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DESCRIPTIVE MANUAL OF RADIOISOTOPES PRODUCED BY NEUTRON BOMBARDMENT IN THE CLINTON PILE

By

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Chemistry Division

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DESCRIPTIVE MANUAL OF RADIOISOTOPES PRODUCED BY NEUTRON BOMBARDMENT IN THE CLINTON PILE

R. T. Overman, L. M. Fry, J. W. Jones, E. Lamb,
W. D. Baldwin, J. E. Savolainen

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ABSTRACT

A manual of radioactivities that can be produced in the Clinton Nuclear Reactor has been started. This information includes the following: Target material, Source of material, Weight in standard shipping unit, the spectrographic analysis, the irradiation length and the flux to which it was subjected, a flow sheet of a purification process, the amount of activity found in the material, absorption and decay curves of the radioactivity observed, the yield in mc/gm/30 day bombardment at 50% maximum flux, the cross sections and the σv and a discussion of the non-routine errors in the determination. The foregoing data are given for S, P, Ca, Sc, Ti, Fe, Co, Ni, Se, Ag, In, Cd, Sb, Eu, Ta, W, Os, Th, Bi. It is hoped that this work will be extended and the manual amplified.

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Figure	Target Material	Type of Curve			
		Decay	Al Absorption	Pb Absorption	Other Absorption
1	S	X			
2	S	X			
3	S	X			
4	S				X
5	S		X		
6	KH_2PO_4	X			
7	"		X		
8	$Ca\ CO_3$	X			
9	"		X		
10	Sc_2O_3	X			
11	"		X		
12	"			X	
13	$Ti\ O_2$		X		
14	Fe	X			
15	"	X			
16	"		X		
17	"			X	
18	Co_3O_4	X			
19	"	X			
20	"		X		
21	Ni	X			
22	"		X		
23	Se	X			
24	"		X		
25	$AgNO_3$	X			
26	"		X		
27	$In(NO_3)_3$	X			
28	"		X		
29	"			X	
30	Cd	X			
31	"		X		
32	"		X		
33	"			X	
34	Sb	X			
35	"		X		
36	$Eu_2(C_2O_4)_3$	X			
37	"		X		
38	$Ta\ O_2$		X		
39	"			X	
40	WO_3	X			
41	"		X		
42	Os	X			
43	"		X		
44	"		X		
45	"			X	
46	$Tl(NO_3)_3$		X		
47	Bi	X			
48	"		X		

A. Introduction

The Chemistry and Operating Departments set up a joint program to obtain specific data on radioisotopes produced in the pile. This program was originally set up to cover all of the long-lived isotopes produced in the pile and then to be extended to as many isotopes as possible. With the departure of the personnel involved it has not been possible to cover more than 19 radioisotopes. It is hoped that this work will continue.

B. Purpose

The previous work of Seren[1] and his group at Chicago was a rapid

1. Seren, L., Friedlander, H. N., and Turkel, S. H., CP-2376 (1944)

survey of cross sections. Many of these measurements were made in the thermal column of the Chicago pile but some were made in the pile itself. Their procedure was to activate the target material and sprinkle some of the powder on scotch tape and count it in a beta counter. They obtained the flux by one of several types of monitors. The accuracy of the cross sections which they measured was limited to 10-20% in most cases according to their report, but in their discussion of the errors in their determinations they listed the following limits for the various components in their measurements:

Conversion coefficients	up to 15%
Extrapolation to zero absorber	15%
Counting of gamma rays	3%
Geometry of beta counters	4%
Geiger counter plateaus	2%
Ra-Be standard pile calibrations	15%

Monitors	15%
Weighing samples	10%
Half life	5%

These factors, coupled with the unsatisfactory knowledge of the flux of the Clinton pile and particularly with the variation of flux from one position to another made it seem desirable to look into the matter here at Oak Ridge National Laboratory in some detail. This was particularly important in that the Isotope Distribution program was in vital need of more precise data on the materials that were being shipped out by the Atomic Energy Commission. It was felt that, with the revised techniques that have been worked out in cooperation with other members of the group of Radiochemical Measurements and Standardization, many of the errors could be materially reduced.

It was hoped, as a result of this study, that:

(1) The yield values in the isotope catalog[2] could be revised

---

(2) AEC Catalog and Price List No. 2 Radioisotopes, Revised September 1947.

---

with more accurate information;

(2) Gross impurities of the target materials could be identified and measured;

(3) Decay and absorption graphs of pure activities could be prepared for reference purposes;

(4) A practical method for measuring the total neutron exposure of samples could be developed;

(5) The radiation hazard in handling isotopes being removed from the pile could be measured. This objective was to be carried out by the Operating Department;

(6) Chemical separation processes could be developed by which the isotope purchasers could purify the material.

C. Procedures

The general procedure in the preparation of the sample was as follows: The target material was obtained from H. E. Bedell of the Operating Division. Duplicate samples of each target material were weighed into two aluminum stringer cans and a monitor clip attached to each by the Chemistry Division. The samples were returned to the Operating Division for irradiation in the pile.

After a period of time, approximately the irradiation time listed in the catalog, the samples were removed. One of the duplicates was brought to the Chemistry Division for chemical separations and measurements; the other was kept by the Operating Department for measuring gross decay and for determining radiation hazards. The radiations from the monitor clips were measured in order to study the total neutron exposure. This last-named work will be described briefly here; a more detailed and separate report is planned later.

If a known weight of a monitor material whose activation and decay characteristics are known is exposed in the pile with the sample, subsequent measurement of the monitor permits calculation of the total neutron exposure.

For this work aluminum alloy clips have been prepared containing 0.53% cobalt and 0.21% manganese. A clip can be attached to a stringer can or placed in the rabbit during irradiation. The activity induced in the clip is measured in an ion chamber[3] calibrated for detecting gamma radiation, and the average

(3) Jones, J. W. and Overman, R. T., Mon C-399 (1945)

flux or neutron density for the exposure is calculated from the cross-section, time of exposure, and decay before measurement. Manganese (half-life of 2.59 hours) is used to monitor short exposures, that is, up to 18 hours. Cobalt

(half-life of 5.3 years) is used to monitor longer exposures from 18 hours to six months.

The alloying was performed by C. Smith of the Metallurgical Section of the Technical Division, and the clips were prepared by M. B. Hawkins of the Research Shops. The clips can be easily removed from the cans after irradiation, without damage to the can, and measured separately.

In the first alloy prepared, some sodium was inadvertently introduced in the alloy from the flux. In order to measure the pure cobalt radiation, at least five days must be allowed for the sodium to die out. It is hoped in the future to prepare the alloy free of sodium.

The total sample brought to the Chemistry Division was dissolved and decay measurements on a small portion of this gross sample were begun as soon as possible after removal from the pile in order to find short-lived activities. In some cases the large amount of long-lived target material activity produced by long bombardment obscured the small amounts of activities due to impurities. A short bombardment was then made to measure the short-lived activities which predominated over the long-lived ones.

Gross chemical separations and purifications were performed when necessary. Decay and absorption data were taken on all fractions.

Disintegration rates and activities were determined by measuring aliquots of the fractions on calibrated Geiger-Muller mica window counters, and, where the radioisotope was a gamma emitter with a known disintegration scheme, by measuring aliquots on the previously-mentioned calibrated ion chamber[4].

---

(4) Ibid, Mon C-399

D. Measurement of Activity

A sample for accurate beta counting was mounted on a polystyrene film 2.5 mg/cm^2 in thickness and fixed over a 15/16" hole in an aluminum card by means of rubber cement. The procedure that was used followed closely the methods outlined by Zumwalt[5]. An aliquot of radioactive solution was placed in the center

(5) Zumwalt, L. R., Mon C-397 (1948)

of the hole on the film and evaporated to dryness under a drying lamp. A sample for ordinary beta counting was sometimes mounted as above, sometimes evaporated to dryness in a small porcelain dish 4.2 cm in diameter and about 400 mg/cm^2 in thickness.

The β absorption curves were taken by placing a sample in the center (with respect to both vertical and horizontal positions) of a shelf of our standard counting apparatus, and placing aluminum absorbers on top of the first shelf.

The γ absorption curves were taken with the sample in the center of the third or fourth shelf, and the lead absorbers on top of the second shelf.

When the ion chamber was used to determine activities, a solution of a gamma-emitting radioisotope in a sealed glass ampoule was put into the glass thimble, inserted in and attached rigidly to the chamber to retain the filling gas (argon at twenty atmospheres). Within the chamber and surrounding the thimble was the negative collecting electrode. The chamber was the other electrode. The entire assembly was shielded with eight inches of lead to obtain low backgrounds.

The ion chamber is calibrated in terms of Co^{60} which decays with two γ's (average energy = 1.2 Mev) per disintegration. When the decay scheme of any other γ-emitter is known, its activity may be measured and then calculated

from its counting efficiency with respect to Co. For example, if a radioisotope emits two γ's (average energy - 0.9 Mev) per disintegration, its efficiency in the ion chamber is 75% of that of Co. The flux measurements were made using the pressure ion chamber method outlined above. The chamber and the monitors were calibrated and the flux was determined by the methods given by Clark, Jones and Overman[6].

---

(6) Clark, H. M., Jones, J. W., and Overman, R. T., Mon C-398 (1948)

Actually, in the case of Seren's measurements as well as ours, the quantity determined that was significant was the product σv. Since the flux was determined by a gold monitor essentially and the cross section of gold is 96 barns at 2000 meters/sec, the $\underline{\sigma v}$ for gold is 2.21×10^7 bcs (barn centimeters/sec). Since the activations were made at some unknown velocity of neutrons, the product determined, for example, for Ca^{44} is 2.9×10^3 bcs. Since this is the constant for the isotope one must only multiply this by $\underline{n}$ or the neutron density for the pile at the given point to obtain the yield per nucleus of the $\underline{nv\sigma}$ for a given irradiation. The value determined by Clark et. al., for $\underline{n}$ was 4.5×10^6 n/cm^3 at the center of the Clinton Pile at operating power level.

Since most of the measurements of these quantities made by physicists are reported in terms of thermal velocities, it is helpful for comparison to made an assumption about the way in which the cross section behaves as a function of energy. If one assumes that the cross section follows a 1/v law then one may divide the $\underline{\sigma v}$ by the thermal velocity and obtain the cross section corresponding to this energy of neutron. This has been given for all of the activities but it is recommended that the product of the cross section times velocity be considered the important nuclear constant for these pile reactions. It is particularly important to note that where resonance levels occur in the thermal region

one may not make this calculation to arrive at a cross section for thermal neutrons.

The use of the σv also has another advantage for those reactions which are brought about by fast neutrons. There has always been considerable question as to how to report yield values for fast neutron reactions. This is occasioned by the fact that cross sections should correctly be reported for the energy of the neutron. We do not know the energy distribution of fast neutrons, in general, in the pile since this will be a function of the amount of moderator between the slug and the sample. This would change the fast spectrum quite markedly in a short distance. It does not seem quite proper to report the fast neutron yields on the basis of the slow neutron flux by the use of an "effective" cross section in which one uses the slow flux and weight of target isotope. The σv, however, is a function of this reaction, too, so the results may be expressed in the bcs. units. This implies that, if one knew the n or density of neutrons above a given threshold for the reaction, one could determine the cross section. This cannot usually be determined.

On the basis of the flux report mentioned above, it seems probable that the flux may be known to an accuracy of about 10%.

E. Errors

The statistical counting error in beta counting was less than 2%. The error in determining counter geometries was about 3%. The error in assay was about 1% except when otherwise stated in the detailed discussion of each individual target material. As mentioned above it is probable that the errors in the flux measurement are of the order of 10%. This gives an overall accuracy which might be expected for the yields of the order of 11%. The error in value for the cross sections would be higher in the case of those elements having resonance peaks. No cadmium differences were taken except those mentioned in the report Mon C-398.

F. Summary

The following table shows the experimental data obtained. It might be noted that these materials were procured by the Operating Department in quantities that were estimated to last a year. It is possible to get samples from there of any of the target materials discussed below.

It should be understood that it was not a purpose of this study to confirm or replace existing literature values for half-lives or radiation energies. The values shown on the graphs on the following pages are experimental and merely confirm the identities of the radioisotopes. The usefulness of the graphs is in showing the kind of data obtained in measuring activities of radioisotopes produced at Oak Ridge National Laboratories.

After the tabular summary, the target materials are discussed in detail. The following information is listed for each material: Target material, source, weight of sample, spectrographic impurities, time of irradiation, the average flux for the time of irradiation, the separations procedure that was used to purify the activity and the percentage recovery in the various steps, the radioactivities found reported both in the percentage of total activity and calculated to parts per million of stable impurity in the target material, the yield in mc/g/30 day bombardment at 50% maximum flux, the σv in barns cm/sec., the cross section per atom of normal element and per atom of isotope assuming a 1/v law, and a statement of non-routine errors.

Acknowledgement

We would like to acknowledge the assistance given us by many members of the Operating Department, particularly C. D. Cagle, H. E. Bedell. We would also like to thank Edna Hennessee and Georgia Gibson for doing most of the tremendous job of counting the samples.

Table I

Summary of Experimental Radioisotope Data

Target Material	Nuclide	Half-Life		Radiation		Yield mc/gm element /mo at 50% maximum flux	$\bar{\sigma}V$ in bcs	Isotopic Cross-Sections (in barns)		Effective Cross-Sections per atom normal Element	Remarks
		Expt'l	Literature	Expt'l	Literature			Effective	Literature		
S	S^{35}	87d	87.1d	0.17β No γ	0.17β No γ	0.279	1.15×10^3	0.124	0.26±20%	0.0052	
	P^{32}	14.3d	14.7d	1.7β No γ	1.7β No γ	0.304	3.68×10^2	0.0017 (thermal neutrons)	0.23 (fast neutrons)	0.0016	n,p react
KH_2PO_4	P^{32}	14.5d	14.7d	1.7β No γ	1.7β No γ	49.6	5.52×10^4	0.251	0.23±20%	0.251	
	K^{42}	12.8h	12.4h	--	3.58β (75%) 2.07β (25%) 1.51γ (25%)	38.6	4.09×10^4	2.81	1.0±20%	0.186	
$CaCO_3$	Ca^{45}	154d	180d	0.21β No γ	0.21β No γ	0.291	2.90×10^3	0.62	0.63±20%	0.013	
Sc_2O_3	Sc^{46}	84d	85d	0.37β 1.0γ	0.36β K ? 1.12γ 0.9γ	838	3.17×10^6	14.4	22±20%	14.4	
TiO_2	Ti^{51}	--	72d	0.5β 0.9γ	0.36β 1.0γ	0.022	1.133×10^2	0.01	0.039±20%	5.15×10^{-4}	

Target Material	Nuclide	Half-Life		Radiation		Yield mc/gm element/sec at 50% maximum flux	σV in bcs	Isotopic Cross Sections (in barns)		Effective Cross-Sections per atom normal Element	Remarks
		Expt'l	Literature	Expt'l	Literature			Effective	Literature		
Fe	Fe^{59}	47.5d	46.3d	0.4β 1.2γ	0.26β 0.46β 1.10γ 1.30γ	0.144	6.03×10^{2}	0.83	0.79	2.7×10^{-3}	
	Fe^{55}		~4yr	X-ray	k,e⁻ 0.007γ				0.7		
Co_3O_4	Co^{60}	~5.3yr	5.3yr	0.3β Hard γ	0.3β 1.10γ 1.30γ	42.5	6.51×10^{6}	29.6	21.7±20%	29.6	
Ni	Ni^{65}	3hr	2.6h	1.9β	1.9β 0.28γ 0.65γ 0.93γ	2.11	3.37×10^{3}	1.32	1.4±20%	0.0153	
	Ni^{59}	--	12yr	--	0.05β				0.5±50%		Did not look for this isotope
Se	Se^{75}	~124d	115d	0.16 e⁻ X-ray γ present	K,e⁻ 0.335γ 0.18γ	9.92	1.29×10^{5}	67.4	22±40%	0.586	X-ray and γ-rays present make Se^{75} a suitable tracer, but absolute measurement is extremely difficult
$AgNO_3$	Ag^{110}	231d	225d	0.4β 0.7β γ Present	1.3 ?β 0.6 β 1.40γ 0.90γ 0.66γ	2.38	7.96×10^{4}	0.74	2.3±20%	0.36	

Target Material	Nuclide	Half-Life		Radiation		Yield mc/gm element /mc at 50% maximum flux	σV in bcs	Isotopic Cross-Sections (in barns)		Effective Cross-Sections per atom normal Element	Remarks
		Expt'l	Literature	Expt'l	Literature			Effective	Literature		
$In(NO_3)_3$	In^{114}	50d	48d	e^- 0.7γ	I.T. e^- 0.19γ	20.4	1.80×10^5	19.4	56±10%	0.82	0.19γ is apparently 100% converted
			72s	2.2β	1.98β				2		
Cd	Cd^{115}	2.4d	2.33d	0.5β 1.3β 0.65γ	0.55β 1.25β 0.65γ	12.8	3.92×10^4	0.63	1.1±20%	0.18	
		54d	43d	1.8β	1.85β ~0.5γ	0.456	3.96×10^3	0.064	0.14±20%	0.018	
Sb	Sb^{124}	60d	60d	2.6β 0.6β γ Present	2.4β(50%) 0.7β(50%) 1.7γ(50%) 0.6γ	54.9	4.0×10^5	4.26	2.5±20%	1.82	
$Eu_2(C_2O_4)_3$	Eu^{154}	~6.3yr	5-8yr.	0.17β 0.6β 2.0β γ Present	0.34β 0.82β K 1.1γ	268	1.13×10^8	1010	768±20%	514	
TaO_2	Ta^{182}	--	117d	0.55β e^- 1.0γ	0.53β 1.22γ(57%) 1.13γ(37%) 0.22γ(4%) 0.15γ(2%)	319 ?, L. $\sigma_a = 121$	3.54×10^6	16.1	21±20%	16.1	

Target Material	Nuclide	Half-Life		Radiation		Yield mc/gm element /mo at 50% maximum flux	σV in bcs	Isotopic Cross-Sections (in barns)		Effective Cross-Sections per atom normal Element	Remarks
		Expt'l	Literature	Expt'l	Literature			Effective	Literature		
WO_3	W^{185}	76d	74d	0.45β No γ	0.6β No γ	7.55	1.54×10^5	2.28	2.1±20%	0.7	
	W^{187}	--	24.1h	--	1.35β 0.6 β 6γ between 0.18 & 0.77 Mev	Didn't look for		--	34 ±20%		
Os	Os^{185}	~60d	95d and ~30h	0.8β 0.7γ(?)	I.T., 1.5β γ	0.230	6x103	152	---	0.0273	
	Os^{191}	—	32h	1.0β	0.95β 1.17γ	7.34×10^{-3}	31.6	5.45×10^{-4}	2.50±20%	1.44×10^{-4}	See remarks under Osmium
	Os^{193}	17.4d	17d	0.16β 0.7γ(?)	0.35β γ	7.11	4.14×10^4	0.58	5.34±20%	0.188	
$Tl(NO_3)_3$	Tl^{204}	---	3.5yr	0.88β No γ	0.87β No γ	1.96	6.71×10^5	10.3	7.5	3.05	
Bi	Bi^{210}	5d	5d	1.2β	1.17β No γ	0.70	3,960	0.018	0.015±20%	0.018	
	Po^{210}	--	140d	α	4.8α						

Sulfur

Target Material: Sulfur, U.S.P., Merck

Weight: 23.72 gm

Spectrographic Impurities:

Ag	FT	Fe	T
Ca	FT	Mg	FT
Cu	FT	Si	T

Irradiation: 31 days at nv = 4.64 x 10" n/cm^2/sec

Separations: See diagram

Activities Found At T_o in Bombardment	% Total Activity	Activity per gm. Sulfur	ppm Impurities
S^{35} (87d)	47.8	0.266 mc.	
P^{32} (14.7d)	51.3	0.286 ← value low	
Si^{31} (170 m)	0.5	0.003	87
Unidentified (17m)	0.4	0.002	

Yields:

0.279 mc S/gm S/30 day bombardment at 50% maximum flux ← value low
0.304 mc P/gm S/ " " " " " " "

Cross sections for sulfur:

$\sigma v = 1.15 \times 10^3$ barns cm/sec
$\sigma = 0.0052$ per atom normal element
$\sigma = 0.124$ per atom isotope

Cross sections for phosphorus:

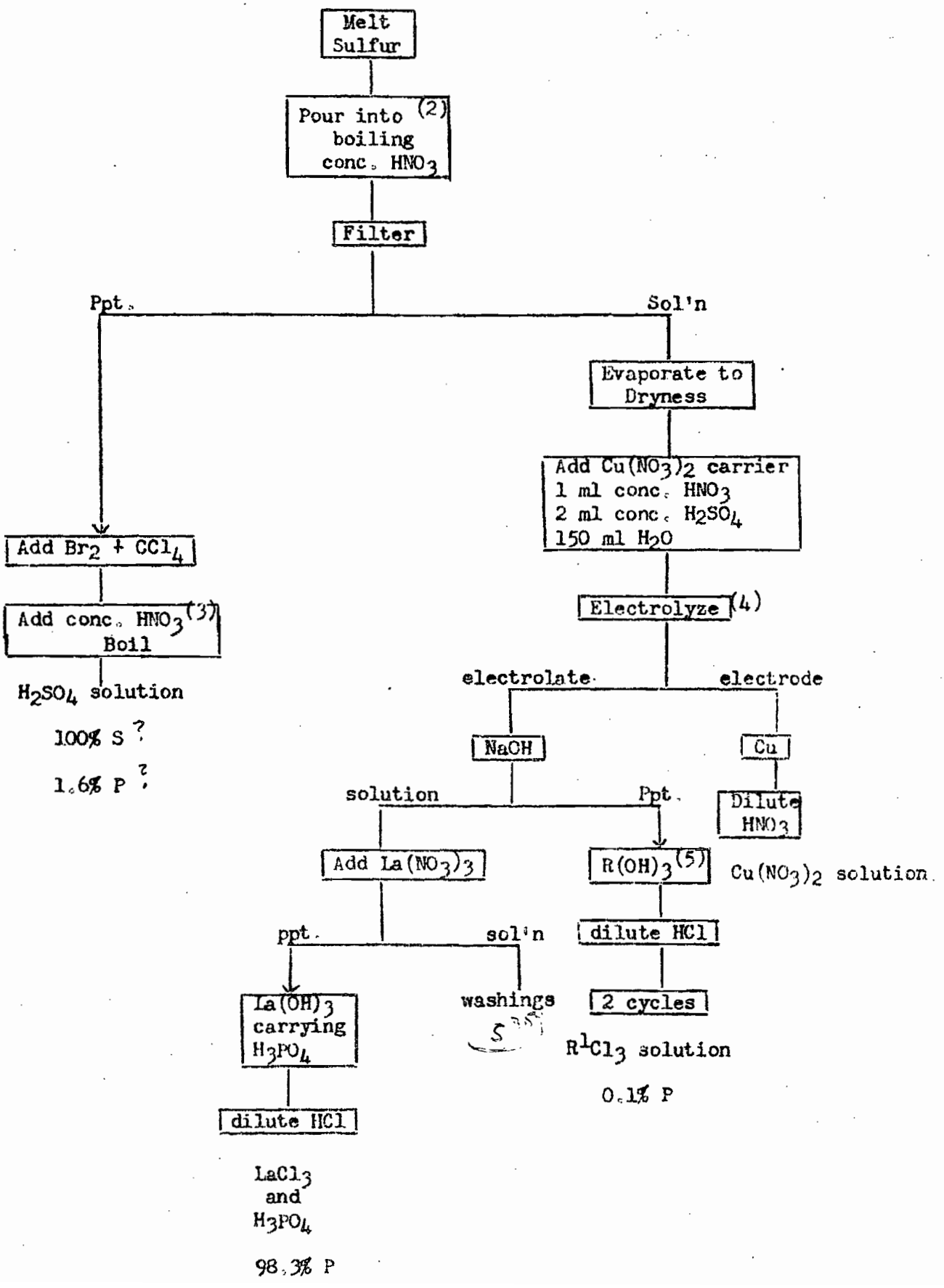
$\sigma v = 3.7 \times 10^2$ barns cm/sec
*($\sigma = 0.0016$ barns per atom normal element)
*($\sigma = 0.0017$ " " " " isotope)

* Of questionable value since it is based on slow nv.

Non-routine Errors: None

Remarks: In measuring absorption of S^{32} beta radiation, absorbers of low Z material were used. Some of the absorbers were made of Formvar plastic material which is a polyvinyl acetal resin. The others were made of aluminum. Formvar and aluminum seem to have approximately the same absorption coefficient.

Sulfur (1)


Melt Sulfur
Pour into (2) boiling conc. HNO_3
Filter
Ppt.
Sol'n
Add Br_2 + CCl_4
Add conc. HNO_3 (3) Boil
H_2SO_4 solution
100% S ?
1.6% P ?
Evaporate to Dryness
Add $Cu(NO_3)_2$ carrier
1 ml conc. HNO_3
2 ml conc. H_2SO_4
150 ml H_2O
Electrolyze (4)
electrolate
electrode
NaOH
Cu
solution
Ppt.
Dilute HNO_3
Add $La(NO_3)_3$
$R(OH)_3$ (5)
$Cu(NO_3)_2$ solution
ppt.
sol'n
dilute HCl
$La(OH)_3$ carrying H_3PO_4
washings
2 cycles
R^1Cl_3 solution
0.1% P
dilute HCl
$LaCl_3$ and H_3PO_4
98.3% P

(1) MDDC-518, W. E. Cohn, Separation of Carrier-Free P^{32} from Sulfur.

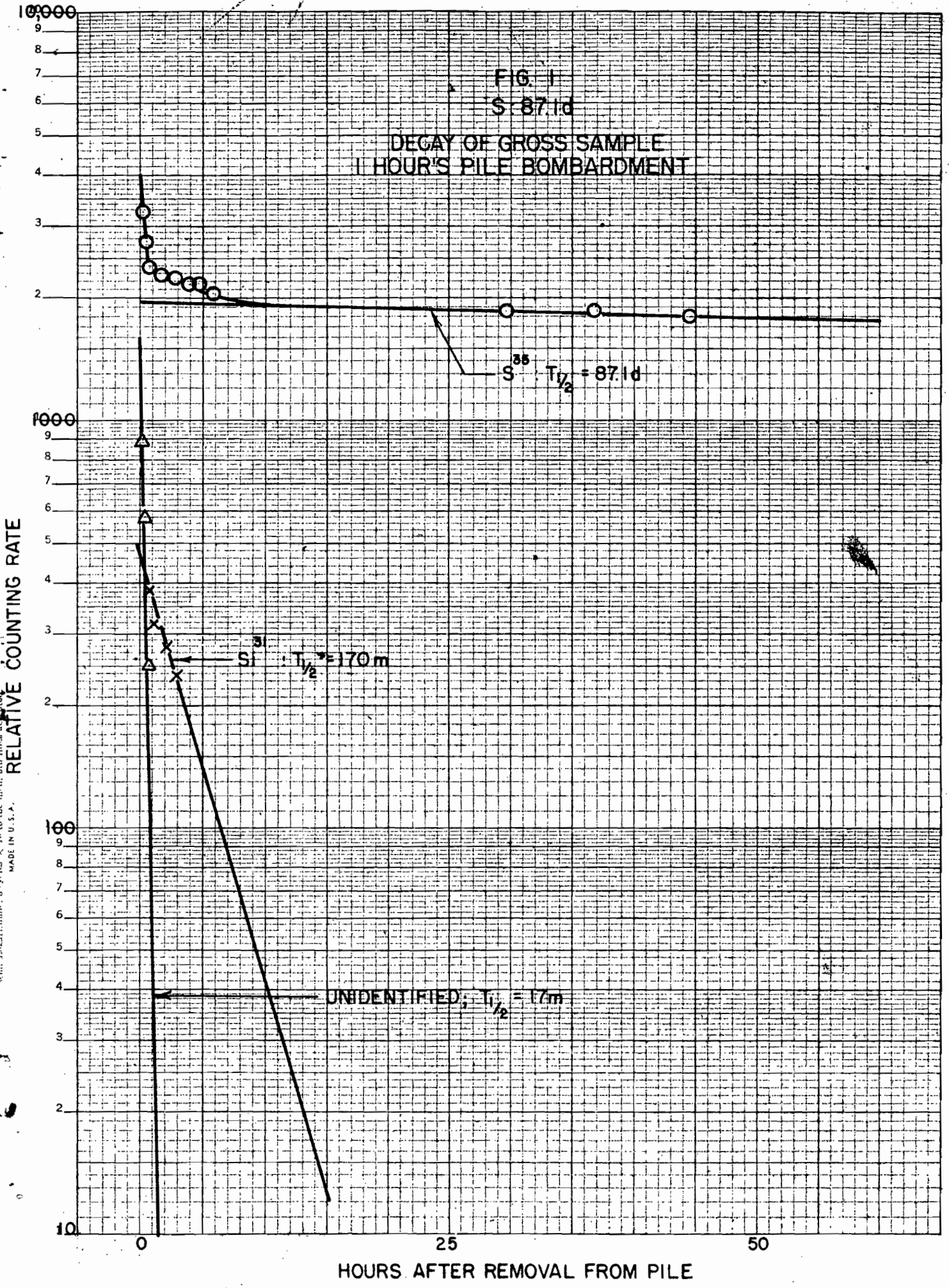
(2) Boiling fuming concentrated HNO_3 will oxidize more P to H_3PO_4 than will the non-fuming acid. this was standard practice in aqua regia

(3) Ten to thirty seconds after the HNO_3 is poured into the Br-CCl_4-S mixture, the reaction becomes violent. A large beaker should be used to prevent losses from overflow and spattering.

(4) Kolthoff and Sandell, Textbook of Quantitative Inorganic Analysis, pp. 423-425.

(5) The hydroxide precipitate should be dissolved and reprecipitated to minimize the amount of P carried on it.

Drawg. No. 5509



Drawg. No. 5510

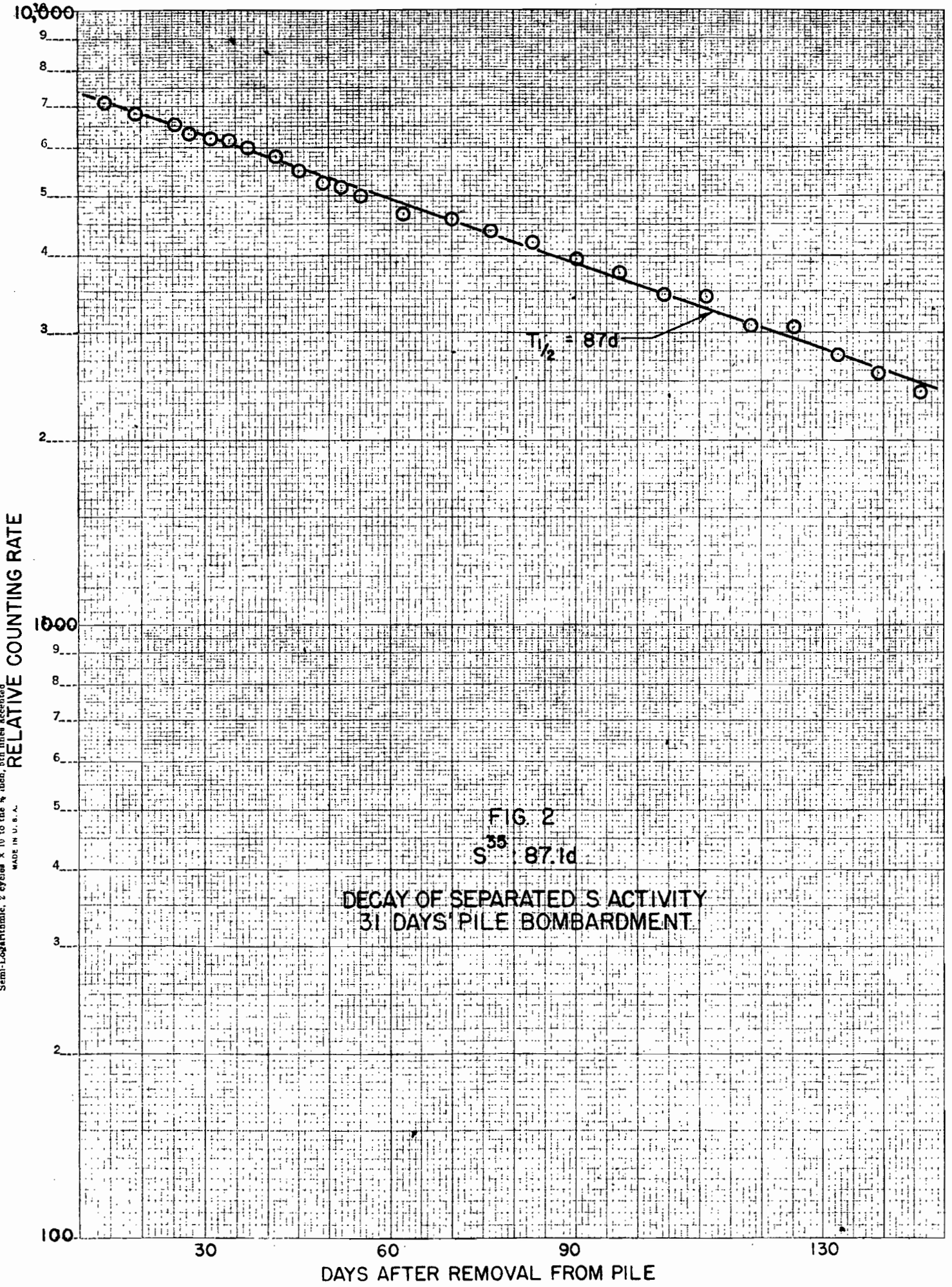


FIG. 2

S^{35} 87.1d

DECAY OF SEPARATED S ACTIVITY
31 DAYS' PILE BOMBARDMENT

Drawg. No. 5511

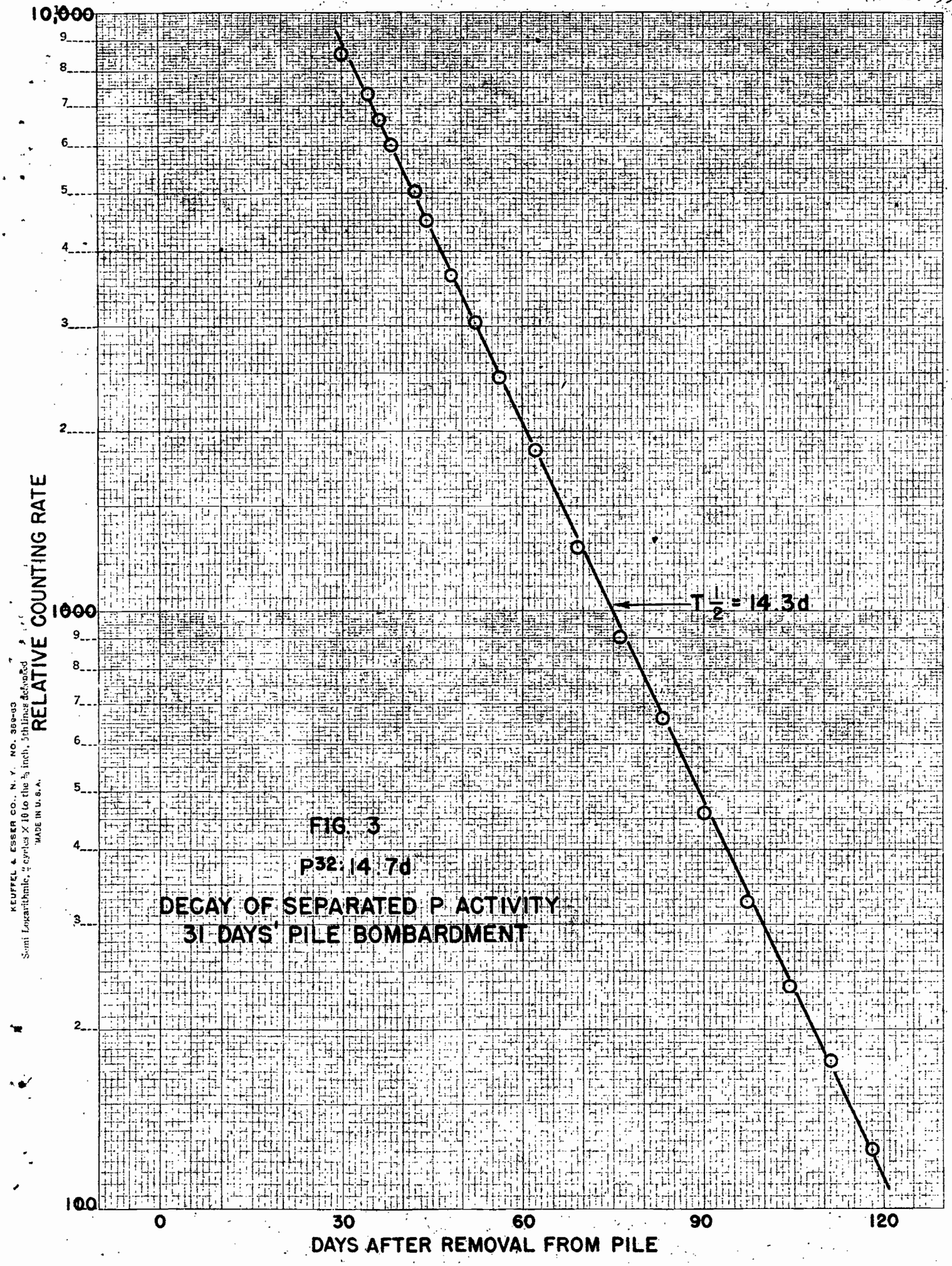


FIG. 3

P^{32}: 14.7d

DECAY OF SEPARATED P ACTIVITY
31 DAYS' PILE BOMBARDMENT

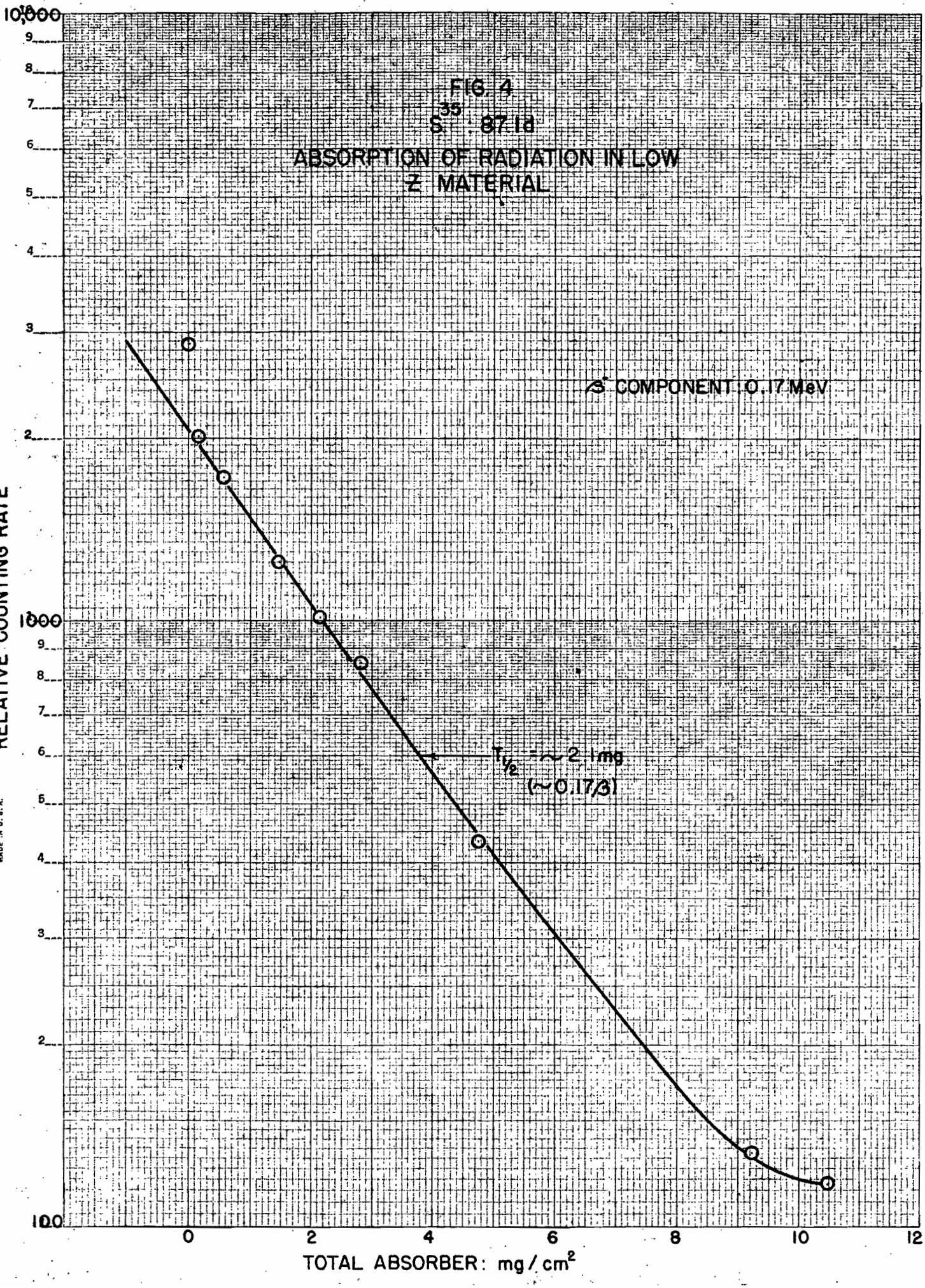


FIG. 4
S^{35} : 87.1d
ABSORPTION OF RADIATION IN LOW Z MATERIAL
β⁻ COMPONENT 0.17 MeV
$T_{1/2}$ = ~2.1mg
(~0.17β)
RELATIVE COUNTING RATE
TOTAL ABSORBER: mg / cm²
10,000
1000
100
0
2
4
6
8
10
12
KEUFFEL & ESSER CO., N.Y. NO. 359-03
Semi-Logarithmic, 2 cycles × 10 to the ½ inch, 5th lines accented
MADE IN U.S.A.

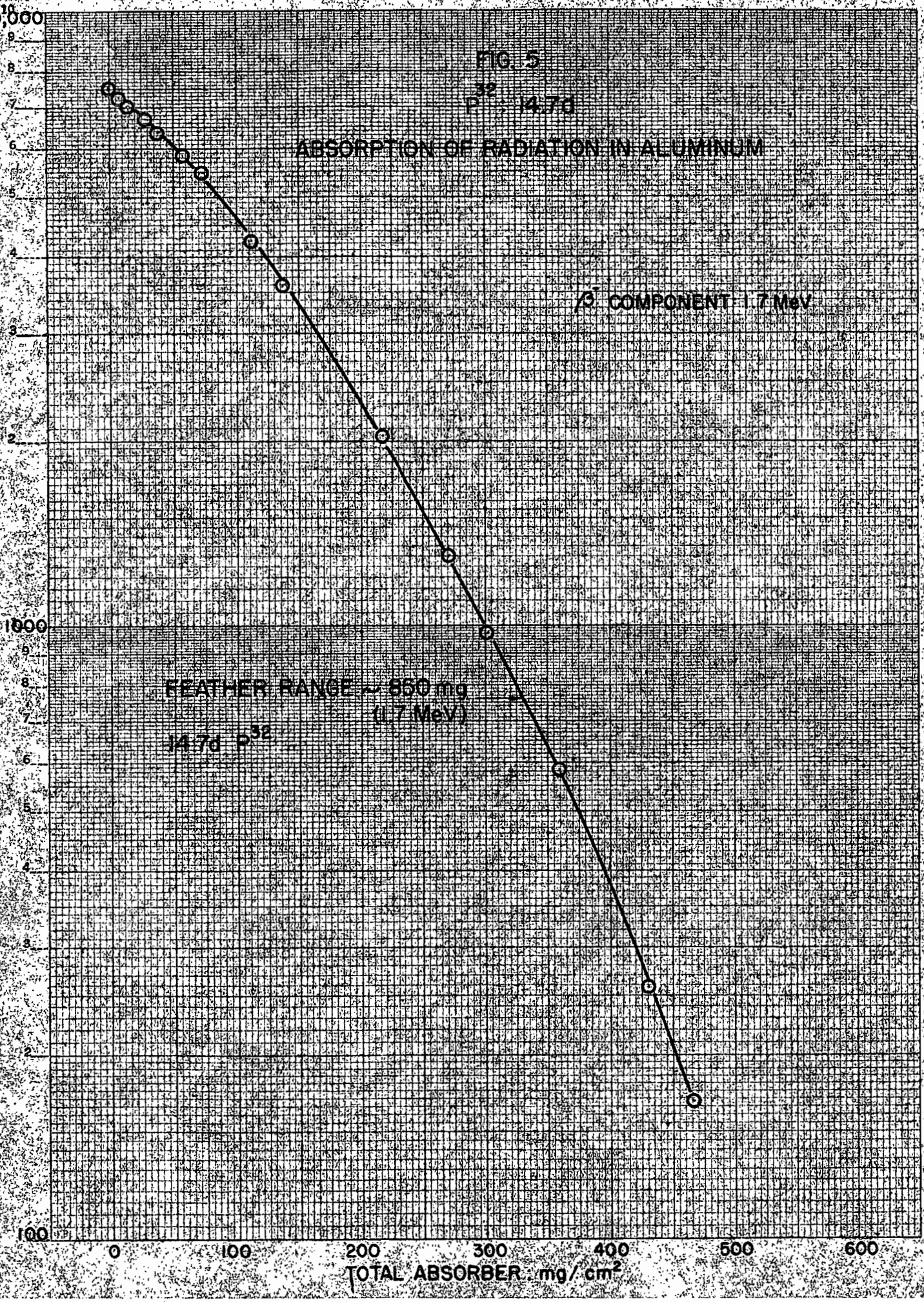


FIG. 5
P^{32} 14.7d
ABSORPTION OF RADIATION IN ALUMINUM
β⁻ COMPONENT 1.7 MeV
FEATHER RANGE ~ 850 mg
(1.7 MeV)
14.7d P^{32}
RELATIVE COUNTING RATE
10,000
1000
100
0
100
200
300
400
500
600
TOTAL ABSORBER: mg/cm²

KH_2PO_4

Target Material: Monobasic Potassium Phosphate, Anhydrous, Reagent, Merck

Weight: 30.96 gm.

Spectrographic Analysis:

Al	FT	Fe	VFT
Ca	FT	Mg	FT

Irradiation: 56 days at nv = 3.54 x 10" n/cm^2/sec

Separations: The sample was dissolved in water, made up to 250 ml, and aliquots taken. Chemical separations were unnecessary because the difference in half-lives of K^{42} and P^{32} made it possible to calculate their activities separately.

Activities Found at T_o in Bombardment:

	% Total Activity	Activity per gm.
K^{42}(12.4 hr)	43.8%	27.3 mc/gm K
P^{32}(14.7 d)	56.2	35.15 mc/gm P

Yields:

38.6 mc K^{42}/gm K/30 day bombardment at 50% maximum flux
49.6 mc P^{32}/gm P/30 day " " " " "

Cross Sections:

K^{42}: $\sigma v = 4.09 \times 10^4$ barns cm/sec
$\sigma = 0.186$ barns per atom normal element
$\sigma = 2.81$ barns per atom isotope

P^{32}: $\sigma v = 5.52 \times 10^4$ barns cm/sec
$\sigma = 0.251$ barns per atom normal element
$\sigma = 0.251$ " " " " "

Non-Routine Errors: None

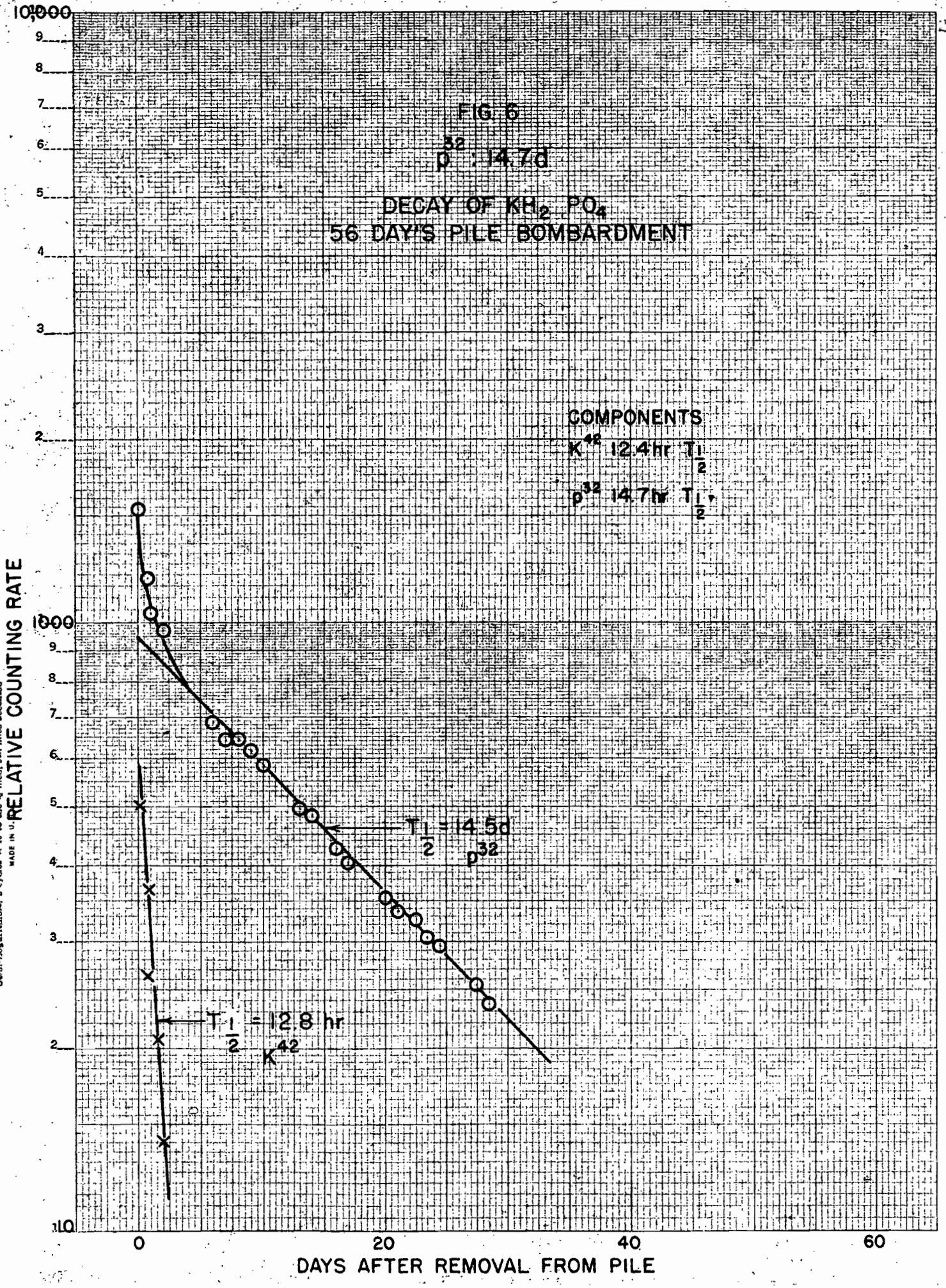
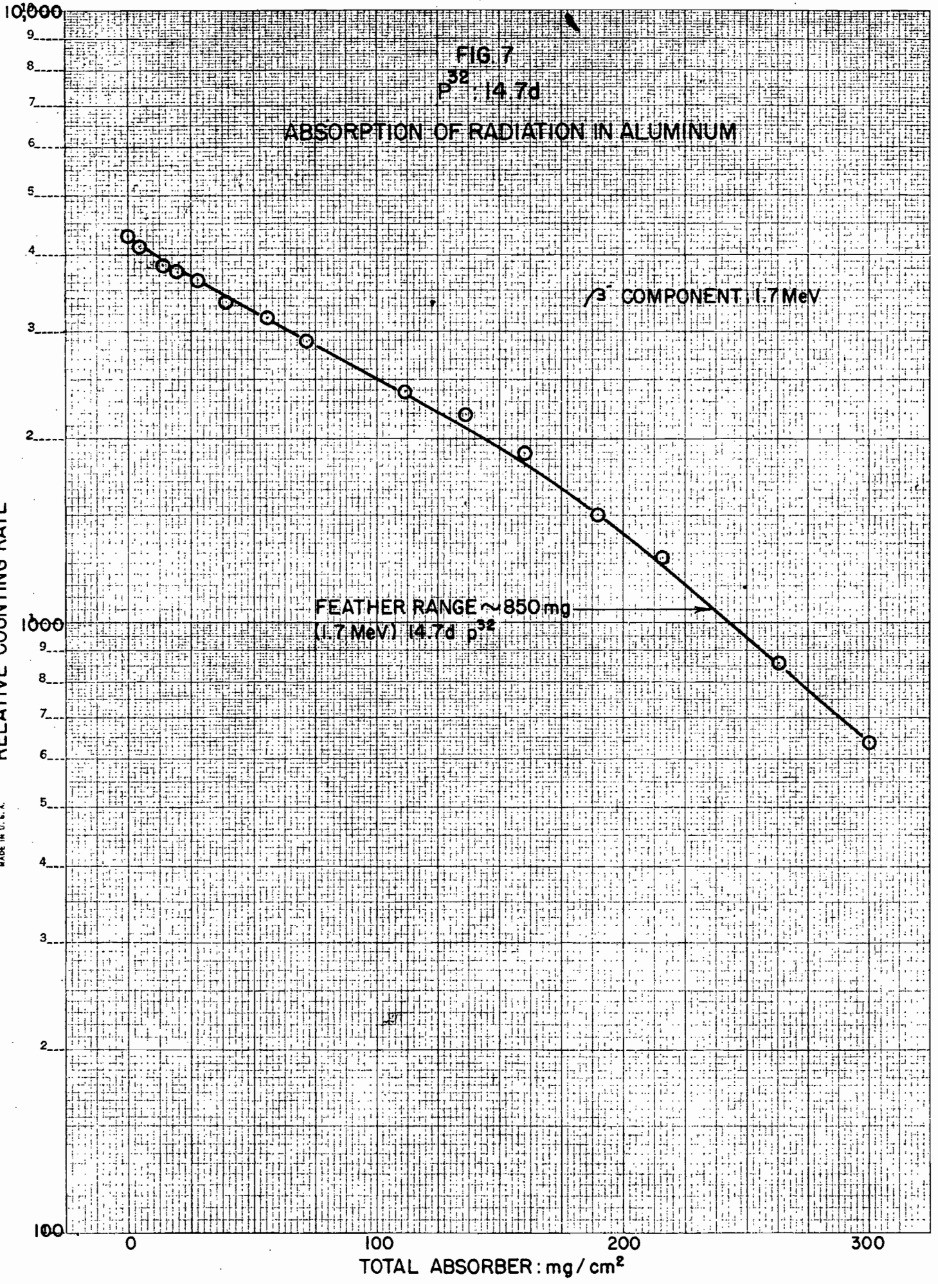


FIG. 6
P^{32} : 14.7d
DECAY OF KH_2PO_4
56 DAY'S PILE BOMBARDMENT
COMPONENTS
K^{42} 12.4hr $T_{\frac{1}{2}}$
P^{32} 14.7hr $T_{\frac{1}{2}}$
$T_{\frac{1}{2}}$ = 14.5d P^{32}
$T_{\frac{1}{2}}$ = 12.8 hr K^{42}
RELATIVE COUNTING RATE
10,000
1000
10
0
20
40
60
DAYS AFTER REMOVAL FROM PILE
KEUFFEL & ESSER CO., N. Y. NO. 359-53
Semi-Logarithmic, 2 cycles × 10 to the ½ inch, 5th lines accented
MADE IN U.S.A.

Drawg. No. 5515



Calcium

Target Material: Calcium Carbonate, Powder, C.P., Baker's

Weight: 24.15 gm

Spectrographic Impurities:

Al	FT	Mg	FT
Cu	FT	Sr	FT
Fe	FT		

Irradiation: 32 days at nv = 4.81 x 10" n/cm^2/sec

Separations: The $CaCO_3$ was dissolved in dilute HCl, made up to 100 ml., and an aliquot taken to work with.

Activities Found at T_0 in Bombardment:

	% Total Activity	Activity per gm. Ca	ppm Impurities
Ca^{45}(180d)	77.6%	0.298 mc	
P^{32} (14.7 d)	22.4	0.086	1,920 P

Yields:

0.291 mc/gm Ca/30 day bombardment at 50% maximum flux

Cross Sections:

σ v = 2.9 x 10^3 barn cm/sec
σ = 0.013 barns per atom normal element
σ = 0.62 barns per atom isotope

Non-Routine Errors: Lost $<$0.5% during assay. A large self-absorption factor introduces an error of ±2%.

Remarks: By comparing the two absorption curves shown in Fig.9, one taken two months later than the other, one can see that the 1.7 MeV β component is decaying much more rapidly than the 0.21 MeV β component. The 1.7 MeV β component is P^{32}, and allowance must be made for its contribution to the total activity of a $CaCO_3$ sample bombarded in the Oak Ridge pile.

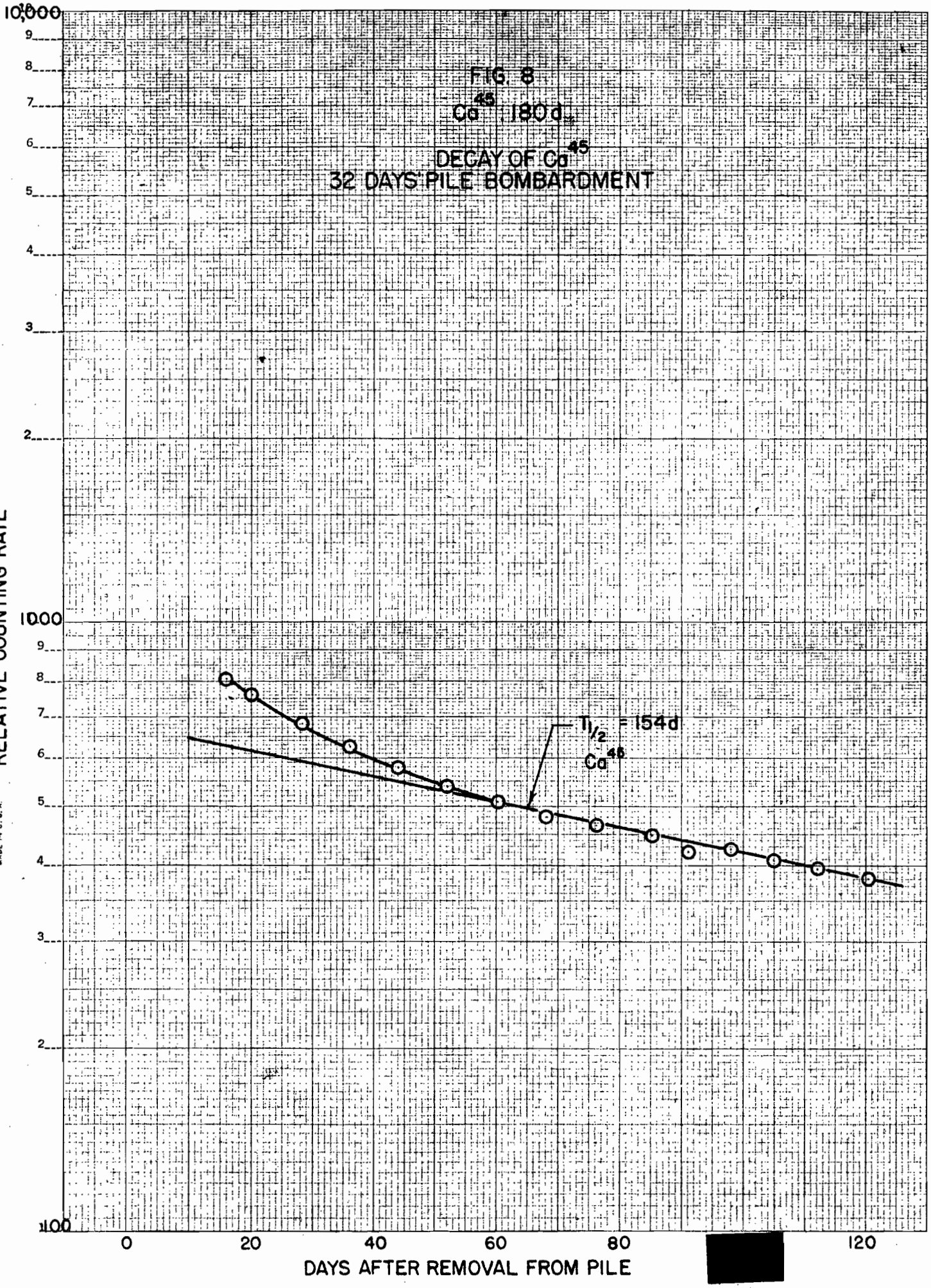


FIG. 8
Ca45 180d
DECAY OF Ca45
32 DAYS PILE BOMBARDMENT
T1/2 = 154d
Ca45
RELATIVE COUNTING RATE
DAYS AFTER REMOVAL FROM PILE
10,000
1000
100
0
20
40
60
80
120
KEUFFEL & ESSER CO., N. Y. NO. 359-63
Semi-Logarithmic, 2 cycles × 10 to the ½ inch, 5th lines accented
MADE IN U.S.A.

Draw. No. 5517

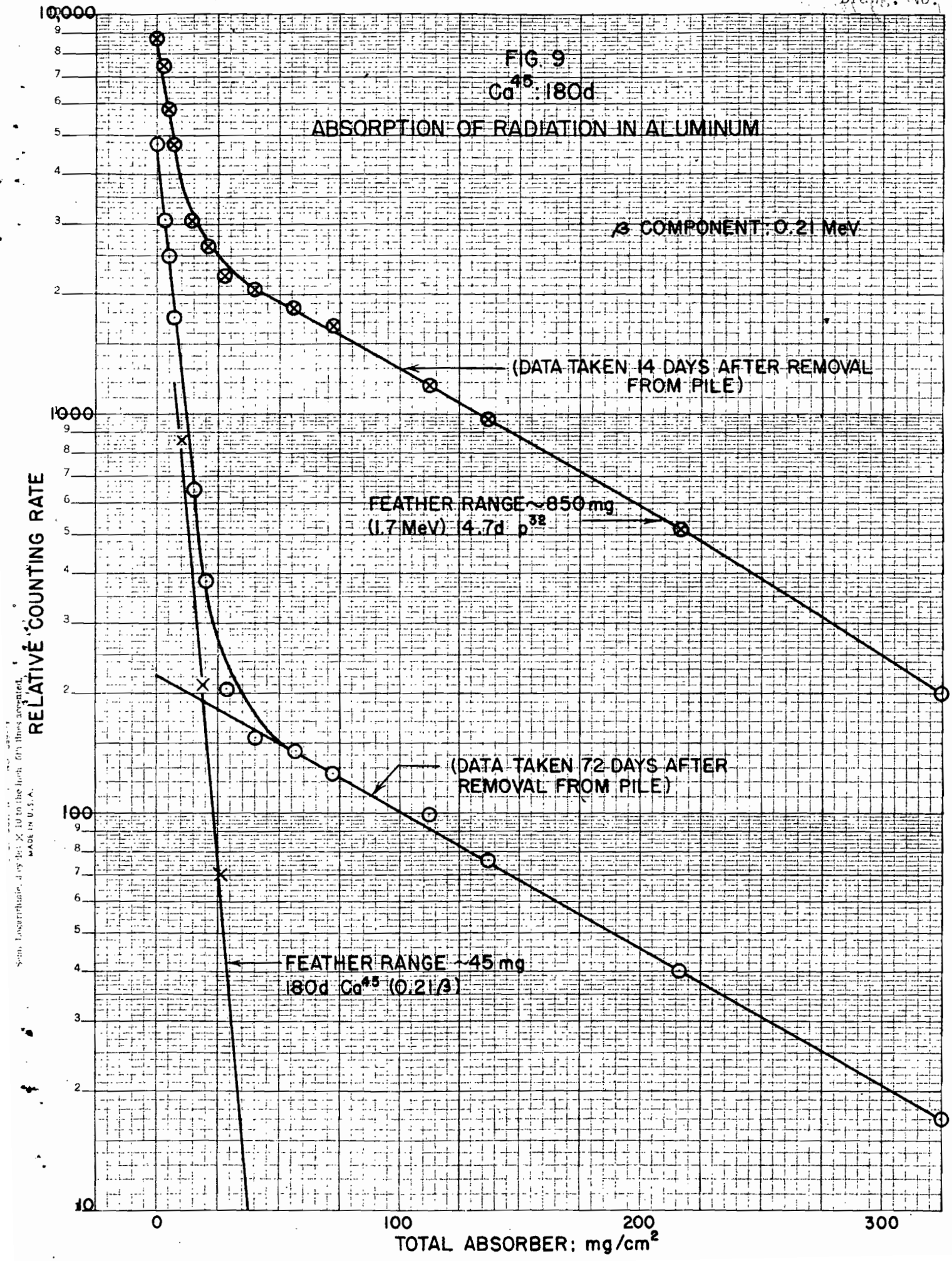


FIG. 9
Ca45 : 180d
ABSORPTION OF RADIATION IN ALUMINUM
β COMPONENT: 0.21 MeV
(DATA TAKEN 14 DAYS AFTER REMOVAL FROM PILE)
FEATHER RANGE ~850 mg
(1.7 MeV) 14.7d P32
(DATA TAKEN 72 DAYS AFTER REMOVAL FROM PILE)
FEATHER RANGE ~45 mg
180d Ca45 (0.21β)
RELATIVE COUNTING RATE
TOTAL ABSORBER: mg/cm2
10,000
1000
100
10
0
100
200
300

Scandium

Target Material: Scandium Oxide, from Adam Hilger, Ltd., London

Weight: 2 mg

Spectrographic Impurities:

Ca	FT	Mg	FT

Irradiation: 68 days at nv = 3.8 x 10" n/cm^2/sec

Separations: See diagram.

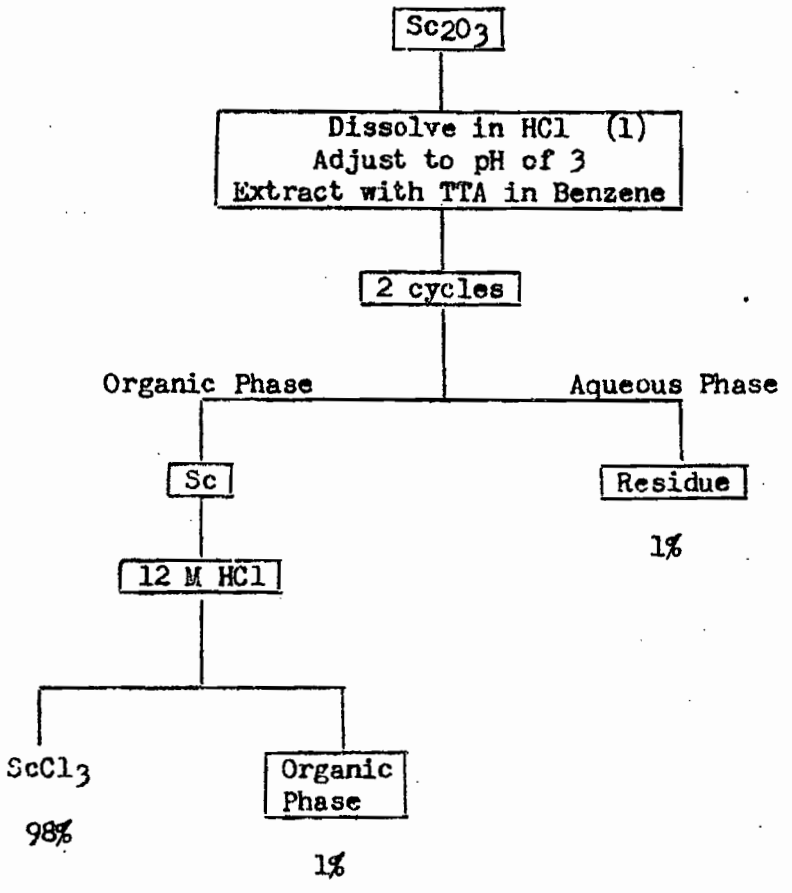
Activity Found at T_0 in Bombardment:	Activity per gm Scandium
Sc^{46} (85d)	838 mc

Yield: 563 mc/gm Sc/30 day bombardment at 50% maximum flux

Cross Sections:

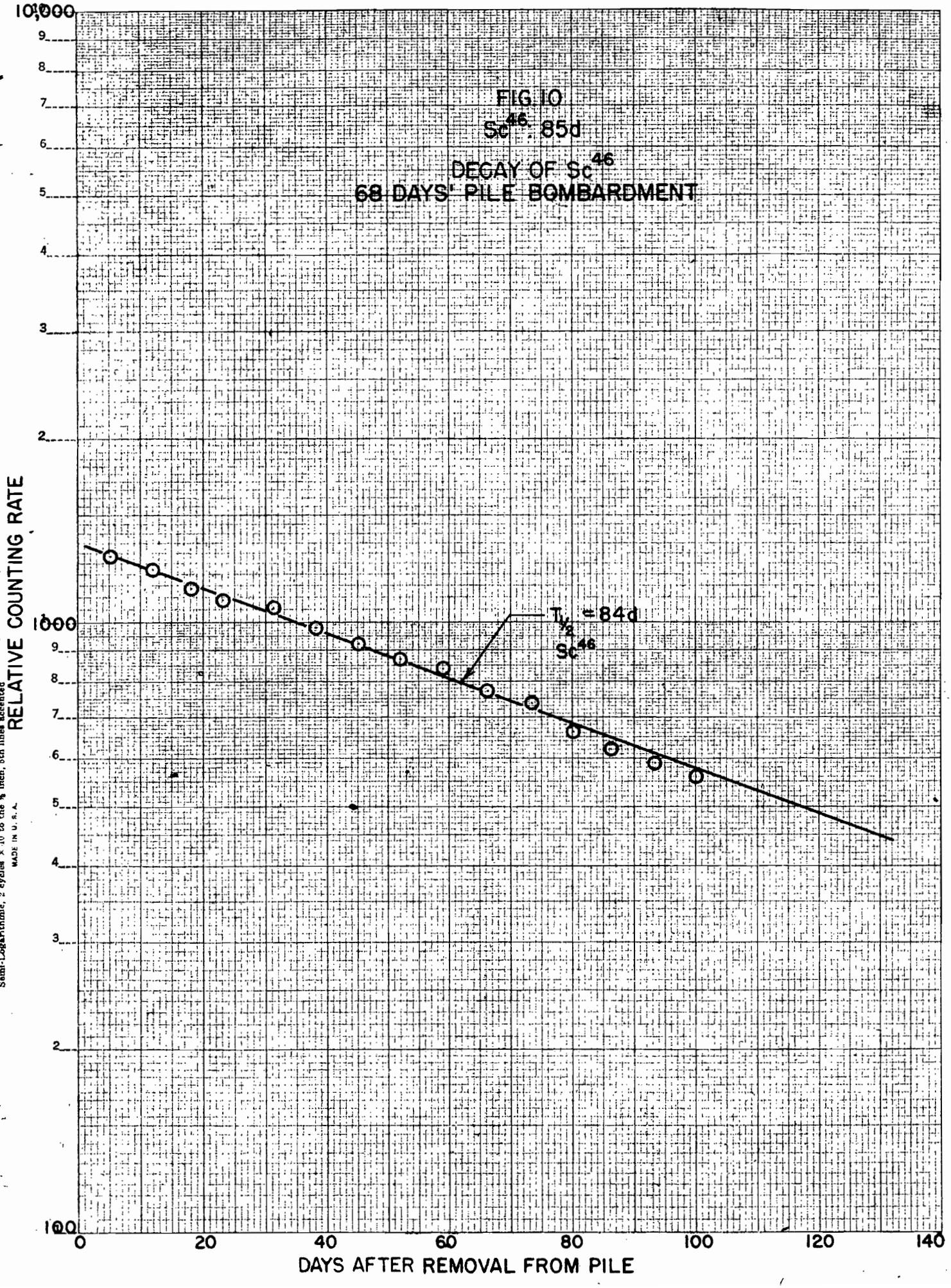
v = 3.17 x 10^6 barns cm/sec
= 14.4 barns per atom normal element
= 14.4 barns per atom isotope

Non-Routine Errors: None

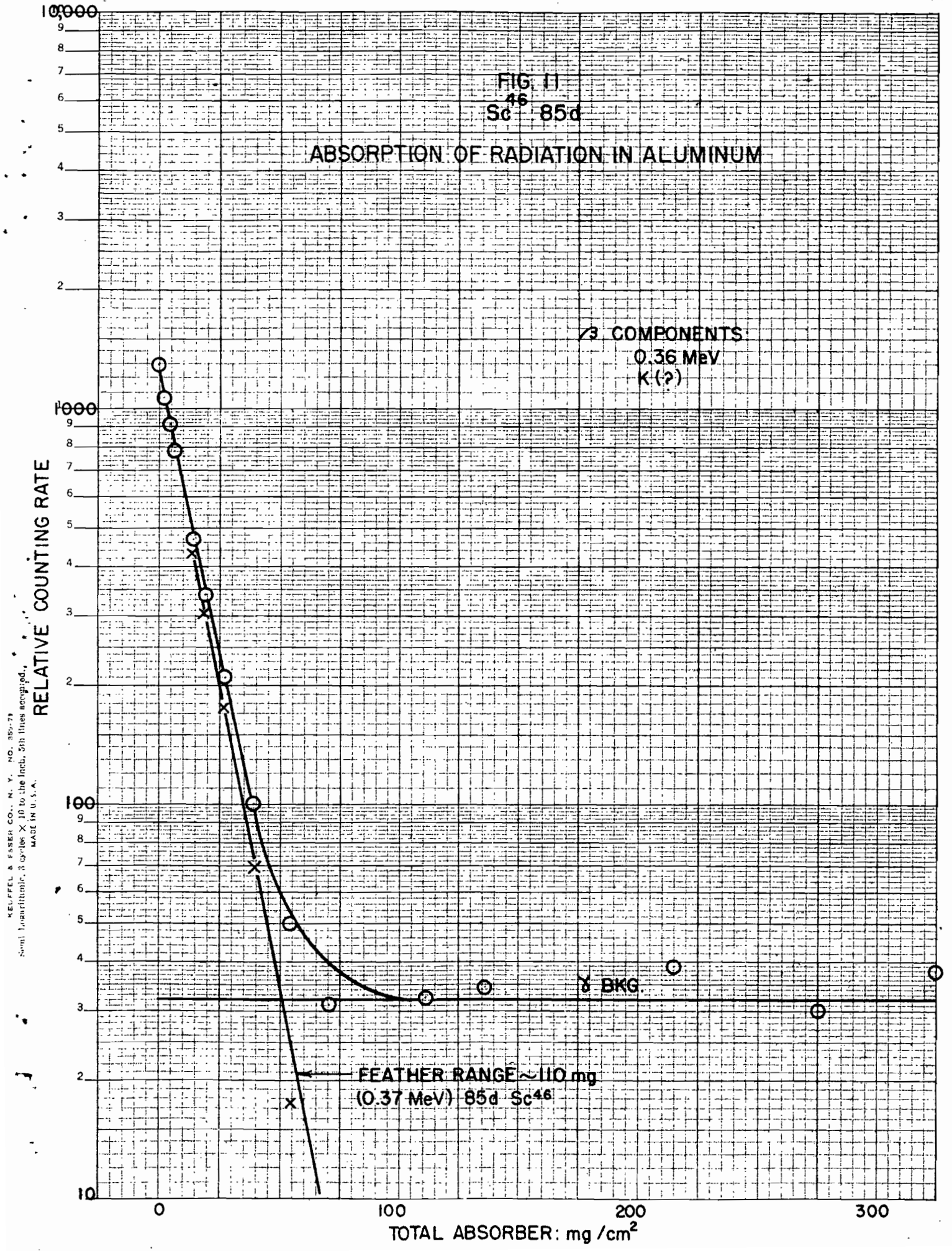


(1) A. Broido, MonC-350, Purification of Scandium and Preparation of Ca^{45}

Drawing No. 5518



Drawg. No. 5519



KEUFFEL & ESSER CO., N. Y. NO. 359-71
Semi Logarithmic, 3 cycles X 10 to the Inch, 5th lines accented.
MADE IN U.S.A.

Drawg. No. 5520

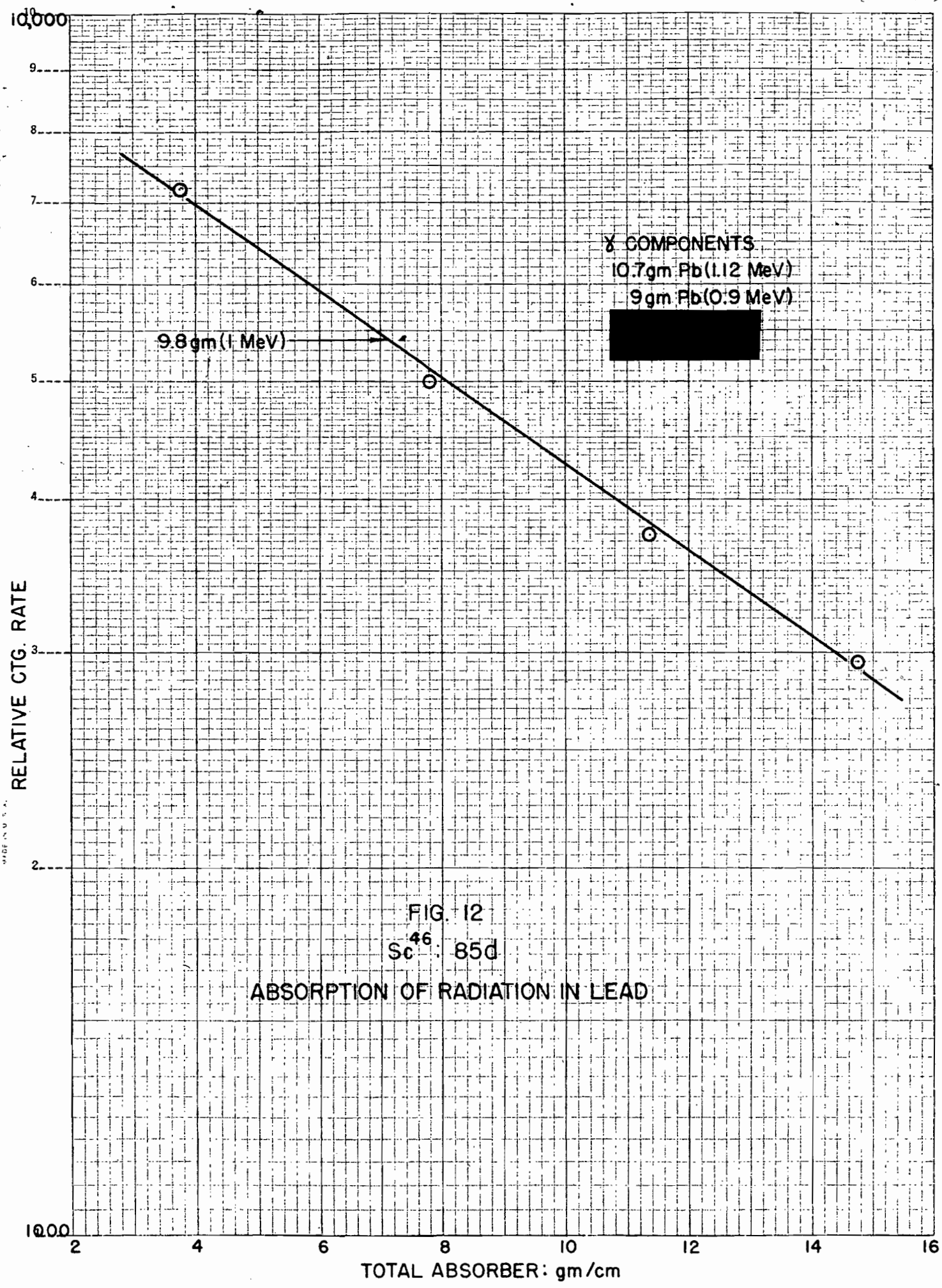


FIG. 12

Sc^{46}: 85d

ABSORPTION OF RADIATION IN LEAD

Titanium

Target Material: Titanium oxide, Pure, Amend Drug & Chemical Corp.

Weight: 18.73 g

Spectrographic Impurities:

Al	FT	Fe	T
Ca	FT	Mg	FT
Cd	FT	Si	T
Cu	FT		

Irradiation: 69 days at nv = 3.2 x 10" n/cm^2/sec

Separations: See diagram

Activities at T_0 in bombardment:	% Total Activity	Activity per Gram	ppm Impurities
Ti^{51}(72 d)	52%	0.027 mc	
P^{32} (14.7d)	48	0.025	1600 S^{32}

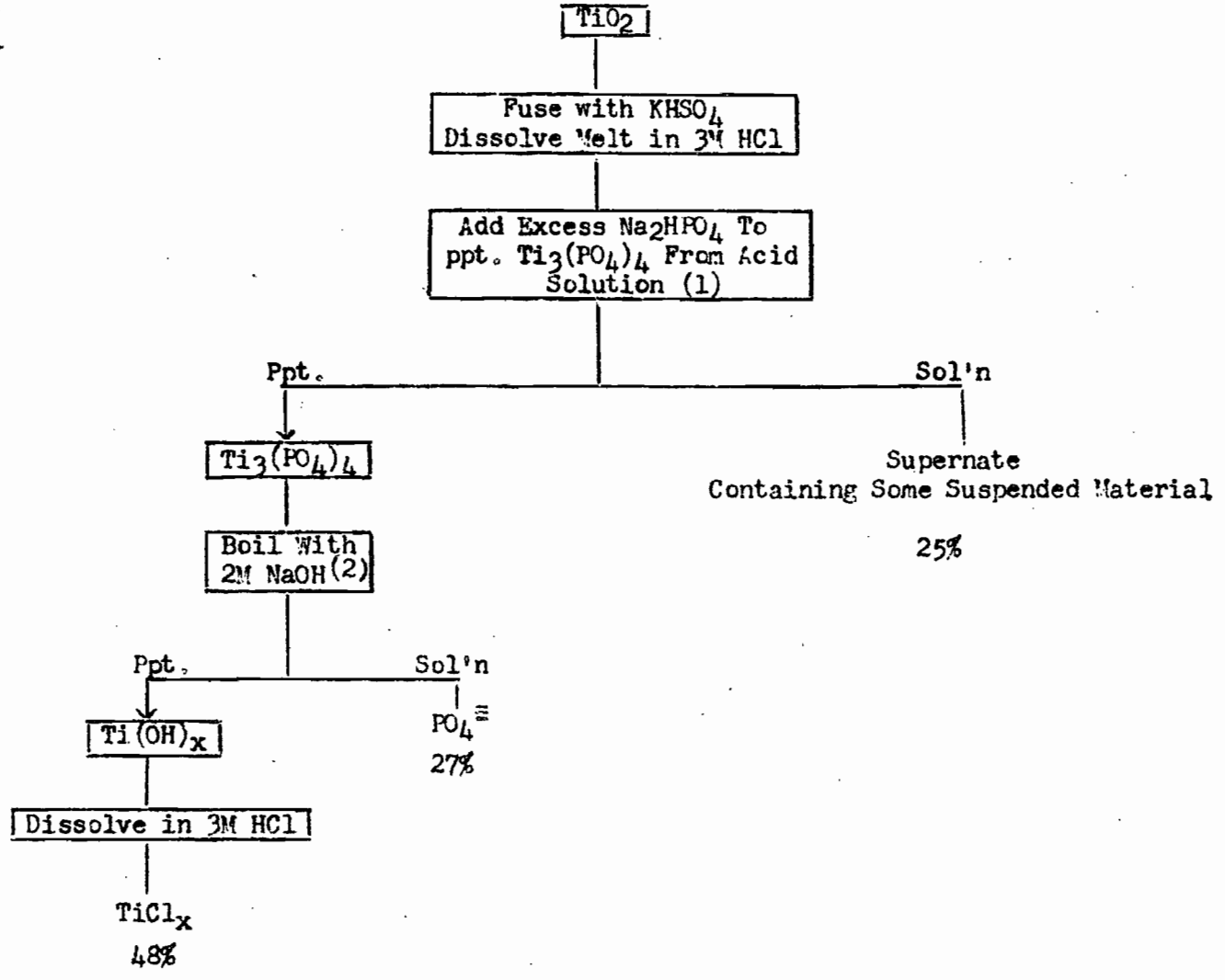
Yield: 0.022 mc/gm Ti/30 day bombardment at 50% maximum flux

Cross Section:

σ v = 1.13 x 10^2 barns cm/sec
σ = 5.15 x 10^{-4} barns per atom normal element
σ = 0.0097 barns per atom isotope

Non-Routine Errors: None

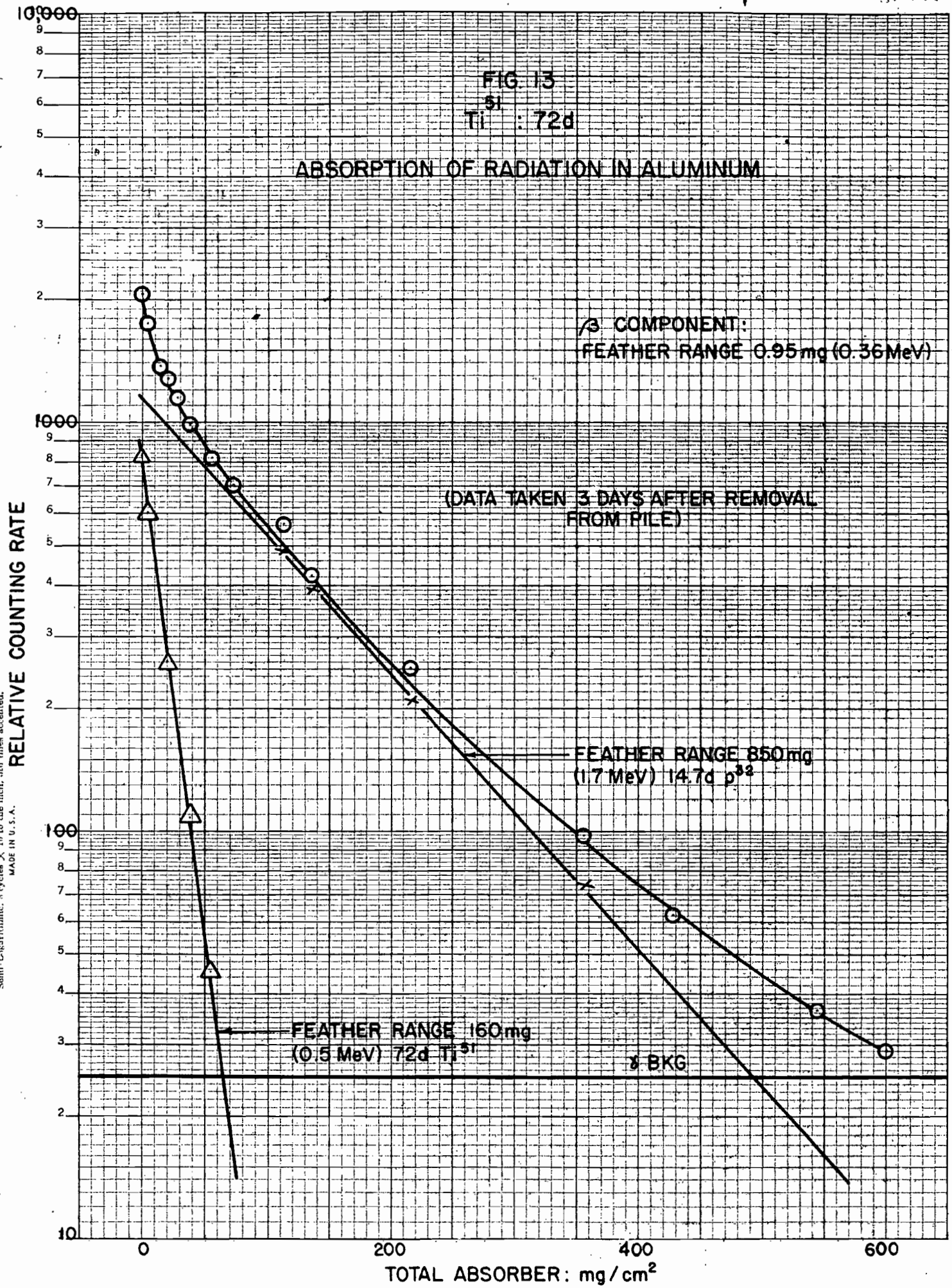
Remarks: The 1.7 MeV β radiation shown in Fig. 13 may be attributed to P^{32} activity originally present in the TiO_2 sample probably as $SO_4^{=}$.



(1) Noyes and Bray, Qualitative Analysis for the Rare Elements, p. 83

(2) Ibid, p. 78.

Drawg. No. 5521



Iron

Target Material: Carbonyl Iron Powder, A. D. Mackay

Weight: 17.73 gm

Spectrographic Impurities:

Cu FT Ni T

Irradiation: 32 days at nv = 4.76 x 10" n/cm^2/sec

Separations: See diagram.

Activities Found at T_o in Bombardment:	Activity per gm Fe	% Total Activity	ppm Impurities
Fe^{59} (46.3d)	0.144 mc	~99.8%	
Fe^{55} (~ 4 yr)	Identified but not calculated		
P^{32} (14.8d)	1.1×10^{-4} mc	0.08%	1 ppm
* (2.5 hr)	2.2×10^{-4}	0.15%	4

* Mn or Ni probably

Yield: 0.144 mc Fe^{59}/ gm Fe/30 day bombardment at 50% maximum flux

Cross Sections:

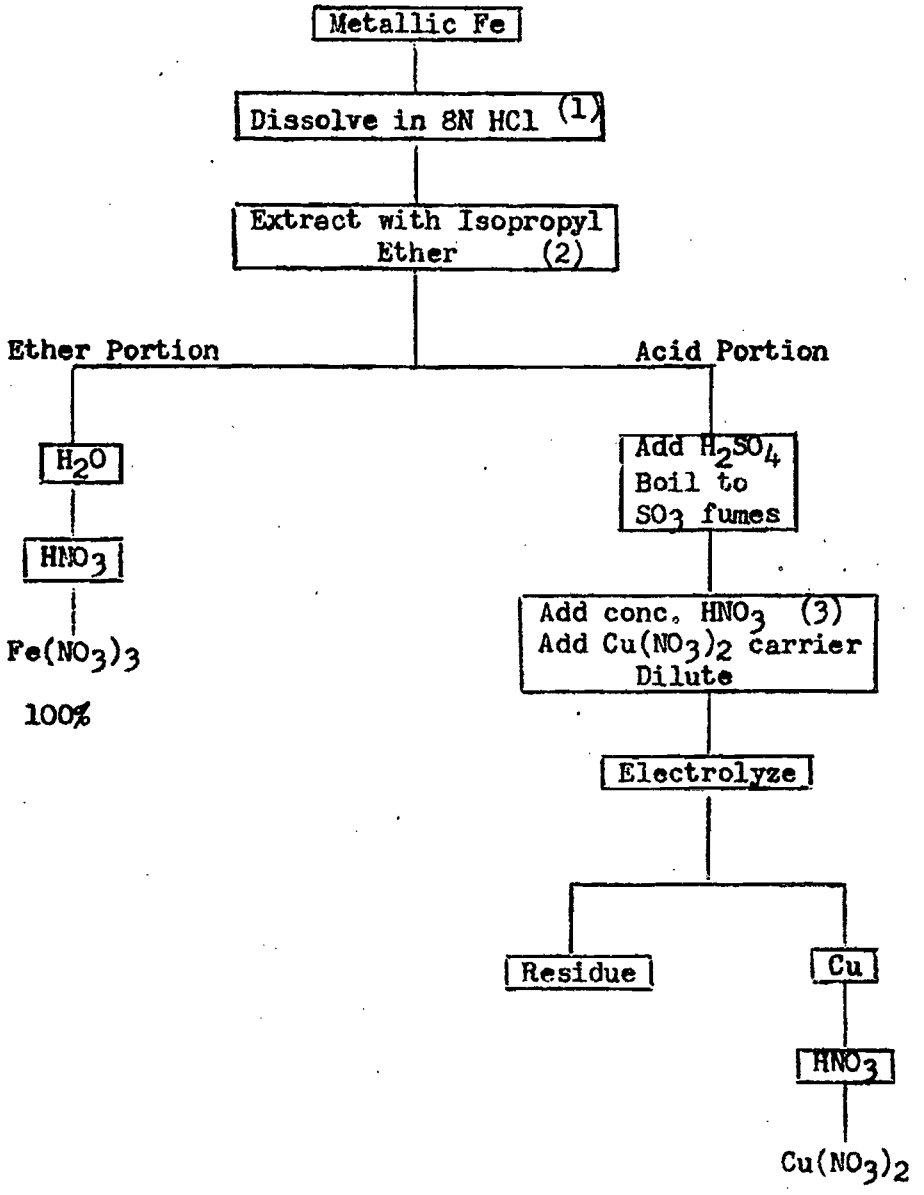
σ v = 639 cm/sec

σ = 2.9×10^{-3} barns per atom normal element

σ = 0.878 " " " isotope

Non-Routine Errors: None

Remarks: The slight amount of very soft component in the Fe absorption curves is due to the ~ 7 KeV x-rays of Fe^{55}. This will vary with the bombardment time and the flux. If it is desired to analyze for it one might use Be or C absorbers to enhance its absorption coefficient.

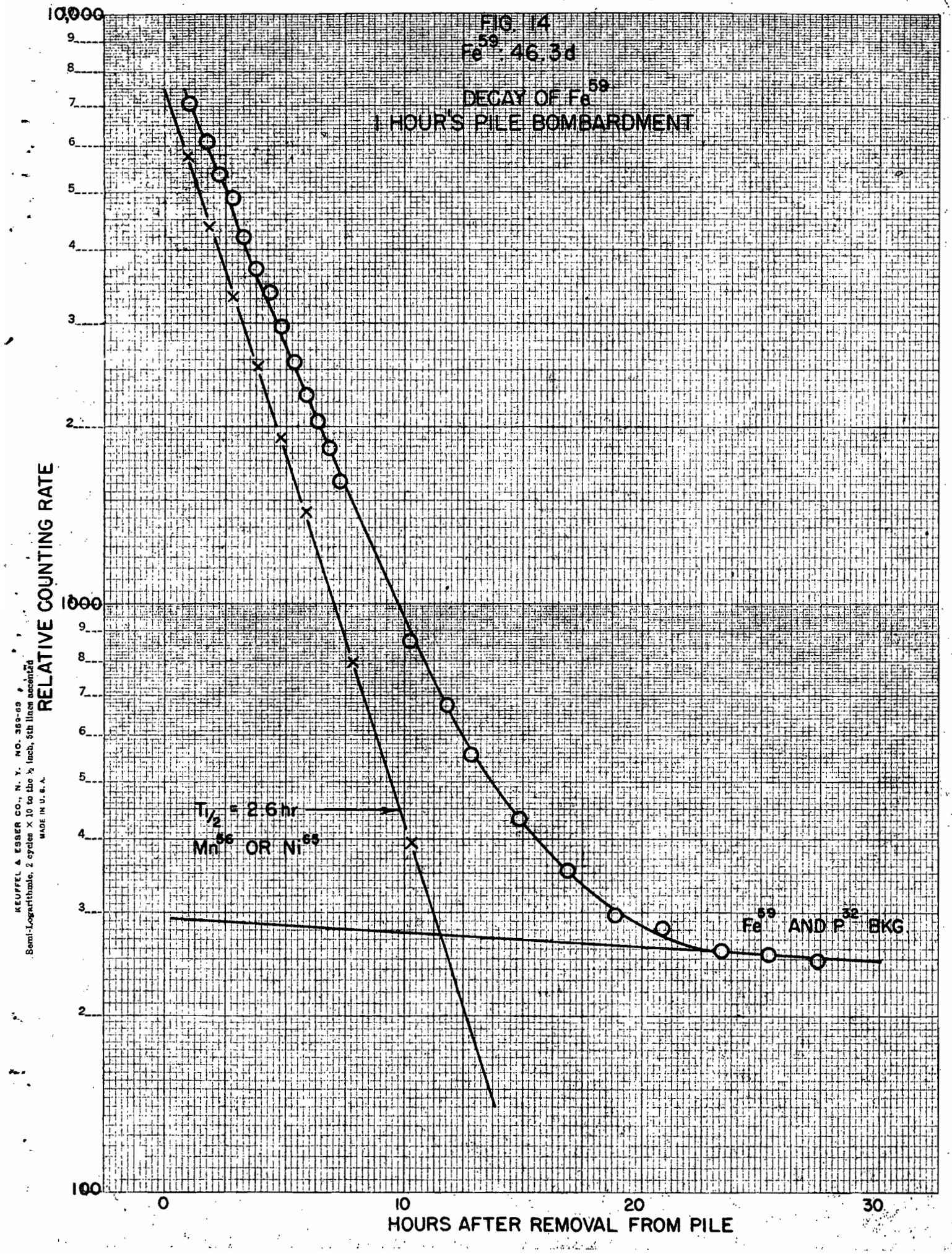


(1) Great care should be taken to subject pile-bombarded iron to as little oxidizing action as possible; "passive" oxidized iron is easily formed, and can be dissolved only with extreme difficulty.

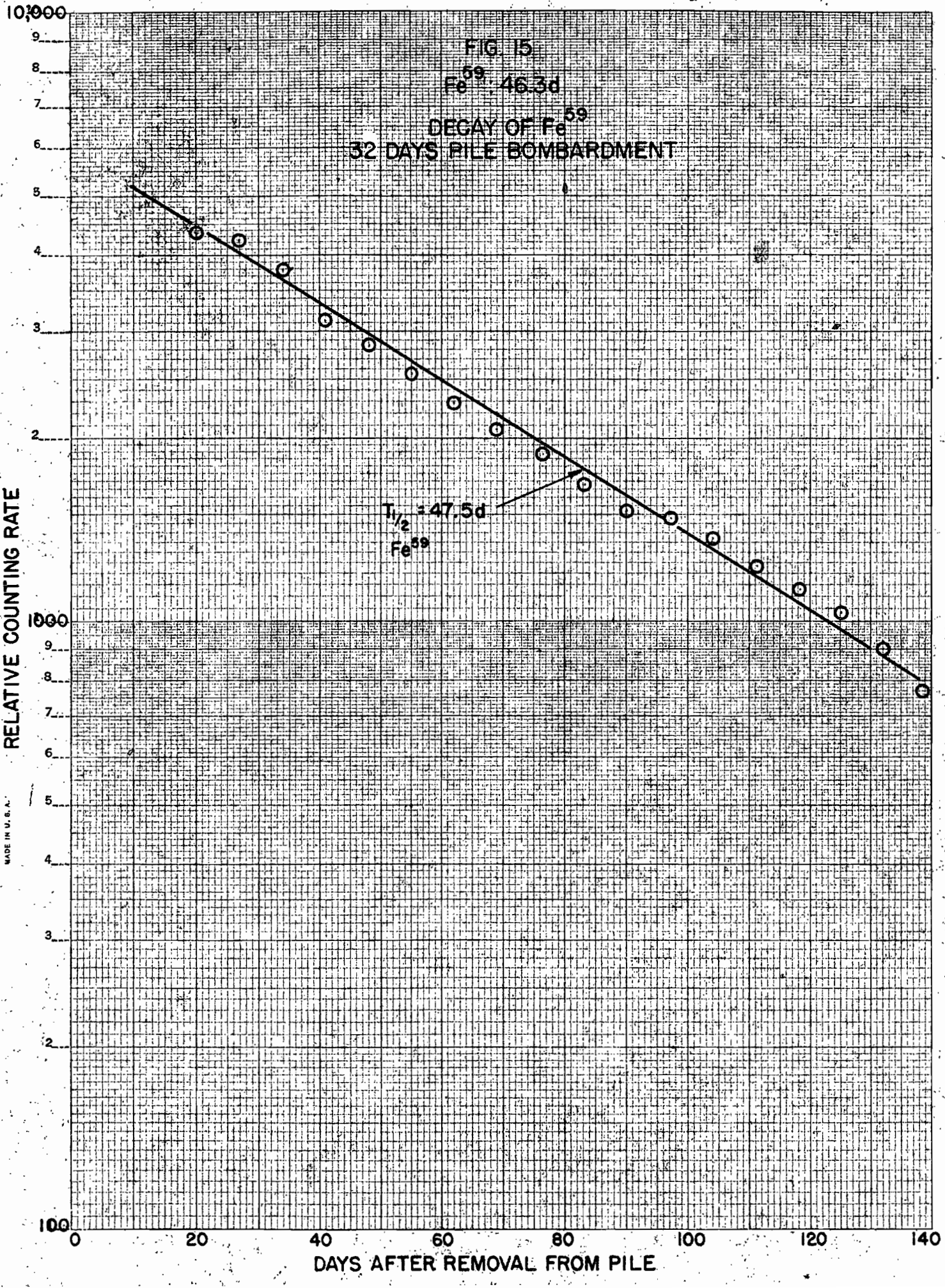
(2) Scott's Standard Methods of Chemical Analysis, pp. 465-466.

(3) Kolthoff and Sandell, Textbook of Quantitative Inorganic Analysis, pp. 423-425.

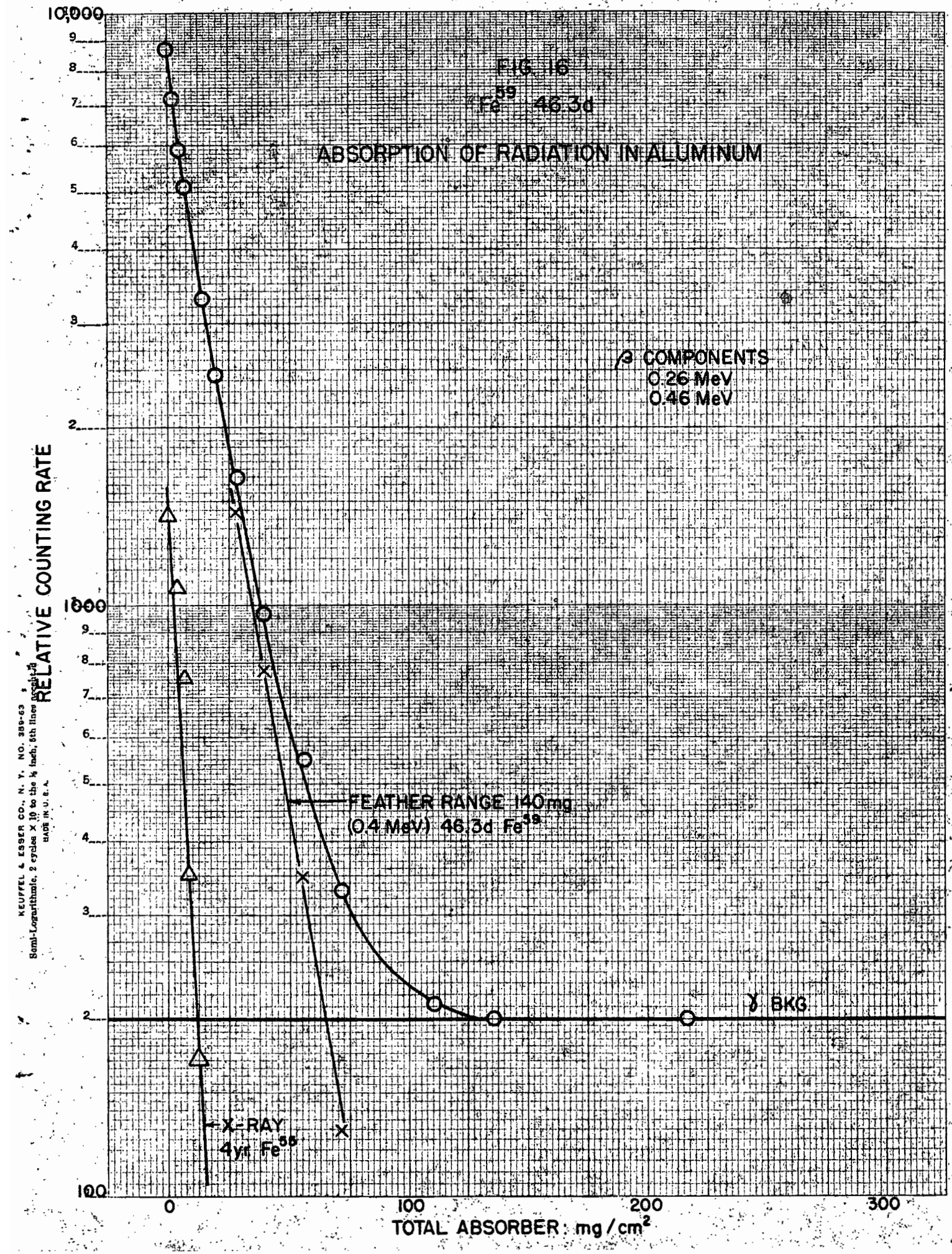
Drawg. No. 5522



Drawg. No. 5523



Drawg. No. 5524



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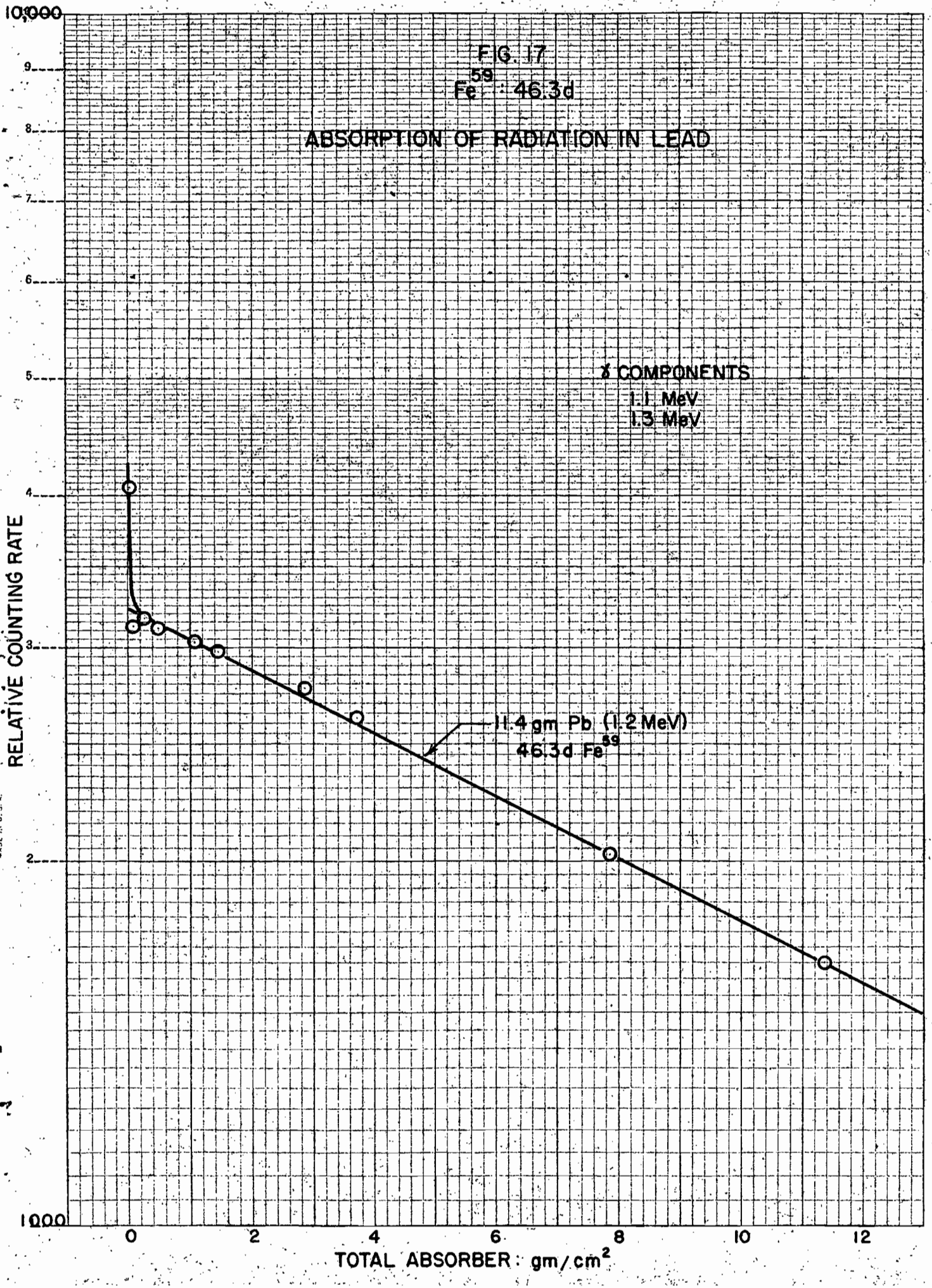

Semi-Logarithmic, 1 Cycle X 10 to the inch. 5 to lines accented.
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Cobalt

Target Material: Cobalt (ic) Oxide, C.P., Baker's

Weight: 1.03 gm

Spectrographic Impurities:

Ca	FT	Mg	VFT
Cu	FT	Ni	FT
Fe	FT		

Irradiation: 32 days at 4.34 x 10" n/cm^2/sec

Separations: Dissolved the sample in 12N H_2SO_4 made it up to 100 ml., and took an aliquot with which to work.

Activities Found at T_0 in Bombardment:	Activity per gm Co
Co^{60} (5.3 yr)	36.8 mc

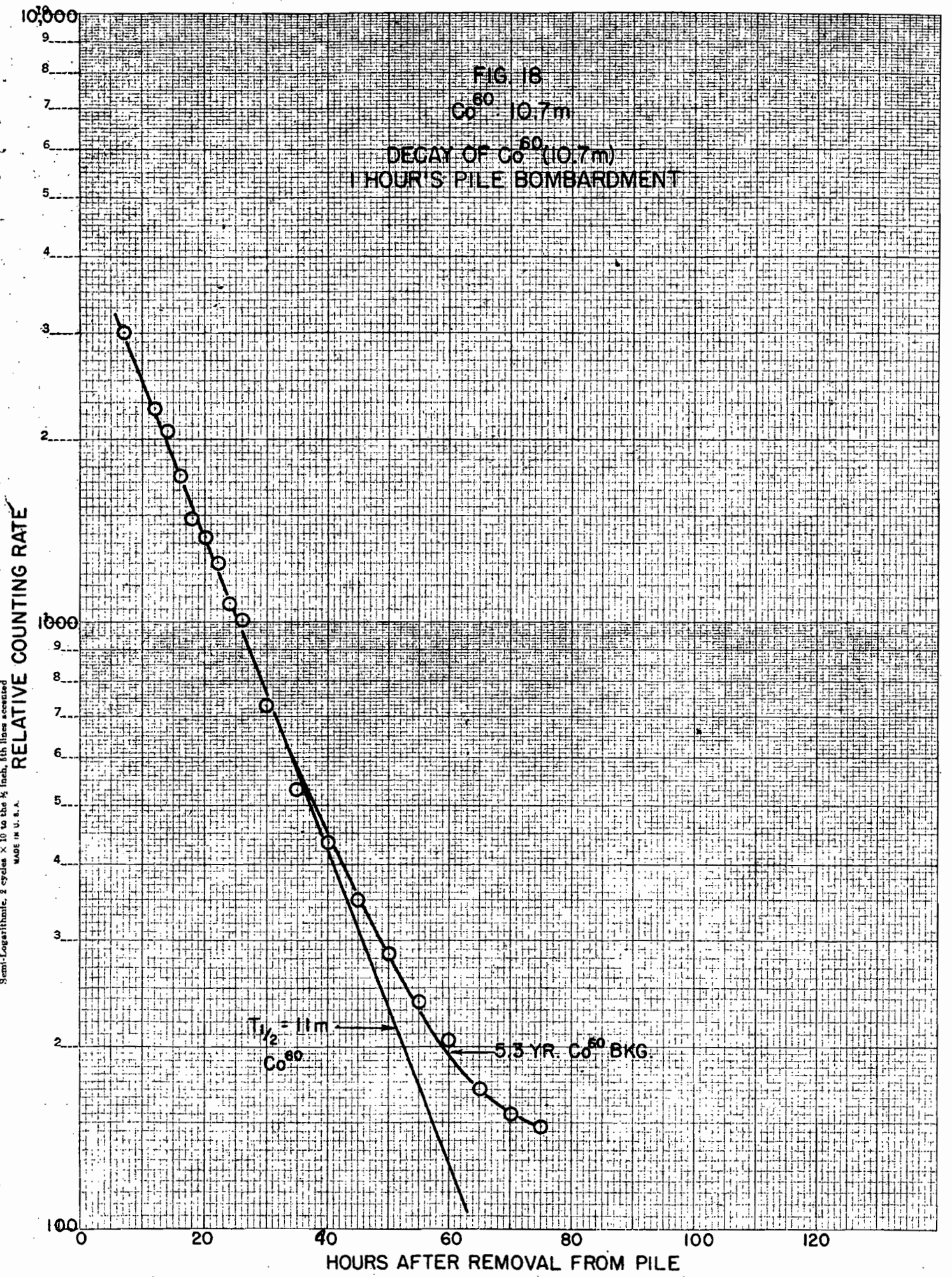
Yield: 42.5 mc/gm Co/30 day bombardment at 50% maximum flux

Cross-Sections:

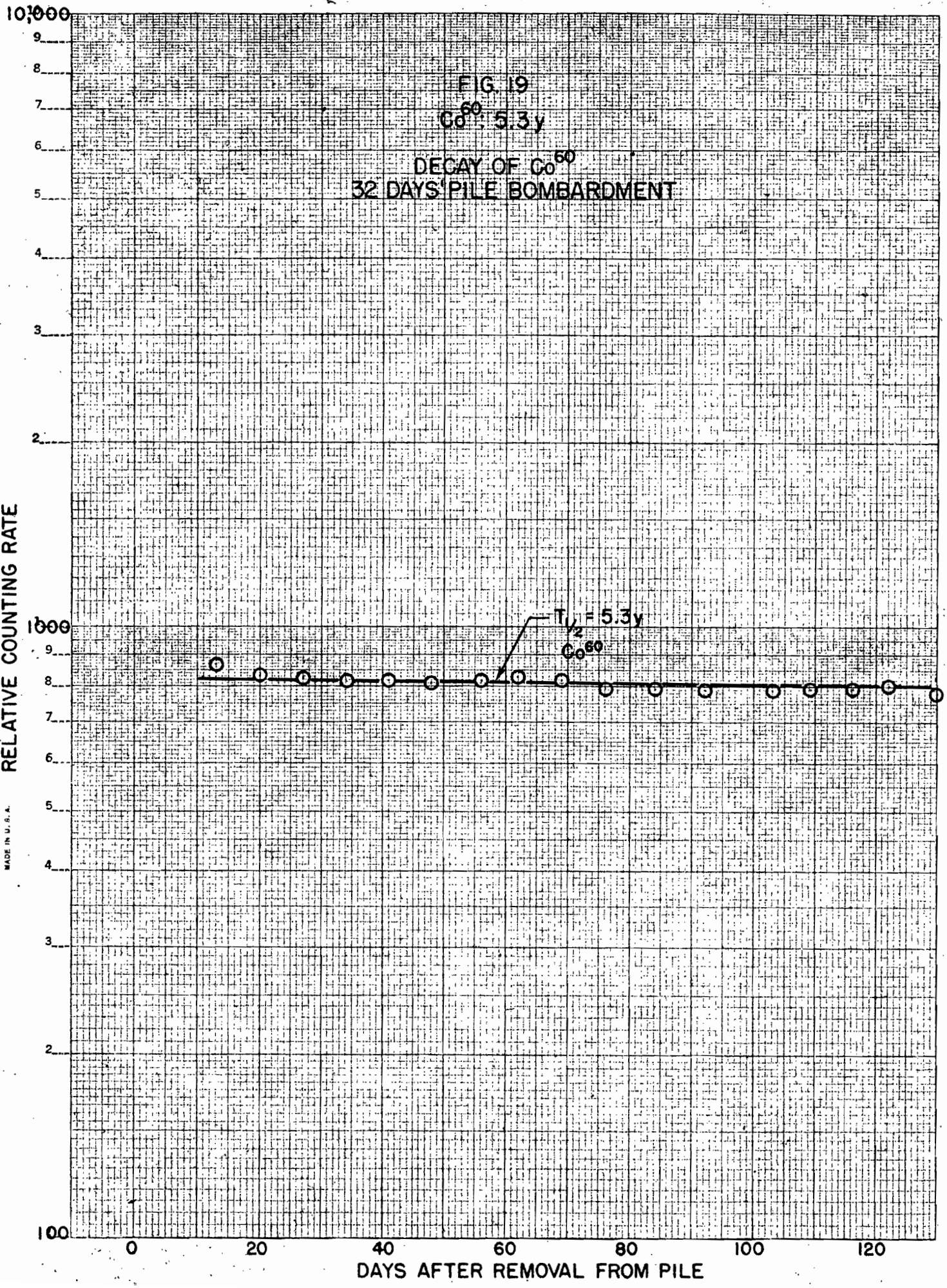
$\sigma v = 6.51 \times 10^6$ barns cm/sec
$\sigma = 29.6$ barns per atom normal element
$\sigma = 29.6$ barns per atom isotope

Non-Routine Errors: None

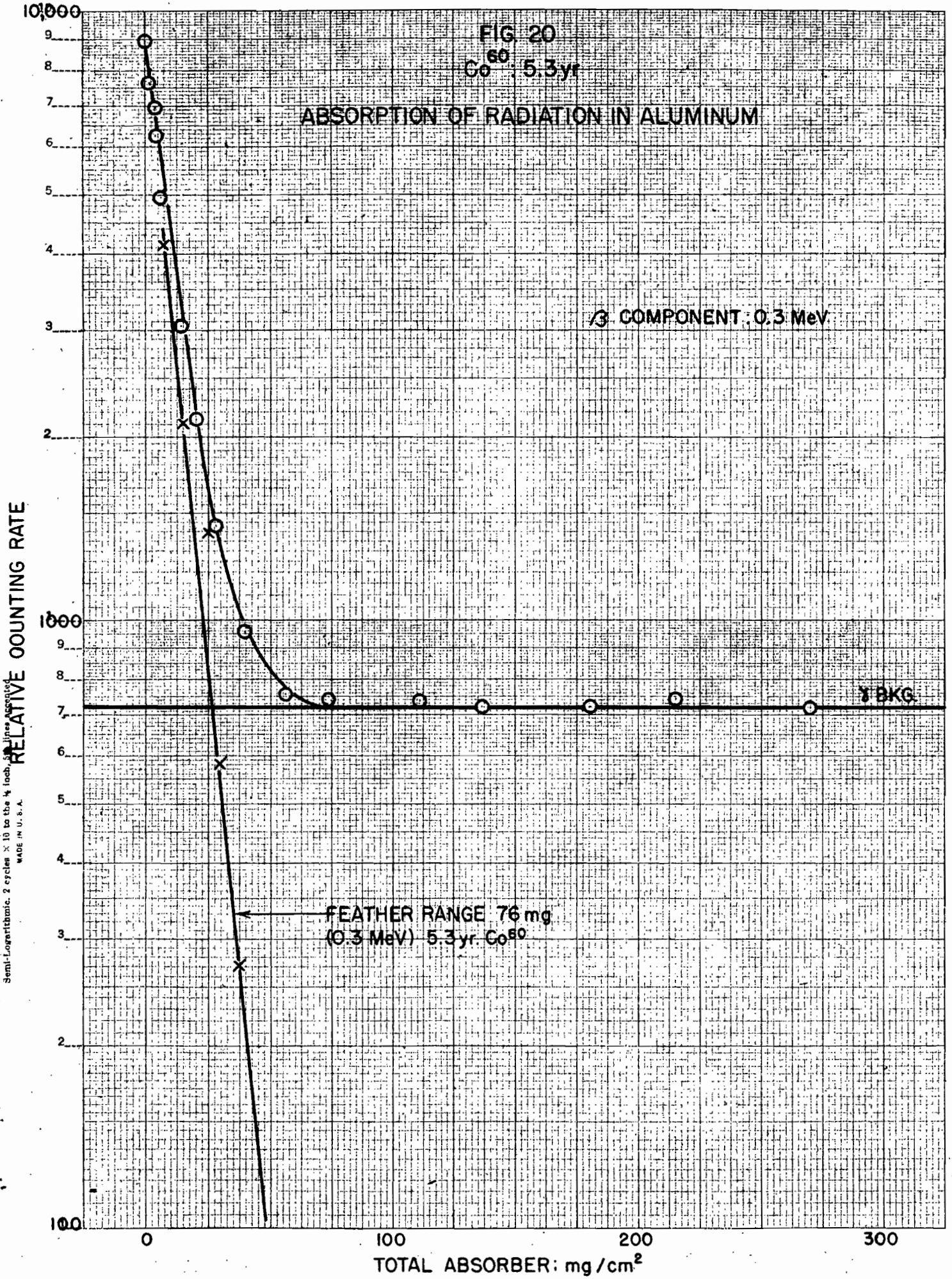
Drawg. No. 5526



Drawg. No. 5527



Drawg. No. 5528



Nickel

Target Material: Nickel Powder, Belmont Smelting & Refining Works

Weight: 10.05 g.

Spectrographic Impurities:

Ca	T	Fe	W
Co	T	Mg	FT
Cu	M	Si	T

Irradiation: 63 days at nv = 4.6 x 10" n/cm^2/sec

Separations: See diagram.

Activities Found at T_0 in Bombardment	% Total Activity	Activity per gm. Ni	ppm Impurities
Ni^{65}(2.6 hr)	92.5%	1.94 mc	
Co^{60}(5.3 yr)	2.5	0.053	1,300
Fe^{59}(46.3 d)	--	<0.0014	8,000
Cu^{64}(12.8 hr)	5.0	0.13	350
Unidentified	--	0.001	

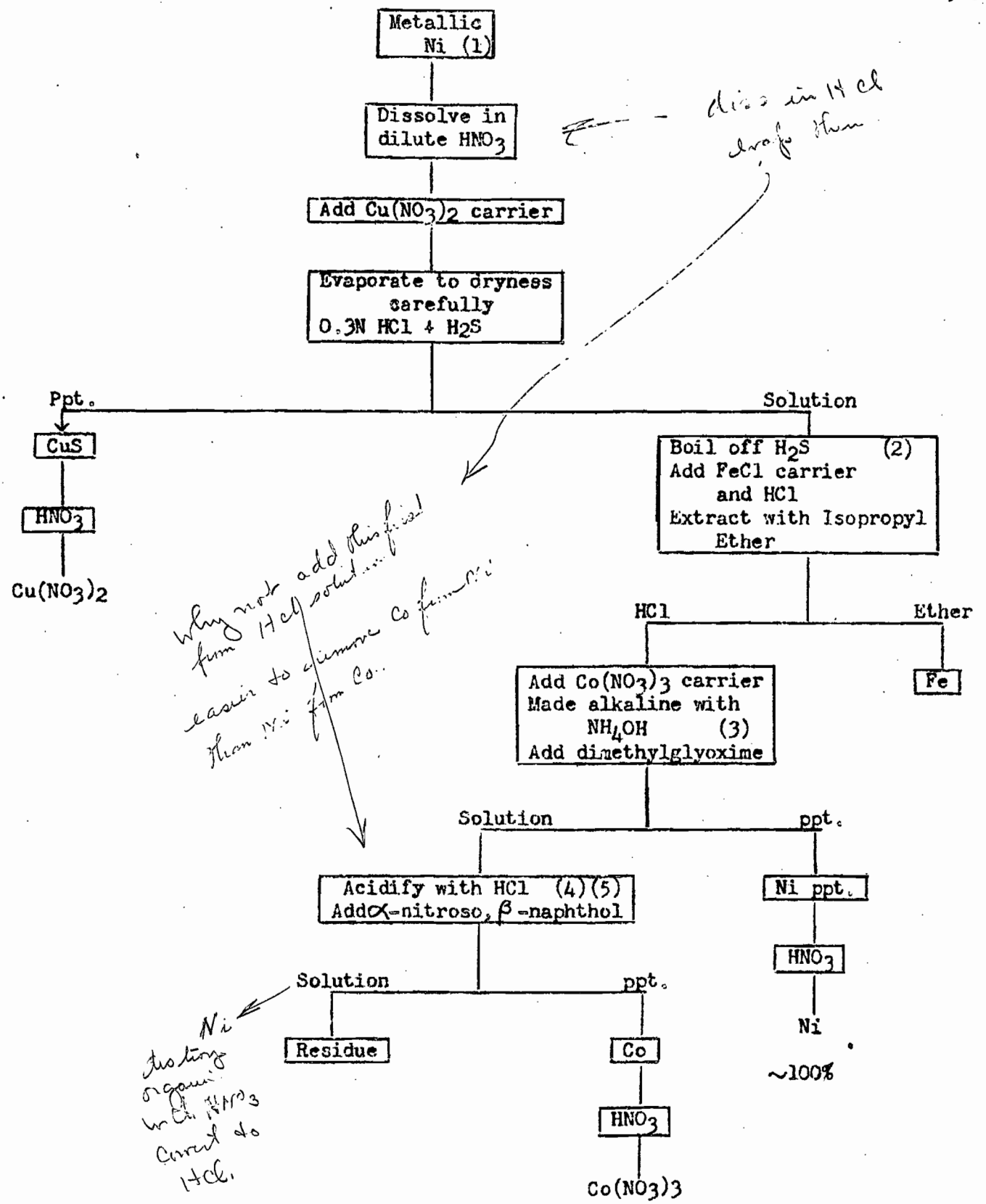
Yield: 2.11 mc/gm Ni/30 day bombardment at 50% maximum flux

Cross-Sections:

σv = 3.37 x 10^3 barns cm/sec
σ = 0.0153 barns per atom normal element
σ = 1.32 barns per atom isotope

Non-Routine Errors: None

Remarks: % chemical recovery figures were not available.


Metallic Ni (1)
Dissolve in dilute HNO_3
diss in HCl drop them
Add $Cu(NO_3)_2$ carrier
Evaporate to dryness carefully
0.3N HCl + H_2S
Ppt.
Solution
CuS
HNO_3
$Cu(NO_3)_2$
Boil off H_2S (2)
Add FeCl carrier and HCl
Extract with Isopropyl Ether
why not add this first from HCl solution easier to remove Co from Ni than Ni from Co.
HCl
Ether
Fe
Add $Co(NO_3)_3$ carrier
Made alkaline with NH_4OH (3)
Add dimethylglyoxime
Solution
ppt.
Acidify with HCl (4)(5)
Add α-nitroso, β-naphthol
Ni ppt.
HNO_3
Ni
~100%
Solution
ppt.
Ni
destroy organic in HNO_3 convert to HCl.
Residue
Co
HNO_3
$Co(NO_3)_3$

(1) The Ni bombarded contains 0.8% Fe which will become "passive" if subjected to strong oxidizing action. The Ni should therefore be dissolved in cold dilute acid, and evaporated to dryness carefully.

(2) Scott's Standard Methods of Chemical Analysis, pp. 465-466.

(3) Dimethylglyoxine precipitates iron as well as nickel.

(4) α-nitroso, β-naphthol precipitates iron as well as cobalt.

(5) Ibid., p. 314

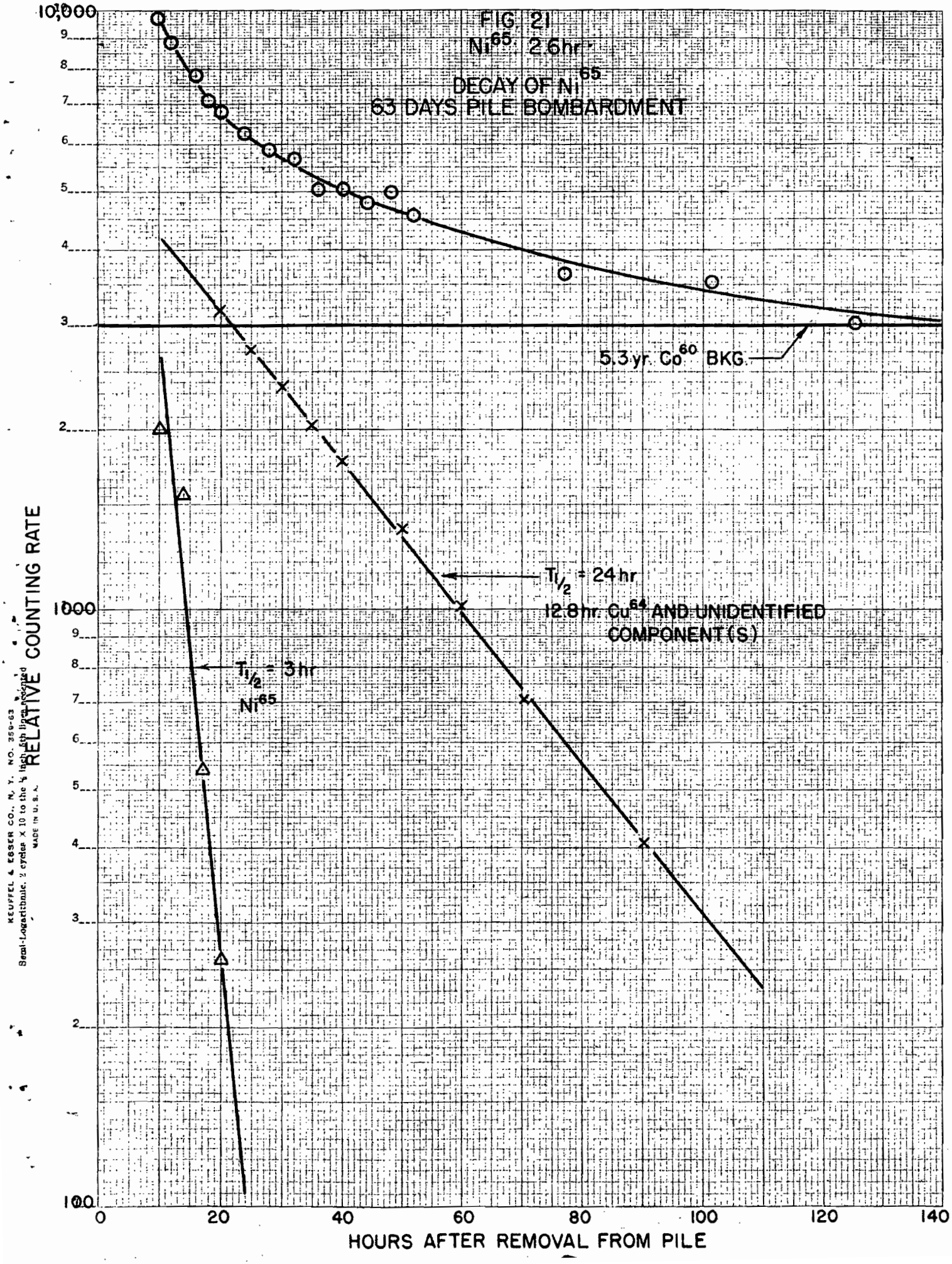
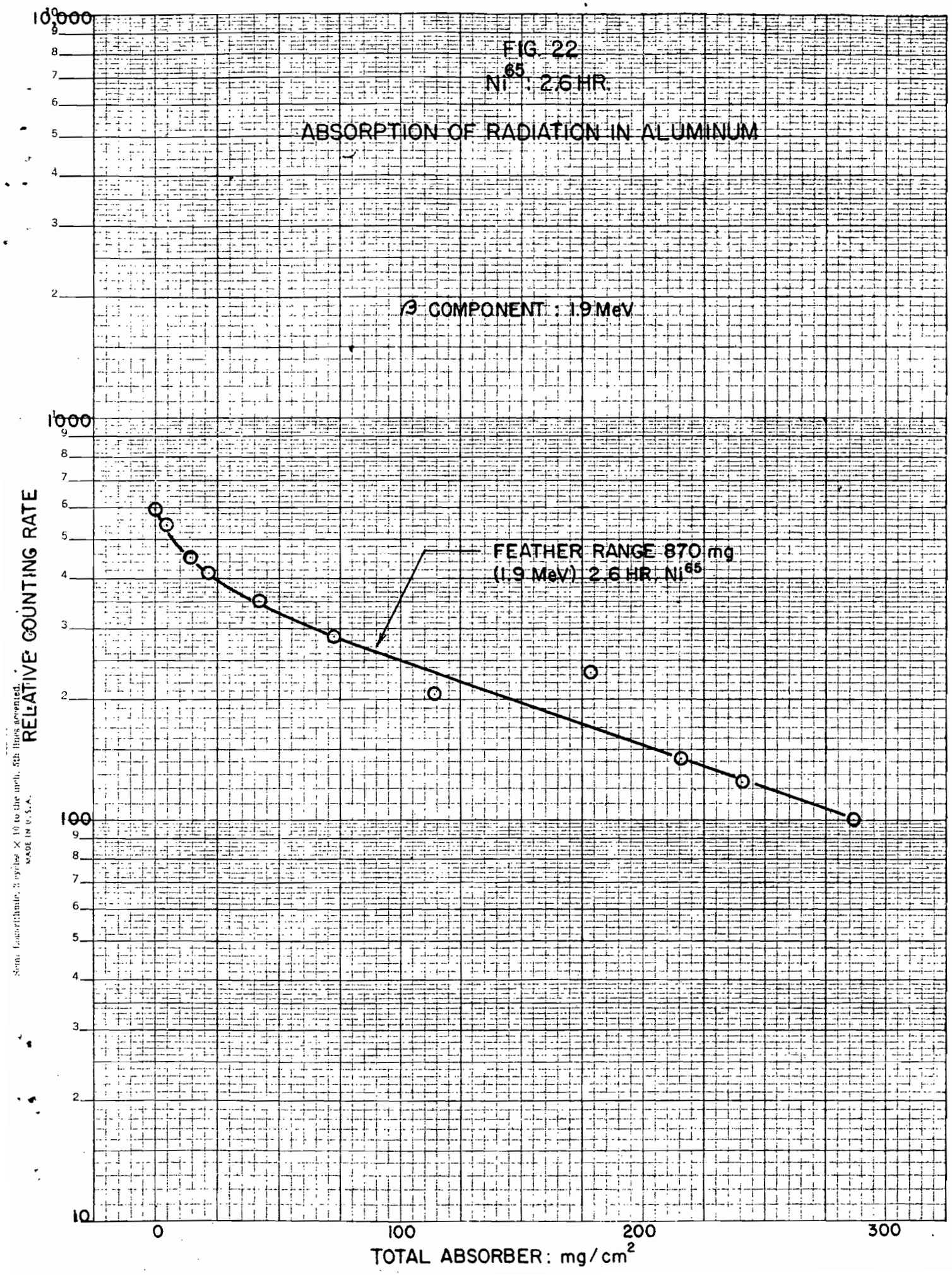


FIG. 21
Ni65 2.6hr
DECAY OF Ni65
63 DAYS PILE BOMBARDMENT
5.3 yr. Co60 BKG.
T1/2 = 24 hr
12.8 hr. Cu64 AND UNIDENTIFIED COMPONENT(S)
T1/2 = 3 hr
Ni65
RELATIVE COUNTING RATE
HOURS AFTER REMOVAL FROM PILE
10,000
1000
100
0
20
40
60
80
100
120
140
KEUFFEL & ESSER CO., N. Y. NO. 359-63
Semi-Logarithmic, 2 cycles X 10 to the ½ inch, 5th line heavy
MADE IN U.S.A.

Drawg. No. 5530



Selenium

Target Material: Selenium powder, General Chemical Co.

Weight: 20.13 g

Spectrographic Impurities:

Al	FT	Mg	T
Ca	T	Si	T

Irradiation: 98 days at nv = 3.1 x 10" n/cm^2/sec

Separations: See diagram.

Activities Found* at T_0 in Bombardment:	Activity per gm. Se
Se^{75} (115d)	15.74 mc

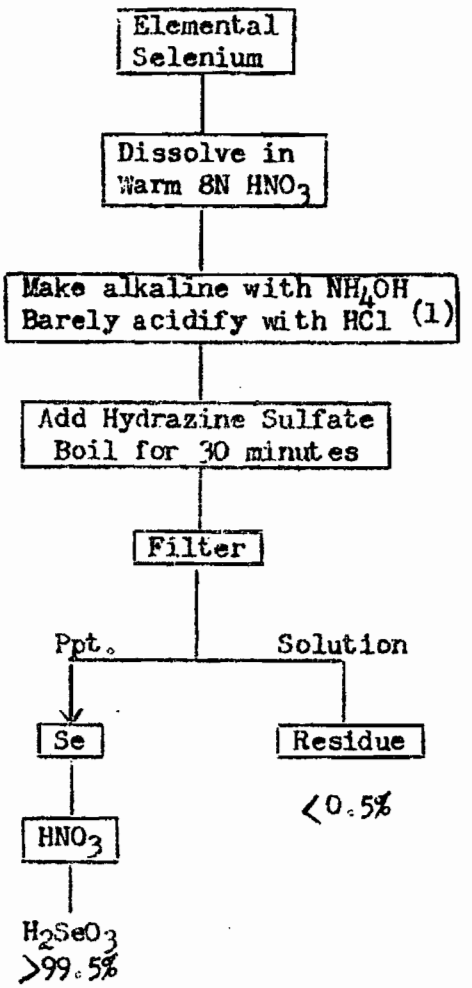
*The above figure was obtained from gamma measurements on the ion chamber; the gamma efficiency was calculated by assuming one 0.335 Mev γ per disintegration. X-rays and γ-rays present make Se^{75} a suitable tracer, but absolute measurement is extremely difficult.

Yields: 9.92 mc/gm Se/30 day bombardment at 50% maximum flux

Cross-Sections:

$\sigma v = 1.29 \times 10^5$ barns cm/sec
$\sigma = 0.586$ barns per atom normal element
$\sigma = 67.4$ barns per atom isotope

Non-Routine Errors: None



(1) Treadwell & Hall, Analytical Chemistry, Vol. II, p. 107.

Drawing No. 5531

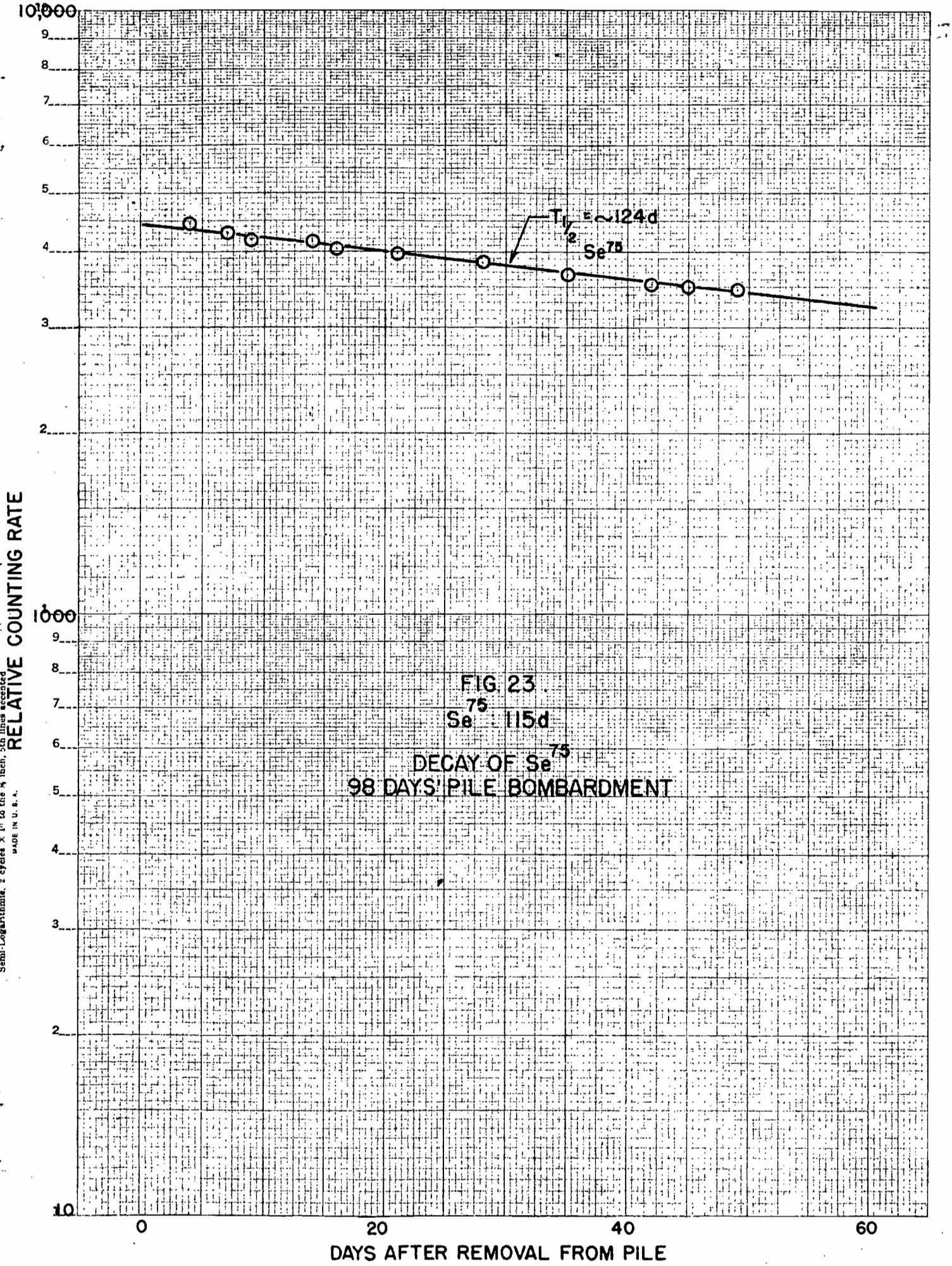


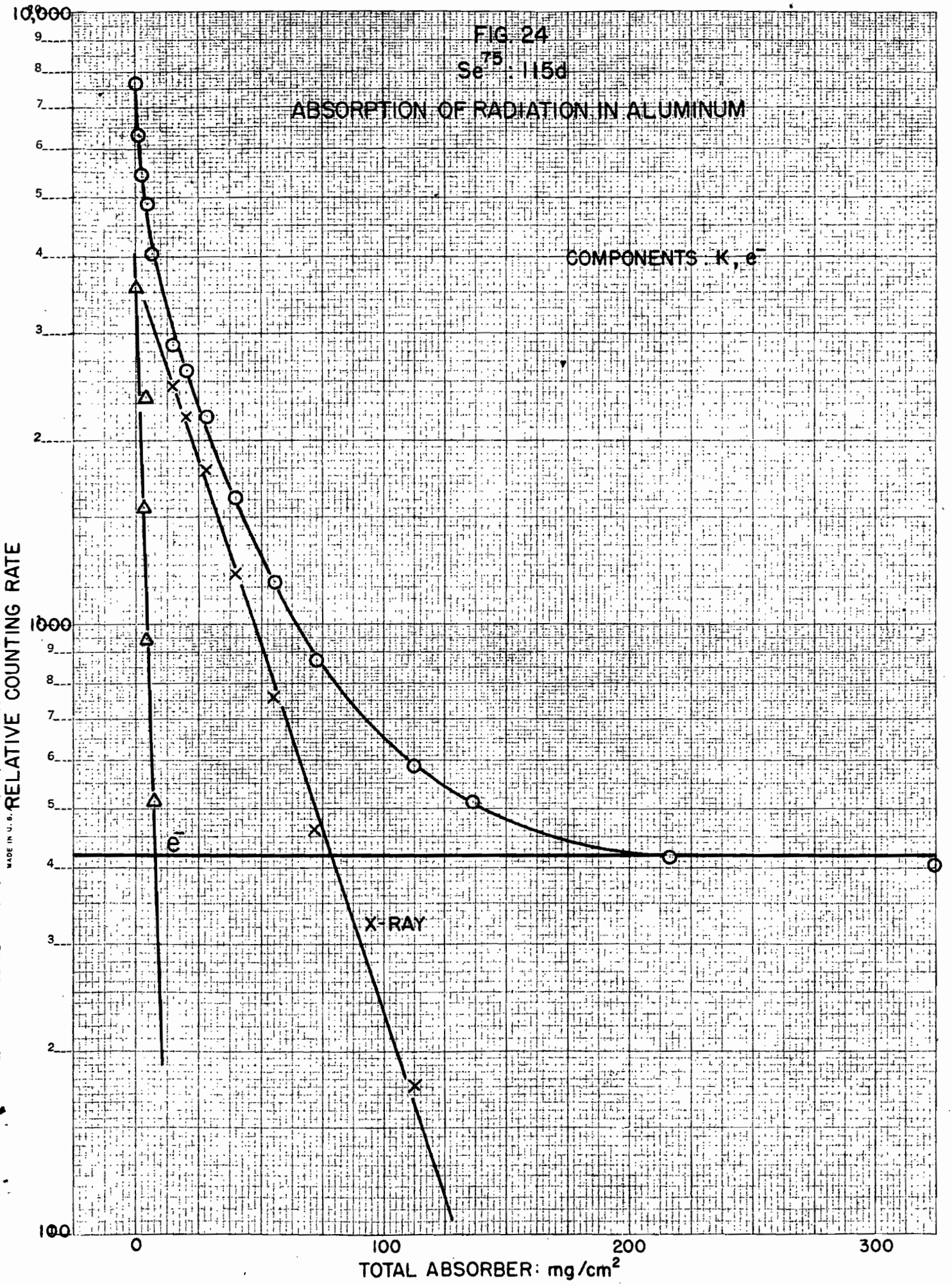
FIG. 23.

Se^{75} : 115d

DECAY OF Se^{75}

98 DAYS' PILE BOMBARDMENT

Drawr. No. 5532



Silver

Target Material: Silver nitrate, crystal, Reagent, General Chemical Co.

Weight: 7.09 gm

Spectrographic Impurities:

Al	FT	Fe	FT
Ca	FT	Mg	T
Cu	T	Si	T

Irradiation: 35 days at nv = 6 x 10" n/cm^2/sec

Separation: See diagram.

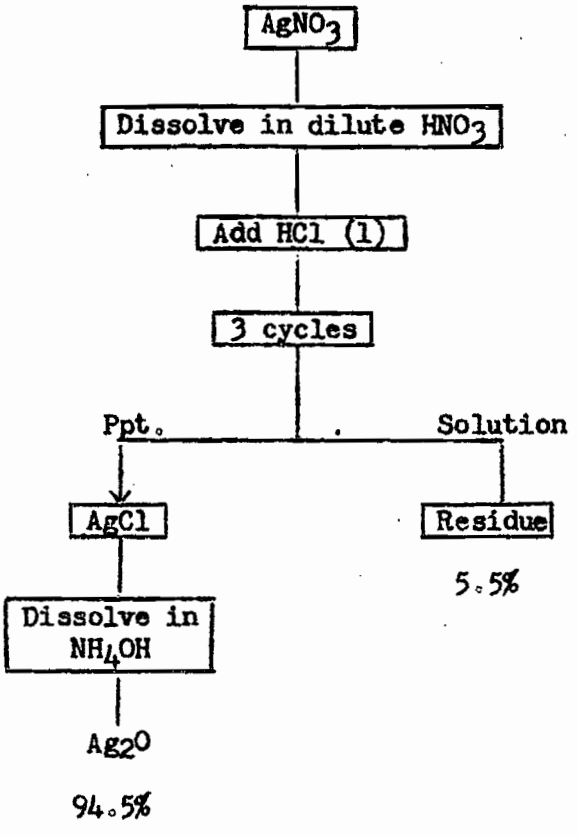
Activity Found at T_o in Bombardment:	Activity per gm. Ag
Ag^{110} (225 d)	3.3 mc

Yield: 2.38 mc/gm Ag/30 day bombardment at 50% maximum flux

Cross-Sections:

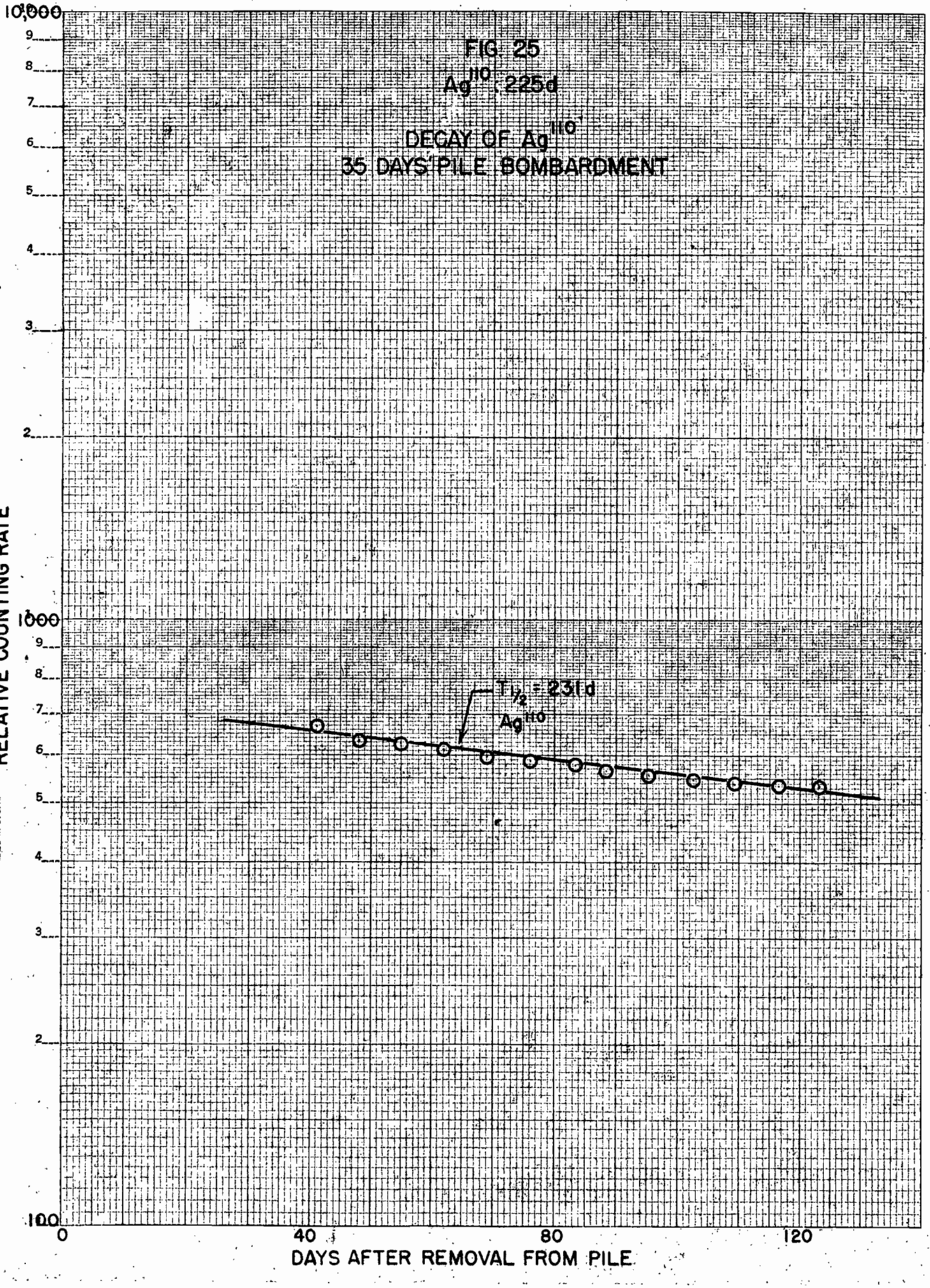
σ v = 7.96 x 10^4 barn cm/sec
σ = 0.36 barns per atom normal element
σ = 0.74 barns per atom isotope

Non-Routine Errors: None

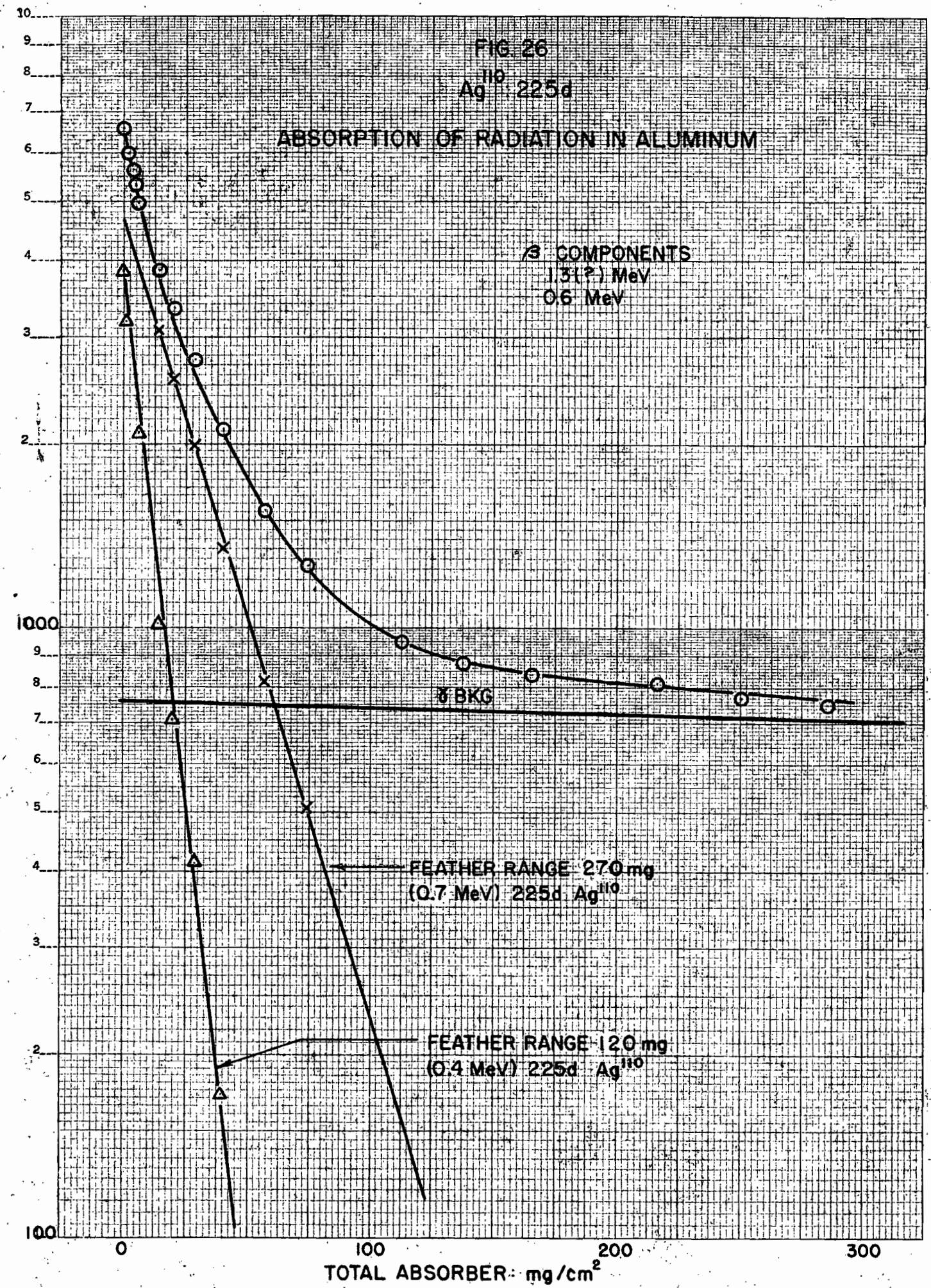


(1) Scott's Standard Methods of Chemical Analysis, p. 818.

Drawg. No. 5533



Drawg. No. 5534



KEUFFEL & ESSER CO., N. Y. NO. 359-62
Semi-Logarithmic, 2 cycles × 10 to the ½ inch, 5th lines accented
MADE IN U.S.A.

Indium

Target Material: Indium Nitrate, C.P., A.D. Mackay

Weight: 0.38 gm

Spectrographic Impurities:

Ag	FT	Cu	FT	Ni	FT
Al	FT	Fe	VW	Pb	FT
Be	FT	Mg	T	Si	FT
		Na	FT		

Irradiation: 27 days at nv = 5.2 x 10" n/cm^2/sec

Separations: See diagram

Activity Found at T_0 in Bombardment: **Activity per gm. In**

In^{114} (48 d)* 19.4 mc

Unidentified impurity with 0.7 Mev γ is present in small quantities

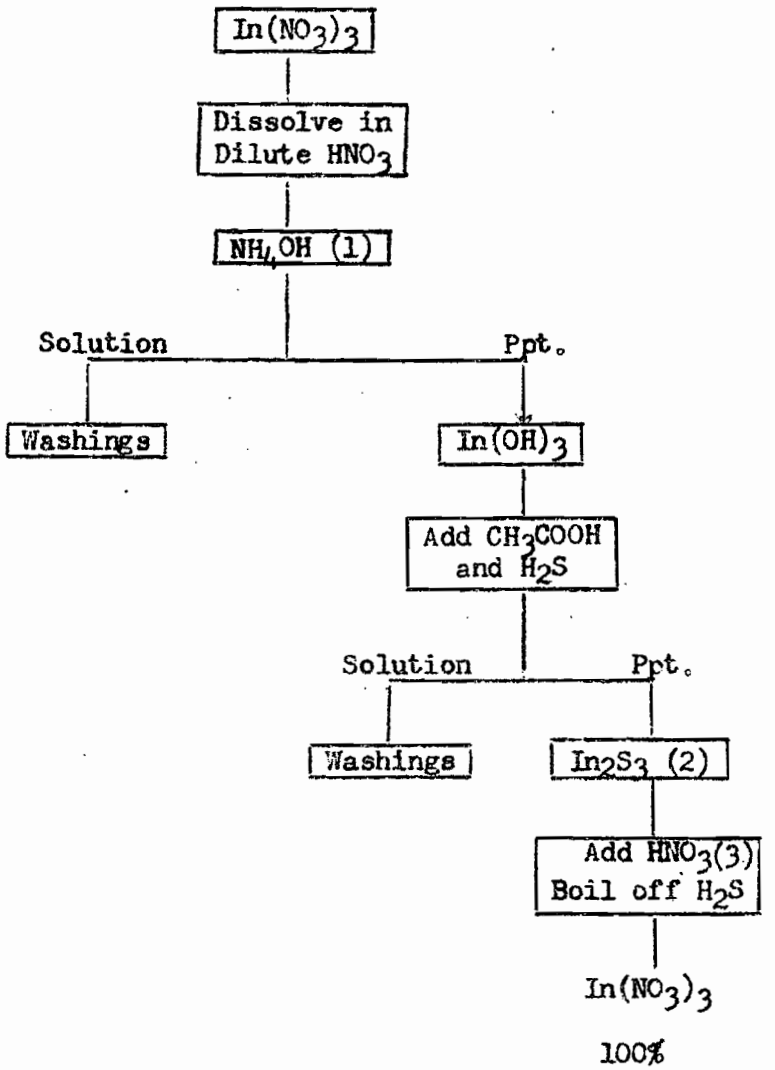
* 0.19 γ is apparently 100% converted

Yield: 20.4 mc/gm In/30 day bombardment at 50% maximum flux

Cross-Sections:

σ v = 1.80 x 10^5 barns cm/sec
σ = 0.82 barns per atom normal element
σ = 19.4 barns per atom isotope

Non-Routine Errors: None



(1) Noyes and Bray, Qualitative Analysis for the Rare Elements, p. 193

(2) In_2S_3 precipitates rapidly and finely from a 6N acetic acid solution, more slowly and flocculently from a more dilute solution.

(3) $InCl_3$ is somewhat volatile, so HNO_3 is to be preferred to HCl for dissolving the In_2S.

Drawg. No. 5535

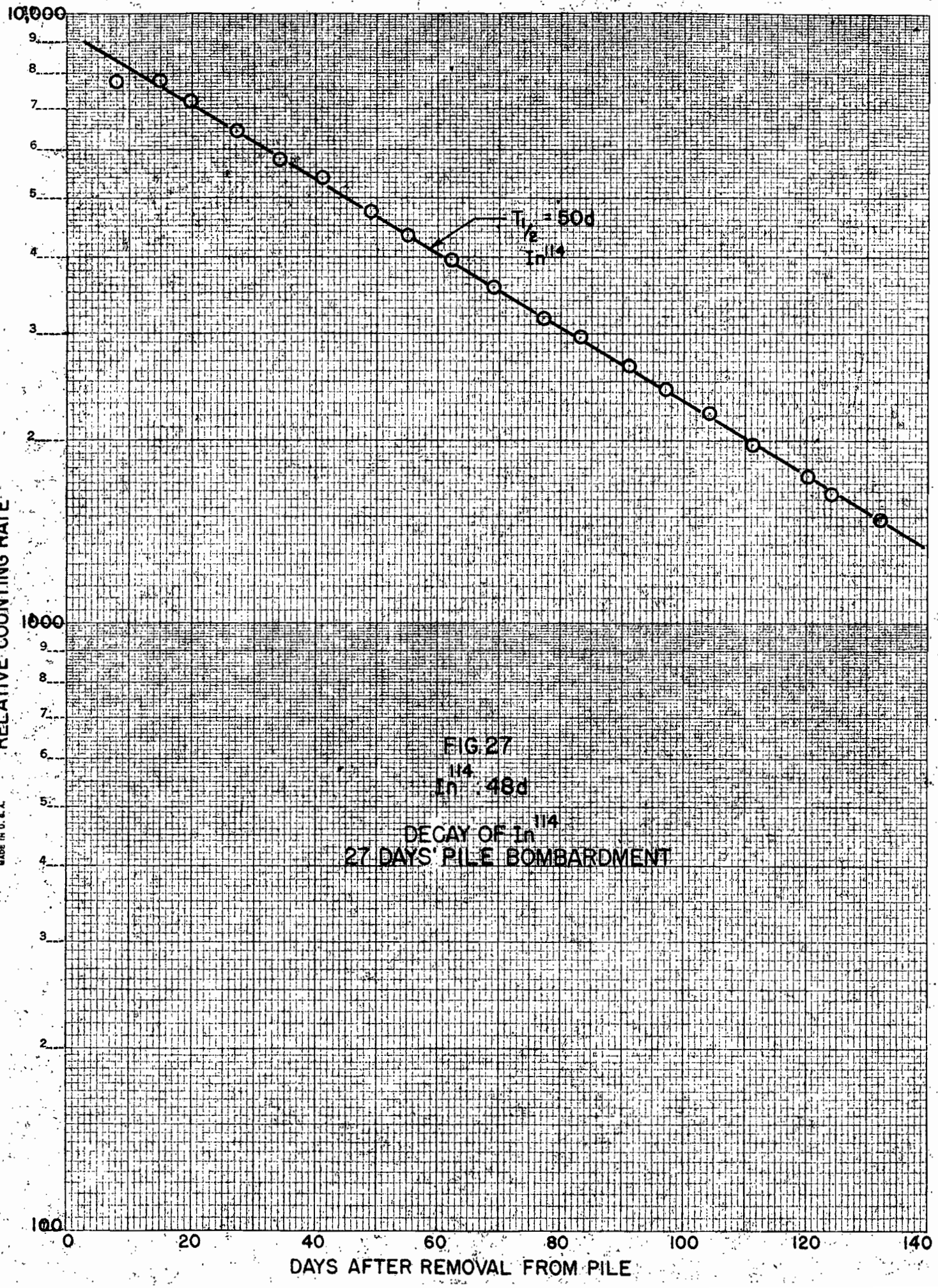


FIG. 27

In^{114} .48d

DECAY OF In^{114}
27 DAYS' PILE BOMBARDMENT

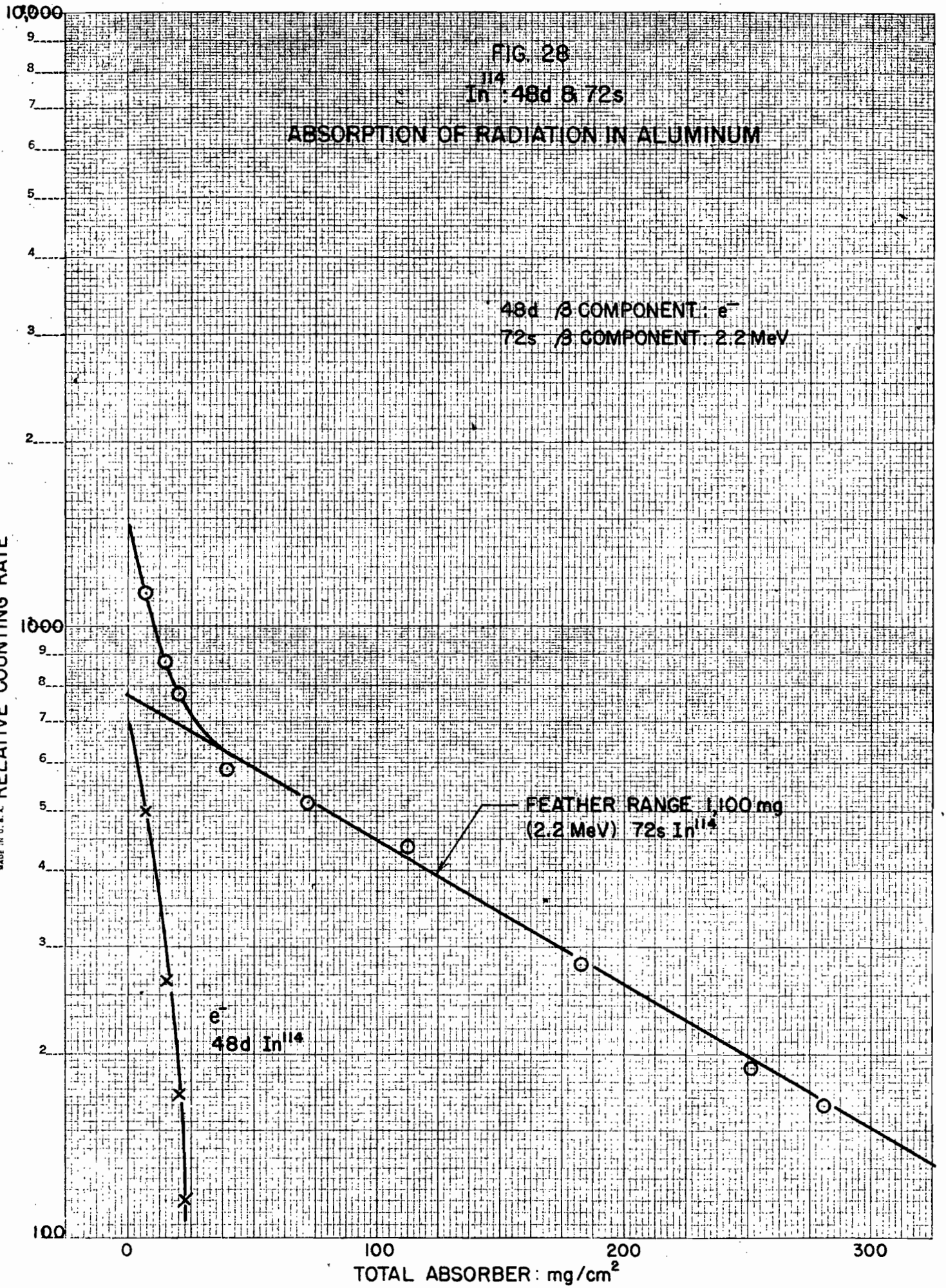
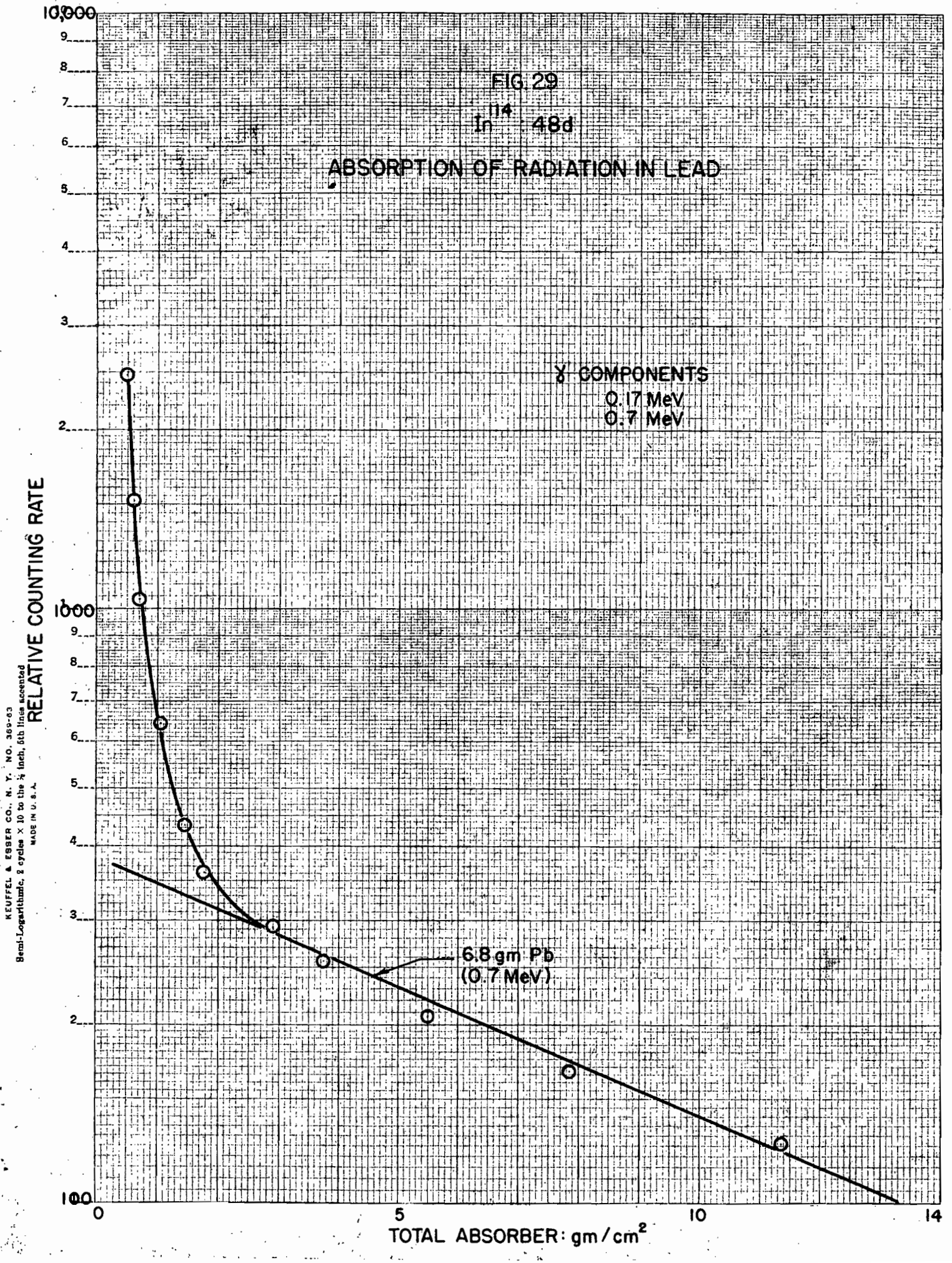


FIG. 28
In114 : 48d & 72s
ABSORPTION OF RADIATION IN ALUMINUM
48d β COMPONENT: e−
72s β COMPONENT: 2.2 MeV
FEATHER RANGE 1,100 mg
(2.2 MeV) 72s In114
e−
48d In114
RELATIVE COUNTING RATE
TOTAL ABSORBER: mg/cm2
10,000
1000
100
0
100
200
300
KEUFFEL & ESSER CO., N. Y. NO. 359-83
Semi-Logarithmic, 2 cycles X 10 to the ½ inch, 5th line accented
MADE IN U.S.A.

Drawg. No. 5537



Cadmium

Target Material: Mossy cadmium metal, General Chemical Company

Weight: 1.03 gm

Spectrographic Impurities:

Ag	VFT	Fe	VFT
Ca	FT	Mg	T
Cu	T	Pb	T
Si	VFT		

Irradiation: 27 days at nv = 4.51 x 10" n/cm^2/sec

Separations: See diagram.

Activities Found at T_0 in Bombardment	% Total Activity	Activity per gm. Cd	ppm Impurities
Cd^{115} (2.3 d)	96.6%	11.54 mc	
Cd^{115} (43 d)	3.4	0.41	
Cu^{64} (12.8 hr)	< 0.02	< .002	< 3 ppm

Yields:

Cd^{115} (2.3 d) 12.80 mc/gm Cd/30 day bombardment at 50% maximum flux
Cd^{115} (43 d) 0.456 mc/ " " " " " " " " "

Cross-Sections:

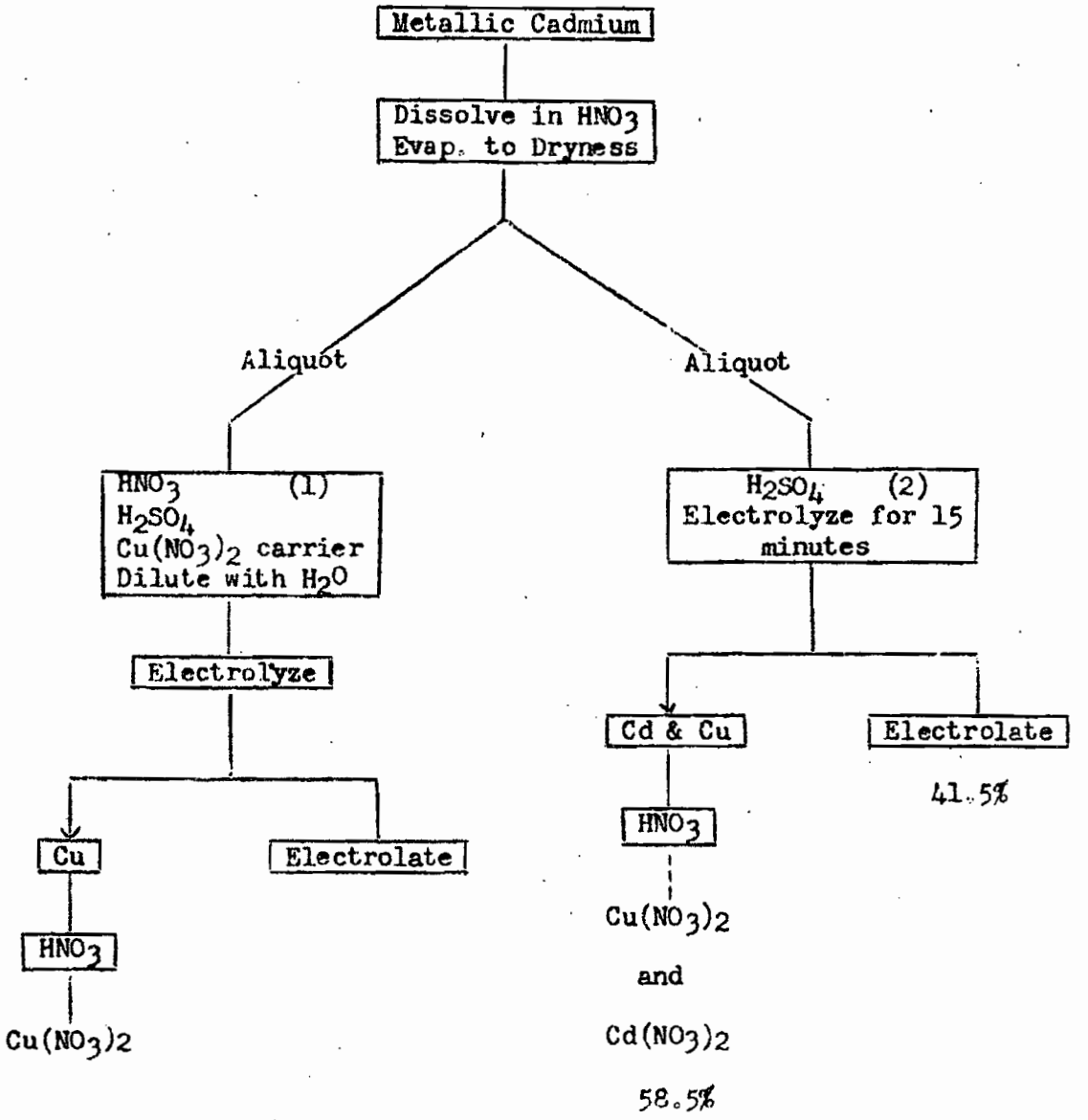
43 d Cd^{115}:

$\sigma v = 3.96 \times 10^3$ barns cm.sec
$\sigma = 0.018$ barns per atom normal element
$\sigma = 0.064$ barns per atom isotope

2.3 d Cd^{115}:

$\sigma v = 3.92 \times 10^4$ barns cm/sec
$\sigma = 0.178$ barns per atom normal element
$\sigma = 0.634$ barns per atom isotope

Non-Routine Errors: None



(1) Kolthoff and Sandell, Textbook of Quantitative Inorganic Analysis, pp. 423-425

(2) Scott's Standard Methods of Chemical Analysis, p. 202

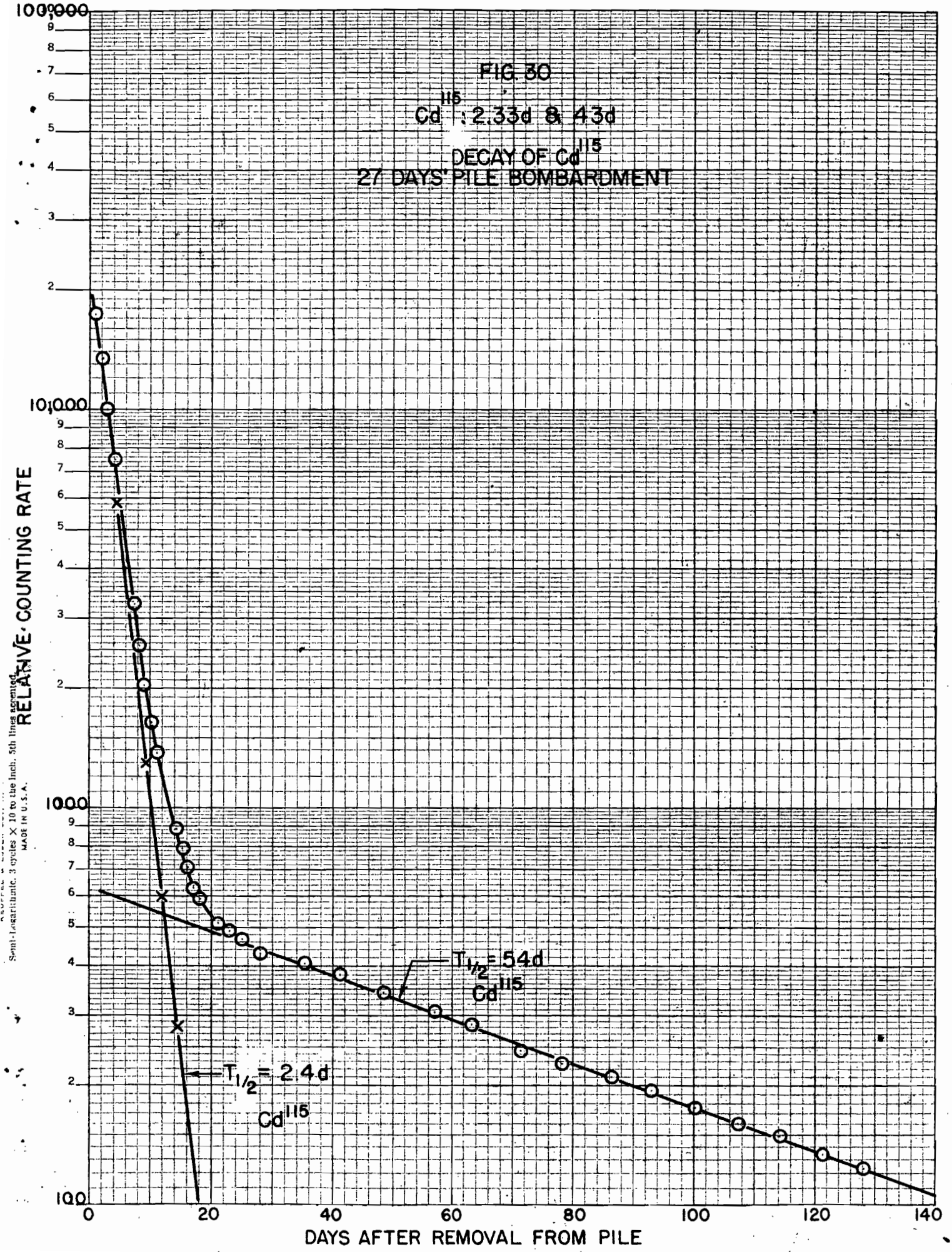
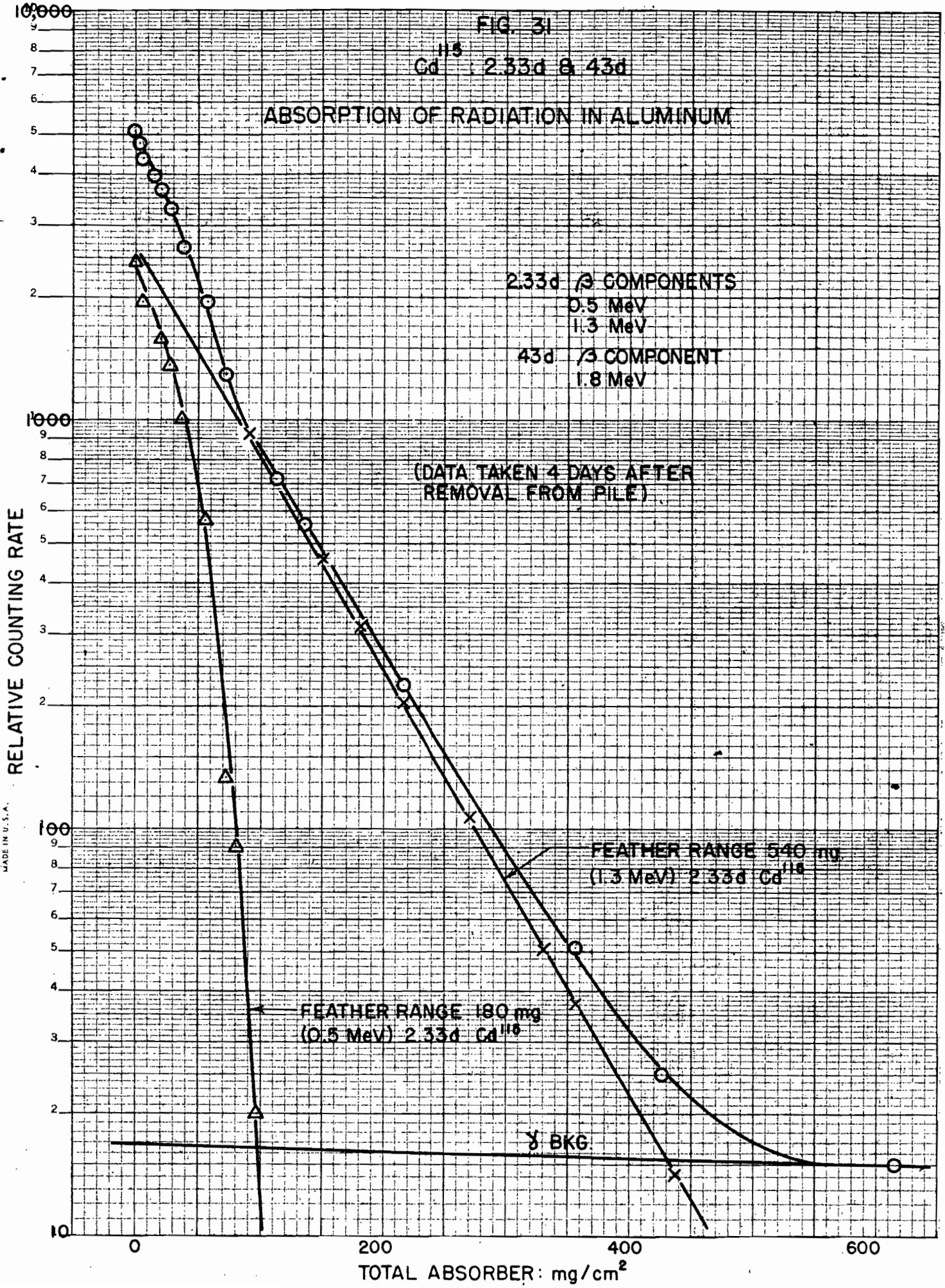


FIG. 30
Cd115 : 2.33d & 43d
DECAY OF Cd115
27 DAYS' PILE BOMBARDMENT
RELATIVE COUNTING RATE
DAYS AFTER REMOVAL FROM PILE
T1/2 = 54d
Cd115
T1/2 = 2.4d
Cd115
100,000
10,000
1000
100
0
20
40
60
80
100
120
140
Semi-logarithmic, 3 cycles × 10 to the inch, 5th lines accented
MADE IN U.S.A.

Drawg. No. 5539



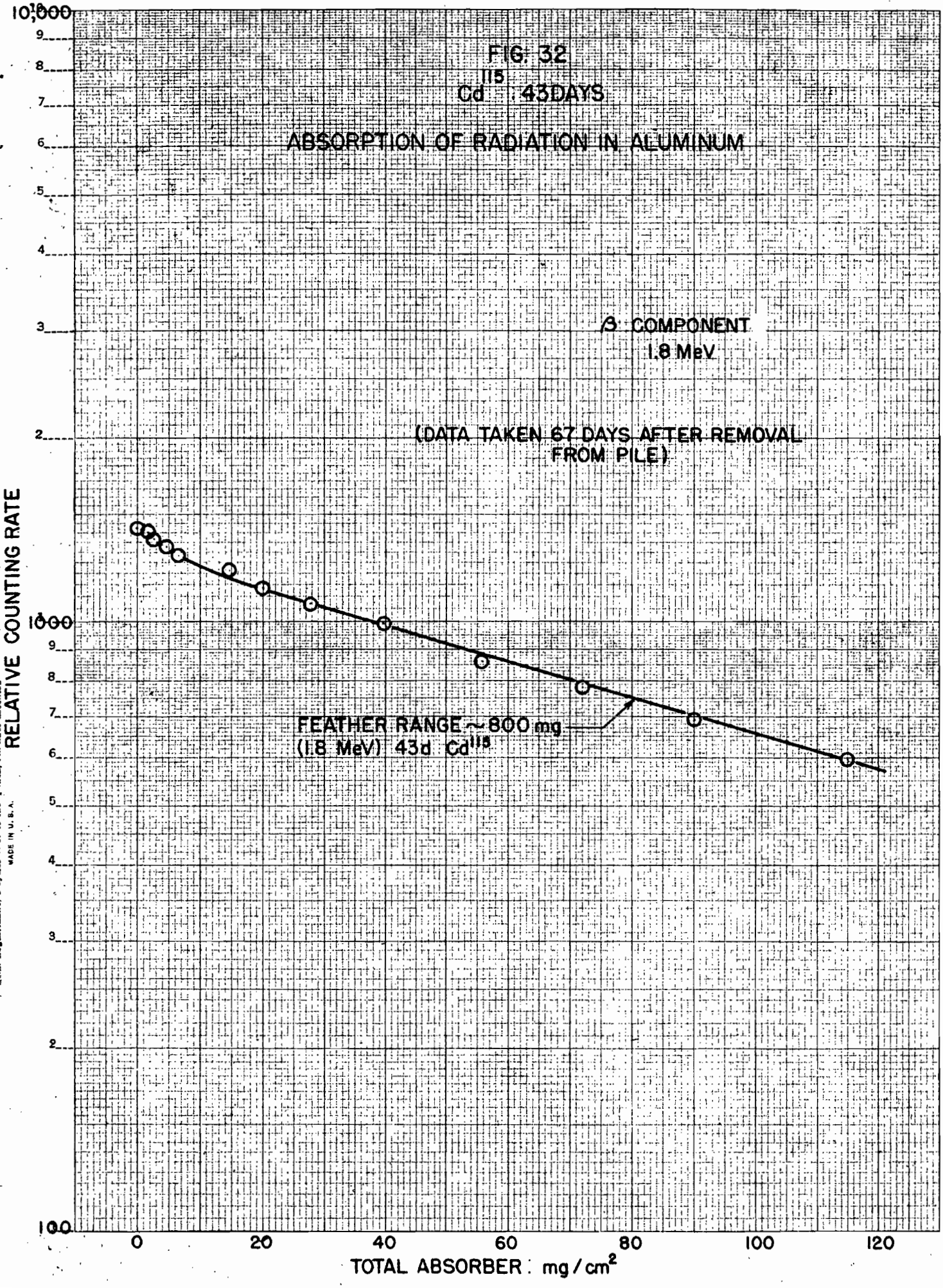
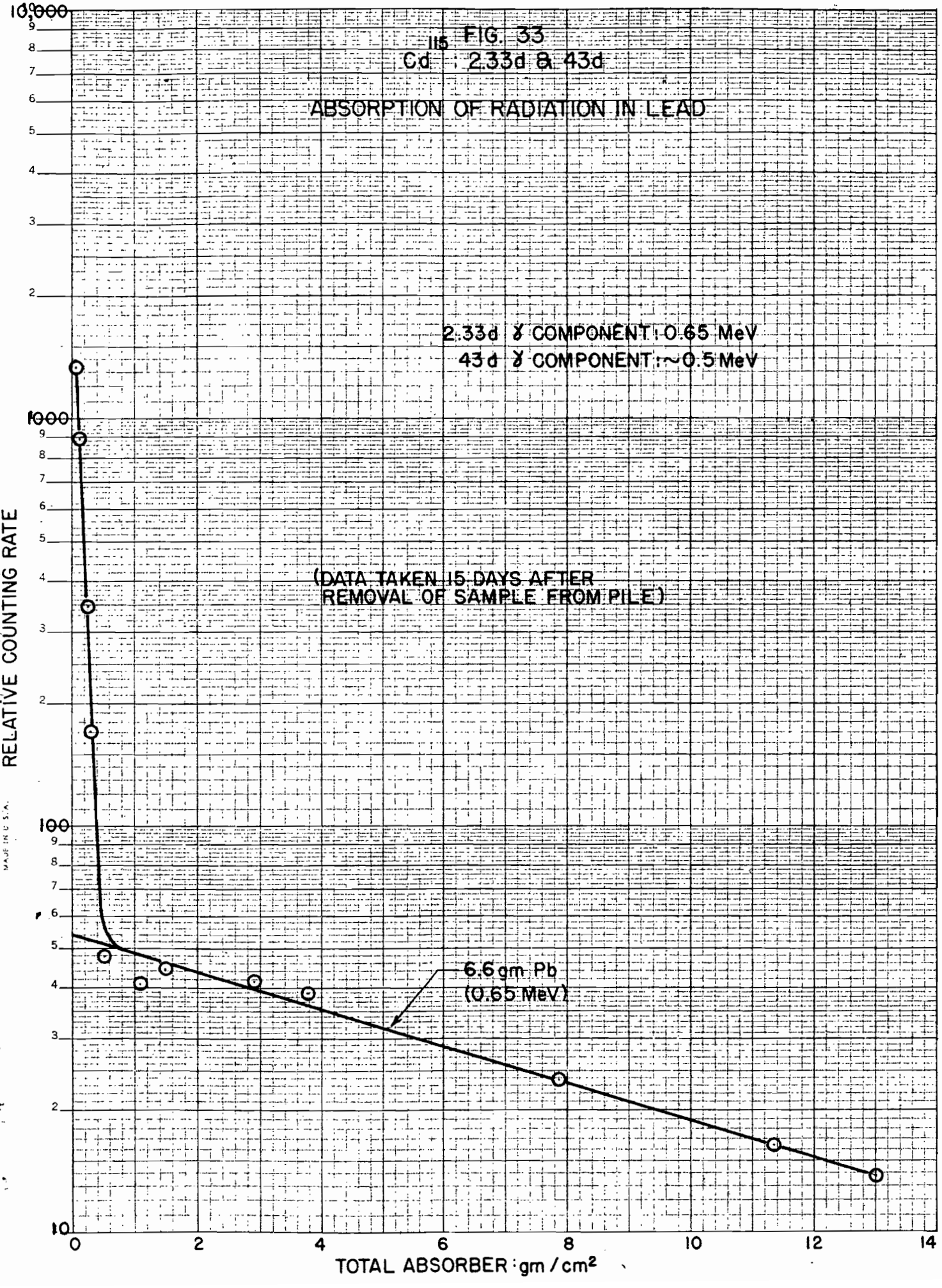


FIG. 32
115
Cd : 43DAYS
ABSORPTION OF RADIATION IN ALUMINUM
β COMPONENT
1.8 MeV
(DATA TAKEN 67 DAYS AFTER REMOVAL FROM PILE)
FEATHER RANGE ~ 800 mg
(1.8 MeV) 43d Cd115
RELATIVE COUNTING RATE
TOTAL ABSORBER : mg / cm2
10,000
1000
100
0
20
40
60
80
100
120
KEUFFEL & ESSER CO., N. Y. NO. 359-63
Semi-Logarithmic, 2 cycles X 10 to the ½ inch, 5th lines accented
MADE IN U. S. A.

Drawg. No. 5541



Antimony

Target Material: Antimony metal, Lump, C. P. Baker's

Weight: 0.206 g

Spectrographic Impurities:

Ag	T+	Ni	T
Cu	T	Pb	VW
Fe	T	Si	FT
Mg	FT		

Irradiation: 28 days at nv = 8.34 x 10" n/cm^2/sec

Separations: The antimony was dissolved in aqua regia, made up to 25 ml., and aliquots were taken.

Activities Found at T_0 in Bombardment	Activity per gm Antimony
Sb^{124} (60 day)	54.9 mc

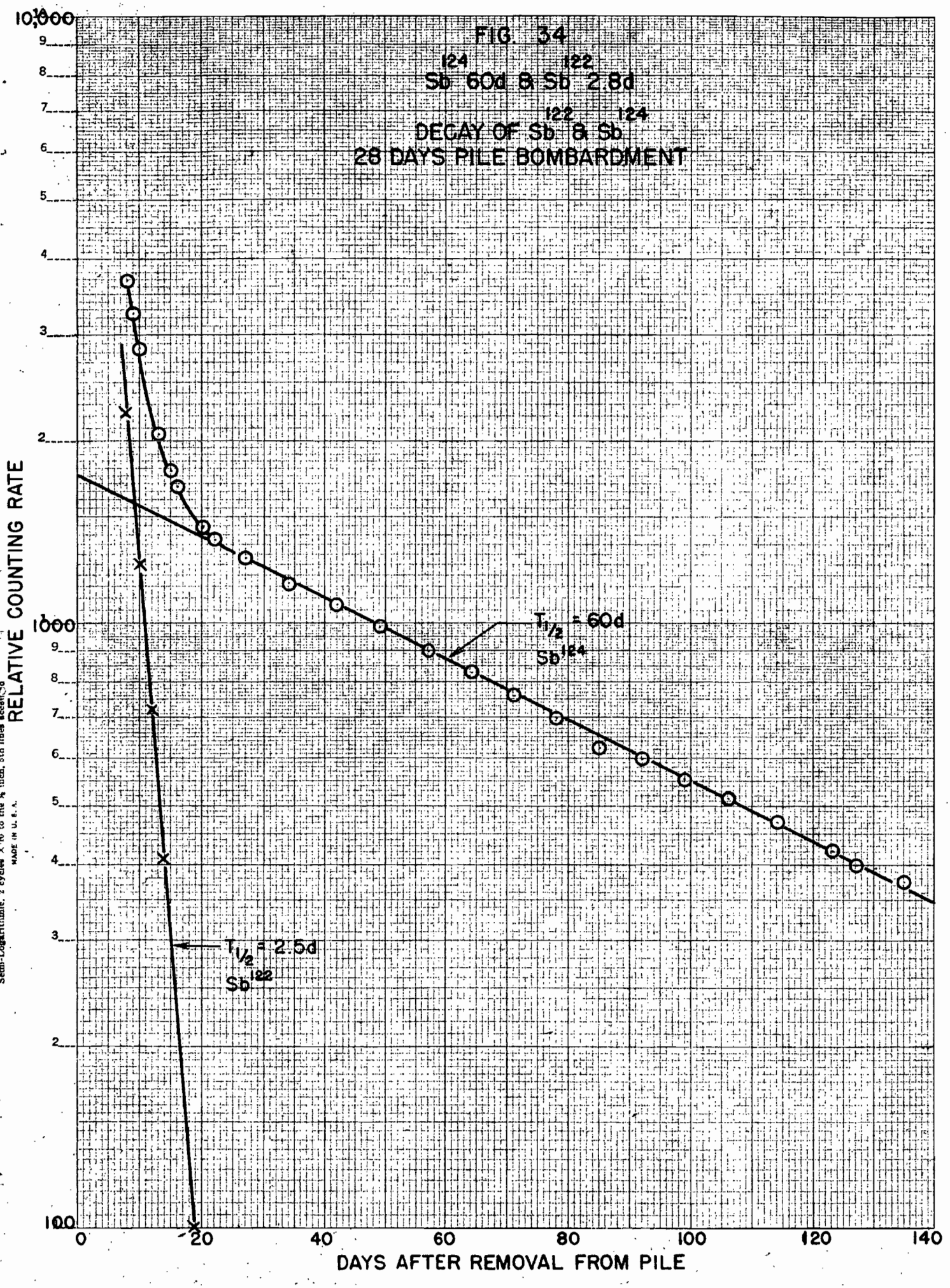
Yield: 34.8 mc/gm Sb/30 day bombardment at 50% maximum flux

Cross Sections:

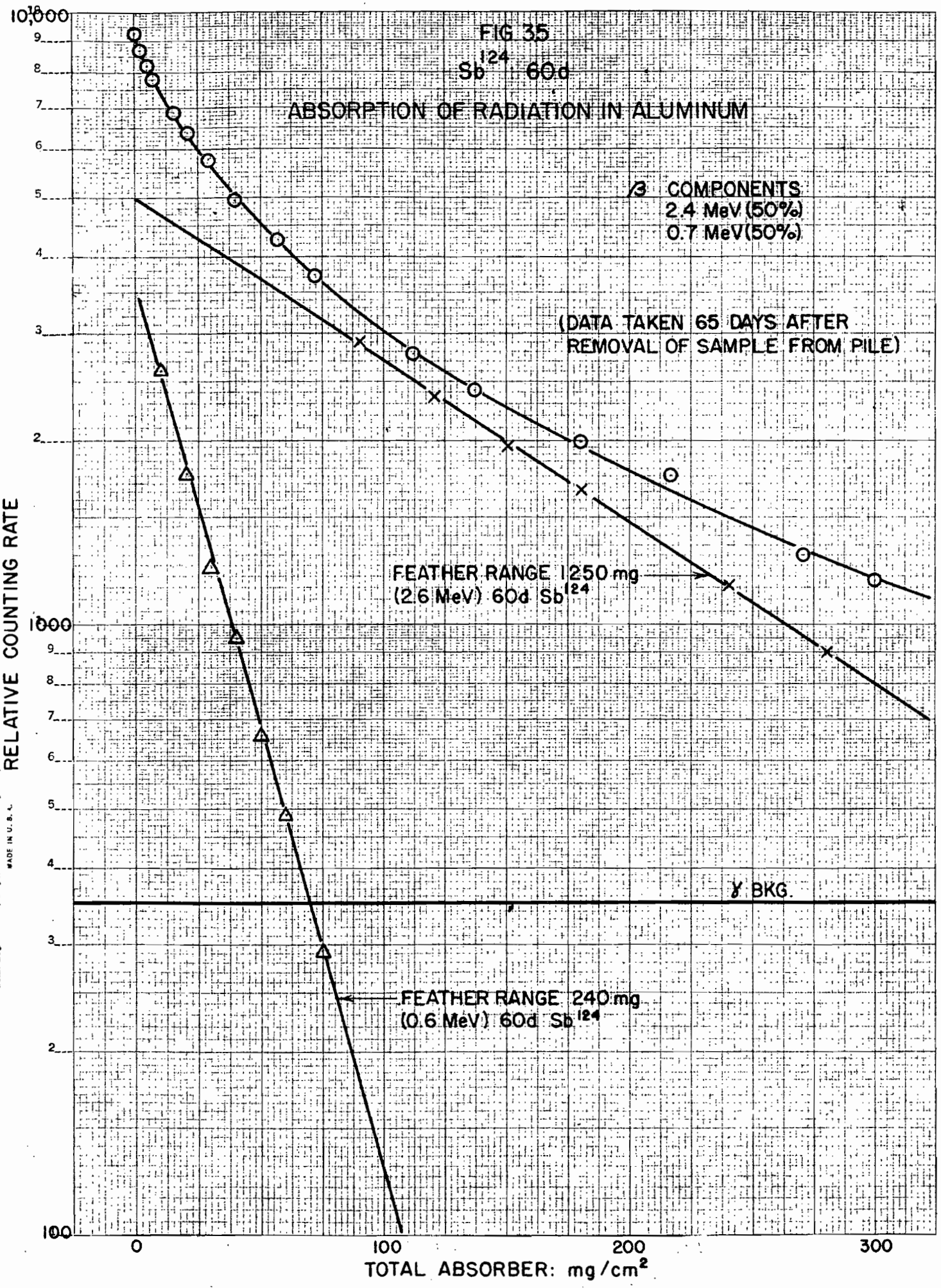
$\sigma v = 4.0 \times 10^5$ barns cm/sec
$\sigma = 1.82$ barns per atom element
$\sigma = 4.26$ barns per atom isotope

Non-Routine Errors: None

Drawg. No. 5542



Drawg. No. 5543



Europium

Target Material: Europium Oxalate

Weight: 0.0112 g

Spectrographic Impurities:

Ca	T	Cd	T	Mg	T

Irradiation: 31 days at 3.17 x 10" n/cm^2/sec

Separations: Dissolved the sample in 10N HNO_3, made it up to 10 ml, and took an aliquot with which to work.

Activities Found at T_0 in Bombardment:	Activity per gm Eu
Eu^{154} (6.3 y)	170 mc

Yield: 268 mc/g/30d bombardment at 50% maximum flux

Cross-Sections:

σ V = 1.13 x 10^8 barns cm/sec
σ = 514 barns per atom normal element
σ = 1010 barns per atom isotope

Non-Routine Errors: None

Remarks: The 2.0 MeV β radiation shown in Fig. 27 indicates presence of 9.2 hr Eu^{152}.

Drawg. No. 5544

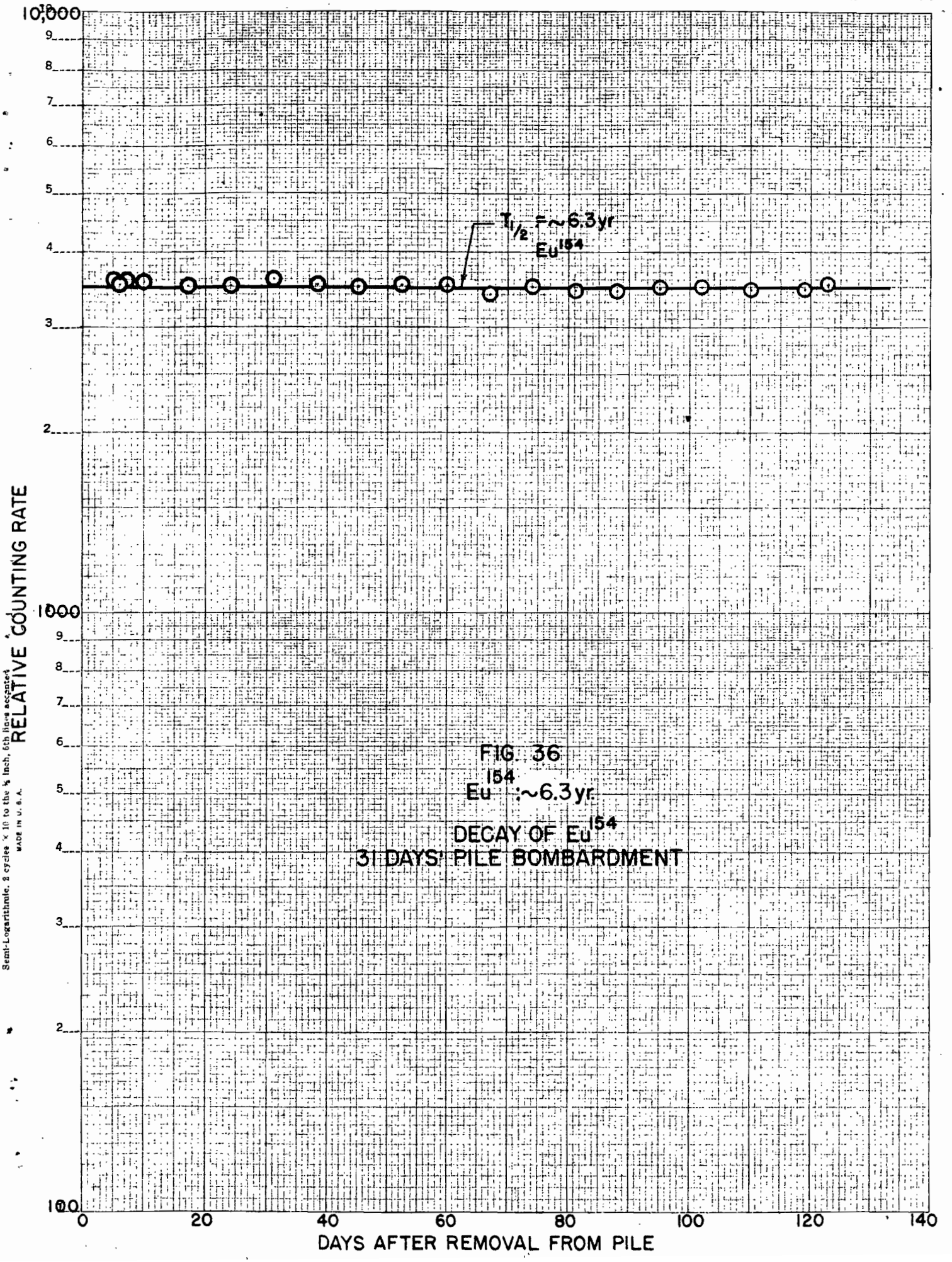


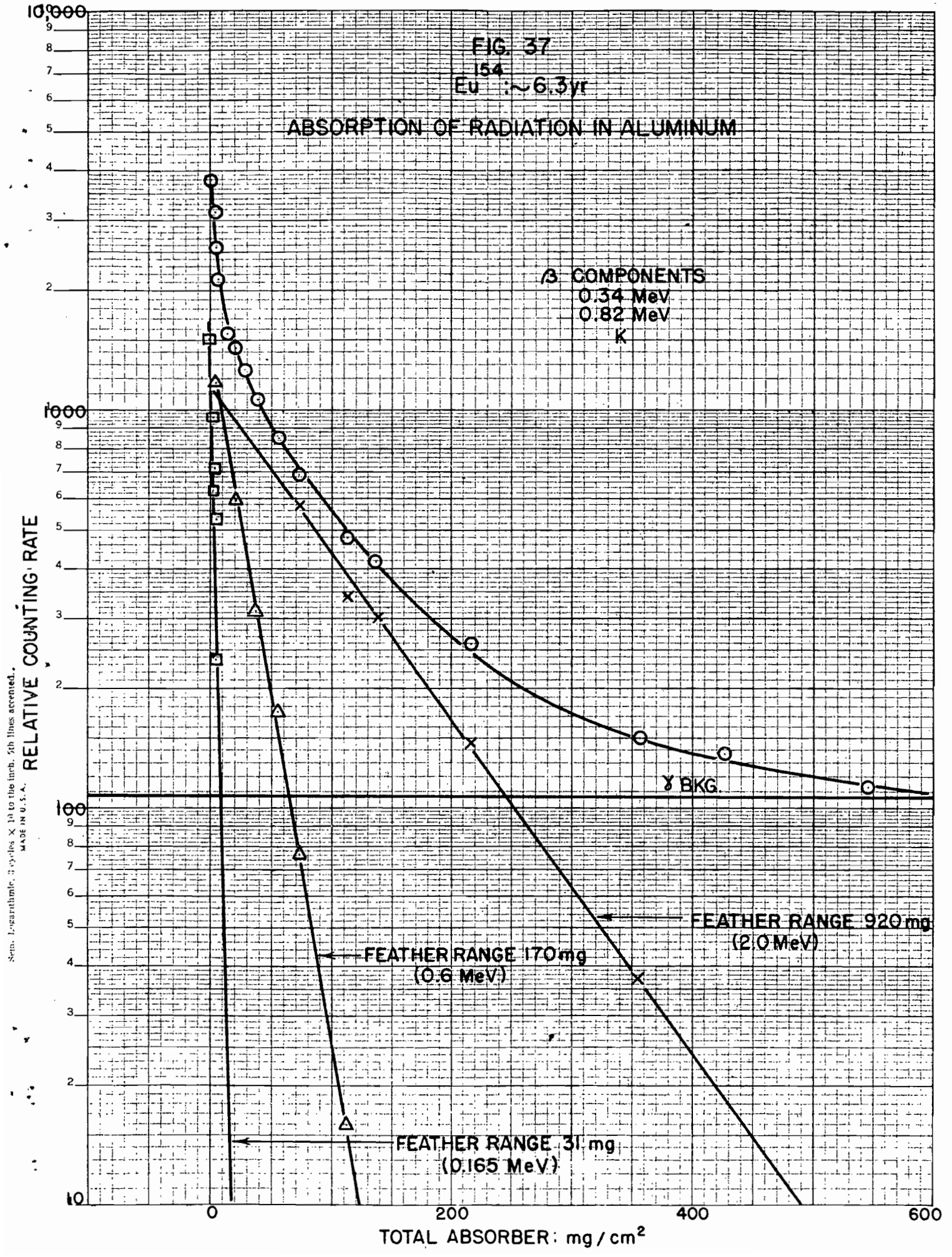
FIG. 36

Eu^{154} :~6.3 yr.

DECAY OF Eu^{154}

31 DAYS' PILE BOMBARDMENT

Drawg. No. 5545



Semi-Logarithmic, 3 cycles X 10 to the inch, 5th lines accented.
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Tantalum

Target Material: Tantalum tetraoxide, C.P., City Chemical Corp.

Weight: 0.22 gm

Spectrographic Impurities:

Al	FT	Mg	T
Ca	FT	Mo	T
Cu	FT	Si	T
Fe	FT	Ti	W

Irradiation: 83 days at nv = 5.7 x 10" n/cm^2/sec

Separations: The sample was dissolved by two successive fusions with KOH in a nickel crucible. This flux dissolved the sample far more readily than did $KHSO_4$. The melt was dissolved in H_2O, made up to volume, and an aliquot taken(1).

---

(1) A Textbook of Inorganic Chemistry, Vol. 6, pt. 3, p. 125

Activity Found at T_o in Bombardment	Activity per gm Ta
Ti^{51} (72 d)	319 mc*

* based on 0.53 Mev β .

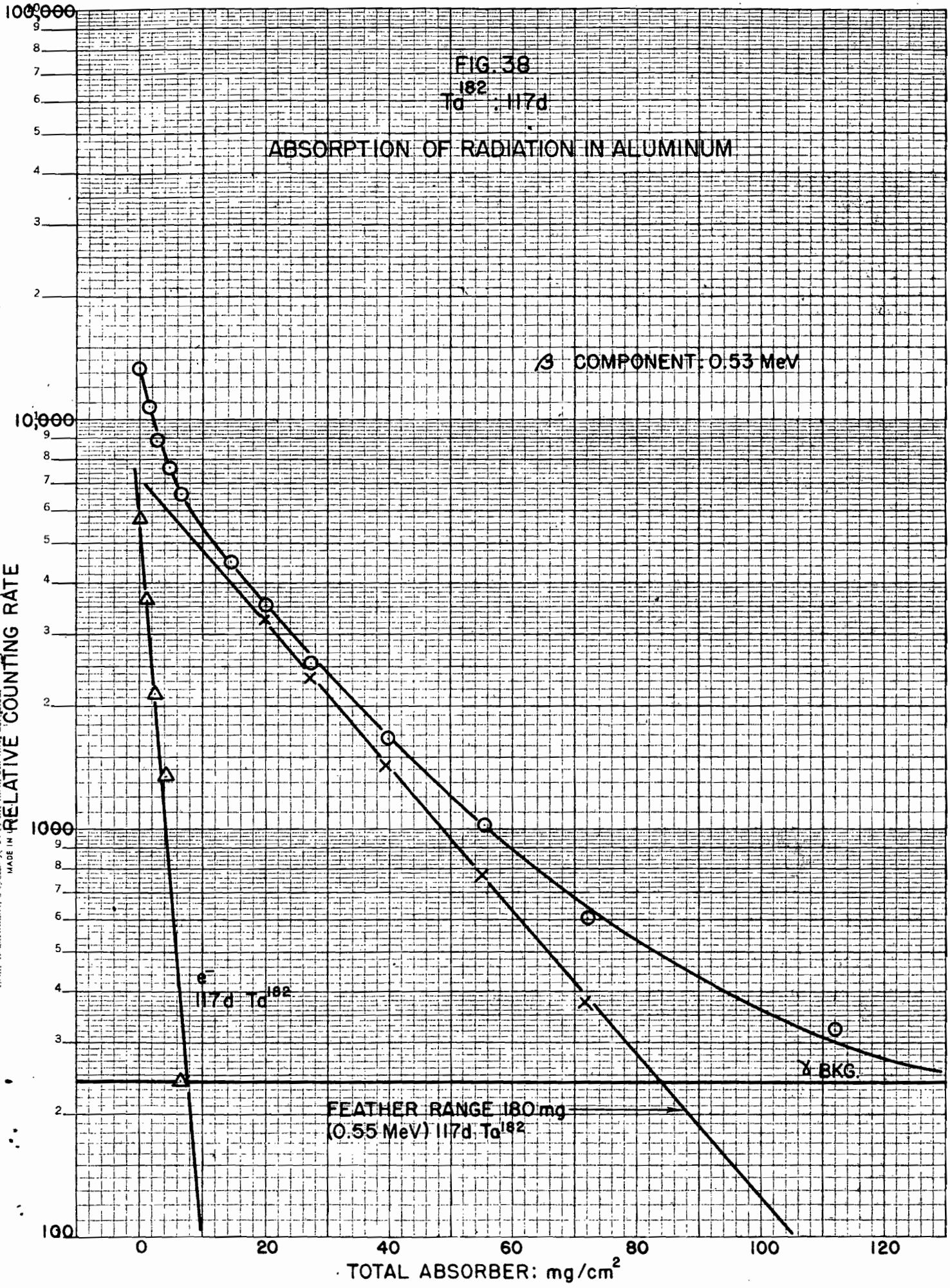
Yield: 121.0 mc/gm Ta/30 day bombardment at 50% maximum flux

Cross-Sections:

σ v = 3.54 x 10^6 barns cm/sec
σ = 16.1 barns per atom normal element
σ = 16.1 barns per atom isotope

Non-Routine Errors: None

Drawg. No. 5546



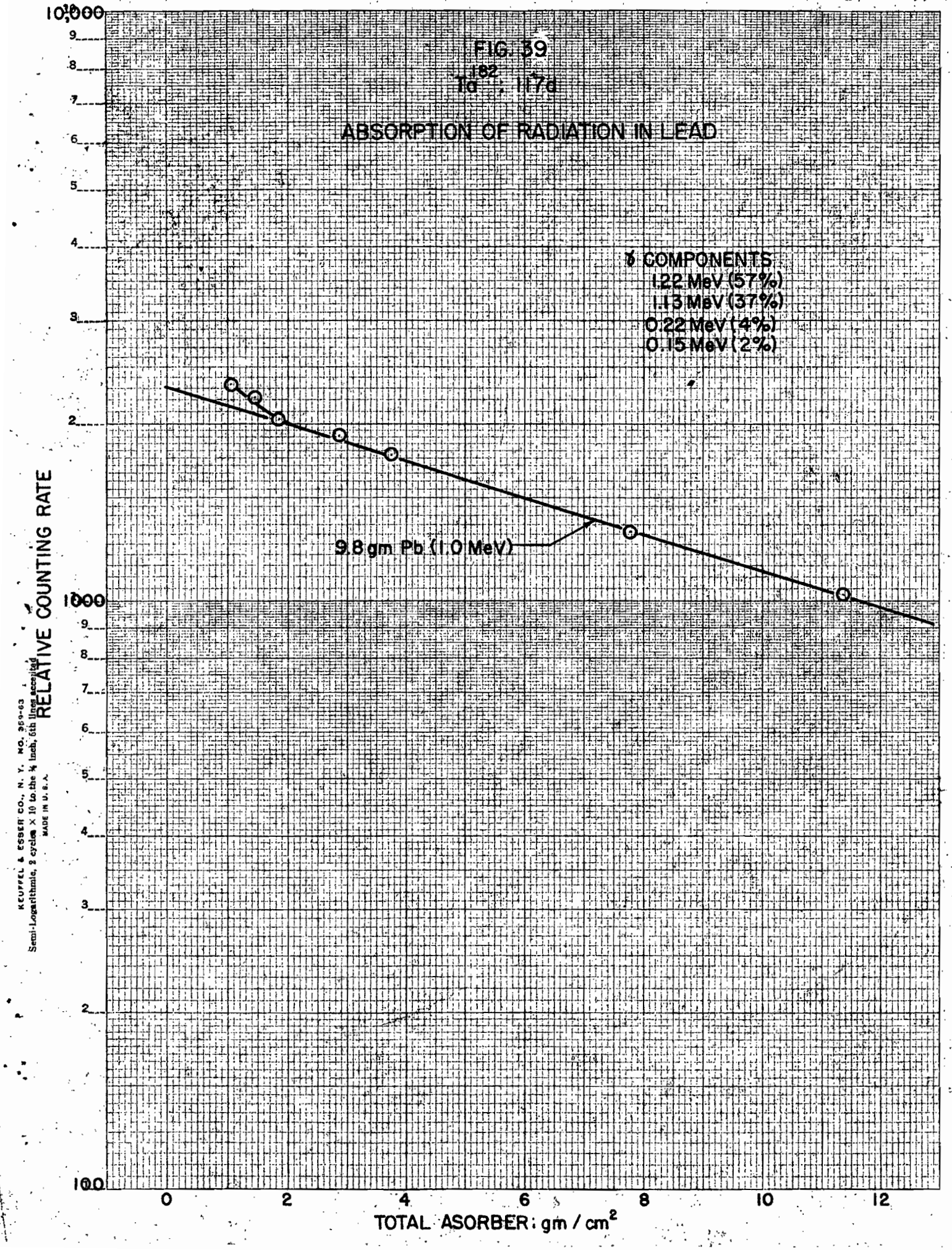


FIG. 39
Ta^{182} : 117d
ABSORPTION OF RADIATION IN LEAD
γ COMPONENTS
1.22 MeV (57%)
1.13 MeV (37%)
0.22 MeV (4%)
0.15 MeV (2%)
9.8 gm Pb (1.0 MeV)
RELATIVE COUNTING RATE
10,000
1000
100
TOTAL ASORBER: gm / cm²
0
2
4
6
8
10
12
KEUFFEL & ESSER CO., N. Y. NO. 359-63
Semi-Logarithmic, 2 cycles × 10 to the ½ Inch, 5th lines accented
MADE IN U.S.A.

Tungsten

Target Material: Tungsten trioxide, C. P., Fisher Scientific Company

Weight: 1.80 gm

Spectrographic Impurities:

Ca	FT	Mo	T
Fe	VFT	Si	W

Irradiation: 69 days at nv = 3.2 x 10" n/cm^2/sec

Separations: See diagram.

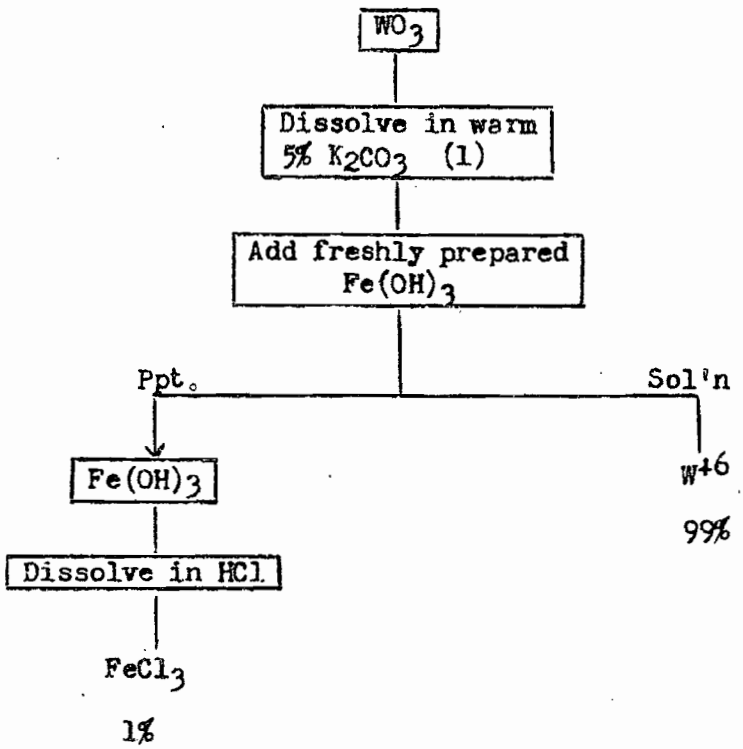
Activities Found at T_o in Bombardment	Activity per gm W
W^{185} (74 d)	9.3 mc

Yield: 7.55 mc/gm W/30 day bombardment at 50% maximum flux

Cross-Sections:

$\sigma V = 1.54 \times 10^5$ barns cm/sec
$\sigma = 0.7$ barns per atom normal element
$\sigma = 2.28$ barns per atom isotope

Non-Routine Errors: None



(1) Scott's Standard Methods of Chemical Analysis, p. 1002

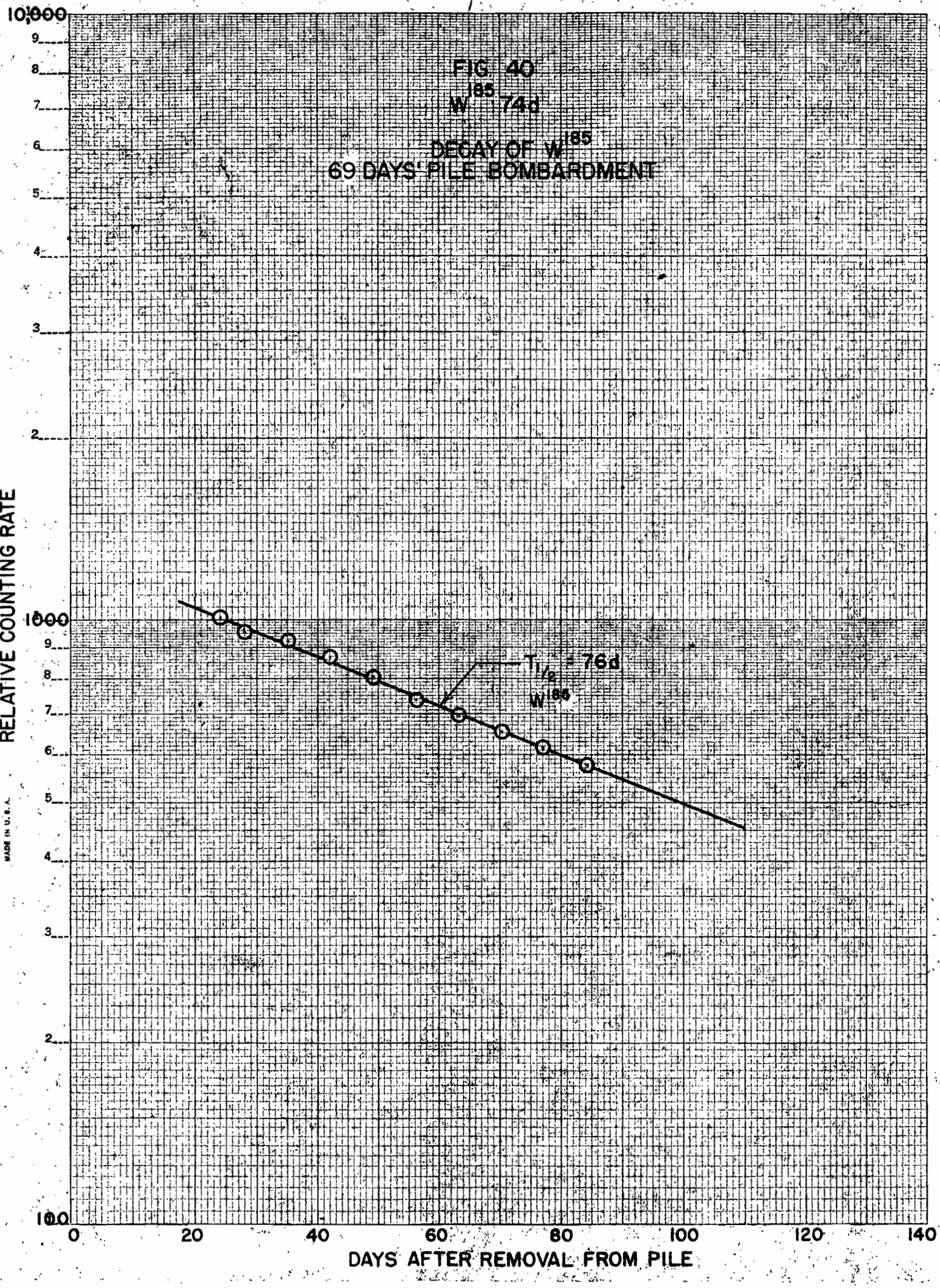
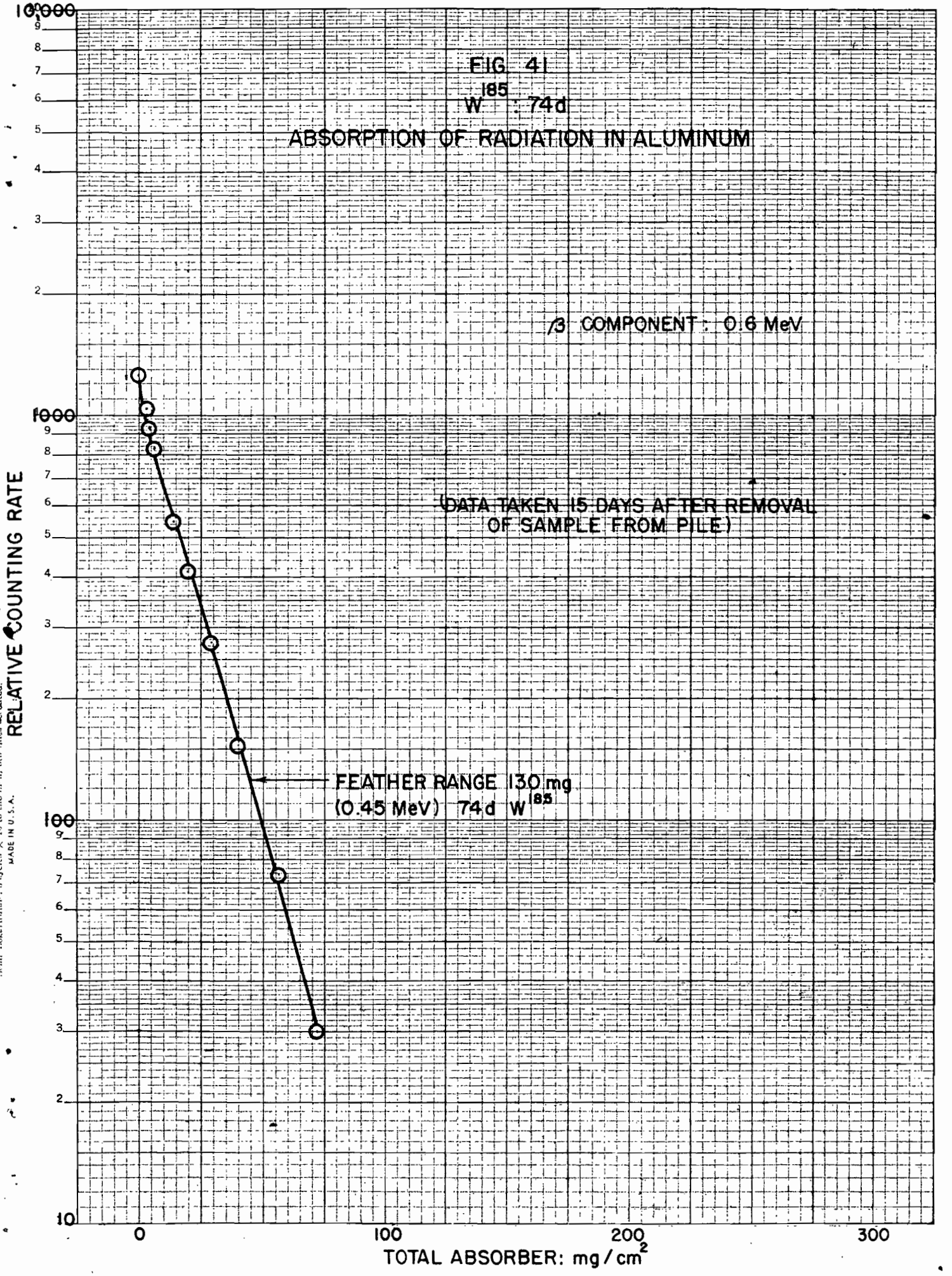


FIG. 40
W^{185} 74d
DECAY OF W^{185}
69 DAYS' PILE BOMBARDMENT
$T_{1/2}$ = 76d
W^{185}
RELATIVE COUNTING RATE
DAYS AFTER REMOVAL FROM PILE
10,000
1000
100
0
20
40
60
80
100
120
140
KEUFFEL & ESSER CO., N. Y. NO. 359-93
Semi-Logarithmic, 2 cycles × 10 to the ½ inch, 5th lines accented
MADE IN U.S.A.

Drawg. No. 5549



KEUFFEL & ESSER CO., N. Y. NO. 359-71
Semi Logarithmic, 3 cycles × 10 to the inch, 5th lines accented.
MADE IN U.S.A.

Osmium

Target Material: Osmium Powder, American Platinum Works

Weight: 0.546 gm

Spectrographic Impurities:

Ag	FT	Fe	FT
CA	T	Mg	FT
Cu	T	Mn	FT
Si	T		

Irradiation: 35 days at nv = 6 x 10" n/cm^2/sec

Separations: See diagram.

Activities Found at T_0 in Bombardment:

Os^{185} (95 d & 30 hr)	0.314 mc
Os^{191} (32 hr)	8.8 x 10^{-3} mc
Os^{193} (17 d)	9.19 mc

Yield:

Os^{185} (95 d & 30 hr) 0.230 mc/gm Os/30 day bombardment at 50% maximum flux

Os^{191} (32 hr) 7.34 x 10^{-3} mc/gm Os/30 day bombardment at 50% maximum flux

Os^{193} (17 d) 7.11 mc/gm Os/30 day bombardment at 50% maximum flux

Cross-Sections:

Os^{185}: σv = 6 x 10^3 barns cm/sec
σ = 0.0273 barns per atom normal element
σ = 152 barns per atom isotope

Os^{191}: σv = 31.6 barns cm/sec
σ = 1.44 x 10^{-4} barns per atom element
σ = 5.45 x 10^{-4} per atom isotope

Os^{193}: σv = 4.14 x 10^4 barns cm/sec
σ = 0.188 barns per atom normal element
σ = 0.575 barns per atom isotope

Non-Routine Errors: Yield figures should be revised upwards because of a loss during assay of an estimated $<8\%$.

Remarks: (A) From Fig. 43 it may be seen that some of the component emitting strong β radiation is present 90 days after the sample was removed from the pile.

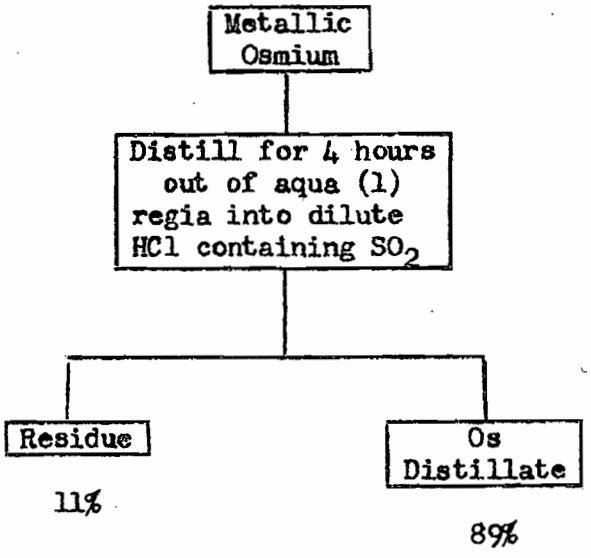
(B) Evidence points to the existence of four activities as characterized as follows:

Probable Mass	Radiation Experimental	Radiation Literature	Yield
Os^{185} (95 d)	**0.7 γ (?)	I.T., γ	*0.314 mc/gm Os
Os^{185} (~30 hr)	0.8 β	1.5 β	0.314 mc/gm Os
Os^{191} (32 hr)	1.3 β, γ(?)	0.95 β, 1.17 γ	8.8 x 10^{-3} mc/gm Os
Os^{193} (17 d)	0.3 β, 0.7 γ(?)	0.35 β, γ	7.11 mc/gm Os

* Measuring 30 hr daughter and assuming equilibrium.

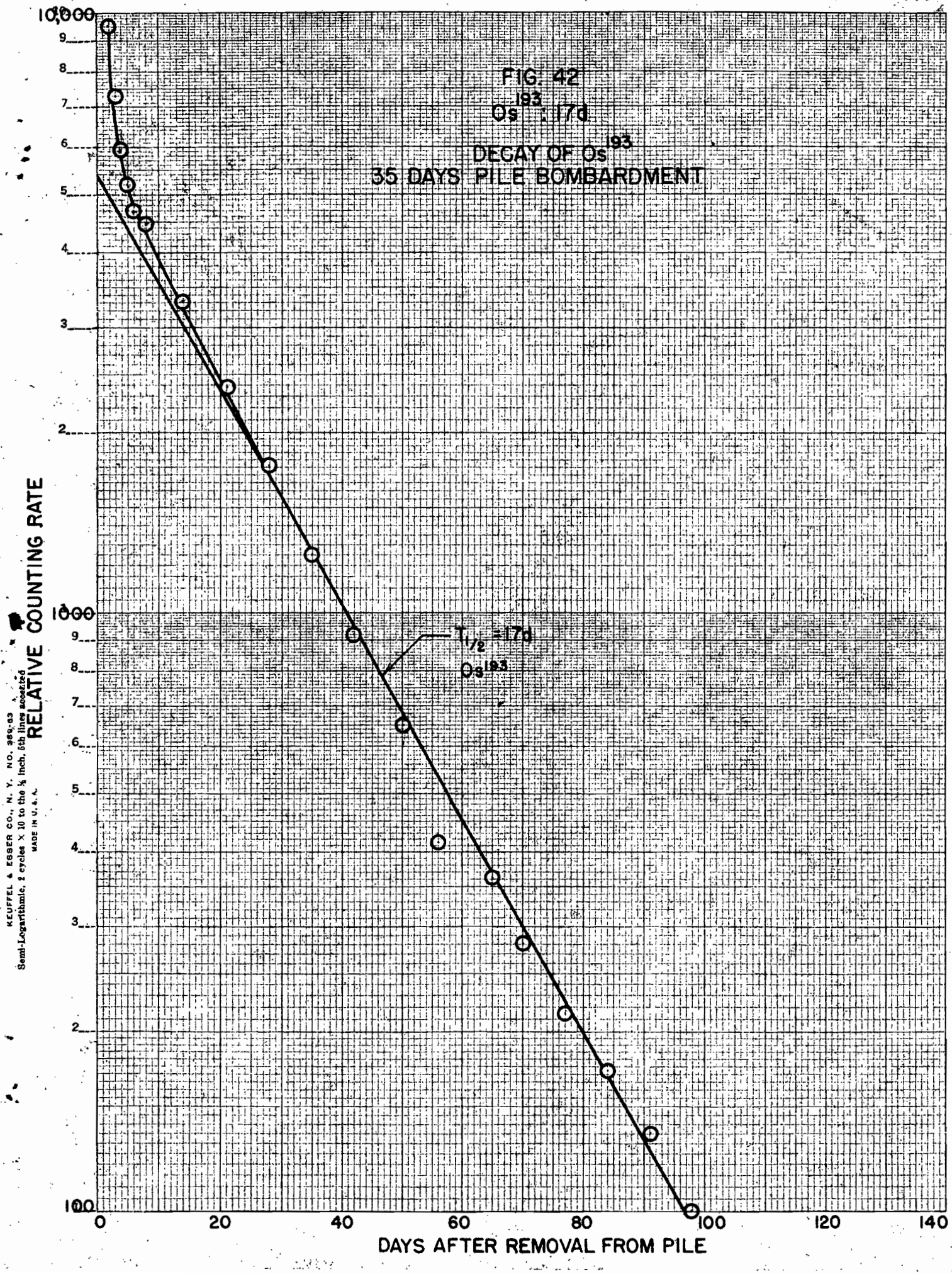
** γ measured at three months out of pile, so it may be composite of 95 d I.T. and 17 d gammas.

No great accuracy is clained for 95 d and shortlived activities. 17 d should be quite satisfactory.

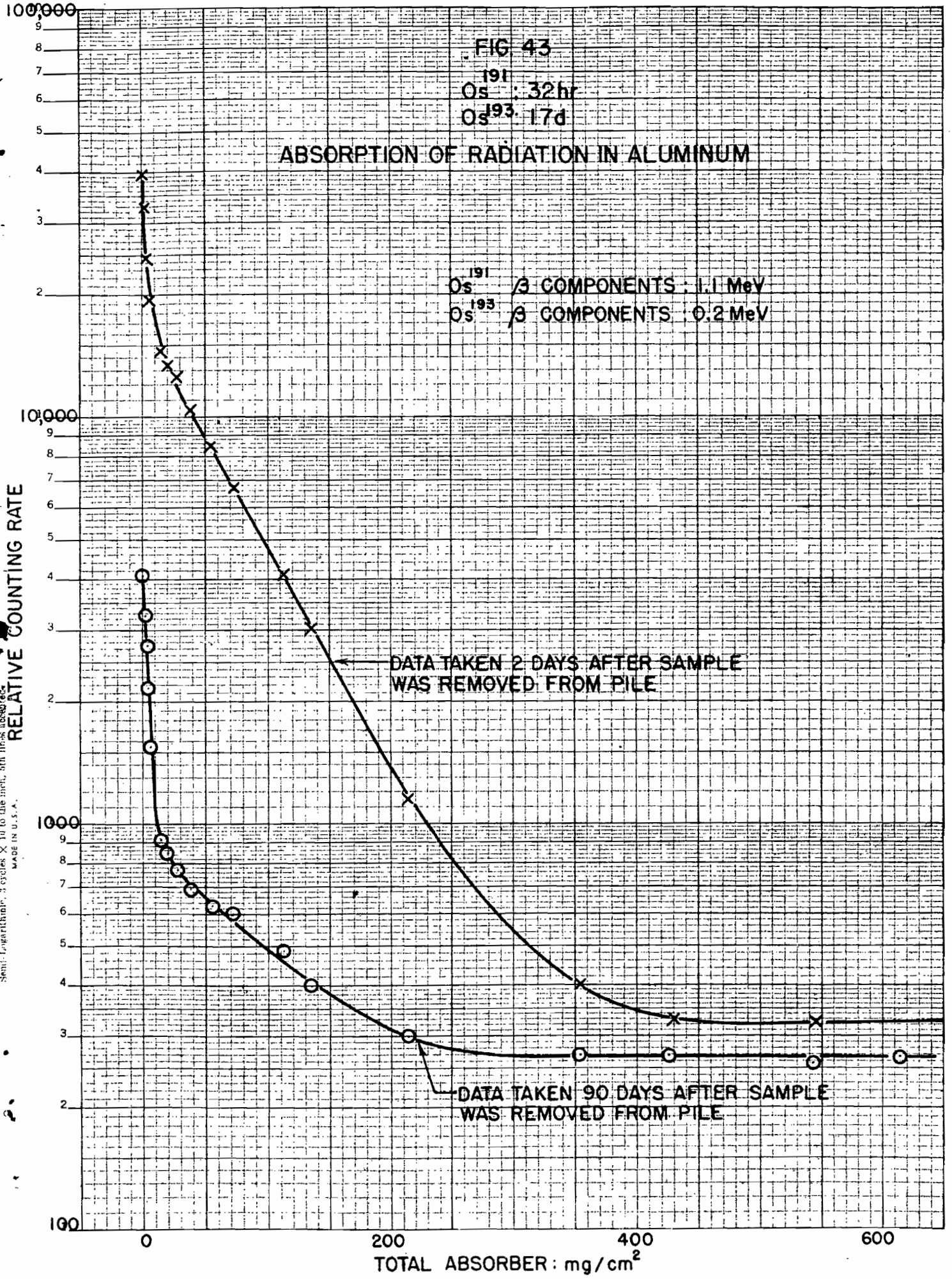


(1) Treadwell and Hall, Analytical Chemistry, Vol. 2, pp. 142-143

Drawg. No. 5550



Drawg. No. 5552



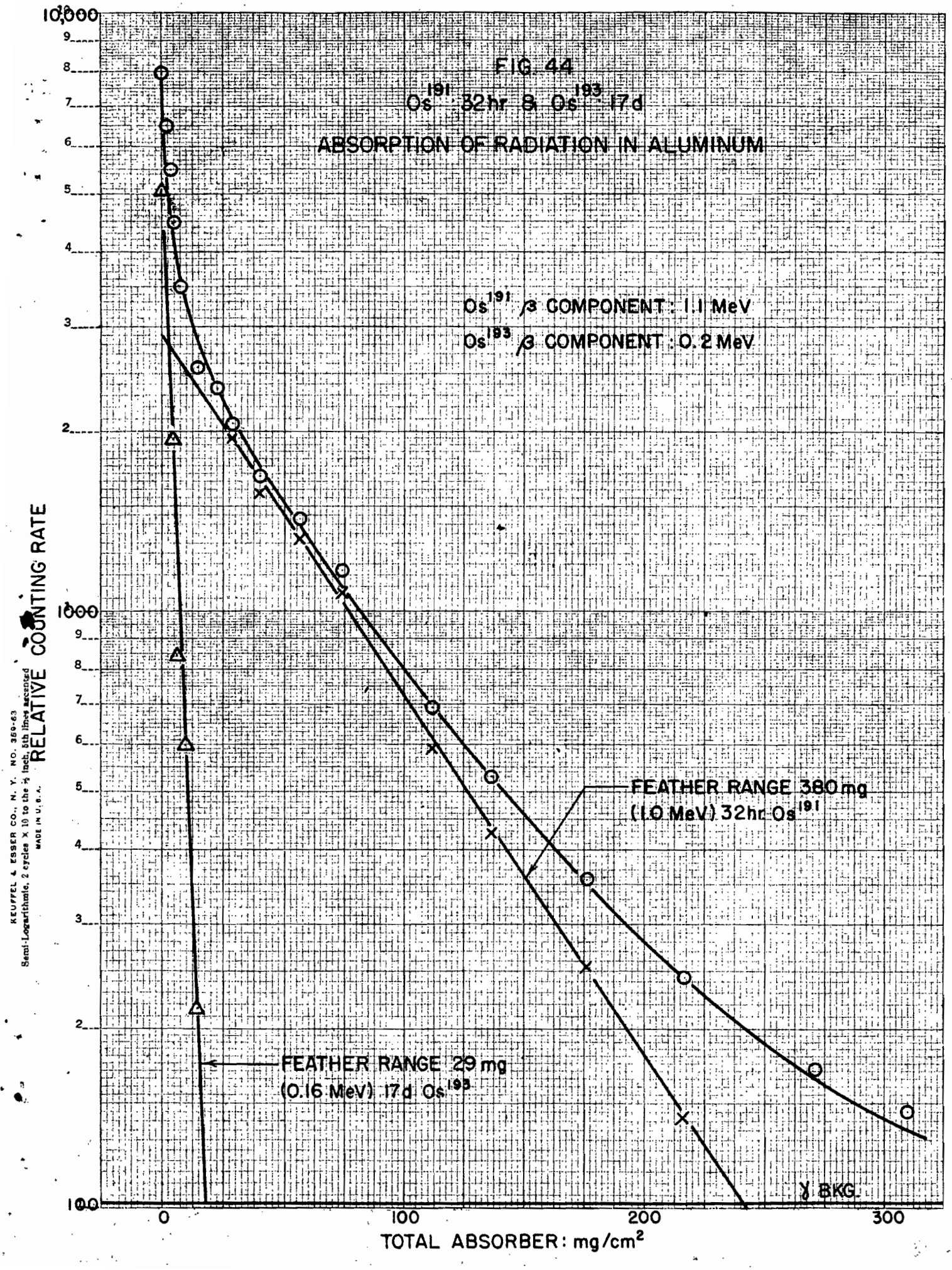
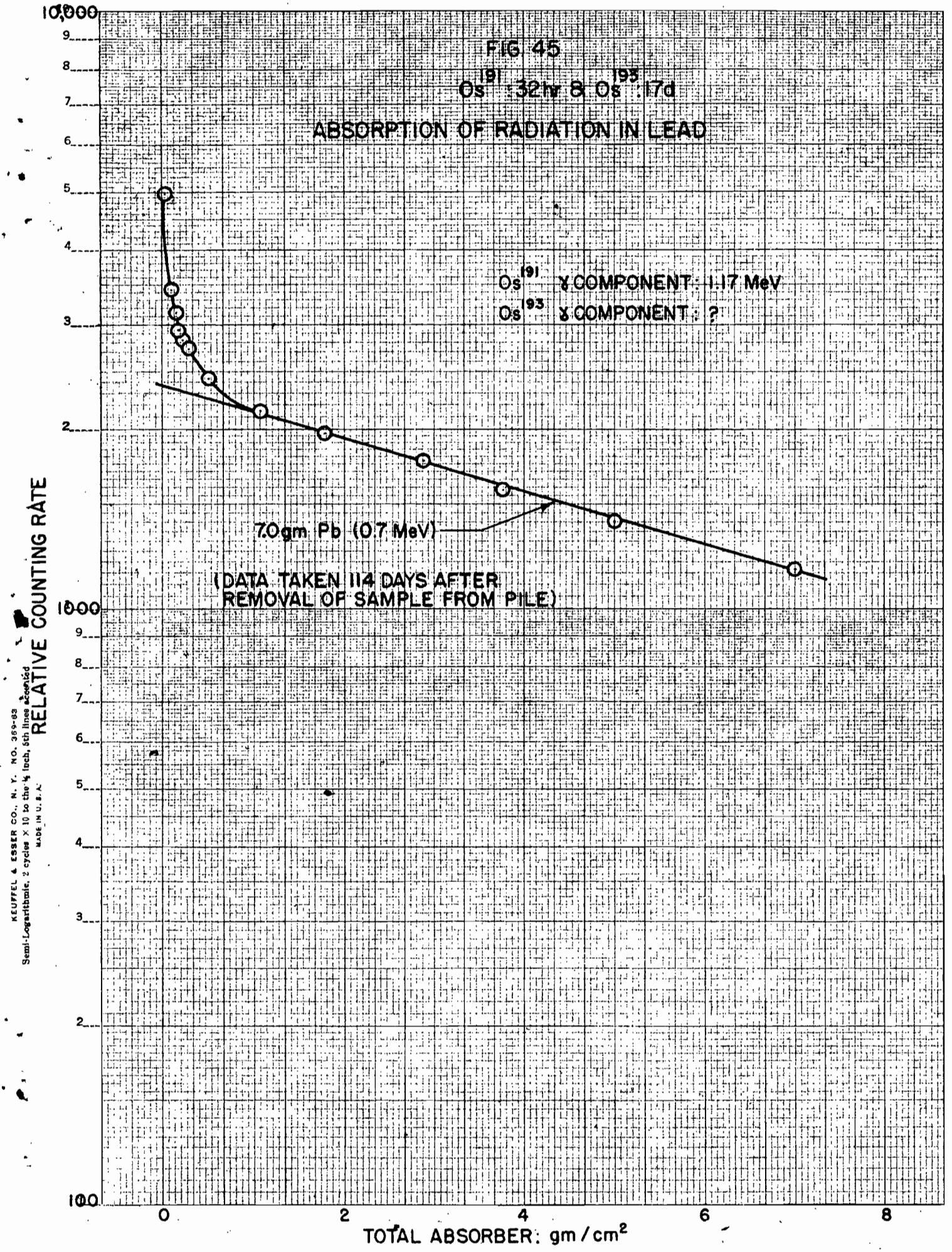


FIG. 44
Os191 : 32hr & Os193 : 17d
ABSORPTION OF RADIATION IN ALUMINUM
Os191 β COMPONENT : 1.1 MeV
Os193 β COMPONENT : 0.2 MeV
FEATHER RANGE 380 mg
(1.0 MeV) 32hr Os191
FEATHER RANGE 29 mg
(0.16 MeV) 17d Os193
γ BKG.
RELATIVE COUNTING RATE
TOTAL ABSORBER : mg/cm2
10,000
1000
100
0
100
200
300
KEUFFEL & ESSER CO., N. Y. NO. 359-63
Semi-Logarithmic, 2 cycles X 10 to the ½ inch, 5th line accented
MADE IN U.S.A.

Drawg. No. 5553



Thallium

Target Material: Thallium (ic) Nitrate, C.P., Fordcmes Trading Company

Weight: 9.98 gm

Spectrographic Impurities:

Ag	FT	Mg	VFT
Al	VFT	Ma	VFT
Ca	FT	Pb	FT
Fe	FT	Si	VFT

Irradiation: 68 days at nv = 4.0 x 10" n/cm^2/sec

Separations: See diagram.

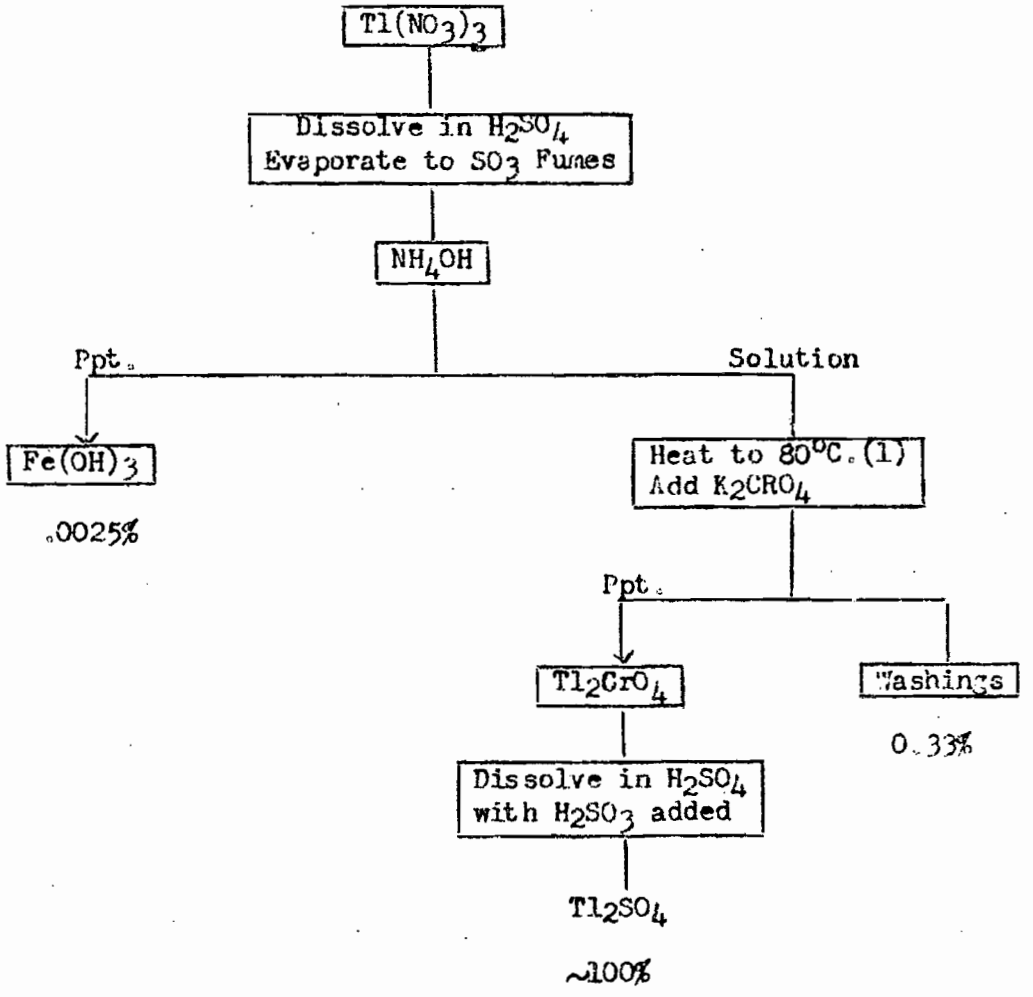
Activities Found at T_0 in bombardment:	Activity per gm Tl
Tl^{204} (3.5 yr)	3.70 mc

Yield: 1.96 mc/gm Tl/30 day bombardment

Cross-Sections:

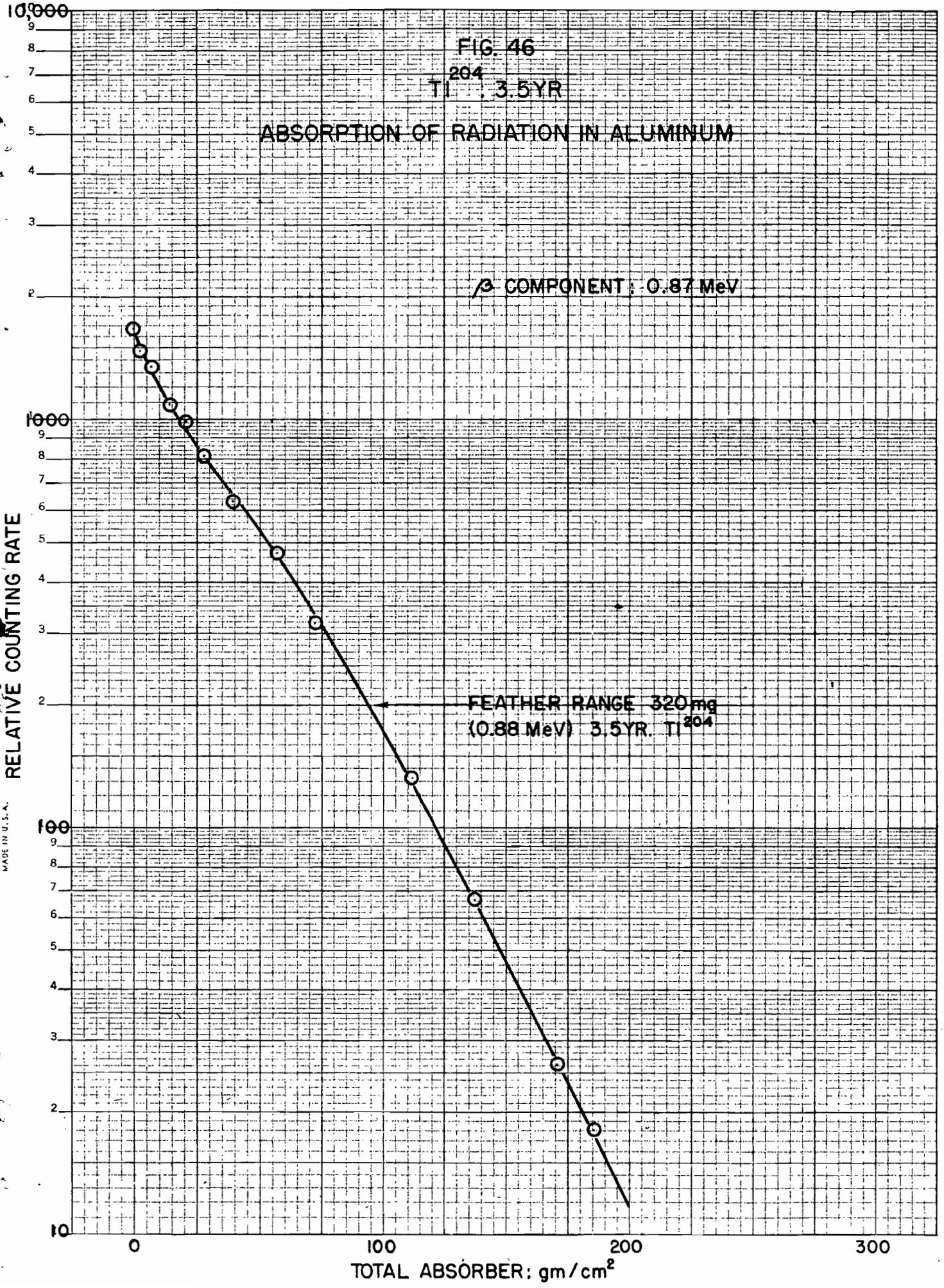
$\sigma v = 6.71 \times 10^5$ barns cm/sec
$\sigma = 3.05$ barns per atom normal element
$\sigma = 10.3$ barns per atom isotope

Non-Routine Errors: None



(1) Browning and Hutchins, Am. J. Sci. 8, 460 (1899)

Drawg. No. 5554



Bismuth

Target Material: 99.8% Bismuth metal, C.P., Baker's

Weight: 24.58 gm

Spectroscopic Impurities:

Ag	T	Fe	VW	Ni	FT
Al	T	Mg	W	Pb	T
Ca	T	Mo	FT	Si	T
Cu	W			Sn	W

Irradiation: 28 days at nv = 3.56 x 10" n/cm^2/sec

Separations: See diagram

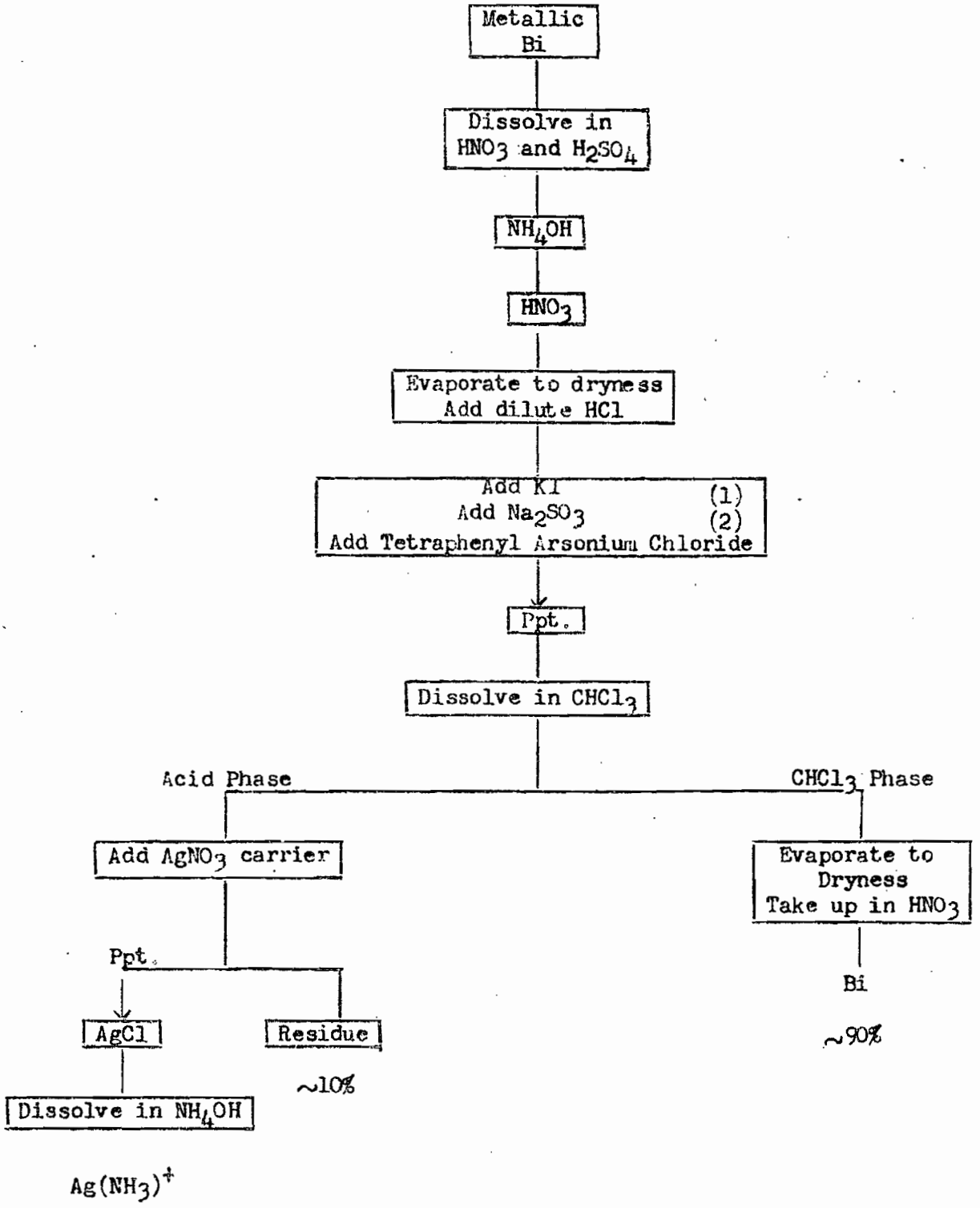
Activities Found at T_o in Bombardment:	Activity per gm Bi
Bi^{210} (5 d)	0.498 mc

Yield: 0.704 mc/gm Bi/30 day bombardment at 50% maximum flux.

Cross-Sections:

$\sigma v = 3.96 \times 10^3$ barns cm/sec
$\sigma = 0.018$ barns per atom normal element
$\sigma = 0.018$ barns per atom isotope

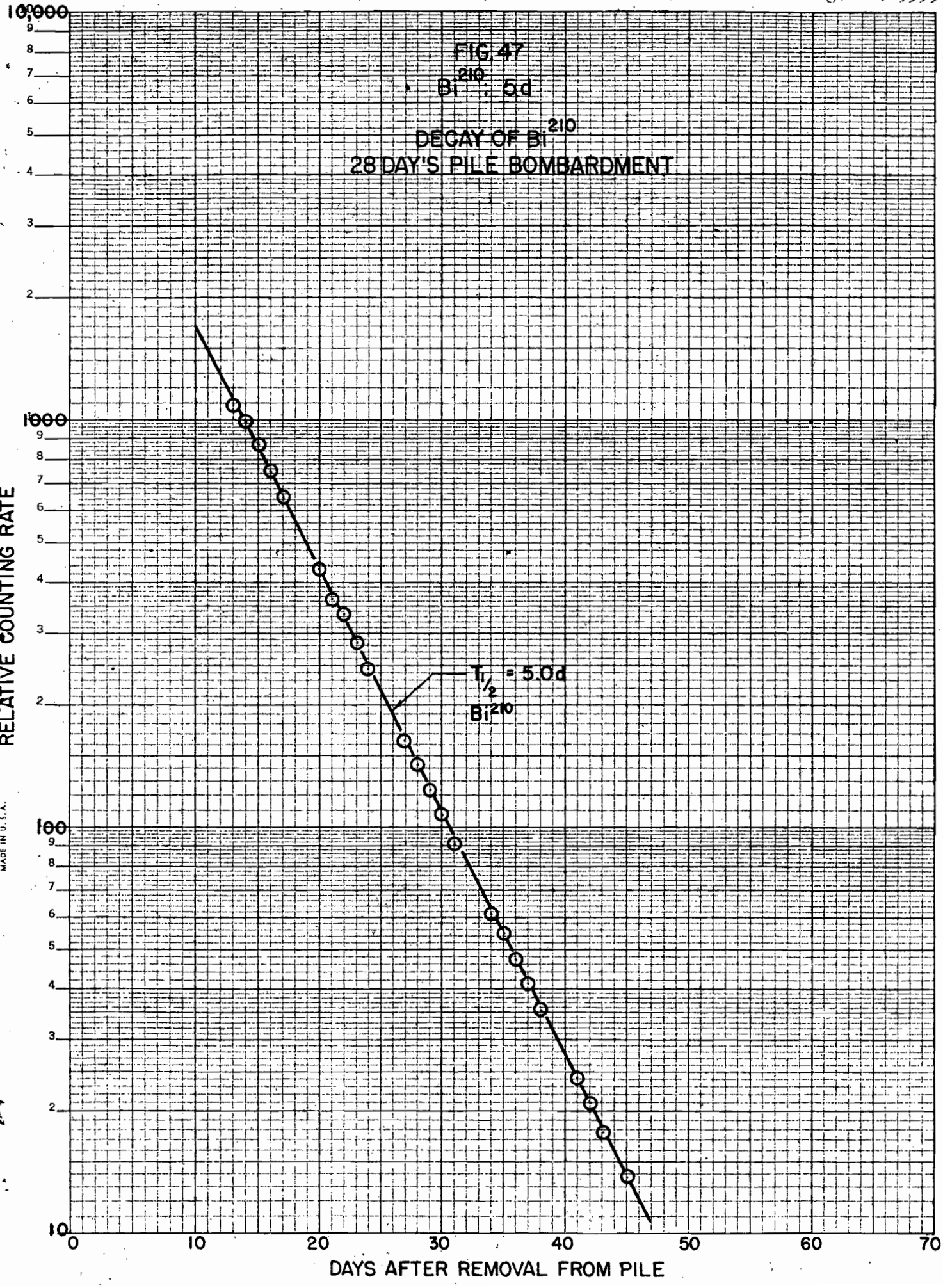
Non-Routine Errors: A large amount of solids in one of the sources made it difficult to determine the disintegration rate more accurately than $\pm$ 10% for the entire sample.

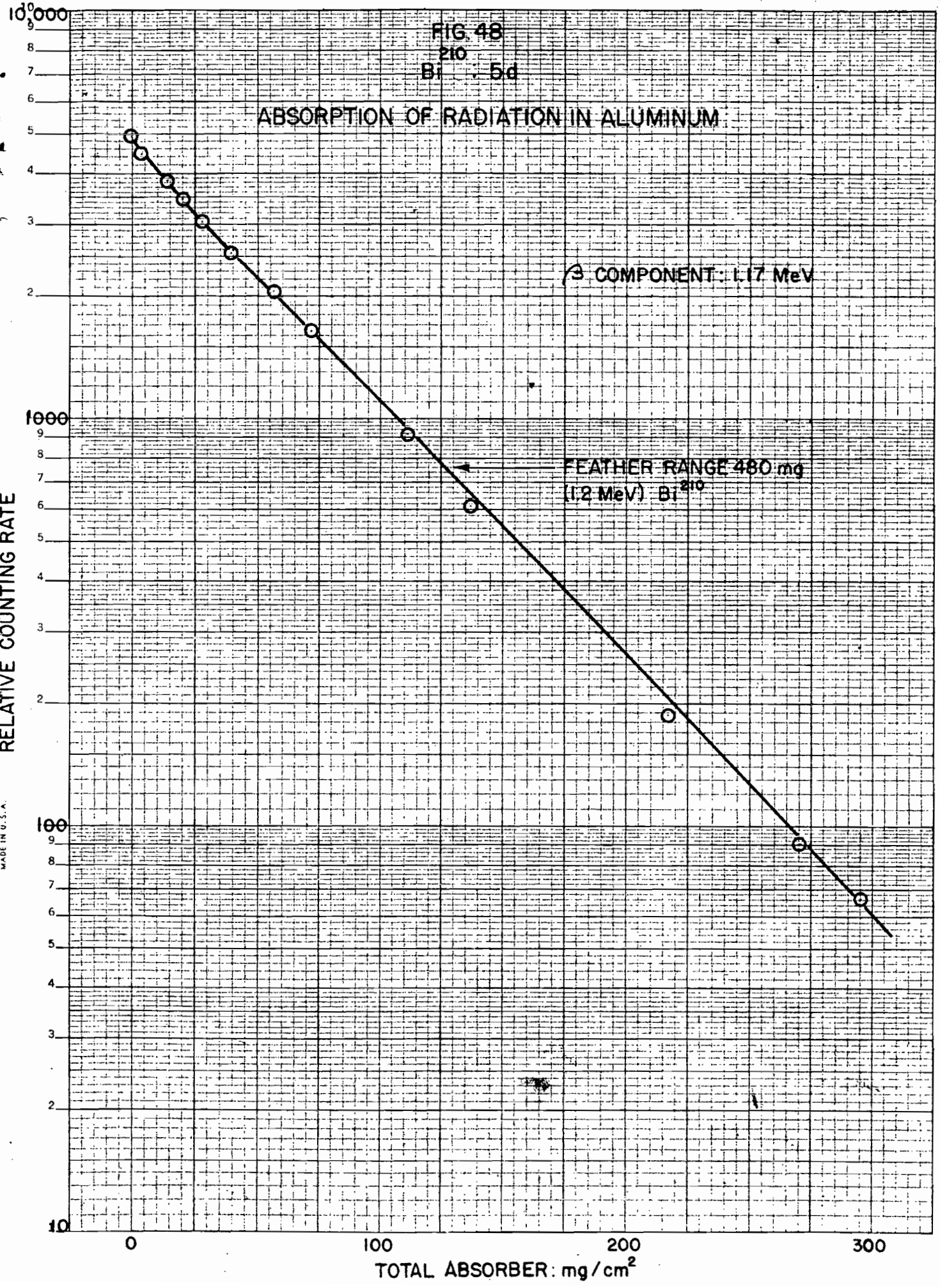


(1) Boyd, et al. in CC-934

(2) If present, Cu, Pb, Sb, Cd, Hg, and Ag will also precipitate

Drawg. No. 5555





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