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ION THRUSTER PROJECT

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16. Abstract

The mercury bombardment electrostatic ion thruster is the most successful electric thruster available today. A 5 cm diameter ion thruster with 3,000s specific impulse and 5mN thrust is described. The advantages of electric propulsion and the tests that will be performed are also presented.

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1. Operation

The specific impulse (I_s) is the quantity of thrust (F) generated in a rocket per unit of emptying in weight of propellant ($\dot{m}g$). /1* This value is directly proportional to the velocity of exhaust of the gases (v) and is limited to 300 s for chemical rockets:

$$I_s = F/\dot{m}g = V/g$$

The ionic thruster by electrostatic acceleration is capable of producing a specific impulse of up to 10,000 s and a thrust on the order of 10 mN. In the thruster (Figure 1), the vaporized propellant (Hg, Cs, Ar, or others) is injected into an ionization chamber where it is bombarded with electrons with an energy of approximately 50eV (in case the propellant is mercury). The impact between the particles gives rise to a plasma of density $N = 10^{12}/cm^3$ and a temperature of KTe = 5eV. The ions created are extracted and accelerated by the electrical field existing between the separation of stage and that of acceleration, near the chamber outlet. The final velocity of the ions is controlled by the potential of the separation stage, and, to maintain the neutrality of the spacecraft, some electrons are emitted together with the ion beam. The primary electrons are obtained by thermionic emission and the path of the electrons from the cathode to the anode is increased by creating an axial magnetic field inside the chamber.

2. Application

Change of Orbit

A thruster is capable of carrying two or three times more payload from an orbit of 300 Km to a geostationary orbit than the thruster using hydrazine (Figure 2).

*Numbers in margin indicate foreign pagination.

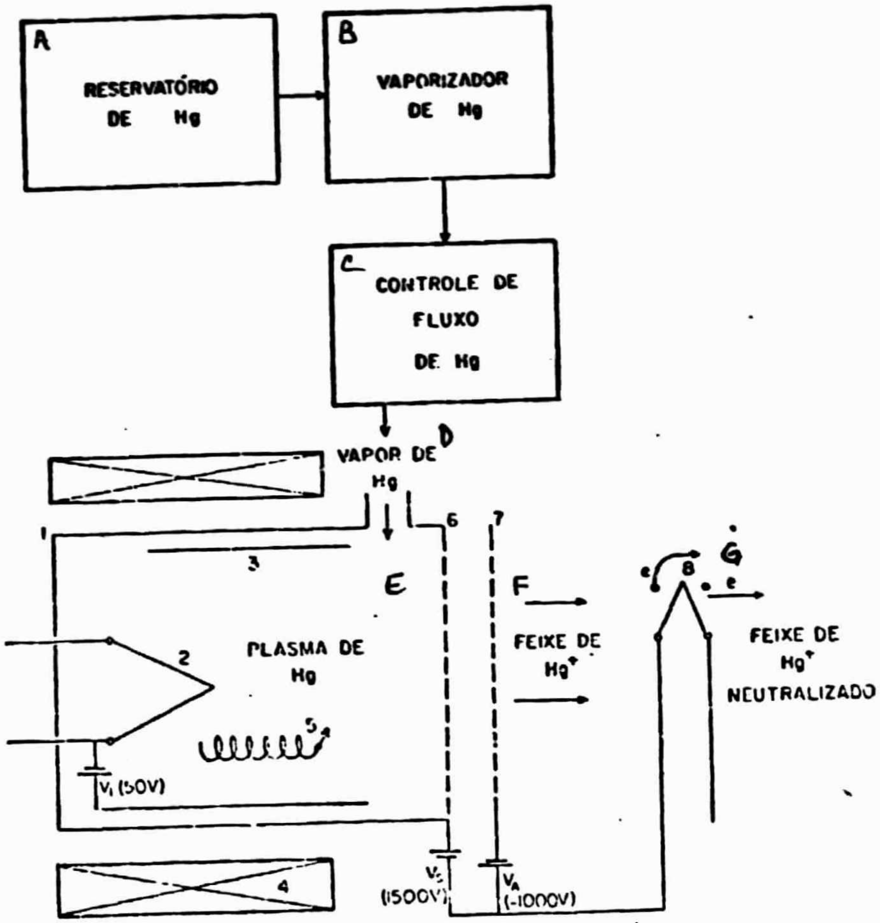

Figure 1. Schematic operation of an ionic thruster.

Key: 1) Ionization chamber; 2) Cathode; 3) Anode; 4) Coils of the magnetic field; 5) Trajectory of the primary electron; 6) Separation stage; 7) Acceleration stage; 8) Neutralizer.

Key: A) Hg tank; B) Hg vaporzier; C) Hg flow control; D) Hg vapor; E) Hg plasma; F) Hg+ beam; G) Neutralized Hg+beam.

Latitude Correction

The thruster is capable of increasing by 300 Kg the payload of a geostationary satellite of 2,000 Kg with a useful life of 7 years (Figure 3).

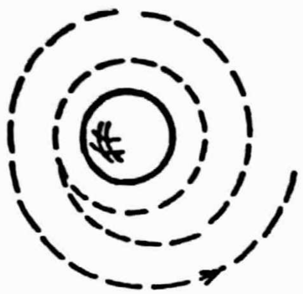

Figure 2. Trajectory for change of orbit used by an ionic thruster.

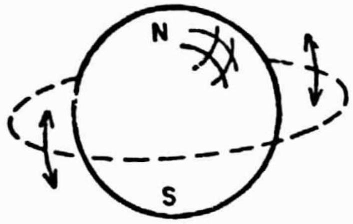

Figure 3. Operation of the thrusters to maintain the correct latitude of a satellite.

Mobile Satellite

The total pulse provided by an electric thruster is nearly twice as large as the one provided by chemical rockets of the same weight (Figure 4).

Figure 4. Alteration of the position of a satellite in space.

Interplanetary Missions

The electrical thrusters are capable of carrying more scientific equipment on board and causing the spacecraft to have a higher velocity (Figure 5).

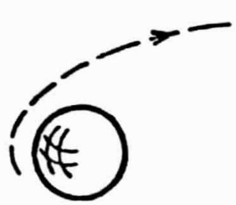

Figure 5. Satellite entering into interplanetary space.

3. Characteristics of the Project

Thrust	5 mN
Specific impulse	3,000 s
Propellant	Hg
Ionization chamber:	Reverse Flow
Design:	Modular
Dimensions	
Potential of the separation stage	1,500 V
Potential of the acceleration stage	12 v
Separation of the stages	1.4 mm
Thickness of the separation stage	* mm
Thickness of the acceleration stage	1.0 mm
Current density through the stages	116 A/m^2
Diameter of the outlet cross section:	100 mA
Diameter of the gaps of the stages	1.4 mm
Length of the ionization chamber	10 cm
Magnetic field in the center of the chamber:	60 G
Diameter of the outlet	5 cm
Power supply sources	
Vaporizer	10 V/5A
Cathode heater:	10 V/5A
Cathode discharge	80 V/8A
Magnetic field:	10 V/5A

* Illegible

Separation stage	1,500/100 mA
Acceleration stage	1,500/100 mA
Heater of the neutralizer	10 V/5A
Neutralizer:	10V/100 mA

The first model of the ionic thruster may be seen on Figure 6.

4. Experimental Part

Figure 7 shows a photo of the first model of the ionic thruster, which consists of: Hg tank, vaporizer, ionization chamber, separation and acceleration stages, magnetic field and neutralizer. Each of the components of the thruster may be modified separately, without altering the others. Thus it is possible to optimize simply each of the components of the thruster. /7

To simulate the conditions found in space, the test chamber of the thruster must be large enough not to interact significantly with the ion beam, maintain a pressure of 10^{-6} torr at maximum, and have a system which assures that all the mercury expelled by the thruster should not interfere with the beam. The ion beam will be studied in a chamber of 85 cm diameter by 120 cm length and with cryogenic cooling. The thruster will be installed in a smaller chamber connected with the first one by a valve of the pendulum type, which allows the smaller chamber to be opened and closed without any loss of the vacuum in the main chamber.

It is intended to carry out tests of thrust, propellant consumption, specific impulse and other operating conditions at the beginning of 1984, while by 1985 it is expected to have sufficient data to build a second improved model.

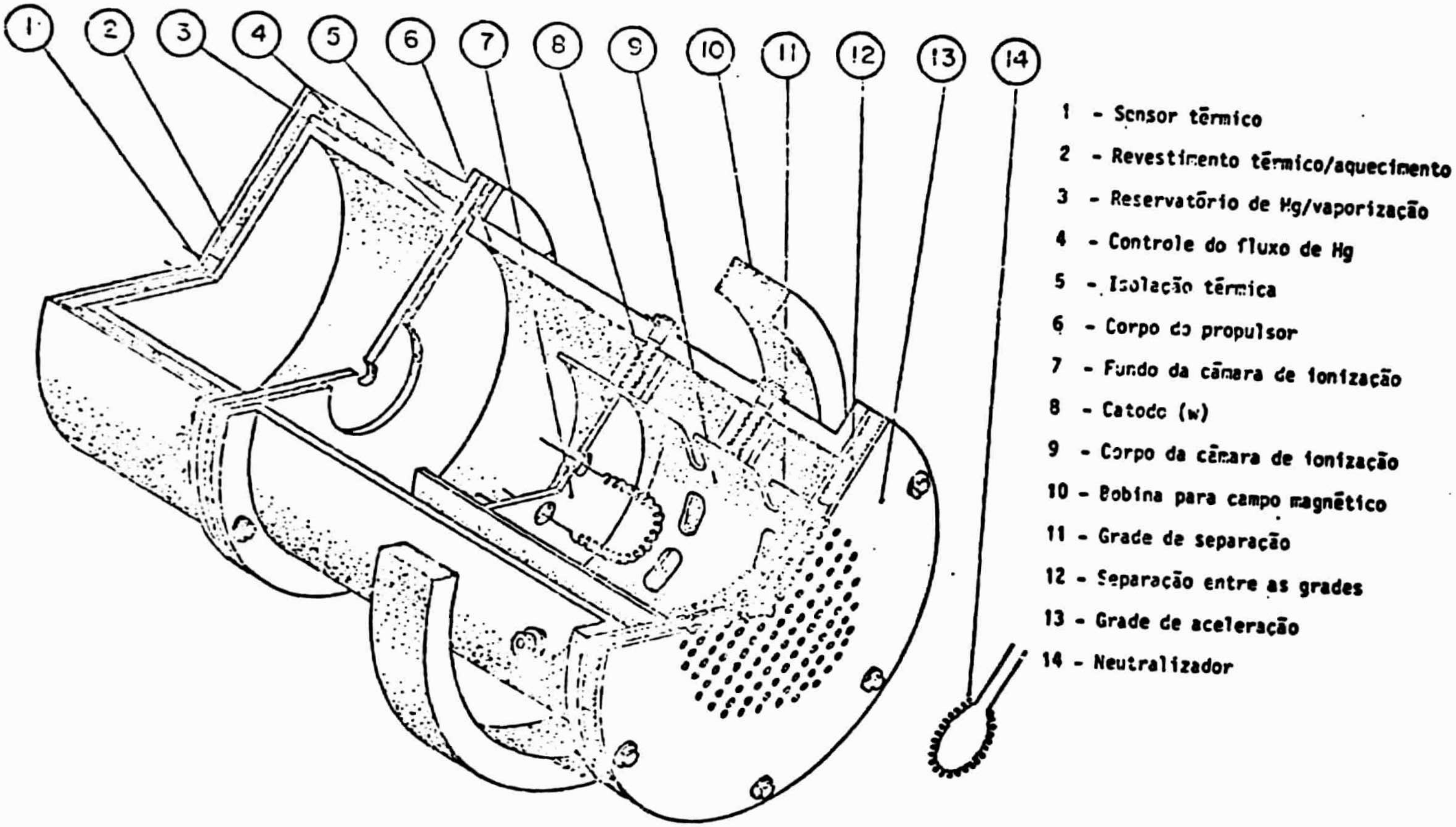

Figure 6. Cross section of the first model of the ionic thruster.

Key: 1) Thermal sensor; 2) Thermal/heating lining; 3) Hg vaporization tank; 4) Hg flow control; 5) Thermal insulation; 6) Thruster body; 7) Bottom of the ionization chamber; 8) Cathode (w); 9) Body of the ionization chamber; 10) Coils for the magnetic field; 11) Separation stage; 12) Separation between the stages; 13) Acceleration stage; 14) Neutralizer.

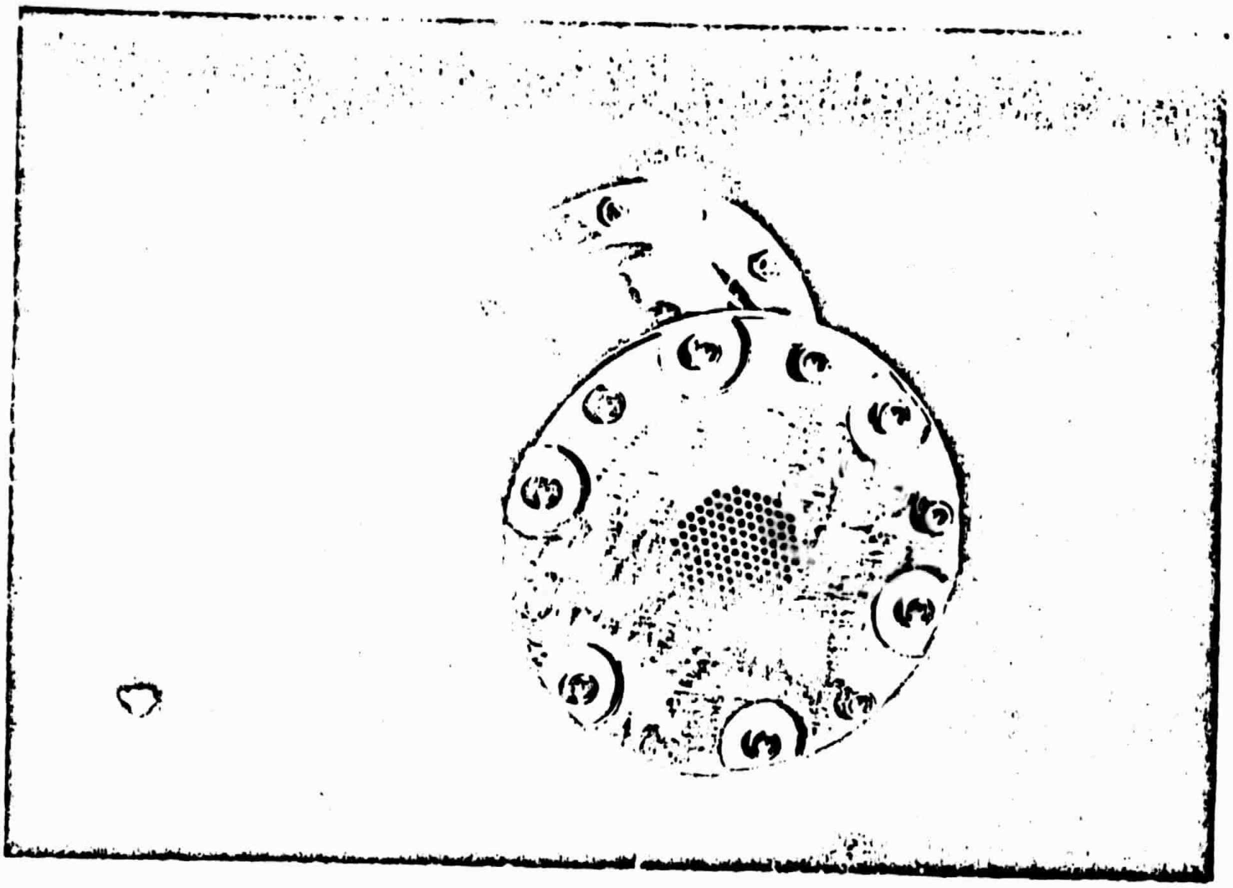

Figure 7. Photo of the first model of ionic thruster.