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2,665,384

ION ACCELERATING AND FOCUSING SYSTEM

Filed July 18, 1950

2 Sheets-Sheet 1

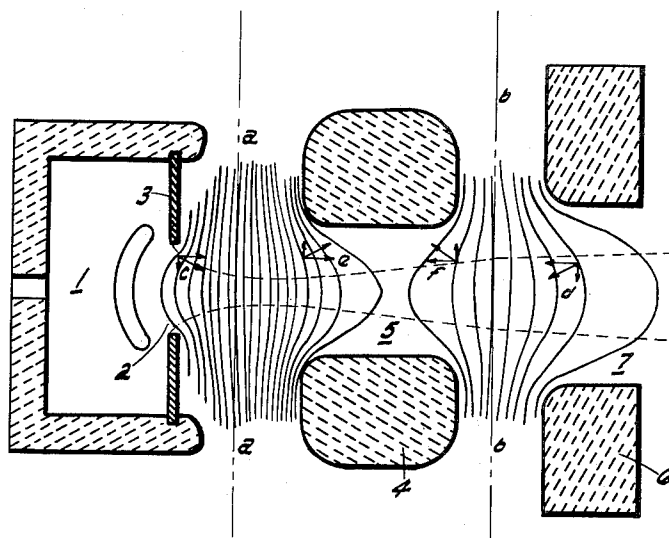


FIG. 1

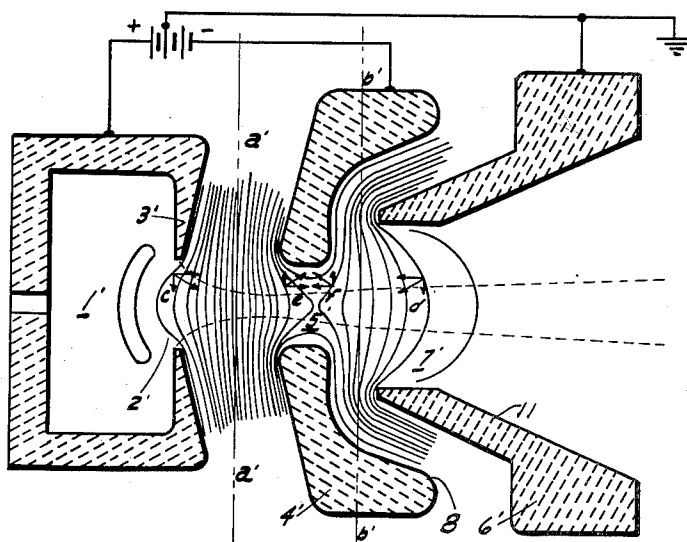


FIG. 2

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2 Sheets-Sheet 2

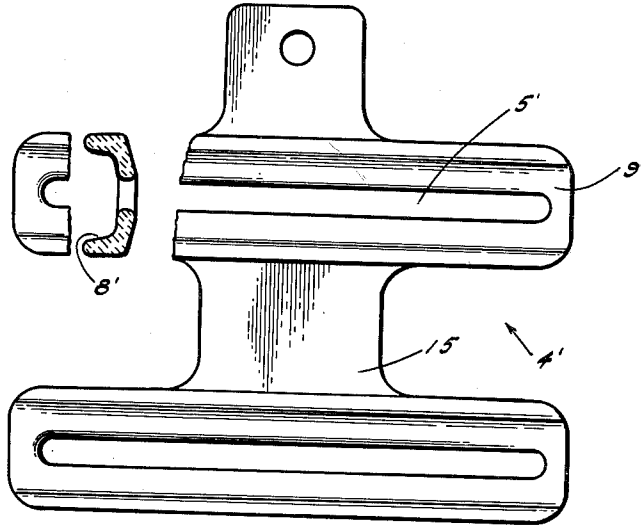


FIG. 3

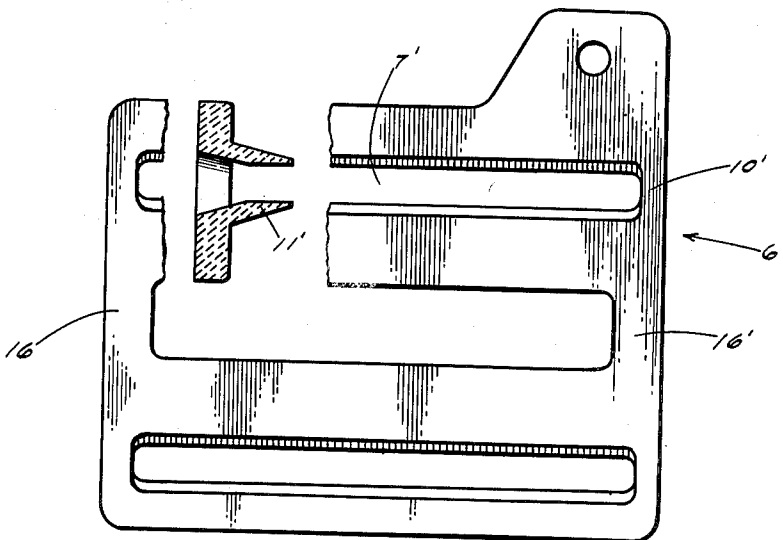


FIG. 4

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ION ACCELERATING AND FOCUSING
SYSTEM

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Atomic Energy Commission

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5 Claims. (Cl. 250—41.9)

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My invention relates to ion accelerating and focusing systems, and more particularly to a system of electrodes for accelerating and focusing ions in electromagnetically operated equipment for the separation of substances or isotopes of elements, such as in calutrons for separating ions on a production scale.

In the calutron, it has been the practice to vaporize a charge material through heating, then pass the neutral vapors into an ionizing chamber where they are subjected to electron bombardment to produce ions, remove the ions from the chamber through an exit slit and accelerate them into a magnetic field at substantially right angles thereto, where they are caused to follow paths whose curvature depends upon their ionic mass, that is, these paths are of generally arcuate configuration having radii which correspond to their respective masses and velocities. These ions are then collected in receivers located at or near the focal points of the ion beams. Magnetic shim-ming places this focal point at the 180° position.

The ionizing source usually takes the form of an electric arc adjacent the exit slit and parallel to the magnetic field of the equipment, between a hot filamentary cathode and a plate anode located at opposite extremities of the ionizing chamber. This source is comprised of positive and negative ions in equilibrium forming a plasma in vapor containing the desired type of atom. The system for removing, focusing, and accelerating the ions from the ionizing chamber into the magnetic field generally relies on the walls of the exit slit and probably on the plasma boundary as one electrode and includes two additional spaced electrodes maintained at appropriate differences in potential with respect to the walls of the exit slit and to each other, with slits therein for alignment with the exit slit of the ionizing chamber.

The electrodes in the arrangements heretofore used were bulky, and in view of the structural support requirements, the high potentials and the configurations employed, it has been customary to space the electrodes at appreciable distances from each other and from the exit slit. This spacing has limited the effect of the accelerating potentials upon the ions in the ionizing chamber, and has been an obstacle to increasing ion flow from the exit slit. This also led to excessive defocusing and loss of ions. It has limited the collection at the receivers and in turn the efficiency of operation of the device.

Applicant with a knowledge of these problems in the prior art has for an object of his invention

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the provision of an ion accelerating and focusing system having electrodes with complementary tapered faces to alter the electrostatic field and improve the focusing of the ion beam.

Applicant has as another object of his invention the provision of an ion accelerating and focusing system having electrodes with overlapping portions for bringing them into close proximity with the exit slit of an ionizing chamber to reduce defocusing in the accelerating slit region, and in turn increase the ions collected by the receivers.

Applicant has as a further object of his invention the provision of an ion accelerating and focusing system having the intermediate electrode of a series of electrodes with an aperture or slit which is smaller than the slits of the other electrodes for increasing the gradient at the exit slit to provide more ions and decrease the defocusing effect of the system, thus making available a greater number of such ions for collection and increasing the efficiency and output of the system.

Applicant has as a still further object of his invention the provision of an ion accelerating and focusing system having the outer accelerating electrode overlapped within the intermediate electrode of the system to reduce defocusing of the ions in the region of deceleration, and to increase the strength of the intermediate electrode.

Applicant has as a still further object of his invention the provision of an ion accelerating and focusing system with improved spacing for the electrodes to reduce the defocusing path of travel of the ions and limit the spread of the beam and the scattering of ions.

Other objects and advantages of my invention will appear from the following specification and accompanying drawings and the novel features thereof will be particularly pointed out in the annexed claims.

In the drawings, Fig. 1 is a detail of a conventional ion accelerating and focusing system in general use in electromagnetically operated equipment for the separation of ions such as the calutron with the equipotential lines diagrammatically shown therein. Fig. 2 is a view showing the arrangement of electrodes in my improved system with the equipotential lines diagrammatically shown therein. Fig. 3 is an elevation view including a revolved section showing a pair of my improved intermediate electrodes joined together for mounting. Fig. 4 is an elevation view including a revolved section showing a pair of

my improved outer electrodes joined together for mounting.

Referring to the drawings in detail, and particularly to Fig. 1, wherein the conventional ion accelerating and focusing system is schematically shown, 1 designates the usual ionizing chamber of a calutron having an exit slit 2 for the removal of ions. In this arrangement a thin plate 3 with a flat outer surface provides the walls defining the exit slit 2 for the ionizing chamber. This thin plate also serves as the inner electrode and is generally maintained at a high positive potential, such as at about 40,000 volts. In practice, this electrode and the slit therein are made by cutting a slot of appropriate size in a single thin plate of carbon, normally of about $\frac{1}{2}$ of an inch to $\frac{1}{4}$ of an inch in thickness, which causes such plate to run at a high temperature in operation because of the ion bombardment. The use of the thin inner electrode 3 thus enables it to run comparatively free from crud, a material usually deposited from the plasma region on the electrode. Moreover, any crud formed on the thin plate or electrode is usually concentrated on the under side of the plate where it cannot choke off or close the exit slit 2.

The intermediate electrode is generally thicker than the inner electrode and has a slit 5 therein for alignment with the exit slit 2 of the ionizing chamber. The walls defining the slit 5 are rounded to reduce sparking and provide an opening for the passage of the ions. This electrode is maintained at a high negative potential of around (—) 40,000 volts, and serves to provide a high accelerating potential for removing ions from the ionizing chamber through the exit slit 2 and/or for projecting them into space where they are acted upon by the usual magnetic field of the calutron. This action tends to push the plasma in the ionizing chamber back toward the arc center, forming on the plasma a concave surface called the miniscus, and its shape helps to determine the sharpness of the focus of the beam. Since this electrode with its high negative potential tends to spread and/or defocus the beam as soon as the ions thereof come within the area of its influence, the relatively great spacing which this form or shape of electrode necessitates requires the ions to move an appreciable distance through the field covered by this electrode, thus giving the beam a considerable spread.

The outer electrode is generally of rectangular shape with a slit 7 therein aligned with the slits in the other electrodes referred to above. It is customarily maintained at the potential of the tank walls and receivers since the ion paths are calculated for a region in which no electric field exists. The outer electrode serves to slow down the ions to a velocity corresponding to the potential of that electrode. It also assists in focusing the beam. In short, the outer electrode is generally maintained at ground potential which is customarily more positive than the intermediate electrode, thereby exerting a focusing effect upon the spreading beam, but the appreciable spacing of this electrode from the intermediate electrode limits its useful effect.

The output of the above conventional arrangement is to a large extent dependent on the intensity of the electric field in the region of the initial ion acceleration, that is, the region of the miniscus. To increase these field gradients it has long been desired to use closer geometries. Such geometries, however, require better focus-

ing of the ion beam in this region than is obtained with the electrodes of conventional shape heretofore used, for otherwise the beam is either too greatly defocused at the receiver end of the calutron, to give good operation, or is partially blocked by the intermediate electrode, causing high drains, sparking, and low efficiency. In the improved electrode system the electric fields are altered so as to provide better focusing, thereby permitting the closer geometries to be advantageously used. Equipotential lines on Fig. 1 indicate the areas of influence of each electrode with the substantially straight lines $a-a$ and $b-b$ between the electrodes being the lines of demarcation. The general shape or scope of the ion beam is dotted in.

The improved system, shown in Fig. 2, gains its improved focusing partially from two features, that is, the use of a thin inner electrode whose surfaces facing the accelerating fields are inclined to the inner electrode plane, forming a flat truncated V, and the use of an intermediate electrode whose surfaces opposite the inner electrode are inclined at roughly the same angle to the plane of the inner electrode as are the inclined outer surfaces of said inner electrode. These inclined surfaces produce electric forces or gradients which are directed more toward the center of the slit in the intermediate electrode, and which tend to reduce any electrostatic defocusing that may occur at the edge of the beam. The inclined surfaces on the inner electrode are in practice obtained by tapering the outer surface thereof toward the inside edges of the exit slit. In this arrangement, the center equipotential line $a'-a'$ is shifted toward the intermediate electrode, thus reducing the influence of that electrode on the beam and increasing the focusing force while decreasing the defocusing force, since to the right of the straight line, there is a defocusing force and to the left of that line there is a focusing force. The lengths of the paths of travel of the ions in the defocusing area are likewise reduced. These features may be apparent from an examination of the figure which indicates that the lines on either side of the straight one are bowed. Lines normal to them have components which exert a focusing or a defocusing force on the ions in the region depending upon the direction in which these lines are bowed. Accordingly, arrows have been placed on the figure to generally indicate the action and direction of these forces for different regions in the system. Of course, it will be understood that the vectors appearing in the drawing are set forth for illustration of the action of the fields involved within particular areas and do not purport to represent the magnitudes of the forces involved. In this connection, arrows c, d indicate focusing components while arrows e, f indicate defocusing components, that is, arrows c, d are repelling forces and e, f are attracting components. The general shape of the narrower beam produced by this arrangement is indicated by the dotted lines of the figure.

Another factor contributing to improved focusing between the inner and intermediate electrodes is the making of the slit through the intermediate electrode of smaller size than that of the exit slit of the ionizing chamber. By reducing the size of this slit in the intermediate electrode and by bringing the walls of the electrode closer to the center of the slit, the slit center more nearly approaches the potential of the electrode. This, in cooperation with the comple-

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mentary walls of the inner and intermediate electrodes, insures improved focusing and permits the closer spacing of the electrodes for ejecting and increasing the number of ions leaving the ionizing chamber.

An additional feature is the positioning of the outer electrode near the ionizing chamber by extending it into the flared outer portion of the intermediate electrode in overlapping relation therewith while not making undue sacrifice in the rigidity of the structure and mounting, thus preserving strength for overcoming the considerable attractive force introduced by the high differences in potential of the system. In this way, the distance, and therefore the time, the ion travels in a region of the electrostatic field is reduced to a minimum, thereby minimizing the space charge defocusing as much as possible while preserving the space clearance which must be maintained to meet electrical tolerance requirements.

Now referring more in detail to the structural details of Fig. 2, the conventional ionizing chamber 1' has an exit slit 2' defined by a plate or electrode 3' of carbon or other suitable material, whose outer walls or faces slope or taper inwardly at an angle of about 15° to the plane of the inner electrode as they approach the exit slit. Positioned adjacent inner electrode 3', which forms one wall of the ionizing chamber, is an intermediate electrode 4' having a central portion 8' which projects or flares inwardly toward the inner electrode 3'. The face or surface of the flaring portion of the intermediate electrode opposite the inner electrode extends in a direction and at an angle which is parallel to the outer face of such inner electrode, that is, it tapers towards the inner electrode at an angle of about 15° to the plane of such electrode. The opening or slit 5' in the electrode 4' is smaller than the exit slit 2' of the ionizing chamber 1'. The body portion 9' thereof is substantially rectangular in shape and when combined with the inwardly flaring central portion 8', provides a slanting space between the inner and intermediate electrodes and probably contributes to the bowed configuration of the equipotential surfaces or lines therein which influence the focusing, while positioning the supporting portion 9' back from the ionizing chamber 1' at a sufficient distance to permit rigid mounting. In addition, this configuration of the intermediate electrode tends to space the body portion 9' thereof back away from the inner electrode 3' and tends to reduce any vibration which might arise from attraction due to electrostatic forces.

The outer electrode 6' has a substantially rectangular body 10' and a relatively long tapered extension 11' which projects into the flared central portion 8' of the intermediate electrode 4'. The bore or slit 7' in the outer electrode is also tapered inwardly toward the exit slit 2'. By positioning the extension 11' of the outer electrode 6' in spaced overlapping relation with respect to the flared central portion 8' of the intermediate electrode 4', it is possible to bring the decelerating portion of the outer electrode 6' into proximity with the exit slit while positioning the body portion 10' thereof remotely from the inner electrode 3' to facilitate rigid mounting and to reduce the tendency to vibrate in response to changes in the electrostatic field.

As will be seen from Fig. 3, the intermediate electrodes 4' are made up in pairs joined by a central supporting web 15' which bridges the bodies of the electrodes. Also in Fig. 4 it will be

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seen that the outer electrodes 6' are similarly fabricated, except that they are joined through a pair of brackets or cross members 16', 16' which bridge the electrodes at their ends. From the foregoing, and from an examination of Fig. 1 it will be apparent that the electromagnetically operated units for the separation of isotopes of elements are generally operated in pairs, and that the calutron includes at least two of such units with two sets of ionizing chambers, two sets of accelerating electrodes, and two sets of receivers, but they may be housed in a single vacuum system and use a single magnetic field. However, the above explanation is not intended as a limitation on this invention, since it is equally applicable to a single, as well as a plurality of units, and individual conventional mountings for the electrodes and other elements can be provided.

Having thus described my invention, I claim:

1. A system of accelerating and focusing electrodes for electromagnetically operated equipment for the separation of isotopes comprising an inner electrode adapted to be maintained at a high positive potential and having an opening for the passage of ions, an intermediate electrode spaced from the inner electrode and having an opening aligned with the opening in the inner electrode, said intermediate electrode being adapted to be maintained at a high negative potential for accelerating the ions passing through the inner electrode, and an outer electrode positioned in overlapping spaced relation with respect to the intermediate electrode, said outer electrode having an opening aligned with and of larger size than the opening in said intermediate electrode for the passage of ions and being adapted to be maintained at a potential intermediate that of said inner electrode and said intermediate electrode for decelerating said ions.

2. A system of accelerating and focusing electrodes for electromagnetically operated equipment for the separation of isotopes comprising a slotted inner electrode adapted to be maintained at a high positive potential for the passage of ions, an intermediate electrode having an opening therein of smaller size than the slot of said inner electrode, said intermediate electrode being spaced from said inner electrode and adapted to carry a high negative potential for accelerating the ions, and an outer electrode spaced from said intermediate electrode and having an opening therein for the passage of ions, said outer electrode being adapted to be maintained at a potential intermediate of said inner electrode and said intermediate electrode to provide deceleration.

3. A system of accelerating and focusing electrodes for electromagnetically operated equipment for the separation of isotopes comprising an inner electrode being adapted to be maintained at high positive potential having an opening for the passage of ions, said inner electrode having an outer surface tapering towards said opening, an intermediate electrode having an opening aligned with that in the inner electrode for the passage of ions, said intermediate electrode being adapted to be maintained at a high negative potential to accelerate said ions through the opening therein, said intermediate electrode also having a surface slanting in a direction parallel to the outer surface of said inner electrode to reduce defocusing, and an outer electrode having an opening therein aligned with the opening

in said intermediate electrode for the passage of ions, said outer electrode being adapted to be maintained at a potential intermediate the potentials of said inner electrode and said outer electrode for decelerating said ions.

4. A system of accelerating and focusing electrodes for electromagnetically operated equipment for the separation of isotopes comprising an inner electrode being adapted to be maintained at high positive potential having an opening therein for the passage of ions, a cup shaped intermediate electrode having a flaring portion projecting towards said inner electrode with an opening therein aligned with the opening in said inner electrode, said intermediate electrode being adapted to be maintained at a high negative potential for accelerating said ions, and an outer electrode having a slotted tapered extension for projecting into the flared portion of said intermediate electrode for alignment with the opening therein, said outer electrode being adapted to be maintained at a potential intermediate the potential of said inner electrode to said intermediate electrode to provide deceleration.

5. A system of accelerating and focusing electrodes for electromagnetically operated equipment for the separation of isotopes comprising an inner electrode being adapted to be maintained at high positive potential having an open-

ing for the passage of ions, said inner electrode having an outer surface tapering towards said opening, a cup shaped intermediate electrode having a flaring portion projecting towards said inner electrode with an opening therein aligned with the opening in said inner electrode and with an outer surface slanting in a direction parallel to the outer surface of said inner electrode, said intermediate electrode being adapted to be maintained at a high negative potential for accelerating the ions from the inner electrode towards said intermediate electrode, and an outer electrode having a slotted tapered extension for projecting into the flared portion of said intermediate electrode for alignment with the opening therein, said outer electrode being adapted to be maintained at a potential intermediate the potential of said inner electrode and said intermediate electrode to provide deceleration.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,452,893	Bachman	Nov. 2, 1948
2,476,005	Thomas	July 12, 1949
2,536,878	Fleming	Jan. 2, 1951
2,551,544	Nier et al.	May 1, 1951