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APPARATUS FOR INCREASING ION ENGINE BEAM DENSITY

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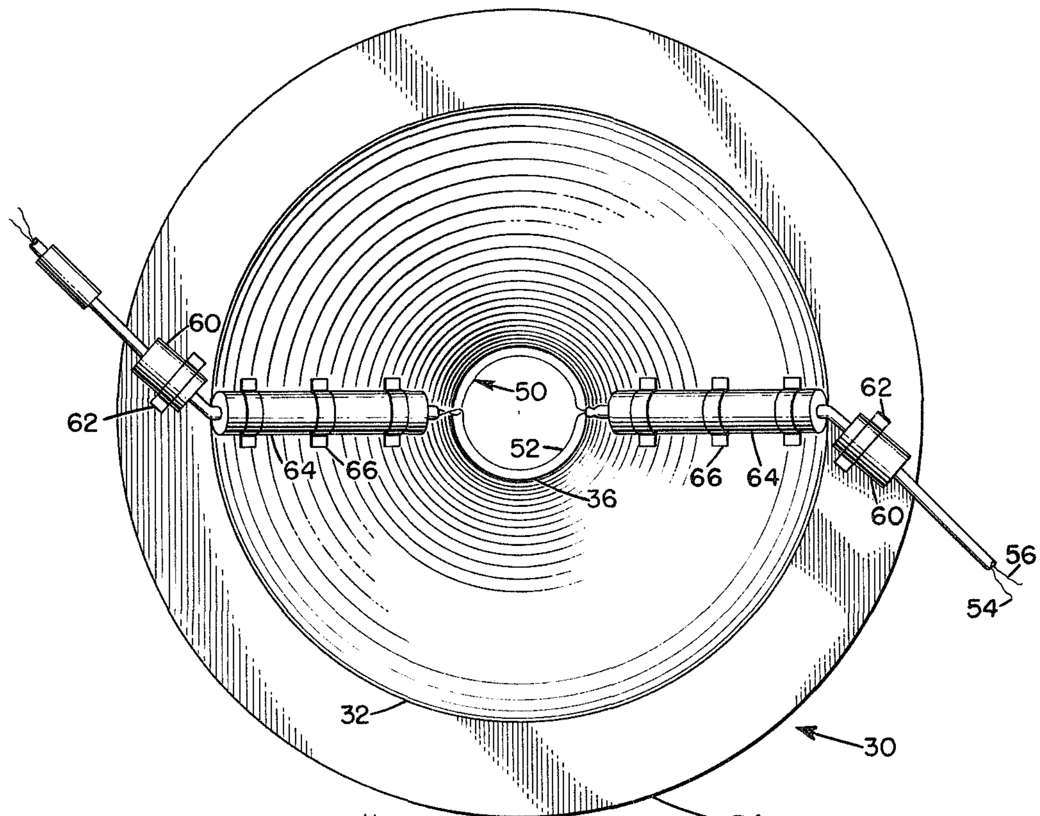

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FIG. 1

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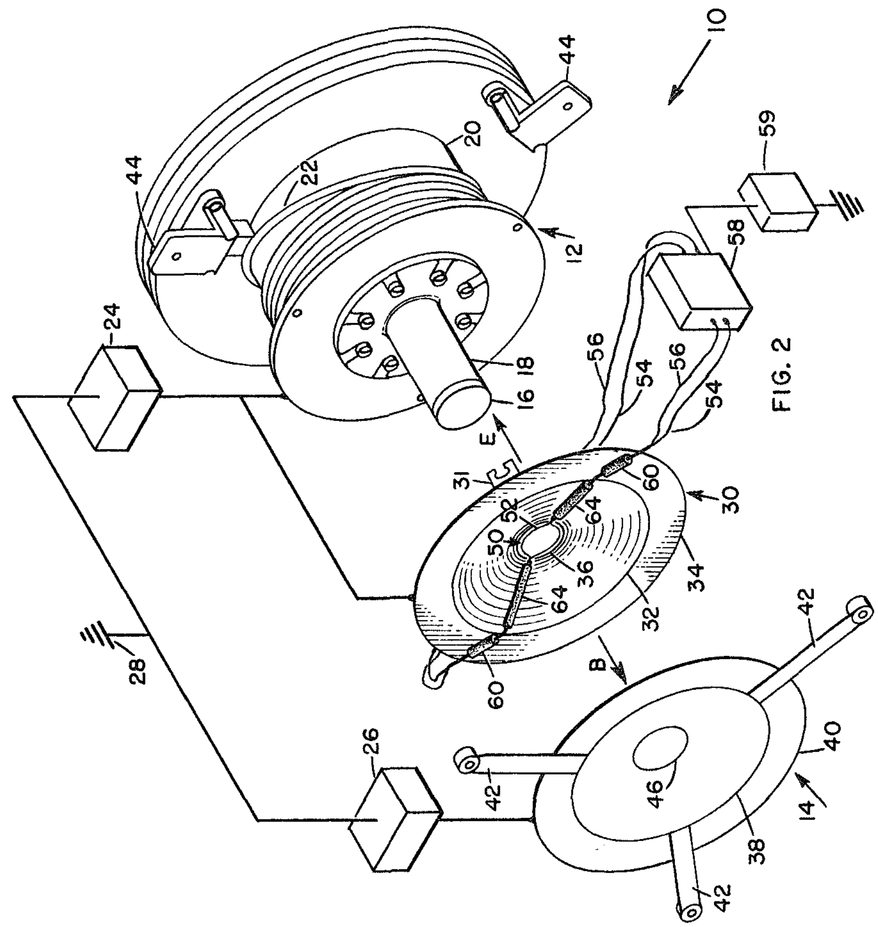

FIG. 2

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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.

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.

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

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.

References Cited by the Examiner

UNITED STATES PATENTS

3,115,591 12/1963 Brunnee ------------ 313—231

FOREIGN PATENTS

1,278,129 10/1961 France.

OTHER REFERENCES

Telegraphie, British Pat. 938,133, Oct. 2, 1963 (2 pp. spec.; 2 sht. dwg.; filed in France Oct. 27, 1960).

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