Oct. 4, 1955 F. OPPENHEIMER 2,719,925

ELECTRIC DISCHARGE DEVICE

Filed Feb. 23, 1944 2 Sheets-Sheet 1

Fig. 1.

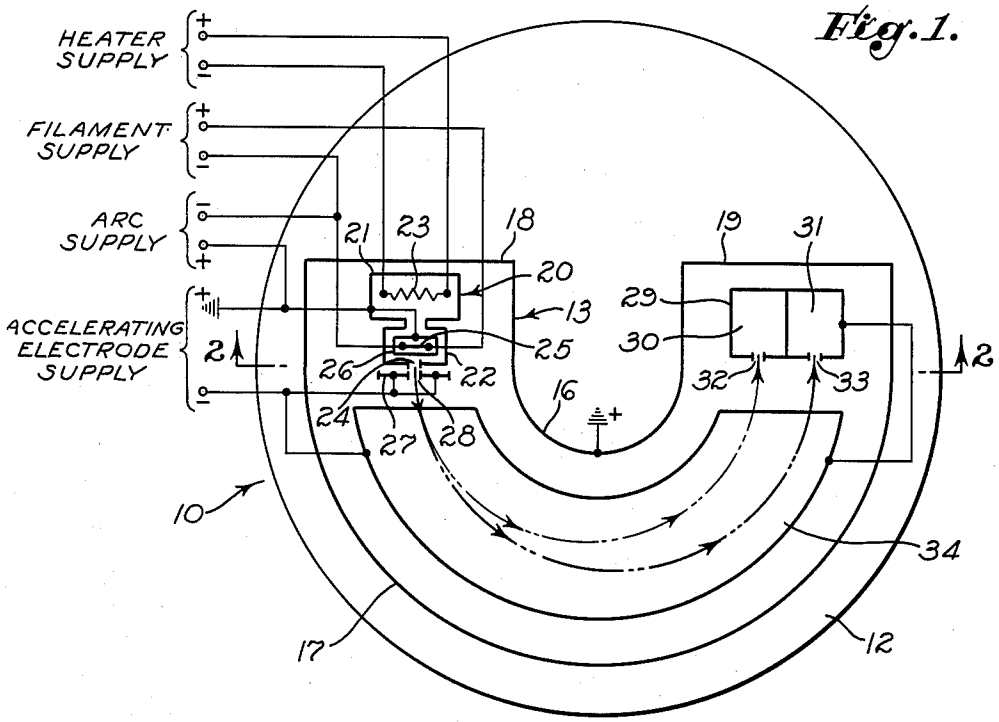


Fig. 2.

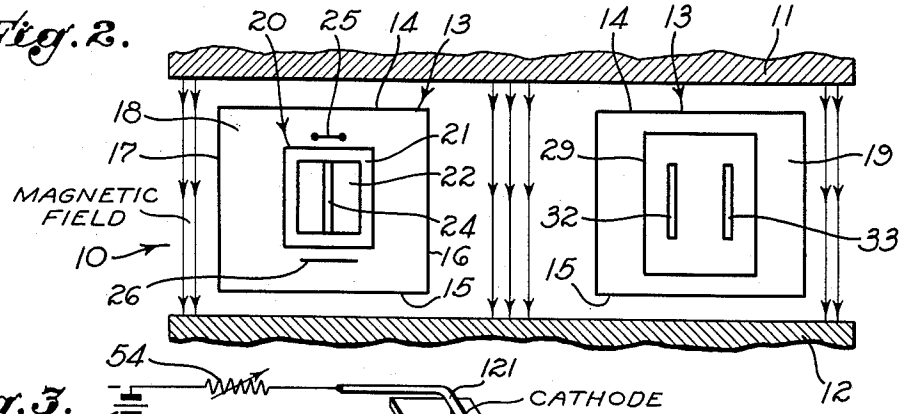
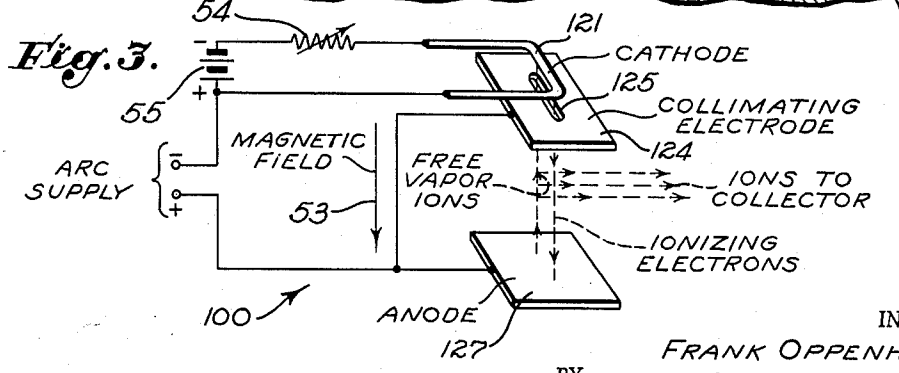


Fig. 3.



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Fig. 4.

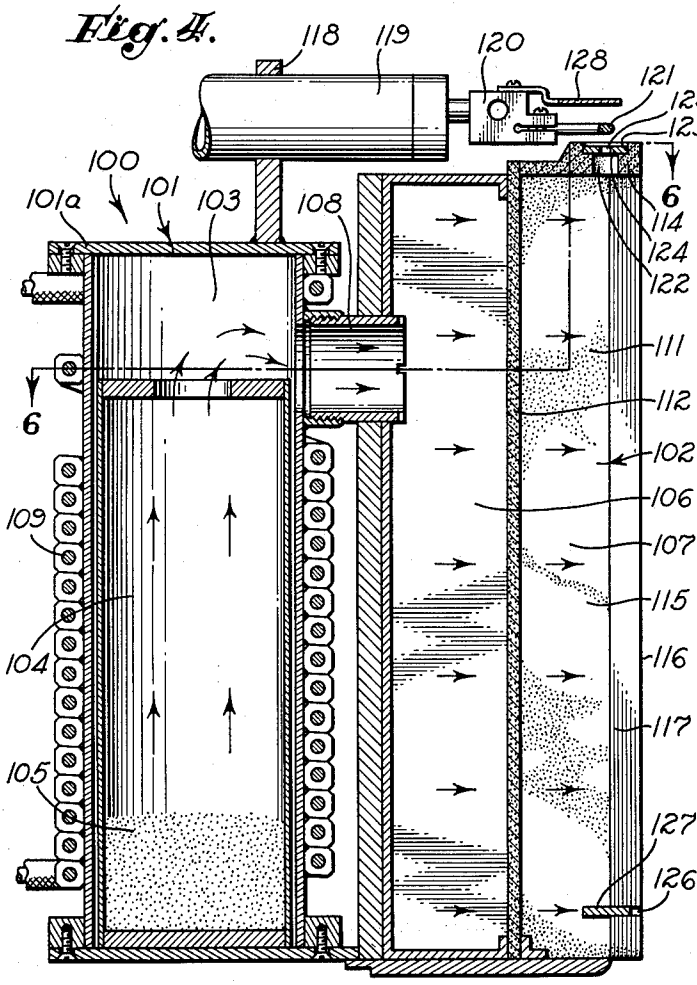


Fig. 5.

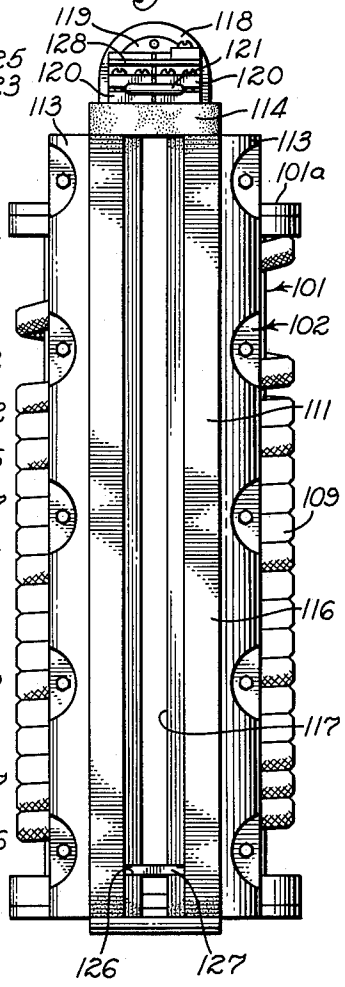
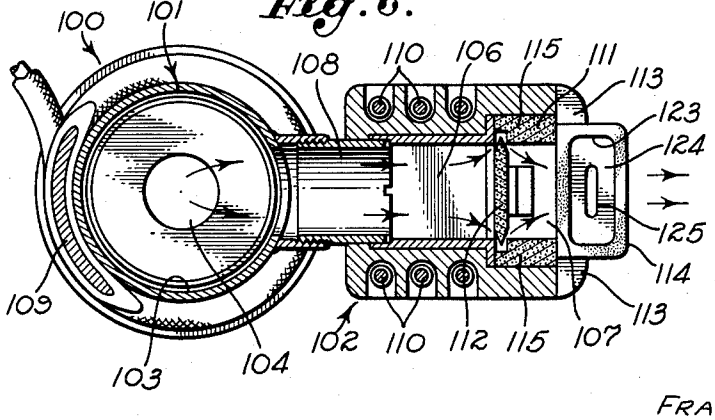


Fig. 6.



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ELECTRIC DISCHARGE DEVICE

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Application February 23, 1944, Serial No. 523,544

5 Claims. (Cl. 250—49.5)

The present invention relates to electric discharge devices and more particularly to calutron ion sources.

It is an object of the invention to provide an electric discharge device comprising an improved arrangement for defining the cross-section of the arc discharge between the main electrodes thereof.

Another object of the invention is to provide an electric discharge device comprising an improved electrode arrangement for producing an electrically stable arc discharge, the ionization over any cross-section of which is substantially uniform.

Still another object of the invention is to provide a calutron ion source of the arc discharge type that consumes less current for the number of ions produced than those ion sources heretofore employed.

A further object of the invention is to provide a calutron ion source having an improved electrode arrangement productive of a uniform and copious supply of ions.

A further object of the invention is to provide a calutron ion source of improved construction and arrangement that is efficient in operation and subject to minimum wear and erosion.

A further object of the invention is to provide in an arc discharge device an electrode arrangement for increasing the life of the arc cathode.

The invention, both as to its organization and method of operation, together with other objects and advantages thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which Figure 1 is a diagrammatic plan view of a calutron into which there may be incorporated an ion source embodying the present invention; Fig. 2 is a diagrammatic sectional view of the calutron taken along the line **2—2** in Fig. 1; Fig. 3 is a schematic perspective view of the electrode arrangement in a calutron ion source embodying the present invention; Fig. 4 is a longitudinal sectional view of a calutron ion source embodying the present invention; Fig. 5 is a front elevation view of the calutron ion source shown in Fig. 4; and Fig. 6 is a sectional view of the calutron ion source taken along the line **6—6** in Fig. 4.

At the outset, it is noted that a "calutron" is a machine of the character of that disclosed in the copending application of Ernest O. Lawrence, Serial No. 557,784, filed October 9, 1944, now U. S. Patent No. 2,709,222, and is employed to separate the constituent isotopes of an element and, more particularly, to increase the proportion of a selected isotope in an element containing several isotopes in order to produce the element enriched with the selected isotope.

Such a calutron essentially comprises means for vaporizing a quantity of material containing an element that is to be enriched with a selected one of its several isotopes; means for subjecting the vapor to ionization, whereby at least a portion of the vapor is ionized causing ions of the several isotopes of the element to be produced; electrical means for segregating the ions from the un-ionized vapor and for accelerating the segregated ions to relatively high velocities; electromagnetic means for deflecting the ions along curved paths, the radii of curvature of the paths of the ions being proportional to the square roots of the masses of the ions, whereby the ions are concentrated in accordance with their masses; and means for de-ionizing and collecting the ions of the selected isotope thus concentrated, thereby to produce a deposit of the element enriched with the selected isotope.

Referring now more particularly to Figs. 1 and 2 of the drawings, there is illustrated a representative example of a calutron **10** of the character noted, that comprises magnetic field structure including upper and lower pole pieces **11** and **12**, provided with substantially flat parallel spaced apart pole faces, and a tank **13** disposed between the pole faces of the pole pieces **11** and **12**. The pole pieces **11** and **12** carry windings, not shown, which are adapted to be energized in order to produce a substantially uniform and relatively strong magnetic field therebetween, which magnetic field passes through the tank **13** and the various parts housed therein. The tank **13** is of tubular configuration, being substantially crescent-shaped in plan, and comprising substantially flat parallel spaced-apart top and bottom walls **14** and **15**, upstanding curved inner and outer side walls **16** and **17**, and end walls **18** and **19**. The end walls **18** and **19** close the opposite ends of the tubular tank **13** and are adapted to be removably secured in place, whereby the tank **13** is hermetically sealed. Also, vacuum pumping apparatus, not shown, is associated with the tank **13**, whereby the interior of the tank **13** may be evacuated to a pressure of the order of 10^{-5} to 10^{-4} mm. Hg. Preferably, the component parts of the tank **13** are formed of steel, the top and bottom walls **14** and **15** thereof being spaced a short distance from the pole faces of the upper and lower pole pieces **11** and **12** respectively, the tank **13** being retained in such position in any suitable manner, whereby the top and bottom walls **14** and **15** constitute in effect pole pieces with respect to the interior of the tank **13**, as explained more fully hereinafter.

The removable end wall **18** suitably supports a source unit **20** comprising a charge receptacle **21** and a communicating arc-block **22**. An electric heater **23** is arranged in heat exchange relation with the charge receptacle **21** and is adapted to be connected to a suitable source of heater supply, whereby the charge receptacle **21** may be appropriately heated, the charge receptacle **21** being formed of steel or the like. The arc-block **22** is formed, at least partially, of carbon or graphite and is substantially C-shaped in plan, an upstanding slot **24** being formed in the wall thereof remote from the charge receptacle **21**. Thus, the arc-block **22** is of hollow construction, the cavity therein communicating with the interior of the charge receptacle **21**.

Also, the removable end wall **18** carries a filamentary cathode **25** adapted to be connected to a suitable source of filament supply, the filamentary cathode **25** overhanging the upper end of the arc-block **22** and arranged in alignment with respect to the upper end of the cavity formed therein. Further, the removable end wall **18** carries an anode **26** disposed below the lower end of the arc-block **22** and arranged in alignment with respect to the lower end of the cavity formed therein. The anode **26** is electrically connected to the source unit **20**, which in turn is grounded; likewise the tank **13** is grounded. Also, the filamentary cathode **25** and the cooperating anode **26** are adapted to be connected to a suitable source of arc supply.

Further, the removable end wall **18** carries ion accelerating structure **27** formed of carbon or graphite, and disposed in spaced-apart relation with respect to the wall of the arc-block **22** in which the slot **24** is formed. More specifically, a slit **28** is formed in the ion accelerat-

ing structure 27 and arranged in substantial alignment with respect to the slot 24 formed in the wall of the arc-block 22. A suitable source of accelerating electrode supply is adapted to be connected between the arc-block 22 and the ion accelerating structure 27, the positive and negative terminals of the supply mentioned being respectively connected to the arc-block 22 and to the ion accelerating structure 27. Further, the positive terminal of the ion accelerating potential is grounded.

The removable end wall 19 suitably supports a collector block 29 formed of stainless steel or the like and provided with two laterally spaced-apart cavities or pockets 30 and 31 which respectively communicate with aligned slots 32 and 33 formed in the wall of the collector block 29 disposed remote from the removable end wall 19. It is noted that the pockets 30 and 31 are adapted to receive two constituent isotopes of an element which have been separated in the calutron 10, as explained more fully hereinafter. Further, the inner wall 16 suitably supports a tubular liner 34 formed of copper or the like, rectangular in vertical cross-section, disposed within the tank 13 and spaced from the walls 14, 15, 16 and 17. One end of the tubular liner 34 terminates adjacent the accelerating structure 27; and the other end of the tubular liner 34 terminates adjacent the collector block 29; the tubular liner 34 constituting an electrostatic shield for the high velocity ions traversing the curved paths between the slit 28 formed in the ion accelerating structure 27 and the slots 32 and 33 formed in the collector block 29, as explained more fully hereinafter. Finally, the tubular liner 34 is electrically connected to the ion accelerating structure 27 and to the collector block 29. Thus, it will be understood that the source unit 20 and the tank 13 are connected to the positive grounded terminal of the accelerating electrode supply; while the ion accelerating structure 27, the tubular liner 34 and the collector block 29 are connected to the ungrounded negative terminal of the accelerating electrode supply; the ion accelerating structure 27, the tubular liner 34 and the collector block 29 being electrically insulated from the component parts of the tank 13.

Considering now the general principle of operation of the calutron 10, a charge comprising a compound of the element to be treated is placed in the charge receptacle 21, the compound of the element mentioned being one which may be readily vaporized. The end walls 18 and 19 are securely attached to the open ends of the tank 13, whereby the tank 13 is hermetically sealed. The various electrical connections are completed and operation of the vacuum pumping apparatus, not shown, associated with the tank 13 is initiated. When a pressure of the order of 10^{-5} to 10^{-4} mm. Hg is established within the tank 13, the electric circuits for the windings, not shown, associated with the pole pieces 11 and 12 are closed and adjusted, whereby a predetermined magnetic field is established therebetween traversing the tank 13. The electric circuit for the heater 23 is closed, whereby the charge in the charge receptacle 21 is heated and vaporized. The vapor fills the charge receptacle 21 and is conducted into the communicating cavity formed in the arc-block 22. The electric circuit for the filamentary cathode 25 is closed, whereby the filamentary cathode is heated and rendered electron emissive. Then the electric circuit between the filamentary cathode 25 and the anode 26 is closed, whereby an arc discharge is struck therebetween, electrons proceeding from the filamentary cathode 25 to the anode 26. The electrons proceeding from the filamentary cathode 25 break up the molecular form of the compound of the vapor to a considerable extent, producing positive ions of the element that is to be enriched with the selected one of its isotopes.

The electric circuit between the arc-block 22 and the ion accelerating structure 27 is completed, the ion accelerating structure 27 being at a high negative potential with respect to the arc-block 22, whereby the positive ions in the arc-block 22 are attracted by the ion accelerating structure 27 and accelerated through the voltage impressed therebetween. More particularly, the positive ions proceed from the cavity formed in the arc-block 22 through the slot 24 formed in the wall thereof, and across the space between the ion accelerating structure 27 and the adjacent wall of the arc-block 22, and thence through the slit 28 formed in the ion accelerating structure 27 into the interior of the tubular liner 34. The high-velocity positive ions form a vertical upstanding ribbon or beam proceeding from the cavity formed in the arc-block 22 through the slot 24 and the aligned slit 28 into the tubular liner 34.

As previously noted, the collector block 29, as well as the tubular liner 34, is electrically connected to the ion accelerating structure 27, whereby there is an electric-field-free path for the high-velocity positive ions disposed between the ion accelerating structure 27 and the collector block 29 within the tubular liner 34. The high-velocity positive ions entering the adjacent end of the liner 34 are deflected from their normal straight-line path and from a vertical plane passing through the slot 24 and the aligned slit 28, due to the effect of the relatively strong magnetic field maintained through the space within the tank 13 and the liner 34 through which the positive ions travel, whereby the positive ions describe arcs, the radii of which are proportional to the square roots of the masses of the ions and consequently of the isotopes of the element mentioned. Thus, ions of a relatively light isotope of the element describe an interior arc of relatively short radius and are focused through the slot 32 into the pocket 30 formed in the collector block 29; whereas ions of a relatively heavy isotope of the element describe an exterior arc of relatively long radius and are focused through the slot 33 into the pocket 31 formed in the collector block 29. Accordingly, the relatively light ions are collected in the pocket 30 and are de-ionized to produce a deposit of the relatively light isotope of the element therein; while the relatively heavy ions are collected in the pocket 31 and are de-ionized to produce a deposit of the relatively heavy isotope of the element therein.

After all of the charge in the charge receptacle 21 has been vaporized, all of the electric circuits are interrupted and the end wall 18 is removed so that another charge may be placed in the charge receptacle 21 and subsequently vaporized in the manner explained above. After a suitable number of charges has been vaporized in order to obtain appropriate deposits of the isotopes of the element in the pockets 30 and 31 of the collector block 29, the end wall 19 may be removed and the deposits of the collected isotopes in the pockets 30 and 31 in the collector block 29 may be reclaimed.

Of course, it will be understood that the various dimensions of the parts of the calutron 10, the various electrical potentials applied between the various electrical parts thereof, as well as the strength of the magnetic field between the pole pieces 11 and 12, are suitably correlated with respect to each other, depending upon the mass numbers of the several isotopes of the element that is to be treated therein.

In the operation of the calutron 10, it is highly desirable that a relatively intense stable beam of positive ions be projected by the ion accelerating structure 27, through the liner 34, toward the collector block 29; which operating condition requires that the source unit 20 be productive of a steady and copious supply of positive ions. To accomplish this end in the source unit 20, the arc discharge through the cavity in the arc-block 22 between the filamentary cathode 25 and the anode 26 must be both relatively intense and uniform. Moreover, it is desirable that such an arc discharge should be steady and free from both intensity and position variations in order that the ion source unit 20 be productive of a highly

continuous, copious and uniform supply of positive ions. Furthermore, the ion source unit **20** should be so constructed and arranged that the parts thereof are subjected to minimum wear and erosion, whereby the unit has a long life and an efficient operating characteristic.

While the source unit in the calutron disclosed in the previously mentioned copending application of Ernest O. Lawrence is satisfactory in operation, it does not possess the characteristics noted to the extent desired; nor has it the long life required for most efficient commercial operation.

Referring now more particularly to Fig. 3 of the drawing, the electrode arrangement in a calutron ion source **100** embodying the features of the present invention is illustrated schematically in perspective. More particularly, this calutron ion source **100** comprises, among other elements, a substantialy U-shaped filamentary cathode **121** formed of tungsten, tantalum, or the like, a plate-like anode **127** formed of tungsten or the like, and a plate-like collimating electrode **124** formed of tungsten, molybdenum or the like. The electrodes mentioned are arranged in the magnetic field of the calutron, the direction of the field between the north pole and the south pole of the field structure being indicated by the arrow **53**. The filamentary cathode **121** and the anode **127** are arranged in substantially parallel longitudinal spaced-apart relation and are aligned with the magnetic field mentioned; while the collimating electrode **124** is arranged between the filamentary cathode **121** and the anode **127** in substantially parallel relation therewith and in alignment with the magnetic field mentioned. The collimating electrode **124** has an elongated, transversely extending slot **125** formed therethrough and disposed in alignment with the central portion of the U-shaped filamentary cathode **121**, the collimating electrode **124** being disposed closely adjacent the filamentary cathode **121**. Accordingly, the filamentary cathode **121**, the collimating electrode **124** and the anode **127** are respectively disposed in three substantially parallel planes spaced apart longitudinally and disposed substantially normal to the magnetic field mentioned. Furthermore, the central portion of the filamentary cathode **121**, the slot **125** formed in the collimating electrode **124** and the central portion of the anode **127** are arranged in alignment with the magnetic field mentioned.

Considering now the structural and dimensional details of the electrodes mentioned, it is noted that the slot **125** formed in the collimating electrode **124** is narrower than the corresponding width of the central portion of the filamentary cathode **121** and is shorter in the transverse direction than the length of the central portion of the filamentary cathode **121**, whereby the dimensions of the slot **125** formed in the collimating electrode **124** are less than the corresponding dimensions of the filamentary cathode **121** disposed thereabove. In the embodiment of the calutron ion source **100** illustrated, highly satisfactory results have been obtained employing a flat filamentary cathode **121** formed of tungsten, the central portion of the filamentary cathode being substantially 0.060″ thick, 0.150″ wide and 1.000″ long; an anode **127** formed of tungsten, 0.125″ thick, 0.687″ wide and 1.063″ long; and a collimating electrode **124** formed of tungsten, 0.100″ thick, 0.625″ wide and 1.250″ long, the centrally disposed slot **125** formed therein being 0.094″ wide and 0.625″ long. Also, in this embodiment the collimating electrode **124** was disposed approximately 0.125″ below the filamentary cathode **121**; and the filamentary cathode **121** and the anode **127** were spaced apart about 12″.

The filamentary cathode **121** is electrically connected by way of an adjustable resistor **54** to a source of filament supply indicated as a battery **55**; while the filamentary cathode **121** and the anode **127** are respectively connected to the negative and positive terminals of a suitable source of arc supply. The collimating electrode **124** is electrically connected to the anode **127**, whereby a substantially electric-field-free zone is defined therebetween in the gaseous region in the arc-block.

Considering now the general principle of operation of the source unit **100**, the filamentary cathode **121** is heated and rendered electron emissive and the arc supply circuit is completed, rendering the filamentary cathode **121** negative with respect to the collimating electrode **124** and the anode **127**. Accordingly, electrons are projected from the filamentary cathode **121** toward the collimating electrode **124** along the magnetic field **53**. Some of these electrons pass through the slot **125** formed in the collimating electrode **124** and continue toward the anode **127**, whereby the gas or vapor in the zone disposed between the collimating electrode **124** and the anode **127** in the gaseous or vapor region is ionized. More specifically, the electrons projected from the filamentary cathode **121** gain substantially all of their energy in traversing the electric field between the filamentary cathode **121** and the collimating electrode **124**, whereby they enter the gaseous or vapor region at velocities higher than that required for ionization. Moreover, the electrons traveling between the filamentary cathode **121** and the anode **127** are, for the most part, confined to paths along the magnetic field, inasmuch as any horizontal motion imparted to these electrons will result in their traveling along helices of extremely small radii, the axes of the helices being along the magnetic field.

In view of the fact that the dimensions of of the slot **125** formed in the collimating electrode **124** are less than the corresponding dimensions of the filamentary cathode **121** disposed thereabove, the cross-section of the electron stream entering the gaseous region disposed between the collimating electrode **124** and the anode **127** is positively defined and electrons only from the uniform electron emissive surface of the central portion of the filamentary cathode **121** are employed. This uniform and steady stream of electrons in the gas or vapor region mentioned results in a discharge therethrough, whereby a uniform copious supply of positive ions is produced. This discharge through this region is of the arc type, being characterized by a high current, a low voltage drop and a luminous plasma. More specifically, most of the electrons projected from the filamentary cathode **121** through the slot **125** in the collimating electrode **124** proceed to the anode **127**, thereby to complete the circuit between the positive and negative terminals of the arc supply, current in the arc discharge flowing from the anode **127** to the filamentary cathode **121**. Some of the positive ions produced in the region disposed between the collimating electrode **124** and the anode **127** travel through the slot **125** in the collimating electrode **124** and bombard the filamentary cathode **121**; while the useful positive ions produced in the region mentioned are drawn off by the ion accelerating structure and projected into the associated liner and ultimately collected in the collector block in the calutron in the manner previously described. It should be noted that the zone disposed between the collimating electrode **124** and the anode **127** is believed to be substantially electric-field-free, the electric field in this zone, both longitudinally and transversely, being of the order of only a few volts.

Due to the construction and arrangement of the electrodes of the ion source, the stream of electrons proceeding from the filamentary cathode **121** through the slot **125** formed in the collimating electrode **124** to the anode **127** is of ribbon-like configuration, within the boundary of which substantially all of the positive ions are formed in the gas or vapor region. This arrangement positively insures a uniform copious supply of positive ions presenting a well-defined surface to the slit in the wall of the arc-block with which the ion accelerating structure is operatively associated. Another advantage of this arrangement is the protection afforded the filamentary cathode **121** from excessive positive ion bombardment. Inasmuch

as the positive ions which travel toward the filamentary cathode **121** are limited by the arc collimating slot **125** formed in the collimating electrode **124**, the resulting alloying and pitting of the filamentary cathode **121** is thus substantially reduced, and consequently the life of the filamentary cathode **121** is increased. Further, the collimating electrode **124** aids in confining the vapor to be ionized to the region between the collimating electrode **124** and the anode **127**, restricting the passage of the vapor into the neighborhood of the filamentary cathode **121**, thus reducing the accumulation of condensed vapor and deposited material around the filamentary cathode **121**.

Referring now more particularly to Figs. 4 to 6, inclusive, of the drawings, there are illustrated the structural details of the calutron ion source unit **100** which is arranged in the magnetic field between the pole pieces of the calutron in the manner previously explained, the ion source unit **100** comprising a charge receptacle **101** and an arc-block **102**. The charge receptacle **101** comprises wall structure, including a removable cover **101***a*, defining an upstanding cylindrical cavity **103** therein, that is adapted to receive a removable cylindrical charge bottle **104** containing a charge **105** which is to be vaporized. The arc-block **102** comprises wall structure defining an upstanding diffusion chamber **106** and an upstanding arc chamber **107** therein, the cavity **103** communicating with the diffusion chamber **106** through a tubular member **108** supported by the wall structure of the charge receptacle **101** and the wall structure of the arc-block **102**. The wall structure of the charge receptacle **101** carries an exteriorly arranged electric heater **109** of any suitable form, whereby the charge receptacle **101** and consequently the charge bottle **104** may be appropriately heated in order to vaporize the charge **105** contained in the charge bottle **104**. Similarly, the wall structure of the arc-block **102** carries an exteriorly arranged electric heater **110** of any suitable form, whereby the arc-block **102**, and more particularly the diffusion chamber **106** therein, may be heated in order to prevent condensation of the contained vapor, as explained more fully hereinafter.

More particularly, the wall structure of the arc-block **102** comprises a substantially inverted U-shaped frame member **111**, supporting an upstanding baffle plate **112**, the frame member **111** and the baffle plate **112** being formed of carbon or graphite. The frame member **111** is secured to the wall structure of the arc-block **102** by an arrangement comprising two upstanding strips **113**, and comprises a top wall **114**, two upstanding substantially parallel spaced-apart side walls **115** and a front wall **116**, the front wall **116** having a centrally disposed longitudinal slot **117** formed therein and communicating with the arc chamber **107**. The side edges of the baffle plate **112** are spaced a short distance from the side walls **115** of the frame member **111** in order to provide communication between the diffusion chamber **106** and the arc chamber **107**, the baffle plate **112** defining the boundary between the chambers mentioned.

The wall structure of the charge receptacle **101** carries a standard **118** which supports cathode structure **119** in cooperating relationship with respect to the arc-block **102**. More particularly, the cathode structure **119** comprises two terminals **120** supporting the opposite ends of the substantially U-shaped filamentary cathode **121**, the opposite ends of the filamentary cathode **121** being removably clamped in place by the respective terminals **120**, and the two terminals being connected to the suitable source of filament supply, as previously noted. The central portion of the filamentary cathode **121** overhangs the central portion of the top wall **114** of the frame member **111**, the top wall **114** having a transversely extending slot **122** formed therethrough communicating with the arc chamber **107**. The upper end of the transverse slot **122** is provided with a counter-recess **123** extending thereabout which receives the collimating electrode **124**, the collimating electrode **124** having the transversely extending slot **125** formed therethrough, as previously noted, and communicating with the transverse slot **122** formed in the top wall **114** and consequently with the arc chamber **107**, the length of the slot **125** being greater than the width of the slot **117** formed in the front wall **116**. More particularly, the filamentary cathode **121** is spaced a short distance above the collimating electrode **124**, the central portion of the filamentary cathode **121** being arranged in alignment with the tranverse slot **125** formed in the collimating electrode **124**. Further, a laterally extending slot **126** is formed in the front wall **116** of the frame member **111** adjacent the lower end thereof, and supports the anode **127** extending into the arc chamber **107** in alignment with the central portion of the filamentary cathode **121** and the transverse slot **125** formed in the collimating electrode **124**.

The negative and positive terminals of the arc supply are respectively connected to the filamentary cathode **121** and to the arc-block **102**, the anode **127** and the collimating electrode **124** being connected together by the frame member **111**, and consequently by way of the arc-block **102** to the positive terminal of the arc supply mentioned, as previously noted. Finally, a shield **128** is supported by one of the terminals **120** and extends laterally over the upper surface of the central portion of the filamentary cathode **121** in order to prevent migration of the electrons emitted by the filamentary cathode **121** upwardly in the longitudinal direction.

Considering now the detailed operation of the calutron ion source **100**, when the electric circuit for the heater **109** is completed, the charge receptacle **101** and consequently the charge bottle **104** are heated, whereby the charge **105** is vaporized, filling the cavity **103** in the charge receptacle **101**. The vapor passes through the tubular member **108** into the diffusion chamber **106**, whereby this chamber is filled with the vapor. The vapor is thoroughly diffused in the diffusion chamber **106** and passes around the side edges of the baffle plate **112** into the arc chamber **107**, whereby this chamber is filled with the vapor. More particularly, the arc chamber **107** is thoroughly and uniformly filled with the vapor to be ionized, due to the arrangement of the diffusion chamber **106** and the baffle plate **112**.

When the circuit for the filamentary cathode **121** is completed, the filamentary cathode **121** is heated and rendered electron emissive; and when the arc supply circuit is completed between the filamentary cathode **121** and the arc-block **102**, electrons are projected from the central portion of the filamentary cathode **121** toward the collimating electrode **124**. More particularly, some of these electrons pass through the transverse slot **125** formed in the collimating electrode **124** into the arc chamber **107** and proceed toward the anode **127**. Accordingly, the collimating electrode **124** causes a stream of electrons having a ribbon-like configuration to be projected through the arc chamber **107**, whereby the vapor in the arc chamber **107** is ionized. Moreover, the width of the stream of electrons is greater than the width of the upstanding slot **117** formed in the front wall **116**, whereby any vapor flowing through the arc chamber **107** and the slot **117** must traverse the electron stream and thus be subjected to its ionizing influence. The positive ions produced in the arc chamber **107** are drawn through the upstanding slot **117** formed in the front wall **116** of the frame member **111** by the associated ion accelerating structure, whereby a beam of positive ions having a substantially ribbon-like configuration is projected into the adjacent end of the associated liner and directed toward the cooperating collector block.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An ion source comprising means for establishing a magnetic field, a hollow arc-block positioned therein defining an arc region, an electron emitter positioned adjacent to said arc region and aligned in the magnetic field with respect thereto, an anode disposed within said arc-block and connected electrically thereto, and an apertured electrode positioned between said electron emitter and said arc region and made electrically positive relative to the electron emitter, said electrode being connected electrically to said anode, the opening of said electrode being less than the emitting portion of said electron emitter as projected along said magnetic field, whereby a selected part only of the electron emission may be projected into the arc region.

2. An ion source comprising means for establishing a magnetic field, a hollow arc block positioned therein and having an exit opening transverse to said magnetic field, two electrical terminals positioned adjacent to said arc block, a filament connected to said terminals and having an intermediate section adapted to be thermally emissive, means for supplying electric current to said terminals, an anode disposed within said arc-block and connected electrically thereto, means for making the arc block electrically positive with respect to the filament, an aperture in said arc block aligned with said filament in said magnetic field and having an opening less than the emitting section of said filament aligned therewith, whereby the most intense and steady electron emission is selected for entry into said hollow arc block and movement to said anode, and means for supplying gas to said arc block whereby said gas is ionized by said electron emission.

3. An ion source comprising means for establishing a magnetic field, a hollow arc block positioned therein having an apertured wall aligned with the magnetic field and an end wall substantially transverse thereto, an anode disposed within said arc-block and connected electrically thereto, said end wall having an opening therein that parallels the inner edge of the magnetically aligned wall and that extends along said aligned wall for a greater distance than the edges of the aperture therein, an electrically negative electron emitter placed over said opening and having an emission surface as projected along the magnetic field greater than the opening area, and means for supplying gas to said hollow arc block, the gas passing through the electron stream before exiting through said aperture.

4. An ion source comprising in combination, an enclosed chamber containing an ionizable vapor, an exit slot in said chamber confining the vapor in its passage therefrom, an anode within said chamber adjacent one extremity of said slot, an elongated cathode having its longer dimension arranged transversely of said slot adjacent the other extremity thereof on the side nearer the

chamber, an electrode plate interposed between the anode and cathode and provided with an aperture smaller in length and width than said cathode, said plate being connected electrically to said anode, said aperture being longer than the width of the slot and occupying a similar relative position as the cathode with respect to said slot, means for producing an arc discharge between said cathode and anode and through the aperture in said electrode plate, whereby the resulting ribbonlike configuration of discharge provides a curtain through which substantially all of the vapor passes on its way through said exit slot.

5. An ion source comprising, means for establishing a magnetic field, a hollow arc-block therein enclosing a gaseous region, a cathode disposed adjacent one end of said arc-block and having an electron emitting surface, an anode disposed adjacent the other end of said arc-block and aligned with said cathode with respect to said field, means for producing an arc discharge between said cathode and said anode through said region, whereby the gas in said region is ionized, a member disposed between said cathode and said anode adjacent said cathode and having an elongated slot magnetically aligned with a part only of said electron emitting surface and defining the cross section of said arc discharge through said region, said member and said anode being connected electrically, whereby said arc discharge between said cathode and said anode through said region has a configuration corresponding to said slot, means for admitting gas to be ionized through an opening in said arc-block into said region, said arc-block having a slit extending along said magnetic field in a wall thereof communicating with said region, and means for drawing a beam of ions from said region through said slit.

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