July 2, 1963 H. SHELTON ETAL 3,096,456

ACCELERATING STRUCTURE FOR A CHARGED PARTICLE ACCELERATING SYSTEM

Filed Oct. 12, 1960

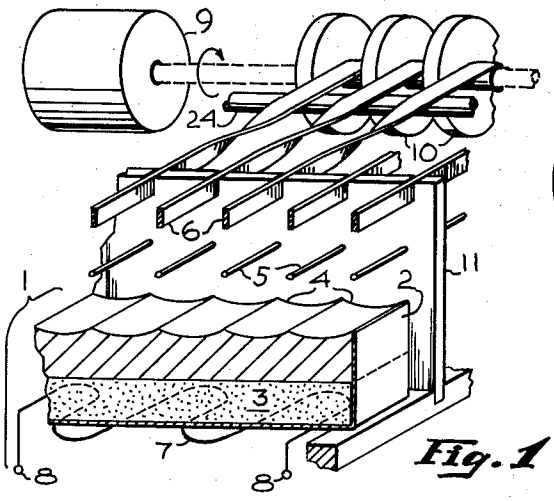


Fig. 1

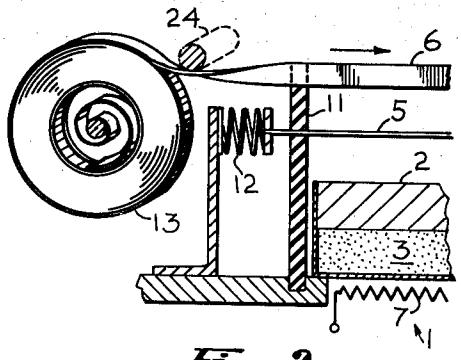


Fig. 2

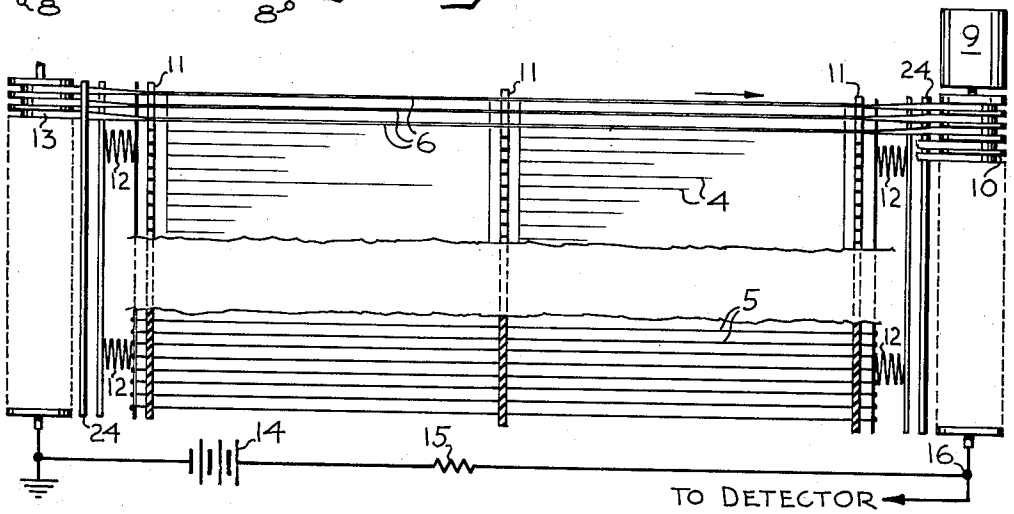


Fig. 3

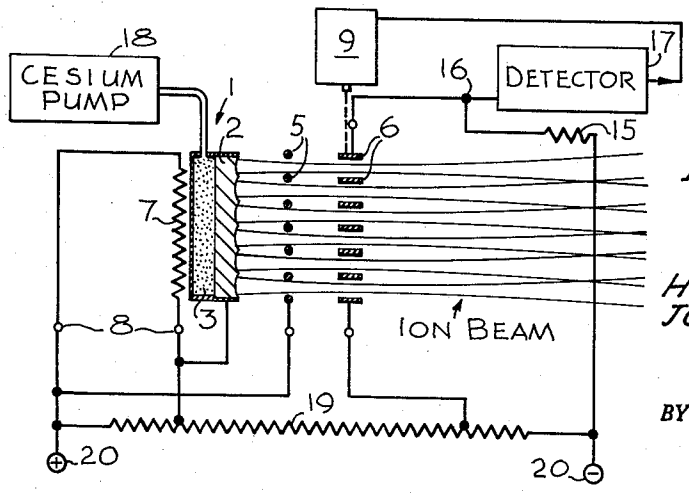


Fig. 4

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3,096,456

Patented July 2, 1963

3,096,456

ACCELERATING STRUCTURE FOR A CHARGED PARTICLE ACCELERATING SYSTEM

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Filed Oct. 12, 1960, Ser. No. 62,272
10 Claims. (Cl. 313—63)

This invention relates to propulsion engines such as may be suitable for space vehicle propulsion and more particularly to such engines utilizing a beam of electrostatically accelerated ions to generate propulsive thrust.

In the search for suitable mechanisms which may be employed to propel space vehicles, various types of propulsion systems have been and are being investigated. One such system operates by virtue of the force developed by accelerating charged particles in an electrostatic field to provide the requisite thrust to propel the vehicle. Systems of this type include propulsion devices which utilize electrically charged atomic or molecular particles, such as ions, as the drive medium. This invention involves an improved arrangement for an ionic propulsion system.

The efficient and copious production of ions is a prerequisite for any ionic propulsion system. The favorable properties of alkali ions in these respects suggests the selection of a material in this class for the ion source. In particular, it has been found that the element cesium provides a desirable combination of the properties required for efficient operation of an ion source. A suitable cesium ion emitter has been developed by utilizing a porous tungsten surface behind which cesium gas is provided at a pressure sufficient to force cesium through the porous tungsten to the emitting surface. The structure is advantageously maintained at an elevated temperature to enhance the generation of cesium ions.

The thrust which is developed by an ion acceleration system is relatively slight compared, for example, with that available from the rocket propulsion systems conventionally employed to lift space vehicles out of the gravitational system immediately associated with a planetary body such as the earth. However, once a space vehicle is free of the effects of gravity, an ionic propulsion system may be employed which is capable of generating vehicle velocities of interest for continuous operation over extended periods encompassing weeks, months, or in some cases even years.

One problem which has heretofore interfered with the development of a successful ionic propulsion system has resulted from the fact that the electrodes for accelerating the ions are bombarded by at least a portion of the ion beam and eventually become pitted and eroded away. This process, which is commonly referred to as "sputtering," deleteriously affects the performance of an ionic propulsion system, not only by changing the shape of and eventually disintegrating the accelerating structure, thus interfering with the ion optics thereof, but by producing vapor deposits of the sputtered accelerating electrodes which may interfere with the function of nearby electrodes. For example, sputtered products deposited on the emitter may tend to alter the work function of the tungsten or to adversely affect its porosity. In addition, cesium ions have a tendency to be adsorbed by the accelerating structure, thus presenting a problem of electron emission which may interfere with the proper operation of the ionic propulsion system.

In other applications of electrostatic particle the accelerating systems the same problem of erosion of portions of the accelerating structure may arise. It should be understood that the instant invention is adaptable to alleviating this problem, however, it may arise.

It is therefore an object of the invention to provide an improved accelerating structure for an electrostatic accelerating system for charged particles.

More particularly, it is an object of this invention to provide an improved propulsion system suitable for inclusion in a space vehicle.

Specifically, it is an object of this invention to provide an improved arrangement for an ionic propulsion engine.

It is a further object of this invention to extend the operating life of an ionic propulsion device.

Another object of this invention is to improve the efficiency of an ionic propulsion device.

Briefly, the invention provides an arrangement incorporating a plurality of replaceable accelerating electrodes operated in conjunction with a specially shaped porous tungsten surface utilized as a cesium emitter. Incorporated in this structure are a plurality of beam forming electrodes for improving the ion optics of the structure and thus reducing the accelerating electrode sputtering to a considerable degree. In accordance with one aspect of the invention, the accelerating electrodes comprise a number of ribbons which are stored upon supply reels and are pulled across the accelerating structure by a motor driven arrangement of takeup reels as the material of the accelerating electrodes becomes sputtered away. In accordance with another aspect of the invention, an appropriate arrangement is incorporated for detecting the degree of sputtering so that the eroded portions of the electrodes may be replaced by fresh material without interfering with the continuous operation of the ion accelerating structure. The material employed for the accelerating electrodes is carefully chosen so that its disintegration will not impair the operation of the remainder of the structure, in particular that of the porous tungsten emitter. Copper has been found to be suitable as an accelerating electrode material, since any deposits of copper tend to re-evaporate from the porous tungsten, thus leaving the emission properties of the tungsten emitter relatively unimpaired. It should be understood, however, that other suitable materials may be employed in the electrode structure. In addition, provision is made for elevating the temperature of the accelerating structure to eliminate adsorbed cesium, thus precluding the emission of electrons from these electrodes from becoming a problem.

A better understanding of the invention may be had from a reading of the following detailed description considered in connection with the drawing, in which:

FIGURE 1 is a perspective view of a portion of the structure of the invention;

FIG. 2 is a view from the right-hand side of the structure of FIG. 1 and depicts details of the supply reels omitted from FIG. 1;

FIG. 3 is a top view, partially broken away, of the structure of FIG. 1; and

FIG. 4 is a diagrammatic representation of the invention.

Turning now to FIG. 1, a portion of the structure of the invention is illustrated in which an emitter assembly 1 is shown comprising a strip 2 of porous tungsten behind which is located a chamber 3 into which cesium is pumped at a pressure sufficient to force it through the porous tungsten strip 2. As shown, the strip 2 is formed with a precisely shaped emitting surface comprising a number of grooves 4. These grooves advantageously form a part of the over-all ion optical system in accordance with recognized principles set forth, for example, in "Theory and Design of Electron Beams," chapter 10, J. R. Pierce, published by the Van Nostrand Company, New York, New York (1949). The cesium ion beams undergo a degree of beam focusing as they leave the individual grooves 4 due to the shape of the emitting surface. This action is enhanced by the presence of the beam forming

electrodes 5 which are maintained at a positive potential with respect to the tungsten strip 2. An accelerating force is imparted to the cesium ions by the accelerating electrodes 6 which are maintained at a negative potential with respect to the tungsten strip 2. The emitter assembly 1 also includes a resistive heating element 7 having a pair of terminals 8 to which a source of heating current may be connected for maintaining the temperature of the entire emitter assembly 1 at a suitable operating point for the efficient emission of cesium ions.

While some sputtering of the accelerating electrodes 6 is inevitable, the operation of the structure in this regard is enhanced by the presence of the beam forming electrodes 5. Because of the positive potential maintained on the electrodes 5, the cesium ions do not impinge thereon and hence the electrodes 5 are not subject to the sputtering problem which is applicable in the case of the accelerating electrodes 6. In accordance with the invention, sputtering of the accelerating electrodes 6 is obviated by providing an arrangement including a drive motor 9 and a number of takeup reels 10 to draw the electrodes 6 across the beam structure as they become eroded away.

The electrodes 5 and 6 are held in place by a support and spacer 11 of a material exhibiting suitable insulating properties, such as sapphire. The spacer 11 contains precisely ground slots to guide the electrodes 6 as they are drawn across the accelerating region. The spacer 11 also serves to separate adjacent emitter assemblies 1. Additional assemblies may be aligned side by side as desired by including additional spacers 11, thus permitting thrust multiplication for the propulsion system by the operation of a number of individual assemblies in parallel.

FIG. 2 is a view from the right-hand side of the structure of the invention as viewed in FIG. 1 and illustrates the emitter assembly 1 together with an associated beam forming wire 5 and an accelerating electrode 6. The electrode 6 is shown as a ribbon which is originally wound upon a supply reel 13. The rod 24 is mounted to give the ribbon a half twist as it is drawn off the supply reel 13 across the ion accelerating structure. Springs such as the spring 12 are provided to hold the wires 5 in tension.

A top view (partially broken away) of the structure of the invention of FIG. 1 is shown in FIG. 3, which depicts how the ribbons comprising the accelerating electrodes 6 are suspended with a predetermined tension between the supply reels 13 and the takeup reels 10, the latter being driven by the motor 9 under the control of a separate circuit (not shown). Connected between the supply reels 13 and the takeup reels 10 is a circuit including a potential source 14 and a resistor 15. This circuit is representative of one particular arrangement which may be employed to serve a dual purpose in accordance with the invention. The circuit provides a current through the individual accelerating electrode ribbons 6 which serves to heat the ribbons to a predetermined temperature, thus eliminating adsorbed cesium therefrom which might otherwise cause unwanted emission of electrons from the accelerating electrode structure. In addition, in the circuit shown, the potential of the takeup reels 10 varies in accordance with the resistance of the accelerating electrode ribbons 6. As the sputtering damage to the ribbons increases with use, the point 16 becomes more positive. The potential of the point 16 is monitored by a detector circuit (FIG. 4) which responds when a particular threshold is reached and causes the motor 9 to operate, thus winding the damaged portions of the ribbons 6 on the takeup reels 10 and drawing a supply of fresh ribbon from the supply reels 13 across the ion accelerating structure. The detector circuit 17 of FIG. 4 may be any of a number of devices known in the art, such as, for example, a vacuum tube circuit sensitive to a change of potential on its control grid. Also shown in FIG. 4 is a cesium pump 18 for maintaining a suitable pressure of cesium within the chamber 3. Operating potentials for the arrangement represented in FIG. 4 are supplied from voltage source terminals 20 connected across a tapped resistor 19. A number of individual propulsion structures, such as that of FIG. 4, may be operated in parallel to provide additional thrust for the vehicle as desired.

While a cesium ion source has been included in conjunction with the above described arrangement of the invention and therefore the ions encountered in the structure carry a positive charge, it is to be understood that a similar structure for replacing damaged accelerating electrodes during operation of an ionic propulsion device may be employed with a source of negative ions. In such a case, of course, the potentials applied to the respective electrodes will be of opposite polarity to those shown herein. Furthermore, as has been mentioned hereinabove, the arrangement of the invention may be employed in other electrostatic accelerating structures not involved in propulsion systems.

It is desirable to maintain electrical neutrality of the space vehicle where propulsive thrust is provided by a stream of electrically charged particles, as shown. While specific arrangements for neutralizing the ion beam have been omitted for the sake of brevity and simplicity, it will be understood that a number of known neutralizing arrangements may be employed as desired. One arrangement for attaining the desired neutralization, for example, is to employ duplicate arrangements of ionic propulsive structures operating with particles of opposite charge. Adjustment of the separate particle beams to carry the same currents therein automatically affords the desired charge neutralization. At the same time desirable thrust is obtained from each of the separate beams.

Although one specific arrangement of the invention has been described above, it will be appreciated that the invention is not limited to this arrangement. Accordingly, any and all modifications, variations, or equivalent arrangements falling within the scope of the annexed claims should be considered to be a part of the invention.

What is claimed is:

1. A charged particle accelerating structure comprising a source of ions, a plurality of beam forming electrodes, replaceable accelerating electrodes, means for automatically replacing the accelerating electrodes during the continuous operation of the structure as the accelerating electrodes becomes sputtered away by impact with the charged particles, and a voltage source for supplying operating potentials to the structure.

2. An electrostatic particle accelerator comprising a source of charged particles, a plurality of beam forming electrodes, a plurality of replaceable accelerating electrodes, a voltage source for supplying operating potentials to the accelerator, and means for replacing the accelerating electrodes as they become damaged without interrupting the operation of the accelerator comprising a motor for moving the accelerating electrodes so that the damaged portion is removed from the charged particle beam while a section of new material is inserted therein.

3. A charged particle accelerating apparatus comprising a source of charged particles, a voltage source for supplying operating potentials to the apparatus, a plurality of accelerating electrodes comprising ribbons arranged side by side between opposed pluralities of storage reels, and means including a motor for driving one plurality of reels in order to replace damaged portions of the accelerating electrodes without interrupting the operation of the apparatus.

4. A charged particle accelerating apparatus comprising a source of charged particles, a plurality of accelerating electrodes subject to sputtering damage by certain of the charged particles, and means for detecting the degree of such sputtering damage as it occurs during the operation of the apparatus and for indicating when the damaged electrodes require replacement.

5. A charged particle accelerating apparatus compris-

ing a source of charged particles, a plurality of electrostatic particle accelerating electrodes subject to sputtering damage by impact with a portion of the charged particles, means for detecting the condition of the accelerating electrodes, and means responsive to the detecting means for moving the accelerating electrodes relative to the path of the charged particles during the operation of the apparatus.

6. Electrostatic ion accelerating apparatus comprising an ion source, a plurality of accelerating electrodes for accelerating the ions in a beam, each comprising a copper ribbon extending between respective supply and take-up reels, a motor for driving the reels in order to move the ribbons relative to the ion beam, and control means for energizing the motor when the portion of the ribbon in contact with the beam needs replacing.

7. Ion accelerating apparatus comprising an ion source, a plurality of ion accelerating electrodes each comprising a copper ribbon suspended between respective storage reels at opposite sides of the ion beam, means for operating the accelerating electrodes at an elevated temperature in order to prevent the adsorption of ions thereon, detecting means in conjunction with said last mentioned means for monitoring the condition of the accelerating electrode ribbons, and a motor responsive to the detecting means for driving the respective storage reels in order to change the ribbon position within the path of the ions.

8. An ion accelerating apparatus comprising a source of positive ions, a plurality of accelerating electrodes for accelerating the ions emitted by the source, said accelerating electrodes comprising individual copper ribbons, means comprising a plurality of beam forming electrodes for improving the ion optics of the apparatus in order to reduce sputtering damage to the accelerating electrodes, detecting means for measuring the degree of sputtering damage of the accelerating electrode ribbons, a motor responsive to the detecting means and a plurality of storage reels driven thereby for changing the portion of the ribbon within the extent of the ion beam, and a voltage source for applying operating potentials to the accelerating apparatus.

9. An ion accelerating apparatus comprising a porous tungsten emitter, means for forcing cesium through the porous tungsten emitter, means for heating the emitter to produce the emission of cesium ions, an accelerating electrode comprising a copper ribbon having a portion thereof within the path of the cesium ions, a beam forming electrode for reducing the portion of cesium ions which impinge upon the accelerating electrode, an insulated spacer for maintaining the relative positions of the beam forming electrode and the accelerating electrode within the apparatus, electrical circuit means for maintaining the accelerating electrode at a temperature to prevent the adsorption of cesium thereon, detecting means connected to the circuit means for detecting the increase of resistance of the accelerating electrode attendant upon a reduction in cross-sectional area thereof, a motor responsive to the detecting means and a plurality of reels driven by the motor for changing the portions of the ribbon within the area of the ion beam, and a voltage source for supplying operating potentials to the apparatus.

10. A charged particle accelerating apparatus comprising a source of electrically charged particles, a plurality of accelerating electrodes subject to sputtering damage by certain of the charged particles, means for replacing the damaged accelerating electrodes during the continuous operation of the apparatus, and means for monitoring the degree of sputtering damage and for automatically energizing the electrode replacing means when the sputtering damage exceeds a predetermined level.

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