ION SOURCE AND PLASMA GENERATOR

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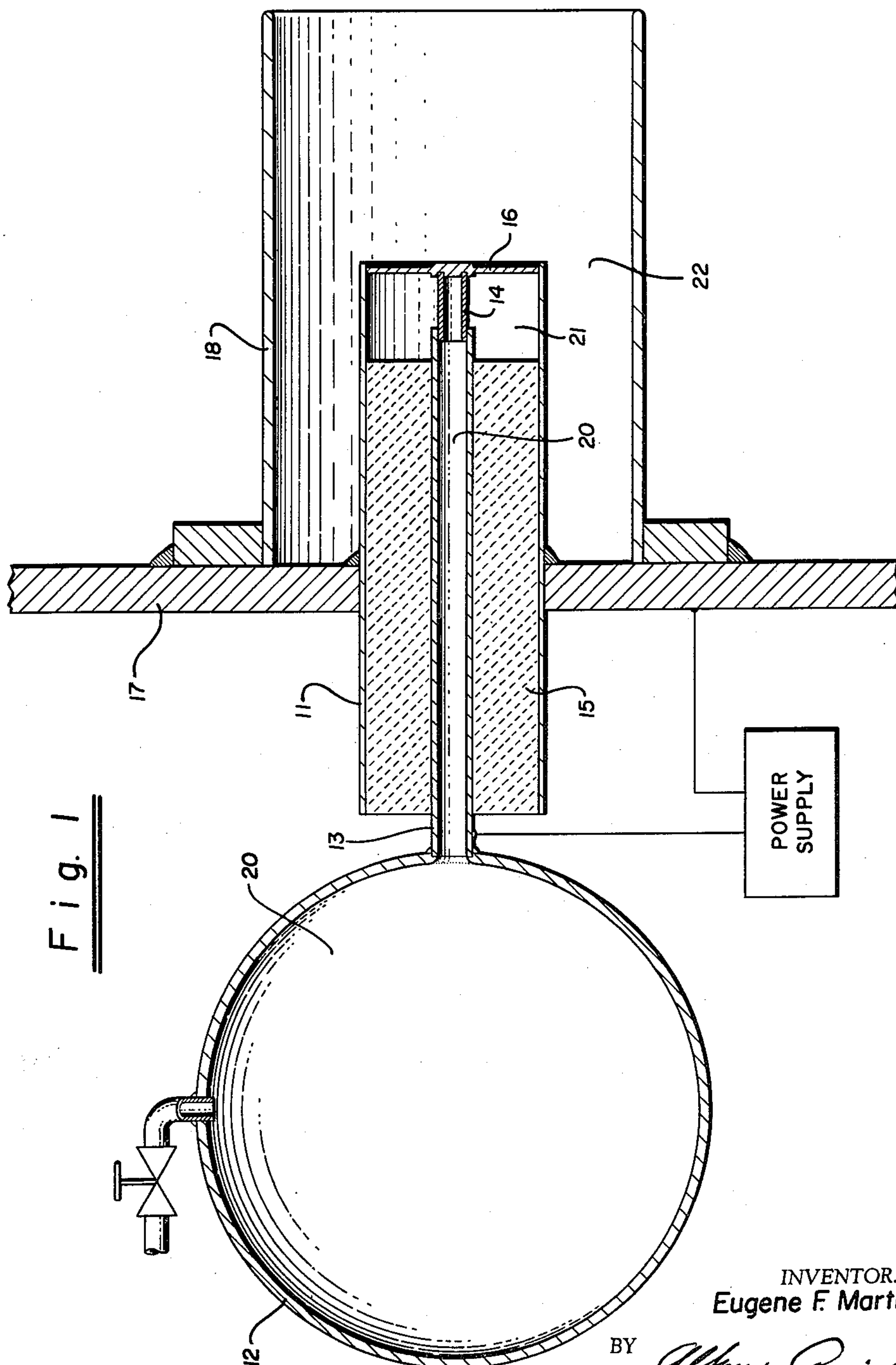

Fig. 1

INVENTOR.
Eugene F. Martina
BY
Attorney

Feb. 6, 1962 E. F. MARTINA 3,020,431

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Fig. 3

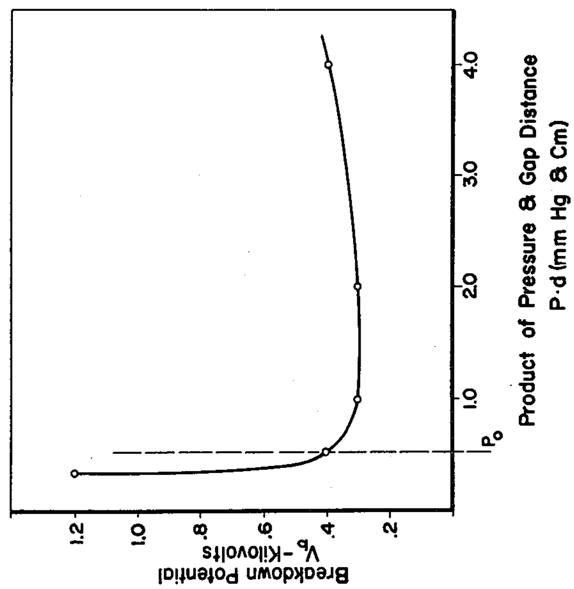
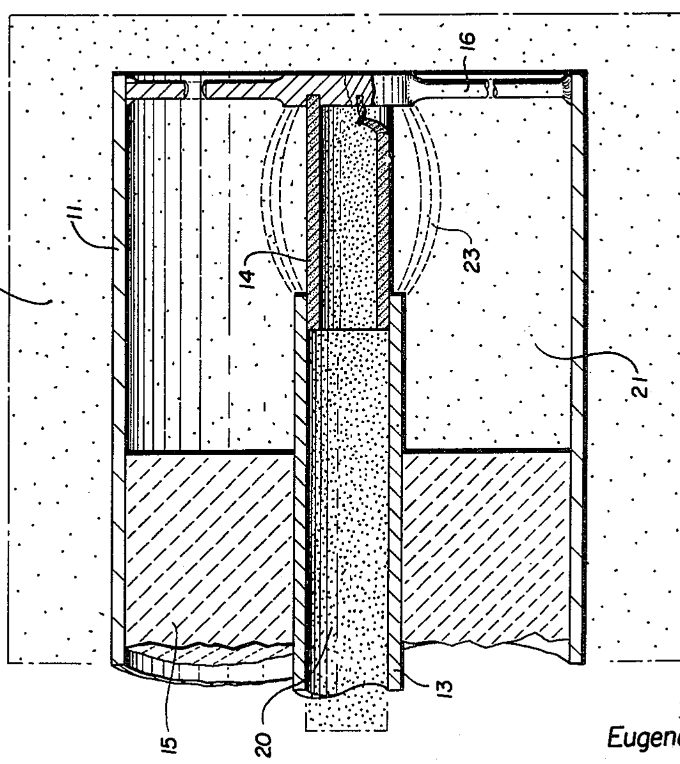


Fig. 2



INVENTOR.
Eugene F. Martina

BY Alfons Puishes

Attorney

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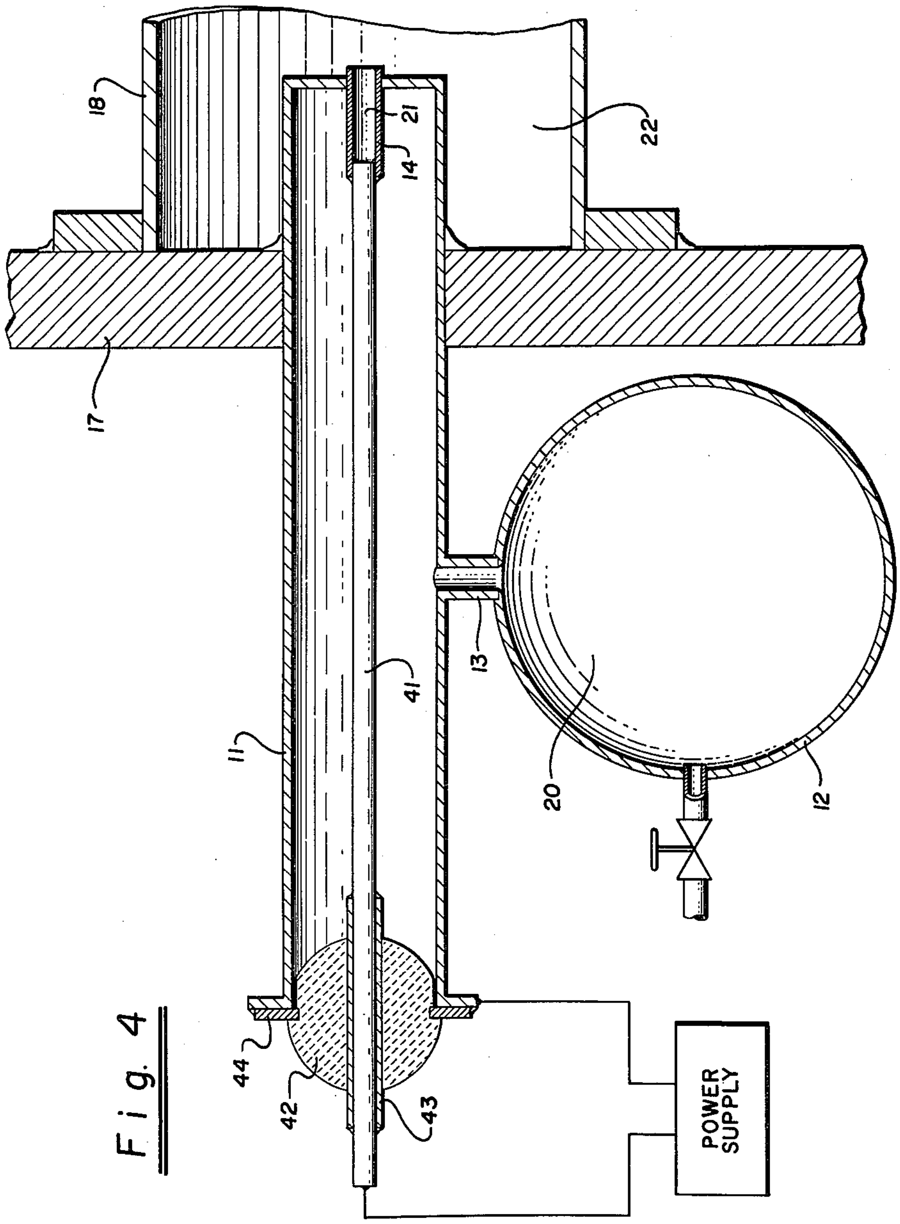

Fig. 4

INVENTOR.
Eugene F. Martina
BY [signature]
Attorney

United States Patent Office

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3,020,431

ION SOURCE AND PLASMA GENERATOR

Eugene F. Martina, Palo Alto, Calif., assignor to American Radiator & Standard Sanitary Corporation, a corporation of Delaware

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This invention relates to ion sources and to methods and devices for producing ions. More particularly it pertains to a novel process and device for producing a pulse of ions of high intensity for short periods of time which is simple, rugged, reliable and of relatively small dimensions.

Ions of the type produced by this invention have many uses in pure applied research in connection with particle accelerators, reactor physics and fusion as well as practical applications in the fields of instrumentation, isotope separation, geophysical exploration and many others connected with nuclear physics and atomic energy.

Ion sources of the type covered by this invention utilize an electric arc or glow discharge to produce a plasma of ionized gas. In conventional sources of this type a filament and electro-magnet are often used to maintain the arc, necessitating considerable extra and troublesome equipment, including special power supplies. In others, beta emitting nuclear sources are utilized but these either have a limited lifetime or are hazardous to use as well as not easily controlled. In existing devices, moreover, either the intensity of the ion beam or the useful life of the device is limited or else it must be of relatively large size. Devices such as these are covered by Crawford Patent 2,764,707 and Laurence Patent 2,785,311.

It is consequently an object of my invention to provide an ion source which would be simple and rugged.

It is a further object of my invention to provide an ion source of relatively small dimensions.

It is another object of my invention to provide an ion source which would produce a high intensity pulsed beam of ions having a relatively long useful life.

It is still another object of my invention to provide an ion source which can be easily regulated and controlled without the use of elaborate electrical circuitry and magnetic fields.

It is yet another object of my invention to provide an ion source which utilizes the permeability of some metals to certain gases sought to be ionized by supplying one of said gases from an external source to one surface of said permeable metal, maintaining a vacuum on a second surface of said permeable metal, applying a high difference of potential to said metal, thereby causing a diffusion of said gas through said metal, resulting in a decrease in vacuum on said second surface causing an electric arc discharge on said second surface, thereby producing ions of the said gas.

Various other objects and advantages of my invention will be apparent to those skilled in the art from a study of the following description and accompanying drawings wherein:

FIG. 1 is a longitudinal section showing the complete assembly of one embodiment of the invention.

FIG. 2 is an enlarged section and end view of the ion emission end of the device.

FIG. 3 is a curve showing the relation between breakdown potential and the product of pressure and gap distance for the embodiment shown in FIGURE 1 in accordance with Paschen's Law.

FIG. 4 is a longitudinal section showing an alternate embodiment for effecting the objectives of the invention.

In general, according to my invention the gas to be ionized is caused to be compressed into a chamber or element known as an "emitter," the walls of which are permeable to the gas, at the same time that a pulsed electrical current is caused to flow through the walls of the emitter so that the heating action of the current aids the diffusion of the gas through the walls. The opposite side of the chamber is surrounded by an evacuated vessel, the pressure in which is caused to increase by the leakage of gas through the walls of the chamber. The pressure close to the emitter rises until a voltage breakdown occurs, generating an arc plasma on the surface of the emitter.

More particularly referring to the accompanying figures, **11** is the body of the ion source which may be made of copper, stainless steel or other suitable metal and **12** is a reservoir containing a supply of the gas to be ionized, which may be hydrogen or one of its isotopes, deuterium or tritium, although other gases may be used. The reservoir **12** connects by means of the gas tube **13** to the ion emitter **14**. The latter is formed from a metal belonging to the so-called transition group such as palladium, zirconium, titanium, tantalum or others having the characteristic of being permeable to certain gases.

The gas tube **13** is supported in the body **11** by the insulating tube **15** which may be of magnesium oxide or other insulating and refractory material.

One end of the emitter **14** is supported by the metal spider **16** while the tube **11** is joined to vacuum tank wall **17** to which is attached also the ion duct **18**. The latter two items may be components of a cyclotron, linear accelerator or other related device.

All metallic joints are made by soldering, brazing, welding or other similar process adapted to the metals being used.

A power supply consisting of a source of high voltage pulsed current is connected to the gas tube **13** and vacuum tank wall **17** as shown.

In the embodiment shown on FIG. 1, I have used a copper reservoir **12** of spherical shape approximately 1½" in diameter, a body **11** of copper ⅜" in diameter and 1½" long, and a palladium emitter .028" inside diameter by .032" outside diameter by .125" effective length. The ion duct **18** is 1½" in diameter and extends 2" beyond the end of tube **18**. The area represented by **22** is maintained under a vacuum of 10^{-5} mm. of mercury by a suitable pump not shown.

In the operation of the above embodiment, deuterium gas **20** is supplied to reservoir **12** at a pressure of 200 lbs. per sq. in. A voltage pulse of 10 kilovolts is applied to the system for approximately 0.1 microsecond. The resultant current flow heats the palladium emitter **14** and causes the deuterium **20** to diffuse through the emitter into the vacuum space **22**. The result is to increase the absolute pressure as shown at **21**, FIG. 2. For the embodiment shown, when the pressure reaches 1.5 mm. of mercury an arc-over or breakdown **23** will take place along the emitter **14**. The breakdown potential is a function of the pressure and length of the gap in accordance with Paschen's Law previously mentioned. For the embodiment shown I have found these values to be as shown on the curve FIG. 3.

I have measured the ions produced by the arc plasma **23** and found that they have average energies of 2 electron volts and arrive at the end of the ion duct 1 microsecond before the gas molecules do. I have measured also the output of deuterons per microsecond pulse and found it to be 10^{15} ions.

I have found still further that with the embodiment shown and described above I can produce 10 pulses per second and using the gas supply as shown, I can produce approximately 1,000,000 pulses, thus providing continuous operation of the device for well over 24 hours despite the fact that the greatest dimension of my device is not over 6".

In the alternate embodiment shown in FIG. 4, I introduce the gas to be ionized **20** around the outside of an emitter chamber **14**. In this embodiment I utilize a rod **41** of copper or other suitable conducting material to connect the emitter **14** with the power supply through a special insulator **42**, a bushing **43** and a seal **44**.

The operation of this alternate embodiment is very similar to that described above with the principal exception that the gas to be ionized diffuses from the outer to the inner surface of the emitter and the arc plasma is consequently generated on the latter. I thus utilize the nozzle effect of the emitter, which may be of any convenient geometry, to help discharge the ions into the duct **18**. With this embodiment I still retain the large ion extraction area which is an important feature of my invention.

Although I have described a preferred embodiment of my invention and have thus illustrated the operation of the process, many modifications will be obvious to those skilled in the art and, therefore, I do not limit myself to the details and arrangements shown here, except as I do so by the claims which follow.

What I claim is:

1. An ion source comprising a chamber at least one wall of which is composed of a metal permeable to a gas sought to be ionized, means of directing said gas to one surface of said wall, means of maintaining a high vacuum at a second surface of said wall, means of applying a high difference of potential between two points on said second surface, said points being so spaced as to cause rapid diffusion of said gas through said wall and create a sudden increase in pressure at said second surface, thereby causing an electric arc discharge of short duration between the two said points on said second surface.

2. The ion source of claim 1 wherein the gas sought to be ionized is an isotope of hydrogen selected from the group consisting of hydrogen, deuterium and tritium.

3. The ion source of claim 1 wherein the metal permeable to a gas sought to be ionized is selected from the group consisting of palladium, zirconium, titanium and tantalum.

4. A plasma generator comprising a chamber at least one wall of which is permeable to a gas sought to be ionized, means of directing said gas to one surface of said permeable wall, means of maintaining a vacuum on another surface of said wall, means of applying a difference of potential between two points on said wall, means of controlling said potential and said vacuum so that an arc plasma is formed on one surface.

5. An ion source comprising a chamber at least one wall of which is permeable to a gas sought to be ionized, means of directing said gas to one surface of said permeable wall, means of maintaining a vacuum on another surface of said wall, means of applying a difference of potential between two points on said wall, means of controlling said potential and said vacuum so that an arc plasma is formed on one surface, means of removing the ions so formed.

6. A plasma generator comprising a chamber at least one wall of which is permeable to a gas sought to be ionized, means of directing said gas to one surface of said permeable wall, means of maintaining a vacuum on another surface of said permeable wall, means of applying a difference of potential between two points on said wall whereby diffusion of said gas through said wall produces an arc plasma on one surface of said wall.

7. An ion source comprising a chamber at least one wall of which is permeable to a gas sought to be ionized, means of directing said gas to one surface of said permeable wall, means of maintaining a vaccum on another surface of said permeable wall, means of applying a difference of potential between two points on said wall, whereby diffusion of said gas through said wall produces an arc plasma on one surface of said wall, means of removing the ions so formed.

8. An ion source comprising a hollow chamber permeable to a gas sought to be ionized, an external source of said gas, means of directing said gas to one side of said hollow chamber, means of maintaining a vacuum on another side of said chamber, means of applying a difference of potential between two points on said chamber, so arranged that diffusion of said gas from said chamber produces an electrical discharge on one surface of said chamber.

9. The ion source of claim 8 in which the means of applying a difference of potential between two points on a permeable chamber comprises a pulse forming network adapted to provide a source of high potential pulsed current to said chamber.

10. A method of producing an arc plasma comprising means of introducing a gas sought to be ionized to the surface of a wall of a chamber, said wall being composed of a material permeable to said gas, means of maintaining a vacuum on an opposite surface of said wall, means of applying a difference of potential between two points on said wall so that said gas is caused to diffuse through said wall and form an arc plasma on said opposite surface of said wall.

11. A method of producing ions comprising means of introducing a gas sought to be ionized to the surface of a wall of a chamber, said wall being composed of a material permeable to said gas, means of maintaining a vacuum on an opposite surface of said wall, means of applying a difference of potential between two points on said wall so that said gas is caused to diffuse through said wall and form an arc plasma on said opposite surface of said wall and means for removing the ions so formed.

12. In a method for producing an arc plasma involving the diffusion of an ionizable gas through a permeable metal the improvement comprising an external source of supply of said gas, means of maintaing a vacuum on one surface of said metal, means of applying a difference of potential to said metal, means of controlling said potential and said vacuum so that an arc plasma is formed on said surface of said metal.

13. In a method for producing ions involving the diffusion of an ionizable gas through a permeable metal the improvement comprising an external source of supply of said gas, means of maintaining a vacuum on one surface of said metal, means of applying a difference of potential to said metal, means of controlling said potential and said vacuum so that an arc plasma is formed on said surface of said metal and means of removing the ions so formed.

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