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CONTROL FOR ISOTOPE SEPARATING APPARATUS

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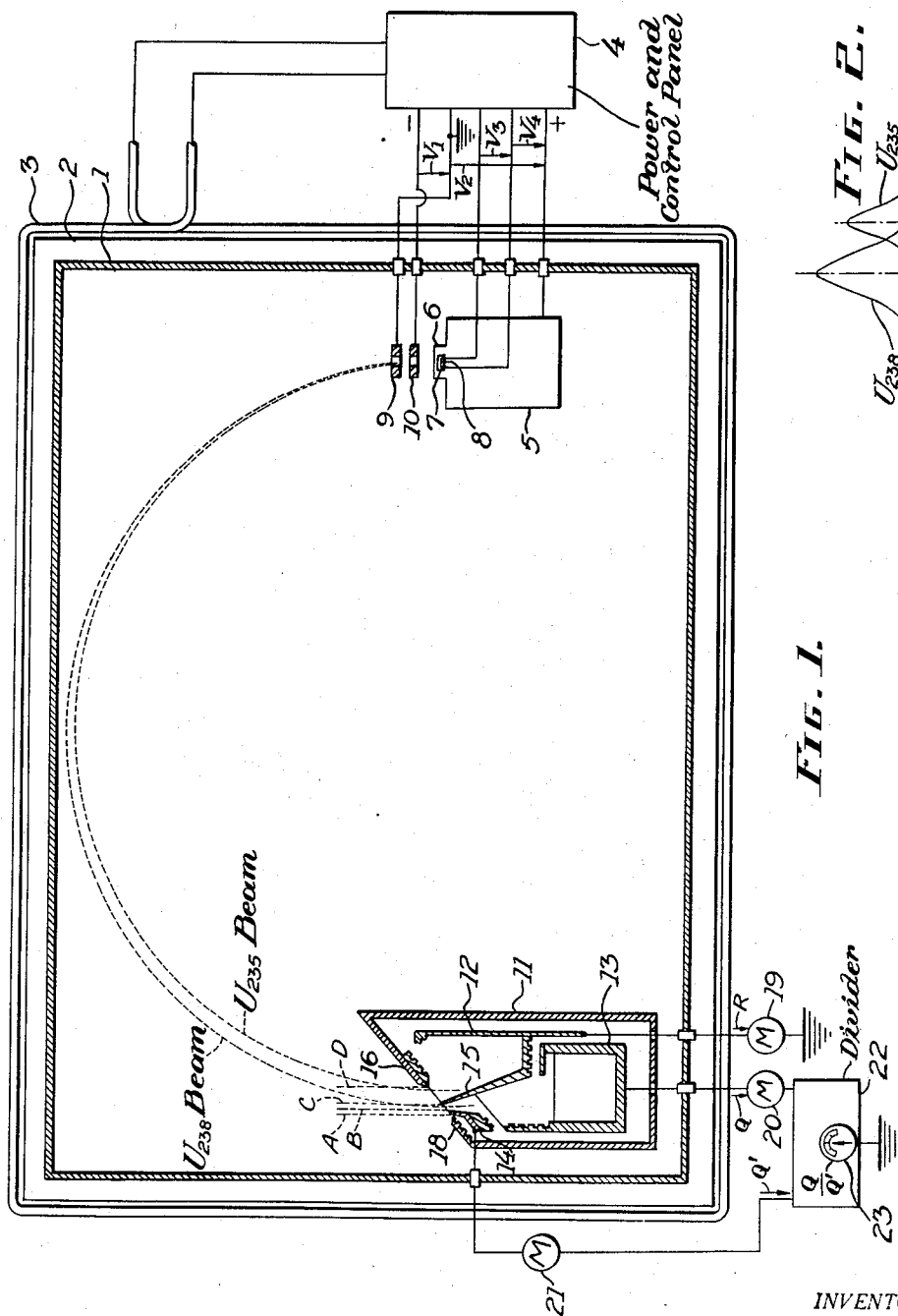
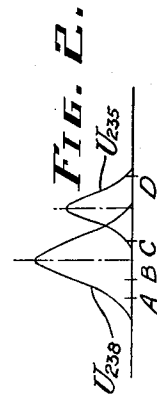


FIG. 1.



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CONTROL FOR ISOTOPE SEPARATING APPARATUS

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This invention relates generally to isotope separating apparatus of the electromagnetic type, commonly referred to as a calutron, and is more particularly concerned with improvements in methods of and means for controlling the position and condition of the ion beam of such calutrons for most efficient operation.

While the apparatus of the present invention is not limited to the separation of the isotopes of any one element, it must of necessity be specially adapted for the masses involved, and in order for its principles to be clearly understood, the invention will be described as embodied in apparatus adapted for the separation of the uranium isotopes having atomic weights 235 and 238, the isotope having an atomic weight of 234 being ignored.

In such calutrons, a beam of positive ions of uranium is formed and projected at a high uniform velocity into an evacuated region traversed by a substantially uniform magnetic field at right angles to the direction of motion of the ions. As a result, each particular ion is caused to describe a circular path having a radius proportional to the square root of its mass. In this way the original single ion beam is split into two more or less distinct component beams, one of which consists of uranium ions having a mass of 238 and the other of which consists of uranium ions having a mass of 235. Because of a geometrical focusing action, these two beams are most distinctly resolved after the completion of 180° of their circular path, and the U_{235} and U_{238} ions may be separately collected at a receiver located at this point.

An important consideration in the efficient operation of such calutrons is the ion beam control or monitoring problem, which in turn may be divided into two separate problems. First, the ion beam as a whole must be positioned with respect to the receiver such that the U_{235} and U_{238} beams fall correctly into their respective receiver pockets. Secondly, the individual beams must be focused or sharpened to as great an extent as possible, that is, the resolution of the beams must be good at the receiver. The control to attain both these conditions must be effected continuously while the calutron is in operation.

The prior method of controlling the ion beam such as to provide most efficient operation was first to adjust the variables controlling the position of the whole ion beam with respect to the receiver so as to provide a maximum reading on the meter connected to the U_{238} collecting pocket, and that having been done, to then adjust the variables controlling the focusing or resolution of the beams such that the ratio of the U_{238} meter reading to that of the U_{235} meter reading was a maximum. This method, however, was not too satisfactory, particularly in cases where the source or charge material has already been enriched with respect to the U_{235} isotope.

The present invention contemplates the addition of a new electrode in the receiver adjacent to and on the far side of the U_{238} pocket, this electrode receiving and metering a small portion of the outer fringe of the U_{238} beam. It has been found that a much more sensitive and accurate control of the focusing of the ion beams may be obtained

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by maximizing the ratio of the current of the U_{238} pocket to the current to this additional electrode.

Accordingly, it is the primary object of the present invention to provide a method of and means for controlling a calutron ion beam for most efficient operation.

Another object of the invention is to provide a novel calutron receiver particularly adapted to provide ion beam current indications useful in determining most efficient operating conditions for the calutron.

Still another object of the invention is to provide a novel calutron receiver having, in addition to the usual insulated pockets for collecting the individual isotope beams, an electrically independent electrode positioned to receive a fringe of one of said beams.

A further object of the invention is to provide in a conventional calutron receiver having two adjacent insulated pockets for respectively collecting two isotope beams, an electrically independent electrode positioned to receive the outer fringe of the more abundant isotope.

A still further object of the invention is to provide a method of ion beam control for a calutron wherein the variables controlling the position of the ion beam are first adjusted until a maximum ion current is received on a first receiver electrode positioned to receive the main portion of said beam, and then the variables controlling the focusing or resolution of said ion beam are adjusted until the ratio of the ion current received on said first electrode to that received on a second electrode, positioned to receive a fringe of said ion beam, is a maximum.

Other objects and advantages will be apparent from the specification taken in connection with the accompanying drawings wherein an embodiment of the invention is illustrated.

In the drawings:

Fig. 1 is a diagrammatic cross sectional view of a calutron showing the new type receiver with its additional electrode.

Fig. 2 is a typical beam intensity pattern for the U_{235} and U_{238} beams across the face of the receiver useful in explaining the principles of the invention.

Referring now to Fig. 1, reference numeral 1 represents an evacuated vessel or tank which it will be understood is traversed by a substantially uniform magnetic field at right angles to the paper and produced by an electromagnet, one pole piece 2 of which is shown. The magnetizing winding 3 of this magnet is supplied with magnetizing current from a power and control panel 4. It will be understood that suitable apparatus is included in the control panel 4 for regulating and adjusting the magnetizing current flowing through winding 3.

Reference numeral 5 indicates a source of positive uranium ions which may be of a type more completely described in U.S. Patent application Ser. No. 561,271, entitled Temperature Control and filed October 31, 1944 in the name of Emmett V. Martin, now Patent No. 2,712,073, issued June 28, 1955. As described in that application, there is included within the ion source 5 a container of charge material and suitable heating means associated with the container for vaporizing the uranium compound contained therein. The uranium vapor is then channeled through a passageway to the elongated constricted top portion of the ion source 5 which portion forms an ionization chamber 6.

A slot 7 is formed in one end of the ionization chamber 6 and adjacent to this slot and aligned therewith is a filament 8. Filament 8 is connected to a filament supply voltage V3 at the power and control panel 4. One side of filament 8 is maintained at a negative potential V4 with respect to the source unit 5 so that the source unit becomes an anode for the filament. As a result an electric arc is maintained from the filament 8 through

the slot 7 and lengthwise along the interior of the ionization chamber 6. This arc serves to disassociate and ionize the uranium compound vapor in the ionization chamber 6, and the resulting uranium ions are then withdrawn by an accelerating system through an elongated slot, not shown, in the top of the ionization chamber 6.

The voltage supply V4 which will henceforth be referred to as the ionization arc voltage is one variable which controls the focusing of the ion beams. This ionization arc voltage is always maintained sufficiently high so that the filament 8 operates at maximum emission. Accordingly, by varying the filament supply voltage V3, the ionization arc current, which is another factor influencing the beam focus, may be controlled.

The accelerating system comprises a slotted electrode 9 maintained at a high negative potential V2 with respect to the ion source 5, and a slotted electrode 10 maintained at a high negative potential V1 with respect to the accelerating electrode 9. In operation the positive uranium ions in the ionization chamber 6 are actually first accelerated by electrode 10, and then decelerated somewhat by electrode 9 to a final constant velocity at which they traverse the tank in a circular path to the receiver indicated generally at 11. Since the final velocity of the ions is determined by the potential V2 of electrode 9, with respect to the source unit 5, this potential V2 will be referred to as the accelerating potential, and the electrode 9 will be referred to as the accelerating electrode. Since the potential V1 of the electrode 10 with respect to electrode 9 does not in any way effect the final velocity of the ions, but rather primarily effects the resolution or focusing of the resulting beams, this potential V1 will be referred to as the focusing potential and the electrode 10 will be referred to as the focusing electrode.

All of the voltage supplies V1, V2, V3, and V4 may be, and preferably are, regulated and adjustable. Although the ground connection may be placed at any point in the potential system, it is found to be more convenient in most cases to connect the accelerating electrode 9 and the receiver 11 to ground, as shown. The polarities of the voltages are from minus to plus in the direction of the arrows.

It will be apparent from the foregoing that the position of the ion beams with respect to the receiver may be varied by adjusting the accelerating potential V2, or by adjusting the magnetizing current which flows through the magnetizing winding 3. The shape of the beam intensity pattern, that is, the focusing of the ion beams, may be controlled by suitable adjustments of the focusing potential V1, the ionization arc potential V4 and the ionization arc current, which latter is controlled by varying the filament supply voltage V3 to thereby vary the emission of the filament 8.

As has been previously stated, the single ion beam emerging from the accelerating electrode 9 is constrained to flow in a circular path, and since the radius of the circular path taken by any individual ion is proportional to the square root of the mass of that particular ion, two more or less distinct ion beams are formed, one of smaller radius (U_{235} beam) consisting of U_{235} ions and the other of a larger radius (U_{238} beam) consisting of U_{238} ions.

The receiver 11 comprises two insulated pockets 12 and 13 for receiving the U_{235} and U_{238} beams, respectively. The entrance slot to the U_{235} pocket 12 is defined by one wall 15 of this pocket and a face plate 16 of the receiver. The entrance slot to the U_{238} pocket 13 is defined by the wall 15 of the U_{235} pocket 12 and an additional insulated electrode 14. The exposed portion of the additional electrode 14 is determined by a second face plate 18. Pockets 12 and 13 and electrode 14 are connected to ground through the respective meters 19, 20, and 21, the deionizing current which flows to each of

these electrodes through the respective meters being designated as the R, Q, and Q' currents, respectively.

The detailed design of the receiver unit may be as set forth in U.S. Patent application Serial No. 669,481 for Isotope Separating Apparatus, filed May 14, 1946, in the name of Sidney W. Barnes, now patent No. 2,901,617, issued August 25, 1959. As therein explained, pockets 12 and 13 and electrode 14 are suitably supported in the receiver and are insulated from each other, and are preferably made of carbon to impart durability.

Prior to being connected to ground, the Q and Q' currents are connected to an electrical divider mechanism 22 of any suitable type adapted to indicate the ratio Q/Q' on an indicator represented by dial 23. One form of divider mechanism which would be appropriate for this purpose is fully described in U.S. application Serial No. 548,588 for a Mass Spectrometer System, filed August 8, 1944, in the name of Alfred O. C. Nier and Edward P. Ney, now U.S. Patent No. 2,456,426, issued December 14, 1948.

Referring now also to Fig. 2, wherein typical ion beam intensity patterns across the receiver face for the U_{235} and U_{238} beams are shown, it will be apparent that that portion of the total ion beam which enters the receiver between lines C and D and is indicated by meter 19 as the R current, consists primarily of U_{235} ions. That portion of the total ion beam which enters the receiver between lines B and C, indicated by meter 20 as the Q current, consists primarily of U_{238} ions. That portion of the total ion beam which enters the receiver between lines A and B, indicated by meter 21 as the Q' current constitutes an outer fringe of the U_{238} beam and consists wholly of U_{238} ions.

From Fig. 2 it will be apparent that the relative values of the R, Q, and Q' currents depends first upon the position of the ion beams with respect to the receiver, and secondly upon the shape of the beam intensity patterns, that is, the sharpness of focus of the beams. The beam intensity patterns may be moved across the receiver face by varying either the accelerating potential V2 or the magnetizing current flowing in winding 3. The shape of the beam intensity pattern may be sharpened by variations in the focusing potential V1, the ionizing arc potential V4, or the filament supply voltage V3. The focus is primarily dependent upon the focusing potential V1 however.

The optimum operating condition of the calutron is obviously attained when the maximum percentage of U_{238} ions falls into the U_{238} pocket 13 and the maximum percentage of U_{235} ions falls into the U_{235} pocket 12. In terms of the beam intensity patterns of Fig. 2, this condition of optimum operation is attained with the patterns have assumed a position with respect to the receiver such that the peaks of the U_{235} and U_{238} patterns are centered over the entrance slots to pockets 12 and 13, respectively, and when these peaks are as high and as sharp as possible.

In operation, the accelerating voltage V2 is first adjusted until the ion beam assumes its desired position with respect to the receiver 11, the attainment of this desired position being indicated by a maximum reading on the Q current meter 20. This desired condition could also be accomplished, but rather less conveniently, by adjusting the magnetizing current of winding 3 and thereby the intensity of the transverse magnetic field. This having been accomplished, the various factors which control the shape or focusing of the ion beam, namely, voltage supplies V1, V3, and V4 are then adjusted such as to focus the U_{235} and U_{238} beams as sharply as possible within the regions C—D and B—C, respectively, in accordance with the principles of the present invention, the attainment of this condition is evidenced by a maximum Q/Q' ratio, as indicated on dial 23. It will be apparent that as the beam is more sharply focused, a greater portion of the U_{238} ions will fall within the

region B—C and be metered by the Q meter 20 and a lesser portion will fall within the region A—B and be metered by the Q' ammeter 21. After these initial adjustments have been accomplished, it may be necessary to repeat the entire procedure several times until the optimum operating condition is attained both with respect to the position of the beam and the focusing of the beam.

Although a divider mechanism 22 has been shown so as to indicate the actual Q/Q' ratio on dial 23, this may not in all cases be necessary, an intelligent and experienced operator being able to accomplish the same result, that is a subconscious computation of the ratio Q/Q' , simply by reading meters 20 and 21.

It will be emphasized that the method of ion beam control described is the preferable one as nearly as can be explicitly described as a specific operating procedure. However, it should be borne in mind that the operation of a calutron is more in the nature of an art rather than an exact science due to the complicated introduction of the many variables involved. In any case whatever variations from the specific method of control set forth may be employed, the introduction of the additional electrode 14 with its consequent Q' current indication on meter 21 provides an additional and very useful indicia of the position and condition of the ion beams within the calutron during operation, which indicia can be used in various ways to good purpose by an experienced operator.

Since many changes in the above construction, and many apparently widely different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A calutron receiver comprising a pocket disposed in said receiver for receiving and collecting an ion beam composed of ions of a particular mass, an insulated electrode disposed adjacent to said pocket for receiving a fringe of said ion beam, and divider means connected to said pocket and said electrode for indicating the ratio of the deionizing current to said pocket to the deionizing current to said electrode.

2. A calutron receiver comprising a first insulated

pocket disposed in said receiver for receiving and collecting a first ion beam composed of ions of a particular mass, a second insulated pocket disposed adjacent to said first pocket for receiving and collecting a second ion beam composed of ions of a different mass, an insulated electrode disposed adjacent to said second pocket for receiving the outer fringe of said second ion beam, and divider means connected to said second pocket and said electrode for indicating the ratio of the deionizing current to said second pocket to the deionizing current to said electrode.

3. A calutron receiver comprising an outer wall provided with a face plate, said face plate being provided with an aperture to permit entry of ions, wall means forming a first insulated pocket disposed in said receiver for receiving and collecting a first ion beam, wall means forming a second insulating pocket disposed adjacent to the said second pocket within said receiver for receiving and collecting a second adjacent beam, one wall of said first pocket forming means extending into said aperture for dividing said aperture into first and second openings for said first and second ion beams, an auxiliary electrode within said receiver and terminating in said second opening to intercept a portion of said second beam, and respective current measuring means connected to said pockets and said auxiliary electrode for indicating the respective deionizing currents thereto.

4. The method of controlling a calutron ion beam for optimum collection of a first ion beam of two adjacent component beams comprising the steps of adjusting the beam accelerating potential until a maximum ion current is received at a first collector and varying the focus of said beam until a maximum ratio is achieved between the current received in a second collector and that received at a third collector disposed in said receiver adjacent the entrance to said second collector.

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