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TIME FOR FISSION

WORK DONE BY:

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REPORT WRITTEN BY:

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ABSTRACT

An experiment has been done to detect if any fissions were delayed by as much as 10^{-8} sec. Less than ~~5×10^{-5}~~ 10^{-3} of the fissions were delayed by this time.

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TIME FOR FISSION

It is of interest to detect any measurable delay between the absorption of a neutron and the occurrence of fission. Feather (Nature 143, 597, 1939) demonstrated by an ingenious experiment that some fissions occurred within 5×10^{-13} sec, the time for the compound nuclei formed by the absorption of very fast neutrons by uranium to be stopped in solid matter. His observed effect, however, was about one-third that calculated. The present experiment was designed to find if any fissions were delayed.

The experimental arrangement is shown in the accompanying figure and photograph. Nearly pure U^{235} was plated uniformly, 10 μg per cm^2, on platinum strips 20 cm x 0.9 cm which were fastened to the side of the grid as shown in the diagram. The fissionable material is applied only up to about 0.2 mm of the edges of the strips. The grid was the high potential (1000 volts) side of the two ionization chambers formed by the two plates a and b which are connected to two amplifiers.

The method can now be explained. Fast neutrons from 11 Mev deuterium on Be (up to 15 Mev) are incident from the left side in the figure. These are absorbed by the U^{235} and the recoiling U^{236} nuclei start across ionization chamber a, which is filled with one cm of hydrogen. If fission occurs instantly, the fragments can only cause a pulse in chamber a for no fragment can "see" into chamber b because of the grid. However, if the recoils travel even a fraction of a mm before fission then some of the fragments can penetrate the grid and pulses will be recorded by chamber b. As the recoils travel farther from the grid, its transparency becomes greater eventually reaching about 0.5 when the recoils have

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traveled a few cm. Hydrogen was chosen to fill the chamber because the recoil and fragment ranges in it are greatest. As an added refinement coincidences were measured between chambers a and b to reduce the number of counts recorded in chamber b due to uranium impurities in that chamber. A boron (one gm/cm^2) and cadmium shield was placed around the whole chamber to reduce fission induced by thermal or low energy neutrons.

The center of the apparatus was placed 60 cm from the target of the cyclotron with the fissionable material on the side of the grid away from the target. A few counts were recorded in chamber b per 10^5 counts in chamber a and this counting rate did not change within the statistical accuracy of counting when the chamber was rotated through 180° so that the fissionable material faced the target such that recoils were driven into the grid. The actual data are shown in Table I. The measured effect obtained by subtracting the coincidences per count in a when the foil was toward the target from the same quantity when the foil was away from the beam is $(0.2 \pm 2.0)10^5$.

A further check on the background was obtained by placing the apparatus, without neutron shields, in the pure thermal neutron flux of the graphite column. Then any counts in b are spurious because there is no recoil energy. As seen in Table I, the coincidences per count in a were smaller than those obtained with the foil toward the target but the coincidences per count in b were about the same. This indicates that the background observed above was due to normal uranium contamination situated such that the fission fragments could pass through the grid and hence both chambers. The contamination was more effective for fast neutrons as then the 238 content of the probably normal uranium could also

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contribute to the spurious counting rate. The amount of this contamination determines the limit of sensitivity of this experiment.

The lower limit to ascribe to the time for fission as given by this experiment depends on an evaluation of the geometry and the stopping power of the uranium film and the hydrogen gas for the recoils. It is perhaps best to state a time for fission and then say what fraction of fissions could have been delayed longer than that without having been detected.

Let us assume that the average neutron energy is 12 Mev. The velocity of the compound 236 nuclei will then be about $\cancel{3 \times 10^8}$ $2 \cdot 10^7$ cm/sec. Teller roughly estimated that the range of such a fragment in U_3O_8 would be about 10 μg/cm^2 and Aage Bohr calculated that the range in H_2 at a pressure of one cm Hg would be many cm. Extrapolation of Blackett's[1)] measurements on recoil nuclei check these calculations. Hence the recoils do travel away from the grid at least a few cm. The transparency of the grid for recoils a few cm away is nearly 0.5 and the time required for a recoil to travel say $\cancel{3}$ 2 cm is $10^{-\cancel{8}\,7}$ sec. The measured effect is $(0.2 \pm 2) \times 10^{-5}$ and as the effect is smaller than the probable error we will use the latter and say that not more than about 5×10^{-5} of the fissions could have been delayed more than $10^{-\cancel{8}\,7}$ sec without having been detected.

For shorter times the fraction of delayed fissions which would have escaped detection increases until for a delay of about 10^{-10} sec the method is completely insensitive. The 10^{-10} second limit is determined by the time for the fragment to travel .002 cm, the shortest distance that a recoil could travel and then just "see" through the grid into chamber b.

1) Blackett, Proc. Roy. Soc. A 103, 62, 1923

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The present experiment was done very hurriedly in the critical days before the first nuclear explosion was tried; the purpose was to be sure that no fissions were delayed as much as 10^{-8} sec, for such delays could have deleterious effects on the efficiency of the explosion. In view of the above I feel that the experiment accomplished its purpose in showing that not more than a few percent of fissions are delayed more than 10^{-8} sec. However, it would be stretching the experiment a bit to say that not over a few percent of fissions are delayed more than 5×10^{-10} sec. A closer scrutiny of the range of the recoils in the U_3O_8 layer as well as in H_2 gas should be made before drawing quantitative conclusions.

It would be possible to reduce the geometry of the apparatus in such a way as to increase the resolution of the method. For example if the grid plates were made .01 cm wide instead of one cm, and if greater precautions against contamination were used one might detect fissions delayed as much as 10^{-12} sec.

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TABLE I

Position of foils	counts in a	counts in b	coinc a, b
Away from target	1.28×10^5	64	5
Facing target	1.27×10^5	64	5
Away from target	1.45×10^5	80	6
Facing target	1.35×10^5	83	5
In graphite	2.07×10^5	32	2

$$\text{Effect} = \frac{11}{2.73 \times 10^5} - \frac{10}{2.62 \times 10^5} = (0.2 \pm 2) \times 10^{-5}$$

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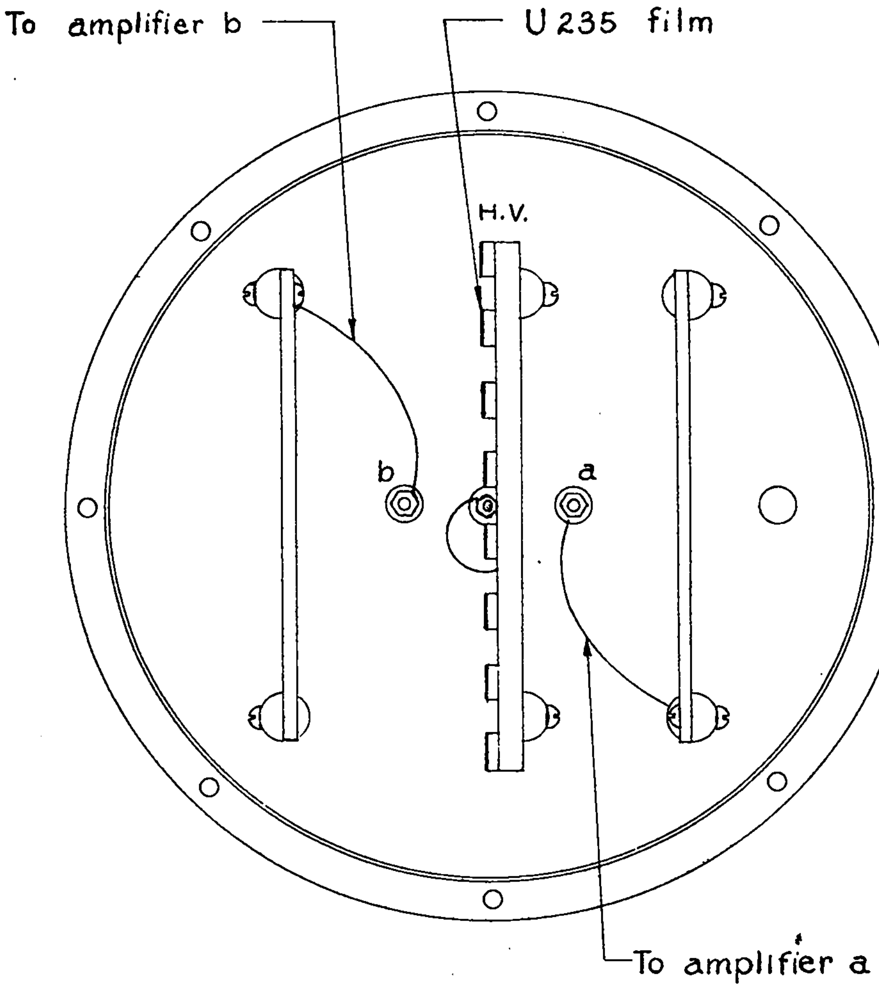

FIGURE # 1

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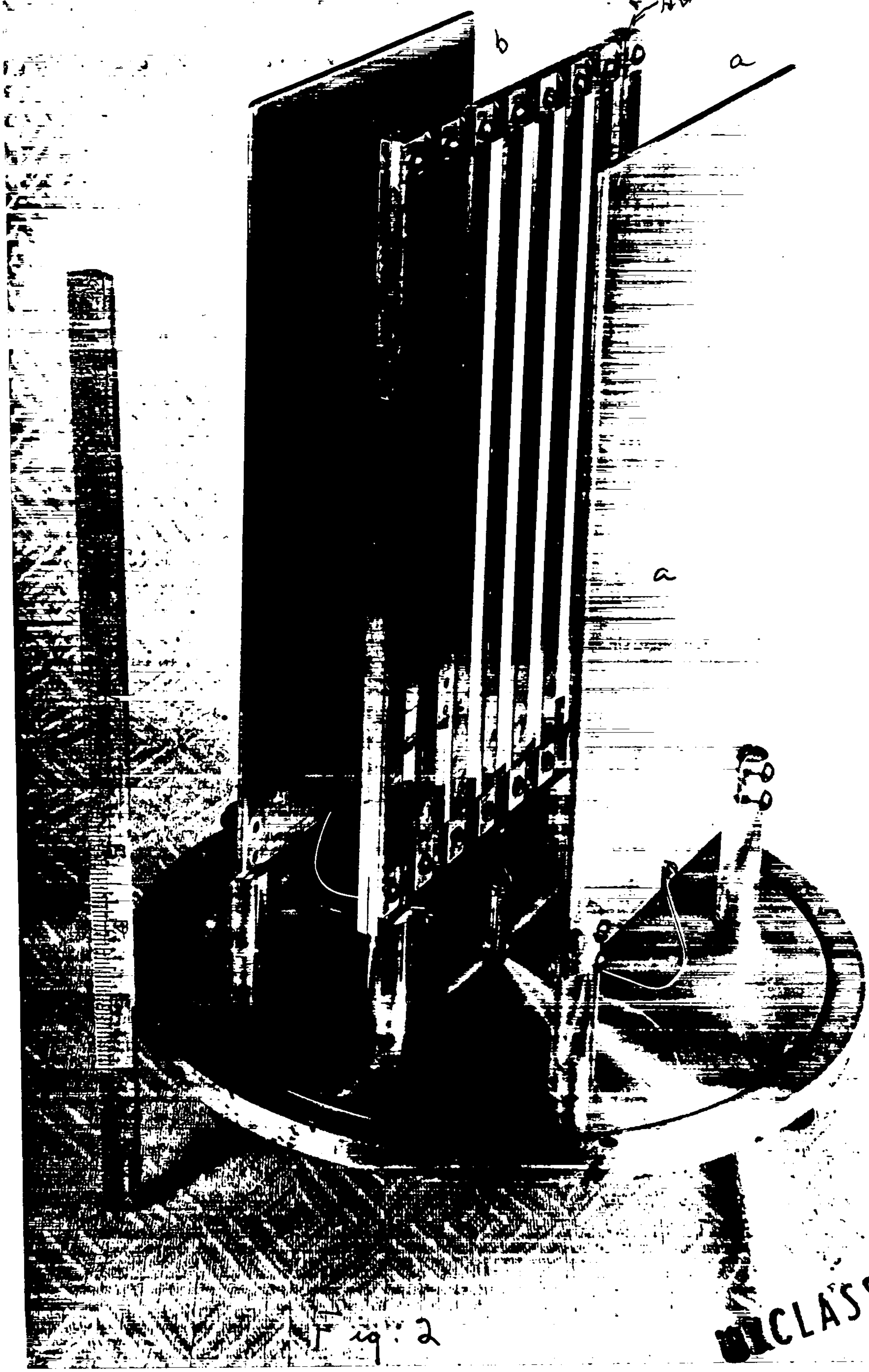

Fig. 2

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