N86-28429

PLASMA CONTACTOR PERFORMANCE CHARACTERIZATION

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1. Simplified schematic of Plasma Coupling process under conditions where excessive currents are being demanded and a double sheath region develops with attendant high voltage drops. This condition should be avoided by designing the plasma source (plasma contactor) so it produces adequate plasma. The key to high plasma densities is a high ion production rate.

2. Plasma contactor performance objectives - This transparency should be self-explanatory.

3. The basic elements of the hollow cathode are shown. Electrons are drawn from the insert by field-enhanced thermionic emission and from the bulk plasma by multistep ionization processes. The bulk plasma is sustained by the expellant gas flow through the cathode tube and orifice plate in the presence of the electrical discharge between the cathode insert and anode. Electrons escape from the cathode interior through the orifice; ions are drawn to the insert and orifice place surfaces where they deposite energy, heating these surfaces. Some ions are produced downstream of the orifice as a result of electron collisions with neutral atoms close to the orifice. Electron or ion currents (J_e) can be drawn from this plasma downstream of the orifice to a plasma further downstream of the hollow cathode assembly on demand and depending upon the cathode to downstream plasma potential difference. For present tests a 0.6 cm diameter cathode with 0.6 mm diameter orifice was used.

4. In order to augment the production of ions the hollow cathode based plasma source was designed and built. Key features of this device are:

- o a hollow cathode
- o an anode moved downstream from the location used for the basic hollow cathode
- o an enclosure that confines the neutral gas

- o a reverse feed expellant flow plenum
- o a ring cusp magnetic field configuration

For the test results presented the basic hollow cathode and the hollow cathode based plasma source used an identical hollow cathode.

5. The ion filings map for the hollow cathode based plasma source. The magnetic field is used to confine ions and electrons and thereby improve ion production performance.

6. The mechanical schematic of the system being used to study the ion and emission characteristics of the hollow cathode (shown) or the hollow cathode based plasma source.

7. The system used to supply power and make electrical measurements in this experiment. The anode supply shown supplies the discharge power. The tank supply is used to bias the hollow cathode or hollow cathode based power source relative to the vacuum tank so ion or electron currents can be drawn to the tank.

8. Typical comparison of the ion/electron emission characteristics of the two devices. The power cited is the discharge power. Either device produces high electron emission currents at modest collector bias conditions. (This situation was observed at all discharge power and expellant flow rate conditions with either argon or xenon expellants.) The hollow cathode based plasma source is a much more effective ion producer than the hollow cathode. The ion current tends to level off at what will be called the ion production rate at sufficiently negative potentials (~ -30 V for the case shown). The term SCCM means standard cubic centimeters/minute.

9. The effects of discharge power and expellant flow are shown. Ion production rates are over an order of magnitude better for the hollow cathode based plasma source than for the basic hollow cathode. The hollow cathode based plasma source operates better (more efficiently) when the bulk of the expellant is fed through the main flow plenum.

10. When argon is used in place of xenon in either device, the performance of that device is degraded.

11. Expellant utilization (fraction of input expellant that leaves the source in an ionized state) vs. the energy cost of a plasma ion that escapes the source is a typical plot that characterizes ion production performance. These curves also show the hollow cathode based plasma source is a much more efficient ion source than the hollow cathode itself for the case of xenon expellant.

12. When argon is used the hollow cathode based plasma source again shows substantially better performance than the basic hollow cathode.

13. A broadly defined performance comparison of the hollow cathode and hollow cathode based plasma source based on the experiments reported is given. This comparison is based on performance goals cited in 2. The comparison suggests substantial gains in ion production capability for the hollow cathode based plasma source for a very modest increase in ion source complexity.

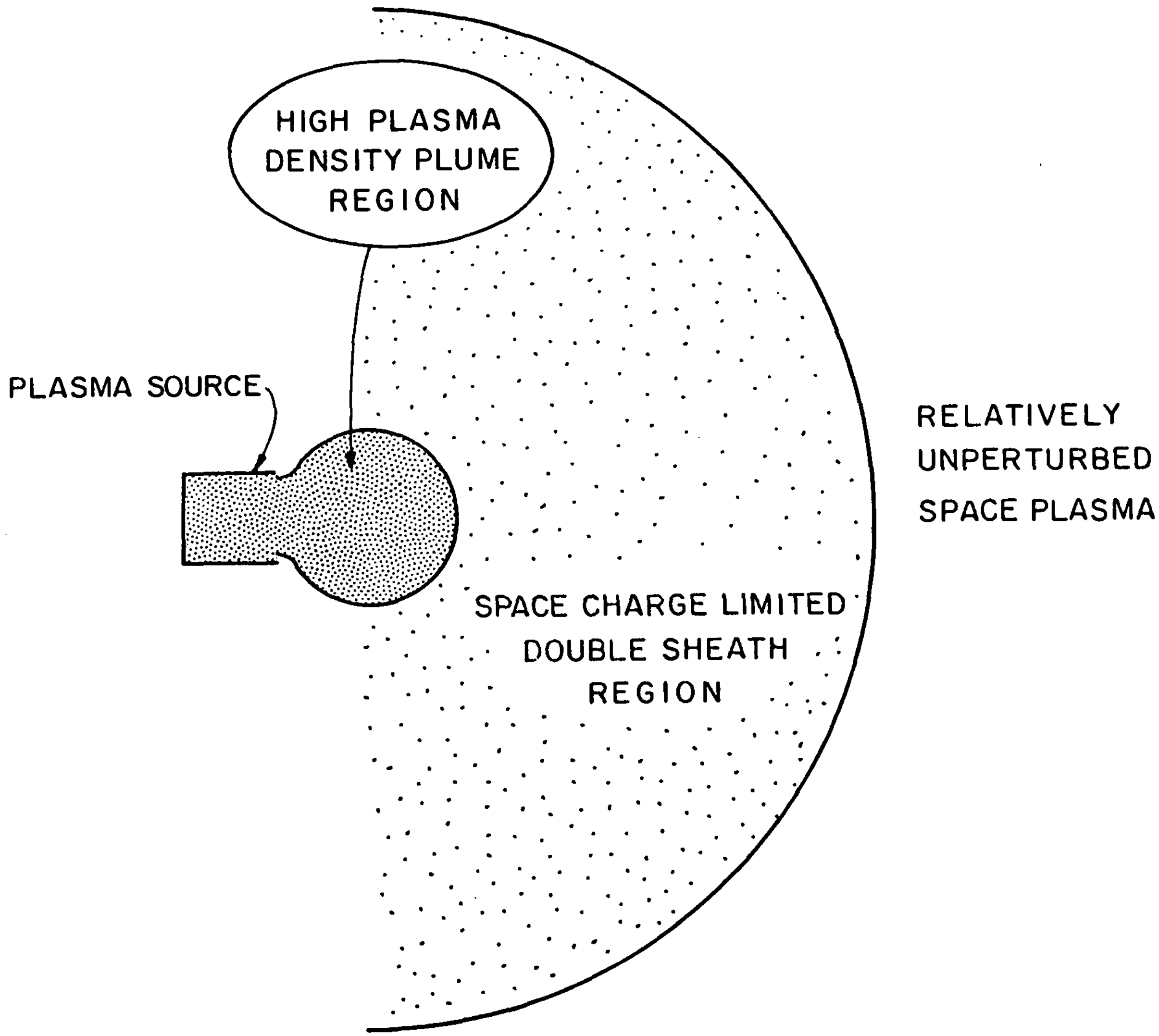
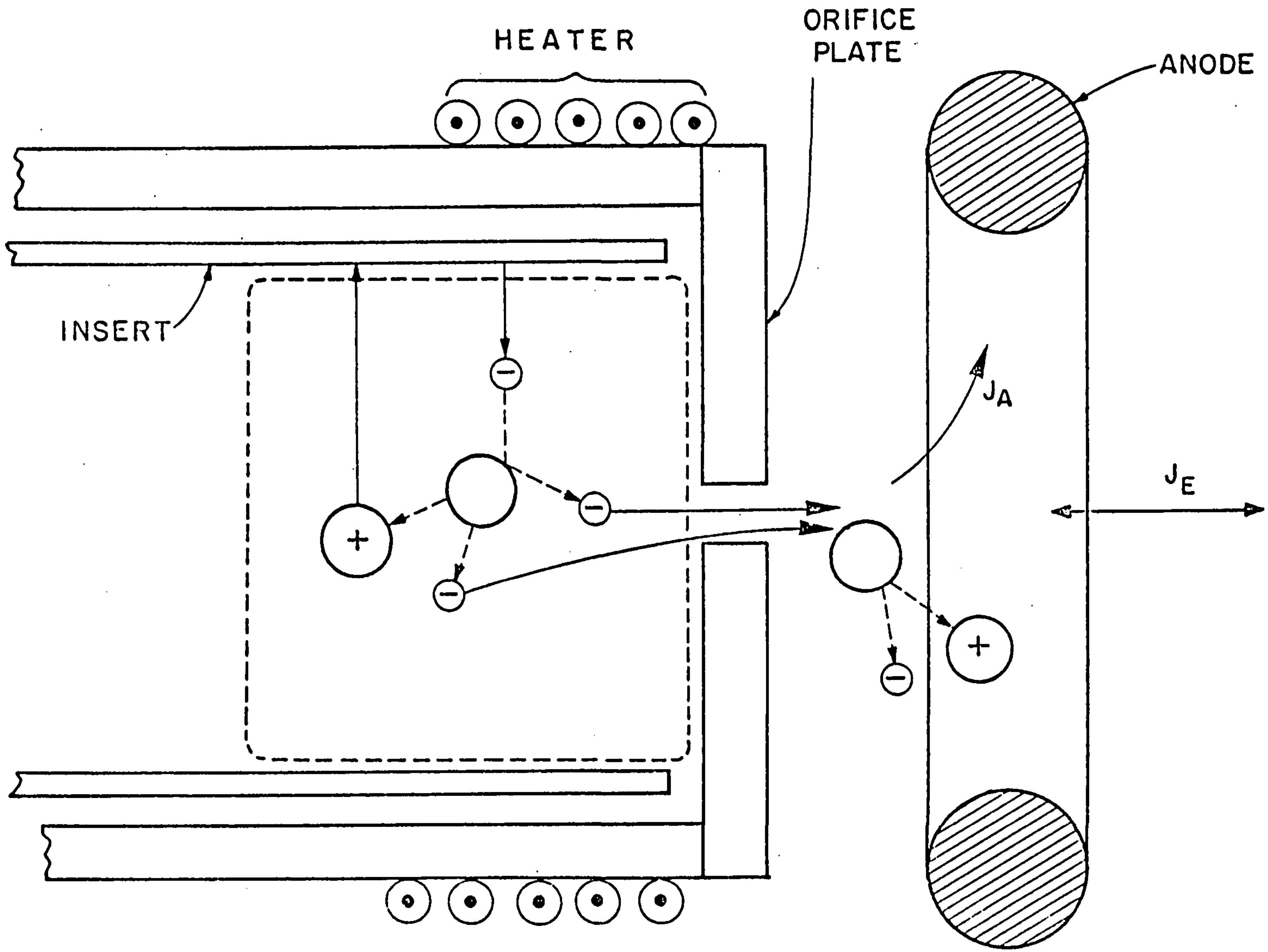

HIGH PLASMA DENSITY PLUME REGION
PLASMA SOURCE
RELATIVELY UNPERTURBED SPACE PLASMA
SPACE CHARGE LIMITED DOUBLE SHEATH REGION

Figure 1

PLASMA CONTACTOR PERFORMANCE OBJECTIVES

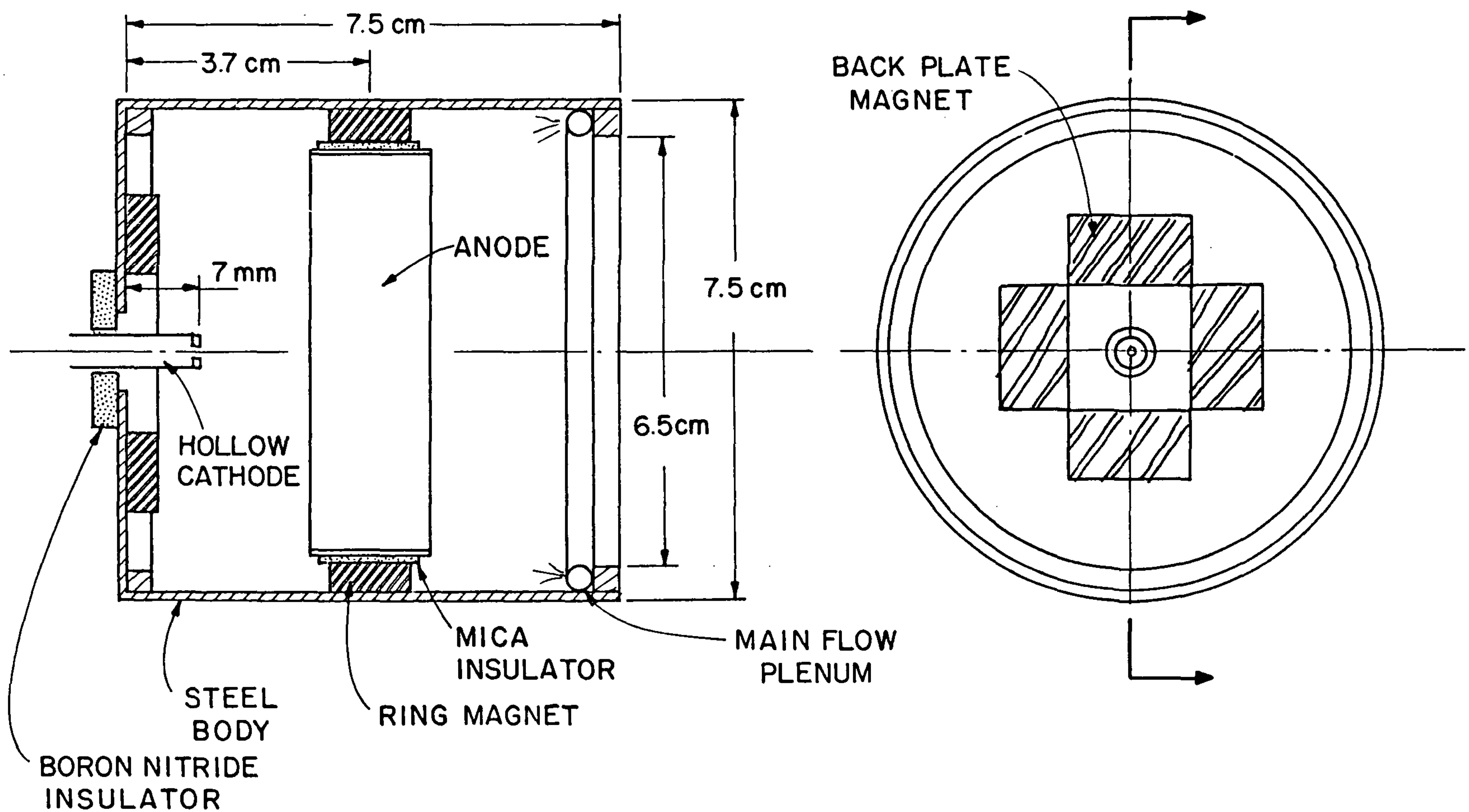
- EXPELLANT COMPATIBILITY WITH SHUTTLE/SCIENCE
- HIGH ELECTRON PRODUCTION CAPABILITY
- HIGH ION PRODUCTION CAPABILITY
- HIGH RELIABILTY (FOR STARTING AND OPERATION)
- PASSIVE EMISSION CONTROL
- SWITCHOVER CAPABILITY (BETWEEN ION/ELECTRON EMISSION)
- LOW ION AND ELECTRON ENERGIES
- LOW SYSTEM MASS
- LOW EXPELLANT CONSUMPTION RATE
- LOW POWER CONSUMPTION
- RAPID STARTUP CAPABILITY
- SIMPLICITY
- LOW SYSTEM COST

Figure 2



HOLLOW CATHODE ASSEMBLY

Figure 3



HOLLOW CATHODE BASED
PLASMA SOURCE

Figure 4

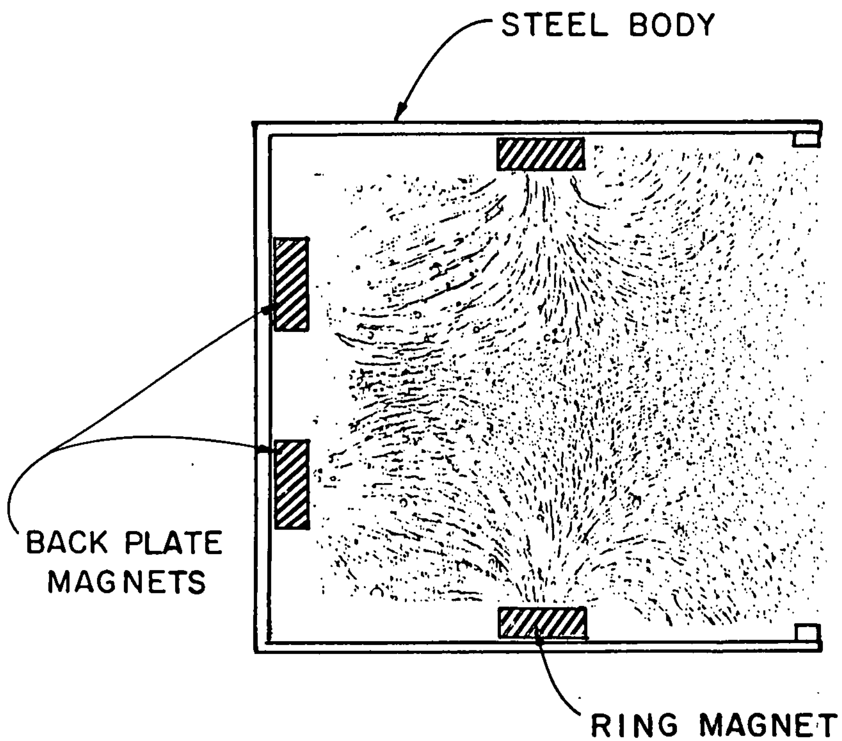
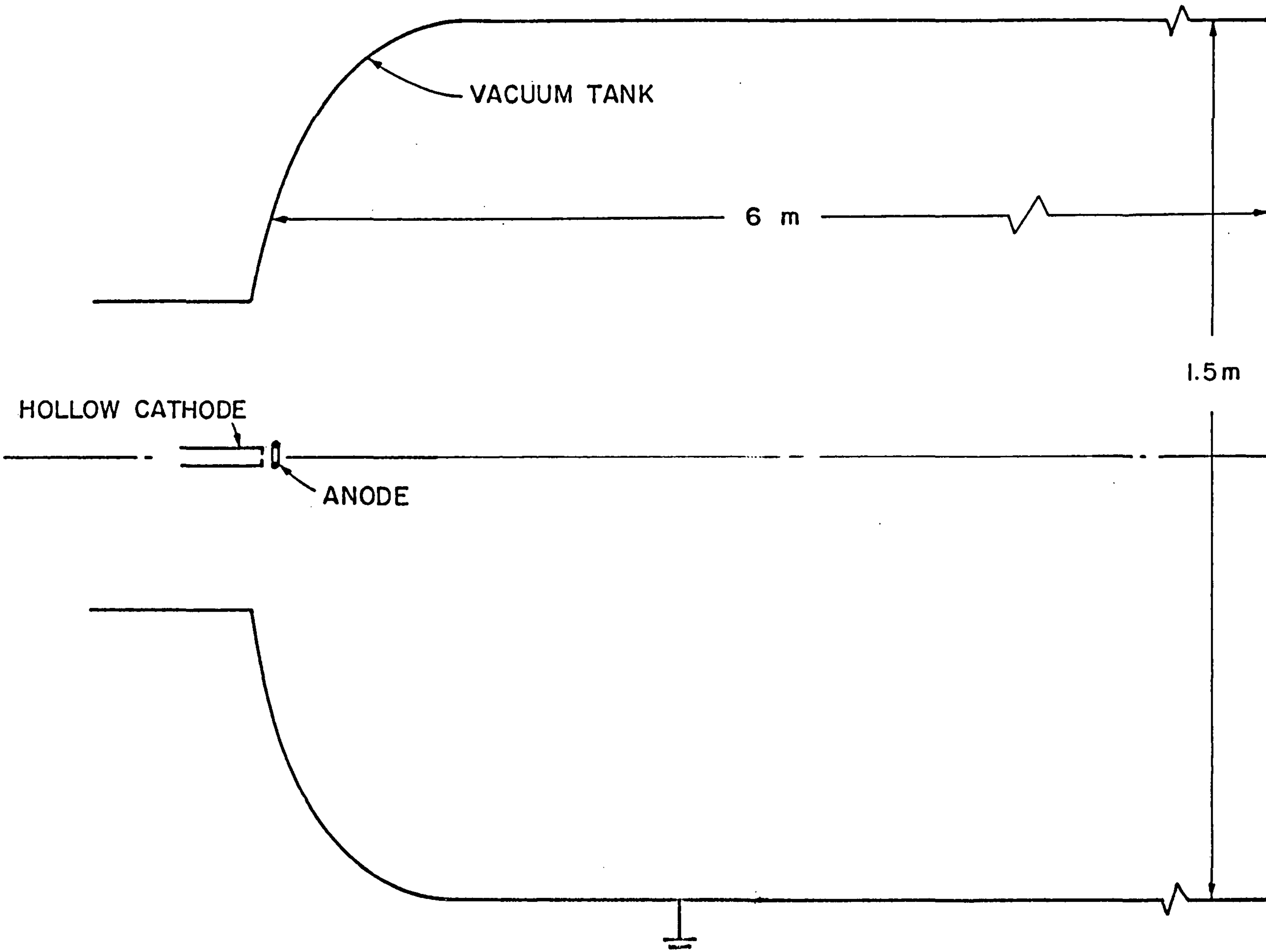
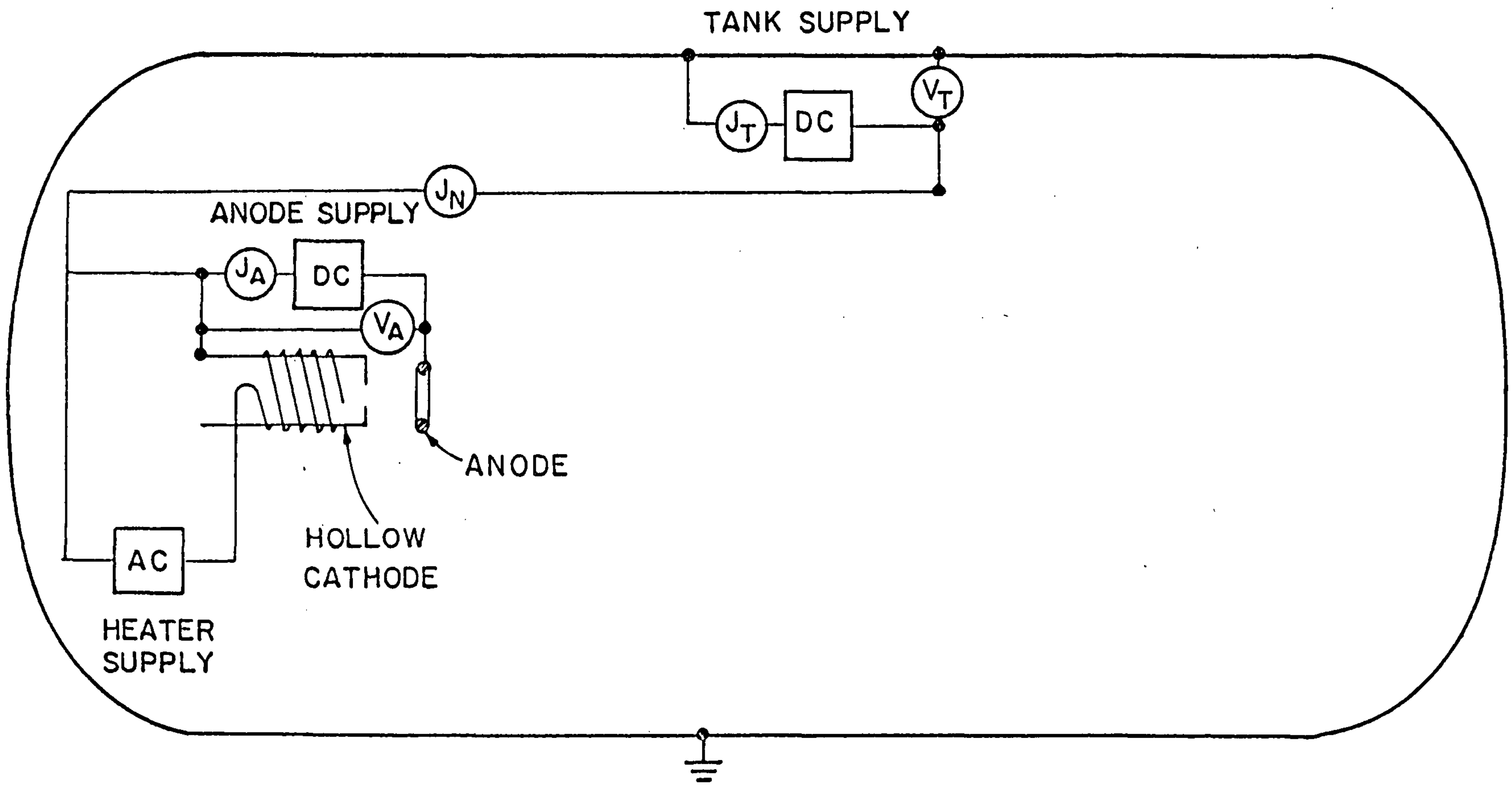


Figure 5



MECHANICAL SCHEMATIC FOR PLASMA CONTACTOR EXPERIMENT

Figure 6

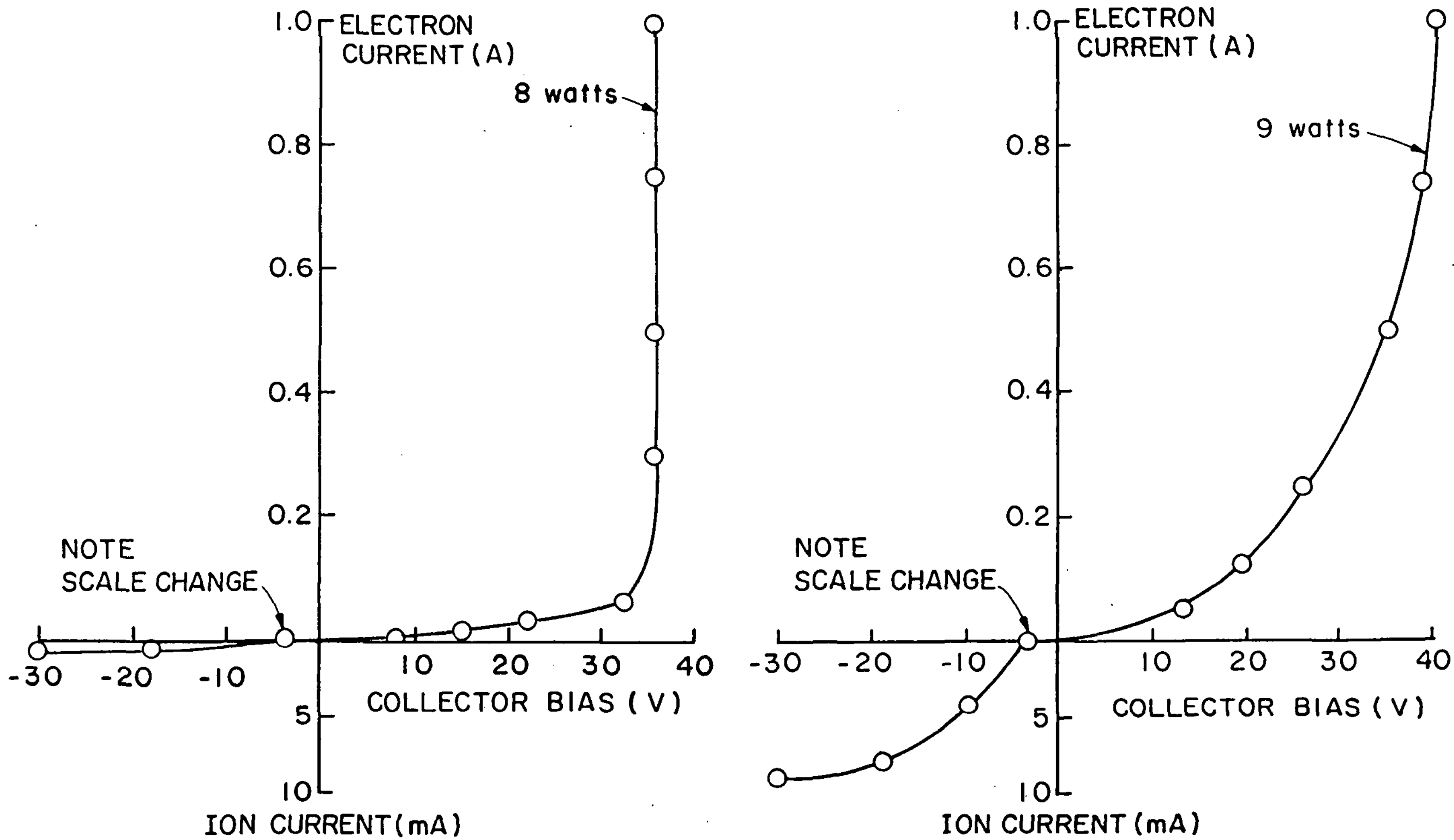


ELECTRICAL SCHEMATIC FOR PLASMA CONTACTOR EXPERIMENT

Figure 7

XENON EXPELLANT

1 sccm THROUGH CATHODE

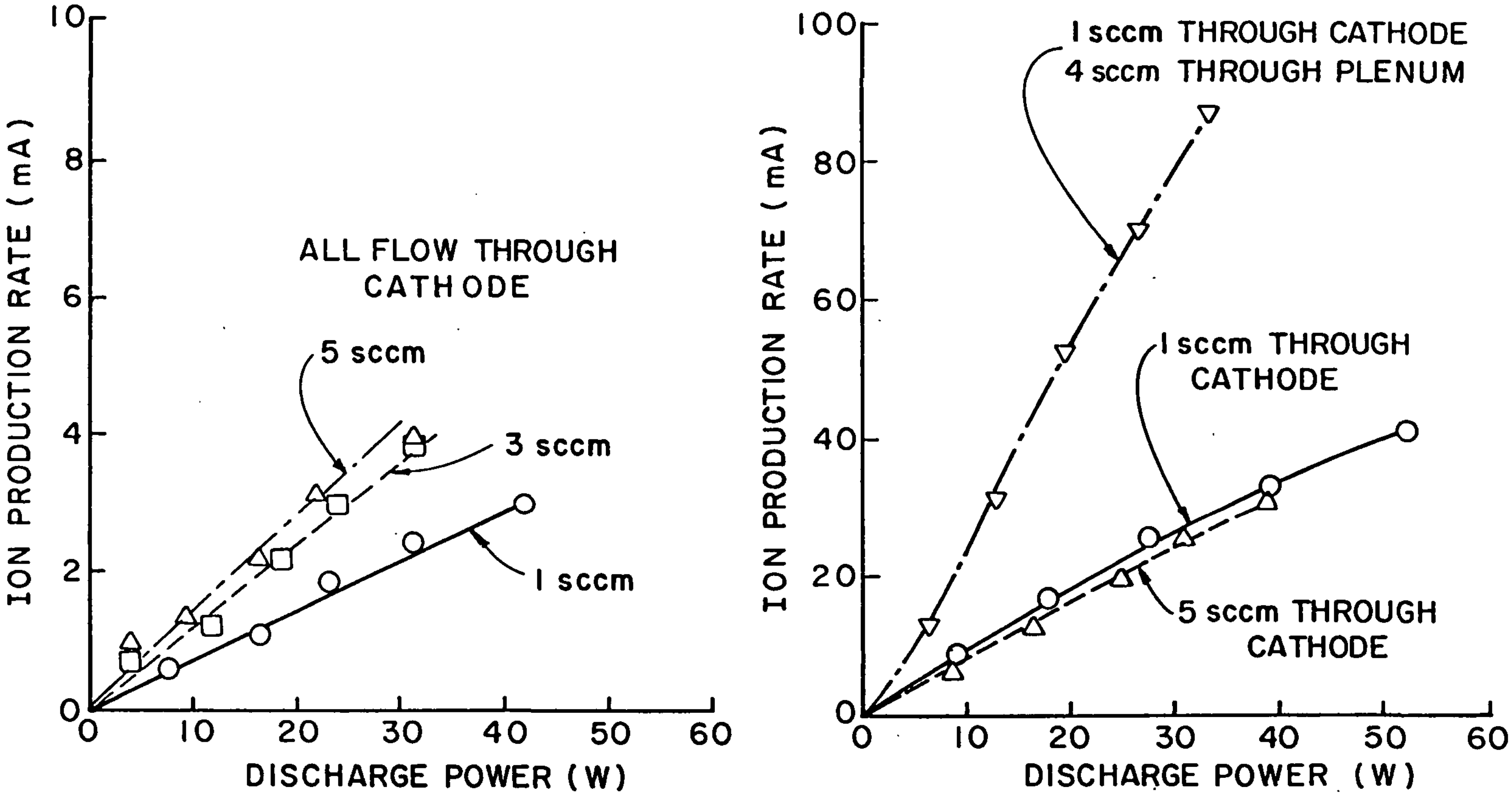


HOLLOW CATHODE

HOLLOW CATHODE BASED PLASMA SOURCE

Figure 8

XENON EXPELLANT



HOLLOW CATHODE

HOLLOW CATHODE BASED PLASMA SOURCE

Figure 9

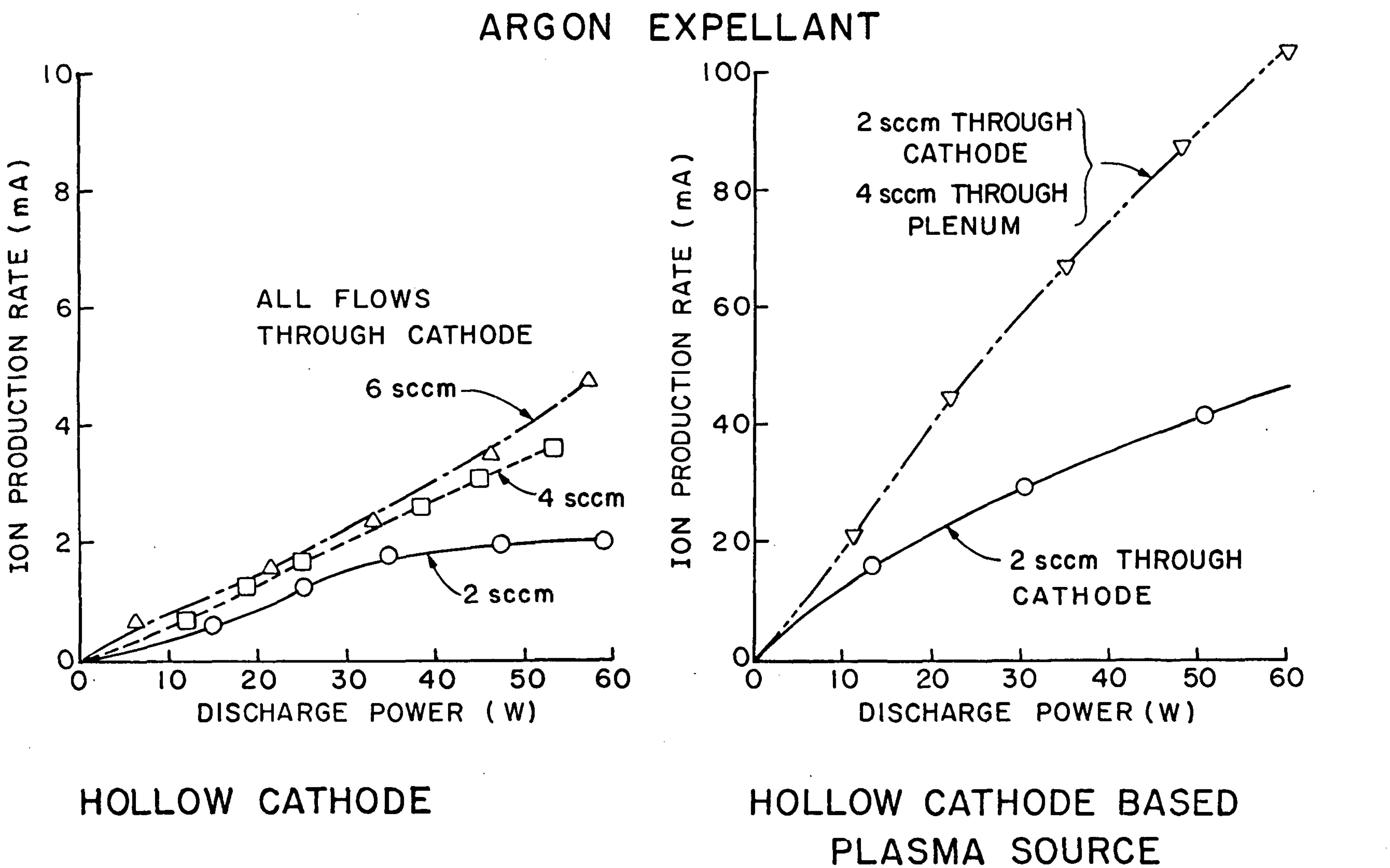

ARGON EXPELLANT
ION PRODUCTION RATE (mA)
0
2
4
6
8
10
ALL FLOWS
THROUGH CATHODE
6 sccm
4 sccm
2 sccm
0
10
20
30
40
50
60
DISCHARGE POWER (W)
HOLLOW CATHODE
ION PRODUCTION RATE (mA)
0
20
40
60
80
100
2 sccm THROUGH
CATHODE
4 sccm THROUGH
PLENUM
2 sccm THROUGH
CATHODE
0
10
20
30
40
50
60
DISCHARGE POWER (W)
HOLLOW CATHODE BASED
PLASMA SOURCE

Figure 10

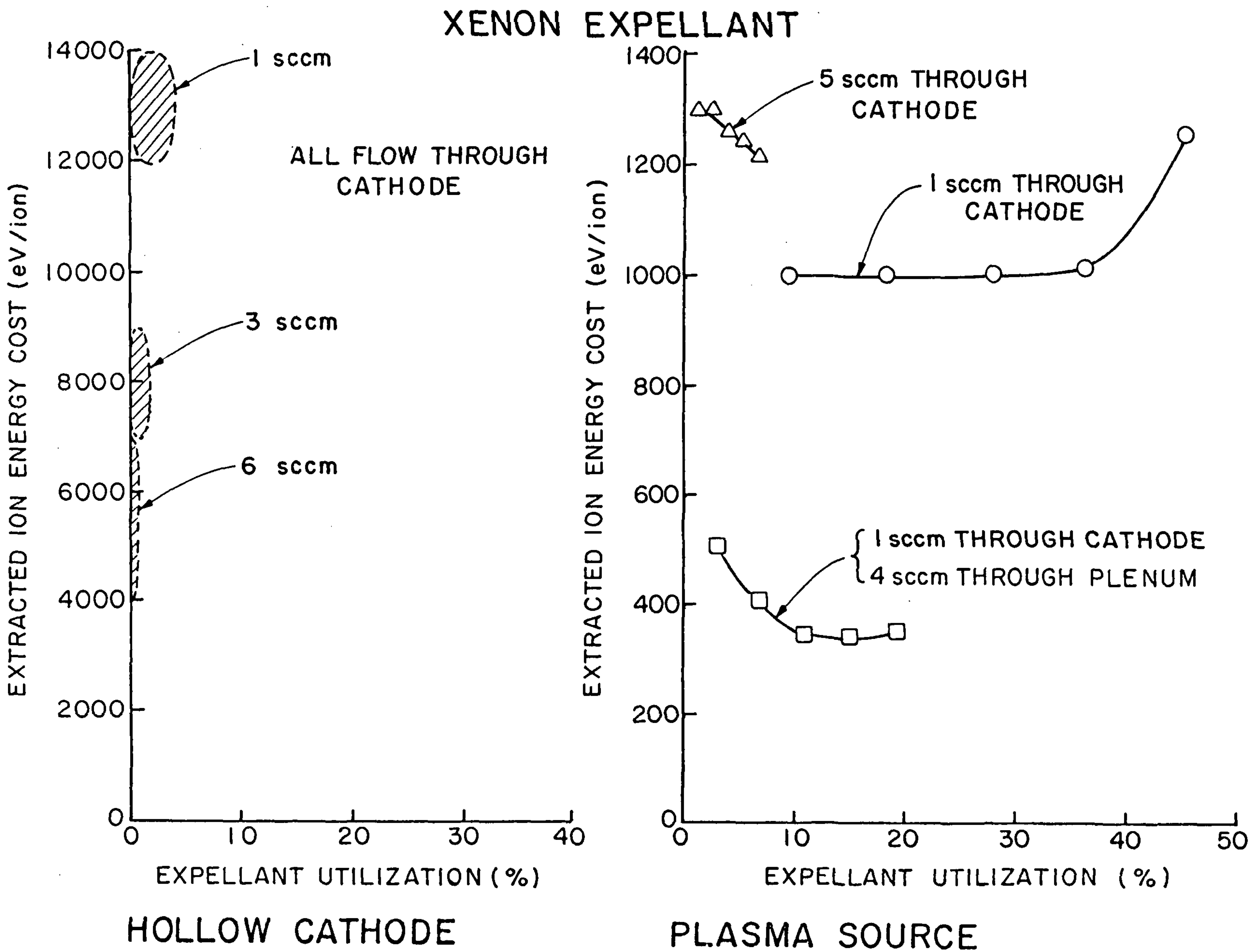

XENON EXPELLANT
14000
12000
10000
8000
6000
4000
2000
0
EXTRACTED ION ENERGY COST (eV/ion)
1 sccm
ALL FLOW THROUGH CATHODE
3 sccm
6 sccm
0
10
20
30
40
EXPELLANT UTILIZATION (%)
HOLLOW CATHODE
1400
1200
1000
800
600
400
200
0
EXTRACTED ION ENERGY COST (eV/ion)
5 sccm THROUGH CATHODE
1 sccm THROUGH CATHODE
1 sccm THROUGH CATHODE
4 sccm THROUGH PLENUM
0
10
20
30
40
50
EXPELLANT UTILIZATION (%)
PLASMA SOURCE

Figure 11

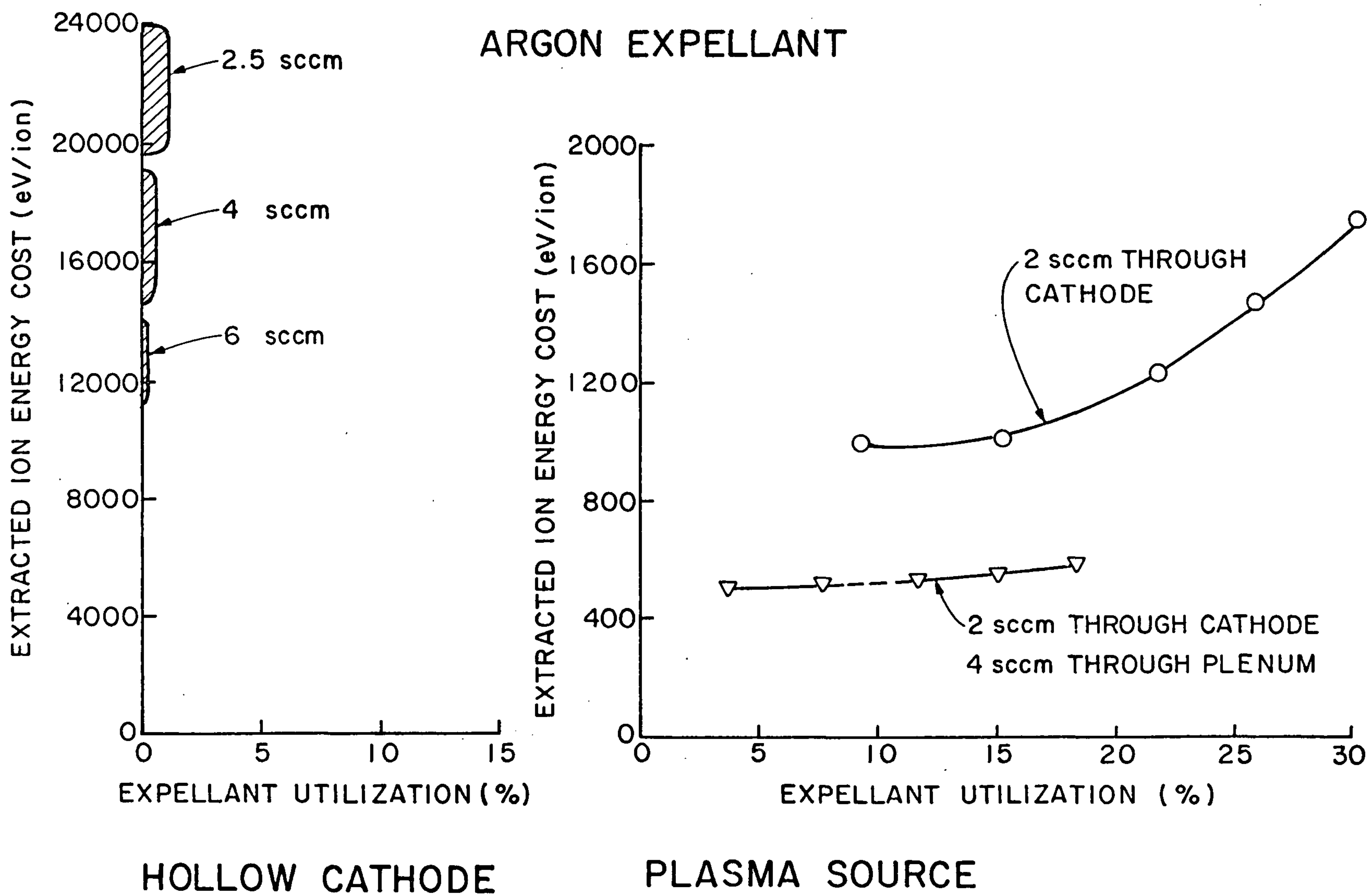

ARGON EXPELLANT
24000
20000
16000
12000
8000
4000
0
2.5 sccm
4 sccm
6 sccm
EXTRACTED ION ENERGY COST (eV/ion)
0 5 10 15
EXPELLANT UTILIZATION (%)
HOLLOW CATHODE
2000
1600
1200
800
400
0
EXTRACTED ION ENERGY COST (eV/ion)
2 sccm THROUGH CATHODE
2 sccm THROUGH CATHODE
4 sccm THROUGH PLENUM
0 5 10 15 20 25 30
EXPELLANT UTILIZATION (%)
PLASMA SOURCE

Figure 12

PLASMA CONTACTOR PERFORMANCE COMPARISON

	HOLLOW CATHODE	HOLLOW CATHODE BASED PLASMA SOURCE
• EXPELLANT COMPATIBILITY	ARGON/XENON	ARGON/XENON
• ELECTRON PRODUCTION CAPABILITY	MULTIAMPERE	MULTIAMPERE
• ION PRODUCTION CAPABILITY	1-10 mA	10-100 mA
• RELIABILITY	~10^4 hours/~10^3 starts	~10^4 hours/~10^3 starts
• EMISSION CONTROL	PASSIVE	PASSIVE
• SWITCHOVER	AUTOMATIC	AUTOMATIC
• ION ENERGY LEVEL	~0.03 eV	SIMILAR
• ELECTRON TEMPERATURE	~1 eV	SIMILAR
• SYSTEM MASS	NEGLIGIBLE CATHODE MASS TWO POWER SUPPLIES ONE VALVE	NEGLIGIBLE SOURCE MASS TWO POWER SUPPLIES ONE VALVE
• EXPELLANT CONSUMTION RATE	1-6 sccm	1-6 sccm
• POWER CONSUMPTION	~30 watts ~10^3-10^4 eV/ion	~30 watts ~10^2-10^3 eV/ion
• STARTUP TIME	~5 min	~5 min
• SIMPLICITY	~5 COMPONENTS ~2 POWER CKTS.	~10 COMPONENTS ~2 POWER CKTS.
• SYSTEM COST	~1-10% ION THRUSTER	~1-10% ION THRUSTER

Figure 13