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ABSTRACT

Activation detectors employing the $^{207}Pb(n, n')^{207}Pb^m$ and the $^{90}Zr(n, n')^{90}Zr^m$ reactions have been calibrated for 2.50-MeV neutrons. The calibration was affected by saturating the activities with neutrons from an accelerator employing the $^2H(d, n)^3He$ reaction at 200 keV. The neutron production rate was calculated from the measured proton production rate due to the associated $^2H(d, p)^3H$ reaction. The results show that the Zr detector is slightly more efficient than the Pb detector, but that neither is useful for 2.50-MeV pulsed neutron sources yielding less than about 2×10^7 neutrons per pulse.

1. INTRODUCTION

In a previous paper[1] we have described a high-efficiency fast-neutron activation detector for 14-MeV pulsed neutron sources. This detector produced $^{207}Pb^{m}$ principally through the reaction $^{208}Pb(n, 2n)^{207}Pb^{m}$, which has a threshold at 7.38 MeV. The yield is augmented to a slight extent by the reaction $^{207}Pb(n, n')^{207}Pb^{m}$, which has a threshold at 1.64 MeV. We have recently examined, for 2.50-MeV neutrons, the efficiency of this detector, and of a similar one employing the $^{90}Zr(n, n')^{90}Zr^{m}$ reaction, whose threshold is at 2.35 MeV. Both of these isomers have half-lives of about 0.8 second, and can be produced free of contaminating decays. Although these detectors would be expected to have excellent energy discrimination, they would also be expected to have rather low efficiency, as indicated, for example, by the cross section data in reference 1.

2. DETECTOR DESCRIPTION

The detector consisted of a fluor encased in the material to be activated, and was constructed essentially as described in reference 1. Four specific configurations were actually used in the experiment: one in which both the front slab and the cylindrical shell were composed of 1-inch thick steel (Fe+Fe); one in which the front slab was 1-inch thick lead, and the cylindrical shell was steel (Pb+Fe); one in which the front slab was 2 1/8-inches thick reactor-grade zirconium, and the cylindrical shell was steel (Zr+Fe); and one in which both the front slab and the cylindrical shell were composed of lead (Pb+Pb) as specified in reference 1. An exploded view of one of the detectors is shown in fig. 1.

3. PROCEDURE

The Livermore Insulating-Core Transformer Accelerator was used to provide neutrons of known energy and intensity with which to calibrate the detectors. The accelerator employed the $^{2}H(d,n)^{3}He$ reaction at an incident deuteron energy of 200 keV. A solid-state detector, mounted at 90° to the titanium-deuteride target, was used to monitor protons from the associated $^{2}H(d,p)^{3}H$ reaction, from which the total neutron production rate was easily calculated.[2] Each detector was calibrated at several distances from the target, as measured to the face of the front slab, and at an angle of 90° to the incident-beam direction. The latter angle is significant, since the neutron energy varies between 2.05 and 3.06 MeV as a function of angle. The gain of the scintillation system was arbitrarily prescribed, but very reproducibly so, using a ^{133}Ba source as described in reference 1. As a convenience, the same net count from the ^{133}Ba source was required of all four detectors, although this resulted in a slightly different gain setting in each case.

A simplified block diagram of the electronics is shown in fig. 2. A multichannel pulse-height analyzer with a multiscaler capability, served two functions during the experiment. The first involved recording the time-decay spectrum of the activity being counted, in order to insure that no interfering decays were present. The second involved monitoring the pulse-height spectrum from the solid-state detector to insure that the peak due to ^{3}H, which was present in the spectrum in addition to ^{1}H, was effectively removed by the biased amplifier, and therefore was not being counted.

The sequence of events was to turn on the accelerator, wait a few seconds until the accelerator became stabilized and the activity of interest was essentially saturated, turn on a clock-controlled scaler to count the proton current for 10.00 seconds, and, finally, turn off the accelerator. The latter was accomplished by changing the arc bias on the duoplasmatron ion source situated at high potential, following which the beam current decayed away within a few microseconds. A pulse was produced coincidently with the turning off of the accelerator, and this pulse was used to turn on another clock-controlled scaler which counted the detector activity for a period of 2.40 seconds. The delay between the beam-off pulse and the turning on of the scaler was approximately 5 milliseconds. Several such cycles were added in order to accumulate good statistics.

4. RESULTS

The neutron production rate was determined from the 10-second proton count, N_p, by means of the formula

$$I_n = (4\pi/\Delta\Omega)R_{d,p}(Y_{d,n}/Y_{d,p})N_p/10.$$

The constants, excepting for the solid-state detector geometrical efficiency factor $(4\pi/\Delta\Omega)$ were taken from reference 2. The equivalent neutron yield from a pulsed neutron source was then computed from the formula

$$S = I_n T.$$

The mean life T, in each case, was determined by the best weighted least-squares fit to the observed decay, using the digital computer code SUPERFRENIC. The corresponding values for the half-lives are 0.835±0.048 second for $^{90}Zr^m$, and 0.837±0.028 second for $^{207}Pb^m$. No decay was observed with the (Fe+Fe) detector, nor was any expected.

In the case of the (Zr+Fe) detector, the net 2.40-second count was only 8.2-26.4% of background, depending on the distance from the target. A very high background was experienced during the experiment, e.g., 1900-3100 counts per second for the (Zr+Fe) detector, whose principal source was the activation of the accelerator components owing to earlier prolonged exposure to 14-MeV neutrons. By comparison, normal laboratory background is only about 60 counts per second. The calculated detector calibration factors in neutrons per count are plotted in fig. 2. Also shown is the approximate calibration that might result from a (Zr+Zr) detector, on the basis of the observed ratio between the (Pb+Pb) and the (Pb+Fe) detectors. It is evident that the $^{207}\text{Pb}^{m}$ detector is somewhat less efficient than the $^{90}\text{Zr}^{m}$ detector, and that most likely neither one is useful in its present form with 2.50-MeV pulsed neutron sources yielding less than 2×10^{7} neutrons per pulse.

REFERENCES

1. L. Ruby and J. B. Rechen, Nucl. Instr. Methods 15, (1962) 74.
2. L. Ruby and R. B. Crawford, Nucl. Instr. Methods 24, (1963) 413.

FIGURE CAPTIONS

Fig. 1. Exploded view of detector.

Fig. 2. Simplified block diagram of electronics.

Fig. 3. Calibration factors versus distance to the neutron source.

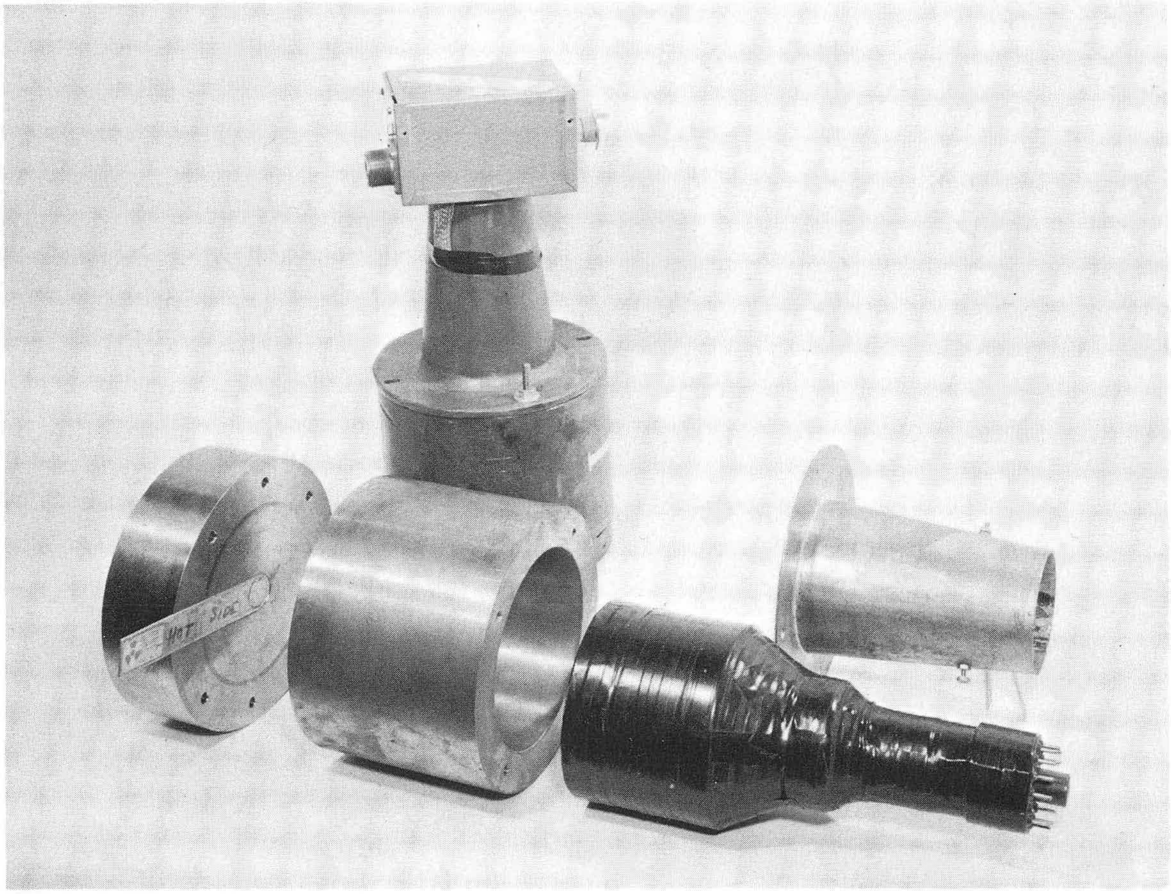

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Fig. 1

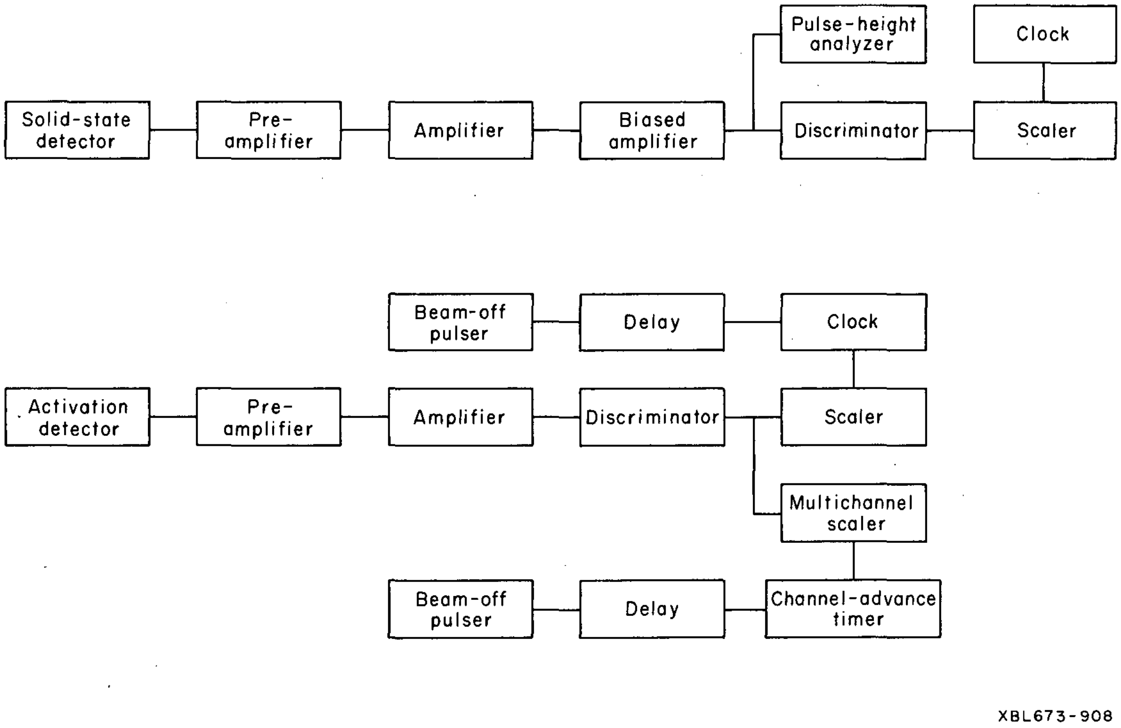
Pulse-height analyzer
Clock
Solid-state detector
Pre-amplifier
Amplifier
Biased amplifier
Discriminator
Scaler
Beam-off pulser
Delay
Clock
Activation detector
Pre-amplifier
Amplifier
Discriminator
Scaler
Multichannel scaler
Beam-off pulser
Delay
Channel-advance timer
XBL673-908

Fig. 2

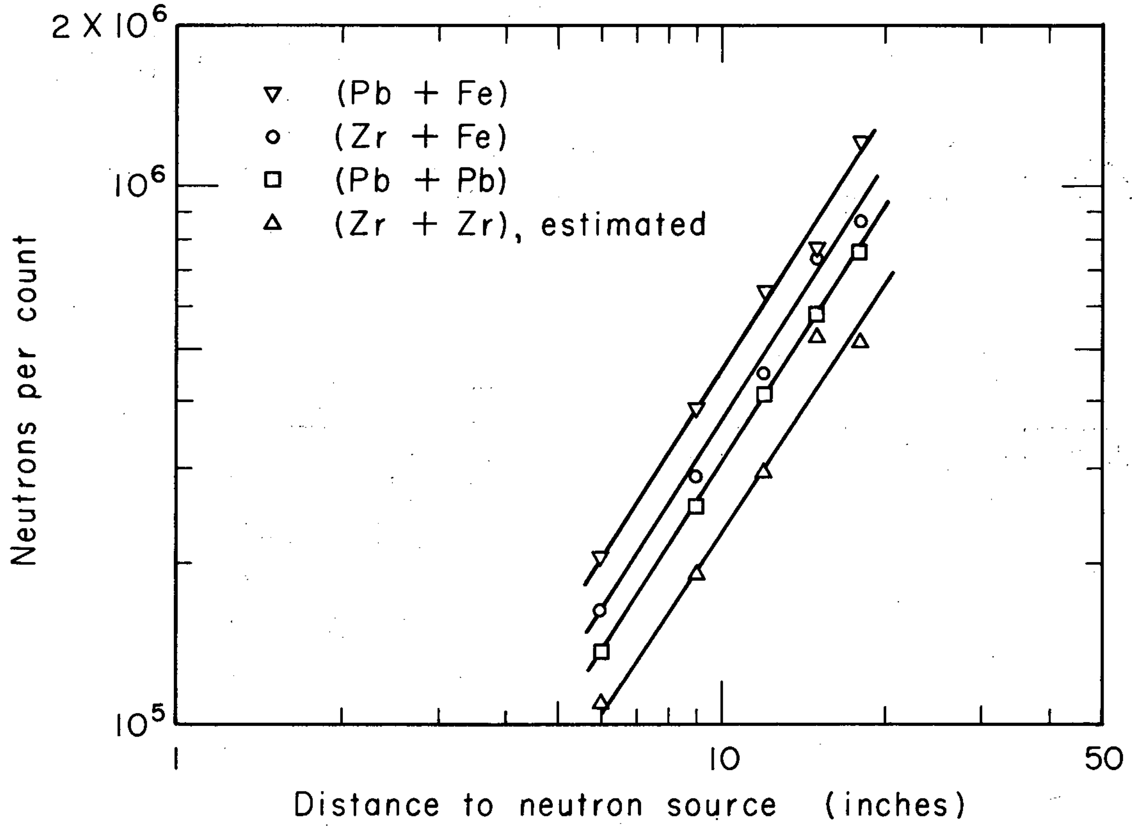

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Fig. 3