Sept. 2, 1952 M. D. MARTIN 2,609,500

INJECTOR MECHANISM

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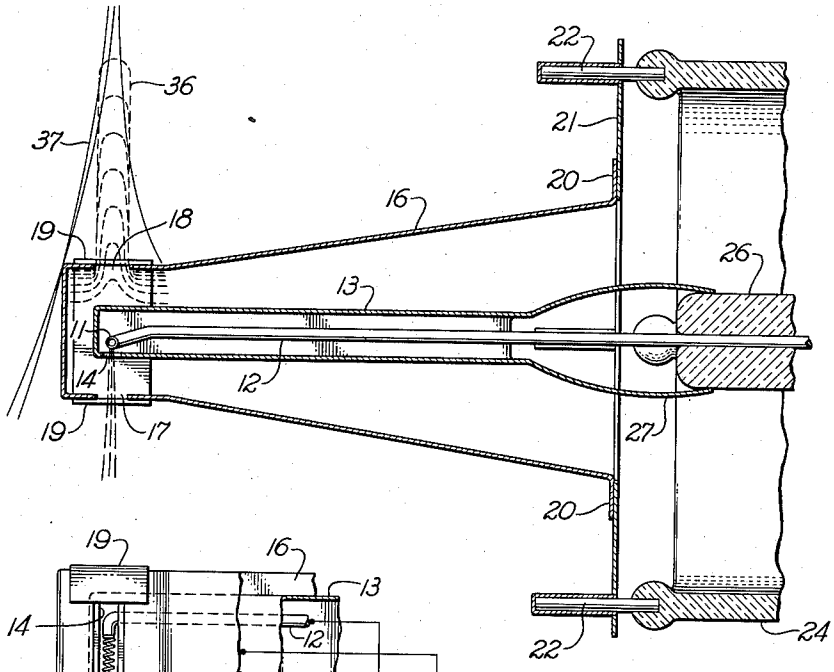


Fig. 1.

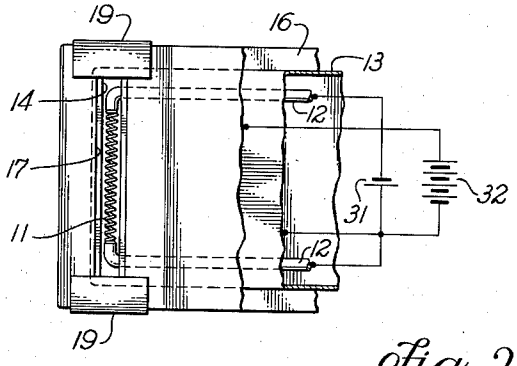


Fig. 2.

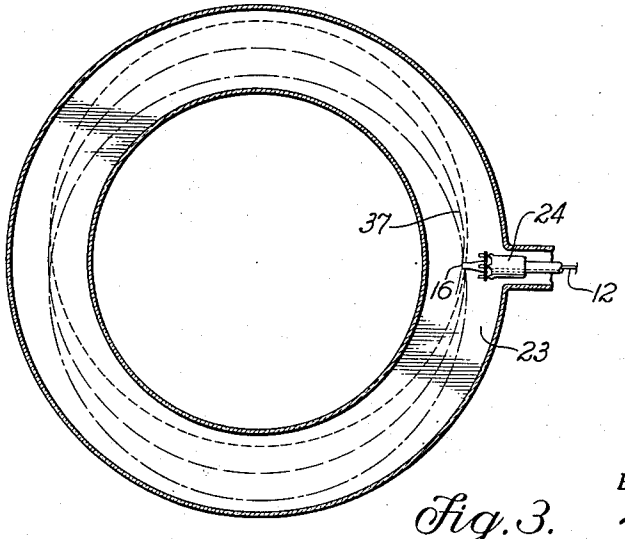


Fig. 3.

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INJECTOR MECHANISM

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8 Claims. (Cl. 250—27)

1

The present invention relates generally to particle accelerators and in more particular to improvements in injectors for synchrotrons and the like.

The injection of charged particles into particle accelerators and similiar apparatus that constrain charged particles to retraverse substantially circular orbits often interferes with the subsequent acceleration of the particles in that the injector mechanism is, of necessity, located in close proximity to the particle orbit. This is particularly true in synchrotrons which constrain injected particles to travel in orbits of constant radius that therefore approach the injector mechanism; and it is thus with reference to particle accelerators of the synchrotron type that the invention is disclosed and described.

Considering first the magnitude of interference normally resulting from the injector mechanism of a synchrotron, it is noted that maximum injector efficiency is obtained with the injector mechanism located approximatley on the circular orbit of the accelerated particles. In a typical synchrotron operation electrons are accelerated about a constant radius orbit wherein, for example, they traverse the orbit about 25 times each microsecond and an accelerating cycle lasting 8,000 microsecends requires 200,000 complete traversals of the orbit within this time. It will be appreciated that only the relatively few electrons which follow displaced orbits or orbits deviating from normal will complete the above accelerating cycle. Thus only these few electrons constitute the final accelerated beam and comprise useful output of the apparatus.

Numerous synchrotron modifications have in the past been developed for the purpose of overcoming the above-noted problems and these modifications have proven more or less advantageous with the maximum increase in the output beam being of the order of 50%. While such an increased output is undoubtedly desirable, the modifications generally relate to magnet modifications or the addition of expansion coils which not only add to the complexity and cost of the acceleration apparatus but also contain inherent limitations which limit further improvement in the accelerator efficiency.

The present invention accomplishes injection without interference with subsequent particle acceleration, in a manner explained in detail below and in conformity with the following objects.

It is an object of the present invention to provide a new and improved injector mechanism for particle accelerators.

2

It is another object of the present invention to provide an improved injector mechanism for particle accelerators which does not interfere with particle acceleration.

It is another object of the present invention to provide synchrotron injector mechanism capable of preventing particle impingement thereon.

It is still another object of the present invention to provide an improved injector mechanism for particle accelerators and including an electrostatic field guiding accelerated particles past said injector mechanism.

It is yet another object of the present invention to provide an improved method of injecting particles into a particle accelerator wherein the acceleration of particles is not impeded by the injection.

It is a further object of the present invention to provide an improved synchrotron injector mechanism having an electrostatic field guiding accelerated particles about the injector.

It is a still further object of the present invention to provide an improved synchrotron injector mechanism having an integral accelerating field further employed to guide accelerated particles past the injector.

The manner in which the above objects are accomplished is fully set forth in the following description of construction and operation which will best be understood when considered in conjunction with the accompanying drawings, wherein:

Figure 1 is a plan view of the injector mechanism in section;

Fig. 2 is a side elevation of the injector tip partially broken away and including a simplified representation of an associated electrical system; and

Fig. 3 is a plan view of a synchrotron chamber showing the injector mechanism in position.

Referring first to an injector mechanism as shown in Figs. 1 and 2, it will be noted that there is provided a filament 11 heated by electrical conductors 12 and formed of an electron emissive material adapted to supply a copious quantity of electrons upon the application of heat thereto. About filament 11 and leads 12 there is disposed a shield 13 which entirely encloses filament 11 and leads 12 adjacent thereto with the exception of one face of filament 11. An elongated aperture 14 in shield 13 disposed adjacent filament 11 and aligned with the major dimension thereof provides exit means whereby electrons produced by filament 11 may be removed therefrom past shield 13. Exterior to

shield 13 and surrounding same is an accelerating electrode 16 which may be formed in the general shape of a square truncated cone with a closed small end or may alternatively comprise a generally U-shaped plate disposed about shield 13 as shown in Fig. 1. Electrode 16 has an elongated aperture 17 therein in general alignment with the aperture 14 in shield 13 and preferably of a greater width to accommodate the passage of a slightly divergent beam of electrons. A second aperture 18 in electrode 16, of the same size as aperture 17, is provided on the opposite side of filament 11 and shield 13 from aperture 17. In the illustrated embodiment of the invention, strengthening of the tip of electrode 16 may be accomplished by the use of braces 19 secured to electrode 16 across the ends of apertures 17 and 18.

The above-described injector elements may be secured in position by any suitable means such as, for example, the mounting arrangement illustrated in Fig. 1. As shown, electrode 16 is provided with a flange 20 extending outwardly from the open end thereof, and this flange is secured as by soldering to a plate 21, which is in turn mounted upon pins 22, as shown. Extending into the synchrotron chamber 23, as shown in Fig. 3, is an insulating stem 24 having indentations upon the inner end thereof into which pins 22 mate to provide support for electrode 16. Within insulating stem 24 there is provided a second elongated insulating member 26 through which filament leads 12 pass in rigid relation thereto and upon which is mounted shield member 13, as by clamping means 27. Synchrotron chamber 23 is made vacuum tight about stem 24 and insulating member 26 by any suitable means, not shown, in order that particle acceleration may be accomplished in a high vacuum.

The elements of the injector are maintained at particular potentials relative to each other in order that they may accomplish their functions, as briefly stated above and more specifically explained below in the description of operation. As shown schematically in Fig. 2, a filament current supply 31 is connected between filament leads 12 to provide heating current for filament 11. Shield 13 is electrically connected to filament 11 to maintain each at the same potential, and potential supply means 32 is electrically connected between electrode 16 and shield 13. In the embodiment of the invention illustrated, electrons are produced at filament 11 for acceleration and in this instance electrode 16 is maintained at a positive potential with respect to shield 13 and filament 11 by potential supply means 32 for the purpose of attracting electrons from filament 11. It will be appreciated, however, that the relative potentials of the elements of the injector are determined by the type of particles to be accelerated, and also the type of source employed may be varied in order to produce the desired type of particles.

Considering now the operation of the invention, attention is first directed to the fact that the injector mechanism contemplates ejection of charged particles into a chamber or other envelope wherein these particles are more or less separately operated upon. For convenience of illustration, the following explanation is with reference to synchrotron operation wherein electrons expelled from the injector mechanism are constrained to travel constant radius orbits with increasing velocities. With filament 11 energized by heating current through conductors 12 from filament current supply 31, electrons are thermally emitted from the surface of filament 11 in copious quantities. Filament 11 and associated conductors 12 are electrostatically shielded by shield member 13 except for one face of filament 11 which lies adjacent aperture 14 in shield 13. The relatively high positive potential upon accelerating electrode 16 establishes an electrostatic field which, acting through aperture 14 in shield 13, attracts electrons formed at filament 11. Under the influence of this field, electrons at filament 11 are accelerated through aperture 14 in shield 13 toward electrode 16 and thence through aperture 17 therein. These electrons emerge from the injector mechanism with a certain minimum velocity and a small divergence in direction. Because of this small but unavoidable divergence in direction, these emerging electrons actually follow slightly different orbits which each have the same radii but which have the centers thereof slightly displaced. For the sake of simplicity, it is desirable to consider the electrons emerging from the injector mechanism as comprising a plurality of beams, as illustrated in Fig. 3. As may be seen from Fig. 3, upon completion of one revolution within the synchrotron, the displaced electron beams converge upon the injector mechanism and in the absence of preventative measures would in the great majority impinge upon the back of the injector mechanism much to the detriment of further acceleration of these beams. The present invention overcomes this difficulty by the novel arrangement described above with respect to construction features thereof. In essence, these features include the provision of shield member 13 adjacent aperture 18 in the back wall of electrode 16. Considering the electrostatic field configuration about shield 13, it will be appreciated that the equipotential lines between electrode 16 and shield 13 lie generally parallel thereto except in the vicinity of apertures in these elements. Immediately adjacent aperture 18 in electrode 16, the equipotential lines are bowed toward the aperture and in fact equipotential lines directly adjacent electrode 16 are materially expanded into a bubble which protrudes through aperture 18 exterior to electrode 16 much in the manner illustrated by dashed lines 36 in Fig. 1. This field configuration extends outwardly from the back of the injector mechanism and directly affects the orbits of electron beams accelerated in synchrotron chamber 23. As previously noted, the electron beams from the injector mechanism travel orbits of constant radius which are, however, slightly displaced from one another as a result of a small divergence in the direction of the electrons leaving the injector mechanism. This divergence is greatly magnified in Figs. 1 and 3, in order to more clearly illustrate the phenomenon. As will be seen from Fig. 3, the beams generally converge in the vicinity of the injector mechanism and it is this portion of the orbits that is depicted by lines 37 in Fig. 1. As the electron beams approach the bubblelike electrostatic field protruding from the back of the injector mechanism, they encounter a repelling force by virtue of the relative polarity of the electrostatic field thereabout and are in the main slightly deflected toward the center of their orbit. This deflection or repelling action is sufficient to guide a large portion of the electrons around the injector mechanism and these electrons then continue to revolve about the synchrotron chamber without subsequent interference by the injector mechanism. As will be seen from

Fig. 1, some few electrons approach the back of the injector mechanism at such an angle that they are deflected away from the center of their orbit and subsequently deaccelerated; however, this proportion is so small as to be negligible. It has been found that maximum advantage is obtained from the guiding electrostatic field at the back of the injector mechanism when aperture 18 is made the same size as aperture 17 and is exactly aligned therewith.

Typical operation of a synchrotron includes electron injection for a period of two microseconds, in the course of which some fifty revolutions are made by electrons in the synchrotron. Total acceleration may last 8,000 microseconds in which time some 200,000 revolutions are made and with a conventional injector a large percent of the electrons impinge upon the back of the injector mechanism; however, with the present injector the synchrotron output is multiplied some fifteen or more times over that possible with conventional apparatus.

The above description of the invention is referenced to only one type of particle accelerator and is disclosed in terms of but a single embodiment; all of which is in no-wise to be taken as limiting but only as one illustration of the invention. As it will be apparent to those skilled in the art that numerous modifications and variations are possible within the spirit and scope of the invention, no limitations are to be taken from the above description but instead attention is directed to the following claims for a precise definition of the novelty contained in the invention.

What is claimed is:

1. Particle accelerator injector mechanism comprising an electron emissive filament, a shield about said filament electrically connected to said filament and having an aperture therein for the passage of electrons therethrough, and an accelerating electrode adapted to be maintained at a positive potential with respect to said shield and filament and encompassing said shield and filament, said accelerating electrode having a first aperture therein aligned with the aperture in said shield and a second aperture situated on the opposite side of said shield and filament and aligned with said first aperture.

2. Synchrotron injector mechanism comprising an electron emissive filament, electrostatic shielding means including first and second electrodes surrounding said filament and defining an electron path therethrough from said filament, said first and second electrodes being disposed in part in front and in back respectively of said filament, and potential supply means connected between said filament and first and second electrodes to maintain said first electrode at a positive potential with respect to said second electrode and filament for attracting electrons from the front of said filament and repelling electrons from the back of said filament.

3. Synchrotron injector mechanism adapted to be disposed within a synchrotron chamber and comprising an electron emissive filament, an electrostatic shield about said filament and electrically connected thereto, said shield having an aperture therein adjacent one face of said filament for the passage of electrons from said filament therethrough, and accelerating electrode structure about said shield at a distance therefrom, said accelerating electrode having a first aperture therein in alignment with said shield aperture and adapted to be maintained at a positive potential with respect to said shield and filament

whereby electrons emitted from said filament are urged through said shield aperture and said first accelerating electrode aperture into said synchrotron chamber, and said accelerating electrode having a second aperture therein on the opposite side of said filament and shield and aligned with said first aperture whereby the positive potential of said accelerating potential is modified in the vicinity of said second aperture to repel electrons approaching said injector mechanism.

4. Synchrotron injector mechanism comprising a source of electrons, first apertured electrode means, power supply means having a positive terminal connected to said first electrode and a negative terminal connected to said source of electrons to establish an electrostatic field for attracting electrons from one side of said source, and second electrode means connected to the negative terminal of said power supply to establish a further electrostatic field exterior to the opposite side of said source of a polarity to repel electrons.

5. A synchrotron injector mechanism including an electron source disposed within a toroidal synchrotron chamber, an apertured electrostatic shield about said source and electrically connected thereto, and an accelerating electrode structure disposed about said shield to be maintained at a positive potential relative thereto whereby electrons are attracted from said source, said accelerating electrode having a first aperture therein in alignment with the aperture in said shield whereby electrons are accelerated therethrough into said synchrotron chamber, and said accelerating electrode having a second aperture in the opposite side thereof from said first aperture and in substantial alignment therewith to thereby form a relatively negative electrostatic field configuration about said second aperture exterior to said accelerating electrode from said electrostatic shield for repelling electrons approaching said injector mechanism.

6. In combination with an electron source having an apertured electrostatic shield thereabout, the improvement comprising accelerating electrode structure disposed exterior to said shield and having first and second apertures therein, said apertures being in substantial alignment with one being disposed on each side of said shield and the first facing the aperture in said electrostatic shield, and said accelerating electrode structure being adapted to be maintained at a positive potential relative to said electrostatic shield and electron source whereby electrons are attracted from said electron source through the aperture in said electrostatic shield and the first aperture in said accelerating electrode structure and electrons are repelled from said accelerating structure in the vicinity of the second aperture therein by virtue of the relatively negative potential upon said electrostatic shield.

7. Injector mechanism for apparatus accelerating electrons along a constant radius orbit comprising an electron source, an apertured electrostatic shield about said electron source, electron accelerating means adjacent and exterior to said electrostatic shield for removing electrons from said source and urging said electrons into the orbit of said apparatus, and electrostatic field producing means for establishing an electron repelling electrostatic field exterior to said ion source and shield on the opposite side thereof from the removal of electrons whereby the orbits of said electrons in said apparatus are deformed to pass said injector mechanism.

8. An improved injector mechanism adapted

for disposition within an evacuated chamber and comprising an electron source, first and second electrodes disposed about said electron source, said first electrode being exposed to said electron source and to said chamber to define an electron path therebetween and said second electrode being exposed to said chamber on the opposite side of said electron source from said electron path, and potential supply means having a positive terminal connected to said first electrode and a negative terminal connected to said second electrode whereby electrons are attracted from said electron source along said electron path and

electrons are repelled from the opposite side of said mechanism from said electron path.

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