Sept. 28, 1954 C. M. TURNER 2,690,521

ION SOURCE UNIT

Filed April 24, 1953

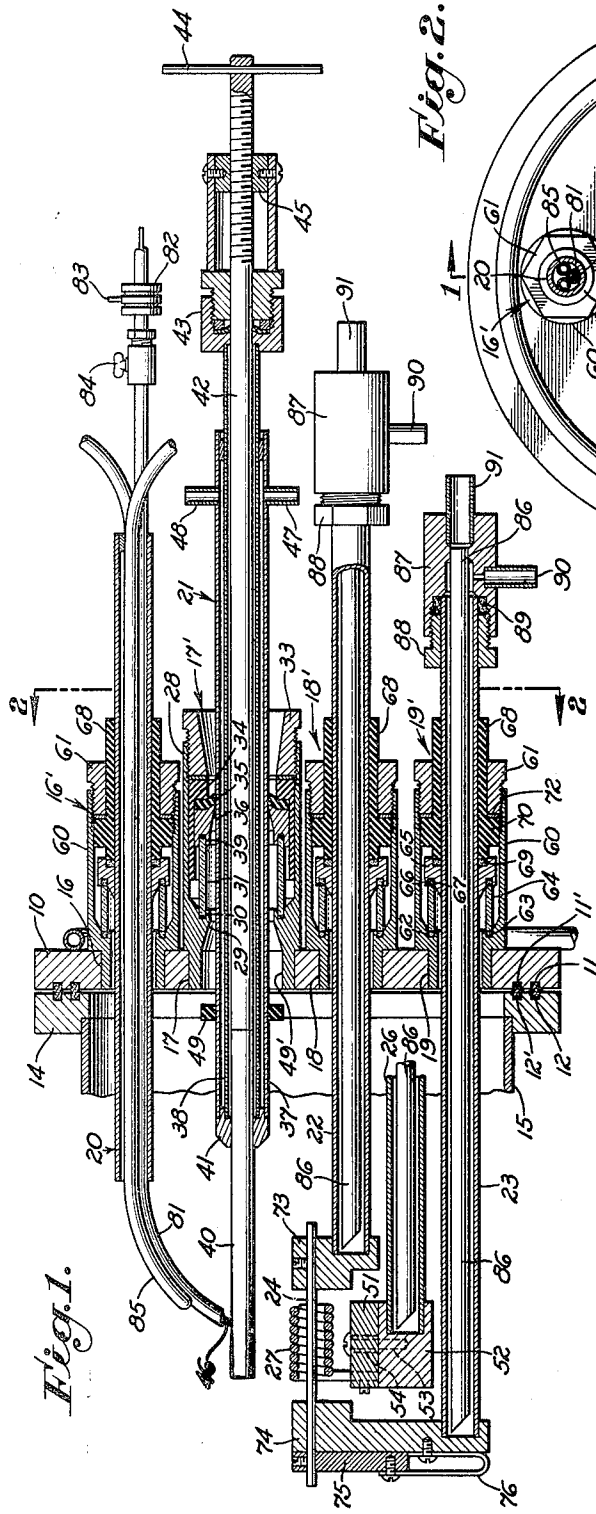


Fig. 1.

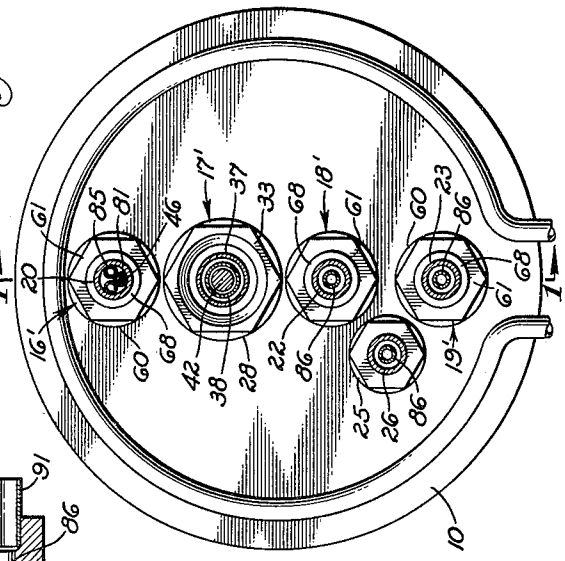


Fig. 2.

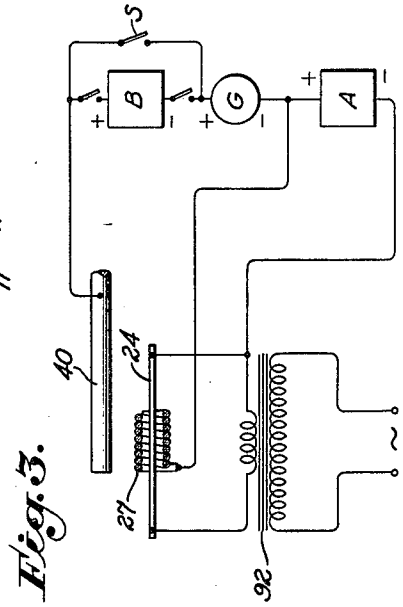


Fig. 3.

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2,690,521

ION SOURCE UNIT

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Application April 24, 1953, Serial No. 350,813

10 Claims. (Cl. 313—231)

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This application is a continuation-in-part of application S. N. 671,981, by Clarence M. Turner, filed May 24, 1946, now abandoned, and discloses an invention which relates to a gaseous electric discharge device and especially to an electric arc discharge device capable of producing in quantity a substantially continuous supply of gaseous ions under vacuum such as are required in procedures and apparatus for separating or concentrating isotopes by appropriate selective operations upon the ions of different mass contained in an ion beam.

It is frequently desirable to separate isotopes of slightly different mass in order to obtain an isotope of known half life and radioactive intensity. For example, certain isotopes of cobalt are useful in medical research and radiographic photography. In both cases a monoisotopic material must be obtained. Among other isotopes of increasing usefulness in medical and other types of research are those of copper, zinc, and uranium.

Accordingly, the present invention is directed to an apparatus for supplying under vacuum a high intensity stream of gaseous ions of a source metal continuously for long periods of time.

It has been the practice to produce the desired stream of source metal ions by establishing an arc discharge between a filamentary cathode and an anode through a vapor containing or comprising the source metal and to withdraw the ions of the source metal from the arc plasma by the application of a suitable electric field. There are, in general, two such types of ion sources, distinguishable by the source of uranium vapor; e. g., those employing a readily vaporizable source metal salt termed "salt sources" and those employing the more difficultly vaporizable source metal itself. These latter sources are referred to as "metal arc sources." It has been noted from the operation of both of the above type ion sources that the uninterrupted operating time of the arc is dependent largely upon the lifetime of the filamentary cathode, i. e., the cathode is subject to bombardment by source metal ions thereby collecting a deposit of the source metal which alloys with the cathode material decreasing its melting temperature.

It has been proposed in the "salt sources" (cf. the application of Louis F. Wouters, Serial No. 528,818, filed March 31, 1944) to avoid filament erosion by utilizing an arc cathode heated to electron emissive temperatures by the bombardment thereof by accelerated electrons emitted from a filamentary cathode. The present application, while employing an indirectly heated arc cathode, distinguishes from the above-referred to application in that it deals with the

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metal arc ion sources, i. e., the type of source that derives its vapor by feeding the metal to be ionized, e. g., the source metal directly into the region of the arc discharge and preferably onto the anode. It is in this general type of ion source that erosion of the electrodes has been most severe. The filament rapidly becomes contaminated with the metal vapor to be ionized since it is exposed directly to the anode where the metal is vaporized. Moreover, there is a tendency for the anode material to be dissolved at the point of feeding.

It is a primary object of this invention to provide an ion source arc structure for ionizing a predetermined metal applied thereto, that is capable of continuous operation for long periods of time.

It has been noted that the interrupted operating time of the cathode can be extended by indirectly heating the cathode by electron bombardment from a suitable source of electrons. I have found as a result of my research on metal arc ion sources, that highly satisfactory results may be obtained through the utilization of a tubular cathode formed of a closely-wound, wire helix of tungsten, for example, wherein this tubular cathode is heated by electron bombardment from a filament, also preferably of tungsten, that is supported within the cathode and along the axis thereof. I have also determined that highly satisfactory results may be had by utilizing an anode formed of a heavy rod of refractory metal such as tungsten disposed above and parallel to the axis of the cathode. The source metal to be vaporized and ionized is fed in the form of a wire to a point near the tip of the rod where it melts and flows around the rod for vaporization and ionization in the arc established between the rod anode and the coil cathode. It has been found as a result of my researches, and despite the use of the invention embodied in the copending application, Serial No. 330,952 (48) filed January 13, 1953, now Patent No. 2,677,060, that tungsten is eroded from the anode by the molten metal flowing from the point of feeding to the point of arc vaporization. While there is apparently no way of completely eliminating this erosion, I have discovered that it can be greatly reduced by varying the point of feeding on the anode by slowly rotating and advancing the anode rod. Furthermore, I have found that erosion of the anode may also be reduced by the following precautions:

First, the anode should be used in a horizontal position.

Second, the anode should be fed directly in the arc region by means of an insulated feeder, since then the tungsten of the anode will be

dissolved and redeposited in the same locality reducing redistribution.

Accordingly, it is a further object of this invention to provide in an arc discharge device for ionizing a predetermined material supplied thereto a support for the arc anode that permits the point of feeding to be varied and provides means for gradually advancing the anode as it is eroded away at the end.

It is a further important object of this invention to provide in an arc discharge device for ionizing a predetermined material supplied thereto a support for the arc cathode and a support for the filament that indirectly heats the said cathode, that permits the said filament and the cathode to expand linearly as a result of temperature change while maintaining a predetermined alignment.

It is a further object of this invention to provide in an arc discharge device for ionizing a predetermined material supplied thereto, a support for the arc anode that permits the spacing between the anode and the cathode to be altered for the purpose of starting the arc discharge.

Further objects and many of the outstanding advantages of this invention will be appreciated more fully as the above becomes better understood by reference to the following detailed description of a preferred embodiment when taken with the accompanying sheet of drawings wherein:

Figure 1 is a detailed elevational view of the preferred embodiment of the present invention shown largely in cross section, the section being taken on line 1—1 of Figure 2;

Figure 2 is an end view of Figure 1, the section being taken on line 2—2 of Figure 1; and,

Figure 3 is a wiring diagram illustrating the electrical connections involved in the operation of the present invention.

Referring now to the drawings and more particularly to Figures 1 and 2, an ion source is illustrated that is adapted to be positioned within an evacuated chamber housing an ion utilization apparatus. In supplying ions to an isotron type of isotope separating apparatus as described in U. S. Patent 2,606,291, Robert R. Wilson, filed March 11, 1946, the ion source of the present invention may be used in a "two-way" isotron tube, i. e., a tube of twice normal length having the source at the center with provisions for accelerating ions from this source in both directions. This arrangement doubles the geometric efficiency of the source and requires that the source unit must have all the supports and leads entering through the side of the source chamber (in a direction perpendicular to the axis of the tube) rather than from the end as in the case of "one-way" isotron tubes. The central portion of the isotron tube (not illustrated) may be insulated from the tube proper so that the source unit supported therein may be maintained at a high potential of the order of 20,000 volts relative to accelerating electrode structure (not shown) supported within the tube and maintained at ground potential. The accelerating electrodes thus provide the electric field necessary for withdrawing the ions from the source unit along the tube axis in both directions and for accelerating these ions to a high velocity.

More specifically, the ion source electrodes are shown supported and sealed in a water-cooled metallic end plate 10 in insulated relation therewith, and this end plate is provided with a pair of concentric circular grooves 11 and 11' into which are inserted the packing ring-gaskets 12 and 12'. These ring-gaskets are firmly compressed by suitable bolt means (not shown) into the grooves 11 and 11' in the end plate 10 and into the cooperating grooves formed in the annulus 14 to maintain the air-tight integrity of the chamber housing indicated at 15. The end plate 10 is shown provided with four diametrically aligned openings 16, 17, 18 and 19 for supporting respectively in the insulated and sealed bushings 16', 17', 18' and 19'; the wire feeding assembly 20, the anode rod assembly 21, and the lead-in conductors 22 and 23 for the electron emissive filament 24. Another opening is also provided in the end plate 10 in a position offset from the diametrically aligned openings for receiving in an insulated and sealed bushing 25 the lead-in conductor and support 26 of the helical tubular cathode 27.

The bushing 17' for supporting the anode rod assembly, as illustrated, comprises a metallic sleeve 28 which is inserted into the opening 17 and secured thereto by being welded to the outside surface of the end plate 10. This metallic sleeve is provided with an inwardly projecting portion 29 having a cylindrical groove or recess 30 formed therein for receiving an end of the tubular insulating member 31, formed of quartz or other suitable refractory material. The portion of the metallic sleeve 28 that projects toward the high pressure side of the plate 10 is of an enlarged diameter and internally threaded at an end thereof to receive the compression packing gland 33. This gland is provided with a central opening that is flared outwardly so as not to interfere with the tilting of the anode rod assembly extending therethrough; and has an end surface in abutting relation with the end surface of the cylindrical insulating bushing 34. This cylindrical insulating bushing 34 has a portion that is of enlarged internal diameter into which is inserted respectively, the rubber-like washer 35 and the conically shaped metallic spacer and force transmitting member 36. This spacing member is also provided with a cylindrical groove 39 formed in the end surface opposite that which abuts the rubber-like washer 35 and into which is inserted suitable packing material and the other end of the tubular insulating member 31.

It is clear, thus, that an insulated and gas-tight seal may be provided for supporting the concentric and spaced apart tubes 37 and 38 of the anode assembly in the opening 17 by taking up on the gland 33 which compresses the rubber-like washer 35 against the spacing member 36, which in turn transmits this force to the ends of the tubular insulating member 31 forcing this member into the gasket material positioned within the recesses 30 and 39. The seal of the outer tube 37 is maintained by the contact of this tube with the rubber-like washer 35. The principle of the seal is that the outer tube 37 slides through the thin piece of sheet rubber forming the washer 35 in which a hole is punched of a diameter considerably smaller than the diameter of the tube. The rubber close to the tube is thus distorted and bent out of its normally plane surface. This bend in the rubber-like washer is maintained toward the high pressure side of the seal by the conically shaped spacing member 36. The gas pressure (from the right hand side of the device as shown in Figure 1) as well as the elasticity of the rubber, forces the inner edge of the rubber washer intimately against the tube 37 so that

no air can leak past the seal on translation of this tube within the bushing.

The anode rod 40, which is formed preferably of tungsten, is supported within the tube 38 so as to project outwardly a distance from the block 41 to which ends of both the tubes 37 and 38 are rigidly secured and sealed. This anode rod is welded or otherwise secured to the elongated rod 42 formed of steel, for example, which is shown projecting through the modified type of Wilson seal 43, (i. e., a seal developed by Robert R. Wilson described in vol. 12, 1941, pages 91–93 of the Review of Scientific Instruments), and is threaded to engage a stationary internally threaded chuck 45. Rotation of the rod 42 in the chuck 45 causes the anode 40 also to be rotated and advanced steadily an amount depending upon the pitch of the threaded parts. It is clear thus that the rod anode may be rotated to change the point of feed of the metal wire 46 and also that the tip of the rod may be advanced as it erodes. Although manual means 44 is illustrated for rotating and advancing the anode, it is apparent that a motor drive may be provided for continuously or intermittantly rotating and advancing the anode. To cool the anode and its supporting structure, the concentric and spaced apart tubes 37 and 38 are partitioned longitudinally a substantial distance of their length so that a cooling fluid may be circulated longitudinally through the annular spacing between these tubes by the supply and return conduits 47 and 48. A collar or plug 49 formed preferably of Lavite or other good insulating and refractory material is secured to the tube 37 so that it may be moved into and out of a position of engagement with the peripheral surface 49' of the metallic sleeve to aid in support of the anode assembly.

The cathode 27 of the arc discharge electrodes comprises a tightly wound wire helix, one end of which is secured in a plate 51 by being inserted into a suitably drilled opening formed therein and held in place by a set screw, for example. This plate is in turn fastened to the water-cooled block 52 by means of the screw 53. As illustrated, the opening 54 in the plate through which the screw 53 extends, is preferably oversized to permit easy adjustment and accurate alignment of the cathode 27 with respect to the filament 24.

The leads 22 and 23 for the filament 24 are supported and insulated from the end plate 10 by the sealing glands 18' and 19'. Any number of insulating seals known to the prior art may be used for the leads 22 and 23. By way of specific example, one markedly successful seal is illustrated in Figure 1 for supporting the lead-in-conductors 22 and 23 and the supporting tube of the wire feeding assembly 20. Since each of these sealing glands are similar in construction, the gland shown for supporting the lead 23 only, will be described in detail. This gland 19' consists essentially of a metallic insert 60 in the form of a cylindrical bushing which is silver soldered or otherwise securely retained in the drilled opening 19 of the end plate 10. The end of the bushing extending to the high pressure side of the end plate is of an enlarged internal diameter and is internally threaded to receive the packing gland 61. The inner surface of the metallic insert at the point of enlargement in diameter provides a shoulder in which is machined an annular groove 62 for receiving the packing ring 63 and an end of the tubular insulator 64 that may be formed of quartz or some other suitable refractory material. A suitable spacing member 65 of copper, for example, surrounds the lead 23 and is adapted to be positioned within the metallic insert 60. The end surface of this spacing member that abuts the quartz insulator 64 is provided also with an annular groove 66 for receiving this end of the said insulating sleeve. A packing ring 67 is also shown positioned within the groove and interposed between the end surface of the insulating sleeve. A bushing 68 of insulating material is shown positioned between the spacing member 65 and the packing gland 61. This bushing has a uniform diameter over a greater portion of its length and surrounds the lead 23 where it projects outwardly through the packing gland 61 serving to insulate this lead from the gland structure. The inner end surface of this insulating bushing 68 abuts the packing ring 69 forcing this ring into a suitable recess formed in the face of the spacing member 65. A portion 70 of the bushing 68 is of enlarged diameter so as to provide a flanged surface abutting the end of the gland 61, compressing the seal washer 72, and serving to transmit this compression force through the spacing member 65 to the quartz cylinder 64 to cause the ends of this sleeve to be firmly pressed against the packing rings 63 and 67 to form an air tight seal.

In order that the filament 24 may be supported centrally along the axis of the helically wound cathode 27, the lead-in conductors 22 and 23 are each respectively recessed in and secured to a pair of rigid upstanding blocks 73 and 74 which have aligned openings drilled therein for receiving the filamentary rod 24; and retaining this rod in a position along the axis of the helical cathode. The end of the filamentary rod 24 that extends through the opening formed in the block 73 is rigidly secured in this opening by means of a set screw, for example. The other end of the rod is not rigidly supported within the opening formed in the block 74, but is free to move longitudinally through this block. In this manner the block 74, although rigidly mounted, serves as a guide for said filament permitting expansion in a linear direction. To provide the electrical connection to this end of the filament rod and at the same time permit this longitudinal movement allowing for the thermal expansion of this filamentary rod and preventing a warping of the rod out of the axis of the cathode; this end of the rod is rigidly secured to a plate 75 by extending through a drilled opening formed therein and by being secured in this opening by means of a set screw, for example. This plate 75 is in turn secured to the block 74 by a U-shaped leaf spring 76, thereby permitting the plate to move relative to the block on the thermal expansion of the filamentary rod. It is apparent, thus, that only one end of the filamentary rod 24 is rigidly secured, the other end being free can slide relative to the block 74 which serves only as a guide; and that the electrical connection is made by the plate 75 through a U-shaped spring strip 76. Thus, when the filament is heated, it will remain straight by pushing the plate 75 away from the rigidly supported block 74.

The feeding of the metal to be vaporized and ionized is accomplished by pushing a wire 46 through a guide tube 81 so that it touches the anode rod 40 near the center of the arc. The wire enters the vacuum through a suitable double-sliding seal indicated at 82 in the drawing. This seal is shown provided with an outlet 83 which extends to an auxiliary pump for evacuating the space between the two seals. The wire is pushed in

through the guide tube, preferably by a pair of steel rollers (not shown) driven by a suitable motor which is energized for about two seconds every minute by means of a suitable switching apparatus. The stopcock illustrated at 84 is provided in the feeding line for convenience in changing wires without letting air into the vacuum system. The entire feeding assembly is insulated from other parts of the source to avoid the possibility of an arc running to the end of the feeder. A cooling tube 85 is shown extending through the supporting tube of the wire feeding assembly 20 in contact with the feeding tube 81 for the circulation therethrough of a cooling fluid to prevent the wire from becoming heated in the said tube to deleteriously effect the feeding operation.

Each of the lead-in conductors for the cathode assembly is shown provided with suitable squirt tubes 86 for circulating cooling fluid through the conductors and regulating heating from the cathode and filament at its position of support. As illustrated, the squirt tubes 86 and the lead-in conductors both terminate in a cylindrical metallic body 87. This cylindrical body 87 has an enlarged hollow portion which contains the packing gland 88 for effecting an air-tight seal between the lead-in conductor and the cylindrical body, the packing material 89 and the exhaust connection 90, the hollow portion of the cylindrical body having the smaller diameter connects to the cooling fluid supply conduit 91 and supports the squirt tube 86 concentrically within the lead-in conductor. Thus, a cooling fluid under moderate pressure may be forced through the inner squirt tube 86 (which terminates a short distance from the end of its respective conductor) and returns around the inner tube to exhaust.

Ignition of an arc, in general, depends upon the electric field and the gas or vapor pressure present. In the arc of the type above described, the metal vapor is supplied at the anode where the anode is heated by electron bombardment. The criterion for starting is that the high vacuum thermionic emission from the hot cathode is sufficient to raise the anode temperature to a point where appreciable metal evaporation occurs. At this point, ions are formed which neutralize the electron space charge between the anode and the cathode and allows more current to pass. This in turn causes an increased heating of the anode and so on until an equilibrium dictated by the external power circuit of the arc is reached and the arc is running steadily. The space charge limited thermionic current between plane electrodes varies inversely as the distance of separation according to the Langmuir-Child's equation. Accordingly, if the distance between the anode and the cathode can be altered (decreased), the voltage required for starting can be greatly reduced thereby reducing the danger of failure of the insulating glands. Accordingly, variation of spacing is provided in the present invention by having the anode support enter the vacuum system through a tipping and sliding vacuum seal. To tip the anode rod for starting and altering the spacing between it and the cathode, the anode rod assembly is pushed forward in its sliding seal to dislodge the supporting plug or flange 49 from its engagement with the inner cylindrical surface 49' of the metallic socket 28. The anode is now free to be tilted close to the cathode. After starting, the anode is again brought back to its horizontal position and the supporting structure is withdrawn through the sliding seal to cause the plug or flange 49 to be inserted into its socket to firmly engage the cylindrical surface 49'.

Referring now to Figure 3 of the drawing, there is shown in the wiring diagram the circuit connections necessary for operation. As illustrated, the filament 24 is heated by alternating current furnished by a transformer 92 which may be provided with a suitable variac control in the supply of its primary. After the filament 24 has been brought to the desired or proper electron emissive temperature, the filament and cathode are connected in circuit with a direct current supply voltage indicated at A in the drawing. This connection is such that the cathode 27 is made positive with respect to the filament 24 so that the electrons emitted by the entire filament surface will be accelerated by the potential difference between the filament and cathode and bombard the cathode to raise its temperature. After the cathode 27 has been heated to its desired electron emissive temperature, the anode 40 is tipped down to decrease the cathode-anode spacing; and the voltage sources indicated in the drawing at G and B are connected in circuit with the anode to make the anode highly positive with respect to the cathode.

Since the initial heating of the anode 40 must be accomplished by purely thermionic electron current from the cathode 27, a high booster voltage B is connected in series with the arc generator G. Once the arc is struck, however, the boosted voltage B is shorted out by means of the switch S and is turned off or otherwise disconnected so that the arc continues to run directly on the generator supply source G.

In view of the foregoing, it will be apparent that what is illustrated and described is but a preferred embodiment of the invention that has been constructed and successfully operated wherein the arc cathode is a 9 turn coil of 100 mil tungsten wire made by winding this wire on a $\frac{3}{8}$'' diameter steel rod. The winding is easily accomplished in an oxygen or hot gas flame if one is careful to keep the tungsten heated to a bright red heat at the point of bending. The filament also comprises a 100 mil diameter tungsten rod and in the specific illustrated embodiment is heated by an alternating current furnished by a 10 volt 400 ampere transformer; a current of about 275 amperes being required. The anode is a $\frac{3}{8}$'' diameter tungsten rod and is connected to the cathode through a 600 volt booster circuit in series with an arc generator. A 600 volt, 10 ampere, full wave rectifier circuit (A) is connected between the filament and the cathode to supply the power to heat the cathode. A thermionic current of about 1 ampere at 600 volts is required to heat the cathode to a sufficiently high temperature. The feeding of the wire to the anode is accomplished by pushing a $\frac{1}{16}$'' diameter uranium wire through a $\frac{3}{16}$'' diameter copper guide tube so that the wire touches the anode near the center of the arc. It is conceived that the structure illustrated may be modified in a substantial manner without departing, however, from the spirit and scope of this invention as defined in the adjoining set of claims.

What is claimed is:

1. In an ion source, in combination, a rod-like anode, a cathode spaced from said anode, means for supplying to a predetermined locality of said anode successive quantities of the metal to be ionized, means for establishing an arc discharge

between said anode and cathode for melting, vaporizing and ionizing said metal, and means for moving said anode relative to the locality of metal supplied thereto and means for longitudinally advancing said anode relative to said cathode for preventing localizing impairment of said anode.

2. In an ion source, a tubular cathode, a filament extending axially from within said cathode and spaced from the interior thereof, a guide for said filament, means rigidly mounting said filament at one end, and means including said guide for flexibly mounting said filament at the other end whereby upon thermal expansion said filament will remain straight and at the axis of said cathode.

3. In an ion source, a tubular cathode, a filament extending axially within said cathode and spaced from the interior, a support, means rigidly mounting one end of said filament to said support, a rigid guide means for said filament, electrically conductive means flexibly mounting said filament to said guide whereby upon thermal expansion said filament will remain straight and at the axis of said cathode, a potential source for heating said filament and means for applying said source to said filament through said support and guide.

4. In an ion source, a tubular cathode, comprising a closely wound helix of a thermally electron emissive wire, a support, and means securing said cathode to said support at an end thereof whereby to permit said cathode to expand thermally in a direction parallel to its axis.

5. In an ion source arc structure for ionizing a predetermined material, said structure comprising a cathode, means for bombarding said cathode with electrons to heat said cathode to electron emissive temperature, an anode spaced from said cathode, means of feeding onto said anode successive quantities of said material to be melted, vaporized and ionized, and means for altering the cathode anode spacing to heat said anode by electron bombardment from said cathode to establish an arc discharge in the vapor of said material.

6. In an ion source, arc structure for ionizing a predetermined material supplied thereto, a wall member cooperating to form a housing for said arc structure adapted for evacuation to the low pressure, said arc structure comprising a rod-like anode, a holder for said anode, and means within said wall for annularly engaging said holder at two separate regions spaced longitudinally thereof, to retain said rod-like anode in a rigid position, said holder being longitudinally displaceable to disengage said means at one of said spaced regions whereby said rod-like anode may be tilted in said wall structure.

7. In an ion source, arc structure for ionizing predetermined material supplied thereto, a wall member cooperating to form a housing for said arc structure adapted for evacuation to a low pressure, said arc structure comprising a rod-like anode, a holder for said anode having a plug secured thereto, flexible means surrounding said holder at a position spaced longitudinally of said plug for supporting said holder in sealed relation within said wall, a socket for receiving said plug to retain said holder and rod-like anode in a rigid position, said plug being displaceable longitudinally from said socket thereby permitting tilting of said holder and rod-like anode.

8. In an ion source arc structure for ionizing predetermined material, a wall member cooperating to form a housing for said arc structure adapted for evacuation to a low pressure, said arc structure comprising a tubular cathode, means supported axially within said cathode for heating said cathode by electron bombardment therefrom, a rod-like anode, a holder for said anode, means within said wall for annularly engaging said holder at two regions displaced longitudinally thereof to retain said rod-like anode in a rigid position spaced from said cathode and parallel to the axis thereof, means for feeding onto the surface of said anode opposite that facing said cathode successive quantities of said material to be melted, vaporized and ionized, said holder being longitudinally displaceable to disengage said means at one of said localities whereby said rod-like anode may be tilted about its position of annular engagement with said means at said other locality to decrease the cathode anode spacing to increase the heating of said anode by electron bombardment from said cathode to establish an arc discharge in the vapor of said material.

9. In an ion source, arc structure for ionizing a predetermined material, a wall member cooperating to form a housing for said arc structure adapted to evacuation to a low pressure, said arc structure comprising a tubular cathode and a rod-like anode; a holder for said anode having a plug secured thereto, annular means within an opening formed in said wall member surrounding said holder and engaging said holder at a restricted region thereof for flexibly supporting and sealing said holder in said opening, a socket adapted to receive said plug for rigidly retaining said anode in position spaced from said cathode and parallel to the axis thereof, said holder being longitudinally displaceable in said annular means to move said plug out of said socket thereby permitting tilting of said holder and rod-like anode out of its parallel relation with the axis of said cathode to decrease the anode-cathode spacing.

10. In an ion source, arc structure for ionizing a predetermined material, a wall member cooperating to form a housing for said arc structure adapted for evacuation to a low pressure, said arc structure comprising a tubular cathode and a rod-like anode, a holder for said rod-like anode having a plug secured thereto, a sleeve adapted to receive said holder, said sleeve being sealed in an opening formed in said wall member and having a socket in an end thereof for receiving said plug, annular flexible means secured in said sleeve and surrounding said holder of a restricted region thereof for sealing said holder in said sleeves whereby said rod will be rigidly supported in position spaced from said cathode with the axis of said rod parallel to the axis of said cathode, said holder being longitudinally displaceable in said annular means for disengaging said plug and socket thereby permitting tilting of said holder and said rod-like anode.

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