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NEUTRON ENERGIES IN U AND WC TAMPERS

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ABSTRACT

By means of absorption measurements in layers of B^{10}, the energies are estimated of neutrons emerging from critical assemblies of 25 metal tamped with WC and with U. The results are compatible with the presumption that one or two percent of the fissions are caused by neutrons of about a kilovolt inside the WC tamper, whereas there seems to be no such slow component in U.

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NEUTRON ENERGIES IN U AND WC TAMPERS

The unexpectedly low time rate of multiplication in 25 surrounded by WC, as revealed by the time-scale experiment[1] carried out by R-1, was tentatively explained by R. Serber by the assumption that the neutrons returned by the tamper are much slower than previously expected or that they contain at least an admixture of very slow neutrons. In LAMS-242 and 242A Bailey, Baker and Hanson reported measurements of the absorption in B^{10} of those neutrons which escape from the tamper. While the experiment showed clearly that the neutrons from WC are less energetic than from a U tamper, corrections due to stray neutrons (scattered in the room) were considerable and make it difficult to draw more detailed conclusions.

The measurements were therefore repeated in a different geometry, such that the absorbers intercepted only neutrons coming from the tamper but not scattered neutrons. The latter thus formed a background which was measured by completely blocking the direct path, and which was then subtracted from all other readings. The absorption curves so obtained are shown in Fig. 1. They show indications of a slow group for a WC tamper.

Another attempt to detect an admixture of very slow neutrons was made by measuring the fission rate along a radius inside the 25, in steps of 1/8", expecting a rise near the inner surface of the WC such as was found with a gold detector (see LAMS-248, Fig. III). No such rise was found with either a U or WC tamper.

Arrangement for B-absorption measurements

The assembly was set up about 5 ft above floor level, near the center of a large room, on top of an iron table 1/4" thick. The 25 core was approximately cubical in shape,

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1) An indication of this effect with tampers alone had been found earlier by R-3, LAMS-222.

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5" x 5" x 4-1/2" with the U tamper (4" thick) 4-1/2" x 4-1/2" x 4-1/2" with the WC tamper (4-1/4" thick). The whole assembly was thus approximately a cube of 13" sides in both cases.

<u>The neutron detector</u> was a proportional counter, 12" long, 1-1/2" diameter, filled with $B^{10}F_3$ at 20 cm pressure. (The counter was lent to us by Helmholtz). It was placed inside a double-walled brass tube filled with enriched boron (80 percent B^{10}), the boron layer being 3/4" thick, i.e., about 2 gms/cm^2. The back of the counter was protected by a similar layer of B^{10}, the front by .6mm/Cd. The relative position of counter and assembly is shown to scale in the insert of Fig. 1. The counter was connected to a linear amplifier (model 100 Preamp) and a scale of 64.

<u>The B^{10} absorbers</u>, 6" x 6" in size, were the ones prepared by Hanson (see LAMS 242). They contained respectively 0.35, 0.82, 1.33, 2.94, and 6.02 gms/cm^2 enriched boron (95 percent B^{10}) in thin brass containers, and one similar but empty container ("dummy") was placed in the beam to measure its intensity without absorber. Each absorber had a hook soldered to it by which it could be suspended from a thin-walled metal tube running about 6" above the line joining the counter with the center of the assembly.

<u>A monitor</u> was used to allow for variations in the reaction rate. It consisted of a thin layer 25 fission chambers, connected to an amplifier and scale of 64. The monitor chamber was placed about a foot from the assembly and protected by Cd to make it less responsive to changes in scattering conditions (people moving, etc.).

<u>Procedure and Results:</u>

After aligning the counter and absorbers and finding how far from the counter the absorbers had to be placed so that one could just be sure that all the neutrons had to pass through them in order to reach the mouth of the boron shield (position 1, see fig. 1), the assembly was made supercritical and stabilized at a power of several

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tenths of a watt (estimated from the counting rate of the monitor). At that power one received a dose of .1r (as indicated by a Chicago type electroscope) in a few hours at a distance of 20 ft. A B^{10} absorber (or the dummy) was then inserted in the beam and both the counter and the monitor were turned on simultaneously and allowed to count until the monitor had counted 1000 clicks = 64,000 fissions in the chamber. (At first 500 clicks were used.) In this way intensity changes are automatically allowed for and no timing is needed.

The results for the U tamper are summarized in Table 1. The first column indicates the absorber used; combinations of polythene and B^{10} were used to block the beam as completely as possible. The next 4 columns give the counter and monitor readings C and M, their ratio R = C/M, and the R.M.S. statistical error, E of this ratio, computed from the number of particles counted thus:

$$E = R \sqrt{(1/64C) + (1/64M)}$$

$$= \sqrt{R(1 + R)} \, / \, 8 \sqrt{M} \, .$$

The reading with the beam blocked is .344 and this was subtracted from all R values, so as to include only neutrons coming directly from the assembly. In the last column the transmission in percent is given.

The results for the WC tamper are presented similarly in Table 2.

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Absorber	C (counter clicks)	M (monitor clicks)	R=C/M	E (RMS error of R)	Background of .344 subtracted	Transmission
Dummy	395	500	.790	.0066		
	389	500	.778	.0066	.440	100 percent
	392	500	.784	.0066		
0.35gm/cm^2 B^{10}	378	500	.756	.0064	.412	93.5 percent
0.82 " "	360	500	.720	.0062	.376	85.5 percent
1.33 " "	366	550	.666	.0056	.322	73 percent
2.94 " "	282	500	.564	.0052	.220	50 percent
4" polythene plus 4.3 gm/cm^2 B^{10}	172	500	.344	.0038	-	

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Table 2. (WC-tamper)

Absorber	C (counter clicks)	M (monitor clicks)	R = C/M	E (RMS error of R)	Background of .140 subtracted	Transmission
Dummy pos. 2	456	1000	.456	.0032		
" "	458	1000	.458	.0032		
" "	459	1000	.459	.0032		
" "	451	1000	.451	.0032	.318	100 percent
" "	457	1000	.457	.0032		
" "	464	1000	.464	.0032		
" "	460	1000	.460	.0032		
" "	458	1000	.458	.0032		
0.35 gm/cm^2 B^{10} "	415	1000	.415	.0030		
" " " "	415	1000	.415	.0030	.275	86.5 percent
" " " "	415	1000	.415	.0030		
" " " "	414	1000	.414	.0030		
0.82 " " "	374	1000	.374	.0028		
" " "	378	1000	.378	.0028	.234	73.5 percent
" " "	371	1000	.371	.0028		
1.33 " " "	336	1000	.336	.0027		
" " "	348	1000	.348	.0027	.201	63 percent
" " "	340	1000	.340	.0027		
2.94 " " "	263	1000	.263	.0023		
" " "	288	1100	.262	.0022	.122	38.5 percent
" " "	262	1000	.262	.0023		
6.02 " " "	205	1000	.205	.0020	.066	21 percent
" " "	207	1000	.207	.0020		
" " pos. 1	209	1000	.209	.0020		
" " pos. 3	211	1000	.211	.0020		
9 " " pos. 2	172	1000	.172	.0018	.032	10 percent
6 gm/cm^{2}B^{10} plus 4" polythene plus 3 gm/cm^2 B^{10}	148	1000	.148	.0016		
3 gm/cm^{2}B^{10} plus 4" polythene plus 6 gm/cm^2 B^{10}	147	1000	.147	.0016		
4" polythene plus 9 gm/cm^2 B^{10}	143	1000	.143	.0016		

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Here the absorber was placed in position 2 (see Fig. 1, insert). This was done after putting the 6 gm/cm^2 absorber in all three positions and finding that this made no appreciable difference. (See table 2.) Position 2 was preferred because there one can be sure that no neutrons from the assembly can go past the absorber and still enter the counter. The background subtracted is .140, because Table 2 indicates that placing more boron between the polythene and the counter improves the blocking of the beam, (although barely outside the statistical error) and it was thought that complete blocking might give a slightly smaller reading than .143, the smallest value observed.

Discussion

In Fig. 1 the transmission (last column of Tables 1 and 2) is plotted against the B^{10} thickness, together with the values reported in LAMS-242A. The large deviation between the two U measurements can probably be explained by the difference in geometry; in the older set-up, neutrons scattered in the B^{10} had still a good chance of hitting the counter. The WC measurements agree much better, as one would expect at the lower neutron energy where scattering in B^{10} is less prominent.

The straight line drawn tentatively to fit our U points corresponds to a $\sigma_t(B)$ of 3.7b. Such a total cross section would correspond to an energy well over 200 Kev and it probably does not vary much with energy in that region, so that the straightness is not very surprising. The dotted line drawn through the WC points corresponds to a mixture of 90 percent neutrons for which $\sigma_t(B)$ is 4.8b and 10 percent for which it is 20b, corresponding to energies of about .1 Mev and 1.5 Kev. In terms of flux (allowing for the greater sensitivity of the BF^3 counter at low energies) the slow component amounts to about 2 percent only. The points would seem to indicate that the slow component is perhaps even slower and weaker.

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The measurements of fission distribution as shown in Fig. 2 neither prove nor disprove the presence of such a slow component. The curve for the U tamper was obtained with a pseudo-spherical 25 core in 4" U tamper, as used for the time scale experiments. The irradiation for the WC curve was done during the B^{10} absorption measurements reported here, with a cubical 25 core, which explains the smaller difference between center and edge. Plates of 25, 1/8" x 1/2" x 1/2", were stacked into the core and their γ-ray activity was measured afterwards and divided by the weight of each plate. The ~~rings~~ crosses in the U curve were obtained by measuring the 1/2" x 1/2" x 1/2" cubes and dividing by a suitable factor so as to match the plates.

The completely smooth decrease of the fission rate right to the edge of the 25 is further emphasized by the activities of the two plates of 1/16" thickness which were placed right at the edge of the core. It does not disprove the assumption that, say, 2 percent of the fissions are caused by 1.5 Kev neutrons returned from the WC tamper; such fissions would be represented by the hatched area and after subtracting them the curve still looks reasonable; it does so (dotted line) even if 4 percent of all fissions are ascribed to the slow component. On the other hand, gold activation (see LAMS-248) appears to show a neutron component of even greater absorbability in 25 and if gold were uniformly distributed through the 25, about 5 percent of its activation would be due to these slow neutrons. Since the activation cross section of gold rises much more rapidly with decreasing neutron energy than that of 25 it is reasonable that gold should show this effect while 25 does not. Unfortunately the discussion of the gold effect rests essentially on one point and the measurements cannot be repeated in the near future.

<u>Conclusion</u> From all the evidence it seems likely that in a WC tamper some neutrons get down to energies of the order of 1 Kev and that 1-2 percent of the fissions are

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caused by such neutrons. While these neutrons would substantially reduce the multiplication rate α near criticality, at high values of k they would hardly contribute to the reaction, which would behave essentially as if the crit were about 5 percent greater than measured. However this conclusion is by no means certain and both a more careful analysis of the data here presented and more measurements as soon as possible seem to be indicated.

In a U tamper no evidence for neutrons below .1 Mev was obtained.

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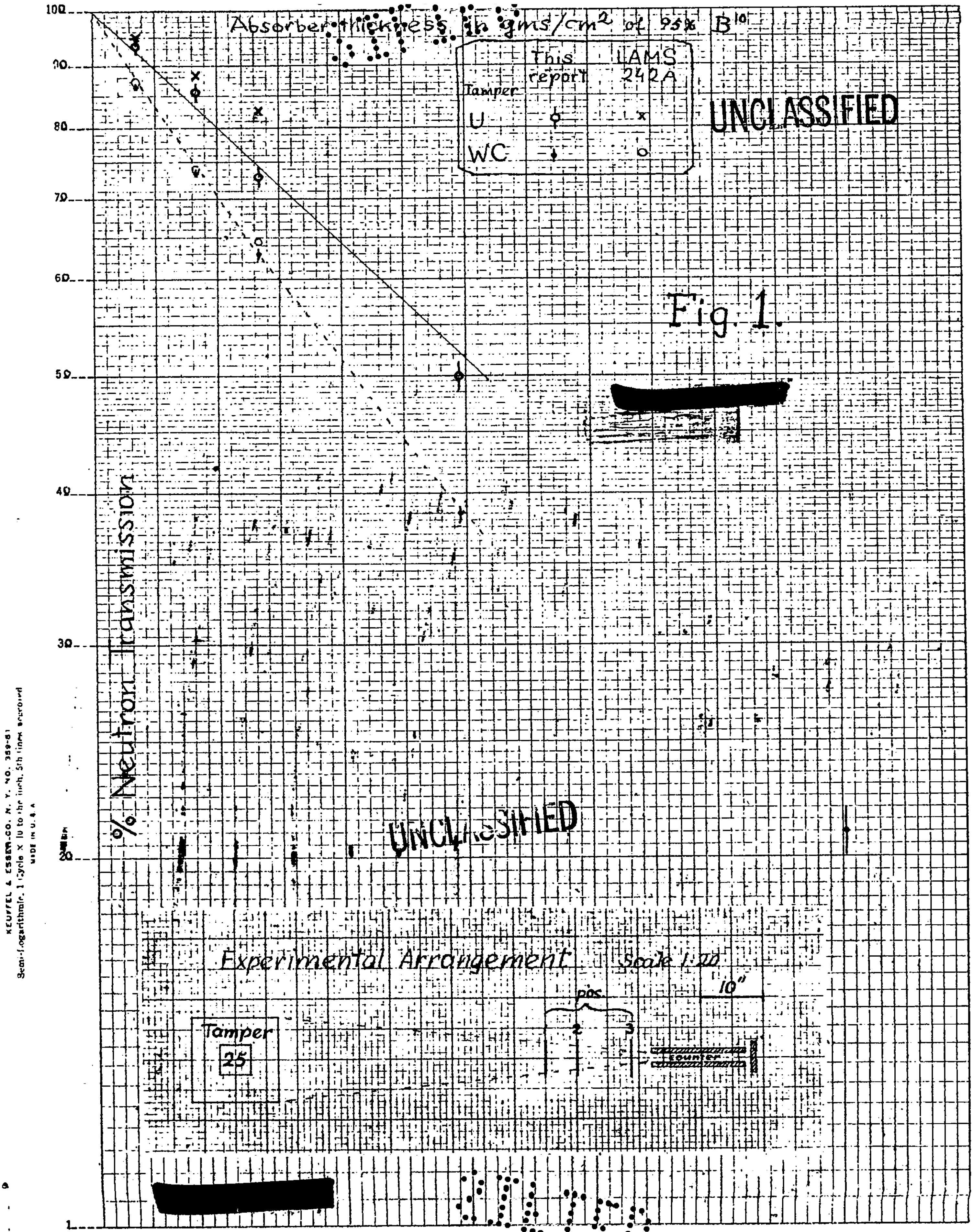
Absorber thickness in gms/cm² of 95% B10
This report
LAMS 242A
Tamper
U
WC
UNCLASSIFIED
% Neutron Transmission
100
90
80
70
60
50
40
30
20
1
UNCLASSIFIED
Experimental Arrangement
Scale 1:20
pos
10"
2
3
Tamper
25
counter

Fig. 1.

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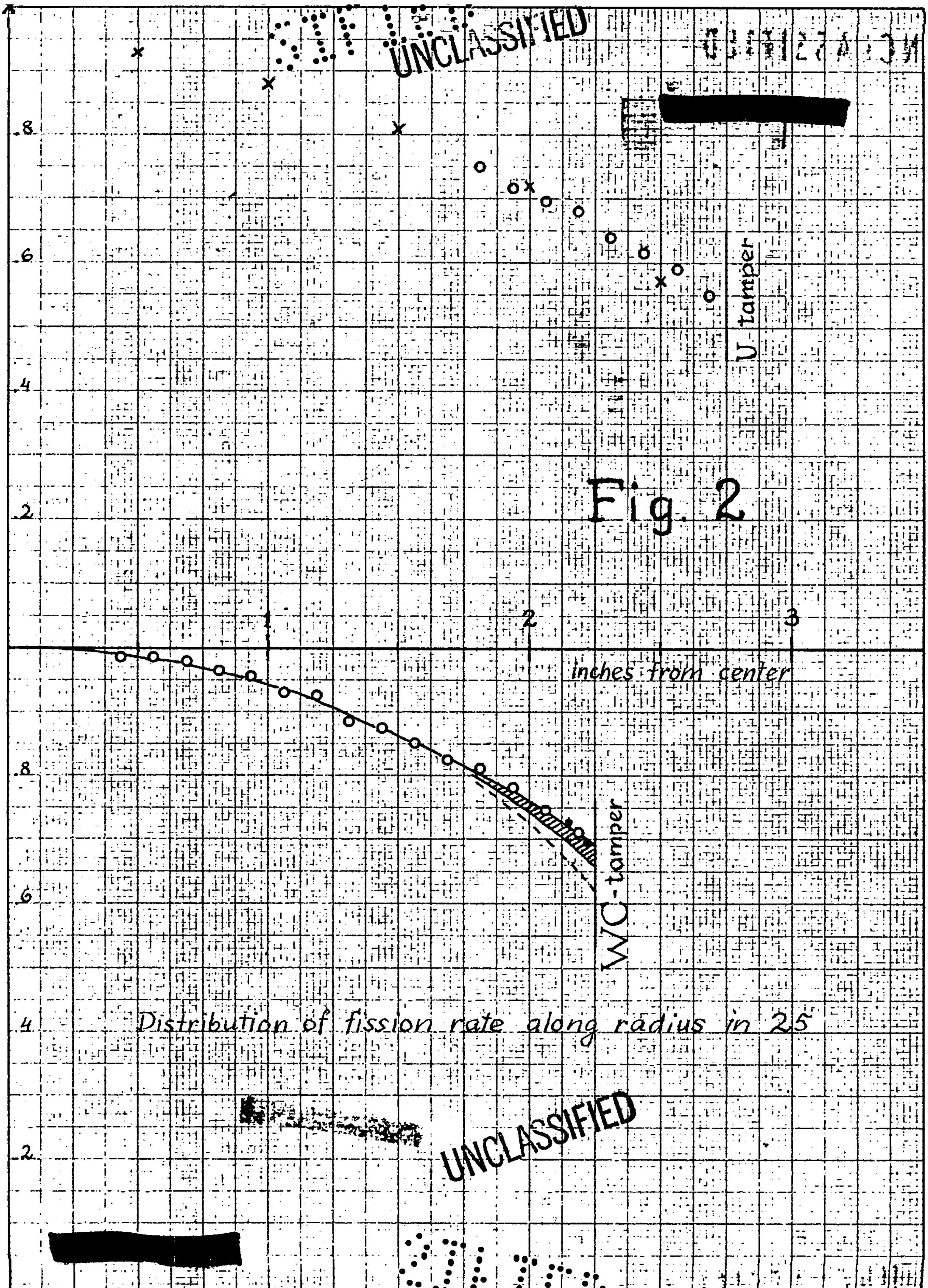

Fig. 2

Distribution of fission rate along radius in 25

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