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Hendry et al.

[11] **3,725,709**

[45] **Apr. 3, 1973**

[54] CYCLOTRON BEAM EXTRACTION

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[73] Assignee: **The Cyclotron Corporation**, Berkeley, Calif.

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[52] **U.S. Cl.** **313/62**, 313/63

[51] **Int. Cl.** **H05h 13/00**

[58] **Field of Search** 313/62, 63; 328/234

[56] **References Cited**

UNITED STATES PATENTS

3,582,700 6/1971 Hendry 313/62

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[57] **ABSTRACT**

A method and apparatus for extraction of high beam currents from an isochronous cyclotron which segregates that portion of the orbiting particles to be extracted at the extraction radius in the absence of any electric deflection field and then electrostatically deflects the segregated particles from orbit with an electrostatic field the location of which increases in radius with respect to the center of the cyclotron. Segregation is made by a long sloped and cooled preseptum preceding an electrostatic deflection channel.

6 Claims, 7 Drawing Figures

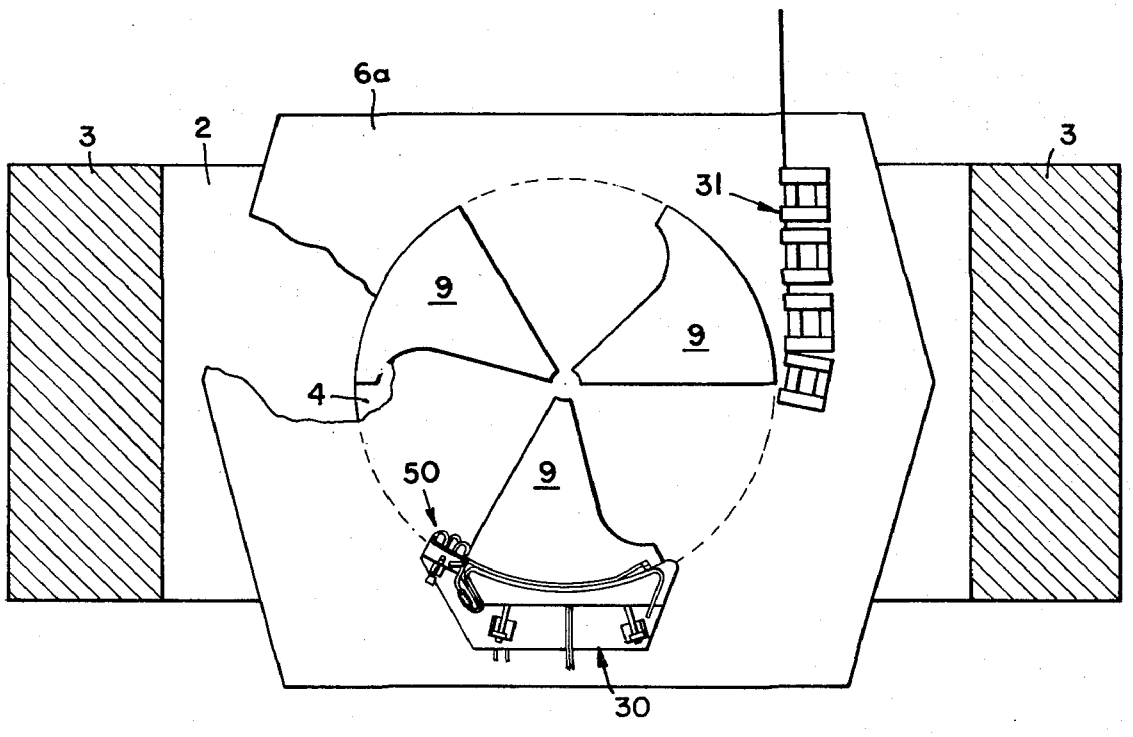


FIG_1

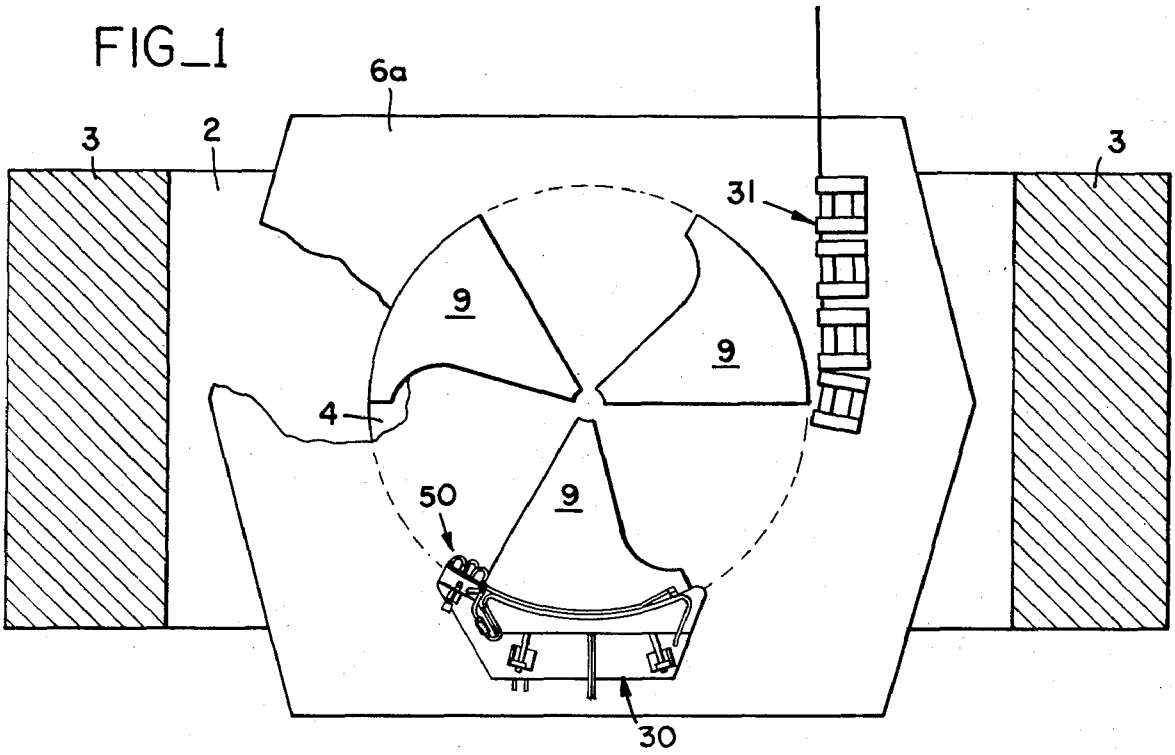
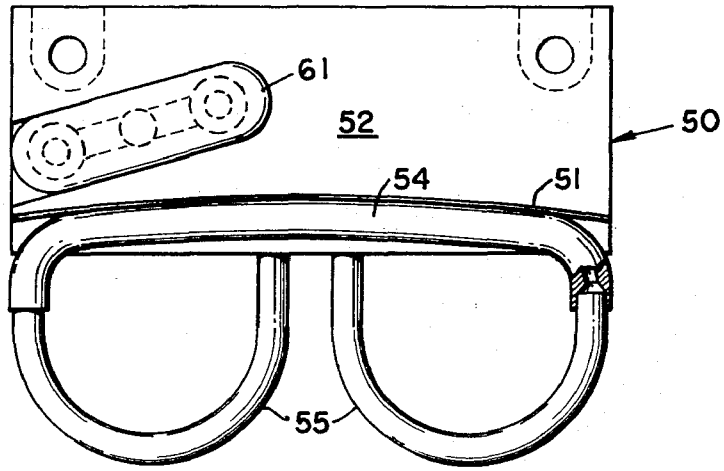


FIG_4



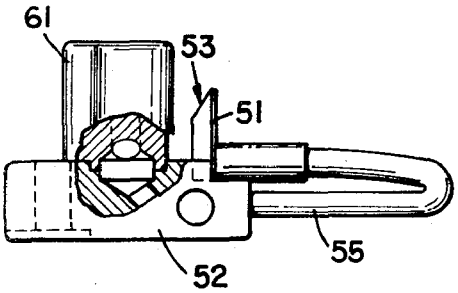


FIG_5

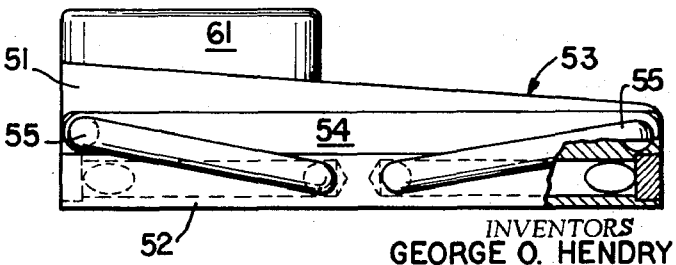


FIG_6

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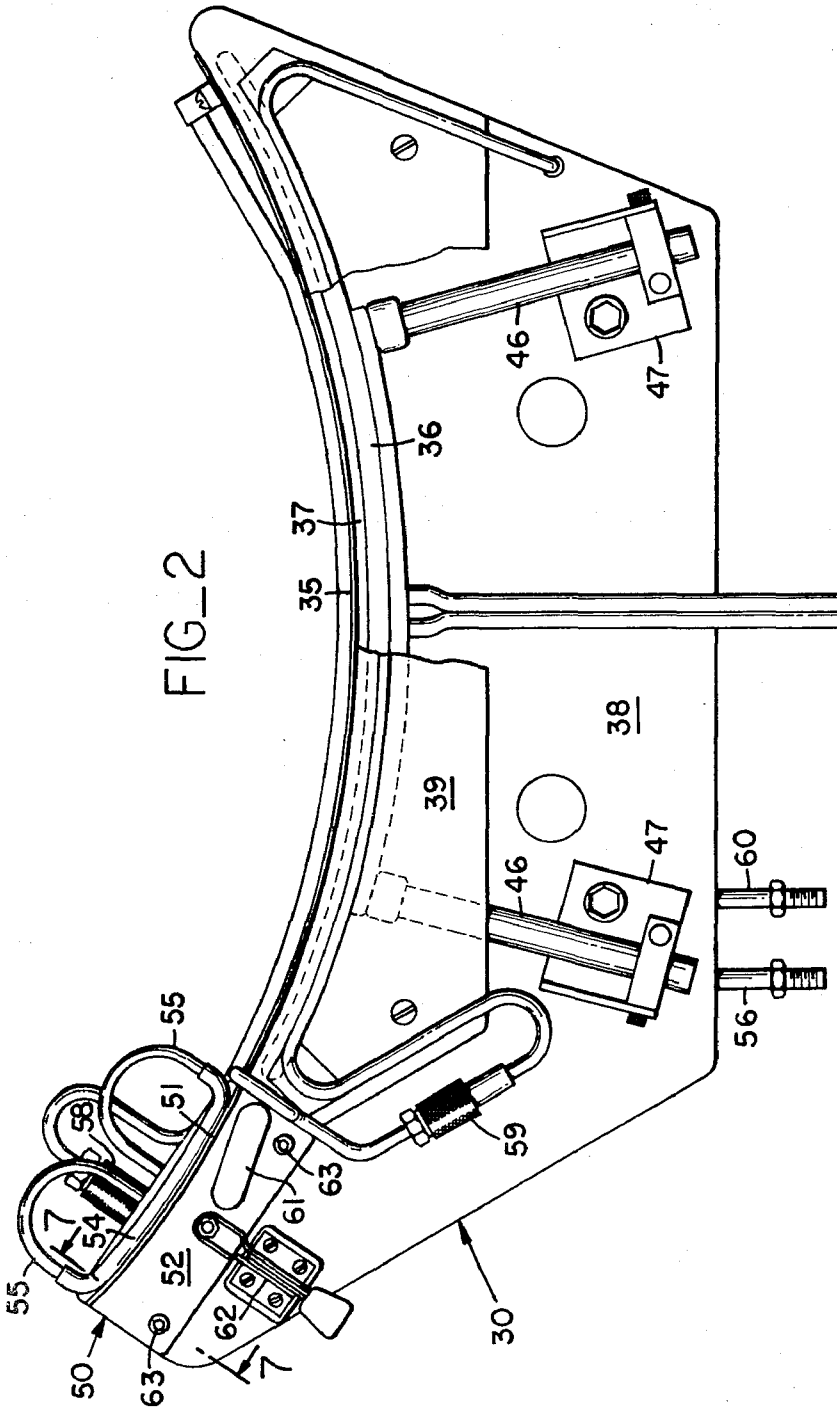

FIG_2

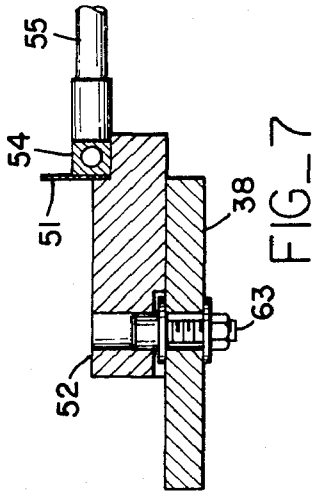

FIG_7

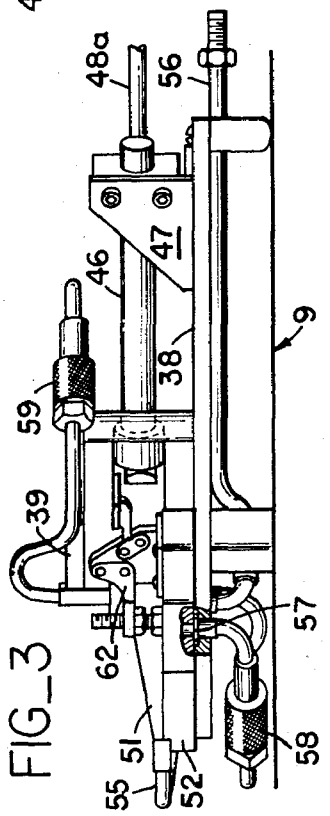

FIG_3

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CYCLOTRON BEAM EXTRACTION

This invention relates generally to beam extraction from isochronous cyclotrons and more particularly to a method and means for extracting a high quality beam with increased power.

One object of this invention is to increase the amount of high quality beam current obtainable from an isochronous cyclotron.

Another object of this invention is to provide a method and means for physically segregating that portion of orbiting particles to be extracted within the cyclotron at the extraction radius in the absence of any electric deflection field preliminary to their exposure to an electrostatic deflection field.

Still another object of this invention is to provide an improved method and means for reducing the power density on and for dissipating the heat generated in electrostatic deflection systems.

One other object of this invention is to enhance uniform beam deflection within the electrostatic deflection channel by preliminary particle segregation over a long sloped preseptum in the absence of any electric deflection field.

Other objects and advantages of this invention will become apparent from a consideration of the following description in connection with the drawings wherein

FIG. 1 is a partially schematic cross-sectional view of a typical isochronous cyclotron at its median plane;

FIG. 2 is a plan view of the preseptum and electrostatic deflection assembly of this invention;

FIG. 3 is an end elevational view of the preseptum and electro-static deflection assembly of FIG. 2;

FIG. 4 is a plan view of the preseptum unit only;

FIG. 5 is an end view partially in section of the preseptum unit of FIG. 4;

FIG. 6 is an elevational view of the preseptum unit of FIG. 4 from the cyclotron central region; and

FIG. 7 is a partial sectional view of the preseptum unit taken along lines 7 — 7 of FIG. 2 to illustrate its locating means.

The external beam from isochronous cyclotrons generally is limited by high power density on the electrostatic extraction system. Any attempt to increase the external beam current increases the power density on the septum until it is destroyed by heat generated from accelerated particles impinging upon it. The septum power densities in isochronous cyclotrons are particularly high in the first place because of their characteristic small internal beam height.

This invention relates to the electrostatic extraction method and apparatus for isochronous cyclotrons disclosed in co-pending application, Ser. No. 775,027 entitled cyclotron beam extraction system filed on Nov. 12, 1968 by George O. Hendry, now U.S. Pat. No. 3,582,700. The external beam current of isochronous cyclotrons therein described can be markedly increased by preliminary segregation of the orbiting particles to be extracted with a preseptum in the absence of any electric deflection field followed by electrostatic deflection of those segregated particles as is therein described. In this manner the heat generated by impingement of orbiting particles is taken by the preseptum where it is effectively distributed and dissipated. More uniform deflection then occurs in the electrostatic deflection channel since it need not be designed with an impingement notch.

FIG. 1 illustrates the orientation of the electrostatic deflection means and preseptum of this invention with respect to the other components of a typical small isochronous cyclotron at its median plane. A main d-c electromagnet defines a magnetic guide field for the particles orbiting within the evacuated region of the cyclotron. The main d-c magnet includes a lower yoke slab **2**, a pair of interconnecting iron legs **3** and two cylindrical iron pole bases **4**, the lower one of which is shown in FIG. **1**. In the described embodiment the lower pole tip is warp plate **6***b* which with sidewalls and with a similar upper warp plate form a vacuum tank within which charged particles are accelerated in the machine.

Three shaped hill pieces **9** mount on each of the warp plates in corresponding locations to produce the azimuthally varying field necessary for isochronous operation. A pair of hollow 120° dees within the vacuum tank provides a radio frequency accelerating field and an ion source supplies ions for acceleration in the central region of the cyclotron between the two dees all as is more fully described in copending application Ser. No. 775,027.

In this embodiment the extraction system comprises electrostatic deflection means **30** like that shown in copending application Ser. No. 775,027 and a magnetic channel **31** which receives and radially focuses a beam of ions deflected by the electrostatic deflection means. Also a preseptum unit **50** mounts adjacent to the electrostatic deflection means **30** at the extraction radius and precedes it with respect to the path of orbiting particles.

FIGS. **2** through **7** show the preseptum unit **50** in detail and its orientation with respect to the electrostatic deflection means **30**. The latter comprises a thin curved tungsten septum **35** maintained at ground potential and a curved deflector electrode **36** which is held at a high negative potential (for positively charged accelerated particles). The septum **35** and deflector electrode **36** define between them a shaped electrostatic channel **37** with a high electric field gradient which is located so it increases in radius with respect to the center of the cyclotron. When traversed by the segregated orbiting particles the field forces the ions to move to a larger radius where they no longer are held to a circular path by the main magnet. With the preseptum unit in place the septum need not have a notch to distribute particle impingement.

The septum and deflector electrode are carefully shaped and located so that the extracted beam remains centered in the channel as it moves to greater radius. Both mount upon a water cooled nonmagnetic base plate **38** pivotally mounted on one of the hill pieces **9** as shown in FIG. **1**. The septum **35** clamps to the base plate **38** and an upper cooling plate **39**. A pair of alumina insulators cantilevered from brackets **47** support the hollow copper deflector electrode **36** from base plate **38**. Electrode **36** is cooled by water coolant supplied to its interior through hollow electrical conductor **48***a* and returned through conductor **48***b*. The same conductors **48***a*, **48***b* provide the high electrical potential to the electrode from its power supply.

After leaving the electrostatic channel **37** the deflected beam of extracted particles follows a path of increasing radius and is focused radially by magnetic channel **31**.

While output beam currents in the order of 50 microamperes of 22 MeV protons can be obtained with the described electrostatic deflection means alone, marked improvement in external beam current is obtained by using the preseptum for preliminarily segregating particles to be extracted prior to their entry into electrostatic channel **37**. The preseptum unit **50** shown in detail on FIGS. **4**, **5** and **6** includes a thin curved tungsten preseptum **51** brazed or soldered to preseptum base plate **52** which in turn mounts upon base plate **38** of the electrostatic deflection means **30**. The leading edge designated **53** of the preseptum **51** as shown in FIG. **6** slopes upwardly with respect to the cyclotron median plane in the direction of the orbiting particles. Preseptum **51** is maintained at ground potential and intercepts and segregates that portion of the orbiting particles at the extraction radius which are to be deflected from orbit by the electrostatic channel **37**. The orbiting particles normally are distributed about the median plane and the slope of the leading edge **53** distributes beam impingement along a considerable length of preseptum to reduce the impingement power density and to facilitate heat removal from the preseptum. Accordingly, the entry portion of the leading edge is on one side and its trailing portion terminates on the other side of the median plane of the machine.

Cooling conduit **54** brazed to preseptum **51** carries cooling water communicated to it through cooling water conduits **55** connected to channels in preseptum base **52** that are in series with the cooling water circulating system for the electrostatic deflector. Coolant from inlet line **56** passes through base plate **38** and an O-ring seal to the channels in preseptum base **52** and through preseptum cooling conduit **54**. It then returns to the preseptum base, emerges through the O-ring seal **57** shown in section in FIG. **3** into conduit **58** which carries it to conduit **59** and the deflector means system for final return at outlet line **60**.

Water cooled copper beam dump **61** mounted on preseptum base **52** and interconnected with the cooling water system in the preseptum base shields the deflector electrode **36** of the electrostatic deflection means from beam impingement.

In the embodiment shown the preseptum unit **50** is secured to the electrostatic deflection means base plate **38** by a miniature toggle clamp **62**. Its orientation with respect to the electrostatic deflection means is maintained by locating pins **63**.

With a preseptum as described a normal beam current of 50 microamperes of 22 MeV protons is increased to the order of 100 to 150 microamperes of 22 MeV protons.

It should be understood that the specific embodiments described herein are for illustrative purposes only and that it will be apparent to those skilled in the art that various modifications may be practiced and equivalents substituted for those specific elements described which are within the scope of the invention defined in the appended claims.

We claim

1. A method for extracting a beam of charged particles orbiting in a cyclotron within its guiding magnetic field and evacuated region comprising the steps of

continuously segregating that portion of the orbiting particles to be extracted at an extraction radius near the fringe of said magnetic field in the absence of any electrostatic deflection field; and

then deflecting the segregated particles from orbit at said extraction radius by exposure to an electrostatic deflection field the location of which increases in radius with respect to the center of the cyclotron.

2. Improved apparatus for extracting a beam of charged particles orbiting in a cyclotron within its guiding magnetic field and evacuated region comprising

means segregating that portion of said orbiting particles to be extracted at an extraction radius near the fringe of said magnetic field in the absence of any electrostatic deflection field; and

electrostatic deflection means receiving said segregated particles and defining at the extraction radius an electrostatic deflection field, the location of which increases in radius with respect to the center of the cyclotron, to deflect the segregated particles from orbit.

3. The apparatus of claim **2** wherein the means segregating the particles is a sloped and cooled preseptum adjacent to and preceding the electrostatic deflection means in the path of said particles.

4. The apparatus of claim **3** wherein the preseptum slopes from one side of the median plane to the other.

5. The apparatus of claim **3** wherein the preseptum is at ground potential.

6. The apparatus of claim **3** further comprising a beam dump shielding the deflector electrode of the electrostatic deflection means from beam impingement.

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