

United States Patent

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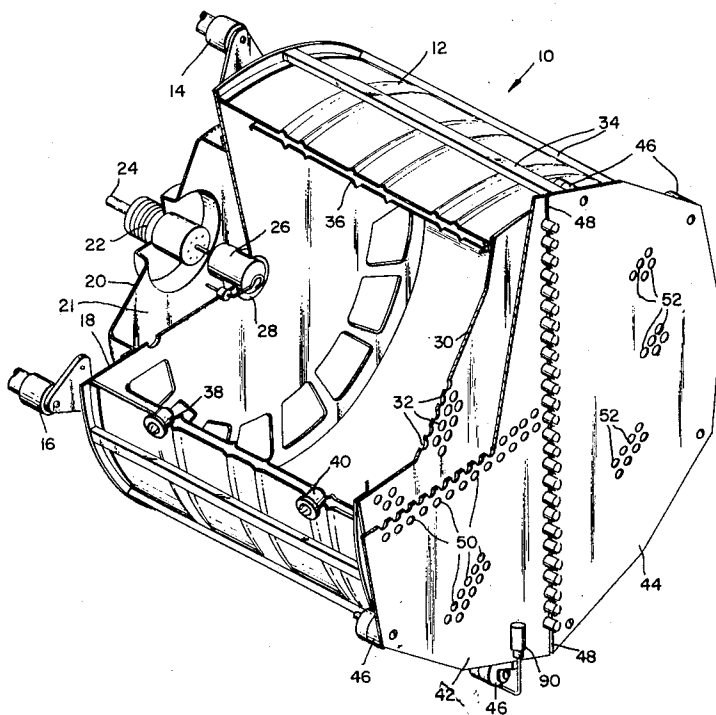
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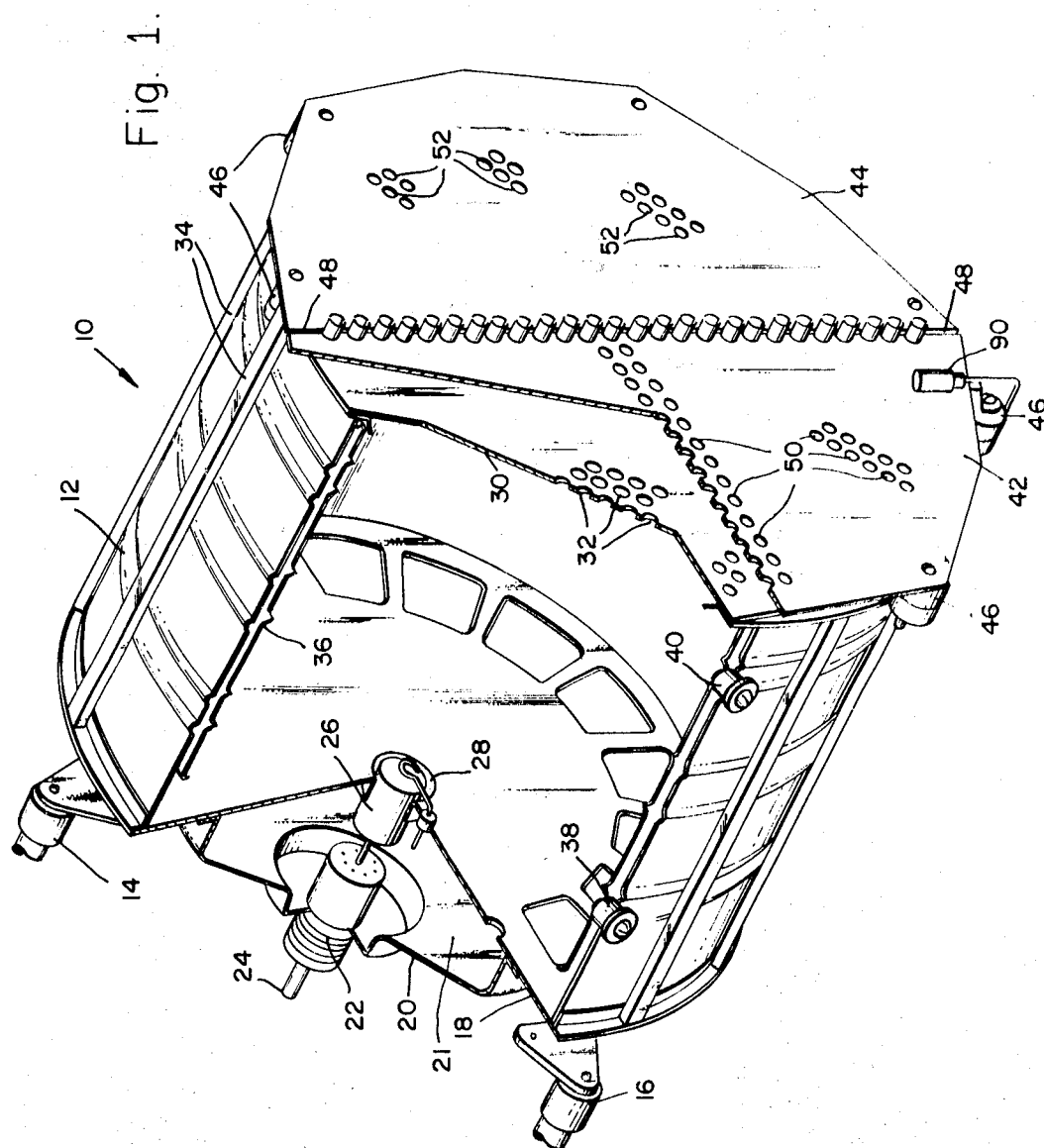
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[54] ION BEAM DEFLECTION SYSTEM
8 Claims, 4 Drawing Figs.

[52]	U.S. Cl.....	60/202, 60/230, 313/78, 313/80
[51]	Int. Cl.....	F03h 5/00, F02k 1/20
[50]	Field of Search.....	60/202, 230; 313/63, 78, 80

ABSTRACT: An ion beam device has a plurality of laterally spaced perforated accelerator electrodes, with the electrodes connected to different negative potentials so that ions discharged out of the perforations along the separating line are deflected. Preferably, these perforations along the separating line are equipped with half-cylindrical tubes to enhance the electrostatic deflection of the beamlets passing through the apertures. Thus, a net deflection of the discharge ion beam is obtained.





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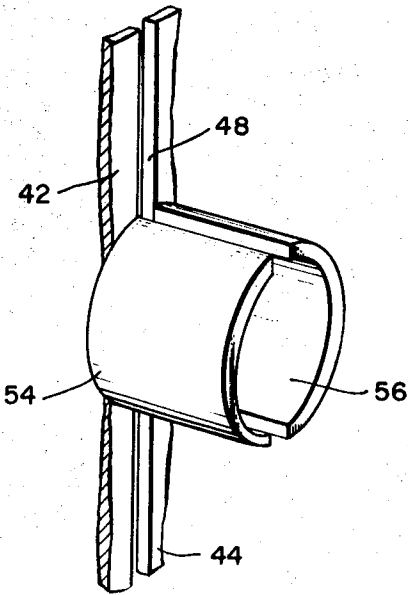


Fig. 2.

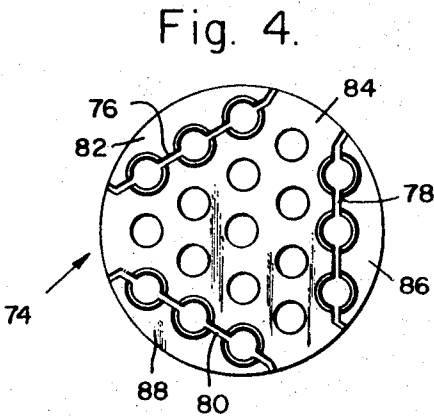


Fig. 4.

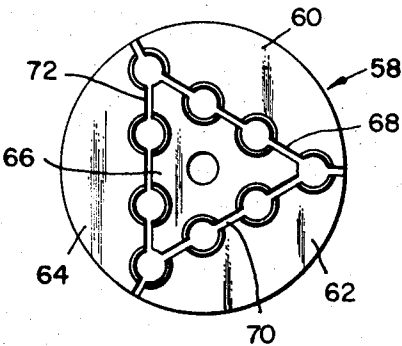


Fig. 3.

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ION BEAM DEFLECTION SYSTEM

BACKGROUND

Ion beams are produced by structures generally identified as electron bombardment ion thrusters. Examples of such thrusters are shown in Harold R. Kaufman U.S. Pat. No. 3,156,090, granted Nov. 10, 1964, and Hugh L. Dryden U.S. Pat. No. 3,345,820, granted Oct. 10, 1967. In such thrusters, beamlets of ions are expelled from the device, with one beamlet extending from each accelerator electrode aperture or perforation. With such a structure, it is impractical to deflect the general beam, so that proposals for the directing of such beams have been limited to the physical movement of the entire engine or movement of the electrodes. However, it is difficult to accomplish such mechanical deflection with a sufficient degree of precision or reproducibility. Accordingly, such approaches to the problem of directing the ion beam have been unsatisfactory.

SUMMARY

In order to aid in the understanding of this invention, it can be stated in essentially summary form that it is directed to an ion beam deflection system. The ion beam deflection system is incorporated as a part of an electron bombardment ion source, and includes a plurality of separate accelerator electrodes, laterally spaced from each other along a dividing space therebetween, together with apertures along the dividing space so that the accelerator electrodes can be held at different potentials for deflecting the ions which pass through the apertures along the dividing space. Preferably, the apertures are equipped with deflection plates, preferably of the same shape as the apertures, to enhance the electrostatic deflection of the ions passing through the divided apertures.

Accordingly, it is an object of this invention to provide an ion beam deflection system whereby ions emitted from a source can be deflected. It is another object of this invention to provide an electrostatic ion beam deflection system whereby electrostatic deflection of at least a portion of the ion beam is accomplished. It is a further object to provide an ion source wherein the ion accelerator electrode is divided into at least two laterally spaced electrodes, with accelerator apertures located along the division between the accelerator electrodes so that the separate accelerator electrodes can be held at different voltages for electrostatic ion beam deflection. It is a further object to provide deflection plates at different voltages adjacent accelerator electrode apertures so that the ion beams passing through the apertures are deflected in accordance with the voltage on the deflection plates. It is a further object to provide a Kaufman thruster configuration with at least two laterally spaced accelerator electrodes, which spaced electrodes can be held at separate voltages for the deflection of the ion beam from the Kaufman thruster. Other objects and advantages of this invention will become apparent from a study of the following portion of the specification, the claims and the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view, with parts broken away, showing an ion beam device with the ion beam deflection system of this invention.

FIG. 2 is an enlarged perspective, with parts broken away, showing the details of the deflection plates adjacent one aperture in laterally spaced accelerator electrodes.

FIG. 3 is another configuration of the manner in which a plurality of laterally spaced accelerator electrodes can be arranged.

FIG. 4 is another arrangement thereof.

DESCRIPTION

Referring principally to FIG. 1, an ion beam producing device is shown generally at 10. The ion beam device has a

casing or housing 12 which is mounted by supports 14 and 16 to a suitable base. The supports 14 and 16 may be insulative in character, if necessary. Housing 12 is closed on its rear end by means of wall 18 upon which is mounted the cover 20 of vapor plenum 21. Vapor plenum 21 is supplied with suitable vapor which can be ionized to form the ions in the ion beam. In the case of thrusters, the vapor is usually mercury, and can be supplied either from a mercury source within the plenum or from a source external of the plenum, together with suitable vaporization means.

Isolator 22 electrically isolates conductor 24 from the dome 20 which forms vapor plenum 21. Cathode 26 is mounted upon conductor 24 and is supported thereby within opening 28 in wall 18. Vapor is discharged from the plenum 21 into the interior of housing 12 through the annular space between cathode 26 and wall 18.

Perforated screen electrode 30 is mounted as an electrode forming the front of the chamber within housing 12. Screen electrode 30 is directly flange mounted upon the front of housing 12 so that it is at the same potential. A plurality of perforations 32 are formed in the screen electrode, and while only a few of such perforations are shown, it is understood that they extend over the entire screen electrode. Permanent magnets 34 are spaced around the exterior of housing 12 and are engaged against the flanges thereof. Rear wall 18 and screen electrode 30 are mounted directly against these flanges, and the flange materials as well as rear wall 18 and screen electrode 30 are formed of magnetic material so that an axial magnetic field is formed through the chamber formed by housing 12. Permanent magnets 34 are of the same polarity to create a substantially uniform field.

Anode 36 is of cylindrical tubular configuration and is mounted interiorly of housing 12. It is insulated from housing 12 by means of suitable insulators, such as those shown in section at 38 and 40.

In the embodiment shown in FIG. 1, accelerator electrodes 42 and 44 are mounted adjacent screen electrode 30. Accelerator electrodes 42 and 44 are spaced from the screen electrode and are mounted upon insulators, such as those shown at 46. The insulators 46 maintain the physical and electrical separation of the accelerator electrodes 42 and 44 from each other and from the screen electrode and the remainder of housing 12 of the ion beam device. Furthermore, accelerator electrodes 42 and 44 are electrically separated from each other. This is accomplished by space 48 between the accelerator electrodes.

This space is maintained as small as possible, consistent with the voltage differences which may be applied between the accelerator electrodes. It is necessary to prevent arcing therebetween. Accelerator electrode 42 has perforations 50 therein, and accelerator electrode 44 has perforations 52 therethrough. These perforations 50 and 52 are in individual axial alignment with perforations 32 in screen 30. Furthermore, perforations 50 and 52 extend substantially over the entire faces of their respective electrodes 42 and 44.

Space 48 defines the dividing line between accelerator electrodes 42 and 44. This dividing line passes through the diameters of perforations so that half of each of the circular perforations is an electrode 42, while the other half of each is in electrode 44. Since the accelerator electrode has some thickness, substantially half cylindrical surfaces are formed by these half circle perforations, which surfaces face each other. As is later explained, the accelerator electrodes can be held at different voltages, so that the half cylindrical surfaces form capacitive deflection plates for the deflection of ion beams passing therethrough.

However, in order to enhance the deflection, the length over which the deflection field is applied is increased by installation of half cylindrical tubes in these divided perforations. This is seen in more detail in FIG. 2, tubular hemicylinders 54 and 56 are installed along the perforations divided by space 48. The interior diameter of the cylinder thus formed by the tubular hemicylinders is substantially that of the remainder of

the perforations 50 and 52. Thus, the perforations along the dividing space 48 act in the same way with respect to small ion beams passing through the perforations, with the addition of the fact that there is greater length in the direction of beam travel along the divided perforations.

FIG. 1 illustrates the accelerator electrode of the conventional Kaufman thruster diametrically divided and provided with additional plate area along the sides of the divided perforations. As will be later described, this permits deflections of the small beams passing through the divided perforations in a direction at right angles to the dividing space. FIG. 3 illustrates accelerator electrode assembly 58 laterally divided into accelerator electrodes 60, 62, 64 and 66 by division along spaces 68, 70, and 72. Since the spaces 68, 70 and 72 are arranged in an equilateral triangle, it is clear that thrust deflection through the divided perforations can be arranged at 120° with respect to each other.

Similarly, FIG. 4 illustrates an accelerator electrode assembly 74 which is divided along spaces 76, 78 and 80 into accelerator electrode 82, 84, 86 and 88. Again, the spaces pass through perforations and are arranged at 120° with respect to each other. In each case, the number of perforations corresponds to the number of perforations in the associated screen electrode, and the reduced number of perforations shown in FIGS. 3 and 4 is merely illustrative of manners in which accelerator electrode assemblies can be divided. In each case, the divided perforations are preferably equipped with tubular hemicylinders, similar to those shown in FIG. 2, so that an increased area is accomplished.

In operation, the ion beam device 10 is located in a vacuum environment. This environment may either be a vacuum chamber, or it may be in space. Referring to housing 12 as being at positive high voltage (Beam Voltage), cathode 26 is also at positive high voltage, so that screen electrode 30 prevents emission out of the perforations of any substantial number of electrons. Anode 36 is held positive with respect to the cathode, for example, at a potential 40 volts higher than the cathode.

An ionizable gas vapor, for example mercury vapor, is introduced into the chamber within housing 12, and interiorly of anode 36, through opening 28. In view of the fact that the electric field is radial between the cathode and the anode, and the magnetic field is axial, the electrons are limited to circular paths around the axis of the device 10, until an electron collides with a vapor atom in the interior space. This collision causes ionization, together with a change in the electron path. The new electron path, on the average, is again circular at a larger radius so that multiple collisions occur until the electrons reach the anode. The vapor pressure within the chamber is such as to give an electron meanfree path of about 1 meter.

The ions drift through the perforations in the screen electrode, whereupon they are acted upon by the negative potential of the accelerator electrode assembly comprised of the electrodes 42 and 44. Assuming that both electrodes are held at the same potential, in this example about -2,300 volts, the ions are accelerated through the perforations in the accelerator electrodes along a straight path axial of the engine to produce thrust. In order to prevent a net charge from building up on the ion beam device, neutralizer 90 is energized to inject electrons into the ion beam to neutralize the beam and provide a net zero charge of the departing beam.

It can be seen that a small beam is emitted from each of the perforations 50 and 52, which small beams totalize the beam output of the device. So long as electrodes 42 and 44 are at the same potential, all of the small beams are emitted axially of the device to produce a total beam which has a net thrust which is axial.

However, when the voltage difference between the two accelerator electrodes is 600 volts, so that one is at -2,000 volts, and the other is at -2,600 volts, beam deflection occurs. This beam deflection is caused by electrostatic deflection of the

small beams which pass through the perforations along the face 48. This electrostatic deflection is enhanced by the tubular hemicylinders of which the hemicylinders 54 and 56 are an example.

With the voltage difference between accelerator electrodes at 600 volts, as in the illustration above, a deflection of about 8° occurs in the small beams along space 48. When the number of perforations along the dividing space amounts to about 3 percent of the total number, about 5 percent of the beam current is actually deflected to this 8°. This is because the average current density of all the perforations is lower than the average current density along the diameter, because the current density is higher in the central area.

It is seen that the structure of FIG. 1, as described above, is capable of two directions of beam deflection, at right angles to the direction dividing slot 48. If other directions of deflection are desired, the dividing spaces can be arranged at 60° with respect to each other as is shown in FIGS. 3 and 4, so that by adjusting the voltages of the various accelerator electrodes, deflection in any direction away from the axis can be accomplished.

This invention having been described in its preferred embodiment, it is clear that it is susceptible to numerous modifications and embodiments within the ability of those skilled in the art and without the exercise of the inventive faculty. Accordingly, the scope of this invention is defined by the scope of the following claims.

1. An ion beam device, said ion beam device having a housing having an axis, the improvement comprising:

first and second electrodes secured to said housing, said first and second electrodes being laterally spaced in a direction perpendicular to said housing axis and having adjacent edges, perforations in said first and second electrodes including perforations intersecting the laterally spaced adjacent edges of said first and second electrodes so that said perforations along said adjacent electrode edges form perforations defined in part by said first electrode and defined in part by said second electrode so that upon application of different voltages to said first and second electrodes, ion beams passing through said perforations along said adjacent electrode edges are deflected.

2. The ion beam device of claim 1 wherein a plurality of first capacitive deflection plates are secured to said first electrode adjacent said perforations along the edge thereof and a plurality of second capacitive deflection plates are positioned on said second electrode adjacent said perforations along the edge thereof so that the perforations along the adjacent edges of said electrodes have a greater length along said axis than other perforations away from said adjacent edges.

3. The ion beam device of claim 2 wherein said perforations are circular and said deflection plates are substantially tubular hemicylinders positioned to substantially define a circular opening of the same diameter as the perforations in the body of said first and second electrodes.

4. The ion beam device of claim 1 wherein said first and second electrodes are separated at a space which substantially lies on a diameter intersecting said axis.

5. The ion beam device of claim 1 wherein said first and second electrodes are separated at a space which lies substantially at right angles to a diameter perpendicular to said axis.

6. The ion beam device of claim 5 wherein there are third and fourth electrodes, said third and fourth electrodes being separated from said first electrode by a space which lies substantially 30° with respect to the diameter defined in claim 5.

7. The ion beam device of claim 6 wherein the spaces laterally separating said second, third and fourth electrodes from said first electrode intersect with one another.

8. The ion beam device of claim 6 wherein the spaces separating said second, third, and fourth electrodes from said first electrode are nonintersecting.