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ABSTRACT

A pulsed neutron generator has been developed which employs an Orbitron ion source, and is capable of producing 10^8 neutrons in pulses of 3 μsec. The ion source, which is unusually simple in design, requires no magnet and operates at pressures as low as 3μ. Operating characteristics have been determined for a 3-in.-diam tube in which deuterons are extracted radially from the ion source.

Introduction

Several designs of pulsed neutron sources of a small self-contained tube variety have appeared in the last few years[1-8]. As an ion source, one of these employs a novel spark-type device[1], and the others use some form of gas discharge. The occluded-gas spark source has the inherent disadvantage, for some applications, of a varying shot-to-shot intensity and a relatively short lifetime. Gas-filled tubes, on the other hand, produce uniform shot-to-shot neutron pulses, have lifetimes of several hundred thousand shots, and in some cases can operate dc.

In a sealed-off gas-filled neutron tube, the ion source operates at the same pressure as the accelerating gap. This pressure must be high enough to allow appreciable ionization, yet low enough to prevent an arc discharge. In general, this pressure range extends from 1 to 20 μ. To produce appreciable ionization at such low pressures, the effective path length of the electrons must be extended far beyond the linear dimensions of the ion source. This is usually done by trapping the electrons in crossed electric and magnetic fields. The use of an electromagnet adds appreciably to the size, weight, and power requirements of the system.

This report describes a gas-filled neutron source which operates at 3 to 15 μ pressure without the use of a magnetic field. Long effective electron path lengths in the ion source are obtained by radial trapping of electrons in orbits between a cylinder and a positive coaxial wire, and by axial reflection at the nearly closed ends of the cylinder. This type of ion source, called an "Orbitron", was investigated previously by McClure[9,10], Rupf[11], and Mourad et. al.[12]. R. H. Hooverman has made a theoretical study of the electron orbits in the Orbitron[13].

Description of the Tube

Several different tube geometries have been investigated, all of which involved radial extraction from the source. The version to be described is a compromise with respect to suitable size, voltage holdoff, and operating pressure.

The Orbitron ion source is located coaxially within the target cylinder (see fig. 1). The Orbitron consists of a 2-in.-long, 1-1/2-in.-diam cylinder closed at each end, along whose axis runs a 0.008-in. tungsten wire. The wire passes through 0.090-in. holes in each end of the cylinder. The wire is centered in each end-hole by further passing through a 0.010-in. hole in a Kovar disc which is brazed to a ceramic insulator and centered on each end of the Orbitron cylinder. Sixteen slots, each 1/16 by 1-3/4 in., are cut longitudinally around the Orbitron cylinder for radial ion extraction. The Orbitron is supported inside the neutron tube by an extension cylinder connecting it to the pumpout flange. The axial wire is connected electrically by means of a lead down the center of the extension cylinder and a ceramic feed-through in the pumpout flange. The gas inlet and a Pirani gauge are also attached to the pumpout flange. In a completely sealed-off version, the gas inlet would be replaced by the usual internal gas reservoir[2,3].

The target consists of tritium absorbed in a titanium film which has been evaporated on the inside of a 3-in.-diam. Kovar cup. Photographs of the tube showing the Orbitron and target before and after assembly are shown in fig. 2. The two flanges are designed to be heliarced together.

Operation of the Tube

The Orbitron ion source is pulsed by a thyratron and pulse-line combination. It operated in either of two modes, with a distinct transition between them. One is characterized by a high impedance and can occur at low pressures, of 0.1 μ and lower, and within a range of impressed voltages from 2 to 14 kV. Currents of a few milliamperes, depending on pressure, are common. The other mode, of much lower impedance, sets in at a rather sharp lower pressure limit. This lower pressure limit is a function of geometry, and will be discussed later. The low-impedance mode is characterized by arc drops of 500 to 1000 V, and currents of 5 to 30 A, depending on the external driving-circuit impedance, voltage, and tube pressure. The Orbitron can operate dc at the low-current mode. The pulse length is limited in the high-current mode by heating of the central wire. As a high-intensity ion source, the high-current mode is of primary interest.

In pulsed operation, the Orbitron always remains for some time in the low-current mode before going over to the high-current condition. This time varies from about 5 to 20 μsec depending on initial voltage and pressure. Higher voltages and higher pressures tend to shorten the time. Typical Orbitron voltage-and current-pulse shapes are shown in fig. 3. The voltage pulse shape is that of an unloaded pulse line until the transition to high current occurs. At this time the pulse line is nearly matched, and proceeds to discharge completely in its characteristic time of 5 μsec, giving a rectangular current pulse. The target is pulsed to high voltage during the high-current portion of the Orbitron pulse, as shown in fig. 3.

Neutron yield was measured at various target voltages and orbitron currents using a Pb-activation detector developed by Ruby and Rechen[14), Representative data are plotted in fig. 4. Neutron yield and target current vary directly with orbitron current for a constant target voltage. Varying the tube pressure throughout the operating range, i. e., 3 to 15 μ, has only a small effect on the operating characteristics. When the pressure is reduced below 3 μ the high-to-low-impedance transition time in the Orbitron becomes erratic, and at still lower pressures the low-impedance discharge cannot be achieved. The upper pressure limit is determined by target high-voltage breakdown. The data presented here were obtained with a tube pressure of 7 μ.

Neutron yields of 10^8 in 3-μsec pulses were obtained consistently with a target voltage of 190 kV, a target current of 30A, and an Orbitron current of 20A. Neutron-yield variation from shot to shot was within the 2% counting statistics of the detector system.

Conclusions

The observed target current of 30A should have produced neutron yields greater than 10^9 per pulse. For even if the most conservative assumptions are made, i. e., pure molecular ions and a secondary-emission coefficient of 7 for the target, there must still exist a real ion current of at least 4A. This would predict a theoretical thick-target yield for the D-T reaction greater than 10^9, based on an assumed 1:1 target-loading ratio. This number might be reduced somewhat by ions formed at intermediate points in the accelerating gap which would not be subjected to the full voltage. However, the number of these ions is thought to be small for the following reasons: The mean free path of electrons at this pressure is many times the gap length. Also, no strong dependence of target current on pressure was observed experimentally, as would be expected if ionization were occurring in the gap.

The quality of the target and extent of loading was not known with certainty, and in this factor probably lies the major source of the discrepancy.

It should be pointed out that the design presented here should not be considered optimum. No attempt has been made to determine the most efficient slit area, and no means of shielding the glass wall from ion bombardment has been provided. Shielding the glass wall would improve its voltage-holding properties, and allow the tube to be shortened considerably. In working with Orbitrons of other sizes, it was found that reducing the cylinder diameter lowers the trapping efficiency, and requires a higher minimum operating pressure. For example, a 1-in. diam Orbitron had a minimum operating pressure of 8μ. This is still low enough to be used in a neutron tube and would allow a smaller overall tube diameter.

Acknowledgments

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FOOTNOTES AND REFERENCES

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FIGURE LEGENDS

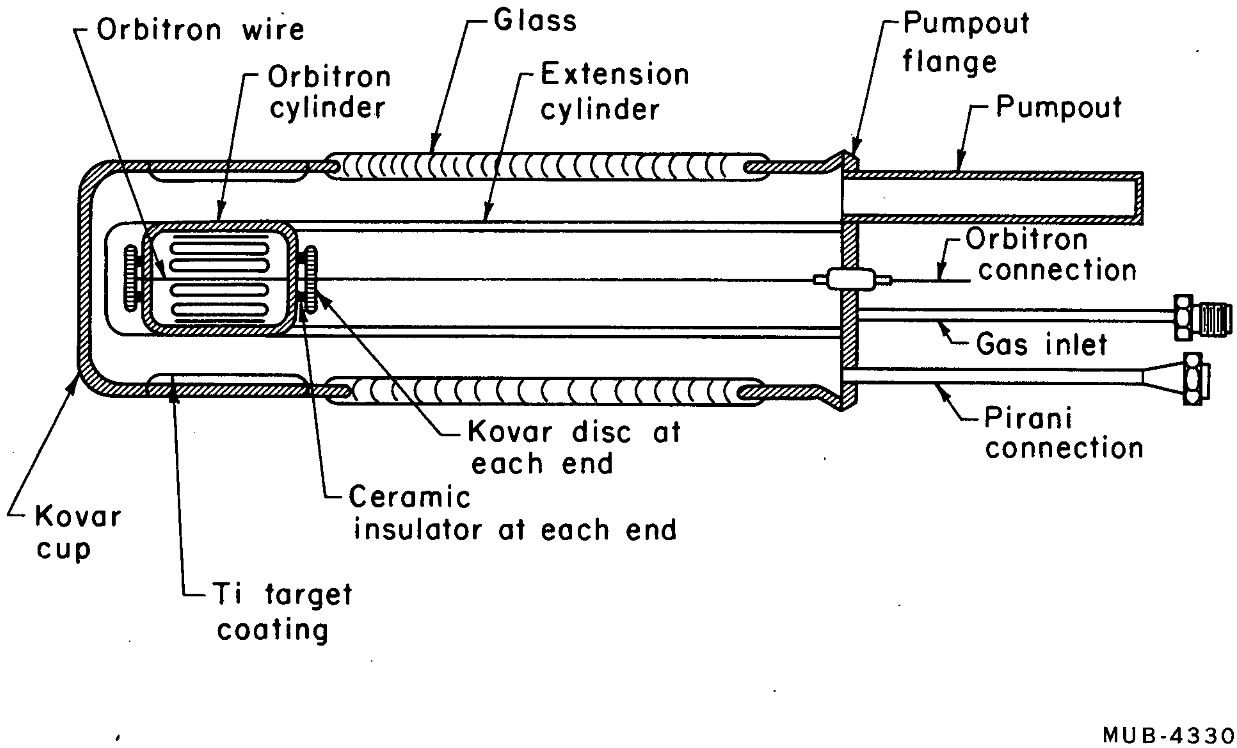
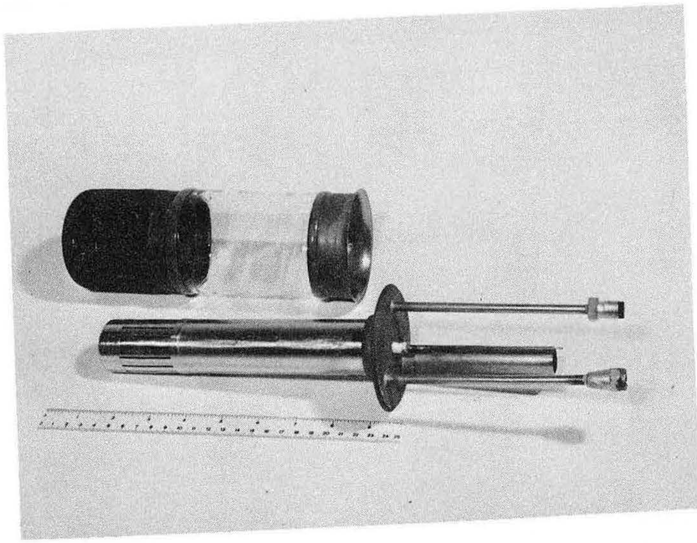
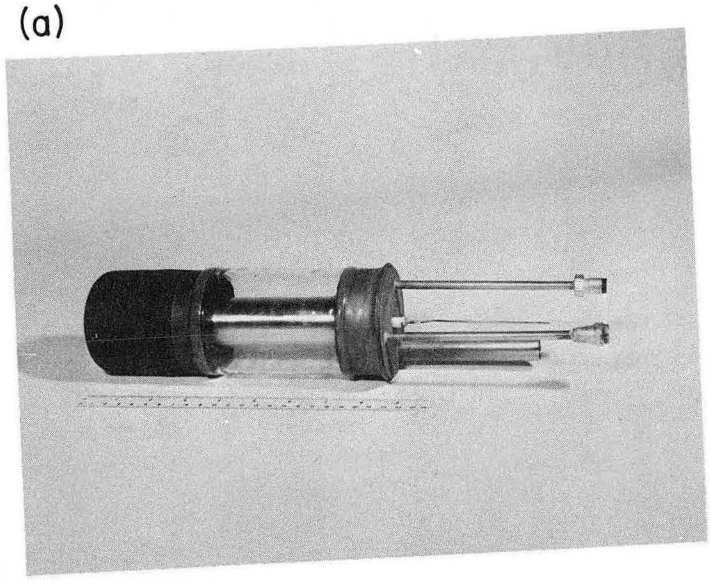

Orbitron wire
Glass
Pumpout flange
Orbitron cylinder
Extension cylinder
Pumpout
Orbitron connection
Gas inlet
Pirani connection
Kovar disc at each end
Ceramic insulator at each end
Kovar cup
Ti target coating
MUB-4330

Fig. 1



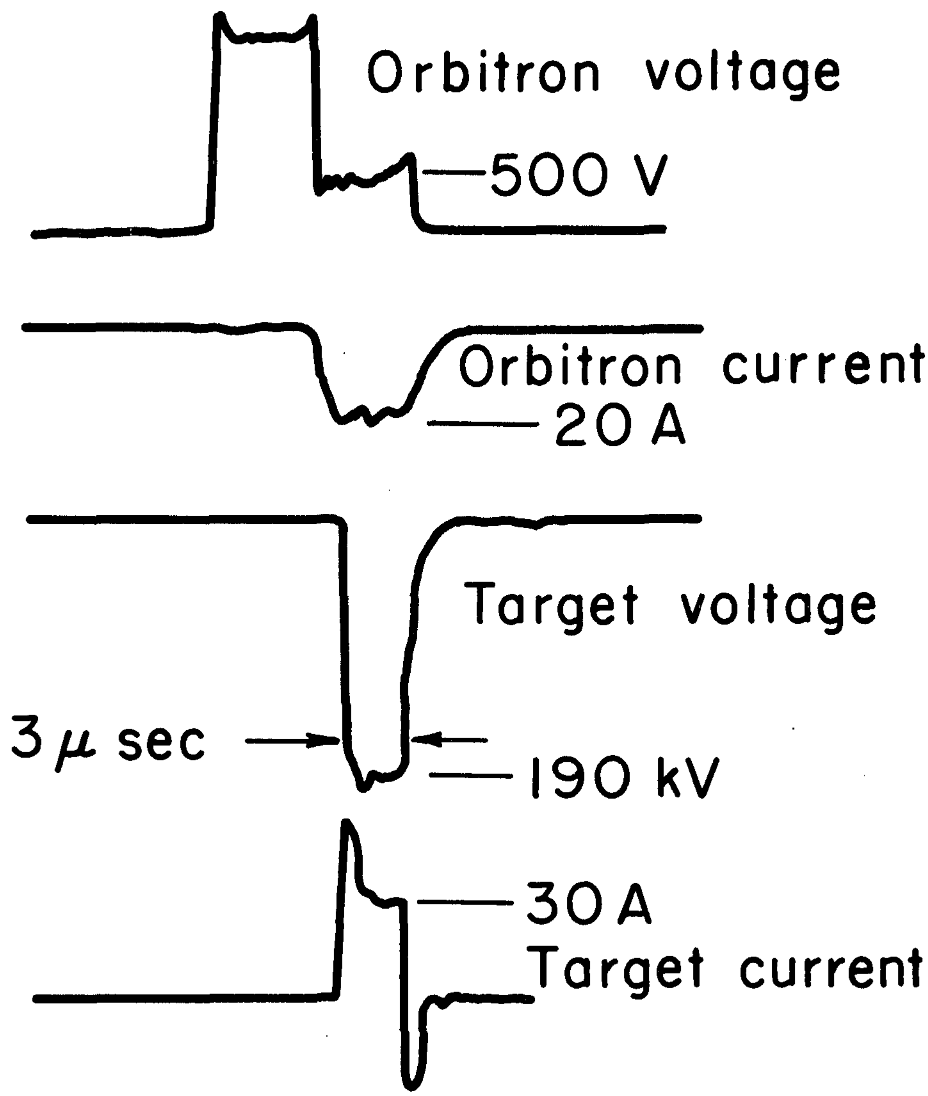
(a)



(b)

ZN-4537

Fig. 2a 2b



MUB-4331

Fig. 3

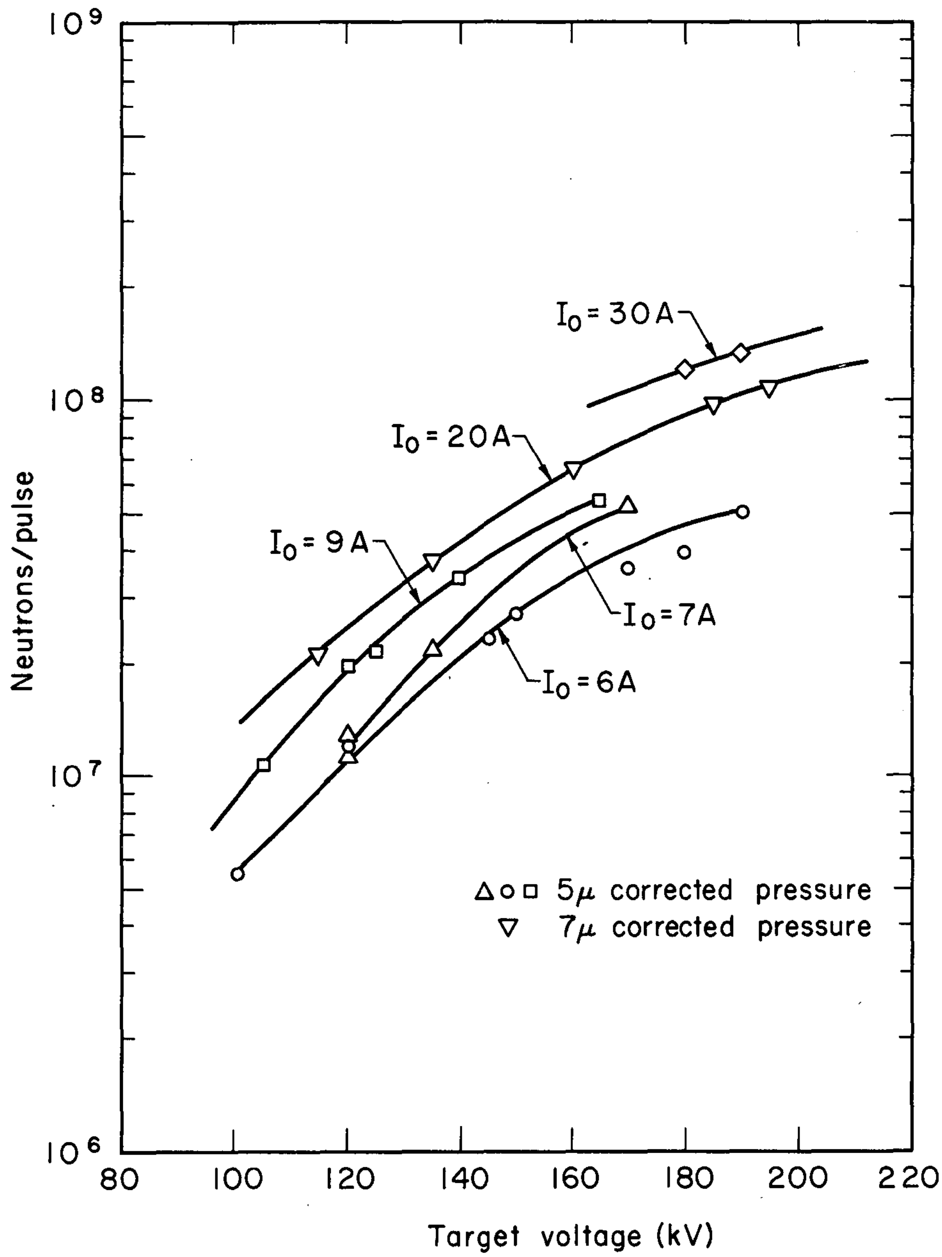


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Fig. 4