Instrumentation

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LAMS - 56 SERIES

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FLAT RESPONSE NEUTRON DETECTOR

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March 15, 1944 This document contains 13 pages

Some further tests have been made on the flat response neutron detector described in CF-212 and CF-618. These tests were made in order to see if such a detector would be useful in determining the capture cross section of certain materials and also to see if such a detector when calibrated could be used to make neutron flux measurements in the energy region from 30-300 kv.

Specifically, tests have been made on three different detectors:

1) The one referred to above, which consists of a B_4C lined central detector 20 cm long and 3/4" in diameter surrounded by a cylinder of paraffin 20 cm long and 17 cm in diameter.

2) A detector lined with a thin film of 25 surrounded by the same amount of paraffin as above but also shielded by an additional 1½" of paraffin and ½" of B_4C (see fig. 1). This shield was to keep the counter from picking up neutrons scattered around the laboratory. This counter also has the advantage that its calibration is permanent since the fission pulses are easily detected and it is easy to be certain that practically all fissions are counted. It is hoped that this detector will be useful in determining relative neutron flux.

3) A more sensitive detector which is to be used with radioactive sources. The central part of this detector consists of a tubular ionization chamber 20 cm long and 1½" in diameter which is filled with one atmosphere [redacted]

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of BF_3. This detector is surrounded by a cylinder of paraffin 8" in diameter and 10" long.

These detector tests will be referred to as detector 1, 2, and 3.

Another detector using a BF_3 proportional counter as the sensitive element is now being constructed and would have some advantages for use near strong γ- ray sources.

The tests on these detectors can be grouped under the following headings: 1) Efficiency of detection; 2) Inter-comparison tests with the Li(p,n) source, Y-Be and RaBe sources; 3) Effect of surrounding source with graphite 10" in diameter, and a paraffin sphere 6" in diameter; 4) Sensitivity to neutrons scattered around room; 5) Variation of sensitivity with the direction of incident neutrons; and 6) Effect of γ-rays on counting rate.

These tests are by no means complete and are being continued. The reason for reporting them at this time is to present existing evidence on the behavior of these detectors so that the advantages and limitations of present detectors can be evaluated in terms of their uses in specific experiments.

Efficiency of detection

The efficiencies for detection of RaBe neutrons by these three detectors are based on the neutrons which strike a paraffin face 7" in diameter. These efficiencies are .012 per cent, .0015 per cent, and 0.5 per cent for detectors 1, 2, and 3, respectively. The highest efficiency counter filled with BF_3 is very convenient to use with radioactive neutron sources and gives about 800 counts per minute from a 200 mc RaBe source placed one meter from the face of the detector.

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I. TESTS WITH VARIOUS CALIBRATED SOURCES

A comparison of the yield of neutrons in the forward direction from the Li(p,n) source as taken with detectors 1 and 2 are shown in Fig. 2. It is seen that the two detectors agree quite well with the yield curve as taken with a recoil counter and an ionization chamber. The higher value obtained by detector 1 at the valley in the yield curve is attributed to scattered neutrons which are picked up by detector 1 much more than by detector 2. All data except that for detector 2 are taken from CP-618. It is fairly safe to say from these measurements that the response of the detectors is flat from 1.8 Mev to 0.3 Mev. A similar result was obtained for detector 3 by observing the relative counting rates obtained from calibrated Y-Be (200 KV) and mesothorium-Be (800 KV) sources, the actual value obtained indicated a sensitivity ~2 per cent greater for the 800 KV source.

An attempt was made to calibrate detectors 1 and 2 by determining the flux from the Li(p,n) reaction for 1 Mev neutrons using 1.6 Barns as the cross section for 25 and measuring the fission rate in 25 samples of known mass. Using the detector sensitivities obtained in this way, and the strengths of the radioactive sources as given by A. C. Graves, the number of counts from a RaBe source is 20 per cent too low for counter 2 and 30 per cent too low for counter 1. Using a calibrated Y-Be source (~200 KV neutrons) as a standard gives a value for the RaBe source which is 20 per cent low as measured by detector 1, 15 per cent low as measured by detector 2, but only 1 per cent low as measured by detector 2. The most likely interpretation of these results are that these detectors are somewhat less sensitive to the fast RaBe neutrons. It would be very interesting to have a better radioactive source of fast neutrons for these tests.

of 2-3 Mev and would be more ideal for such tests. So far no such source of sufficient intensity has been available.

The results mentioned above, however, do seem to indicate fair agreement between Li(p,n) and the Y-Be calibrations.

Effect of Surrounding Sources by Graphite Sphere 10" in Diameter and by a Paraffin Sphere 6" in Diameter

It was estimated by Konopinski and Serber that the 10" graphite sphere would reduce the average energy of the neutrons from a Y-Be source (initially ~200 KV) by about a factor of 2 or 3. This sphere is therefore a rather moderate degrader and is useful in establishing the reliability of such a counter in determining the amount of capture in metals where the degradation is not severe.

The 6" paraffin sphere is a much stronger degrader and is a very severe test on the behavior of the detectors. A rough calculation of the effect of the 6" sphere was made by Christy and he obtained the following results: 5 per cent of neutrons would be captured in paraffin; 5 per cent would be absorbable by cadmium; 40 per cent would have energies above 100 KV; 50 per cent would be in an intermediate group with an average energy of about 5 kilovolts.

An independent estimate of the number of thermals from the 6" paraffin sphere was made by observing the counting rate in a BF_3 chamber filled to a known pressure and placed at a known distance from the source. Using a cross section of 500 Barns for these neutrons we found that 7 per cent of the initial number of neutrons came out of the sphere as thermals. According to diffusion

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theory the number of thermal neutrons which are captured can be expressed as:

$$N_c = \frac{R^2}{\pi^2 L^2} N_e$$

where N_e is the number of neutrons which escape out of the paraffin.

N_c = total number of neutrons captured in the paraffin sphere.

R = radius of the paraffin sphere.

L = diffusion length of thermal neutrons in paraffin.

(taken as 2.1 cm)

This relation gives 9 per cent as the fraction of the initial number of neutrons which are captures in the paraffin sphere.

A similar experimental estimate was made of the number of thermals getting out of a source consisting of the Y-Be source in a 3" paraffin sphere. The result was 17 per cent thermal, 16 per cent captured in the paraffin sphere, and as estimated by Christy the remainder was degraded to an average energy of around 1 KV.

The comparisons of the sensitivities with degraders to that of the bare sources are as follows: where S_p, S_B, S_G, and S_p and cd mean the counting rates of the detectors where the source is surrounded by paraffin, nothing, graphite and paraffin plus cadmium.

1. For RaBe neutrons on detector 1:

$$\frac{S_G}{S_B} = 0.97 \pm .03$$

$$\frac{S_p}{S_B} = .92 \qquad \frac{S_p + Cd}{S_B} = .78$$

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For ?-Be neutrons on detector 1:

$$\frac{S_G}{S_B} = 0.98 \pm .03$$

2. RaBe neutrons on detector 2:

$$\frac{S_G}{S_B} = 0.88$$

$$\frac{S_p}{S_B} = .84 \qquad \frac{S_p + Cd}{S_B} = .75$$

For Y-Be neutrons on detector 2:

$$\frac{S_G}{S_B} = 0.92$$

The response of this detector (2) to lower energy neutrons was improved by making four $1\frac{1}{4}$" holes 2" deep in the front face of the paraffin.

After this modification, tests were made with the Ra-Be source with the following results:

$$\frac{S_G}{S_B} = 0.98 \pm .02$$

$$\frac{S_p}{S_B} = 0.86$$

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3. For RaBe neutrons on detector 3.

This detector has a cadmium shield over the central sensitive portion which keeps slow neutrons from getting directly into the BF_3 gas.

$$\frac{S_G}{S_B} = 0.98 \pm 1$$

$$\frac{S_p}{S_B} = 0.79 \qquad \frac{S_p}{S_B} = 0.74$$

Further tests on detector 3 were made using the Y-Be source, bare, in the 10" graphite sphere, and in a 5" paraffin sphere.

The results were as follows:

$$\frac{S_G}{S_B} = 0.98$$

$$\frac{S_p}{S_B} = 0.60 \qquad \frac{S_p + Cd}{S_B} = 0.50$$

Another test was made with a mesothorium beryllium source which emits mostly 800 KV neutrons. The ratio of counting rate in the graphite to that obtained directly was

$$\frac{S_G}{S_B} = 0.97$$

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Effect of Scattered Neutrons

The effect of scattered neutrons on these detectors has been checked by placing a 1 foot cube of paraffin between the source of neutrons and the detector. The remaining count was considered as due to scattered neutrons. This conclusion was checked by placing a B_4C absorber in front of the detector. The result indicated that for detectors 1 and 3 with the source 1 meter from the detector about 20 per cent of the counts were due to scattered neutrons. This count is not reduced appreciably by cadmium around the detector. The effect of scattered neutrons on the shielded detector #2, however, was only about 5 per cent. This result was confirmed by measurements of the counting rate as a function of distance from the Li(p,n) source which indicated that the inverse r^2 law held at distances from 2 to 10 feet from the source.

Angular Dependence of Sensitivity

The dependence of the sensitivity to direction of two of the detectors were examined for two special conditions. It is clear that this sensitivity will depend quite strongly on the energy of the neutrons.

Detector 2 was rotated through 45° and 90° while placed in a 1 Mev neutron flux from the Li(p,n) reaction. The relative sensitivities (call ing the 0° value 1.00) were:

0°	1.00
45°	0.71
90°	0.88

Detector 3 was examined with RaBe neutrons both with and without the

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6" degrading paraffin sphere. The results were

	Bare Source	Source inside 6" paraffin sphere
0°	1.00	0.86
45°	1.05	
90°	1.40	0.99

Effect of Increasing Amount of Paraffin Around the Sides of a Detector

A test was made on detector 3 to determine the effect of adding 6" more paraffin to the sides of the detector. This test indicated that the efficiency for undegraded RaBe neutrons could be increased by 30 per cent. A similar test with RaBe neutrons degraded by the 6" paraffin sphere indicated that only a 7 per cent increase due to the added paraffin. This seems to indicate that it is possible to increase the sensitivity somewhat for high energy neutrons by increasing the size of the paraffin cylinder around the detector.

Effect of γ-rays on Counting Rate

A word might be said about the behavior of the BF_3 counter in the presence of γ-rays. The chamber consists of an outer tube $1\frac{1}{2}$" in diameter and 8" long and a central collecting rod $\frac{1}{2}$" in diameter. The seals are of the Kovar and glass type with a grounded guard ring between the high voltage exterior and the central collecting rod. This collecting rod is connected to a linear amplifier. The normal noise lever is equivalent to about 400 kv energy loss in the counter. When a collecting voltage of 1800 volts is applied to the counter there is a semiplateau in the bias curve for counting boron disintegrations which gives a change in counting rate of about 1 per cent for a

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change of 4 per cent in the amplifier gain. If the bias is set so as to just count 800 kv pulses the counting rate is not changed when the γ-ray intensity is increased by a factor of two over that which would be obtained from a 500 mc source at 1 meter. Detector 2 of course is completely unaffected by gamma rays since fission pulses are so large as to make any γ-ray ionization.

Discussion

Although the results are somewhat qualitative, we might try to summarize them for the different detectors. It should be remembered that detectors 1 and 3 are affected considerably by scattered neutrons and that the results might be affected by scattering material in the room in which it is used. The results will be given in terms of the sensitivities of the various detectors to neutrons of different energies. These sensitivities are listed in the table below and are given as a percentage of the sensitivity to that at 1 Mev.

	Detector 1	Detector 2	Detector 3
Sensitivity to very high energy neutrons from RaBe	Low	Low	Good
Sensitivity to 0.2 to 2 Mev neutrons	100%	100%	100%
Sensitivity to neutrons of 5 Kev	85%	80%	80%
Sensitivity to 1 Kev neutrons	?	?	70%
Sensitivity to thermals	200%	130%	60%

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The high sensitivities of detectors 1 and 2 for thermal neutrons are due to the fact that there is no cadmium shield over the front face of the central sensitive portion of the detectors. A cadmium shield was placed over this area in the third detector which reduces its sensitivity to thermals by a factor of 2. From the general behavior of these detectors one might conclude that detectors of this size and construction are quite flat in the region from 0.20 Mev to 2 Mev and that there is a decrease in the sensitivity for the lower energy neutrons. The sensitivity is probably around 75 per cent for 1 to 10 Kev neutrons. It might be possible to increase the relative sensitivity to the slower neutrons by changing the paraffin geometry around the central detector or by suitable use of additional absorbers or detectors placed inside the paraffin. Work toward improving these detectors is now in progress.

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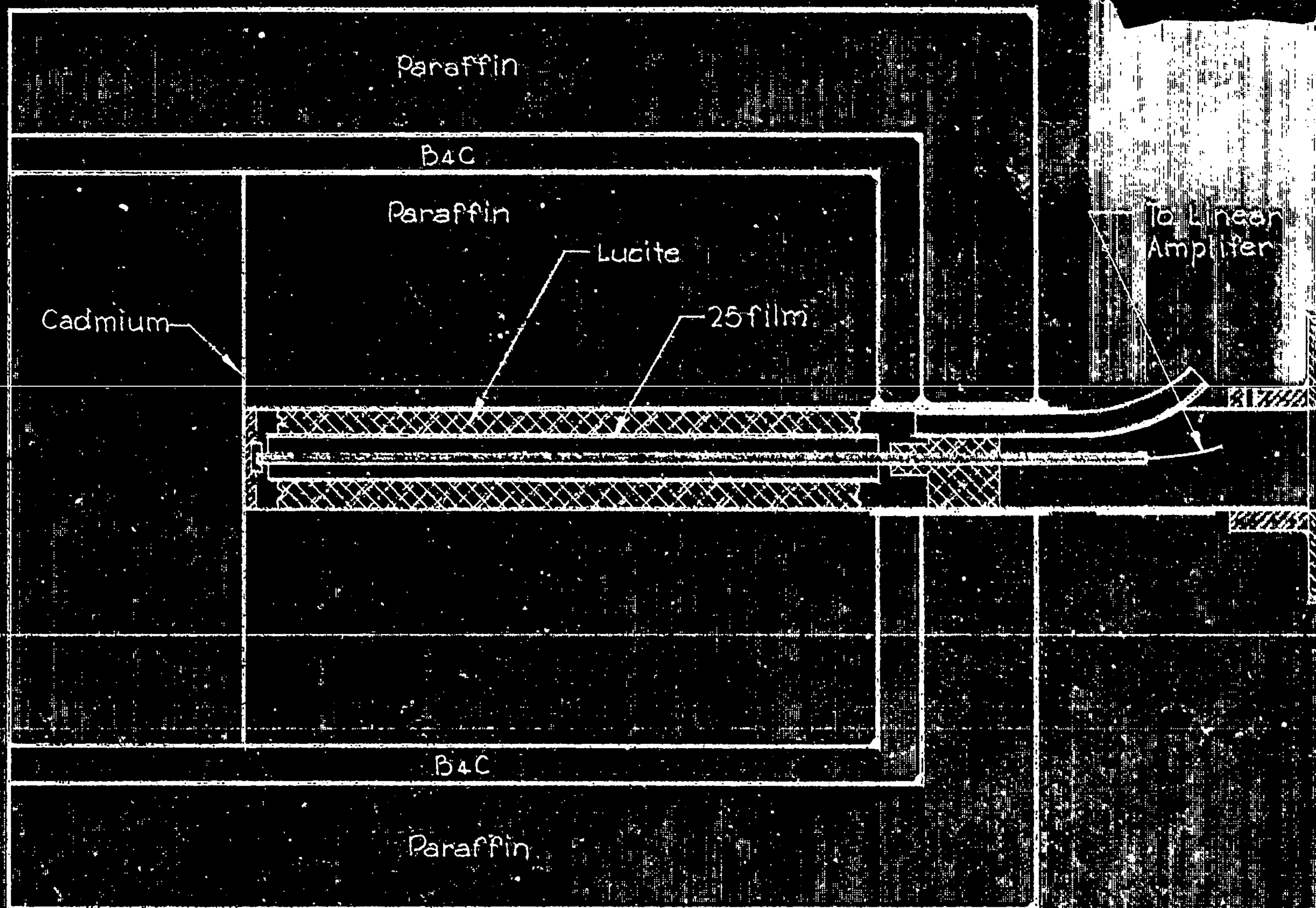

FIG. 1
DETECTOR 2
Scale: $\frac{1}{2}" = 1"$

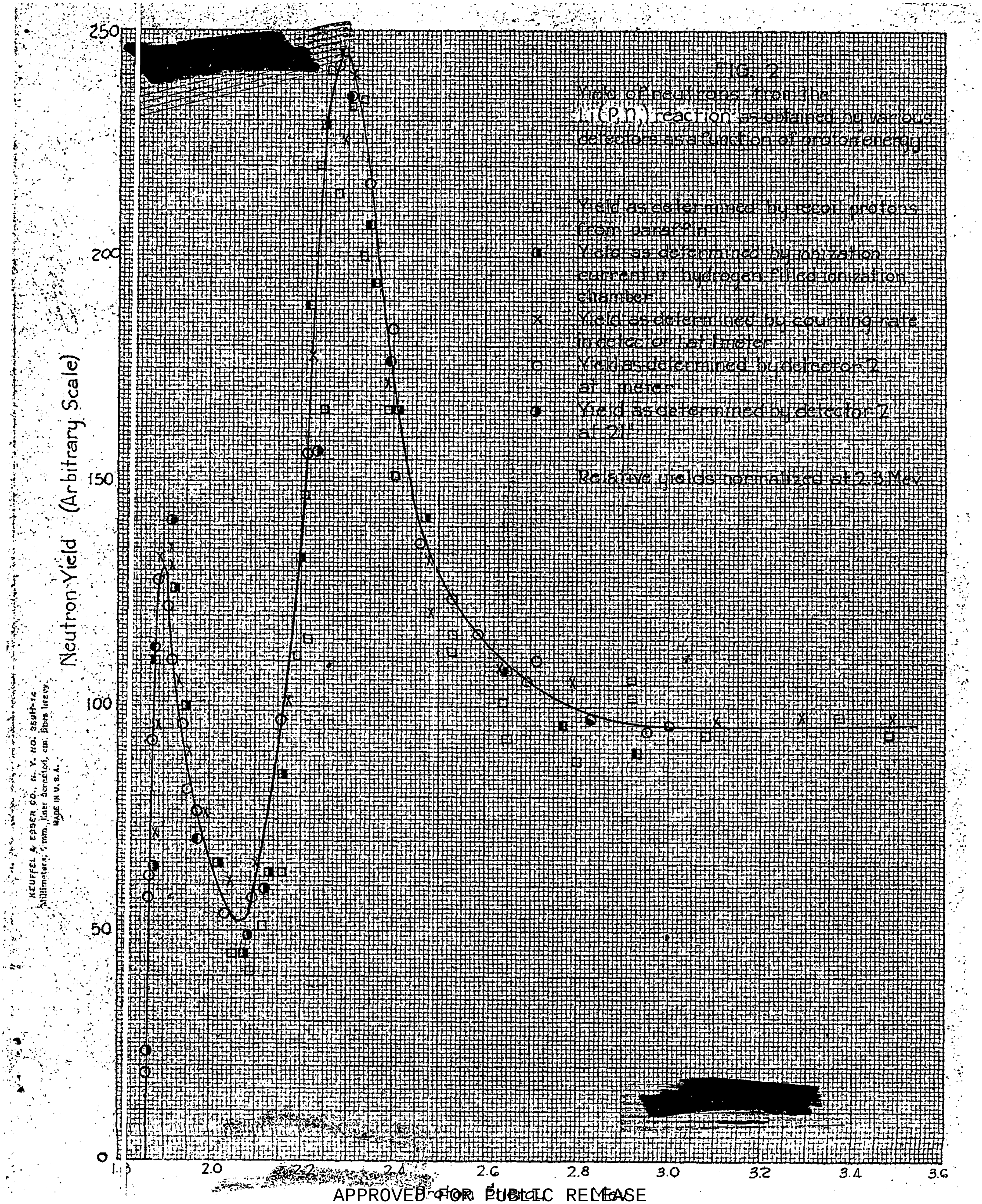
FIG. 2
Yield of neutrons from the Li(P,n) reaction as obtained by various detectors as a function of proton energy
Yield as determined by recoil protons from paraffin
Yield as determined by ionization current in hydrogen filled ionization chamber
Yield as determined by counting rate in detector 1 at 1 meter
Yield as determined by detector 2 at 1 meter
Yield as determined by detector 2 at 21"
Relative yields normalized at 2.3 Mev.
Neutron Yield (Arbitrary Scale)
250
200
150
100
50
0
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6

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