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1976 Intercomparison of Personnel Dosimeters

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1976 INTERCOMPARISON OF PERSONNEL DOSIMETERS

L. W. Gilley, H. W. Dickson and D. J. Christian

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1976 INTERCOMPARISON OF PERSONNEL DOSIMETERS*

L. W. Gilley, H. W. Dickson and D. J. Christian

ABSTRACT

1976 INTERCOMPARISON OF PERSONNEL DOSIMETERS--The second Personnel Dosimeter Intercomparison Study (PDIS) was conducted at Oak Ridge National Laboratory's DOSAR Facility during the period February 18-19, 1976. Eleven independent organizations participated in an intercomparison of neutron and gamma-ray dosimeters used for routine personnel dosimetry. The dosimeters, which were shipped to the DOSAR Facility, were exposed at the Health Physics Research Reactor to one of three "standardized" radiation fields which have been used for the past several years for intercomparing nuclear accident dosimeters. The results of PDIS reveal that estimates of dose equivalent vary over a wide range. For a given radiation field these dose estimates may vary by more than a factor of 2, indicating the need for continued evaluation of the response of personnel dosimeters used in mixed fields of neutron and gamma radiation.

*Research sponsored by the Energy Research and Development Administration under contract with Union Carbide Corporation.

The second Personnel Dosimetry Intercomparison Study[1] (PDIS) was conducted at Oak Ridge National Laboratory's DOSAR Facility during the period February 18-19, 1976, with eleven groups participating. Two other groups irradiated dosimeters under essentially identical conditions a few days later and their results are included in this report. The participants are listed in Appendix A. The Health Physics Research Reactor was used to produce radiation fields with known energy spectra and intensities. These fields were produced under conditions similar to those previously used for other intercomparison studies[2,3] and, as such, are considered "standard" fields. The bare, unshielded reactor or the reactor used with either of two shields, a 12-cm-thick Lucite shield or a 13-cm-thick steel shield, provides three different neutron and gamma-ray spectra. A 14 MeV neutron generator was also used to expose dosimeters, but the generator failed to operate properly and produced a neutron dose less than 4 mrad and a gamma dose less 3 mrad. Therefore, the results of the 14 MeV exposures are not included in this report.

In order to produce the levels and spectra likely to be encountered in routine personnel monitoring, the reactor was operated as shown in Table 1. All badges were placed on water-filled trunk portions of Bomab phantoms at three meters. The placement of dosimeters on the phantoms is shown in Fig. 1 and a typical experimental arrangement with the steel shield in place is shown in Fig. 2.

Generally, the dosimeters were mailed or shipped to the DOSAR a few days in advance of the intercomparison. The dosimeters were returned in a similar manner the day after the intercomparison exposures were completed. Local laboratories hand carried their dosimeters back and forth. Dosimeters from two participants arrived late and, therefore, an additional "identical" exposure was made. The types of dosimeters used by the participants are listed in Table 2. The participants were provided with information on the position of their dosimeters as shown in Fig. 1.

Sulfur pellets exposed at a standard location on the reactor during the intercomparison gave kerma estimates for the three meter positions of 41, 47, and 44 mrad for the unshielded, steel-shielded, and Lucite-shielded runs, respectively. Hurst detector measurements yielded corresponding values of 43, 55, and 43 mrad. A standard deviation of about ±10% is to be expected due to counting statistics and other sources of error. The dose also can be calculated based on the HPRR neutron spectra[4] for the three exposure configurations used and the dose conversion factors which have been calculated[1] previously for these spectra. Average quality factors determined by Murthy et al.[5] were used for calculating dose equivalent. These values also are given in Table 4. Using the fission yield and the calculated leakage[6] of the HPRR, the neutron fluence was calculated for each reactor run. By applying the previously determined dose conversion factors and average quality factors, the dose and dose equivalent were calculated and are given in Table 5.

Results of gamma dose measurements were less satisfactory due primarily to a very large background exposure of many dosimeters. It is felt this exposure came from inadvertent exposure at the shipping storage area at ORNL. The participants reported higher doses than those measured by the DOSAR group. This may be explained by the difficulty in making corrections for this elevated background. The DOSAR dosimeters were not exposed to any appreciable background. Furthermore, the neutron-to-gamma ratio of the DOSAR data is in reasonable agreement with past measurements, while the participants data exhibits large variations in this ratio.

Reference values of dose and dose equivalent as measured or calculated by DOSAR personnel are given in Table 6. Results reported by eleven participanting groups are given in Tables 7, 8, and 9 for unshielded, Lucited-shielded, and steel-shielded configurations, respectively. A summary of the results is shown in Table 10. Data of two experimenters were not included in the summary because the dosimeters of one experimenter were in the development stage and the other experimenter felt he did not have good background corrections. There is a relatively large variation in dose determination among the participants as shown by the standard deviations in Table 10 and the raw data in Tables 7, 8, and 9. If one arbitrarily eliminates the extreme data points of the neutron dose for the three configurations the standard deviations reduce from a range of $\pm 30\%$ to $\pm 40\%$ to about $\pm 15\%$ to $\pm 25\%$.

This intercomparison study appears to be of value in view of the wide range of results obtained. Some of the badges were apparently in

a developmental stage rather than in routine use. It would be helpful in the future if all such badges could be clearly identified or exposed on separate runs. This facility will provide such exposures on a mail-in basis to qualified experimenters throughout the year. It is anticipated that this type of dosimetry intercomparison study will be worthwhile on an annual basis until the problems in dosimetry response and interpretation have been identified and solved.

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APPENDIX A

PERSONNEL DOSIMETER INTERCOMPARISON STUDY

February 18-19, 1976

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APPENDIX A (cont.)

Name	Affiliation
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Table 1

SUMMARY OF REACTOR OPERATIONS FOR INTERCOMPARISON

Run No.	Shield	Power (watts)	Time (min.)	Fissions ($\times 10^{13}$)
1	Unshielded	2	3.12	1.16
2	Lucite	2	16.5	6.14
3	Steel	2	8.68	3.23

Table 2

DOSIMETERS USED BY PARTICIPANTS

	Dosimeter Type	
Group	Neutron	Gamma
A	Thorium	TLD
B	TLD	TLD
C	Polycarbonate film	---
E-1	TLD	TLD
E-2	TLD	TLD
E-3	TLD	TLD
F	NTA Film	TLD
G	TLD	---
H	NTA Film	Film
I	TLD	TLD
J	Film	TLD
K	NTA Film	---

Table 3. Calculation of HPRR Spectrum for NAD Intercomparisons

Group	Upper Energy (ev)	Mid Energy (ev)	N(E)ΔE*		
			No Shield	Lucite Shield	Steel Shield
1	1.49 E7	1.22 E7	9.53 E7	3.31 E7	1.35 E7
2	1.0 E7	8.19 E6	1.18 E9	3.63 E8	1.5 E7
3	6.7 E6	5.77 E6	3.43 E9	4.29 E8	3.8 E8
4	4.97 E6	3.87 E6	1.44 E10	2.58 E9	1.57 E9
5	3.01 E6	2.12 E6	3.76 E10	5.56 E9	7.94 E9
6	1.5 E6	1.16 E6	3.16 E10	3.19 E9	1.21 E10
7	9.07 E5	6.08 E5	4.61 E10	3.69 E9	3.34 E10
8	4.08 E5	2.13 E5	3.39 E10	3.08 E9	5.02 E10
9	1.11 E5	9.80 E4	2.60 E9	4.18 E8	2.13 E9
10	8.65 E4	7.64 E4	2.0 E9	3.81 E8	2.91 E9
11	6.74 E4	5.95 E4	1.5 E9	3.49 E8	1.41 E9
12	5.25 E4	4.63 E4	1.21 E9	3.24 E8	1.25 E9
13	4.09 E4	3.61 E4	9.71 E8	3.05 E8	5.61 E8
14	3.18 E4	2.81 E4	8.40 E8	2.98 E8	6.64 E8
15	2.48 E4	2.19 E4	7.35 E8	2.76 E8	2.5 E8
16	1.93 E4	1.70 E4	6.37 E8	2.66 E8	1.01 E8
17	1.50 E4	1.03 E4	1.58 E9	7.60 E8	1.14 E8
18	7.10 E3	4.88 E3	1.39 E9	7.23 E8	1.02 E8
19	3.35 E3	2.03 E3	1.62 E9	9.48 E8	1.16 E9
20	1.23 E3	8.48 E2	1.04 E9	6.97 E8	4.2 E8
21	5.83 E2	3.54 E2	1.24 E9	9.21 E8	4.47 E8
22	2.14 E2	1.47 E2	8.45 E8	6.91 E8	3.14 E8
23	1.01 E2	6.96 E1	7.76 E8	6.90 E8	2.88 E8
24	4.79 E1	3.73 E1	4.72 E8	4.59 E8	1.69 E8
25	2.90 E1	2.26 E1	4.54 E8	4.60 E8	1.67 E8
26	1.76 E1	1.37 E1	4.34 E8	4.61 E8	1.61 E8
27	1.07 E1	7.34	6.09 E8	6.93 E8	2.11 E8
28	5.04	3.93	3.82 E8	4.58 E8	1.28 E8
29	3.06	2.18	4.84 E8	6.11 E8	1.71 E8
30	1.56	1.25	3.04 E8	3.79 E8	1.12 E8
31	1.0	8.06 E-1	2.81 E8	3.41 E8	9.16 E7
32	0.65	5.41 E-1	2.42 E8	2.86 E8	7.83 E7
33	0.45	2.12 E-1	1.78 E9	2.67 E9	5.63 E8
34	0.1	2.24 E-2	3.36 E9	1.95 E10	1.09 E9
	5.0 E-3				

*This number is the area of the histogram for each energy interval.

Table 4

DOSE CONVERSION FACTORS AND AVERAGE

QUALITY FACTORS FOR HPRR SPECTRA

Shield	Dose Conversion Factor ($mrad/cm^2 \times 10^{-7}$)	$\overline{QF}$
Unshielded	25.5	9.4
Steel	17.9	9.5
Lucite	14.6	8.9

Table 5

NEUTRON ABSORBED DOSE AND DOSE EQUIVALENT CALCULATED

FROM HPRR FISSION YIELDS

Reactor Run	Shield	Fissions ($\times 10^{12}$)	Fluence ($cm^{-2} \times 10^{-7}$)	Dose (mrad)	Dose Equivalent (mrem)
1	Unshielded	11.6	2.28	58	545
2	Steel	32.3	3.91	70	665
3	Lucite	61.4	3.26	48	427

Table 6

REFERENCE VALUES OF DOSE AND DOSE EQUIVALENT

Run	Shield	Neutron Dose (mrad)		Neutron Dose Equivalent (mrem)		Gamma Dose Equivalent
		Calculated	Measured	Calculated	Calculated from Measured	Measured (mrem)
1	Unshielded	58	43 ± 4.3	545	404	16 ± 1.6
2	Steel	70	55 ± 5.5	665	523	8 ± 1.2
3	Lucite	48	43 ± 4.3	427	383	41 ± 4.1

Table 7

RESULTS OF PERSONNEL DOSIMETER INTERCOMPARISON

February 18-19, 1976 - Unshielded

Group	Location on Phantom	Phantom No. 1		Phantom No. 2		Phantom No. 3	
		n(mrem)	γ(mrem)	n(mrem)	γ(mrem)	n(mrem)	γ(mrem)
A	Front	210	72	210	72	210	72
B	Front	470	20	470	20		
B	Back	90	5	90	5		
C	Front					81	
D	Front	705	105				
E-1	Front	560	15	560	15	560	15
E-2	Front	620	23	620	23	620	23
E-3	Front	1000	35	1000	35	1000	35
F	Front					640	40
F	Back	90	20				
G	Front	486		486		486	
H	Front			497	10		
H	Back					54	
I	Front			330	25	305	20
J-1	Front						25
J-1	Back				6		
J-2	Front						16
J-2	Back				6		
K	Front	200					
K	Back					30	

Table 8

RESULTS OF PERSONNEL DOSIMETRY INTERCOMPARISON

February 18-19, 1976 - LUCITE SHIELD

Group	Location on Phantom	Phantom No. 1		Phantom No. 2		Phantom No. 3	
		n(mrem)	γ(mrem)	n(mrem)	γ(mrem)	n(mrem)	γ(mrem)
A	Front	260	164	260	164	260	164
B	Front	720	60	720	60		
B	Back	40	20	40	20		
C	Front					102	
D	Front	418	157				
E-1	Front	560	43	560	43	560	43
E-2	Front	720	48	720	48	720	48
E-3	Front	700	80	700	80	700	80
F	Front					570	90
F	Back	120	30				
G	Front	432		432		432	
H	Front			532	120		
H	Back					95	33
I	Front			395	65	420	70
J-1	Front						100
J-1	Back				30		
J-2	Front						48
J-2	Back				18		
K	Front	260					
K	Back					30	

Table 9

RESULTS OF PERSONNEL DOSIMETRY INTERCOMPARISON

February 18-19, 1976 - Steel Shield

Group	Location on Phantom	Phantom No. 1		Phantom No. 2		Phantom No. 3	
		n(mrem)	γ(mrem)	n(mrem)	γ(mrem)	n(mrem)	γ(mrem)
A	Front	510	54	510	54	510	54
B	Front	560	5	560	5		
B	Back	160	3	160	3		
C	Front					38	
D	Front	710	105				
E-1	Front	740	20	740	20	740	20
E-2	Front	840	26	840	26	840	26
E-3	Front	1300	35	1300	35	1300	35
F	Front					770	30
F	Back	100	20				
G	Front	842		842			
H	Front			542			
H	Back					158	
I	Front			700	10	730	15
J-1	Front						12
J-1	Back				6		
J-2	Front						9
J-2	Back				5		
K	Front	120					
K	Back					30	

Table 10

SUMMARY OF RESULTS OF FRONT EXPOSURES

Exposure Condition	Neutron Dose Equivalent (mrem)	Gamma Dose Equivalent (mrem)
Unshielded Reactor	550 ± 217	35 ± 29
Steel Shielded Reactor	753 ± 226	31 ± 30
Lucite Shielded Reactor	532 ± 154	86 ± 46

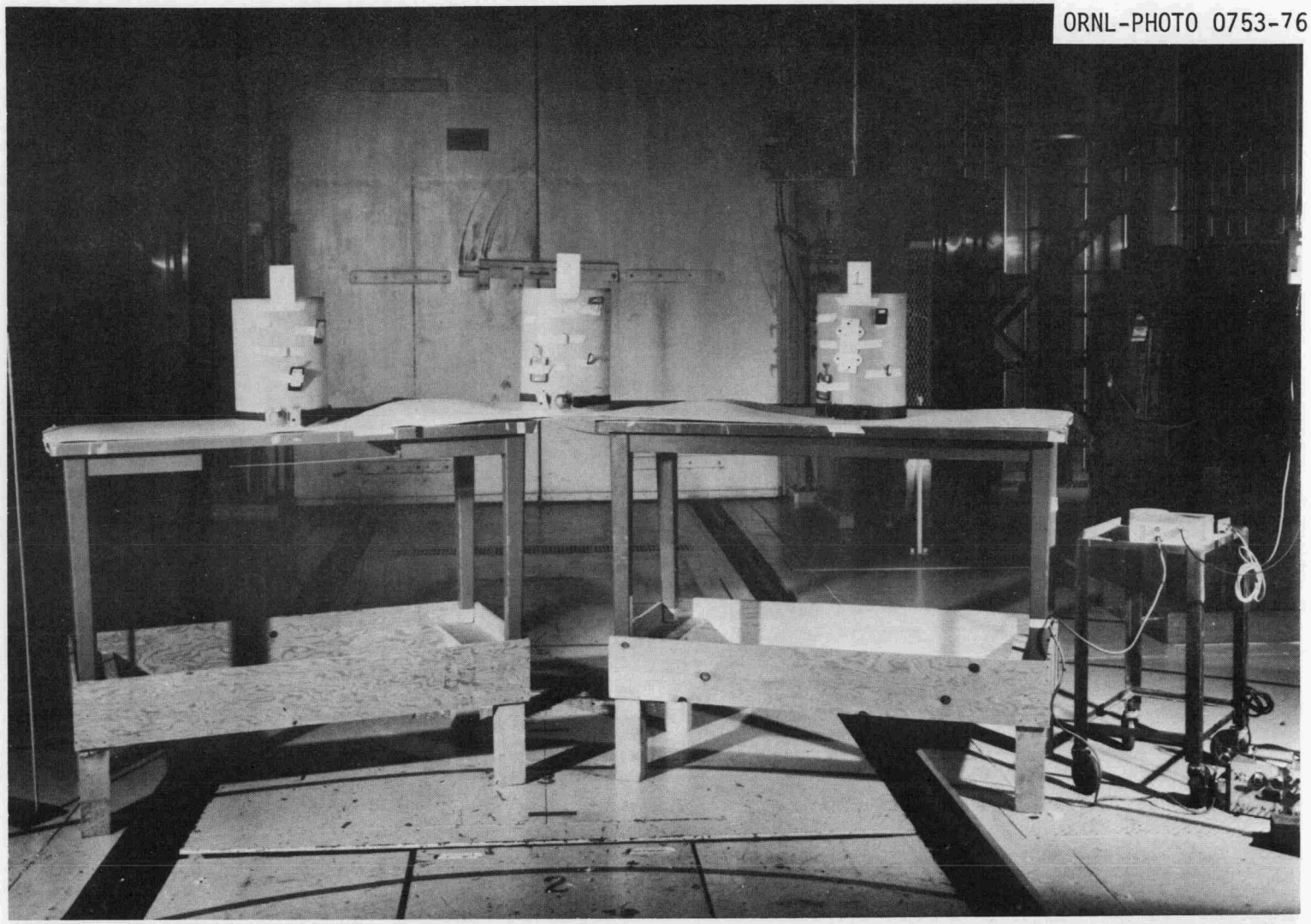

Fig. 1. A Typical Placement of Dosimeters on the Front of Phantoms.

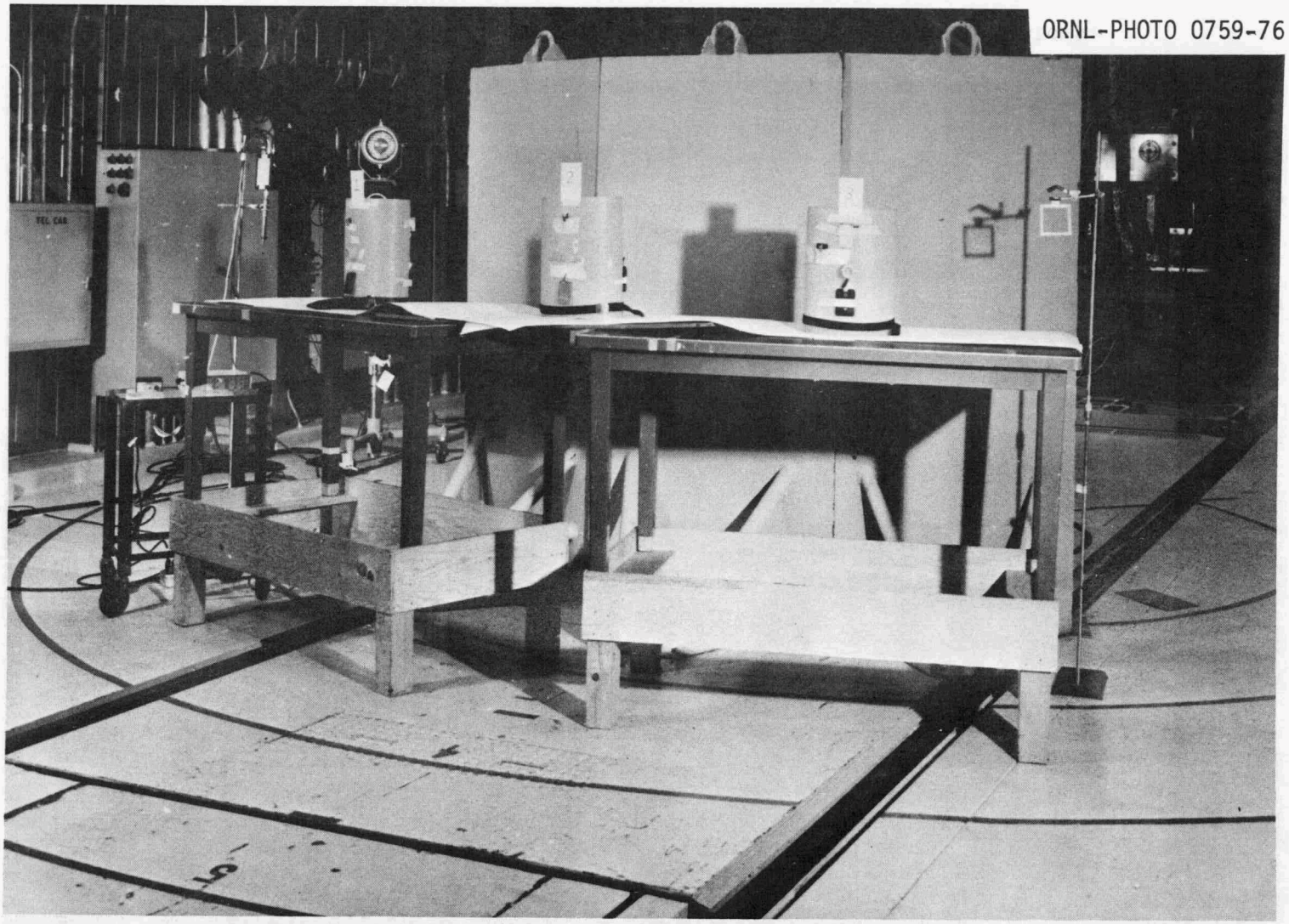

Fig. 2. A Typical Experimental Setup with the Steel Shield in Place.

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