Aug. 16, 1955 E. O. LAWRENCE 2,715,682

ION SOURCE FOR CALUTRONS

Filed Feb. 3, 1945 4 Sheets-Sheet 1

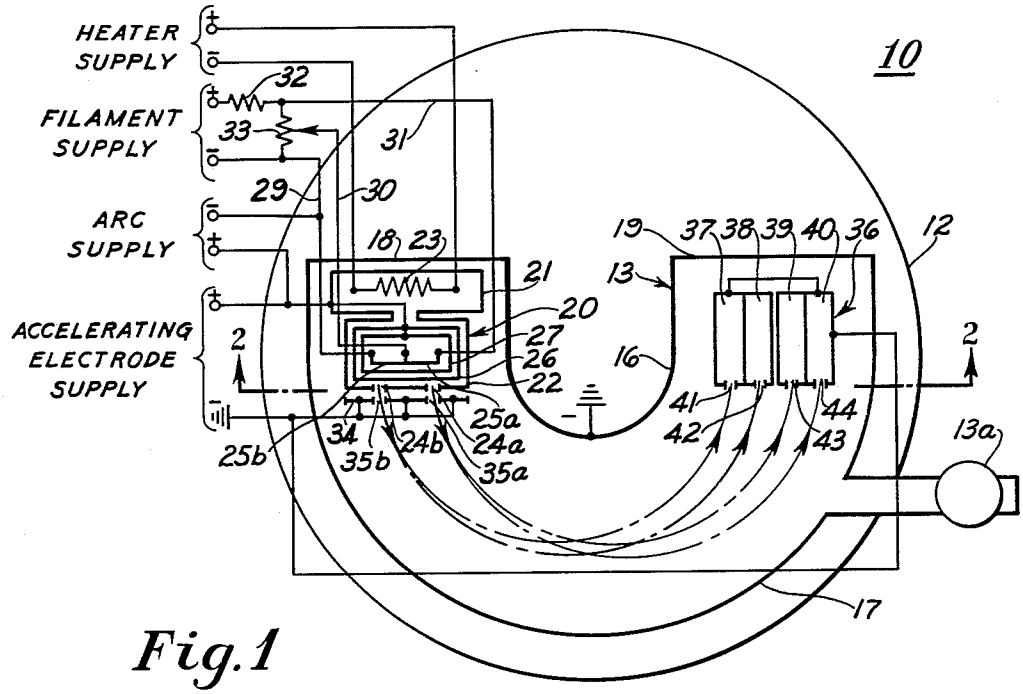


Fig. 1

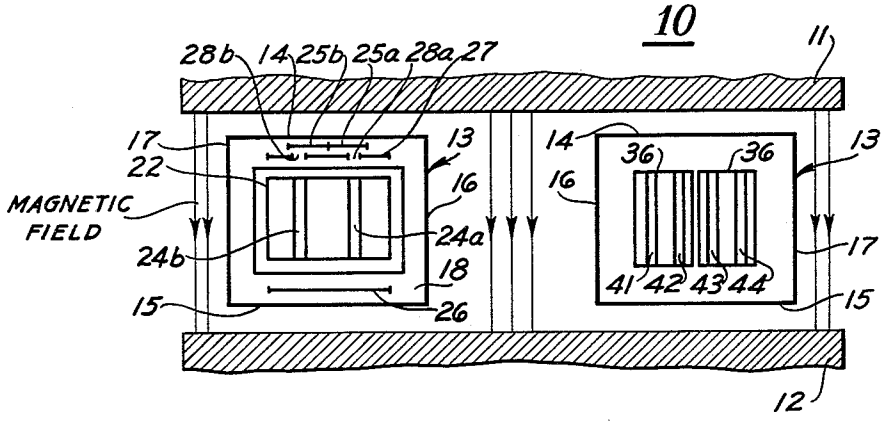


Fig. 2

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ION SOURCE FOR CALUTRONS

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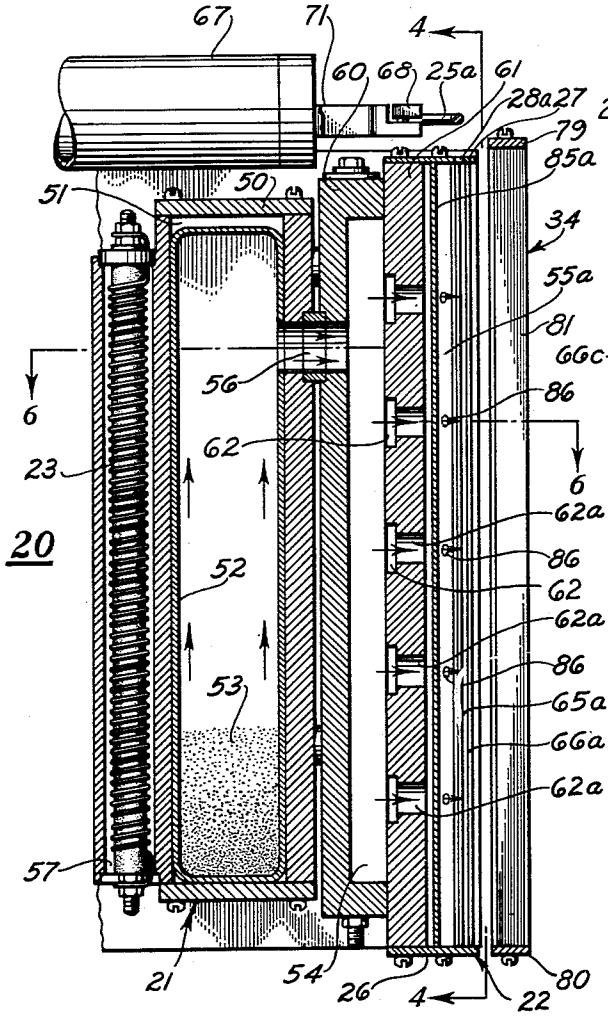


Fig. 3

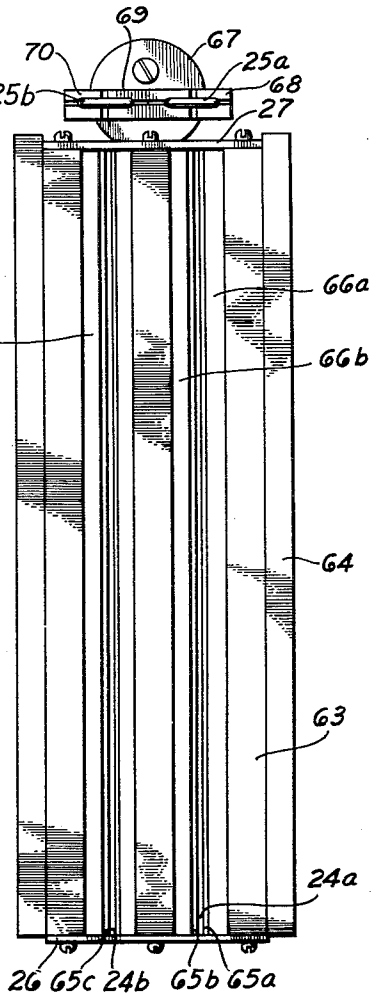


Fig. 4

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ION SOURCE FOR CALUTRONS

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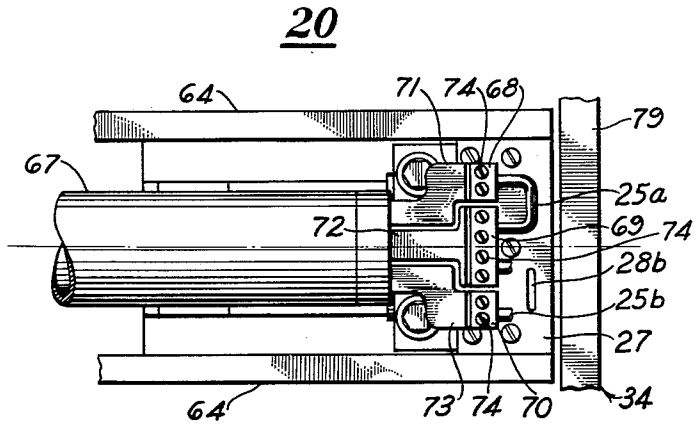


Fig. 5

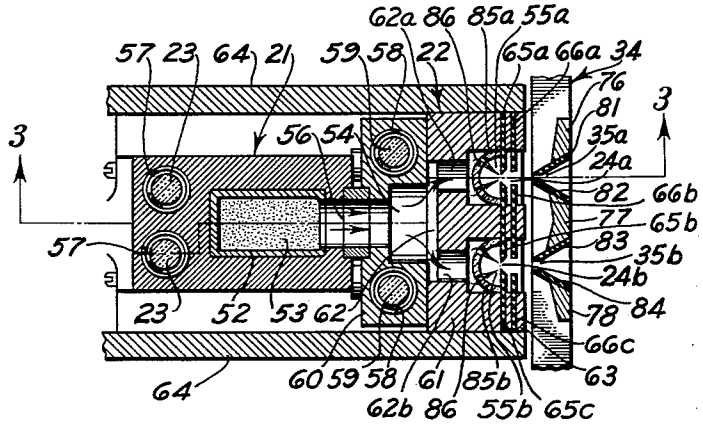


Fig. 6

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ION SOURCE FOR CALUTRONS

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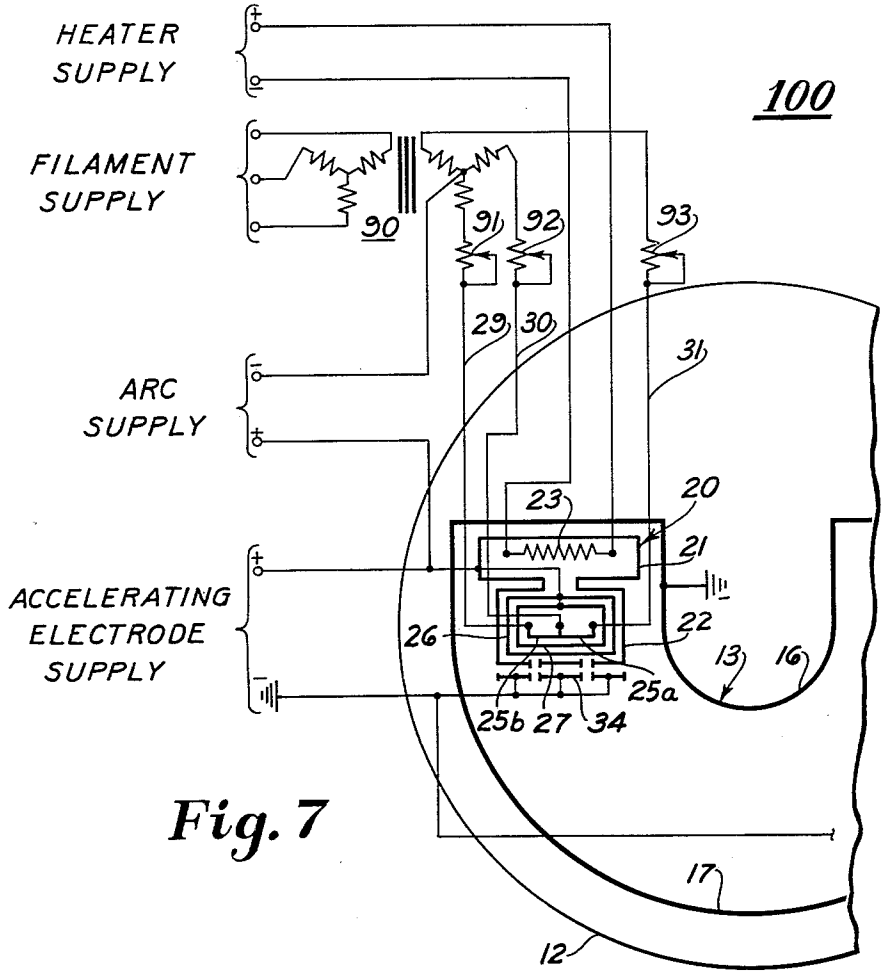


Fig. 7

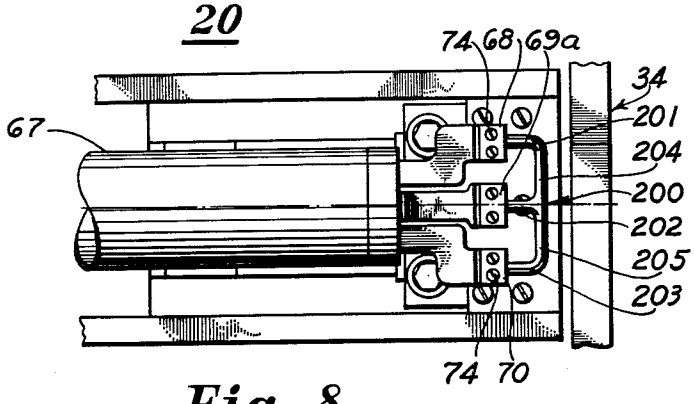


Fig. 8

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United States Patent Office 2,715,682 Patented Aug. 16, 1955

2,715,682

ION SOURCE FOR CALUTRONS

Ernest O. Lawrence, Berkeley, Calif., assignor to the United States of America as represented by the United States Atomic Energy Commission

Application February 3, 1945, Serial No. 576,123

8 Claims. (Cl. 250—41.9)

This invention relates to improvements in electric discharge devices, and more particularly to calutrons of the type disclosed in my copending applications, Serial No. 557,784, filed October 9, 1944, and Serial No. 536,401, filed May 19, 1944.

A calutron is a device for increasing the proportion of a selected isotope in an element containing a plurality of isotypes in order to produce the element enriched with the selected isotope. Such a calutron essentially comprises means for vaporizing a quantity of material containing the element that is to be enriched with the selected isotope; means for subjecting the vapor to ionization, whereby at least a portion of the vapor is ionized, so that ions of the different isotypes are produced; electrical means for segregating the ions from the un-ionized vapor and for accelerating the segregated ions to relatively high velocities; magnetic 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 deionizing and collecting the ions of the selected isotype thus concentrated, thereby to produce a deposit of the element enriched with the selected isotope.

The apparatus is especially useful in producing uranium enriched with U^{235}.

In the previously-mentioned copending application, Serial No. 536,401, there is disclosed a calutron of the multiple beam type, including, as shown in Figures 24, 25, and 26 thereof, an ion source unit provided with an arc block having a number of arc chambers formed therein. In this source unit, each arc chamber is provided with electron emitting structure individual thereto which is utilized to ionize the vapor contained in the associated arc chamber.

Likewise, the instant application pertains to a calutron of the multiple beam type including an ion source unit provided with an arc block having a number of arc chambers formed therein. In this source unit, however, the arc chambers are provided with electron emitting structure common to all of them that is utilized to ionize the vapor contained in the associated arc chambers. In another aspect, two or more electron emitting devices may be combined electrically in such manner as to reduce the total number of electrical leads.

One object of this invention is to provide in a calutron ion source unit, an improved cathode arrangement that is efficient in operation.

Another object of the invention is to provide a calutron ion source unit with cathode structure requiring a reduced number of electrical leads connected thereto.

Another object of the invention is to provide in a calutron ion source unit including a cathode, an improved arrangement for controlling the ratio between the emissions of a plurality of portions of the cathode.

Another object of the invention is to provide a calutron ion source unit with an improved arrangement utilizing a single cathode to produce a plurality of arc discharges.

A further object of the invention is to provide a calutron ion source unit with improved cathode structure utilizing a multi-phase source of power.

Further objects of the invention will appear from a reading of the following detailed description of apparatus embodying the invention.

In the accompanying drawings, forming part of the specification,

Fig. 1 is a diagrammatic plan view of a calutron comprising an improved ion source unit;

Fig. 2 is a vertical sectional view of the calutron taken along the line 2—2 of Fig. 1;

Fig. 3 is a vertical sectional view of the ion source unit incorporated in the calutron shown in Fig. 1 and taken along the line 3—3 in Fig. 6;

Fig. 4 is a front view of the ion source unit taken along the line 4—4 in Fig. 3;

Fig. 5 is a fragmentary plan view of the ion source unit;

Fig. 6 is a horizontal sectional view of the ion source unit, taken along the line 6—6 in Fig. 3;

Fig. 7 is a fragmentary diagrammatic plan view, similar to Fig. 1, of a calutron comprising a source unit including a modified cathode arrangement; and

Fig. 8 is a plan view, similar to Fig. 5, of an ion source unit including a cathode of modified structure, which may be incorporated in either of the calutrons shown in Figs. 1 and 7.

Referring now more particularly to Figs. 1 and 2, there is illustrated a calutron **10** comprising magnetic field structure, including upper and lower pole pieces **11** and **12** provided with substantially 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 arcuate 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 **13***a* 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 an ion 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 stainless steel or the like. The arc-block **22** is formed, at least partially, of brass or the like and has a plurality of upstanding slots formed in the front wall thereof remote from the charge receptacle **21**. By way of example, two such slots **24***a* and **24***b* are shown, but it is understood that more than two may be employed. 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 having electron emitting portions **25***a* and **25***b* adapted to be connected to a suitable source of filament supply, the filamentary cathode overhanging the upper end of the arc-block **22** and arranged in alignment with respect to the upper end of the cavity formed therein. The arc-block **22** carries an anode **26** disposed adjacent the lower end thereof and arranged in alignment with respect to the cavity formed therein. Also, the arc-block **22** carries a collimating electrode **27** disposed adjacent the upper end thereof and having two elongated collimating slots **28***a* and **28***b* formed therethrough and arranged in alignment with respect to the filamentary cathode electron emitting portions **25***a* and **25***b* respectively as well as the anode **26** and the cavity formed in the arc-block **22**. Both the anode **26** and the collimating electrode **27** are electrically connected to the source unit **20**, which in turn is connected to the positive terminal of a suitable source of accelerating electrode supply, as explained more fully hereinafter. On the other hand, the tank **13** is grounded. Also, the filamentary cathode electron emitting portions **25***a* and **25***b* and the cooperating anode **26** are adapted to be connected to a suitable source of arc supply. The electron emitting portions **25***a* and **25***b* of the cathode are connected by three conductors **29**, **30** and **31** to the potentiometer **33** and the resistance element of the potentiometer **33** is connected across the filament current source through the resistor **32**. The common terminal of the cathode portions **25***a* and **25***b* is connected to the variable contactor of the potentiometer **33** by the conductor **30** for the purpose of varying the proportion of the cathode current flowing in the electron emitting portions **25***a* and **25***b* for the purpose explained more fully hereinafter.

Further, the removable end wall **18** carries ion accelerating structure **34**, formed at least partially of tungsten or the like, and disposed in spaced-apart relation with respect to the wall of the arc-block **22** in which the slots **24***a* and **24***b* are formed. More specifically, two slits **35***a* and **35***b* are formed in the ion accelerating structure **34** and these are arranged in substantial alignment with respect to the slots **24***a* and **24***b*, respectively, formed in the wall of the arc-block **22**. The source of accelerating electrode supply is adapted to be connected between the arc-block **22** and the ion accelerating structure **34**, the positive and negative terminals of the supply mentioned being respectively connected to the arc-block **22** and to the ion accelerating structure **34**. Further, the negative terminal of the ion accelerating electrode supply is grounded.

The removable end wall **19** suitably supports an ion collector block **36** formed of stainless steel or the like, and provided with four laterally spaced-apart cavities or pockets **37**, **38**, **39**, and **40** which respectively communicate with four aligned slots **41**, **42**, **43**, and **44** formed in the wall of the collector block **36** disposed remote from the removable end wall **19**. It is noted that the pockets **39** and **40** are adapted to receive two constituent isotopes of an element which have been separated in the calutron **10** and projected through one slot **24***a* in the arc block **22**, as explained more fully hereinafter, and that the pockets **37** and **38** are similarly adapted to receive two constituent isotopes which have been projected through the other slot **24***b* in the arc block **22**. Finally, the collector block **36** is electrically connected to the ion accelerating structure **34**. Thus it will be understood that the source unit **20** is connected to the positive ungrounded terminal of the accelerating electrode supply; while the tank **13**, the ion accelerating structure **34** and the collector block **36** are connected to the negative grounded terminal of the accelerating electrode supply; the source unit **20** being electrically insulated from the component parts of the tank **13**. Thus the portion of the tank **13** disposed between the ion accelerating structure **34** and the collector block **36** constitutes an electrostatic shield for the high-velocity ions traversing the curved paths between the slits **35***a* and **35***b* formed in the ion accelerating structure **34** and the slots **41**, **42**, **43**, and **44** formed in the collector block **36**, as explained more fully hereinafter.

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 **13***a* 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 wtih 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 circuits for the filamentary cathode electron emitting sections **25***a* and **25***b* are closed, whereby the filamentary cathodes are heated and rendered electron emissive. Then the electric circuit between the filamentary cathode electron emitting sections or portions **25***a* and **25***b* and the anode **26** is closed, whereby an arc discharge is struck therebetween, electron streams proceeding from the filamentary cathode electron emitting sections **25***a* and **25***b* through the collimating slots **28***a* and **28***b* formed in the collimating electrode **27** to the anode **26** and these electron streams may be controlled in intensity by moving the variable contactor of the potentiometer **33**. Moving the contactor of the potentiometer **33** increases the current through one of the cathode electron emitting sections and decreases the current through the other electron emitting section thereby controlling the intensities of the electron streams through the collimating slots. The collimating slots **28***a* and **28***b* formed in the collimating electrode **27** define the cross-sections of the streams of electrons proceeding into the arc-block **22**, whereby each arc discharge has a ribbon-like configuration and breaks 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 **34** is completed, the ion accelerating structure **34** 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 **34** and accelerated through the voltage impressed therebetween. More particularly, the positive ions proceed from the cavity formed in the arc-block **22** through the slots **24***a* and **24***b* formed in the wall thereof, and across the space between the ion accelerating structure **34** and the adjacent wall of the arc-block **22**, and thence through the slits **35***a* and **35***b* formed in the ion accelerating structure **34**. The high-velocity positive ions form two vertical upstanding ribbons or beams proceeding from the cavity formed in the arc-block **22** through the two slots **24***a* and **24***b* and the two aligned slits **35***a* and **35***b* respectively.

As previously noted, the collector block **36**, as well as the tank **13**, is electrically connected to the ion accelerating structure **34**, whereby there is an electric-field-free path for the high-velocity positive ions disposed between the ion accelerating structure **34** and the collector block **36** within the tank **13**. The high-velocity positive ions are deflected from their normal straight-line path and from a vertical plane passing through the slots **24***a* and **24***b* and the aligned slits **35***a* and **35***b*,

due to the effect of the relatively strong magnetic field maintained through the space within the tank **13** 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 the relatively light isotope of the element describe interior arcs of relatively short radius and are focused through the slots **41** and **43** into the pockets **37** and **39** formed in the collector block **36**; whereas ions of the relatively heavy isotope of the element describe exterior arcs of relatively long radius and are focused through the slots **42** and **44** into the pockets **38** and **40** formed in the collector block **36**. Accordingly, the ions of the relatively light isotope of the element are collected in the pockets **37** and **39** and are de-ionized to produce a deposit of the relatively light isotope of the element therein; while the ions of the relatively heavy isotope of the element are collected in the pockets **38** and **40** 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 have been vaporized in order to obtain appropriate deposits of the isotope of the element in the pockets **37**, **38**, **39**, and **40** of the collector block **36**, the end wall **19** is removed and the deposits of the collected isotopes in the pockets **37**, **38**, **39**, and **40** in the collector block **36** are 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 one another, depending upon the mass numbers of the several isotopes of the element which is to be treated therein. In this connection reference is again made to the previously-mentioned copending application, Serial No. 557,784, filed October 9, 1944, for a complete specification of a calutron especially designed for the production of uranium enriched with the isotope U^{235}. By way of illustration, it is noted that when the calutron **10** is employed in order to produce uranium enriched with U^{235}, the compound of uranium which is suggested as a suitable charge in the charge receptacle **21** is UCl_4, as this compound may be readily vaporized and the molecular form of the vapor may be readily broken up to form positive ions of uranium. In this case, uranium enriched with U^{235} is collected in the pockets **37** and **39** of the collector block **36**, and uranium comprising principally U^{238} is collected in the pockets **38** and **40** of the collector block **36**. Also, it is noted that from a practical standpoint, the deposit of uranium collected in the pockets **37** and **39** of the collector block **36** contains considerable amounts of U^{238}, in view of the fact that this isotope comprises the dominant constituent of normal uranium. Furthermore, the deposit of uranium collected in the pockets **37** and **39** of the collector block **36** contains a considerably increased amount of U^{234}, in view of the fact that it is not ordinarily feasible to separate U^{234} and U^{235} in the production of relatively large quantities of uranium enriched with U^{235} for commercial purposes. Accordingly, in this example the uranium deposited in the pockets **37** and **39** of the collector block **36** is considerably enriched, both with respect to U^{234} and U^{235}, and considerably impoverished with respect to U^{238}, as compared with natural or normal uranium.

Referring now more particularly to Figs. 3 to 6, inclusive, of the drawings, there are illustrated the structural details of the ion source unit **20** which is arranged in the magnetic field between the pole pieces of the calutron in the manner previously explained, the source unit **20** comprising the charge receptacle **21** and the arc-block **22**. The charge receptacle **21** comprises wall structure, including a removable cover **50**, defining an upstanding cavity **51** therein, that is adapted to receive a removable charge bottle **52** containing a charge **53** which is to be vaporized. The arc-block **22** comprises wall structure defining an upstanding distributing chamber **54** and two upstanding arc chambers **55***a* and **55***b* therein, the cavity **51** communicating with the distributing chamber **54** through a tubular member **56** supported by the wall structure of the charge receptacle **21** and the wall structure of the arc-block **22**. The wall structure of the charge receptacle **21** has two upstanding cavities **57** formed therein, in which two elements of the electric heater **23** are arranged. Preferably, each element of the electric heater **23** comprises a coil of resistance wire wound on a supporting insulator, as indicated, whereby each element of the electric heater **23** may be independently placed in and removed from the associated cavity **57**. Thus, the charge receptacle **21**, and consequently the charge bottle **52**, may be appropriately heated in order to vaporize the charge **53** contained in the charge bottle **52**. Similarly, the arc-block **22** has two up-standing cavities **58** formed therein, in which two electric heating elements **59** are arranged. Preferably, each of the electric heating elements **59** comprises a coil of resistance wire wound on a supporting insulator, as indicated, whereby each of the electric heating elements **59** may be independently placed in and removed from the associated cavity **58**. Thus, the arc-block **22**, and more particularly the distributing chamber **54** 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 charge receptacle **21** is formed of copper or brass; and the wall structure of the arc-block **22** is formed of copper or brass and comprises two primary members **60** and **61**. The distributing chamber **54** and the cavities **58** are formed in the member **60**; while the arc chambers **55***a* and **55***b* are formed in the member **61**, a series of longitudinally spaced-apart openings **62***a* and **62***b* are formed in the wall of the member **61** and communicate between the arc chambers **55***a* and **55***b* and laterally extending manifold passages **62**, also formed in the wall of the member **61**, the manifold passages **62** communicating with the distributing chamber **54**. Also, the arc-block **22** comprises a front plate **63** formed of copper or brass and secured to the member **61**; the source unit **20** being supported by two rearwardly extending arms **64** which are secured to the member **61** and the front plate **63**.

Upstanding strips **65***a*, **65***b* and **65***c*, formed of tungsten or the like, are secured to the member **61** adjacent the arc chambers **55***a* and **55***b*, thereby to define upstanding slots therebetween communicating with the arc chambers **55***a* and **55***b*. Also, upstanding strips **66***a*, **66***b* and **66***c*, formed of tungsten or the like, are secured to the front plate **63** adjacent the strips **65***a*, **65***b* and **65***c* respectively and spaced a small distance forwardly with respect thereto, thereby to define upstanding slots communicating with the arc chambers **55***a* and **55***b*. Thus, the slots defined between the strips **65***a*, **65***b* and **65***c* and the slots defined between the strips **66***a*, **66***b* and **66***c* constitute the upstanding slots **24***a* and **24***b* formed in the front wall of the arc-block **22** and communicating with the arc chambers **55***a* and **55***b*, respectively.

The filamentary cathode comprises two structurally separate U-shaped members **25***a* and **25***b* which are carried by a cathode support **67** arranged in cooperating relation with respect to the arc-block **22**. The central portions of the cathode elements **25***a* and **25***b* overhang the central portions of the arc chambers **55***a* and **55***b*, respectively, with which they are associated; and the collimating electrode **27** is secured to the top wall of the arc-block **22**, the collimating electrode **27** having the transverse slots

28a and 28b formed therein, as previously noted, and communicating with the arc chambers 55a and 55b respectively. More particularly, the cathode elements 25a and 25b are spaced a short distance above the collimating electrode 27, the central portions of the cathode elements 25a and 25b being arranged in alignment with the transverse slots 28a and 28b, respectively, formed in the collimating electrode 27. Also, the anode 26 is secured to the bottom wall of the arc-block 22 adjacent the lower end of the arc chambers 55a and 55b, and in alignment with the cathode elements 25a and 25b and the transverse slots 28a and 28b formed in the collimating electrode 27.

The cathode support 67 includes three terminals 68, 69, and 70, which are connected to the three conductors 29, 30, and 31 by the respective conductors 71, 72, and 73. The adjacent legs of the cathode members 25a and 25b are removably clamped to the middle terminal 69 by a number of clamping screws 74 or the like, while the outside legs of the cathode members 25a and 25b are removably clamped to the respective terminals 68 and 70 in a similar manner. It will be understood, therefore, that three conductors will suffice to supply electrical energy to the two cathode members 25a and 25b. The negative and positive terminals of the arc supply are respectively connected to the filamentary cathode members 25a and 25b and to the arc-block 22, the anode 26 and the collimating electrode 27 being connected together by the arc-block 22 and consequently to the positive terminal of the arc supply mentioned, as previously noted.

Further, the ion accelerating structure 34 comprises three upstanding strips 76, 77, and 78 disposed forwardly of the strips 66a, 66b and 66c, respectively, and secured to two transversely-extending top and bottom members 79 and 80 to form a unitary structure. The three strips 76, 77, and 78 are arranged in transverse spaced-apart relation and carry four electrodes 81, 82, 83, and 84, formed of tungsten or the like, the middle strip 77 carrying two electrodes 82 and 83, one on each side. The four electrodes 81, 82, 83, and 84 are arranged in transverse spaced-apart relation to define two upstanding slits 35a and 35b therebetween, and arranged in alignment with the slots 24a and 24b formed in the front wall of the arc-block 22.

As previously noted, the ion accelerating structure 34, together with the source unit 20, is supported by the removable end wall 18 of the calutron 10, and the positive and negative terminals of the accelerating electrode supply are respectively connected to the arc-block 22 and the ion accelerating structure 34. Finally, upstanding semicircular baffle plates 85a and 85b, formed of quartz or the like, are arranged in the arc chambers 55a and 55b, respectively, and a series of longitudinally spaced-apart openings 86 is formed in each of these baffle plates.

Considering now the detailed operation of the ion source unit 20, when the electric circuit for the heater 23 is completed, the charge receptacle 21 and consequently the charge bottle 52 are heated, whereby the charge 53 is vaporized, filling the cavity in the charge bottle 52. The vapor passes through the tubular member 56 into the distributing chamber 54, whereby this chamber is filled with the vapor. The vapor is distributed in the distributing chamber 54 and passes through the laterally extending manifold passages 62 and the openings 62a and 62b formed in the wall of the member 61 into the rear part of the arc chambers 55a and 55b. The vapor then passes through the openings 86 formed in the baffle plates 85a and 85b into the front parts of the arc chambers 55a and 55b, whereby these parts of the arc chambers are filled with the vapor. More particularly, the arc chambers 55a and 55b are thoroughly and substantially uniformly filled with the vapor to be ionized, due to the arrangement of the distributing chamber 54 and the baffle plates 85a and 85b.

When the circuit for the filamentary cathode elements 25a and 25b is completed, the filamentary cathode elements are heated and rendered electron emissive; and when the arc supply circuit is completed between the filamentary cathode elements 25a and 25b and the arc-block 22, electrons are projected from the central portions of the filamentary cathode elements 25a and 25b toward the collimating electrode 27. More particularly, some of these electrons pass through the two transverse slots 28a and 28b formed in the collimating electrode 27, into the arc chambers 55a and 55b, and proceed toward the anode 26. Accordingly, the collimating electrode 27 causes two streams of electrons having ribbon-like configurations in the shape of the slots 28a and 28b respectively to be projected into the arc chambers 55a and 55b, whereby the vapor in the arc chambers is ionized and the intensities of these electron streams may be varied by adjusting the variable contactor of the potentiometer 33 so that the ionization of the vapors in the arc chambers may be controlled. When the accelerating electrode supply circuit is completed, the positive ions produced in the arc chambers 55a and 55b are drawn through the two upstanding slots 24a and 24b, formed in the front wall of the arc-block 22, by the associated ion accelerating structure 34, to form two beams of positive ions, having upstanding substantially ribbon-like configurations and proceeding through the slits 35a and 35b between the electrodes 81—82 and 83—84, respectively, which beams of positive ions are projected through the evacuated tank space toward the cooperating collector block 36, in the manner previously explained.

The current in the filamentary cathode elements 25a and 25b, which current is of the order of 100 amperes or more, may be controlled by means of the impedance 32. The current in each of the individual cathode members 25a and 25b may be further controlled by means of the potentiometer 33 as described hereinbefore. As a result, the intensity of the electron stream in one arc chamber 55a may be made equal to, greater than, or less than that in the other arc chamber 55b, for the purpose of controlling the ionization in the arc chambers 55a and 55b.

Referring now to Fig. 7, there is shown a calutron 100 comprising a source unit 21 including the improved cathode arrangement hereinabove described in conjunction with Figs. 1 to 6, inclusive, and also including a modified form of cathode heater supply. More particularly, this arrangement comprises a polyphase transformer 90, including a primary winding connected to a suitable source of polyphase alternating current filament supply and a secondary winding connected by way of variable resistors 91, 92, and 93 to three conductors 29, 30, and 31, which in turn are connected to the three terminals 68, 69 and 70 supporting the two filamentary cathodes 25a and 25b. The midtap of the secondary winding of the transformer 90 is connected to the negative terminal of the arc supply; while the positive terminal of the arc supply is connected to the arc block 22, as previously explained.

It will be understood that the operation of the calutron 100 shown in Fig. 7 is substantially identical to that of the calutron 10 shown in Fig. 1; and specifically, when the filament supply circuit is closed, the filamentary cathodes 25a and 25b are heated by the flow of polyphase current therethrough. Also it will be understood that the division of current between the cathodes 25a and 25b may be suitably controlled by adjusting the resistors 91, 92, and 93 in an obvious manner.

Referring now to Fig. 8, there is shown a modified form of cathode structure 200 which may be employed in the ion source unit 20 utilized in the calutrons 10 and 100, respectively shown in Figs. 1 and 7. More particularly, the cathode 200 is of one-piece construction, having a substantially E shape including three legs 201, 202, and 203 and two intermediate electron emitting portions 204 and 205. It will be understood that the legs 201, 202, and 203 are respectively clamped to the terminals 68, 69a, and 70, and that the emitting portions 204 and 205 are

respectively disposed over the two collimating slits formed in the associated collimating electrode disposed therebelow, or for the purpose previously explained.

In view of the foregoing descriptions of the calutrons **10** and **100** respectively shown in Figs. 1 and 7, it will be understood that the adjustment of the potentiometer **33** to control the division of current between the filamentary cathodes **25***a* and **25***b* in the calutron **10**, as well as the adjustment of the resistors **91**, **92**, and **93** to control the division of current between the filamentary cathodes **25***a* and **25***b*, is effective to control the heating and consequently the temperature of the two cathode sections **25***a* and **25***b* in either case. Control of the temperatures of the two cathode sections **25***a* and **25***b* is, of course, effective to govern the electron emission therefrom and the consequent arc discharges through the associated arc chambers **55***a* and **55***b*, respectively. This control of the arc discharges through the arc chambers **55***a* and **55***b* is effective to govern ionization therein, and consequently the intensity of the respective ion beams which are projected from the two arc chambers mentioned.

While the embodiments of the cathode structure have been illustrated in conjunction with an ion source unit **20** comprising an arc block **22** provided with two arc chambers **55***a* and **55***b*, it will be understood that the arc block may comprise only one arc chamber with which the cathode structure is associated; and in this case, the control of the heating of the two sections of the filamentary cathode is effective to control ionization in the corresponding portions of the associated arc chamber, and consequently the intensity from side to side of the ion beam drawn from the arc chamber mentioned.

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. In a calutron, an ion source comprising wall structure defining an arc chamber, an electron emissive cathode operatively associated with said arc chamber and adapted to discharge electrons thereinto, a source of current connected to three spaced-apart points along said cathode, and means for proportioning the potentials applied from said source between said three spaced-apart cathode points in order to control the electron emission of the corresponding intervening portions of said cathode.

2. In a calutron, an ion source comprising wall structure defining an arc chamber, an electron emissive arc cathode adapted to discharge electrons into said chamber, a source of current connected at a plurality of points to said cathode, and means including an adjustable potentiometer for varying the potentials applied from said source to said cathode points in order to control the electron emission of different portions of said cathode.

3. In a calutron ion source, well structure defining an arc chamber, an E-shaped cathode having a back-portion and three legs projecting therefrom, a current supply connected to said three legs for passing current through said back-portion to heat said back-portion to electron emitting temperature, said back-portion being positioned adjacent to said arc chamber to project electrons into said chamber, and control means connected to said three legs for regulating electron emission from sections of said back-portion.

4. In a calutron, an ion source comprising wall structure defining an arc chamber, an electron emissive cathode adapted to discharge electrons into said chamber, a source of polyphase current connected to three spaced-apart points along said cathode, and a variable resistor connected to each of said spaced-apart points for varying the potentials applied from said source between the adjacent pairs of said cathode points in order to control the electron emission of different portions of said cathode.

5. In a calutron, an ion source comprising wall structure defining an arc chamber, an electron emissive cathode adapted to discharge electrons into said chamber, a source of polyphase current connected to said cathode at a plurality of spaced-apart points, and means for varying the potentials applied from said source between the spaced-apart points of said cathode in order to control the electron emission of different portions of said cathode.

6. Apparatus for producing ions of vaporous material comprising a receptacle for the material, wall structure defining a plurality of elongated arc chambers connected to said receptacle by channels extending through the rear walls of said elongated arc chambers so that said vaporous material is fed to said arc chambers at a plurality of places and distributed substantially throughout the length of said arc chambers, a pair of electron emitting elements having the adjacent ends thereof connected together to form a common terminal and having the outer ends thereof connected to outer terminals, each of said arc chambers having an aperture at an end thereof, said electron emitting elements being positioned adjacent said apertures to project electron streams into the respective arc chambers and to ionize the vaporous material therein, a polyphase current supply source having one of the phases thereof connected to the common terminal of said electron emitting elements and other phases connected to the outer terminals thereof, and current control apparatus connected to said current supply source phases for controlling the current to said electron emitting elements to vary the intensities of the electron streams into said arc chambers.

7. Apparatus for producing ions of vaporous material comprising a receptacle for the material, wall structure defining a plurality of elongated arc chambers connected to said receptacle by channels extending through the rear walls of said elongated arc chambers so that said vaporous material is fed to said arc chambers at a plurality of places and distributed throughout the length of said arc chambers, a cathode having a pair of electron emitting sections connections together to a common terminal, each of said arc chambers having an aperture at an end thereof, said electron emitting cathode sections being positioned adjacent said apertures to project electron streams into the respective arc chambers and to ionize the vaporous material therein, current supply means for said cathode, and current control apparatus connected to said current supply means for proportioning the current to said cathode sections to control the intensities of the electron streams into said arc chambers.

8. Apparatus for producing ions of vaporous material comprising a receptacle for the material, wall structure defining a plurality of elongated arc chambers connected to said receptacle by channels extending through the rear walls of said elongated arc chambers so that said vaporous material is fed to said arc chambers at a plurality of places and distributed substantially throughout the length of said arc chambers, a cathode having a pair of electron emitting sections connected together to a common terminal, each of said arc chambers having an aperture at an end thereof, said electron emitting cathode sections being positioned adjacent said apertures to project electron streams into the respective arc chambers and to ionize the vaporous material therein, a polyphase current supply source connected across the terminals of said cathode, and a potentiometer connected across said current supply source, the contactor of said potentiometer being connected to said common cathode terminal for varying the current to said cathode sections to control the intensities of the electron streams into said arc chambers.

(References on following page)

References Cited in the file of this patent

UNITED STATES PATENTS

1,610,863	Kucher	Dec. 14, 1926
1,657,986	Zworykin	Jan. 31, 1928
1,771,704	Bethenod	July 29, 1930
1,966,242	Gurtler	July 10, 1934
2,160,605	Suits	May 30, 1939
2,215,426	Machlett	Sept. 17, 1940
2,341,551	Hoover	Feb. 15, 1944
2,373,151	Taylor	Apr. 10, 1945

FOREIGN PATENTS

317,096	Germany	May 26, 1921

OTHER REFERENCES

Tuve et al.: Physical Review, vol. 48, August 1, 1935, pp. 241–247.

Livingston et al.: Review of Scientific Instruments, vol. 10, February 1939.