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STANDARD β AND γ ABSORPTION CURVES OF THE LONGER LIVED ISOTOPES

Problem Assignment #332 MLC 3212 and #333 MLC 3307

(R. P. Metcalf, W. Rubinson, J. Seiler, E. P. Steinberg, and L. Winsberg).

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This set of absorption curves is being published at this time for its practical value to the project, although the manner in which the curves were taken (described below) may not be the best method. However, these curves can serve as valid standards for curves taken in the same manner.

The radioelements on which these curves were taken were isolated by our best chemistry from a very active solution of a slug which had been in the "X" pile during a 5.86 megawatt day run extending over 11 days. The large amounts of activity available permitted individual elements to be mounted with negligible self-absorption.

The samples were mounted by our new technique: a small aliquot of a solution of a radioelement is evaporated (infra-red lamp) within a penciled ring (9/16" diameter) on thin mica, the mica is then fixed over a 15/16" hole in an aluminum card by means of deKhotinsky cement, and then covered with cellophane.

The β absorption curves were taken by placing a sample on the third shelf of our standard counting apparatus, and piling aluminum absorbers on the second shelf.

The γ absorption curves were taken with the sample on the third shelf and 1887 mg of lead on the top shelf, subsequent lead absorbers being placed at any position under the top absorber. Special experiments have shown that the position of the absorbers is immaterial as long as an 1887 mg absorber is close to the counter window. Placing the γ sample in an aluminum sandwich, as we used to do, is unnecessary, and often introduces a spurious indication of a low-energy γ component.

For general convenience, the curves have been graphed in a standard manner.

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β absorption curves are graphed on three-cycle semi-log paper having twelve divisions per inch of abscissa. Each small division of abscissa represents 10 mg absorber. The first count, i.e., the count with no added absorber, is normalized to 100 (from an original count of ~5000 c/m) and entered on the graph as the count at 10 mg absorber, 10 mg being the total weight/cm^2 of cellophane cover, air gap and counter window. Normalized experimental points are represented by circled dots (⊙). Points obtained from the normalized experimental points by successive subtraction of one, two, or three components are represented by, respectively, triangled dots (△), squared dots (⊡), and diamonded dots (◇). Various pertinent information is included on the graphs. "Feather Range" refers to the maximum β range obtained by Feather's method for the analysis of absorption curves (see report CC-529, p.24 ff.). Using Feather ranges, maximum β energies are read off curve F' in Charles D. Coryell's Fig.A in the Seaborg Lecture Series.

γ absorption curves are graphed on two-cycle semi-log paper having ten divisions per inch of abscissa. Five divisions of abscissa represent 2 gm of lead absorber. The γ count taken through 1887 mg Pb on the top shelf is normalized to 100 (from an original count of ~ 1000 c/m) and entered on the graph as the count at 1887 mg absorber. Normalized experimental points and points obtained by successive subtractions of components are designated as in the β curves. Half thicknesses ($T_{\frac{1}{2}}$) are obtained directly from the curves, and the corresponding energies are read off Charles D. Coryell's Fig.B in the Seaborg Lecture Series.

The β and γ energies obtained by absorption methods depend strongly on the absorption technique used. Because of this factor, in some cases the β and γ energies listed in the table accompanying this report differ somewhat from those listed in CL-697, III-D, in which energy data from absorption and spectrographic studies were given. The usefulness of the absorption curves for identification purposes is in no way affected by these discrepancies in energy values.

In cases where more than one isotope is present in the sample (e.g., 40d Ru and 330d Ru), the relative proportions of the isotopes, and hence the absorption curves, vary with time. In such cases, there is noted on the curves the relative proportions of the isotopes at the time the curves were taken.

It is obvious that any curves which are to be compared with these by superposition should be graphed just as these are, except that normalization is not necessary. Curves taken on samples with appreciable amounts of self-absorption should be superposable by sliding on these standard curves in which self-absorption is negligible. An absorption curve of the soft Cb radiation (~0.15 MEV) taken on a

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sample of 8.8 mg weight, was superposable on the standard Cb curve when the bends at ~40 mg were made to coincide. Ce absorption curves on samples of zero mg, 4.2 mg, and 19.2 mg weight (the β^- radiations involved are 3.1 MEV, 0.6 MEV, and ~ 0.2 MEV) were all quite superposable. In all cases, identification of the activity by superposition of absorption curves s should be unmistakable.

Our section (C-III, Sugarman) is now keeping a file of all absorption curves, taken by standard method or otherwise. These are available for inspection by other members of the project.

DATA ON THE LONGER-LIVED ISOTOPES

(Energy data derived from Figs.1-26.)

Element	Half-Life	Fission Yield %	E_{β^-} (max) (MEV)	β^- Range (mg Al/cm^2)	E_{γ} (MEV)	γ Half-thickness (gm Pb/cm^2)	Daughter
$_{38}Sr^{89}$	55d	4.6	1.9	865	None	—	Stable $_{39}Y^{89}$
$_{38}Sr^{90}$	~30y	~5	~0.4	~90	None	—	$_{39}Y^{90}$ (β^-, 2.5; no γ), 60h
$_{39}Y^{(91)}$	57d	5.9	1.8	810	None	—	Stable $_{40}Zr^{(91)}$
$_{40}Zr^{(95)}$	65d	>4.5	1.0 (2%) 0.42 (98%)	415 ~100	0.88	8.8	$_{41}Cb^{(95)}$, 35d
$_{41}Cb^{(95)}$	35d	>4.5	~0.15	~25	~0.92	9.2	Stable $_{42}Mo^{(95)}$
$_{44}Ru^{103}$	42d	~3.5	0.3	60	.58	5.5	Stable $_{45}Rh^{103}$
$_{44}Ru^{(106)}$	330d	0.5	0.2	35	None	—	$_{45}Rh^{(106)}$ (β^-, ~3.0; no γ) 30s
$_{45}Rh^{(106)}$	30s	0.5	~3.1	1500	None	—	Stable $_{46}Pd^{(106)}$
$_{47}Ag^{111}$	7.5d	0.006	1.0	400	None	—	Stable $_{48}Cd^{111}$
$_{48}Cd^{115}$	43d	0.001	1.85	840	None	—	Stable $_{49}In^{115}$
$_{52}Te^{129}$	32d ↓ 72m	0.19	β^-, 0.2 1.8	~37 820	0.3 0.7	1.96 7.4	72m Te Long-Lived $_{53}I^{129}$
$_{53}I^{131}$	8d	1.7	0.6	210	0.36	2.7	Stable $_{54}Xe^{131}$
$_{55}Cs^{135}$	20-30y	4.3	~0.84 (50%) 0.5 (50%)	~300 ~130	0.7	7	Stable $_{56}Ba^{135}$
$_{56}Ba^{140}$	12.5d	6.1	1.0	390	0.5 (25%)	4.8	$_{57}La^{140}$ (β, 1.8; γ, 1.9, 0.36) 40h
$_{57}La^{140}$	40h	6.1	1.8	~830	1.9 0.36	15.5 2.8	Stable $_{58}Ce^{140}$
$_{58}Ce^{141}$	28d	5.0	0.6	~170	0.22	0.8	Stable $_{59}Pr^{141}$
$_{58}Ce^{(144)}$	300±30d	5.5	~0.2	~50	1.25 (10%)	11.9	$_{59}Pr^{(144)}$ (β^-, 3.1; no γ) 17m
$_{59}Pr^{(144)}$	17m	5.5	3.1	1420	None	—	Stable $_{60}Nd^{(144)}$
$_{59}Pr^{143}$	13.5d	5.4	1.0	380	None	—	Stable $_{60}Nd^{143}$
$_{63}Eu^{(155)}$	15.4d	0.019	0.5 2.5	~140 1180	2.0	15.6	Stable $_{64}Gd^{(155)}$
$_{234+5}UX^{(1+2)}$	24.5d	—	0.1 2.42	23 1160	None	—	$_{92}U^{234}$ (α emitter)

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INDEX TO FIGURES

Fig.	Radioisotope(s)	Title
1	55d Sr^{89} + 30y Sr^{90}	Absorption of radiations in Al
2	57d $Y^{(92)}$	" " " " Al
3	65d $Zr^{(93)}$	" " " " Al
4	65d $Zr^{(93)}$	" " " " Pb
5	35d $Cb^{(93)}$	" " " " Al
6	35d $Cb^{(93)}$	" " " " Pb
7	42d Ru^{103} + 330d $Ru^{(106)}$	" " " " Al
7a	42d Ru^{103} + 330d Ru^{106} (preponderantly 42d Ru)	" " " " Al
8	42d Ru^{103}	" " " " Pb
9	7.5d Ag^{111}	" " " " Al
10	43d Cd^{115}	" " " " Al
11	32d Te^{129}	" " " " Al
12	32d Te^{129}	" " " " Pb
13	8d I^{131}	" " " " Al
14	8d I^{131} + 22h I^{133}	" " " " Pb
15	20-30y Cs^{135}	" " " " Al
16	20-30y Cs^{135}	" " " " Pb
17	12.5d Ba^{140}	" " " " Al
18	12.5d Ba^{140}	" " " " Pb
19	40h La^{140} + 13.5d Pr^{143}	" " " " Al
19a	40h La^{140}	" " " " Al
20	40h La^{140}	" " " " Pb
20a	12.5d Ba^{140} + 40h La^{140} (equilibrium mixture)	" " " " Al

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INDEX TO FIGURES (cont'd)

Fig.	Radioisotope(s)	Title
21	28d Ce^{141} + 300±30d $Ce^{(144)}$	Absorption of radiations in Al
22	28d Ce^{141} + 300±30d $Ce^{(144)}$	" " " " Pb
23	13.5d Pr^{143}	" " " " Al
24	15.4d $Eu^{(155)}$	" " " " Al
25	15.4d $Eu^{(155)}$	" " " " Pb
26	24.5d UX^{234}	" " " " Al

FIG. 1

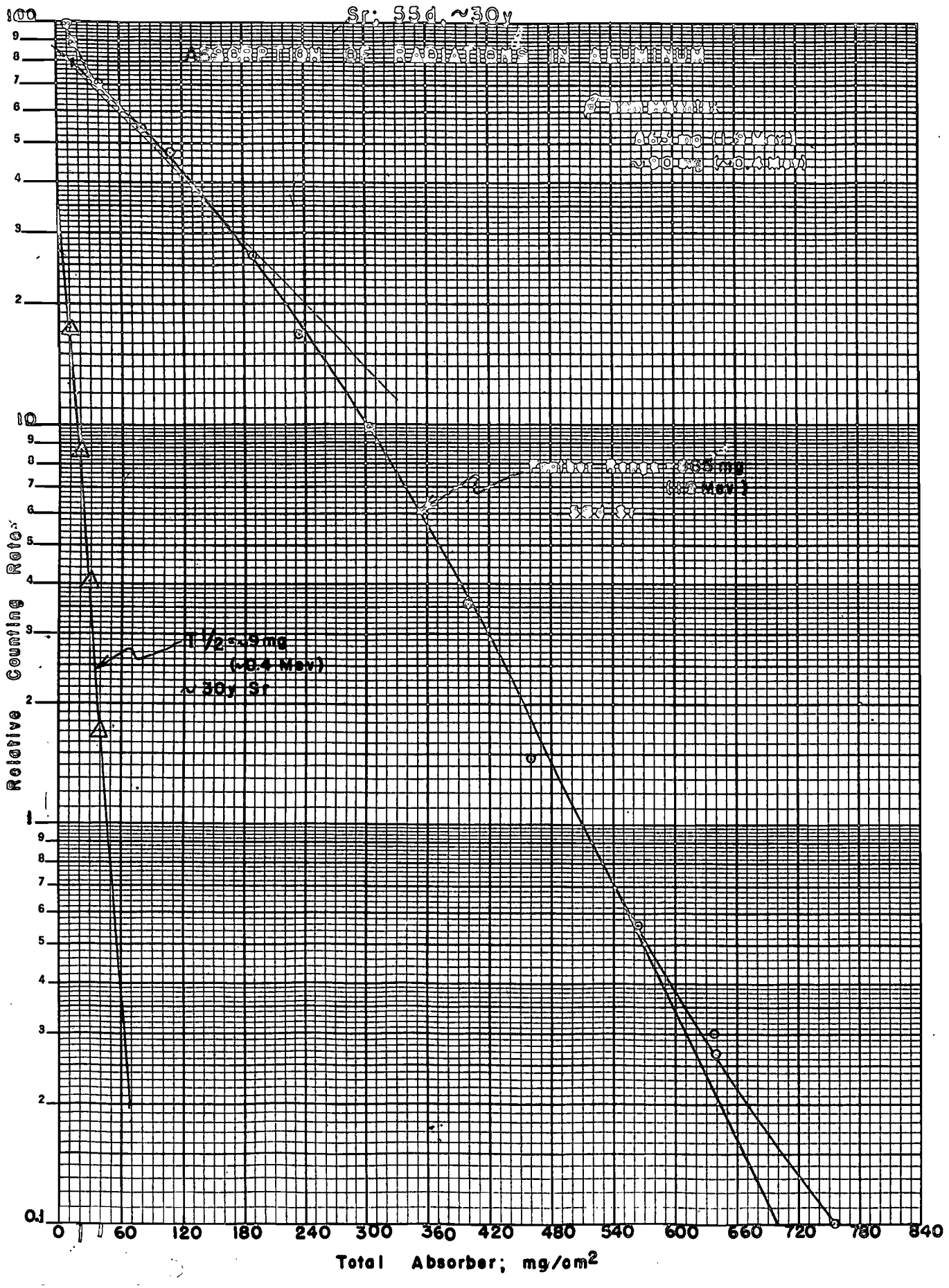

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FIG. 2

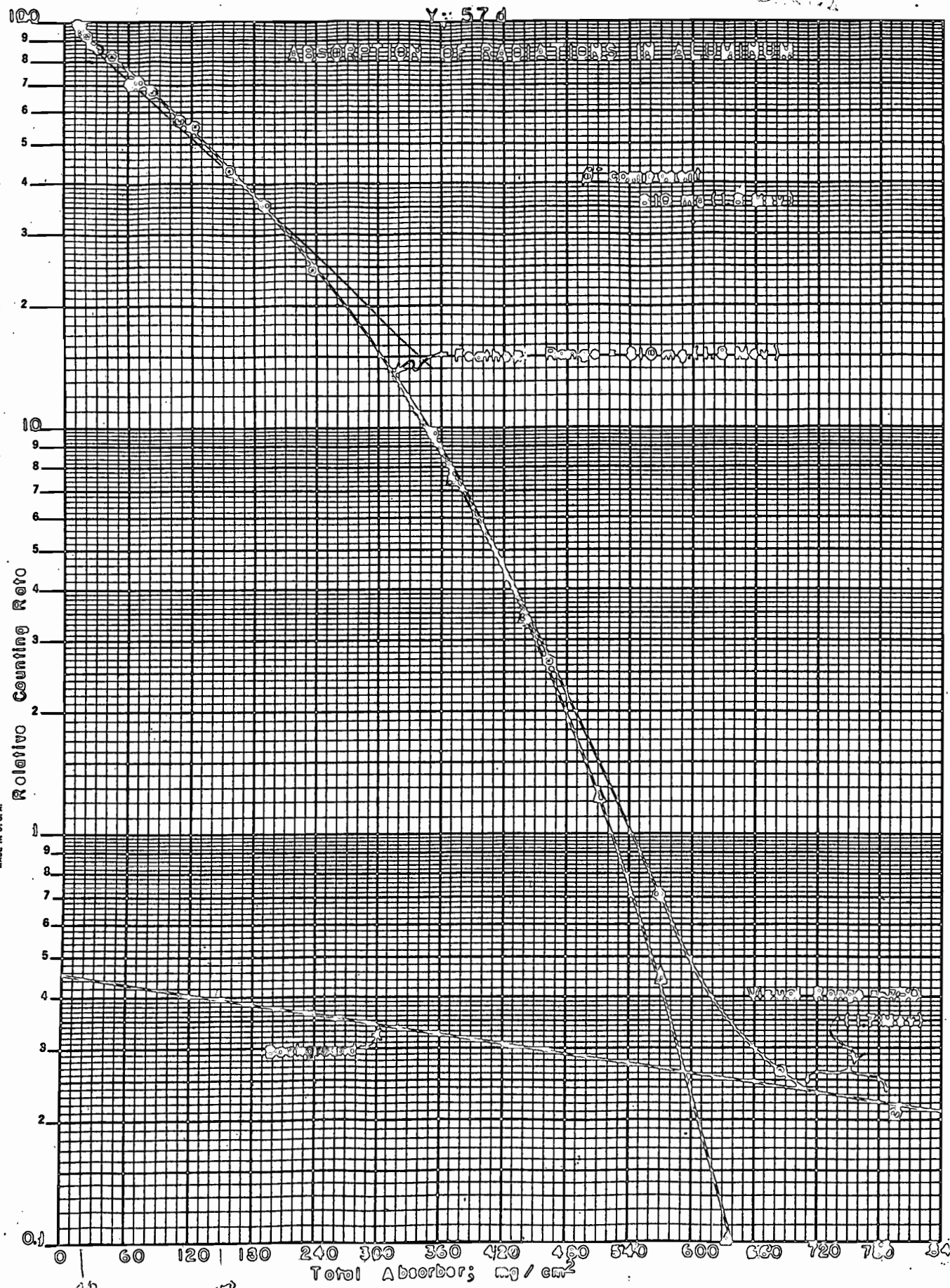
Relative Counting Rate
100
10
1
0.1
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
Total Absorber; mg / cm²
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FIG. 3

Zr; 65 d

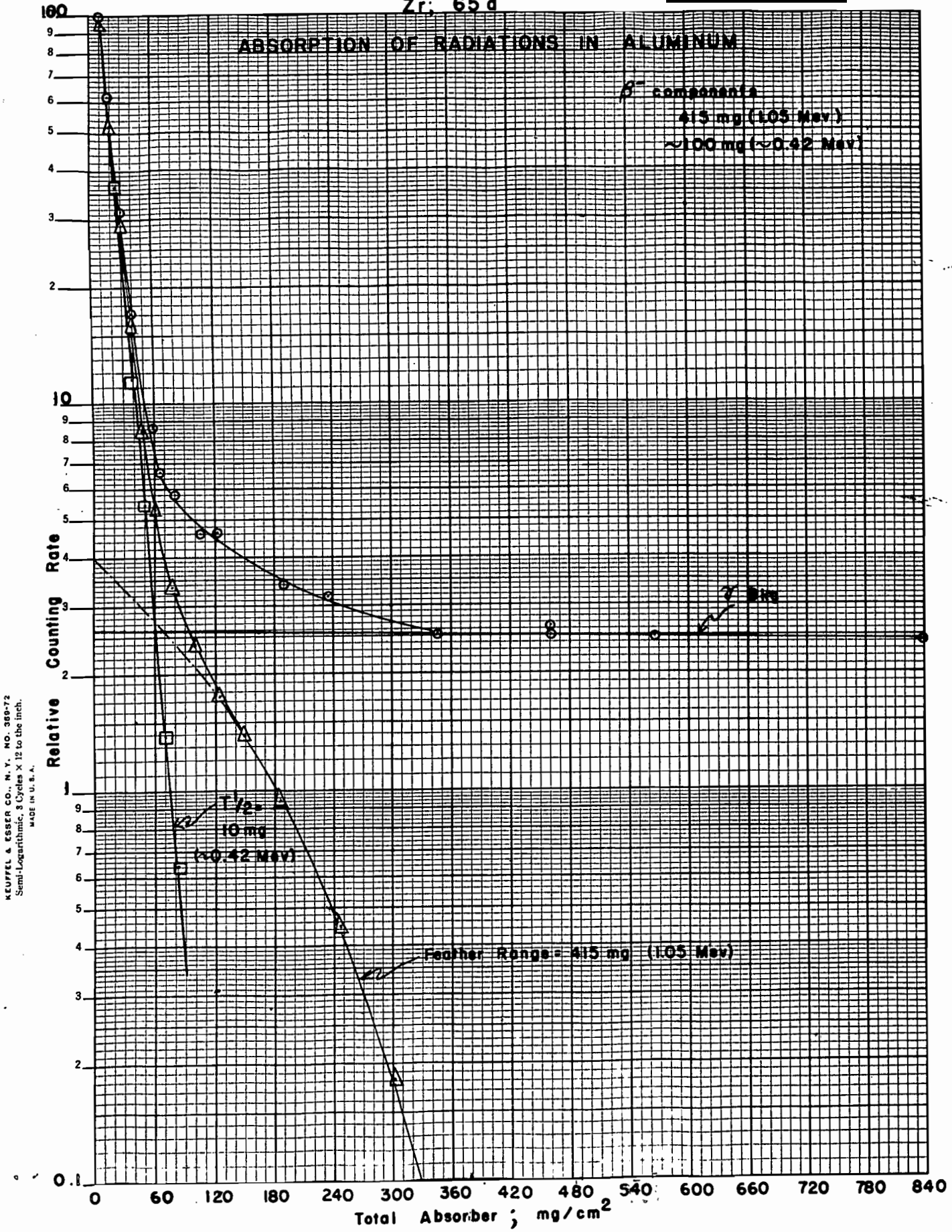

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FIG. 4

$Zr_{\frac{1}{2}}$ 65d

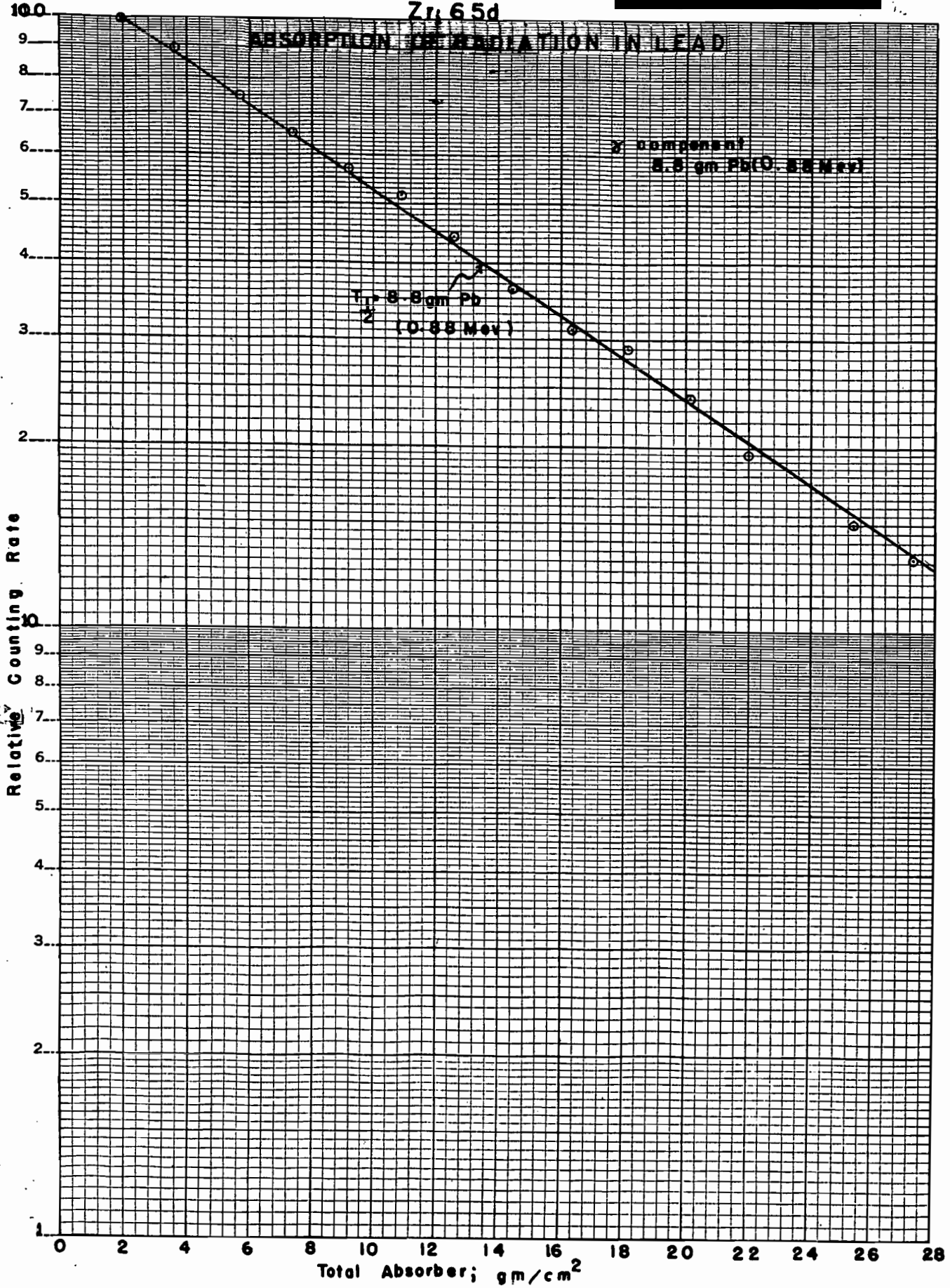

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FIG. 5

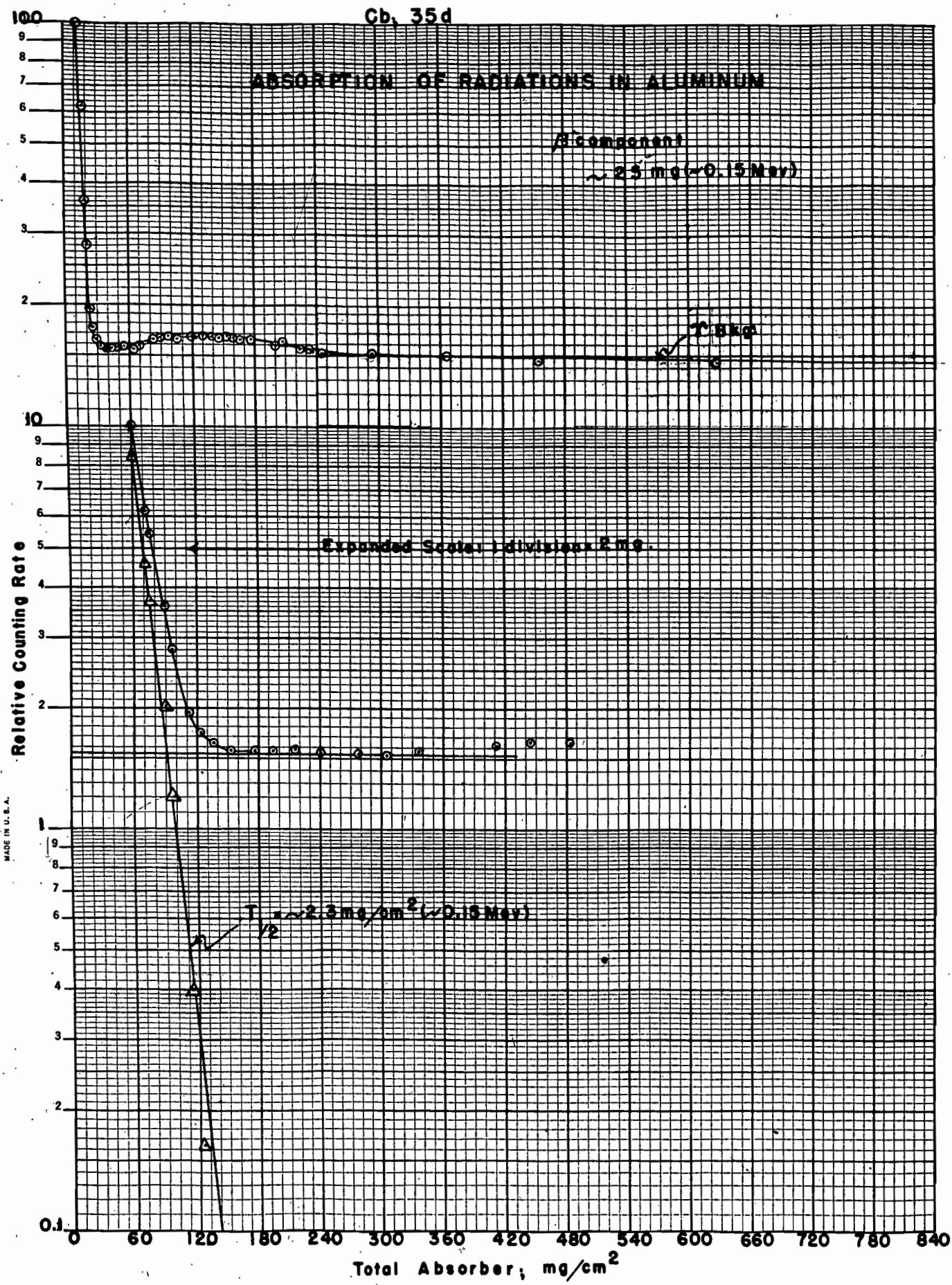

FIG. 6

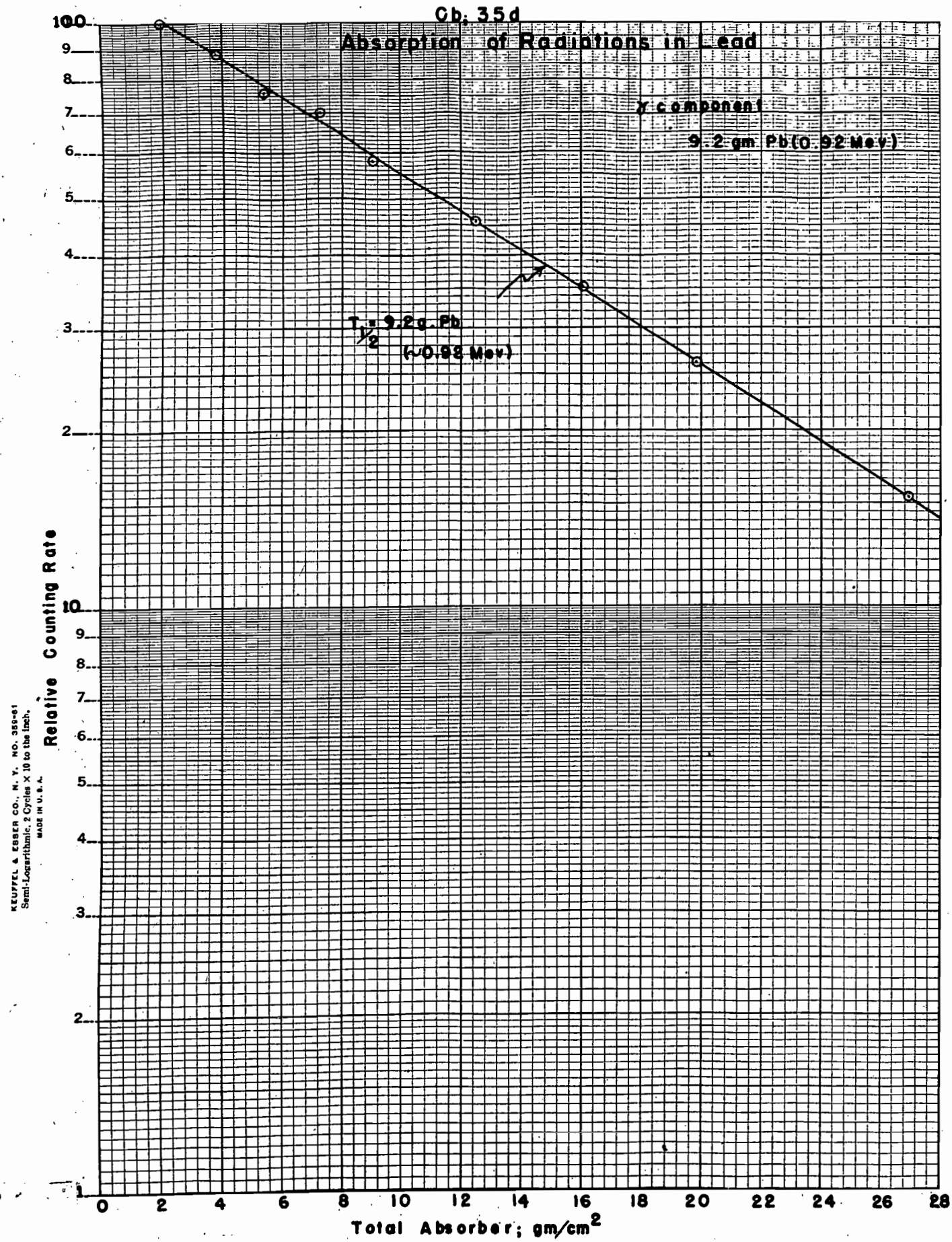
Cb. 35 d
Absorption of Radiations in Lead
γ component
9.2 gm Pb (0.92 Mev)
$T_{1/2}$ = 9.2 g. Pb
(~0.92 Mev)
Relative Counting Rate
Total Absorber; gm/cm²
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FIG. 7

Ru, 42 d + 330 d

ABSORPTION OF RADIATION IN ALUMINUM

330d Ru / 42d Ru = .169

330 d Ru + 30 s Rh / 40d Ru = .37

$T_{1/2}$ = 5 mo (~0.3 Mev)

γ Bkg

β of 30s Rh Feather Range = 1500 (3.08 Mev)

β components

42d Ru, ~30 mg/cm² (~0.8 Mev)

30s Rh, 1500 mg/cm² (3.1 Mev)

330d Ru, Extremely weak; has not been observed

Relative Coutlng Rate

Total Absorber; mg/cm²

0 60 120 180 240 300 360 420 480 540 600 660 720 780 840 900 960 1020 1080 1140 1200 1260 1320 1380 1440 1500 1560 1620 1680 1740 1800

100 9 8 7 6 5 4 3 2 10 9 8 7 6 5 4 3 2 1 9 8 7 6 5 4 3 2 0.1

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FIG. 7a

Ru; 42d + 330d
(Preponderantly 42d Ru)
ABSORPTION OF RADIATIONS
IN ALUMINUM

EXPANDED SCALE

β^-, Range = ~48mg/cm² (0.3Mev)
β^-, Range = ~330mg/cm² (0.9Mev)
β^-, Range = ~1700mg/cm² (3.4Mev)

$T\frac{1}{2}$ = ~4.8mg/cm²
(0.3 Mev)

Feather Range (extrap.) = ~330 mg/cm² (0.9 Mev)

Feather Range (extrap.) = 1700 mg/cm²
(~3.4 Mev)

γ

Relative Counting Rate

Total Absorber mg/cm²

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FIG. 8

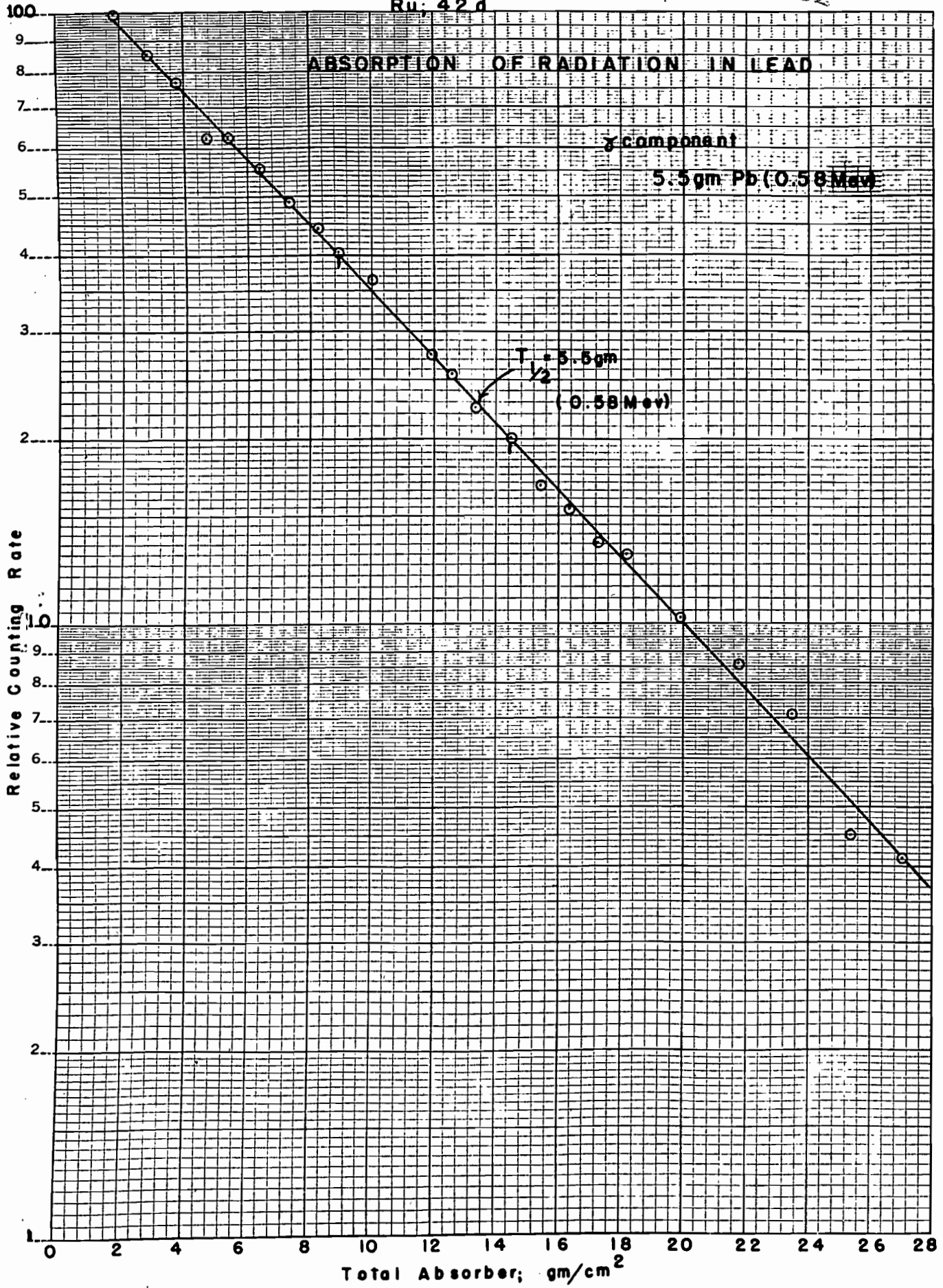

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FIG. 9

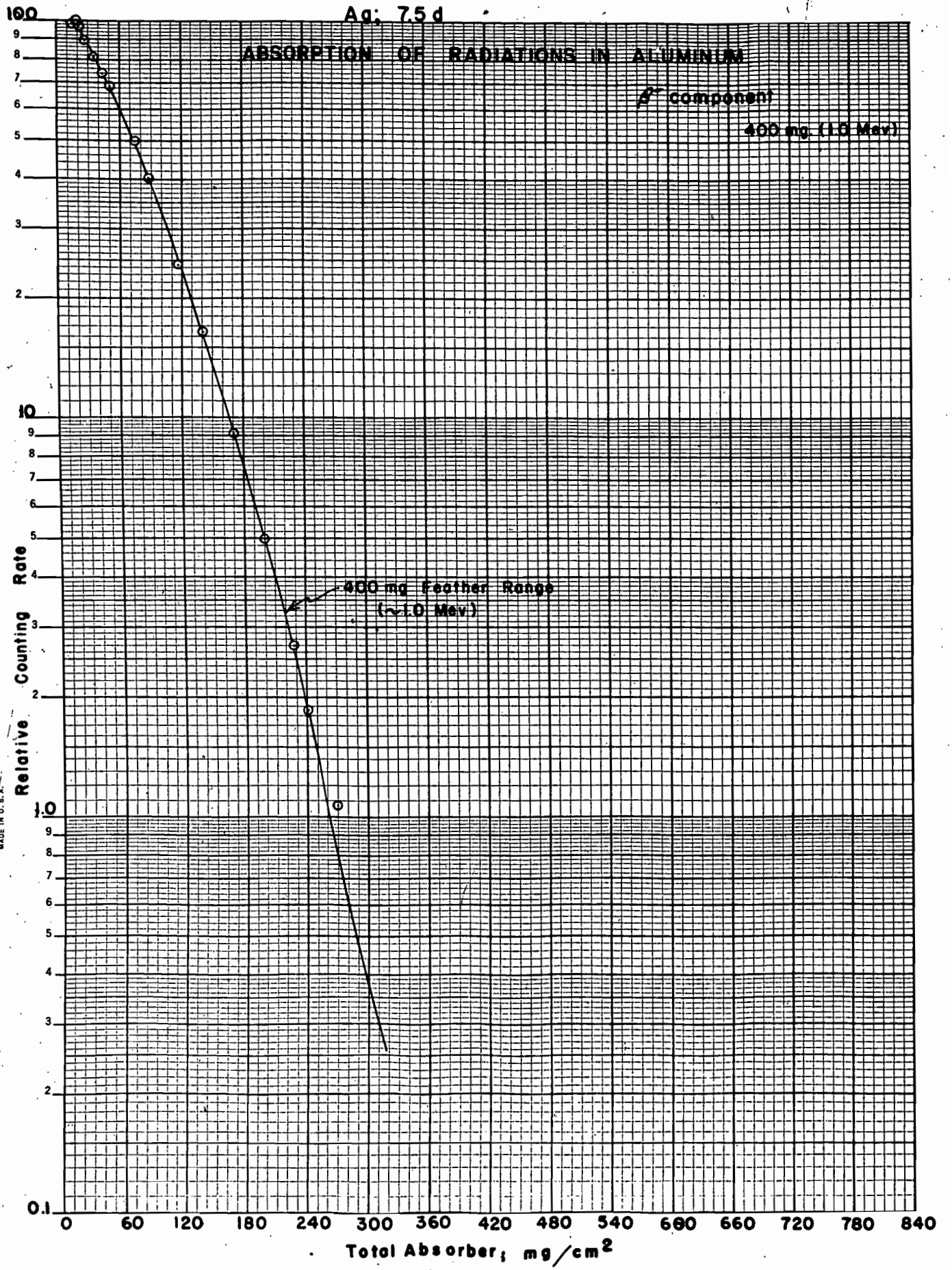

FIG. 10

Cd; 43 d

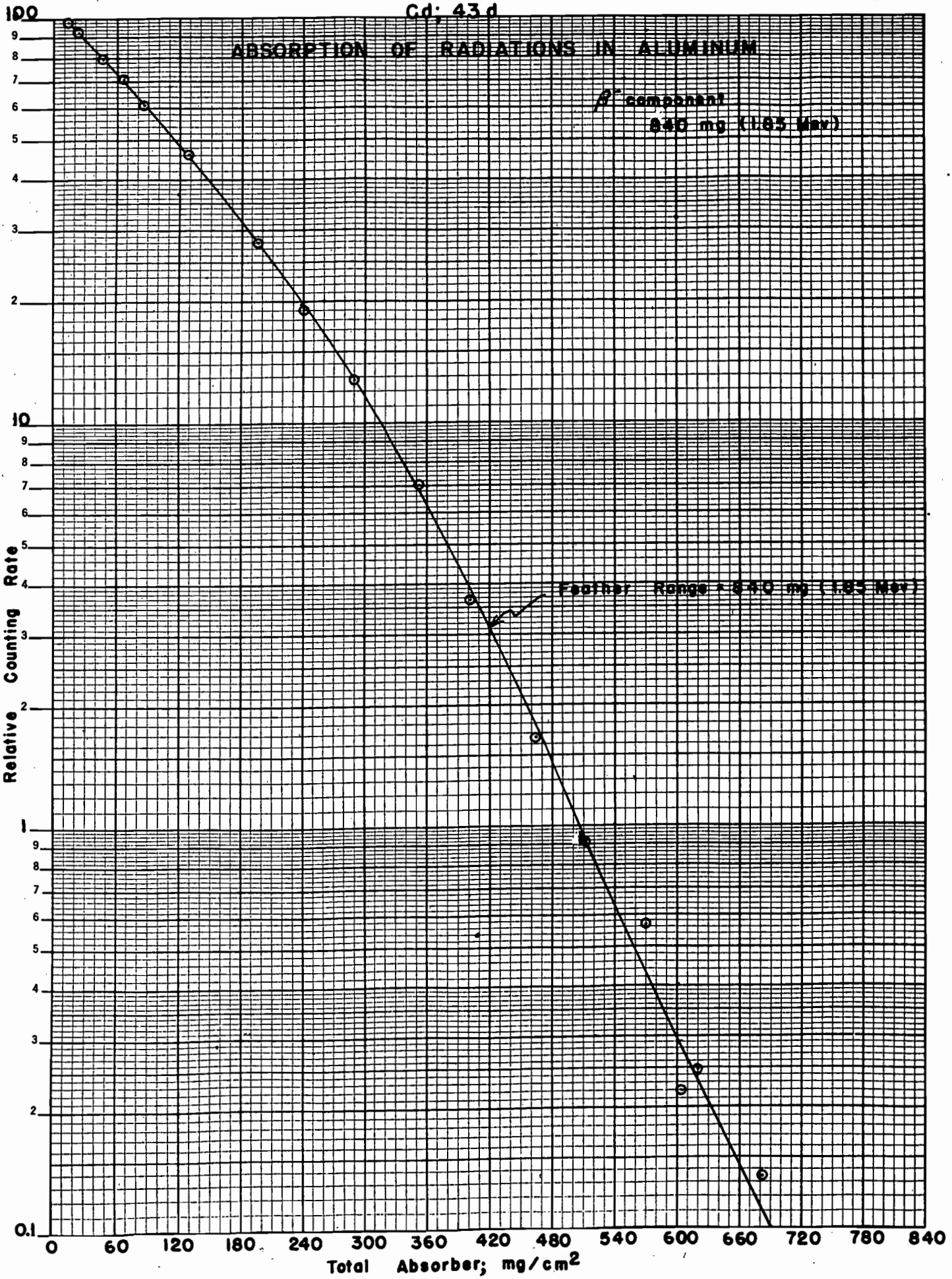
ABSORPTION OF RADIATIONS IN ALUMINUM
β⁻ component
840 mg (1.85 Mev)
Feather Range = 840 mg (1.85 Mev)
Relative Counting Rate
100
10
1
0.1
0 60 120 180 240 300 360 420 480 540 600 660 720 780 840
Total Absorber; mg/cm²
KEUFFEL & ESSER CO., N.Y. NO. 359-72
Semi-Logarithmic, 3 Cycles X 12 to the Inch.
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FIG. II

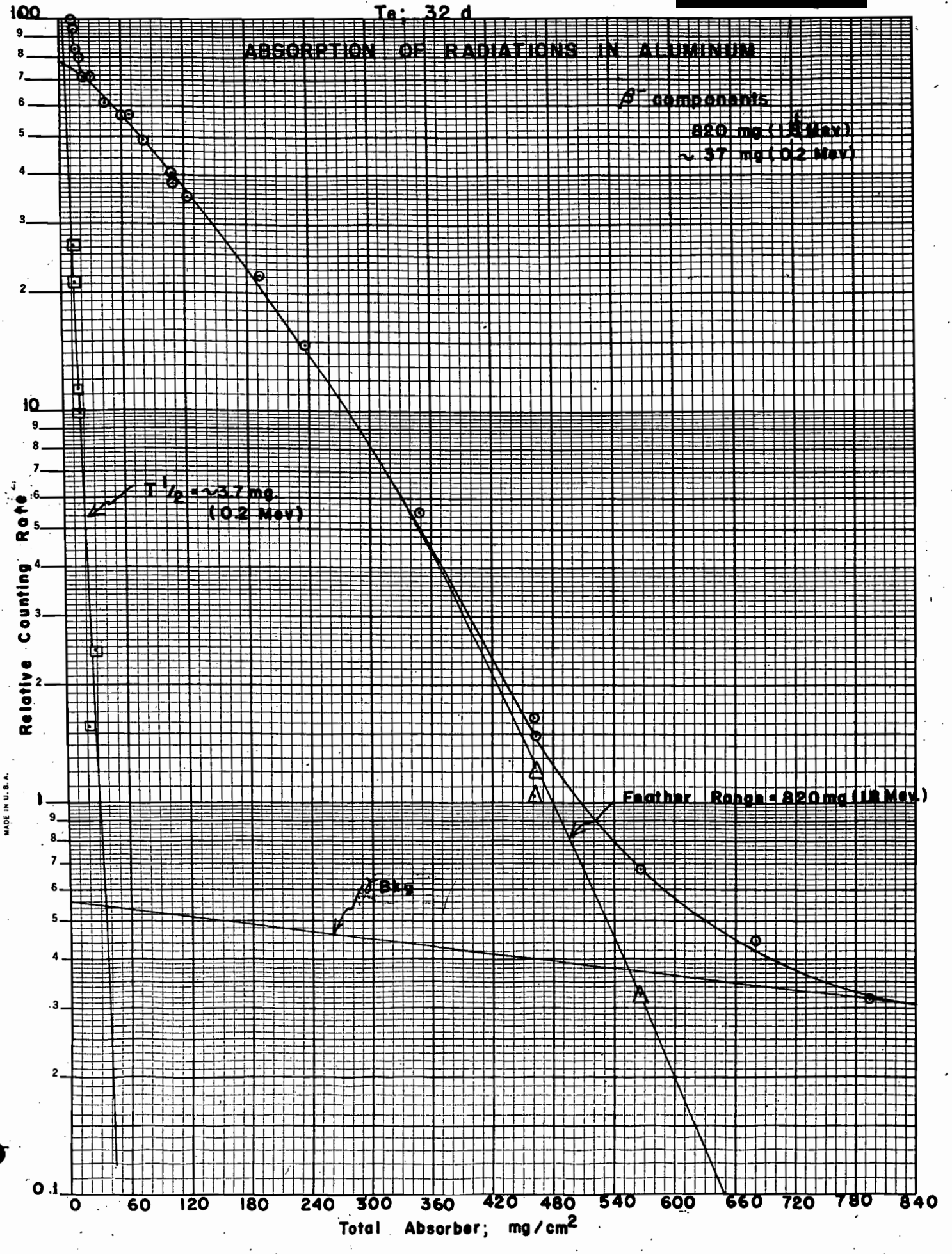

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FIG. 12

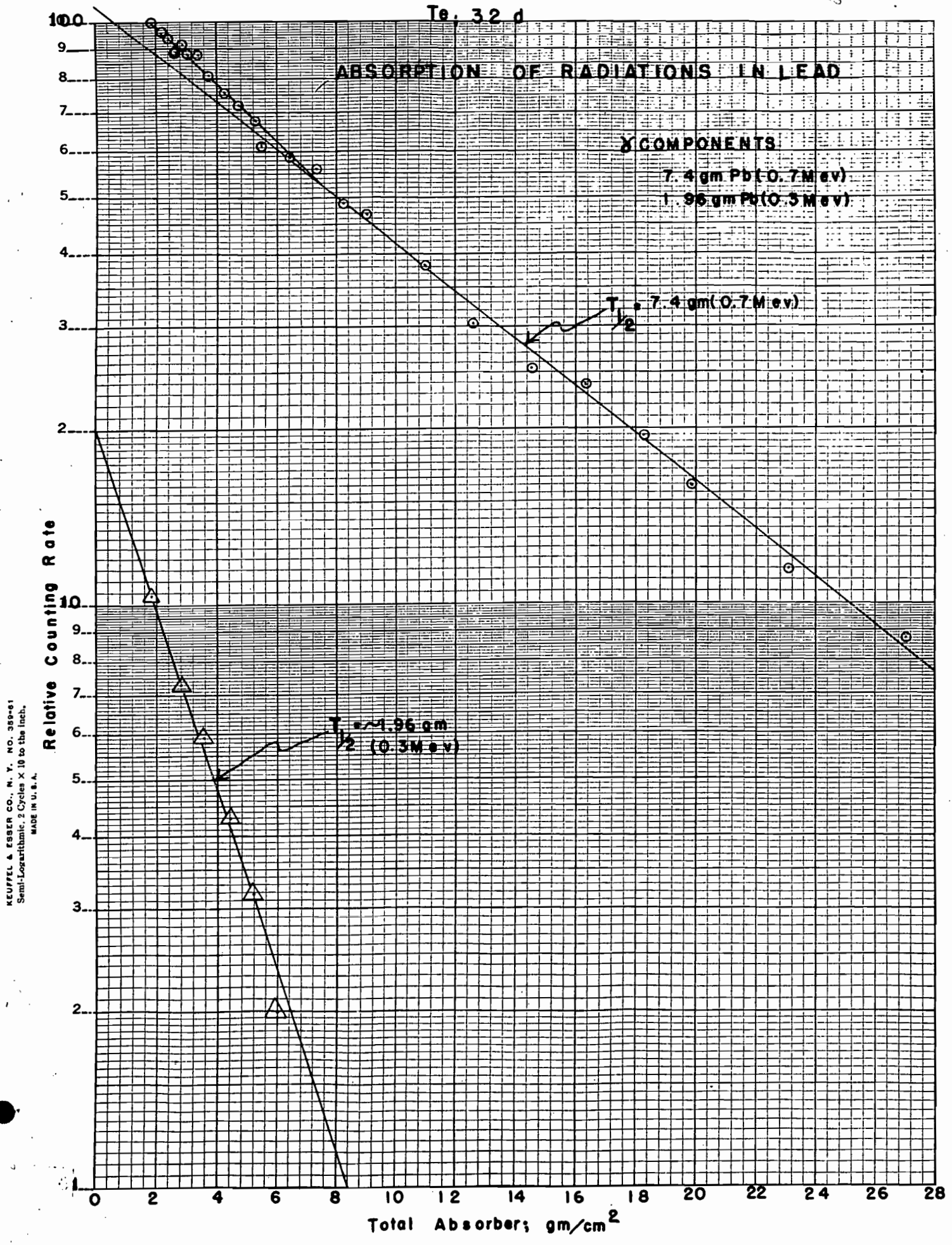
Te; 32 d
ABSORPTION OF RADIATIONS IN LEAD
γ COMPONENTS
7.4 gm Pb (0.7 M ev)
1.96 gm Pb (0.3 M ev)
T½ • 7.4 gm (0.7 M ev)
T½ • 1.96 gm (0.3 M ev)
Relative Counting Rate
Total Absorber; gm/cm²
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FIG. 13

I; 8d

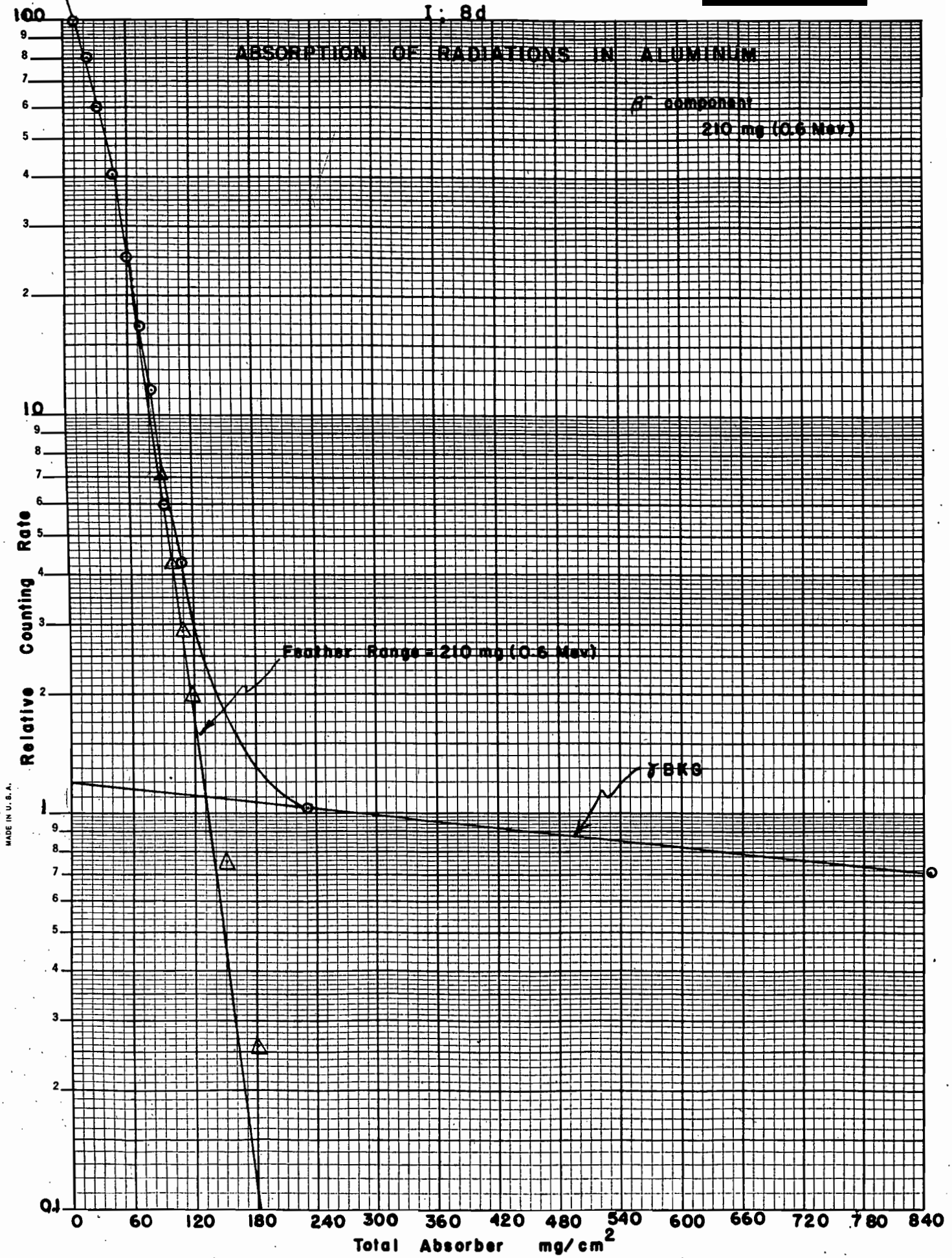

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FIG. 14

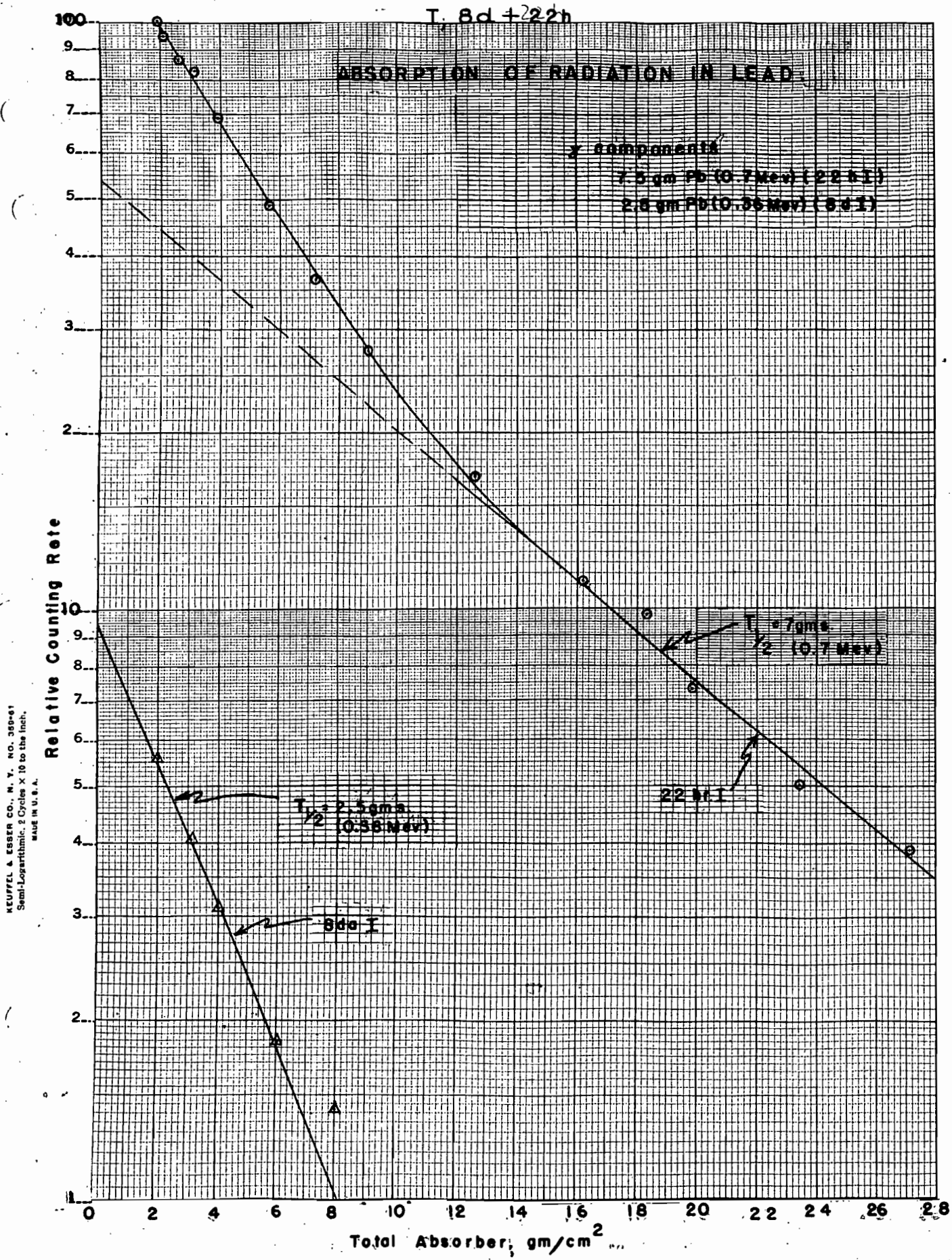
T, 8d + 22h
ABSORPTION OF RADIATION IN LEAD
γ components
7.5 gm Pb (0.7 Mev) (22 d I)
2.5 gm Pb (0.36 Mev) (8 d I)
T½ = 7 gms. (0.7 Mev)
22 d I
T½ = 2.5 gms. (0.36 Mev)
8 d I
Relative Counting Rate
Total Absorber, gm/cm²
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FIG. 15

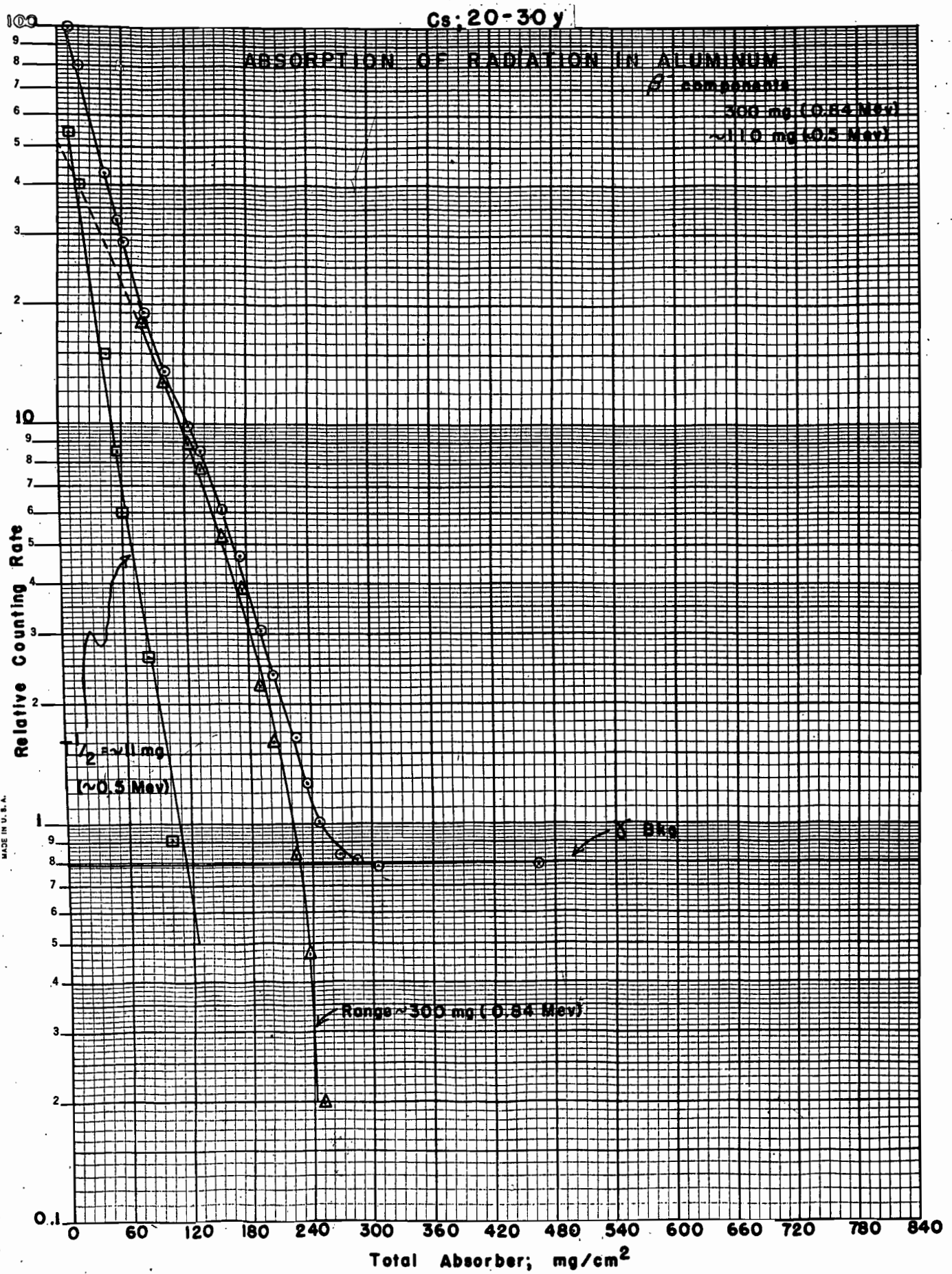

FIG. 16

Cs. 20-30y

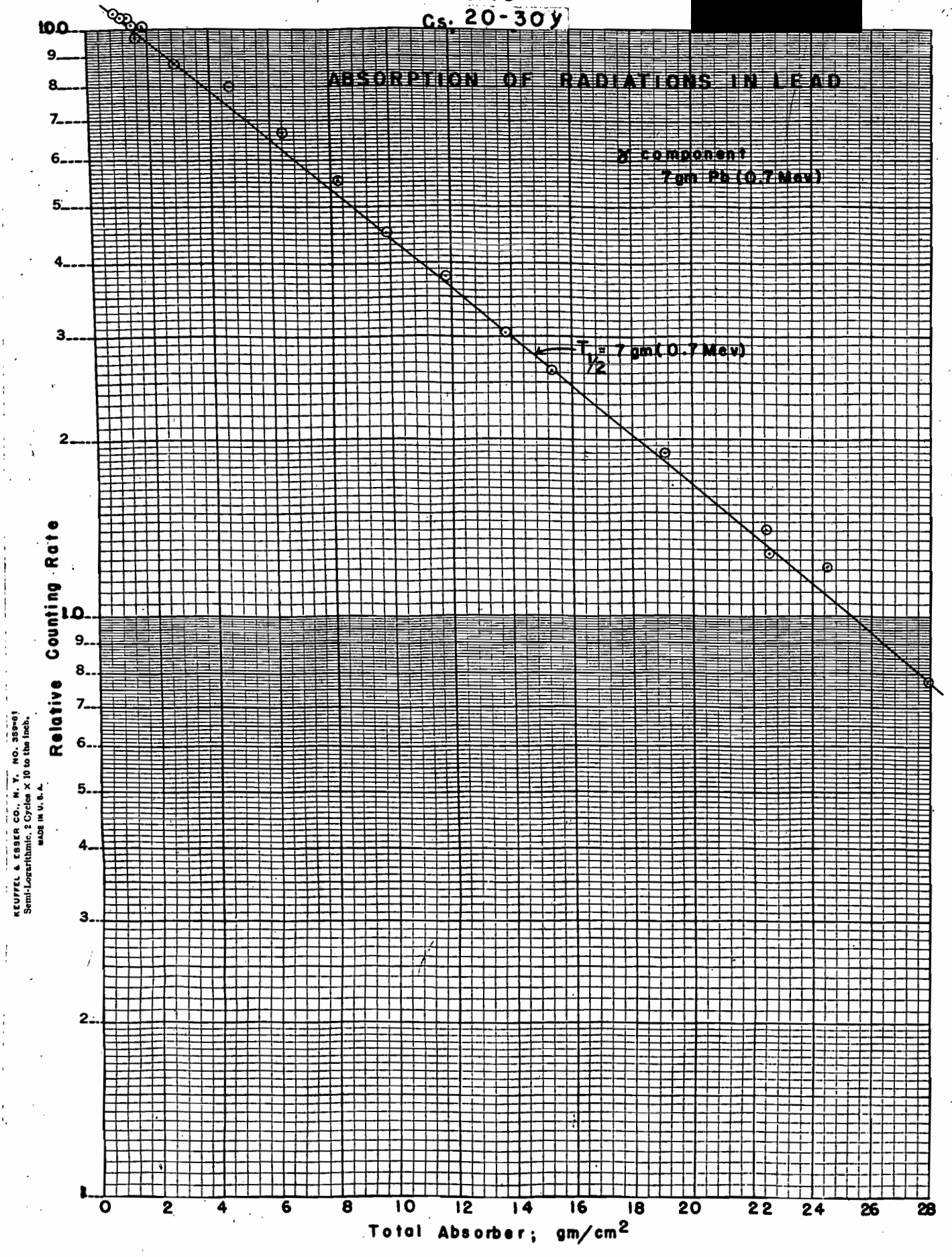

FIG. 17

Ba; 12.5 d

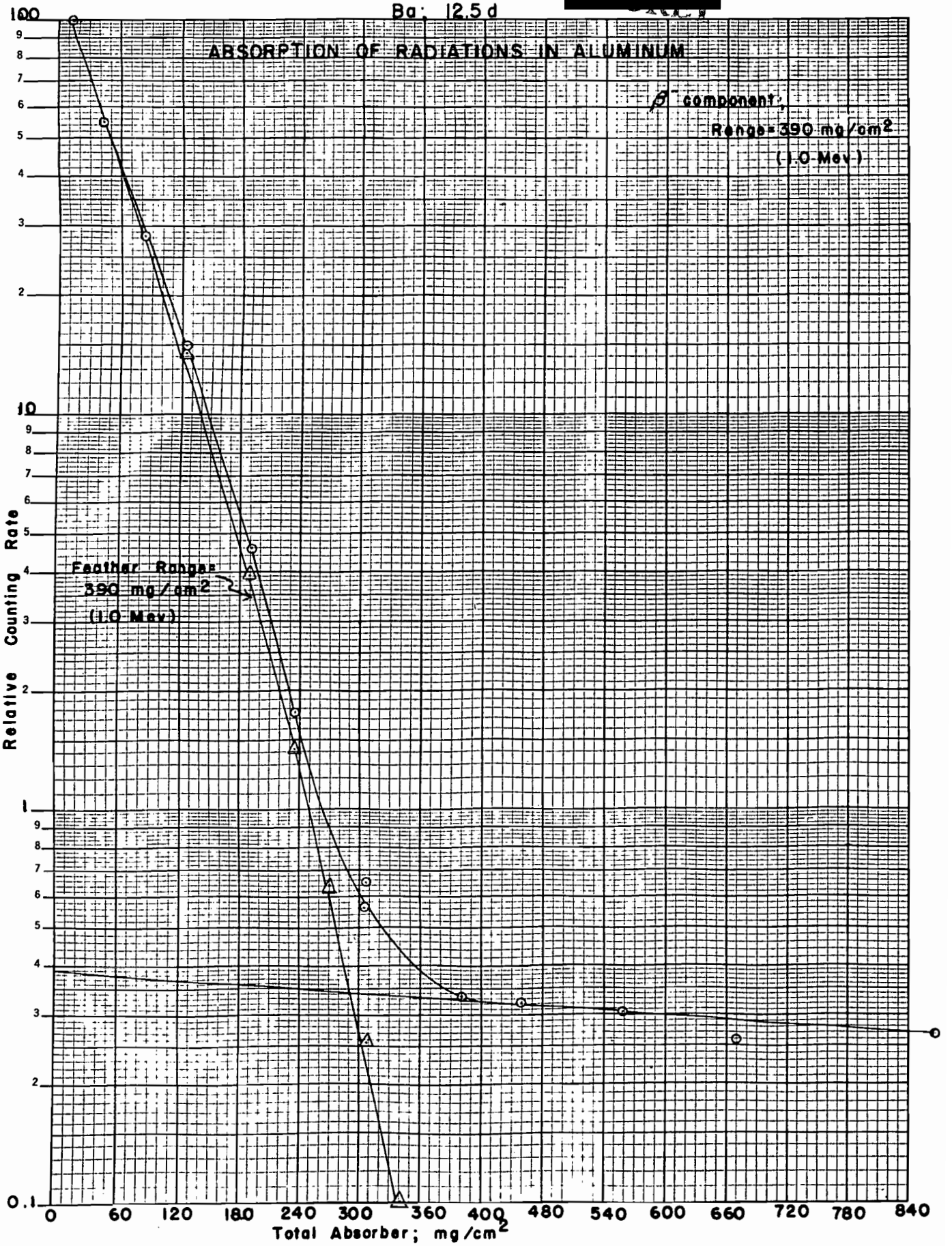

FIG. 18

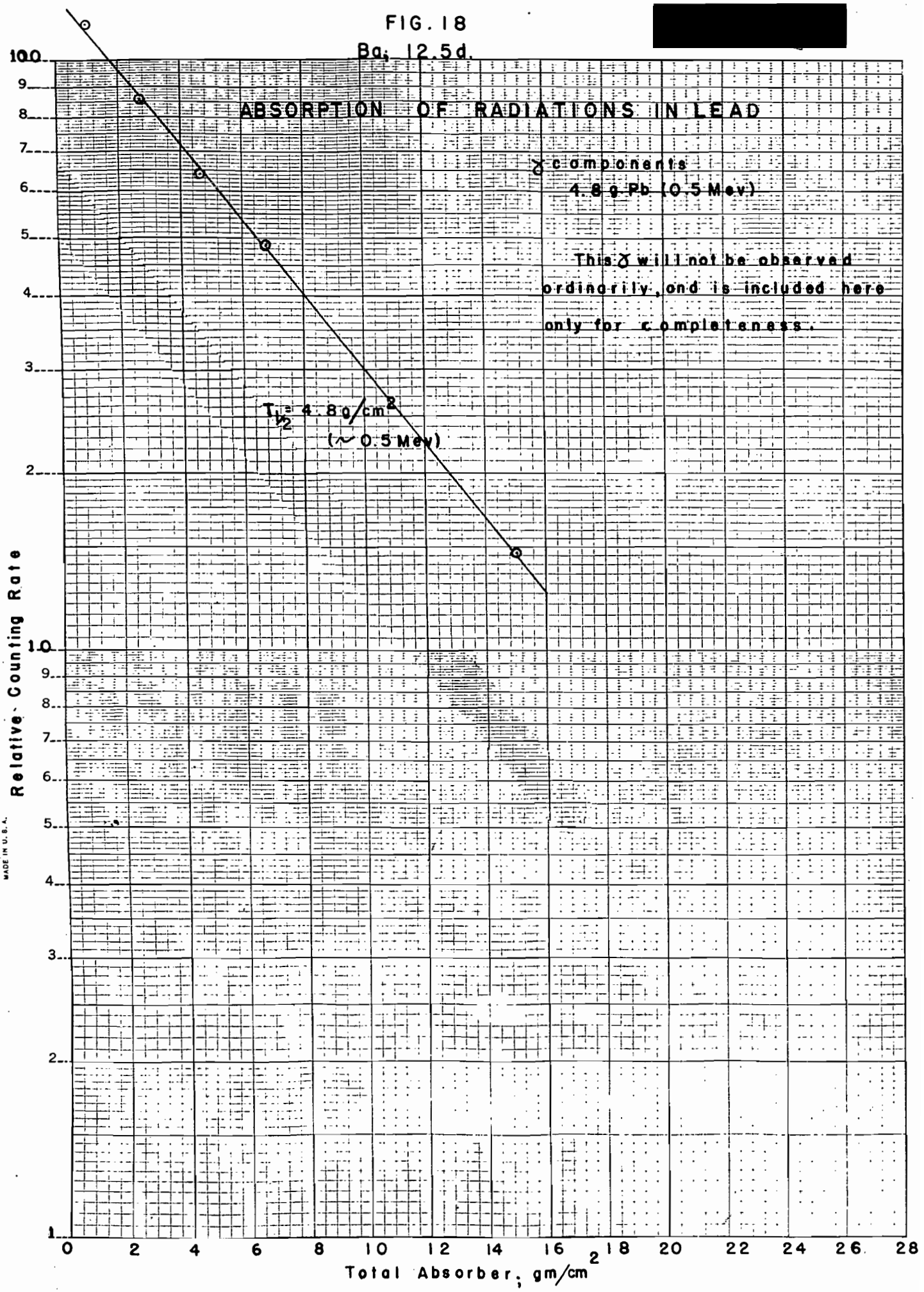
Ba; 12.5d.
ABSORPTION OF RADIATIONS IN LEAD
γ components
4.8 g Pb (0.5 Mev)
This γ will not be observed ordinarily, and is included here only for completeness.
$T_{1/2}$ = 4.8 g/cm²
(~ 0.5 Mev)
Relative Counting Rate
Total Absorber, gm/cm²
100
9
8
7
6
5
4
3
2
1.0
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
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FIG. 19

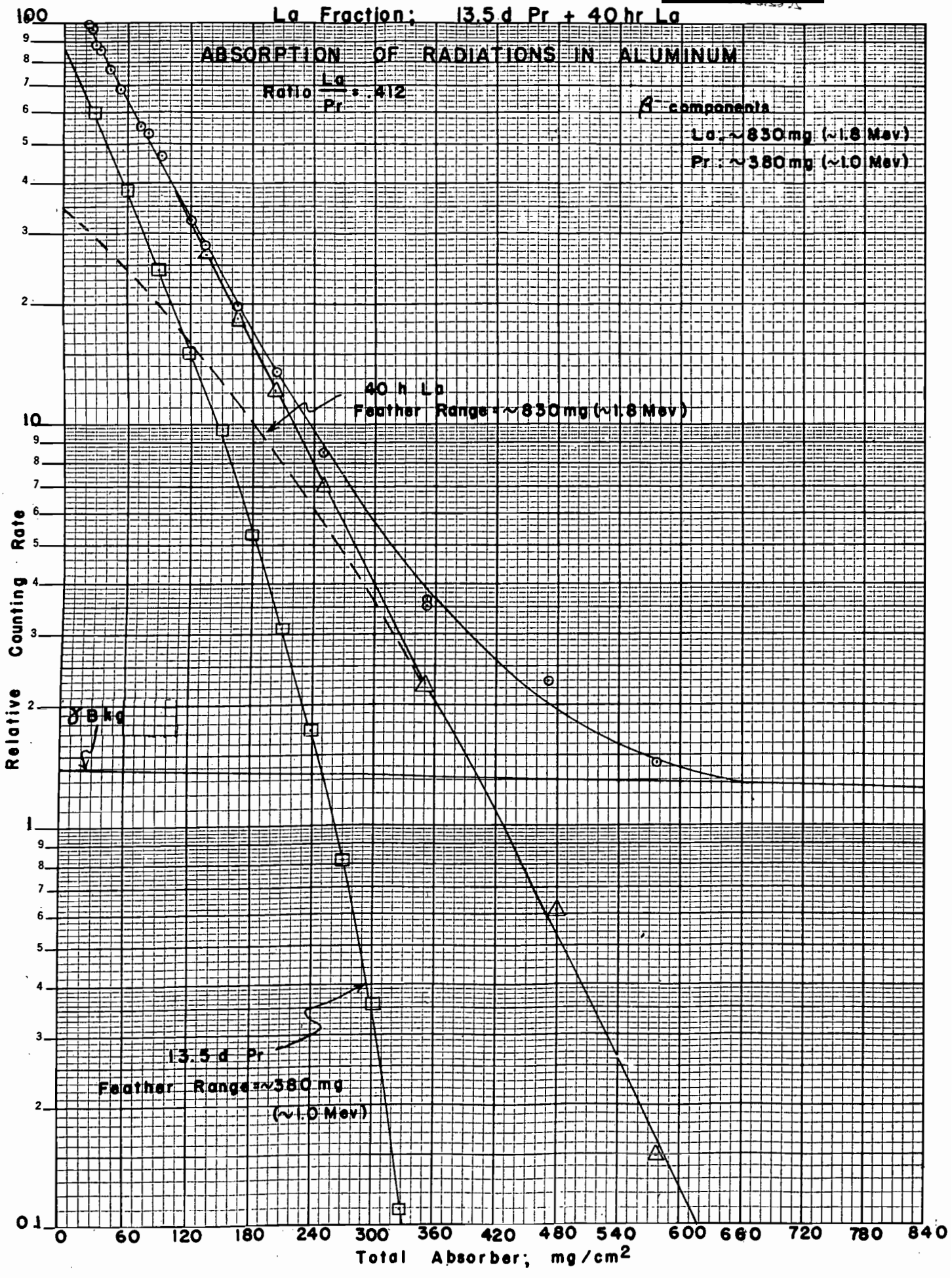

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FIG. 19a

La; 40h

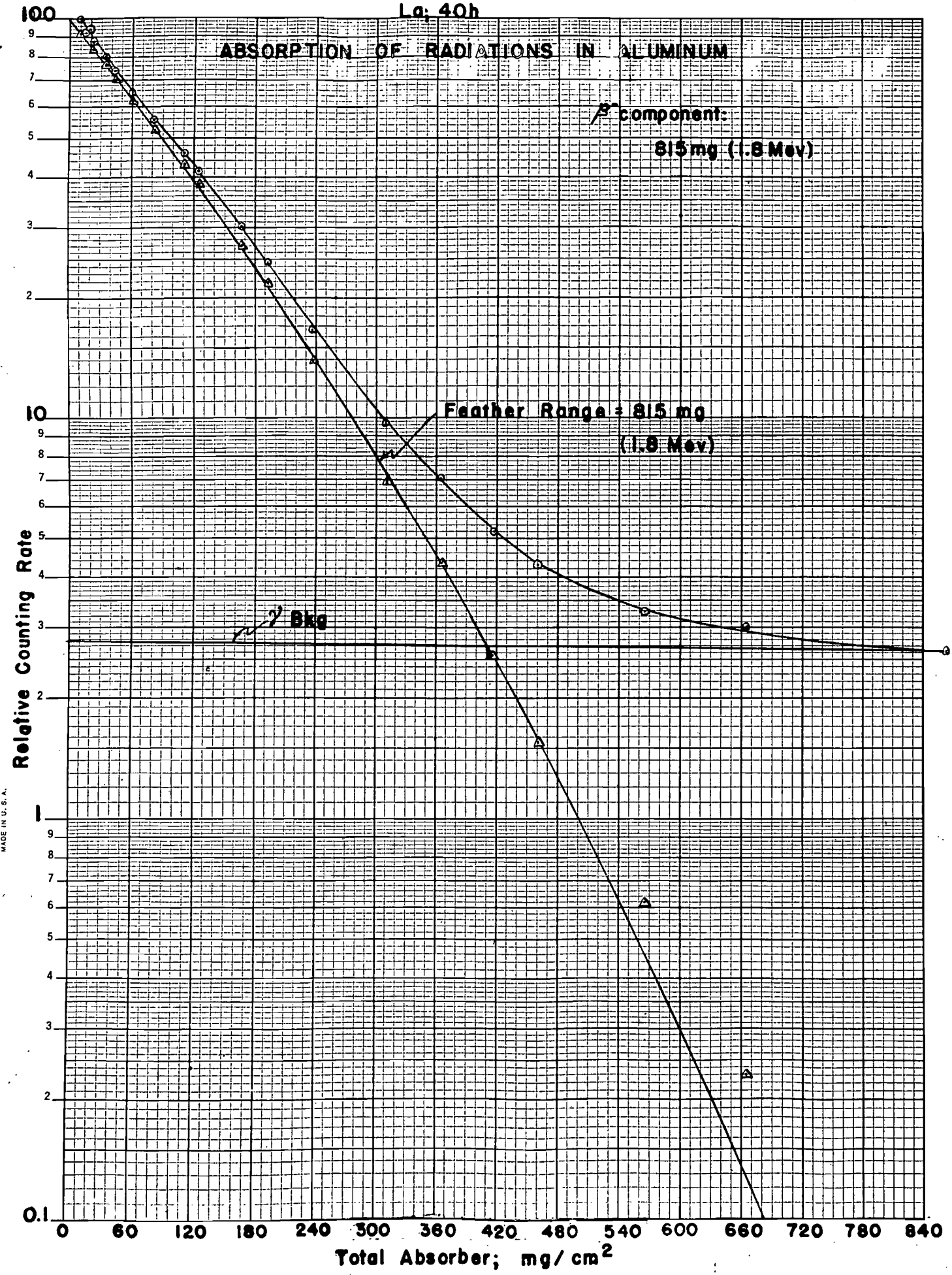

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FIG. 20

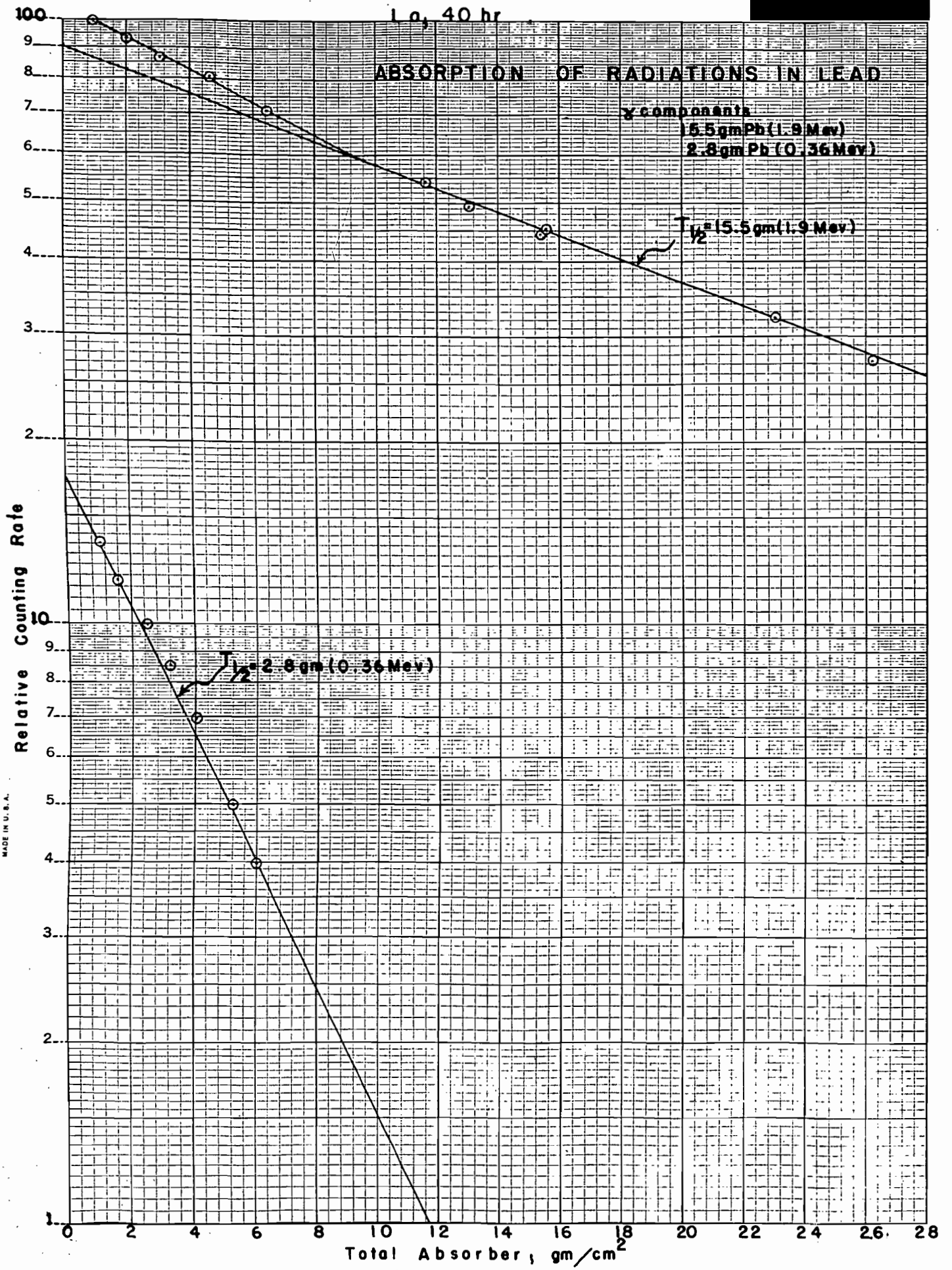

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FIG. 20a

Ba (12.5 d) and La (40 hr) in Equilibrium

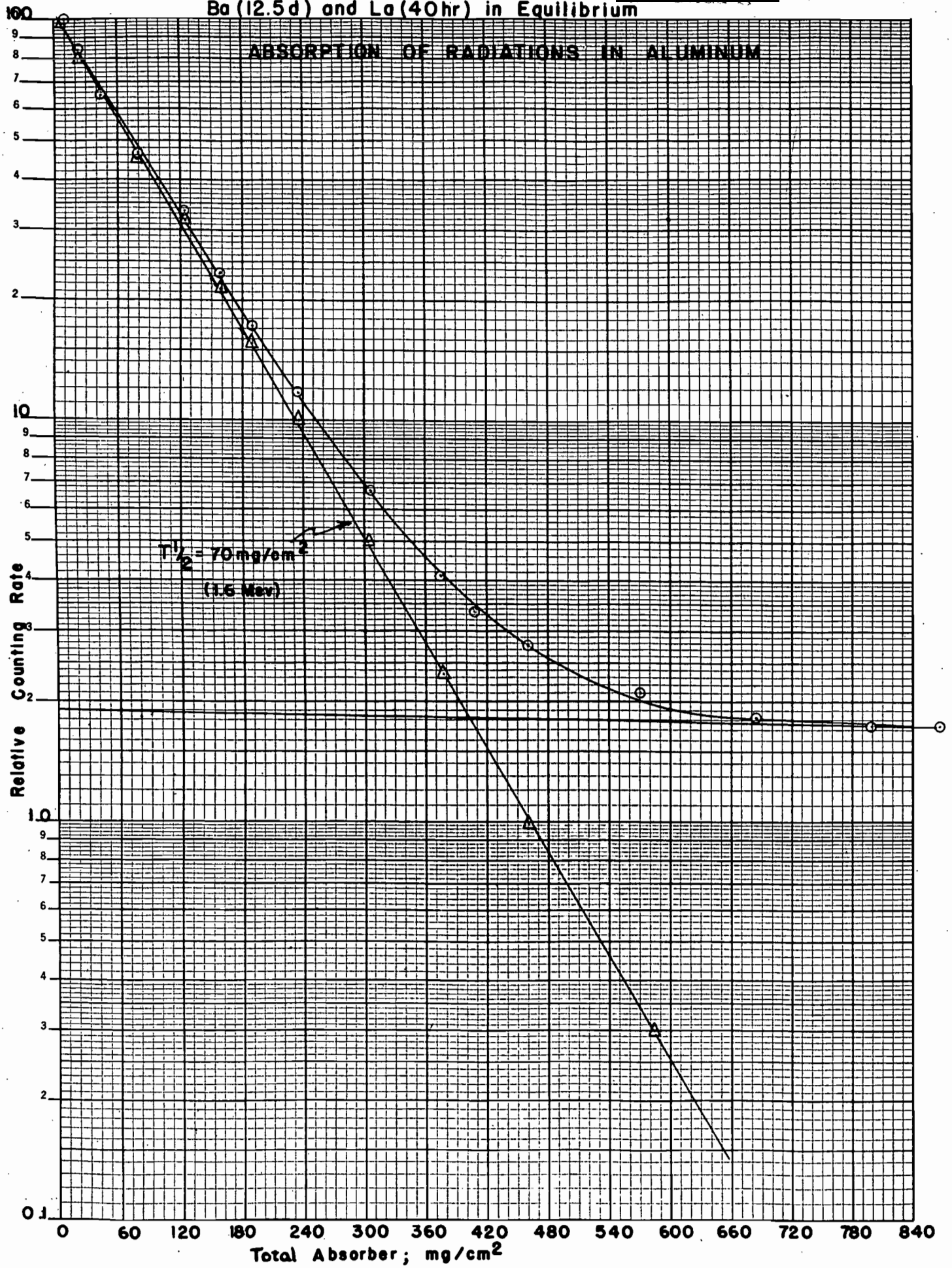

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FIG. 21

Ce. 28d & 300±30d

ABSORPTION OF RADIATION IN ALUMINUM

Ratio $\frac{28\,d\,Ce}{300\,d\,Ce} \sim .5$

β^- components

17m Pr daughter of 300 d Ce: ~1600mg (~3.1Mev)

300 d Ce: ~50mg (~0.2 Mev)

28 d Ce: ~170mg (0.6 Mev)

(See expanded Scale)

Feather Range: ~ 1600mg (3.1 Mev)

γ Bkg

Weak β's; Expanded scale

28 d Ce

Feather Range = ~170mg

(0.6Mev)

300 d Ce

$T_{1/2}$ = ~5mg

(~0.2 Mev)

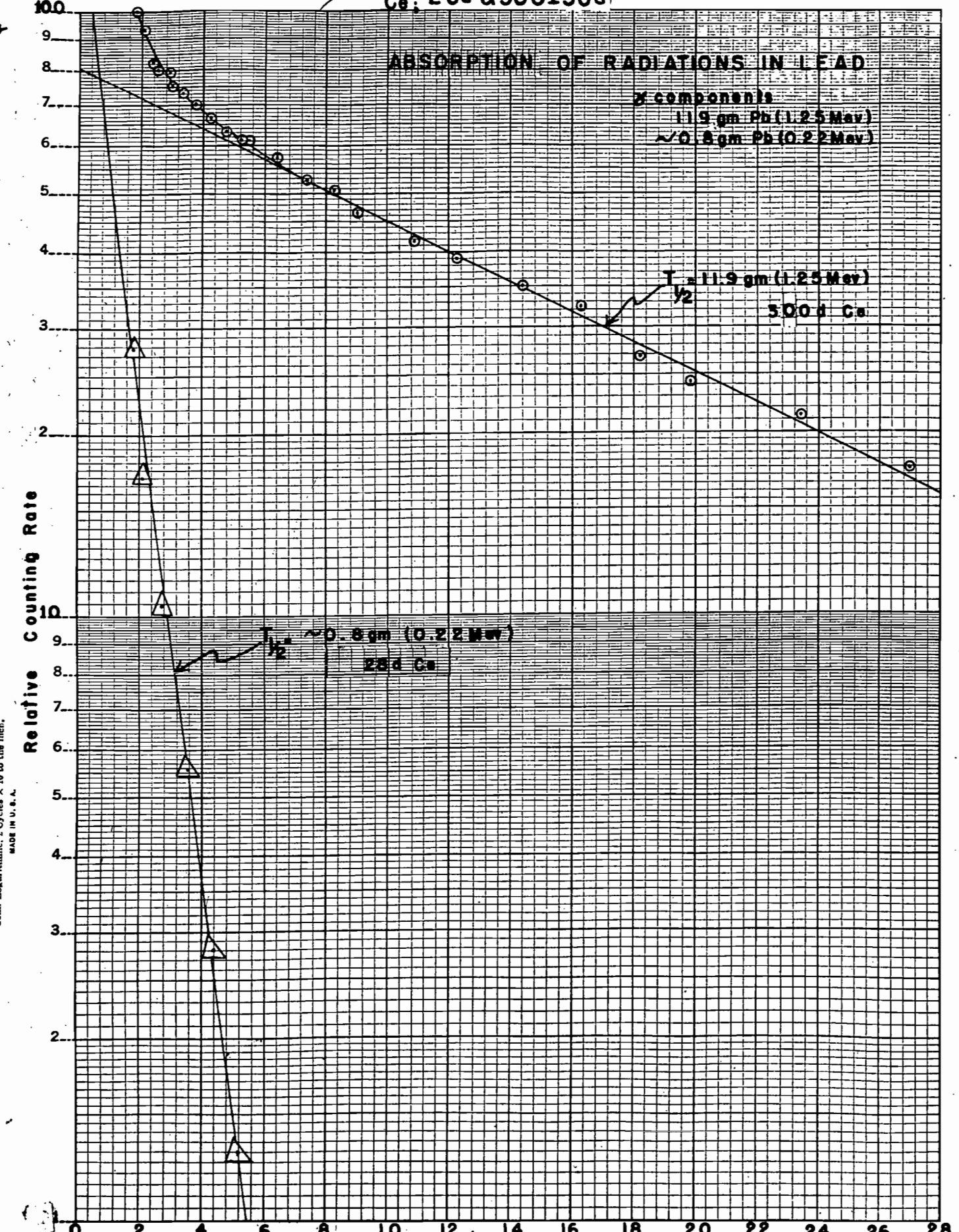
Relative Counting Rate

Total Absorber, mg/cm²

KEUFFEL & ESSER CO., N.Y. NO. 359-721
Semi-Logarithmic, 3 Cycles × 12 to the inch.
MADE IN U.S.A.

FIG. 22

Ce: 28d & 300±30d

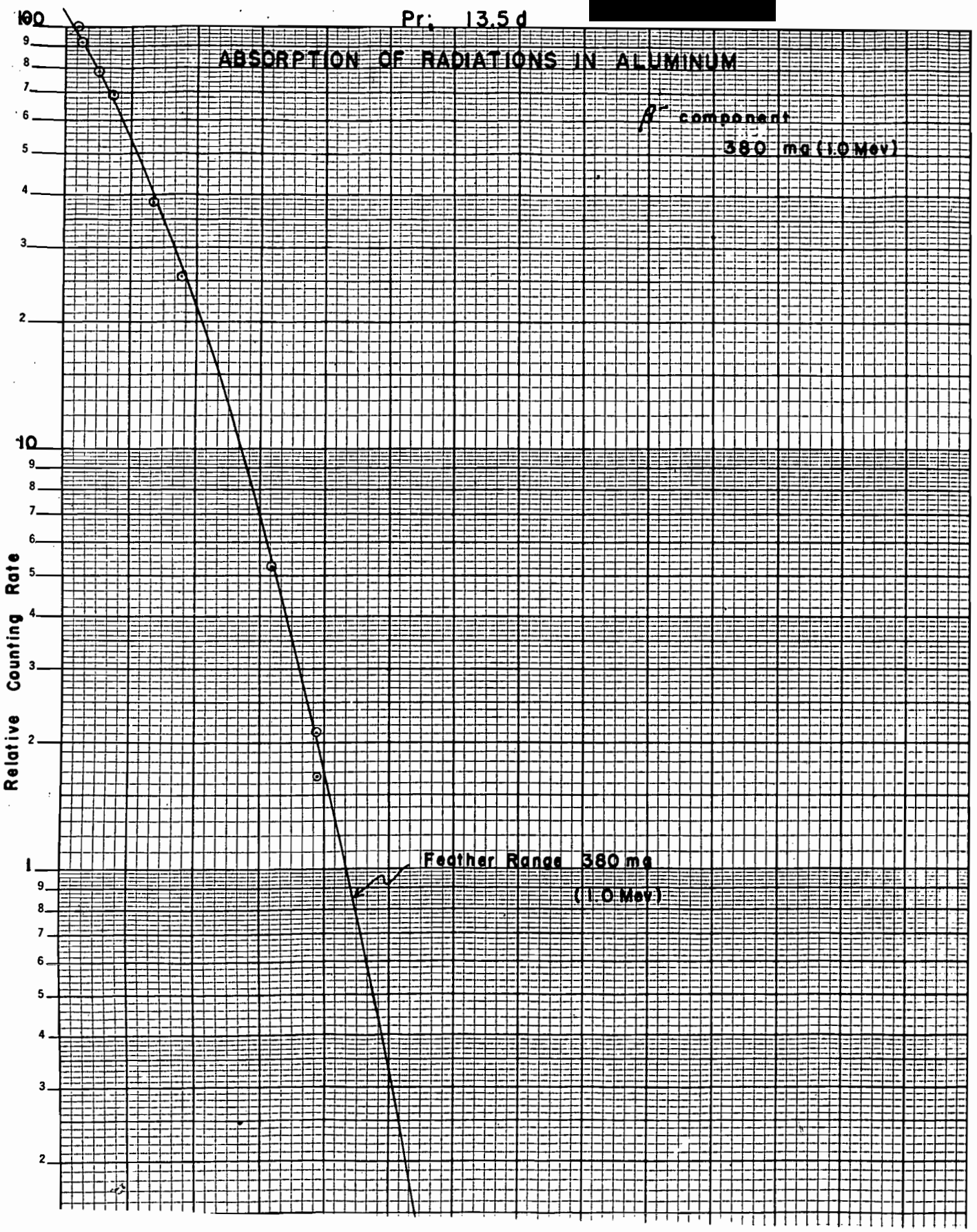


KEUFFEL & ESSER CO., N. Y. NO. 359-61
Semi-Logarithmic, 2 Cycles X 10 to the Inch.
MADE IN U. S. A.

FIG. 23

[redacted]

Pr; 13.5 d



KEUFFEL & ESSER CO., N. Y. NO. 359-72
Semi-Logarithmic, 3 Cycles X 12 to the inch.
MADE IN U.S.A.

[redacted]

FIG. 24

Eu; 15.4 d

ABSORPTION OF RADIATION IN ALUMINUM

β components

1180 mg (2.5 Mev)

~140 mg (~0.5 Mev)

FEATHER RANGE = 1180 mg/cm² (2.5 Mev)

$T_{\frac{1}{2}}$ = 14 mg/cm² (~0.5 Mev)

38 kg/cm²

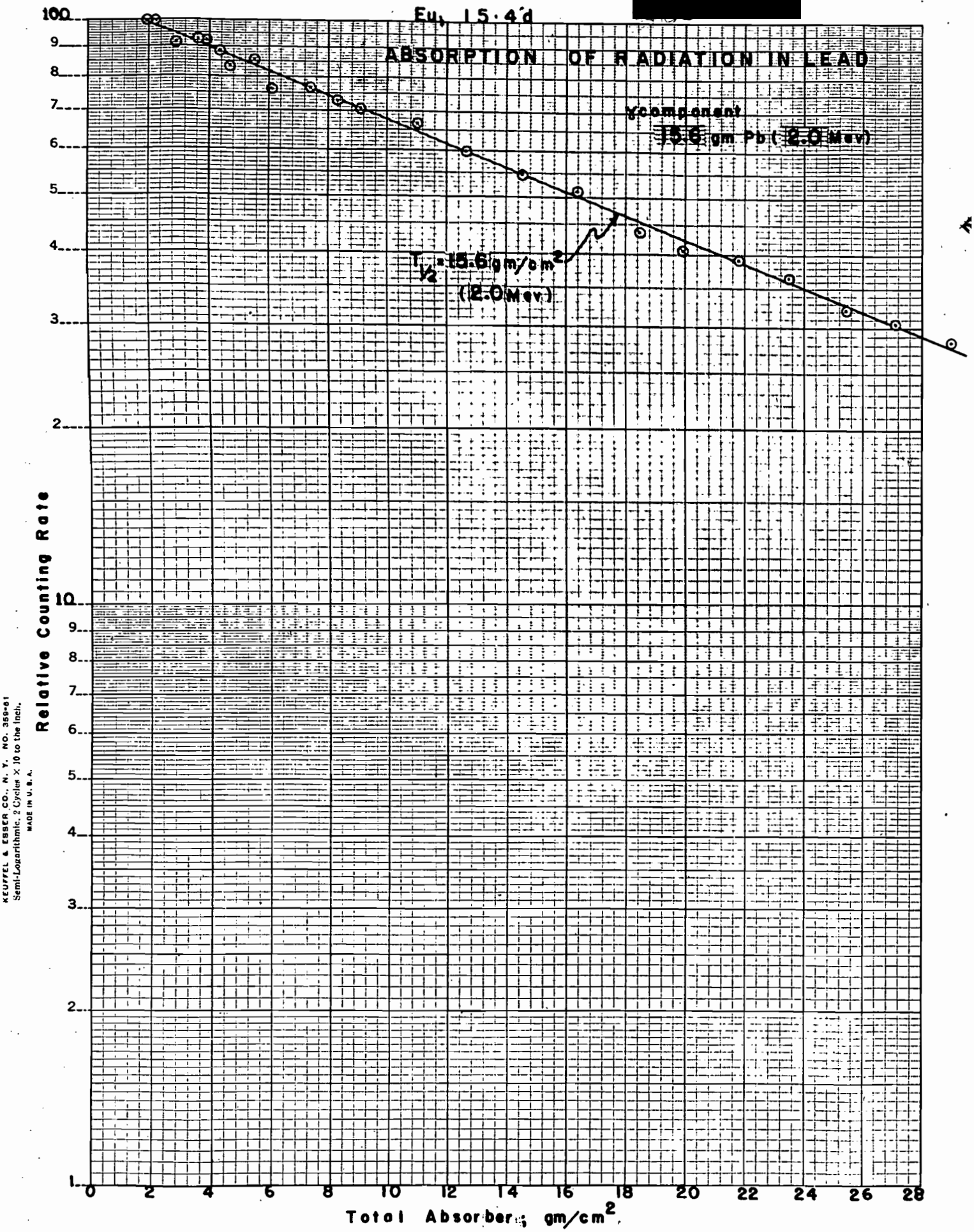
Relative Counting Rate

Total Absorber: mg/cm²

KEUFFEL & ESSER CO., N. Y. NO. 359-721
Semi-Logarithmic, 3 Cycles X 12 to the Inch.
MADE IN U. S. A.

FIG. 25

[redacted]



KEUFFEL & ESSER CO., N. Y., NO. 359-81
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FIG. 26

UX 24.5d

ABSORPTION OF RADIATIONS IN ALUMINUM

β COMPONENTS

(160mg (2.42Mev)
23mg (0.1Mev)

Relative Counting Rate

100
10
1
0.1

T=6mg/cm² (Reported=23.3mg) Range (0.1Mev)

FEATHER RANGE= 1160 mg (2.42 Mev)

SCATTERING B K G

0 60 120 180 240 300 360 400 480 540 600 660 720 780 840 900 960 1020 1080 1140 1200 1260 1320 1380 1440 1500 1560 1600 1680 1740 1800

TOTAL ABSORBER MG/CM²

KEUFFEL & ESSER CO., N.Y. NO. 359-72
Semi-Logarithmic, 3 Cycles X 25 to the Inch.
MADE IN U.S.A.