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MAGNETOPLASMADYNAMIC THRUSTER FLOWS: PROBLEMS AND PROGRESS

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MPD THRUSTER WORKSHOP

OVERALL STRATEGY FOR MPD THRUSTER DEVELOPMENT

NEEDS

Efficiency

Lifetime

PROBLEMS	APPROACHES
Exhaust flow	Magnetic nozzle
-- Angular spread	-- Flow collimation
-- Frozen flow	-- Expansion control
	Design/control of thrust chamber plasma
Electrodes	Design/control of near-electrode plasma
-- Voltage drops	-- Hollow cathode
-- Heat transfer	-- Anode MPD flow
-- Erosion	

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ACTIVITIES IN THE OSU AERO/ASTRO ENGINEERING DEPARTMENT

HIGH POWER MPD FLOWS

-- Godzilla

Gigawatt, quasi-steady, LC-ladder pulseline (3 kV matched-load, with 333 kA for 1.6 msec; also 111 kA for 4.8 msec, etc.)

MODERATE POWER MPD THRUSTERS AND COMPONENTS

-- Magnetic nozzle experiments

Qualitative spectroscopic studies

Long pulse, applied field (York)

-- Hollow cathode studies

Theoretical modeling

Experiments at NASA LeRC in both MPD and ion engine regimes

-- Applied-field MPD flow modeling

MACH2 code adapted to steady, applied-field operation

Examination of flow near the anode

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TOPIC	PARTICIPANT
Magnetic nozzle spectroscopy	T. Umeki, MS student, Ohio State
Hollow cathode studies	A. Salhi, PhD student, Ohio State R. Myers, M. Mantenieks, NASA LeRC, (for experiments)
Anode flow studies	P.G. Mikellides, PhD student, Ohio St N.F. Roderick, Professor, Dept. of Chemical and Nuclear Engineering, University of New Mexico

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QUALITATIVE SPECTROSCOPIC STUDIES OF MAGNETIC NOZZLE FLOW

MOTIVATION

-- Build on earlier studies, based on electrostatic probes, pressure probes, magnetic probes, and single-point laser scattering, to estimate energetics of magnetic nozzle flow field.

-- Attempt to capture larger region of flow field through spectroscopic flow-visualization.

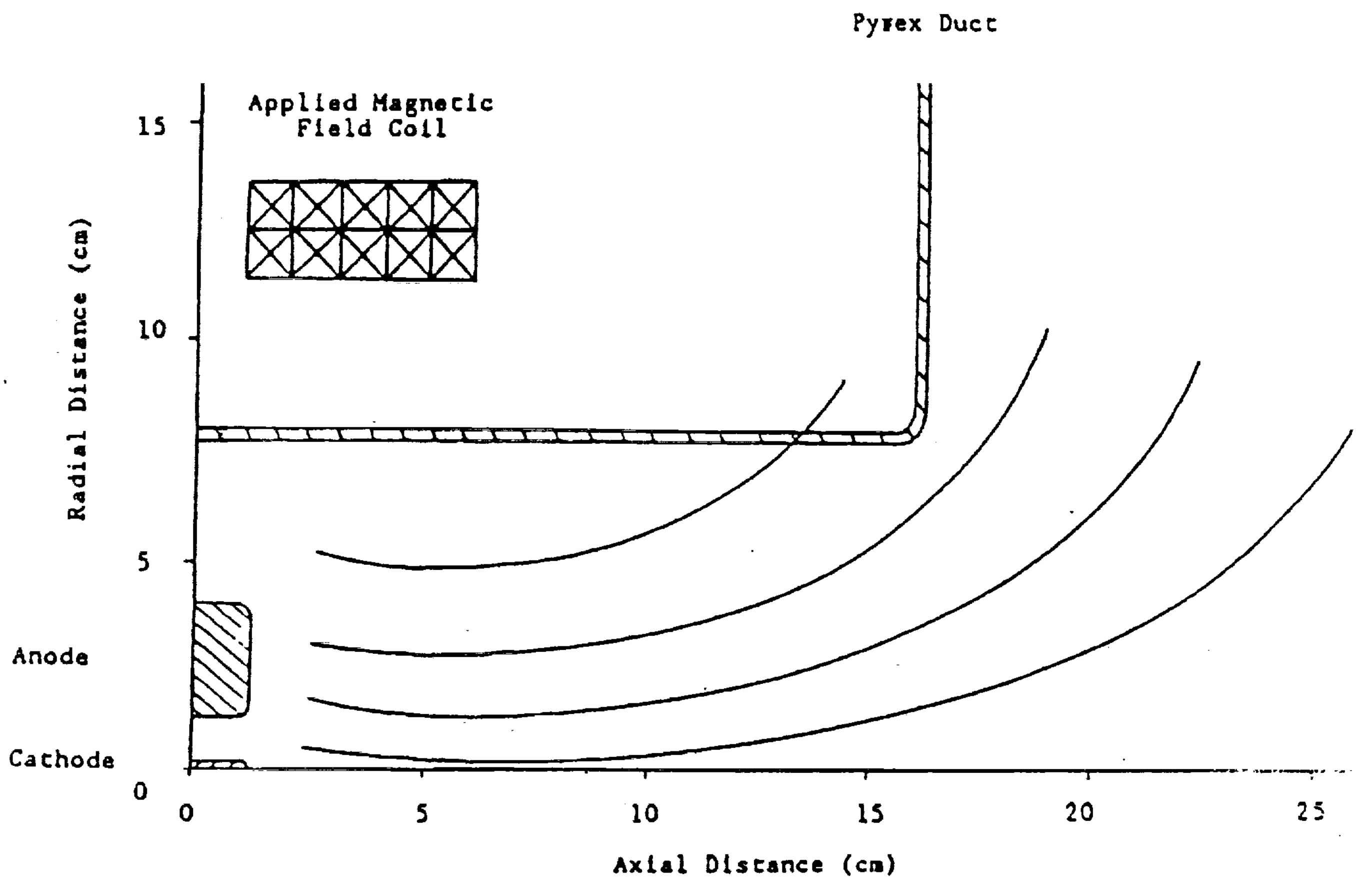
APPROACH

-- Combine spectroscopy with photographic imaging in order to obtain (qualitatively) line intensities as function of position in flow field.

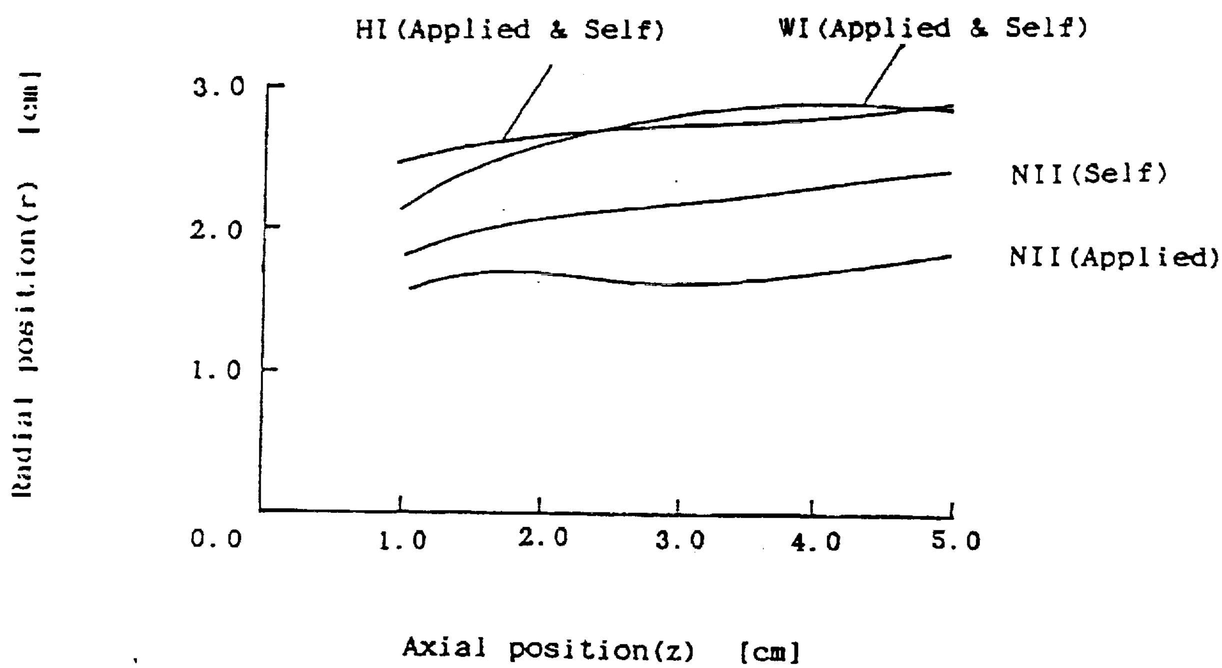
-- Perform photoelectric measurements of selected lines.

-- Compare with available probe data (at downstream positions).

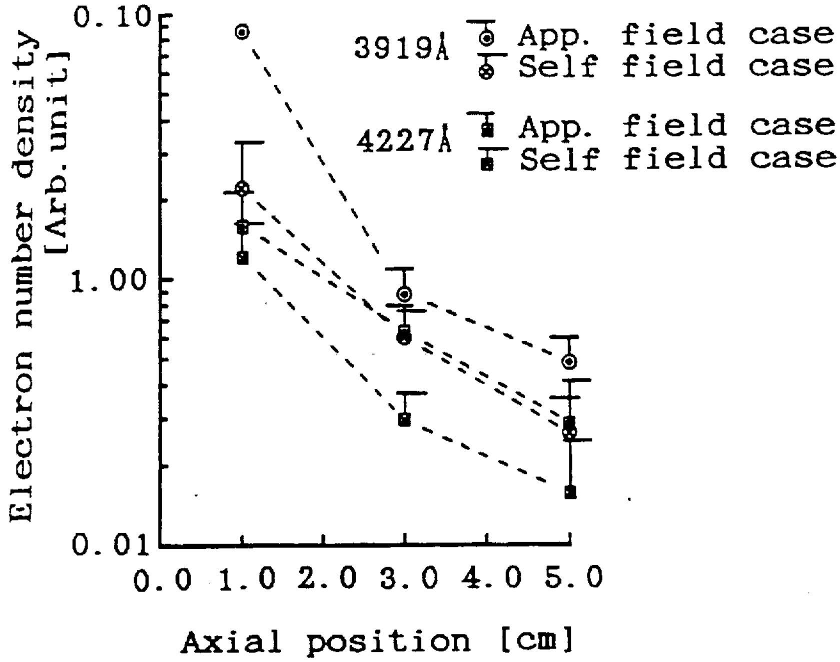
-- Examine distributions of derived plasma parameters (e.g., electron temperature, electron and heavy particle densities).



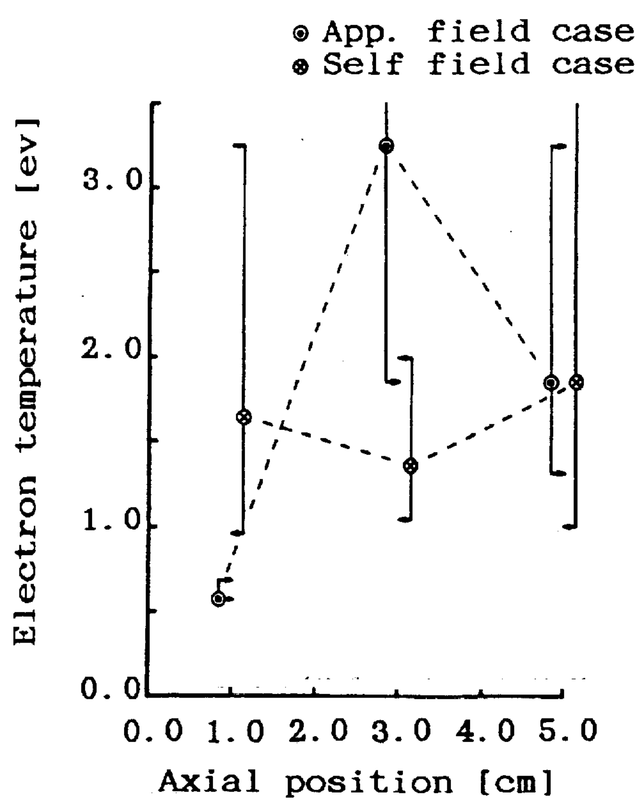
Applied magnetic field lines



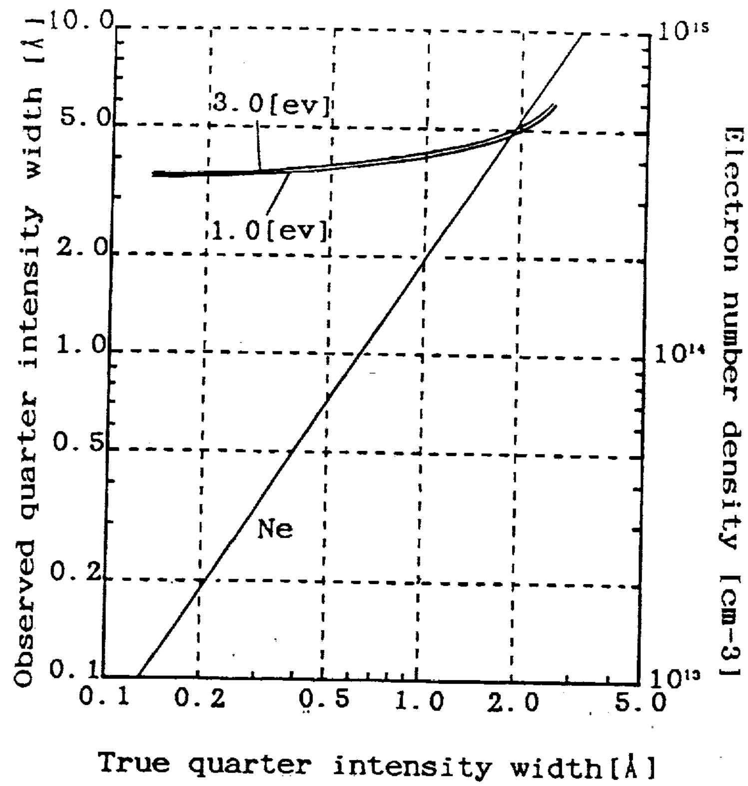
Species distribution



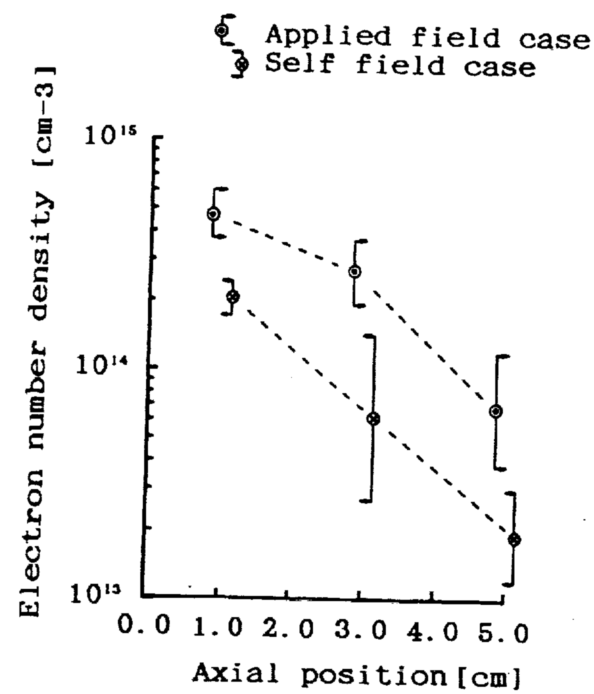
Chordal averaged radiator number density on the axial position



Electron temperature on the axial position (chordal averaged on axis)



H_β quarter intensity width for the electron number density



Electron number density on the axial position from Stark broadening (chordal averaged on axis)

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HOLLOW CATHODE STUDIES

MOTIVATION

-- Improve cathode performance in MPD arcjets by controlling the plasma near the cathode surface, (rather than merely accepting the plasma conditions provided by the thrust chamber flow).

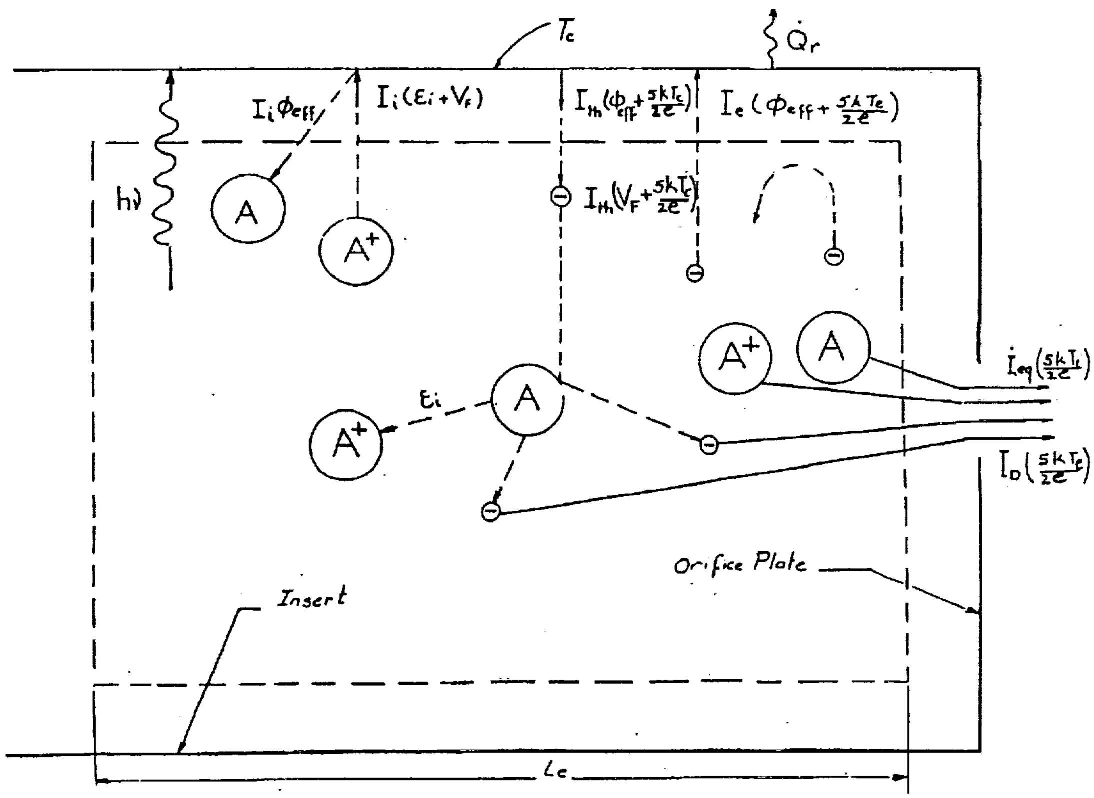
-- Extend understanding of hollow cathode design to embrace both low current and high current regimes.

APPROACH

-- Start theoretical modeling from the notion of reducing losses from the vicinity of the cathode by operating in a hohlraum, and at high current density.

-- Cast model in terms of operating values of current, and mass flow rate, material properties, and cathode dimensions. Extend from first-principles only as needed to encompass new aspects of operation.

-- Compare theory with existing data, and generate new data to test model.



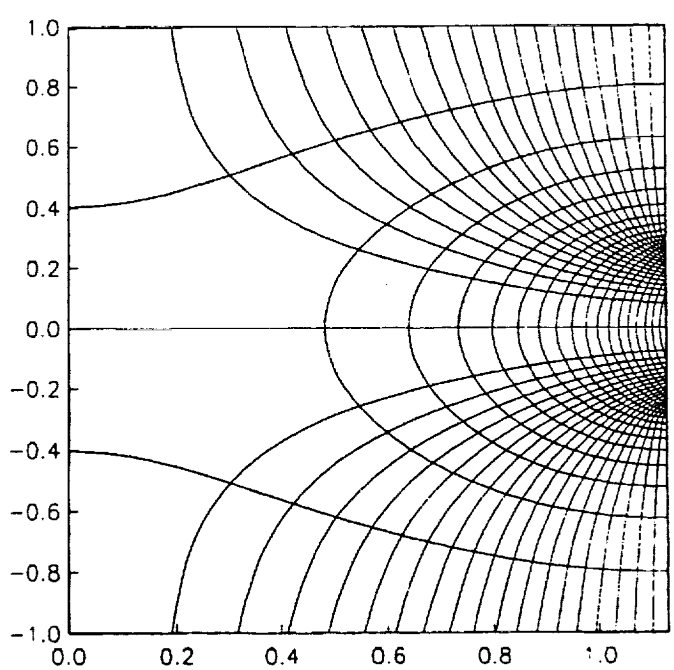


FIGURE 31: Equipotential and Current Lines (I_D = 3.3 A)

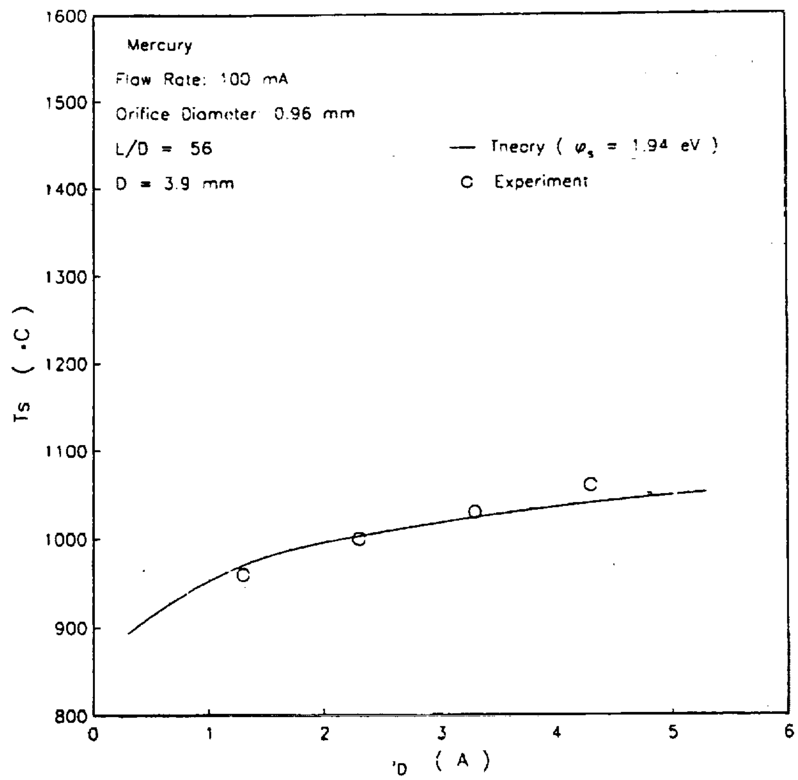


Figure 1 : Effect of Discharge Current on Emission Surface Temperature

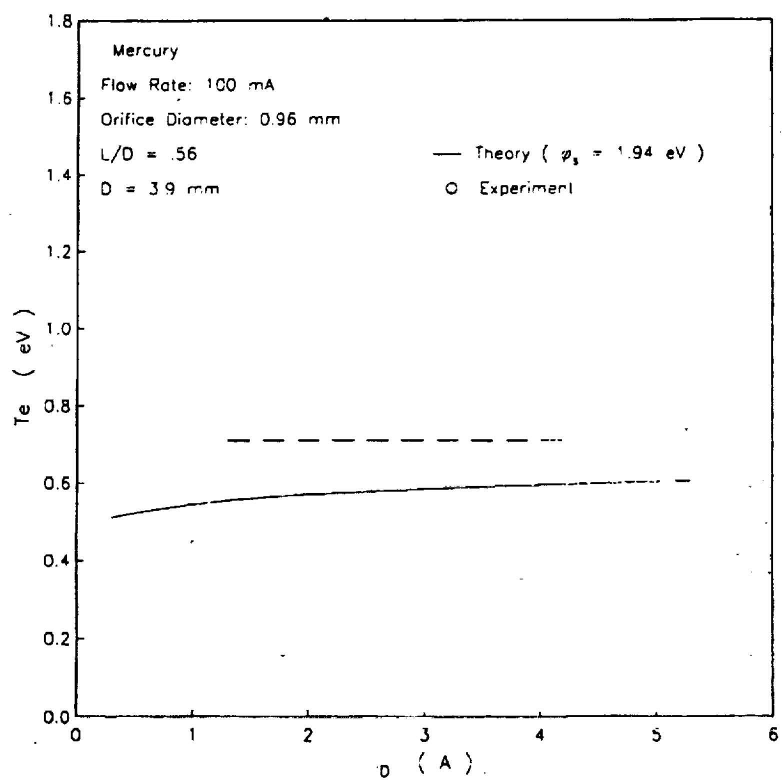


Figure 2 : Effect of Discharge Current on Electron Temperature

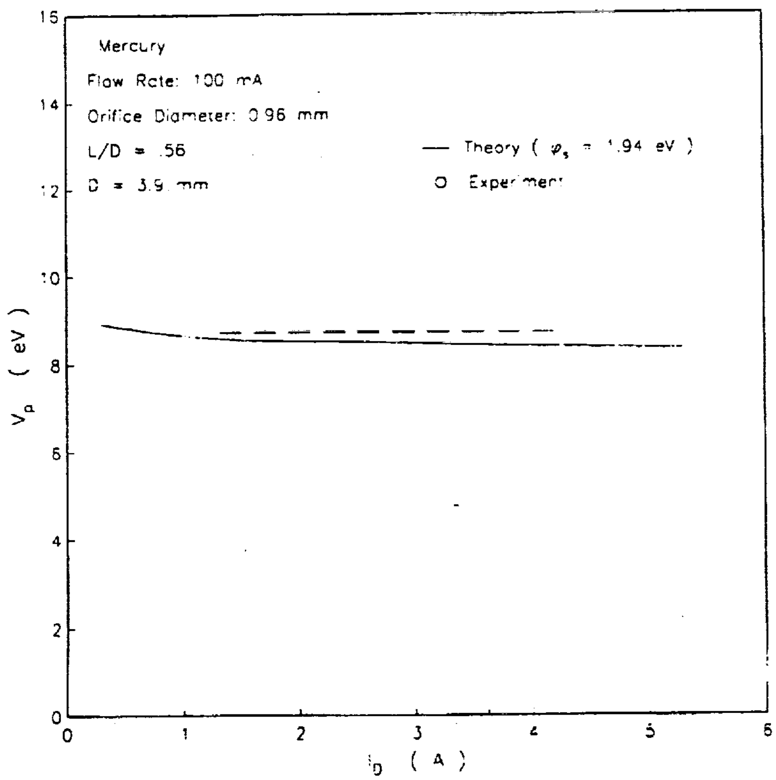


Figure 3 : Effect of Discharge Current on Plasma Potential

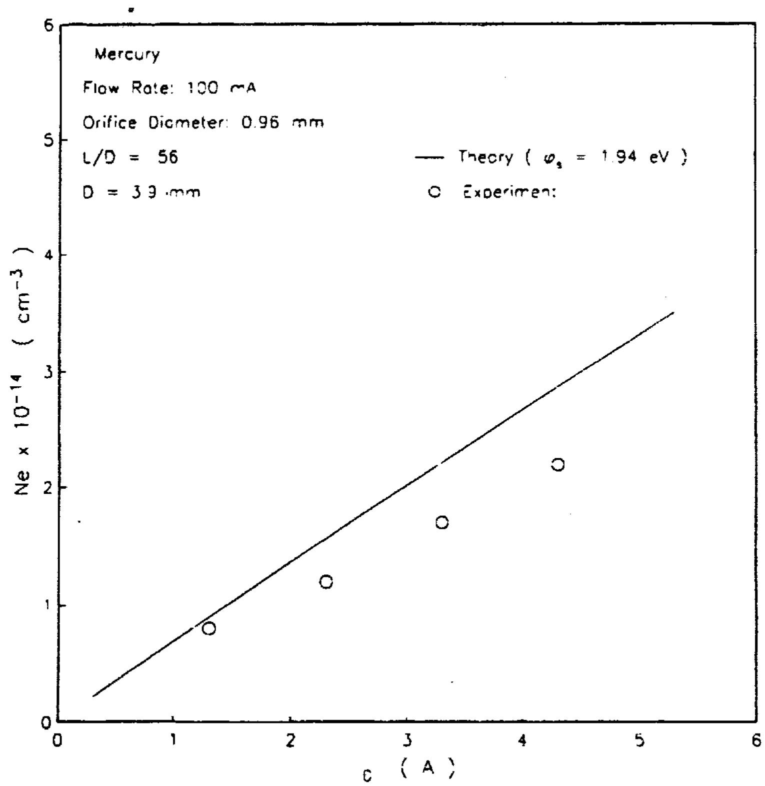


Figure 4 : Effect of Discharge Current on Plasma Density

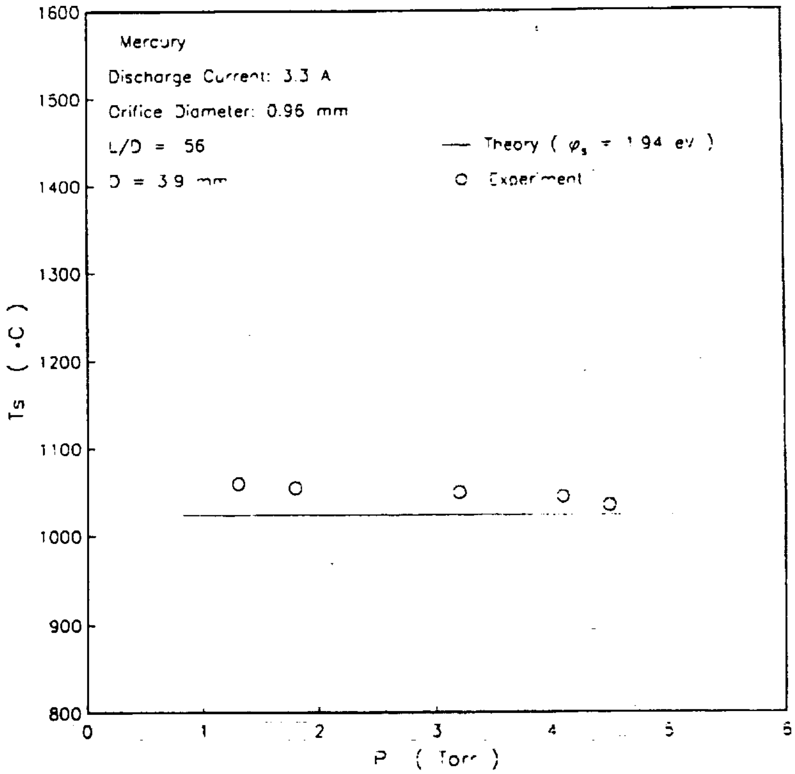
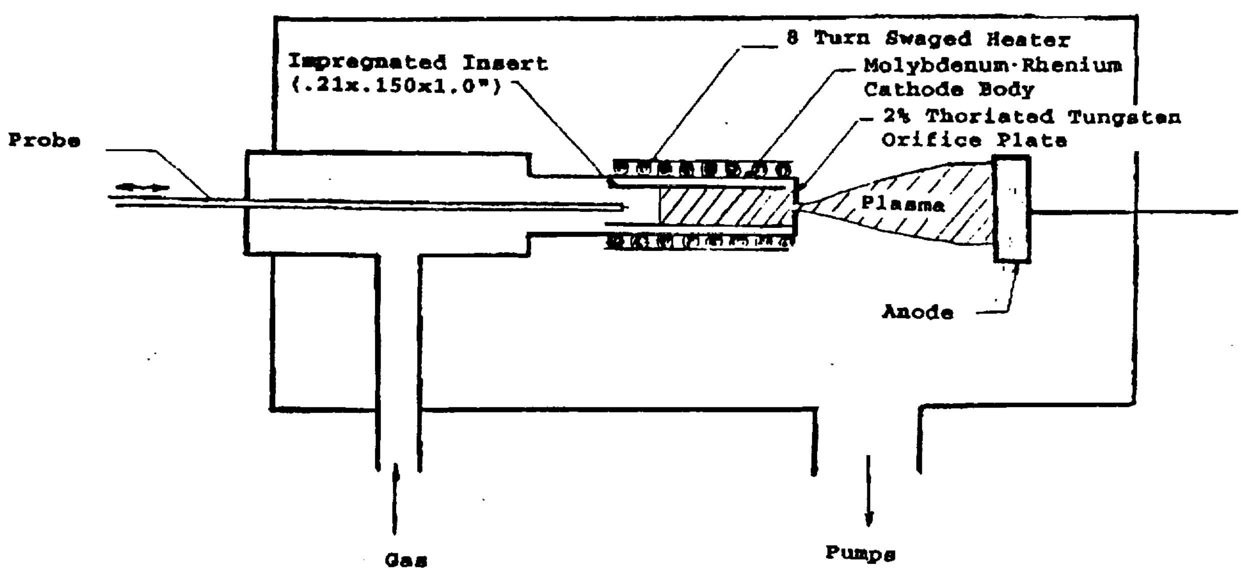


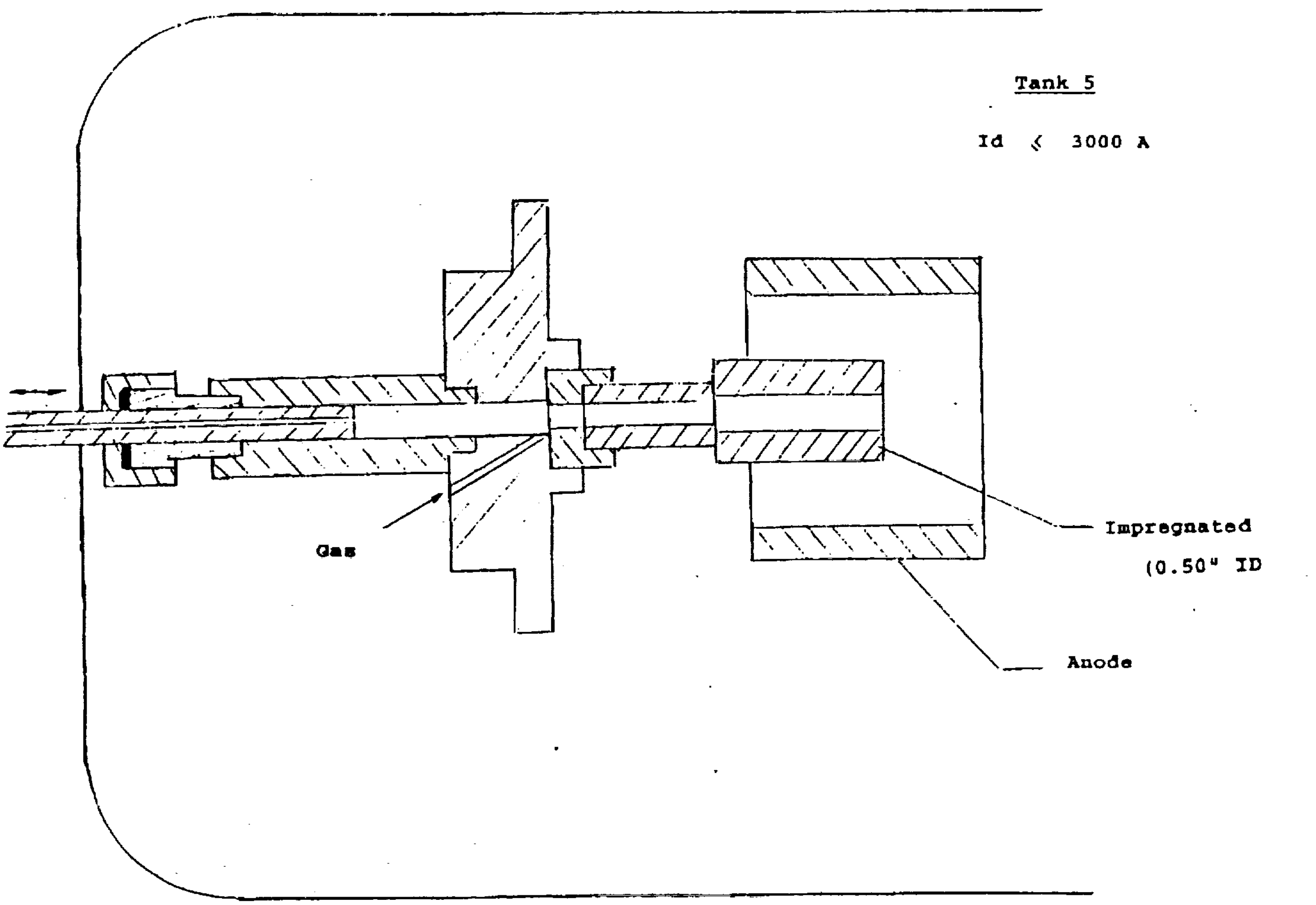
Figure 5 : Effect of Pressure on Emission Surface Temperature

Bell Jar 6

Id ≤ 30 A



A Typical Experimental Arrangement of HCA



Schematic Representation of Hollow Cathode

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ANODE FLOW-FIELD STUDIES

<u>MOTIVATION</u>

-- Present moderate power MPD arcjets appear to be losing substantial fractions of the input power near the anode. We need to understand the MPD flow field near the anode in order to improve performance.

<u>APPROACH</u>

-- Accept that there are too many competing mechanisms in the vicinity of the anode surface to proceed confidently in predicting the flow-field densities, temperatures, Hall parameters, etc.

-- Use a state-of-the-art MHD code (MACH2) to perform the arithmetic in a self-consistent fashion to describe the flow-field. Develop and extend models (and MACH2) from this description of the flow-field.

-- Explore flow-field behavior to develop candidates for improved performance.

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NEW THINGS IN MACH2 SINCE LAST YEAR'S WORKSHOP

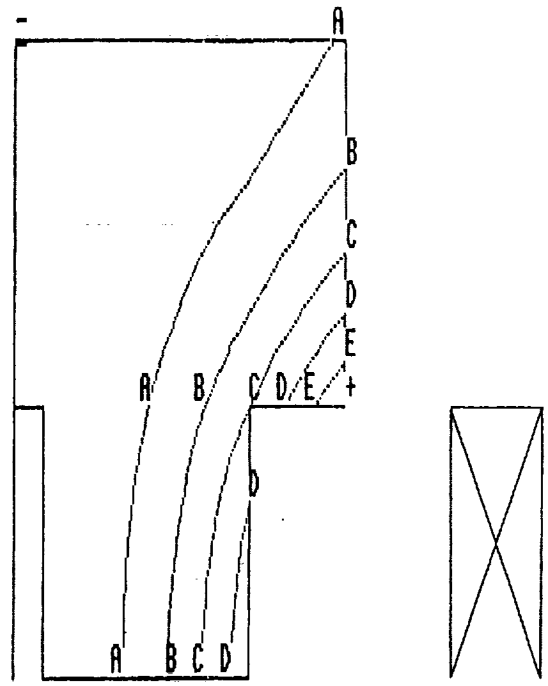
-- Two-temperature (heavy-particle <u>vs</u> electron) equation-of-state is now available within SESAME tables.

-- Magnetic field generation routines and boundary conditions for <u>steady</u>-<u>state</u> poloidal (rz) magnetic fields due to both plasma currents and external field coils have been added.

-- Magnetic fields due to external coils with (specified) time-varying currents are also included.

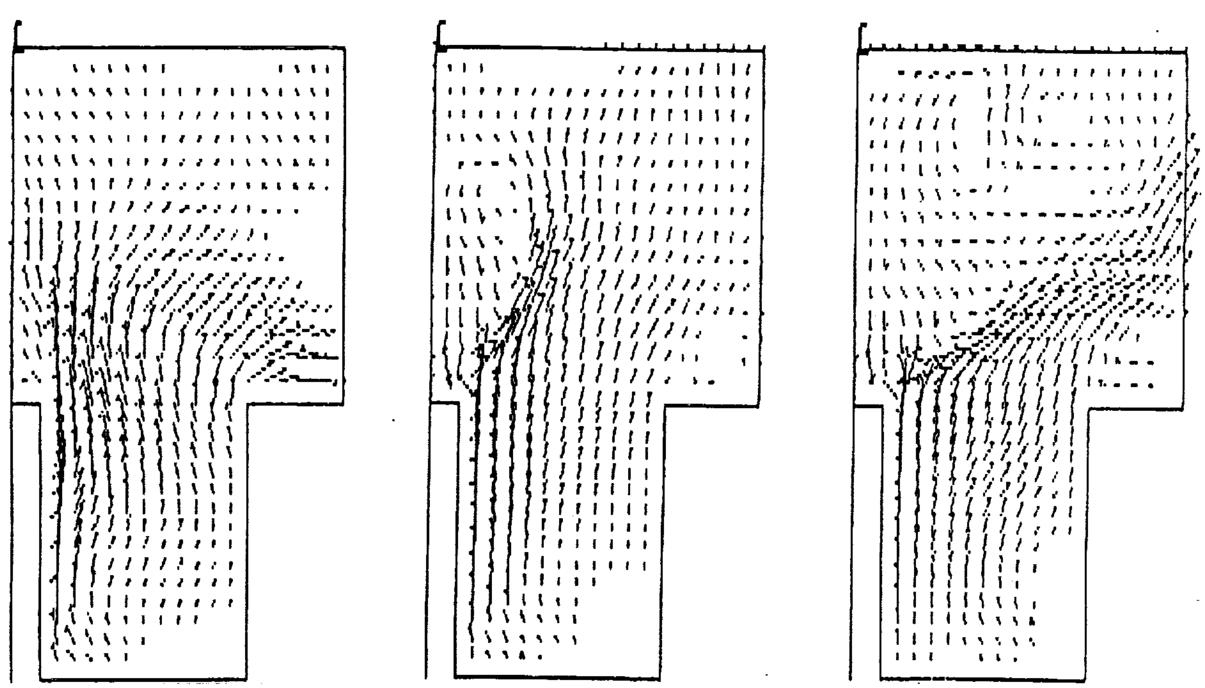
MACH2 STUDIES OF APPLIED FIELD MPD ARCJET

PROPELLANT : ARGON
MASS FLOW RATE : 0.1 g/s
DISCHARGE CURRENT : 1000 Amp



MAGNETIC FLUX

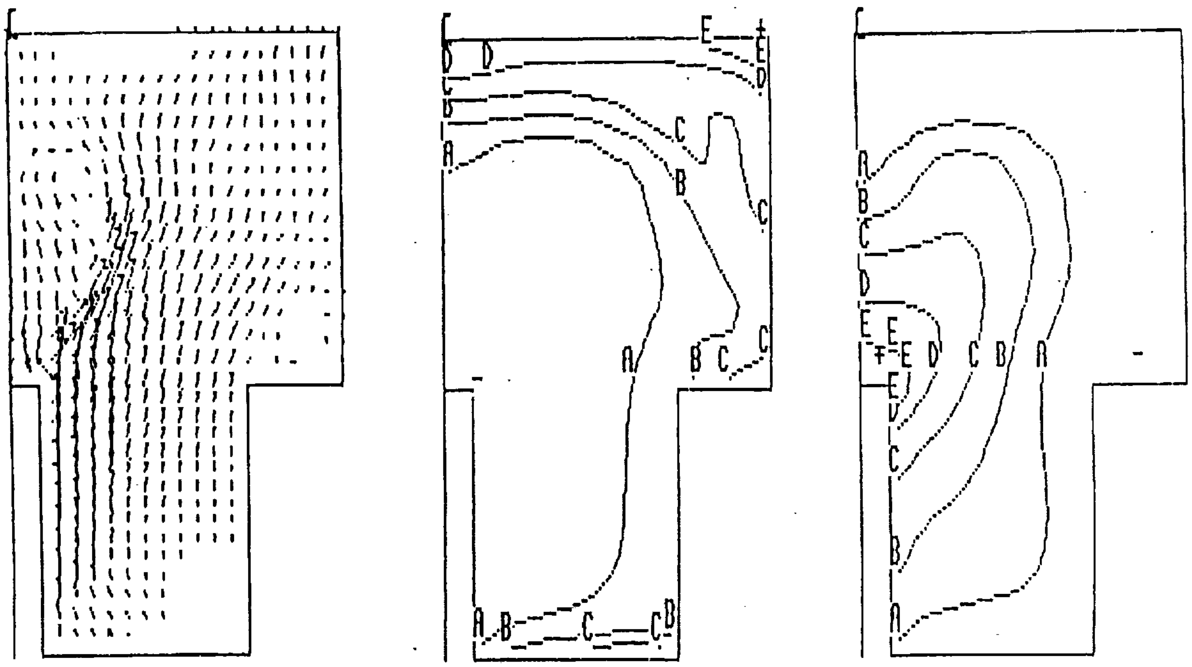
MACH2 STUDIES OF APPLIED FIELD MPD ARCJET



T = 40 μsec   T = 80 μsec   T = 200 μsec

MACH2 STUDIES OF APPLIED FIELD MPD ARCJET

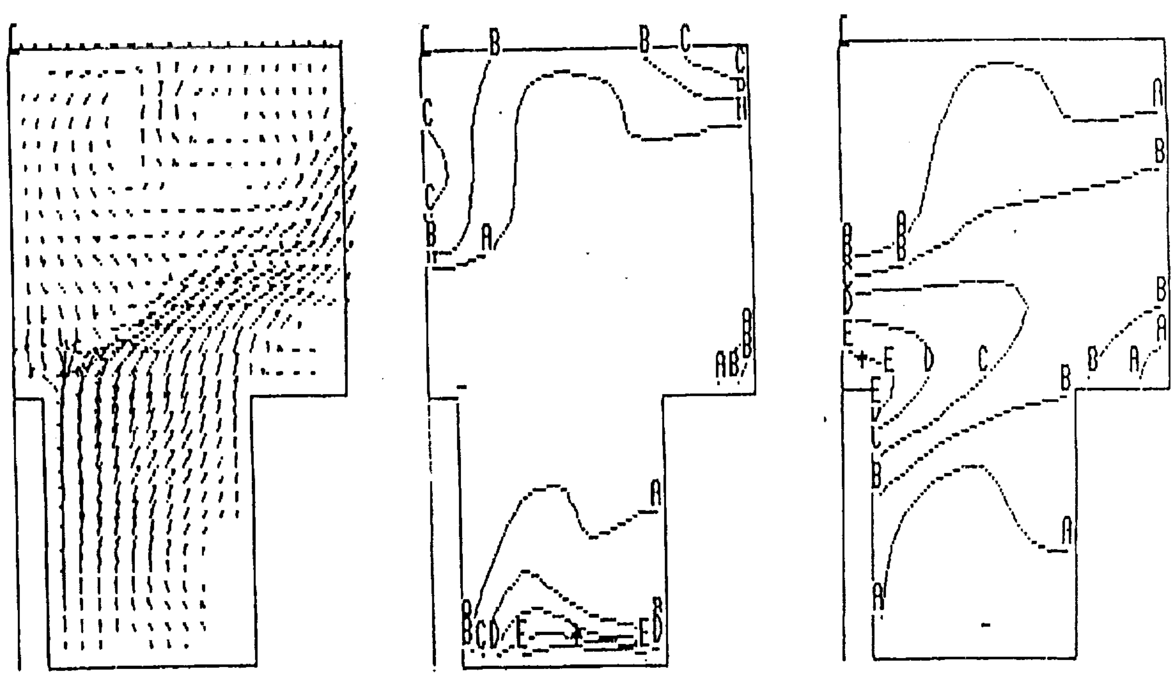
TIME = 80 μsec



VELOCITY DENSITY TEMPERATURE

MACH2 STUDIES OF APPLIED FIELD MPD ARCJET

TIME = 200 μsec



VELOCITY DENSITY TEMPERATURE

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ISSUES

PHILOSOPHICALLY

"Ah Love, if you and I with Fate but could conspire
    To grasp this sorry scheme of things entire,
Would not we shatter it to bits,
    And remold it nearer to the heart's desire"

- Omar/Fitzgerald

PROGRAMMATICALLY

Designing what we want <u>vs</u> Cataloging what we have