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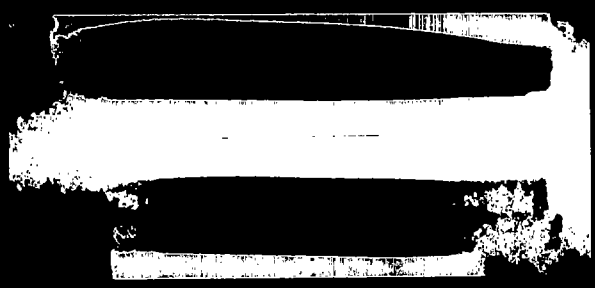

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FURTHER MEASUREMENTS OF THE FISSION AND ABSORPTION CROSS SECTIONS OF 25 BELOW 1000 EV

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ABSTRACT

The absorption cross section of 25, $\sigma_a(25)$, has been measured by the time-of-flight method in the interval extending from 0.01 to 200 ev. Also the variation in cross section for fission $\sigma_f(25)$ has been remeasured in the interval from 0.01 to 1000 ev by a comparison with the boron cross section. The results of these measurements indicate that the ratio $\sigma_f(25)/\sigma_a(25)$ is constant to within 10 percent in the range extending from 0.025 to about 2 ev. At 2.0 and 4.8 ev, two resonances are found in absorption which were not found in fission. These unresolved resonances show cross sections of approximately 10 and 37 barns respectively. Because of the possibility that these resonances may be due to 24 impurity in the enriched samples, it is not possible to assign the absorption definitely to the 25 isotope. Between these two absorption resonances, the ratio $\sigma_f(25)/\sigma_a(25)$ is essentially the same as that below 2 ev. In order to correct for the 28 which was present in the samples, the transmission of samples of normal uranium was also measured. Resonances at 6.6, 21, and 38 ev were observed. Above 5 ev, the ratio $\sigma_f(25)/\sigma_a(25)$ is qualitatively the same as that below 2 ev, but because of resolution effects and 28-absorption resonances, the determination of the 25 absorption cross section is rather poor. The absorption cross section at 0.025 ev was found to be 653 $\pm$ 16 barns. The value of $\sigma_f v$ at 1000 ev was found to be 2.8 $\pm$ .1 times the value at 0.025 ev.

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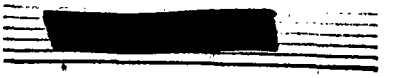

FURTHER MEASUREMENTS OF THE FISSION AND ABSORPTION CROSS SECTIONS OF 25 BELOW 1000 EV

INTRODUCTION

Earlier measurements[1,2] of the fission cross section of 25 have proved the existence of neutron resonance levels in fission. Investigation of the widths of these levels led to the discovery of absorption in 25 without fission. It has been shown that the ratio $\alpha(25)$ of the cross section for capture without fission $\sigma_r(25)$ to the fission cross section $\sigma_f(25)$ is about 0.16[3] for thermal neutrons. Since the variation of this ratio as a function of energy is of very great importance, especially at high energy, it was felt that knowledge of its behavior even at low energy is of considerable value. The experiment described in this report was designed to obtain information about such a variation as well as to verify the results of the previous fission measurements, and if possible to improve upon them.

The experiment using the time-of-flight method consists essentially of two parts. The first part to be considered is the remeasurement of the fission cross section in the range from 0.01 to 1000 ev. The other part consists of an absorption measurement on samples of beta-stage 25 material in the range extending from 0.01 to 200 ev. From the absorption measurements, the total absorption cross section is computed. The variation of this computed cross section is then compared to the variation which is observed in the fission cross section.

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1) Anderson, Lavatelli, McDaniel, Sutton LA-82
2) Bailey, Hanson, Konopinski, LA-46
3) Bailey, Blair, Greisen, Perry, Group P-2, LAMS-96

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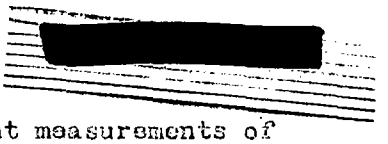

The techniques used in making the time-of-flight measurements of the fission cross section have been described in reference (1). The cyclotron arc is modulated to produce bursts of fast neutrons at the target. The neutrons are then slowed down in a hydrogenous "source" and pass down a paraffin and boron-carbide collimator to the detector which has the form of an ionization chamber. The pulses from the detector are passed to an amplifier which is modulated so that the time distribution of the pulses occurring in the ionization chamber can be observed. Since the measured time of flight for a neutron to pass from the source to the detector is a function of the energy, the time distribution of pulses in the ionization chamber is a function of the sensitivity of the detector for neutrons of various energies and of the energy distribution of the neutron beam. By comparing the distribution of counts in a 25 chamber to that of a BF_3 detector, whose energy sensitivity is known[4] to be proportional to $1/v$, the relative energy sensitivity of the 25 and boron chambers can be determined, and thus the ratio $\sigma_f(25)/\sigma_a(B)$ within a constant.

For absorption measurements, it is simply necessary to take the ratio of the number of counts received in a given time-of-flight interval with no absorber, to the number of counts in the same interval with the absorber between the detector and source. The integrated beam intensity is made the same for the two runs. This ratio yields the transmission of the absorber as a function of energy. From this the cross section is readily determined. A detailed summary of the techniques is given in an earlier report[5].

In the thermal range, the hydrogenous source which was used consisted

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4) Anderson, Lavatelli, McDaniel, Sutton, LA-92
5) Anderson, Lavatelli, McDaniel, Sutton, LA-91

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of a flat tank which contained B_2O_3 in a water solution in the concentration of 7 gm per liter. This was used to reduce the thermal mean life of the source. The region immediately above the thermal region was studied using a B_2O_3 absorber of about 2.5 g/cm^2 in addition to the water tank in order to reduce the number of very-low-energy neutrons in the beam to permit the use of a higher repetition rate. In the region about 1 ev, the detectors were covered with 0.060 inches of cadmium to permit the use of a still higher repetition rate.

FISSION EXPERIMENT

The fission measurements were made with a three-deck ionization chamber which is shown in Fig. 1a. The combination consists of three adjacent coaxial sections. The axis of the combination is placed in the direction of the incident beam. The front and rear sections of the chamber contain foils coated with beta-stage 25 in 65% concentration and deposited as oxide in thickness of 1.16 mg/cm^2. The two sections are connected together electrically to compose the 25 detector. The center section is a BF_3 parallel-plate detector. The chamber was designed in this way for the following reasons. By using adjacent chambers in this manner, except for certain very small second-order corrections, the average neutron spectrum seen by the 25 detector and by the boron detector is the same, even though there may be some absorption in the foils or in the windows separating the sections. In addition, to make point-by-point comparisons of the counting rates in the two chambers, it is essential that the centers of the two detectors be at the same place. By placing the two sections of the 25 detector symmetrically about the center of the boron detector, it is not necessary to move the chamber between the boron and 25 runs. In the thermal-energy region, there is some absorption in the BF_3 chamber

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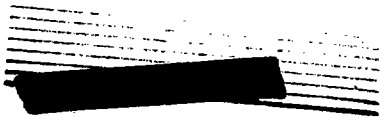

and windows which weights the front section a little more heavily than the rear, thereby moving the average position of the 25 chamber forward. This correction is very small, being not greater than 0.1 percent of the distance of flight.

The 25 sections of the chamber were filled with argon at atmospheric pressure, and the BF_3 section was filled with tank gas at the same pressure. Electron collection was used and the amplifier had a 1.5 μsec clipping time.

The method of taking measurements is the following. The value of C, the number of counts in a given time-of-flight interval, and the value of T, the total number of counts due to neutrons of all energies, are recorded. For either 25 or boron, the ratio C/T is independent of discriminator bias setting (which affects all channels equally) and of the geometry of the chamber. For a given neutron spectrum, this ratio is proportional to the product of the cross section and the fractional neutron flux in the time-of-flight interval as was shown in LA-82. In order to eliminate the fractional neutron flux, the ratio

$$R = (C/T)_{25}/(C/T)_B$$

is calculated. This ratio is proportional to the ratio of the cross sections, in the given interval, with a constant of proportionality which depends on the shape of the spectrum. Because of this dependence on the shape of the spectrum, great care was exercised to prevent undesired changes in the source and detector geometry during the course of the experiment. When changes were made in the source geometry it was necessary to measure the relative changes in the total counting rates of the two chambers to permit the data taken with one geometry to be compared with those taken with another[1]. The experimental conditions and the sequence of the runs were so chosen that only two such changes and normalizations were necessary. In order to determine the absolute cross

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section from these measurements, it is necessary to determine the absolute cross section of 25 at one point. By adjusting the arbitrary constant in the relative cross section to bring about agreement at this point, and utilizing the knowledge that boron follows the 1/v law, the cross section at all other measured points is determined absolutely. The point usually chosen for reference is 0.025 ev (or neutron velocity = 2200 m/sec, which is about the same) for which such absolute-cross-section measurements have been made[6].

For the sake of comparing the fission data with the absorption data for 25, instead of obtaining the absolute value of the cross section for fission $\sigma_f(25)$ or $\sigma_f(25)v$, where v is the neutron velocity, the scale for plotting $\sigma_f(25)v$ in the figure, was arbitrarily adjusted to make it numerically equal to the value of $\sigma_a(25)v$ obtained from the absorption measurements at 0.025 ev. The experimental conditions under which the various runs were made are given in Table I and the results of the measurements are given in Figs. 2, 3, and 4. The measurements under different experimental conditions have been normalized to each other to permit comparison and then multiplied by a factor bring about coincidence with the absorption value at 0.025 ev. The coordinates used in the figures are σv in barns meters/μsec against time of flight in μsec/m.

In Fig. 14, these results are combined in curve (f), with the logarithm of time of flight as abscissa. In curve (f) of Fig. 15, the same results are plotted, this time with the logarithm of the energy as abscissa. In Fig. 16, the results of the fission experiment are compared with the earlier values reported in reference (1). In Fig. 17 curve (f), the absolute fission cross section of 25, is shown as a function of log energy, using the value $\sigma_f(25)$ equal to 542 barns at .025 ev[6].

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6) LA-140, p. 8.

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ABSORPTION MEASUREMENTS

For the absorption measurements, a BF_3 detector, 20 cm long and 6 cm in diameter, was used. In addition, a secondary collimator was placed immediately around the detector as shown in Fig. 1b so that only neutrons which went through the absorber could reach the detector. The absorbers were placed at the front end of the collimator. A total of 5 different absorbers were used in various combinations. Two of these were composed of uranium tetrafluoride, while the other three were of the metal. These absorbers were composed of enriched material of concentration approximately 64 percent 25 by weight. In addition to these absorbers of enriched material, five samples of the normal isotopic mixture of uranium were used which corresponded approximately in weight to the enriched samples. Table II gives the weight and identification for the absorbers[7]. Table I gives the experimental conditions under which the various combinations of the absorbers were measured. The results of the transmission measurements are shown in Figs. 5, 6, 7, 8, 9, 10, where transmission vs time of flight is plotted. The usual background corrections for the unmodulated beam have been made. The recycling background was essentially zero.

From these transmission measurements, it is desirable to compute the capture cross section of 25. One method for computing this quantity was used for the measurements taken with the fluoride sample in the region from .01 to .5 ev, while a slightly different method was used for the measurements at higher energy with the metal sample.

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7) The samples are contained in aluminum cups. The faces of the cups were 0.030 inches thick. Aluminum blanks were supplied for the "no absorber" run.

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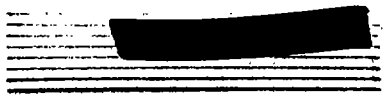


For the measurements with the fluoride sample the following method was used.

Define

$\sigma_a(x)$ = absorption cross section of isotope (x)

$\sigma_s(x)$ = scattering cross section of isotope (x)

$\sigma_t(x)$ = total cross section of isotope (x)

n_{25}, n_{28} = atoms/cm^2 of 25 and 28 respectively in enriched sample

n_{25}^0, n_{28}^0 = atoms/cm^2 of 25 and 28 respectively in normal sample

The transmission of the enriched sample is

$$T = e^{-\alpha}$$

and for the normal sample

$$T = e^{-\alpha^0}$$

Where

$$\alpha = \sigma_t(25)n_{25} + \sigma_t(28)n_{28} + 4\sigma_t(F)\ (n_{25} + n_{28})$$

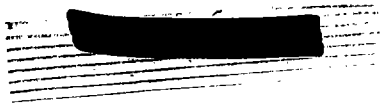
$$\alpha^0 = \sigma_t(25)n_{25}^0 + \sigma_t(28)n_{28}^0 + 4\sigma_t(F)\ (n_{25}^0 + n_{28}^0)$$

The weight of the samples were chosen so that

$$n_{25} + n_{28} = n_{25}^0 + n_{28}^0 \quad \text{and thus also} \quad n_{28} - n_{28}^0 = n_{25}^0 - n_{25}$$

This enables us to eliminate the terms containing $\sigma_t(F)$ by subtracting the equation for α^0 from the equation for α, which gives us

$$\alpha - \alpha^0 = \sigma_t(25)\ (n_{25} - n_{25}^0) + \sigma_t(28)\ (n_{28} - n_{28}^0)$$



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or

$$\sigma_t(25) = (\alpha - \alpha')/(n_{25} - n_{25}') + \sigma_t(28)$$

If we assume that $\sigma_a(28)$ varies as $1/v$ in the thermal region, then since $\sigma_a(28) = 2.6$ barns[8] at 0.025 ev or $\tau = 457\ \mu$sec,

$$\sigma_a(28) = (2.6 \times \tau)/457$$

where τ is time of flight in μsec/meter. Also if one assumes $\sigma_s(25) = \sigma_s(28)$ (for lack of better knowledge) then

$$\sigma_a(25) = (\alpha - \alpha')/(n_{25} - n_{25}') + (2.6\tau/457)$$

It is desirable to use this method since it cancels out the effect of the scattering of the fluoride. It is, of course, possible to use this method only in regions in which $\sigma_a(28)$ is well known. Because of this fact, for the higher-energy measurements where $\sigma_a(28)$ has resonances, another method was used. In addition, since metal samples were used for the higher-energy measurements, the cancellation of the scattering was not as important.

By this method we have again

$$T = e^{-\alpha} \qquad T' = e^{-\alpha'}$$

where

$$\alpha = \sigma_t(25)n_{25} + \sigma_t(28)n_{28}$$

$$\alpha' = \sigma_t(25)n_{25}' + \sigma_t(28)n_{28}'$$

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8) Anderson, Lavatelli, McDaniel, Sutton, CP-2079

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In this case we may eliminate $\sigma_t(28)$ and find

$$\sigma_t(25) = \frac{\alpha - (n_{28}/n_{28}^0)\alpha^0}{n_{25} - n_{25}^0(n_{28}/n_{28}^0)}$$

Since the concentration of 25 in the enriched sample is about 0.64 while in the normal sample it is 0.0071, and if the two samples are of approximately the same weight, then

$$n_{25}^0(n_{28}/n_{28}^0) \approx (.007/.64) \cdot (1 - .64) \quad n_{25} \approx .004\, n_{25}$$

So, to a high degree of accuracy

$$\sigma_t(25) = \left[\alpha - (n_{28}/n_{28}^0)\alpha^0\right]/(.996 \times n_{25})$$

Since

$$\sigma_t(25) = \sigma_a(25) + \sigma_s(25)$$

then

$$\sigma_a(25) = \left[\alpha - (n_{28}/n_{28}^0)\alpha^0\right]/(.996 \times n_{25}) - \sigma_s(25)$$

It is seen that to obtain $\sigma_a(25)$, it is necessary to insert the value of $\sigma_s(25)$. One must again assume that the scattering of 25 is equal to that of 28 for lack of better information. It is unlikely that the correct value for $\sigma_s(25)$ is different from this by more than one or two barns. An error of 1 barn in the cross section results in an error of less than one percent up to 0.5 ev, and the maximum error is less than 5 percent in the entire region which was investigated except at one point near 5 ev, where an error of one barn in

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scattering amounts to about 10 percent in $\sigma_a(25)$. Because $\sigma_a(25)$ is thus in general only slightly sensitive to the value which is used for the 28 scattering, the value of $\sigma_s(28)$ used was determined in the following manner. In the region from 1.4 to 4 ev, the capture cross section of 25 is quite low and there are no resonances in 28 in this neighborhood or below. From the transmission measurements in this region on the thick normal samples, the total cross section was determined. This cross section is composed primarily of the scattering of 28. In addition to this, there is the absorption cross section of 28 and also a small amount due to absorption in 25. The thermal cross section of 28 absorption is 2.6 barns[8].

Because of the absence of 28 resonances in this neighborhood, the cross section $\sigma_a(28)$ is assumed to vary as 1/v up to 5 ev. Thus the cross section for absorption in 28 would be about 0.26 barns. From the measured values of $\sigma_a(25)$ in this region, its contribution to $\sigma_t(28)$ will be about 0.11 barn. The measured value for the total cross section of 28 here is 9.6 barns. Subtracting off the contribution due to absorption, we find a scattering cross section of 9.2 barns. This is somewhat higher than the values 8.5 reported recently by Fermi[9]. This difference may be due to experimental error or to the failure of 28 to follow the 1/v law. The value of 8.8 barns given by extrapolation from the work of Rainwater and Havens is in better agreement.

The value of 9.2 barns was used for the scattering cross section of 25 and inserted in the above formula to determine the absorption cross section of 25. For convenience of plotting the results, the value of $\sigma_a v$ was obtained by dividing the cross section by the time of flight. The computed values for

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9) Chicago Report for Month Ending August 26, 1944 CP 2081

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$\sigma_a v$ are shown plotted in Figs. 11, 12, 13 on a linear time-of-flight scale. In Figs. 14, 15 curves (a), they are also shown in comparison with the fission measurements over the entire range on both log time of flight and log energy. In Fig. 17 curve (a) is given the absolute cross section as a function of energy.

Among the important features of the curves are the following. Up to about 2 ev the shape of the fission curve is the same as that obtained from the absorption measurements within the experimental errors of the measurements. This includes the region of the two resonances at 0.28 and 1.0 ev. In the region from 0.025 to 0.1 ev the value of $\sigma_a v$ decreases with increasing energy; the slope corresponds roughly to that found in the earlier measurements[1]. At about 2 ev there occurs a small resonance in absorption which is not present in fission. Above this resonance the fission and the absorption again become equal. They remain essentially the same through the resonance occurring in both fission and absorption at about 3.3 ev and up to about 4 ev. At 4.8 ev is found another resonance which is present only in absorption. Above this point and up to about 200 ev, the qualitative behavior of the fission and absorption are the same, but quantitatively they are somewhat different. It seems probable that most of the differences are due to the difference in the effect of the resolution upon the fission and the absorption measurements, for in this energy range the resolution width is much greater than the resonance width. The presence of resonances in $\sigma_a(28)$ at 6.6, at 21 and at 38 ev confuses the issue even more because of the difficulty in correcting for the absorption of the 28 in the enriched samples.

The effects of finite resolution on the cross-section measurements are, in brief, as follows. If there is a resonance in the cross section for

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which the width of the resonance is much smaller than the resolution width, then both in absorption and in fission, the measured cross section at resonance will be smaller than the real cross section. This is due to the fact that the measurement at resonance is actually an average over the resolution width. In the fission measurements, this average is taken over the cross-section function, while in absorption, this average is taken over the transmission function, and from this the cross section is computed. Because these averages are not made in the same manner the effect of the resolution is different for the two. The effect is greater for the absorption measurements with the result that if the same resonance cross section is to be measured both for fission and absorption, the value obtained from the absorption measurement will be still less than the value obtained from fission. (An extreme example of this is the case in which the resonance is very strong and very narrow compared to the resolution. The observed fission resonance will be very strong because the linear average over the sensitivity function is taken. However, the absorption resonance which is observed will be weak because the observed absorption at resonance is a smear of a narrow line which cannot go below zero transmission and is thus very insensitive to the maximum cross section.) Thus in regions where there are only 25 resonances, the 25 resonances which are observed in absorption should appear relatively weaker than they appear when measured in fission.

A closely related resolution effect exhibits itself in regions where only 28 resonances occur. In the absorption measurements, since the cross section is obtained from the average of the resolution function over the transmission (an exponential function of σn) the value obtained for the cross section depends on the thickness of the absorber. This dependence is such that the thicker the absorber, the smaller the value of the cross section which is obtained. Since the enriched samples of 25 contain a considerable amount of 28,

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to compute the cross section of 25 the measured cross section of the sample is corrected for the 28 as shown earlier. The correction is based upon the absorption measurement of the normal sample of 28 which contains about three times as much 28 as the enriched sample. Because the thicker sample (normal) yields a smaller value of the cross section than the thinner sample (enriched), the correction is not large enough to fully compensate for the amount of 28 in the enriched sample. Thus in regions of 28 resonances, the measured absorption cross section of 25 is too great. The situation is further complicated by a mixture of the two effects in regions where there are both 25 and 28 resonances.

Of the various features of the cross section curves, perhaps the most interesting are the resonances which are present in absorption and not present in fission. The resonance at 2 ev shows a change in cross section of about 15 barns per 25 atom. The one at 4.8 ev shows a change of cross section of about 37 barns. It must be remembered that neither of these resonances were resolved so that the cross section is likely to be much larger than this. These resonances are possibly due to 25. However, there is a reasonably good chance that they may be due to the isotope 24 which is present in the enriched sample. These samples contain about 0.7 percent of 24 relative to 25. For the resonances to be explained by absorption in 24, their cross sections would be 2150 and 5500 barns respectively which would be rather strong. Their strength would have to be comparable to that of the resonances in Ag or Au. Perhaps the one at 4.8 ev is even stronger than either of these. Checks were made to verify the presence of these two resonances, particularly for the one at 2 ev and it seems quite certain that they do really exist. Until further measurements of some different nature are made, it will not be possible to assign definitely the isotope to which these are due. If they had been somewhat stronger, one

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would probably be forced to assign them to 25, but since they are very weak for resonances in 25, the assignment is quite difficult. One method which might be used to clarify the situation is to observe the transmission of absorbers of 25 having different amounts of 24 of them. A fifty percent difference in the 24 content would make it possible to decide whether or not these resonances are due to 24.

It is to be concluded that in the range from 0.01 to 2 ev the value of $\left[1+\alpha(25)\right]$, defined by $\left[1+\alpha(25)\right] = \left(\sigma_a(25)/\sigma_f(25)\right)$, is essentially constant except for possible differences of the order of 10 percent or less in small regions about the resonances. These differences may not really exist but may be due, at least in part, to the statistical inaccuracy of the data. With the exception of the two resonances at 2 and 4.8 ev it seems reasonable to believe that $\left[1+\alpha(25)\right]$ does not vary greatly in the interval from 2 to 200 ev.

In two regions, measurements were made of fission which were not made with comparable resolution in transmission. One of these is in the vicinity of the 0.28-ev resonance. It was thought the coarse resolution which was used to examine this resonance was not adequate to resolve completely the resonance, so the work was repeated with finer resolution. No sharpening of the level was observed. Thus, the conclusion is that it has the width as measured. The width at half maximum is of the order of .15 ev.

The second region which was investigated only in fission was that in the range 100-1000 ev. In order to obtain the value of the cross section at about 1000 ev, one of the runs was repeated with the single change of setting the timing for slightly higher energy to obtain two new points, one at 760 ev and the other at 330 ev. The point at 760 ev has a spread due to resolution extending from 3000 ev to 330 ev. Extrapolating the curve through the points

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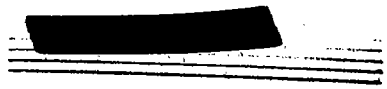

to the time of flight corresponding to 1000 ev (2.27 μsec per meter) one finds that the ratio of σv at 1000 ev to the value of σv at 0.025 is 2.80. This value should be considered as the average over the resolution function when considered on a time-of-flight plot. This resolution function extends in energy from 6000 ev to 410 ev with the mean energy at 1000 ev. The earlier value[1] for the same ratio under the same resolution was also 2.80. We give this value then as $2.80 \pm .11$.

The cross section for absorption at 0.025 ev is found to be 653 ± 16 barns. This is to be compared with the value of 640 found by Fermi[10] and our value of 650 published earlier[1].

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10) Chicago Monthly Nuclear Physics Report, CP-1389

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TABLE I

Series	Type of* Measurement	On-time μsec	Frequency cps	Source	Figure	Symbol
I	F 11 15	200	100	Tank	2 5,11 6,11	△ ▲ ▲
II	F 11 15	200	100	Tank	2 5,11 6,11	⊙ ◐ ◔
III	F 12	100	200	Tank and Tray	2 7,11	⌀ ⌀
IV	F	50	200	Tank and Tray	2	⬡
V	F 13	20	1000	Tank and Cd	2,3 8,11,12	⊡ ⊡
VI	F (12,13,14)	20	1000	Tank and Cd	3 9,12	X X
VII	Low resolution, therefore not included.					
VIII	F 13	10	1000	Tank and Cd	4 10,13	▮ ▮
IX	F 13	10	1000	Tank and Cd	3,4 10,12,13	▮ ▮
X	F	10	1000	Tank and Cd	4	▮

* Fission measurements denoted by F. Absorption measurements denoted by absorber identification number.

All distances of flight 7.6 meters.

[redacted]

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[redacted]

TABLE II

Absorber	Area= sq cm	Weight= gms	gms of 25 per sq cm	gms of 28 per sq cm	atoms of 25 per sq cm	atoms of 28 per sq cm
11 E	31.7	25.1811 fluoride	.389	.212	1.005×10^{21}	$.540 \times 10^{21}$
11 N	31.7	25.1694 fluoride	.0042	.595	.0109	1.515
12 E	16.1	47.1 metal	1.870	1.06	4.82	2.70
12 N	20.3	61.4 metal	.0212	3.00	.055	7.65
13 E	17 47	130 35 metal	4.77	2.71	12.3	6.91
13 N	20.4	152.6 metal	.0527	7.43	.1361	18.9
15 E	15.45	25.1694 fluoride	.795	.434	2.05	1.107
15 N	15.45	25 3309 fluoride	.0086	1.228	.0222	3.12
12,13 14 E			11.44	6.49	29 5	16.8
12,13 14 N			.128	17.94	.330	45.7

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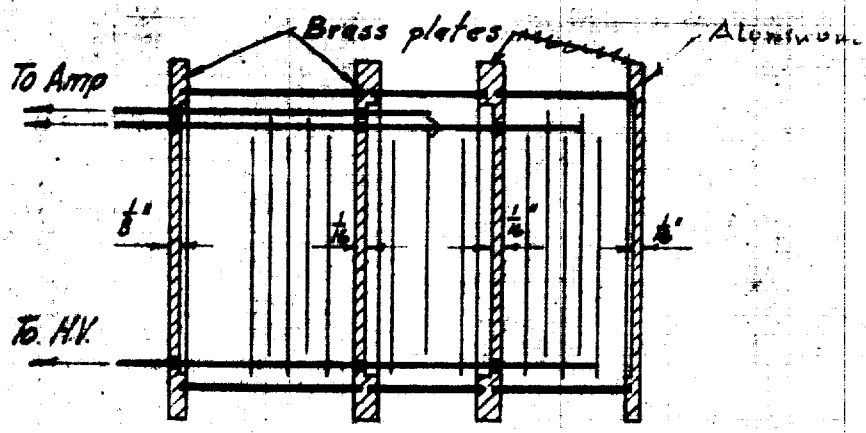

Fig. 1a
THREE-DECK IONIZATION CHAMBER
½" = 1"

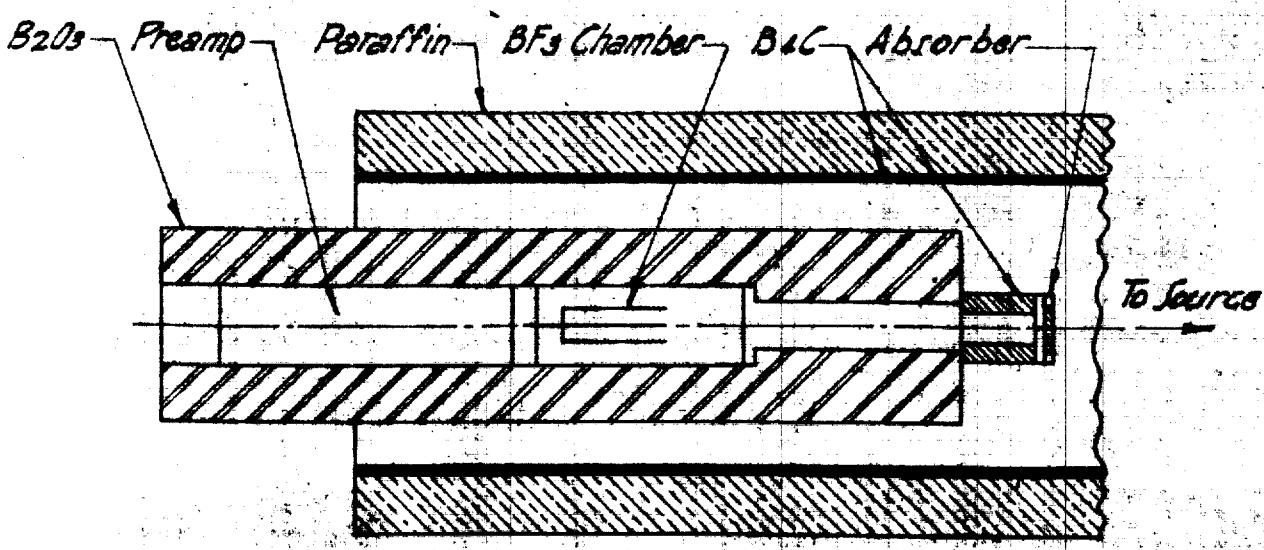

Fig. 1b
Collimator For Absorption Measurements
⅛" = 1"

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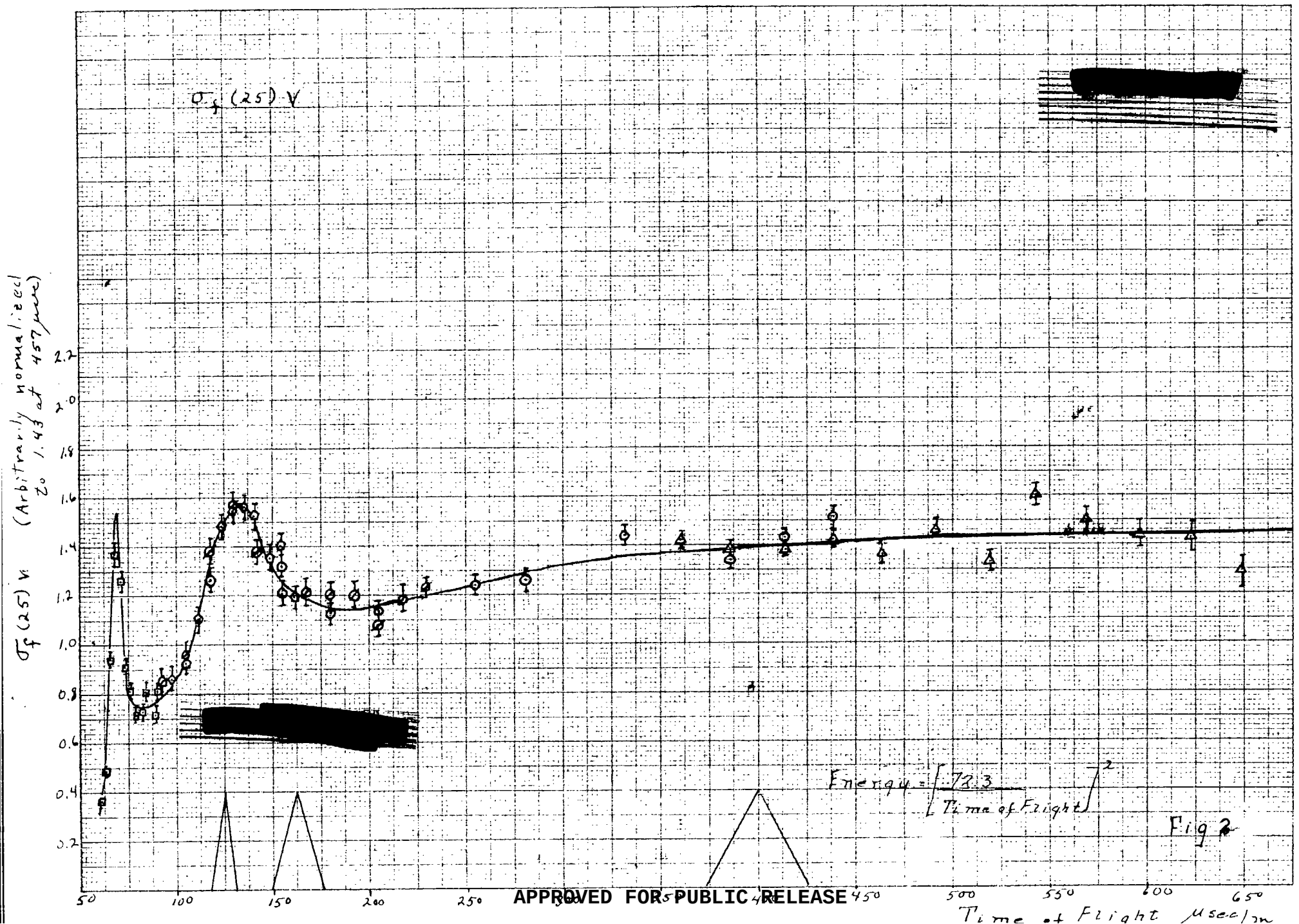

Fig 2

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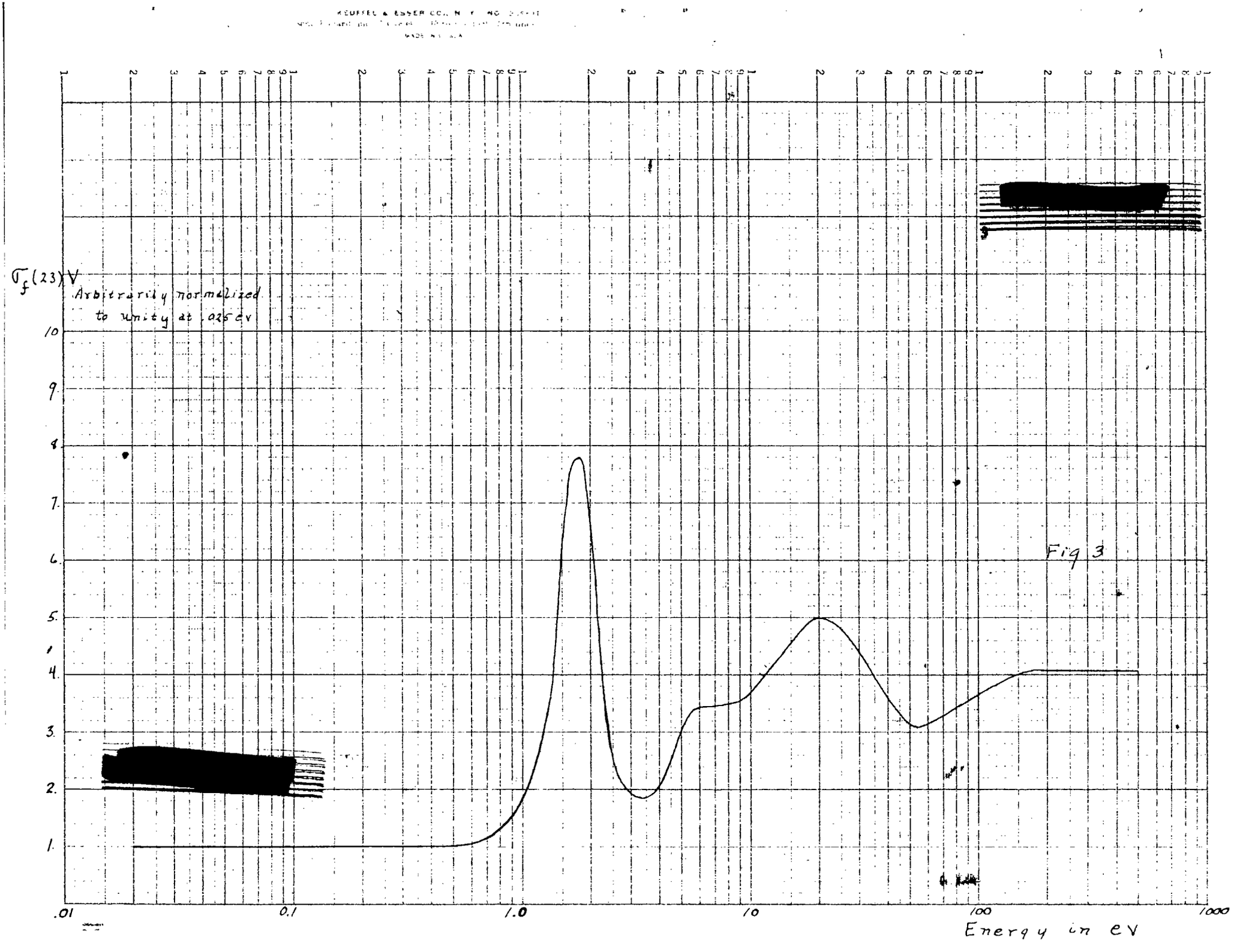

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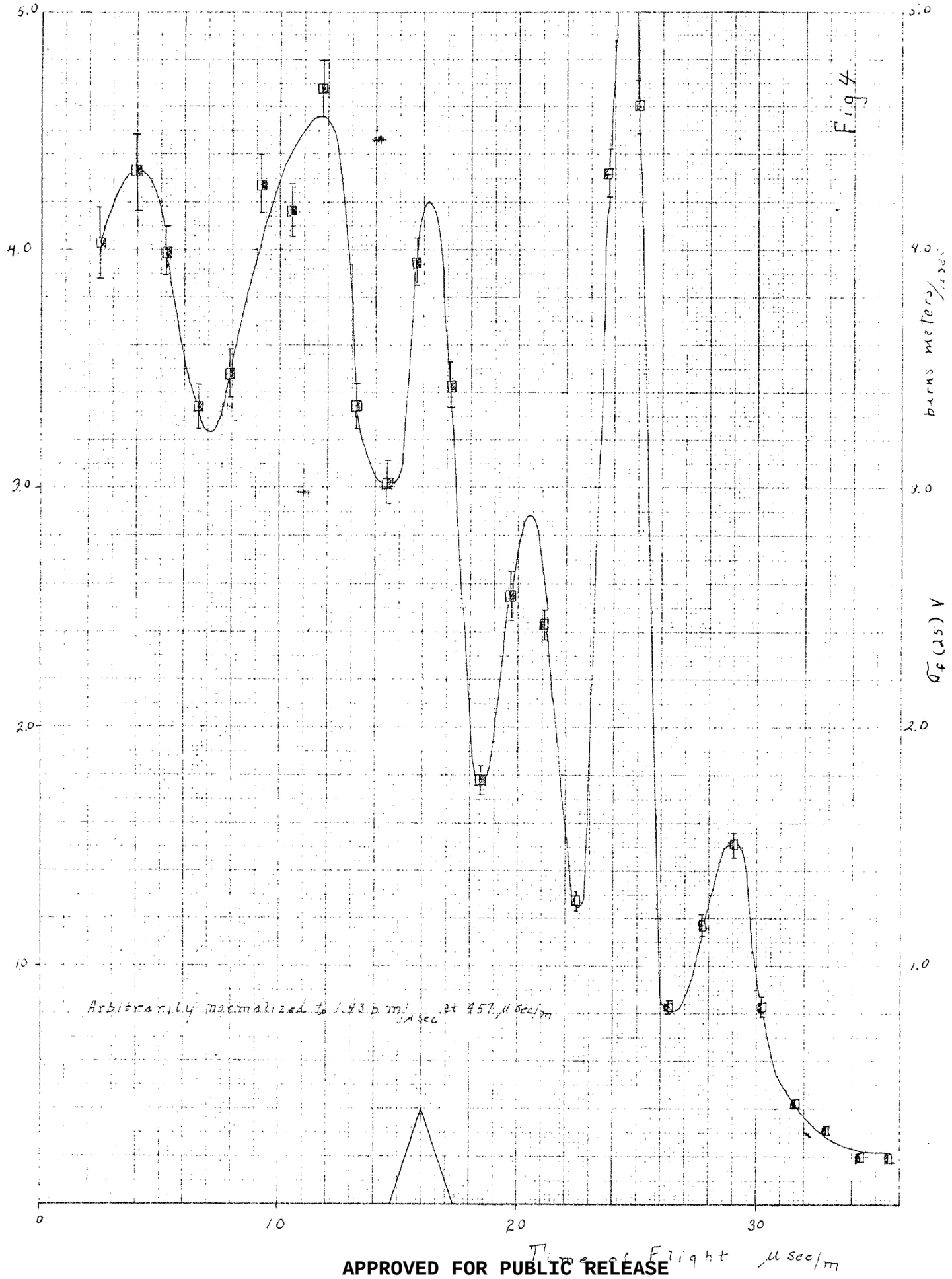

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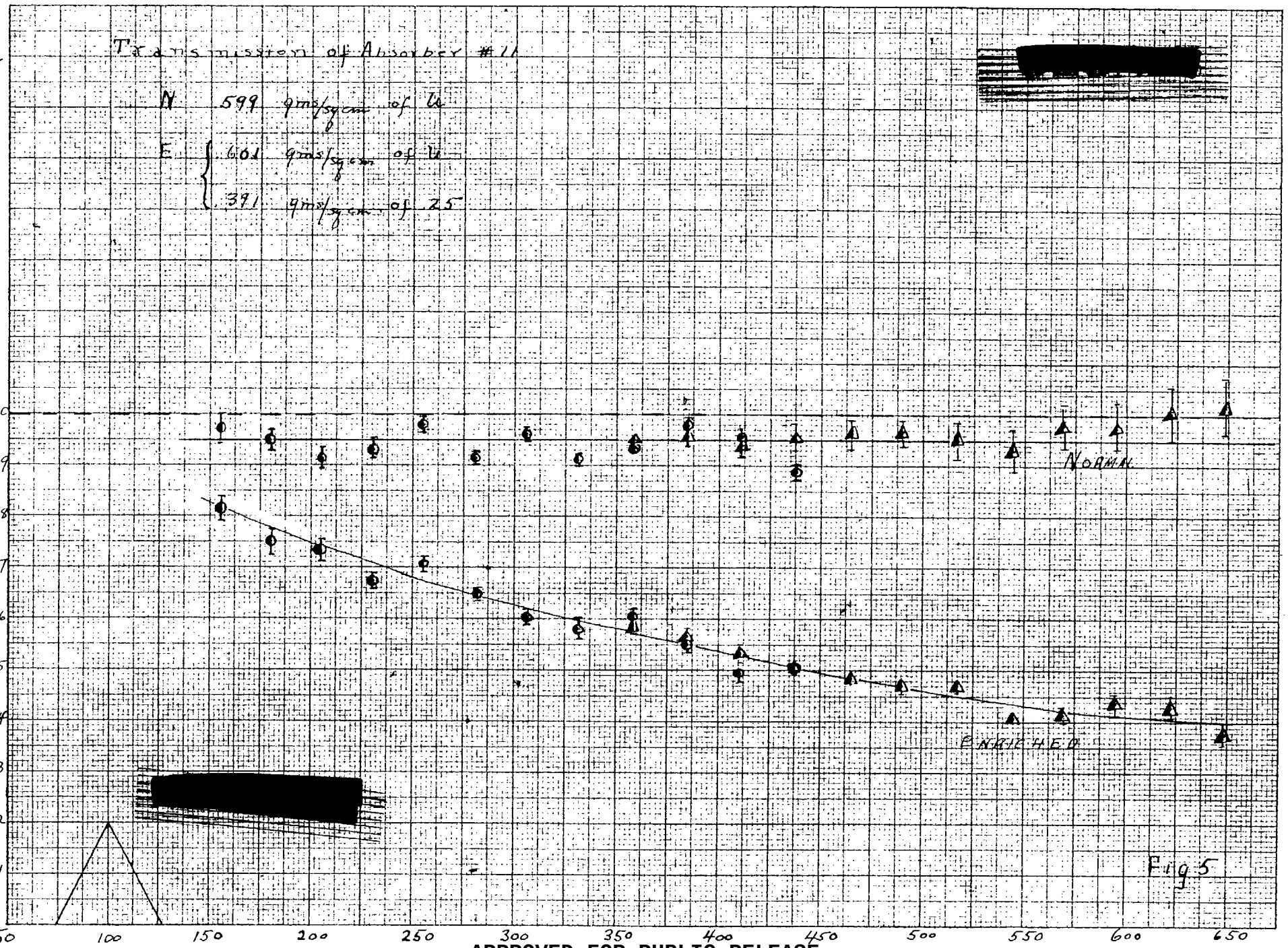

Fig 5

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KEUFFEL & ESSER CO. N.Y. No. 358-14

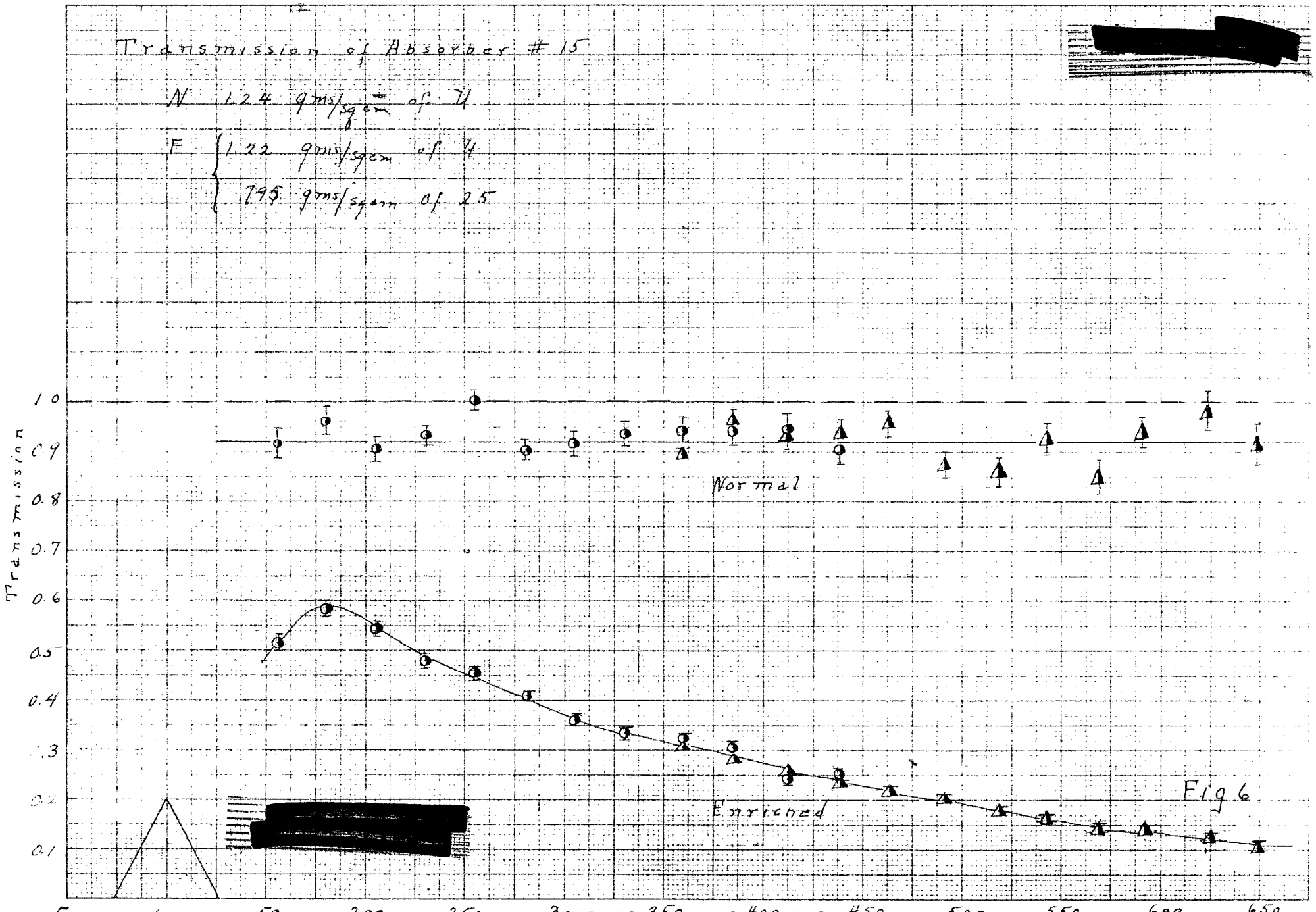

Fig 6

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Millimeters, 5 mm. lines accented, cm. lines heavy
MADE IN U. S. A.

Transmission of Absorber # 12

N 3.02 gms/sq cm of U

E { 2.92 gms/sq cm of U
  1.87 gms/sq cm of 25

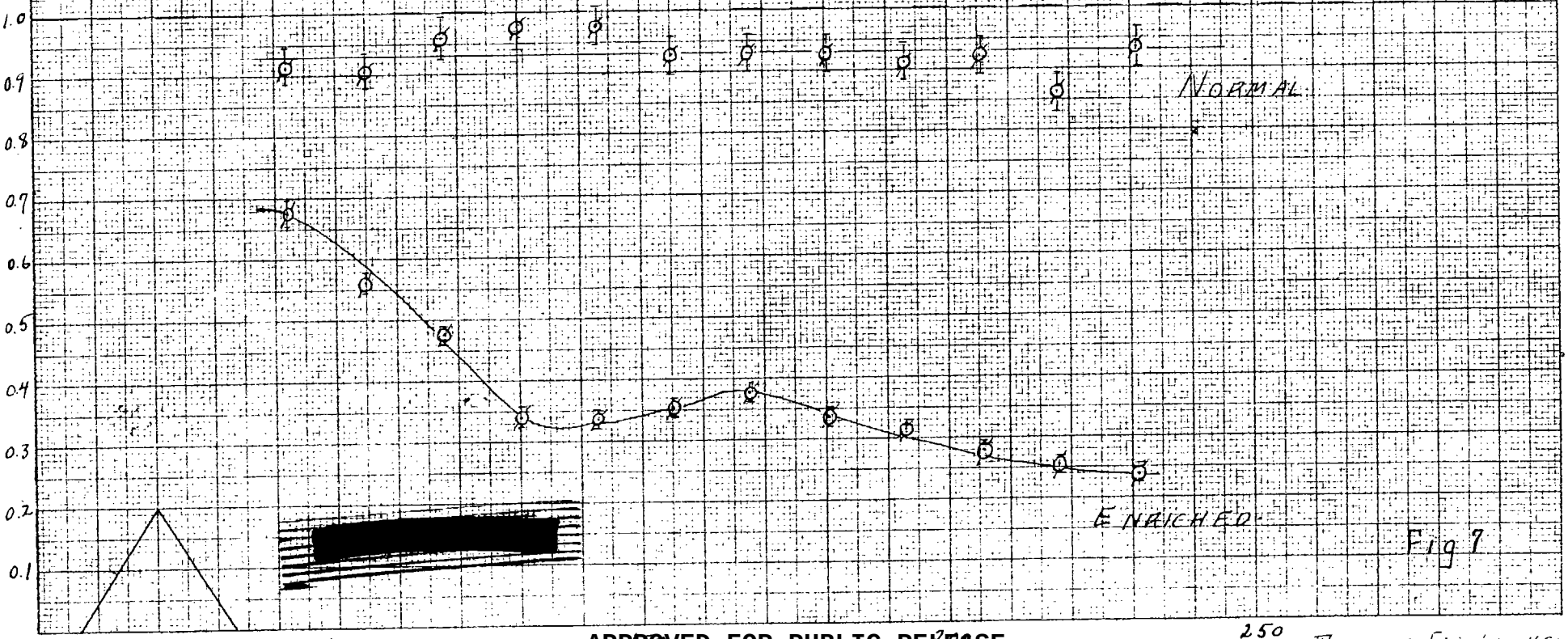

Fig 7

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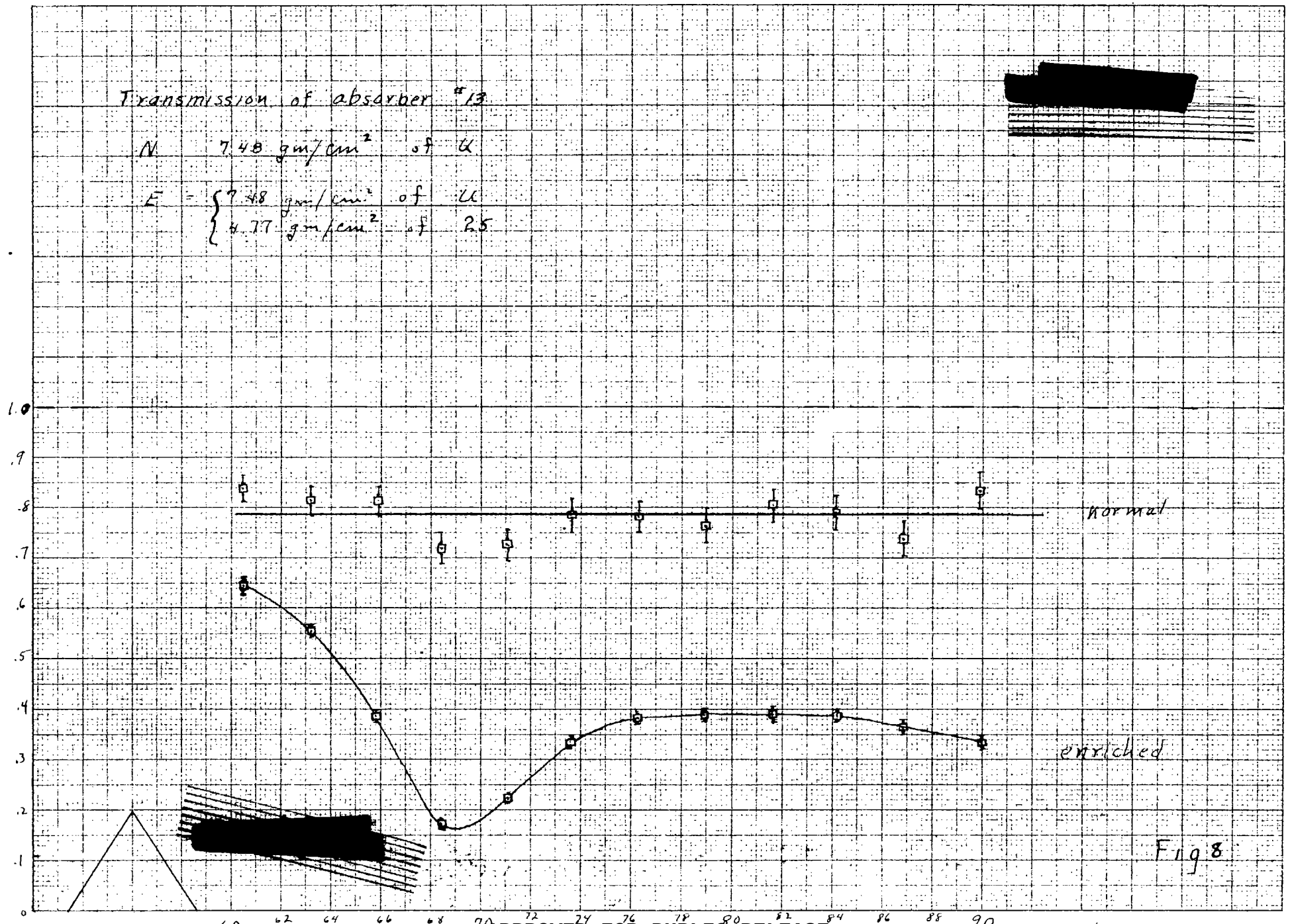

Fig 8

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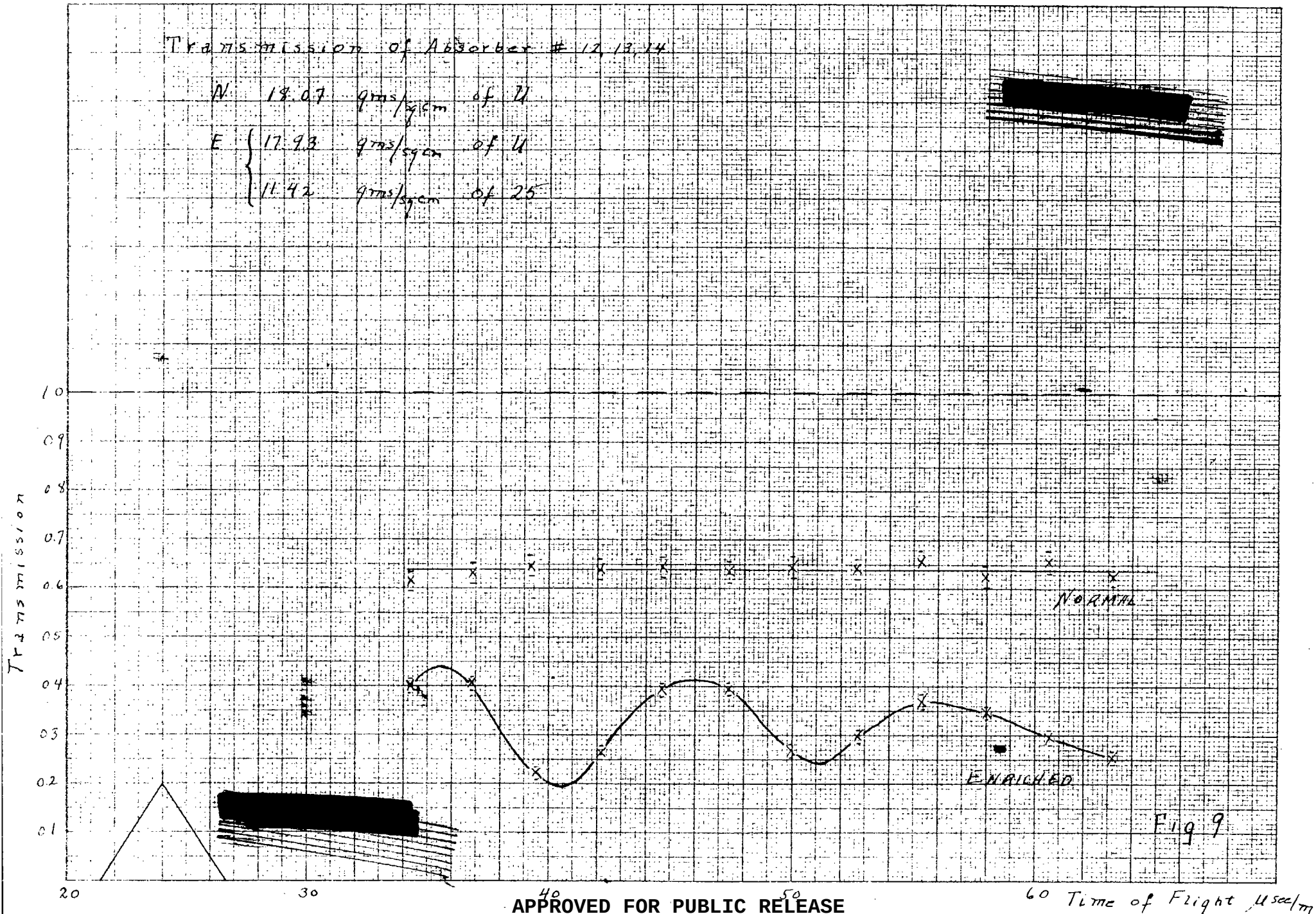

Fig 9

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Millimeters, 5 mm. lines accented, cm. lines heavy
MADE IN U. S. A.

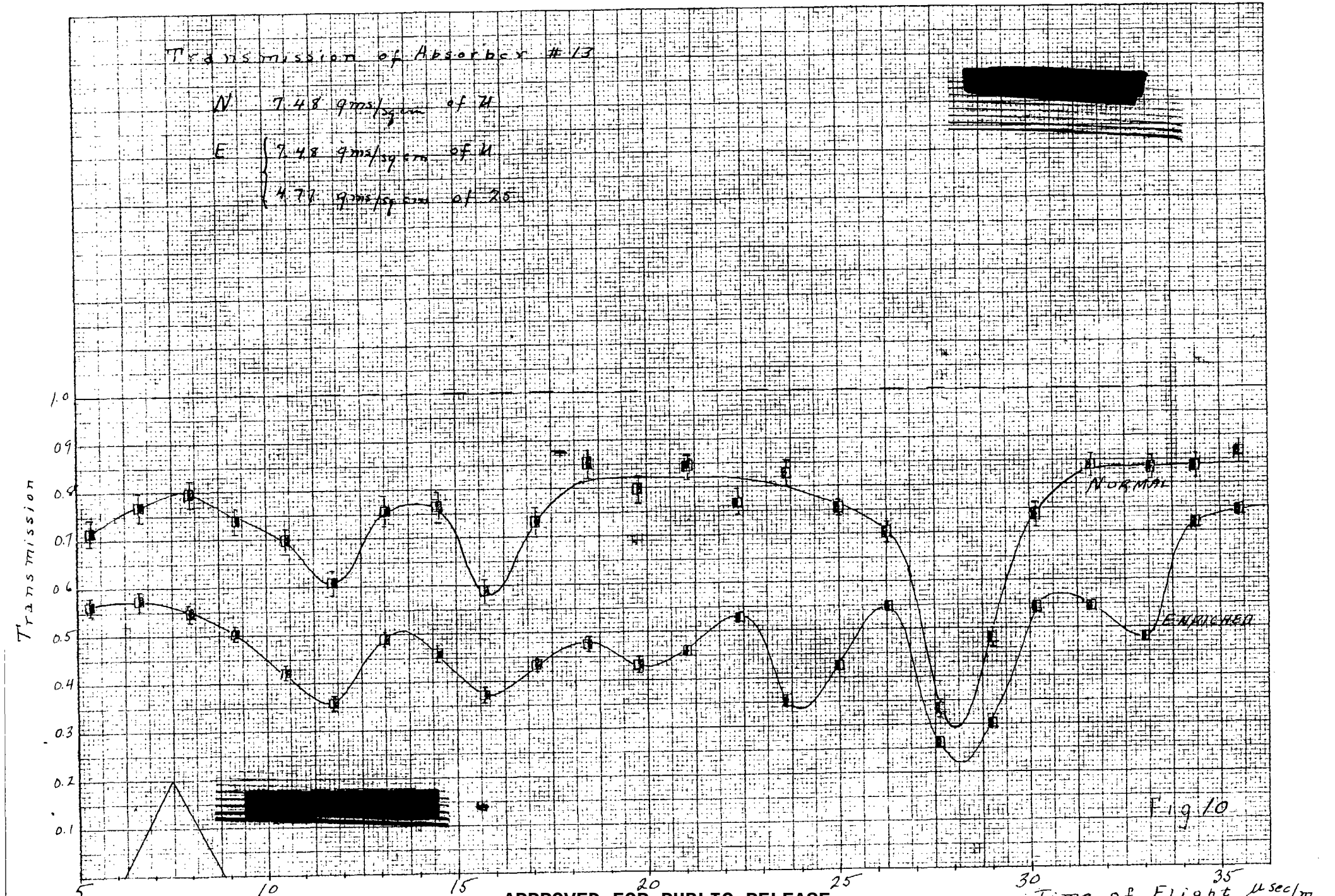

Fig 10

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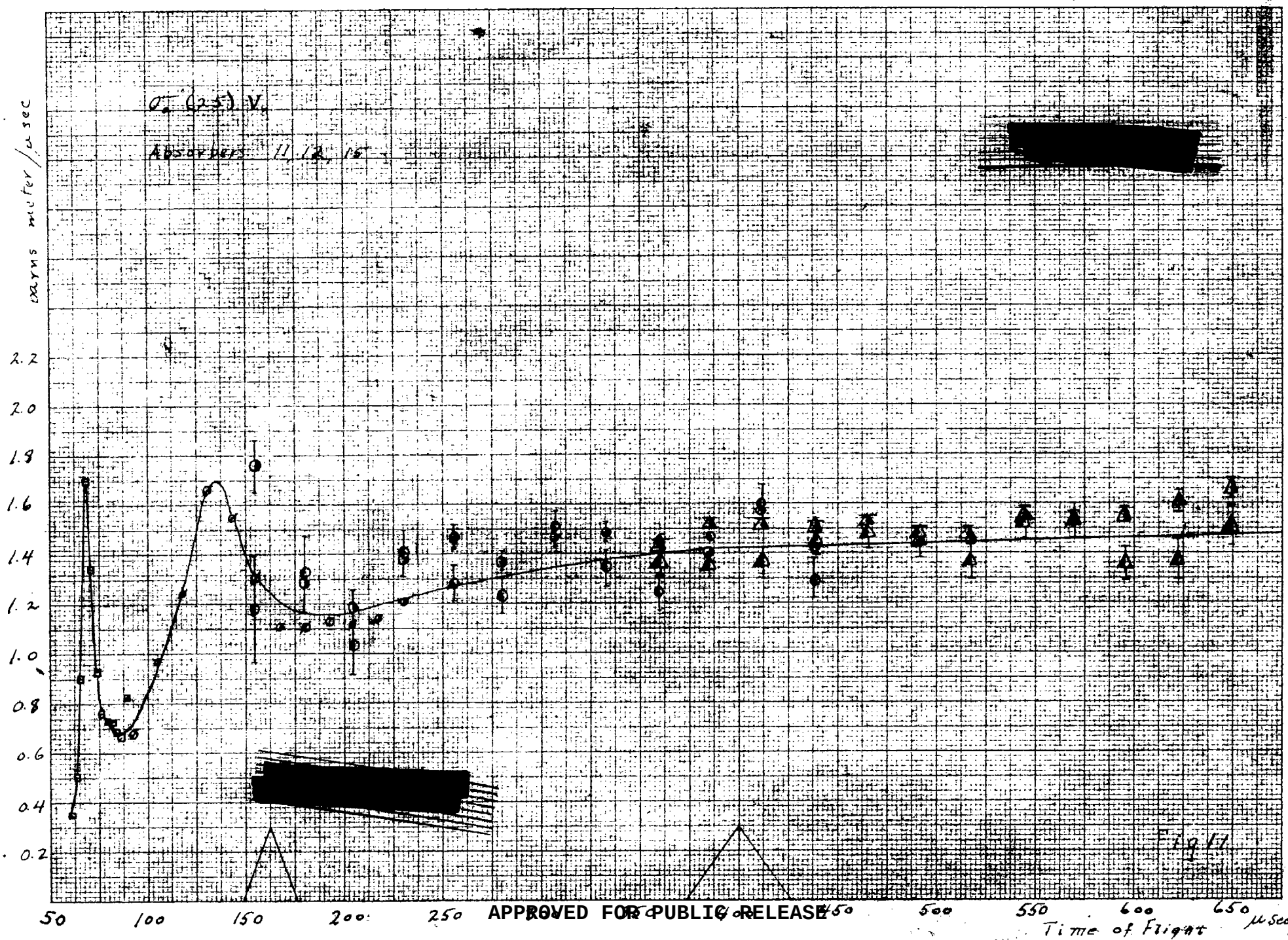

Fig 11

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Millimeters, 5 mm. lines accented, cm. lines heavy
MADE IN U. S. A.

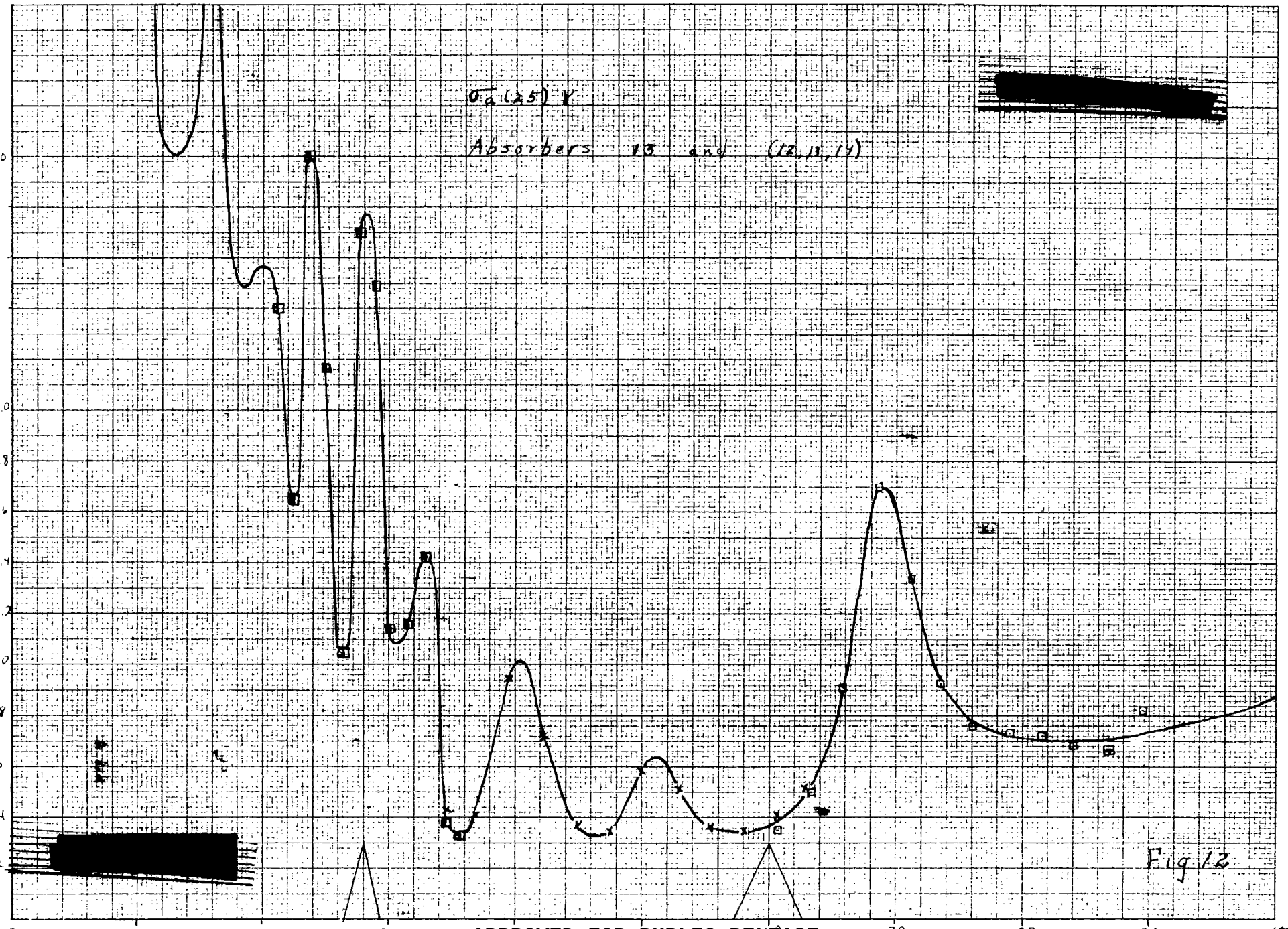

Fig 12

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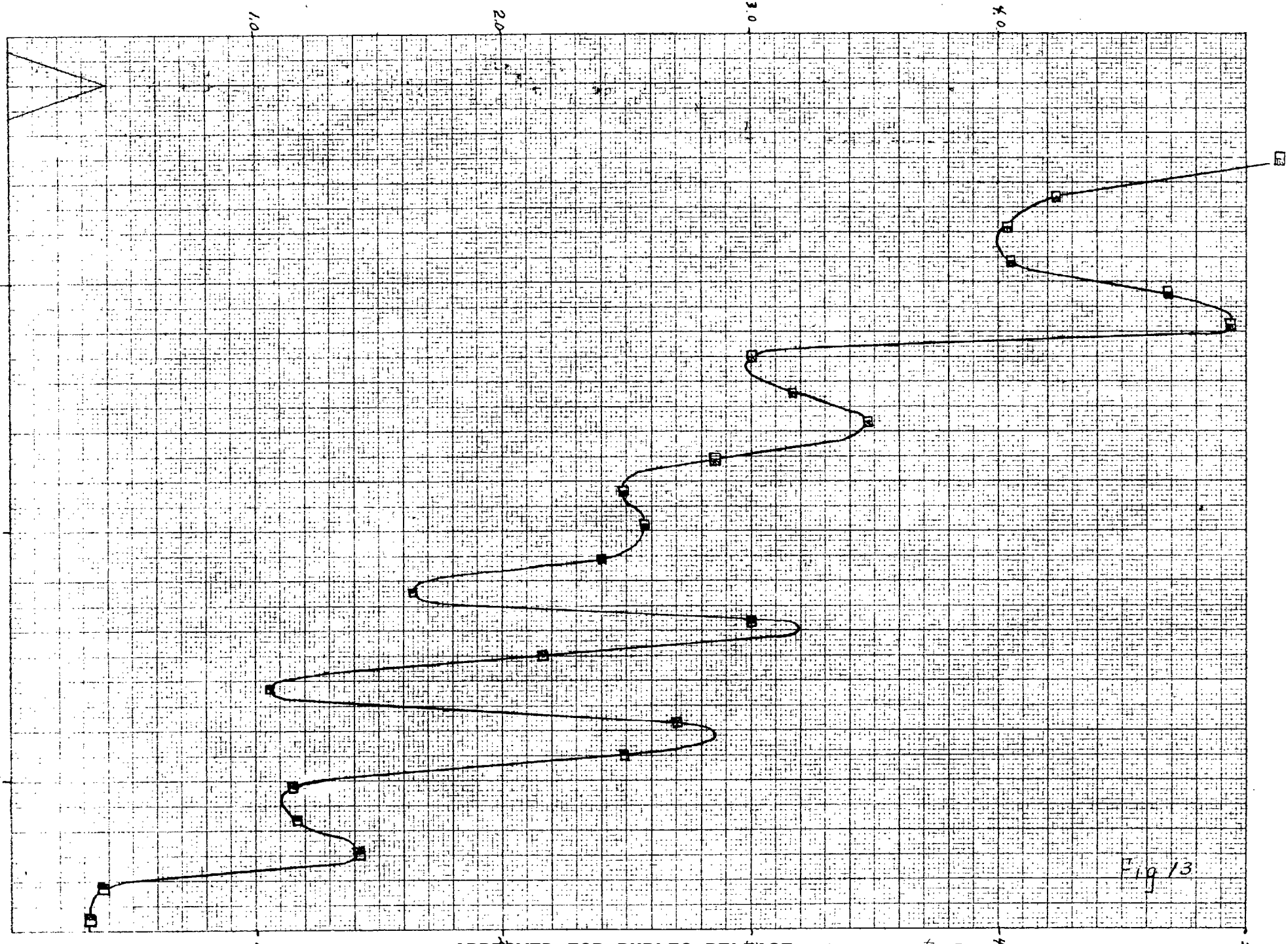

Fig 13

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

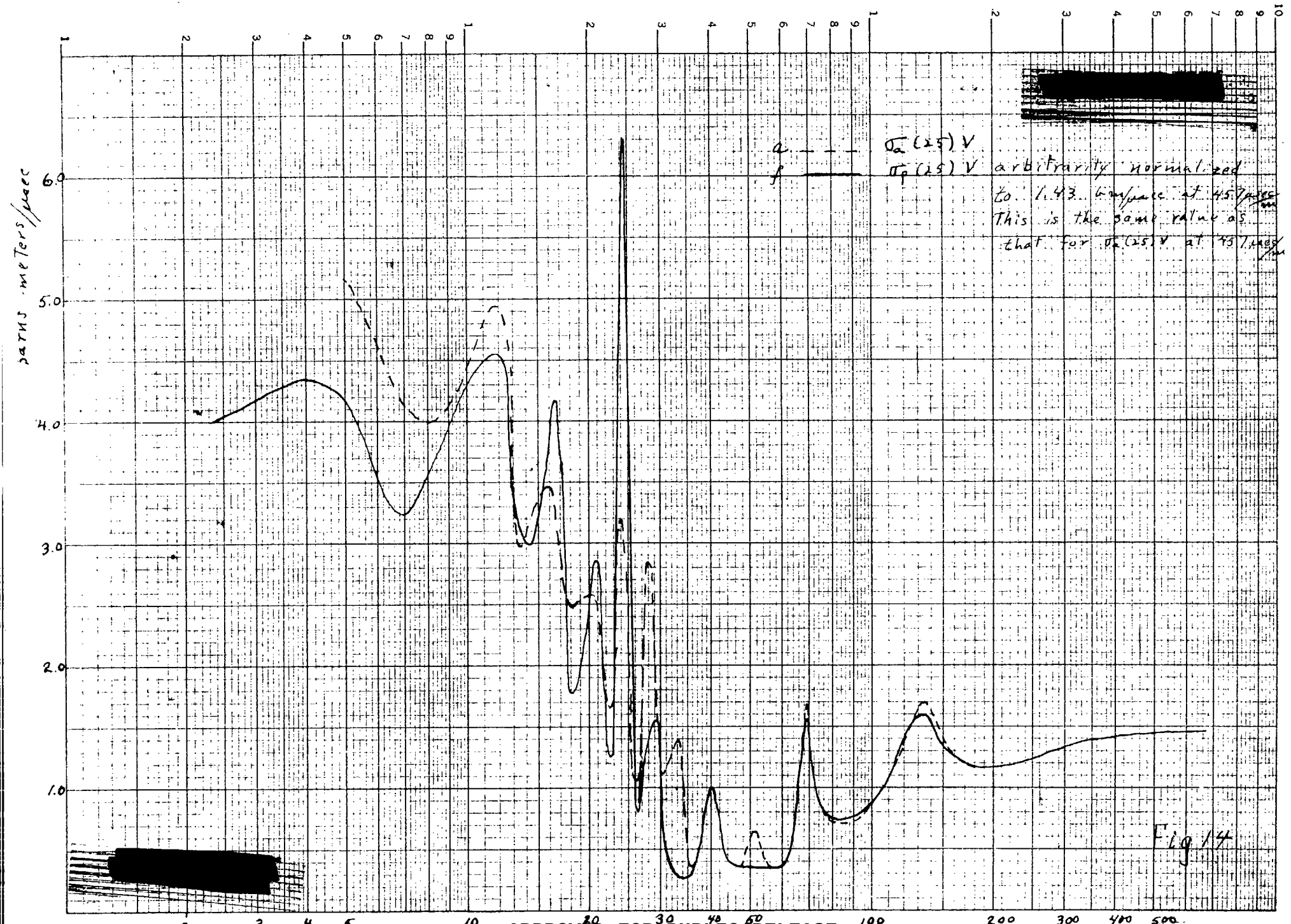

Fig 14

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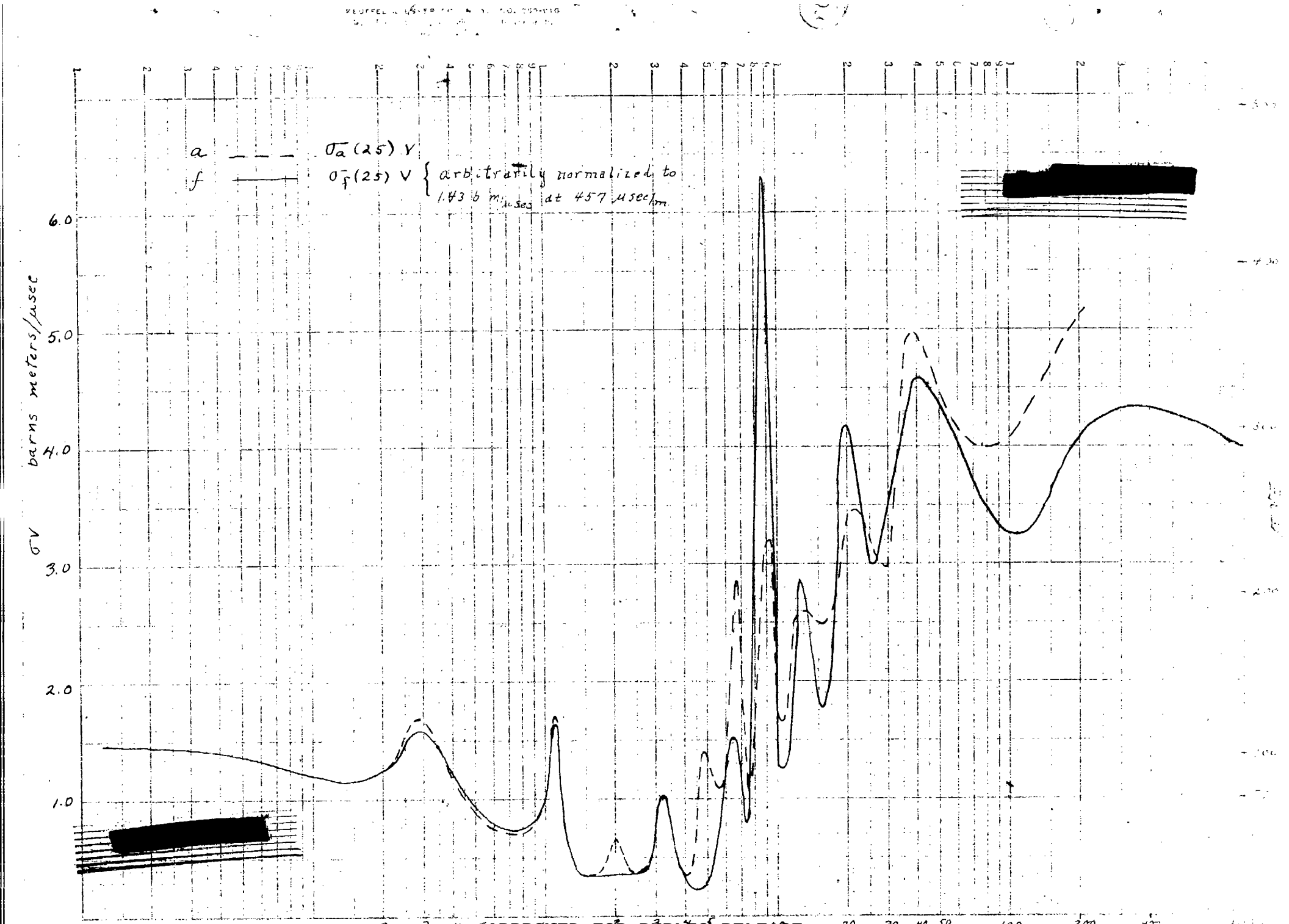

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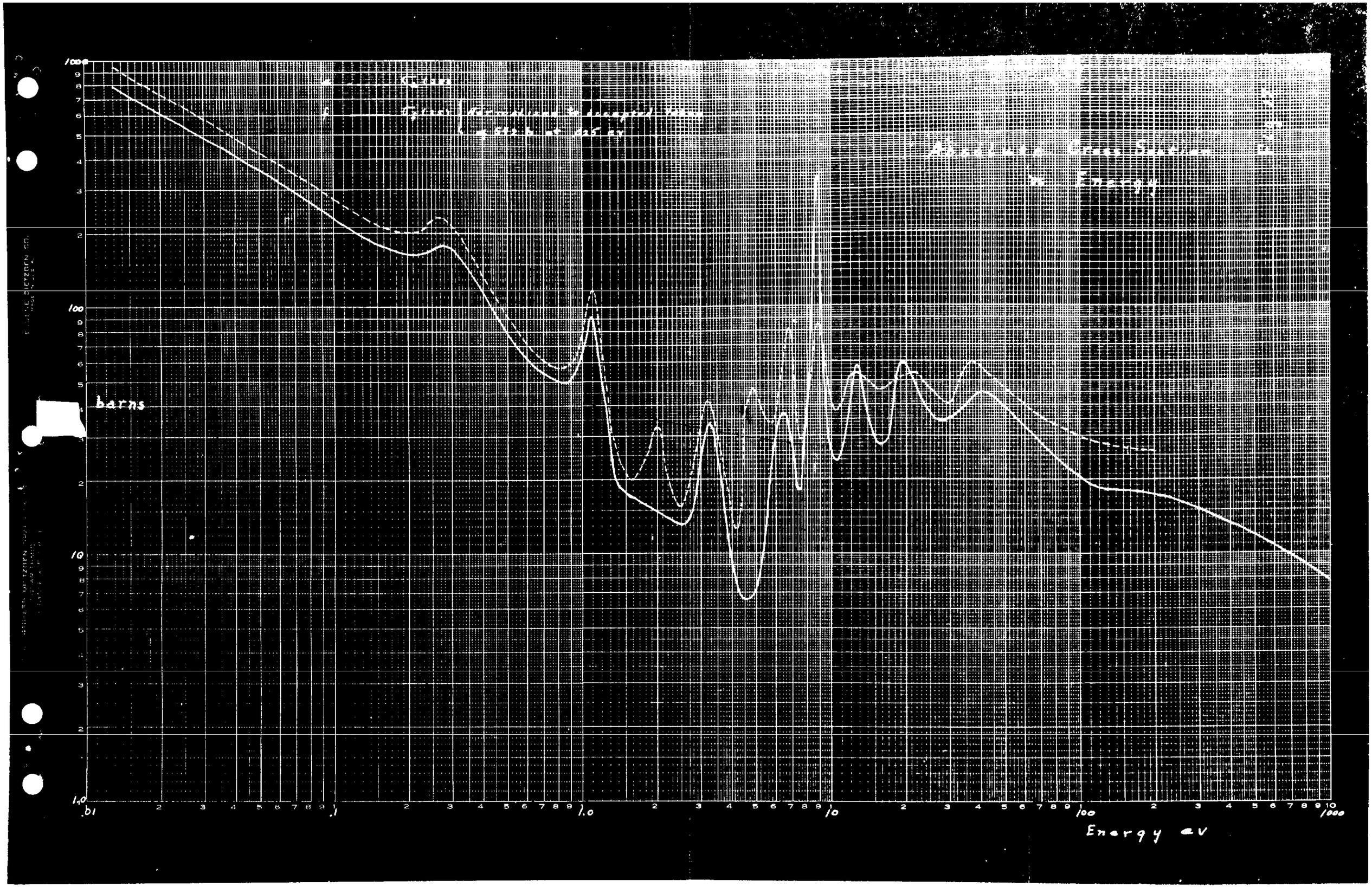

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