

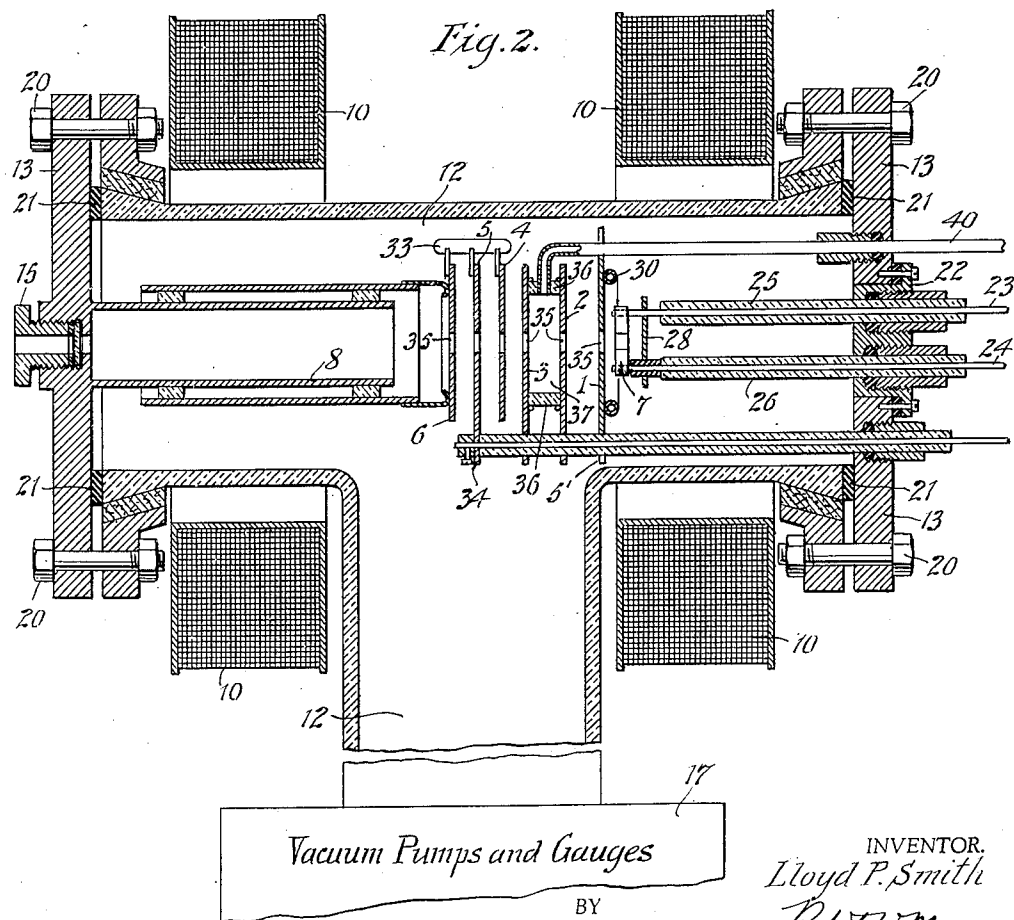
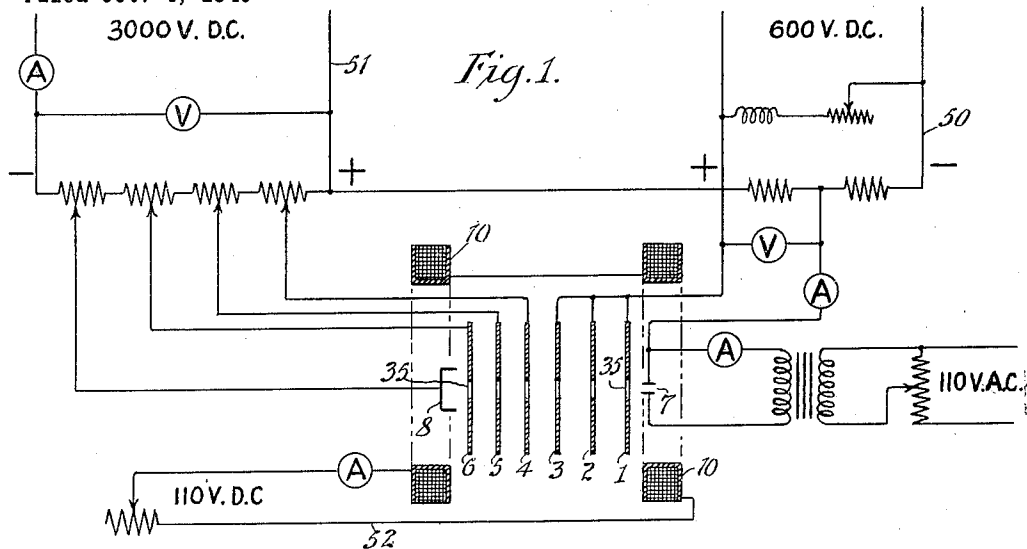
May 16, 1950

L. P. SMITH
ION SOURCE

2,507,652

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3 Sheets-Sheet 1



Vacuum Pumps and Gauges

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3 Sheets-Sheet 2

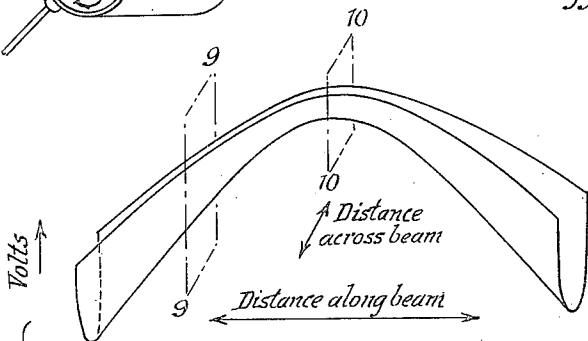
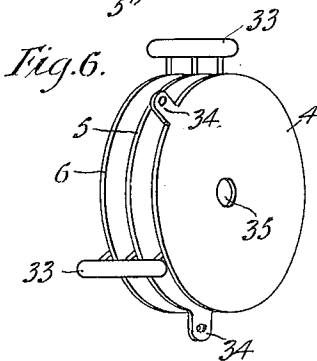
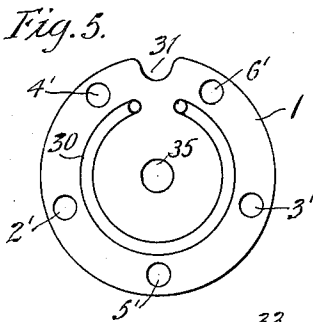
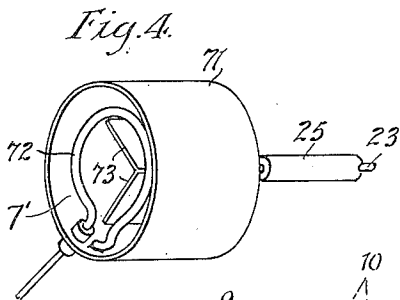
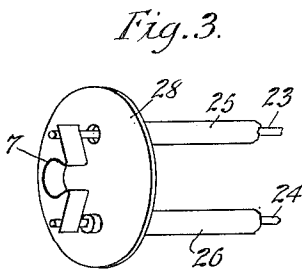


Fig. 8.

Fig. 9.

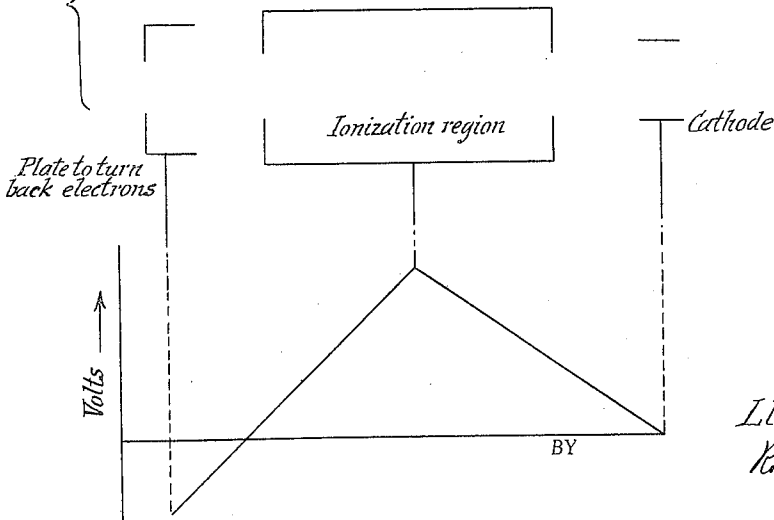


Fig. 10.



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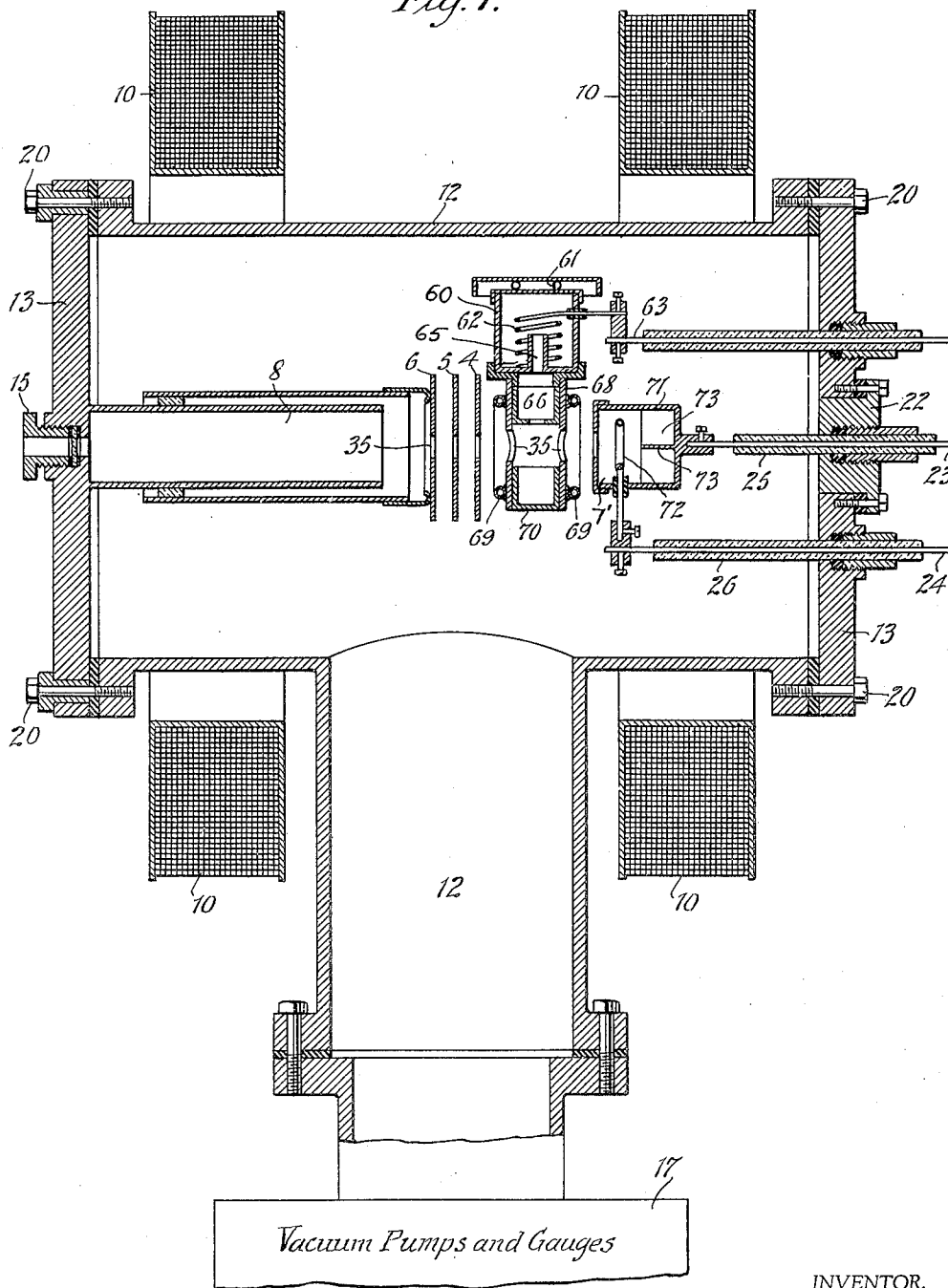
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3 Sheets-Sheet 3

Fig. 7.



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ION SOURCE

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3 Claims. (Cl. 250—41.9)

1

This invention relates to matter and electricity, and particularly to the production of an ion source of relatively high efficiency, so that the atoms of various materials may be more readily ionized. Ionization is useful in the chemical and physical fields, as is well known—for example in chemical combinations, production of isotopes, nuclear transmutations, production of light, transfers of energy—and various ion sources have been developed in the past. The principal object of the present invention is to improve the efficiency of ionization and reduce the cost and complexity of such apparatus, with a view to furthering the practical utilization of such phenomena. Various other objects will become apparent as the description proceeds.

One general method of ionization has been to direct a beam of electrons thru volatilized matter, so that the atoms in the vapor are ionized by electron collisions. As the spaces in the atomic particles are relatively great, and the electrons are relatively small and travel with great speed, the collisions have not been very frequent. In order to increase the probability of collision, I have invented a method by which the electrons are compelled to pass back and forth thru the atoms a great many times, until the collision takes place, instead of merely passing thru once. Another important feature of the device is that all of the ions thus produced can be extracted for useful purposes without the loss by escape heretofore common. The efficiency of ionization is thereby greatly increased. The ions produced by such collisions are controlled so that they pass down the axis of the electron beam, in which they are held by the increasing electron space charge as the electrons slow down to reverse their direction. In general the invention is characterized by oscillating electrons with the ion path controlled by the electron beam.

Referring now to the drawings, Fig. 1 is a schematic diagram of one form of the apparatus, of which Fig. 2 shows a typical constructional form in greater detail, in cross-section. Fig. 3 is a perspective view of one type of cathode. Fig. 4 is a perspective view of another type of cathode. Fig. 5 is an elevation view of the water cooled first plate. Fig. 6 is a perspective view of the fourth, fifth and sixth plates comprising the ion gun. Fig. 7 is a cross-sectional view of another typical form in which a continuous stream of atoms is intercepted by a transverse electron stream. Fig. 8 is a diagram of the potential fields. Fig. 9 is a cross-section on the plane 9—9 of Fig. 8. Fig. 10 is a cross-section on the plane 10—10 of Fig. 8. Similar reference numerals refer to similar parts thruout the various views.

The apparatus may be described in general as consisting of a cathode for emitting electrons, a positive field to accelerate the electrons up to the

2

point where the stream of atoms to be ionized is crossed, and then a negative field on the other side of said stream to stop and reverse the electrons that have slipped thru and compel them to pass thru the stream of atoms repeatedly until an electron strikes an atom and ionizes it; in which case the ionized atom escapes along the axis of the electron beam, in which it is held by the electronic space charge. The active electrons oscillate with great rapidity back and forth between the cathode which repels them on the one hand and the negative field on the other side of the atomic stream which repels them on the other hand; so that the electrons are bounced back and forth indefinitely until they finally collide with atoms. It will be seen that the chances of electrons colliding with atoms to ionize them are thus very greatly increased; and this has been confirmed by the results obtained.

In the apparatus illustrated in Fig. 1 and Fig. 2 for example, the field which compels the electrons to shuttle back and forth thru the atomic stream is produced by a number of suitably charged plates, of which various numbers may be used, six being shown in the example illustrated. Of these, plate 1, plate 2 and plate 3 are positively charged to accelerate the electrons, and plate 4, plate 5 and plate 6 are negatively charged to retard, reverse and accelerate the electrons back again in the opposite direction. The electrons are originally shot off by the cathode 7, adjacent plate 1, and the ionized atoms are caught by the collector 8 on the opposite side beyond plate 6. Holes 35 in the centers of the plates provide a path thru which the electron beam extends, and the atoms to be ionized are introduced at any suitable intermediate point where they will cross the path of the electrons, as for example between the plates 2 and 3. The electrons are held together by a uniform magnetic field parallel to the axis of the electron beam, this field being created by the magnetizing coils 10.

The foregoing parts, shown in the schematic view, Fig. 1, are shown in the greater detail of an actual structure in Fig. 2, in which the plates are enclosed in a "Pyrex" glass T-shaped flanged pipe fitting 12, one branch of which carries the lead-in plate 13 supporting the various plates described, the opposite branch containing the ion collector 8 and observation window 15, and the third leg of the T leading to the vacuum pumps 17 by which the low pressure in the apparatus is maintained.

The leads to the cathode and the various plates described extend thru the lead-in plate 13, and these leads are also used as a convenient means for supporting the cathode and plates in the glass T member 12. The lead-in plate 13 is clamped over the opening of the glass T member 12 by the bolts 20, using a rubber packing 21 to

3

make it gastight. The cathode assembly is carried on a removable plug 22 sealed in the center of the lead-in plate 13, the lead-in wires 23 and 24 being sealed in glass tubes 25 and 26 respectively, which support them. The cathode 7 is carried on the end of the wires 23 and 24, and while this particular form of the cathode is immaterial, so long as it is a metal heated sufficiently to give off electrons, the cathode 7 illustrated is made of a strip of roughened or protruded nickel oxide coated on both sides. This is backed by a heat shield 28 and the general form may be seen in the perspective view of Fig. 3.

The first plate 1 which carries a positive electric charge is cooled by the water pipe 30, which is soldered or welded to it and which also serves as the electrical connection and supporting member. This plate 1 is shown in elevation in Fig. 5 as well as in cross-section in Fig. 2, and it will be seen from Fig. 5 that it has five holes 2', 3', 4', 5' and 6' around its rim as well as a notch 31 in the top. The five holes are for the passage of the leads to the plates 2, 3, 4, 5 and 6 respectively, which leads also serve as supports. For the same reason plate 2 has four such holes and plate 3 has three. Bringing the leads thru the plates in this manner gives rigidity to the system. Plates 4, 5, and 6 comprise a separate unit (also shown in Fig. 6), which will be referred to as the ion gun, and this is mounted rigidly and accurately parallel by means of the glass beads 33, which also serve as insulation. At points between the glass beads 33 the plates 4, 5, and 6 are provided with projections 34 for electrical connections and mechanical supports. In operation these plates 4, 5, and 6 are negatively charged so as to repel the electrons. All the plates 1, 2, 3, 4, 5, and 6 are provided with central holes 35 to permit the passage of the electron beam.

A cylindrical glass wall 36 is provided between plates 2 and 3 to enclose a chamber 37 into which the gas or vapor containing the atoms to be ionized may be introduced. These gaseous atoms are led in thru the tube 40 which extends over the top of plate 1 thru the notch 31 shown in Fig. 5. This suffices when the material to be ionized is in the form of a gas or vapor brought in from an exterior source. The material to be ionized can also be volatilized within the apparatus, as is sometimes desirable with solid materials for example, and that will be described further in connection with Fig. 7.

The apparatus is energized as shown for example in Fig. 1, the plates 1, 2, and 3 being maintained at the same positive potential and plates 4, 5, and 6 diminishing in steps to the negative potential of the collector 8. The power for the cathode 7 and the first three plates 1, 2, and 3 was in a typical installation, supplied by a 600 volt D. C. generator system; the power for the plates 4, 5, and 6 and collector 8 was from a 3000 volt D. C. system; and the magnetic coils 10 were energized by a 110 volt D. C. system 52. Any suitable sources of power may of course be used, and those shown are merely illustrative.

In operation the electrons emitted by the cathode 7 are accelerated by the plates 1, 2 and 3, due to their positive potential, the electron stream passing thru the holes 35 in the plates and shooting thru the atoms of the material to be ionized, as that vapor flows down between plates 2 and 3 and crosses or flows thru the stream of electrons. The purpose of the apparatus is to cause collisions between the atoms and electrons and thereby create the ionized atoms desired. The electrons

4

being relatively small and fast particles as compared with the atoms, and the spaces between the atoms being relatively great, it is known from past experience that an electron may shoot thru a great many atoms without collision. Therefore, in order to increase the effectiveness of the apparatus, the present invention compels such electrons—that have passed thru the atoms without collision—to return and pass thru the stream of atoms repeatedly until collision results. To accomplish this the plates 4, 5, and 6, known as the ion gun, are given such reversed potentials as to slow down, stop and turn back the electrons that are still free and have not collided with atoms. These returning electrons are accelerated by the potentials of the plates 4, 5, and 6 back toward plate 3; and passing thru the region of plates 3, 2, and 1, encounter the negative field of the cathode 7, which together with the positive plates 1, 2 and 3 sends them back again thru the atoms as before. This shuttling process is repeated indefinitely, and the electrons oscillate back and forth until they are picked up by one of the plates or stopped by collision with atoms. In the latter event the ionized atoms emerge along the axis of the electron beam, being held there by the electronic space charge.

The controlling potentials created by the electron and ion space charges in the magnetic field are illustrated in Fig. 8, Fig. 9 and Fig. 10. The magnetic field created by the coils 10 restricts the electrons to a beam, and the resulting electron space charge, which increases as the electrons slow down and come closer together, forces the ions to travel along the axis of the beam. The distribution of potentials is shown diagrammatically in Fig. 8. The net effect of the electron and ion space charge is to create a saddle point in the potential distribution between plates 2 and 3, as indicated in the upper part of Fig. 8, so that all the ions are confined to the beam and all those produced on the ion collector side of the saddle point are accelerated toward the collector 8. The potential also varies as one passes farther from the axis of the beam, so that cross-sections of the saddle such as Fig. 9 and Fig. 10 are U-shaped. It will be noted that the magnetic field does not control the ions directly; but that the magnetic field controls the electrons, and the electrons control the direction of the ions. The fact that the electrons (which are negative particles), increase their space charge as they slow down, results in confining the positive ions to a beam which permits the ions to be readily extracted along the axis. This arrangement of the space charge to confine and extract the ion beam is another characteristic feature of the present invention.

Considering the operation in greater detail, if the electrons were not stopped until they were almost at the surface of the collector, the ions would be held in the beam by the negative space charge and all the ions would reach the collector. If the potentials on the ion gun were such that the electrons were stopped sooner, say in the region of plate 4, the ions would tend to diverge from that point. It is possible in the latter case to adjust the potentials on the plates to produce a radial field which will just balance out the radial field due to space charge and keep the ions moving in parallel paths.

The extent of the electron beam can easily be seen by the excitation produced in the hydrogen. The manner in which the point where the elec-

trons are stopped draws away from the collector toward the third plate, as the potentials on the ion gun and collector are made more negative, is readily observed. During this process the ion current first decreases due to the fact that, when the collector potential is several hundred volts below the cathode potential, the electrons are stopped a considerable distance from the collector and the ions diverge because the accelerating voltage is not sufficient to collimate them. With continued decrease in the collector potential the ion current passes thru a minimum and then climbs back to its original value, when the potentials reach the values theoretically required.

The fact that this was experimentally found to be true, indicates not only the correctness of the above explanation but also that the gas pressure was much higher where the gas was introduced and that only a small fraction of the ionization could have taken place between plate 3 and the collector. As would be expected, varying the potentials of the ion gun plates makes considerable difference in the ion current when the collector potential is far below that of the cathode, but almost no difference when the collector and cathode are at almost the same potential. In some cases, especially when dealing with a solid material to be ionized, it is desirable to vaporize it inside the apparatus, instead of introducing the gas or vapor from an exterior source. The form shown in Fig. 7 provides means for vaporizing the material inside the apparatus, but otherwise is substantially the same as Fig. 2. Referring now to Fig. 7, the material to be ionized is placed in the heater or furnace 60, which is covered by a double heat-insulating lid 61. The furnace 60 contains a heating coil 62, preferably of tungsten or similar high temperature material, which receives its current thru the lead 63. The bottom of the furnace 60 is provided with orifices 65 and 66 thru which the stream of vaporized material containing the atoms to be ionized is directed down across the electron beam emitted from the cathode 7', (corresponding to the cathode 7 of Fig. 1 and Fig. 2). The furnace 60 and its associated parts are mounted on a tubular member 68 corresponding to the plates 2 and 3 of Fig. 2, and cooled by water tubes 69 (corresponding to the tubes 30 of Fig. 2), which also serve as supports. In the bottom of the member 68 is located the receptacle 70 to catch the residue.

The cathode 7' shown in Fig. 7 differs somewhat from the one shown in Fig. 2, and consists of a casing 71 containing a molybdenum stocking 72 filled with an activating salt, and a number of vanes 73 (shown in cross-section) to increase the emitting surface. This is sometimes known as the "Hull" type. The particular form of cathode is immaterial, the types shown being merely by way of example.

The operation is in general the same as Fig. 2, the stream of vaporized material passing down from the tube 66 across the line of the openings 35 containing the electron beam in which the electrons oscillate rapidly back and forth, until by chance they strike atoms to form ions, which is the desired purpose. The resulting ions escape down the axis of the magnetic field created by the coils 10, for the reason that the magnetic field confines and controls the electrons, which in turn confine and control the ions. This is due to the fact that the electron space charge, which increases as the electrons slow down and consequently come closer together, forces the ions to travel along the axis.

It will be seen from the foregoing that the principal features of the invention are the use of oscillating electrons crossing the atomic stream repeatedly, and the escape of the resulting ions being restricted to a central path by the space charges in the electron beam.

While I have in the foregoing described certain particular embodiments of the invention, it will be understood that they are merely for purposes of illustration to make clear the principles thereof, and that the invention is not limited to the particular forms described, but is subject to various modifications and adaptations in different installations as will be apparent to those skilled in the art without departing from the scope of the invention as stated in the following claims.

I claim:

1. In an ion source operating in a vacuum, the combination of an electron source providing a beam of electrons, positive potential means for accelerating the electrons, negative potential means for decelerating and reversing the electrons so that they oscillate in their beam, means for continuously supplying atoms to the oscillating portion of the electron beam, whereby the atoms may be ionized by collisions with the electrons, and means for producing a magnetic field to confine the electron beam and produce an axial path for the ions, and a collector for said ions, the vacuum being held at a moderate value to preclude diffusion of the ions to the surrounding walls.

2. In an ion source operating in a vacuum, the combination of an electron beam, a magnetic field restricting said beam, means for continuously introducing atoms to be ionized into said beam, and negative electric potential means for reversing the travel of the electrons in said beam, whereby the electrons may traverse repeatedly the region into which the atoms are introduced, to increase the chances of ionization, and a collector for extracting the ions, the vacuum being held at a moderate value to preclude diffusion of the ions to the surrounding walls.

3. In an ion source operating in a vacuum, the combination of a cathode for emitting electrons, positive potential means for accelerating said electrons, means for continuously introducing atoms in the region of said positive potential means, whereby the atoms may be ionized, negative potential means for decelerating the electrons to increase their space charge, so as to confine the ions to the axis of the electron beam, a magnetic field restricting the electron beam, and means for extracting the ions, the vacuum being held at a moderate value to preclude diffusion of the ions to the surrounding walls.

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