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During the last six years, considerable efforts have been made to increase the ion energy in rotating plasma devices.[1] This led, in this laboratory, to the construction and operation of the Homopolar V device,[2] which produces a plasma with Larmor energies of the deuterons in the keV range at densities of 10^{14} to 10^{15} cm^{-3}. Although these energies are considerably lower than the energy of the ions obtained from a Marshall gun,[3] the energy of the ions produced in a rotating plasma device is transverse energy and therefore more desirable for most experiments, such as injection into a mirror machine. Further advantages of using this type of apparatus as a gun are (a) the operation of rotating plasma devices is basically fairly simple and well understood, and (b) due to the fact that particles with high M/Q values are not contained in these machines, they should produce a very clean plasma; this has been confirmed by preliminary investigations.

Since the Homopolar V geometry requires only minor modifications in order to obtain a device that can be used as a gun, we built and will operate in the very near future a device that is schematically represented in Fig. 1. The operation of this apparatus is very similar to the operation of Homopolar V: After the fast capacitor bank is charged, the magnetic-field coils are energized and, at the time of maximum magnetic field, the fast-acting valve at the end of the center electrode releases D_2 into the evacuated machine. According to our experience with the Homopolar V device, the subsequent breakdown can be expected to be so slow (1 to 2 μsec) that it will be possible to keep the voltage between the electrodes essentially constant during the breakdown. This will also result, as we know from Homopolar V experiments, in the production of a rotating plasma with roughly equal energies in Larmor motion and mass rotation. Since the mass rotation will most likely be undesirable for most applications of the gun, it will be possible to eliminate this by crowbarring the machine immediately after the breakdown.

Although the azimuthal magnetic field associated with the discharge current will impart some axial momentum to the plasma as a whole, in general this will not be enough to obtain a reasonable transfer time of the plasma from the valve region to the experiment region. We therefore plan to have a mirror field behind the valve region and the valve region itself located at the preferable gentle mirror slope. We intend to make the magnetic field in the valve region about 10% higher than in the long drift region, thus transforming 10% of the transverse energy into axial energy. With a deuterium plasma having a transverse Larmor energy in the keV range, this should result in axial velocities of the order of 10^5 m/sec, which will be fast enough to obtain reasonable transfer times for most experiments. Another alternative would be to use an initially uniform magnetic field and then pulse on a transfer coil at the proper time and location to provide an additional fast-rising mirror field.

We plan to keep the important parameters of this gun in the same range that has been shown to result in the satisfactory operation of Homopolar V:

(a) The fast capacitor bank supplying the electric field should be reasonably large compared to the hydromagnetic capacity[4] of the gun.

(b) The Larmor radius of the deuterons should not be too large of a fraction of the distance between the electrodes.

(c) The electron density should be large enough to avoid the formation of an anode sheath. It can be concluded from theoretical considerations[5] that this sheath becomes unstable when the plasma frequency is equal to the electron cyclotron frequency. Although, under certain circumstances, this instability might appear at lower densities, we always keep the density high enough to satisfy the former condition to ensure the breakdown of the anode sheath.

(d) To avoid excessive field distortions because of centrifugal forces, the kinetic energy density should be small (< 1/10) compared to the magnetic-field energy density.

The last two conditions can be expressed as

$$10^{13} < \frac{n}{B^2} << \frac{2.5\times 10^{15}}{E} ,$$

where n is the electron density in cm^{-3}, B is the magnetic field in Weber/m^2 = 10 kG, and E is the deuteron energy in keV.

FOOTNOTES AND REFERENCES

*Work done under the auspices of the U. S. Atomic Energy Commission.

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Figure Caption

Fig. 1. Schematic representation of Homopolar Gun I.

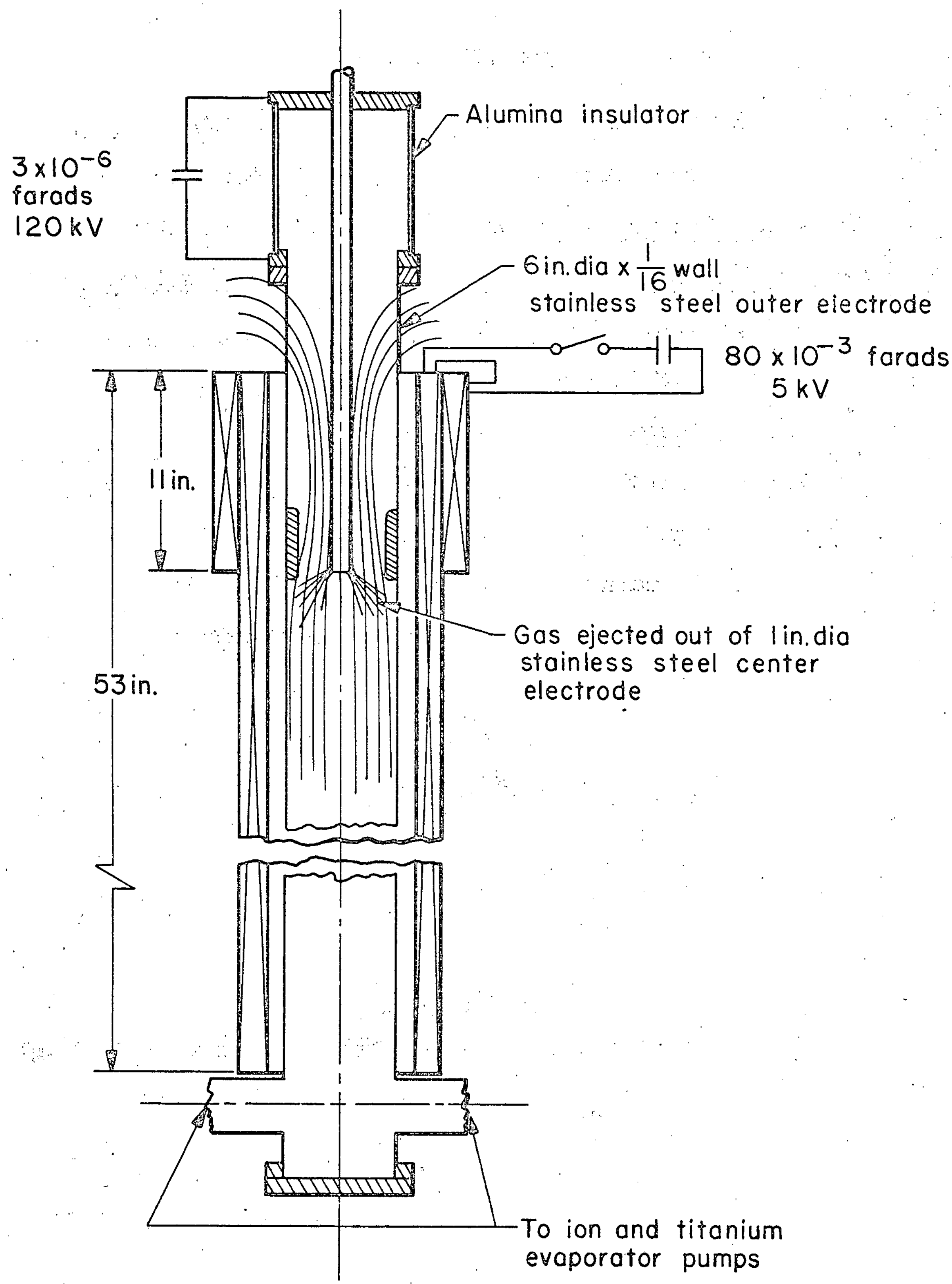

Fig. 1.

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