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ABSTRACT

The neutron energy spectrum of a Po-Be(α ,n) source was measured as part of an intercomparison of neutron energy spectral measurements sponsored by Oak Ridge National Laboratory. Intensity maxima for neutron energies > 1 MeV were seen at or near 1.4, 2.1, 3.1, 5.0, 6.7, 7.7, and 9.7 MeV.

INTRODUCTION

Mound Laboratory participated in an intercomparison of neutron energy spectral measurements sponsored by Oak Ridge National Laboratory. This paper is a report of the measurements made at Mound Laboratory. A summary of these measurements is being incorporated into a report to be issued by ORNL.

There are slight differences between the data in the ORNL report and this report, a consequence of an improved calibration of our spectrometer subsequent to submitting our results to ORNL. However, the differences between these two reports are within the experimental uncertainties of either report. For the > 1 MeV portion of the spectrum, the neutron energies in this report are $\sim 1\%$ less than the corresponding points in the ORNL report while the neutron intensities are $\sim 1\%$ more. For the < 1 MeV portion, the neutron intensity for this report is 13% less than for the ORNL report. Structural details of the spectrum are the same in both reports.

EXPERIMENTAL TECHNIQUES

A Po-Be(α ,n) source, ORNL serial number PN-19, was used for this inter-comparison. The source is 2.4 cm long and approximately 2.1 cm diameter. The total emission rate of PN-19, determined with a long counter, was 8.08×10^6 n/sec on September 29, 1970, with an absolute uncertainty of $\pm 0.23 \times 10^6$ n/sec (one standard deviation). Pu-Be(α ,n) source M-591, which had been calibrated at the National Bureau of Standards, was used to calibrate the long counter.

A single stilbene crystal, fast neutron spectrometer and a long counter were used for the spectral determination. The stilbene crystal (2 cm diam x 1 cm high) was used to obtain that portion of the spectrum with neutron energies greater than 1 MeV. The portion of the spectrum with energies less than 1 MeV was obtained by a difference calculation using the following two values: 1) the total neutron flux at the stilbene crystal calculated from measurements made with the long counter, and 2) the neutron flux for energies > 1 MeV obtained from the stilbene data. The difference between these two values is then the neutron flux with energies < 1 MeV.

Pulse shape discrimination, utilizing space charge limitation at the last dynode of a 14-stage photomultiplier, was used to separate the pulses originating from neutron interactions in the crystal from those pulses originating from gamma interactions. Both amplitude and time requirements were used to define the gating pulses for the multichannel pulse height analyzer. Energy calibration of the spectrometer and the reduction procedure have been described elsewhere.¹ Briefly, the energy calibration is based on the spectrum of Pu-Be(α ,n) source M-591 as measured several years ago with nuclear emulsions. The data reduction procedure uses matrices and takes into account the dependence of the light output of the crystal in the direction of travel of the recoil protons in the crystal.

Two sets of energy measurements were made. Both sets were made in an 18 ft x 20 ft room with a 15 ft ceiling. The first set of measurements was made with a source-detector separation of 100 cm using a support provided by ORNL. In order to reduce the amount of neutron scattering from the concrete floor, the base of the stand was raised so the height of the source and detector above the floor was 223 cm. Figure 1 shows this experimental arrangement. The shadow shield, a water-filled aluminum container, was used to determine the scattered neutron background. For the foreground measurement, the V-shaped support for the shadow shield remained in position. The cesium-137 calibration source was used for routine energy calibration when use of the 800 keV gamma from polonium-210 was impractical.

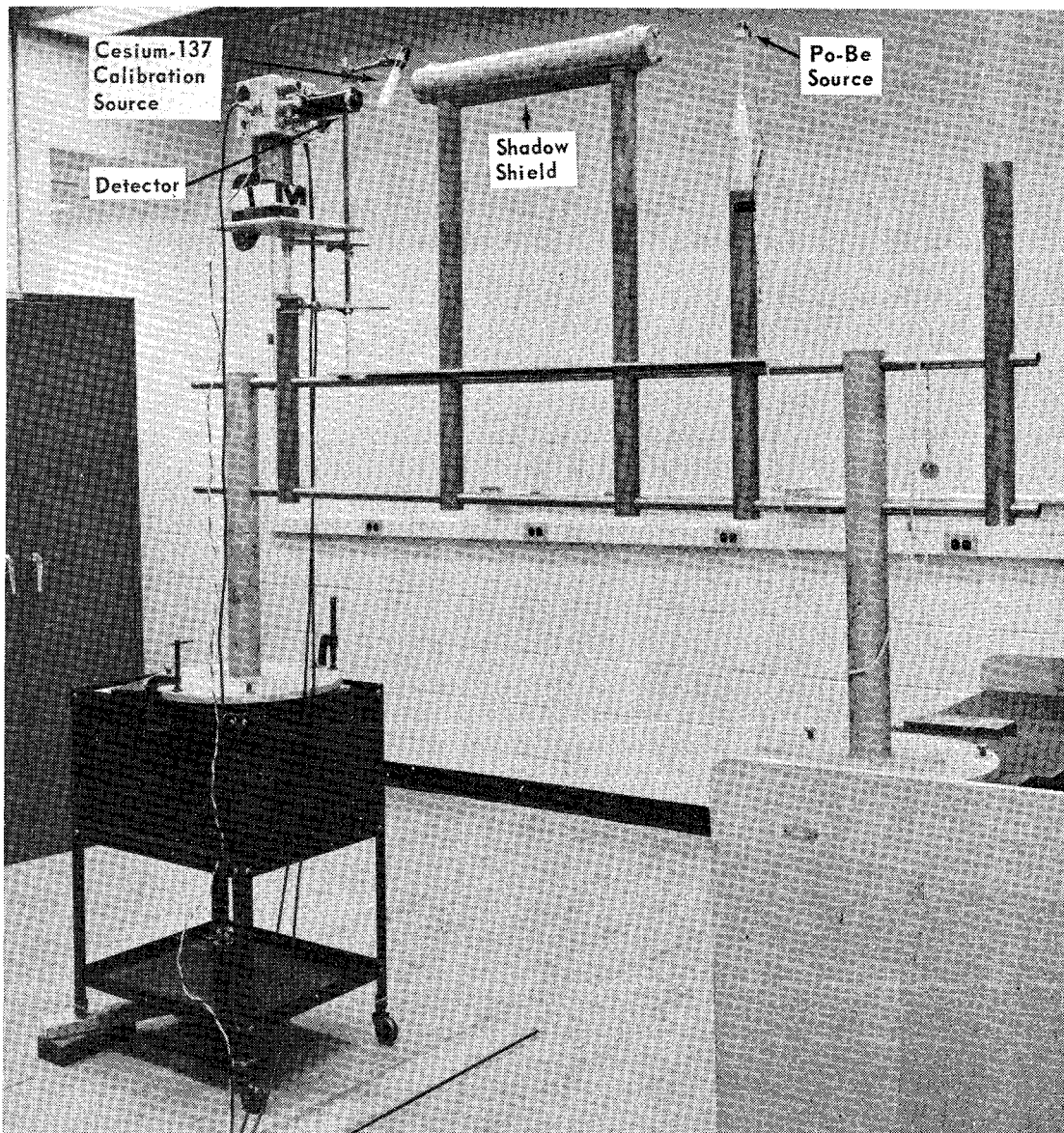


FIGURE 1 - A view of the experimental arrangement when using the support supplied by ORNL.

Since a source-detector separation of 100 cm is greater than would normally have been used at Mound Laboratory for this spectral determination, a second set of measurements was made following a procedure which has been used for other sources of comparable size. For this second set, a source-detector separation of ~20 cm was used to determine the shape of the spectrum from 1-11 MeV. The source was held with a test-tube clamp in such a manner that the clamp was not in the line-of-sight between the source and detector. The source orientation relative to the crystal was the same as for the first set of measurements. At this closer separation, counting rates were much greater than at 100 cm, and the room-scattered neutron background was negligible*. However, at a source-detector separation of ~20 cm, the effective separation between the source and the crystal cannot be determined with sufficient accuracy for use in the difference calculation. Therefore, a measurement of the ≥ 4 MeV portion of the spectrum for use in the difference calculation was made at a separation of ~60 cm. At this greater separation, a small background correction must be made. Since the difference calculation requires the spectrum for energies ≥ 1 MeV at 60 cm, the 1-4 MeV portion of the spectrum was obtained by direct ratio from the 20 cm data. The total flux at the crystal was calculated from a long counter measurement made with the source in the same orientation relative to the detector as for the stilbene measurement and in the same clamp.

RESULTS

The neutron energy spectrum determined with the use of the stand supplied with the source is shown in Figure 2. The error bars represent \pm one standard deviation and are from counting statistics only. The background correction, applied to the data for Figure 2, is shown in Figure 3. The spectrum for the measurement at 20 cm is shown in Figure 4A and, for convenience, the same data are shown as a linear plot in Figure 4B. In Figures 4A and 4B the large cross at the left is from the difference calculation. Since the data shown in Figure 2 were not used for the difference calculation, the cross representing the <1 MeV portion of the spectrum was not included in Figure 2. The uncertainty shown for the difference is between two numbers which are not greatly different. A somewhat detailed description of the determination of the uncertainty in the difference calculation is given in Reference 2. The partial spectrum for use in the difference calculation, measured at 60 cm, is shown in Figure 5.

*No attempt was made to determine either the effect the photomultiplier assembly had on either set of measurements or the effect the test-tube clamp had on the second set.

DISCUSSION

The measured spectra at 1 m and at 20 cm agree quite well. The 20 cm measurement, however, has better counting statistics even though the total measurement time was much shorter than for the 1 m measurement. The energy calibration for the 60 cm measurement appears to be slightly higher than for the other spectra. Since this latter measurement was used in the difference calculation, this energy uncertainty made the uncertainty in the difference calculation greater than it otherwise might have been.

Because of the better statistics, individual intensity maxima show up better in the 20-cm measurement than in the 100-cm measurement. Prominent maxima are seen at or near 3.1, 5.0, 6.7, 7.7, and 9.7 MeV. The maximum at 2.1 MeV has been seen in the spectra of $^{239}\text{Pu-Be}(\alpha, n)$ sources² as well as in the spectrum of another $\text{Po-Be}(\alpha, n)$ source³. The small maximum at 1.4 MeV has also been seen in the spectra of Pu-Be sources.² A maximum near this point has been suggested by Lehman³.

REFERENCES

1. M. E. Anderson and R. A. Neff, "Neutron Emission Rates and Energy Spectra of Two ^{239}Pu Power Sources", Nucl. Appl. Technol., **7**, 62 (1969).
2. M. E. Anderson and R. A. Neff, "Neutron Energy Spectra of Different Size $^{239}\text{Pu-Be}(\alpha, n)$ Sources" (to be published in Nucl. Instr. Methods).
3. R. L. Lehman, "The Origin of Neutron Groups in $\text{Be}(\alpha, n)$ Sources", Nucl. Instr. Methods, **60**, 253 (1968).

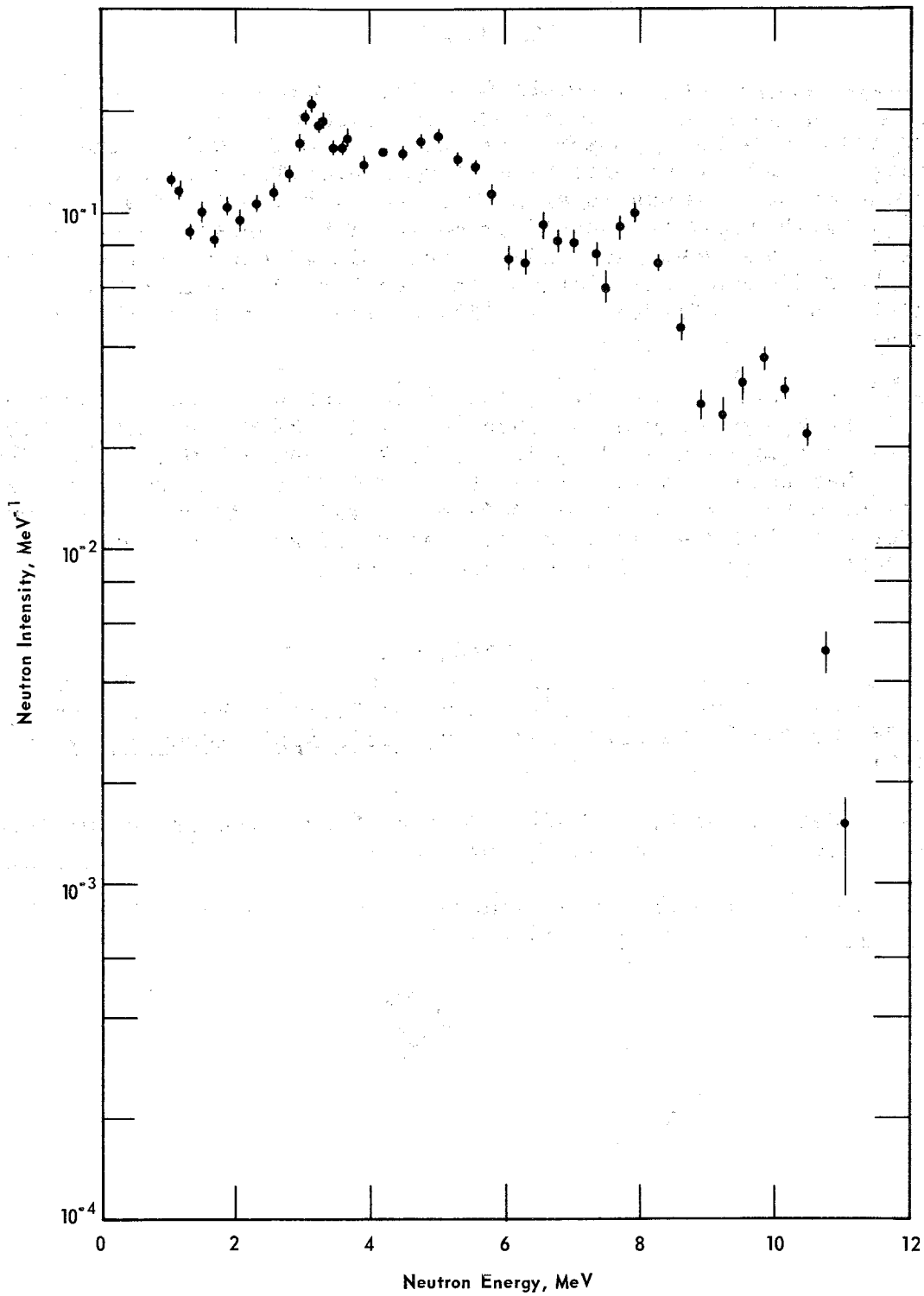


FIGURE 2 - Neutron energy spectrum of Po-Be source PN-19 obtained at a source-detector separation of 1 m with the use of the support shown in Figure 1, but without the shadow shield.

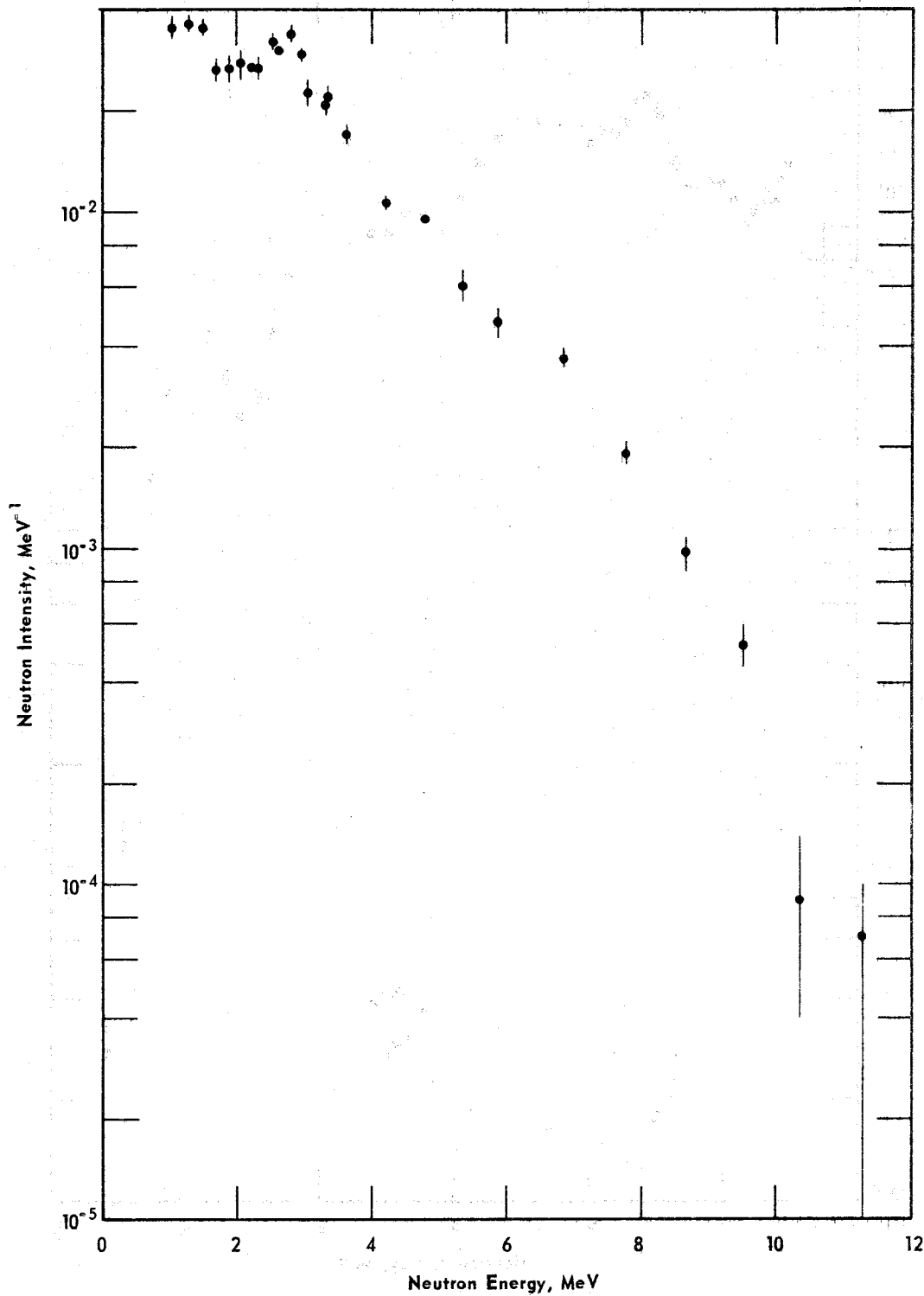


FIGURE 3 - The background correction, which was used in obtaining spectrum in Figure 2, measured with the use of the support shown in Figure 1, including the shadow shield.

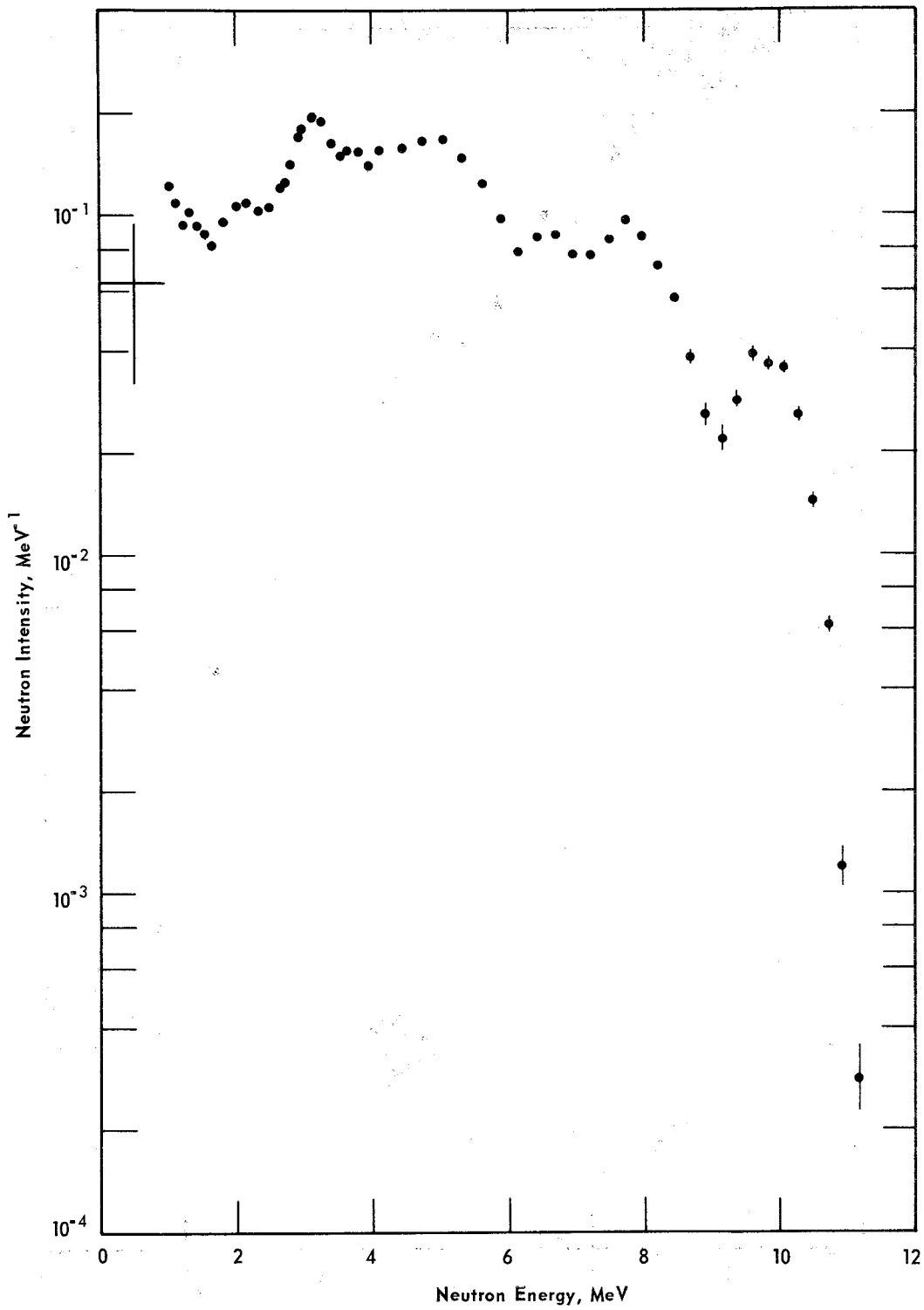


FIGURE 4a - Neutron energy spectrum of Po-Be source PN-19 obtained at a source-detector separation of 20 cm and using a test-tube clamp to support the source.

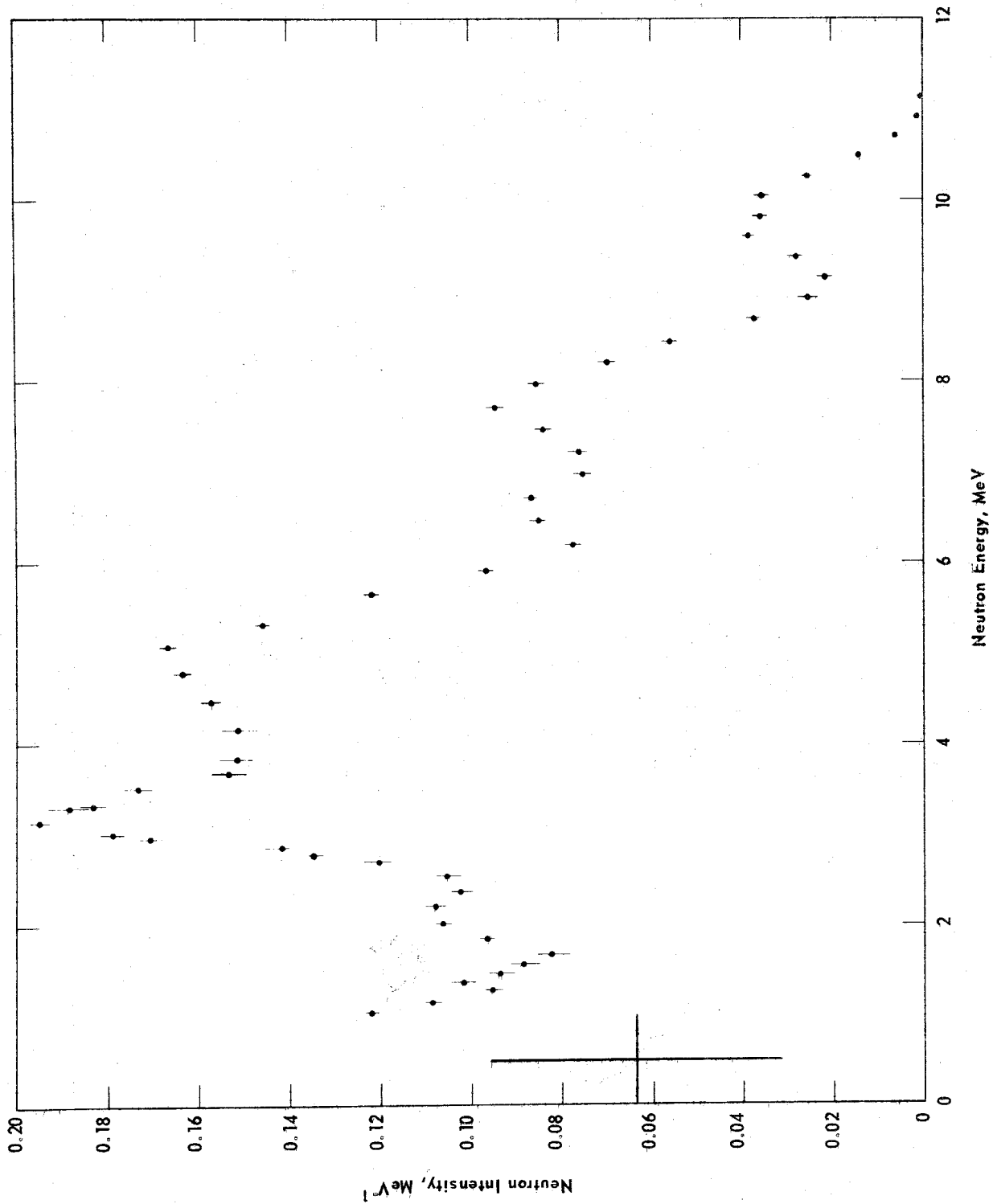


FIGURE 4b - A linear plot of Figure 4a.

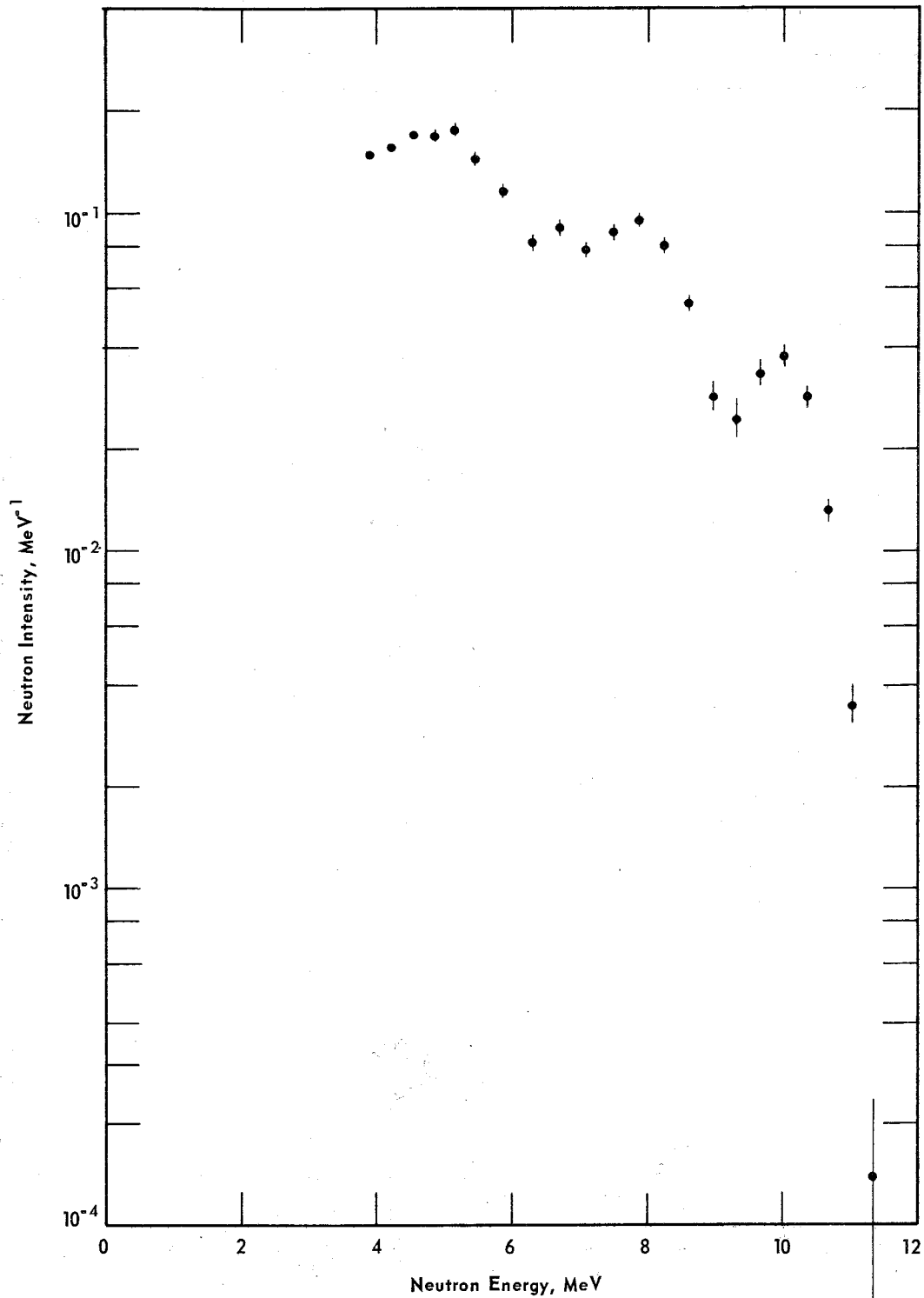


FIGURE 5 - Partial neutron spectrum obtained at a source-detector separation of 60 cm for use in the difference calculation to obtain the fraction of the spectrum with energies <1 MeV shown in Figures 4a and 4b.