April 27, 1954 R. R. WILSON 2,677,061

ION SOURCE

Filed Feb. 5, 1953 5 Sheets-Sheet 1

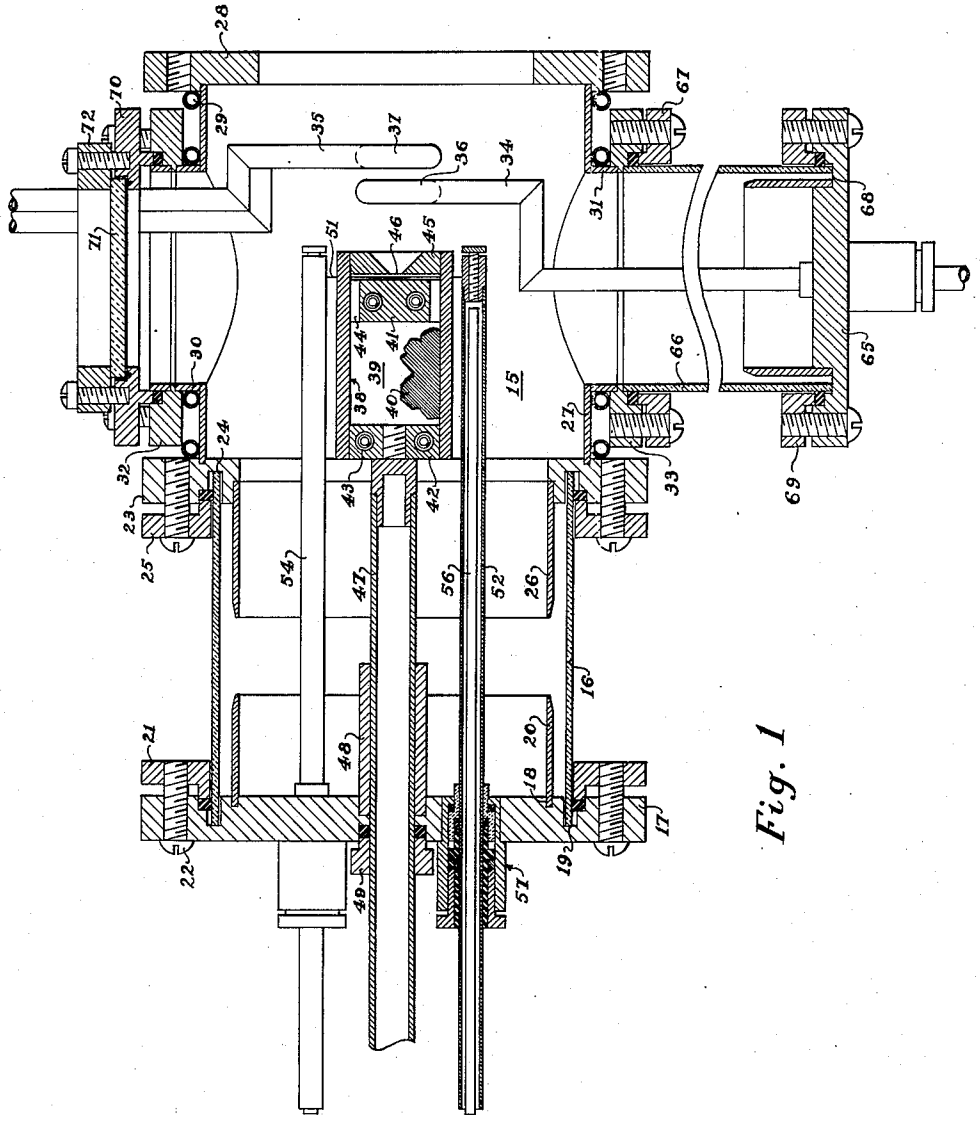


Fig. 1

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ION SOURCE

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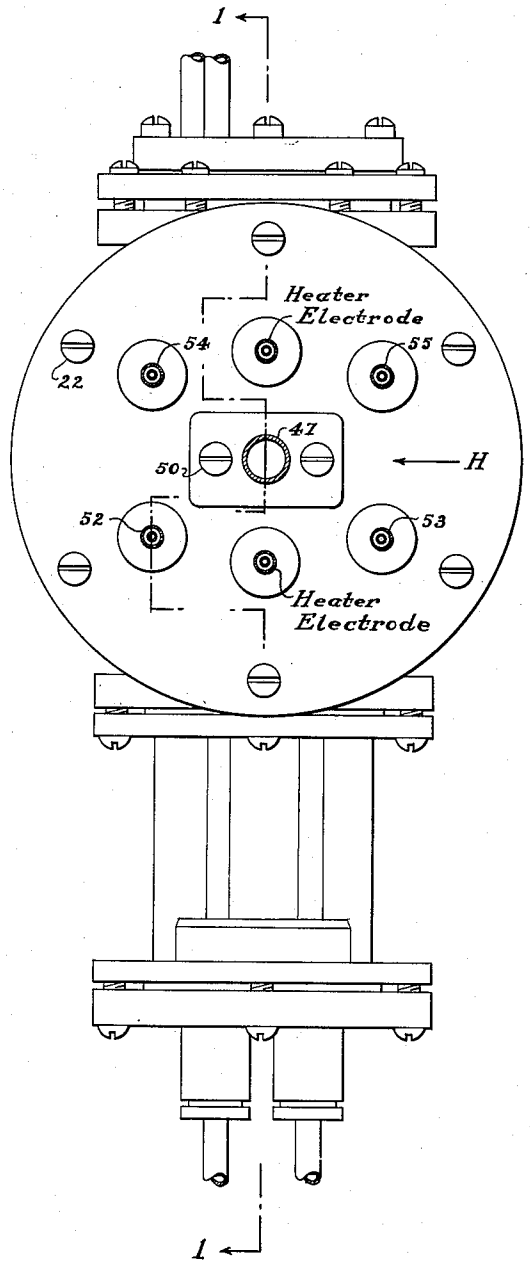


Fig. 2

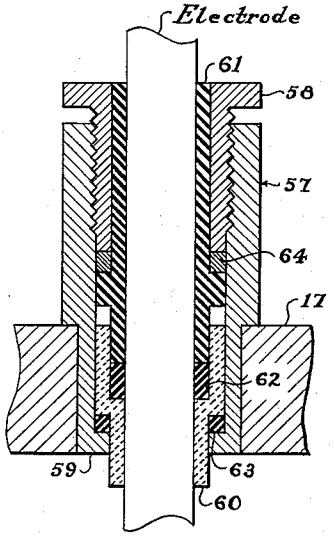


Fig. 3

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Filed Feb. 5, 1953 5 Sheets-Sheet 3

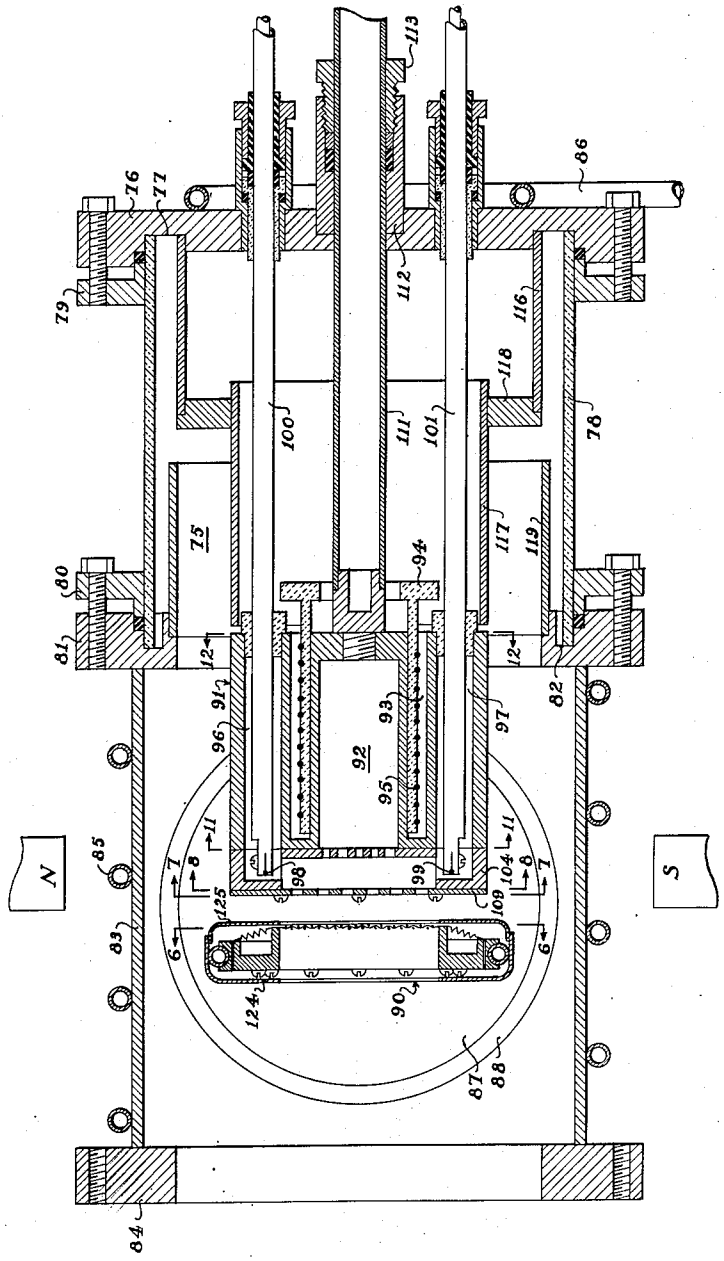


Fig. 4

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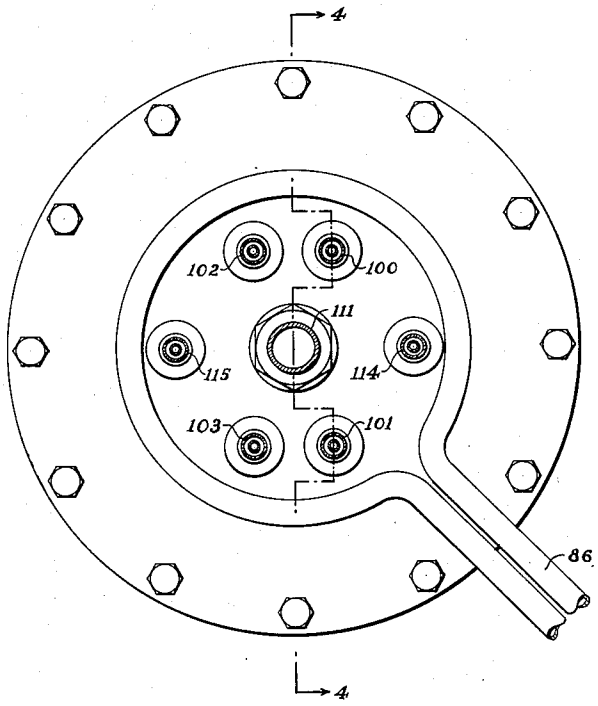


Fig. 5

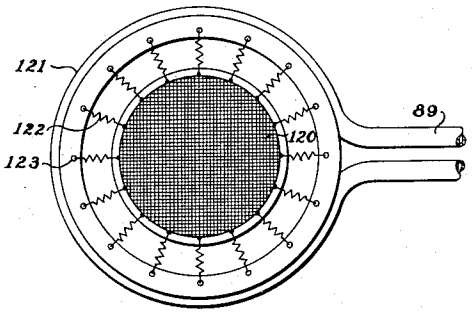


Fig. 6

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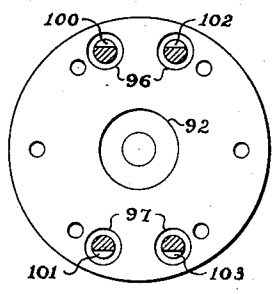


Fig. 11

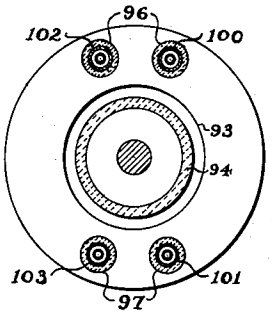


Fig. 12

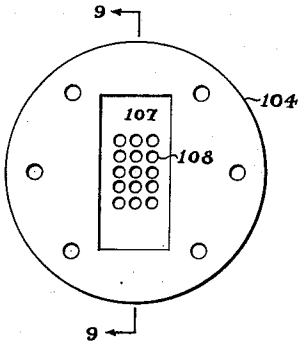


Fig. 8



Fig. 9

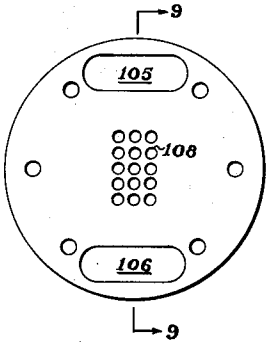


Fig. 10

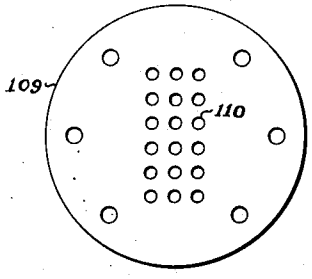


Fig. 7

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2,677,061

UNITED STATES PATENT OFFICE

2,677,061

ION SOURCE

Robert R. Wilson, Ithaca, N. Y., assignor to the United States of America as represented by the United States Atomic Energy Commission

Application February 5, 1953, Serial No. 335,190

11 Claims. (Cl. 250—41.9)

1

This invention is a continuation-in-part of application Serial No. 555,616, filed September 25, 1944, and relates to apparatus for separating ions of different mass from one another. More particularly it relates to apparatus for separating metallic materials of very nearly equal atomic mass by producing a relatively high velocity beam of positive ions of the heavy metals or compounds of the metals. For example it is desirable to be able to separate the zinc isotope 64 from the other zinc isotopes 65, 66, 67, 68 and 70, or to separate the isotopes of heavy metals, such as the isotopes U^{238} and U^{235}.

In the ionic methods for separating the isotopes of metals such as zinc and particularly heavy metals such as uranium, an extended source of ions as distinguished from a slot source used ordinarily in mass spectrometers, is essential for efficient large scale operation of the isotope separator. Isolated isotopes of a number of metals including those above mentioned are important to provide quantities of selected isotope for research, medicinal or industrial purposes such as radiography. The most efficient method available for ionizing atoms is by bombardment with electrons of suitable energy and the literature is replete with ion sources capable of supplying intense ion currents, especially protons, deuterons and alpha particles, by bombarding gas atoms with a focused beam of electrons. These prior art ion sources which have been developed for the ionization of gases such as hydrogen or helium are not particularly well suited for the production of ions of metals such as zinc and heavy metals such as uraniun primarily because the metal or its compound exists normally as a solid and must be heated to a high temperature to evaporate the metal or compound to obtain the vapor for electron bombardment. Accordingly the ion generators utilized in the ionic type of mass separating devices must be provided with a furnace for generating the vapors of the various metals, or metal compounds.

I have found it to be highly desirable to provide an ion source of the arc type and to utilize as an anode of the arc discharge a hollow cup shaped furnace for containing the material which is vaporized by the heat applied to the furnace to generate vapors of the particular metal desired. These vapors are allowed to effuse through perforations formed in the wall of said furnace anode into an arc region. The provision of the furnace type anode of my invention has the further advantages in that the

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source of vapor is directly adjacent the source of electrons to permit the use of a confined arc plasma, furthermore by having the vapor source adjacent the arc, heated conduits for distributing the vapor to the arc region are not required, and the heat necessary for evaporating the metal or its compounds may be localized.

It should be understood that I make no claim broadly to the method of ionizing metals by first vaporizing the metal in a furnace and then subjecting the vapor discharge of said furnace to bombardment of electrons, since it has been customary in the prior art to employ this method for obtaining charged particles of sample materials for analysis by mass spectrometers. In these prior art ion sources the vapor from the boiler is introduced into an ionizing region defined generally by a pair of insulated electrically conductive plates, and is here subjected to bombardment by electrons projected into the space from an electron gun position at one side thereof and consisting of an emitter and an electron accelerator.

One of the plates defining the ionizing region is held at a potential negative to the potential of the other plate and is provided with a longitudinal slot for the escape therethrough of the positive charged particles. The electrons and negative ions are attracted to the positive plate whereas the positive charged particles are forced through the slot in the negative plate.

The problem of providing a supply of positive ions of the particular metal, for large scale isotope separation, is not solved completely by the production of the desired number of ions within the arc region since the ions of the arc plasma must not be wasted but must be removed, rather, from the arc region and made to contribute to the useful beam current. The two most important factors which prevent the recovery of all the ions formed are the positive ion space charge in the ionizing chamber and the divergence of the ion beam caused by mutual electrostatic interaction of the ions in the beam. To counteract the positive ion space charge, I set up a counteracting electric field between an improved and novel accelerating electrode structure and the arc chamber. The accelerating electrode structure of my invention also assists in counteracting the natural divergence of the ion beam.

Accordingly it is an object of this invention to provide an ion generator that will produce a copious supply of positive ions suitable for use in an electrical mass separating device wherein it

is desirable to separate large quantities of the isotopes of a particular element, such as zinc or uranium.

It is also an object of this invention to provide an ion generator of the arc type having a furnace anode for enclosing a vaporizable material containing the element of the ions that are desired and an electron emissive cathode cooperating therewith to provide a copious supply of electrons adjacent said furnace anode for bombarding the vapor discharged from said furnace.

It is a further object of this invention to provide an improved accelerator electrode for withdrawing the positive charged ions from the arc plasma whereby they may be made to contribute to the useful beam current.

A still further object of this invention is to provide an ion source for an electrical mass separating device that may be maintained at a high positive potential with respect to its enclosing structure by shielding the source lead in conductors from the enclosing structure of the mass separating device.

It is another object of this invention to provide an ion source in which an elongated arc is propagated along a magnetic field and channelized behind and parallel to an exit slit for the withdrawal of the ions; the said channelization of the arc providing a maximum ionization of the gaseous charge directly adjacent the exit slit whereby a greater withdrawal of ions is achieved with a lesser expenditure of energy.

Other objects and many of the attendant advantages of my invention will be appreciated or become better understood by reference to the following detailed description when taken with the accompanying sheets of drawing wherein:

Figure 1 is an elevational view in longitudinal section of the structural details of one type of an ion generator made in accordance with my invention, the section being taken on lines 1—1 of Figure 2;

Figure 2 is an elevational side view of the structure shown in Figure 1;

Figure 3 is a cross-sectional view of the insulating seal 57 shown in Figure 1;

Figure 4 is an elevational view in longitudinal section of a further and preferred embodiment of the invention shown in Figure 1, the section being taken on line 4—4 in Figure 5;

Figure 5 is an elevational end view of the structure shown in Figure 4;

Figure 6 is an elevational view of the accelerator of the ion source shown in Figure 4, the section being taken on lines 6—6 and the cover plates 124 and 125 being omitted;

Figure 7 is an elevational view of the ion transparent plate 109, the section being taken on lines 7—7 in Figure 4;

Figure 8 is an elevational view of the cover plate 104, the section being taken on lines 8—8 in Figure 4;

Figure 9 is a cross-sectional view of the cover plate 104, the section being taken on lines 9—9 in Figures 8 and 10;

Figure 10 is an elevational view of the cover plate 104, the view being of the side opposite to Figure 8;

Figure 11 is an elevational view of the front of the furnace anode 91, the section being taken on the lines 11—11 in Figure 4; and

Figure 12 is an elevational view of the rear of the furnace anode 91, the section being taken on the lines 12—12 in Figure 4.

Referring now to the drawings and more particularly to Figure 1, the ion source illustrated is contained within a chamber indicated generally at 15 which is adapted to be evacuated and sealed at a sub-atmospheric pressure. The portion of the chamber containing the ion source may be regarded as consisting essentially of two main parts, an electrical insulating part and an electrical conducting part, readily detachable for the purpose of renewing or replenishing the supply of the vaporizable material from which the ions are derived. The first or electrical insulating part which constitutes the support for the arc chamber and furnace anode may consist of a heavy end plate 17, of copper or other suitable material. This conductive end plate of the insulating part is shown provided with a pair of concentric grooves 18 and 19 cut into its inner surface for supporting respectively the cylindrical tubing 16 of insulating material and the metallic shield 20. The junction between the cylindrical tube 16 of insulating material, preferably glass, and the end plate 17 is sealed by a packing gland illustrated in the drawings as consisting of a flange ring 21 of internal diameter slightly greater than the external diameter of the tubing 16. This ring is slidable over the tubing 16 and is adapted to be drawn toward the end plate 17 by the screws 22 which are threaded into tapped spaced openings in the flange ring 21 to force the end of the flange into the recess 19 containing the packing material to cause the packing material to be wedged tightly between the lateral surface of said recess and the surface of the glass tubing 16.

The opposite end of the glass tubing 16 is similarly terminated in the groove 24 formed in a heavy metallic ring 23 of the conducting part of the chamber to which the packing gland 25 is secured for sealing the junction of this end of the glass tubing and the metal ring. In this respect the chamber for the ion source and ion accelerator may be regarded as comprising a first conductive member, namely the end plate 17 for supporting the source; a second conductive member, namely the ring 23, for supporting an accelerating electrode structure; and an intermediate insulating portion, namely the glass tube 16 into which the ion source extends. A metallic shield 26 similar in construction to the metallic shield 20 is secured to the ring 23 by being hard-soldered thereto, for example, to extend parallel with the under surface of this glass tubing. Since the end plate 17 and ion source are maintained at a high positive potential with respect to the ring 23 to provide an accelerating voltage for the ions as will be more apparent presently, these shields 20 and 26 serve to distribute the electric field between the various parts of the apparatus and particularly between the end plate 17 and the ring 23, over the surface of the insulating tubing 16 and prevent the tubing from being subjected to excessive stresses caused by the concentration of the lines of flux at the junction of the tubing and the metallic parts. The importance of the shields 20 and 26 will be more evident when it is considered that the potential difference between the end plate 17 and the ring 23 may be as high as twenty thousand volts. A metallic cylinder 27, preferably of brass, is shown secured to the side of the ring 23 opposite the shield 26 and is terminated in a massive ring 28 to which the ion utilization part of the apparatus may be secured to complete the enclosure.

As illustrated in the drawings, water-cooling tubes 29 encircle this metal cylinder 27 for re-

moving the heat therefrom. The cylinder 27 is also shown provided with two windows in the form of cylindrical flanges 30 and 31 to which metallic rings 32 and 33 are respectively secured by being hard-soldered thereto, for example. These windows provide means for introducing into the evacuated chamber 15 two accelerating electrodes 36 and 37, consisting essentially of two long water-cooled tubes 34 and 35 preferably of copper, which are each bent double in such a way that each end where the tubing doubles back on itself forms a rectangular loop in front of the arc region. The ions accelerated from the arc region pass through these loops 36 and 37 to form the useful ion beam.

The vapor source of my invention consists of a furnace anode which in the construction illustrated takes the form of a rectangular block 38 of copper or other material of high thermal conductivity having a cavity 39 extending lengthwise of the block for containing the vaporizable material indicated at 40. Since the ion source illustrated was designed primarily for supplying the ions of zinc or uranium to an electrical mass separating device a halide or zinc or uranium, especially zinc chloride or uranium tetrachloride, is preferred as the vaporizing material; it being understood, that the compound is substantially dissociated in the arc to produce the respective metal ions. This cavity is shown closed by a pair of plugs or lids 41 and 42, each of which may be provided with a pair of spirally coiled molybdenum heaters in the holes 43 which are drilled through each of the plugs and transversely of the block 38. The plug 41 in the front end of the furnace anode has a plurality of longitudinal and peripheral slots 44 drilled therethrough to provide a peripheral escape path for the vapor from the furnace into the arc region. The front of the furnace adjacent the slots 44 is covered with a plate 45 to define a partially enclosed region for the arc discharge which region extends through the sides of the furnace block. As illustrated this cover plate 45 is provided with a splayed longitudinal opening or slot 46 for the current drain. The efficiency of ionization is improved by thus confining the arc to the region between the rear wall of the plate 45 and the front face of plug 41. In this respect, the plug 41 serves as a blocking member or confining strip for the arc discharge restricting the arc to a narrow ribbon-like path immediately adjacent the discharge slit.

The furnace anode is shown supported centrally within the evacuated chamber 15 by an elongated electrically conductive tube 47 of brass or other such material of good thermal conductivity. The tube itself is supported and sealed in the end plate 17 by means of a cylindrical bearing block 48 and a packing gland 49, which is adapted to be drawn toward the end plate 17 by the screws 50 (shown in Figure 2) which are threaded into the end plate, to compress the packing material about the tubing 47.

The cathode of the arc source of the present invention consists of either of two filamentary emitters, preferably straight tungsten wires 51, each supported by a pair of lead-in conductors 52—54 (and 53—55 in Figure 2). The filamentary cathodes are strung across the ends of their respective pairs of lead-in conductors so as to lie at the sides of and opposed to the arc chamber, as will be clear from the drawings. The lead-in conductors are preferably formed of copper tubing, and as will be noted in the cross-sectional showing of conductor 52, are provided with a second tube 56 which is supported concentrically therein for permitting the flow of cooling fluid through these tubes to remove the heat from the ends of the filamentary cathodes where they contact the lead-in conductors. Since a suitable heater voltage must be applied to the filamentary cathodes it is apparent that the four lead-in conductors must be insulated from each other and insulated and sealed from the plate 17.

Although any number of insulating seals known to the prior art may be used for these conductors, one novel, markedly successful seal is illustrated in the cross section in Figures 1 and 3. This seal consists essentially of a metallic insert 57 in the form of a cylindrical bushing which is silver soldered or otherwise securely retained in a drilled opening of the end plate 17. The end of the bushing 57 extending to the high pressure side of the plate 17 is of an enlarged diameter and is threaded internally to receive the packing gland 58, whereas the inner end of the bushing is provided with an inwardly projecting flange or shoulder 59. Interposing between the electrode and the metallic insert 57 are the two insulated bushings 60 and 61, at least the former being formed preferably of a refractory insulating material. The bushing 60, of refractory material, is fashioned with a section of enlarged diameter into which the uniform diameter portion of the insulated bushing 61 may be inserted. A sealing ring 62 is interposed between the end surface of the bushing 61 and the inner shoulder of the bushing 60, so also is a sealing ring 63 placed at the rear of the bushing 60 between the shoulder formed by the enlarged portion thereof and the shoulder 59 on the metallic insert 57. The bushing 61 has a flange or enlarged cylindrical portion which is adapted to be engaged by the end surface of the packing nut 58 through the sealing ring 64 to respectively compress the sealing ring 64 between the foregoing opposing surfaces, the sealing ring 62 between the end surface of the bushing 61 and the inner flange formed by the enlarged section of the bushing 60, and the sealing ring 63 between the outer flange surface of the bushing 60 and the inner flange surface 59 of metallic insert.

As shown in Figure 2, lead-in conductors are provided for conducting a heating current to the heaters such as the molybdenum coils which are adapted to be positioned in the openings 43 of the end plugs 41 and 42 of the furnace anode 38. These lead-in conductors are also sealed and insulated where they pass through the end plate 17 by means of insulating bushings similar to the insulated bushing illustrated in cross-section in Figure 3.

The water-cooled tubing 34 which is fashioned to form the loop 36 in front of the arc region defined by the plate 46 and plug 41 and which constitutes the first accelerating electrode is preferably maintained at a potential of several thousand volts negative relative to the potential of the anode, which in the particular illustrated embodiment of this invention is connected electrically to the plate 17 and is maintained at a high positive potential of perhaps 20 kv. relative to ground. The ends of the tubing 34 extend through and are sealed in the plate 65 which is shown insulated from the chamber 15 by means of the insulating tubing 66 of glass, for example. One end of this tube is sealed to the ring 33 by the packing gland 67, and the other end is terminated in the cylindrical groove 68 formed in

the metallic plate 65. The tube 66 is also sealed to the plate 65 at the groove 68 by means of the packing gland 69. As a matter of convenience the seals surrounding the tube 34 where it projects through the plate may be regarded as being similar in construction to the insulated seals shown in cross-section in Figure 3 although obviously these seals need not insulate the tubes from the plate 65.

The loop 37 which constitutes the second accelerating electrode is maintained at ground potential, consequently the copper tubing 35 of which the loop 37 is formed need not be insulated from the enclosure 15. Accordingly the ends of the tubing 35 are brought out through a flanged metallic plate 70 and soldered thereto to form a sealed passage. This metallic plate 70 is sealed to the ring 32 by virtue of the packing material into which the laterally projecting flange is forced to form the seal. The plate 70 is also provided with a glass window 71 which is sealed to the plate by the clamp ring 72 to permit visual inspection of the operating conditions of the arc.

A source embodying the features of the present invention has been constructed and operated wherein the anode furnace consists of a copper box one and one-half inches wide, two inches long and two inches high. This furnace was heated by four spiral molybdenum heaters which pass through holes in the walls of the box and enclosures therefor. In front of the furnace, the copper plate 45, together with the enclosure 41, defines a partially enclosed region in which the arc discharge was restricted. A path for the vapor from the furnace to the arc region is through the slots 44 which extend into the cavity along the sides of the furnace front. Two 40 mil tungsten filaments are provided, either of which was used as a cathode for the arc discharge. These filaments are supported at the sides of the arm chamber or partially enclosed ionizing region. The furnace was used as the anode. A magnetic field having a direction along the arc enclosure, indicated by the arrow H (in Figure 2), collimates the electrons and so causes the electrons of the arc to be extended along the chamber or ionizing region. The source magnet for providing this field is not shown, it being understood that conventional magnetic field producing means may be utilized. The accelerated electrode system utilized with this source consisting of two rectangles of copper tubing one-half inches wide and two inches long. The first rectangle loop was held about one-half inch from the front of the arc region. The source constructed as described above when utilizing uranium tetrachloride as the vaporizable material operated under substantially the following conditions:

Furnace temperature	°C	450
Arc voltage drop	volts	150
Arc current	amperes	1

A slightly lower temperature is suitable when utilizing zinc chloride.

The ion current available from this source was found to depend on the transparency of the cover 45 over the front of the arc region. With a slot 46, one-sixteenth inch high and as long as the arc chamber, a current drain of about 8 milliamperes was obtained with an accelerating voltage of about twenty thousand volts. That is, the anode was maintained at a positive potential of 20 kv. relative to the grounded accelerating electrode 37. The first accelerating electrode 36 was at 12 kv. for best conditions.

The operation of the ion source described above is associated with the appearance, at times, of a discharge around the leads to the source in the region behind the furnace 38. I believe the gas present is effected by electrons oscillating in the crossed fields of the accelerating potential and source magnet, since I have found that the intensity of this discharge is dependent upon the strength of the fields and the pressure within the chamber 15, that is, there is a critical accelerating voltage above which the ion current drain will decrease. This critical voltage for the source described above appears to be about 20 kv. Furthermore I have noted that on lowering the magnetic field or the pressure within the chamber 15 the amount of the discharge around the leads decreases. Since the presence of this discharge gave rise to some difficulties in operation particularly in that it prevents operation at very high accelerating potential desirable for high ion current drain, I set out to develop the embodiment of my invention illustrated in Figures 4 to 12 wherein the leads to the source are surrounded by a cylindrical metallic shield having a high positive potential substantially equal to the potential of the source so as to provide a region for these source leads which is free from the field of the accelerating voltage. This inner shielding electrode is made to underlie the grounded shielding electrode underlying the insulating tube and extending from the low potential conducting portion of the chamber to provide opposing conducting surfaces for shortening the equi-potential paths for electron oscillation.

Referring now to Figure 4, the source shown therein consists essentially of an enclosure 75 comprising a first electrically conducting portion, namely, an end plate 76, of copper or other suitable material provided with a concentric cylindrical groove 77 on its inner surface, for supporting the insulating tube 78 that constitutes the insulating portion of the enclosing chamber and may be constituted of glass or other suitable material. The packing glands 79 and 80 respectively seal the insulating tube 78 where it contacts the groove 77 of the end plate 76 and the groove 82 of the heavy metallic ring 81. A metallic cylinder 83 constitutes the second conducting portion of the enclosing chamber and is shown secured to the side of the ring 81 opposite the end of the insulating tube 78 and is terminated in a massive ring 84 to which an ion utilization part of the apparatus may be secured to complete the enclosure. As illustrated in the drawings, water cooled tubes 85 and 86 surround respectively the metallic cylinder 83 and the end plate 76 for removing heat therefrom. The metallic cylinder 83 is also shown with a window 87 from which the cylindrical flange 88 projects to support a cover plate through which the cooling tubes 89 (Figure 6) extend to support the ion accelerating electrode structure indicated generally at 90.

The vapor source of this embodiment of my invention consists of a cylindrical block 91, of copper or other suitable material, having a cup-shaped portion 92 formed therein for containing the material to be vaporized. A circular slot 93 is drilled about the periphery at the bottom portion of the cup to extend axially in the longitudinal walls of said cup for a distance just short of its open end. The annular cavity thus formed is adapted to support a heater for the furnace which may, for example, consist of a hollow cyl-

inder block 94 of refractory insulating material, such as Alundum, about which is wound in spiral fashion the heating coil 95 of molybdenum wire, for example, which may be partially recessed in the grooves formed in the block for the purpose of receiving this heater coil. Two pairs of holes 96 and 97 spaced about the periphery are drilled into the block and extend throughout its length to accommodate the tubular lead-in conductors 100—102 and 101—103 for the alternatively used filament cathodes 98 and 99 which extend respectively across the ends of the foregoing pair of lead-in conductors. Bushings of refractory insulating material surround the lead-ins where they enter the holes 96 and 97 of the cylindrical block 91.

A cover plate 104 (Figures 8, 9 and 10) which may likewise be of copper or other suitable material is secured to the furnace block 91 by screws, for example. This cover plate is provided with cavities 105 and 106 for respectively containing the filamentary cathodes 98 and 99. These cavities for the filamentary cathodes each open into a recess 107 formed in the cover plate as is clear from Figures 8, 9 and 10 to form a region for containing an arc discharge established between either of the cathodes and the face portion of the cover plate 104 which contacts the lip of the cup 92 and forms the rear wall of the recess 107. This portion of the cover plate 104 has a plurality of holes 108 drilled therein for the effusion therethrough of the vapor derived from the material contained within the cup portion 92 of the furnace anode.

An ion transparent plate 109 (Figure 7) is shown secured to the outer edge of the cover plate to complete the enclosure 107 for the arc region, the ion transparency, of course, being attained by a plurality of openings 110 drilled through the plate 109 which permit the withdrawal of ions from the arc region.

The furnace anode 91 is shown supported within the evacuated chamber 75 by an elongated tube 111 of brass or other suitable material having a high thermal conductivity. This tube itself is supported and sealed in the end plate 76 by means of cylinder bushing 112 of metal which is recessed into the outer surface of the plate 76 and sealed therein. The exposed end of the bushing 112 is tapped to receive the packing material and the packing gland 113.

The lead-in conductors 100—102, and 101—103, for the filamentary cathode and the lead-in conductor 114 (shown in Figure 5) for conducting current to the heating coil 95 and the thermocouple 115 (shown in Figure 5) for control of the temperature of the furnace block, are all insulated, supported and sealed in the end plate 76 through which they pass by virtue of the seals for these conductors, which seals are similar in construction to that illustrated in cross section in Figures 1 and 3 and described above. As stated above this source was designed primarily for the purpose of eliminating the presence of the discharge around the lead-in conductors in the region behind the furnace anode 91. This discharge is believed to result from an increase in ionization of the vapor within this region caused by the oscillation of electrons in the crossed magnetic and electric fields. As the electrons oscillate in the magnetic field their path length is increased thus increasing the danger of a flash over between the high positive potential of the ion source or the lead-in conductors and the grounded enclosure. The ionization of the gas within the region of oscillation produces both electrons and positive ions, and the electrons so produced are also subject to oscillation adding to the ionization.

These difficulties due to electron oscillation may be eliminated, substantially, by reducing the effective volume within which this oscillation may take place and providing a substantially field free space for the leads to the source behind the furnace 91. Accordingly there is illustrated in Figure 4 a shield for the anode source and its lead-in conductors which comprises the cylinder tubes 116 and 117 of electrically conductive material and an intermediate support disk 118 also of electrically conductive material by means of which two tubes are joined together. The tube 116 is shown supported to the end plate 76 by the groove 77 so as to extend along the under surface of the insulating tube 78 and distribute the electric field over this insulating material. The tube 117, however, is of smaller diameter and closely encircles the lead-in electrodes at the rear of the arc region. That the insulating tubing 78 may be quite completely shielded from the electrons an outer grounded shielding electrode in the form of a cylindrical tube 119 of electrically conductive material surrounds the free end of the first shielding electrode 117. More specifically the cylindrical tube 119 is secured to the grounded ring 81, by being hard soldered thereto for example, so as to extend parallel to the under surface of the glass tubing to shield this portion of the insulator from electron impact. With this arrangement the oscillating electrons are reduced in number and their paths along the equipotential lines are shortened.

The full significance of this shield from the standpoint of protecting the insulating tube 78 will be more apparent when it is considered that substantially all of the oscillating electrons now discharge on a conducting rather than an insulating surface. Without the shield the electrons present in this region, in moving in a general direction along equipotential lines, would collide with the insulating surface, charge it up, and thus modify the distribution of equipotential lines. More specifically, by charging up the insulator the equipotential lines concentrate at the juncture of the insulated tube 78 and the high positive potential electrode or end plate 76. The concentration of electrons that continue to strike the insulating surface would eventually cause rupture of the insulation.

As is apparent from the drawings the ion withdrawing and accelerating structure 90 (Figures 4 and 6) differs materially from that disclosed in Figure 1 and consists essentially of the ion transparent plate 109 secured to the front of the source and a wire screen 120 spaced from and parallel to the front of the source as is clear from Figure 4. The structure for supporting the screen 120 at a distance spaced from the ion source consists of a metallic ring portion 121 having a circular groove cut into the face thereon and cut away partially at the outer side to form a projecting cylindrical flange across which may be stretched the accelerator screen 120 which preferably consists of tungsten wire. Since the screen 120 becomes hot and expands when bombarded by the ions being accelerated therethrough it is held under tension by the coil springs 122. One end of each of these springs is secured to the tungsten wire mesh forming the accelerator and the other end is brought through the holes 123

in the ring 121 and held in place under the screw. A periphery groove, for retaining the cooling tube 89 is cut in the rim of the ring 121. The shields 124 and 125 (Figure 4) which protect these springs 122 from ion bombardment are supported also by the cooling tubes 89 thus the entire electrode accelerating structure 90 is supported by the cooling tubes 89 which are in turn supported by the cover plate for the flange window 87. Thus it may be easy to alter the position of the accelerating electrode relative to the front of the arc source.

Remarkably satisfactory results have been obtained from the operation of this latter embodiment of my invention wherein the anode furnace consists of a cylindrical block of copper two inches long and two and three-eighths inches in diameter into the front surface of which a cylinder cavity one and five-eighths inches deep and five-eighths inch in diameter is bored for containing the uranium tetrachloride of the ion source. Four holes each three-eighths inch in diameter drilled along the length of the block 90° from each other and five-sixteenths inch from the edge of the cylinder block provide passages for the lead-ins to the filamentary cathodes which are preferably 40 mil tungsten wire. The cover (Figure 7) for the arc chamber facing the accelerating screen was provided with eighteen one-eighth inch holes for permitting a current drain therethrough.

A heater comprising a coil of molybdenum wire wound spirally on a cylinder block of Alundum is inserted in a three-sixteenths inch wide slot of one inch overall diameter drilled in the back of the furnace. A magnetic field producing means indicated by the pole pieces N and S was again provided to establish a magnetic field in the direction of the arc chamber to collimate the electrons of the arc. One of the filaments was used as a cathode and the arc chamber was used as the anode.

The operating conditions for this source utilizing zinc chloride or uranium tetrachloride as the vaporizing material are similar to those of the source previously described. The typical values are:

Furnace temperature	°C	450
Arc drop	volts	100
Arc current	amperes	0.6

Under these conditions a drain current of from ten to fifteen m. a. is expected with an accelerating voltage of about twenty to thirty kv. The capacity of this source was such that runs of from three to four hours were obtained. The use of the metallic shield around the source leads was successful in suppressing the discharge at the back of the source.

It is known that zinc chloride or uranium tetrachloride vapor will corrode the copper with which it comes in contact. It is important therefore in the operation of ion source similar to either embodiment of this invention described above that the walls of the arc chamber be protected with a suitable material which will not be attacked by the halide vapor. The condition of the surface of the walls of the arc chamber is particularly important when the ion source is to be used in large scale separation of isotopes by ionic methods since it may be demonstrated that the reproductability of the ion beam is dependent upon the condition of the surface of the arc chamber. To avoid the corrosive effect noted above it has been found advisable to utilize graphite as a covering for the walls of the arc region, although this has not been shown in the drawings in the interest of clarity in the disclosure and furthermore since it is not a part of the present invention.

It will be appreciated that the above preferred embodiments of my invention have been illustrated and described so that others may likewise obtain the good results and objects of this invention with the understanding however, that changes and modifications in construction and arrangement of parts can be made without departing from the spirit of the invention, and that the described embodiments are for the purpose of illustration only and not for the purpose of limitation upon the scope of the invention as expressed in the appended set of claims.

In the claims:

1. An ion generator comprising in combination a chamber evacuated to a sub-atmospheric pressure enclosing a substantially cup-shaped anode adapted to contain a vaporizable material of the ions that are desired, a cover for closing all but a peripheral portion of the open end of said cup-shaped anode, a filamentary cathode immediately adjacent the outside portion of said cover, a plate adjacent at least a portion of said cathode and in confronting and spaced relationship with said peripheral portion of said cover forming a partially enclosed region for the vapor effusing from said cup-shaped anode through the open peripheral portion of said cover, a slot in said plate, and an accelerating electrode adjacent to said plate adapted to have a negative potential applied thereto so as to withdraw through said slot the positive ions formed within said region by an arc discharge established between said anode and said cathode when energized by a suitable electrical potential.

2. The combination defined in claim 1 above wherein said accelerating electrode comprises a looped portion of a liquid cooled tube supported in confronting and spaced relationship to said ionizing region and at a negative potential relative to the plate forming said region whereby the ions within said region will be accelerated through said loop.

3. An ion generator comprising in combination a chamber evacuated to sub-atmospheric pressure and containing a substantially cup-shaped anode for enclosing a vaporizable material of the ions that are desired, a cylindrical slot in the longitudinal walls of said anode extending short of the open end of said cup, a cylindrically shaped electrical heater within said slot, a plurality of lead-in conductors extending through longitudinal opening in the walls of said cup exterior of said heater for supporting and energizing a filamentary cathode, a perforated lid for covering the open end of said cup having a recess for said filament and a partially enclosed region for ionizing the vapor effusing through said perforations, means for establishing an arc discharge between said cathode and the perforated lid of said anode, and means for causing the electrons of said arc to flow through said region.

4. A discharge device including in combination a chamber sealed at a sub-atmospheric pressure including an insulating and conducting portion, an ion generator supported in said insulating portion, an accelerating electrode comprising an annular conductive member, a metallic screen, and resilient means maintaining said screen tightly stretched across said annular member, and a liquid cooled tube sealed in the conducting

portion of said chamber for supporting said annular member in confronting and spaced relation with said generator whereby said generator may be maintained at a high positive potential relative to said screen.

5. A discharge device including in combination a chamber sealed at sub-atmospheric pressure including an insulating and conductive portion, an ion generator supported in said insulating portion, an accelerating electrode supported by said conducting portion in confronting and spaced relation with said ion generator, means for maintaining said generator at a high positive potential relative to said electrode whereby to provide an accelerating field for said ions, a first outer shielding electrode extending from said conductive portion at a potential substantially that of said accelerating electrode to underlie the insulating surface of said chamber in spaced relation therefrom, and a second inner shielding electrode extending from said insulating portion at the potential of said generator to underlie said insulating portion and to confront said first shielding electrode, said second shielding electrode having an offset portion positioned to underlie said first shielding electrode whereby the electric field between the high potential of the electrically conductive portions of said ion generator and the lower potential of the conducting portion of said chamber will be distributed between said electrodes.

6. A discharge device including in combination a chamber sealed at sub-atmospheric pressure including a first and second electrically conducting portion and an intermediate insulating portion, an ion generator supported by said first conducting portion to extend within said insulating portion, an accelerating electrode supported by said second conductive portion in confronting and spaced relation with the said generator, means for maintaining said generator at a high positive potential relative to said electrode to provide an accelerating field for said ions, a first outer shielding electrode extending from said second conducting portion to underlie the surface of said insulating portion in spaced relation therewith, a second inner shielding electrode extending from said first conducting portion to underlie the first shielding electrode whereby the electric field resulting from the high potential between said conducting portions will be distributed along the surface of said shielding electrodes.

7. An apparatus for developing gaseous ions from a source material including a hollow block member, adapted to contain a gaseous atmosphere and having a communicating elongated exit slit for ions of said gaseous atmosphere in a frontwall thereof, means for propagating an arc discharge parallel to said slit and coextensive therewith, and means for channelizing said arc to a narrow region of ribbon-like configuration directly behind said slit whereby the density of ionization of said gaseous atmosphere is increased at said exit slit.

8. An apparatus for developing gaseous ions from a source material comprising a plurality of wall members forming a confined region of ribbon-like configuration, one of said wall members defining the width of said region having an elongated aperture extending at least substantially the length of said region and communicating therewith, the other remaining one of said wall

members defining the width of said region also having at least one communication elongated aperture extending at least substantially the length of said region, said apertures in said wall members being laterally offset, means for propagating an arc discharge substantially throughout the length of said region, means for conducting a gaseous atmosphere comprising said source material into said region throughout the length of said aperture in said second wall member, and means for withdrawing gaseous ions of said material from said region throughout the length of the aperture in said first wall member.

9. In an apparatus for developing gaseous ions, the combination of means for establishing an arc discharge, said means comprising an elongated arc chamber including means constituting an anode, an electron emissive cathode positioned adjacent an end of said chamber, said chamber having a slit-like aperture extending in the direction of its elongation and substantially co-extensive therewith for the withdrawal therethrough of said gaseous ions, and means for introducing a gaseous medium into said chamber substantially uniformly throughout the length thereof and at a position relative to said slit so that its path of flow through said chamber to said slit will have a component in a direction normal to the direction of ion withdrawal.

10. In an apparatus for developing gaseous ions from a vaporizable source compound comprising means for establishing an arc discharge throughout a region of ribbon-like configuration, said means comprising an elongated arc chamber having said ribbon-like configuration and including means constituting an anode, an elongated electron emissive cathode positioned at an end of said chamber extending in a direction corresponding to the width of said region, means for directing the electron emission from said cathode lengthwise of said region, means for introducing a flow of vapor of said compound into said chamber substantially uniformly throughout the length thereof, and means for withdrawing ions of said vapor from said chamber along the entire length thereof and in a direction corresponding to the direction of said ribbon-like region, the direction of flow of said vapor through said chamber to said slit having a component in the direction of the width of said chamber.

11. In an apparatus for developing gaseous ions, the combination of means for establishing an arc discharge of ribbon-like configurations, said means comprising an elongated arc chamber having said ribbon-like configuration including means constituting an anode and an electron emissive cathode positioned adjacent an end of said chamber, a side of said chamber defining the width of the ribbon-like region having a slit-like aperture extending in the direction of its elongation and substantially co-extensive therewith for withdrawal therethrough of said gaseous ions, and means for introducing a gaseous medium into said chamber substantially uniformly throughout the length thereof and at a position laterally offset with respect to said aperture whereby said gaseous medium will be made to flow through a path having a length greater than the thickness of said ribbon-like region to increase the degree of ionization thereof.

No references cited.