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PULSED ION SOURCE

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Fig. 1.

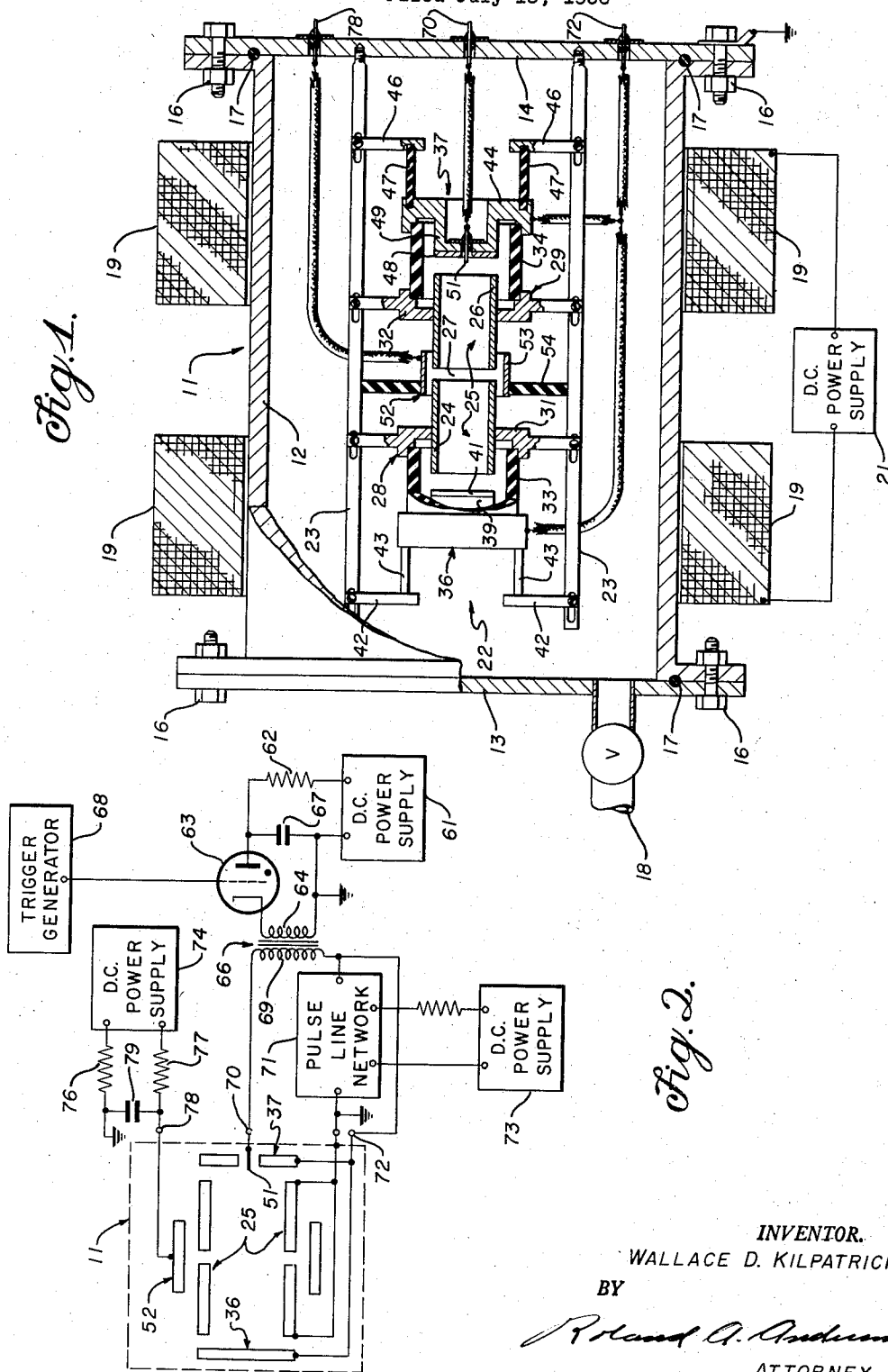


Fig. 2.

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PULSED ION SOURCE

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The present invention relates to an ion source for producing high intensity pulses of ions with precise time control of pulse initiation.

One of the common requirements of ion sources is that of high output and most sources strive to produce a large quantity of ions per unit time. With the advent of modern ion utilizing equipment other than mere analyzers, it has been found advantageous to produce bunched or pulsed beams of ions and for such applications it is even more important that the individual beam pulses or bunches contain a large quantity of ions in order that the average beam current may be appreciable to produce desired effects with appreciable magnitude.

The realization of large ion currents necessitates the use of arc discharges, for low order discharges fail to generate ions in sufficient quantity. Difficulties have been encountered, however, in the use of arc discharges for producing pulsed ion beams in that the pulsed operation of arc discharges poses certain control problems. Inasmuch as arc discharge initiation depends upon a variety of factors it is hard to accurately time same and thus pulsed arcs usually suffer from variations in pulse duration and variations in time of initiation, this latter being some times termed jitter.

An example of the difficulties in pulsed arc operation is the problem of gas supply. It appears not to be feasible to mechanically control gas flow in pulses to an arc area for pulsed discharge as time lag in gas flow and the relatively slow control possible is not consonant with rapid electrical pulsing. However, constant gas flow to a pulsed arc produces a large quantity of un-ionized gas in the time between pulses to the detriment of the vacuum and also to the time control of arc initiation which is, in part, dependent upon ambient pressure. The use of constant vacuum pumping does not entirely solve this problem and additionally entails an undesirable quantity of pumping equipment with attendant cost and maintenance, together with a material loss in source compactness.

The present invention provides a high output pulsed ion source while overcoming the above-noted difficulties of arc discharge sources. The pulsed ion source of the present invention provides precise control over pulse initiation and duration while electrically generating the gas to be ionized in controlled pulses in the arc discharge area and in proportion to the ionizing ability of the arc so that not only is the evacuation problem minimized but it is substantially eliminated.

It is an object of the present invention to provide an improved pulsed arc ion source.

It is another object of the present invention to provide an ion source electrically generating gas to be ionized by the ionizing medium and only in the quantity ionized thereby.

It is a further object of the present invention to provide a pulsed ion source producing large current pulses with precise control of pulse initiation time.

It is yet another object of the present invention to

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provide a pulsed ion generator requiring no continuous evacuation.

It is a still further object of the present invention to provide a compact, light weight pulsed ion source.

Numerous other advantages and possible objects of the invention will become apparent to those skilled in the art from the following description of a single preferred embodiment of the invention taken together with the accompanying drawing wherein:

Figure 1 is a plan view of a preferred embodiment of the invention with portions broken away, as indicated, to show interior source construction; and

Figure 2 is a schematic representation of the invention including associated electrical circuits.

Considering now the invention in some detail and referring to the illustrated form thereof in the drawing, there is provided a vacuum envelope 11 including a cylinder 12 having flanged ends to which are attached plates 13 and 14 as by bolts 16. The envelope 11 is maintained vacuum tight as by suitable seals 17 about the flanged cylinder ends and a vacuum pump-out connection 18 is provided in the envelope, as in the back wall 13 thereof. About the cylinder 12 are disposed magnet windings 19 energized from a direct current power supply 21 to establish a constant magnetic field having lines of force extending axially through the cylinder 12. These windings 19 may take any desired shape such as Helmholtz coils spaced apart a distance equal to the coil radius.

Within the vacuum envelope is disposed an ion generator 22 and a number of spaced parallel support rods 23 extend axially of the envelope within same from attachment with the face plate 14 for mounting of the source elements. The center of the source is a split anode 25 including a pair of axially aligned cylinders 24 and 26 separated by an annular slit 27. The anode cylinders 24 and 26 are similarly mounted by like mounting elements 28 and 29, respectively, and element 28, for example, includes a ring 31 having arms extending radially inward into fixed attachment with the anode cylinder 24 and other arms extending radially outward into adjustable connection with the support rods 23 as shown. The other mounting element 29 is similarly constructed with a central ring 32 and both elements 28 and 29 are provided with an annular indentation on the outer faces thereof for receiving and retaining cylindrical insulators 33 and 34 having larger diameters than the anode cylinders and extending beyond the outer cylinder ends. At the outer ends of the anode cylinders are disposed a pair of cathodes 36 and 37 with the former adjacent the anode cylinder 24 and the latter adjacent the anode cylinder 26.

The cathode 36 includes a generally annular member 38 adapted to engage and retain the cylindrical insulator 33 as in a groove thereabout and a boss 39 extends therefrom toward the anode cylinder 24 in axial alignment thereof and into close proximity with the outer cylinder end. A disc 41 of electron emissive material is mounted on the face of the boss 39 across the end of the anode cylinder 24 out of contact therewith and the annular member 38 is additionally supported by rods 42 adjustably connected to the support rods 23 and affixed through insulators 43 to the annular member 38. The other cathode 37 is similar in including an annular member 44 engaging the insulator 34 and further mounted by arms 46 adjustably engaging the support rods 23 and the annular member 44 through insulators 47. Also, this cathode includes a disc 48 upon the inner face of a boss 49 thereon extending toward the adjacent anode cylinder 26 in axial alignment therewith; however, this disc 48 is gas loaded as by occlusion with a gas to be ionized in the source. Additionally, the annular member 44 of this cathode 34 has a central aperture therethrough with a trigger electrode 51 mounted in insulating relationship therein and

extending through the cathode disc 48 out of contact therewith.

Within the vacuum envelope 11 there is additionally provided ion extraction means 52 which may take the form of a metal cylinder 53 of a greater diameter than the anode cylinders and disposed about the slit or gap 27 in the split anode 25. This electrode 53 may be mounted by means of a number of insulators 54 extending from same radially outward into contact with the support rods 23. Also, depending upon the desired use of the ions generated, the accelerating electrode 53 may be apertured to provide ion egress, or alternatively the electrode 53 may comprise an ion target for ion bombardment whereat neutrons are formed, for example. In the latter application, neutrons, having high penetrative power and being electrically neutral so as to be unaffected by ambient electrical and magnetic fields, would pass radially outward through the electrode 53 and envelope cylinder 12 between the magnet windings for interception and use exteriorly of the source. Should it be desired to deliver ions exteriorly of the source envelope 11 suitable slits may be formed in the accelerating electrode 53 and in the envelope 12 for ion passage; however, in the latter case vacuum tight connection would be made along the ion path to ion utilizing apparatus. Note also that the circumferential extent of anode slit 27 may be varied in the circumstances where directional ion extraction is desired and similar limitations would then be made in the extent of any openings in the accelerating electrode 53 and envelope cylinder 12.

Energization of the components of the above-described ion source is accomplished by circuits, such as illustrated in Fig. 2, to enable these elements to perform their designated functions. A first direct current power supply 61 is connected with the positive terminal thereof coupled through a resistor 62 to the plate of a discharge tube 63, such as a thyratron, and the negative terminal thereof connected as by a ground line to the tube cathode through the primary winding 64 of a pulse transformer 66. A storage capacitor 67 is connected between the plate of the tube 63 and the negative power supply terminal so as to be connected across the power supply and resistor as well as across the tube and transformer primary. Actuation of this circuit is controlled by a trigger generator circuit 68 producing a positive trigger voltage and connected to the control electrode of the discharge tube 63. The trigger generator output pulse preferably has a very short rise time so as to minimize variations in firing point of the discharge tube and the trigger generator may be controllable to produce timed output pulses of predetermined separation or single manually time controlled pulses. A trigger pulse at the discharge tube 63 causes the latter to conduct and to connect the capacitor 67 across the transformer primary whereby the former discharges through the latter. The discharge tube 63 is cut off by low plate voltage from capacitor discharge and during tube cut-off the capacitor 67 is recharged through the resistor 62 by the power supply 61. A secondary winding 69 of the pulse transformer 66 has one end thereof connected to an ion source terminal 70 that is, in turn, connected via a suitable lead-through insulator to the trigger electrode 51. The other end of the transformer secondary winding 69 is connected to one terminal of a pulse line network 71 and to an ion source terminal 72 in turn connected to the ion source cathodes 36 and 37. It will thus be seen that the pulse induced in the transformer secondary winding is impressed between the trigger electrode 51 and adjacent cathode disc 48 and there is produced thereby an initiating arc operating to the ends set out below. The pulse line network 71 is connected at the other terminal thereof to the ion source anode 25 as by means of a ground connection through the source envelope 12 and a second direct current power supply 73 is connected to the pulse line network 71 whereby the latter upon energization from the transformer pulse actuates the pulse

line network to impress a high current low voltage pulse between the anode 25 and cathodes 36 and 37 with the anode terminal thereof positive.

An additional circuit is provided for energizing the ion extractor 52 and same may include a direct current power supply 74 having the positive terminal thereof grounded through a resistor 76. The negative power supply terminal is coupled through a resistor 77 to an ion source terminal 78 that is joined internally of the source to the ion extractor electrode 53 and a capacitor 79 grounds this terminal 78. This capacitor 79 serves to smooth out fluctuations in the ion extractor resulting from ion beam impingement.

As regards the operation of the present invention, the third direct current power supply 74 normally continuously energizes the ion extractor 52 to maintain an ion extracting field as substantially no drain occurs therefrom in the intervals between ion generation. A trigger pulse from the trigger generator 68 drives the control electrode of the tube 63 positive so that the tube conducts to discharge the previously charged capacitor 67 through the transformer primary winding 64. A voltage pulse induced in the transformer secondary winding 69 is applied between the trigger electrode 51 and the cathode 37 so that an arc is struck between the trigger electrode and the cathode disc 48. This arc discharge frees gas occluded or otherwise stored in the disc 48 and simultaneously ionizes the gas. At this point, note that only a short arc discharge path is provided for the aforementioned arc so that with a substantial arc voltage applied thereacross accurately reproducible arc initiation times are achieved. The transformer secondary winding voltage also triggers the pulse line network 71 wherein a substantial energy derived from the power supply 73 is stored and this energy is then applied between the anode 25 and cathodes 36 and 37. Although the voltage impressed between the anode and cathodes may not be sufficient to start an arc discharge, at least with any degree of reliability, the arc is actually started by the trigger electrode with precise timing and expands throughout the anode. Electrons within the anode, freed from the cathodes by ion bombardment and freed in space by gas molecule ionization, travel generally axially of the anode under lateral constraint of the magnetic field and are repelled at each cathode by the negative fields thereof so that electrons oscillate between the cathodes under attraction from the anode and repulsion from the cathodes to provide a maximized path length. Optimum ionizing probability results from lengthened electron path as above. Many of the ions formed from gas molecules strike the cathodes to increase secondary electron emission thereby further increasing electrons traversing the anode region.

Release of gas from the cathode disc 48 is accomplished by the arc discharge in a conventional manner and this same discharge ionizes the gas released. Thus an increase in gas release brought about by a stronger arc also increases the ionization so that automatic regulation results, i.e., the arc generates only so much gas as it can ionize and no gas surplus results to contaminate the system.

As a result of the foregoing, there is established a strong arc discharge extending through the anode under radial restraint from the magnetic field and extending almost to the cathodes. Between the arc ends and the cathodes there occurs substantially all of the anode-cathode voltage differential and in the present case this voltage is maintained low enough to minimize metallic ion production by ion cathode bombardment. The strong negative field of the ion extraction means extends through the anode slit 27 into the anode whereat a radial ion accelerating effect is achieved on the outer arc surface. The ion extracting field thus accelerates ions radially outward of the anode to withdraw ions from the arc region through the anode slit 27 and as illustrated these ions

strike the accelerating electrode 53 as a target, although other provision may be made for ion utilization, as noted above.

With the dissipation of the arc energy applied between anode and cathodes, i.e., discharge of the pulse network line 71, the arc extinguishes, having ionized all of the gas released from the cathode disc 48 by the arc. There is thus produced within the anode region a strong pulsed arc that is precisely controlled as to time of initiation and duration and which liberates the gas ionized thereby and, in turn, ionizes all gas liberated.

Although the present invention has been described in connection with a single preferred embodiment thereof, it will be appreciated by those skilled in the art that numerous modifications and variations are possible within the spirit and scope of the invention and thus it is not intended to limit the invention except by the terms of the following claims.

What is claimed is:

1. A pulsed ion source comprising a plurality of electrodes including a pair of spaced cathodes, an apertured anode disposed between said cathodes, means establishing a magnetic field having flux lines between said cathodes through said anode aperture, at least one of said electrodes having a gas to be ionized occluded therein, a trigger electrode spaced close to said occluded gas electrode and adapted to receive pulsed energization for establishing a triggering arc between same and said occluded gas electrode, means applying low voltage pulsed electrical energy between said anode and cathodes in synchronism with the pulsed energization of said trigger electrode for establishing an ionizing arc discharge through said anode, and means for extracting ions from said arc discharge.

2. A pulsed ion source as claimed in claim 1 further characterized by said occluded gas electrode comprising one of said cathodes with said trigger electrode disposed adjacent thereto.

3. A pulsed ion source comprising a cylindrical anode, means establishing a magnetic field axially through said anode, a pair of cathodes disposed one at each open end of said anode with one of said cathodes having an aperture therethrough, said apertured cathode having a gas loaded surface facing said anode, a trigger electrode extending through said cathode aperture, means impressing a trigger voltage between said trigger electrode and apertured cathode for establishing a triggering arc discharge therebetween whereby gas is liberated from said apertured cathode and ionized, means impressing a pulsed voltage between said anode and cathodes in synchronism with said trigger voltage for establishing an ionizing arc discharge through said anode, and an ion extracting electrode communicating with said arc discharge and maintained at a negative potential relative to said anode for extracting ions from said arc discharge.

4. A pulsed ion source comprising a closed evacuated

envelope, first and second cathodes separated by a spaced cylindrical anode having at least one radial opening therein, a gas loaded element secured to the first of said cathodes, a trigger electrode disposed adjacent said gas loaded element, means impressing a trigger voltage between said trigger electrode and said first cathode for establishing a triggering arc discharge therebetween to liberate gas from said gas loaded element and ionize same, means impressing a pulsed voltage between said anode and cathodes in synchronism with said trigger voltage for expanding said triggering arc to substantially the volume of said anode, means maintaining a magnetic field through said anode for confining said arc discharge, and ion extracting means maintained at a negative potential relative to said anode and disposed exteriorly of same adjacent the anode opening for extracting ions from the arc discharge.

5. A pulsed ion source comprising a sealed-off evacuated envelope, an anode and at least one cathode spaced therefrom disposed within said envelope, means impressing a pulsed low arc voltage between said anode and cathode, a gas loaded element forming a part of said cathode, a trigger electrode disposed adjacent said gas loaded element, means impressing a pulsed voltage in synchronism with said arc voltage between said trigger electrode and said gas loaded element with said pulsed voltage having a magnitude substantially in excess of arcing voltage between said trigger electrode and said electrode for liberating gas from the latter and establishing an arc that expands substantially to said anode and cathode, and ion extraction means for withdrawing ions from said arc discharge.

6. A pulsed ion source comprising an anode and at least one cathode having a portion thereof loaded with a gas to be ionized, a trigger electrode disposed adjacent said gas loaded cathode, a triggered discharge tube controllably connecting a charged capacitor between said trigger electrode and gas loaded cathode for impressing therebetween a pulsed voltage of rapid rise time and a magnitude in excess of arc initiation voltage, a pulse line network including charging means and actuated by said discharge tube connected between said anode and cathode for impressing therebetween a low arc voltage and establishing a low voltage arc discharge, and ion extraction means for removing ions from said arc discharge.

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