Accident Dosimetry systems
Measurements[a] at air stations
Pulse No. 1 Yield = 6.60 (10^{16}) fissions, Shield: 5-cm steel/15-cm concrete

Study group[b]	Neutron dose, rads	Gamma dose, rads	10^{-10} x Neutron fluence, n/cm^2					Detector system	
			Au, thermal	Pu, >1 keV	Np, >0.75 MeV	U >1.5 MeV	S, >2.5 Mev	Neutron	Gamma
AECL	115[c]							ACT+TRACK	
CEA	104[c]	37	3.50	6.70	2.25	1.34[d]	0.58	ACT	TLD+RPL
DOSAR	87[c]	35		3.95	2.15	1.10	0.46	TDU	RPL
EG&G	90[e]		2.52		1.38	1.01	0.45[f]	ACT	
GAC									
GSF	88	47	0.43		2.50		0.40	TDU	TLD
GFK									
LLL	80[c]	36	1.90	4.50[g]	1.80	1.10	0.35[h]	TDU	TLD
SLA[i]	175	47	0.68					ACT	TLD
SRL		60	5.40				0.45[h]	ACT	TLD
UCND	184[e]	38	4.80				0.40[f]	ACT	TLD
Mean	115	43	2.8	5.1	2.0	1.1	0.44		
σ[j]	41	9	1.9	1.5	0.4	0.1	0.07		
σ(%)	36	21	68	29	20	9	16		
n	8	7	7	3	5	4	7		

[a]Average results are presented where groups reported more than one result.
[b]See Appendix II for full name of group.
[c]Kerma.
[d]>1.4 MeV.
[e]Protons + recoils.
[f]>2.9 MeV.
[g]>10 keV.
[h]>3 MeV.
[i]Measurements made at 4 m and extrapolated to results at 2 m.
[j]One standard deviation.

ORNL/DWG 79-9440

Table 4. ORNL Fourteenth Intercomparison of Nuclear Accident Dosimetry systems
Measurements[a] at air stations
Pulse No. 2 Yield = 8.51 (10^{16}) fissions, Shield: None

Study group[b]	Neutron dose, rads	Gamma dose, rads	10^{-10} x Neutron fluence, n/cm^2					Detector system	
			Au, thermal	Pu, >1 keV	Np, >0.75 MeV	U >1.5 MeV	S, >2.5 Mev	Neutron	Gamma
AECL	973[c]							ACT+TRACK	
CEA	675[c]	112	2.01	28.50	17.40	12.20[d]	6.10	ACT	TLD+RPL
DOSAR	636[c]	100		25.65	19.05	9.0	4.65	TDU	RPL
EG&G	608[e]		1.27		12.90	9.76	4.69[f]	ACT	
GAC	630[c]		1.20				4.20	ACT	
GSF	465	134	0.22				4.50	TDU	TLD
GFK									
LLL	692[c]	103	1.90	32.4[g]	19.50	10.20	3.40[h]	TDU	TLD
SLA[i]	1232	145	0.91					ACT	TLD
SRL									
UCND	646[e]	114	2.16				4.20[f]	ACT	TLD
Mean	729	118	1.4	28.9	17.2	10.3	4.5		
σ[j]	231	18	0.7	3.4	3.0	1.4	0.8		
σ(%)	32	15	50	12	17	14	18		
n	9	6	7	3	4	4	7		

[a]Average results are presented where groups reported more than one result.
[b]See Appendix II for full name of group.
[c]Kerma.
[d]>1.4 MeV.
[e]Protons + recoils.
[f]>2.9 MeV.
[g]>10 MeV.
[h]>3 keV.
[i]Measurements made at 4 m and extrapolated to results at 2 m.
[j]One standard deviation.

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Table 5. ORNL Fourteenth Intercomparison of Nuclear Accident Dosimetry systems
Measurements[a] at air stations
Pulse No. 3 Yield = 5.39 (10^{16}) fissions, Shield: 20-cm concrete

Study group[b]	Neutron dose, rads	Gamma dose, rads	10^{-10} x Neutron fluence, n/cm^2					Detector system	
			Au, thermal	Pu, >1 keV	Np, >0.75 MeV	U >1.5 MeV	S, >2.5 Mev	Neutron	Gamma
AECL	129[c]							ACT+TRACK	
CEA	91[c]	44	3.40	5.10	2.20	1.50[d]	0.76	ACT	TLD+RPL
DOSAR	85[c]	46		3.60	2.20	1.25	0.74	TDU	RPL
EG&G	97.4[e]		2.36		1.54	1.13	0.51[f]	ACT	
GAC	115[c]		2.60				0.53	ACT	
GSF	75	55	0.40		2.20		0.52	TDU	TLD
GFK									
LLL	88[c]	37	2.00	4.60[g]	2.20	1.30	0.48[h]	TDU	TLD
SLA[i]	204	52	0.92					ACT	TLD
SRL		45	3.40				0.50[h]	ACT	TLD
UCND	177[e]	42	4.80				0.51[f]	ACT	TLD
Mean	118	46	2.5	4.4	2.1	1.3	0.57		
σ[j]	45	6	1.4	0.8	0.3	0.2	0.11		
σ(%)	38	13	56	18	14	15	19		
n	9	7	8	3	5	4	8		

[a]Average results are presented where groups reported more than one result.
[b]See Appendix II for full name of group.
[c]Kerma.
[d]>1.4 MeV.
[e]Protons + recoils.
[f]>2.9 MeV.
[g]>10 keV
[h]>3 MeV.
[i]Measurements made at 4 m and extrapolated to results at 2 m.
[j]One standard deviation.

ORNL/DWG 79-9446

Table 6. ORNL Fourteenth Intercomparison of Nuclear Accident Dosimetry systems
Measurements[a] at air stations
Pulse No. 4 Yield = 6.94 (10^{16}) fissions, Shield: 12-cm Lucite

Study group[b]	Neutron dose, rads	Gamma dose, rads	10^{-10} x Neutron fluence, n/cm^2					Detector system	
			Au, thermal	Pu, >1 keV	Np, >0.75 MeV	U >1.5 MeV	S, >2.5 Mev	Neutron	Gamma
AECL									
CEA									
DOSAR	59[c]	53		2.35	1.55	0.84	0.73	TDU	RPL
EG&G									
GAC									
GSF									
GFK									
LLL									
SLA									
SRL									
UCND									
Mean	59	53		2.35	1.55	0.84	0.73		
σ[d]									
σ(%)									
n	1	1		1	1	1	1		

[a]Average results are presented where groups reported more than one result.
[b]See Appendix II for full name of group.
[c]Kerma.
[d]One standard deviation.

ORNL/DWG 79-9434

Table 7. ORNL Fourteenth Intercomparison of Nuclear Accident Dosimetry systems
Phantom studies[a,b]
Pulse No. 1 Yield = 6.60 (10^{16}) fissions, Shield: 5-cm steel/15-cm concrete

Study group[c]	Neutron dose, rads	Gamma dose, rads	10^4 x Na-24 activity		Basis for estimating	
			μCi/ml	μCi/mg	Neutron dose	Gamma dose
AECL	132[d]	69			ACT+TRACK	TLD
CEA	125[d]	59		4.4[e]	ACT	TLD+RPL
DOSAR	124[f]	69	5.1	3.1	Na ACT	TLD
EG&G	119[g]				ACT	
GAC						
GSF	117	79			ACT	TLD
GFK						
LLL	110[h]	71	7.2	4.4	ACT+Na ACT	TLD
SLA	230				ACT	
SRL	117[d]	84	6.5		Na ACT	TLD
UCND	113[g]	70	7.7		Na ACT	TLD
Mean	132	72	6.6	4.0		
σ[i]	37	8	1.1	0.8		
σ(%)	28	11	17	20		
n	9	7	4	3		

[a]Phantom facing the HPRR only; data sparse for side-looking phantom.
[b]Average results are presented where groups reported more than one result.
[c]See Appendix II for full name of group.
[d]Protons + recoils.
[e]Calculated.
[f]Element 57 dose.
[g]Kerma.
[h]Protons + recoils + H(n, γ)D.
[i]One standard deviation.

ORNL/DWG 79-9444

Table 8. ORNL Fourteenth Intercomparison of Nuclear Accident Dosimetry systems
Phantom studies[a,b]
Pulse No. 2 Yield = 8.51 (10^{16}) fissions, Shield: None

Study group[c]	Neutron dose, rads	Gamma dose, rads	10^4 x Na-24 activity		Basis for estimating	
			μCi/ml	μCi/mg	Neutron dose	Gamma dose
AECL	1102[d]	215			ACT+TRACK	TLD
CEA	822[d]	173		15.9[e]	ACT	TLD+RPL
DOSAR	506[f]	242	20.6	12.7	Na ACT	TLD
EG&G	753[g]				ACT	
GAC	860		27.0	19.0	ACT+Na ACT	
GSF	605	244			ACT	TLD
GFK						
LLL	619[h]	197	28.4	17.6	ACT+Na ACT	TLD
SLA	1046				ACT	
SRL						
UCND	751[g]	115	31.0		Na ACT	TLD
Mean	785	198	26.8	16.3		
σ[i]	199	49	4.4	2.7		
σ(%)	25	25	16	17		
n	9	6	4	4		

[a]Phantom facing the HPRR only; data sparse for side-looking phantom.
[b]Average results are presented where groups reported more than one result.
[c]See Appendix II for full name of group.
[d]Protons + recoils.
[e]Calculated.
[f]Element 57 dose.
[g]Kerma.
[h]Protons + recoils + H(n, γ)D.
[i]One standard deviation.

ORNL/DWG 79-9436

Table 9. ORNL Fourteenth Intercomparison of Nuclear Accident Dosimetry systems
Phantom studies [a,b]
Pulse No. 3 Yield = 5.39 (10^{16}) fissions, Shield: 20-cm concrete

Study group[c]	Neutron dose, rads	Gamma dose, rads	10^4 x Na-24 activity		Basis for estimating	
			μCi/ml	μCi/mg	Neutron dose	Gamma dose
AECL	151[d]	83			ACT+TRACK	TLD
CEA	139[d]	61		5.0[e]	ACT	TLD+RPL
DOSAR	121[f]	84	4.7	3.0	Na ACT	TLD
EG&G	108[g]				ACT	
GAC	105		6.1	4.3	ACT+Na ACT	
GSF	114	85			ACT	TLD
GFK						
LLL	100[h]	62	6.5	4.2	ACT+Na ACT	TLD
SLA	248				ACT	
SRL	92[d]	71	5.8		Na ACT	TLD
UCND	93[g]	74	6.9		Na ACT	TLD
Mean	127	74	6.0	4.1		
σ[i]	47	10	0.8	0.8		
σ(%)	37	14	13	20		
n	10	7	5	4		

[a]Phantom facing the HPRR only; data sparse for side-looking phantom.
[b]Average results are presented where groups reported more than one result.
[c]See Appendix II for full name of group.
[d]Protons + recoils.
[e]Calculated.
[f]Element 57 dose.
[g]Kerma.
[h]Protons + recoils + H(n, γ)D.
[i]One standard deviation.

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Table 10. ORNL Fourteenth Intercomparison of Nuclear Accident Dosimetry systems
Phantom studies[a,b]
Pulse No. 4 Yield = 6.94 (10^{16}) fissions, Shield: 12-cm Lucite

Study group[c]	Neutron dose, rads	Gamma dose, rads	10^4 x Na-24 activity		Basis for estimating	
			μCi/ml	μCi/mg	Neutron dose	Gamma dose
AECL						
CEA						
DOSAR		70				TLD
EG&G						
GAC						
GSF						
GFK						
LLL	52[d]	59			ACT	TLD
SLA						
SRL						
UCND						
Mean	52	65				
σ[e]		8				
σ(%)		12				
n	1	2				

[a]Phantom facing the HPRR only; data sparse for side-looking phantom.
[b]Average results are presented where groups reported more than one result.
[c]See Appendix II for full name of group.
[d]Protons + recoils + H(n, γ)D.
[e]One standard deviation.

ORNL/DWG 79-9441

Table 11. Summary of neutron and gamma dose measurements made during the Fourteenth Nuclear Accident Dosimetry Intercomparison Study

Pulse	Shield	Air station dose, rads		Phantom dose, rads	
		Neutron	Gamma	Neutron	Gamma
1	5-cm steel/ 15-cm concrete	115 ± 41 (36%)[a]	43 ± 9 (21%)	132 ± 37 (28%)	72 ± 8 (11%)
2	None	729 ± 231 (32%)	118 ± 18 (15%)	785 ± 199 (25%)	198 ± 49 (25%)
3	20-cm concrete	118 ± 45 (38%)	46 ± 6 (13%)	127 ± 47 (37%)	74 ± 10 (14%)
4	12-cm Lucite	59	53	52	65 ± 8 (12%)

[a]One standard deviation (percent standard deviation is in parenthesis). Where no ±σ is given, only one measurement is available.

ORNL/DWG 79-9439

Table 12. Comparison of dose measured on phantoms with that measured at air stations

Pulse No.	Shield	Phantom dose (rads)/air station dose (rads)	
		Neutron	Gamma
1	5-cm steel/15-cm concrete	1.2 ± 0.5[a]	1.7 ± 0.4
2	None	1.1 ± 0.4	1.7 ± 0.5
3	20-cm concrete	1.1 ± 0.6	1.6 ± 0.4
4	12-cm Lucite	0.9	1.2

[a]One standard deviation. Where no ±σ is given, only one measurement is available.

ORNL/DWG 79-9443

Table 13. Normalized dose at air stations[a]

Pulse No.	Shield	Normalized dose, rads/10^{16} fissions	
		Neutron	Gamma
1	5-cm steel/15-cm concrete	17.4	6.5
2	None	85.7	13.9
3	20-cm concrete	21.9	8.5
4	12-cm Lucite	8.5	7.6

[a]See Table 1 for distances from the various shields and air stations to the HPRR.

ORNL/DWG 79-9445

Table 14. Measured neutron-to-gamma ratio at air stations

Pulse No.	Shield	Shield distance from HPRR, m	Air station distance from from HPRR, m	n/γ[a]
1	5-cm steel/ 15-cm concrete	1	2	2.7 ± 1.1[b]
2	None		2	6.2 ± 2.0
3	20-cm concrete	1	2	2.6 ± 1.0
4	12-cm Lucite	2	3	1.1

[a]Average reported neutron dose (rads) divided by the average reported gamma dose (rads).

[b]One standard deviation. Where no $\pm\sigma$ is given, only one measurement is available.

APPENDIX I

PROGRAM
FOURTEENTH DOSIMETRY INTERCOMPARISON STUDY
July 13-22, 1977

Date		Activity
July 13		
a.m.	9:00	Convene in DOSAR Conference Room
	9:05	Welcome
	9:20	Orientation
	9:35	Review of Intercomparison Program
	10:00	Assignment of Equipment and Workspace
p.m.	1:00	Lecture: *Status of IAEA Dosimetry Intercomparison Studies* - Dr. Franz Flakus, IAEA
	2:00	Lecture: *Personnel Dosimeter Testing Program* Robert Alexander, NRC
	3:00	Preparation for Pulse No. 1
July 14		
a.m.	8:00	Final Setup of Dosimeter Systems
	9:00	Pulse No. 1 -- 5-cm steel + 15-cm concrete shield
	10:30	Collect Dosimeters
p.m.	1:00	*Compendium of Spectra,* Dr. Harry Ing, Chalk River Laboratory
	2:00	Analysis of Data
July 15		
a.m.	8:30	Lecture: *Medical Aspects of Nuclear Accident Dosimetry* Dr. Gould Andrews, ORAU
	9:45	Break

Fourteenth Dosimetry Intercomparison Study Program (contd.)

Date		Activity
July 15		
a.m.	10:00	Discussion: *International Activities in Nuclear Accident Dosimetry*
p.m.	1:00	Lecture: *Overview of Radiation Accidents* Dr. Clarence Lushbaugh, ORAU
	2:15	Break
	2:30	Lecture: *The Current Status of Albedo Dosimeters* Dale Hankins, LLL
July 18		
a.m.	8:00	Final Setup of Dosimeter Systems
	9:00	Pulse No. 2 -- unshielded
	10:30	Collect Dosimeters
p.m.	1:00	Data Analysis
July 19		
a.m.	8:30	Discussion: *Evaluation of Personnel Dosimetry Intercomparison Study* - Howard Dickson, ORNL
	9:30	Break
	10:00	Lecture: *Environmental Dosimetry Intercomparison Studies* Dr. Richard Gammage, ORNL
	11:00	Lecture: *Criticality Alarm Systems* - Charles Newlon, UCND, Y-12
p.m.	2:00	Discussion: *Dosimeter Needs of the Nuclear Industry*
	3:00	Break and Setup for Pulse No. 3
	7:00	DOSAR Barbeque

Fourteenth Dosimetry Intercomparison Study Program (contd.)

Date		Activity
July 20		
a.m.	8:00	Final Setup of Dosimeter Systems
	9:00	Pulse No. 3 -- 20-cm concrete shield
	10:30	Collect Dosimeters
p.m.	1:00	Data Analysis
July 21		
a.m.	8:00 - 12:00	Pulse No. 4
p.m.	1:00	Lecture: *Criticality Accident Dosimetry Manual* Fred Haywood, ORNL
July 22		
a.m.	9:00	Presentation of Dose Estimates
	10:00	Final Critique

APPENDIX II

ORGANIZATIONS PARTICIPATING* IN THE FOURTEENTH NUCLEAR ACCIDENT DOSIMETRY INTERCOMPARISON STUDY

1. Atomic Energy of Canada Limited (AECL)
2. Dosimetry Applications Research Facility, Oak Ridge National Laboratory (DOSAR)
3. EG&G, Inc. (EGG)
4. France - Commissariat a L'Energie Atomique (CEA)
5. Germany - Gesellschaft fur Strahlen-und Umweltforschung (GSF)
6. Germany† - Kernforschungszentrum Karlsruhe (GFK)
7. Goodyear Atomic Corporation (GAC)
8. Lawrence Livermore Laboratory (LLL)
9. Sandia Laboratories (SLA)
10. Savannah River Laboratory (SRL)
11. Union Carbide Nuclear Division, Y-12 Plant (UCND)

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*Lecturers and observers are not included. Participants exposed dosimeters.

†Participation by mail.

INTERNAL DISTRIBUTION

1-7. H. W. Dickson
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57. R. E. Alexander, U.S. Nuclear Regulatory Commission, 5650 Nicholson Lane, Rockville, MD 20555
58. Edward Anderson, Monsanto Mound Laboratory, P. O. Box 32, Miamisburg, OH 45342
59. Larry Anderson, Hazards Control Department, Lawrence Livermore Laboratory, University of California, Livermore, CA 94550
60. Gould Andrews, Oak Ridge Associated Universities, Oak Ridge, TN 37830
61. George Burger, Gesellschaft fur Strahlen-und Umweltforschung, 8042 Neuherberg, Post Oberschleissheim, Ingolstadter Landstrassel, Munich, West Germany
62. B. Burgkhardt, Kernforschungszentrum Karlsruhe, Postfach 3640, 7500 Karlsruhe, Federal Republic of Germany
63. Jan Cusimano, Department of Energy-RESL, Idaho Operations Office, 550 Second Street, Idaho Falls, ID 83401
64. Joseph David,Gesellschaft fur Strahlen-und Umweltforschung, 8042 Neuherberg, Post Oberschleissheim, Ingolstadter Landstrassel, Munich, West Germany
65. Greta Ehrlich, Room C-210, Radiation Physics Building, National Bureau of Standards, Washington, D.C. 20234
66. Bill Endres, Battelle Northwest Laboratories, Richland, WA 99352
67. Guillermo Espinosa, Instituto de Fisica, UNAM, Apartado Postal 20-364, Mexico 20, D.F.
68. Roger Falk, Rockwell International, Rocky Flats Plant, P. O. Box 464, Golden, CO 80401

69. Franz Flakus, International Atomic Energy Agency, Karntner Ring P. O. Box 590, A 1011 Vienna, Austria
70. Judith Foulke, U. S. Nuclear Regulatory Commission, 7915 Eastern Avenue, Room 1014, Silver Springs, MD 20555
71. Eric Geiger, Eberline Instrument Corporation, P. O. Box 2108, Santa Fe, NM 87501
72. Richard Griffith, Lawrence Livermore Laboratory, L383, P. O. Box 808, Livermore, CA 94550
73. D. E. Hankins, Lawrence Livermore Laboratory, L383, P. O. Box 808, Livermore, CA 94550
74. John Harvey, Berkeley Nuclear Laboratories, Central Electricity Generating Board, Gloucestershire, United Kingdom
75. Harry Ing, Atomic Energy of Canada Ltd., Health Physics Branch, Chalk River, Ontario, Canada
76. A. H. Kazi, Army Pulse Radiation Facility, Attn: STEAP-MT-R, Aberdeen Proving Ground, MD 21005
77. John L. Lobdell, River Oaks Building, Tennessee Valley Authority, Muscle Shoals, AL 35660
78. Wayne Lowder, Environmental Monitoring Laboratory, Department of Energy, 376 Hudson Street, New York, NY 10014
79. Clarence Lushbaugh, Oak Ridge Associated Universities, Oak Ridge, TN 37830
80. L. E. May, Savannah River Plant, Health Physics Department, Aiken, SC 29801
81. Steve A. McGuire, Office of Standards Development, Nuclear Regulatory Commission, Washington, D.C. 20555
82. John McMahan, Savannah River Plant, Health Physics Department, Aiken, SC 29801
83. Roger Medioni, Commissariat A L'Energie Atomique, Centre D'Etudes Nucleaires, B.P. n°6, 92260 Fontenay-Aux-Roses, France
84. Bill O'Neal, Sandia Laboratories, Albuquerque, NM 87115
85. John W. Poston, School of Nuclear Engineering, Georgia Institute of Technology, Atlanta, GA 30332
86. W. M. Quam, EG&G, 130 Robin Hill Road, Goleta, CA 93017
87. E. M. Rollins, Savannah River Plant, Aiken, SC 29801
88. Robert B. Schwartz, U.S. Department of Commerce, National Bureau of Standards, RADP B119, Washington, D.C. 20234
89. Billy Short, Goodyear Atomic Corporation, P. O. Box 628, Piketon, OH 45661
90. John Shubiak, National Bureau of Standards, Washington, D.C. 20234
91. H. S. Spring, Goodyear Atomic Corporation, P. O. Box 628, Piketon, OH 45661
92. Ellery Storm, H. Division, Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, NM 87545
93. Dan Thompson, Sandia Laboratories, Albuquerque, NM 87115
94. L. Tommasino, Comitato Nazionale per L'Energia Nuclear Centro Di Studi, Nucleari Della Casaccia, Rome, Italy
95. C. M. Unruh, Battelle Northwest Laboratories, Richland, WA 99352

96. Ed Vallario, U.S. Department of Energy, Division of Operational and Environmental Safety, Mail Station E201, Washington, D.C. 20545
97. Robert W. W. Wheeler, R. S. Landauer, Jr., & Co., Glenwood Science Park, Glenwood, IL 60425
98. Robert W. Wood, Division of Pollutant Characterization and Safety Research, Department of Energy, Washington, D.C. 20545
99. MacDonald Wrenn, University of New York Medical Center, P. O. Box 483, Tuxedo, NY 10987
100. Office of Assistant Manager, Energy Research and Development, Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37830

101-127. Technical Information Center, Oak Ridge, TN 37830

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