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FORMATION AND DIAGNOSTICS OF A CYLINDRICAL SHELL PLASMA.(U)
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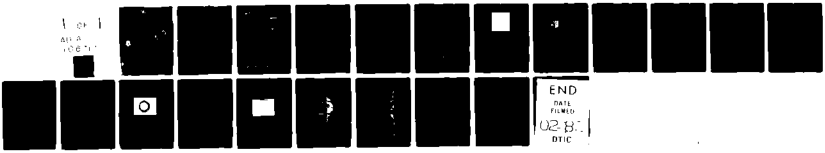

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FORMATION AND DIAGNOSTICS OF A CYLINDRICAL SHELL PLASMA

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December 1979

Final Report

Approved for public release; distribution unlimited.

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base, NM 87117

AFWL-TR-78-255

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This technical report has been reviewed and is approved for publication.

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Pre-Ionization	Supersonic Nozzle

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The formation and diagnostics of a cylindrical plasma shell suitable for electromagnetic implosion plasma generation is discussed. The plasma shell is formed by a 5 kV, 30 kVA, 6 μs risetime capacitor discharge through a 20 cm radius, 2 2 cm tall, 0.1 to 1.0 mg injected gas shell. The gas shell (H_2, D_2, He or Ar) is injected through a circular array of 36 Mach 6 nozzles, fed by a 100 to 1000 lb/in2, 3 cm fast gas valve. The injected gas flows axially through the electrode gap, through an array of flow-through (diffusor) ports in the opposite electrode. Gas injection was checked with transient gas density measurements →

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ionization gauges. Gas shell ionization diagnostics included current probes, Langmuir probes, and transient optical spectroscopy--using a 1 m monochromator with photomultiplier tube and a PAR 500 optical multiple channel analyzer. Electron densities approximately 2×10^{14} to 10^{15} cm^{-3} and electron temperatures approximately 1 to 2 eV were obtained. Open shutter photography indicated a fair degree of azimuthal symmetry in the ionization discharge.

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FORMATION AND DIAGNOSTICS OF A CYLINDRICAL SHELL PLASMA....

Work on the AFOSR contract was begun March, 1977 and continued through May, 1978. A renewal period began June, 1978. The present report discusses the activities up to August 1, 1978.

We have developed and operated a flow-through gas injection-ionization system. Essential features of the apparatus are shown in Figure 1, and an overall view of the experiment is shown in Figure 2. The basic functional sequence of the experiment is shown in Figure 2. The basic functional sequence of the flow-through geometry has three parts: fast gas valve, gas spreader and injection flow-through nozzles. We are using a pulsed fast gas valve originally designed by Marshall[1] and further utilized by Degnan[2] to produce a finite pressure reservoir to drive the flow-through nozzles. The valve plenum can be operated in the range from 100 to 1000 psi, producing a mass loading from .1 to 1 mg argon in the electrode gap with the present nozzle design. Thirty-six nozzles are arranged symmetrically on a 20 cm radius circle. Gas is distributed evenly to the nozzles via a secondary plenum volume gas spreader when the primary valve plenum is opened. During the flow-through conditions, gas is dumped into the evacuated volume above the diffuser.

The nozzle design was carried out by Bob Golobic.* Figure 3 shows the nozzle details for the injection nozzle and diffusor nozzle in their orientation in the apparatus. This geometry is executed in a two inch aluminum plate which serves the dual function of injection nozzle system and discharge electrodes. The nozzle design is such as to establish a flow-through velocity of the order of Mach 6.

Discharge circuit characteristics are shown in Figure 4. Ionization is

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*Bob Golobic, Private Communication.

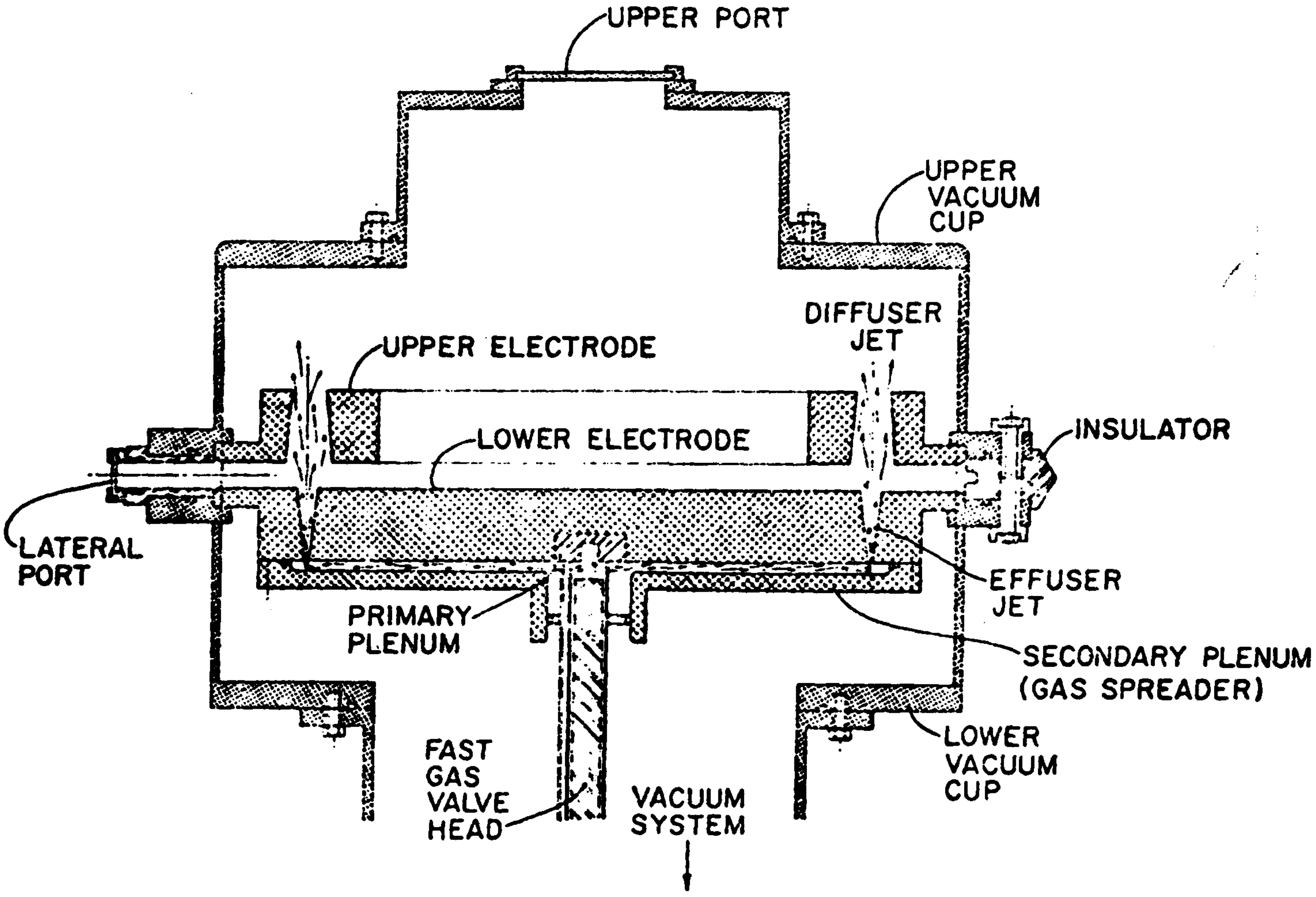


Figure 1. Injection schematic.

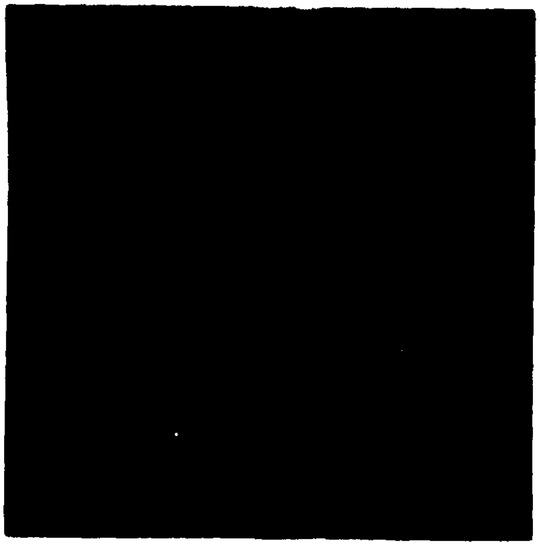


Figure 2. Gas shell apparatus.

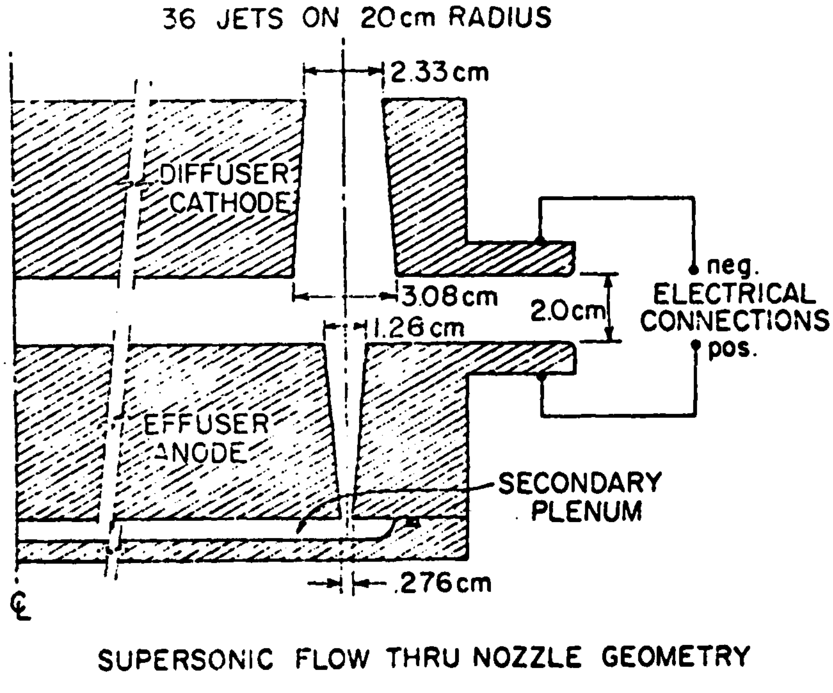


Figure 3. Supersonic flow-through nozzle geometry.

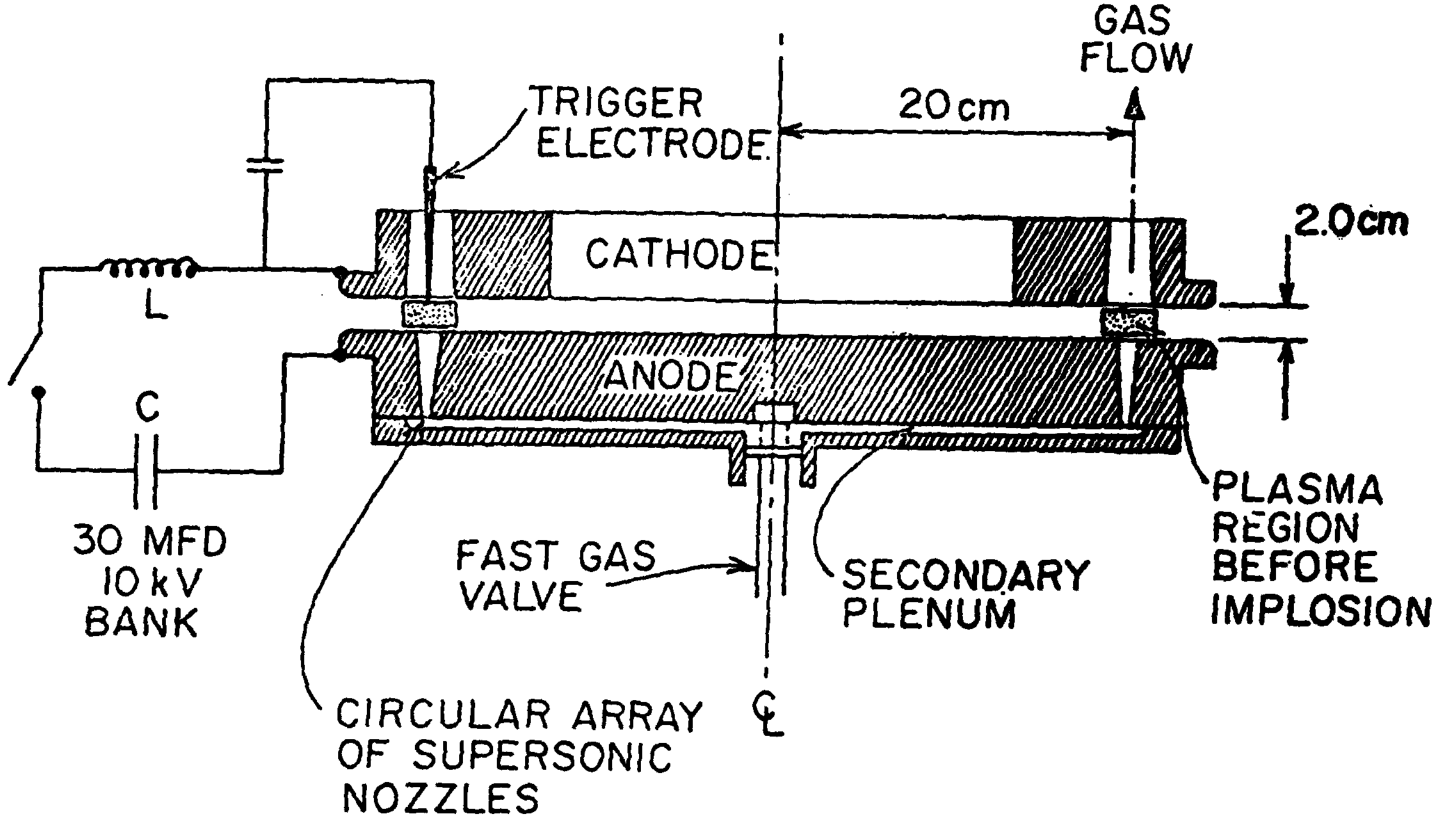


Figure 4. Discharge circuit schematic.

created and maintained by a 30-60 μfd capacitor bank switched into the load by an ignitron. Breakdown is to be aided by the presence of trigger needles suspended in the diffusor nozzles to create a uniform distribution of initial electrons. The cold plasma lies between the two nozzles and is on the order of a 3 cm x 2 cm cross section torus of 20 cm radius. Primary circuit inductance comes from the interconnection cables, but the overall geometry lends itself easily to application in the parallel plate geometry of the implosion apparatus.

Due to the two part nature of this approach, it is possible to investigate the performance of the injection system independent of the plasma stage. To do so, we have used a fast ion gauge diagnostic technique similar to that used by Degnan.[2] In this technique an opened 6 AH6 Pentode is used as an ion gauge. The collection volume is about 1 cubic centimeter and the gauge has a time response to a discontinuity of about 30 μs. The gauges are first calibrated in a static pressure condition. A typical calibration curve is shown in Figure 5. Saturation occurs at 100 to 150 microns, somewhat limiting the usefulness of the gauges in high pressure regions. Because of this saturation level and the size of the collection volume it is not possible to map the flow channel with the existing system. However the gauges are exceedingly useful in establishing the diffusion of the gas out of the nozzle system. Radial scans were performed using these gauges. Figure 6 shows the positioning of the gauges. Data were taken on the range from R = 0 cm to R = 15.5 cm, and the results were uniform in this range. R = 15.5 cm corresponds to the inner radius of an access cutout in the upper electrode. The gauge was positioned over the jet primarily to reference the timing of the gas pulse.

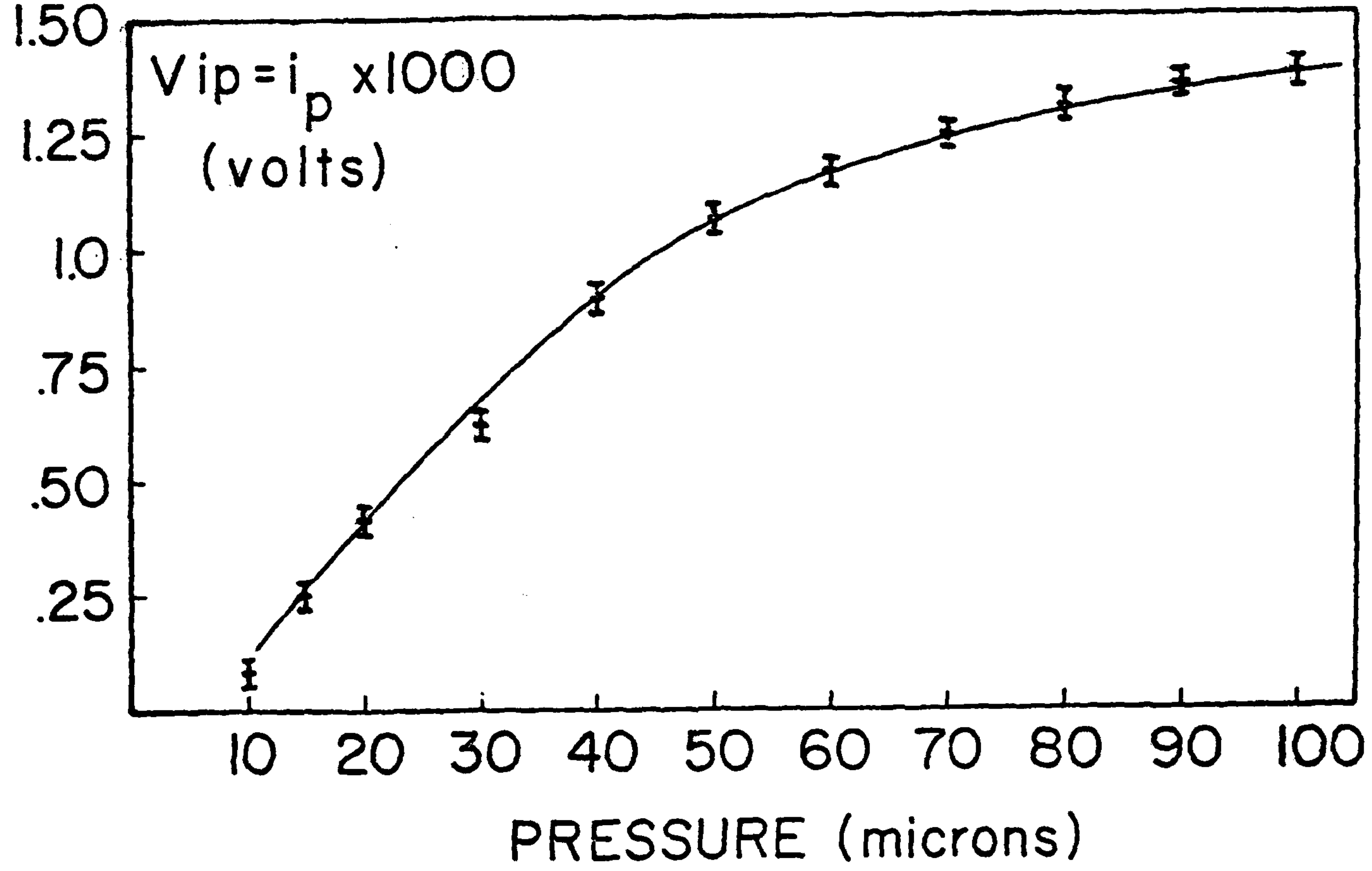


Figure 5. 6AH6 static calibration curve.

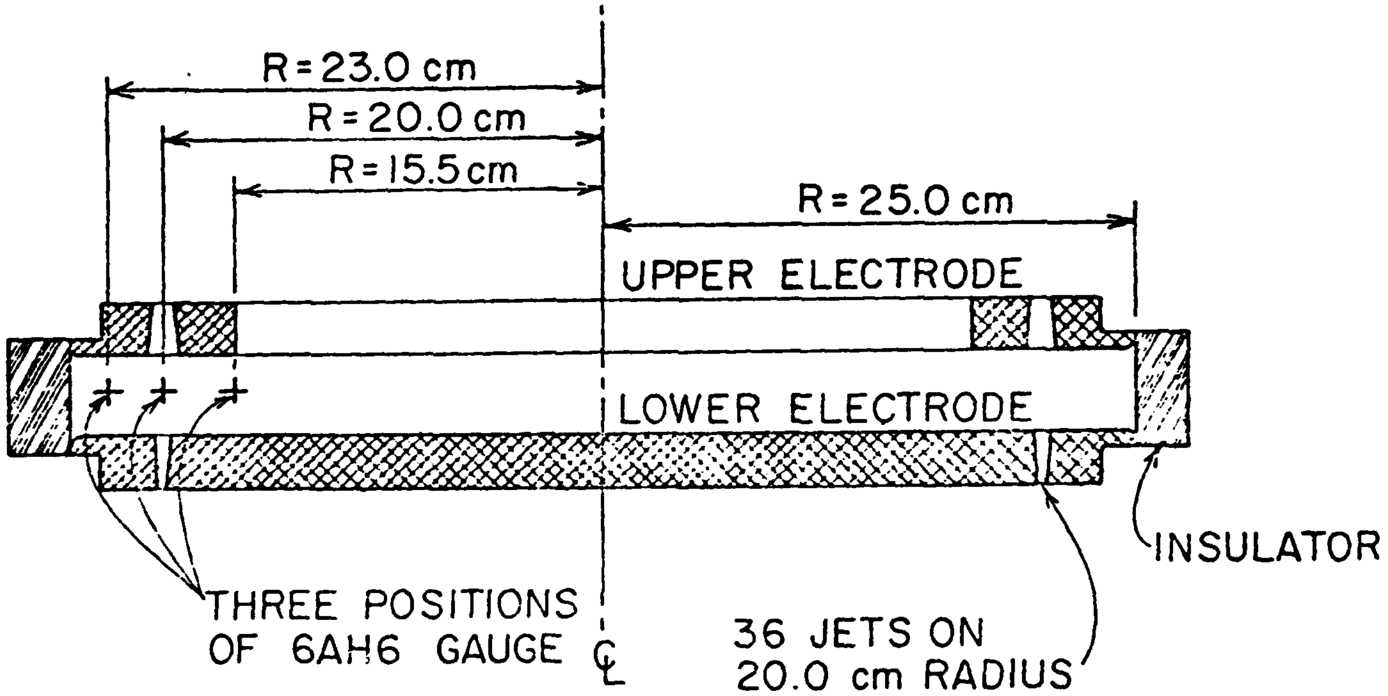
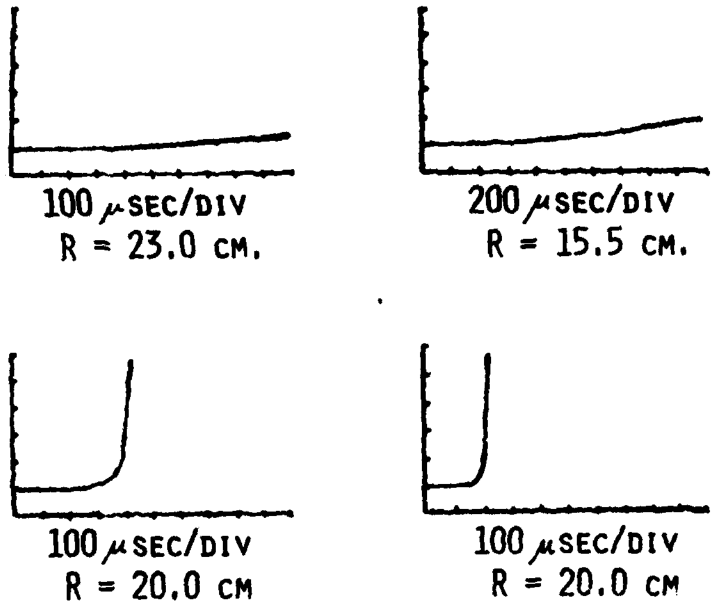


Figure 6. Locations of 6AH6 ion gauge for density profile measurement.

As can be seen from Figure 7, the results of the gauge measurements are quite promising in terms of sharply defined radial profiles. With the gauge at R = 23.0 cm and also at R = 15.5 cm, there is no appreciable pressure rise for at least 500 μs after the flow-through is established in the electrode gap. This allows ample time for the application of the fast implosion pulse before flash over at the insulator could become a problem due to increased pressure. At 500 μs the pressure in the vicinity of the insulator has risen to only about 10 microns. The jet lies some 5 cm from the insulator. This is a rather strong indication that the diffusion from the gas stream is minimal. Assuming a thermal expansion velocity for argon of .03 cm/μs, one expects to see a pressure rise at the insulator some 500-700 μs after the gas is introduced in the jets. This corresponds well with the timing observed.

Ionization is achieved by switching the capacitor bank into the electrode-nozzle system after the flow-through conditions are established. Breakdown has been repeatably observed with the bank voltage from 2 kV to 8 kV. Circuit inductance in this configuration gives a slow 10 μs risetime pulse. Typical voltage and current curves are shown in Figure 8. At an operating point of 5 kV bank voltage one sees on the order of 30 kA plasma current. As a preliminary indicator of plasma homogeneity, open shutter photos of the discharge were taken using a truncated cone mirror, lying on the lower electrodes, positioned in the cutout of the upper electrode. Figure 9 shows a photo of the discharge, indicating an acceptable degree of homogeneity. We found that it was very important to have the trigger system operating to achieve a homogeneous discharge. With our latest triggering set-up, we could strike a discharge on



100 μSEC/DIV
R = 23.0 CM.

200 μSEC/DIV
R = 15.5 CM.

100 μSEC/DIV
R = 20.0 CM

100 μSEC/DIV
R = 20.0 CM

FIG. 7 ION GAUGE DATA
(ALL TRACES 200 MV/DIV)

Figure 7. Ion gauge data
(all traces 200 mV/div)

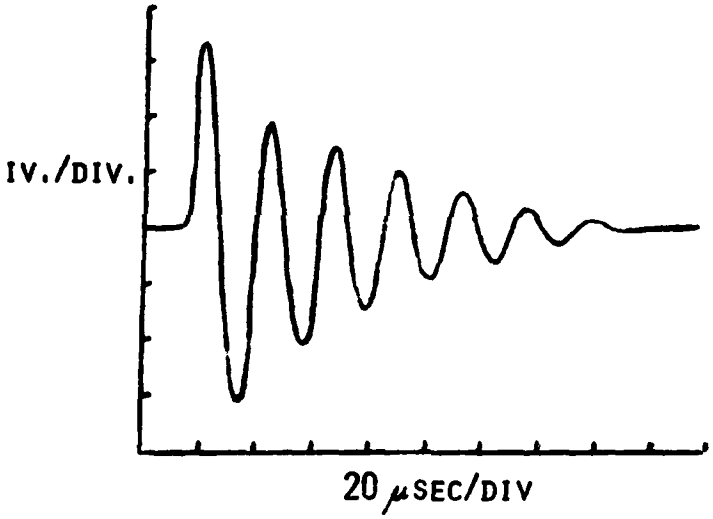


Figure 8. Typical current trace.

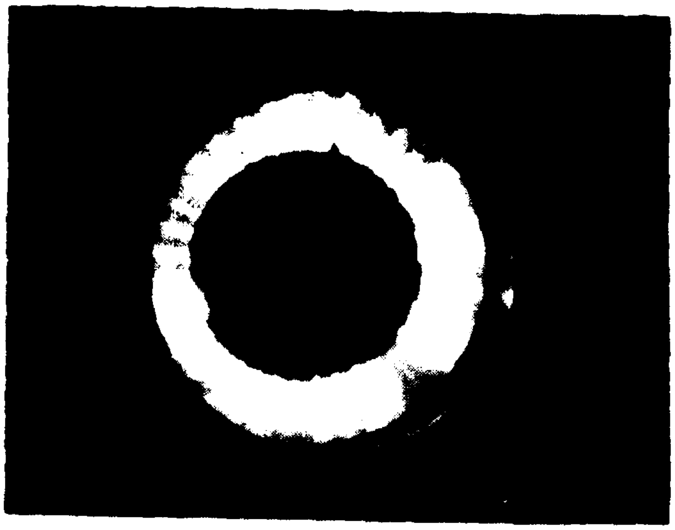


Figure 9. Open shutter photo of discharge.

at least 34 of the 36 jets. We expect that with proper adjustment of the trigger electrodes, we would breakdown on all jets as the failures were always on the same position.

We have also made spectroscopic measurements to determine electron density and temperature. This data were taken before the latest version of the trigger system was installed so reproducibility was not as good as our present apparatus. We were also viewing the edge of a jet rather than the center.

We use a 1 m McPherson monochromater with an RCA 7265 photomultiplier tube to obtain intensity vs. time traces for a number of AI and AII lines. Typical data were shown in Figure 10. There was considerable shot-to-shot variation. We also used a PAR 500 channel optical multichannel analyzer (OMA) to obtain a spectra on a single shot. Typical gating times for spectra were about 5-20 μs. Figure 11 shows a typical spectra centered at 4180Å showing AI and AII lines while in Figure 12 we show the spectra around H_β (4861Å). We used a mixture of argon and hydrogen to give the hydrogen spectra for measuring electron density. The only impurities observed were a few AℓIII lines.

To summarize the results of the spectroscopic diagnostics, we found the following three characteristics:

1) Electron densities were typically $2 \times 10^{14} - 10^{15}$ cm $^{-3}$. Electron density scaled with capacitor voltage but scatter masked any scaling with plenum pressure.

2) Using Saha-Boltzmann equation and the electron density, we found a typical electron temperature of about 1.2 eV.

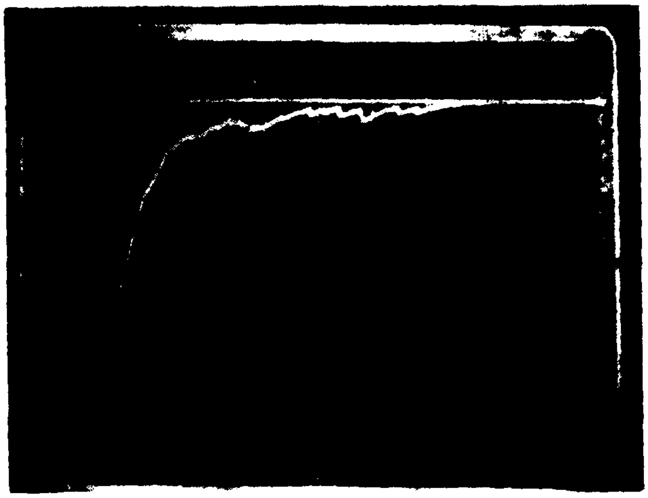


Figure 10. Emission of Ar line as function of time.

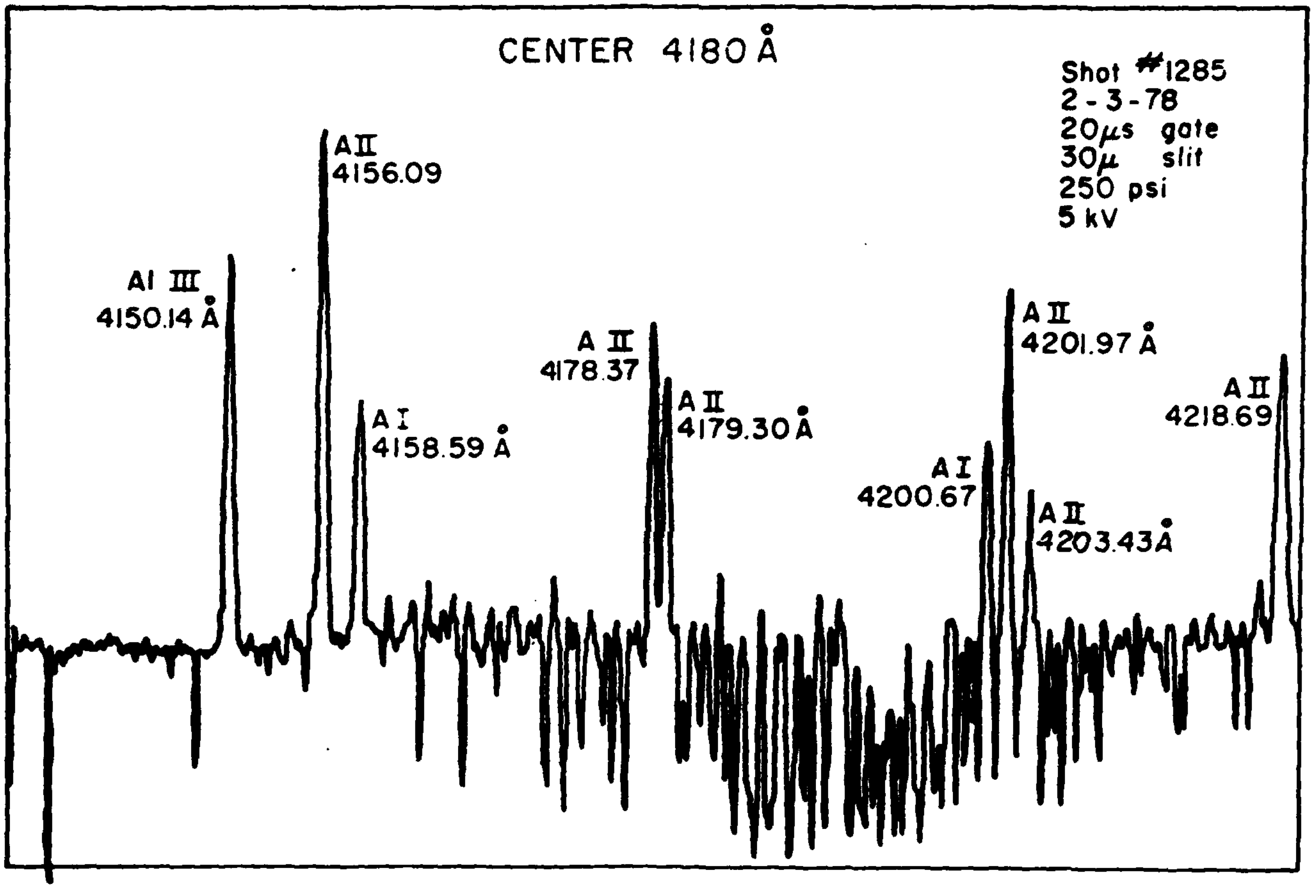


Figure 11. Spectra taken at 4180 Å.

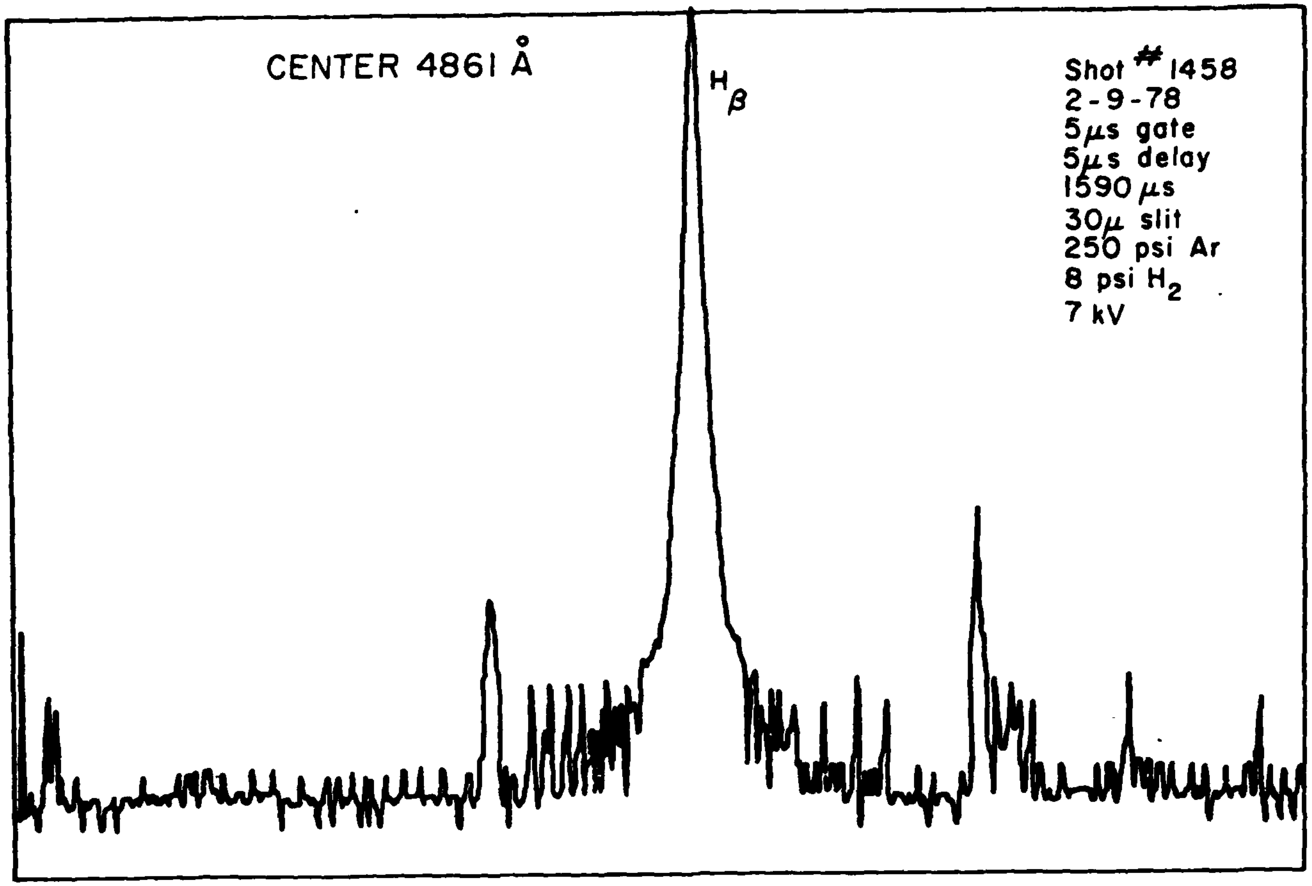


Figure 12. Spectra showing H_β used in electron density measurement.

We plan to repeat these measurements with the improved trigger system and a better optical system which views a jet directly. The observed electron density may increase then, but it is expected that the electron temperature will remain about 1-2 eV.

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2. Degnan, J. H., and Reinovsky, R. E., On Forming Cylindrical Gas Shells for Electromagnetic Implosions Plasma Generation, AFWL-TR-75-265, Air Force Weapons Laboratory, Kirtland Air Force Base, NM, 1976.

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