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THE BLACKENING EFFECT OF NEUTRON AND GAMMA RADIATION ON DUPONT 552 AND EASTMAN V-120 FILM

BEN KALMON

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HEALTH PHYSICS DIVISION

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Ben Kalmon

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The Blackening Effect of Neutron and Gamma Radiation on DuPont 552 and Eastman V-120 Film

Summary

The blackening of DuPont 552 film and Eastman Kodak type V-120 film due to gamma and neutron radiation has been investigated. In the case of the DuPont 552 film, one curie of an unfiltered Po-Be neutron source, at one centimeter, would produce blackening equivalent to 504.4 mr/hr of unfiltered radium gamma radiation. For filtered neutron and gamma radiation, the equivalent blackening was 236.8 mr/hr. For Eastman V-120 film, the equivalent blackening was 472.1 mr/hr for unfiltered radiation. No detectable blackening was observed with V-120 film when exposed to a two inch lead filtered Po-Be neutron source on exposures up to 3.75×10^8 neutrons/cm^2. A portion of each film was surrounded with 1/16 inch lead sheet. For both neutron and gamma radiation it was observed that, in general, the lead sheet acted as an intensifying screen. The exceptions were with the 552 film exposed to the unfiltered gamma source and for the V-120 film exposed to the unfiltered gamma source. In the case of the 552 film, the blackening was less and for the V-120 film the blackening was the same behind the lead sheet.

Experimental Procedure

The neutron source was a Po-Be neutron source of known emission. The source casing was unknown and hence the attenuation through the casing was not considered. The gamma source was rated at 23.35 milligrams of radium filtered through 0.5 mm of platinum. The gamma exposure rate was measured by a Lauritsen electroscope at each film position. The neutron flux was calculated at each position from the known emission value. For the case of the lead filtered neutron source the cross section of the lead was taken as 2.22 barns at 4 Mev. Assuming this value, the calibration curves for one inch and two inches of lead filtering were essentially the same within the sensitivity limits of the densitometer.

Each series of films was exposed to the sources unfiltered and with the Po-Be source filtered with two inches of lead and the radium source filtered with 0.5 inches of lead. The films were placed at various distances from the source in the form of concentric circles varying from 15 to 30 centimeters in radius. The films were developed with Eastman Kodak Dektol developer for five minutes at 68° F. and placed in the fixer for ten minutes and washed for thirty minutes. The film blackening was measured with an Ansco-Sweet Densitometer having a range up to three.

An empirical equation, for the film blackening, had been determined for each set of conditions. The equation is given with each table (the blackening is represented by the symbol B). These equations were the bases for all calculations. Calculations were made for the blackening ratio of the 552 film to that for the V-120 film for both the gamma and neutron exposures as shown in Figures 3 and 4. Further calculations were made for the blackening ratios due to gamma exposure for various milliroentgens to the same milliroentgen equivalent physical exposures due to neutrons (Figure 5). For unfiltered sources, the blackening ratio for the 552 film approaches 3 and for the V-120 film approximately 2. For the filtered sources the 552 film approaches 10. The calculated curves are plotted in Figure 5.

Sample Calculations

Calculations for the blackening ratio of 552 film to V-120 film, Figure 3, Table 9, were done in the following manner:

$B_{552} = .000537\ n + .028$ for unfiltered neutrons (Table 3).

$B_{V-120} = .000211\ n + .0063$ for unfiltered neutrons (Table 8).

Assume $n = 300$

$$\therefore\ B_{552} = .1611 + .028 = .1891$$

$$B_{V-120} = .0633 + .0063 = .0699$$

or $$B_{552}/B_{V-120} = \frac{.1891}{.0699} = 2.71$$

Calculations for the blackening ratio of 552 film to V-120 film, Figure 4, Table 10, were done as follows:

$B_{552} = .000563\ mr + .011$ for unfiltered gamma (Table 1).

$B_{V-120} = .000126\ mr + .0093$ for unfiltered gamma (Table 6).

Assume 1000 mr

$$B_{552} = .563 + .011 = .574$$

$$B_{V-120} = .126 + .0093 = .1353$$

or $$B_{552}/B_{V-120} = \frac{.574}{.1353} = 4.24$$

Calculations for the blackening ratio of gamma exposure for various milliroentgens to the same milliroentgen equivalent physical exposures due to neutrons, Figure 5, Table 12, are given in the sample calculations shown below.

$B_{gamma} = .000563$ mr $+ .011$ for unfiltered gammas for 552 film (See Table 1)

$B_{neutron} = .000537n + .028$ for unfiltered neutrons for 552 film (See Table 3)

Assume an exposure of 500 mr or 500 mrep

assuming that 200 neutrons/cm^2/sec for 8 hours is equivalent to 20 mrep,

then 1 mrep $= 10$ neutrons/cm^2 8×3600

$= 28.8 \times 10^4$ neutrons/cm^2

then 500 mrep $= 144 \times 10^6$ neutrons/cm^2

or n $= 144$

thus $B_{gamma} = .000563 \times 500 + .011 = .2925$

$B_{neutron} = .000537 \times 144 + .028 = .1053$

or $$\frac{B_{gamma}}{B_{neutron}} = \frac{.2925}{.1053} = 2.77$$

No explanation is offered for the anomalous curves for the case of the blackening ratio for the portion of the film behind the lead sheet, exposed to the filtered radium source (see Figure 4) or in the case of the blackening ratio of gamma to neutron exposure for the V-120 film, behind the lead sheet, exposed to the unfiltered sources (see Figure 5). This memorandum is considered as a progress report of the work covered to date and not a formal finished report. Further work is being carried out with other types of film.

Results of observations are shown in the following tables and figures.

This work was carried on with the assistance of T. E. Shea, Lieutenant Commander, USN.

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2. Pardue, L. A., Goldstein, N., and Wollan, E. O., "Photographic Film as a Pocket Radiation Dosimeter," Project report MDDC-1065.

3. Nucleonics, May, 1948, page 82.

4. Evans, Robley D., "Physical, Biological and Administrative Problems Associated with the Transportation of Radioactive Substances," Part 1.

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Table 1

DuPont 552 Film - Unfiltered Radium Source

mr	Blackening	Blackening behind lead sheet
82.9	0.050	0.040
84.6	0.058	0.040
144.6	0.080	0.078
148.1	0.100	0.082
268.8	0.155	0.155
286.2	0.175	0.138
576.6	0.340	0.285
806.4	0.490	0.455
942.0	0.530	0.480
1188.0	0.675	0.600

$B = .000563 \text{ mr} + .011$

$B = .000520 \text{ mr}$ Behind lead sheet

Table 2

DuPont 552 Film

0.5 inches lead filtered radium source

mr	Blackening	Blackening behind lead sheet
31.2	0.020	0.023
33.6	0.022	0.035
58.2	0.040	0.045
88.4	0.050	0.055
117.0	0.060	0.070
132.0	0.070	0.080
252.6	0.120	0.125
348.0	0.158	0.178
374.0	0.150	0.160
374.0	0.160	0.180
414.0	0.175	0.200
522.0	0.200	0.240
716.0	0.305	0.338
986.0	0.401	0.440
1172.0	0.460	0.510
1172.0	0.468	0.515

$B = .000397 \text{ mr} + .014$

$B = .000436 \text{ mr} + .013$ Behind lead sheet

Table 3

DuPont 552 Film - Unfiltered Po-Be Source

(Neutrons/cm^2) x 10^{-6}	Blackening	Blackening behind lead sheet
22.3	0.035	0.040
22.7	0.050	0.050
38.8	0.040	0.060
39.8	0.040	0.050
72.0	0.070	0.100
76.7	0.060	0.090
155.0	0.115	0.150
217.0	0.142	0.200
253.5	0.170	0.238
320.0	0.200	0.265

$B = .000537\ n + .028$ where n equals the number of (neutrons/cm^2) x 10^{-6}

$B = .000811\ n + .026$ Behind lead sheet

Table 4

DuPont 552 Film

1 inch lead filtered Po-Be Neutron Source

(Neutrons/cm^2) x 10^{-6}	Blackening	Blackening Behind lead sheet
41.0	0.010	0.015
69.9	0.010	0.020
71.6	0.010	0.020
130.1	0.020	0.030
138.4	0.022	0.030
279.0	0.035	0.065
390.0	0.055	0.100
457.0	0.060	0.120
576.0	0.080	0.160

$B = .0001198\ n + .0048$ where n equals the number of (neutrons/cm^2) x 10^{-6}

$B = .000234\ nn + .0033$ Behind lead sheet

Table 5

DuPont 552 Film

2 inch lead filtered Po-Be Neutron Source

(Neutrons/cm^2) x 10^{-6}	Blackening	Blackening Behind lead sheet
22.8	0.010	0.015
40.8	0.010	0.010
74.1	0.010	0.020
159.1	0.020	0.025
222.4	0.025	0.045
260.9	0.038	0.055
328.6	0.045	0.075

$B = .0001198\ n + .0048$ where n equals the number of (neutrons/cm^2) x 10^{-6}

$B = .000234\ n + .0033$ Behind lead sheet

Table 6

Eastman V-120 Film - Unfiltered Radium Source

mr	Blackening	Blackening Behind lead sheet
54.4	0.017	0.017
128.4	0.020	0.020
183.5	0.020	0.020
217.5	0.030	0.030
326.0	0.050	0.050
445.4	0.060	0.060
560.0	0.060	0.060
793.0	0.120	0.120
994.0	0.140	0.140

$$B = .000126 \text{ mr} + .0093$$

$$B = .000126 \text{ mr} + .0093 \quad \text{Behind lead sheet}$$

Table 7

Eastman V-120 Film - 0.5 inches lead filtered radium source

mr	Blackening	Blackening Behind lead sheet
98.4	0.015	0.150
148.6	0.020	0.020
239.8	0.020	0.030
310.0	0.030	0.040
426.0	0.040	0.080
566.4	0.065	0.100
660.0	0.058	0.090
708.0	0.080	0.140

$$B = .0000858 \text{ mr} + .0060$$

$$B = .000166 \text{ mr} - .0041 \quad \text{Behind lead sheet}$$

Table 8

Eastman V-120 Film - Unfiltered Po-Be Neutron Source

(Neutrons/cm^2) x 10^{-6}	Blackening	Blackening Behind lead sheet
112.0	0.020	0.025
162.4	0.030	0.040
185.0	0.055	0.080
235.4	0.060	0.070
254.0	0.050	0.090
327.0	0.095	0.120
417.0	0.100	-----
451.0	0.110	0.160
524.0	0.125	0.170

$B = .000211\ n + .0063$ where n equals number of (neutrons/cm^2) x 10^{-6}

$B = .000410\ n - .0186$ Behind lead sheet

Table 9

Ratio of Blackening of 552 Film to V-120 Film

Unfiltered Po-Be Neutron Source

(Neutrons/cm^2) x 10^{-6}	Blackening Ratio 552/V-120	Blackening Ratio 552/V-120 Behind lead sheet
100	2.99	4.78
150	2.87	3.44
200	2.80	2.97
250	2.75	2.73
300	2.71	2.58
350	2.70	2.48
400	2.68	2.41
450	2.67	2.36
500	2.65	2.31

Table 10

Ratio of Blackening of 552 Film to V-120 Film

Unfiltered Radium Source

mr	Blackening Ratio 552/V-120	Blackening Ratio 552/V-120 Behind lead sheet
100	3.05	2.37
200	3.57	3.01
300	3.81	3.31
400	3.95	3.48
500	4.04	3.60
600	4.10	3.67
700	4.15	3.73
800	4.19	3.78
900	4.22	3.81
1000	4.24	3.84

Table 11

Ratio of Blackening of 552 Film to V-120 Film

Filtered Radium Source

mr	Blackening Ratio 552/V-120	Blackening Ratio 552/V-120 Behind lead sheet
100	3.65	4.53
200	4.01	3.44
300	4.18	3.15
400	4.27	3.01
500	4.33	2.93
600	4.38	2.88
700	4.41	2.84
800	4.43	2.81
900	4.45	2.79
1000	4.48	2.77

Table 12

Ratio of Blackening Due to Gamma or

Neutron Exposures, Unfiltered Sources

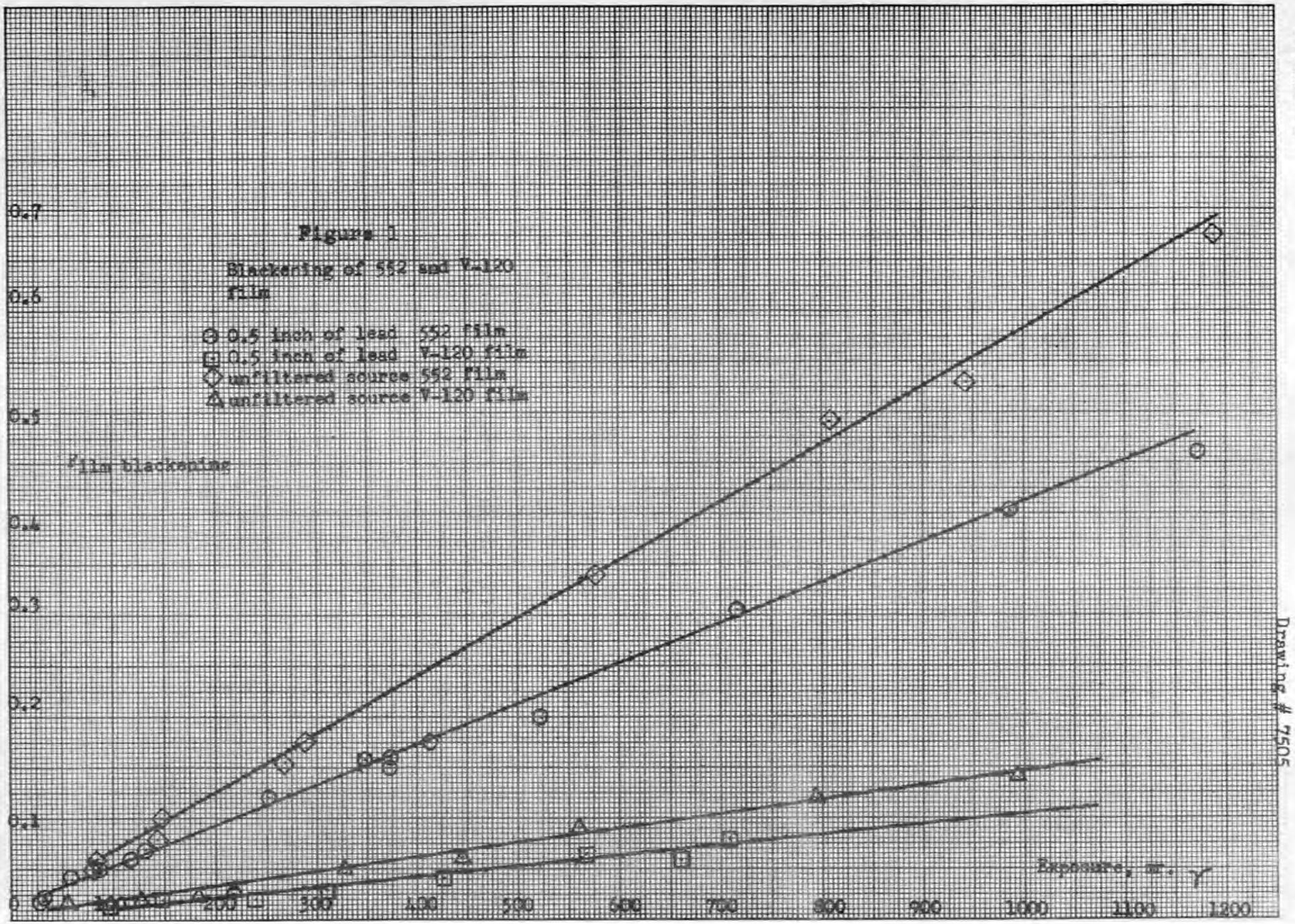
		Gamma Blackening / Neutron Blackening			
mr gamma or mrep neutron	(Neutrons/cm^2) x 10^{-6}	552 Film	552 Film Behind Lead Sheet	V-120 Film	V-120 Film Behind Lead Sheet
25	7.2	.77	.41	1.60	No
50	14.4	1.08	.69	1.67	Detectable
75	21.6	1.33	.90	1.73	Blacken-
100	28.8	1.53	1.05	1.77	ing
200	57.6	2.08	1.43	1.87	6.88
300	86.4	2.41	1.62	1.92	2.80
400	115.2	2.62	1.74	1.95	2.09
500	144.0	2.77	1.82	1.97	1.79
600	172.8	2.88	1.88	1.99	1.62
700	201.6	2.97	1.92	2.00	1.52
800	230.4	3.03	1.95	2.01	1.45
900	259.2	3.09	1.98	2.01	1.40
1000	288.0	3.14	2.00	2.02	1.36

Table 13

Ratio of Blackening Due to Gamma or Neutron Sources

Filtered Sources - 552 Film

mr gamma or mrep neutron	(Neutrons/cm^2) x 10^{-6}	Gamma Blackening / Neutron Blackening	Gamma Blackening / Neutron Blackening Behind lead sheet
25	7.2	4.13	4.88
50	14.4	5.11	5.19
75	21.6	5.85	5.44
100	28.8	6.44	5.66
200	57.6	7.93	5.96
300	86.4	8.75	6.13
400	115.2	9.26	6.18
500	144.0	9.61	6.24
600	172.8	9.87	6.28
700	201.6	10.06	6.30
800	230.4	10.21	6.32
900	259.2	10.34	6.34
1000	288.0	10.44	6.36



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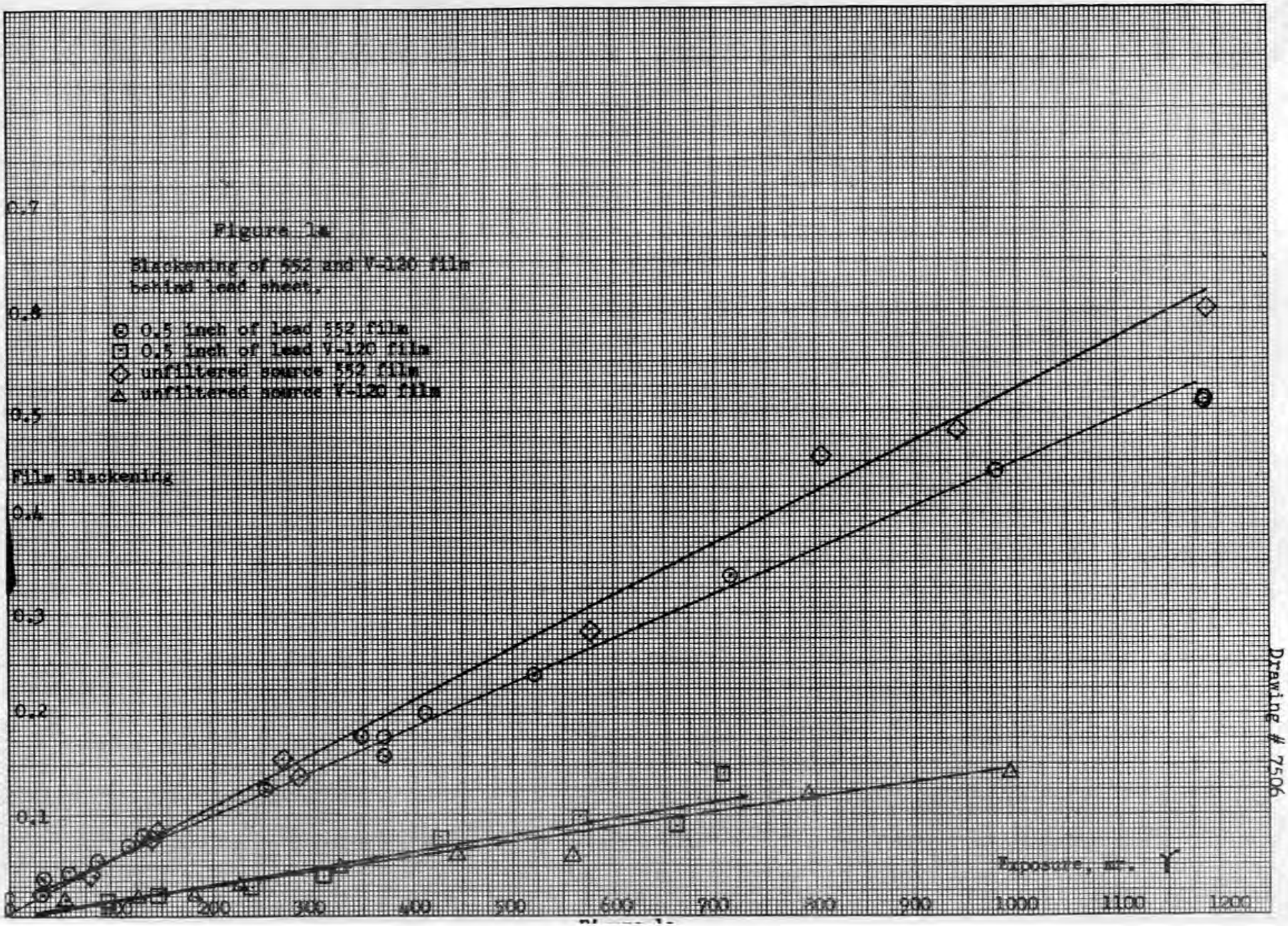

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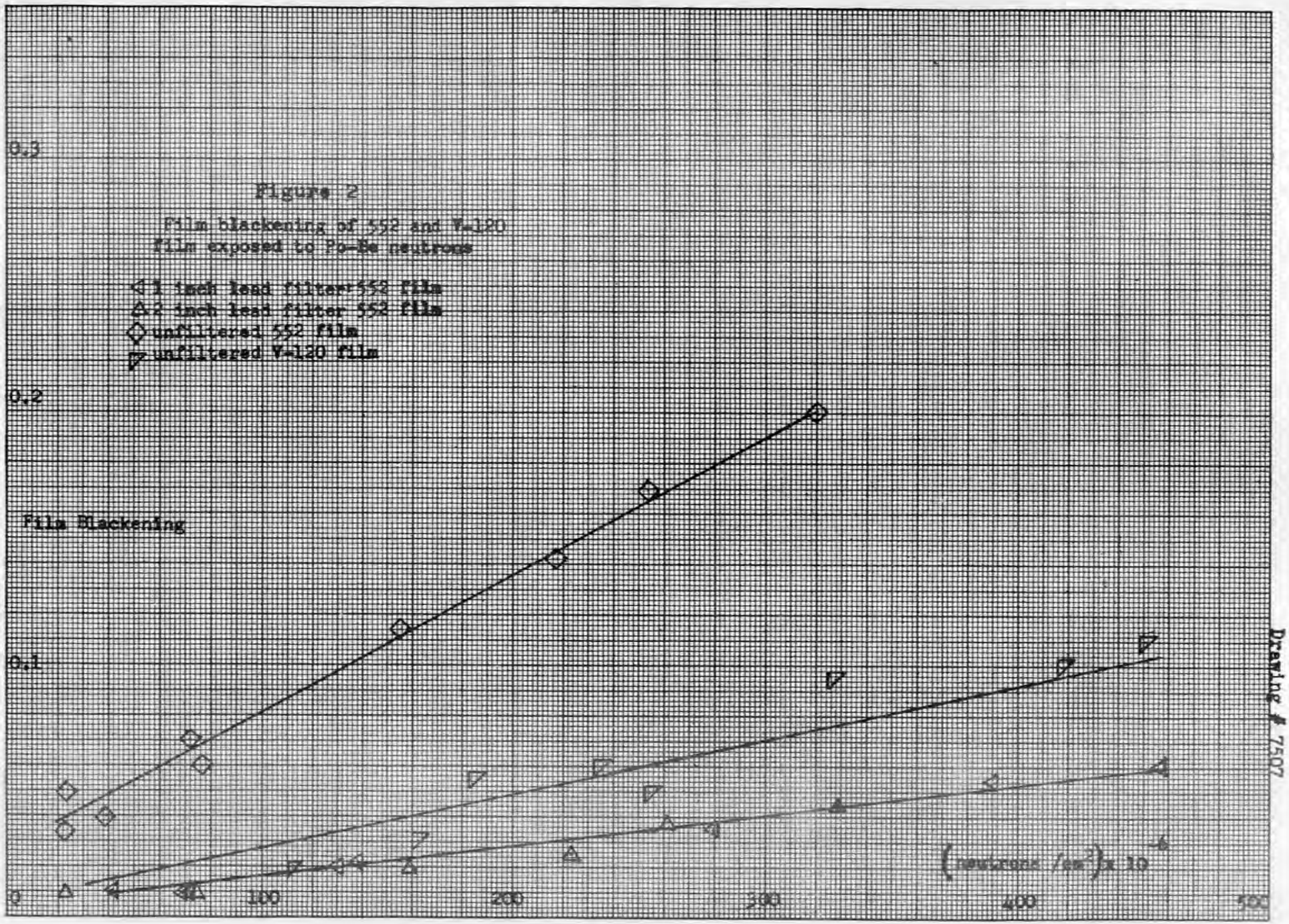

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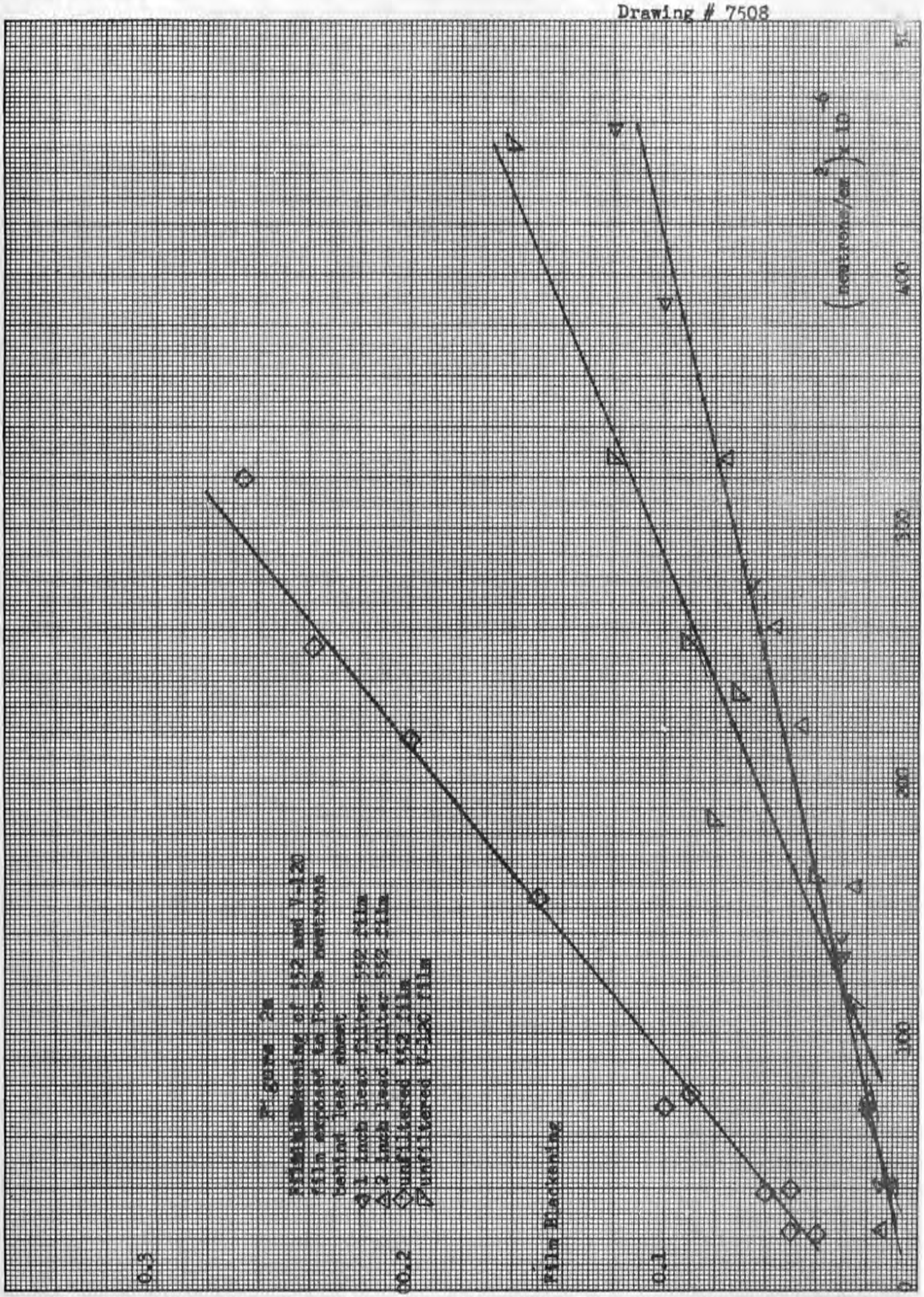

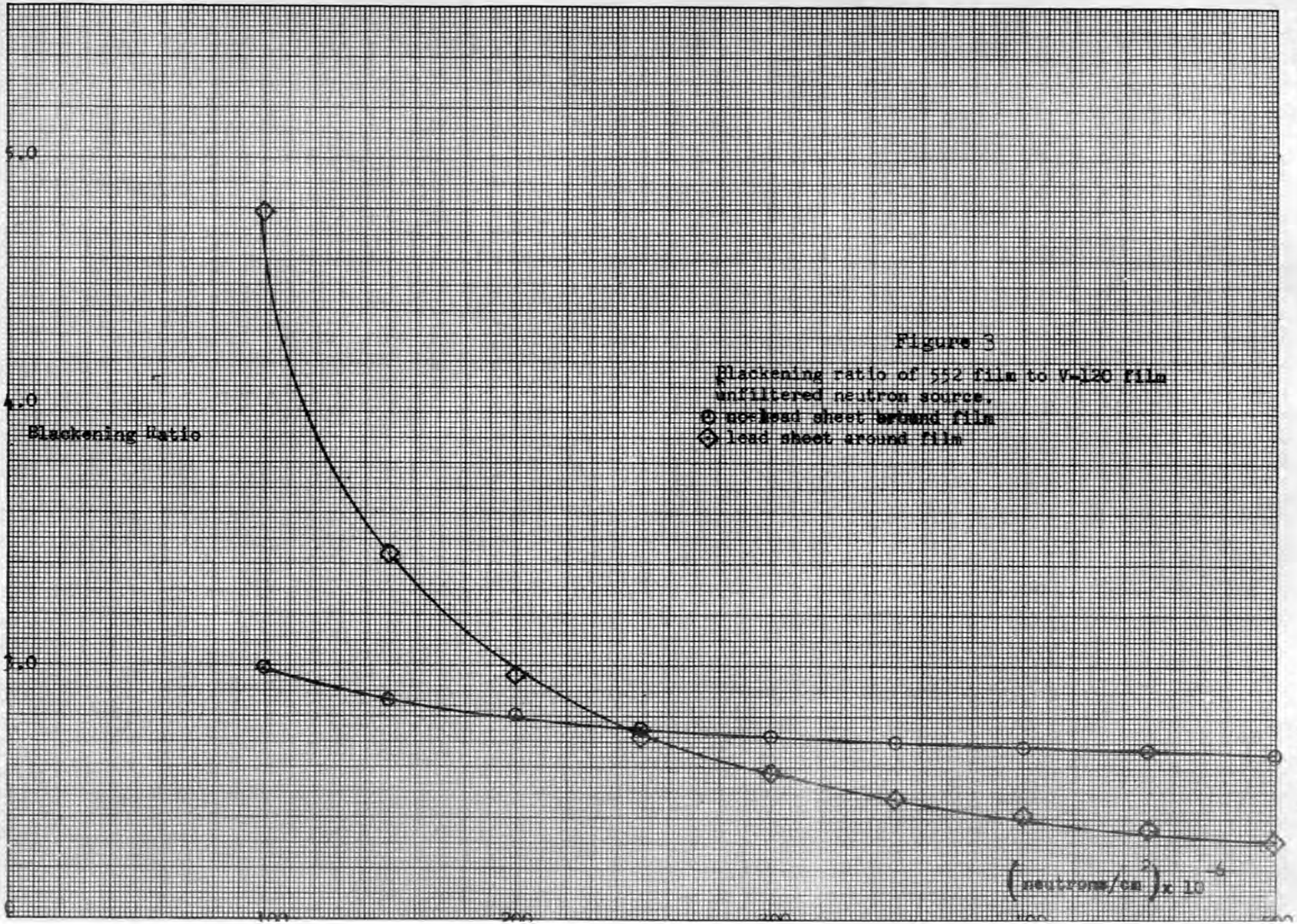

Figure 3

Blackening ratio of 552 film to V-120 film
unfiltered neutron source,
○ no lead sheet around film
◇ lead sheet around film

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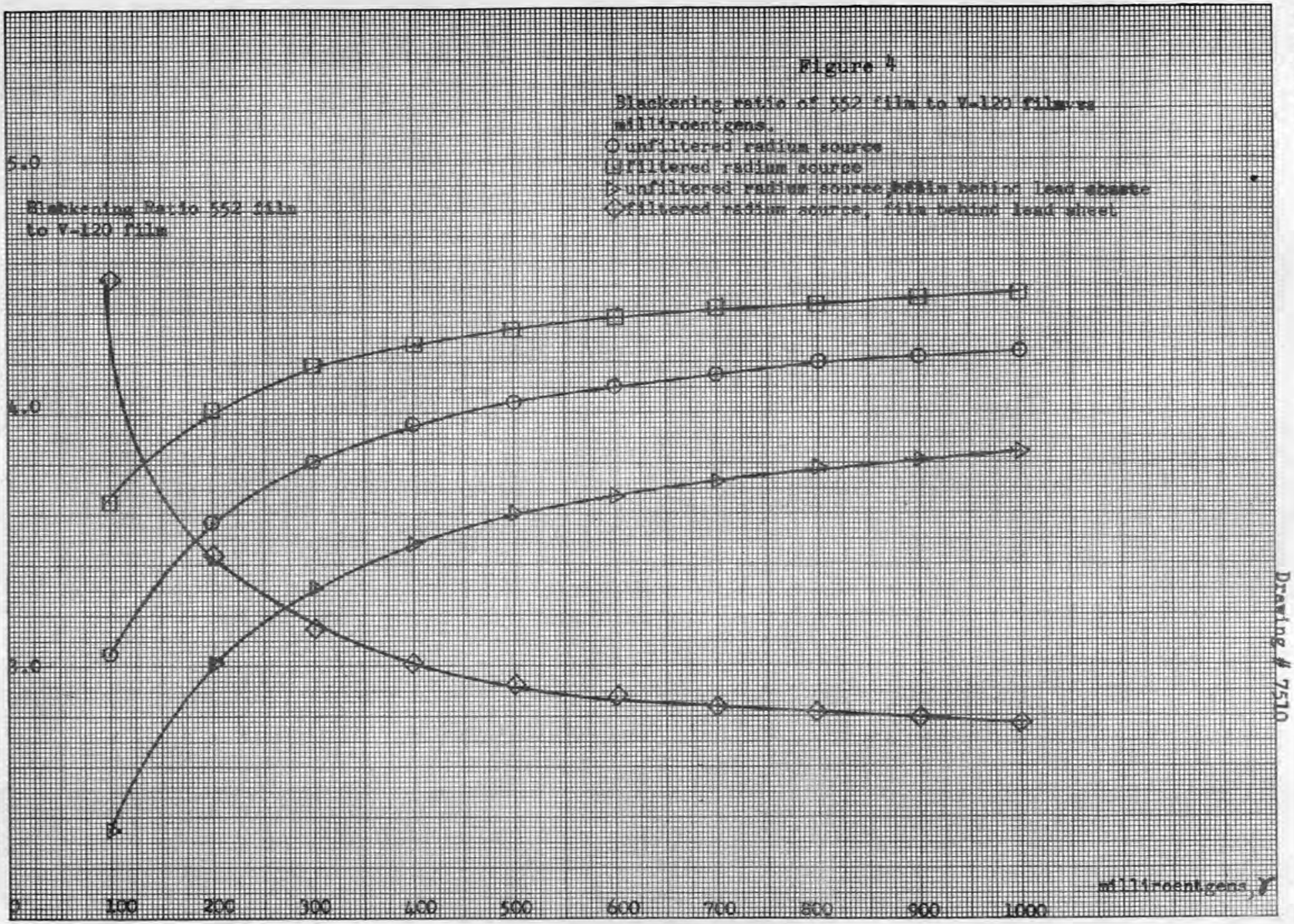

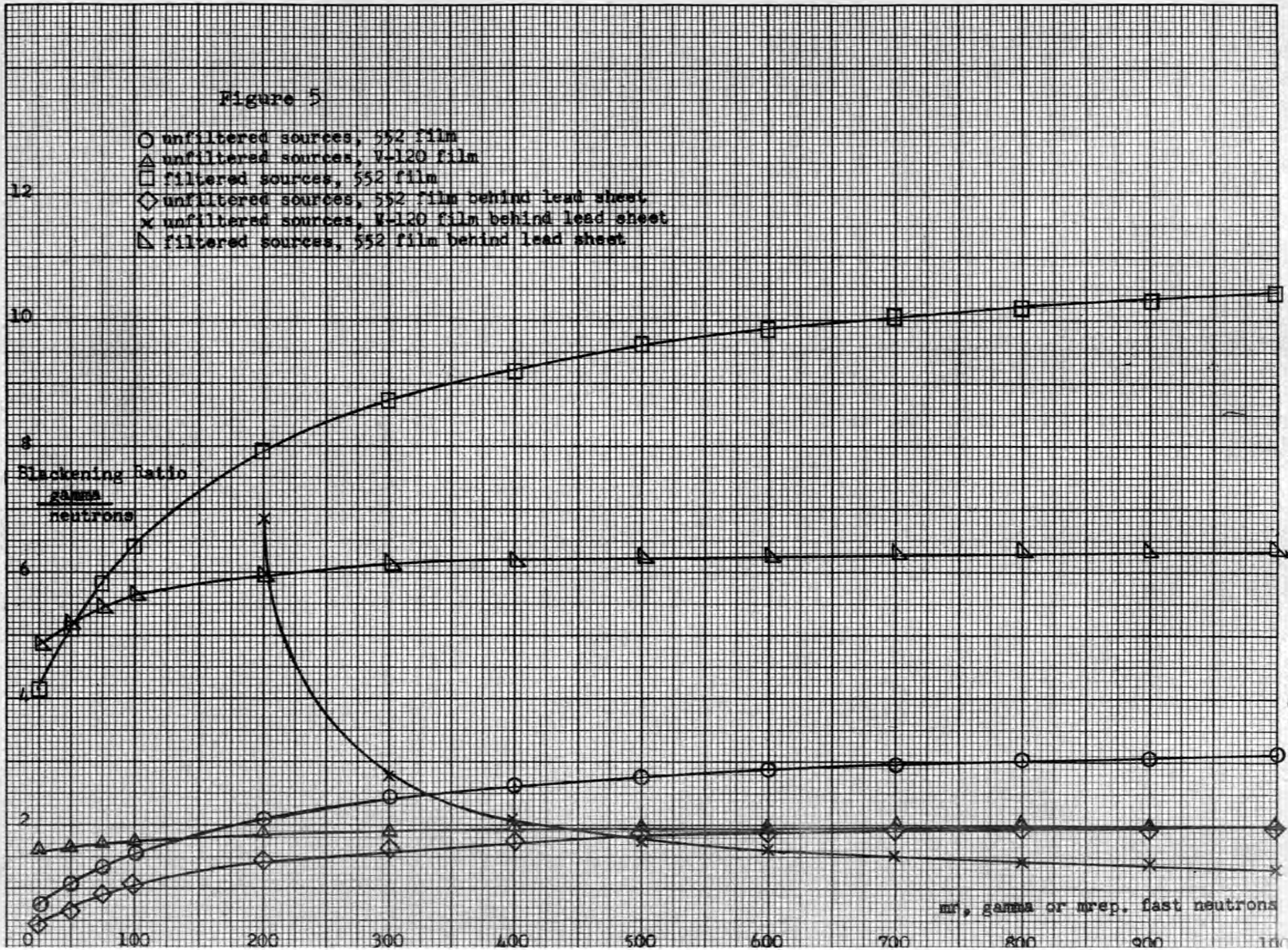

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