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HEALTH PHYSICS ASPECTS OF THE BORAX EXPERIMENT OF JULY 22, 1954, AT THE NATIONAL REACTOR TESTING STATION

By
P. Griffiths - C.W. Sill - M. Wilhelmsen

December 1954

Idaho Operations Office
Idaho Falls, Idaho

3042

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HEALTH PHYSICS ASPECTS OF THE BORAX EXPERIMENT OF JULY 22, 1954, AT THE NATIONAL REACTOR TESTING STATION

BY

P. GRIFFITHS - C. W. SILL - M. WILHELMSEN

ABSTRACT

During the summer and fall of 1953, and the spring of 1954, Argonne National Laboratory conducted an experimental program at the National Reactor Testing Station, utilizing a water-cooled, water-moderated reactor, wherein a series of intentional "runaway" type tests were completed with no health physics involvement beyond the immediate reactor area.

At 0820 on July 22, 1954, in an experiment in which the reactor core was subjected to a runaway test, an extreme reaction occurred resulting in the destruction of the reactor.

Extensive radiation monitoring proved that no immediate health hazard had occurred, either on the N. R. T. S., or its environs, as a result of this experiment.

Subsequent interpretation of air samples collected in the immediate vicinity of the reactor gave no indication of radioactivity greater than background levels, with the exception of an area affected by material blown out of the reactor, which was subsequently covered with gravel and roped off in order to eliminate any hazard.

A site ecological evaluation is presently being attempted in respect to the biological effect of this release.

Salvage operations progressed without incident, and a considerable amount of equipment was subsequently decontaminated and utilized in the Borax 2 facility.

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I. IDO-HP PREPARATION FOR BORAX OPERATION AND FAST EXCURSION

During the entire Borax operation of 1953, and initial runs in 1954 (Reference: -ANL-5211 and ANL-WHZ-373) the IDO radiological monitoring team was maintained on an alert basis while criticality excursions were in progress. Regular emergency monitoring kits were supplemented with additional instruments and supplies. Site survey vehicles were equipped with two-way radios, and a transmitter was installed in the field headquarters office.

Early in 1954, A.N.L. and IDO-HP personnel initiated joint plans to cover the possibility of an extensive energy release during the "fast excursion." At 0600 on July 22, five radio-equipped monitoring vehicles, each manned by two men, were at predetermined stations encircling the Borax area. Prior to the release these teams were frequently shifted by radio directions from the control vehicle, in order to conform to meteorological conditions, which were being constantly determined by U. S. Weather Bureau personnel on duty at the control area.

A smoke generator was operated sporadically at a point approximately one mile from the reactor and at an extreme location from the control area. A.N.L. personnel detonated smoke bombs within the reactor area prior to the release and one simultaneously with it. Smoke patterns produced proved to be extremely valuable as meteorological conditions were extremely variable in the early morning.

A maintenance crew manning gravel trucks and loading equipment was prepared to deliver and spread gravel over roads which might have become contaminated as a result of radioactive material blowing or falling out as a result of a possible extreme release.

Fallout plates, beta-gamma and neutron film were placed approximately downwind from the reactor, and within the reactor area proper, in order to supplement the regular site radiation monitoring network. All observers at the control area were issued film badges.

Shortly before 0800 the U. S. Weather Bureau notified A.N.L. officials that meteorological conditions were favorable for the experiment to be conducted. A.N.L. personnel in turn notified observers and alerted IDO-HP that operations would commence.

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II. IDO-HP MONITORING FOLLOWING FAST EXCURSION

At 0820, in the course of the experiment, the reactor "blew," following which an instantaneous dosage rate in excess of 500 mr/hr was indicated on C.P. Survey Meters at the control area, approximately one-half mile distant from the reactor. Within approximately thirty seconds the rate was established at 25 mr/hr and rapidly declining. Within less than 5 minutes, readings at this point had decreased to less than 1 mr/hr.

Construction personnel working within the E.B.R. area, approximately 0.6 miles from the Borax Reactor, were immediately evacuated pending evaluation of the situation, in order to limit the number of persons involved should a hazardous situation arise in the form of airborne radioactive material. Simultaneously vehicular traffic control was established from U. S. Highway 20 on Van Buren Avenue to the E.B.R.

At 0936 restrictions were modified to allow traffic free access to E.B.R., and construction crews were permitted to return to the construction site. At this time exposure rates over the extent of Van Buren Avenue, including E.B.R., were less than 0.5 mr/hr with no evidence of fallout.

Subsequent results from film badges worn by observers at the control area gave no evidence of exposure attributable to the release.

By 0825 monitoring teams had been dispatched to intercept the cloud as it crossed Adams Boulevard and the Union Pacific Railroad right-of-way. By 0900 these teams had determined the trajectory, as evidenced by radiation surveys as having been roughly in a southwesterly direction, passing over Adams Boulevard approximately 1-1/2 miles from the Van Buren Avenue - Adams Boulevard junction, thence over the Union Pacific Railroad tracks at the same angle of travel. (Figure 2). Within 45 minutes of the release, the bulk of the material had passed the railroad right-of-way and initial fallout surveys had been accomplished.

The following briefly summarizes effect of the cloud in this area, which was the only locale where fallout could be determined as being significant.

Maximum readings at 3 feet above ground during passage of cloud:

Across Adams Boulevard at 0835	5 mr/hr
Across U.P.R.R. right-of-way at 0845	2 mr/hr

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Maximum readings at 1 inch above ground after passage of cloud:

Across Adams Boulevard at 0915 (7-22)	6 mr/hr
Across Adams Boulevard at 1430 (7-22)	0.5 mr/hr
Across Adams Boulevard at 1030 (7-23)	0.05 mr/hr
Across U.P.R.R. tracks at 0920 (7-22)	6 mr/hr

As entry into the path of the cloud was made with caution following the release, maximum airborne levels observed were not necessarily the highest levels present at any time.

Maximum ground readings were apparent in a width of approximately 500 feet, each side of which gave indications averaging approximately 0.5 mr/hr over strips about 1500 feet in width. Airborne material was apparent in a similar pattern.

A Union Pacific Railroad section crew of three men, travelling on a handcar toward the west at about 0835, stopped and commenced work on the right-of-way about 500 feet west of the estimated trajectory center. Between the time they were observed and that when contact could be made the cloud had passed. Immediate surveys of the area established over-all dosage rate in this locale at less than 0.5 mr/hr from fallout.

When it was established that no widespread hazard existed, monitoring teams concentrated in a co-operative effort with A.N.L. to salvage film records within the Borax area proper. The first attempt to enter the area through the gate failed when a radiation dosage rate of 40 R/hr. in a rapidly increasing field of approach was encountered about 100 feet from the gate. In a second attempt, entry was accomplished through the rear fence by the expedient of cutting the wire. Film from the instrument trailer was removed at about 0930 in a radiation field of 1.0 R/hr. Subsequent entries were made for the purpose of removing cameras containing film records, and in order to establish emergency time limits for the purpose of inspection.

Radiation dosage rates within the Borax area on 7-22-54:

75 feet NE of reactor	at 0930	0.1 R/hr
75 feet SE of reactor	at 0930	0.8 R/hr
60 feet SSE of reactor	at 0930	1.5 R/hr
65 feet S of reactor	at 0930	6.0 R/hr
West end of reactor pit	at 1400	10.0 R/hr
Over reactor tank hold	at 1400	8.0 R/hr

(All readings taken with C.P. Survey Meter - 3 feet above ground)

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Investigation proved that an area 350 by 200 feet south of the reactor fence had been covered with radioactive debris, presumably a result of fuel element "blow out." (Figure 2).

On 8-2-54 the area outside the fence so affected was set up on a ten-foot grid pattern and surveyed at intersections. One set of readings was taken with a C.P. Survey Meter (open window) positioned at 3 feet above the ground. The resultant readings were plotted according to levels of 1.0 to 10.0 mr/hr; 10.0 to 50.0 mr/hr; and greater than 50.0 mr/hr. (Figure 3).

Corresponding readings were taken in a similar manner at 2 inches above the ground. The results were similarly plotted. (Figure 3A).

Within the Borax area proper this type of survey was not attempted due to the high background from large fragments of radioactive material, and numerous particles and debris scattered over the area; therefore, only an approximation of the radiation pattern has been attempted inside the area for illustrative purposes.

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III. RESULTS

A. FALLOUT PLATES

The normal network of fallout plates used in monitoring the NRTS and its surrounding area had been supplemented for the Borax experiments, and even more intensively for the July 22 experiment.

It appears that positioning of these plates did not coincide in any instance with the trajectory center. Fortunately those placed outside the reactor area were beyond the area affected by fragments blown to the south. (Figure 2). Direct survey results indicate that fallout occurred in a direction of about 215 degrees from the reactor. Plates within the reactor area proper were grossly contaminated with material "blown out" of the reactor and were not representative of fallout material.

Radioautograph data obtained from regular and supplemental plates indicates that fallout from the experiment, affecting the NRTS and its environs was not in excess of that which had been observed for some time previously, obviously from an undetermined source outside the NRTS. Visual inspection of radioautographs establishes the belief that airborne radioactive materials present prior to the experiment were similar to those following the experiment. In both cases, the radioautographs indicate material of slight intensity, with a minimum of exception.

Table I shows radioautograph results obtained from fallout plates placed for Borax operation.

Table II shows radioautograph results obtained from fallout plates routinely processed in conjunction with NRTS operations.

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TABLE I

BORAX OPERATION FALLOUT PLATES

Station	From Reactor Direction	From Reactor Distance	Field Exposure From	Field Exposure To	Particles
P-2	360°	11,220 Ft.	6-28	7-2	30
			7-2	7-9	25
			7-9	7-16	20
			7-16	7-20	100
			7-20	7-23	4
P-4	270°	22,540 Ft.	6-28	7-2	25
			7-2	7-9	20
			7-9	7-16	75
			7-16	7-20	100
			7-20	7-23	9
F-2	130°	2,640 Ft.	6-28	7-2	20
			7-2	7-9	30
			7-9	7-16	50
			7-16	7-20	100
			7-20	7-23	3
F-3	169°	1,500 Ft.	6-29	7-2	20
			7-2	7-9	10
			7-9	7-16	41
			7-16	7-20	70
			7-20	7-22	8
F-4	193°	5,300 Ft.	6-29	7-2	25
			7-2	7-9	10
			7-9	7-16	60
			7-16	7-20	100
			7-20	7-22	8
S-1	186°	3,050 Ft.			3
S-2	197°	1,900 Ft.	Exposed on 7-22		2
S-3	200°	2,275 Ft.			2
S-4	206°	1,450 Ft.	From 0800 to 1030		10
D-1	195°	4,550 Ft.			2
D-2	186°	2,900 Ft.			4
D-3	183°	2,700 Ft.			2
D-4	178°	2,500 Ft.			2
D-5	170°	2,225 Ft.			2

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TABLE II

NRTS FALLOUT PLATES

Location	Field Exposure From	Field Exposure To	Particles
E. B. R.	7-2	7-7	50
	7-7	7-14	20
	7-14	7-20	50
	7-20	7-23	17
M. T. R.	7-2	7-7	35
	7-7	7-14	15
	7-14	7-21	50
	7-21	7-23	3
C. F. A.	7-2	7-7	50
	7-7	7-14	Spoiled
	7-14	7-21	70
	7-21	8-2	~ 100
DUBOIS	7-2	7-6	4
	7-6	7-9	10
	7-9	7-16	20
	7-16	7-23	10
	7-23	7-30	25
SPENCER	7-4	7-11	25
	7-11	7-18	15
	7-18	7-25	25
ABERDEEN	7-2	7-9	21
	7-9	7-16	13
	7-16	7-23	35

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B. FILM

Film packets (beta-gamma, and neutron) were placed throughout the Borax area prior to the experiment. However, due to the extreme radiation level encountered, none of this film was interpretable after developing. One badge packet originally placed under a lead brick on top of the reactor was found 120 feet southeast of the reactor following the experiment.

A number of beta-gamma packets placed in conjunction with fallout plates south of the reactor area showed varying degrees of exposure, attributable to the initial release. These results follow:-

Distance from Reactor		Milliroentgens
1450 feet	50 feet	50
1500 feet	50 feet	50
1900 feet	63 feet	30
2250 feet	75 feet	20
5300 feet	175 feet	0

As the corresponding fallout plates exposed with this film showed no evidence of contamination, and the background in the specific locale was established at less than 1 mr/hr shortly after the incident, it appears that this exposure was caused by the initial release from the reactor.

C. BETA-GAMMA COUNTING RATE METERS

Following the experiment all continuous site air monitoring stations were checked, after prevailing meteorological conditions had given the possible trajectory time to pass various locations covered by the NRTS monitoring network.

The check showed only one instance which can be attributed to the experiment: The beta-gamma counting rate meter located at the Central Facilities area recorded an increase amounting to approximately five times background between 11:30 a.m. and 1:00 p.m. on 7-22-54. Decay indicated radioactive materials other than naturally occurring radon-thoron daughter products, normally collected during nocturnal inversion periods.

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Figure 4 is the plot from the counting rate meter at Central Facilities, showing the increase at 11:30 a.m. on 7-22-54. The subsequent slow decay was then enveloped in a collection of naturally radioactive material during the following inversion period, terminating at a peak approximating two and one-half times normal background for this instrument location.

Figure 5 is the plot from the counting rate meter installation at Terreton, Idaho, covering the identical period described in Figure 4. This station did not detect radioactive material other than natural material collected during the inversion period. Return to normal background following this phenomenon is apparent in this illustration.

D. ANALYSIS FOR ALPHA ACTIVITY

More than 50 samples were analyzed for alpha activity. The samples included both filter paper samples of air particulates from the continuous air monitors permanently located around the periphery of the NRTS, and gummed paper fallout plates from special stations established for the Borax experiment. The latter were placed downwind from the reactor at distances of 1000 to 2300 feet. (Table I). In most cases the activity of the air samples was statistically zero under conditions such that the maximum permissible level of plutonium in air would have given 15 d/m per hour of sampling at the rate used of 2 cubic feet per minute. Each sample represents from one to five days of continuous sampling. Samples that were counted within one day after termination of sampling gave activities ranging from 32 to 200 d/m. In every case but one, the activity dropped to a statistical zero after 2 to 3 days, indicating the decay of natural activity, i.e., of radon and thoron daughters. The exception was inadvertently thrown away before the second count was made. Fallout papers were uniformly low in alpha activity.

In summary: No unnatural alpha activity of any significance was detected in any of the samples tested.

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E. ANALYSIS FOR BETA ACTIVITY

A piece of plastic shoe cover that had been worn inside the Borax area a few hours after the release was counted in an end-window G-M counter at intervals. The decay curve is shown in Figure 6. In an attempt to get information on the composition of the cloud without contamination by material blown out of the reactor, a decay curve was also plotted for material taken from a fallout plate. This curve is shown in Figure 7. Although the activity of all fallout plates was low, the observed slope of 0.9 fits the $t^{-1.2}$ law fairly well.

F. GAMMA ENERGY ANALYSIS OF CONTAMINATION

Three samples of contamination from the Borax area were analyzed on a sodium iodide crystal gamma spectrometer to determine the energy of the contamination.

The spectrometer consisted of a 1-1/2" x 2" sodium iodide crystal on a 6292 photomultiplier tube feeding through a linear preamp and amplifier, and a single channel pulse height analyzer. The base line control on the analyzer is driven directly by the recorder and scans the range of pulses which are fed from the analyzer through a counting rate meter to the recorder.

The samples checked were as follows:

1. A piece of shoe cover that had been worn in the contaminated area. (Figure 8).
2. A film badge packet cover that was in the area which presumably had "blownout material" on it. (Figure 9).
3. A small metal fragment, presumably aluminum, that had been blown out of the reactor. (Figure 10).

These curves indicate by their close similarity that the activity on all three is the same.

Submitted for comparison is a curve of fission products (Figure 11) of three years or older; also a curve of fallout debris from the Pacific bomb tests approximately 6 days old. (Figure 12).

Comparison of Figures 8, 9, and 10 (of Borax contamination) with Figure 11 (old fission products) indicates that there is little similarity.

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Comparing the fallout from the Pacific bomb tests with the Borax contamination, a definite similarity is noted. In both of these instances the material involved was approximately 6 days old when the gamma energy curves were made.

G. CLEANUP AND SALVAGE

On July 26, an attempt was made to reduce the radiation background by physically removing all visible pieces of radioactive material which were scattered south of the reactor. A large number of these fragments were collected, single items in many instances reading in excess of 50 R/hr at a distance of 1 inch. However, the background was not appreciably reduced by this method and subsequently an area of approximately 11,000 square feet was isolated by roping off and posting. Within this area, approximately 5000 square feet, comprising the contaminated zone, have been gravel covered to a minimum depth of six inches. Presently dosage rates have been reduced to less than 5 mr/hr over this entire area, as compared to average rates of from 500 to 800 mr/hr previously.

Assistance was given to A.N.L. personnel engaged in salvage of motors, pumps, and other items located in the reactor pit. Radiation dosage rates encountered in this operation were in the magnitude of 5 R/hr. All persons working under IDO-HP were limited to exposures of less than 0.3 R/week. Decontamination facilities were set up and operated by A.N.L. at the Borax area. Upon commencement of construction of Borax No. 2, approximately 500 yards NNE of the site of No. 1, salvaged equipment and material was utilized in the new construction. IDO-HP provided health physics service to contractors engaged in construction of this new facility.

A number of motor vehicles used in survey and salvage operations were contaminated. Two Ford radio-equipped survey cars were washed on the Central Facilities wash rack after hot spots up to 20 mr/hr were reduced to 0.25 mr/hr by physical means. A pickup truck and a 4-wheel drive Marmon Herrington power wagon were steamcleaned within an improvised decontamination area at the health physics area. The motors and chassis of these vehicles were affected to levels of up to 50 mr/hr. Following vigorous steaming these vehicles were returned to normal service.

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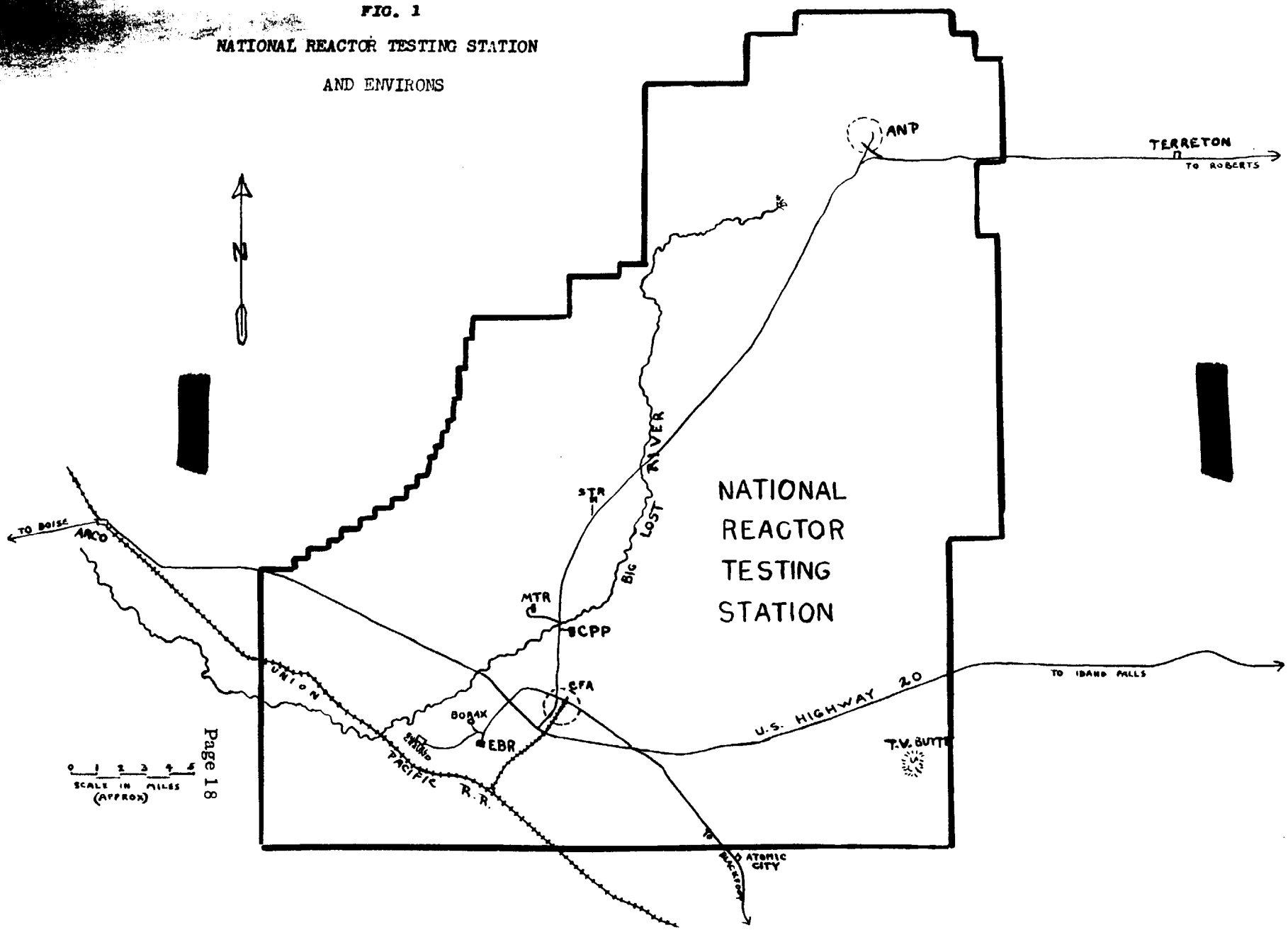
FIG. 1

NATIONAL REACTOR TESTING STATION

AND ENVIRONS



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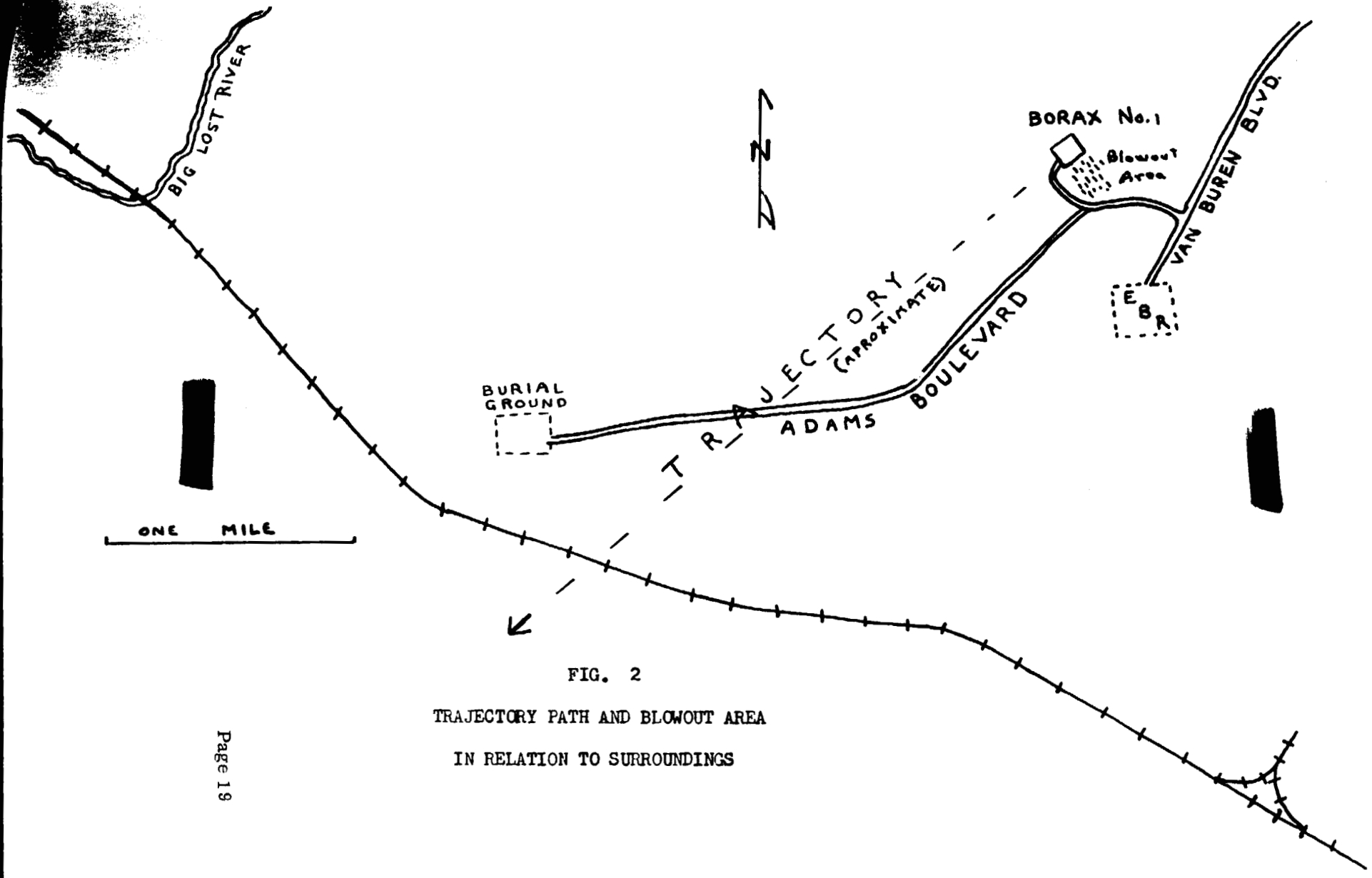

FIG. 2

TRAJECTORY PATH AND BLOWOUT AREA

IN RELATION TO SURROUNDINGS

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--- >50 mr/hr

--- 10 - 50 mr/hr

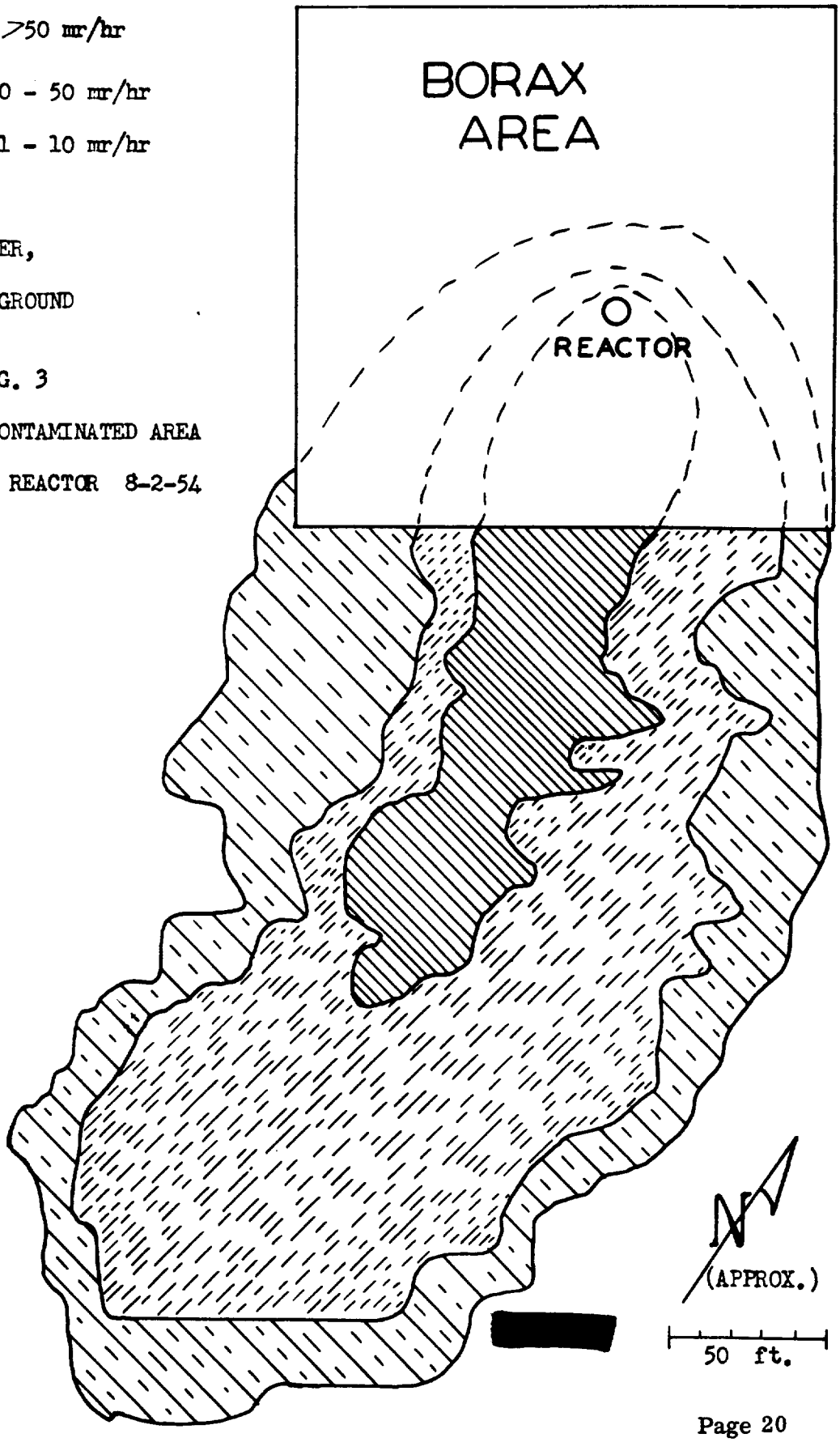
--- 1 - 10 mr/hr

CP SURVEY METER,
OPEN WINDOW
3 feet ABOVE GROUND

FIG. 3

SURVEY OF CONTAMINATED AREA

AROUND BORAX REACTOR 8-2-54



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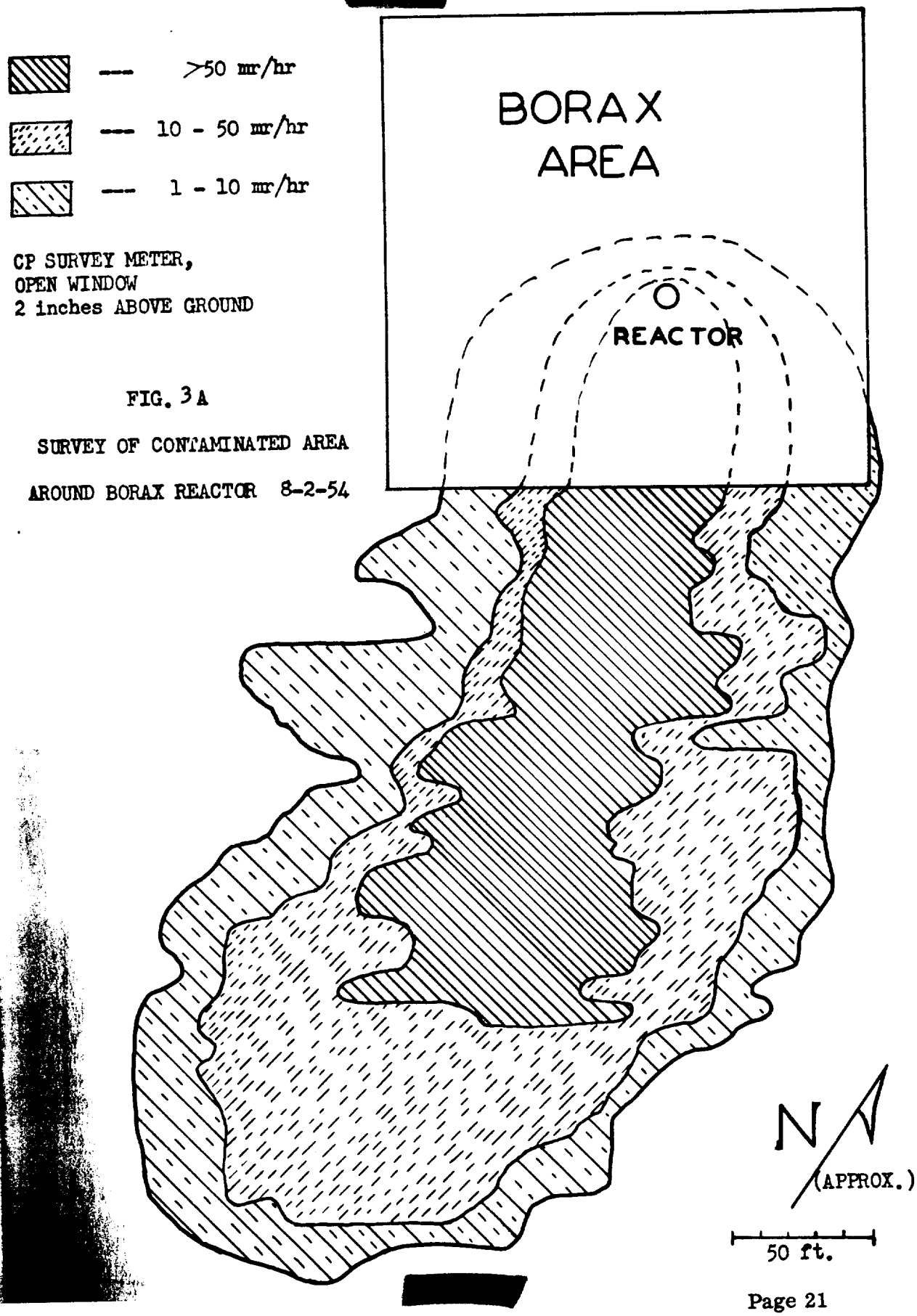

FIG. 3A

SURVEY OF CONTAMINATED AREA

AROUND BORAX REACTOR 8-2-54

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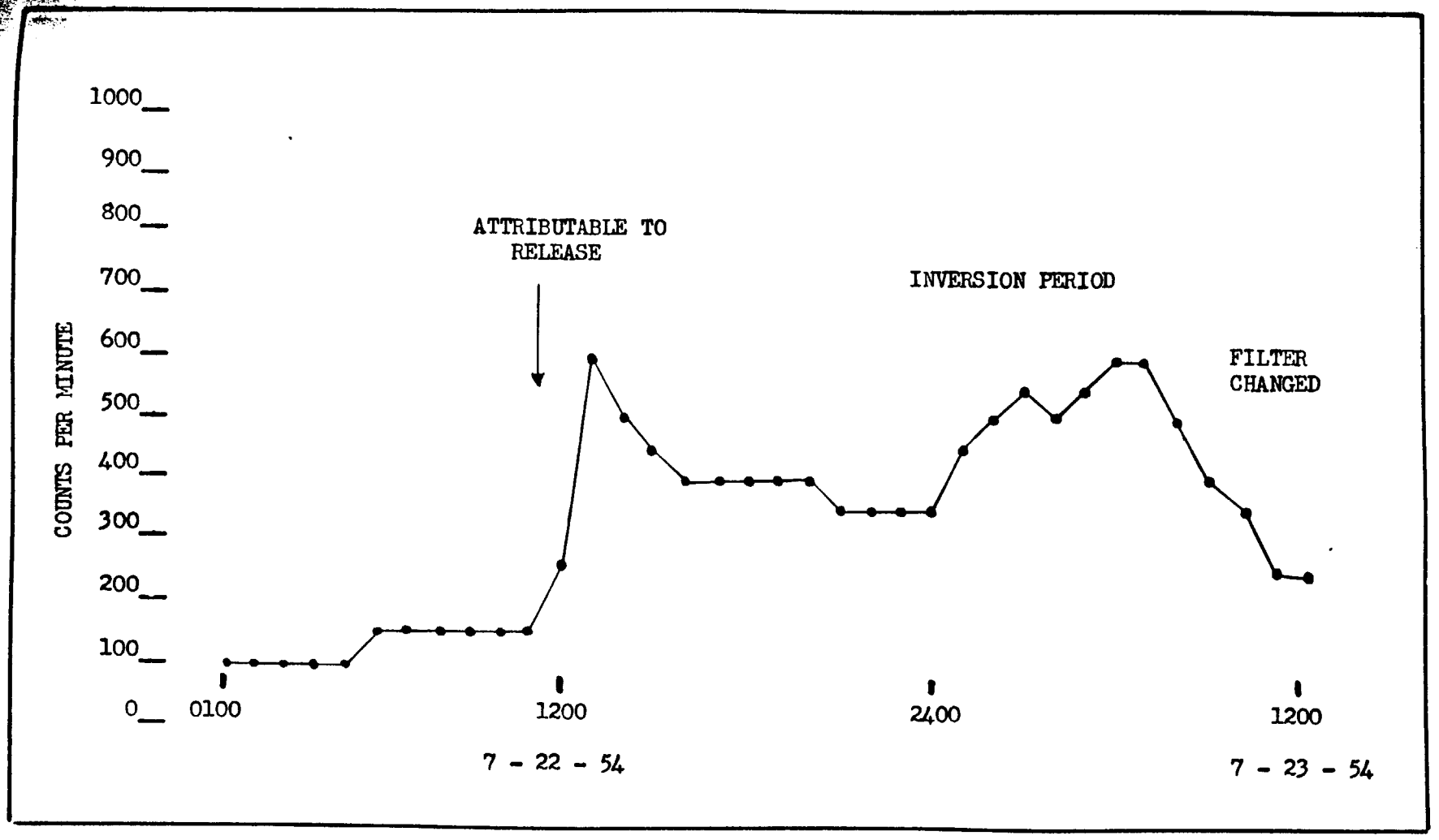

FIG. 4

PLOT FROM COUNTING RATE METER

AT CENTRAL FACILITIES - NRTS - 7-22 and 7-23-54

1190001

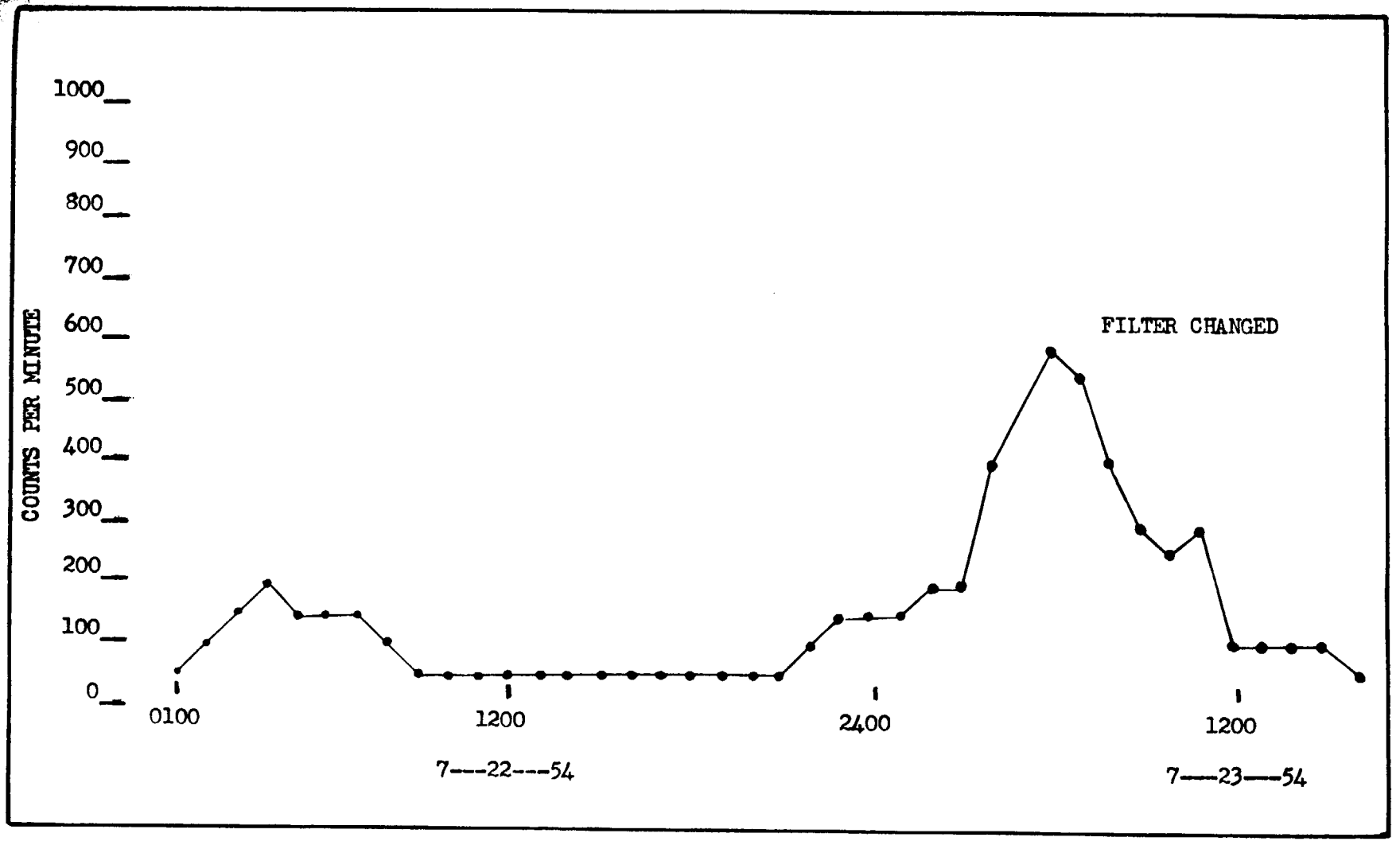

FIG. 5

PLOT FROM COUNTING RATE METER

AT TERRETON, IDAHO - 7-22 and 7-23-54

1190002

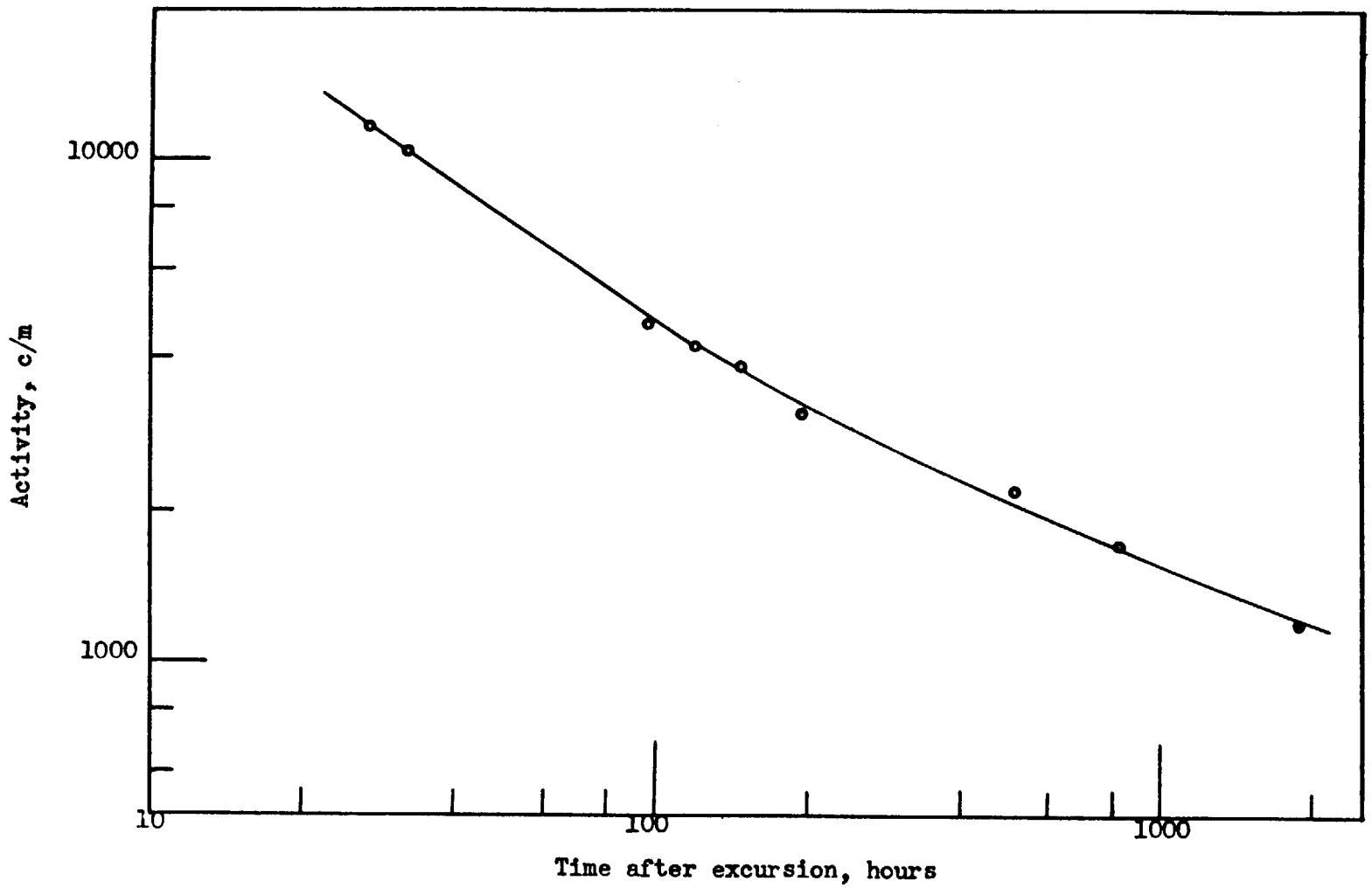

Fig. 6 DECAY CURVE OF MATERIAL FROM SHOE COVER

1190003

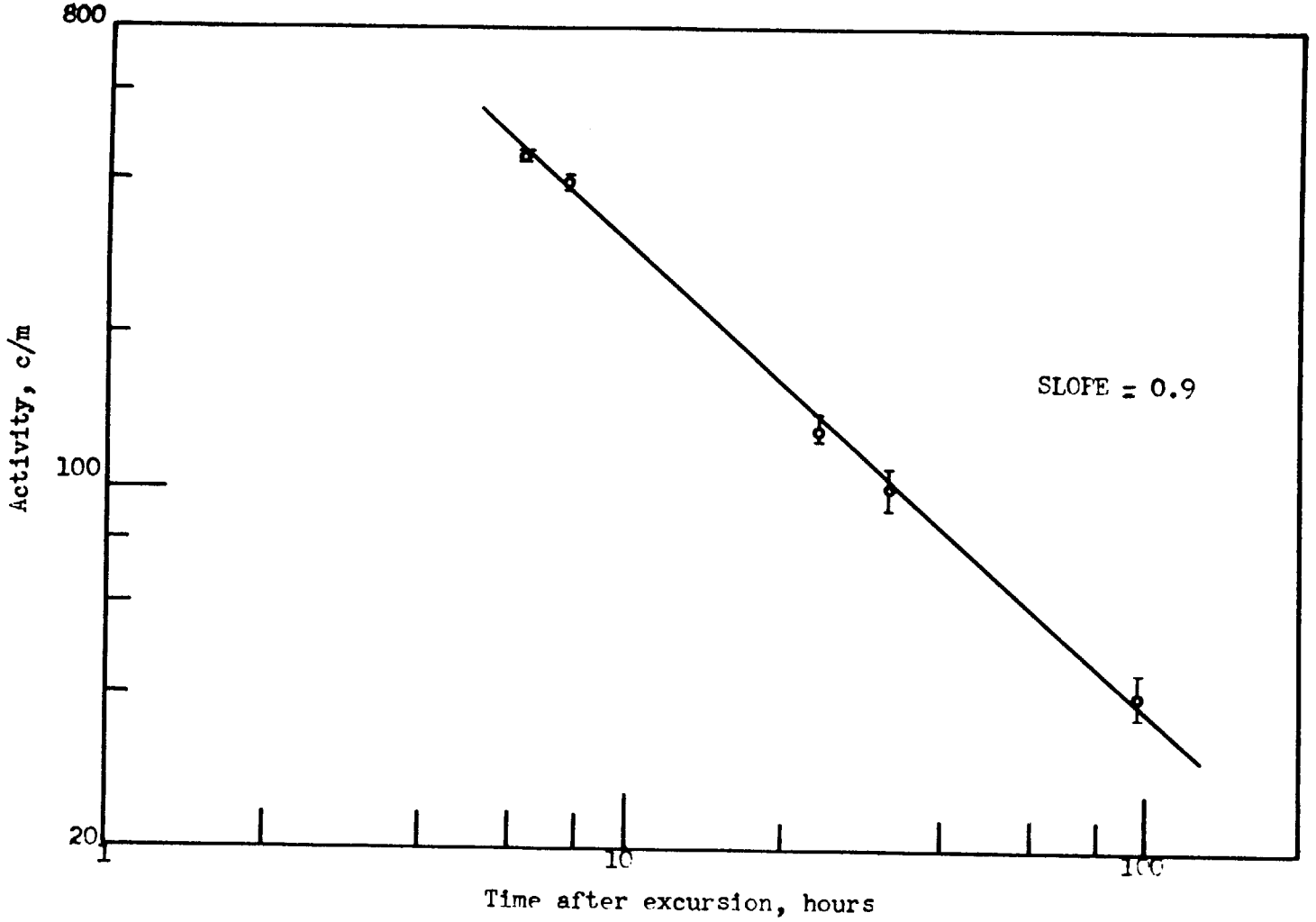

Fig. 7 DECAY CURVE OF FALLOUT

1190004

[redacted]

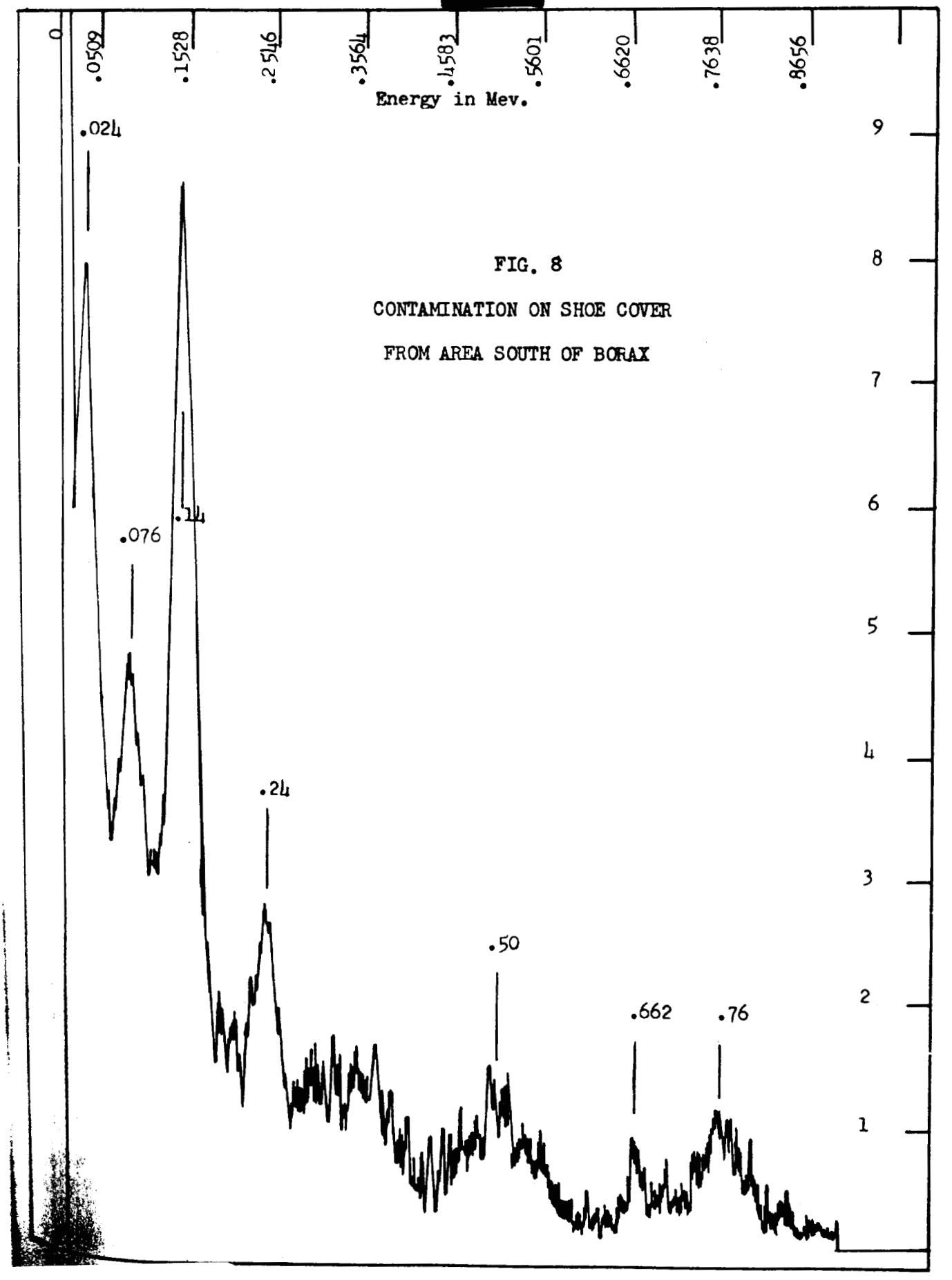

FIG. 8

CONTAMINATION ON SHOE COVER

FROM AREA SOUTH OF BORAX

1190005

[redacted]

[redacted]

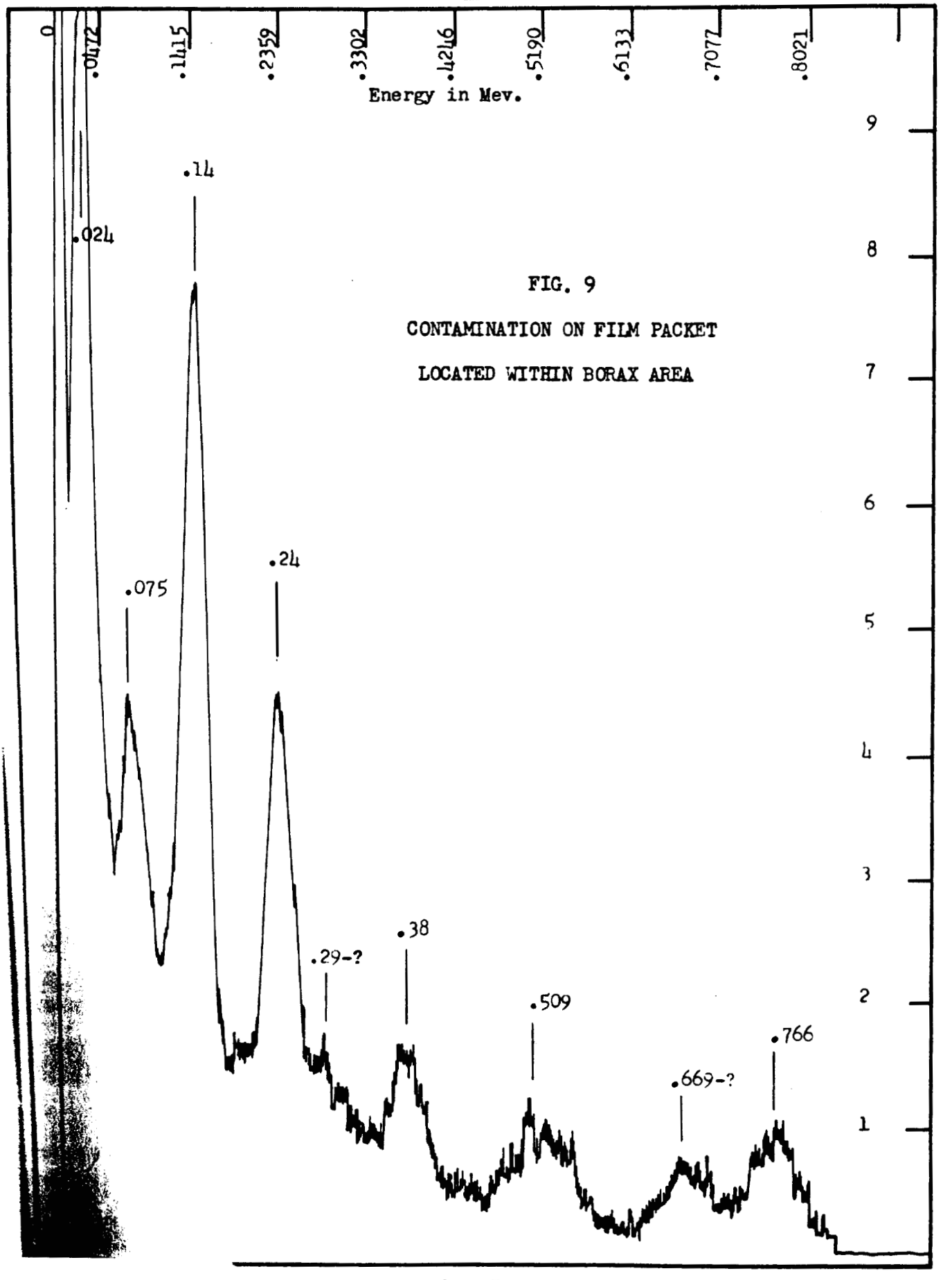

FIG. 9

CONTAMINATION ON FILM PACKET

LOCATED WITHIN BORAX AREA

[redacted]

1190006

[redacted]

[redacted]

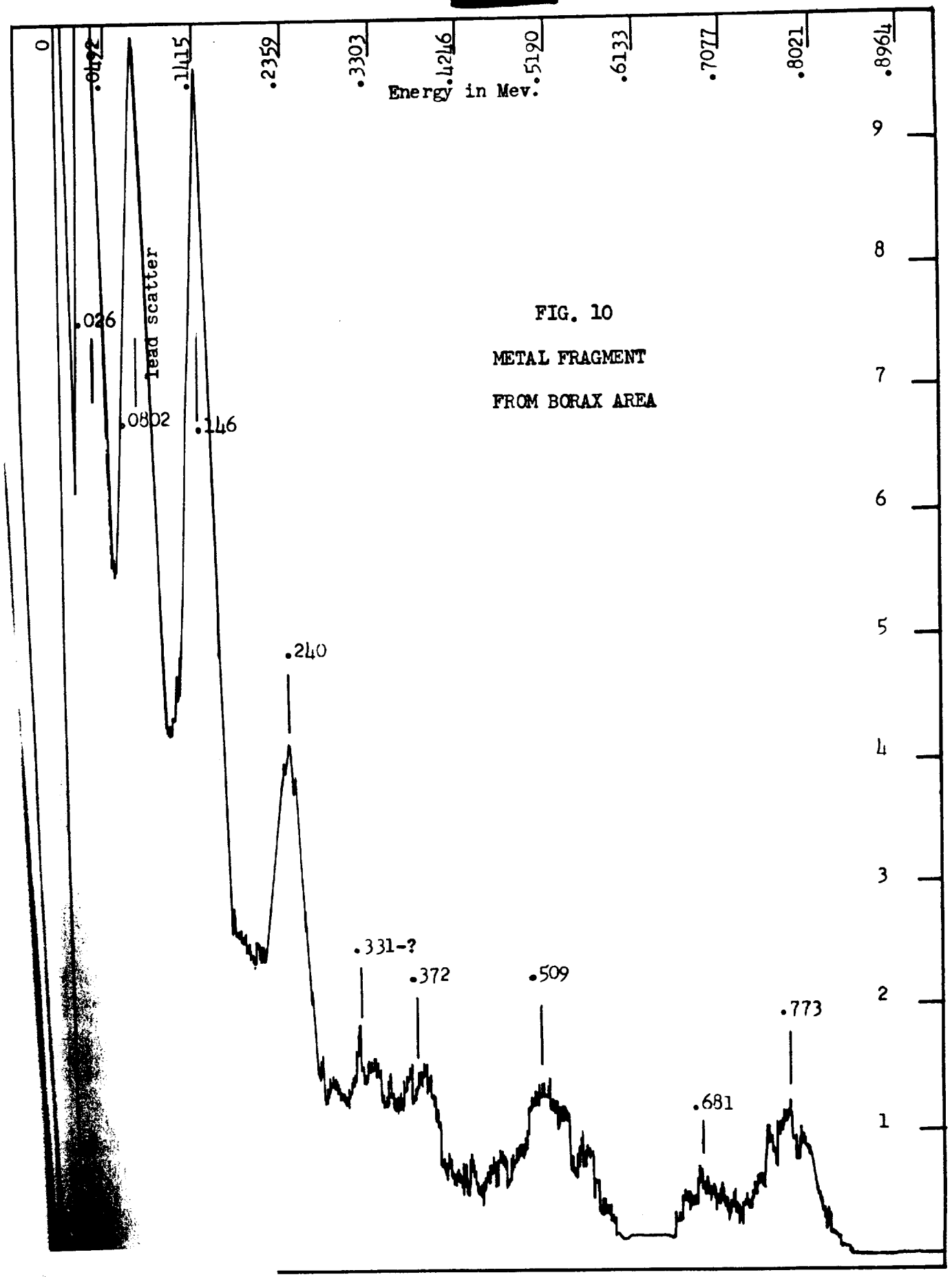

FIG. 10

METAL FRAGMENT

FROM BORAX AREA

[redacted]

1190007

[redacted]

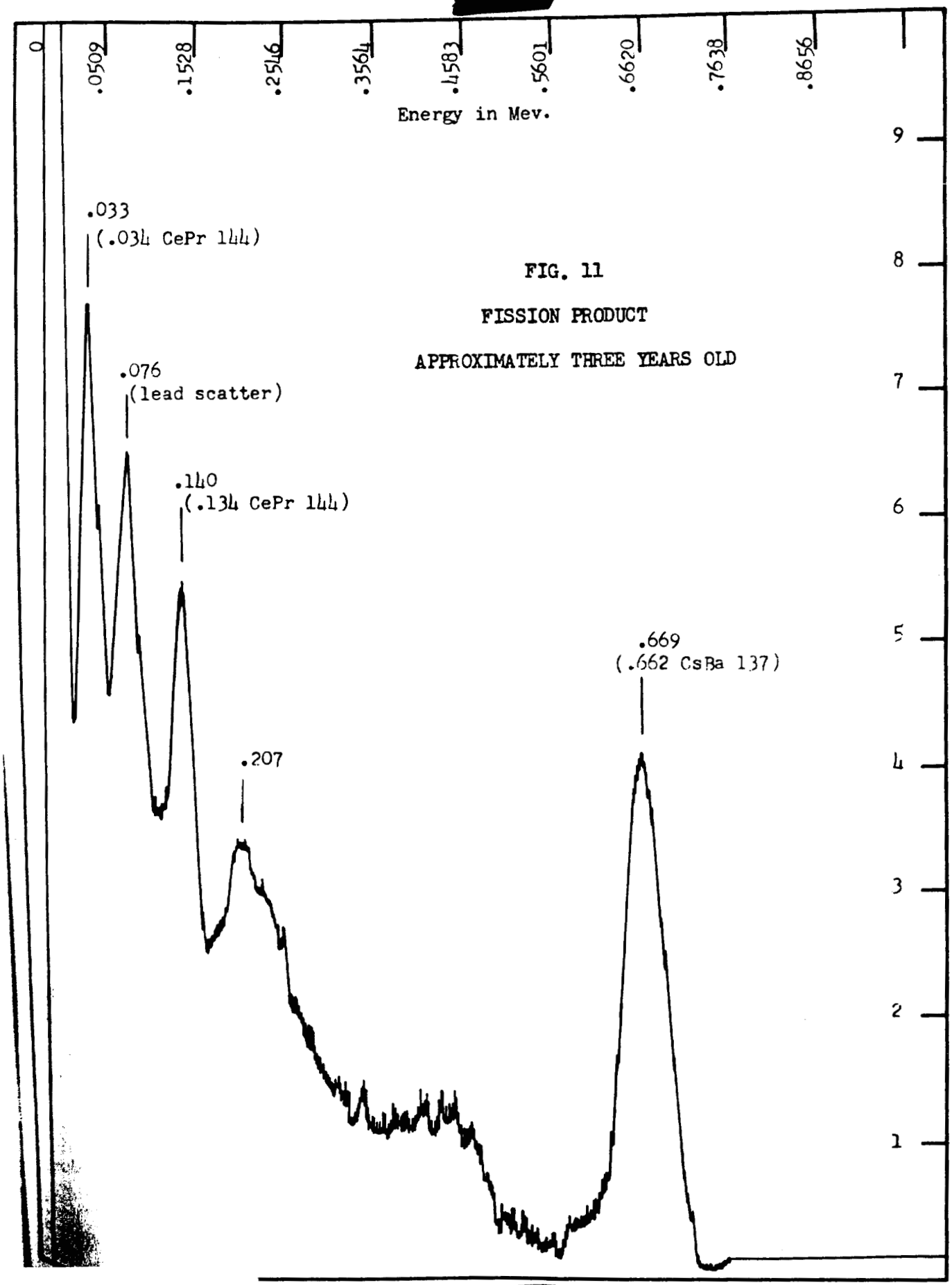

FIG. 11

FISSION PRODUCT

APPROXIMATELY THREE YEARS OLD

[redacted]

1190008

[redacted]

[redacted] DECLASSIFIED

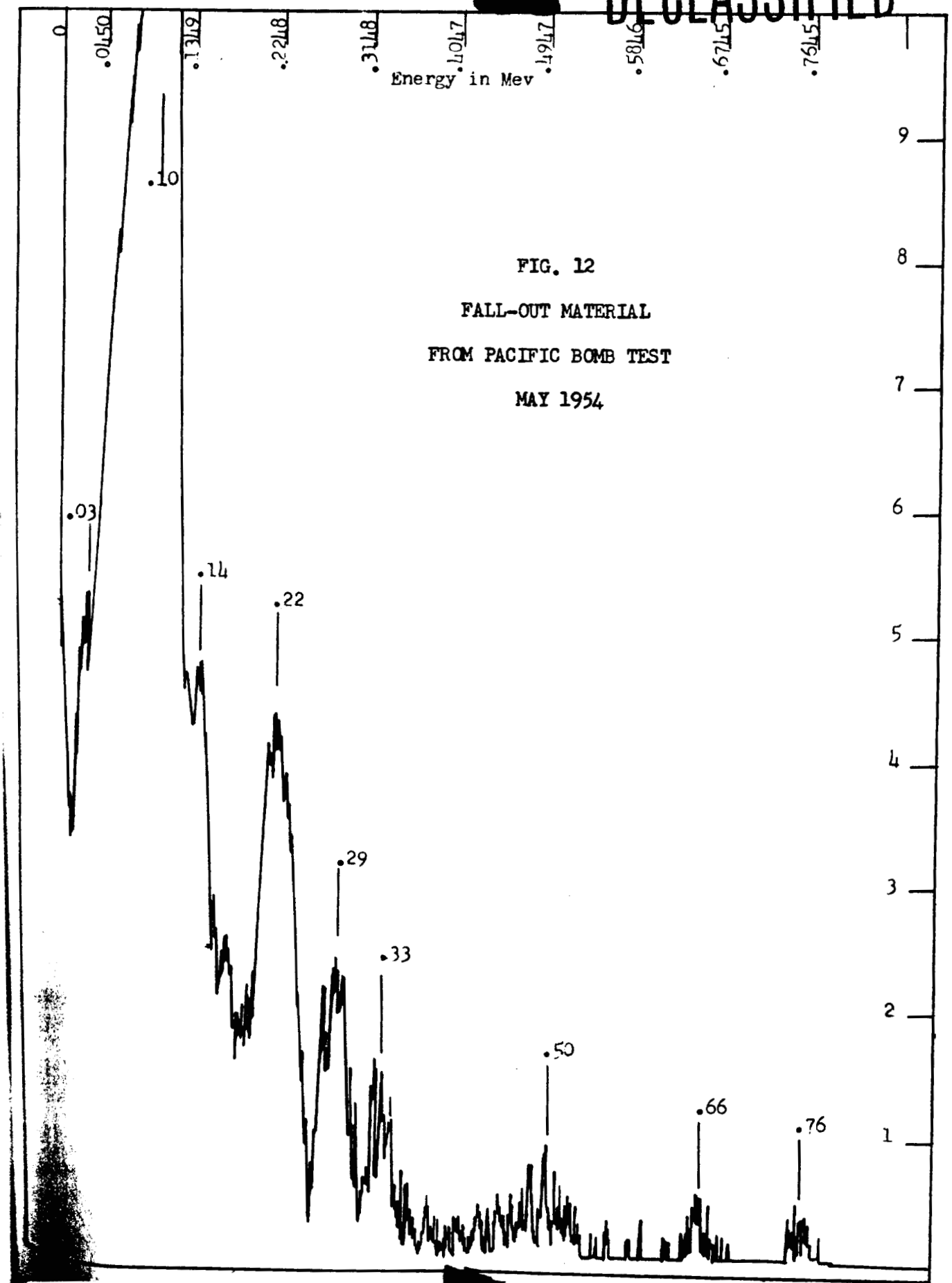

FIG. 12

FALL-OUT MATERIAL

FROM PACIFIC BOMB TEST

MAY 1954

1190009

[redacted]