Aug. 16, 1955 J. G. BACKUS ET AL 2,715,683

ION SOURCE FOR A CALUTRON

Filed Feb. 16, 1945 4 Sheets-Sheet 1

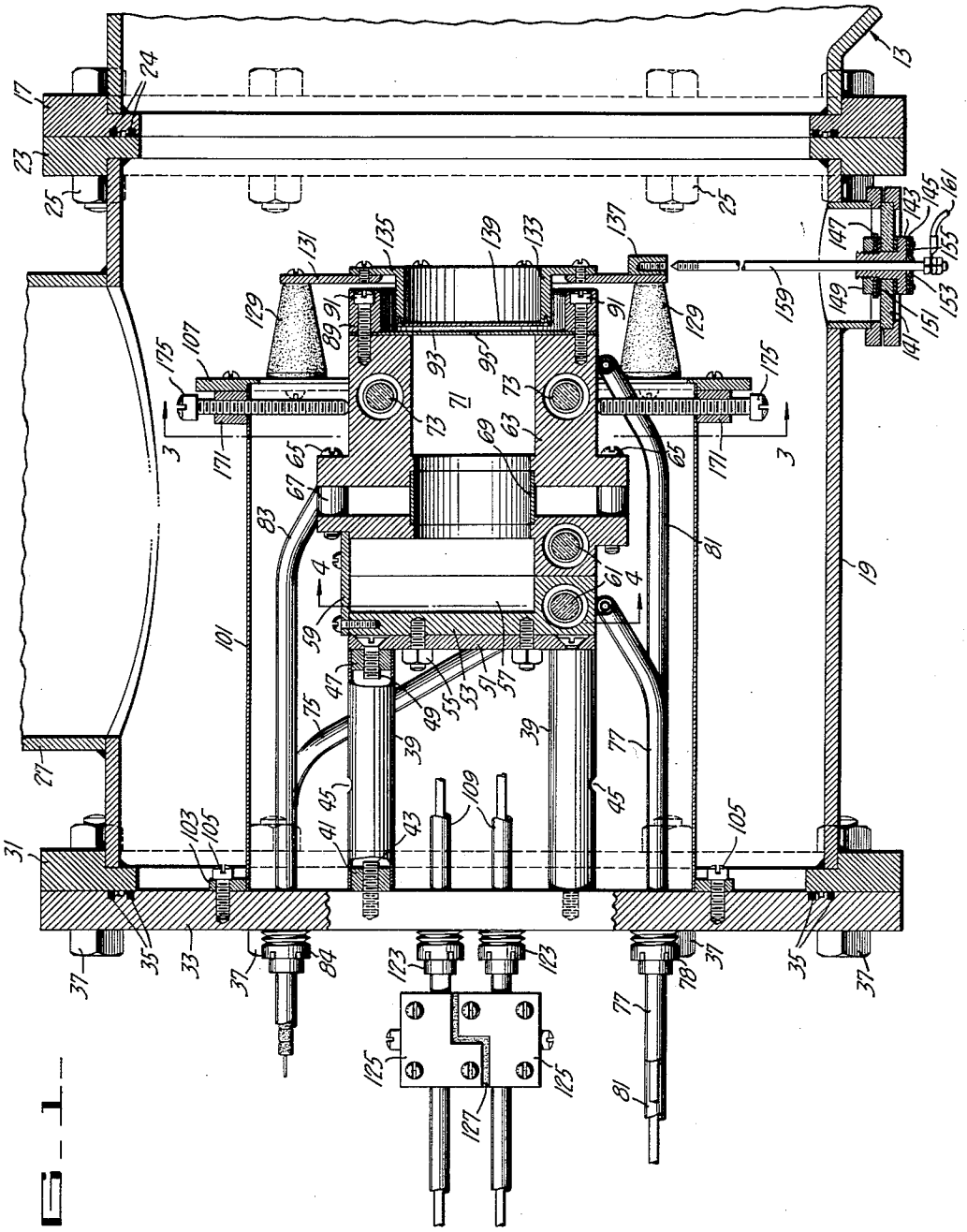


FIG. 1

INVENTORS
John G. Backus
Bernard Peters
BY
Robert A. Kennedy

Aug. 16, 1955 J. G. BACKUS ET AL 2,715,683

ION SOURCE FOR A CALUTRON

Filed Feb. 16, 1945 4 Sheets-Sheet 2

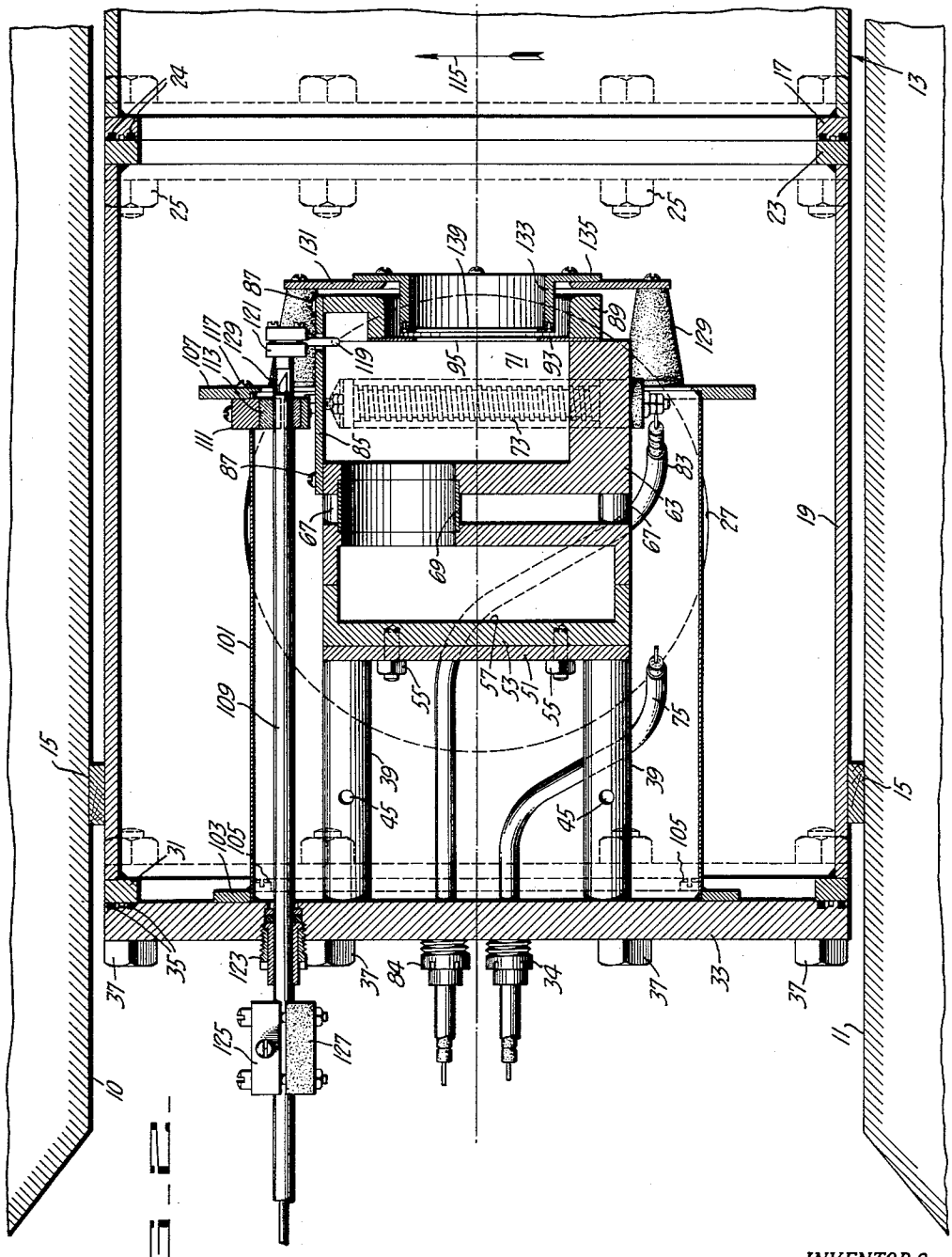


FIG. 2.

INVENTORS
John G. Backus
Bernard Peters
BY
Robert A. Townsend

Aug. 16, 1955 J. G. BACKUS ET AL 2,715,683

ION SOURCE FOR A CALUTRON

Filed Feb. 16, 1945 4 Sheets-Sheet 3

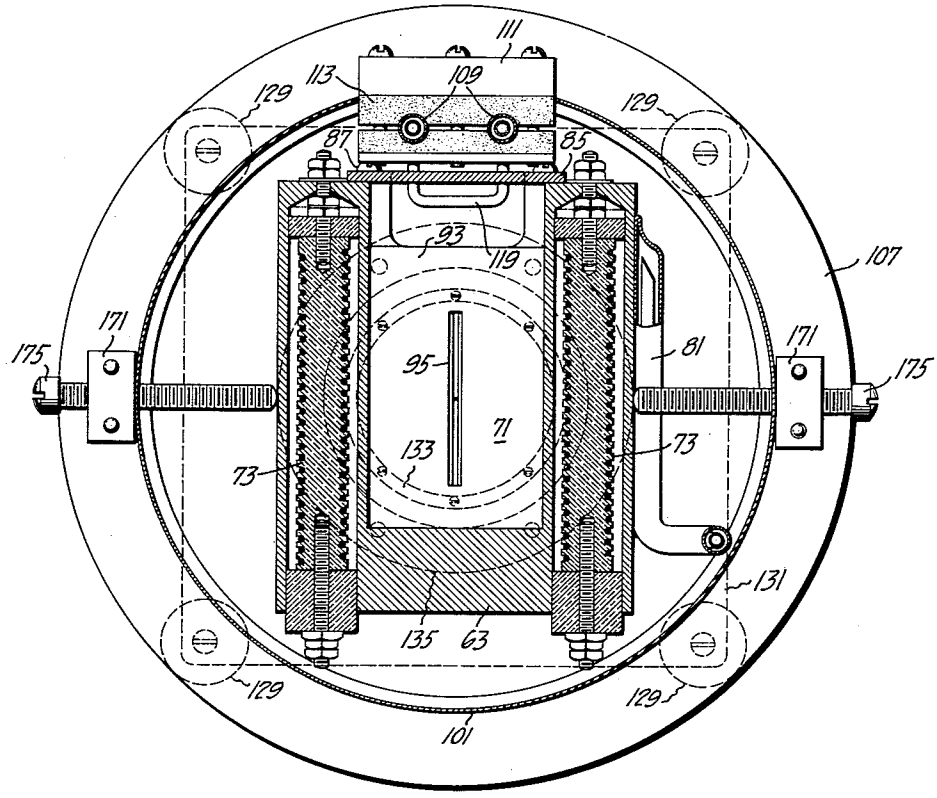


FIG_3_

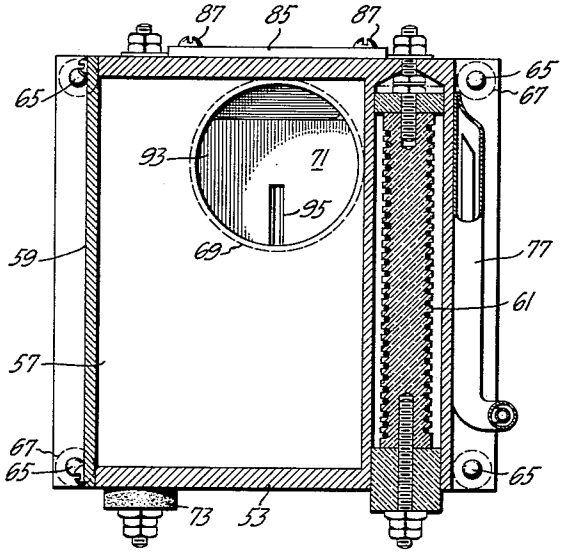


FIG_4_

INVENTORS
John G. Backus
Bernard Peters
BY
Robert A. Lemmers

Aug. 16, 1955 J. G. BACKUS ET AL 2,715,683

ION SOURCE FOR A CALUTRON

Filed Feb. 16, 1945 4 Sheets-Sheet 4

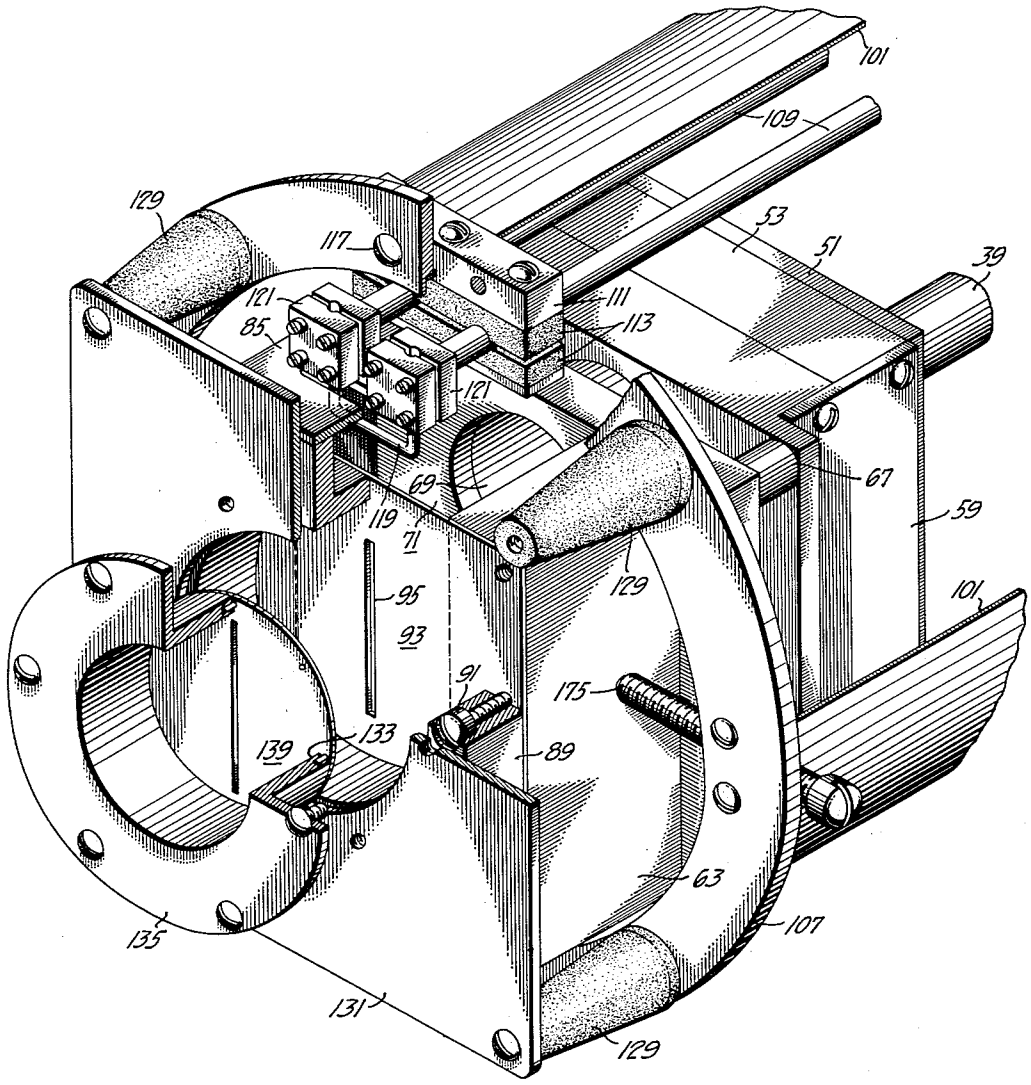


FIG. 5.

INVENTORS
John G. Backus
Bernard Peters

BY

Robert A. Saunders

United States Patent Office 2,715,683 Patented Aug. 16, 1955

2,715,683

ION SOURCE FOR A CALUTRON

John G. Backus and Bernard Peters, Berkeley, Calif., assignors to the United States of America as represented by the United States Atomic Energy Commission

Application February 16, 1945, Serial No. 578,280

6 Claims. (Cl. 250—41.9)

The present invention relates to the art of separating a polyisotope into a plurality of substantially mono-isotopic masses. More particularly, my invention relates to a calutron, a device wherein a polyisotopic substance is vaporized and then ionized under conditions causing a beam of positive ions to traverse an evacuated tank disposed between the pole pieces of a powerful magnet. The action of the magnetic flux causes the beam of ions to follow a curved path; ions of heavier isotopes tend to concentrate along the outer periphery of the curve, and ions of lighter isotopes follow the inner periphery of the curve. By placing a suitable collector in the path of the beam, preferably 180° from its source, it is possible to segregate and collect masses in which the distribution of isotopes has been radically changed or in which isotopes are substantially completely separated. For example, a calutron is useful for separating naturally occurring uranium containing U^{235} and U^{238} into two masses of which one is enriched with respect to U^{235} and the other is correspondingly impoverished.

It is with the mechanism for producing the beam of ions that this invention particularly deals. It has been found that a satisfactory device for generating a beam of ions may comprise a charge chamber in which a charge of material to be vaporized is heated, and an arc chamber having a filamentary cathode suitably positioned to strike an arc across the chamber and ionize the molecules of the vaporized polyisotope. In one wall of the arc chamber there is an elongated exit slit, and an accelerating electrode maintained at a highly negative potential is disposed in advance of the exit slit. The function of the latter electrode is to attract the positive ions formed in the arc chamber and draw them through the exit slit with considerable velocity in the form of a narrow ribbon or beam which traverses the evacuated tank in a path normal to the direction of the flux in the magnetic field formed between pole pieces of the magnet. A complete description of a calutron and its theory of operation is to be found in the copending application of Ernest O. Lawrence, Serial No. 557,784, filed October 9, 1944.

One object of the invention is to produce in a calutron a more stable beam of positive ions.

A further object of the invention is to provide a simple and compact ion source for a calutron.

Another object of the invention is to provide an ion source for a calutron in which a large percentage of vaporized material is ionized and formed in a beam.

An important feature of the invention resides in the combination of a diaphragm closing one side of the arc chamber and having an elongated slit disposed in register with a similar slit in a second diaphragm mounted closely adjacent the first diaphragm and maintained at a highly negative potential with respect thereto.

Another feature of the invention resides in disposing the accelerating electrode adjacent the bottom of a cup-shaped depression formed in one wall of the arc block. This feature has the advantage of preventing the random escape of ions from the arc chamber and increases the

efficiency of the ion source in that substantially all of the ions formed in the arc chamber are drawn into the beam.

A further feature of the invention resides in a cylindrical shield encompassing the arc block, providing support for the accelerating electrode, and provided with means whereby the shield may be displaced laterally with respect to the arc block in order that the slit in the accelerating electrode may be registered with the slit in the diaphragm closing the wall of the arc chamber.

These and other objects and features of the invention will be more readily understood and appreciated from the following detailed description of a preferred embodiment thereof selected for purposes of illustration and shown in the accompanying drawings, in which:

Figure 1 is a plan view of an ion source constructed according to the invention, portions thereof being broken away to show some of the features in cross section,

Fig. 2 is a view in side elevation with portions of the structure broken away to show certain features in cross section,

Fig. 3 is a view in cross section along the line **3—3** of Fig. 1,

Fig. 4 is a view in cross section along the line **4—4** of Fig. 1, and

Fig. 5 is a view in perspective wherein the accelerating electrode structure has been displaced to show certain features of construction.

Referring particularly to Fig. 2, there is shown a tank **13** disposed between the pole pieces **10** and **11** of a powerful magnet (not shown). The tank **13** is supported in spaced relation between the pole pieces **10** and **11** by means of spacers **15** interposed at suitable intervals between the walls of the tank and the adjacent faces of the pole pieces **10** and **11**. The tank proper terminates in a rim or header **17** to which is bolted a terminal section **19** having a cooperating rim **23** carried on its inner end. Bolts **25** serve to clamp the headers **17** and **23** together, a vacuum seal being effected by gaskets **24** disposed between the headers. In one wall of the section **19** is an outlet pipe **27** which is connected to a series of vacuum pumps (not shown) by means of which the tank is evacuated before the calutron is placed in operation.

At its outer end the tank section **19** terminates in a rim or face plate **31** to which a heavy mounting plate **33** is secured by means of bolts **37**. Received in recesses in the inner face of the mounting plate **33** is a pair of gaskets **35** which serve to form a vacuum seal. Four hollow tubular supports **39** carry at oine end integral plugs **41** in which are received bolts **43** by means of which the supports are anchored against the inner face of the mounting plate **33**. At their inner ends, the supports **39** carry plugs **47** provided with tapped holes for the reception of screws **49** which serve to clamp a plate **51** against the inner ends of the supports **39**. Each of the supports **39** is provided with a vent **45** in order that the pressure within the supports may be equal to the pressure within the tank.

A block **53** is secured to the plate **51** by means of a number of bolts **55** and is cut away as shown at **57** to form a charge chamber for the reception of a quantity of material to be vaporized. The chamber **57** is closed at one side by means of a cover plate **59** which is secured in position after the charge has been inserted in the chamber **57**. One side of the block **53** is provided with a pair of bores in each of which is disposed a heater **61** of conventional type, in which a coil of high resistance wire is wound upon a core of refractory material. The function of the heaters **61** is to heat the block **53** and vaporize the material placed in the charge chamber **57**.

A second block **63** is secured to the block **53** by means of screws **65**, the blocks being spaced apart by tubular

spacers 67 surrounding the screws 65. A tube 69 is received in shoulders formed in holes in the blocks 53 and 63 and clamped by the screws 65. The chamber 57 communicates with the tube 69, and formed in the block 63 is an arc chamber 71 also communicating with the tube 69. On either side of the arc chamber 71 the arc block 63 is bored to receive a heater 73 similar in all respects to the heaters 61. The heaters 61 are supplied by a conductor 75 which passes through a vacuum plug seal 34 in the mounting plate 33, and the heaters 73 are served by a lead 83 also piercing the mounting plate 33 through a vacuum plug seal 84.

The charge chamber and the block 53 are cooled by means of a squirt tube 77 which pierces the mounting plate 33 through a vacuum plug seal 78 and is welded to the outer surface of the block 53. The squirt tube 77 comprises a pair of concentric tubes, the inner tube being open at its inner end so that cooling fluid may be passed in through the inner tube and back out through the outer tube. By this means, a continuous flow of cooling liquid may be brought to the block 53. A similar squirt tube 81 is welded to the outer surface of the block 63 and serves to cool the arc chamber. Inasmuch as the block 53 and the block 63 each has separate heaters and squirt tubes the temperatures of the charge chamber and the arc chamber may be independently controlled.

Access to the arc chamber 71 may be obtained by removing the cover plate 85 secured to the top of the arc chamber by screws 87. The arc block 63 terminates in a tubular member 89 secured to the inner end of the block by bolts 91 and having a flange across its upper portion. A thin diaphragm 93 is clamped between the tubular member 89 and the inner face of the arc block 63 to close one side of the arc chamber 71. A long narrow slit 95 is formed in the diaphragm 93 and provides an exit from the arc chamber 71.

Surrounding the arc block and its supporting structure is a metal shield or cylinder 101 having at its outer end a rim or flange 103 welded or otherwise suitably secured to it and providing means for anchoring the shield 101 to the inner face of the mounting plate 33. Screws 105 pass through apertures in the rim 103 and are received in holes tapped in the inner face of the plate 33. At its inner end the shield 101 carries a circular flange 107 which serves to stiffen the shield 101 as well as to provide a base upon which are mounted four stand-off insulators 129 of conventional ceramic construction.

Secured to the outer surface of the flange 107 and extending into the interior of the shield 101 is a block 111 having an insulating insert 113 formed in two parts between which are clamped a pair of conductors 109 which extend along the interior of the shield 101 and through vacuum seals 123 in the mounting plate 33. Outside the plate 33 and adjacent thereto is a Bakelite block 127 provided in its upper surface with a pair of parallel grooves in which the cathode leads 109 lie. A pair of metal cap blocks 125 are screwed to the Bakelite block 127 to clamp the leads 109 in place. The block 111 is secured to the flange 107 by means of a pair of screws 117. The inner end of each of the conductors 109 carries a clamp block 121 in which are received the legs of a substantially U-shaped filamentary cathode 119. The clamp blocks 121 serve to support the filament 119 in a plane parallel to the direction of the magnetic flux between the pole pieces 10 and 11, the direction of the flux being indicated by the arrow 115. The filament 119 extends through an aperture formed in the cover plate 85 and into the interior of the arc chamber 71, and in the assembly of the device the axis of the filament 119 is aligned with the inner face of the slotted diaphragm 93. The filament 119 may be of tungsten or any of the materials commonly used for electron emissive cathodes. When the filament is rendered electrically negative with respect to the arc block 63, an arc or stream of electrons flows from the filament 119 along the inner face of the diaphragm 93 to the bottom of the arc chamber 71. Although the entire block 63 is positive with respect to the filament 119, the arc assumes a pencil shape because the powerful magnetic flux collimates the electron stream. The slit formed in the diaphragm 93 is aligned with the path of the arc and is so dimensioned that substantially all material leaving the arc chamber 71 through the slit 91 must first traverse the arc.

In order to form a beam of positive ions an accelerating electrode is mounted adjacent the slit 95, and as shown herein, comprises a second diaphragm 139 having a centrally located elongated slit and pinned to the end of a sleeve 133 having an outwardly extending radial flange 135 mounted in a circular aperture formed in a rectangular metal plate 131 which is carried upon the four stand-off insulators 129 previously described as mounted on the flange 107. The diaphragm 139 is thus received within a re-entrant portion of the arc block 63.

In order to render the accelerating electrode 139 electrically negative with respect to the arc block 63 a metal block 137 is welded to the plate 131 and provided with a tapped hole for the reception of a threaded conductor 159 adapted to be inserted through a wall of the tank section 19.

To provide a mounting for the electrode 159 a portion of the wall of a tank section 19 is cut away to receive a glass window 141 which is provided with an aperture through which extends a brass bushing 143 having an external thread on its inner portion. A washer 147 surrounding the bushing 143 bears upon a ring gasket 151 disposed against the inner surface of the glass window 141. A retaining ring 149 is internally threaded to engage the threads on the bushing 143. The bushing 143 has an integral flanged head which bears against a ring gasket 145 disposed against the outer surface of the glass window 141. When the retaining ring 149 is tightened, the gaskets 145 and 151 are compressed to form a vacuum seal. A ring 155 is riveted to the head of the bushing 143 and clamps in position a rubber gasket 153 having less diameter than the diameter of the aperture in the bushing 143. The electrode 159 is inserted through the aperture of the bushing 143, the gasket 153 bearing against the periphery of the electrode 159 and forming a vacuum seal.

After the arc block, the filament, and the accelerating electrode have been assembled on the mounting plate 33 and secured in place within the tank, the electrode 159 is inserted in the tank and screwed into the block 137. A conductor 161 is connected to the outer end of the electrode 159 and is connected to a suitable source of potential.

In order to provide an adjustment between the diaphragms 93 and 139 in order that the slits therein may be brought into register, the flange 107 is provided with integral blocks 171 through which are threaded long machine screws 175 one of which bears against each side of the arc block 63. By loosening one screw 175 and tightening the opposite one, the shield 101 and its associated structure may be displaced laterally with respect to the arc block 63, thus in effect adjusting the position of the slit in the diaphragm 139 with respect to the slit 95 in the diaphragm 93.

In operating the device constructed according to the invention, a charge of a vaporizable polyisotope, such as uranium tetrachloride, is placed within the charge or vaporizing chamber 57 after which the side plate 59 is screwed in place. The mounting plate 33 is then secured to the face plate 31 so that the ion beam source is mounted within the tank section 19. The electrode 159 is screwed into the block 137. The tank is then evacuated by means of vacuum pumps connected to the manifold 27 and the magnet is energized. The heaters 61 are energized to heat the block 53 and to cause the material therein to become vaporized. The vapor formed in the charge chamber 57 travels through the

tube **69** into the arc chamber, the difference in pressure between the two chambers serving to draw vapor in a constant stream from the chamber **57** into the arc chamber **71**. The filament leads **109** are connected to a suitable source of potential for heating the filament **119** which thereupon becomes electron emissive. By suitable connections (not shown) the arc block **63** is rendered electrically positive with respect to the filament **119** whereupon an arc discharge is struck from the filament **119** across the inner face of the diaphragm **93** to the bottom of the arc chamber **71**. The electrode **159** is connected to a source of potential serving to render the accelerating electrode or diaphragm **93** highly negative with respect to the arc block **63**.

The arc in the chamber **71** ionizes the vapor coming from the chamber **57**, forming, in the case of uranium tetrachloride, negative chlorine ions and positive ions of U^{234}, U^{235}, and U^{238}. The positive ions are attracted by the negative accelerating electrode and are drawn from the chamber **71** at high velocity through the slit **95** and pass as a beam or ribbon through the slit in the diaphragm **139**. As previously explained the beam of positive ions thus produced traverses the tank **13** in a curved path, the magnetic flux between the pole pieces **10** and **11** serving to bend the beam into a curve. The heavier U^{238} ions are slightly less affected by the magnetic flux, due to their heavier mass, than are the lighter ions of U^{234} and U^{235}. Consequently, as the ions leave the source and progress along the path of the beam, the heavier ions drift to the outer periphery of the curved path, whereas the lighter ions concentrate along the inner periphery of the curve. As explained in the copending application of Ernest O. Lawrence, collectors are disposed within the tank a suitable distance from the source and so arranged that the heavier ions of U^{238} are collected separately from the lighter ions of U^{234} and U^{235}. The collecting mechanism is not shown herein, since it forms no part of the present invention.

While one preferred embodiment of the invention has been described herein, it will be evident to those skilled in the art that the invention is not limited to the details of the apparatus shown and described. An infinite number of variations might be effected in the source discussed without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. A calutron comprising a vacuum vessel having a wall, means for establishing a magnetic field, structure fixed on said wall for forming an arc chamber with an exit slit, means for supplying gas to be ionized to said arc chamber, arc generating means mounted on said structure and associated with said arc chamber and said exit slit, a shield encompassing said structure mounted on said wall, insulating means mounted on said shield, accelerating means mounted on said insulating means in operative relationship with said exit slit, oppositely disposed screws received in said shield and bearing on said structure for displacing said shield with respect to said structure and aligning said slit and said accelerating means, and a collector unit disposed in said vessel for intercepting said accelerated ions.

2. A calutron comprising a vacuum vessel having a wall, means for establishing a magnetic field, structure fixed on said wall for forming an arc chamber with an exit slit, means for supplying gas to be ionized to said arc chamber, arc generating means mounted on said structure and associated with said arc chamber and said exit slit, a shield encompassing said structure mounted on said wall, insulating means mounted on said shield, accelerating means mounted on said insulating means in operative relationship with said exit slit, means for adjustably displacing said shield with respect to said exit slit for aligning said exit slit and said accelerating means, and a collector unit disposed in said vessel for intercepting said accelerated ions.

3. A calutron comprising a vacuum vessel having a wall, means for establishing a magnetic field through said vessel, an ion source mechanism fixed on said wall, a cylindrical shield encompassing said mechanism and mounted on said wall, an accelerator mounted on said shield in operative relationship with said mechanism, means for adjustably displacing said shield with respect to said mechanism, and means disposed within said vessel for intercepting said accelerated ions.

4. A calutron comprising a vacuum vessel having a wall, means for establishing a magnetic field through said vessel, an ion source mechanism mounted on said wall, a shield encompassing said mechanism mounted on said wall, insulating means mounted on said shield, an accelerator mounted on said insulating means in operative relationship with said mechanism, means for adjustably displacing said shield with respect to said mechanism, and means disposed within said vessel for intercepting said accelerated ions.

5. An ion beam source for a calutron comprising an arc block having a chamber formed therein, a diaphragm closing one side of said chamber and provided with an elongated slit, means for supplying gas to be ionized to said chamber, arc generating means mounted on said arc block and associated with said chamber and said slit, a tubular member secured to said block and surrounding said diaphragm, a sleeve mounted within said tubular member, a second diaphragm carried on said sleeve and provided with an elongated slit, said second diaphragm being disposed closely adjacent said first diaphragm, electrical means for maintaing said second diaphragm negative with respect to said first diaphragm, means for adjustably displacing said second diaphragm with respect to said first diaphragm for aligning the slits therein, and means for establishing a magnetic field in the direction of said arc.

6. An ion beam source for a calutron comprising an arc block having a chamber formed therein, a diaphragm closing one side of said chamber and providing an elongated slit, means for supplying gas to be ionized to said chamber, arc generating means mounted on said arc block and associated with said chamber and said slit, a tubular member secured to said block and surrounding said diaphragm, a shield encompassing said arc block mounted on one end of said arc block, insulators mounted on the free end of said shield, a sleeve mounted on said insulators within said tubular member, a second diaphragm carried on said sleeve and provided with an elongated slit, said second diaphragm being disposed closely adjacent said first diaphragm, electrical means for maintaining said second diaphragm negative with respect to said first diaphragm, oppositely disposed screws received in said shield and bearing on said arc block for displacing said shield with respect to said structure and aligning said slits, and means for establishing a magnetic field in the direction of said arc.

References Cited in the file of this patent

UNITED STATES PATENTS

2,221,467	Bleakney	Nov. 12, 1940
2,341,551	Hoover	Feb. 15, 1944
2,374,205	Hoskins	Apr. 24, 1945
2,376,877	Langmuir	May 29, 1945