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TITLE

CALIBRATED NEUTRON SOURCES FOR THE 234-5 BUILDING

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CALIBRATED NEUTRON SOURCES FOR THE 234-5 BUILDING

By

J. De Pangher

Radiological Physics
Physics and Instruments Research and Development
HANFORD LABORATORIES OPERATION

March 21, 1958

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ABSTRACT

The neutron-emission rates for a fission-neutron source and for a PuF_4 neutron source were measured. Arguments for accepting a new neutron spectrum for PuF_4 are presented.

CALIBRATED NEUTRON SOURCES FOR THE 234-5 BUILDING

To facilitate measurements on neutrons from Pu metal and PuF_4 powder in the 234-5 Building, two neutron sources made from these materials were borrowed from that building during November 4 - 8, 1957, for calibration in the 3745-B Building. With the aid of the double moderator neutron detector[1,2] and a long counter[3], the calibration was done in the low-flux room of the positive ion accelerator to minimize the effect of room scattered neutrons on the results and to take advantage of stabilized counting equipment and low background not generally available under field conditions. For example, the background counting rates of the long counter and double moderator were only 0.17 and 1.9 count/min during the measurements which lasted over a period of several days.

The long counter like the double moderator detects fast neutrons by slowing them down in paraffin to a speed where they are readily captured in a BF_3 proportional counter. The long counter measures neutron flux density, approximately independent of neutron energy, over the energy range 0.025-9.0 Mev and was used originally to calibrate the double moderator with monoergic neutrons from the positive ion accelerator. During the present experiment, it served as a check on the double moderator which was exposed to the two neutron sources, having neutrons with extended energy ranges.

The double moderator measures flux density, dose and average neutron energy over a fairly wide range of neutron energies. The core of this instrument consisting of a sensitive BF_3 proportional counter enclosed by a cylindrical paraffin shell constitutes a fluxmeter while the addition of a second enclosing shell of paraffin converts it into a dosimeter. The ratio of counts

$$R = \frac{\text{dosimeter counts}}{\text{fluxmeter counts}}$$

[redacted]

is a measure, within certain restrictions, of the average neutron energy to which the arrangement is exposed.

All measurements were performed at a distance of about 100 cm from each of the two sources.

The first neutron source was a button of plutonium metal weighing 1285.3 grams. The neutrons are produced primarily by the spontaneous fission of the Pu^{240} isotope contained in the source and have the same energy spectrum, presumably, as the energy spectrum[4] of the neutrons from the fission of U^{235}. The absolute neutron activity of the source was computed by assuming isotropic emission of neutrons from the sample and by using the data obtained with the long counter. Measurements made at two angles partially verified the assumption of isotropic emission. The absolute yield of the button was 1.24×10^5 neutrons/sec or 96 neutrons/sec/gram. The average energy obtained with the double moderator was 1.4 Mev. It is to be compared with the average of 1.9 Mev calculated for the U^{235} fission spectrum appearing in Fig. 1.

The second neutron source was 166.5 grams of PuF_4 powder which was placed in an aluminum tube with wall thickness 1/16 in., I.D. 1-1/16 in. and length 8-1/2 in. One end was closed by an aluminum cap 1/16 in. thick, the other by a rubber stopper. The rubber stopper 5/8 in. long penetrated into the tube 1/2 in. and apparently left no air space between it and the powder. The assembly was placed in a light plastic bag and sealed in it to prevent possible contamination during handling.

The absolute yield of the fluoride sample was measured to be 1.13×10^6 neutrons/sec or 6800 neutrons/sec/gram. This number was obtained by integrating the yield measured at various angles of emission. The yield was shown to closely obey cylindrical symmetry. Table I lists the flux and dose rate at 100 cm from the source as a function of the angle of emission. The experimental arrangement

FISSION NEUTRON SPECTRUM

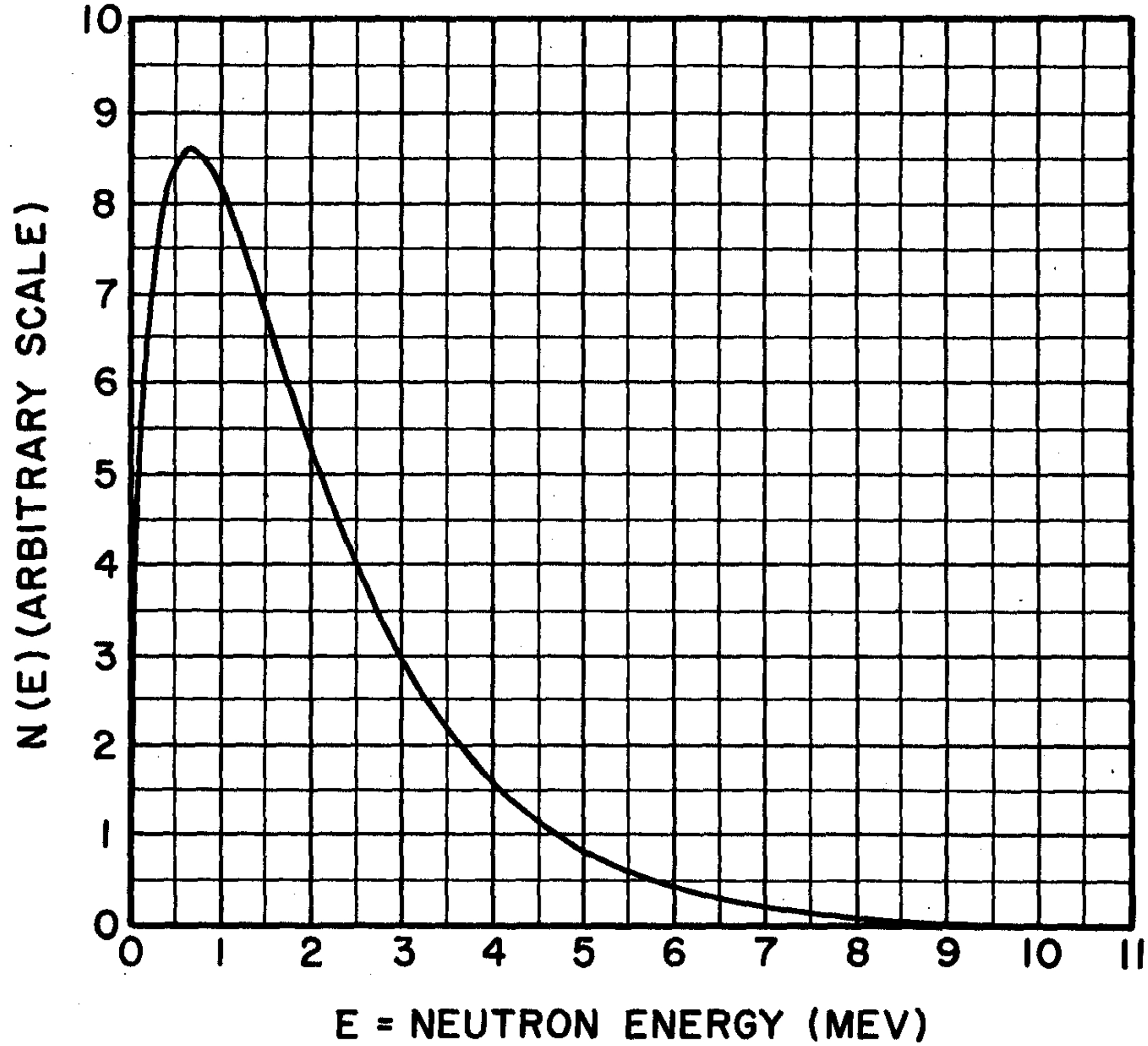

Fig. 1. Energy spectrum of neutrons produced in the fission of U^{235}. The curve is a plot of Cranberg's equation

$$N(E) = \text{const.} \times E^{1/2} \exp(-0.775E).$$

 [redacted]

 [redacted]

is shown in Fig. 2.

TABLE I

θ	Neutrons/sec/cm² at 100 cm	mrad/hr at 100 cm
0°	6.4	.060
10°	7.4	.069
20°	8.1	.075
30°	8.6	.080
40°	8.9	.083
50°	9.1	.085
60°	9.2	.086
70°	9.3	.086
80°	9.3	.086
90°	9.3	.086

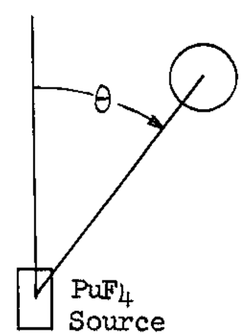

Fig. 2. Experimental arrangement for measuring the angular yield of the PuF_4 neutron source.

In a previous report[5], HW-20785, the calculated neutron spectrum of PoF was shown which gives an average energy of 0.7 Mev.

By performing the integration[2]

$$R = \frac{\int S_1(E)\ N(E)\ dE}{\int S_2(E)\ N(E)\ dE}$$

[redacted]

for the double moderator over the neutron energy distribution N(E), we obtain R = 0.462 and $\bar{E}$ = E(R) = 0.71 Mev. We should expect that the neutron energy spectra from PuF_4 and PoF to be similar. However, the experimental result for PuF_4 with the double moderator gives R = 0.636 and $\bar{E}$ = E(R) = 1.1 Mev in obvious disagreement with what was expected. We conclude that either the two spectra are dissimilar or the spectrum for PoF in HW-20785 is incorrect.

Recently Hess[6] in UCRL-3839 calculated the PoF neutron spectrum from the assumption of isotropic emission of neutrons in the center-of-mass system and from the yield of the $F^{19}(\alpha,n)$ reaction. This spectrum along with the one obtained from HW-20785 are plotted in Fig. 3.

The calculated value of R based on Hess' spectrum for PoF neutrons turns out to be R = 0.641 in excellent agreement with the experimental value for PuF_4 neutrons. This is one argument for demonstrating the validity of Hess' spectrum. The average energy

$$\bar{E} = \frac{\int E\, N(E)\, dE}{\int N(E)\, dE}$$

computed for Hess' spectrum is $\bar{E}$ = 1.4 Mev.

It appears that the neutron spectrum presented in HW-20785 was based on cloud chamber data[7] containing only 163 tracks. The method of calculation is unknown.

A further, but perhaps, less convincing argument for accepting the spectrum in UCRL-3839 rather than the one presented in HW-20785 can be demonstrated by referring to Fig. 4. It turns out that if neutrons with an energy distribution N(E) are directed into any hydrogeneous detector, like the high-pressure hydrogen-filled cloud chamber used by Bonner and Mott Smith, they produce a proton-recoil spectrum described by $N(E_p)$ which is proportional to the expression[8]

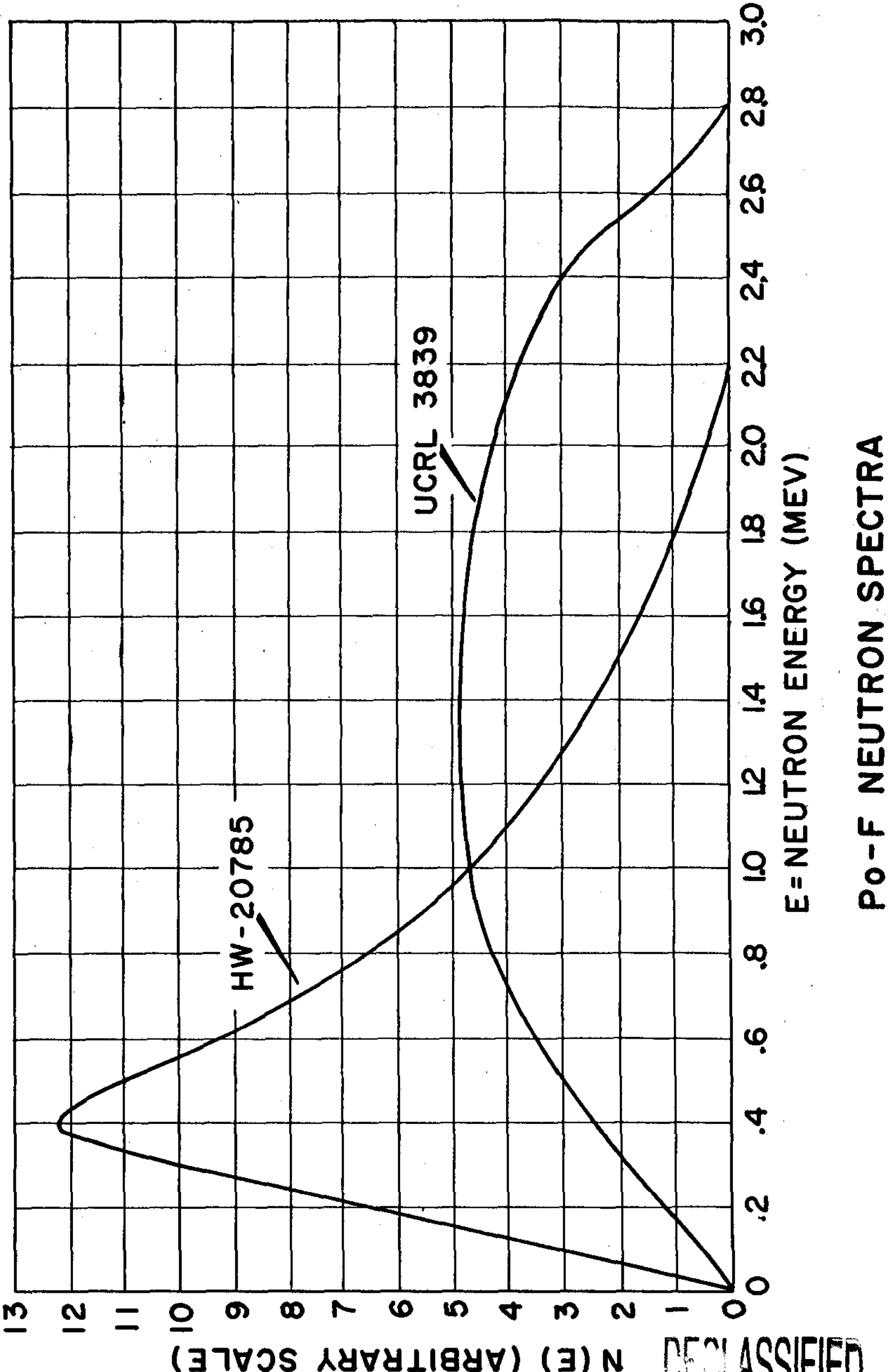

Fig. 3. Energy spectra calculated for a PoF neutron source.

[redacted]

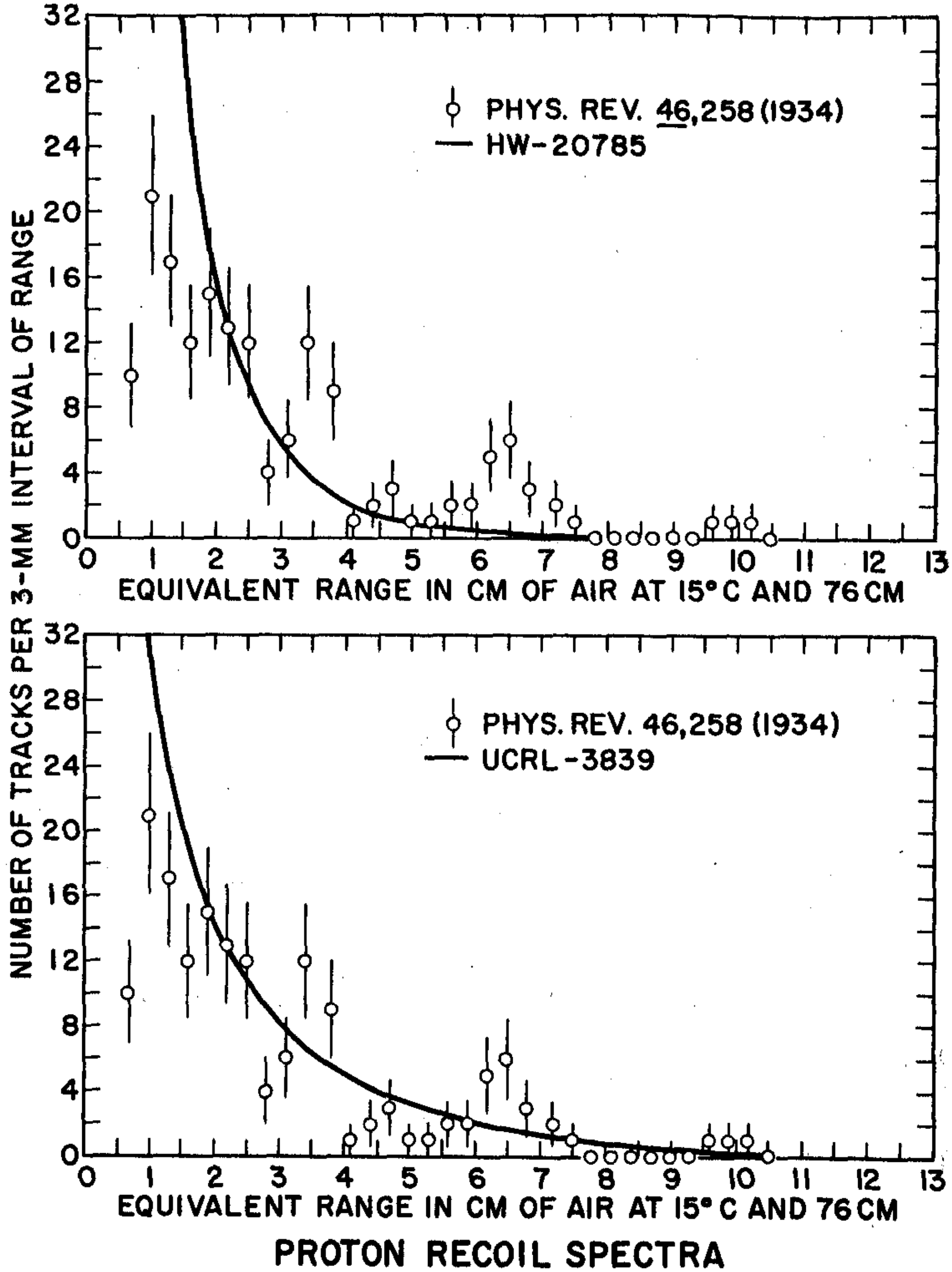

Fig. 4. Comparison of calculated and measured proton-recoil spectra.

[redacted]

$$\int_{E_p}^{\infty} N(E)\ \sigma(E)\ \frac{dE}{E}$$

The integrand contains the neutron-energy distribution function N(E), the total cross section for elastic n-p scattering $\sigma(E)$ and the lower limit of the integration is E_p the proton energy. A further step converts the proton-energy distribution into a proton-range distribution.

Bonner and Mott Smith investigated the proton-recoil spectrum obtained from neutrons generated in CaF_2 by bombardment of alpha particles from polonium. The experimental points on the range distribution of protons is shown in Fig. 4.

Calculations of $N(E_p)$ were made from the curves displayed in Fig. 3. The results normalized to the cloud-chamber data are presented in Fig. 4. It is seen that Hess' data gives the best fit and thus is to be favored over the data presented in HW-20785.

The present knowledge of the PuF_4 neutron energy spectrum leaves something to be desired. Detailed energy measurements by a low-energy neutron spectrometer would be desirable.

Table II lists some constants of the fission neutron source and the PuF_4 neutron source

TABLE II

Source	Average Energy	mrad/hr neutron/cm^2/sec
Fission	1.9 Mev	.0101
PuF_4	1.4 Mev	.0093

calculated from Fig. 1 and from Hess' curve in Fig. 3 and by using the results of first-collision theory[9].

 [redacted]

It is hoped that these two calibrated sources, or secondary standards derived from them, will help serve as checks on future neutron radiation measurements made in the 234-5 Building.

Acknowledgement is due R. E. Slater for his cooperation in obtaining the two neutron sources for calibration.

Author J. DePangher

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