Title
LOW CAPACITY GIANT FISSION IONIZATION CHAMBER

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ABSTRACT

An ionization chamber for the detection of neutrons with an energy greater than 50 Mev is described. A special electrode and circuit arrangement is employed to avoid high capacitance with large plate area.

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I. INTRODUCTION

Various types of fission ionization chambers have been built for the detection of neutrons. For experiments in which the neutron counting rate with the desired fissionable materials is low, types of detectors have been developed[1] with the object of exposing large areas of fissionable material to the neutrons. Bismuth, which has a fission threshold of about 50 Mev [2] and a cross section of 30 millibarns ($\pm$ 30 percent) for the neutrons of mean energy 90 Mev resulting from the stripping of 190 Mev deuterons with a 0.5 in. Be target, has been extensively used for monitoring the high energy neutron beams produced by the University of California 184-inch cyclotron. A multiple plate bismuth fission ionization chamber[3] having a capacity of 100 $\mu\mu$f (measured) and a total bismuth surface area of 570 cm^2 has proved successful in experiments here. The detection efficiency of a chamber of this type having 30 surfaces with 1.5 mg/cm^2 of bismuth is about 3.5×10^{-6} for a 90 Mev neutron.

A fission chamber having a bismuth surface area greater by a factor of 10 than the above chamber was needed for recent experiments and for surveys of the high energy neutron background occurring outside the cyclotron shielding when the machine is operating.

The usual multiple plate chamber has alternate plates coated on both sides with a thin layer of bismuth and the remaining plates collect the electrons resulting from the intense ionization of fission fragments in the interelectrode gas. A chamber of the same type with a factor of ten increase in the plate area would require greater amplification because of the increased capacitance and might have an unfavorable signal to noise ratio. To circumvent these difficulties a different type of electrode arrangement has been tried and proved successful.

II. DESCRIPTION OF CHAMBER

Nineteen aluminum plates 4 in. x 12.5 in. x 1/32 in. were separated by cylindrical 3/16 in. thick ceramic insulators. Eighteen plates were coated on one side only with a layer containing about 1.4 mg/cm^2 of bismuth. The center plate was uncoated and the other eighteen plates were mounted with their bismuth coated surfaces facing toward the center plate. The coated plates are joined in pairs: plates of equal distance from the center are electrically connected as shown in the schematic drawing Fig. 1. Interelectrode capacity between one plate and its neighbor is about 60 $\mu\mu f$. The electrical paralleling of the plates, of course, doubles the capacity for sets of joined plates. A voltage divider consisting of a series of megohm resistors establishes uniform gradient steps between adjacent plates, with 200 volts between plates representing a good operating condition. The outer plates are grounded and the voltage increases to + 1800 volts at the center plate.

Let us assume that a neutron produces a fission in one of the bismuth nuclei and that the fission fragment ionizes the gas near the bismuth layer. If electrons are formed and travel the distance d across the gap, the drop in voltage between the plates is $\frac{q}{2C_i}$ (since plates are paired) where C_i is the capacity between adjacent plates. Since the collecting time of the electrons is less than a microsecond and the time constant of the paired cells, $2RC_i$, is over 100 μseconds, this voltage drop is communicated to the center plate. In other words during the rise time of the pulse the paired plates appear as a series of parallel plate condensers charged to a given voltage and the drop in voltage in one of the condensers due to a partial discharge causes an equal drop across the entire series between the center plate and ground. The pulse is coupled to the preamplifier by a 1000 μμf condenser connected to the center electrode. The particular geometry chosen has little stray capacity from the center plate to ground. Grounding the outer plates simplified mounting the assemblage. Pairing of plates results in a series of nine condensers of individual capacity $2C_i = 120$ μμf and series capacity $C_s = 2C_i/9$.

Another way of looking at the problem is as follows. The series has a total gas gap of 9d, but the electrons can only cross one interelectrode distance d. The drop in voltage occurring is $\Delta V = \frac{q}{C_s} \times \frac{1d}{9d} = \frac{q}{2C_i}$. The intervening plates propagate the pulse by charge induction to the center electrode. As the series capacity, $2C_i/9 = 13.3$ μμf, is still fairly large compared to the grid input capacity of the first amplifier tube (4 μμf), many more stages could be added before low series capacity became a limiting factor.

The series resistors comprising the voltage divider are mounted on a lucite plate at one end of the plate assemblage and are beneath the end cover plate; so only one Kovar seal is required to bring the filtered high voltage to the divider and to deliver the pulse to the coupling condenser. Six teflon rods, threaded on both ends, hold the plate assemblage together. Brackets down the sides of the grounded plates suspend the assemblage from the cover plate (Fig. 3).

III. OPERATING CONDITIONS

Since the fission fragments leaving a bismuth layer have a spread in energies due to the ionization loss in the layer before reaching the surface, a "discriminator curve" of the counting rate versus bias must be examined. A chamber with bismuth layers greater than the range of the fission fragments will not have a plateau since fragments from zero to the maximum energy will emerge from the layer. Unfortunately the new chamber has no pulse distribution plateau even though the average bismuth thickness is only one-quarter of the fragment range; so the chamber cannot be absolutely calibrated in terms of a plateau counting rate. This lack of plateau may be partly due to the spray technique of coating the plates, which results in non-uniform layer thicknesses. For a gain of 200,000 the counting rate varies about 7 percent per discriminator volt. The discriminator was set at 60 volts and "pileups" of proton and alpha pulses were negligible at a counting rate of twenty fission counts per second.

A mixture of 96 percent argon and 4 percent carbon dioxide at a pressure of one atmosphere has been used to fill the chamber. The gradient between adjacent plates is about 400 volts/cm at normal operating conditions and the electron collection time should be of the order of 0.2 microsecond. An amplifier time constant of 2.0 microseconds is used to suppress "pileup" of non-fission pulses.

To test how well the counter behaved as an ionization chamber the high voltage on the chamber was varied from 0.75 to 4.0 kv with the chamber in the 90 Mev neutron beam. The variation of the counting rate with voltage is shown in Fig. 2. The counting rate was practically constant from 1.5 to 3.0 kv. At 2.2 kv the potential between adjacent plates is 200 volts and 0.2 ma. current is drawn from the high voltage supply. Above 3.0 kv the Glassmike filter condensers "leak" across their exterior surfaces, especially during damp weather, and these discharges increase the observed counting rate. After cleaning the condensers with isopropyl alcohol the plateau is extended beyond 3.0 kv.

IV. COATING OF PLATES WITH BISMUTH

Previously fission chambers constructed at the Radiation Laboratory were plated with bismuth by evaporation in an evacuated system. The size of the present plates made evaporation with the system previously used impractical so a technique developed by A. Redmond was employed. A solution containing 75 g bismuth nitrate, 1000 m.l. acetone, 500 m.l. acetic acid, and 30 m.l. zapon was sprayed on the surface with a painter's spray gun. Each plate was sprayed about a dozen times to obtain the desired thickness of bismuth. The plates are heated to 400° for several minutes to drive off the solvents and to decompose higher oxides of bismuth. Bi_2O_3 remains and its characteristic yellow color is readily recognized. The oxide adheres very well to the plates - washing with isopropyl alcohol failed to remove any of the oxide. Some spray accidentally coated the back edges of a few of the plates and the oxide was finally removed by abrasion.

An average amount of 0.485g per plate was deposited with extremes of 0.530g and 0.405g. The total amount of oxide on the plates is 8.74g Bi_2O_3 or 7.84g of bismuth, and the average thickness is 1.53 mg/cm^2 Bi_2O_3 or 1.37 mg/cm^2 bismuth.

This development was performed under the auspices of the A.E.C. Thanks must be given to A. Redmond who developed the plating technique and directed the spraying operation, to W. Knox who assisted in the chamber assemblage, and to Dr. B. J. Moyer who encouraged the development of a "large" chamber.

Information Division
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V. REFERENCES

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2. E. Kelly and C. Wiegand, Phys. Rev. 73, 1135 (1948)

3. C. Wiegand, Rev. Sci. Instruments 19, 790 (1948)

4. J. DeJuren and N. Knable, Phys. Rev. 77, 606 (1950)

FIG. 1
SCHEMATIC DIAGRAM OF CHAMBER

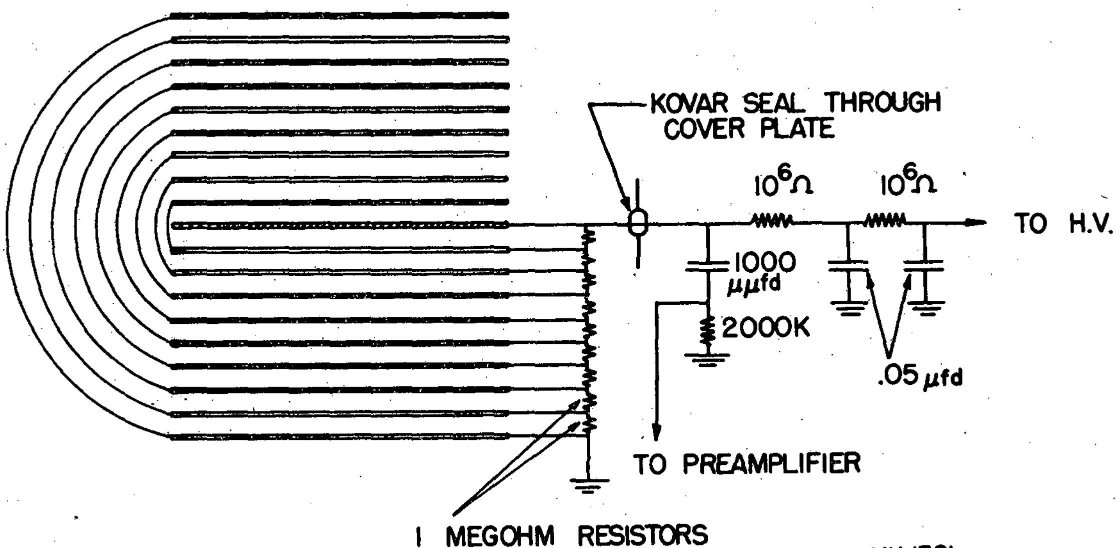

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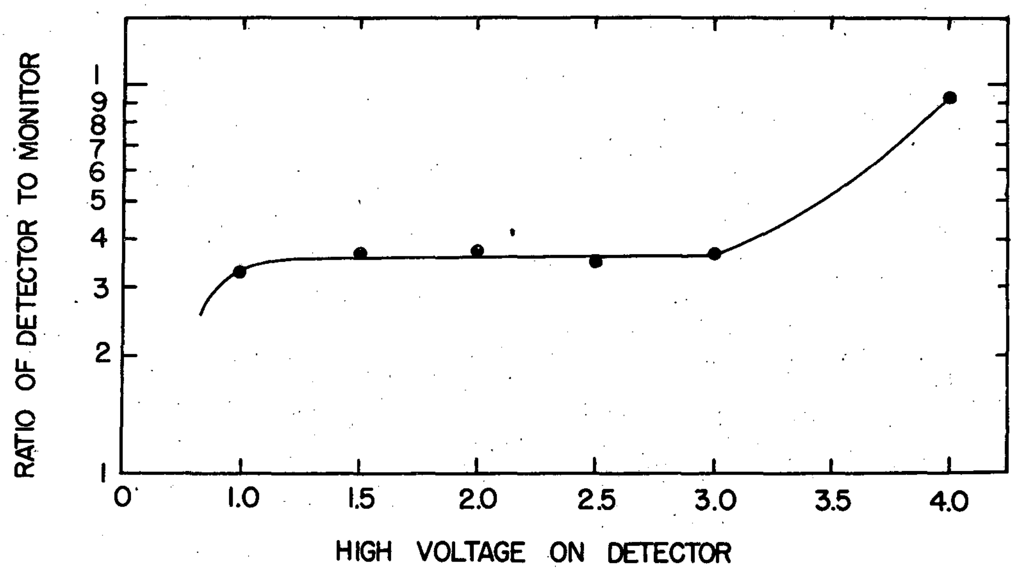
FIG. 2

VARIATION OF BISMUTH FISSION CHAMBER COUNTING RATE AS A FUNCTION OF HIGH VOLTAGE



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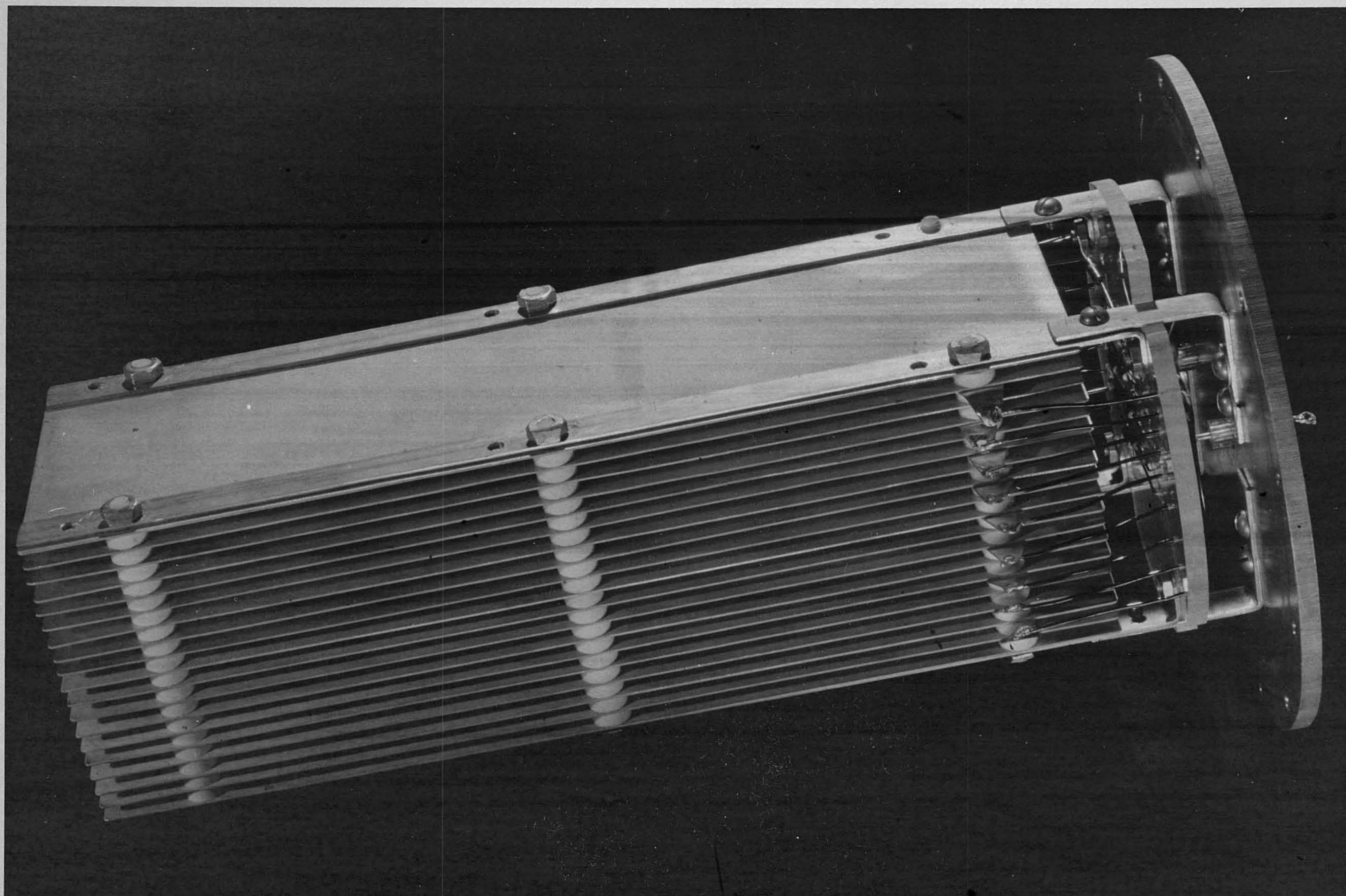

FIG. 3 BISMUTH FISSION CHAMBER ASSEMBLAGE

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