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ATOMIC ENERGY COMMISSION

PROPORTIONAL FISSION NEUTRON COUNTERS* †

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ABSTRACT

Some proportional fission neutron counters are described with information on methods of preparation and details of a circuit for a portable model. The portable instrument has an efficiency of .01% for neutrons from polonium beryllium sources.

INTRODUCTION

Several proportional fission neutron counters have been built in this laboratory which have a coating of a uranium compound on the inside walls of the cathode. Neutrons are detected by observing uranium fission pulses. Slow neutron counters use enriched material while fast neutron counters use depleted material.

Fission neutron counters of various designs have been reported (1-5).

Most of these counters use a uranium compound as the neutron sensitive material, but in general, they operate as ionization chambers. A

* This is a revision of report K-497 issued August 1, 1949

† This document is based on work performed for the Atomic Energy Commission by Carbide and Carbon Chemicals Company, Union Carbide and Carbon Corporation, at Oak Ridge, Tennessee.

1. Bright, W. C., "Spiral Fission Chambers," MDDC-91.
2. de Hoffmann, F., B. T. Feld, O. R. Frisch and P. R. Stein, "Delayed Neutrons From U-235 After Short Irradiation", AECD-1971.
3. Hyde, G., C. G. Blanchard, A. E. Cameron, "Neutron Detection By Fission Counting", B-6.480.2, Clinton Engineer Works, Tennessee Eastman Corporation Report.
4. Rossi, B. and H. Staub, "Los Alamos Section of the National Nuclear Energy Series, Manhattan Project Technical Series, Vol. I, Experimental Techniques, Part II, Ionization Chambers and Counters."
5. Richards, H. T., "The Use of Thorium as a Threshold Detector For Fast Neutrons," LA-19.

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discriminator is required because of the alpha activity of uranium. The counters to be described differ in that they operate in the proportional region, allowing a simpler, more rugged and portable electronic circuit to be used.

FAST NEUTRON COUNTER

A fast neutron counter was built using nearly isotopically pure U-238 oxide as the sensitive surface. The uranium oxide was electroplated onto a nickel tube approximately one inch in diameter and six inches long. The thickness of the coating was about one mg/cm². Electroplating methods have not produced adherent films of thicknesses much greater than this.

Kovar to glass seals designed to have a long leakage path were used to bring in the leads to the counter. The tube was filled with argon gas to a pressure of about 40 cm. of mercury and sealed off.

The smallest neutron flux for which the counter was tested was about 6×10^4 neutrons/cm²/sec. This flux was easily detected. The tests were made with a Po-Be source which gives neutrons with energy ranging from 1/2 MEV to 11 MEV and averaging about 5 MEV (6).

The main advantage of a counter using depleted material is that the threshold detection energy is 1.0 ± 0.1 MEV (7). Response to thermal neutrons is less than 1% of that for neutrons of 1-1/2 MEV or greater. For neutrons of intermediate energies up to 1 MEV, this figure is considerably less than 1%.

SLOW NEUTRON COUNTERS

A slow neutron counter was prepared in a manner similar to the counter just described. This counter used enriched U-235 oxide as the sensitive material. The plated cylinder in this counter was placed in a glass envelope with the necessary leads introduced through glass to metal seals. It was found necessary to enclose the tube in a boron free glass envelope, since glass containing boron reduced the efficiency of the counter by a large factor. This counter was submitted to a rough test

6. Anderson, H. L., "Neutrons From Alpha Emitters", Preliminary Report No. 3, Nuclear Science Series, National Research Council (December, 1948).
7. Shoupp, W. E. and J. E. Hill, "Thresholds for Fast Neutron Fission in Thorium and Uranium", Phys. Rev. 75, 785, (1949).

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and found to have an efficiency of about $9 \times 10^{-4}\%$. Percent efficiency as used here is defined to be the number of neutrons detected by the counter, divided by the number of neutrons which pass through the counter and multiplied by 100. The smallest flux for which the counter was tested was one of 14000 neutrons/cm²/sec. This flux was easily detected at a rate about 15 times the background count.

Since the plated coating of the counter just described was only 1 mg/cm², it was believed that the efficiency of this counter would be improved considerably if a heavier coating could be applied. The thickness for which a fission fragment can just escape through the entire thickness of the coating is about 5 mg/cm². This "saturation thickness" could not be obtained by the available electroplating methods.

Some experiments were performed in an effort to determine the properties of an evaporated layer of uranium tetrafluoride. The compound was found to be easily evaporated and to yield a uniform, strongly adherent film. Further experiments proved that a coating of 5 mg/cm² could be obtained on the inside of a one-inch brass cylinder about six inches long.

The filament used for the evaporation was a strip of 1 mil tantalum sheet about four inches long and 1/2 inch wide formed into a boat. The tantalum strip was attached to heavy copper rods and mounted on insulators so that the filament was on the axis of the cylinder.

The brass cylinder to be coated was mounted on a set of bearings, one on each end, which held the cylinder rigidly in place. A chain and sprocket arrangement connected the cylinder to a Telechron 4 RPM clock motor which enabled the cylinder to be rotated during the entire period of the evaporation. The bearings were lubricated with a small amount of silicone grease which prevented binding at higher temperatures. The clock motor was encased in a brass housing to prevent serious outgassing problems when it was placed in the vacuum chamber.

The counter was assembled using standard copper tubing fittings and specially designed Kovar-glass seals having a long leakage path. The central wire was a 3 mil electropolished tungsten wire which was spot-welded to the Kovar leads. One insulator was pushed in while the other end was spotwelded and the two insulators were then adjusted until the central wire was taut and were then soft soldered.

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The finished tube was filled with argon to a pressure of 50 cm. of mercury and tested. It was found to have an efficiency for slow neutrons of about .01%. This is a factor of 10 over the counter with the lighter coating. A flux as small as 10 neutrons/cm²/sec. was detected at a rate of twice background.

The high voltage supply for the counter consisted of two 300 volt batteries in series. The signal was passed through a three tube pre-amplifier, cathode follower, two tube high level amplifier, cathode follower, discriminator, polarity inverter and finally to the scaler.

Since the use of enriched uranium 235 involves the presence of a large number of α particles, the discriminator circuit is necessary. By operating the counter in the proportional region, the fission pulses average very much larger than the α pulses. The discriminator level was set at four times the average α pulse height. There are enough α particles so that an occasional pile up of α pulses occurs and gives a large pulse, but the occurrence of such a pulse greater than four times the α pulse height is extremely rare.

These tests were performed with a paraffin moderated polonium beryllium source.

PORTABLE CIRCUIT

The equipment used in the tests described above was suitable only for fixed installations. A portable instrument to provide an indication of the neutron flux in general survey work was deemed desirable. Requirements for such an instrument included a discriminator circuit to block out the α pulses produced and an indicating rate meter.

The circuit developed was a five stage device consisting of an inverter, a discriminator, a second inverter and a multivibrator. Sub-miniature tubes CK 571 AX and CK 512 AX were chosen because of their small physical dimensions and tube characteristics such as low current drain and relatively high amplification factor. The circuit diagram is shown in Figure 1.

The detector tube may be encased in a two inch paraffin envelope to thermalize some of the incident fast neutrons. The tube operates with a positive potential of 600 volts applied to the central wire with the outer brass cylinder held at ground. Pulses are developed across the 10

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megohm resistor in series with the high voltage battery supply. These pulses are negative and need to be reversed in polarity before they reach the discriminator. The first stage provides an amplified signal of the proper polarity to the discriminator grid. The grid of this input stage is protected from the high potential that is on the center wire of the detector by means of a high voltage 20 μ f coupling capacitor. The second stage is biased well beyond cutoff when only the signal due to the α pulses is applied. Occasional pile up alpha pulses are barely detected in the plate circuit. Under this condition, fission pulses readily drive the tube into conduction producing large negative pulses on the plate. The third stage inverts the pulses from the discriminator and couples them to the grid of the first stage of the multivibrator (8). The final two stages make up a one kick multivibrator which operates statically with the first tube cut off and the second conducting.

When a positive pulse initiates the multivibrator action, a constant plate current flows through the meter and charges the shunting capacitor for a period of time determined by the grid leak resistors and coupling capacitors. The time constant can be changed by varying the value of the coupling capacitor. This variability provides the increased range of the rate meter. After the multivibrator has returned to static condition, the charge developed across the 500 μ f capacitor leaks off slowly through the meter and the series 25,000 ohm resistor. The time constant of the meter circuit is such that the current through the meter is proportional to the rate at which pulses are coupled to the multivibrator.

With the low voltage supplies on, the plate load resistance of the first stage of the multivibrator is adjusted to provide a reasonable plate current. This varies with individual tubes and the adjustment is only necessary when the tubes or tube characteristics are changed. The bias of the first multivibrator stage is adjusted for cutoff and acts as a zero adjustment for the rate meter. The high voltage is then turned on and the discriminator bias adjusted so that the meter indicates a small deflection on the low range scale. This signal is due to pile up alphas and is taken as background.

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8. The third and subsequent stages of the circuit are essentially the same as the portable alpha detector circuit developed by Mr. Clyde Warram of the Instrument Engineering Department.

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Operation. The portable model was tested with a polonium beryllium source of about 0.1 millicurie strength. The source was encased in a paraffin cylinder having 1 inch wall thickness. With a background of 0.5 microamperes on the low range scale the instrument detected a flux of 11 neutrons/cm²/sec at twice background. This is comparable to the tests made with laboratory equipment. The fast neutron tolerance flux of 200 n/cm²/sec. gave a reading of about 8µa on the rate meter. The calibration curve is given in Figure 2. Full scale deflection on the low scale represents a flux of 670 neutrons/cm²/sec. On the high scale, a full scale deflection represents 1600 fast neutrons/cm²/sec.

The instrument has operated satisfactorily as a neutron detector in laboratory tests. A 10 mg radium source 2-1/2 inches from the tube shows no effect on the rate meter. The circuit is stable and insensitive to normal shocks expected in handling portable instruments. A period of one minute is required for each reading. A reset button enables the operator to read lower level radiation without waiting for the charge to drain off the shunting capacitor. The battern life of the experimental model is 600 hours. The model measures 5" x 10" x 26" and weighs 21 pounds with the paraffin around the tube.

In a field test, the instrument performed satisfactorily in mapping neutron intensities near equipment embodying shielded sources of 1, 2 and 5 grams of radium beryllium. It is felt that physical dimensions and weight might be reduced in other models without sacrificing any of the desirable electrical characteristics.

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FIGURE 2

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