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ION THRUSTER MAGNETIC FIELD CONTROL

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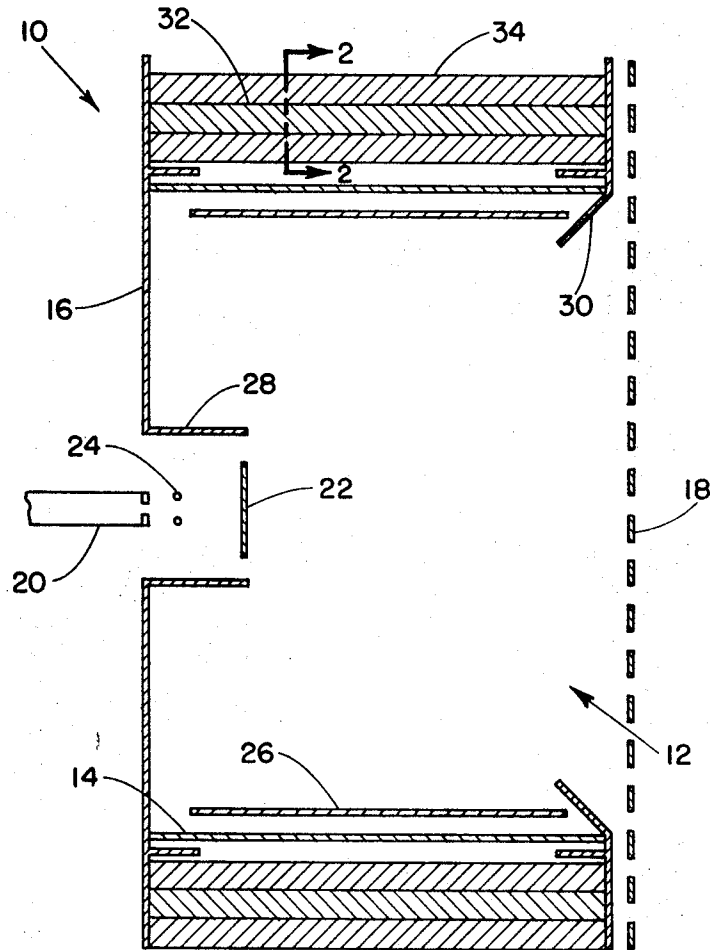


FIG. 1

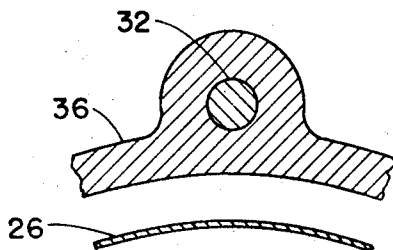


FIG. 3

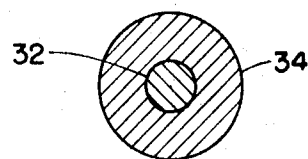


FIG. 2

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ION THRUSTER MAGNETIC FIELD CONTROL
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10 Claims

ABSTRACT OF THE DISCLOSURE

The magnetic field of an ion thruster is automatically shunted when the thruster is not operating.

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention is concerned with controlling the magnetic field of an ion thruster for improved starting and to enable adjacent magnetic field sensing devices to properly sense the natural magnetic field. The invention is particularly directed to a temperature controlled magnetic shunting system that is self-control and operates without power.

An electron bombardment ion engine of the type shown in U.S. Pat. No. 3,156,090 has a chamber in which a vaporized propellant is ionized by high velocity electrons emitted by a cathode. A magnetic field is used to increase the path traveled by the high velocity electrons so that more electrons will collide with propellant particles in the chamber.

Transient difficulties have been encountered with starting a thruster having a high magnetic field. Also satellites and planetary probes using electron bombardment ion thrusters may carry magnetic field sensing devices. The natural magnetic field will not be properly sensed if the sensing device is influenced by the ion thruster.

An electromagnet has been used to produce the required magnetic field. While an electromagnet provides accurate control of the magnitude of the magnetic field it consumes power and requires power conditioning equipment. This equipment adds weight and complexity to the thruster.

Electrostatic ion thrusters of the type shown in U.S. Pat. No. 3,238,715 utilize permanent magnets to produce the required magnetic field. While these permanent magnets require no power there is no control of the magnetic field.

SUMMARY OF THE INVENTION

These problems have been solved by the present invention wherein a thruster is provided with a permanent magnet shunting structure that functions automatically. During operation of the thruster the required magnetic field is provided by a permanent magnet. When the thruster is not operating the magnetic field is confined to a very small region to eliminate stray field lines which might interfere with the natural magnetic field found by adjacent magnetic field sensors.

OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to provide an automatic control for the magnetic field of an ion thruster.

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Another object of the invention is to provide a control which effectively turns on and off the magnetic field in the discharge chamber of an ion thruster without any external control equipment.

A further object of the invention is to provide a magnetic field control for an ion thruster which does not require any external power.

These and other objects of the invention will be apparent from the specification which follows and from the drawing wherein like numerals are used throughout to identify like parts.

DESCRIPTION OF THE DRAWING

FIG. 1 is an axial sectional view of an ion thruster having a magnetic field control constructed in accordance with the invention;

FIG. 2 is a sectional view taken along the line 2—2 in FIG. 1;

FIG. 3 is a partial view illustrating an alternate embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing there is shown in FIG. 1 an electron bombardment ion thruster 10 having an ionization chamber 12 within a tubular housing 14. A distributor 16 in the form of a mild steel plate is mounted at one end of the chamber 12.

An accelerator system 18 is mounted at the opposite end of the ionization chamber 12. The accelerator system 18 may be of the double grid type disclosed in U.S. Pat. No. 3,156,090. This system may also be of the single grid type disclosed in application Ser. No. 758,390 which was filed Sept. 9, 1968.

In operation, a gaseous propellant, such as mercury, discharges from the end of a hollow cathode 20 and passes through a baffle 22 into the chamber 12. A potential is applied between a keeper cap 24 and the cathode 20. Electrons emitted from the heated cathode initiate an arc discharge as described in copending application Ser. No. 38,262 entitled "Ion Thruster Cathode" which was filed May 18, 1970.

An anode 26 mounted in the chamber 12 receives electrons from the cathode 20 as described in U.S. Pat. No. 3,156,090. The electron paths are lengthened by a suitable magnetic field within the chamber 12. Such a magnetic field is formed between a cathode pole piece 28 and a grid pole piece 30.

The cathode pole piece 28 is mounted on the distributor plate 16 in surrounding relationship relative to the baffle 22. The grid pole piece 30 is mounted adjacent the grid 18. Both pole pieces 28, 30 are preferably of mild steel to guide the magnetic lines of flux which flow between the pole pieces 28, 30.

According to the present invention the magnetic field is established by high ferromagnetic Curie temperature permanent magnets 32 which are mounted adjacent of the housing 14 as shown in FIG. 1. These magnets 32 extend between the distributor plate 16 and the grid pole piece 30.

Each permanent magnet 32 is completely surrounded by a low ferromagnetic Curie temperature alloy shunt 34 as shown in FIGS. 1 and 2. When the thruster 10 is not operating the thruster housing 14 and magnet system are cool. Because the thruster is cool the low ferromagnetic Curie temperature alloy 34 provides a magnetic shunt for the magnetic flux which would normally go through the pole pieces 30 and into the ionization chamber 12. In this manner the magnetic field lines stay essentially confined to each permanent magnet and the shunt alloys surrounding it when the thruster is cool. The temperature of the thruster 10 is well below the ferromagnetic Curie

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temperature of the surrounding shunt alloy 34 when the thruster is not operating.

When a weak discharge is obtained between the cathode 20 and the anode 26 the housing 14, the anode, the permanent magnets 32, and a low Curie temperature alloy 34 begin to heat. When this occurs the shunt formed by the alloy 34 begins to lose permeability and does not divert as much of the permanent magnet flux as it did when it was cool. When the shunt 34 heats up to or above its Curie temperature it becomes paramagnetic, and all of the permanent flux as if the shunt were not there.

When the thruster 10 is hot the magnet system allows the normal operating flux to pass through the ionization chamber 12. When the thruster is cool the flux is confined to the shunt-magnet system.

The shunt material 34 may be a nickel-iron alloy. One satisfactory alloy of approximately 34% nickel and 70% iron has a Curie temperature of about 300° F.

With such a shunting material the permanent magnet 32 may be alnico 5. This material has a Curie temperature of about 1634° F.

DESCRIPTION OF THE ALTERNATE EMBODIMENT

Referring now to FIG. 3 there is shown an alternate embodiment of the invention. In this embodiment a shunting material 36 not only surrounds each permanent magnet 32, but also forms the housing of the thruster. In this embodiment no other housing structure is utilized. The anode 26 is adjacent the shunting material 36.

While the preferred embodiment of the invention has been shown and described it will be appreciated that various structural modifications may be made without departing from the spirit of the invention or the scope of the subjoined claims. By way of example, the anode 26 may also be made of the shunting alloy. Also the body of the thruster may be fabricated in the form of concentric cylinders of permanent magnet and shunting alloys. It is further contemplated that the cathode pole piece may be fabricated in the form of concentric cylinders of permanent magnet and shunting alloys.

What is claimed is:

1. An electron bombardment ion thruster comprising:
 - a housing forming the peripheral wall of the chamber for containing an ionizable propellant,
 - a source of said propellant in communication with said chamber,
 - an anode within said chamber,
 - a cathode for emitting high velocity electrons to said anode for bombarding said propellant to form ions,
 - an apertured grid positioned at one end of said chamber to accelerate said ions away from said thruster,
 - a plurality of permanent magnets adjacent said housing

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to form a magnetic field about said anode and cathode whereby the paths of said high velocity electrons are lengthened to increase the rate of collision of said electrons with particles of said propellant, and means in close proximity with said permanent magnets for shunting said magnetic field only when the temperature in said chamber is below a predetermined minimum value.

2. An electron bombardment ion thruster as claimed in claim 1 wherein the magnetic field is established by high ferromagnetic Curie temperature permanent magnets spaced about the chamber.

3. An electron bombardment ion thruster as claimed in claim 2 wherein the permanent magnets are of an aluminum-nickel alloy.

4. An electron bombardment ion thruster as claimed in claim 2 wherein the means for shunting the magnetic field comprises a low ferromagnetic Curie temperature material adjacent the permanent magnets.

5. An electron bombardment ion thruster as claimed in claim 4 wherein the shunting material is a nickel-iron alloy.

6. An electron bombardment ion thruster as claimed in claim 5 wherein the nickel-iron alloy contains about 30% nickel and 70% iron by weight.

7. An electron bombardment ion thruster as claimed in claim 4 wherein the shunting material surrounds the permanent magnets.

8. An electron bombardment ion thruster as claimed in claim 7 wherein the low ferromagnetic Curie temperature material forms the housing of the thruster.

9. An electron bombardment ion thruster as claimed in claim 1 wherein the anode is of a low ferromagnetic Curie temperature shunting material.

10. An electron bombardment ion thruster as claimed in claim 1 wherein the housing is in the form of concentric cylinders of permanent magnetic and shunting alloy materials.

References Cited

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