United States Patent [19]

Fletcher et al.

[11] **3,728,861**

[45] **Apr. 24, 1973**

[54] **ION THRUSTER WITH A COMBINATION KEEPER ELECTRODE AND ELECTRON BAFFLE**

[76] Inventors: **James C. Fletcher,** Administrator of the National Aeronautics and Space Administration with respect to an invention by; **Eugene V. Pawlik,** La Canada; **Dennis J. Fitzgerald,** Pasadena, both of Calif.

[22] Filed: **Dec. 20, 1971**

[21] Appl. No.: **209,535**

[52] **U.S. Cl.** **60/202,** 313/63, 313/204, 313/231, 313/DIG. 8

[51] **Int. Cl.**.....**F03h 5/00**

[58] **Field of Search** 60/202; 313/63, 204, 313/DIG. 8

[56] **References Cited**

UNITED STATES PATENTS

3,620,018	11/1971	Banks	60/202
3,603,088	9/1971	Nakanishi	60/202
3,320,475	5/1967	Boring	313/DIG. 8

Primary Examiner—Carlton R. Croyle
Assistant Examiner—Robert E. Garrett
Attorney—Monte F. Mott et al.

[57] **ABSTRACT**

An ion thruster is disclosed in which the cathode front end, surrounded by our insulator, is mounted flush with the front end of the flanged portion of the cathode pole piece. The thruster's baffle positioned in front of the cathode's front end supports the thruster's keeper electrode which is spaced apart and directed to the cathode's open end. The baffle is at the keeper's electrode potential.

6 Claims, 4 Drawing Figures

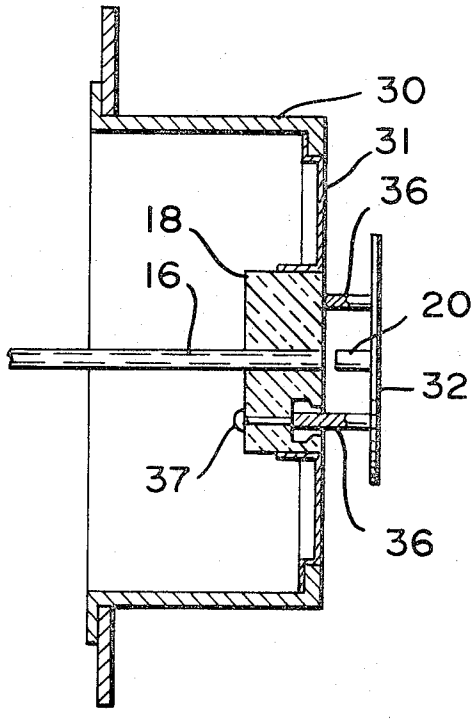


FIG. 1
PRIOR ART

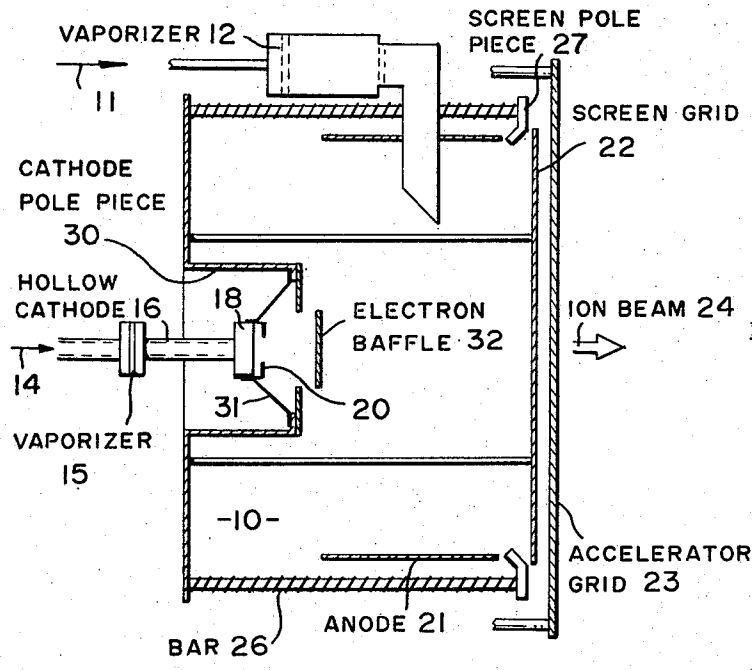


FIG. 2
PRIOR ART

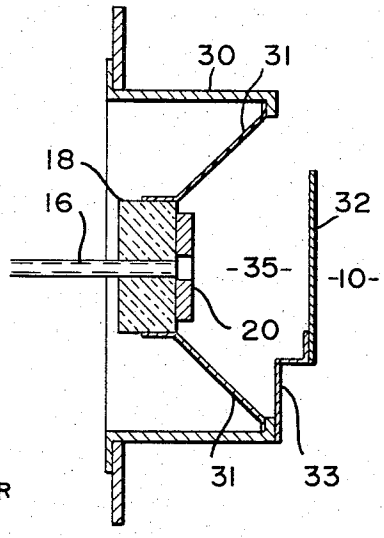


FIG. 3

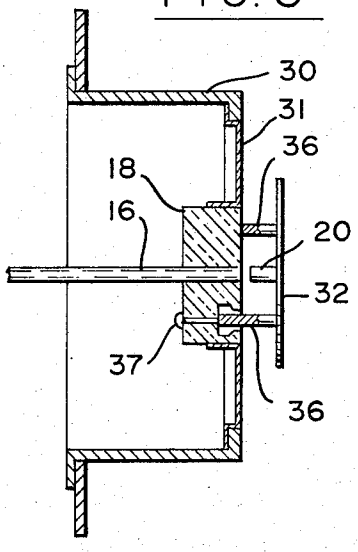
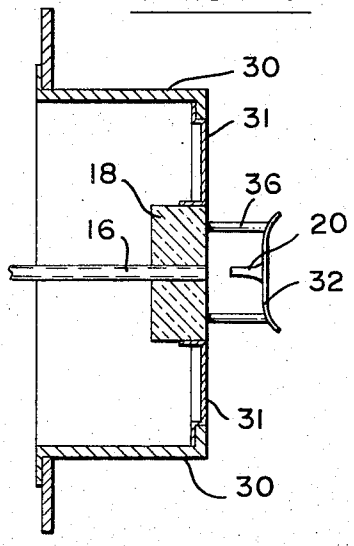


FIG. 4



EUGENE V. PAWLIK
DENNIS J. FITZGERALD
INVENTORS

BY Paul F. McCaul
Monte F. Mott
ATTORNEYS

ION THRUSTER WITH A COMBINATION KEEPER ELECTRODE AND ELECTRON BAFFLE

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is generally related to an ion thruster and, more particularly, to improvements in a hollow cathode ion thruster.

2. Description of the Prior Art

The potential use of ion thrusters in space exploration is well known. Briefly, an ion thruster includes a main ionization chamber wherein a vaporized propellant is ionized by electron bombardment. An electromagnet is included to provide a magnetic field to confine the electrons in order to increase ionization efficiency. The ions exit the thruster through the screen and accelerator grids to form a thrust-producing ion beam. The electrons are provided by a cathode, located at the chamber end opposite the exit end.

The electro-magnet includes two pole pieces, one located near the screen grid and is therefore referred to as the screen grid pole piece. The other pole piece encloses the chamber end at which the cathode is located. It surrounds the cathode and is therefore known as the cathode pole piece. Spaced apart from the cathode toward the main chamber and generally connected to the cathode pole piece is an electron baffle, whose primary function is to deflect and thereby distribute the electrons flowing into the main chamber. The front end of the cathode is generally surrounded by an insulator which supports a keeper electrode in front of the cathode. The function of the latter is to initiate the discharge of electrons and maintain it.

In the prior art the baffle is placed ahead of the cathode pole piece front end and the cathode is placed farther backward so that the keeper electrode with insulators which connect the insulator to the cathode pole piece, the side walls of the pole piece and the baffle form a small chamber ahead of the main ionization chamber. With a hollow cathode, supplied with vaporized propellant, ions are formed within this small chamber. However their contribution to the overall ion population, forming the desired beam, is minimal. This is due to the fact that an electrostatic barrier is formed between the baffle and the cathode pole piece which prevents any ions, produced in the small chamber, from entering the main chamber. Thus, from an ion-producing point of view the small chamber represents wasted volume or reduced efficiency. Another major disadvantage of the prior art ion thruster is noise during normal operation. High amplitude oscillations were observed in the arc current or plasma ion source. These oscillations interfere with the thruster control loops and is an undesirable source of electro-magnetic radiation, such as spurious induced voltages in nearby equipment. Thus even though the prior art ion thruster operates satisfactorily in some respects, it is desirable to increase its efficiency and reduce, if not completely eliminate, the noise produced thereby.

OBJECTS AND SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide an improved ion thruster.

Another object of the present invention is to provide a hollow cathode type ion thruster with increased efficiency.

A further object of the present invention is to provide an improved hollow cathode type ion thruster which produces less noise than similar prior art thrusters.

These and other objects of the invention are achieved by eliminating the small chamber, herebefore referred to, and by combining the keeper electrode and the baffle into a single structure of equal potential. Basically, the cathode is moved forward so that its front end and that of the insulator surrounding it are flush with the end of the cathode pole piece at the rear end of the main chamber. Spaced apart from the cathode is a structure supported by the insulator. The structure includes the baffle and the keeper electrode which extends from the structure toward the cathode's hollow end. The baffle and the keeper electrode are maintained at the same potential.

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a prior art ion thruster;

FIG. 2 is a partial cross-sectional view of the thruster shown in FIG. 1;

FIG. 3 is a partial cross-sectional view of an ion thruster with the present invention; and

FIG. 4 is a cross-sectional view of other embodiments of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention may best be explained by first describing the structure of a prior art ion thruster in connection with FIGS. 1 and 2. FIG. 1 is a simplified cross-sectional view of the prior art ion thruster and FIG. 2 is a partial cross-sectional view of the portion of the prior art thruster in which significant changes are made in accordance with the present invention. As shown in FIG. 1, the prior art thruster forms a main ionization chamber **10** into which a main propellant flowing in the direction of arrow **11** enters after being vaporized by vaporizer **12**. Propellant also flows, as indicated by arrow **14**, after vaporization by vaporizer **15** into a hollow cathode **16** which is the source of the electrons. Surrounding the front end of the cathode is an insulator **18** which supports a keeper electrode **20** ahead of the cathode.

The electrons from the cathode are attracted by an anode **21** in chamber **10** and bombard the varporized propellant in the chamber to produce ions. The ions are directed under the influence of a magnetic field to exit the thruster through a screen grid **22** and an accelerator grid **23** in the form of a thrust-producing ion beam **24**. The magnetic field is provided by an electro-magnet consisting of a wound bar **26**, a screen pole piece **27**

and a cathode pole piece **30**. The latter in essence forms the rear wall of chamber **10**. It is flanged so that the flanged portion is spaced from and surrounds the cathode extending toward chamber **10**.

The cathode **16** by means of insulator **18** is physically coupled to the cathode pole piece by means of a support member **31** so that the cathode end, the insulator **18** and the keeper electrode are farther back from the end of the flanged portion of pole piece **30**. Also included is an electron baffle **32** which is placed ahead of the flanged end of pole piece **30** so that electrons can pass from the cathode to the chamber **10** between the pole piece **30** and the baffle. As shown in FIG. **2**, the baffle is spaced apart from the pole piece **30** by a support bracket **33**. The baffle potential is generally the same as that of the thruster which could be the same as the cathode potential or is permitted to float.

In such a prior art thruster the flanged portion of pole piece **30**, the insulator **18** with support member **31** and the baffle form a small chamber **35** ahead of chamber **10**. Therein ions are formed by the bombardment of electrons of the vaporized propellant, flowing through the hollow cathode. However, these ions don't contribute to the ion beam. Due to an electrostatic barrier which is formed in the space between the pole piece **30** and baffle **32**, the ions formed in the small chamber **35** do not pass into chamber **10**. Thus their production and the space of chamber **35** are wasteful thereby unnecessarily limiting the thruster's efficiency. Also, the thruster exhibits undesirable noise as herebefore discussed.

These disadvantages are eliminated by moving the cathode structure forward toward chamber **10** as shown in FIG. **3** and by providing a structure which includes the baffle and the keeper electrode, with both being at the same potential. In FIG. **3** elements like those previously described are designated by like numerals.

By moving the cathode **16** and insulator **18** forward, so that the latter is effectively flush with the flanged end of pole piece **30**, chamber **35** is effectively eliminated, thereby greatly increasing thruster efficiency. It has been discovered that the efficiency increases as chamber **35** is decreased. Also, it has been discovered that the noise problems of the prior art thruster are eliminated, or at least reduced significantly, by providing a single structure for the baffle **32** and the keeper electrode and by keeping the baffle at the keeper electrode potential.

As shown in FIG. **3** the keeper electrode **20** extends from the baffle toward the hollow end of the cathode **16**. The baffle is supported by support memebrs **36** which are fastened, such as by screws **37**, to insulator **18**. The baffle is supported to be in the path of the electrons and spaced apart from the pole piece **30**, while the keeper electrode **20** is spaced apart from the cathode end.

In FIG. **3** baffle **32** is diagrammed as a circular flat disk and the keeper electrode **20** as a solid short cylinder. Although such an embodiment was found to greatly improve the thruster's performance, the invention is not limited thereto. If desired the outer end of the baffle may be flaired outwardly as shown in FIG. **4** and the keeper electrode shaped differently, such as in the form of a truncated curved cone to maximize the electron flow from the cathode into the main chamber **10**. Such flow may further be optimized by controlling the distance between the top of electrode **20** and the cathode end.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art and consequently it is intended that the claims be interpreted to cover such modifications and equivalents.

What is claimed is:

1. In an ion thruster of the type including a main ionization chamber in which ions are formed by the electron bombardment of a vaporized propellant, with said ions exiting said chamber through a front end of said chamber, said ions further including magnetic means for providing a magnetic field in said chamber, said magnetic means including a cathode pole piece forming the back end of said chamber and having a flanged portion extending inwardly toward said chamber front end, a cathode for providing a source of electrons, a keeper electrode at a selected potential for initiating and maintaining the discharge of electrons from said cathode and an electron baffle for controlling the path of electrons entering said main chamber, the improvement comprising:

first means for supporting said cathode with the front end thereof substantially aligned with the front edge of the flanged portion of said cathode pole piece; and

second means for supporting said keeper electrode and said baffle in front of said cathode end toward said main ionization chamber.

2. The arrangement as recited in claim **1** wherein said baffle is at the potential of said keeper electrode.

3. The arrangement as recited in claim **2** wherein said keeper electrode is directly coupled to said baffle and said second means support said baffle so that it is in a plane perpendicular to the cathode axis and the keeper electrode is directed toward the cathode front end and spaced therefrom.

4. The arrangement as recited in claim **1** wherein said first means include an insulator surrounding said cathode at the open end thereof, and means for connecting said insulator to said flanged portion of said pole piece so that the cathode is centrally disposed in said flanged portion.

5. The arrangement as recited in claim **4** wherein said baffle is at the potential of said keeper electrode.

6. The arrangement as recited in claim **5** wherein said keeper electrode is directly coupled to said baffle and said second means include support means for supporting said baffle so that it is in a plane perpendicular to the cathode axis and the keeper electrode is directed toward the cathode front end and spaced therefrom.

* * * * *