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APPARATUS FOR INCREASING ION ENGINE BEAM DENSITY

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2 Sheets-Sheet 1

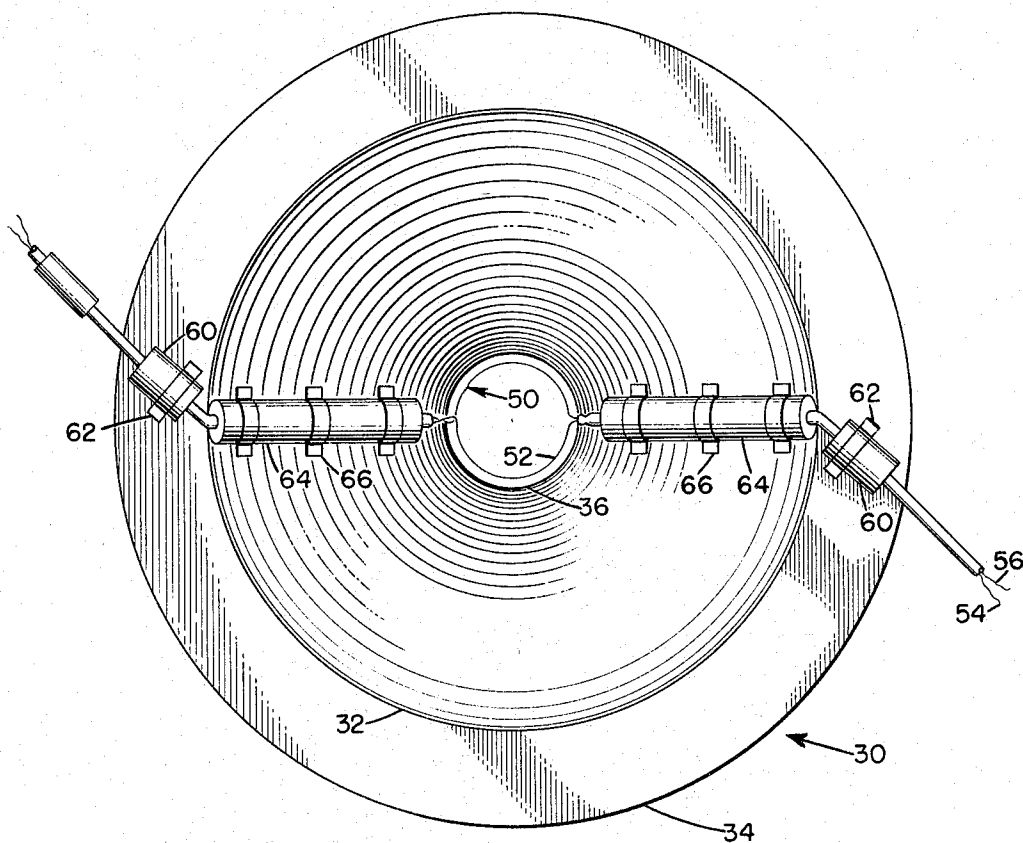


FIG. 1

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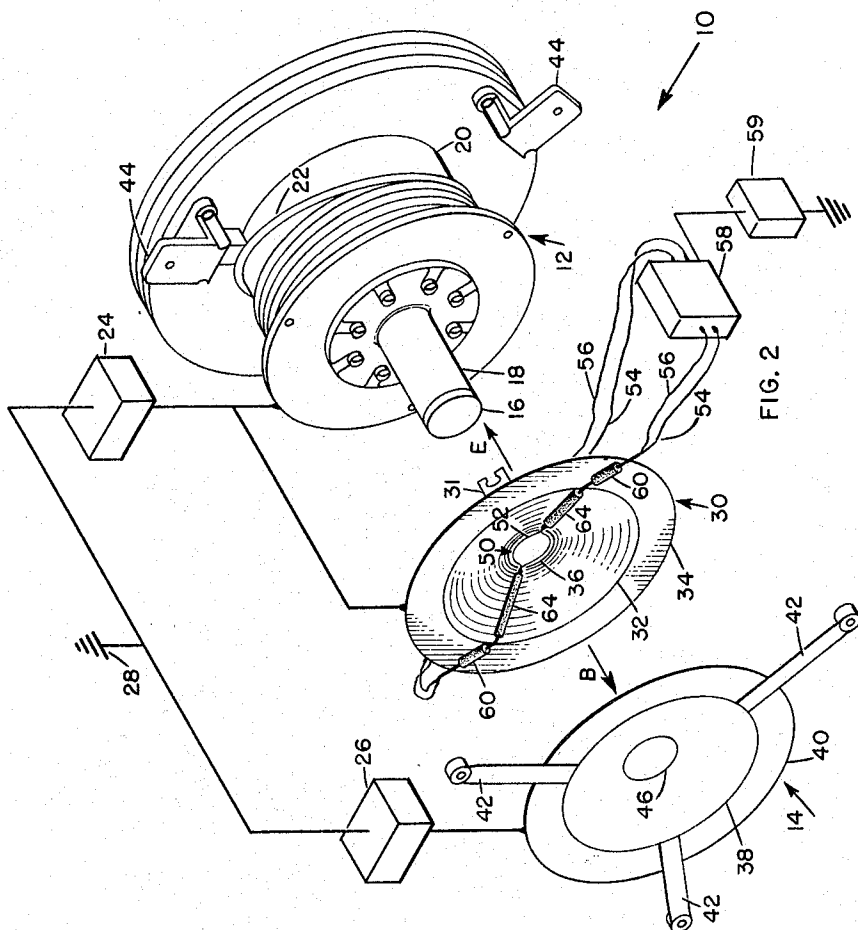
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APPARATUS FOR INCREASING ION ENGINE BEAM DENSITY

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1 Claim. (Cl. 313-63)

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

This invention is concerned with the electrostatic acceleration of ions, and more particularly with an apparatus for increasing the beam density of an ion engine. The apparatus of the present invention is intended to supplement present electrostatic ion accelerator concepts to increase the maximum power obtainable from ion engines.

The electrostatic acceleration of ions is achieved in an ion engine by applying a large electrical potential in an ion accelerator in such a manner that ions are forced out of the engine system into the adjacent space at very high velocities. The geometry of the accelerator may vary from simple grid wires to complex metal forms, and only a limited number of ions can be accelerated in a given electrostatic field because the ions also have an electrostatic charge.

For each electrostatic accelerator geometry, a saturation condition is reached where further increase in the number of ions accelerated does not occur; hence, the thrust available from the engine is correspondingly limited. This is known as space charge limited operation. The space charge limited conditions for various engines have been computed for their specific geometries and found to agree closely with actual measurements. This space charge limited condition can be overcome with the present invention thereby greatly increasing the possible power per unit area available from ion rockets.

The present invention utilizes an ion beam generating apparatus of the type having an ion emitter and an ion accelerator spaced therefrom. An electrical potential gradient is established between the emitter and the accelerator so that ions flow from the emitter towards the accelerator thereby forming an ion beam, and according to the present invention means are provided for increasing the density of this ion beam. This means comprises an electron source, such as a heated filament, mounted between the ion emitter and the accelerator. The fast-moving electrons from this filament travel within the ion beam in a direction opposite that of the ion movement; i.e., towards the ion emitter and away from the ion accelerator.

These fast-moving electrons are believed to strike the ion emitter surface and produce slow-moving secondary electrons which, in turn, alter the local space charge adjacent the ion emitter. Another theory of operation can be formulated which is based on instability of wave phenomenon in the flow of electrons counter to the accelerating ion beam.

It is, therefore, an object of the present invention to provide an apparatus for increasing the beam density of an ion engine to overcome the space charge limited condition of the engine.

Another object of the invention is to increase the beam density of an ion engine by supplying electrons to the beam to increase the available power per unit area in an ion rocket.

Other objects and advantages of the invention will be apparent from the specification which follows and from the drawings wherein like numbers are used throughout to identify like parts.

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In the drawings:

FIG. 1 is a plan view of a focusing electrode utilized in an ion engine having mounted thereon a device constructed in accordance with the present invention for increasing the ion beam density; and

FIG. 2 is an exploded perspective view of an apparatus for producing a high density ion beam according to the method of the present invention.

Referring now to the drawings, there is shown in FIG. 2 an ion beam generating apparatus 10 of the type utilizing an ion source 12 and an ion accelerator 14 spaced therefrom. The ion source 12 includes an ion emitter in the form of a disc 16 having a circular exposed surface facing toward the accelerator 14. The disc 16 is mounted on a tubular member 18 which protrudes from a vaporizer 20. Good results have been obtained from an ion emitter comprising a porous tungsten disc having a thickness of 0.048 inch that is brazed into one end of a molybdenum tube having a 1 inch inside diameter.

The emitter assembly comprising the disc 16 and the tube 18 is heated by any convenient means until the disc 16 reaches the required temperature. One means of heating this assembly utilizes a wire radiation emitter heater (not shown) that encircles the tube 18. The heat transfer from the tube 18 to the vaporizer 20 is adequate for heating an ionizable material such as cesium. Air cooling tubes 22 are provided around the vaporizer 20 to control the temperature which, in turn, determines the amount of vapor of the ionizable material that flows through the tube 18 to the disc 16.

To illustrate the operation of the ion source 12, a glass capsule of cesium metal is placed in the vaporizer 20 and the disc 16 is heated to a temperature of around 2,000° F. while the temperature of the vaporizer 20 is maintained below 300° F. with cooling air moving through the tubes 22. When these conditions are reached, the capsule is broken whereupon some of the cesium is vaporized. As this vapor flows through the porous tungsten disc 16, the cesium molecules are ionized by the hot tungsten surface.

The positive cesium ions are accelerated from the disc 16 by establishing an electrical potential gradient between the ion emitter 16 and the ion accelerator 14. This is accomplished by attaching a power supply 24 to the ion source 12 and by connecting another power supply 26 to the accelerator 14 as shown in FIG. 2. Satisfactory results have been obtained when the power supply 24 has a positive potential in the range from 0-20 kilovolts while the power supply 26 is in the range from 0-10 kilovolts and is negative with respect to a common ground 28. All of the components of the complete ion source 12, including the emitter 16, the tube 18, and the vaporizer 20 have the same electrical potential established by the power supply 24.

A beam forming or focusing electrode 30 is provided to control the initial focusing of the ion beam. While FIG. 2 shows the electrode 30 as being spaced from the ion source 12, it is actually mounted immediately adjacent the ion emitter 16 and held firmly in place by clips 31 that engage suitable mounting members (not shown) on the ion source 12. Because the focusing electrode 30 has the same electrical potential as the ion source 12, it may contact any of its components including the ion emitter 16.

The focusing electrode 30 includes a conical portion 32 surrounded by a marginal circular portion 34 having a generally planar surface as shown in FIGS. 1 and 2. The focusing electrode 30 further has an aperture 36 at the center of the conical portion 32 with a diameter substantially equal to the diameter of the ion emitting surface of the disc 16. The aperture 36 is coaxial with the tube 18, and ions from outer surface of the disc 16 pass through the aperture 36 as shown by the arrow B in FIG. 2.

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The ion accelerator 14 has a configuration similar to that of the focusing electrode 30 in that it includes a conical surface 38 surrounded by a generally circular flat portion 40 having mounting brackets 42 extending therefrom. The ion accelerator 14 is mounted in parallel relationship with the focusing electrode 30 by the brackets 42 that are secured to lugs 44 on the ion source 12. Suitable insulators (not shown) are inserted between the brackets 42 and the lugs 44 to make certain that an electrical potential gradient exists between the source 12 and the accelerator 14 so that the ions are accelerated through an aperture 46 in the center of the conical portion 38.

According to the present invention, a controllable electron source 50 is provided for supplying electrons to the ion beam to neutralize part of the space charge. This electron source comprises a circular filament 52 mounted on the focusing electrode 30 and positioned in the region between the ion source 12 and the accelerator 14. Leads 54 and 56 connected to a suitable power source 58 supply a heating current to the circular filament 52 while a power supply 59 is used to pump electrons from ground into the ion beam. The leads 54 and 56 pass through insulators 60 secured to the marginal flat portion 34 of the focusing electrode 30 by clips 62. A pair of spaced elongated insulators 64 are mounted on the surface of the conical portion 32 of the ion beam focusing electrode 30 by clips 66 as shown in FIG. 1.

The diameter of the circular filament 52 is less than the diameter of the ion emitting surface of the disc 16. For example, an electron source comprising a thoriated tungsten wire loop having a diameter of 0.57 inch was spaced 0.15 inch away from an ion emitter having an effective ion emitting surface diameter of 0.82 inch, and an ion accelerator was mounted 0.82 inch away from the ion emitter.

In operation, the voltage of the electron emitter 50 is set at approximately the corresponding space charge voltage at its location relative to the ion emitter, and this potential is usually within a few hundred volts of a positive ion emitter potential. In the above example, the voltage of the electron source is set at the potential existing at 0.15 inch from the ion emitter. As current is passed through the thoriated tungsten wire, it is heated to boil off negatively charged electrons.

As these electrons are introduced into the ion beam, they move at a high velocity along the path of the ion beam but opposite to the direction of movement of the positively charged ions. The direction of movement of the electrons is indicated by the arrow E in FIG. 2. The

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impingement of fast-moving electrons on the outer surface of the disc 16 gives rise to locally sputtered secondary electrons that increase the density of the ion beam. The fast-moving electrons will not travel with the ions in the direction of the arrow B because the accelerator 14 is operating at a high negative potential.

While one embodiment of the invention has been shown and described, it will be apparent that various modifications may be made to the disclosed apparatus without departing from the spirit of the invention or the scope of the subjoined claim.

What is claimed is:

In an ion beam generating apparatus of the type having a porous electrode at a positive potential forming an ion emitter spaced from an ion accelerator electrode at a negative potential with an apertured focusing electrode having a positive potential positioned therebetween whereby an ion beam is emitted from the porous electrode through the aperture of the focusing electrode at space charge limited operation, the improvement comprising

a filament in the ion beam within the aperture of the focusing electrode having a positive potential within a few hundred volts of the positive potential of the porous electrode corresponding to the space charge potential adjacent said aperture, and

means for supplying a heating current to said filament for heating the same so that electrons are emitted therefrom to move at a high velocity along the path of the ion beam in the opposite direction to impinge on the porous electrode for increasing the density of the ion beam with locally sputtered secondary electrons.

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