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NEUTRON FLUX AND SPECTRA MEASUREMENTS IN THE VOID TANK OF THE TRIGA MARK-F REACTOR

by

K C Humpherys

February 1962

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ABSTRACT

Neutron flux and spectra measurements were made in the void tank irradiation chamber of the TRIGA Mark-F reactor in support of radiation effects studies in that facility. Threshold foils were used for the measurements. Measurements were made with three lead-shielding thicknesses; zero, 3, and 4 inches between the reactor core shroud and the points of measurements.

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NEUTRON FLUX AND SPECTRA MEASUREMENTS IN THE VOID TANK OF THE TRIGA MARK-F REACTOR

Introduction

Measurements of the neutron flux and spectra have been made in a portion of the void tank irradiation chamber of the TRIGA Mark-F reactor in conjunction with radiation effects studies being performed by Sandia Corporation. The reactor is owned and operated by General Atomics, La Jolla, California. Measurements were made by the activation analysis of several threshold foils. The foils used and their effective threshold energies[1] were Pu^{239}, 10 kev; Np^{237}, 0.70 mev; U^{238}, 1.5 mev; and S^{32}, 3.0 mev. The measurements were made with zero, 3, and 4 inches of lead shielding between the reactor core shroud and the point of measurements. The neutron flux above 3.0 mev energy was measured with S^{32} at numerous points throughout the irradiation volume used, while full sets of foils were used for spectra measurements at two or three representative points for each shielding configuration. Neutron flux and spectra measurements have previously been measured in the TRIGA Mark-F core and void tank by others,[3,4] using different shielding configurations.

Description of Reactor Facility

The TRIGA Mark-F[2] reactor is designed for pulsed, as well as steady state, operation and has a cylindrical core with aluminum clad fuel elements of enriched uranium-zirconium hydride. These fuel elements give the reactor a prompt negative temperature coefficient of reactivity which limits automatically the reactor power to a safe level and ensures its inherently safe operation as a pulsed reactor.

The reactor core is located in a 25 ft deep pool of water. The water serves as both shield and reflector. The reactor core is suspended from a movable carriage mounted on rails on the reactor room floor and can be moved within the water tank and positioned adjacent to the void tank irradiation chamber. Figure 1 shows a sketch of the reactor, movable carriage, and void tank. The void tank is a semi-annular dry irradiation chamber pressurized with helium gas to prevent water leakage. Figure 2 gives detailed dimensions of the void tank and reactor core.

Pulsed operation of the reactor is accomplished by the rapid ejection from the core of a control rod with compressed air. This results in an excess reactivity which yields a power excursion that is terminated by the negative temperature coefficient of the fuel elements. The reactor operates typically with the following transient characteristics:[2]

Reactivity insertion	1.9% = $\Delta k/k$
Maximum power level	1200 Megawatts
Prompt energy release	18 Megawatt-sec
Minimum pulse width	13 millisec
Maximum repetition rate	12 per hour
Minimum period	4 millisec

A typical pulse shape[3] is shown in Fig. 3 where the transient power is plotted as a function of time after a reactivity insertion of 1.9% $\Delta k/k$.

Experimental Measurements and Results

Sulfur measurements were made in three horizontal planes within the void tank; at reactor midplane, 25 cm above reactor midplane, and 25 cm below reactor midplane. The midplane, as used for these measurements, was parallel to and located 46 cm below the bottom surface of the void tank lid. Foils were placed on three radial arcs in each of the three horizontal planes. The arcs were restricted to the volume beneath the void tank lid. (The remainder of the void tank volume was filled with styrafoam.) The radii of the three arcs from the axial centerline of

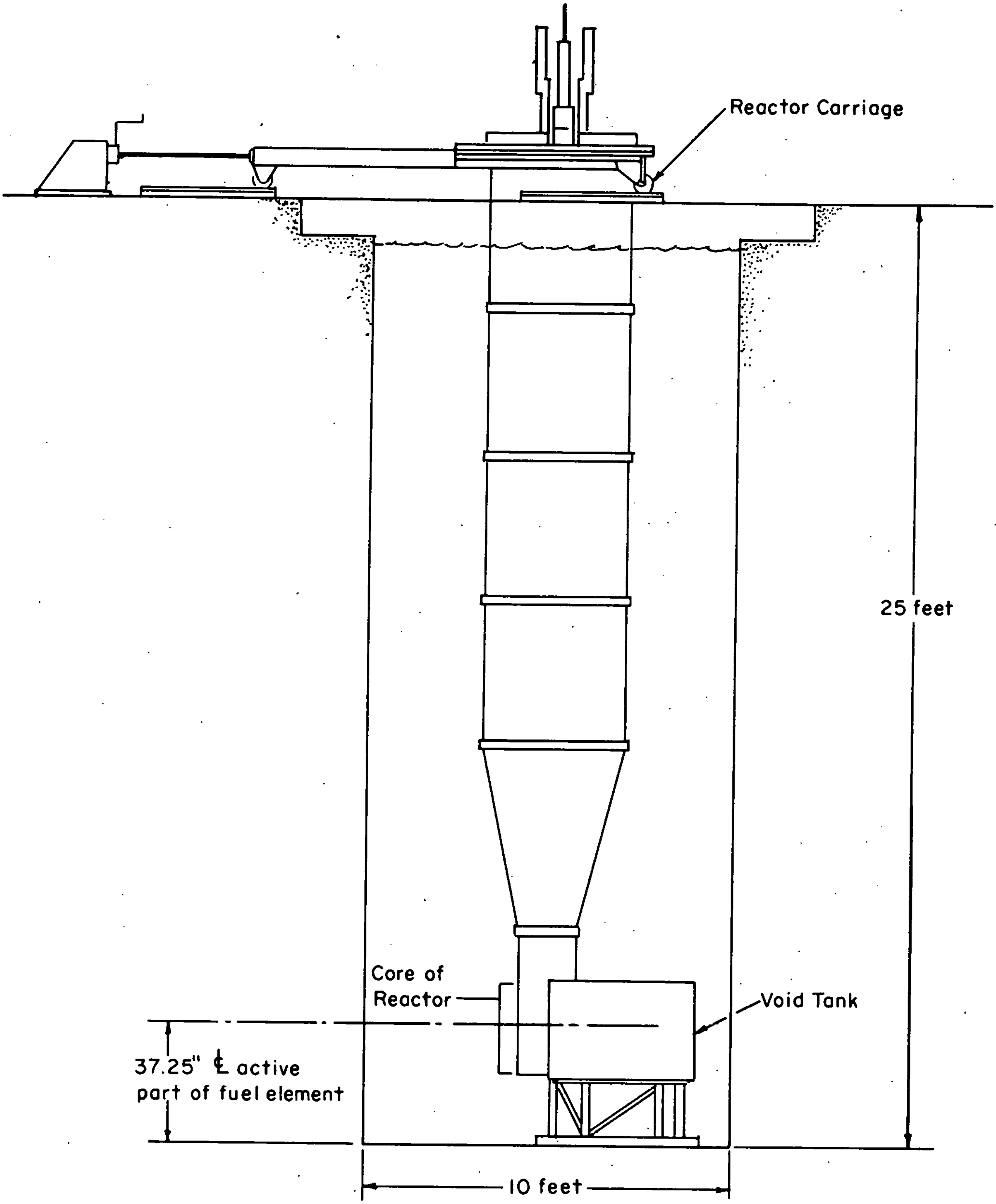

Fig. 1 -- TRIGA Mark-F Reactor

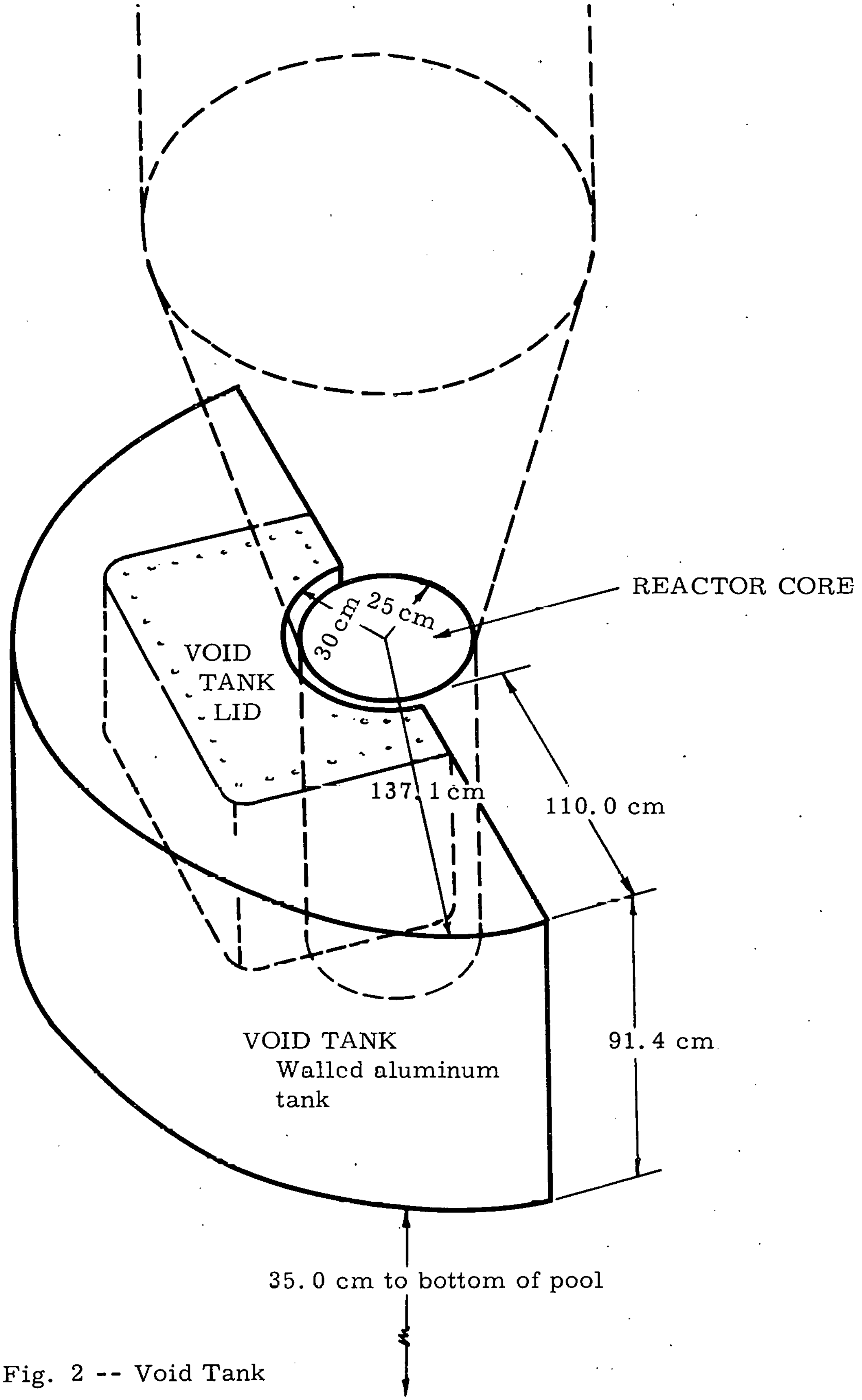

Fig. 2 -- Void Tank

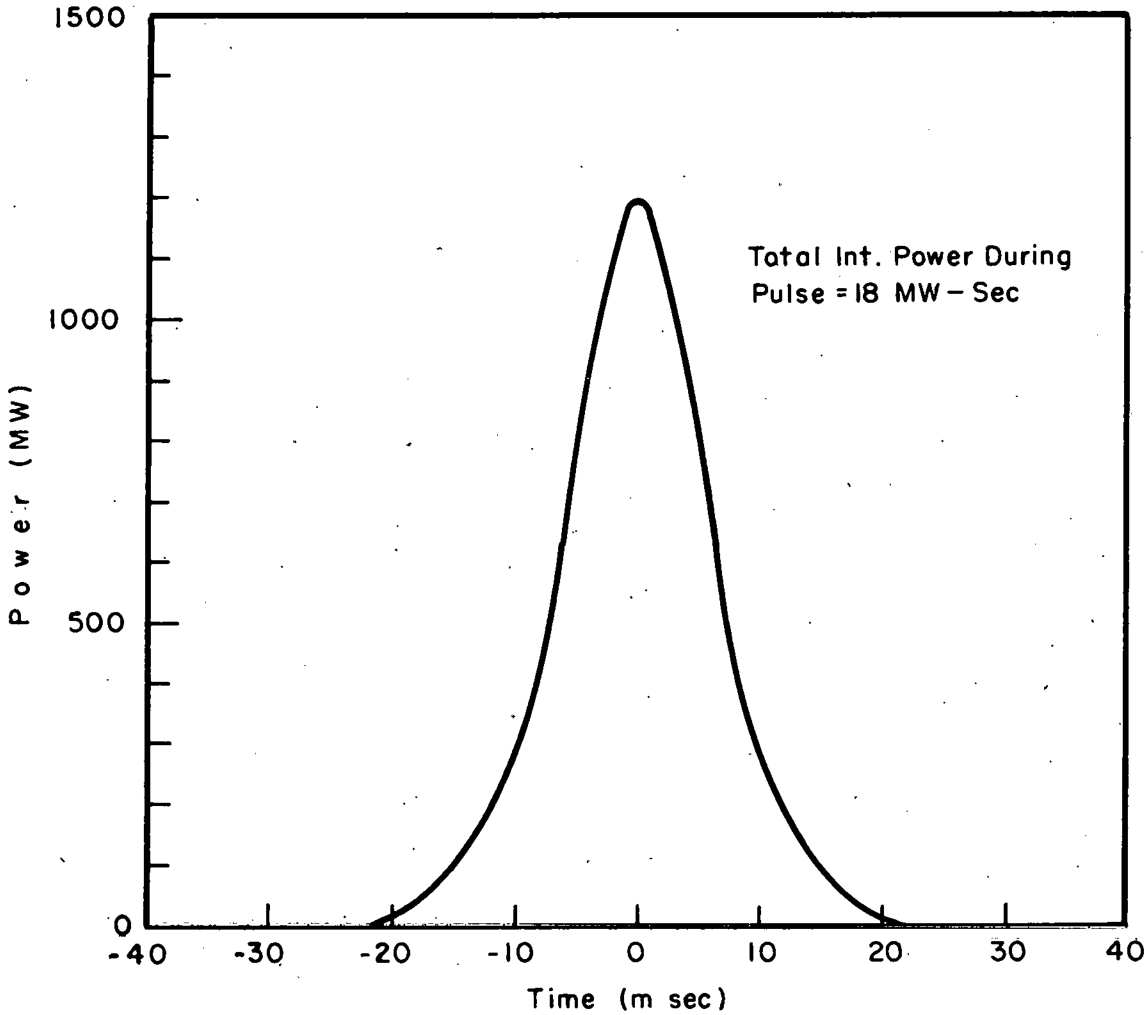

Fig. 3 -- Transient Power as a Function of Time After Reactivity Insertion of 1.9% $\Delta k/k$

the reactor core were 43 cm, 50 cm, and 62 cm. From three to five sulfur foil measurements were made at various locations on each arc and in each of the three horizontal planes. The locations within the void tank and the measured neutron flux from the sulfur foils are given for the three shielding configurations in Table I. As can be seen from Table I, there is very good agreement (approximately ±5%) on a given radial arc in the irradiation volume. The data in Figs. 4, 5, and 6 were taken from Table I and show integrated neutron flux averages versus radial distance from the axial centerline of the reactor core for each of the three shielding configurations and in each of the three horizontal planes.

Complete sets of threshold foils (Pu^{239}, Np^{237}, U^{238}, and S^{32}) were positioned at various locations on the 43 cm and 62 cm arcs in the midplane shelf for each of the three shielding configurations. Measurements were also made on the 50 cm arc of the midplane with 4 inches of lead shielding. The location within the void tank and the measured data are given in Table II. The data are also given normalized to the flux above 0.01 mev. Figure 7 is a plot of neutron flux as a function of lead shield thickness in the midplane on the 62 cm radial arc for each of the four threshold foils.

All data were taken with reactor transients of 18 ± 2 MW-sec energy release, as measured by General Atomics. The neutron flux measurements on the various transients were normalized with respect to each other by means of sulfur monitor foils positioned in a reproducible position outside of the void tank. The transient giving most nearly the median activity on the monitor foil was used as the normalization reference point.

TABLE I

Neutron Flux (> 3.0 mev) Radial Profiles in Void Tank

0" of Lead Shielding

25 cm Above Midplane			Midplane			25 cm Below Midplane		
43 cm arc from core centerline	50 cm arc from core centerline	62 cm arc from core centerline	43 cm arc from core centerline	50 cm arc from core centerline	62 cm arc from core centerline	43 cm arc from core centerline	50 cm arc from core centerline	62 cm arc from core centerline
1.51×10^{12} nvt	1.22×10^{12} nvt	9.83×10^{11} nvt	2.57×10^{12} nvt	1.62×10^{12} nvt	1.15×10^{12} nvt	10.30×10^{11} nvt	9.56×10^{11} nvt	7.27×10^{11} nvt
1.44	1.27		2.54	1.82		9.84	9.53	
1.55	1.30	10.3	2.61	1.94	1.18	9.84	9.55	8.25
1.62	1.38		2.52	1.94		9.72	9.59	
1.71	1.43	9.56	2.71	1.92	1.27	10.64	9.44	7.88
1.55×10^{12} ave	1.32×10^{12} ave	9.89×10^{11} ave	2.59×10^{12} ave	1.84×10^{12} ave	1.20×10^{12} ave	1.01×10^{12} ave	9.54×10^{11} ave	7.73×10^{11} ave

3" of Lead Shielding

25 cm Above Midplane			Midplane			25 cm Below Midplane		
6.21×10^{11}	5.41×10^{11}	4.22×10^{11}	1.11×10^{12}	6.83×10^{11}	5.11×10^{11}	4.07×10^{11}	3.91×10^{11}	3.15×10^{11}
6.08	5.38		1.23	7.91		4.09	3.96	
6.95	5.24	4.20	1.25	8.52	5.08	4.00	3.78	3.13
6.78	5.51	4.20	1.11	8.48	5.41	3.91	3.46	3.17
6.50×10^{11} ave	5.39×10^{11} ave	4.21×10^{11} ave	1.18×10^{12} ave	8.05×10^{11} ave	5.21×10^{11} ave	4.02×10^{11} ave	3.79×10^{11} ave	3.15×10^{11} ave

4" of Lead Shielding

25 cm Above Midplane			Midplane			25 cm Below Midplane		
4.37×10^{11}	3.86×10^{11}	3.15×10^{11}	8.39×10^{11}	5.03×10^{11}	3.82×10^{11}	2.57×10^{11}	2.69×10^{11}	2.20×10^{11}
4.71	4.06	3.24	8.24	5.93	3.76	2.63	2.66	2.42
4.80	4.26		8.50	5.99		2.80	2.82	2.42
4.34	4.65	3.46	8.34	6.16	3.64	3.27	2.88	
4.58×10^{11} ave	4.21×10^{11} ave	3.28×10^{11} ave	8.37×10^{11} ave	5.78×10^{11} ave	3.74×10^{11} ave	2.80×10^{11} ave	2.76×10^{11} ave	2.35×10^{11} ave

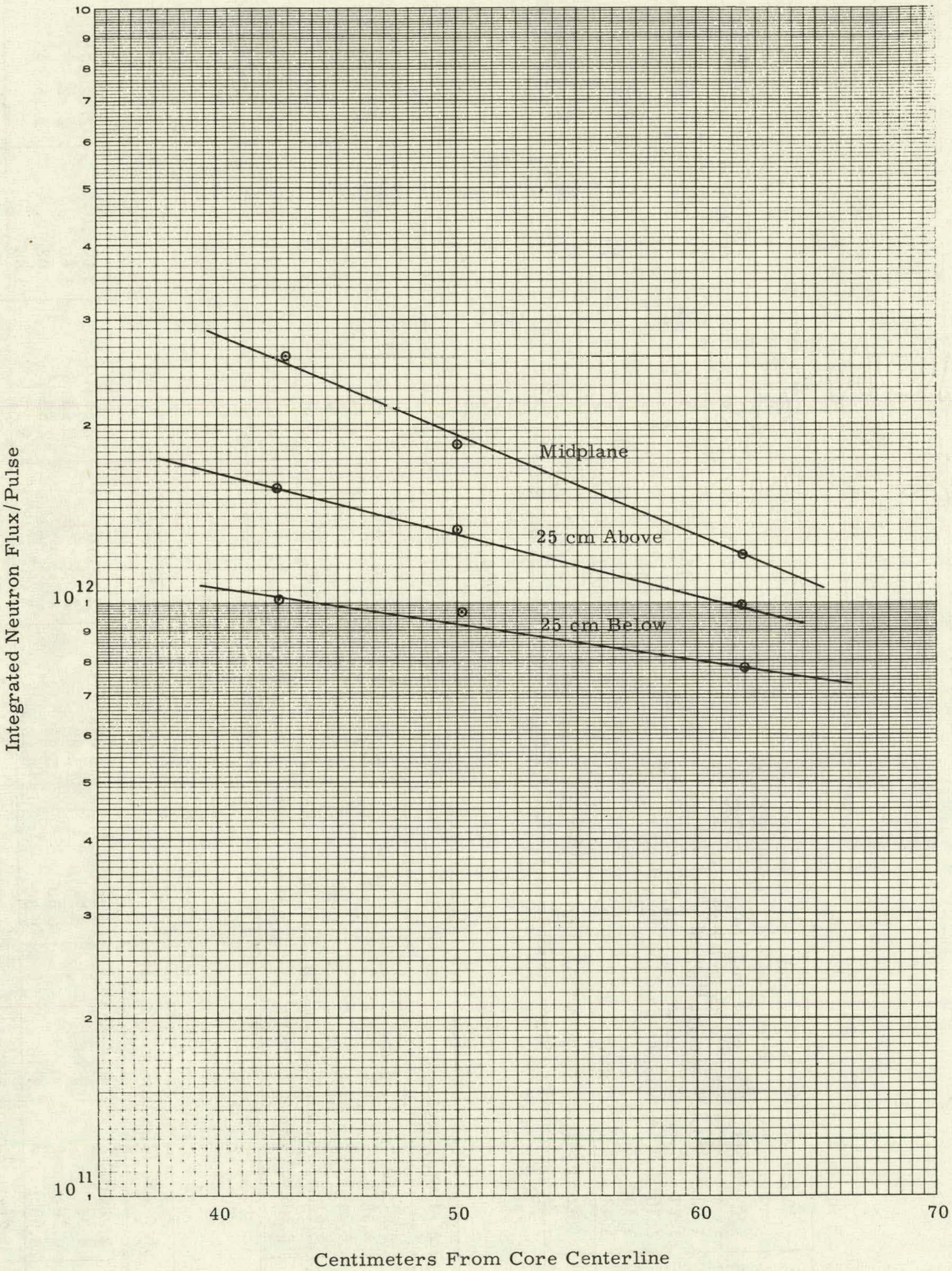

Fig. 4 -- Neutron Flux (> 3.0 mev) Horizontal Profiles in Void Tank of TRIGA Mark-F Reactor With No Lead Shielding

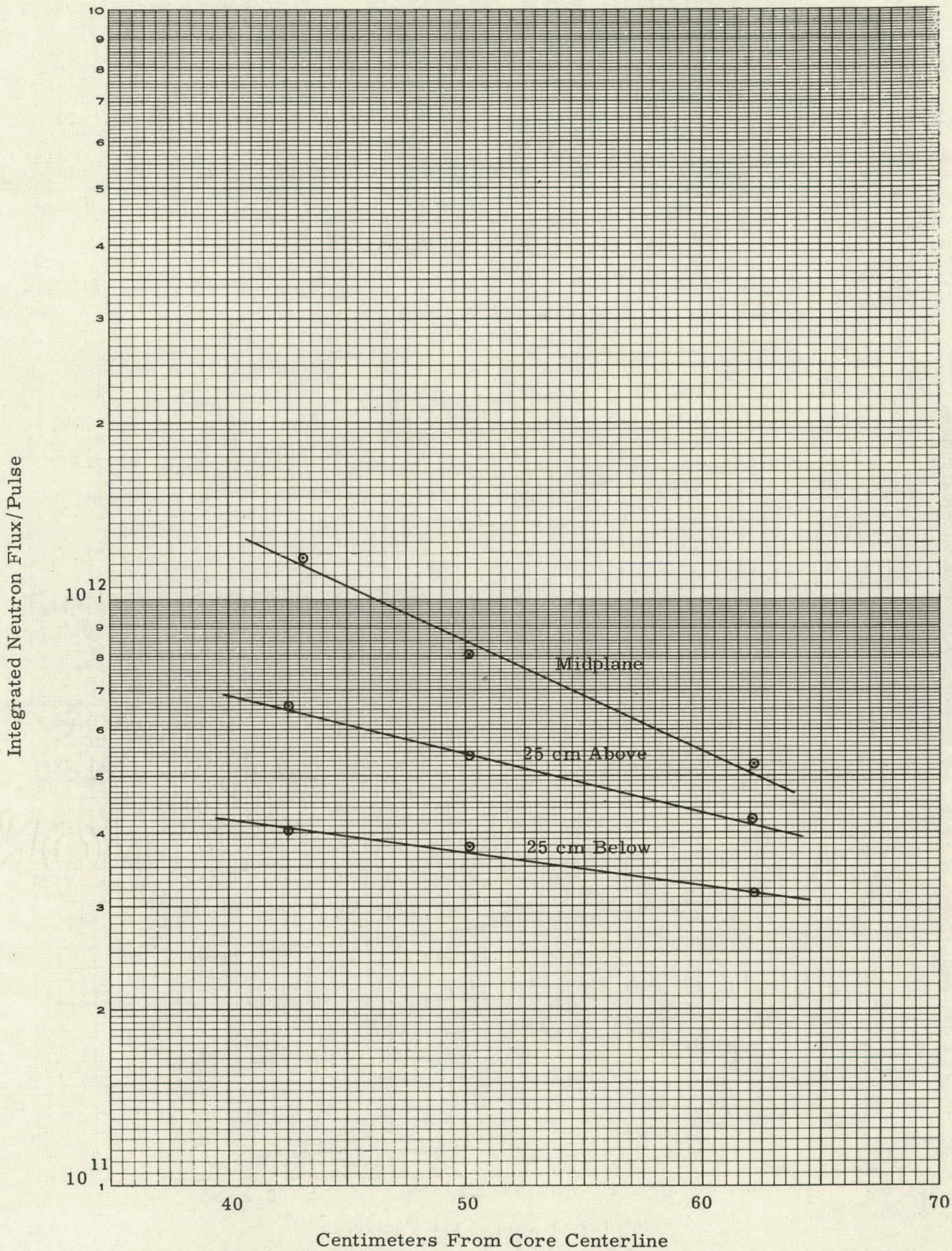

Fig. 5 -- Neutron Flux (> 3.0 mev) Horizontal Profiles in Void Tank of TRIGA Mark-F Reactor With 3" Lead Shielding

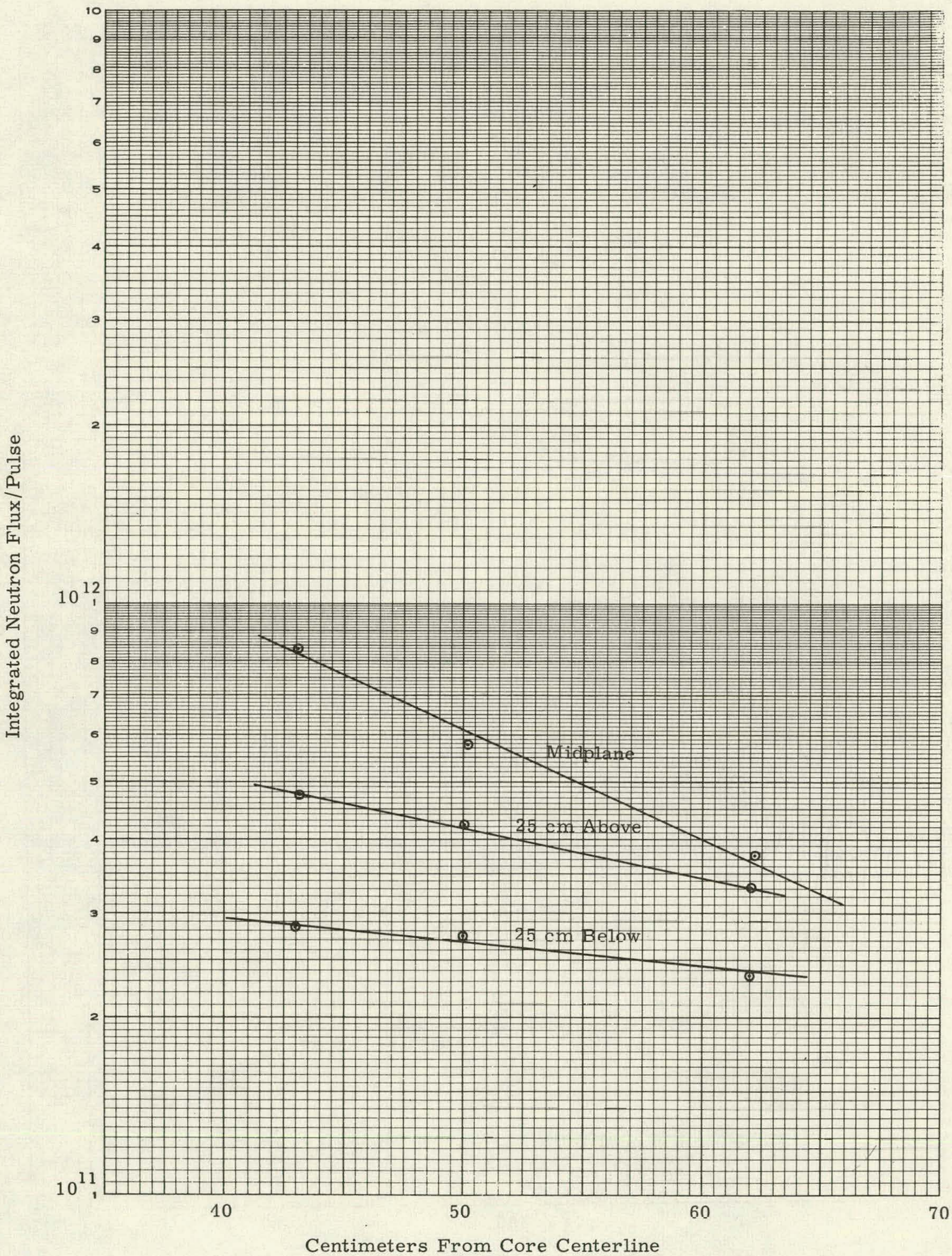

Fig. 6 -- Neutron Flux (> 3.0 mev) Horizontal Profiles in Void Tank of TRIGA Mark-F Reactor With 4" Lead Shielding

TABLE II

Void Tank Midplane Neutron Spectra Measurements

0" of Lead Shielding

Foil and threshold		43 cm from centerline		50 cm from centerline		62 cm from centerline	
		nvt	normalized	nvt	normalized	nvt	normalized
Pu^{239}	0.01 mev	1.63×10^{13}	1.00			7.98×10^{12}	1.00
Np^{237}	0.07	1.23×10^{13}	.75			6.06×10^{12}	.76
U^{238}	1.5	8.50×10^{12}	.52			2.94×10^{12}	.37
S^{32}	3.0	2.59×10^{11}	.16	1.84×10^{12}		1.20×10^{12}	.15

3" of Lead Shielding

Foil and threshold		43 cm from centerline		50 cm from centerline		62 cm from centerline	
		nvt	normalized	nvt	normalized	nvt	normalized
Pu^{239}	0.01 mev	1.20×10^{13}	1.00			5.75×10^{12}	1.00
Np^{237}	0.7	8.75×10^{12}	.73			3.60×10^{12}	.63
U^{238}	1.5	4.57×10^{12}	.38			1.65×10^{12}	.29
S^{32}	3.0	1.18×10^{12}	.10	8.05×10^{11}		5.21×10^{11}	.09

4" of Lead Shielding

Foil and threshold		43 cm from centerline		50 cm from centerline		62 cm from centerline	
		nvt	normalized	nvt	normalized	nvt	normalized
Pu^{239}	0.01 mev	9.38×10^{12}	1.00	7.42×10^{12}	1.00	4.87×10^{12}	1.00
Np^{237}	0.7	6.71×10^{12}	.71	4.65×10^{12}	.63	3.13×10^{12}	.64
U^{238}	1.5	3.20×10^{12}	.34	2.02×10^{12}	.27	1.22×10^{12}	.25
S^{32}	3.0	8.40×10^{11}	.09	5.78×10^{11}	.08	3.75×10^{11}	.08

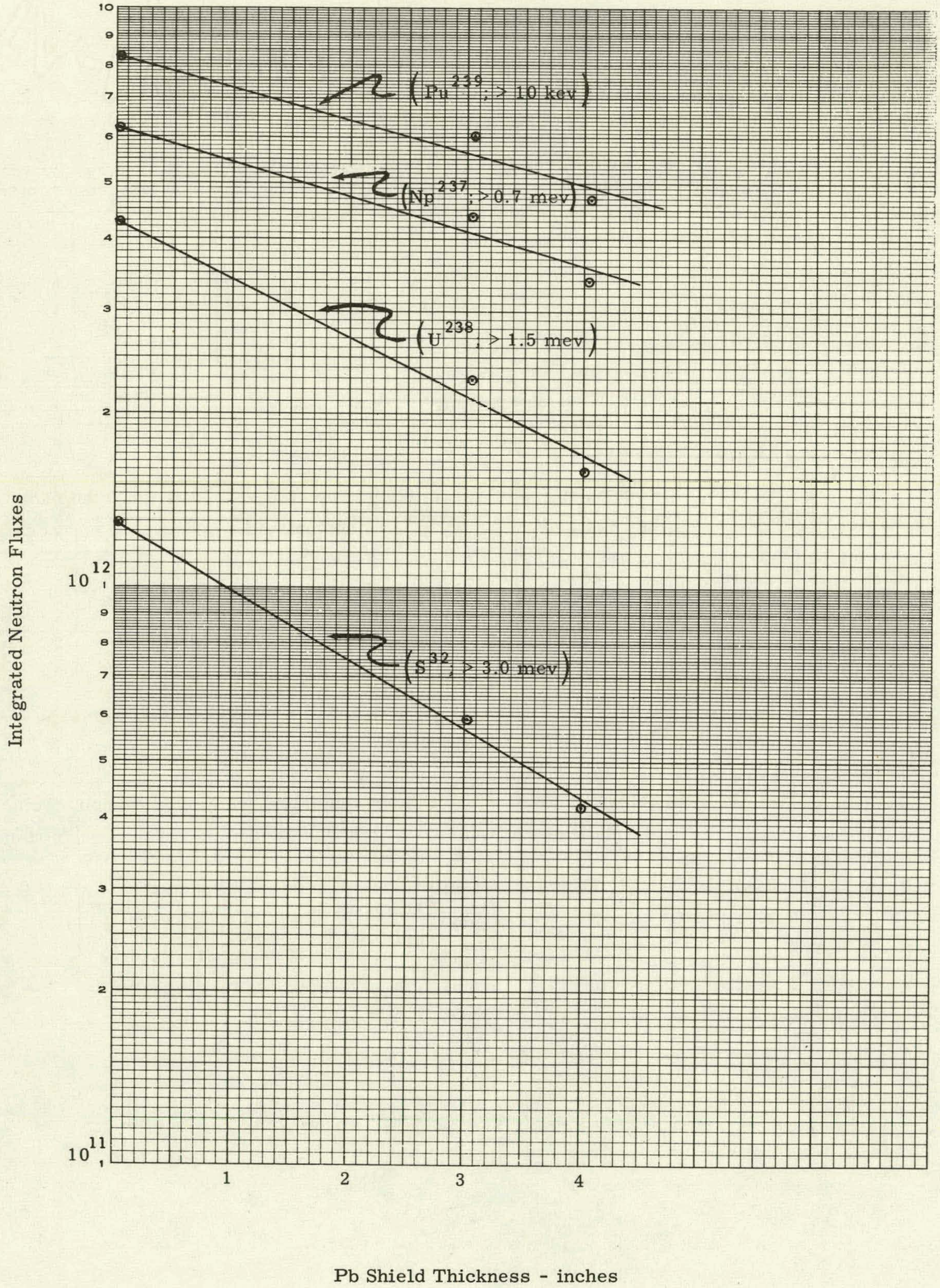

Fig. 7 -- Attenuation of Neutron Fluxes by Lead Shielding

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