Jan. 6, 1953 R. W. THOMPSON 2,624,845

ION SOURCE

Original Filed Sept. 2, 1944 3 Sheets-Sheet 1

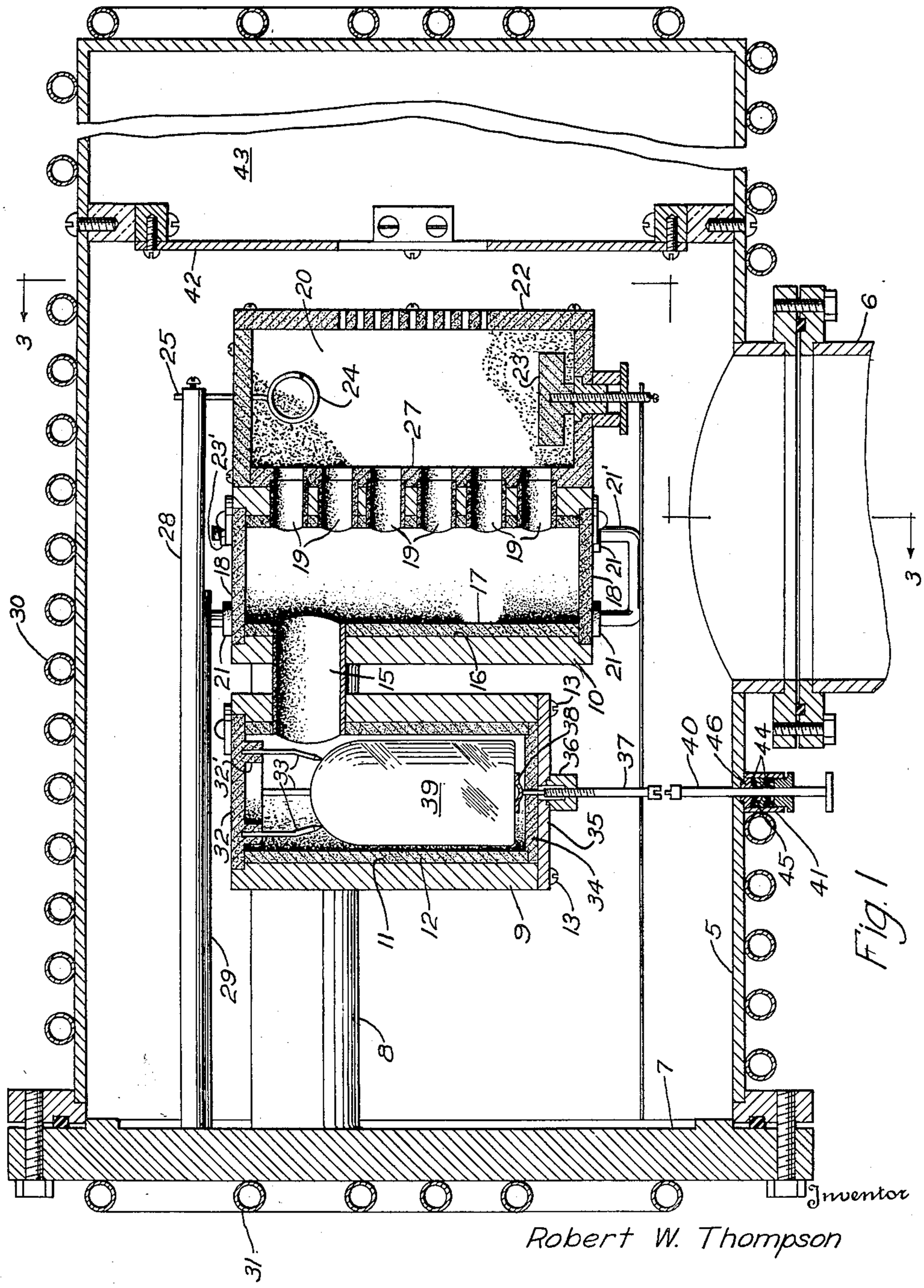

Fig. 1

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Jan. 6, 1953 R. W. THOMPSON 2,624,845

ION SOURCE

Original Filed Sept. 2, 1944 3 Sheets-Sheet 2

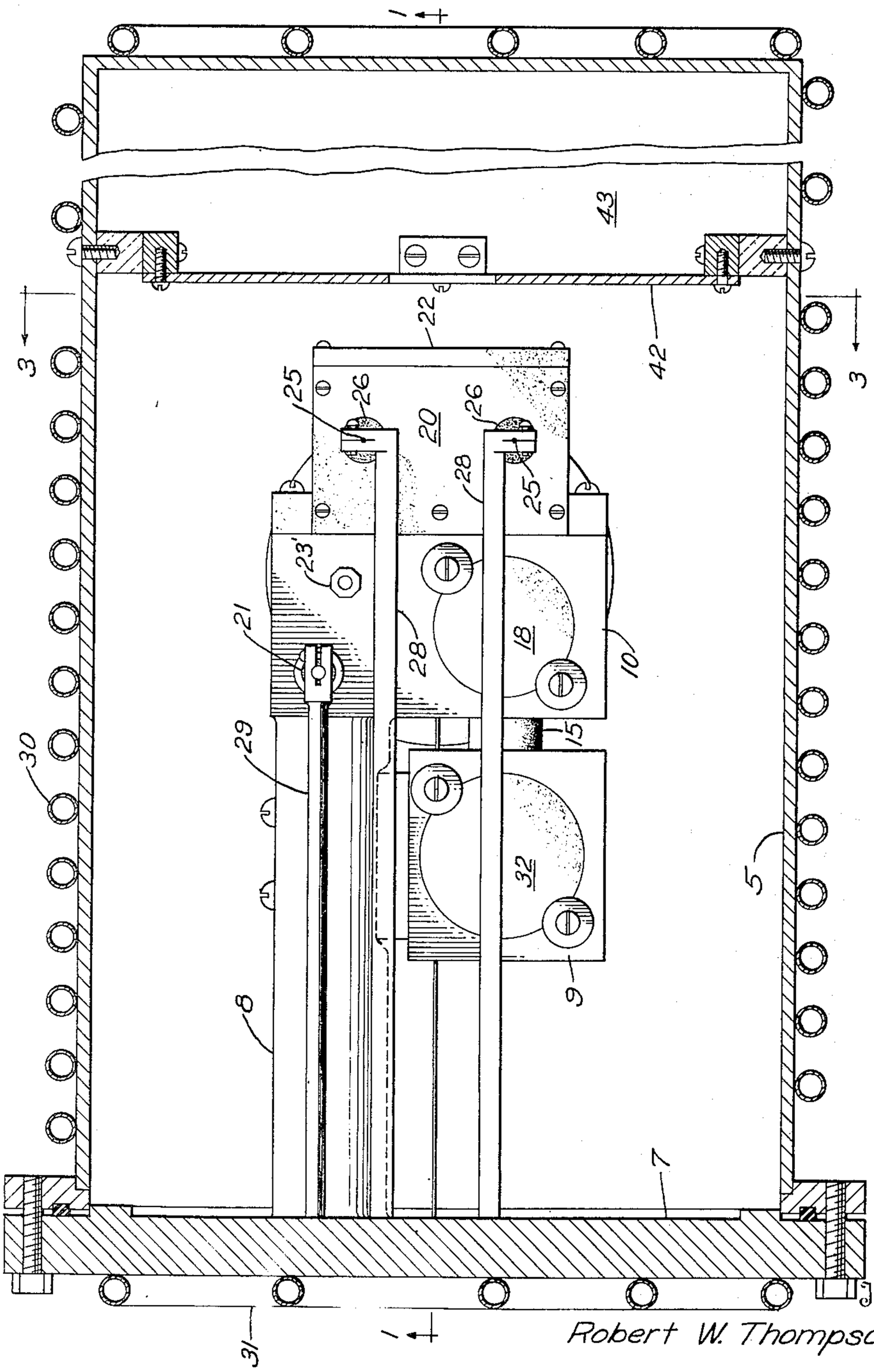

Fig. 2

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ION SOURCE

Original Filed Sept. 2, 1944 3 Sheets-Sheet 3

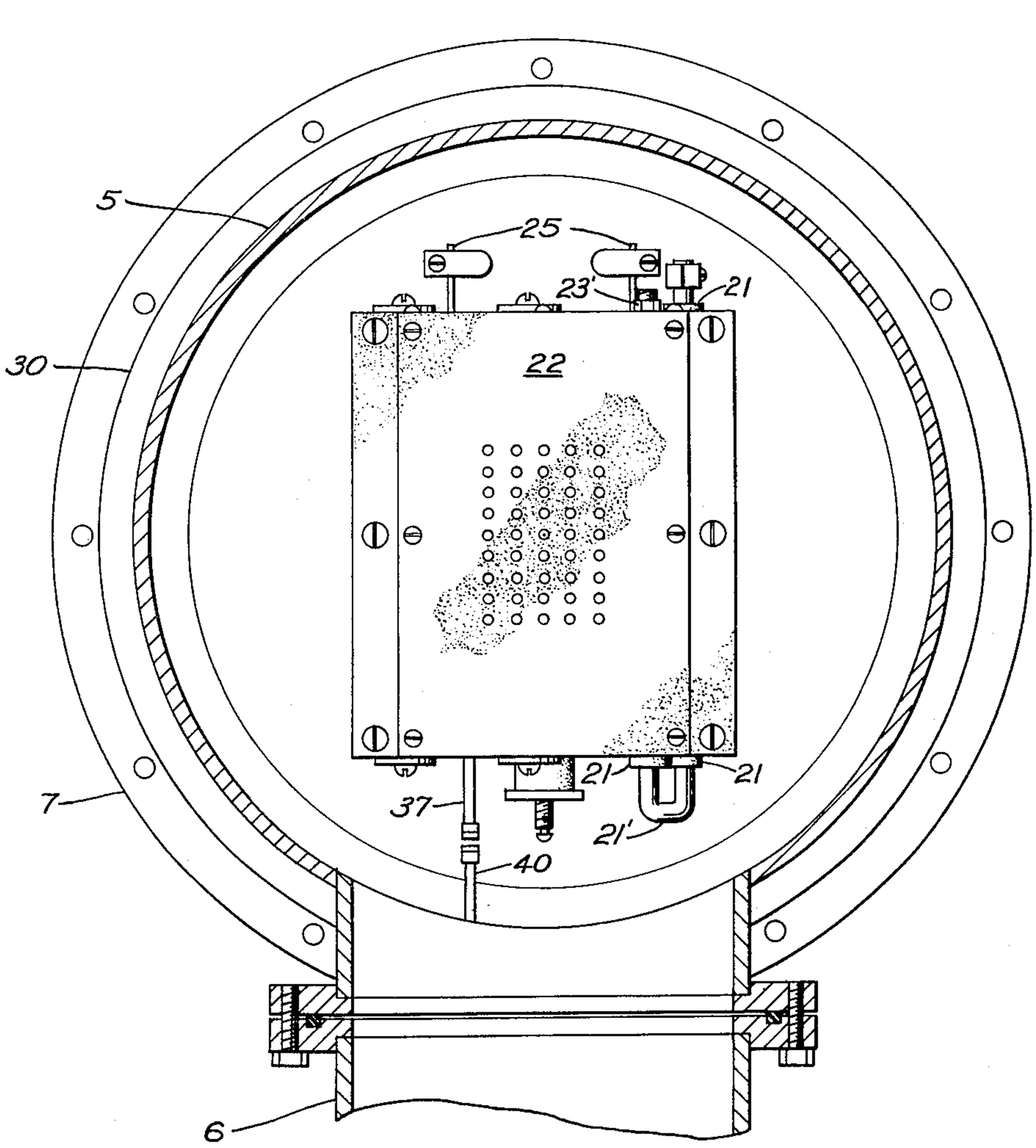

Fig.3

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UNITED STATES PATENT OFFICE

2,624,845

ION SOURCE

Robert W. Thompson, Minneapolis, Minn., assignor to the United States of America as represented by the United States Atomic Energy Commission

Original application September 2, 1944, Serial No. 552,553. Divided and this application January 16, 1946, Serial No. 641,613

10 Claims. (Cl. 250—41.9)

1

This invention relates to methods and apparatus for producing gaseous ions, especially to the methods and apparatus for producing gaseous ions of the heavy metals useful in the ionic separation of isotopes of these heavy metals and is a division of my prior application, Serial Number 552,553, filed September 2, 1944. More particularly this invention relates to new and improved methods and apparatus for producing, in vacuum, gaseous ions of the heavy metals by vaporizing in vacuum a volatile compound of these metals, especially the metal halides such as the uranium halides, and then passing an arc through the vapors thus obtained.

One type of isotope separator in which the ion source of the present invention may be advantageously used is termed an Isotron and may be found described and claimed in a copending application of Robert R. Wilson, Serial No. 653,518, filed March 11, 1946, now Patent No. 2,606,291. The "Isotron" consists essentially of an evacuated and sealed chamber, that may be cylindrical and of predetermined proportions, designed to support at one end the extended ion source of the present invention. The ions from this extended source are first accelerated by a constant, high intensity, electric field and are then further accelerated by a low intensity electric field varying at radio frequency and in "saw tooth" manner. The effect of the constant electric field is to project a strong beam of ions down the cylindrical chamber with uniform kinetic energy and therefore with velocities inversely proportional to the square root of the masses of the ions. The varying electric field introduces small periodic variations in ion velocity; and has the effect of causing the ions to bunch at a certain distance down the tube. The bunches of ions of different mass travel with different velocities and therefore become separated. At the position where this occurs, an analyzer applies a transverse focussing electric field with a radio frequency component synchronized with the travel of the bunches. The synchronization is such that the varying component of the transverse field strength is zero when the bunch of ions of the desired isotopes comes through and is a maximum when the bunch of ions of the undesired isotope comes through. In this manner the ions of the desired isotope will be focused into collector pockets supported at the end of the tube opposite the ion source whereas the ions of the undesired isotope will be deflected away from the collector pockets.

That the operation of such a device described

2

above may be effective on a production basis it is essential that the ion source be capable of producing the gaseous ions of the heavy metals in sufficient number and continuously for sufficiently long periods to permit a large scale separation of the isotope. In the operation of apparatus designed to produce a copious supply of gaseous ions from a source material consisting of a heavy metal salt notably uranium tetrachloride and uranium tetrabromide, considerable difficulty was experienced in maintaining a high vacuum while the source was in operation. These vacuum difficulties had to be overcome before the ion generating devices employing the heavy metal salts as a source material could be used to supply an isotope separating device of the general type described above, since the ionic separation can be carried out only under very high vacuum; e. g. of the order of 10^{-5} mm. Hg.

In the course of investigation undertaken to determine the cause of these vacuum difficulties it was discovered, contrary to indications resulting from experiments conducted with salt and metal sources, that the difficulties were not traceable to the particular source material itself; that is to say, the uranium tetrahalide vapors per se were found to offer no vacuum difficulties. Rather, it was found that the vapors obtained from the source material were impure and that these impurities were the cause of the vacuum difficulties. It was also observed that these impurities in the source vapor resulted not only from the impurities in the solid salt to be volatilized but more significantly from the products of reaction, consisting of non-volatile oxyhalides, oxides, hydroxides and corrosive vapors, formed when the salt vapors came into contact with materials with which they were not inert and with which they would react to liberate these products. For example, it was found that uranium tetrachloride would readily react with water vapor and oxygen at high temperatures to produce chlorine and hydrochloride gases that attack the oil in the mechanical and diffusion pumps in the vacuum system. In this respect, the tetrabromide is similar to the tetrachloride except that oxidation probably takes place more readily due to the lower heat of formation of the bromide. Thus after uranium tetrachloride or tetrabromide had been used in a given system for a time it was entirely impossible to hold a good vacuum. It was found that other vacuum troubles encountered were traceable also to the fact that these uranium salts, especially uranium tetrachloride, tetrabromide and tetraiodide are hy-

droscopic and do not reverse their water absorption readily, thus necessitating prolonged periods of out-gasing during initial evacuation.

In order to illustrate the comparatively slow rate at which the water vapor absorbed by these hydroscopic salts of uranium is given up, a piece of quite anhydrous fused uranium tetrachloride of 1.2143 grams was exposed overnight to humid air. The next morning it was found to have increased its weight through water absorption by 34.6 mg. The material was then placed in a drying vessel and evacuated through a liquid air lock. Even under the good pumping conditions prevailing 30 hours were required to remove only one-half of the water originally taken up; and all of the moisture absorbed was not removed even after 120 hours of continuous pumping.

Accordingly it may be stated that the vacuum difficulties encountered in experimentation with these early sources were found to be traceable to the following: (1) the slow rate at which moisture can be pumped from the hydroscopic salt, and (2) the oxidation of the salt at elevated temperatures with consequent release of corrosive gases.

After the discovery of the cause of these vacuum difficulties encountered in the ion sources utilized prior to this invention, it was realized that the said salt source material must be maintained very pure and strictly anhydrous to be converted into a vapor while maintaining a high vacuum. Accordingly, it was proposed that a pure source material be obtained by distillation under vacuum into a sealed and evacuated frangible capsule or receptacle which is to be introduced into the vapor generator of the ion source prior to the application of vacuum pumps to the system. In utilizing the capsule technique the system may be out-gassed after the capsule is inserted for a sufficient period at an elevated temperature, essentially of the order of the operation of the apparatus. The apparatus is then brought to the desired operating temperature at high vacuum and the capsule is fractured or otherwise opened to permit the flow of the vapor of the material contained therein, into the arc region for ionization. With the discovery of the capsule technique; i. e., the employment of a sealed capsule containing an anhydrous source compound, purified by distillation under vacuum, it was possible to isolate the main cause of the vacuum difficulties of the prior ion sources. It was found that by utilizing the capsule technique the pressure in the system remained at the desired low value (about 2×10^{-5} mm.) continuously throughout the run. However if air was admitted to the system after the capsule was broken the pumping down and out-gassing time was materially increased.

It is therefore a primary object of this invention to provide an improved ion source unit utilizing a sealed receptacle containing a relatively pure anhydrous charge material that is to be vaporized and ionized, which receptacle may be opened after the ion source unit has been placed in the chamber of the separator; and the chamber has been evacuated.

It is also an object of this invention to provide in an ionic mass separating apparatus a means for maintaining the source material anhydrous and out of contact with the atmosphere, at least until the apparatus is substantially evacuated and at the operating temperature; and hence substantially free of moisture, and air or other oxidizing and decomposing conditions.

It is a further object to provide a new and improved method of operating an ion source for production of gaseous ions from a non-gaseous source material under vacuum.

The present invention also has as its object an improved method of operation of an isotope separating device that permits employing a relatively pure anhydrous source material and maintaining said source compound anhydrous and out of contact with air and oxidizing or other decomposing conditions throughout the operation of said device.

With the adoption of the capsule technique, it was found necessary to perfect a capsule breaking system and apparatus that would not interfere with maintaining a control of the desired vapor pressure in the ion source. It had previously been shown (see prior copending and parent application Serial No. 552,553, filed September 2, 1944), that the vapor pressures of the volatile salt in the ionization region is a unique function of the temperature of the zone in which the solid salt is converted into a vapor. Conforming with this prior research it was found to be important that the breaking device for the capsule not present any cold surfaces upon which vapor condensation may take place. Accordingly the capsule breaking device of the present invention was developed by means of which it is possible to maintain all surfaces, especially the surfaces of the breaking mechanism, with which the vapor may come into contact at the same or preferably higher temperatures than the vapor source.

Accordingly, it is a further object of the present invention to provide a simple, positive device for breaking or otherwise opening the evacuated sealed capsule positioned within a vapor generator of an apparatus for producing gaseous ions under vacuum and containing a source material purified by distillation under vacuum, that will provide thermal insulation between the means within the generator for breaking, or otherwise opening the capsule and the enclosing envelope maintaining the vacuum and through which the breaking means must be operated.

It is a still further object of the present invention to provide an improved apparatus for exposing a source material contained within a sealed and evacuated capsule to the evacuated interior of a vapor generator of a gaseous ion source into which the capsule has been placed by breaking or otherwise opening the capsule; this breaking or opening action being effected without interference with the vacuum of the vapor generator or with the operation of the ion source.

Additional objects, features and advantages of this invention will be apparent from the following detailed description and accompanying drawings forming part of the specification, wherein: Figure 1 is a longitudinal sectional view of one embodiment of an apparatus for carrying out this invention; said section being taken on line 1—1 of Figure 2;

Figure 2 is a plan view of the apparatus shown in Figure 1 with the enclosing envelope in section; and Figure 3 is a sectional view taken along line 3—3 of Figure 2.

Referring now to the drawings, the entire apparatus is contained within an envelope 5, which may be evacuated to a relatively high degree with respect to air, such as 10^{-5} mm. Hg. through an evacuation manifold 6. The envelope 5 is closed at one end by a water-cooled plate 7 on which the

ion source is mounted rigidly through a heat-conducting support member 8 attached to a vapor generator 9 and a distribution manifold and heater block 10. The component parts of this structure comprising the vapor generator 9 and the distribution manifold and heater block 10 are constructed of massive blocks of metal of high heat conductivity with the vapor contact surface coated with graphite or other inert material preferably of high heat conductivity. Referring to Figures 1 and 2 the vapor generator 9 is preferably constructed of the massive block of copper having a cylindrical hole 11 therethrough. This hole is lined with a material 12, such as graphite which is inert to the vapors produced. The hole 11 with graphite cylindrical lining is closed at the top with a plate 32 of graphite or other inert substance, the underside of which has an annular formed portion 32' in which are embedded or affixed a plurality of pointed molybdenum rods 33. The hole 11 and graphite cylindrical liner 12 is closed at the bottom by a plate or disc 34 of an inert material such as graphite and the high heat conductive metallic plate 35 having a threaded bushing 36 secured thereto through which passes a threaded molybdenum rod 37, said plate 35 supporting the plate 34 and being removably attached to the underside of the vapor generator block by screws 13, for example. The plate 34 has a hole of a diameter sufficient to permit a translatory movement of rod 37 and allow the minimum escape loss in pressure. The inner end of the rod 37 has attached thereto a disc or plate 38 of molybdenum which disc is rotatable relative to said rod. On this disc 38 rests the thin fracturable glass vial, capsule or envelope 39 evacuated with respect to air and containing an anhydrous relatively pure source material, for example, uranium tetrabromide, purified by distillation into the glass vial or capsule under vacuum.

As is apparent from the foregoing it is vital in the maintenance of control of vapor pressure throughout the system that the vapors leaving the clean surface of the anhydrous source compound do not come into contact with any cold surface upon which the vapor may condense. In order that the plate 38 will have no direct thermal conductive path through the rod 37 to the outer cooled envelope 5 translatory motion is given to the rod 37 by engagement with and rotation of the rod 40. As illustrated the rod 40 is supported to pass through the envelope 5 by means of a sliding compression seal 41, and is maintained in an inoperative position of non-thermal conductive engagement with the rod 37. Thus during operation of the apparatus the plate 38 will be maintained at a temperature above that at which condensation of the vapors and the source material can take place.

While it is clear that any number of seals known to the prior art can be utilized for sealing the rod 40 the seal illustrated and indicated generally by reference numeral 41 has been found to be remarkably satisfactory. The principle of the seal illustrated is that the rod 40 slides through thin pieces of sheet rubber 44 in which a hole has been punched of a diameter smaller than the diameter of the rod. The rubber closest to the rod is thus distorted and bent out from its normally plane surface. This bend in the rubber-like washers is maintained toward the high pressure side of the seal by the conical shape of the spacer element 45 and the end plate 46. Thus the gas pressure from the outer surface of the envelope 5 as well as the elasticity of the rubber forces the

inner edge of each washer intimately against the sliding rod 40 so that no air leaks past the seal on the translation of the rod.

The vapor generator 9 is provided with a vapor duct 15 of a material which is inert to the vapor, such as graphite, said duct 15 communicating from the hole 11 through the wall of the heater and distribution manifold block 10 and into cylindrical hole 16 extending through the distributing manifold and heater block 10. The manifold and heater block is also constructed of a massive block of material highly conductive to heat, such as copper, and the hole 16 therein likewise is provided with a cylindrical coating or sleeve 17. The hole 16 is closed by graphite covers 18. The vapor duct 15 is made with thin walls in order to minimize heat transfer from the vapor manifold 10 to the vapor generator 9.

On the side of the manifold block 10, opposite from the vapor duct 15, is provided one or more vapor channels 19 from the hole 16 into a hot ionizing arc chamber 20 which is made of some inert material, e. g., graphite. These channels 19 may be formed of small diameter sleeves of graphite. As illustrated, six of these vapor channels 19, each one-quarter inch internal diameter, are employed to provide a total cross-sectional area of about 0.295 square inch for the discharge of the vapor from the reservoir 10. In the structure shown, the duct 15 is one-half inch in internal diameter to give a total cross-sectional area for vapor flow of approximately 0.197 square inch. The ionizing chamber is at the highest temperature of the ion source by reason of the arc therein. In this embodiment it supplies heat to the heater and manifold block 10 by conduction.

Auxiliary means are provided to heat the manifold and heater block 10. For example, one or more auxiliary heaters 21 (e. g., one-quarter inch diameter graphite rods carrying large A. C. currents) are positioned in wells in the heater and manifold block 10 but which do not communicate with the hole 16. As shown in the drawing only one lead-in conductor 29 is utilized to connect the heaters 21 to a suitable A. C. source. This lead-in conductor 29 is connected to the upper end of graphite rods 21, the lower end of which is serially connected with the lower end of the other graphite rod by means of the U-shaped member 21'. The upper end of this second graphite rod is grounded to the manifold block 10, by means of the nut 23'. The vapor generator 9 is heated solely by conduction from the heat conducting supporting member 8 which in turn is heated solely by conduction from the heater and manifold block 10 connected at one end thereof. The manifold block is heated by the higher temperature arc and by the auxiliary heaters 21. The heat conducting supporting rod 8 has a uniform linear temperature gradient between the predetermined temperature of the heater block and the water cooled plate 7. The vapor generator receiving its heat by conduction intermediate these extremities of the support 8, will have a predetermined temperature intermediate the extremity temperatures of the supporting rod 8, depending on the generator's position along said supporting rod. Preferably the point of support of the vapor generator along the member 8 is so adjusted that the temperature of the vapor generator is 50° C. or more below that of the manifold.

Although very satisfactory operation has been obtained with an embodiment, wherein the

amount of power dissipated in the arc discharge influences by radiation the temperature in the vapor-generating zone, this requiring adjustable auxiliary heating and cooling means, it is believed to be advantageous to have the temperature in the vapor generator completely independent of said power dissipation in the arc discharge.

It has also been found that the transfer of energy between the vapor generator and the source material is largely radiative. Hence, the material to be vaporized for supplying vapor to the arc is screened from the arc region so that there is no radiation from the arc or other higher temperature source back to the material in the vapor generator. The source material in the vapor generator is thus at temperature equilibrium with the vapor generator.

The front 22 of the arc chamber 20 is shown in Figure 3 as being provided with a plurality of openings for the effusion of the ions. It should be clear that the size and number of holes is limited only insofar as they effect the control of pressure. The ionization chamber 20 is constructed of graphite plates forming a box-like enclosure containing means for developing an electric discharge in the atmosphere of the vapor flowing into the enclosure through the channels 19. More particularly, the electric discharge means may comprise electrodes between which an electric arc may be struck in the vapor atmosphere. Various electrodes and electrode configurations may be used although it is preferred to provide a carbon anode 23 at one side of the enclosure 20 and an oppositely disposed cathode comprising a 40 mil coiled tungsten filament 24, each insulated from the chamber walls to form a discharge path between the anode and cathode.

More particularly the filament terminals 25 are brought out of the arc chamber through the bushings 26 formed of Alundum into which is pressed a thin wall graphite lining to protect the Alundum from contact with the hot filament. The bushings are assembled tightly around the terminals and pressed into the arc chamber 20 in such a way that there are no vapor leaks or cold spots at which condensation of the vapor may occur.

In a satisfactory form of construction for the apparatus shown in the drawings, the arc chamber 20 is attached to the manifold block 10 and has ducts in the rear wall thereof which are in alignment with the channels 19 to the manifold chamber 16. Inasmuch as considerable power is dissipated in the arc chamber, it is desirable to provide a relatively large area of contact between the back plate 27 of the arc chamber and the face of the manifold block 10. In addition, the high end losses from the cathode make desirable the use of water-cooling of the cathode leads which may be double walled tubular conduits 28 so designed that water may be circulated the full length of the conduits from outside of the end wall 7. These water cooled leads 28 are brought up near the ends 25 of the filament 24 to remove the heat therefrom so that the temperature of the filament in contact with the graphite will be below the sublimation temperature of the graphite. In a similar manner, the power lead for the heaters is likewise preferably enclosed in or comprises one wall of a double walled conduit 29 for water cooling of this lead. Because of the heat developed by the heaters 21 and by the discharge in the ionization chamber, the entire envelope 5 or at least that part thereof adjacent the apparatus described is preferably water-cooled as

by a helically wound tubing 30 in heat conductive relation with the envelope. Furtherfore, the heat conducted to the end wall 7 by the massive copper rod 8 which carries the vapor generator and manifold is preferably absorbed by the water flowing through copper tubing 31 in heat conductive relation with the said end wall.

Although the drawings do not show insulators and seals for each of the various leads extending through the end wall 7 it is obviously apparent that these leads are sealed to maintain the vacuum within the envelope 5 and are insulated from the wall by suitable insulated bushings through which they extend.

Particularly good results have been obtained with an ion source of the following specific description: The vapor generator 9 was a rectangular copper block measuring two and one-half inches in width transverse to the vapor outlet duct 15, and one and one-quarter inches in the direction parallel to the vapor duct leading into the heater and manifold block 10; the diameter of the chamber 11 being approximately one and one-eighth inches to provide a large surface area for evaporation. The vapor generator block 9 was separated approximately one-quarter inch from the manifold block 10 which had dimensions of three inches, two and five-eighths inches and one and three-eighth inch taken respectively along the same directions as in the specification of the dimensions of the vapor generator block 9, the manifold chamber 16 being about one inch in diameter. The support member 8 was made of one inch diameter copper, silver-soldered at opposite ends to the manifold and heater block 10 were designed to be heated up to a maximum temperature of about 650° C. by radiation from the two heaters 21 comprising two one-quarter inch graphite rods through which passed up to several hundred amperes A. C. The total power input was of the order of 2.2 kilowatts, and under these conditions the temperature of the heaters was about 2200° C. For control of the temperature to obtain various vapor pressures within the system, the heaters 21 may be energized through a variable auto-transformer or other controlling device, the temperature being noted by imbedding a conventional thermocouple in the vapor generator 9, although this is not shown in the drawings.

To place the apparatus illustrated in Figures 1, 2 and 3 in operation the end wall 7 and the various component parts supported thereon are removed from envelope 5 and a capsule or vial 39 containing the anhydrous and relatively pure source material is inserted into the hole 11 of the vapor generator 9 preferably by removing the top cover plate 32, so that the flat end of the capsule 39 rests against the molybdenum plate 33. The top plate 32 is then replaced with the pointed molybdenum rods 33 extending downwardly toward the capsule. After the source material has been inserted in the vapor generator 9 the apparatus is then assembled as shown in Figures 1 and 2 and evacuation of the envelope 5 through the manifold 6 is begun. Circulation of water in the various cooling tubes 30 and 31 is started and the ion source is heated to at least 400° C. by means of the auxiliary heater 21. When the desired vacuum has been reached say 10^{-4} mm. of Hg, the cathode filament 24 is also heated by passing an alternating current therethrough to assist the outgassing. Sufficient water is circulated in the various cooling tubes 30, 31 to keep

the envelope, etc., from overheating. When the vacuum has reached one or two$\times 10^{-5}$ mm. of Hg the source is brought to the desired operating temperature, which for a uranium tetrabromide source, is of the order of 400° to 600° C. for the manifold 10 and correspondingly of the order of 350° to 450° C. for the vapor generator 9. Since the temperature gradient if linear along the support member 8, the temperature of the vapor generator 9 is determined by positioning on this support 8 at such a position that its temperature is approximately 50° C. less than that of the heater block 10 at the one extremity of the supporting rod 8. This temperature differential is, however, not critical.

The filamentary cathode 24 which has been heated as noted before by passing an alternating current therethrough is also adjusted to a proper temperature to emit sufficient electrons. The capsule 39 is then broken by engaging rod 40 in rod 37 and rotating the rods so that the plate 38 is forced up against the capsule 39 by translatory movement caused by the threaded bushing 36. The capsule 39 is fractured by the pressure against the molybdenum prongs of pointed rods 33, releasing a flow of vapor of the uranium halide through the apparatus including the arc chamber. Since the source material in the sealed glass capsule 39 has been deposited therein by distillation under vacuum for example, it is insured that the charge of source material is anhydrous and free of oxygen and water at the start of the operations. Consequently the source material does not present vacuum difficulties and no change in pressure is observed when the capsule 39 is ruptured.

The next step in operation is to strike an arc in the arc chamber 20 by bringing the anode 23 to a potential 700 volts positive with respect to the cathode 24. The arc power supply must have a negative voltage regulation characteristic, this being achieved in one case by connecting the arc in series with a constant voltage supply and a suitable ballast resistor. In this circuit there is inserted a large inductance which increases the stability thereof. This inductance plays an important part in getting the arc started, for transition from a glow discharge to a low voltage arc, the discharge is unstable. However once a current is flowing in the circuit any sudden decrease in arc current is accompanied by an induced voltage across the inductance which restrikes the arc.

The starting vapor pressure using vaporized uranium tetrabromide as a source material may be of the order of 15 microns, and after starting the pressure may be reduced to the order of 2–10 microns. If the arc does not start immediately under the above conditions the graphite arc chamber 20 may be shorted to the cathode 24 by a suitable switch. This effects a shorter cathode-anode path, i. e., making the arc chamber 20 the anode, thereby initiating the arc which may then be transferred to the anode by opening the switch. The positive ions in the plasma of the arc are drawn from the arc chamber 20 by an insulated electrode such as the electrode 42, maintained at a high negative potential with respect to the cathode 24. Thus the charged ions may be collected in accordance with their charge and mass by the use of an apparatus for carrying out a large separation of the isotopes in the utilization chamber 43. Consequently, one of the principal uses in which this apparatus may be employed, is as a component part of a separator for the various isotopes of the elements comprising the source material.

Since as indicated above, the present apparatus is of particular advantage in developing, under vacuum, ions of matter that is normally solid but capable of being vaporized such as the various halides of uranium, it will be appreciated that the invention is not concerned with the particular substance of the parts comprising the ion utilization apparatus; suffice to say, that in any ionic isotope separation apparatus of which the invention may be a component part there would usually be provided an accelerator such as the insulated electrode 42 maintained at a negative potential with respect to the cathode to withdraw the developed ions from the arc and to direct positive ions into another portion of the envelope 5 such as a utilization chamber 43. It might be pointed out also that such a device would involve suitable valve means for sealing off the portion of the chamber 5 indicated as the utilization chamber, so that the capsule of the ion source may be replaced without the necessity of letting the entire ion utilizing part of the apparatus down to air.

While the invention has been described with reference to a particular structure, it will be appreciated that the adaptation of the specific illustrated embodiment to large scale operation might entail substitution of other convenient means and automatic devices available in the art for controlling pressure, temperature and/or the arc, and that these alternatives do not fall outside the scope of this invention otherwise than defined by the appended set of claims.

I claim:

1. In combination with an ionic mass separating device comprising a closed tank housing an ion source unit including structure providing a charge reservoir and a communicating charge ionizing chamber, a normally closed receptacle containing a charge and positioned within said charge reservoir, and means controllable from the exterior of said tank for opening said receptacle thus positioned into communication with said charge reservoir, whereby the charge in said receptacle fills said charge reservoir and enters said communicating charge ionizing chamber.

2. In combination with an ionic mass separating device comprising a closed tank housing an ion source unit including structure providing a gas reservoir and a communicating gas ionizing chamber, a normally closed receptacle containing a charge capable of being vaporized and positioned within said gas reservoir, means controllable from the exterior of said tank for opening said receptacle thus positioned into communication with said gas reservoir, and means for heating said receptacle, whereby the charge in said receptacle is vaporized and fills said gas reservoir and enters said communicating gas ionizing chamber.

3. In combination with an ionic mass separating device comprising a closed tank housing an ion source unit including structure providing a charge reservoir and a communicating charge ionizing chamber, a normally sealed receptacle having a frangible portion and containing a charge and positioned within said charge reservoir, and means controllable from the exterior of said tank for breaking the frangible portion of said receptacle thus positioned, whereby the charge in said receptacle fills said charge reservoir and enters said communicating charge ionizing chamber.

4. In combination with an ionic mass separating device comprising a closed tank housing an ion source unit including structure providing a charge reservoir and a communicating charge ionizing chamber, a normally closed receptacle containing a charge and positioned within said charge reservoir, and means including a movable member extending through an opening formed in said tank and controllable from the exterior of said tank for opening said receptacle thus positioned into communication with said charge reservoir, whereby the charge in said receptacle fills said charge reservoir and enters said communicating charge ionizing chamber.

5. In an apparatus for developing gaseous ions under vacuum, the combination including an enclosing envelope evacuated to a relatively high degree with respect to air and housing an ion source unit including a sealed evacuated receptacle containing an anhydrous compound of the material to be vaporized and ionized, and an ionizing chamber having an inlet opening for receiving the vapors to be ionized, means responsive to the movement of said receptacle within the said envelope for causing said receptacle to open into communication with said ionizing chamber, and means operable from the exterior of said envelope for moving said receptacle.

6. In an apparatus for developing gaseous ions under vacuum, the combination including an envelope evacuated to a relatively high degree with respect to air and enclosing an ion source unit comprising a vapor generator having a compartment adapted to receive a closed evacuated receptacle containing an anhydrous compound of the material to be ionized, a chamber communicating with said compartment wherein said vapors are ionized, movable means supported within said envelope for exposing the interior of the said receptacle to said compartment and communicating ionizing chamber, and means external of said envelope movable from a position of non-thermal conductive engagement with said first named means for effecting movement thereof, whereby the vapors of the anhydrous compound may flow into said compartment and said ionizing chamber.

7. In an apparatus for developing gaseous ions under vacuum, the combination including an enclosing envelope, evacuated to a relatively high degree with respect to air, a vapor generator having within said envelope a chamber adapted to receive an evacuated, sealed, frangible capsule containing an anhydrous compound of the material to be ionized, said compound being purified by distillation into said capsule under vacuum, relatively movable means supported within said chamber for breaking said capsule, means external of said envelope movable from an inoperative position to a position for effecting the relative movement of said breaking means, said external means at least when in said inoperative position having no thermal conductive engagement with said breaking means whereby said breaking means may be maintained at the temperature precluding condensation of the vapor from the anhydrous compound.

8. In an apparatus for developing gaseous ions under vacuum, a combination including an enclosing envelope evacuated to a relatively high degree with respect to air for housing an ion source unit including a vapor generator, said vapor generator having a chamber adapted to receive an evacuated sealed frangible receptacle containing an anhydrous compound of the material to be ionized, and breaking means for said receptacle, said breaking means including movable means supported within said chamber and means extending through said envelope in sealed relation therewith and movable relative thereto from a normal position of non-thermal conduction with said movable means into a position of engagement therewith for effecting the breaking operation only, whereby said breaking means will be ineffective in conducting heat from said vapor generator to said enclosing envelope during the operation of said apparatus.

9. In an apparatus for developing gaseous ions under vacuum, the combination including an enclosing envelope evacuated to a relatively high degree with respect to air, a thermally conducting member having a predetermined temperature gradient supported within said envelope, means for heating said member, a vapor generator secured to said member in heat transfer relation therewith and having a chamber adapted to receive an evacuated, sealed, frangible capsule containing anhydrous compound of the material to be ionized, said compound being purified by distillation under vacuum, means movably supported within said chamber for breaking said capsule, means for operating said movable means extending through said envelope in sealed relation therewith, said operating means being movable relative to said envelope from a normal position of non-thermal conduction with said movable breaking means to a position of operative engagement therewith for effecting the breaking operation only, whereby the temperature throughout said vapor generator will be determined substantially by the position of support of said vapor generator along said thermally conductive member.

10. In an apparatus for developing gaseous ions under vacuum, the combination including an enclosing envelope having a heat conducting wall portion, a vapor generator adapted to enclose an evacuated, sealed, frangible capsule containing an anhydrous compound of the material to be vaporized and ionized, means operable for breaking said capsule to release the vapor of said compound, a distribution manifold for receiving said vapor, thermally conductive means attached to and extending between said manifold and said wall portion for supporting said vapor generator intermediate said manifold and said wall portion whereby said vapor generator is maintained at a temperature lower than said manifold and higher than said wall portion, and means external of said envelope movable from a position of non-thermal engagement with said breaking means to effect the operation thereof whereby during the operation of said apparatus the only thermally conductive path from said vapor generator to said wall portion is through said thermally conductive supporting means.

ROBERT W. THOMPSON.

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The following references are of record in the file of this patent:

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