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SHORT-PERIOD DELAYED GAMMAS FROM FISSION OF 25

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ABSTRACT

Measurements of gamma-ray activity have been made immediately following pulses of the "dragon", both by means of an ionization chamber and a counter shielded with lead. The activity is given in curies per fission in the period from a few milliseconds to a few seconds after fission. The absolute calibration is uncertain because of unknown absorption, but the results join on reasonably smoothly to earlier results for longer delays.

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SHORT-PERIOD DELAYED GAMMAS FROM FISSION OF 25

Introduction and Summary

The delayed gamma-ray activity of the pulsed fission source ("dragon") recently made by Group G-1 was measured at times varying from a few milliseconds to a few seconds after the pulse. The relative intensities at different times are believed correct to about ± 20 percent, but the absolute intensities, owing chiefly to uncertainty about the self-absorption of the dragon, might be wrong by a factor of two. This accuracy is, however, sufficient for anticipating the general features of further tests involving 25. More accurate measurements, particularly on 49, are desirable.

Measurements were made (a) with an ionization chamber surrounded by one inch of lead and (b) with a Geiger Müller counter in a standard lead "pig" having a wall thickness of about two inches. Each detector was calibrated in terms of a radium (plus products) source placed outside the lead, the number of fissions in each pulse was measured by G-1 by means of the rise of temperature of the active material, and the delayed activity was thus obtained in curies per fission.

Reasonable agreement was found not only between the counter and the chamber measurements, but also between measurements analysed as above and measurements in which the "prompt" gamma-ray pulse was recorded and its size used to estimate the number of fissions in the pulse. Finally, our curve joins reasonably well to the measurements made at Chicago on longer-period activities.

Methods of Observation

(a) Ionization Chamber

The chamber was of parallel-plate construction with an electrode separation of 1 cm, and was filled with air at atmospheric pressure. The collection

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voltage was 1000V, giving a collection time of about half a millisecond; the voltage developed across 1 megohm by the ion current was amplified by a battery-driven dc amplifier and recorded by an oscilloscope and G.R. moving-film camera. The whole electrical circuit had a time-constant (measured experimentally by superposing a sudden increment upon the 1000V polarising voltage) of 8×10^{-4} sec.

The chamber was slung by rubber cords within a one-inch-wall lead box and was 76 cm from the center of the dragon. A calibration record was made on each film by bringing a 200-mc radium source to a fixed position. In order to have the convenience of a large deflection, this position was within the lead box, and a separate comparison was made between this deflection and that obtained with the source at a known point outside the lead. A small neon lamp, run from 60-cycle mains and placed immediately in front of the oscilloscope screen, provided time marks at intervals of 1/120 second.

(b) Counter

The counter was placed in a 2"-wall lead chamber at a distance of 18-1/2 meters from the dragon; the neon-lamp indicators of the "4", "8", "16", "32" and "64" stages of the scale-of-two recorder were mounted immediately in front of the oscilloscope so that the counter record was obtained on the same film as the chamber record. Calibration was performed with a 10-mc source at a standard distance outside the lead.

The correction for loss of counts at high rates of counting was obtained in a semi-experimental way by finding what value of the saturation rate in the elementary formula

$$\frac{\text{corrected rate}}{\text{observed rate}} = \frac{\text{saturation rate}}{\text{saturation rate} - \text{observed rate}}$$

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gave consistency between records taken with pulses of various magnitudes.

Records

Typical records for fission pulses of different sizes are shown in Figs. 1a(chamber only), and in Figs. 1b, 1c and 1d (chamber and counter). Since the oscilloscope spot, deflecting in a direction parallel to the line of neon lamps, was displaced from that line by an amount equivalent to 6 mm on the record, the counter record must be moved by 6 mm to the left in order that the time-scales of counter and chamber records shall agree. Bearing this in mind, it will be seen from Fig. 1d that the counter shows clearly the existence of an activity having a period of only a few milliseconds, as well as other activities of larger periods evident in the other records. These short-period gammas are also to be seen in the chamber records, but there it is possible to argue that they might be due to slow collection of a few ions from the main pulse (for example, ions formed in the amplifier box drifting to the grid-lead). Their registration by the counter proves their reality though it cannot, of course, show whether they are emitted by fission products or are due to some other process such as the capture of delayed neutrons in the tamper. It will be noted that except with the smallest pulse (d) the counter "blocks" during the "prompt" pulse.

Evaluation of Results.

G-1 operated three successive arrangements:

1. UH_{10} core, BeO tamper, surrounded by several inches of lead.
2. UH_{10} core, BeO tamper, no lead.
3. UH_{80} lattice core, BeO tamper, no lead.

The first of these was clearly not very suitable for absolute measurements; the inhomogeneous core of the third made it impracticable to infer the number of

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fissions from the rise in temperature, and therefore all absolute measurements (i.e. measurements expressed in curies/fissions) were based on the second arrangement. Relative measurements on the third dragon are, however, of interest, and are discussed below; they are expressed in terms of curies, the number of fissions being unknown.

The chief difficulty in analysing the results is the correction for "self-absorption" in the dragon. The core and the tamper were not of simple geometrical shape, the distribution of fissions within the core was not accurately known and the absorption and degradation of the gammas depend upon their unknown energies. Now all measurements were made through a considerable thickness of lead, and Chicago measurements have shown that the gammas emitted at later times have energies not far from these at which heavy elements are most transparent. It therefore seemed reasonable to assume that the short-period gammas recorded by our apparatus had an absorption coefficient of .03 cm^2/gm in 25. The effective absorption coefficient in the BeO tamper was taken to be equal to the Compton scattering coefficient in that material for 1.9-Mev gammas -- viz., .042 cm^2/gm. The core and the tamper were taken to be cubical, and the activity was assumed to be uniformly distributed within a sphere inscribed in the core cube. On the above assumptions the self-absorption correction comes out to be a factor of 6, but this might well be wrong by a factor of 2 and is the greatest source of uncertainty in the <u>absolute</u> evaluation of the measurements.

It should also be noted that no correction was attempted for the scattering of gammas by the ground; this correction is very small for the chamber, which was considerably nearer to the dragon than to the ground, but might be appreciable for the counter which was much further from the dragon.

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Results

(a) Comparison between counter and ionization chamber.

In spite of its heavy shielding and great distance the counter was much more sensitive than the chamber; the overlap between their ranges of effective measurement was however enough to provide a comparison. Fig. 2, giving the results of two pulses (Nos. 524 and 531) from the third dragon, shows close agreement for 524 but a ratio of about 3:2 for 531. The counter was certainly less reliable than the chamber, for its plateau was not very wide and its sensitivity could not be checked very frequently, owing to the necessary safety restrictions on the entry of personnel into the experimental room.

The counter was installed as a check that no fundamental or large systematic error was present in the chamber measurements or their evaluation, and the agreement is sufficient to give confidence in the chamber measurements. It should be pointed out that the counter and the chamber should give identical values only if the delayed gammas and those from the calibrating source were of equal hardness.

(b) Comparison of various pulses from UH_{10} dragon.

Figs. 3 and 4 show results of chamber measurements (expressed absolutely in curies/fission) made on six different pulses of varying size from the second (UH_{10}) dragon. The scatter of the points is such that one would estimate the accuracy of the mean curve to be of the order of $\pm$ 10 percent if it were not for the much greater systematic error arising from the uncertainty in the self-absorption correction. The points marked ● were obtained, at the suggestion of M. Deutsch, from a pulse in which the activity was so small that the area beneath the "prompt" pulse could be measured and used as a measure of the number of fissions. Deutsch and Rotblat's value of 5 Mev. of prompt gamma-radiation per fission was used, and

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one curie-second was taken as equivalent to 7.4×10^{10} Mev. If the prompt and the delayed gammas had the same hardness, this method would be independent of the self-absorption of the dragon; the good agreement with the other points (in which, as already explained, the rise of temperature was used to estimate the number of fissions) gives some hope that the estimate of 6 for the self-absorption correction was not far wrong.

(c) Comparison of decay curves from UH_{10} and UH_{80}

Figs. 5 and 6 show that the shapes of the decay curves from the UH_{10} and UH_{80} dragons are substantially identical. Since no temperature measurements were made in the UH_{80} (lattice) core, the number of fissions was unknown and the UH_{80} curves were moved up or down to secure the best fit with the UH_{10} curve.

(d) Comparison with Chicago measurements

Fig. 7 shows a portion of a graph, kindly supplied by E. Segrè, that summarizes Chicago values for delayed-gamma-ray intensity at times somewhat later than those to which our measurements extend. Our measurements are plotted on the same scale, the conversion factor between curies and Mev/sec being taken as before, to be 7.4×10^{10} (i.e., 2 Mev of hard gamma radiation per radium chain).

The discrepancy between the two curves is probably a fair illustration of the uncertainties of the absolute value determined by us. It may be mentioned that Fig. 7 is so plotted that if the intensity varied inversely with time a horizontal line would be obtained.

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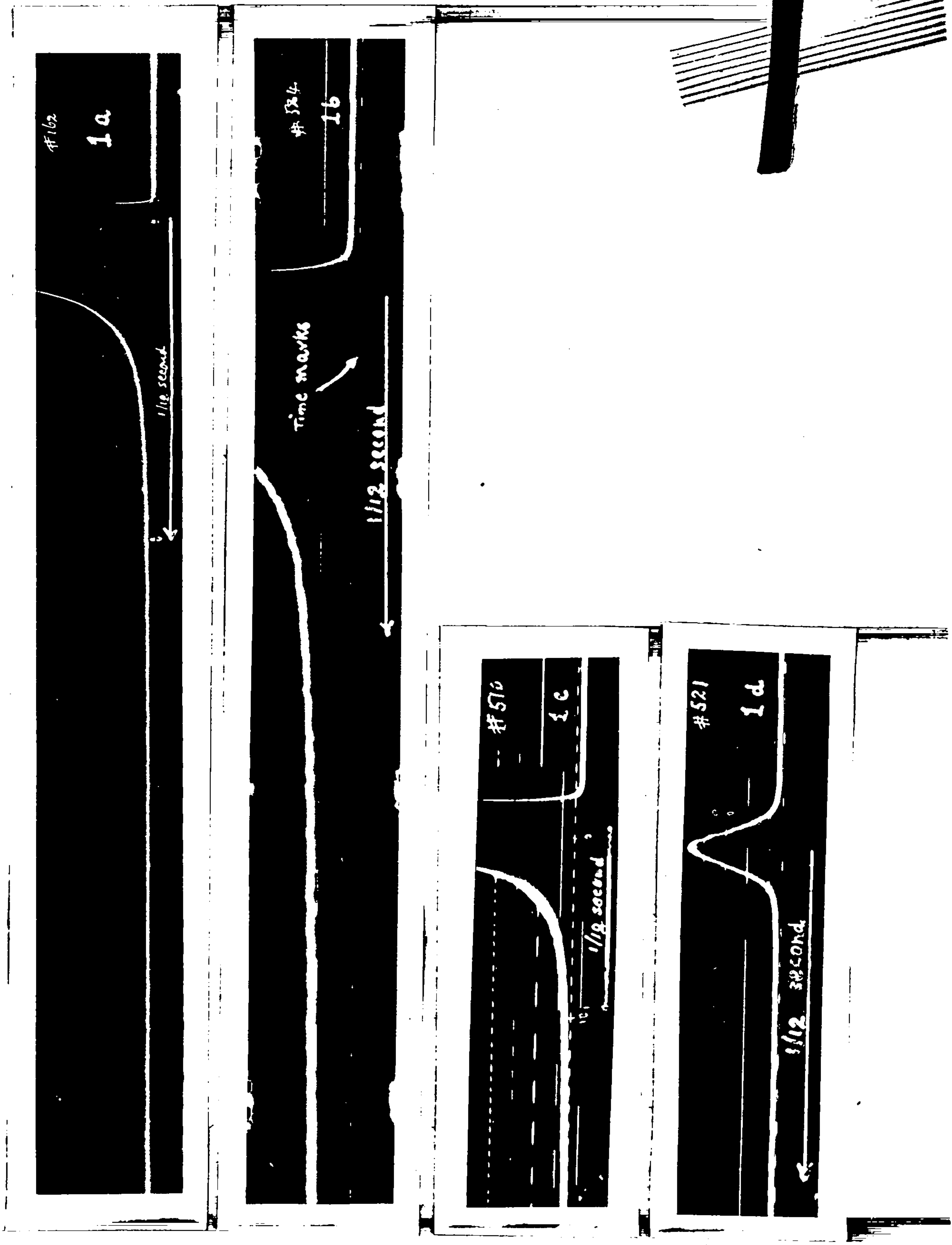

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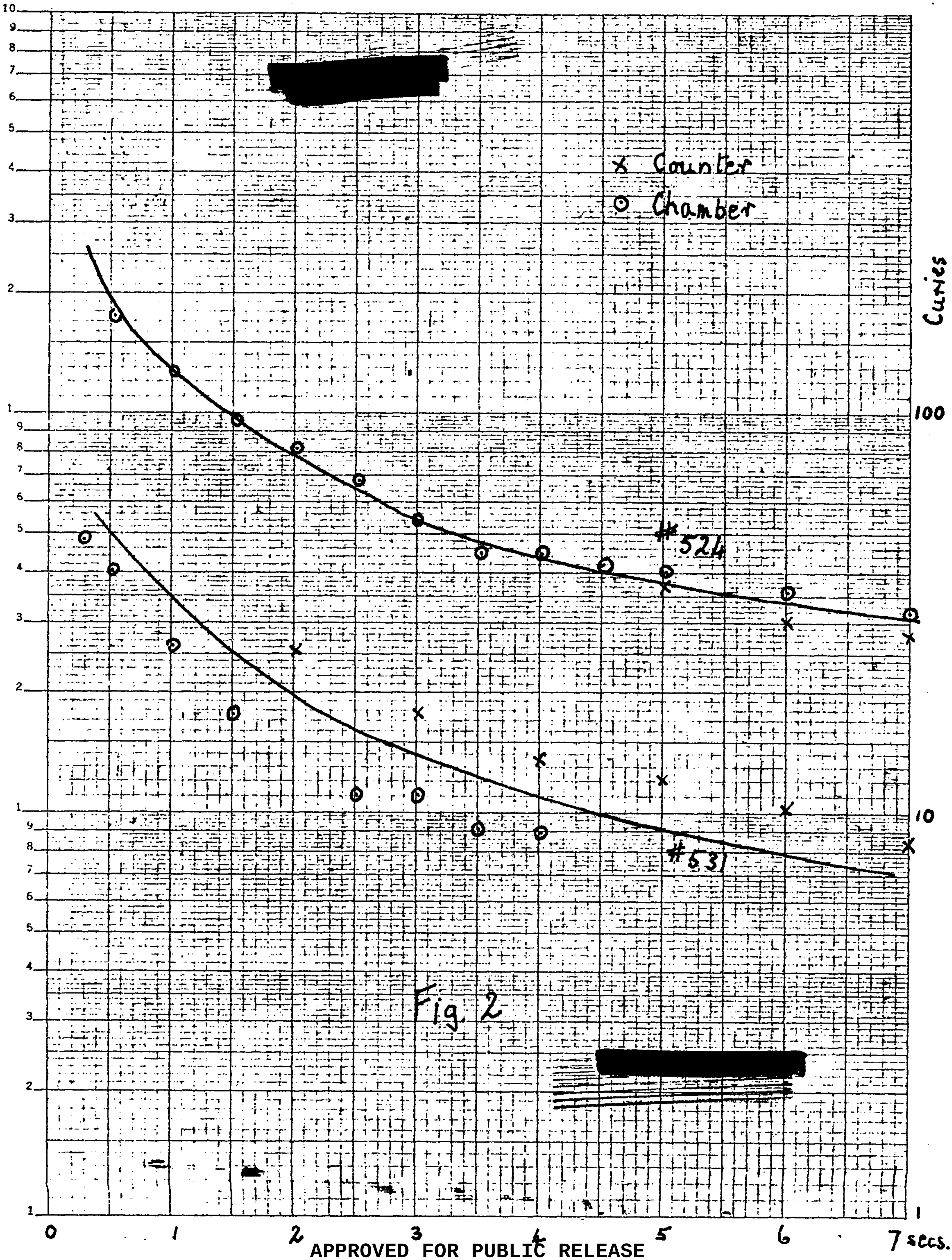
[redacted]
x Counter
⊙ Chamber
Curies
100
10
1
#524
#531
Fig. 2
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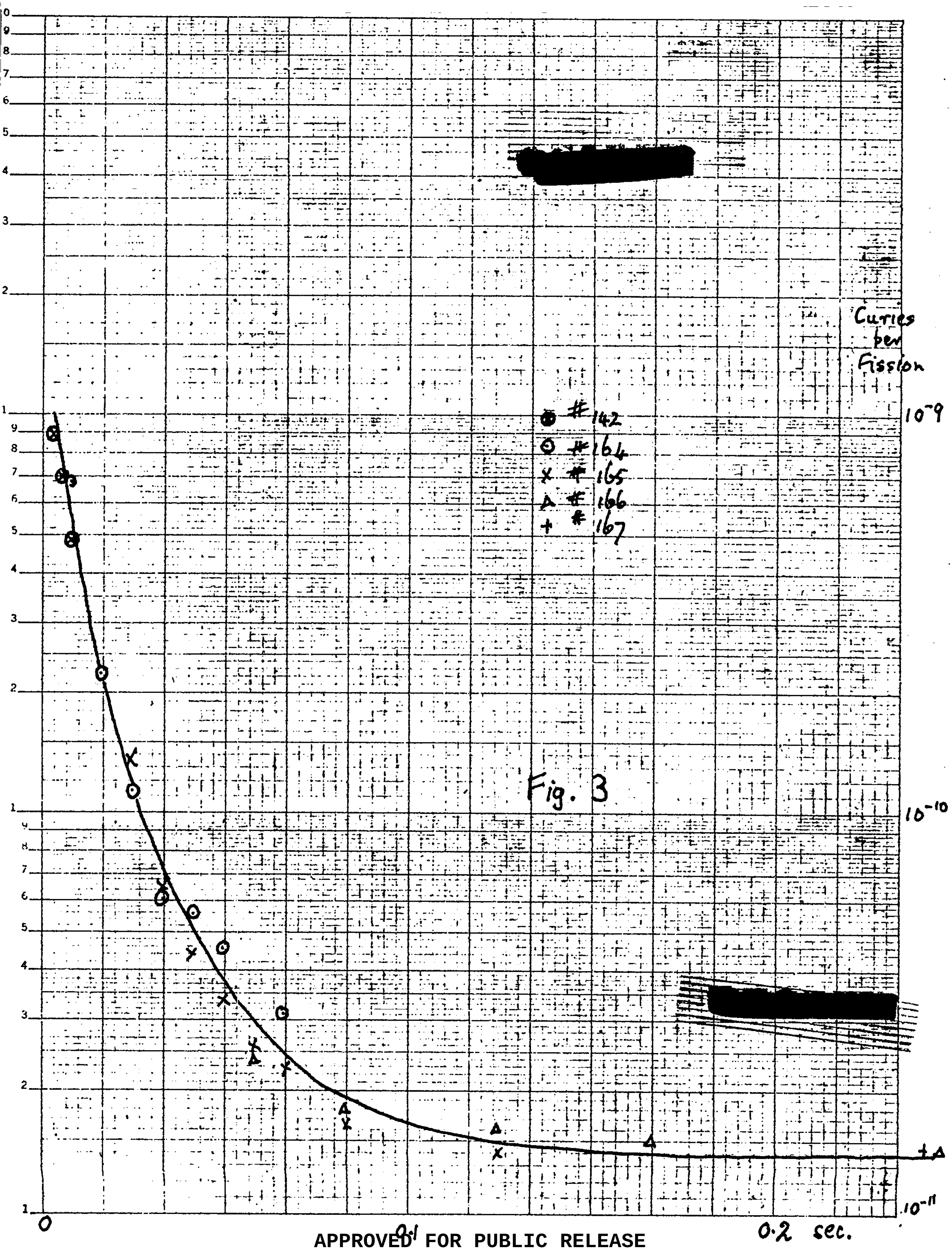
0
1
2
3
4
5
6
7 secs.



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Curies per Fission
10^{-9}
10^{-10}
10^{-11}
⊗ #142
⊙ #164
x #165
Δ #166
+ #167
Fig. 3
[redacted]
0
0.1
0.2 sec.

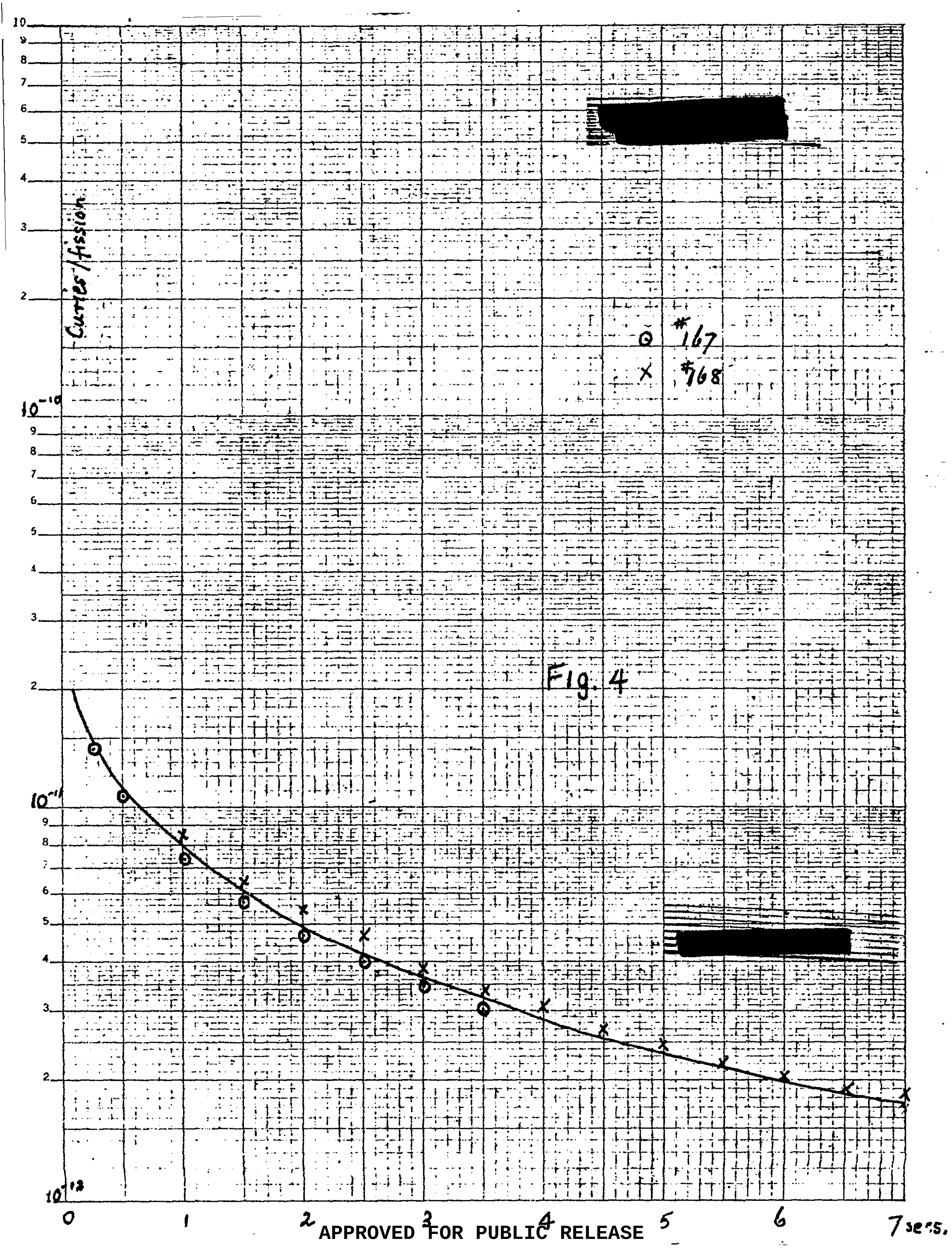
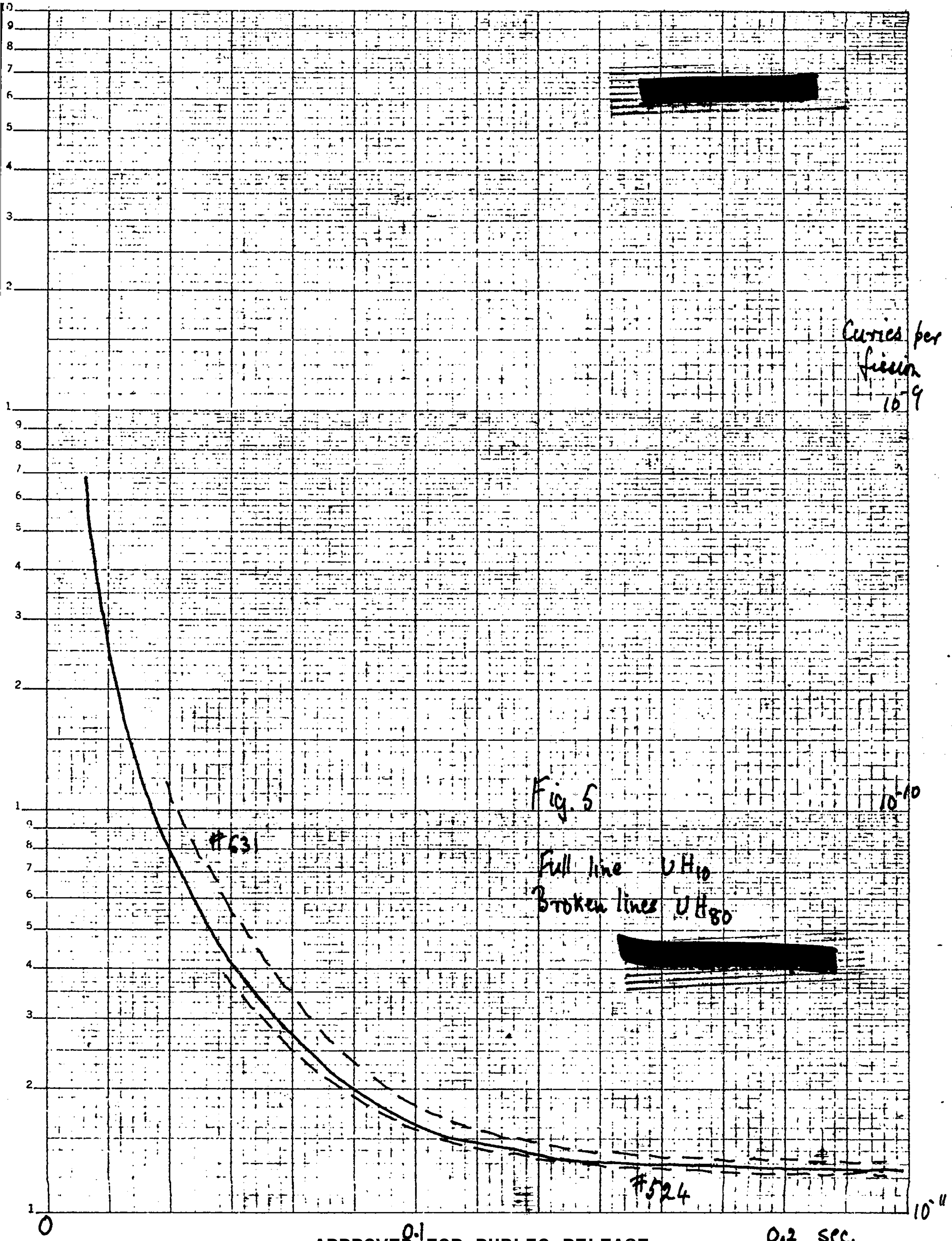
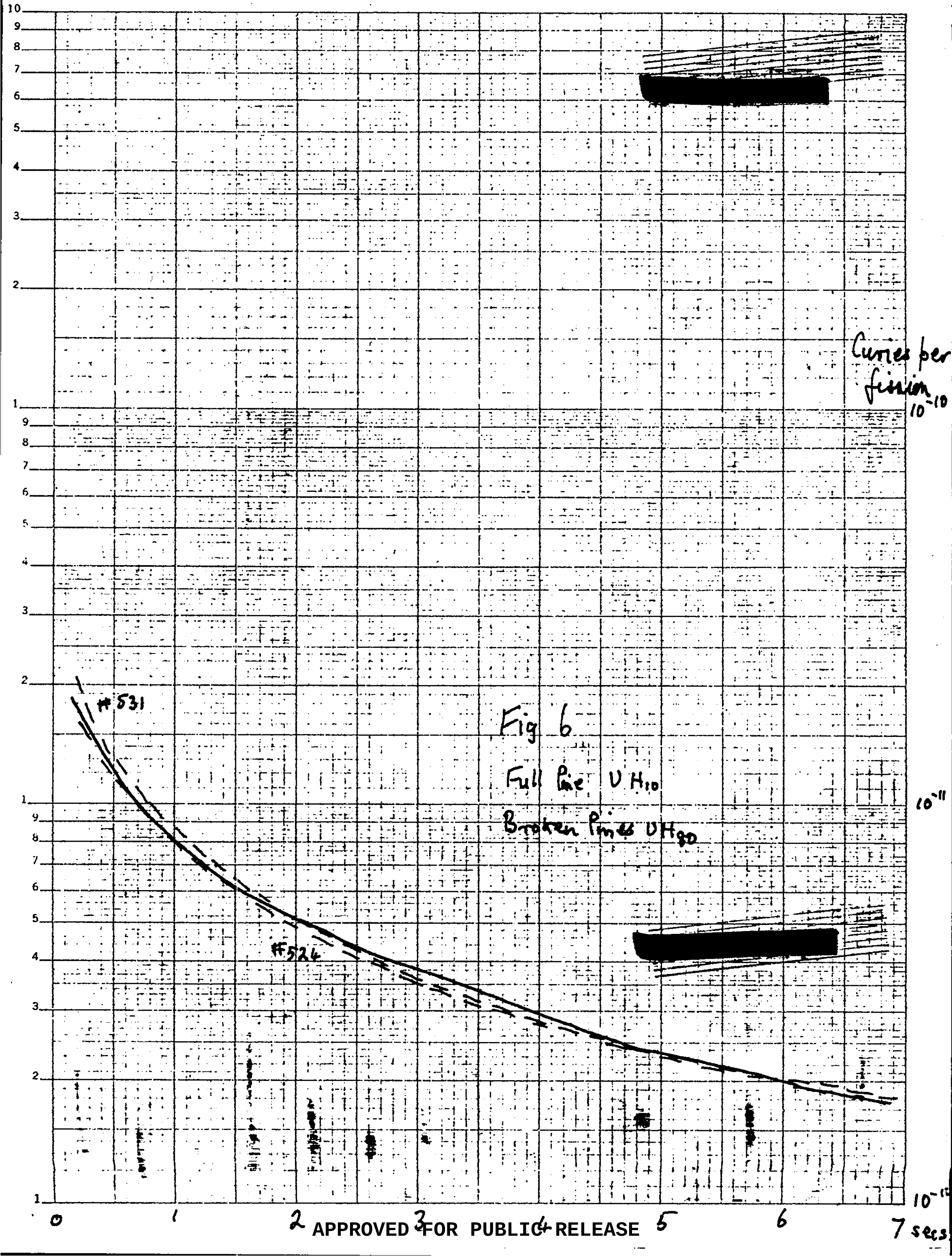

Curies/fission
10^{-10}
10^{-11}
10^{-12}
○ #167
× #168
[redacted]
[redacted]
0
1
2
3
4
5
6
7 secs.

Fig. 4


[redacted]
Curies per fission
10^{-9}
Fig. 5
10^{-10}
#631
Full line UH_{10}
Broken lines UH_{80}
[redacted]
#524
10^{-11}
0
0.1
0.2 sec.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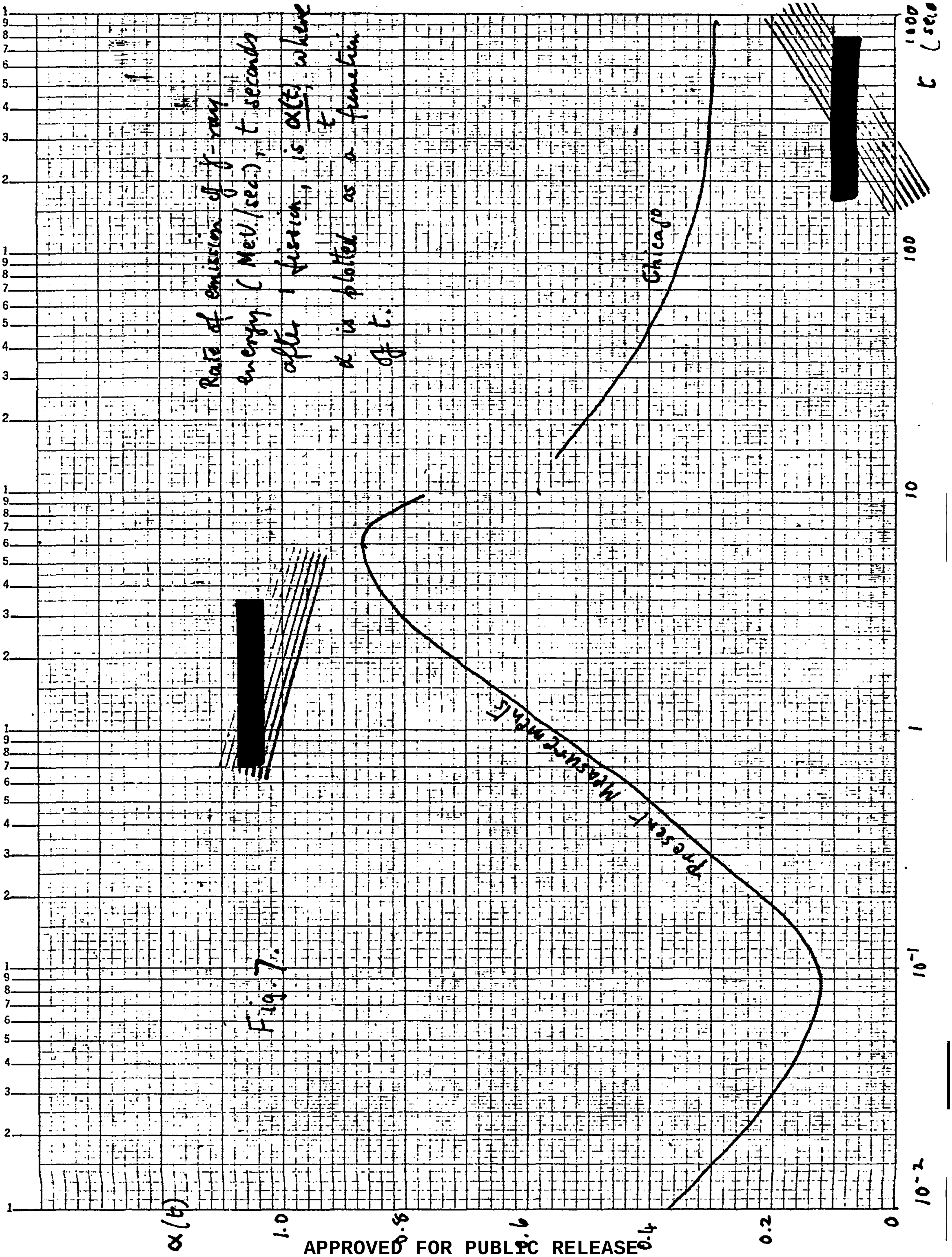
Curies per fission
10^-10
#531
Fig 6
Full line UH10
Broken lines UH80
10^-11
#524
[redacted]
10^-12
0
1
2
3
4
5
6
7 secs



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