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PHYSICS DIVISION

LABORATORY RECORDS
1954

REACTOR SHIELDING WITH AN IRON AGGREGATE CONCRETE COMPARISON WITH ORDINARY CONCRETE

E.P. BLIZARD

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PHYSICS DIVISION

REACTOR SHIELDING WITH AN IRON AGGREGATE CONCRETE —COMPARISON WITH ORDINARY CONCRETE

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First attempts to make a monolithic shield equivalent to the laminated Hanford structure centered on iron aggregate concretes with approximately the same ratio of iron to hydrogen as in the Hanford prototype (80:1 by wt.).

Compositions

Uncertainties in the water content of portland cement, due to different ageing as well as different original composition, make the iron to hydrogen ratio in doubt as much as 50%.

At the time that the first portland concrete and iron aggregate samples were poured, our techniques for determining water content were not developed, as such wide variations were not anticipated. On the basis of recommendations by several people in the industry, the water of hydration was taken to be 20% of dry weight of portland cement.

A satisfactory technique is now used, due in large part to David LaValle of Oak Ridge National Laboratory, Chemistry Division. A small uncrushed sample is heated to 1000°C. in a quartz tube, and the water vapor is trapped and weighed.

Although the samples of concrete could now be remeasured, ageing and curing so change their water content that the new determination would be only a poor clue to the value at the time of the radiation attenuation tests. On the basis of his recent experience, however, Rockwell has estimated 12% water of hydration, which is to be compared to 16.7% (or 20% of the dry cement weight) which he used in his memorandum to Kyger of December 23, 1947*.

Rockwell has also revised his estimate of water in an oxychloride cement sample, designated M1, from 50% to 40% of the cured cement. On these assumptions, the compositions are recalculated and reproduced here in Table I. Corresponding values are also given for several other shields, for comparison.

Measuring Techniques

Measuring techniques are described and pictured in ORNL-32. Briefly, the sample material is made up in two, three, or four blocks approximately 2' × 2' in cross section and 16" to 24" long. These are exposed to the Clinton reactor by insertion in a hole in the shield, and attenuation is observed by several different detectors.

* Summary of Technical Division Work on Shielding, C.F. 48-1-118.

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Neutrons

Neutron fluxes were measured by means of gold foils inserted in the concrete samples, as described in ORNL-32. The gold foils have since been calibrated in a known standard source. With the counting apparatus used in the present tests, saturated gold activities in counts per minute can be converted approximately to neutron flux, neutrons/cm^2/sec by multiplication by 2/5. Absolute thermal flux is, however, not directly useful for comparing total neutron flux within various shielding materials. For a method of estimating total flux from thermal activation, refer to a forthcoming report by Welton* and Goertzel written for the Lexington project. Attenuation within the outer part of a homogeneous shield is fairly well indicated by thermal activation, provided the shield has a high thermal absorption.

Gamma Rays

Gamma data was taken with a Geiger Mueller counter mounted in a lead shield. Early measurements (runs I - XIV incl.) differed in two respects from later work. Firstly, the counter was in a much smaller shield. A 4" × 4" × 8" lead block was pierced by a $1\frac{3}{8}$" hole along the long axis, and the counter was mounted therein. Secondly, the counter in its shield was placed solidly against the outer face of the last shield sample block in the core hole. Thus readings were taken behind one, two, three or four blocks.

Background at high power level was evaluated by long readings with the counter completely shielded. Because the counter could not cover the range of fluxes that appear throughout the shield, the measurements with only one or two blocks in place were made with a much lower pile power level. In these cases, background was evaluated by taking a pair of readings at different pile power. The pertinent flux was then taken to be proportional to the power level. It was found out later that this procedure is not to be trusted as the pile power calibration is not very accurate, especially at very low levels. More recently a BF_3 neutron counter has been used and the power taken as proportional to the response of this detector.

* LP-141

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EVALUATION OF DATA

Gamma Rays

The gamma data reported in ORNL-32 is taken, as described therein, with the counter in a much larger lead shield, approximately 16" × 16" × 20", and mounted at the far end of a 16" long $1\frac{3}{8}$" diameter hole. The whole apparatus was then mounted on a dolly so that it could be moved easily to a point in line with the shield sample, and $8\frac{1}{2}$' back from the pile shield face. The set up was designed so that the counter would "see" only the outside face of the shield sample.

To test the collimation of the counter, its response to a radium point source at different positions on and off the collimation axis was measured with the help of H. P. Sleeper. The results are seen in figure 18, a plot of counting rate "N" times radius "r" from the counter axis. It is seen that most of the counting rate arises from a circle within the rear face of the sample block. For the case of only one sample block in the hole, which corresponds roughly to 14" from counter to source, an appreciable fraction of the count could come from the area beyond the rear face of the sample. This would be a serious difficulty only if the gamma flux emerging from the bare core hole walls were greater than that emergent from the rear face of the sample block. This was not the case in the present shield measurements.

As a further check on the validity of the method, run X was repeated (run 29), and gamma data was taken both with the counter against the rear block and with it $8\frac{1}{2}$' back and collimated. The two sets of data exhibit the same rate of attenuation with the exception that the innermost point with the counter back $8\frac{1}{2}$' seems to be high by about a factor of two. At least part of this discrepancy is due to the fact that this reading was taken just after the pile power was reduced from 200 to 10 kw. without allowing sufficient time for the radioactivity within the pile to decay. The data in general is a significant proof that the two gamma measuring techniques are comparable.

It should nevertheless be emphasized that the gamma measuring techniques used for data presented in this report were in a state of developement. Also pile shutdowns were short, resulting in hurried measurements, and in many cases incomplete data. Even though very accurate measurements are not essential for shielding work, the gamma measurements were not considered satisfactory. The results presented were chosen as carefully as possible, but are subject to verification.

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It is unfortunate that additional gamma data was not taken with ionization chambers or films. These are not as sensitive as Geiger counters, but they do indicate the biological dosage. Later experiments include this type of measurement and as is to be expected in the latter half of the shield the attenuation appears to be the same whether counter or ionization chamber is used.

Neutrons

To minimize exchange of flux between sample and surrounding X-shield, in several of the experiments the blocks were spaced apart in an effort to match their flux with that of the adjacent material. As will be seen from the data, this did not solve the difficulty as there was considerable streaming in the spaced between the blocks. Because the transverse leakage was not overcome, and because an adequate theory for correction involves an accurate theory for shield performance, the flux measured in the last foot or so of sample is not necessarily characteristic of the sample being tested. The whole question of corrections to these flux measurements will be discussed by F. H. Murray in the forthcoming Shielding Program Annual Report.

The data for Run 10, on ordinary concrete, exhibits rather flat neutron traverses (sets of readings at the same shield thickness, but spaced across the sample) indicating a minimum transverse leakage. One would therefore expect that this data is truly characteristic of the material tested. Furthermore, it indicates that the performance of the X-shield is approximately the same as the ordinary concrete sample.

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TABLE I

COMPOSITION OF SHIELDING SAMPLES

	WO	W½	W1	M1	ord. concrete
	WT. PER CENT				
Fe	62.9	62.0	63.0	74.5	.28
H	.501	.546	.563	.983	.204
O	16.2	17.1	17.25	13.6	49.2
B	0.0	.52	.98	.934	
Si	3.42	3.2	2.82		18.8
Al	1.23	1.14	1.01		.50
Ca	14.9	14.5	13.5	1.15	25.0
Mg	0.5	.46	.41	5.65	.20
S	0.2	.2	1.16		.08
Mn	0.3	.3	.3	.37	
Cl				2.5	
C					5.7
	Gms/cc				
Fe	2.57	2.23	2.42	3.35	.007
H	.0205	.0197	.0217	.044	.0048
O	.665	.616	.664	.610	1.15
B	0.0	.019	.038	.042	
Si	.140	.114	.109		.44
Al	.050	.041	.04		.012
Ca	.613	.522	.52	.052	.58
Mg	.0205	.017	.016	.254	.005
S	.008	.007	.006		.002
Mn	.013	.011	.012	.017	
Cl				.11	
C					.13

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TABLE I (continued)

COMPOSITION OF SHIELDING SAMPLES

	Mg. Mol./cc									
	W0	W½	W1	M1	Ord. Concrete	M0 (1)	Hanford Biological (1)	X (2)	Brookhaven (3)	BC (4)
Fe	46.0	39.9	43.3	60.0	.13	85.3	64.0	.674	54.1	
H	20.3	19.5	21.5	43.9	4.76	38.3	42.3	20.0	25.0	79.1
O	41.6	38.5	41.5	38.1	71.8	30.4	21.7	54.2	51.8	68.2
B	0.0	1.76	3.5	3.88						7.98
Si	4.99	4.06	3.9		1.56			6.30	3.75	
Al	1.85	1.52	1.45		.44			2.88	1.12	
Ca	15.3	13.02	13.0	1.3	14.5				6.1	2.66
Mg	0.84	.70	.66	10.4	.2	12.7			0.43	16.42
S	0.25	.22	.19		.06			5.33	.067	
Mn	0.24	.20	.22	.3		.36	0.19		.025	
Cl				3.2		2.96				6.93
C					10.8		26.5			
N							1.0			
Cu								3.84		
Ba								5.08		
Density	4.10	3.61	3.85	4.50	2.33	5.80	4.27	2.2	4.27	2.0

1 see ORNL 32 2 see ORNL 203 3 see BNL-C-641 4 see ORNL 228, pg. 71

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TABLE II

NEUTRON ATTENUATION

WO Type Concrete with 4" Spacing

Run 5 Exposed 9/2 - 9/9/47

Distance from Center Line of Sample (Horiz. & Vert.) →	12"	Up or Left 8"	4"	0	-4"	Down or Right -8"	-12"
	Gold Foil Activities After 7 Day Exposure at 3800 K.W.						
Thickness of Sample Inches							
* 4		3.63×10^{8}	3.87×10^{8}	4.05×10^{8}	3.77×10^{8}	3.62×10^{8}	
12		1.48×10^{7}	1.10×10^{7}	1.07×10^{7}	9.96×10^{6}	1.20×10^{7}	
* 20	1.11×10^{6}	9.19×10^{5}	8.21×10^{5}	7.87×10^{5}	8.50×10^{5}	8.62×10^{5}	1.02×10^{6}
28		1.024×10^{5}	5.10×10^{4}	4.19×10^{4}	4.50×10^{4}	7.61×10^{4}	
* 36	1.04×10^{4}	6.51×10^{3}	4.92×10^{3}	4.75×10^{3}	4.74×10^{3}	5.67×10^{3}	8.17×10^{3}
44		1.49×10^{3}	487	279	291	541	
* 52	267	104	72	61.3	63.0	70.4	146.0
60	199	84	10.7	3.8	5.3	8.7	23.2

* Horizontal (Alternate with Vertical)

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TABLE III

NEUTRON ATTENUATION

$W\frac{1}{2}$ Type Concrete with 4" Spacing

Run 6 Exposed 9/9 - 9/15/47 at 3800 K.W.

	Gold Foil Activities After 7 Day Exposure at 3800 K.W.						
Distance from Center Line of Sample (Horiz. & Vert.) →	12"	Up or Left 8"	4"	0	-4"	Down or Right -8"	-12"
Thickness of Sample Inches							
* 4	1.22×10^{8}	1.18×10^{8}	1.06×10^{8}	1.06×10^{8}	1.07×10^{8}	1.12×10^{8}	1.21×10^{8}
12		5.22×10^{6}	4.58×10^{6}	4.45×10^{6}	4.39×10^{6}	5.24×10^{6}	
* 20	7.20×10^{5}	3.77×10^{5}	2.87×10^{5}	2.64×10^{5}	2.75×10^{5}	3.46×10^{5}	6.30×10^{5}
28		3.974×10^{4}	1.968×10^{4}	1.544×10^{4}	1.594×10^{4}	2.615×10^{4}	
* 36	4380	3045	2490	2293	2440	3160	5000
44		486	226	145.0	152	254	1158
* 52	151.2	41.5	24.7	22.1	21.3	24.15	26.6
60		2.6	5.1	6.1	7.6	4.5	5.3

* Horizontal (Alternate with Vertical)

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TABLE IV

NEUTRON ATTENUATION

$W\frac{1}{2}$ Type Concrete with 8" Spacing

Run 7 Exposed 9/15 - 9/23/47 at 3800 K.W.

	Gold Foil Activities after 7 Day Exposure at 3800 K.W.						
Distance from Center Line of Sample (Horiz. & Vert.) →	12"	Up or Left 8"	4"	0	-4"	Down or Right -8"	-12"
Thickness of Sample Inches							
12		6.32×10^{6}	6.14×10^{6}	6.14×10^{6}	5.84×10^{6}	6.82×10^{6}	
* 20	6.02×10^{5}	4.52×10^{5}	4.10×10^{5}	3.85×10^{5}	4.10×10^{5}	4.63×10^{5}	6.66×10^{5}
28		3.14×10^{4}	2.02×10^{4}	1.63×10^{4}	1.64×10^{4}	2.00×10^{4}	
* 36	7.30×10^{3}	2.87×10^{3}	2.30×10^{3}	2.12×10^{3}	2.13×10^{3}	2.37×10^{3}	2.86×10^{3}
44		360	164	136	116	120	194
* 52	161	14.7	28.6	28.0	25.1	28.6	43.8
60		16.8	5.6	5.1	2.4	4.3	12.7

* Horizontal (Alternate with Vertical)

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TABLE V

NEUTRON ATTENUATION

First Block - W0 Type Concrete
Blocks 2, 3, 4 - W½ Concrete
No Space between Blocks

Run 8 Exposed 9/23 - 9/30/47

Gold Foil Activities after 7 Day Exposure at 3800 K.W.							
Distance from Center Line of Sample (Horiz. & Vert.) →	12"	Up or Left 8"	4"	0	-4"	Down or Right -8"	-12"
Thickness of Sample Inches							
* 4[a]	2.69×10^{8}	3.21×10^{8}	3.32×10^{8}	3.25×10^{8}	2.83×10^{8}	2.46×10^{8}	1.62×10^{8}
12[a]		9.61×10^{6}	9.67×10^{6}	8.98×10^{6}	8.37×10^{6}	7.95×10^{6}	
* 20[b]	2.82×10^{5}	1.63×10^{5}	1.60×10^{5}	1.58×10^{5}	1.52×10^{5}	1.54×10^{5}	2.73×10^{5}
28[b]		1.97×10^{3}	8.79×10^{3}	7.36×10^{3}	6.85×10^{3}	9.86×10^{3}	
* 36[b]	1.84×10^{3}	572	390	405	443	658	2.55×10^{3}
44[b]		266	58.2	25.3		285.6	285.6
* 52[b]				4.31			
60[b]		9.81	3.10	2.63	4.42	1.39	9.28

* Horizontal (Alternate with Vertical)

a W0 Block (No Boron)

b W½ Block (½% Boron)

[redacted]

[redacted]

TABLE VI

NEUTRON ATTENUATION

First Block - W½ Type Concrete
Blocks 2, 3, 4 - WO Concrete

Run 9 Exposed 9/30 - 10/7/47

	Gold Foil Activities after 7 Day Exposure at 3800 K.W.						
Distance from Center Line of Sample (Horiz. & Vert.) →	12"	Up or Left 8"	4"	0	-4"	Down or Right -8"	-12"
Thickness of Sample Inches							
* 4[a]	7.27×10^{7}	8.54×10^{7}	9.98×10^{7}	9.32×10^{7}	8.54×10^{7}	7.94×10^{7}	6.46×10^{7}
12[a]		3.24×10^{6}	3.45×10^{6}	3.43×10^{6}	3.06×10^{6}	2.71×10^{6}	
* 20[b]	4.39×10^{5}	3.32×10^{5}	3.15×10^{5}	3.31×10^{5}	3.24×10^{5}	3.21×10^{5}	4.24×10^{5}
28[b]		5.71×10^{4}	2.70×10^{4}	2.14×10^{4}	2.10×10^{4}	2.82×10^{4}	
* 36[b]	4.60×10^{3}	2.07×10^{3}	1.35×10^{3}	1.20×10^{3}	1.37×10^{3}	1.99×10^{3}	4.92×10^{3}
44[b]		6.912×10^{2}	1.960×10^{2}	1.018×10^{2}	1.033×10^{2}	2.565×10^{2}	
* 52[b]	97.2	51.3	16.1	15.8	19.1	42.0	167
60[b]	62.7	17.2	2.59	1.40	.69	4.16	20.2

* Horizontal (Alternate with Vertical)

a W½ Block (½% Boron)

b WO Block (No Boron)

[redacted]

[redacted]

TABLE VII

NEUTRON ATTENUATION

Ordinary Concrete

Run 10 Exposed 10/7 - 10/14/47

	Gold Foil Activities after 7 Day Exposure at 3800 K.W.						
	Regular Foils						
Distance from Center Line of Sample (Horiz. & Vert.) →	12"	Up or Left 8"	4"	0	-4"	Down or Right -8"	-12"
Thickness of Sample Inches							
* 8	5.30×10^{8}	7.56×10^{8}	8.73×10^{8}	8.88×10^{8}	8.64×10^{8}	7.25×10^{8}	4.22×10^{8}
16		3.71×10^{7}		3.65×10^{7}		3.74×10^{7}	
* 25			2.42×10^{6}	2.31×10^{6}	2.51×10^{6}		
35		2.28×10^{5}	1.74×10^{5}	1.55×10^{5}		2.55×10^{5}	
* 45		1.98×10^{4}	1.37×10^{4}	1.51×10^{4}	1.70×10^{4}	2.16×10^{4}	2.51×10^{4}
55	3501	2976	1794	1326	1170	1548	1370
* 66	196	209	168	151	133	139	147
78	7.23			5.76			46.1

	One cm^2 Foils, Normalized to Large Foil Data							
	14"	10"	6"	2"	-2"	-6"	-10"	-14"
* 8		6.47×10^{8}	8.11×10^{8}	8.06×10^{8}	8.52×10^{8}	7.99×10^{8}	6.57×10^{8}	
16		3.09×10^{7}	2.89×10^{7}	3.82×10^{7}	3.74×10^{7}	3.68×10^{7}	3.22×10^{7}	
* 25	2.49×10^{6}	2.47×10^{6}	2.09×10^{6}	2.39×10^{6}	2.40×10^{6}	2.78×10^{6}	3.25×10^{6}	3.08×10^{6}

* Horizontal (Alternate with Vertical)

[redacted]

[redacted]

TABLE VIII

NEUTRON ATTENUATION

W1 Type Concrete

Long Forms, No Spaces

Run 11 Exposed 10/28 - 11/4/47

Thickness of Sample Inches	12"	8"	4"	Center	-4"	-8"	-12"
* 5	3.10×10^{7}	3.50×10^{7}	3.71×10^{7}	4.29×10^{7}	4.23×10^{7}	3.46×10^{7}	3.17×10^{7}
15		6.95×10^{5}	5.95×10^{5}	5.68×10^{5}	5.27×10^{5}	5.41×10^{5}	
* 29	7944	3231	2535	2585	2640	3091	6840
39	2477	513.8	118.2	73.5	76.9	158.9	589.9
* 46	283.5	36.18	10.53	10.43	9.39	23.6	97.1
58	99.5	12.9				5.05	1.14

* Horizontal (Alternate with Vertical)

[redacted]

[redacted]

TABLE IX

CADMIUM RATIOS

Blocks 1, 3, 4 - W0 Concrete
Block 2 - W½
No Spaces Between Blocks

Run 12 Exposed 11/4 - 11/11/47

Thickness of Sample Inches	Gold Foil Activity for 7 Day Exposure at 3800 K.W.				Cadmium Ratio	
	Center		Bottom or Outer Position in Block		Center	Bottom or Outside
	Bare	Cd. Covered	Bare	Cd. Covered		
20[a]	1.08×10^{5}	6.05×10^{4}	8.22×10^{4}	9.29×10^{4}	1.78	.885
28[a]	6387	2679	5104	3684	2.38	1.39
52[b]	13.32	3.15	20.80	29.07	4.23	.716
60[b]	2.36	not above background	9.42	9.71	—	.97

[a] W½ Block (½% Boron)

[b] W0 (no Boron)

[redacted]

[redacted]

TABLE X

First Block - WO Concrete
Blocks 2, 3 - M1 Concrete
No Spaces Between Blocks

Run 13 Exposed 11/11 - 11/18/47

Thickness of Sample Inches	12"	8"	4"	Center	-4"	-8"	-12"
* 21[a]	3.95×10^{5}	1.26×10^{5}	9.84×10^{4}	1.03×10^{5}	1.04×10^{5}	1.36×10^{5}	3.82×10^{5}
31[a]		1.31×10^{4}	3.63×10^{3}	2.50×10^{3}	3.97×10^{3}	1.26×10^{4}	
* 45[a]	731.1	139.7	57.8	46.6	58.6	113.3	369.9
55[a]	114.6	23.4	7.5	2.9	19.9	52.5	331.7

[a] M1 Block (1% Boron)

* Horizontal (Alternate with Vertical)

[redacted]

[redacted]

TABLE XI

CADMIUM RATIOS

First Block - W0 Concrete
Blocks 2 & 3 - M1 Concrete
No Spaces Between Blocks

Run 14 Exposed 11/18 - 11/25/47

Thickness of Sample Inches	Gold Activity at Center of Block for 7 Day Exposure at 3800 K.W.		Cadmium Ratio
	Bare	Cd. Covered	
21[a]	1.47×10^{6}	8.21×10^{4}	1.79
31[a]	5504	2020	2.73
45[a]	77.7	33.1	2.35
55[a]	9.24	4.60	2.01

[a] M1 Blocks (1% Boron)

[redacted]

[redacted]

TABLE XII

Blocks 1 & 2 - M1 Concrete
Block 3 - W0 Concrete
No Spaces Between Blocks

Run 15 Exposed 11/25 - 12/1/47

Thickness of Sample Inches	12"	8"	4"	Center	-4"	-8"	-12"
* 5	2.41×10^{7}	2.85×10^{7}	3.23×10^{7}	3.62×10^{7}	3.31×10^{7}	2.79×10^{7}	2.46×10^{7}
15		4.33×10^{5}	3.86×10^{5}	4.14×10^{5}	3.81×10^{5}	3.44×10^{5}	
* 29	3.65×10^{3}	1.22×10^{3}	923	959	999		5.09×10^{3}
39	1698	294	63.9	33.2	32.4		388

Thickness in Inches				Inserts			
				Center			
2		Front		7.15×10^{7}			
18		Back		5.28×10^{4}			
22		Front		1.08×10^{4}			
42		Back		Background			

* Horizontal (Alternate with Vertical)

[redacted]

[redacted]

TABLE XIII

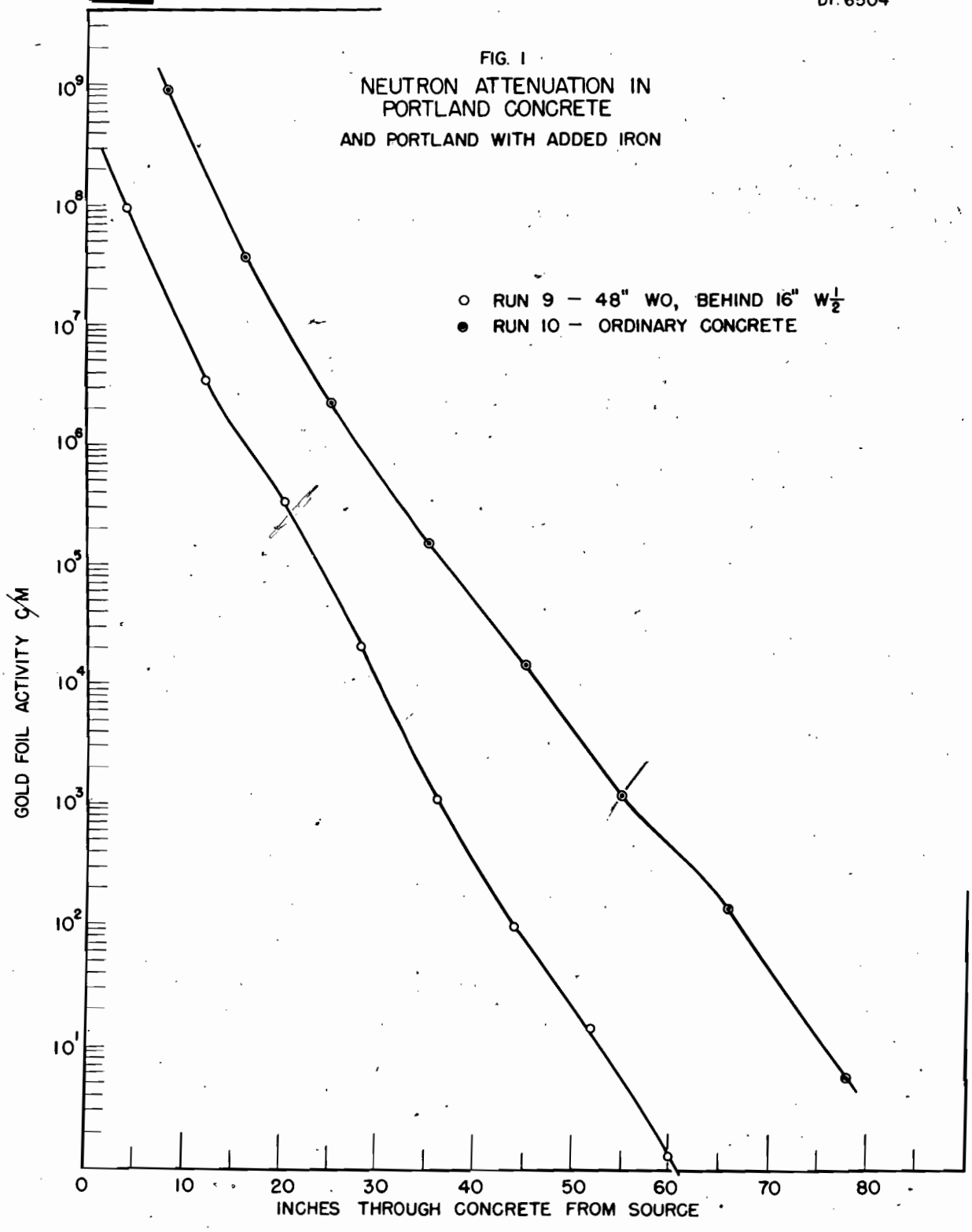
GAMMA ATTENUATION

	Inches of Concrete	Counts/min/kw on G.M. Tube	Grams/cm^2
Run 2 - Brookhaven with 6" Fe Thermal Shield	46"	.0608	553
Run 3 - Brookhaven without 6" Fe Thermal Shield	40	.457	434
Run 6 - W½ Concrete 4" Spacings	32	81.2	293
	48	1.00	440
	64	.0242	588
Run 7 - W½ Concrete 8" Spacings	32	94.6	293
	48	2.01	440
	64	.035	588
Run 8 - 1st Block - W0 Blocks 2, 3, 4 - W½	32	88.6	312
	48	1.46	460
	64	.037	607
Run 9 - 1st Block - W½ Blocks 2, 3, 4 - W0	32	44.9	312
	48	.428	480
	64	.026	647
Run 10 - Ordinary Concrete	40	57.1	238
	60	19.2	354
	84	.336	496
Run 13 - 1st Block - W0 Blocks 2, 3 - M1	36	8.93	396

[redacted]

[redacted]

Dr. 6504



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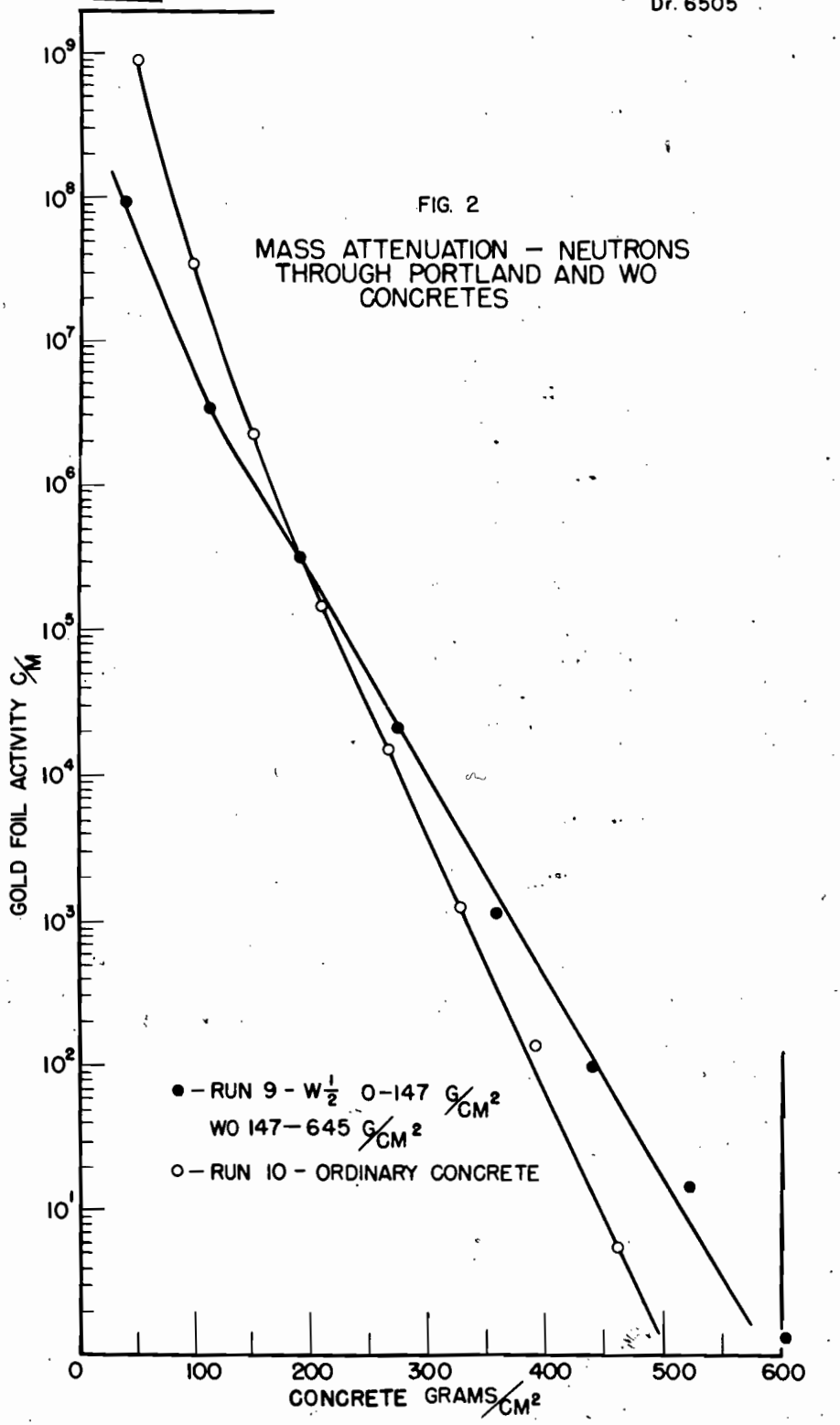
Dr. 6505



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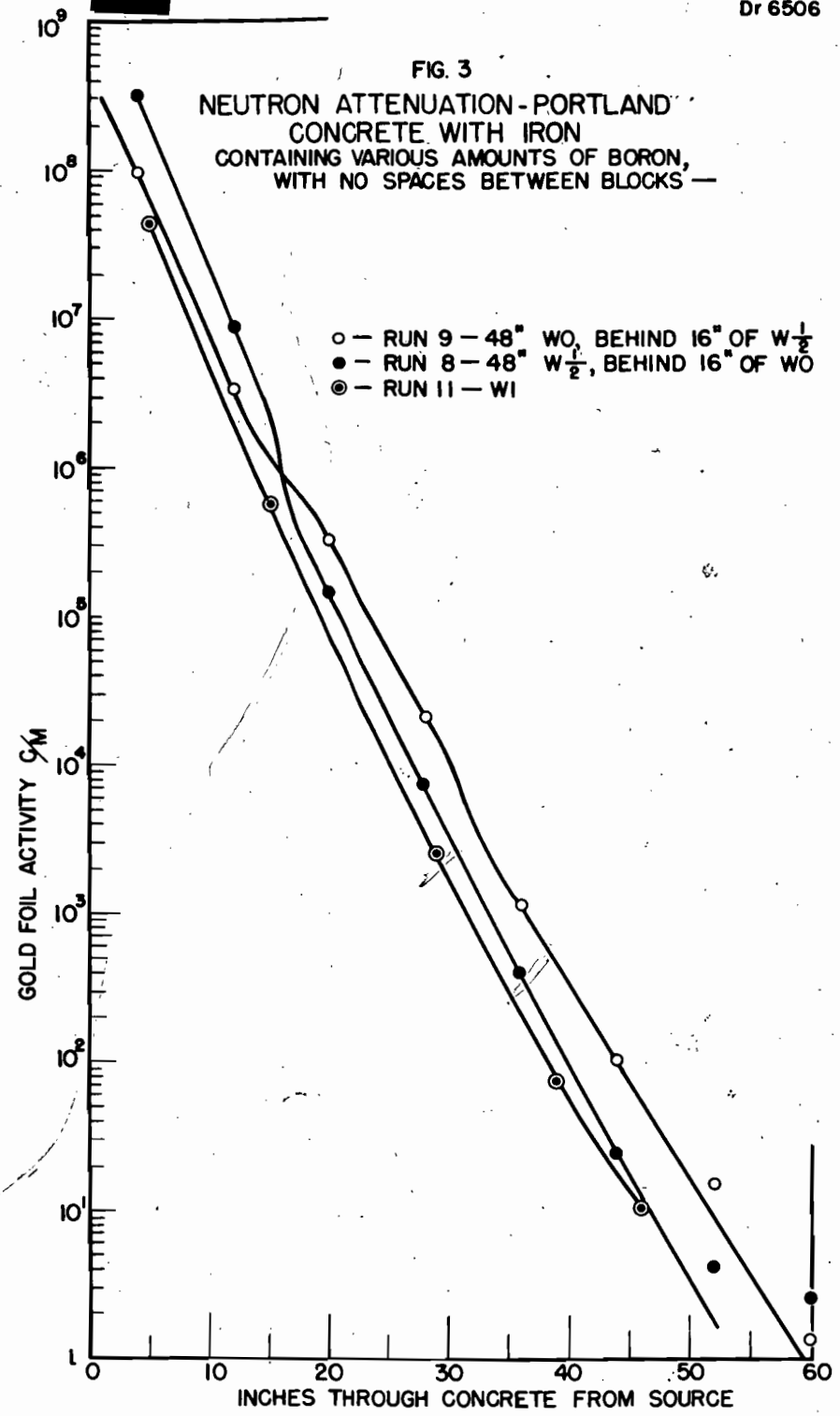
Dr 6506



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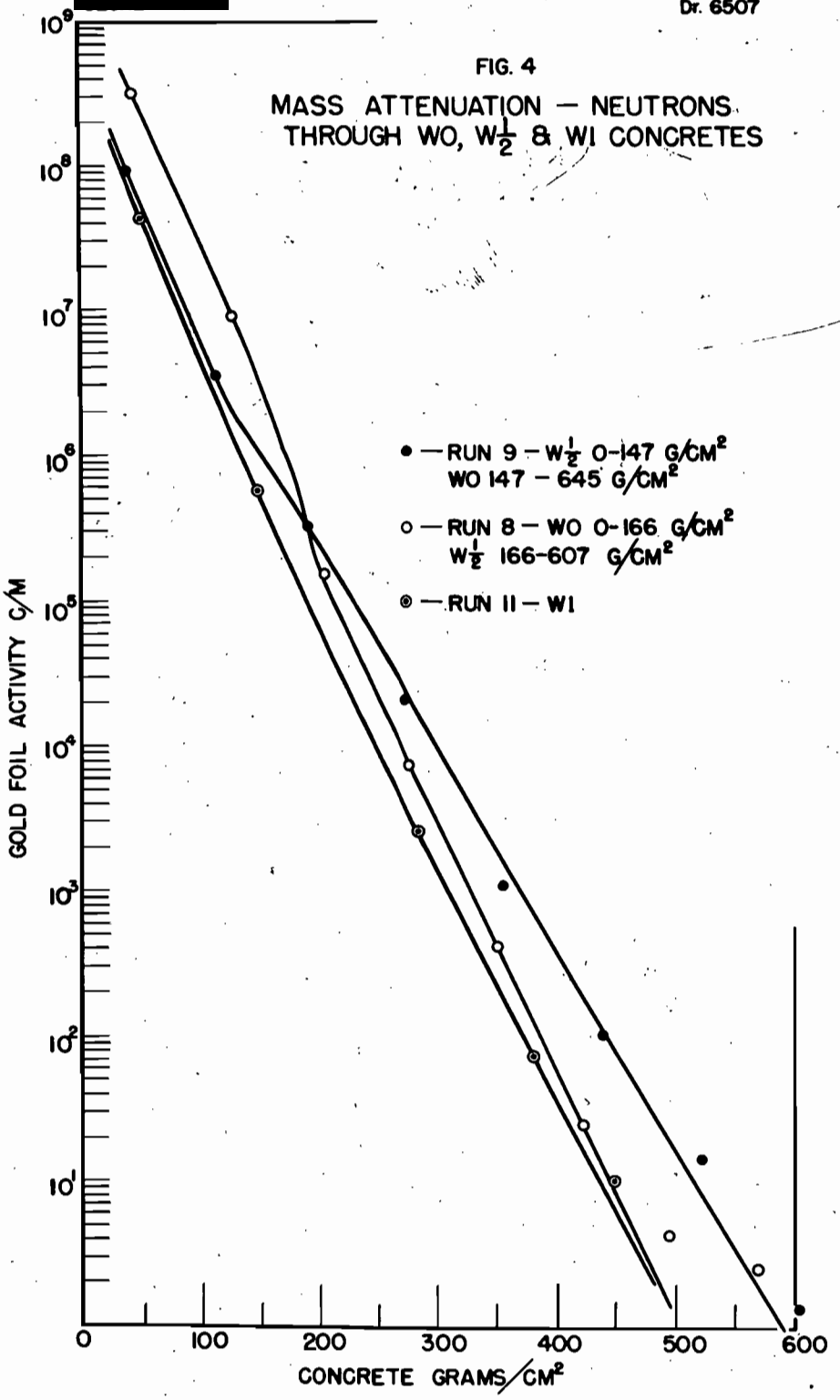
Dr. 6507

FIG. 4

MASS ATTENUATION — NEUTRONS THROUGH WO, W½ & WI CONCRETES



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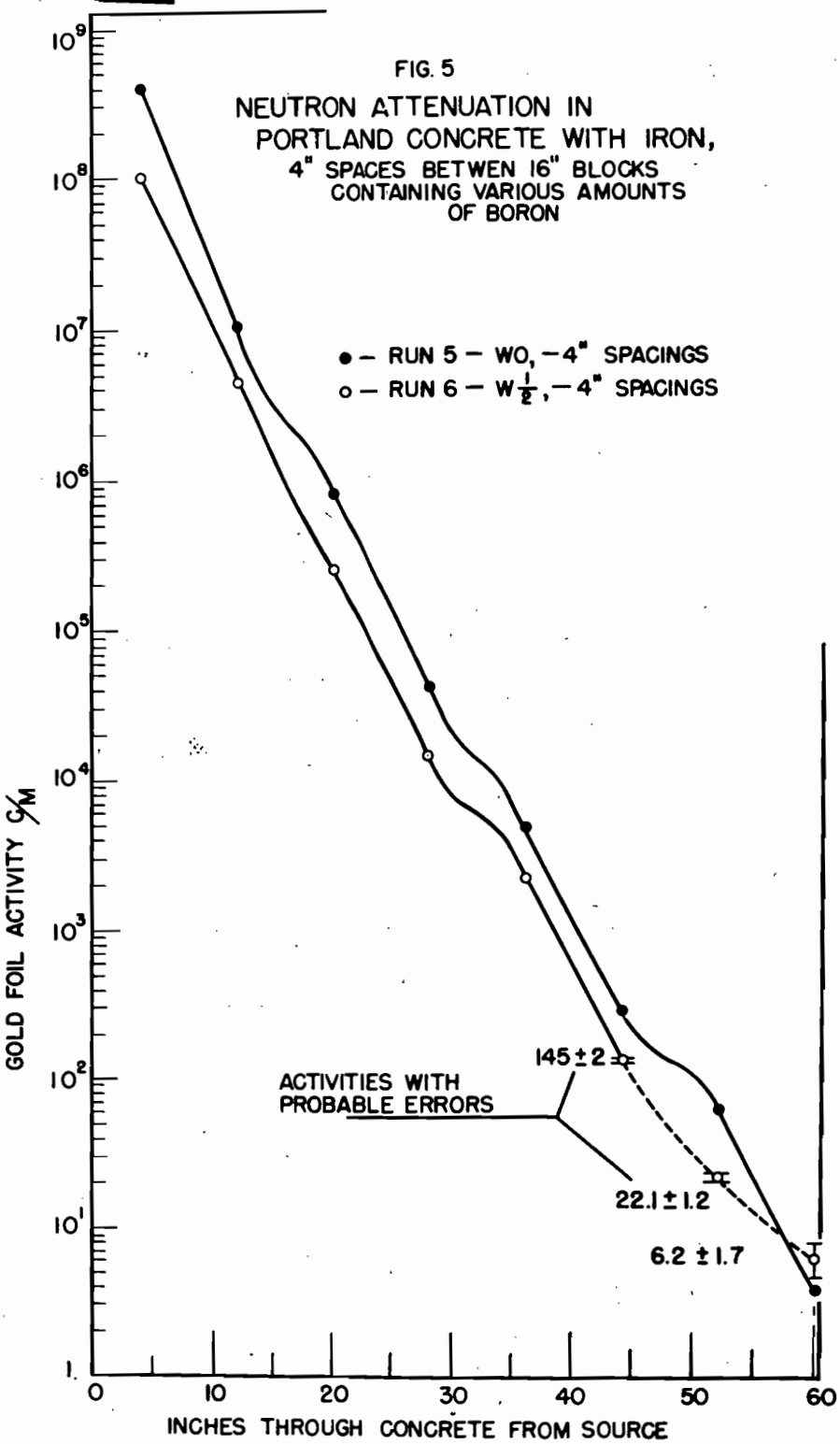
Dr. 6508



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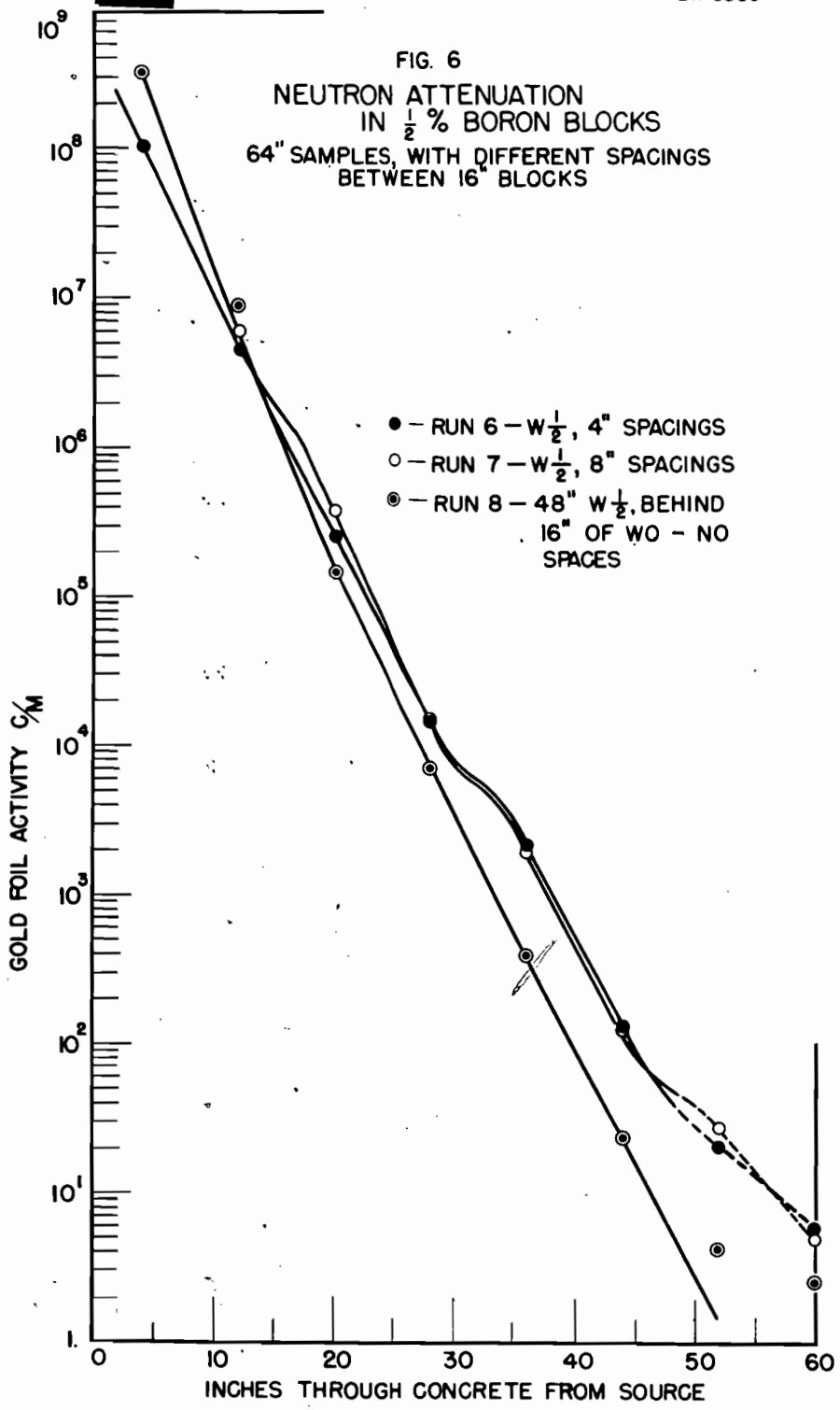
Dr. 6509



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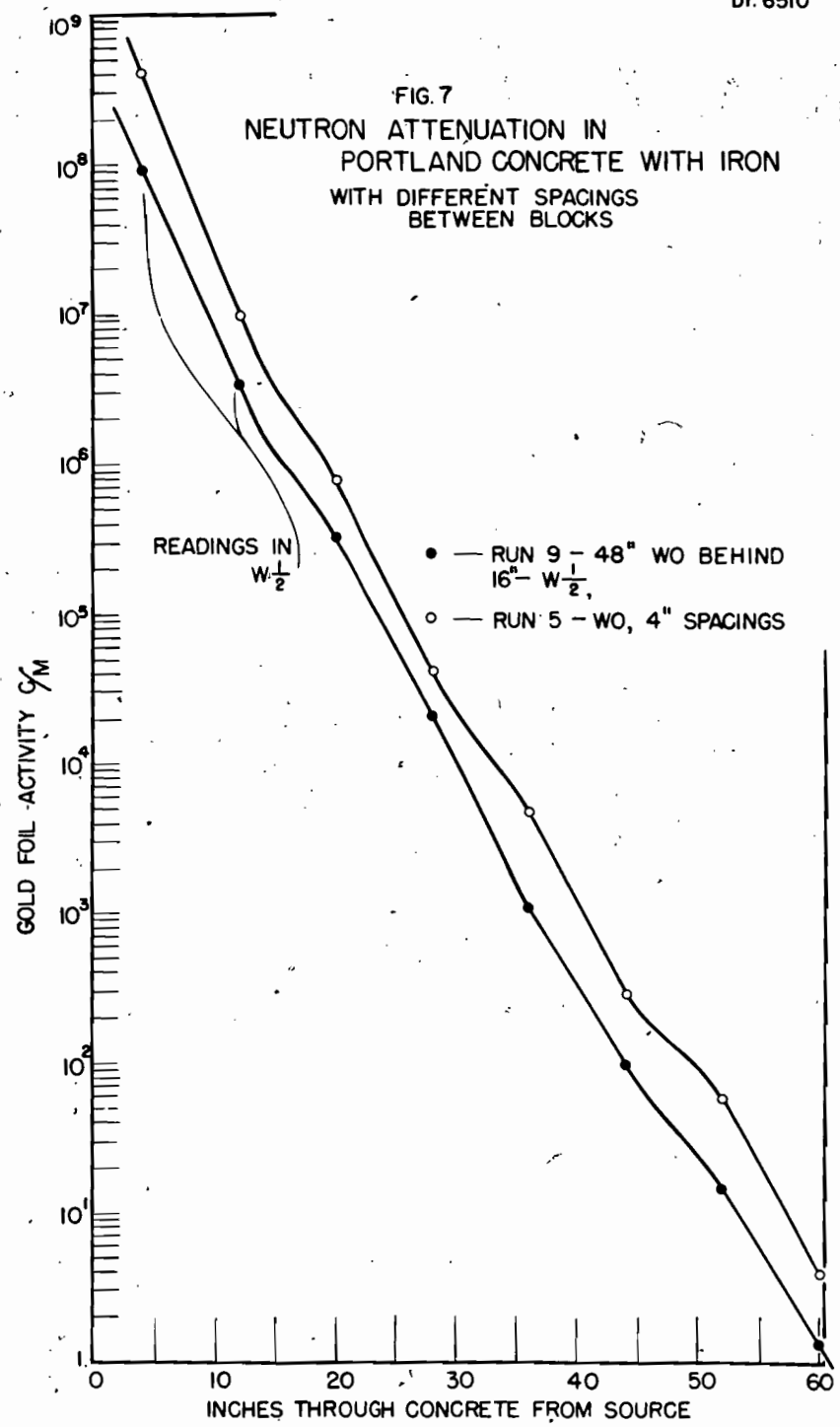
Dr. 6510

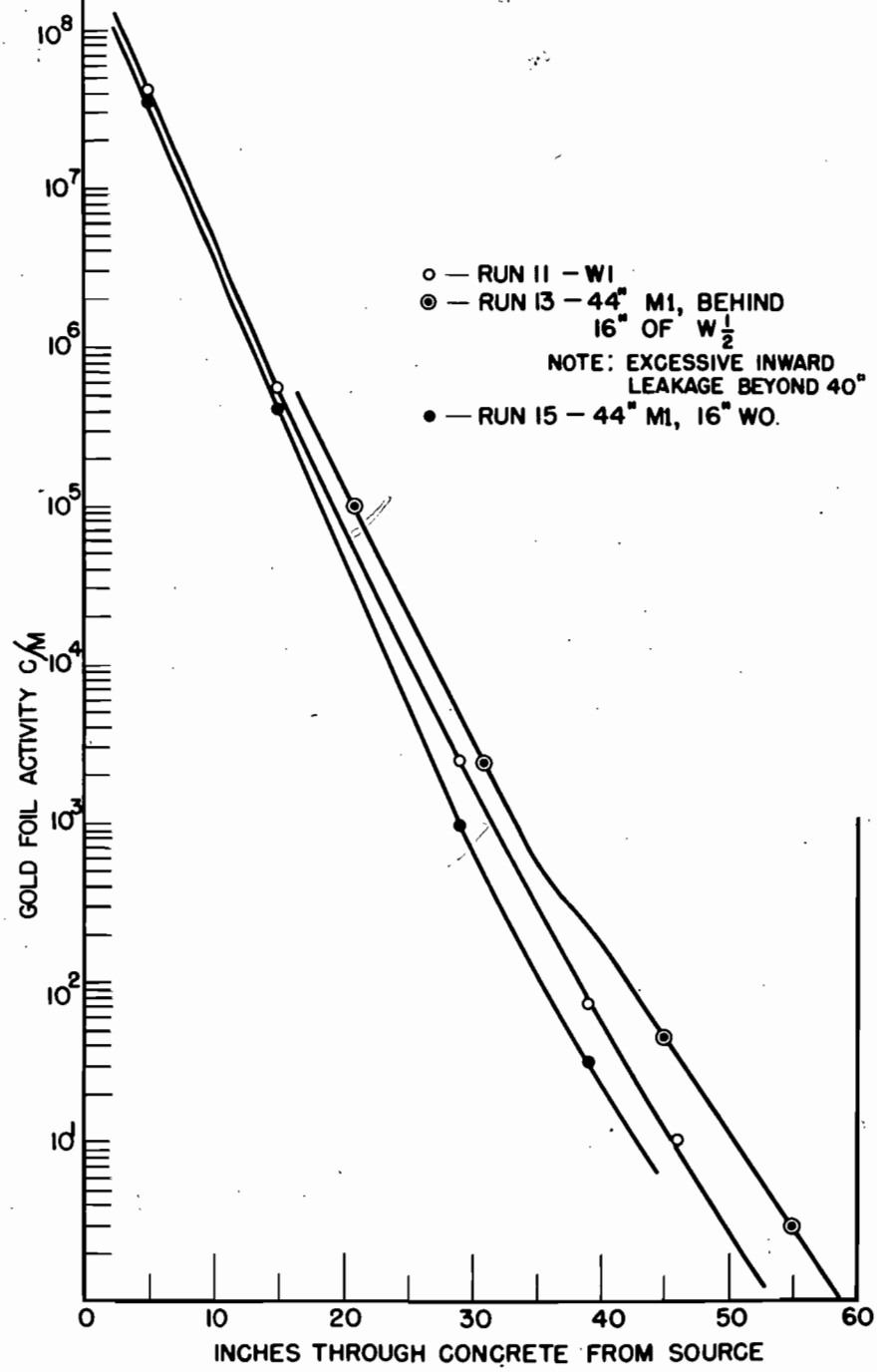


[redacted]

Dr. 6511

FIG. 8

NEUTRON ATTENUATION IN M1 & W1 CONCRETES



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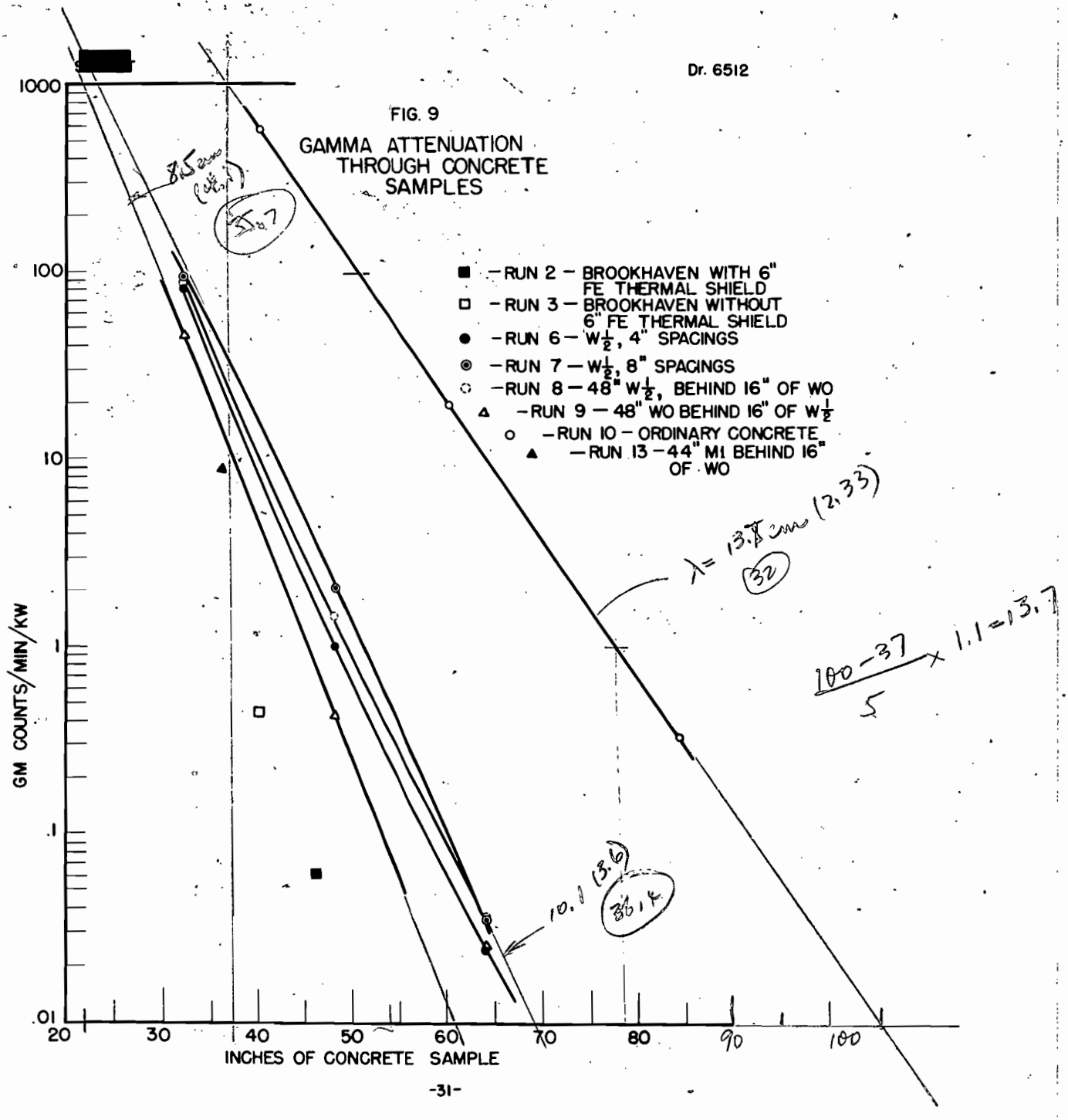
Dr. 6512

FIG. 9

GAMMA ATTENUATION THROUGH CONCRETE SAMPLES

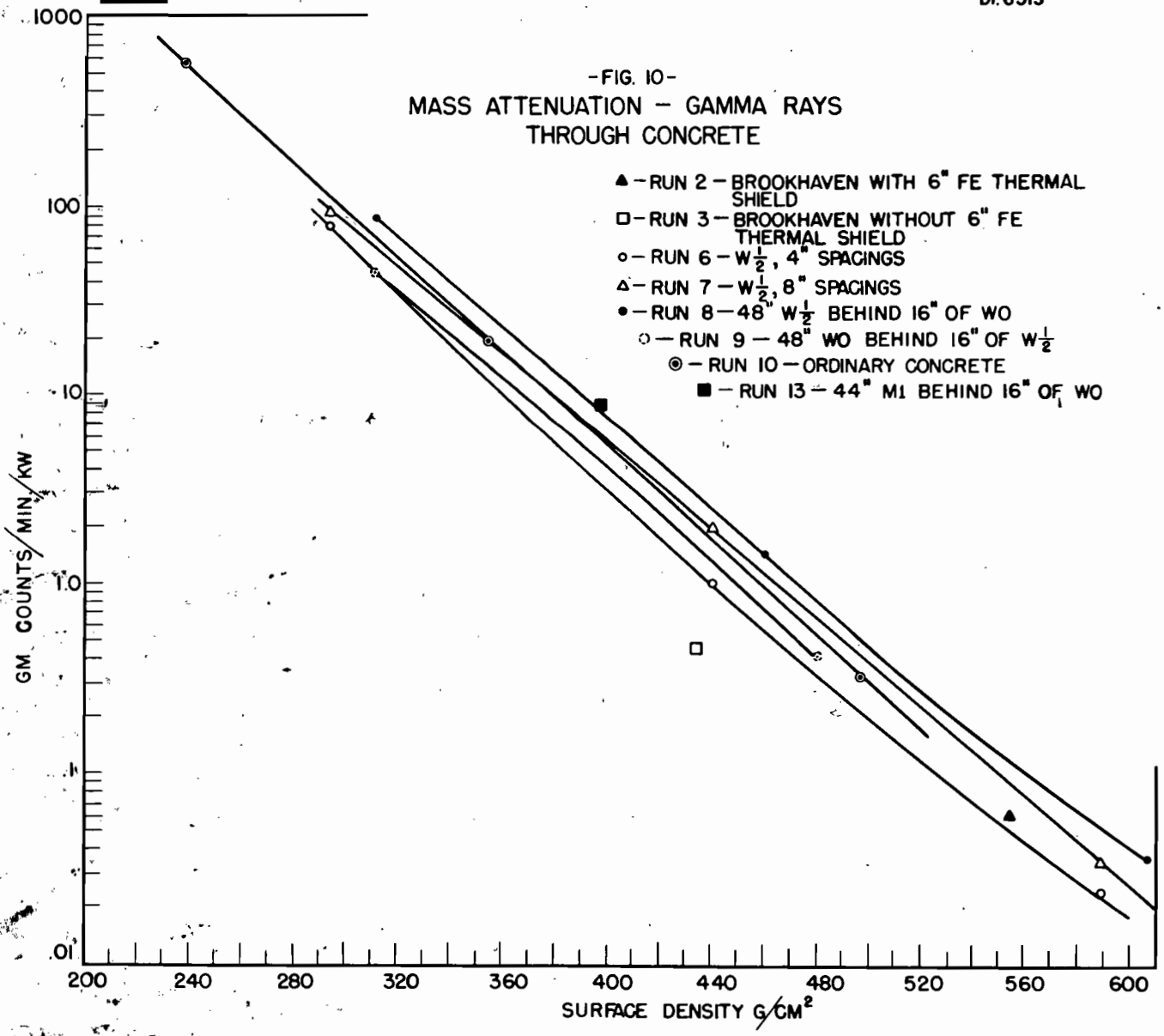


[redacted]

Dr. 6513

-FIG. 10-

MASS ATTENUATION – GAMMA RAYS THROUGH CONCRETE

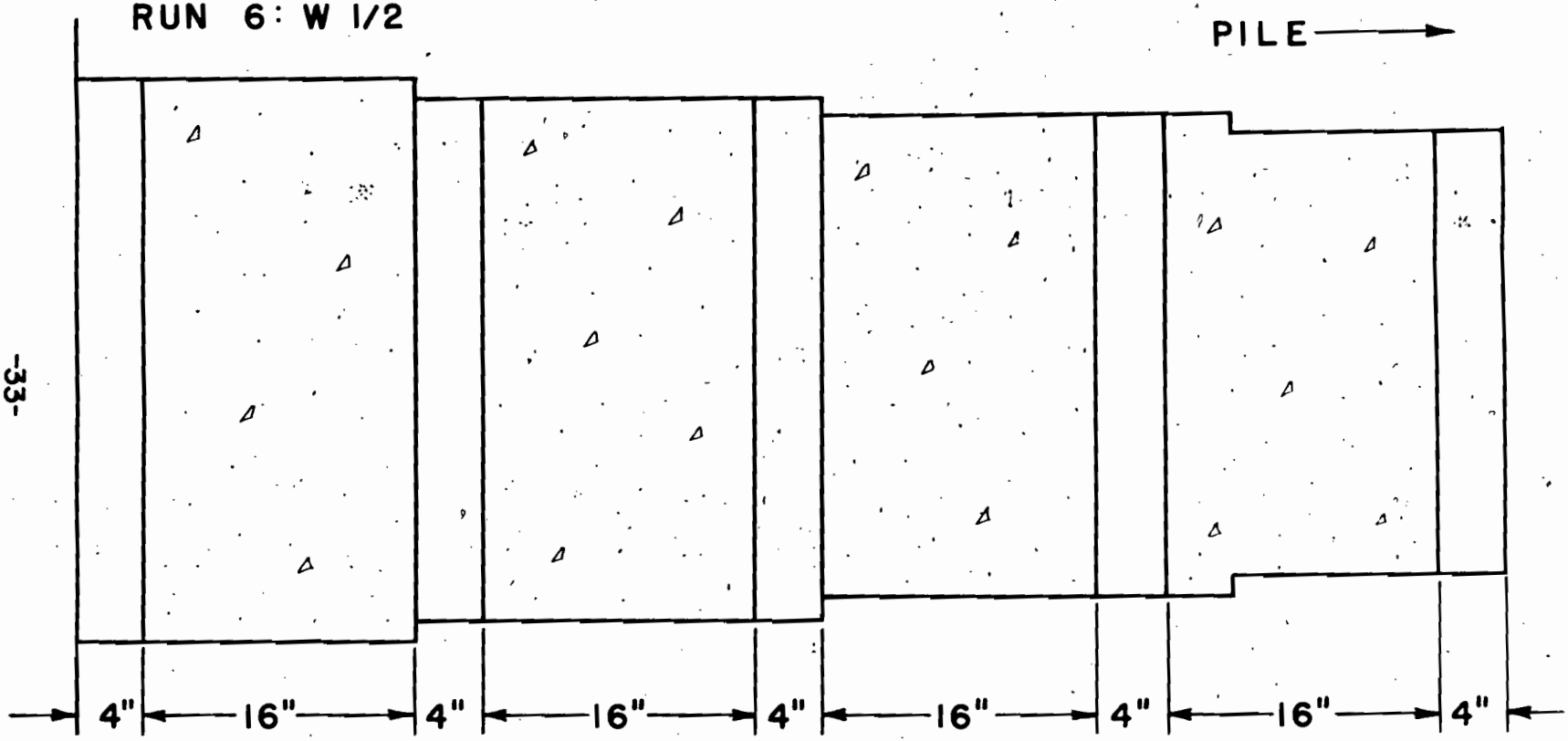


[redacted]

Dr 6514

FIG. 11

RUN 5: WO
RUN 6: W 1/2

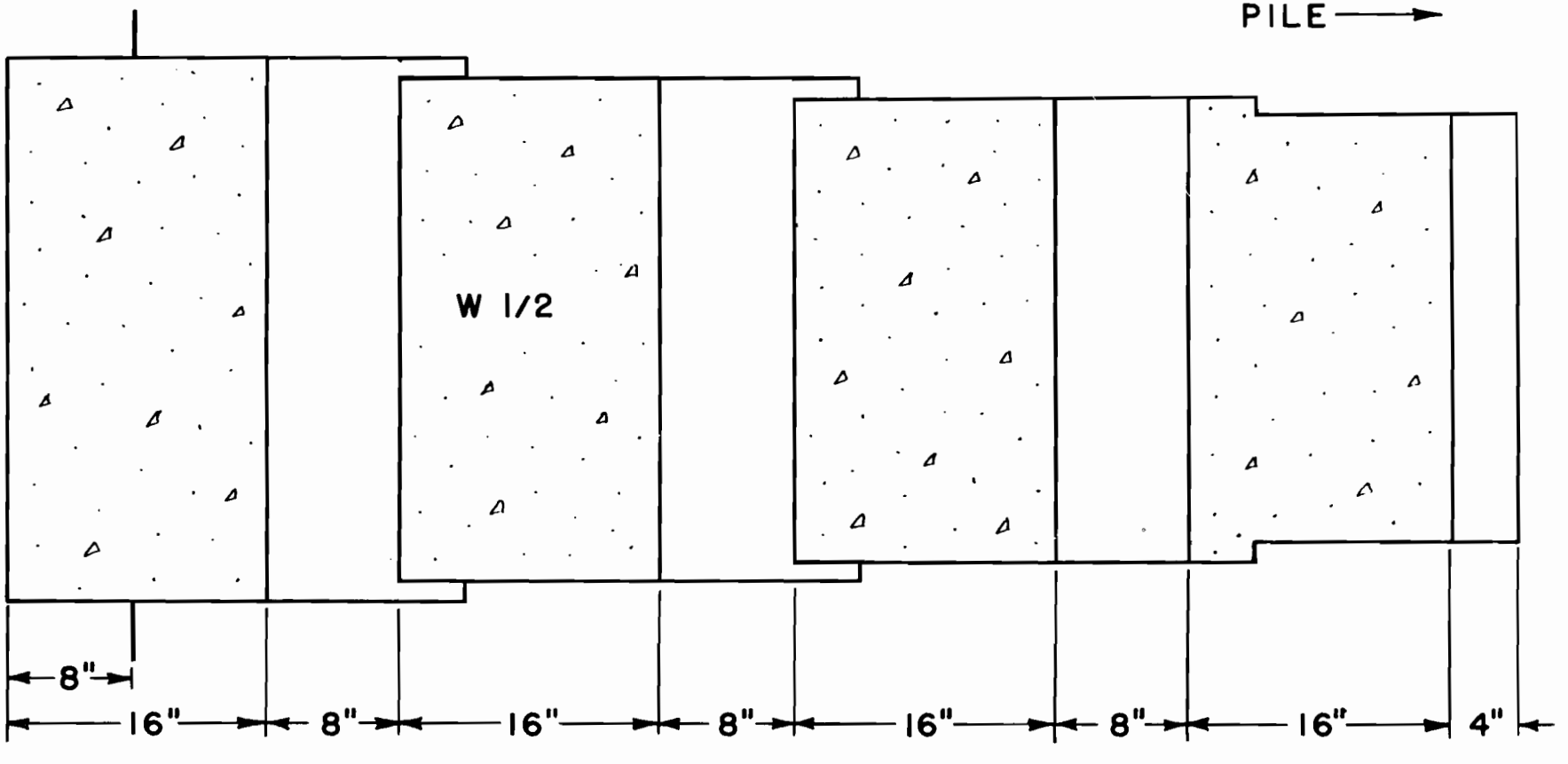


ARRANGEMENT FOR RUNS 5 & 6

[redacted]

Dr 6515

FIG. 12

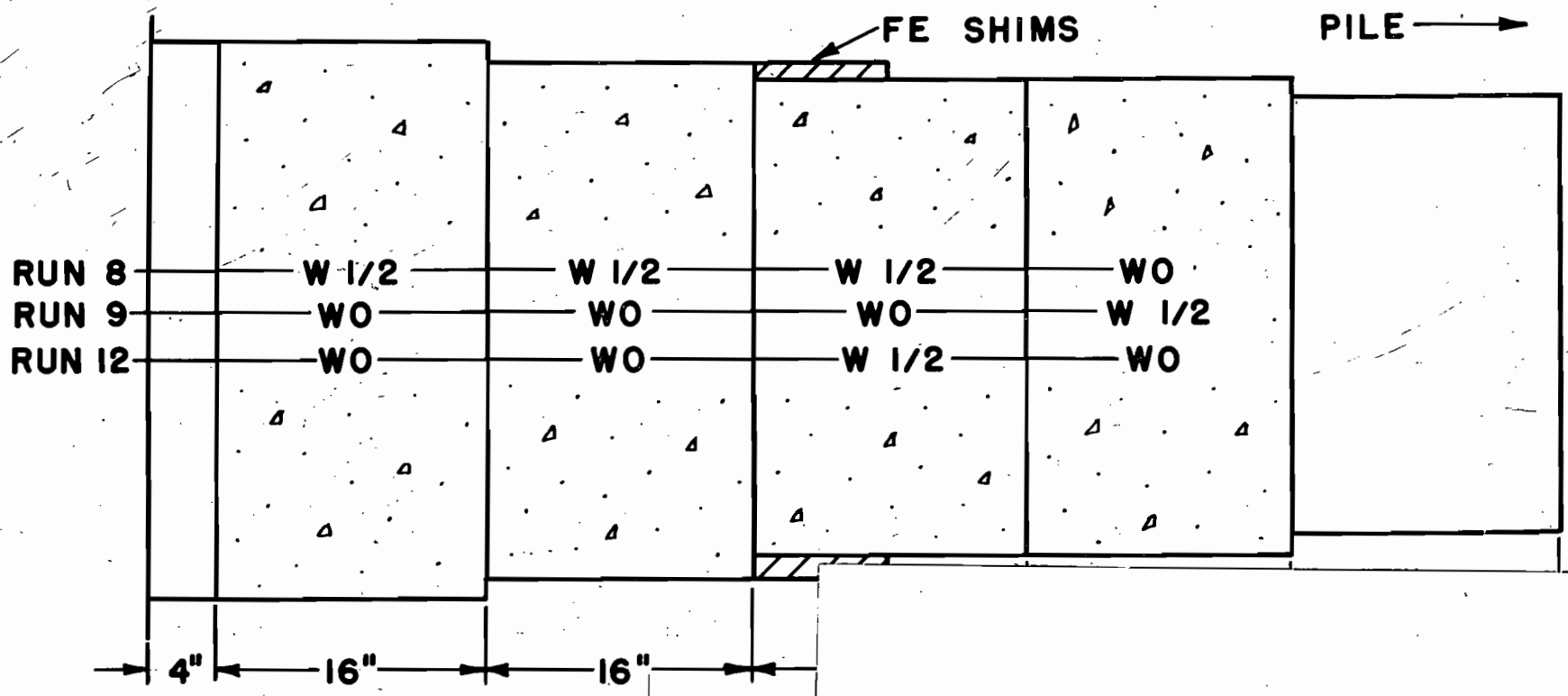


ARRANGEMENT FOR RUN 7

[redacted]

Dr 6516

FIG. 13



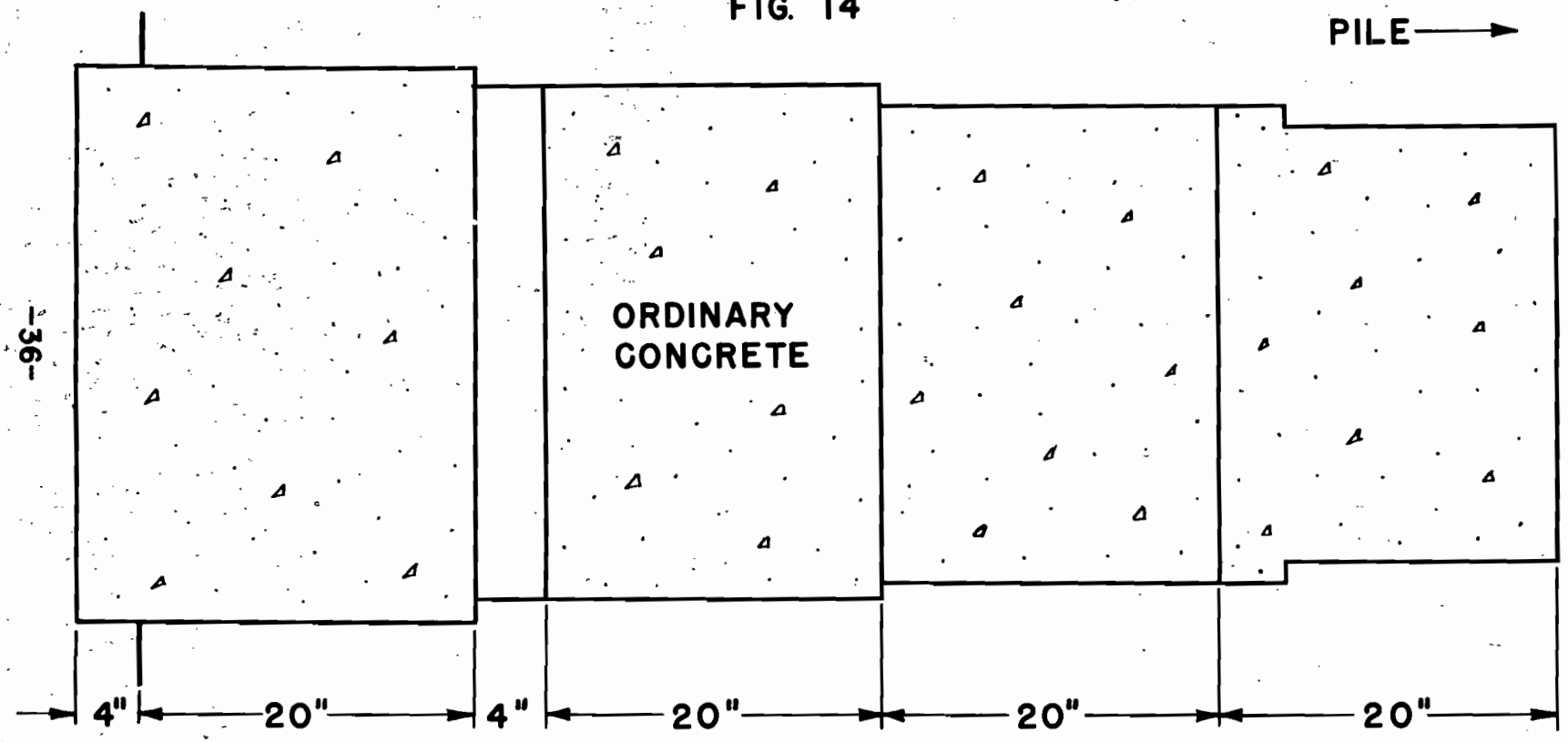
ARRANGEMENT

357

[redacted]

Dr 6517

FIG. 14

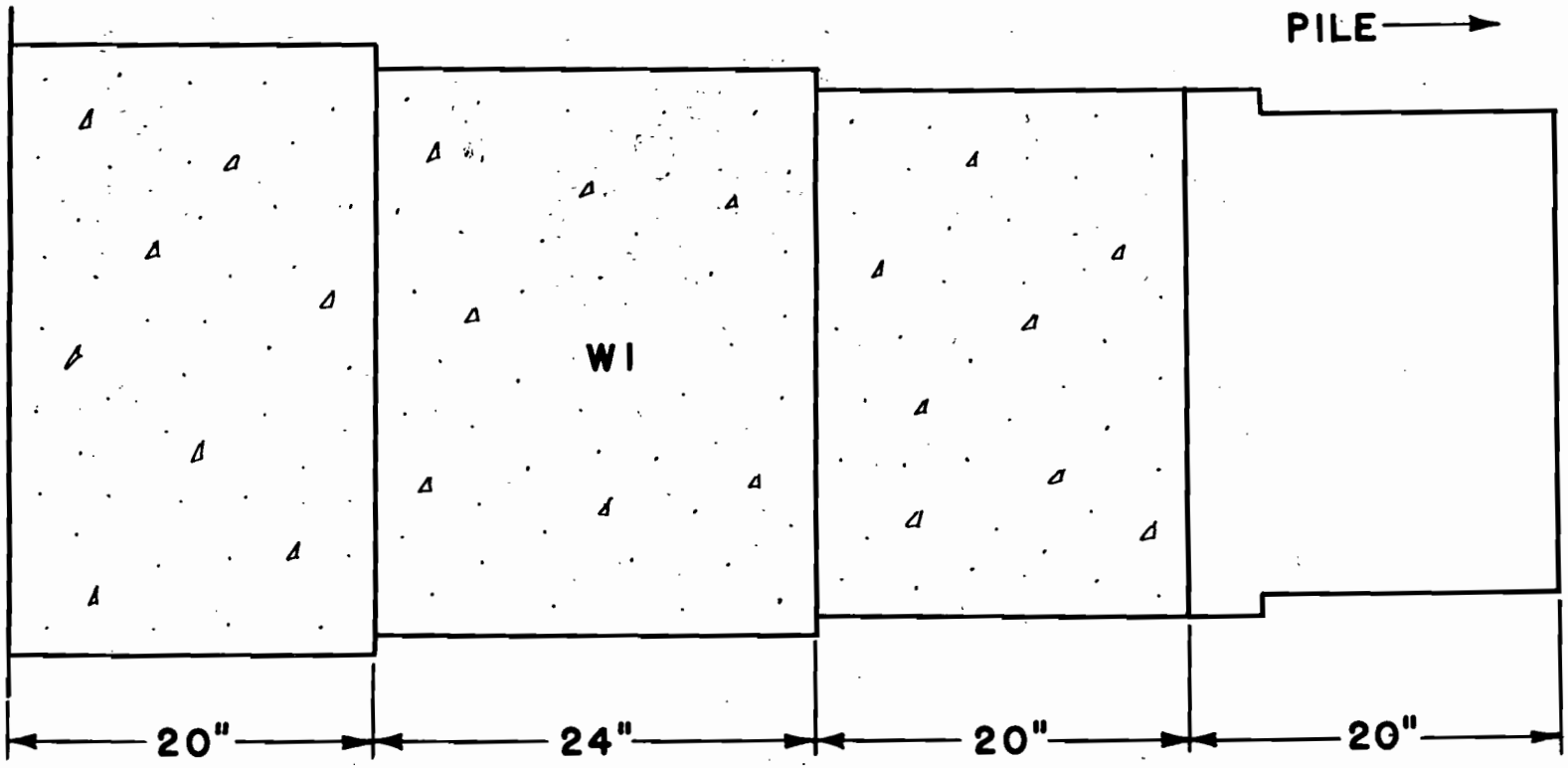


ARRANGEMENT FOR RUN 10

[redacted]

Dr 6518

FIG. 15

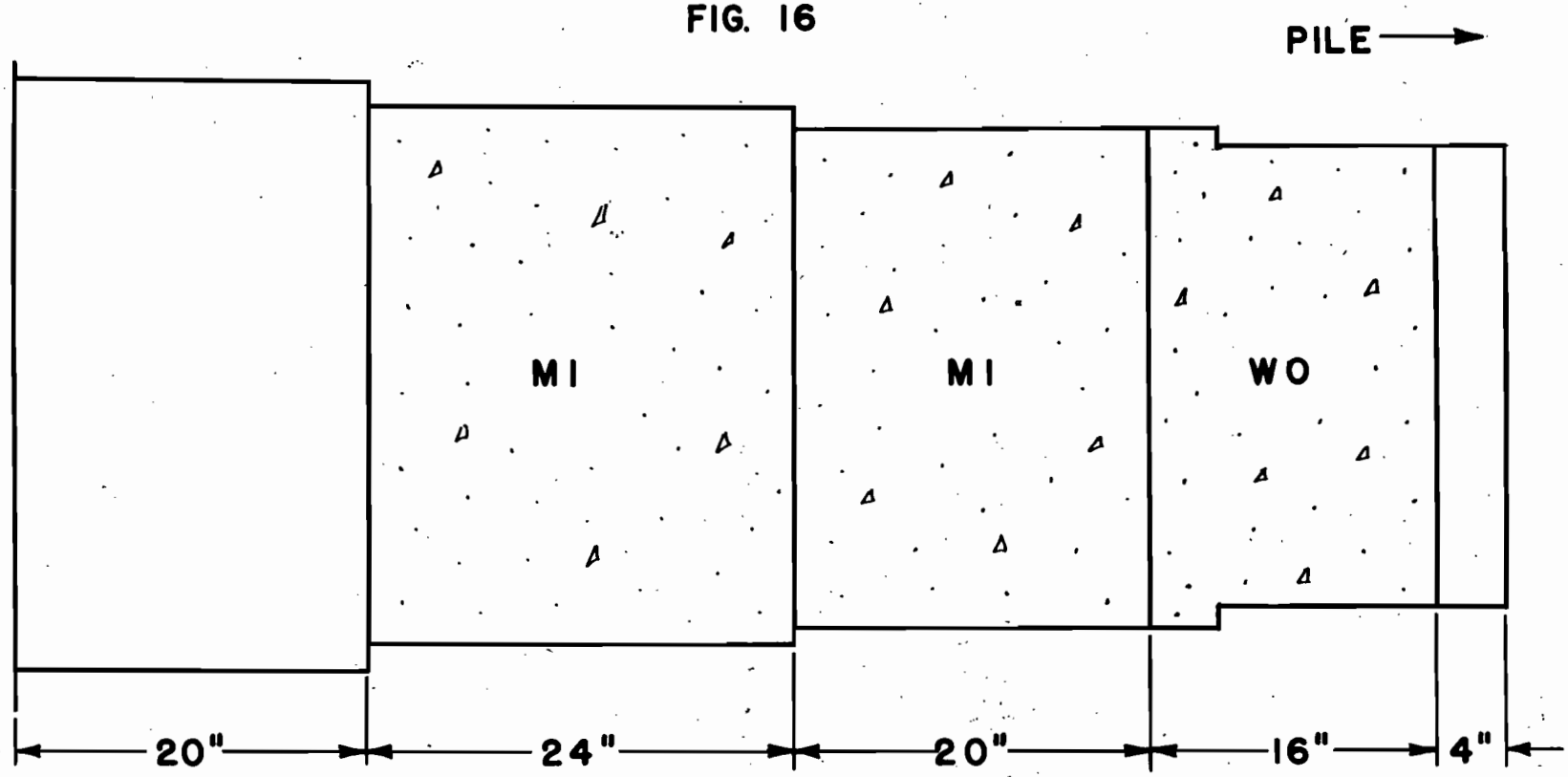


ARRANGEMENT FOR RUN II

[redacted]

Dr 6519

FIG. 16

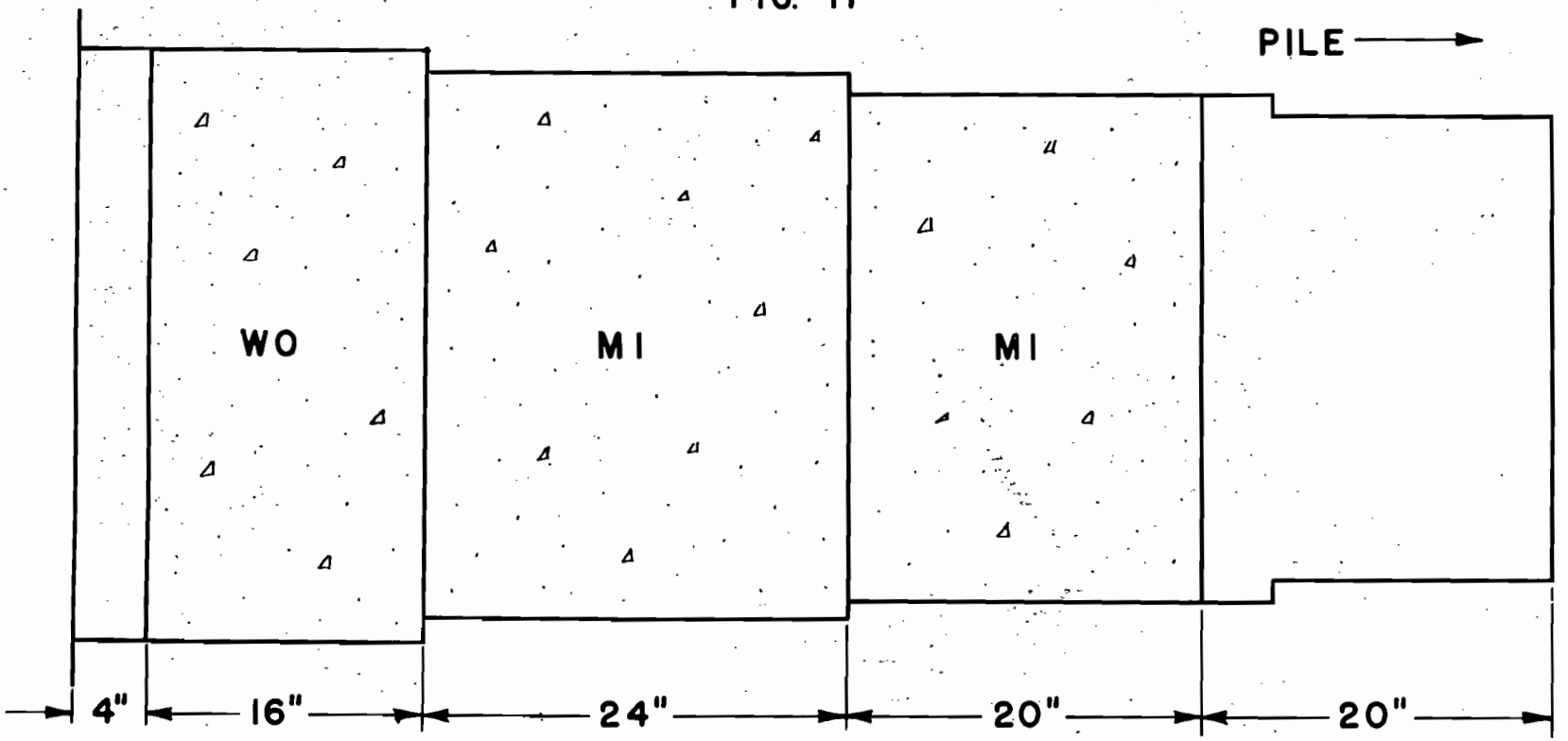


ARRANGEMENT FOR RUNS 13 & 14

[redacted]

Dr 6520

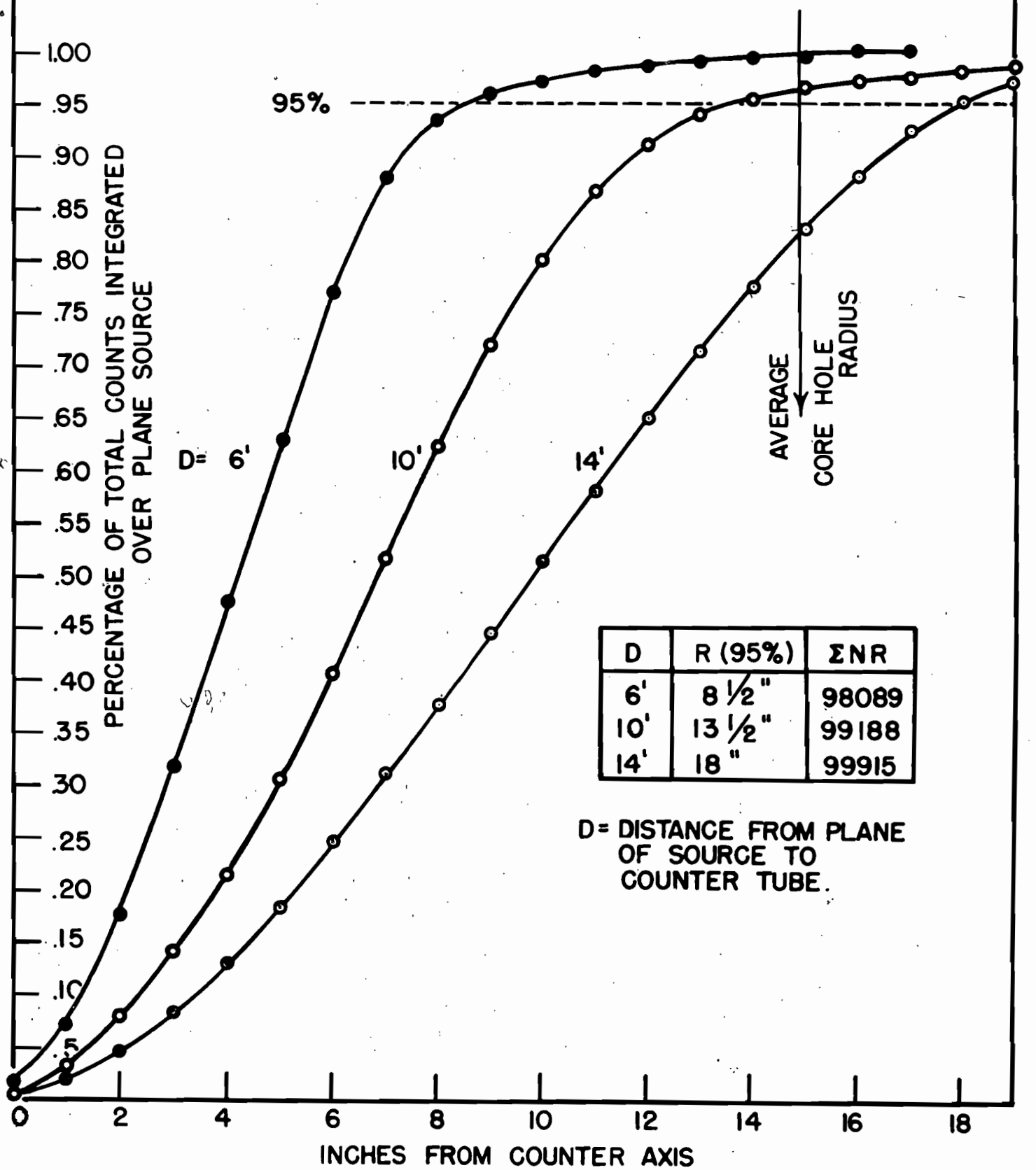
FIG. 17



ARRANGEMENT FOR RUN 15

FIG. 18

—GEIGER COUNTER COLLIMATION CHARACTERISTICS



D	R (95%)	ΣNR
6'	8 1/2"	98089
10'	13 1/2"	99188
14'	18"	99915

D= DISTANCE FROM PLANE OF SOURCE TO COUNTER TUBE.