[redacted]

LA REPORT 104

[redacted] C.3

July 4, 1944

This document contains 14 pages

PUBLICLY RELEASABLE
LANL Classification Group
4-11-96

I. NEUTRONS PER FISSION FROM 49 COMPARED WITH 25.

II. SLIGHTLY DELAYED NEUTRONS FROM 49 AND 25.

Classification changed to UNCLASSIFIED
by authority of the U. S. Atomic Energy Commission,
Per H. F. Carroll 2-1-56
By REPORT LIBRARY E. Martinez 3-16-56

WORK DONE BY:	REPORT WRITTEN BY:
J. W. DeWire	R. R. Wilson
R. R. Wilson	
W. M. Woodward	

[redacted]

[redacted]

[redacted]

ABSTRACT

The ratio ν_{49}/ν_{25} has been measured by a coincidence method to be 1.18 ± .01. The ratio was found to be the same for a neutron detector with threshold bias at about 20 KeV and for one at about 300 KeV. It was possible to measure the number of neutrons delayed more than 5×10^{-9} sec after fission for 49 as well as for 25. To an accuracy of seven percent, no short time delayed neutrons were found for either 49 or 25.

[redacted]

[redacted]

I. NEUTRONS PER FISSION FROM 49 COMPARED WITH 25.

II. SLIGHTLY DELAYED NEUTRONS FROM 49 AND 25.

The number of neutrons emitted by a 49 nucleus in fission, ν_{49}, is important because the critical mass of a fast neutron chain reaction in 49 is so sensitive to this quantity. Any delay in the emission of the neutrons by more than 10^{-8} seconds must be known because it can lower the efficiency of energy release from the reaction by lengthening the time scale.

A comparison method has been used to determine ν_{49} in which coincidences between 49 fissions in an ionization chamber and proton recoils in a paraffin lined proportional counter caused by the neutrons given off during fission are compared to similar coincidences when 25 is used in an identical geometry. Assuming the neutron energy spectrum is the same for 49 as for 25, then the ratio of recoils per 49 fission to recoils per 25 fission is equal to ν_{49}/ν_{25}. By choosing the best known value for ν_{25} one obtains ν_{49}.

The counters were arranged as shown in Fig. 1. The 49 and 25 were deposited as uniformly as possible on identical removable platinum cylinders A which were about two cm long and one cm in diameter. Electrons produced by the fission recoils were collected on cylinder B which was connected to a high gain amplifier. The neutron recoils were detected in the proportional counter C which was inside of and concentric with the platinum cylinders. The counter was lined with about 0.5 mm of paraffin, and the negative pulse was taken from the five mil wire and led to another high gain amplifier. It was possible to fill the proportional counter with hydrogen or argon at various pressures thereby changing the energy thresh-

[redacted]

[redacted]

old and energy sensitivity of the counter. The fission chamber was usually filled with 60 cm of hydrogen.

It was found possible to incorporate into the apparatus a method of measuring very short time delays in the emission of neutrons from both 49 and 25 fission. This was done by making the fission pulse electrode B of fine screen - transparency 0.85. An aluminum cylinder D could be slid over this screen by a rod passing through the sliding seal E. Thus fission fragments could be stopped at the screen or allowed to pass through to the outside walls of the chamber. As C. P. Baker has pointed out, if neutrons are delayed by as long as it takes the fission fragments to move to the outside wall, about 5×10^{-9} seconds, and then are emitted, the solid angle subtended by the proportional counter as seen from the collector electrode or from the outside wall changes. Hence the number of neutrons recorded by the proportional counter should change if an appreciable number of neutrons are delayed.

Fig. 2 shows a block diagram of the amplifiers, coincidence circuit, and scalers. The amplifiers were similar to those built by Crouch and Allen, and have a rise time of about 0.1 μsec. The coincidence circuit was designed and built for us by J. S. Allen. It consisted, as shown in Fig. 3, of a blocking oscillator discriminator in each channel which could produce a square pulse of variable duration from about 0.25 μsec to 1.0 μsec. The square pulses from each channel were then applied to the Rossi coincidence stage. Three Higinbotham type scalers were used, as shown in Fig. 2, to count the coincidences, the fissions, and the recoils simultaneously. The coincidences could be counted with a scale of 32 or one, the fissions could be counted with a scale of 32 or 1024, and the recoils were counted with a scale of 64.

To produce fissions, the chamber was placed in the 11' x 7' x 6'8" graphite

[redacted]

[redacted]

block about 4" back from the face exposed to the cyclotron neutrons. It was found necessary to insert a cadmium shield between the sample and the recoil chamber in order to keep the recoil-channel counting rate down. The cadmium decreased spurious counts which were caused by thermal neutron disintegrations of boron or other materials in the proportional counter. The fission counting rate was on the average about 1000 counts/sec during a run. The recoil-channel counting rate was about 20 counts/sec and of these about one percent were in coincidence with the fissions.

The procedure in taking data was to make a thirty minute run using the 25 sample and with the aluminum cylinder D covering the screen B. The time interval T, Fission counts F, recoil counts R, and coincidences C were recorded. The run was then repeated but with the aluminum foil pulled back allowing the fission fragments to penetrate to the chamber walls. Then the 49 sample was substituted for 25 sample and two more measurements were made; one with the aluminum cylinder covering, and one with it not covering the screen. This procedure was repeated continuously for as many days as the experimenters or amplifiers could hold out, and the set of data so obtained constituted a run. Sometimes as many as fifty measurements were made per run.

The number of coincidences per fission C/F obtained from each measurement of a run is comprised of actual coincidences between recoils and fissions C_o/F and accidental coincidences A/F. To determine A/F, the counting rate was varied over a wide range. One can use the relation $A/T = 2\tau(R/T)(F/T)$, where τ is the resolving time. This can be written $A/F = 2\tau(R/T)$ or $C/F = (C_o/F) + (A/F) = (C_o/F) + (2\tau)(R/T)$. Hence if C/F is plotted as a function of R/T, one should obtain a straight line with the intercept at R/T equal zero correspond-

[redacted]

[redacted]

ing to C_0/F. In Fig. 4 is shown a typical curve of $(C/F)_{25}$ as a function of R/T. Such curves were frequently made for 49 as well as for 25. The slopes of lines so obtained were consistently the same and the average resolving time from them was 0.28 microseconds; this time was used in correcting the data for accidental coincidences. This resolving time also is in agreement with the length of the square pulse as measured with a fast sweep oscillograph. All the data were taken at the lowest R/T point on the curve where the correction for accidental coincidences was less than three percent.

Table I gives the results of the best runs, i.e., those in which the apparatus herein described was used and in which there was no appreciable drift in the gain of the amplifiers.

The sample of 49 used in these runs weighed about 200 micrograms; two samples of 25 were used, one containing 160 micrograms and the other containing 670 micrograms of 25. The two samples of 25 gave the same number of coincidences per fission, which is a check on the reliability of the experiment. The probable error of each run as computed from the deviations of each measurement from the mean of the run is given in column three; in column four is given the probable error computed from the number of coincidences recorded. That these two errors agree to within the probable error of the probable error is a further check on the reliability of the experiment.

As noted in column five, half the runs were taken with the proportional counter filled with tank hydrogen at 15 cm Hg and half were taken with the counter filled with tank argon at 100 cm Hg. Measurements made with monoenergetic neutrons from the electrostatic generator show that the threshold of the proportional counter when filled with cm Hg of hydrogen is about 20 KV, while the threshold is about

[redacted]

[redacted]

500 KV if the counter is filled with 100 cm Hg of argon. The sensitivity increases almost linearly with neutron energy in each case. That the values of ν_{49}/ν_{25} for each type of counter filling are the same within the probable errors indicates that there is no difference in the energy of neutrons from 49 and 25 1).

The weighted mean of ν_{49}/ν_{25} from Table II is 1.18 ± .01. It should be noted that this result is independent of any determination of the mass of 25 or 49 in the samples or of the thickness of the samples as what one actually measures is proportional to the neutrons per fission counted. If a fission occurred and was not counted it could not cause a coincidence. The result does depend very insensitively on the identity of the geometry of the samples and considerable precautions were taken to insure that this was the same for all samples.

Two earlier runs were made using less elegant equipment each of which gave $\nu_{49}/\nu_{25} = 1.02 \pm .05$. In the first case the amplifier gain drifted badly and hence made the experiment suspect. In the second run a very tiny sample of 49 was used, less than 30 micrograms, but we are at a loss to explain the low result.

Now let us consider wha information can be obtained about the short time delayed neutrons. The ratio, B, of C_o/F with the cylinder not covering the fission collector electrode to C_o/F with the cylinder covering the electrode is 0.999 ± .016 for 25 and 0.996 ± .016 for 49. In calculating these ratios all the data have been used inasmuch as measurements with and without the cylinder

---

1) This result assumes that the neutron spectra from 49 and 25 are roughly similar in shape. The measurements of H. T. Richards, LA-84, and Staub and Nicodemus, LAMS-75, page 20, demonstrate the similarity of the two spectra.

[redacted]

[redacted]

covering the fission electrode were made much closer together than measurements made by changing the sample. Now if all neutrons were delayed after fission by a time greater than that taken by the recoil fragments in travelling to the chamber wall, less than 5×10^{-9} sec, the ratio B calculated on the basis of solid angle and screen transparency would be $B_{100\%} = 0.772$2). Hence the measured percentage of delayed neutrons is;

$$\% \text{ delays} = \frac{1 - B_{exp}}{1 - B_{100\%}} 100$$

For 25 this gives (0.4 ± 7.0)% delayed neutrons, and for 49 it gives (1.8 ± 7.0)% delays.

If the neutrons were emitted while the fragments were still moving from the sample to the walls, the change in solid angle would be less, making $B_{100\%}$ closer to unity, but the neutrons coming back to the counter would have less energy because the velocity of the fission fragment would have to be subtracted from that of the neutron; hence the counter would be less sensitive, and $B_{100\%}$ would tend to be smaller. As the change in solid angle is small once the fragments are a few cm from the sample, it is felt that the second effect would predominate to make the experiment more sensitive to delayed neutrons. The experiment does not measure any neutrons delayed by more than the resolving time, 0.28 μsec; but rough measurements made by increasing the resolving time indicate no delays of that

---

2) This was calculated by R.P. Feynman on the basis of the following dimensions; counter length, 3.8 cm; sample length, 2.0 cm; counter diameter, 0.70 cm; foil diameter, 1.11 cm; aluminum cylinder diameter, 1.70 cm; chamber wall diameter, 7.3 cm; transparency of screen, 0.683.

[redacted]

order of magnitude.

The conclusions to be drawn from this experiment are that $\nu_{49}/\nu_{25} = 1.18 \pm .01$, that the energy of the neutrons from 49 is about the same as from 25, and that no neutrons could be detected from 49 or 25 which were delayed by more than 5×10^{-9} sec. Our value of ν_{49}/ν_{25} is to be compared to an earlier value measured by Williams[3] which gave $1.20 \pm .11$. Snyder and Williams[4] found no delayed neutrons from 25 in performing the conventional Baker experiment.

---

3) Williams, et al LA-25.
4) Snyder and Williams, LAMS-50.

[redacted]

APPROVED FOR PUBLIC RELEASE

[redacted]

TABLE I

Date of Run	ν_{49}/ν_{25}	Experimental probable error	Theoretical probable error $.67\ \sqrt{N}$	Recoil counter filling
December 27, 1943	1.18	.015	.017	100 cm argon
January 26, 1944	1.25	.048	.042	15 cm hydrogen
January 27, 1944	1.14	.054	.047	15 cm hydrogen
March 10, 1944	1.18	.009	.024	100 cm argon
March 12, 1944	1.19	.044	.020	100 cm argon
March 14, 1944	1.18	.018	.014	15 cm hydrogen

Weighted mean of ν_{49}/ν_{25} for low energy bias = 1.183 ± .016.

Weighted mean of ν_{49}/ν_{25} for high energy bias = 1.182 ± .011.

Weighted mean of ν_{49}/ν_{25} for all data = 1.182 ± .009.

[redacted]

[redacted]

[redacted]

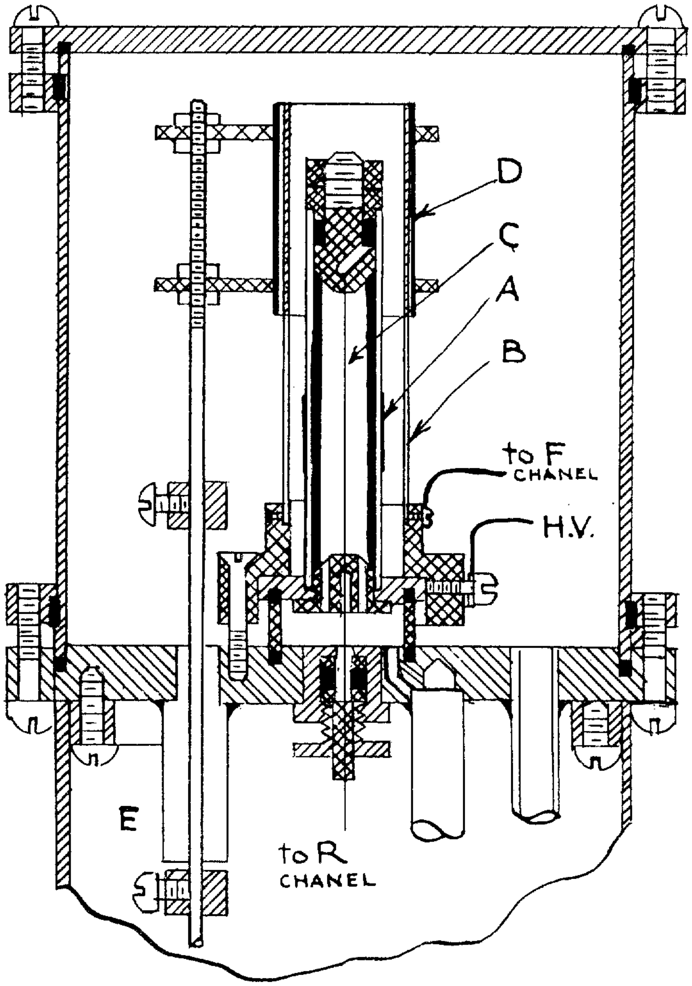


FIG. 1

[redacted]

[redacted]

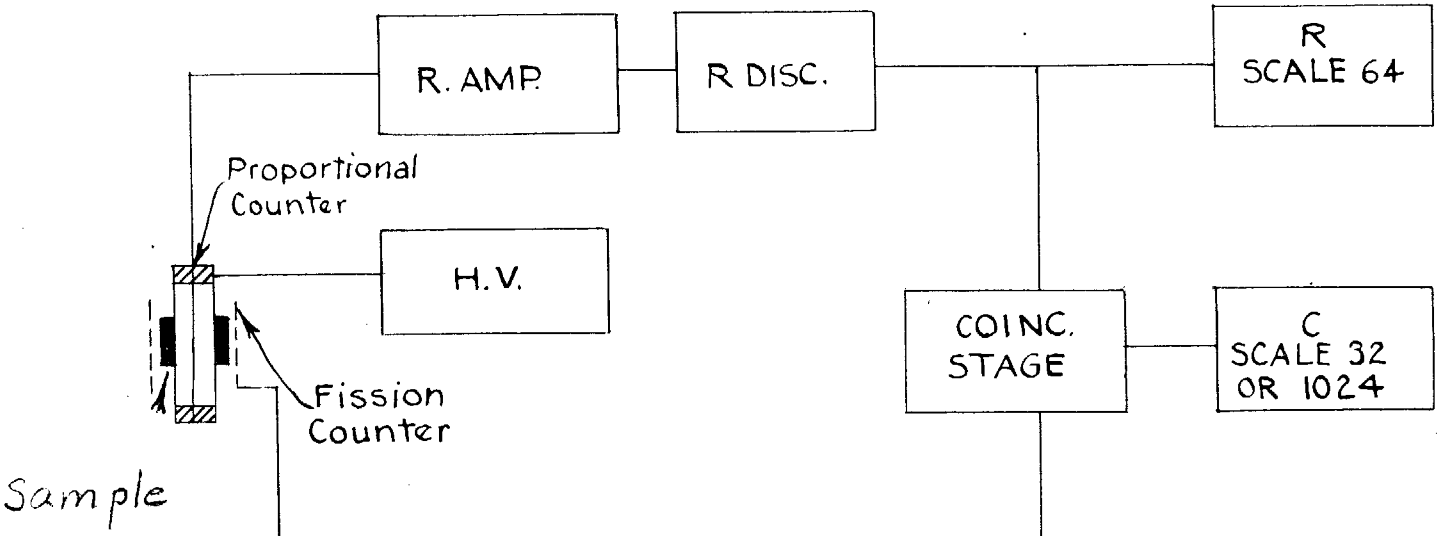
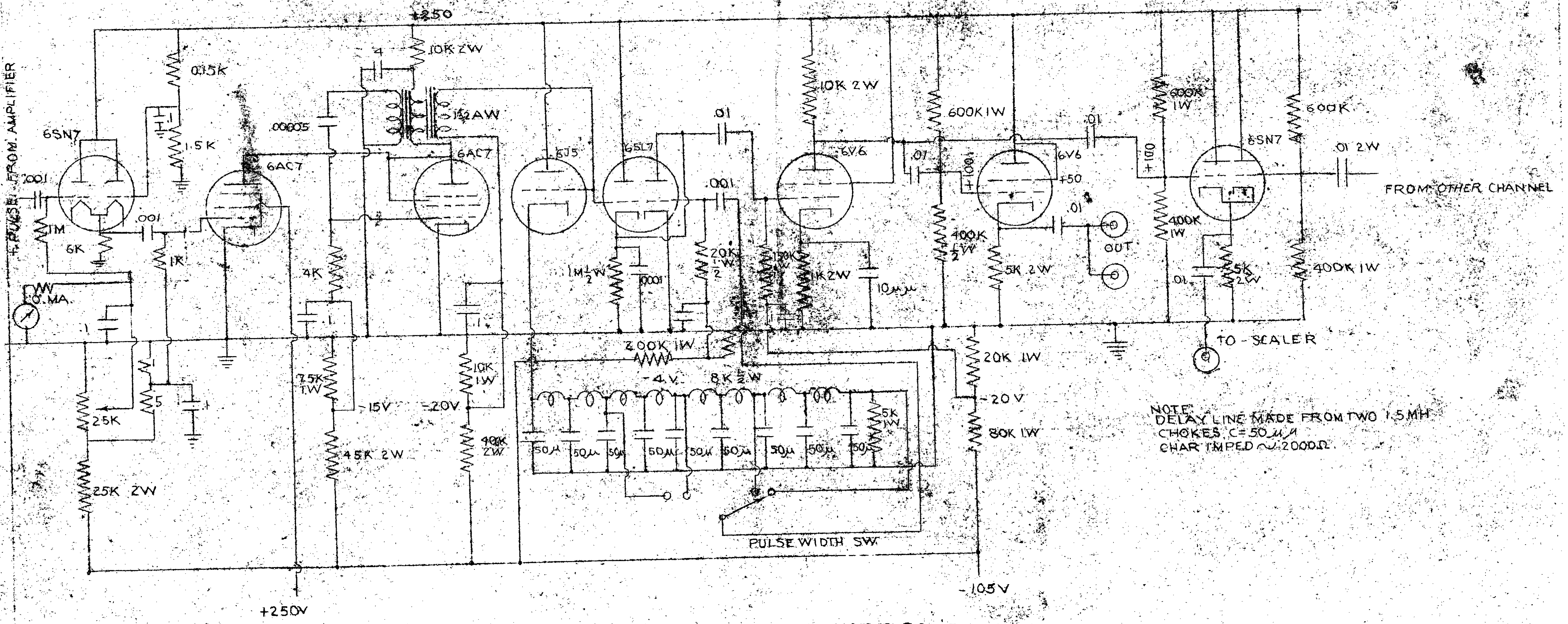


FIG 2

[redacted]

[redacted]

[redacted]



DISCRIMINATOR COINCIDENCE CIRCUIT

FIG. 3

[redacted]

[redacted]

[redacted]

[redacted]

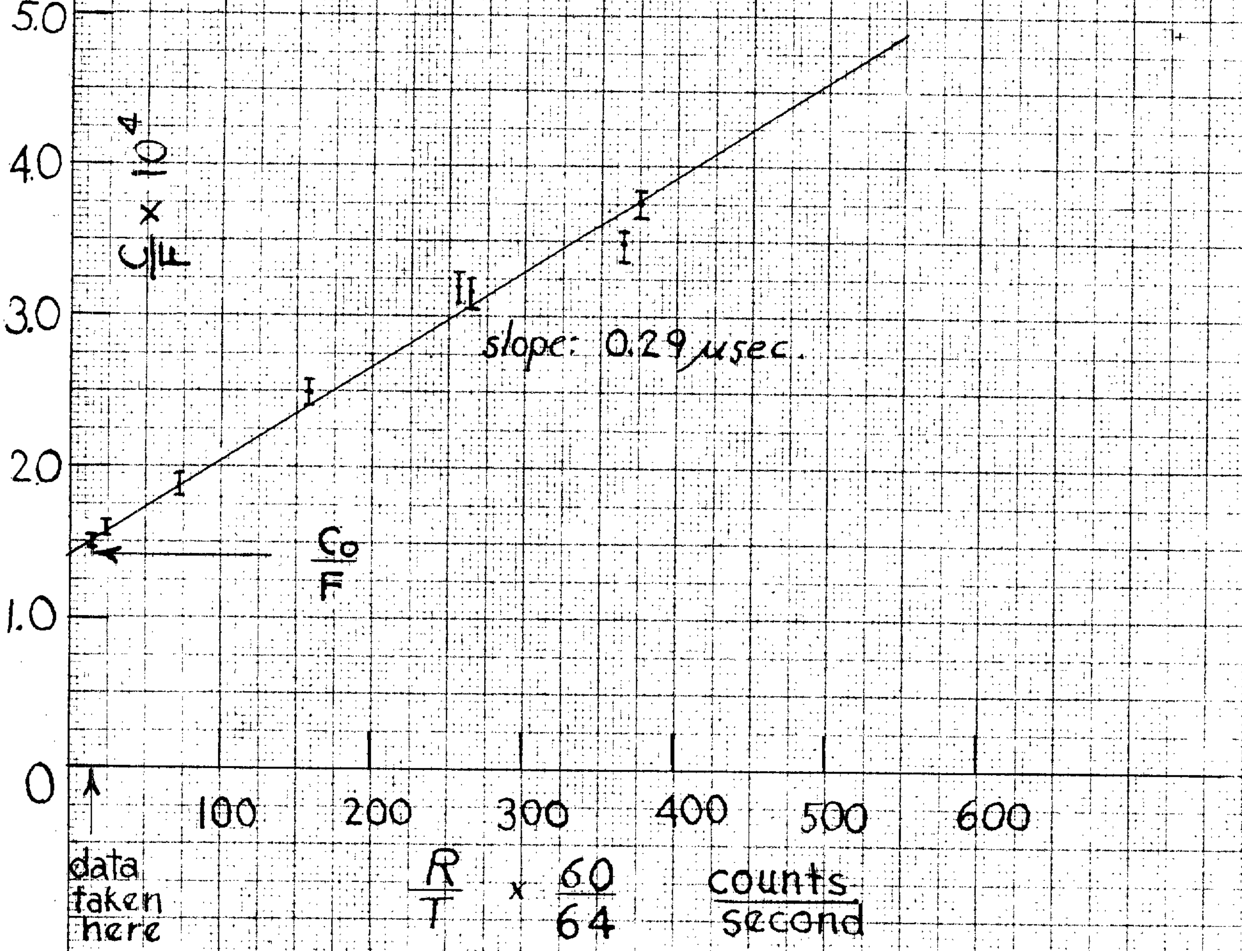


Fig. 4

[redacted]