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ORNL SUMMER SHIELDING SESSION

ATTENUATION MEASUREMENTS IN HEAVY AGGREGATE M-1 CONCRETE

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Gale Young, Leader

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This report is one of a series on shielding and represents part of the work of a summer group working principally at Oak Ridge National Laboratory. Participants are drawn from Nuclear Development Associates (Navy contract), NEPA, Bureau of Ships and Bureau of Aeronautics (Navy Department), AEC, RAND, General Electric, Argonne and Oak Ridge National Laboratory.

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ATTENUATION MEASUREMENTS IN HEAVY AGGREGATE M-1 CONCRETE

H. P. Sleeper, Jr.* and C. E. Clifford

Attenuation measurements in heavy aggregate M-1 concrete were made in the core hole in the west face of the Oak Ridge pile shield. This hole extends 7' through the shield at the center of the active lattice and is 28" x 32" at the outside with a reduction due to 3 steps in the hole to 23½" by 27½" at the inside.

OBJECT

In the past,[1,2] shield measurements on heavy aggregate concretes in the core hole facility have been made with test blocks 16 inches thick, or larger. With these large blocks neutron measurements were made in the concrete at intervals of several inches by placing gold foils behind thin concrete inserts near the block interfaces, and by mounting them around wooden dowels inserted in pipes at intervals in the concrete. Since gamma measurements inside a shield are not feasible without providing a spiral hole through the sample,[3] gamma measurements were taken with a lead collimated GM tube "looking" at the rear face of the shield sample. A brief discussion of the method and its validity is given in ORNL-209.

Since previous gamma measurements were taken at large intervals and attenuations, of the order of a factor of 100 per block, it was considered desirable to obtain better gamma measurements for a high density concrete of interest. At the time the tests were performed, M-1 concrete, density 4.5 gm/cm^3, was considered a likely competitor for M.O. concrete.[1,4]. M.O. concrete has a density of 5.8 gm/cc,

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1. ORNL-32
2. ORNL-209
3. ORNL-33
4. ORNL-228

*On loan from Knolls Atomic Power Laboratory

and contains no boron. The composition of M.O. concrete, given in Table I, has been recomputed based on measurements of iron aggregate densities. M-1 concrete differs from M.O. by having a lower density, a boron content of about 1% by weight, and a higher hydrogen to iron ratio. Early experiments with M-1 concrete were made in run 15, on 11-25-47, reported in ORNL-209, but no satisfactory gamma attenuation data were obtained.

METHOD OF MEASUREMENT

The method used in these experiments with M-1 concrete (run 46) differed in two main respects from that used in previous concrete tests. The heavy concrete was cast in two inch thick slabs, encased in a steel channel frame. Special methods were used by the ORNL shielding laboratory personnel, under the supervision of T. Rockwell, to insure uniform density and thickness of the slabs. These techniques are described in ORNL-323. With these 2" slabs, it was possible to make both neutron and gamma measurements at much closer intervals than heretofore in concrete samples. Secondly, the frames for the concrete were made to fit in the steel NEPA transport boxes, designed to fit the stepped core hold. These transport boxes were built to enable the changing of samples quickly since they are mounted on wheels which ride on rails into the core hole. The samples for the first box were 27½" x 23 5/8" x 2". The construction of the transport boxes, and description of loading techniques are given in CF #48-10-44, p. 165, of the ORNL shielding symposium notes.

Neutron data were obtained with gold foils. These were placed on thin aluminum strips which were mounted in turn on the face of the test slabs, to obtain neutron traverses. The method of foil mounting, the concrete samples and the transport box are illustrated in Figure 4. The foils were used only in the first transport box so that streaming from the surrounding shield would not be significant.

Gamma data were taken with the collimated GM tube, 8 feet from the Oak Ridge shield face. The data were taken behind successive four inch slabs of concrete. As a rough check, data were also taken with a hand-held portable "cutie pie" ion chamber at the face of the surrounding shield. Sample changes and background measurements were made with the pile shut down. Since the time required for these operations was considerable, and the shutdown time allowed was limited, measurements were made only every four inches in the first transport box.

DISCUSSION OF RESULTS

The neutron data for run 46 are plotted in Figure 1, covering a range of attenuation of 10^4. The striking characteristic of the data is the nearly exponential attenuation from the origin. This indicates that the spectrum from the pile is nearly the same as the "equilibrium" spectrum for the shield . That is, there is evident no transition of pile spectrum to equilibrium spectrum in the shield. In previous measurements it has been shown that interposing a boron or an iron "thermal" shield, between the pile and the shield, changes the incident spectrum in such a way that there is a transition region of positive or negative curvature, asymptotic to an "equilibrium" relaxation length in cases were streaming is not dominant. There is a slight deviation from exponential in the attenuation curve in Fig. 1, indicating that the spectrum is still changing slowly.

In Figure 2 the neutron data for run 46 are compared with the data for run 15. The compositions for the two runs were only slightly different, as shown in Tables II and III. The average density of the samples in run 46 was 4.7 gm/cc, compared with 4.5 gm/cc for run 15. It was not expected that this small difference would change the neutron characteristics significantly, inasmuch as much larger composition

differences between M-1, M.O. and Brookhaven shields have all yielded relaxation lengths of about 6 cm. This expectation was vindicated, with a relaxation length of 5.9 cm for run 46 and 5.8 cm for run 15. The former was computed from data for the last half of the measured shield, since there is a slight curvature, and the latter is the average relaxation length over the whole range of attenuation.

The data for the inserts plotted in Fig. 2 were normalized to the dowel data by multiplying the former by a factor of two. This difference is due primarily to the ¼" paraffin tube around the foil dowels. The useful data for run 15 covers an attenuation of 10^5. The last point recorded in Table V was affected by streaming, as shown by the traverses reported in ORNL-209. Data for M.O. concrete reported in ORNL-228 indicate that there is no appreciable change in relaxation length from 10^5 to 10^9 attenuation for iron magnesium oxychloride type shields, and also that the difference in the relaxation length for the pile spectrum and the fission spectrum is very small.

The gamma data for run 46 are plotted in Figure 3. G.M. tube data were taken at two pile power levels behind each slab, in order to obtain comparable counting rates for successive slabs. There are two known difficulties in the measurements. First the pile power galvanometer is not known to be linear, and second the counting rates at the higher of the two power readings were too fast, causing coincidence losses in the G.M. tube. Since the counting rates for the high power measurements were nearly the same, these data were plotted in Figure 3. The relaxation weight of 42 gm/cm^2 compares well with a rough check with the portable ion chamber of 40 gm/cm^2. These correspond to relaxation lengths of 8.9 cm and 8.5 cm respectively.

The ratio of the measurements at low and high power levels could not be used to normalize the data to a single power level because of the cumulative error

due to fast counting rates of 15,000 counts per minute. However, the cumulative error would have amounted to only a 5 per cent increase in the relaxation length, which is within the experimental error. This correction also indicated that the pile power normalization was very good except at 5 KW. These readings were normalized to the 30 KW measurements in Fig. 3.

The results of the experiment indicate that both M.O. and M.1. have nearly equal shield performance in terms of relaxation length for neutrons, and relaxation weight for gamma-rays.

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TABLE I

COMPOSITION OF M. O. CONCRETE

Material	Wt. %	gm/cc	mg mole/cc
Fe	90.0	5.24	93.6
H	0.41	0.024	23.8
O	4.70	0.273	17.0
Mg	2.73	0.158	6.5
Cl	1.54	0.088	2.5
Mn	0.38	0.022	0.4
Total	100	5.80	144

TABLE II

COMPOSITION OF M-1 CONCRETE

Run 46 12/31/48

Material	Wt. %	gm/cc	mg mole/cc
Fe	79.9	3.83	68.5
H	0.76	0.036	35.9
B	0.88	0.042	3.91
O	10.64	0.511	31.95
Mg	4.30	0.206	8.50
Cl	2.14	0.102	2.89
Ca	1.08	0.052	1.29
Mn	0.33	0.016	0.28
Total	100	4.80	153.2

TABLE III

COMPOSITION OF M-1 CONCRETE

Run 15 - 11/25/47

Material	Wt. %	gm/cc	mg mole/cc
Fe	74.48	3.35	60.0
H	0.98	0.044	43.9
B	0.93	0.042	3.88
O	13.55	0.61	38.1
Mg	5.65	0.25	10.4
Cl	2.52	0.11	3.2
Ca	1.15	0.085	1.3
Mn	0.37	0.016	0.3
Total	100	4.48	161.1

TABLE IV

NEUTRON ATTENUATION DATA

Run 46 12/31/48

M-1 Concrete (ρ = 4.7 gm/cc)

Composition Specified in Table II

Average Pile Power - 3600 KW

Concrete Thickness (inches)	Foil Activity Saturated (cts/min KW)	Concrete Thickness (inches)	Foil Activity Saturated (cts/min KW)
0	2.22×10^4	12	110
2	9.01×10^3	14	43.6
4	3.95×10^3	16	18.2
6	1.51×10^3	18	7.79
8	6.00×10^2	20	3.49
10	2.65×10^2	22	2.52

TABLE V

NEUTRON ATTENUATION DATA

Run 15 11/25/47

M-1 Concrete (ρ = 4.5 gm/cc)

Composition Specified in Table III

Average Pile Power - 3600 KW

Dowels		Inserts	
Concrete Thickness (inches)	Foil Activity Saturated (cts/min KW)	Concrete Thickness (inches)	Foil Activity Saturated (cts/min KW)
5	1.00×10^4	2	1.99×10^4
15	1.15×10^2	18	1.47×10
29	2.66×10^{-1}	22	3.0
39	9.24×10^{-3}*	42	background

* Streaming in from top and bottom (ORNL-209)

TABLE VI

GAMMA ATTENUATION DATA

Run 46 12/31/48

M-1 Concrete (ρ = 4.7 gm/cc)

Concrete Thickness (inches)	Surface Density (gm/cc)	G.M. Tube (cts/min KW)	C.P. Ion Chamber (mr/hr)	Pile Power (KW)
2	24.4		16	5
6	72.0	1300*	5.0	5
10	118.7	480		30
14	166.2	157	0.44	100
18	212.4	49.2	0.17	300
24	281.5	10.3		1200

* Normalized to 30 KW Power Reading

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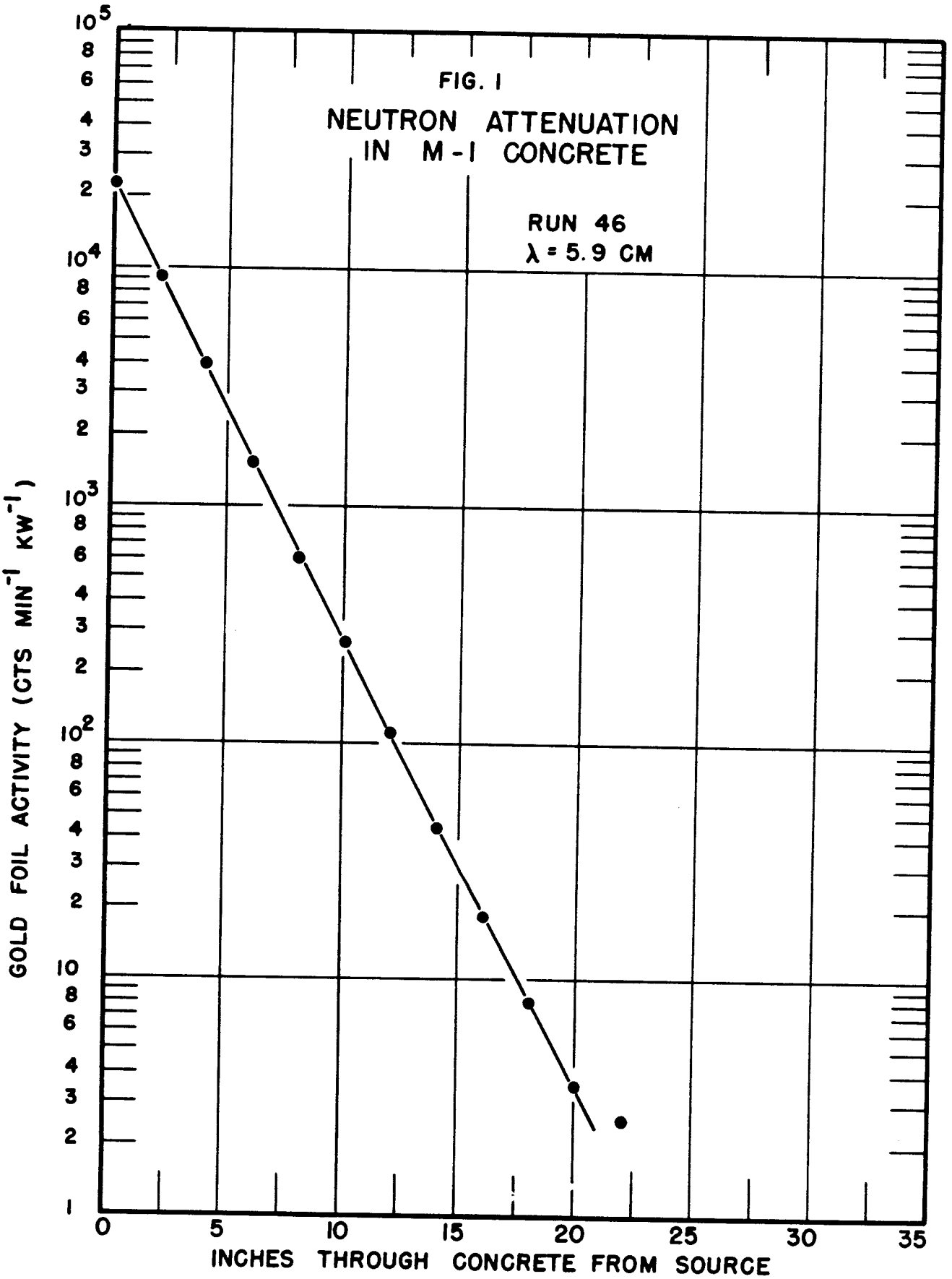
FIG. 1
NEUTRON ATTENUATION
IN M-1 CONCRETE
RUN 46
λ = 5.9 CM
GOLD FOIL ACTIVITY (CTS MIN^{-1} KW^{-1})
INCHES THROUGH CONCRETE FROM SOURCE
10^5
10^4
10^3
10^2
10
1
0
5
10
15
20
25
30
35

[redacted]

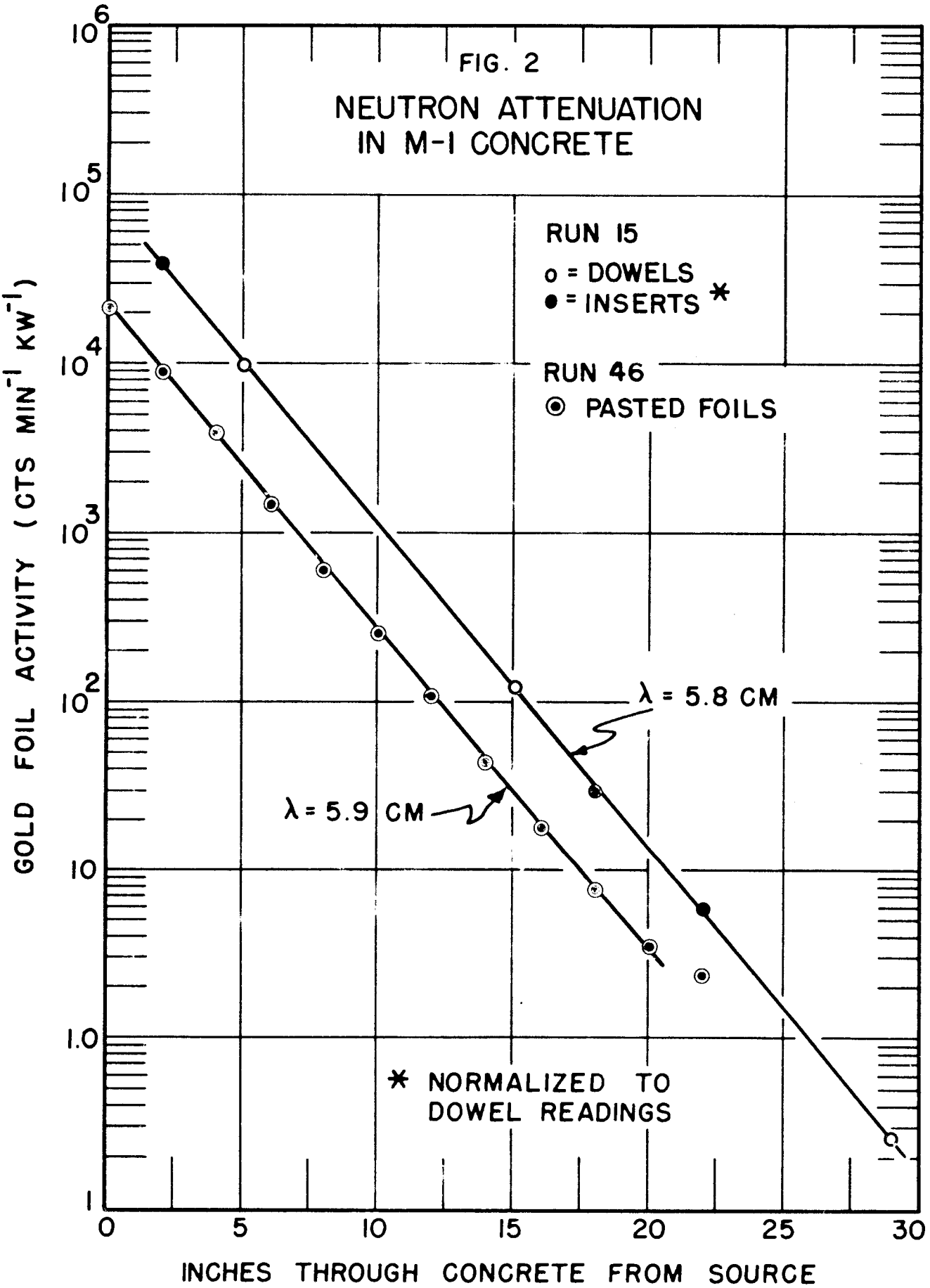
FIG. 2
NEUTRON ATTENUATION
IN M-I CONCRETE
RUN 15
o = DOWELS
● = INSERTS *
RUN 46
⊙ PASTED FOILS
λ = 5.8 CM
λ = 5.9 CM
* NORMALIZED TO
DOWEL READINGS
GOLD FOIL ACTIVITY (CTS MIN^{-1} KW^{-1})
10^6
10^5
10^4
10^3
10^2
10
1.0
1
0
5
10
15
20
25
30
INCHES THROUGH CONCRETE FROM SOURCE

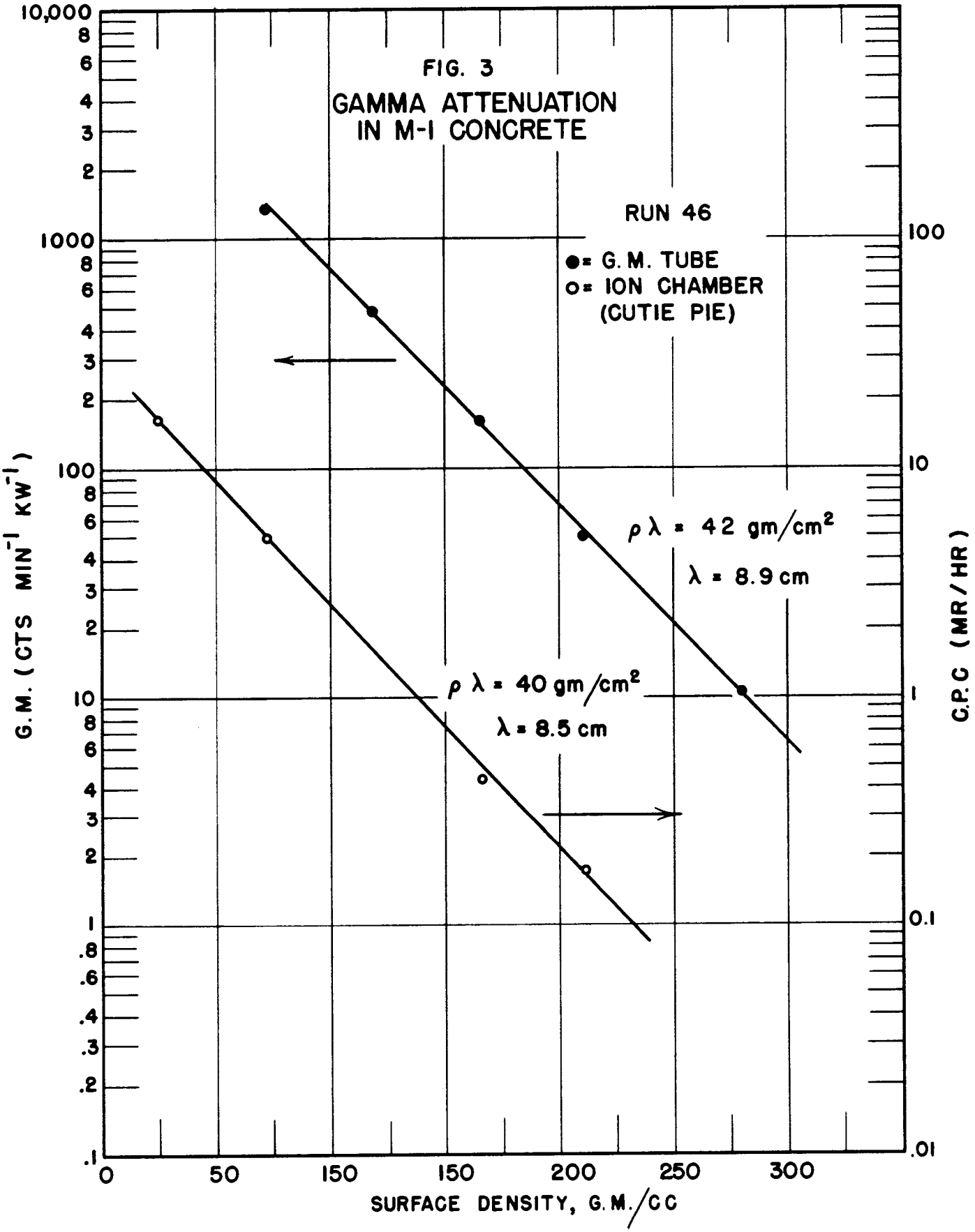
FIG. 3
GAMMA ATTENUATION
IN M-I CONCRETE
RUN 46
●= G. M. TUBE
○= ION CHAMBER
(CUTIE PIE)
ρλ = 42 gm/cm²
λ = 8.9 cm
ρλ = 40 gm/cm²
λ = 8.5 cm
G.M. (CTS MIN⁻¹ KW⁻¹)
C.P.C (MR/HR)
SURFACE DENSITY, G.M./CC
10,000
1000
100
10
1
.1
100
10
1
0.1
.01
0
50
150
150
200
250
300

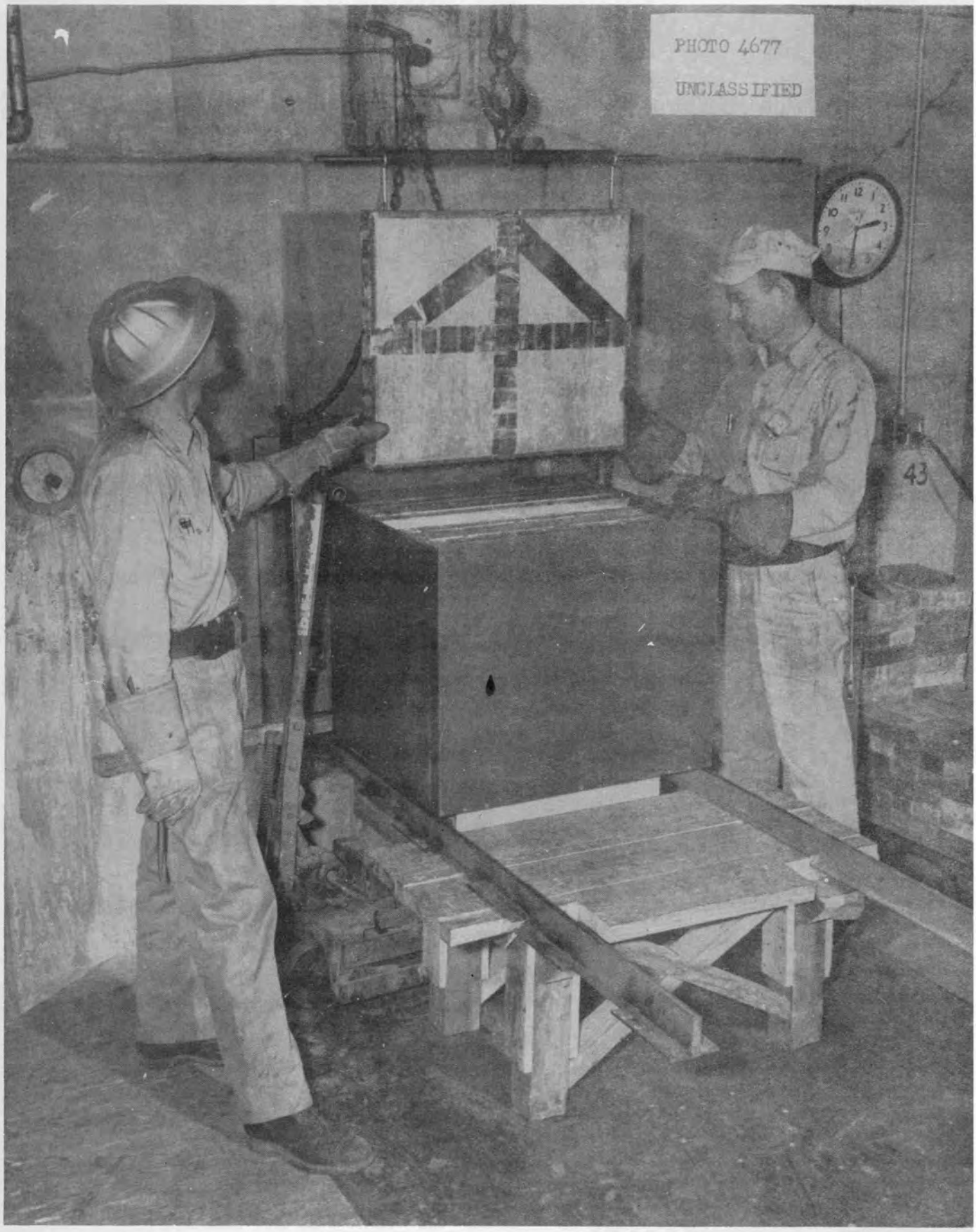

FIG. 4

M I SLAB BEING PUT INTO ATTENUATION TEST FACILITY