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SHORT-PERIOD DELAYED GAMMAS FROM FISSION OF 25 AND 49

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SUMMARY OF LA-253

In the experiment written up as LA-253, measurements of the delayed activity of 25 had been made following pulses of the "dragon" (see LA-397). These measurements were made by means of an ionization chamber and a counter shielded in lead and the results were given in curies per fission for times ranging from a few milliseconds to a few seconds after fission.

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SHORT-PERIOD DELAYED GAMMAS FROM FISSION OF 25 AND 49

I. INTRODUCTION

The discrepancy between the results of LA-253 and those obtained more recently by ourselves and others has made it desirable to record some of the new results and to re-examine the records and results of LA-253.

The discrepancy occurs mainly for times up to 100 milliseconds. Whereas the results of LA-253 show activities decreasing from about 5×10^{-10} curies per fission at 10 milliseconds, to 10^{-11} curies per fission at 100 milliseconds, the measurements of group F-2 on 25 show fairly constant activities of the order of 10^{-11} curies per fission during this entire time interval. Furthermore group F-2 has also shown (and it is to be expected from theoretical considerations) that the delayed γ activity of 49 is quite closely of the same order as that of 25. We have ourselves measured the activity of 49 using the Van deGraaff generator as a neutron source and although our results were somewhat rough because of difficulties with background we have found that they are of the same order of magnitude as the results of group F-2 on 25 and 49, and not at all of the same order, therefore, as the results on 25 of LA-253.

II. THE RESULTS OF GROUP F-2

L.D.P. King and E. Fermi and their group have measured the delayed γ radiation from the fission of 25 and of 49. Their preliminary results appear in LAMS-255 and LAMS-265, and their final results will be published soon.

Their method of measurement is a cleaner one than that of LA-253. No complications arise from doubts about self-absorption, etc., as they did in the dragon experiment. Essentially the method of group F-2 consists of shooting a

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slug of either 25 or 49 through the water boiler into a chamber where the activity of the slug can be counted. The time the slug spends between water boiler and counting chamber is variable and is measured in order to be able to express the observed activities as a function of time after irradiation.

Using this method group F-2 has established that the short-period delayed γ activity from the fission of 25 and 49 lies on curves that are roughly parallel and of the same order of magnitude (the 25 is perhaps 30% more active than the 49). Although there is no good reason such order of magnitude agreement is not to be expected, it is comforting to have the experimental verification.

Some points from the preliminary results of group F-2 on 25 are plotted in Fig. 1 with the dragon results of LA-253 and two points that we have obtained for 49, to be discussed in the next section.

III. THE DELAYED γ ACTIVITY OF 49 AS MEASURED WITH THE VAN DE GRAAFF

It was planned to estimate the nuclear efficiency at Trinity by measuring the delayed γ activity (see LA-430). In order to convert from γ activities to nuclear efficiencies, it is necessary to know the number of curies per fission of the fissionable material (49). Because of the discrepancy between the preliminary results of group F-2 and those of LA-253, it was decided to measure the number of curies per fission of the delayed γ activity of 49 for times up to 100 milliseconds by means of the Van deGraaff generator.

The Experimental Setup

A piece of plutonium was irradiated by neutrons from a Van deGraaff generator for periods of time of the order of a millisecond and observed by a Geiger counter for its γ activity during and after the irradiation. R. Perry

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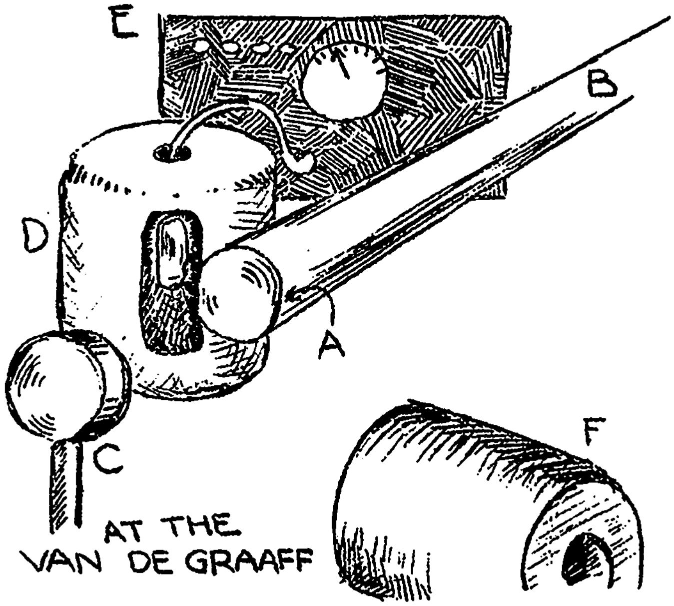
modified the Van deGraaff generator so that this could be a periodic process. Deflector plates were inserted into the target tube and a square wave applied to them. This periodically deflected and returned the generator's proton beam to the lithium target. Thus the neutron source ($H^1 + Li^7 \rightarrow n^1 + Be^7$) was pulsed. The pulses from the Geiger counter were fed to an oscillograph and photographed. Both the pulses due to prompt γ's (i.e., those that appeared while the beam was on the target) and those due to the delayed γ's were photographed. A somewhat more detailed description of the experimental arrangement follows

A beam of protons impinges on the lithium target (A) of the Van deGraaff electrostatic generator. The beam is modulated by a square wave circuit acting on deflector plates in the target tube (B). The neutrons ($\sim$ 600 Kv) from the proton-lithium reaction hit the plutonium which acts as one electrode of a fission counter (C).



The G.M. tube counting the γ rays is placed in a lead cylinder (D) with two inch walls and a window facing the plutonium. Nearby are the G.M. power supply (E), a long neutron counter (F), and a cathode follower which transmits the γ pulses to the control room.

These pulses are fed onto the vertical plates of an oscilloscope (G) whose sweep circuit has been replaced by a laboratory sweep (H) of adjustable sweep length and speed. The sweep is triggered by the modulation circuit. A

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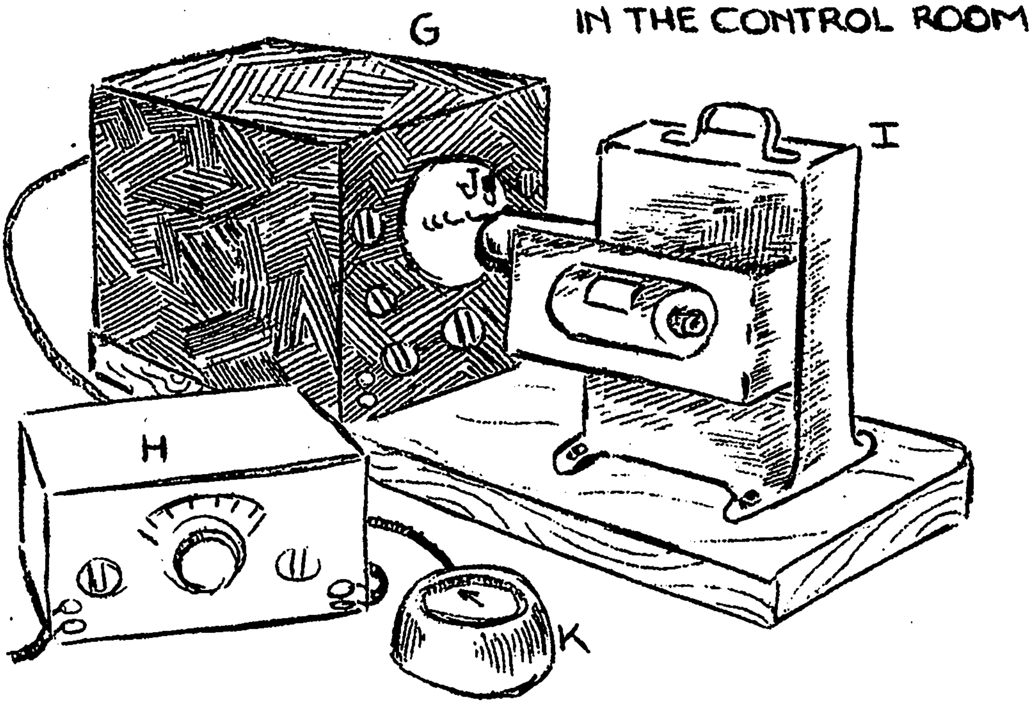
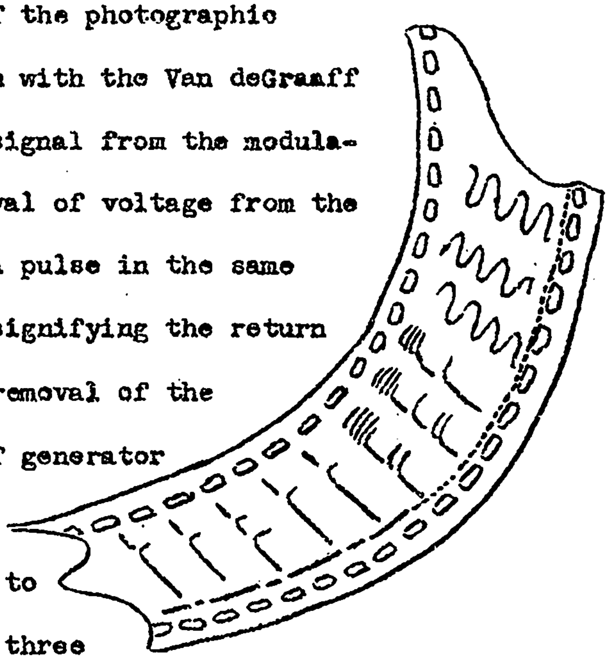


General Radio recorder (I) photographs the scope traces and the "scale of one" neon bulb (J) mounted at the scope screen. The mechanical counter (K) operates from the scaling circuit output.



At the right is drawn a strip of the photographic record. The bottom five traces were taken with the Van deGraaff generator off. Each trace starts upon a signal from the modulation circuit that coincides with the removal of voltage from the plates in (B). Each trace further shows a pulse in the same place, also from the modulation circuit, signifying the return of voltage to the plates (and consequent removal of the beam from the target when the Van deGraaff generator is on). The third of these traces shows an additional pulse. This is a count due to background. Above this set of traces are three representing those that would appear with the generator on. The many pulses that occur before the beam is deflected are counts of the prompt γ's. Those to the right are the delayed γ's. At the very top are 400 cycle timing signals from an oscillator.

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The Data

The object of the experiment is to find the curies of γ radiation per fission of 49 as a function of time after fission. The G.M. tube data can be evaluated in γ counts per second at any time interval after irradiation. The fission counter and the long neutron counter (which was used as acheck on the fission counter) tell us the total number of fissions occurring during the irradiation. The number of γ counts per second per fission (call this number A) for our particular apparatus is thus readily obtainable. By placing a known calibrated γ source (we used one millicurie of radium in equilibrium with its products as our standard) at the position of the plutonium, one can find B, the number of γ counts per second per curie for our arrangement of the apparatus. Assuming that a curie of fission γ's gives about the same counting rate as a curie of radium γ's, then the number sought, the curies per fission of the delayed γ radiation is simply A/B. This number can be evaluated for various time intervals after radiation.

The Results

In such a manner the average curies per fission for the first six 1.7-millisecond intervals after irradiation were calculated. For these runs the time of irradiation was 1.2 milliseconds. It was found that for all but the first two intervals the ratio of signal to background was too small to attach very much absolute significance to the results. However if the signal were as large as one would expect from the results of LA-253 (assuming again that the delayed γ activity of 49 and 25 are of the same order of magnitude at all times) then it would have been easily observable over the background. In this sense the lack of absolute results in these time intervals is significant, for it sets an upper limit to the γ activity

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of 49 for these times. Similarly all our data for 10-millisecond irradiation followed by 100-millisecond observation was made uncertain because of background. However the upper limit that could be set on the delayed γ activity from the fission of 49 was everywhere lower than the activity observed in LA-253. The 2 points we did get whose probable error is less than $\sim 30\%$ are plotted on the graph (Fig. 1) that gives the curve from LA-253 and that from LAMS-255.

IV. A RE-EXAMINATION OF THE RESULTS OF LA-253

From the results of Sections II and III, it is clearly desirable to re-examine the records and methods on which LA-253 was based. This was accordingly done, special attention being paid to possible sources of error that could explain so large a discrepancy as is indicated in Fig. 1.

First, one could consider purely instrumental errors. For example, one might suspect that there was an instrumental spreading out of the prompt γ pulse in the ionization chamber that was used in LA-253, and that it is this spreading that gives erroneously large activities at the short times immediately following the dragon pulse. This suspicion could be ruled out if it were established that the Geiger counter gave the same activities for these early times. The early time counter data of LA-253 had hitherto not been analyzed for two reasons: 1) with a counter having a saturation counting rate of about 1000 per second, it is impossible to get good statistics from one or a few runs lasting but a short fraction of a second. 2) Most of these counter records were partially fogged. However, two of these records have now been analyzed, with the results indicated in the histogram of Fig. 2. The number of particles counted for each time interval is shown at the top of each block of the histogram. It will be seen that the statistics are extremely poor but sufficient to show that the counter results at these short times

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agree roughly with our chamber measurements. If it is kept in mind that the chamber was 0.76 m from the dragon and the counter $18\frac{1}{2}$ meters from the dragon, and that the recording and evaluation of data for the two types of measurement was independent, one must conclude from the observed agreement of counter and chamber measurements that serious instrumental error was very likely absent from the results of LA-253.

One is led to assume that any error in LA-253 would consist of unwittingly counting something in addition to the delayed γ's from the 25 and the known background. What, then, could contribute to a γ background immediately following a dragon pulse? In order to affect both chamber and counter, any radiation capable of causing the background would have to be fairly penetrating. Among the radiations from the dragon only γ's and neutrons would fit this requirement. It is difficult to see how the prompt γ's of the dragon pulse could cause an appreciable delayed γ count, unless it was that one was actually still counting the prompt γ's themselves when it was thought that delayed γ's were being counted. That is, one might assume that the activity vs. time curve in a dragon pulse was not strictly Gaussian, as is indicated by the simple theory, but that it has a long tail. (One might conceivably blame such a tail on the delayed neutrons of the pulse.) Frisch assures us, however, that this is not the case because such a tail 1) would be very small from theoretical considerations and 2) is experimentally negligible as determined from the form of the observed neutron pulse.

Then let us consider the neutrons. How could they contribute to a background of delayed γ's? One would have to find a probable (n,γ) reaction with an appreciable cross-section and assume at least one of the following. 1) The number of delayed neutrons emitted is sufficient to account for the delayed γ background by means of the assumed (n,γ) reaction. 2) The prompt neutrons are slowed down in some

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medium and gradually captured resulting in the gradual emission of γ rays. 3) The prompt neutrons are responsible for the γ's by means of an (n,γ) reaction where the 's come off delayed. One might assume here that neutron capture is followed by β emission with a period of about 10 milliseconds, accompanied by γ emission.

In order to explain the observations, a theory of the excess of γ's at short times in the dragon experiment would have to account for the following facts.

a) The chamber and counter gave comparable results at all times although they were 0.76 and 18.5 meters respectively from the dragon.

b) The change of dragon tamper from BeO to graphite and polythene had no important effect on the results.

Of the three theories, the first can be eliminated at the outset. The delayed neutrons of about 6-millisecond period contain only about one neutron for every 5000 fissions, whereas the γ rays of this period observed with the dragon are much more numerous, being about one for every 10 fissions. Thus the delayed neutrons cannot be blamed for the observed γ intensity.

The second theory is somewhat unlikely because if one were to assume that slowing down and capture in the tamper gives rise to the γ's, one would come into conflict with requirement b, It would be very unlikely that both the BeO and polythene-graphite tamper should have the same slowing down and capturing properties. Were one to assume that the slowing down and capturing medium was away from the dragon, say the walls and floor of the room, one would run into conflict with a, for it would be difficult to explain why the γ intensity that appeared at counter and chamber behaved as though there were a source of γ's at the center of the dragon (i.e., we are brought into conflict with the inverse square law).

The third theory is somewhat less unlikely. About one prompt neutron per fission escapes the dragon and if one neutron ~~in 10 were captured~~ in say the brass

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walls of the counter and chamber and if this capture gave rise to β emission of a few millisecond period then one would observe in the instruments a count corresponding to a flux of γ's of the order of one γ for 10 fissions, as is required. Furthermore this explanation is not in conflict with the requirements a and b. It should be remarked too that in our measurement with 49, it was observed that the counter did get "hot", presumably due to scattered neutrons, and although the observed decay periods were fairly long and the generator was operated so that this activity was never built up too strongly, it may have been quite different with the dragon.

Finally it is conceivable, of course, that the difference in the observations of LA-253 and the others is genuine, although it is difficult to see at present how the known differences of the dragon and, for example, the water boiler experiment (i.e., the existence of the tamper in the dragon experiment, the difference of the neutron spectrum causing the fission, etc.) could account for so large a discrepancy as was observed.

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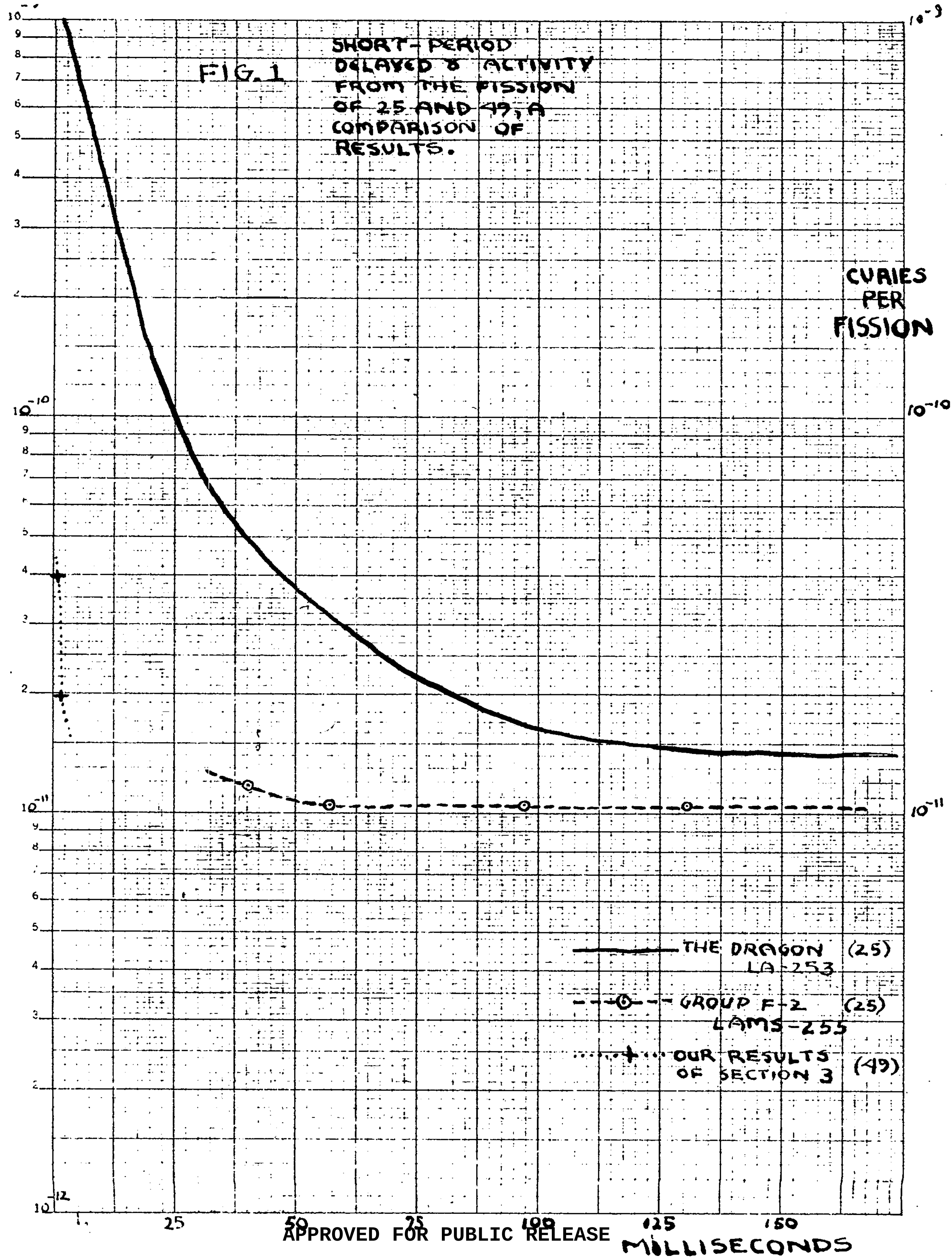
FIG. 1
SHORT-PERIOD DELAYED γ ACTIVITY FROM THE FISSION OF 25 AND 49, A COMPARISON OF RESULTS.
CURIES PER FISSION
10^{-9}
10^{-10}
10^{-11}
10^{-12}
THE DRAGON (25) LA-253
GROUP F-2 (25) LAMS-255
OUR RESULTS OF SECTION 3 (49)
25
50
75
100
125
150
MILLISECONDS

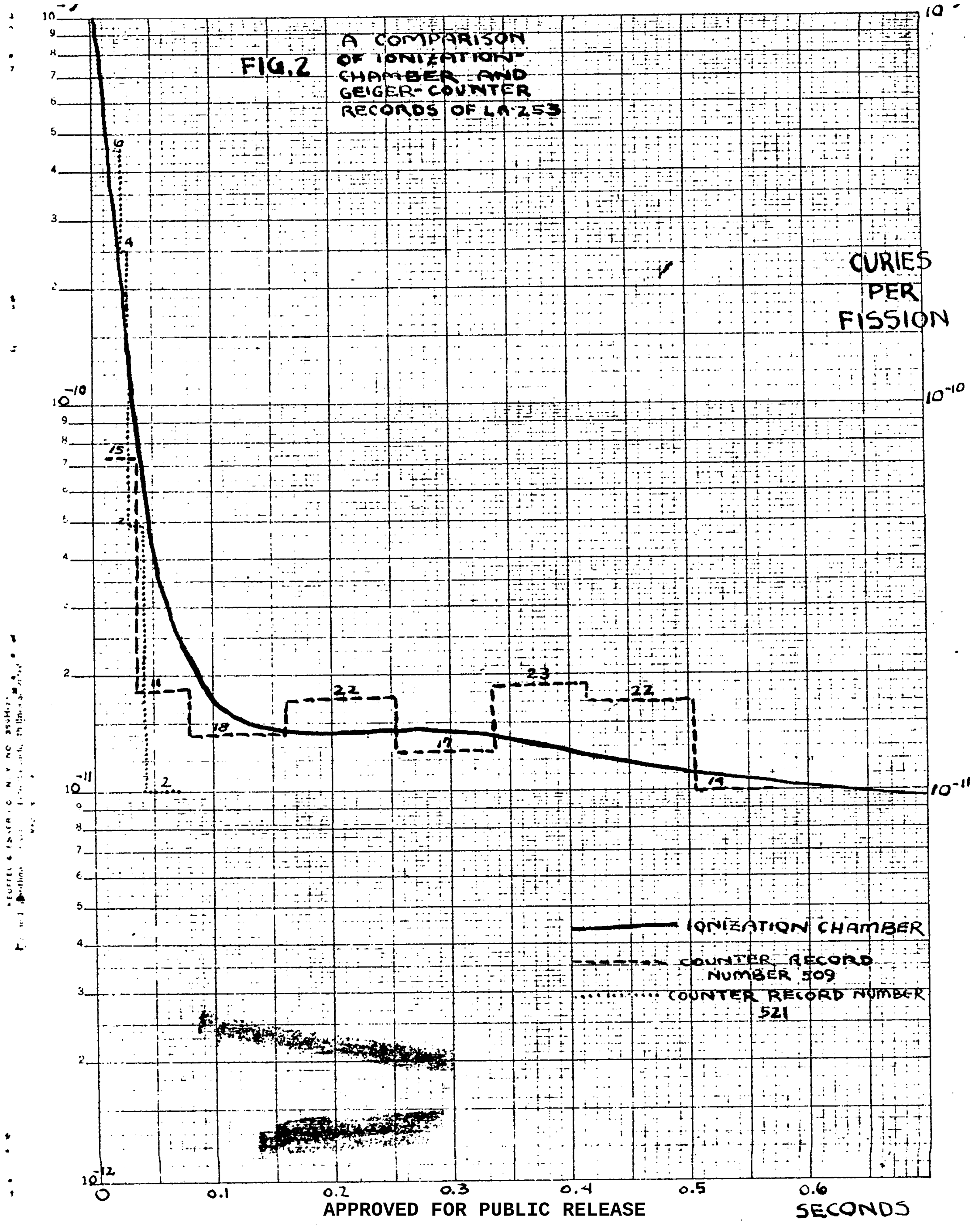
FIG. 2
A COMPARISON OF IONIZATION CHAMBER AND GEIGER-COUNTER RECORDS OF LA-253
CURIES PER FISSION
10^{-10}
10^{-11}
10^{-12}
IONIZATION CHAMBER
COUNTER RECORD NUMBER 509
COUNTER RECORD NUMBER 521
0
0.1
0.2
0.3
0.4
0.5
0.6
SECONDS

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