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PLASMA ACCELERATOR HAVING A COOLED PREIONIZATION CHAMBER

Original Filed Oct. 21, 1964 2 Sheets-Sheet 1

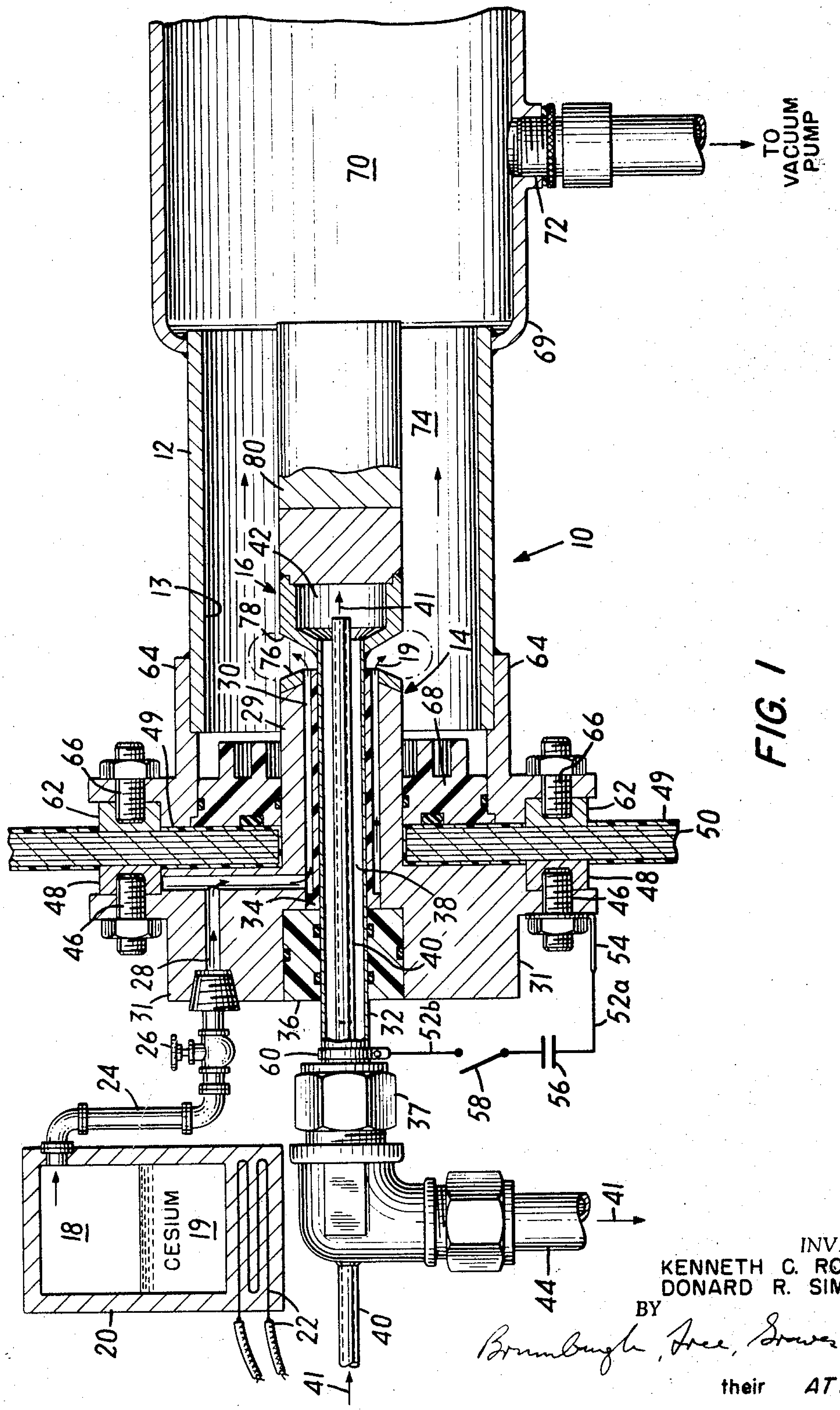

FIG. 1

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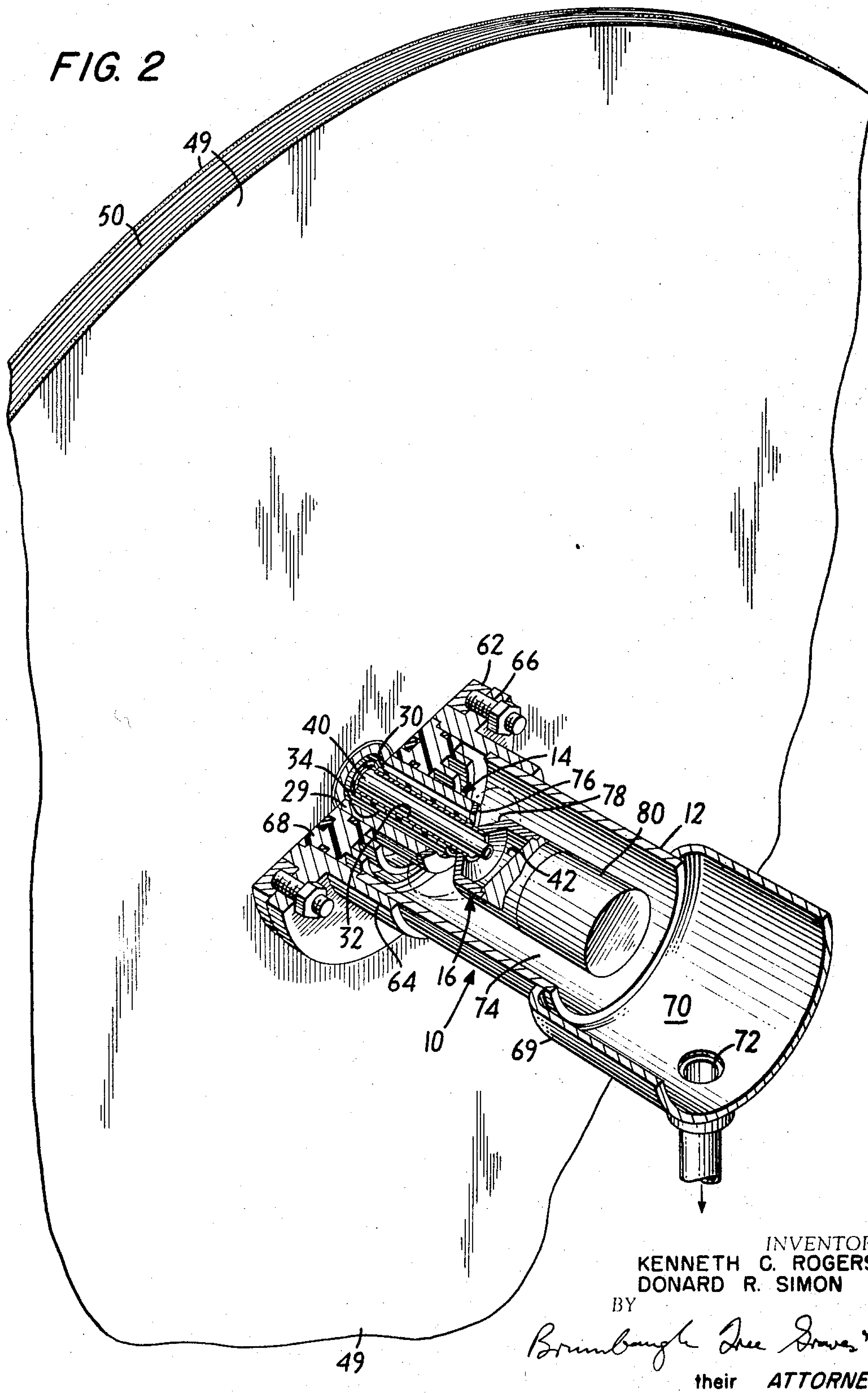
FIG. 2



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Continuation of application Ser. No. 405,517, Oct. 21, 1964. This application June 21, 1967, Ser. No. 647,878
16 Claims. (Cl. 315—111)

This application is a continuation of application, Ser. No. 405,517, filed Oct. 21, 1964 and now abandoned.

The invention relates in general to a plasma accelerator and more particularly to a plasma accelerator in which a triggering pulse across a first pair of electrodes preionizes the working substance prior to the subsequent accelerating discharge of the main electrical energy storage system. The working substance is partially ionized by surface ionization and more completely ionized by collison ionization.

Basically the plasma accelerator or gun is a coaxial electrode system relying on the (J×B) force in an axial direction to perform the desired work on the plasma. Specifically, this invention provides a method for accelerating alkaline metal plasmas and other plasmas to velocities in the order of 10^8 centimeters per second wherein the efficiency of the energy transfer to a plasma is much higher than any other method presently known.

Heretofore, when using the old methods for performing this function such as exploding wires, gas ejection and back-strap acceleration, the major portion of ionization occurred during the main capacitor discharge. This resulted in a slow ignition current rise and large deposits of energy in the internal modes of the plasma. Furthermore, these devices were not only very inefficient in operation but could not accelerate to high velocities a heavy working substance and use pure alkaline metals as plasmas.

This invention calls for the placing of alkaline metals or other materials which are to be accelerated in positions adjacent the terminal surfaces of two insulated electrodes which are connected through a switch-controlled circuit to a first potential storage unit. In some embodiments the plasmoid material to be accelerated is deposited in part on the cooled surface of one of these two first potential electrodes by condensation of the vaporized plasmoid material or by other means. In all cases, however, the potential first discharges in an arc between these two electrodes and, through the material to be accelerated, vaporizing and preionizing the plasmoid material in its path. This working substance expands and closes the gap between one of these first potential electrodes and a third high potential electrode which, when the gap is sufficiently closed, discharges through the vaporized and preionized material accelerating it in the form of plasma down the coaxial accelerator tube at extremely high velocities.

This invention preionizes and rapidly ejects the working plasma, permitting the use of extremely fast capacitors and thereby permitting the use of alkaline metals as a working fluid. The preionization step, coupled with the use of fast capacitors, allows much higher efficiences and velocities to be reached than was heretofore possible when using the prior art methods.

Other objects and a fuller understanding of this invention may be had by referring to the following description and claims taken in conjunction with the accompanying drawing, in which:

FIGURE 1 shows a cross section, elevational view of the plasma accelerator disclosed in this invention; and

FIGURE 2 shows a partially cut away isometric view of the plasma accelerator of FIG. 1.

With reference to the drawings, the invention is illus-

trated as being incorporated in the cylindrical apparatus as shown in FIGS. 1 and 2, and indicated generally by the reference character **10**. As illustrated, the plasma accelerator is composed of an outer cylindrical electrode **12** which is concentric with and surrounds a first inner electrode **14** and a second inner electrode **16**. The device is such that the material to be ionized and accelerated is stored in chamber **18** in tank **20** prior to its delivery to the area between the first and second inner electrodes.

In the preferred embodiment the material to be accelerated **19** is either cesium or potassium. As shown in FIG. 1, the cesium **19** is heated in chamber **18** by electrically controlled heated elements **22** to a temperature above its melting point. Thereafter, cesium vapor passes from chamber **18**, through conduit **24**, control valve **26** and through conduit **28** in the large cylindrical portion **31** of first electrode **14**. The conduit **28** directs the cesium vapor to cylindrical chamber **30** in the elongated tubular portion **29** of first inner electrode **14** which, in turn, leads to an area between the terminal end **76** of the first electrode **14** and the terminal end **78** of the second electrode **16**.

Within chamber **30** the tubular conduit portion **32** of second inner electrode **16** passes through the center of the first inner electrode **14** and is spaced therefrom by insulating elements **34** and **36**. The tubular portion **32** of second inner electrode **16** is held firmly in place by supporting section **37** which also houses the means for delivering and exhausting coolant **41** to and from chamber **42** within the second inner electrode **16**.

The coolant **41** is delivered through conduit **40** which passes from support **37**, through hollow tube **31**, into chamber **42** within inner electrode **16**. The coolant, which in the preferred embodiment is liquid nitrogen, then circulates within chamber **42** and exits through the channel **38** formed between the external surface of conduit **40** and the inner surface of tubular conduit portion **32** of second inner electrode **16**. The coolant **41** then passes through to the channels within supporting elements **37** and exits through channel **44**.

As stated above, the cylindrical end **31** of first inner electrode **14** is connected through insulating material **36** to the outer surface of tubular conduit **32**. This end portion **31** is then connected through electrically conductive studs **46** and the first terminal ring **48** on high potential capacitor **50**. Another portion of cylindrical end **31** of first inner electrode **14** is then connected through fastening element **54** and electrical lines **52***a* and **52***b* to tubular portion **32** of the second inner electrode **16** by fastening means **60**. Line **52***a*, however, first passes through the electrical storage capacitor **56** and switch element **58**, which, prior to firing of the plasma accelerator, is maintained in the open position shown schematically in FIG. 1.

The opposite end of capacitor **50** is connected to second terminal ring **62** which, in turn, is fastened to electrical conductive tube **64** by fastening means **66**. The tube **64** is held in position by insulating ring **68** which surrounds and is directly adjacent the outer surface of the tubular portion **29** of first inner electrode **14**. Capacitor **50** is also electrically insulated by shield **49** from all of the elements adjacent to it with the exception of terminal rings **48** and **62**.

In the preferred embodiment, both the first capacitor **56** and the main low-inductance, high-energy storage capacitor **50** have been precharged by electrical energy sources which are not shown.

Outer electrode **12** is tubular in shape and is held in its position concentric with the first and second inner electrodes **14** and **16**, respectively, by electrical ring **64**. The opposite end of outer electrode **12** engages shield **69** which forms a chamber **70**. The chamber **70** is, in turn, connected with the area **74** between the outer electrode **12** and the inner electrodes **14** and **16**, the chanel area **30**, the conduit areas **28** and **24**, and the area within chamber **18**. The space between the inner surface **13** of the electrode **12** and the outer surface of the electrode **16** forms an acceleration chamber which also directs the gas in the desired direction upon discharge of the condenser **50** between those electrodes. All of these areas are vacuum sealed and are designed to maintain a pressure of about 10^{-8} torr when a vacuum is provided through line **72** by a vacuum pump (not shown).

The extreme end portion **76** of first inner electrode **14** is, in the preferred embodiment, composed of tungsten as is the entire outer section **78** of second inner electrode **16**. The inner surface **13** of the outer electrode **12** is, on the other hand, in the preferred embodiment, made from tantalum. The surfaces **76** and **78** are shown in the preferred embodiment in a nonparallel arrangement, the surfaces diverging slightly toward the inner surface **13** of outer electrode **12**. The space between the surfaces **76** and **78** defines a preionization chamber for the material to be accelerated. The outer end portion **80** of second inner electrode **16** is composed of a conducting nonmagnetic material and serves as a guide for the accelerated plasma without adversely influencing its movement toward chamber **70**.

The plasma accelerator **10** is placed in an operative condition by first energizing heating element **22** and vaporizing the cesium **19** within chamber **18**. The heated cesium vapor at approximately 100° F. passes through chamber **24** when valve **26** is open, entering conduit **28**, which, in turn, in some embodiments may be separately heated by additional electrical elements. The cesium vapor passes through conduit **28** to tubular channel **30** whereupon it passes along the outer surface of insulator element **34** which surrounds tubular portion **32** of second inner electrode **16**. The cesium vapor then emerges from channel **30** in the circular area adjacent the diverging surfaces **76** and **78** of the first and second inner electrodes **14** and **16**, respectively.

Surface **78** in the preferred embodiment is maintained at a low temperature by the passing of liquid nitrogen **41** through conduit **40** and into inner chamber **42**. At this point, a portion of the cesium vapor comes in contact with the cold tungsten surfaces **76** and **78** and solidifies, or condenses, on both of these surfaces, although the primary deposit is on surface **78**. In the preferred embodiment, when the cesium vapor is in the area adjacent surfaces **76** and **78** and a certain portion of the cesium vapor has been deposited on the tungsten surfaces, the plasma accelerator **10** is ready to be discharged.

The preionization occurs when switch **58** is closed and the energy stored in the first capacitor **56** discharges in an electric arc between surfaces **76** and **78**. This triggering pulse causes a substantial degree of surface ionization, thermal ionization, and electron impact ionization of the cesium deposited on these two surfaces.

The conventional current flow for the triggering pulse passes from surface **76**, through portions **29** and **31** of first inner electrode **14**, through stud **46**, fastening element **54**, line **52*a***, capacitor **56**, switch **58**, line **52*b***, fastening element **60**, tube portion **32** and surface **78**, respectively, of second inner electrode **16**, and across the gap between the surfaces **76** and **78**.

The cesium electric arc discharge between surfaces **76** and **78** extends outwardly toward the inner tantalum surface **13** of outer electrode **12** and, when the gap has been sufficiently closed, the low-inductance, high-energy storage capacitor **50** discharges circumferentially between surface **76** and the inner surface **13** at many points along both surfaces.

The conventional current flow for the main capacitor circuit passes from surface **76**, through portions **29** and **31** of first electrode **14**, through studs **46**, first terminal ring **48**, main capacitor **50**, second terminal ring **62**, studs **66**, conductive tube **64**, outer electrode **12**, and across the gap between the inner tantalum surface **13** of the outer electrode **12** and the surface **80** of second electrode **16** to surface **78** of electrode **16** to surface **76** of electrode **14**.

In the preferred embodiment the cesium vapor in chamber **74**, and generally adjacent surfaces **76** and **78**, and the inner surface of outer electrode **12** is preionized to a large extent by three separate actions prior to the discharge of the main capacitor. First, surface ionization between the cesium and tungsten adjacent surfaces **76** and **78**, secondly heating of the cesium vapor by the electric current flowing between surfaces **76** and **78** as the capacitor **56** is discharged, and thirdly, surface ionization at tantalum surface **13**.

In view of the preionization of the cesium vapor between the first inner electrode **14** and the electrode **16**, substantially all of the 20,000 volts of the low-inductance, high-energy storage capacitor **50** acts to accelerate the cesium. Thus, in the instant invention only a minimum of the energy released by the main capacitor **50** is used to ionize the vapor.

Although the invention has been described with a certain degree of particularity, it is to be understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and scope of the invention as herein claimed. For example, as mentioned above, the working material may be any alkaline metal or any other element rather than cesium that can be ionized by surface ionization, e.g. barium or rhenium, as described in the preferred embodiment. Furthermore, embodiments within the scope of this invention are envisioned which do not use the vapor of the material but rather only the solid or liquid of the material.

What is claimed is:

1. A plasma accelerator comprising
a first electrode having a first surface,
a second electrode having a second surface spaced from the first electrode surface to form a preionization chamber,
means for cooling at least one of the first and second electrode surfaces,
means for introducing a vaporized material to be accelerated into the preionization chamber between the first and second electrode surfaces to condense and deposit the material on at least the cooled electrode surface,
a third electrode spaced from and cooperating with said first and second electrodes,
means for establishing a first electrical potential to provide a first arc discharge between said first and second electrode surfaces for vaporizing and preionizing the material deposited on the cooled electrode surface and for preionizing the vaporized material in the preionization chamber,
the first arc discharge narrowing the electrical gap between the third electrode and at least one of the first and second electrodes and propelling the preionized material into said gap, and
means for establishing a second electrical potential to provide a second arc discharge when the first arc discharge sufficiently narrows the gap between the third electrode and at least one of said first and second electrodes, the second arc discharge accelerating the preionized material from said electrodes.

2. A plasma accelerator as defined in claim **1**, wherein the electrode surfaces are opposed conical surfaces which diverge radially toward said third electrode.

3. A plasma accelerator as defined in claim **1**, wherein the material is an alkaline metal.

4. A plasma accelerator as defined in claim **1**, wherein the material is cesium.

5. A plasma accelerator as defined in claim **1**, wherein the material is potassium.

6. A plasma accelerator as defined in claim **1**, wherein the cooling means comprises liquid nitrogen.

7. A plasma eccelerator comprising

a first inner electrode having a first conical surface,

a second inner electrode concentric with the first inner electrode and having a second conical surface spaced from and opposed to the first conical surface to form a preionization chamber,

means for cooling at least one of the first and second conical surfaces,

means for introducing a vaporized alkaline metal to be accelerated into the preionization chamber between the first and second conical surfaces to deposit the alkaline metal on at least the cooled conical surface,

a third outer electrode concentric with and surrounding the first and second inner electrodes,

means for establishing a first electrical potential to provide a first arc discharge between said first and second conical surfaces for vaporizing and preionizing the alkaline metal deposited on the cooled conical surface and for preionizing the vaporized alkaline metal in the preionization chamber,

the first arc discharge narrowing the electrical gap between the third electrode and at least one of the first and second electrodes and propelling the preionized alkaline metal into said gap, and

means for establishing a second electrical potential to provide a second arc discharge when the first arc discharge sufficiently narrows the gap between the third electrode and at least one of said first and second electrodes, the second arc discharge accelerating the preionized alkaline metal from said electrodes.

8. A plasma accelerator as defined in claim **7**, wherein the alkaline metal is cesium.

9. A plasma accelerator as defined in claim **7**, wherein the alkaline metal is potassium.

10. A plasma accelerator as defined in claim **7**, wherein the cooling means comprises liquid nitrogen.

11. A plasma accelerator as defined in claim **7**, wherein the first and second conical surfaces diverge radially toward said third electrode.

12. Apparatus for generating a high velocity plasma comprising:

means for vaporizing an ionizable material;

means defining a preionization chamber for receiving the vaporized material;

means associated with the preionization chamber for cooling the vaporized material to convert a major part of the introduced vaporized material into a deposit in the preionization chamber;

means for establishing a first electric arc discharge effective to revaporize and simultaneously preionize the deposited material to form a plasma;

means defining a plasma acceleration chamber communicating with the preionization chamber to receive the preionized material; and

means for establishing a second electric arc discharge in the acceleration chamber upon passage of the preionized material thereinto, thereby to propel the preionized material in a direction determined by the geometry of the acceleration chamber.

13. Apparatus as defined in claim **12**, in which:

the preionization chamber has an annular configuration defined between first and second electrodes upon the surface of at least one of which the vaporized material is deposited, and

the acceleration chamber is tubular about an axis substantially normal to the annular ionization chamber.

14. Apparatus as set forth in claim **13**, in which:

the ionization and acceleration chambers communicate over an annular area to effect radial outward motion of the preionized material from the preionization chamber into the acceleration chamber.

15. In combination with the apparatus defined in claim **12**:

a potassium alkaline metal material to be vaporized by the vaporizing means.

16. In combination with the apparatus recited in claim **12**:

a cesium alkaline metal material to be vaporized by the vaporizing means.

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