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GAS DISCHARGE NEUTRALIZER INCLUDING A CHARGED PARTICLE SOURCE

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FIG. 1.

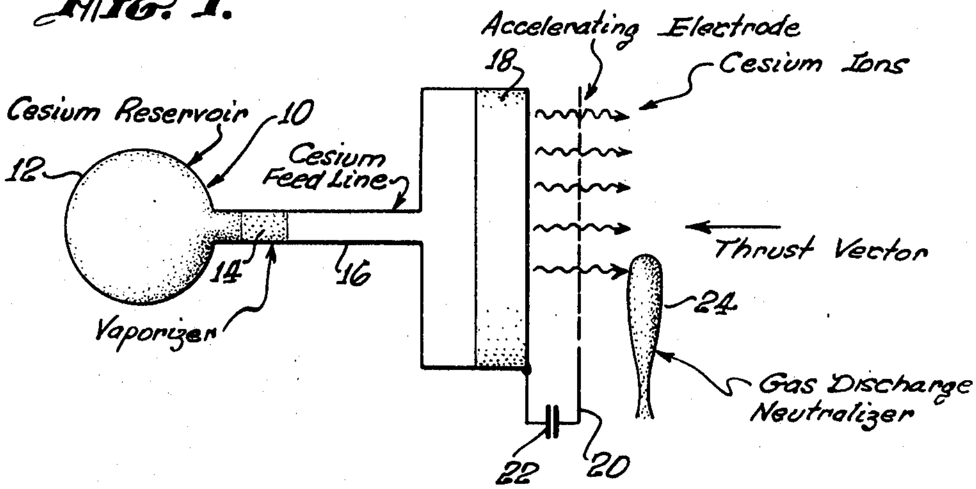
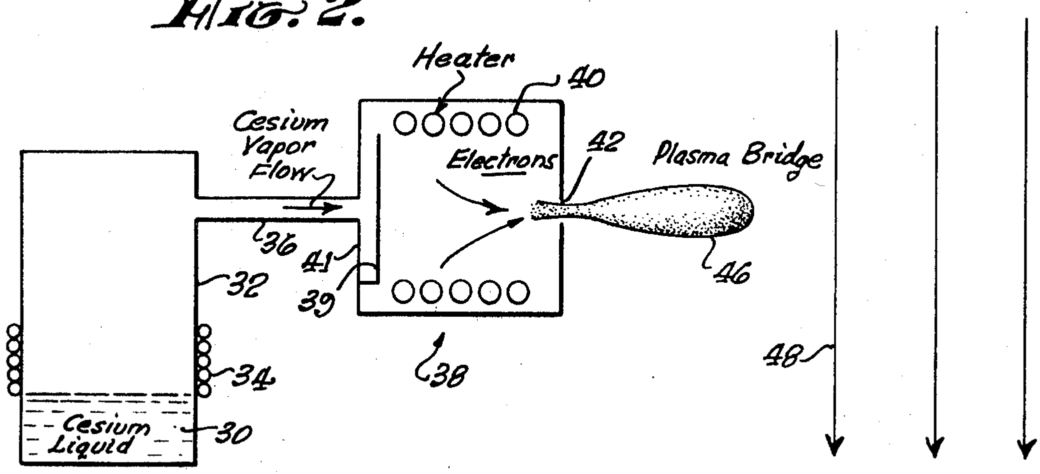


FIG. 2.



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GAS DISCHARGE NEUTRALIZER INCLUDING A CHARGED PARTICLE SOURCE

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ABSTRACT OF THE DISCLOSURE

This application relates to an improved ion engine having a gas discharge neutralizer coupled to the ion beam. The neutralizer comprises a particle emitting means supported with an enclosure which is additionally connected to a source of ionizable material. The enclosure has an orifice of such diameter that particles generated therein efflux freely in a stream and such that vapor from the ionizing material is partially restricted within the enclosure whereby a stream of particles mixed with ions flow towards the ion beam.

This invention pertains to a source for charged particles wherein the charged particles are coupled to a receiver by a defined relatively low-density plasma or gas of oppositely charged particles. In one particular application of the invention, the neutralization of a beam of positively charged particles is accomplished by the source supplying a stream of negatively charged particles wherein positive ions are included to couple the stream of negatively charged particles to the beam of positively charged particles.

To provide a meaningful environment for the invented charged-particle source the discussion which follows is directed at the use of the source as a neutralizer for an ion engine. It should be understood that the charged-particle source may be employed in any other suitable environment.

It is well known in the electrical art that a neutralizer is required when an ion beam of positively charged particles is emitted by a device such as an ion engine. The reason for such a neutralizer is that if the beam is not neutralized by electrons from the ion engine, the ion engine becomes negatively charged with respect to the reference space potential. Since the ion engine's thrust is derived from the acceleration of positive ions from a positive potential with respect to space, the engine would soon lose all thrust if the negative charge were not disposed of. To prevent this, the prior art approach has been to place a neutralizer, such as a thermionic electron emitter, very close to, or even in, the path of the propulsion beam. Electrons emitted by the neutralizer neutralize the positively charged propulsion beam. While neutralizers including conventional thermionic electron emitters have partially solved this problem, they have several major disadvantages. The flow of neutralizing electrons from such neutralizers to the propulsion beam is severely retarded by space-charge limitations. As a result, to obtain a sufficient flow of electrons, prior art neutralizers require high voltages and require placement very close to the ion propulsion beam. By placing the neutralizer close to the ion propulsion beam, its surfaces are subject to ion bombardment and quickly become eroded. Its operating life span is, therefore, sharply reduced. The utilization of larger neutralizers also is unsatisfactory because of weight penalties and because of the higher power requirements

involved. Other prior art attempts to solve this problem include making the source of neutralizing electrons large and providing grids for accelerating the neutralizing electrons into the ion beam. This solution adds weight, cost and complexity to the system and increases power consumption.

In order to overcome the disadvantages of prior art devices, a simple means has been invented for neutralizing a beam of charged particles of one polarity with a stream of charged particles of an opposite polarity. This means is a charged-particle source which may be applied as a neutralizer but has primary utility as a source. In particular, the source comprises: an enclosure means containing a contact surface, inlet means for directing gas flowing therethrough over the contact surface and outlet means adapted to restrict gas flow therethrough while permitting the flow of electrons therethrough, source means for supplying easily ionizable gas to the inlet means, receiver means for accepting the flow of electrons from the outlet means, and power means for maintaining a potential difference between the enclosure means and the receiver means, the potential difference being adapted to generate a high density of electron flow through the outlet means.

By employing this invention, an effective source is provided which can be used to neutralize a beam of positive particles.

It has also been found in employing this invention that because of reduced space-charge limitations on the flow of negative particles, the neutralizers can be placed at a distance from the beam of positively charged particles such that it is not subject to bombardment by the particles and is, therefore, not eroded.

It has further been shown in using this invention that a lower voltage is required to maintain the flow of negatively charged particles to the beam of positively charged particles than is required by prior art neutralizers due to reduced space-charge limitations.

In addition, in employing this device it has been found that because of the cooperation of the ionized material with the negative-particle emitting means negative particles are more copiously emitted than in prior art neutralizers.

These advantages and structural features of the invention will be more fully apparent from a detailed consideration of this entire specification, the appended claims and the accompanying drawing in which:

FIG. 1 is a simplified side elevation view of an ion engine employing this invention; and,

FIG. 2 is a simplified side elevation view of an embodiment of the invention.

This invention will be explained in conjunction with an ion engine because it is in this application that the invention is exposed to severe operating conditions and has demonstrated its advantageous features. It will be apparent from this particular use that the invented source may be readily employed in many different applications. It should be understood in the board sense that the invention is a new and novel charged-particle source. Referring to FIG. 1, an ion engine is shown comprising an ionizable material reservoir **10** which may contain an ionizable material **12**, such as cesium. The ionizable material is passed through a vaporizer **14** which is kept at the vaporization temperature of the ionizable material usually stored in reservoir **10** in liquid form. Vaporized ionizable material is passed from vaporizer **14** via the feed line **16** to the backside of an ionizer **18**. The ionizable material then passes through the ionizer **18** which may be a porous tungsten ion emitter of the contact type that is maintained at a temperature in the neighborhood of 1200° C. or which may be an electron bombardment type ionizer as described in the publication "Test Results for a Cesium Electron Bombardment Ion Motor" by R. C. Speiser et al. IAS. The ions emitted from ionizer 18 are accelerated by an accelerating electrode 20 which is connected to an energy source 22. A neutralizer 24 is placed in the vicinity of the ion propulsion beam 48 to prevent the ion engine from becoming charged with respect to space in such a manner that thrust and efficiency would deteriorate.

The above general description of an ion engine is only for purposes of placing the invented source (e.g., neutralizer) in an environment in which its advantages and significance may be clearly pointed out. The significant aspects and advantages of the invention will also be apparent when the invention is employed in other environments and this particular form should only be considered illustrative. The significant aspects and advantages of this invention become apparent by considering FIG. 2.

Referring to FIG. 2, reservoir means 32 is a container for storing ionizable material 30. Mounted adjacent to the walls of reservoir means 32 are heater means 34 which, when operating, liquify and vaporize ionizable material 30 stored in reservoir means 32. In operation reservoir means 32 is maintained at approximately 300° C. or less. Inlet means or conduit 36 connects a reservoir means 32 to negative-particle emitting means 38 and serves to conduct ionizable material 30 from reservoir means 32 to negative-particle emitting means 38. Although, in the present embodiment of the invention, reservoir means 32 is described as the source of ionizable material, any other convenient source could, of course, be used including zero-G feed systems as developed for ion engines.

Ionizable material 30 is an important aspect of this invention; in its preferred form it is cesium metal. Cesium is the most readily ionized of the alkali earth metal group of the periodic chart of the elements. Many other ionizable materials could be employed in this invention. For example, the other elements of the alkali metal group of the periodic chart are rubidium, potassium, sodium and lithium. The choice of ionizable material depends in part upon the ease of ionization of the material, so in the present embodiment of the invention cesium is used because it is easily ionized.

Contact surface or negative-particle emitting means 38 comprises a cathode member 39, an enclosure 41, a heater means 40 for heating cathode member 39 which causes the cathode member to emit electrons, and outlet means or orifice 42 located at the discharge end of enclosure 41 to allow particles to flow from within enclosure 41 to ion beam 48, alternatively. The resulting emission of electrons from cathode 39 may be accomplished by the collision of ions therewith or a combination of heater means and collision. The diameter of orifice 42 is such that electrons efflux freely but cesium vapor is able to efflux only very slowly. An example of the cesium efflux is one (1) percent or less of the electron efflux with the ratio of the diameter of orifice 42 to the dimension of enclosure 41 in the range of 1:10 to 1:100 or greater. The orifice 42 typically is 0.2 millimeter in diameter or less which is referred to herein as a point. Through this feature as well as others the supply of cesium vapor is conserved within enclosure 41 and a high density of charged particles (electrons) is provided from the source (greater than 1000 amps/cm.^{2}). During operation cathode member 39 is grounded to enclosure 41 to maintain a zero reference potential. It is, of course, within the scope of this invention to vary the geometric configuration of negative-particle emitting means 38 to any convenient forms and to alter its potential.

As described in this embodiment of the invention, the beam of positive particles 48 is the ion propulsion beam of an ion engine such as shown in FIG. 1. Ion beam 48 functions as a receiver means being at a potential different from that maintained by negative-particle emitting means 38. An electrical discharge is struck and maintained between ion beam 48 and negative-particle emitting means 38. Ionizable material 30 is ionized by the discharge forming plasma 46.

In operation an ionizable material 30 is placed in reservoir 32 by suitable means. Heater means 34 is brought up to an operating temperature sufficient to liquify and to vaporize ionizing material 30. Vaporized ionizable material flows through conduit 36 into enclosure 41. In this specific embodiment of the invention, the ionizable material is cesium. Cesium vapors entering cylindrical enclosure 41 contaminate or cesiate the surfaces of the cathode member 39 which because it is cesiated has a low work function and, therefore, emits electrons copiously when heated, while requiring less heat than noncesiated surfaces. It has been demonstrated in the operation of this device that it can produce as many as fifty milliamperes of electrons per watt of input power compared to twenty milliamperes or less per watt for other neutralizers. This, of course, is a significant improvement over prior art thermionic neutralizers and other electron sources.

The difference in potential between negative particle emitting means 38 and ion beam 48 causes an electrical discharge to be struck between them. The electrical discharge ionizes ionizable material 30 at orifice 42, thereby creating a plasma. Electrons emitted by cathode member 39 are propelled through orifice 42 by the attractive forces exerted on them by the positively charged ion beam 48 and move toward the ion beam 48 via the plasma 46 to neutralize beam 48.

An important aspect of the invention is the formation of a plasma 46 by the ionization of ionizable material 30 at orifice 42 and by drift of ions and electrons out through orifice 42. The plasma so formed serves to overcome space-charge limitations on the flow of electrons emitted by negative-particle emitting means 38 to ion beam 48. It is this aspect of the invention that makes possible the flow of large quantities of electrons to the ion beam 48 without large potential differences being required between negative-particle emitting means 38 and ion beam 48.

In the operation of prior art neutralizers, the quantity of electrons flowing toward a positive ion beam is controlled by space-charge limitations which in effect cause electrons emitted from the cathode member to repel other electrons seeking to be emitted. In order to overcome these retarding forces, it is necessary to increase voltage between a cathode member and the positive ion beam. In the present device, however, the space-charge limitations on the flow of electrons from negative-particle emitting means 38 to ion beam 48 have been overcome by the ion bridge produced by the ionization of ionizable material 30. It is believed that this is accomplished by the dispersion of positively charged ions among the stream of electrons which serves to at least in part cancel out the negative repelling forces exerted by the electrons on other electrons. This results in the efficient flow of large quantities of electrons from cathode member 39 via a bridge of positive ions to ion beam 48. In the language of the art, the electrons are coupled to the ion beam. Because of this efficient coupling process, it is possible to maintain a flow of electrons from negative-particle emitting means 38 to ion beam 48 when orifice 42 is as much as a foot from the ion beam 48 and when the voltage required to maintain the flow is as low as 7 volts. This compares to a voltage requirement of 100 volts and distances of less than 1/10-inch for other neutralizers.

An additional advantage of this device is concerned with an efficient operation of cathode member 39. To promote the emission of electrons from its surface, cathode member 39 is heated by a heater means 40. The bombardment of negative-particle emitting means 38 by ions from the cesium plasma provides additional heat. This process reduces heater power requirements, allowing the heater means to be operated at a lower temperature than would otherwise be possible. The operating life of the heater means is thereby substantially extended, and operating power is saved. It is within the broad scope of the invention to employ only the heater means **40** for the emission of electrons or to employ primarily the bombardment process for the emission of electrons.

Although this invention has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications, which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

Various modifications and variations may be made without departing from the spirit and scope of the invention. For example, other ionizing materials could be used and other enclosure geometries and heater arrangements could be used.

What is claimed is:

1. An electron emission device consisting essentially of:
an enclosure means containing a contact surface, inlet means for directing gas flowing therethrough over said contact surface and outlet means adapted to restrict gas flow therethrough while permitting the flow of electrons therethrough;
source means for supplying easily ionizable gas to said inlet means;
receiver means for accepting the flow of electrons from said outlet means;
power means for maintaining a potential difference between said enclosure means and said receiver means, said potential difference being adapted to generate a high density of electron flow through said outlet means, said outlet means including an orifice of such a diameter that electrons efflux freely in a stream and such that vapor from said ionizable gas is partially restricted within said enclosure means, whereby a stream of electrons mixed with ions flow toward said receiver means.

2. A gas discharge neutralizer comprising:
an ion beam emitting means for emitting a beam of ions, said beam of ions having a first potential;
a particle emitting means for emitting particles, said particle emitting means comprising a cathode member within an enclosure having a top wall, a bottom wall and a front wall, said front wall having a centrally located orifice of a predetermined diameter, said particle emitting means having a second potential resulting in a potential difference between said particle emitting means and said ion beam emitting means, said potential difference between said particle emitting means and said ion beam being sufficient to strike a discharge between said means;
a reservoir means for providing an ionizing material adjacent said particle emitting means;
said material being ionized by said discharge between said particle emitting means and said ion beam, ions from said ionizing material coupling a stream of particles from said particle emitting means to said ion beam, whereby said ion beam is neutralized by said stream of particles;
said orifice in said enclosure being of a diameter such that particles from said cathode member efflux freely in a stream and such that vapor from said ionizing material is partially restricted in said particle emitting means whereby a stream of particles mixed with ions flow toward said ion beam.

3. The structure recited in claim **2**, wherein said particle emitting means is an electron emitting means.

4. The structure recited in claim **2**, wherein said ionizable material is cesium metal.

5. A gas discharge neutralizer comprising:
an ion beam emitting means for emitting a beam of ions having a first polarity and a first potential; and,
a particle emitting means for emitting a stream of neutralizing particles having a polarity opposite to said ion beam and a lesser number of particles having the same polarity as said ions to minimize space charge effects, said particle emitting means having a second potential resulting in a potential difference between said particle emitting means and said ion beam emitting means which causes a stream of neutralizing particles to flow toward said ion beam via said emitted particles of the same polarity, said particle emitting means emitting particles of a first and second polarity in such proportions that space charge aspects are reduced, whereby said ion beam is readily neutralized by such stream of particles, said particle emitting means including an enclosure having a top wall, a bottom wall, and a front wall, said front wall having a centrally located orifice of a diameter such that particles having a polarity opposite to said ion beam efflux freely in said stream and such that said particles having the same polarity as said ion beam are partially restricted within said enclosure.

6. The structure defined in claim **5**, wherein said ion beam emitting means emits a beam of positive ions and said particle emitting means includes a cathode member at a second potential different from said first potential, a heater located within said enclosure for heating the surfaces of said enclosure to emit electrons therefrom, and a reservoir means containing cesium and coupled to said enclosure to supply cesium thereto, said cesium facilitating the emission of electrons from said heated enclosure and also ionizing as a result of a potential difference between said cathode member and said ion beam emitting means, whereby electrons and ionized cesium form a stream of particles having a net negative charge that flows toward said ion beam as a result of the potential difference and effectively neutralizes said beam.

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