April 16, 1957 E. O. LAWRENCE 2,789,229

ION PRODUCING MECHANISM

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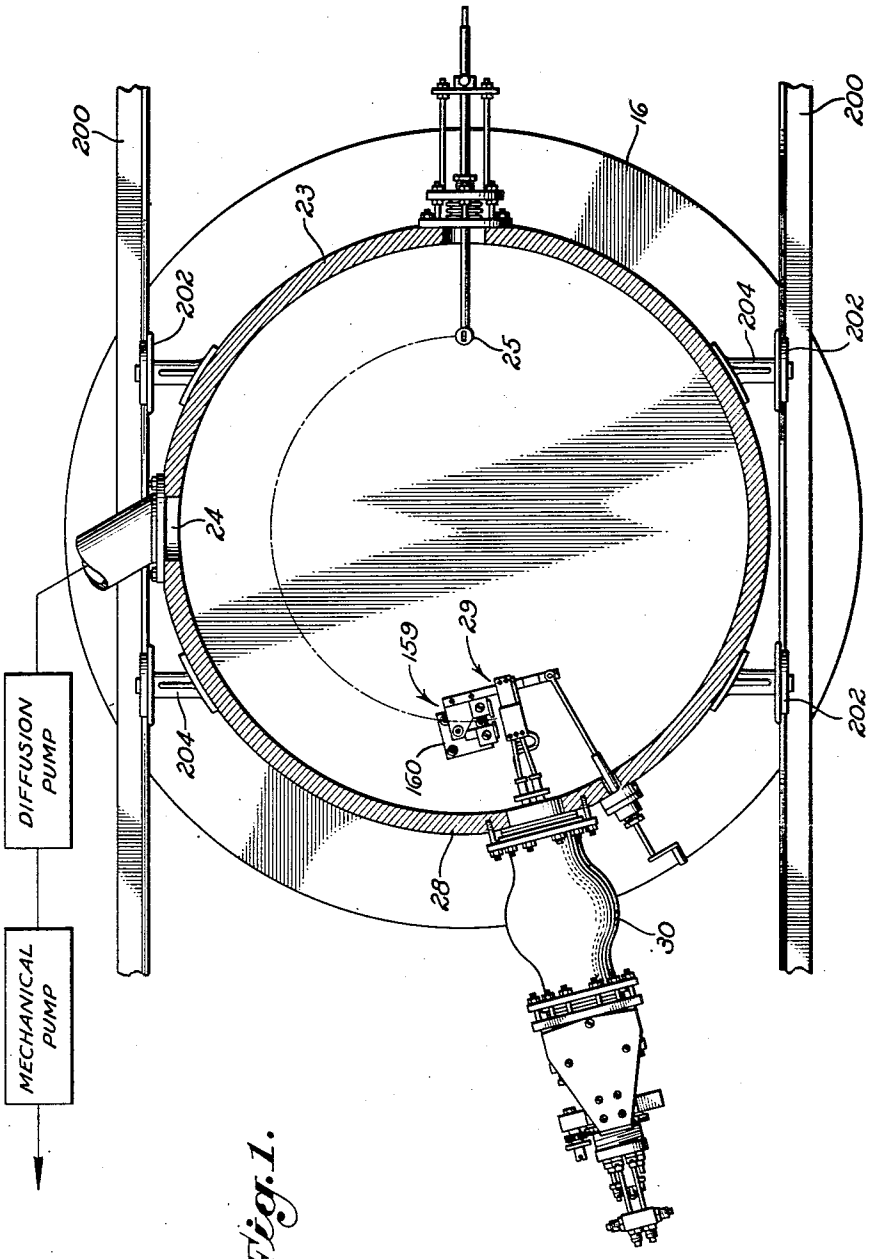


Fig. 1.

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Fig. 2.

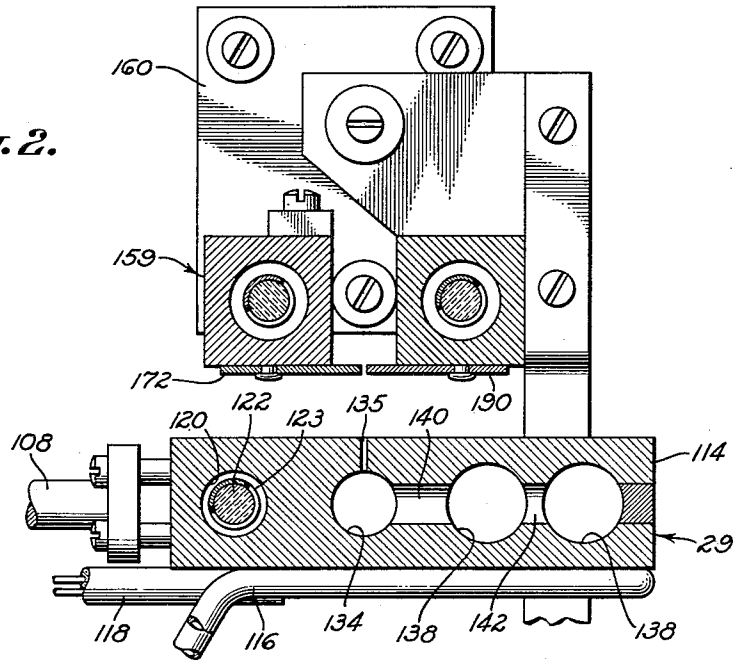
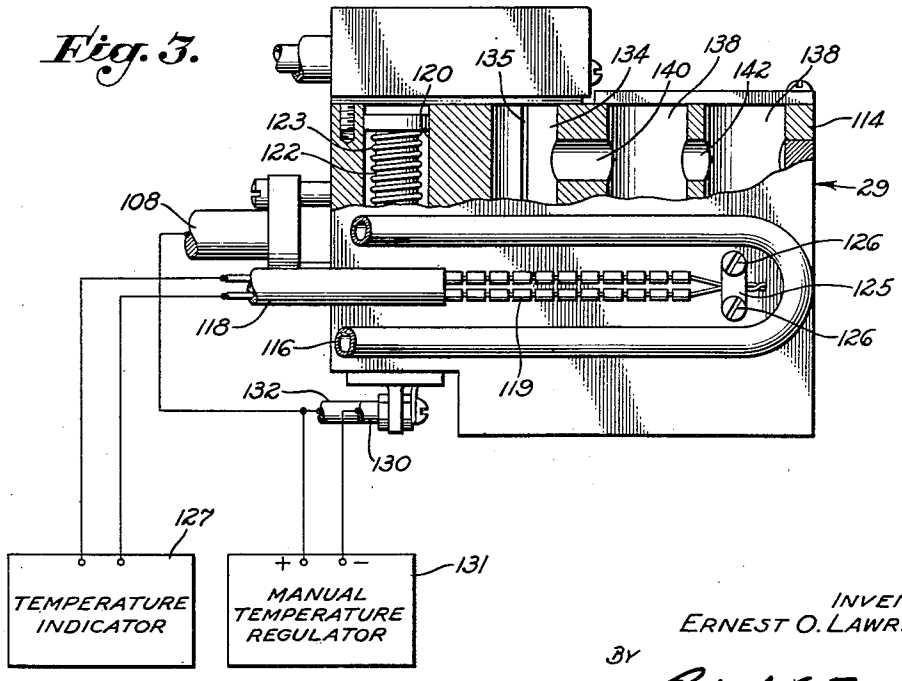


Fig. 3.



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ION PRODUCING MECHANISM

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Application May 14, 1946, Serial No. 669,479

6 Claims. (Cl. 250—41.9)

The present invention relates to the art of treating a polyisotopic substance to produce a plurality of segregable masses wherein the normally occurring distribution of the constituent isotopes has been altered so that one of the masses produced is enriched with respect to at least one isotope. More specifically, the invention relates to a device of the type known in the art as a "calutron," a term which has been defined as "any apparatus or machine wherein isotope separation or enrichment is achieved on a large scale, yielding commercially useful quantities of one or more isotopes, by appropriate separative action on gaseous ions with electrostatic or electromagnetic means or combinations of them."

The foregoing definition has been taken from U. S. Patent No. 2,708,222, issued May 24, 1955, to Ernest O. Lawrence. In the referenced patent the theory of isotopic separation and the principles of operation of a calutron are so fully treated and thoroughly explored that no useful purpose would be served by here repeating the discussion contained therein.

It may be stated in passing, however, that by projecting a beam of positive ions of a vaporized or gaseous polyisotopic substance through an evacuated receptacle disposed in a magnetic field acting normally to the path of the beam, the beam is caused to follow a curve wherein the ions of the heavier isotope tend to concentrate in the region adjacent the outer periphery and the ions of the lighter isotope congregate in the region adjacent the inner periphery. In other words, ions of greater mass travel along a curve of greater radius than the ions of lesser mass. By disposing suitable pockets or collectors in the path of the beam, preferably 180° from the source of the beam, it is possible to collect at least two masses, one of which is enhanced with respect to one isotope while the other is correspondingly impoverished with respect thereto.

Of course there are many conditions which must be fulfilled before a calutron can be successfully operated. For example, the ion source, the region surrounding the beam, and the collector must be incorporated in a reduced pressure system evacuated to a pressure of the order of 10^{-5} to 10^{-4} mm. Hg. Such matters will be herein referred to but briefly, inasmuch as it is with the ion beam producing mechanism, or "source," that the present invention is concerned.

A source for a calutron includes a chamber for holding a quantity of material capable of being vaporized, a heater for the chamber, a cathode and anode for establishing an arc discharge, and accelerating electrodes; the arrangement is such that when the circuits are closed, the material vaporizes and is drawn through the electron stream of the arc where dissociation and ionization take place. The ions are then drawn through a slit by the accelerating electrodes to form a beam.

The most important object of this invention is to produce an ion beam more efficiently than has heretofore been accomplished and particularly to make more efficient use of the charge material by improved thermal control of the source block and its associated mechanism.

Another object of this invention is an improved method of operating a calutron including a close regulation of the temperature of the ion producing mechanism within predetermined limits.

An important feature of this invention consists in providing cooling means in good heat exchange relation with an ion producing mechanism which includes a heater for vaporizing the material to be ionized and also providing a temperature responsive indicator by means of which the operator is enabled to control closely the temperature of the ion producing mechanism.

Another feature of the invention consists in providing in the circuit including the heater, a temperature responsive indicator and a regulator by means of which the operator is enabled to regulate the temperature of the ion source mechanism in accordance with conditions indicated by the temperature responsive indicator.

It is characteristic of such ion producing mechanisms as are contemplated by the present invention that on initiating operation, it is necessary to energize the heater in order to vaporize the charge material at the desired rate but upon continued operation, heat is evolved by the ionizing arc at such a rate that excessive heat may be imparted to the charge reservoir, thus vaporizing the charge material at a rate in excess of the ionizing capacity of the arc. Accordingly, it is a feature of this invention to provide temperature indicating means and temperature regulating means including a regulator for the heater and cooling tubes mounted in good heat exchange relation to the source block, whereby the temperatures of the source block may be maintained at the desired degree.

Further objects, advantages and features will be apparent from the annexed specification, in which:

Figure 1 is a diagrammatic plan view showing the general organization of a calutron embodying a source unit constructed according to the present invention;

Fig. 2 is an enlarged plan view, partly in section, of the source unit; and

Fig. 3 is a fragmentary front elevation of the source unit shown in Fig. 2.

The calutron is organized around a flat circular vacuum tank disposed between the pole faces of a powerful magnet and containing means for generating a beam of positive ions of a polyisotopic substance such as uranium. The beam of ions is caused to follow a curved path by reason of the magnetic flux flowing between the pole faces of the magnet. As the beam pursues its course, ions of greater mass concentrate along the outer periphery of the beam, whereas ions of lesser mass congregate along the inner periphery thereof. For example, in the case of uranium the ions of U^{238} will be found in the outer portion of the beam, while ions of U^{234} and U^{235} are relatively more predominant in the inner portion. By interposing a suitable receiver or collector in the path of the beam, preferably 180° from its source, separate aggregates of uranium may be collected. One aggregate will be substantially enriched in its percentage of U^{235}, and the other aggregate will be correspondingly impoverished with respect thereto.

Referring particularly to Fig. 1, there is shown a calutron including an electromagnet (not shown) having an upper pole piece (not shown) and a lower pole piece 16 on which rests the bottom of an evacuated vessel indicated generally at 23. As will be well understood by those skilled in the art, the electromagnet includes suitable windings by means of which a strong substantially uniform magnetic flux is caused to traverse the evacuated vessel 23 in a direction normal to the top and bottom walls thereof.

The vessel 23 includes a port 24 to which are connected suitable conduits leading to a suitable diffusion pump and a suitable mechanical backing pump, by means of which the vessel 23 may be evacuated. In practice, the pressure in the vessel 23 is reduced to the order of 10^{-4} or 10^{-5} mm. Hg.

Guide rails 200 may be disposed between the pole pieces of the magnet on which may ride flanged wheels 202 carried by brackets 204 mounted on the side walls of the vessel 23, thus mounting the vessel 23 for longitudinal movement into or out of position between the pole pieces.

The vessel 23 is provided with a suitable ion receiving mechanism 25. This ion receiving mechanism forms no part of the present invention and is described in detail in the above-mentioned patent to Ernest O. Lawrence. It may be noted, however, that such ion receiving mechanism includes a pair of ion trapping pockets, each adapted to receive and collect a sample of de-ionized material from the ion beam treated in accordance with above-described principles.

Located approximately 180° from the ion receiving mechanism 25 is an ion source mechanism 29. A suitable aperture is provided in the side wall 28 of the vessel 23 and an elongated, hollow bulbous insulator 30 of heavy glass is suitably sealed against the exterior of the wall 28 in alignment with this aperture.

Associated with the insulator 30 is suitable mechanism for supporting and positioning the source 29, which mechanism forms no part of the present invention and is described in detail in the copending case of John G. Backus, Serial No. 613,158, filed August 28, 1945. Such mechanism includes, however, a source supporting stem 108, a cooling coil 116, an electrical lead 130 leading to an electric heating element 122, and electrical leads 118 extending to the thermocouple 119, all extending into the vessel 23 through the hollow insulator 30.

Referring particularly to Figs. 2 and 3, it is noted that the ion source mechanism 29 includes a block 114 of thermally conductive material. The block 114 is bored to provide a pair of charge chambers 138 interconnected by a passage 142. The block 114 is also bored to provide an arc chamber 134 interconnected to the charge chambers 138 by a passage 140. An elongated slot 135 is provided in the wall of the block 114 communicating with the chamber 134. Suitable arc generating mechanism is provided including an electron-emissive cathode (not shown) by means of which an arc is struck through the chamber 134 for ionizing the vaporized charge material. In practice, the walls of the chamber 134 form the anode member of the arc generating mechanism and, accordingly, the block 114 is maintained at a positive potential with respect to the cathode. The stem 108 is utilized as the positive lead in this system. Reference is made to the above-mentioned copending case of John G. Backus for full details of the arc producing mechanism.

The block 114 also includes a chamber 120 bored therein in which is positioned the heating element 122 comprising a ceramic grooved core wound with high resistance wire 123 of Nichrome or other suitable material. The lead 130 is connected to one end of the winding 123 and to the negative terminal of a suitable source of supply, the positive terminal of which is connected to the stem 108; and a lead 132 connects the other end of the winding 123 to the stem 108. The circuit including the winding 123 and the lead 130 contains a manual temperature regulator 131 for regulating the amount of heat generated by the heater 122.

Attached to the block, as by the clamp 125 secured thereto by screws 126, is a thermocouple 119, the leads 118 of which extend to a suitable temperature indicator or meter 127. Both the temperature regulator 131 and the temperature indicator 127 are located outside of the vessel 23 and preferably in a convenient position to be accessible to the operator.

Referring to Figs. 1 and 2, it will be noted that mounted on the bottom wall of the vessel 23 is a bracket 160 of an accelerating mechanism indicated generally at 159. This accelerating mechanism is described in detail in the above-mentioned copending case of John G. Backus, and it suffices for purposes of the present case to note that the accelerating mechanism 159 includes a pair of accelerating electrode plates 172 and 190 mounted on the bracket 160 and spaced apart to define a narrow slit, as shown. As shown, the plates 172 and 190 are grounded and hence are electrically negative with respect to the source block 114.

When it is desired to operate the above-described calutron unit in accordance with the present invention, the charge chambers 138 are loaded with a supply of the material to be treated. Uranium tetrachloride is a suitable charge material. The vessel 23 is then evacuated by means of the diffusion pump and the backing pump to a pressure of the order of 10^{-4} or 10^{-5} mm. Hg. The coils of the electromagnet are then energized to pass a strong magnetic flux, preferably of the order of 4000 gauss, through the vessel 23. Next, the manual temperature regulator 131 is set to energize the heater 122, causing vaporization of the charge material contained in the chambers 138. The vapors thus generated will pass from the chambers 138 through passages 142 and 140 into arc chamber 134 and outward through slit 135. Simultaneously, an arc is struck from the electron-emissive cathode to the block in the arc chamber 134 adjacent the slit, thus causing the vapors to be ionized. When using UCl_4, positive ions of uranium will be generated. Also, the source block 114 is brought to a high positive potential, with respect to the accelerating plates 172 and 190, preferably by applying a source of such potential to the rod 108. In practice, potentials of the order of 30 kv. have been employed. The positive ions thus generated are withdrawn from the slit 135 by means of the accelerating plates 172 and 190 and collimated by means of the slit defined by these plates to form a beam of ions. This beam of ions will have the heavier ions of the polyisotopic material concentrated in the region adjacent its outer periphery and the lighter ions concentrated in the region of its inner periphery, thus enabling them to be segregated in the two pockets of the ion receiving mechanism 25.

The continued operation of the arc from the cathode to the block 114 will tend to increase the heat of the block 114 and hence tend to increase the rate of vaporization of the charge material contained in the chambers 138. Accordingly, the coil 116 may be utilized to pass air or water in good heat exchange relation to the block 114 and simultaneously the amount of energy supplied to the heater 122 may be regulated by the manual regulator 131. The rate of supply of air or water to the coil 116 and the setting of the regulator 131 may be controlled by the operator in accordance with the temperature conditions of the source block 114, as shown by the temperature indicator 127.

The above-described arrangement permits the operator to adjust closely the temperature of the source block 114 and hence to control the flow of vaporized charge material to the arc chamber 134. By this means, the flow of vapors may be adjusted to the capacity of the ion source, thus preventing any failure to operate the unit at full capacity or any excessive waste of charge material.

While there is disclosed what is at present considered a preferred embodiment of the invention, it will be understood that various changes and modifications may be made therein, and it is intended to cover such as come within the true spirit and scope of the appended claims.

What is claimed is:

1. In an apparatus for producing gaseous ions under vacuum the combination including an evacuated chamber

housing an ion source unit comprising a vapor generator and a communicating arc chamber, a heater thermally united to said source unit for imparting heat thereto, a cooler thermally united to said source unit for extracting heat therefrom, means for controlling the amount of heat imparted by said heater, and means for indicating the thermal condition of said unit whereby said means may be controlled in accordance with said indicated conditions.

2. An apparatus for producing gaseous ions of uranium for use in an ionic mass separating device comprising the combination including a housing sealed at sub-atmospheric pressure for enclosing a vapor generator adapted to contain a vaporizable uranium compound and including means establishing an arc discharge through a chamber for ionizing the vapors effusing into said chamber, a thermally conductive means thermally united to said arc chamber and said vapor generator, means for heating said thermally conductive means for imparting heat to said vapor generator and chamber, means for cooling said thermally conductive means for extracting heat therefrom to remove at least a portion of the additional heat supplied by said arc discharge, means for controlling the amount of heat supplied to said thermally conductive means, and means for indicating the thermal condition of said thermally conductive means whereby the temperature thereof may be controlled during operation to maintain a predetermined temperature condition therein through said control means irrespective of variations in heat energy supplied by said arc discharge to be dissipated through said thermally conductive means.

3. A calutron comprising a thermally conducting source block, a heater thermally united to said block for imparting heat thereto, a cooler thermally united to said block for extracting heat therefrom, means for indicating the thermal condition of said block, and means for controlling said heater and said cooler to maintain a desired degree of ionization in said source block.

4. A calutron comprising a thermally conductive source block, a heater thermally united with said block for imparting heat thereto, a cooling coil thermally united to said block for extracting heat therefrom, means indicating the thermal condition of said block, means for supplying water or air to said cooling coil, and means for controlling said heater and the rate of supply of said air or water for maintaining a desired source block temperature.

5. In the production of ions involving the introduction of a stream of molecules into a chamber, the continuing ionization of molecules therein, and the projection of a stream of resulting ions from the chamber, the improvement comprising maintaining the temperature of the interior of the chamber substantially constant by applying controllable amounts of heat thereto and removing controllable amounts of heat therefrom for stabilizing ionization in the chamber.

6. In an ionization process including the steps of projecting a stream of molecules into a chamber, establishing an ionizing arc discharge in said chamber, and accelerating ions from the chamber in a beam, the improvement comprising regulating ionization in said arc discharge by supplying a controllable amount of heat to said chamber and removing a controllable amount of heat from said chamber.

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