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ACCELERATOR TARGET POSITIONER

3 Sheets-Sheet 1

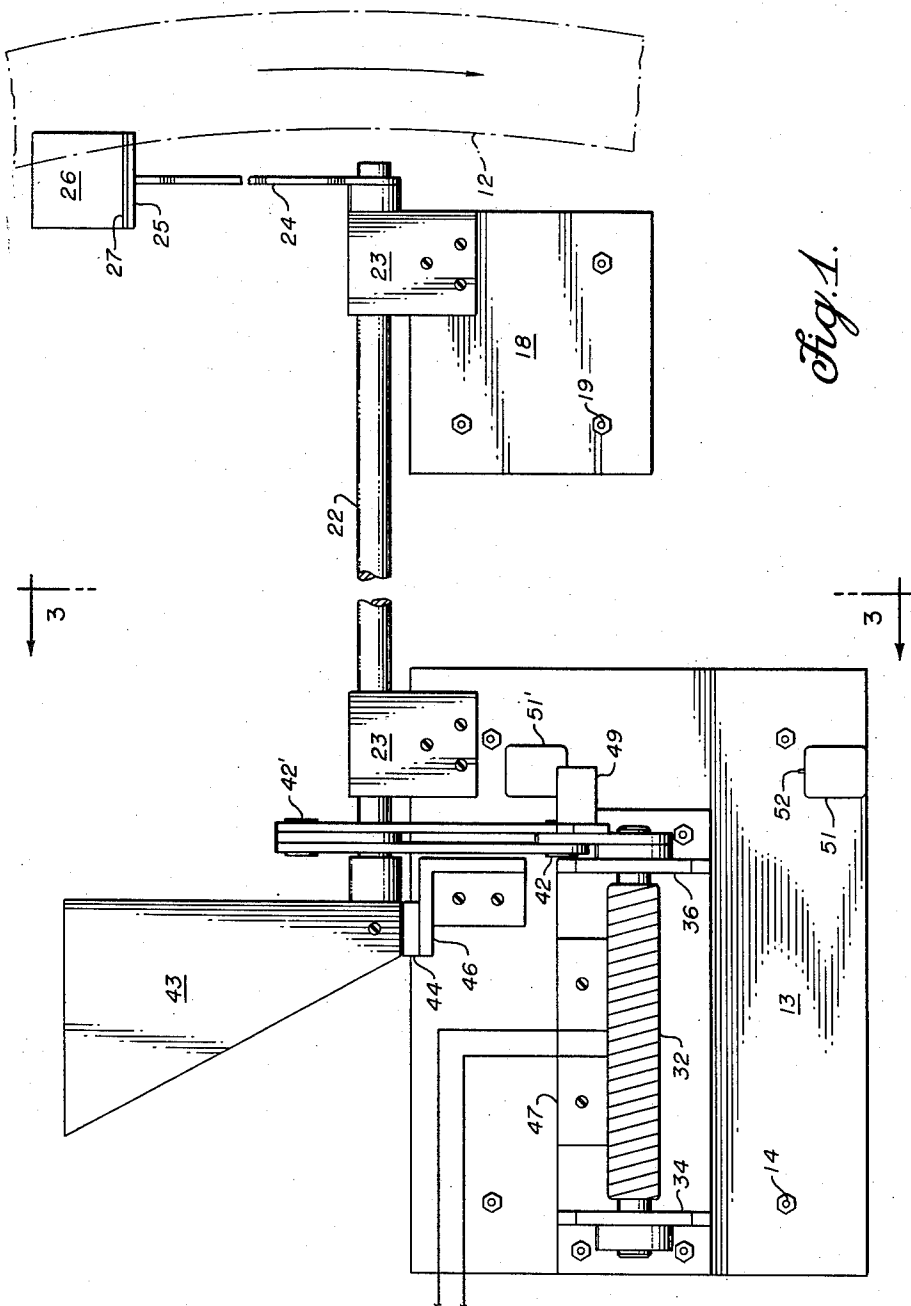


Fig. 1.

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July 2, 1957

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3 Sheets-Sheet 2

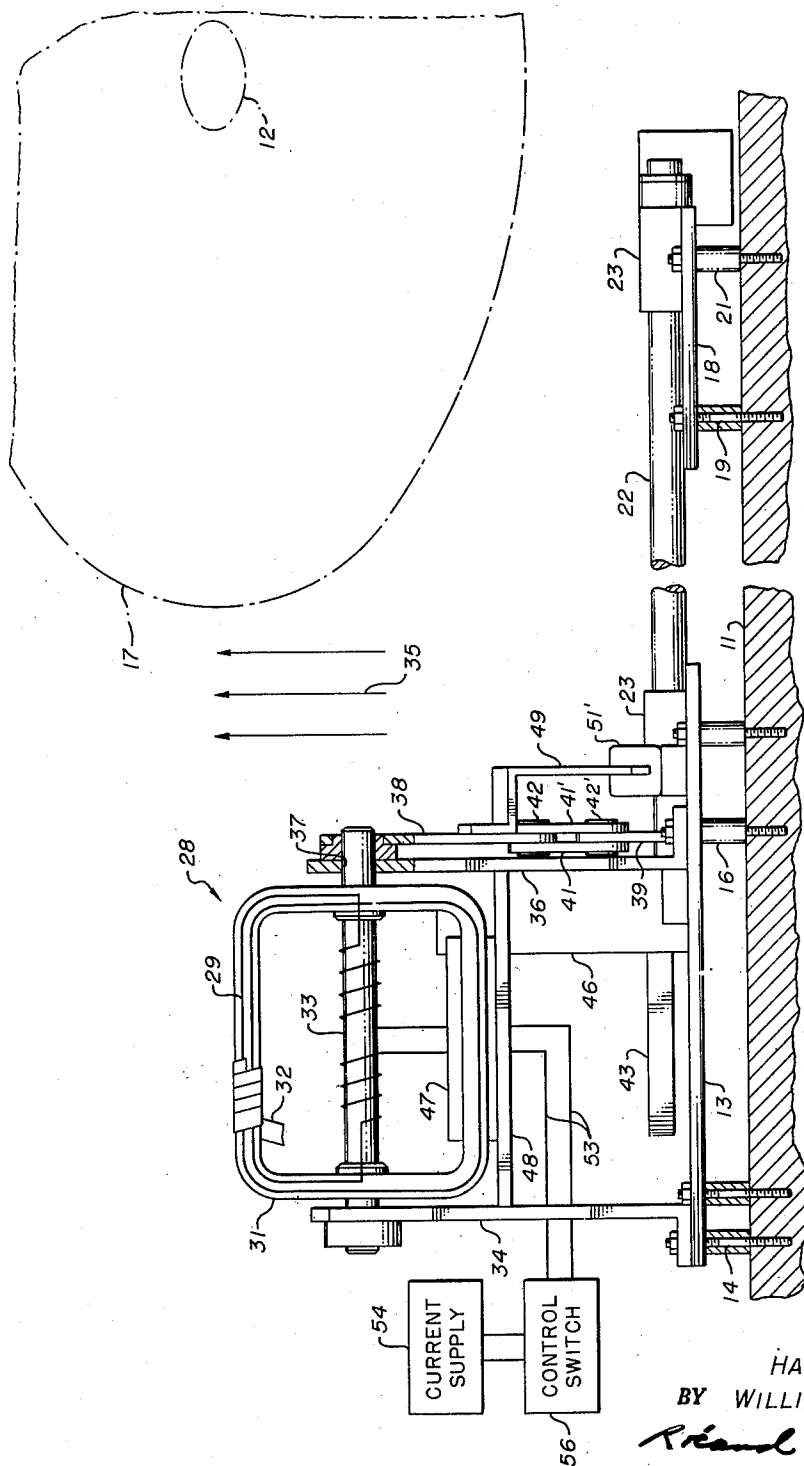


Fig. 2.

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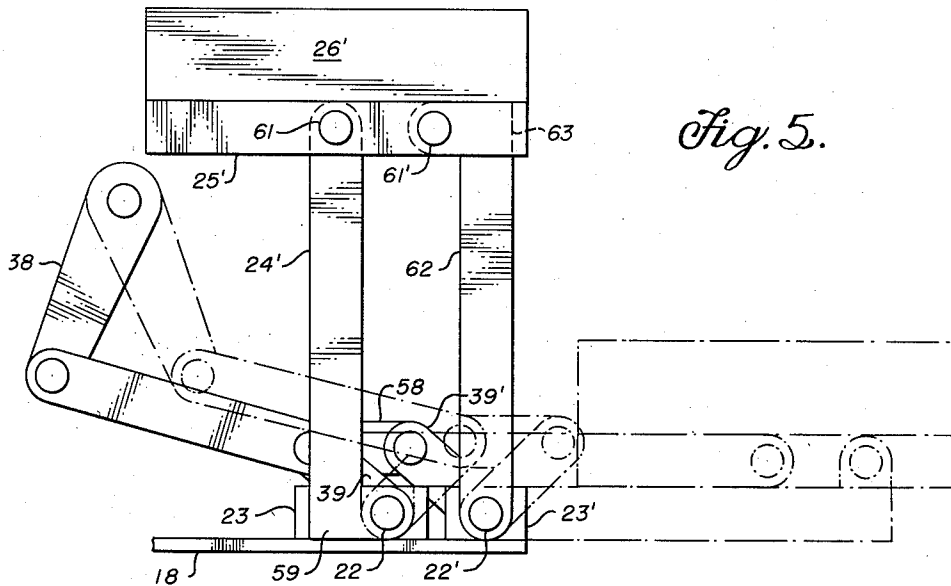


Fig. 5.

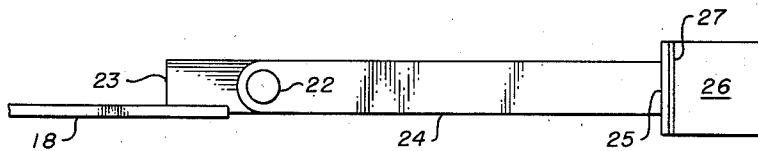


Fig. 4.

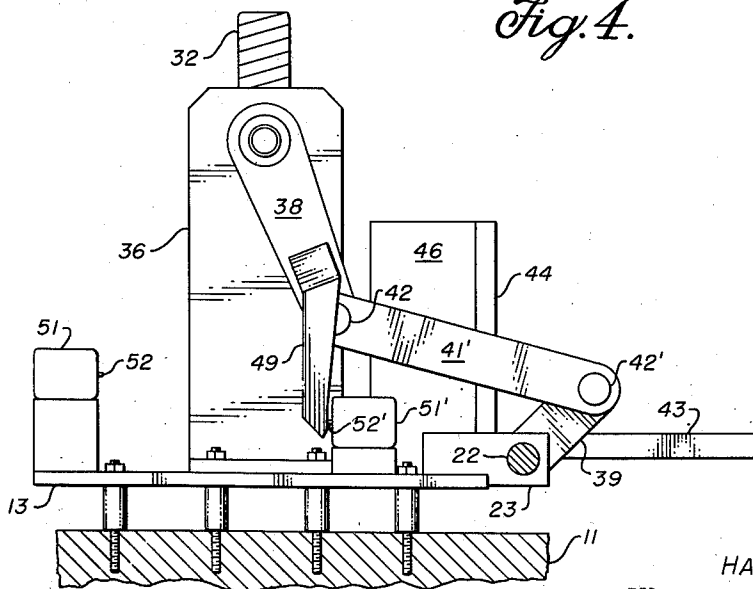


Fig. 3.

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1

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ACCELERATOR TARGET POSITIONER

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18 Claims. (Cl. 313—62)

This invention relates to charged particle accelerators and, more particularly, to apparatus employed therewith for the timed insertion of target substances into the path of the particle beam.

The extraction of high energy beams from certain forms of charged particle accelerators, a proton synchrotron for example, is a complex procedure requiring bulky and costly equipment. Where such extraction of the beam is carried out, it is usually possible to extract only a small proportion of the beam which circulates within the accelerator, thus reducing the available beam intensity by a very large factor. Accordingly, it is desirable, where conditions permit, to mount the substance to be irradiated within the accelerator itself.

In the case of an accelerator having a beam orbit which is substantially constant in radius throughout the accelerating cycle, as in a synchrotron or proton synchrotron, a target obviously cannot be positioned in the beam trajectory until the acceleration of a pulse of particles is completed, at which time it must be rapidly inserted to obtain maximum irradiation. As the life of an individual beam pulse is short, about one and three quarter seconds in the University of California bevatron, the target insertion apparatus must operate quickly and precisely. Since the beam is of comparatively great cross-sectional diameter during the initial phase of acceleration, the target must have a retracted position at a considerable distance from the median beam orbit. It is apparent that the mechanism should be adapted to insert target substances of widely varying mass and should come to rest with a minimum of whiplash.

It is accordingly a principal object of this invention to provide means facilitating the irradiation of substances within the beam accelerating region of a particle accelerator.

It is another object of this invention to provide a target mounting for the rapid positioning of a target substance in the beam of a particle accelerator.

It is an important object of this invention to provide means for rapidly inserting a target substance into the beam orbit of a particle accelerator, which insertion is characterized by the absence of whiplash.

Still another object of this invention is to provide an accelerator target mounting which interposes a target substance within the beam orbit of the accelerator at a precise and fixed position and at a desired instant in the accelerating cycle.

A further object of the present invention is to provide a target positioner for a charged particle accelerator, which target positioner minimizes disturbance of the magnetic field of said accelerator.

The invention, both as to its organization and method of operation together with further objects and advan-

2

tages thereof, will best be understood by reference to the following specification taken in conjunction with the accompanying drawing, of which:

Figure 1 is a plan view of one embodiment of the invention shown mounted within the vacuum envelope of a proton synchrotron and with the target in retracted position;

Figure 2 is an elevation view of the apparatus of Fig. 1;

Figure 3 is a sectional elevation view taken along line 3—3 of Fig. 1;

Figure 4 is an elevation view of the target mounting arm of Fig. 1; and

Figure 5 is a view of a portion of the apparatus modified to position an elongated target substance.

Referring now to the drawing and more particularly to Figs. 1 and 2 thereof, the invention is shown mounted within the vacuum envelope 11 of a proton synchrotron. As is well known within the art, the vacuum envelope of this class of particle accelerator has a generally toroidal configuration conforming to the annular magnet employed. In some instances the annular magnet structure may be broken into quadrants which are physically spaced apart and joined by straight sections of vacuum envelope to form a continuous beam accelerating chamber. In these latter cases, the present invention must be mounted within or adjacent one of the quadrants inasmuch as the invention makes use of the magnetic field of the accelerator.

The embodiment of the invention to be herein described was designed for use in the University of California bevatron in which the vacuum envelope 11 has a rectangular cross-section, the apparatus being disposed on the floor of the envelope radially inward from the region occupied by the circulating particle beam 12. It will be apparent however that other positions are possible, particularly in accelerators of different configuration.

A first base plate 13 is secured to the floor of the vacuum envelope 11 by means of screw fasteners 14, a plurality of cylindrical spacers 16 being disposed beneath the base plate, coaxial with the fasteners, in order to provide a gap beneath the plate for the passage of such cooling coils, magnet windings or other facilities as may be required. It will be appreciated that the particle beam varies in cross-sectional area, being relatively large during the initial portion of the acceleration cycle as indicated by the dashed beam profile 17, and narrowing to the much smaller cross-section 12 during the terminal period of the cycle. Accordingly, in fixing the position of the base plate 13, as well as other components of the invention, ample clearance from the maximum beam cross-section 17 must be provided.

A second smaller base plate 18 is similarly disposed on the vacuum tank floor by means of fasteners 19 and spacers 21 and is positioned radially outward from the first base plate 13 and a slight distance radially inward from the edge of the minimum beam orbit 12. An elongated rotatable shaft 22 is mounted over the two base plates 13 and 18, transverse to the beam orbit 12, by bearings 23 one secured to each of the base plates. The bearings 23 are spaced apart a distance less than the total length of the shaft 22 so that the extremities of the shaft project through the bearings.

An elongated target mounting arm 24 projects from the shaft 22, at right angles thereto, at a position immediately beneath the inside edge of the final particle orbit 12, the arm thus being adapted to swing a target from a position adjacent the floor of the vacuum tank to a position where-

3

the circulating high energy particle beam is intercepted. Transversely secured to the free end of the target arm 24 is a platform 25 upon which a substance 26 to be irradiated may be placed and secured by suitable means as by an adhesive layer 27, for example.

Means controlling rotation of the shaft 22, and thus controlling motion of the target arm 24, comprises an electrical rotor assembly 28 mounting a flat multi-turn electrical coil or winding 29. The coil 29 is, in this embodiment, wound in a generally rectangular configuration and affixed to a rectangular dielectric stiffener frame 31 by a wrapping of insulating tape 32. An axle 33 bisects the coil assembly 28, passing through diametrically opposed apertures in the stiffener frame 31, the ends of the axle thus forming journals by means of which the rotor assembly 28 may be supported. Two spaced upright posts 34 and 36 project upward from the first base plate 13, the upper extremities of the posts having apertures 37 which serve as bearings for the journals formed by ends of the axle 33 thus mounting the coil assembly 28 for rotation about a diameter thereof. It will be appreciated that the positioning of the members described above must be such that the axle 33, which is the pivot axis of the coil assembly 28, is transverse to the magnetic field of the accelerator. Thus, in the present embodiment the field is vertical, as indicated by field lines 35 of Fig. 2, and the axle 33 is horizontal and positioned above, offset from, and parallel to the shaft 22.

The end of the axle 33 most adjacent the beam orbit 12 is projected a short distance through the bearing aperture 37 of the post 36 and a crank arm 38 is radially secured thereto. A second shorter crank arm 39 is radially secured to the shaft 22 at a longitudinal point thereon corresponding to the plane of rotation of the first crank arm 38. To transfer rotation of the coil assembly 28 to the target arm 24, the two crank arms 38 and 39 are connected by a pair of parallel rigid links 41 and 41' which are secured to the extremities of the two crank arms by transverse pivot pins 42 and 42'.

To damp any tendency towards vibration or whiplash in the moving elements described above, a damping vane 43, interacting with the magnetic field of the accelerator, is projected radially from the shaft 22 at the extremity thereof furthest from the beam orbit 12. The vane 43, formed of electrically conducting material, has a generally triangular shape with the apex closest to the shaft 22, and projects from the shaft in the plane defined by the shaft and the target arm 24 in order that maximum coupling with the magnetic field will occur as the target arm swings to a position nearest the beam orbit.

To limit motion of the target arm 24 and damping vane 43 to a ninety degree arc, a resilient stop 44 backed by an angled bracket 46 projects upward from the first base plate 13, the bracket and attached stop being positioned to be struck by the vane when the latter reaches a vertical position. Motion of the target arm 24 and vane 43 below a horizontal position is prevented by a second resilient stop 47 secured between the two upright posts 34 and 36 by means of a crosspiece 48, the stop being positioned to prevent the coil stiffener 31 from rotating past a vertical position.

To provide a remote indication, external to the accelerator chamber, of the position of the target arm 24, a trip rod 49 is secured to the first crank arm 38 in a downwardly projecting relationship. A pair of spaced microswitches 51 and 51' are mounted on the first base plate 13 at positions corresponding to the limits of travel of the lower end of the trip arm where the actuator buttons 52 and 52' of the microswitches are contacted by the trip rod when it is at either of its extreme positions. As is apparent the microswitches 51 and 51' may be connected to operate indicator lamps on a remotely situated control panel, the lamps thus giving an indication of whether the

4

target substance 26 is retracted or in a beam intercepting position.

In operation, the apparatus being positioned within the particle accelerator as previously described, movement of the target substance 26 into and away from the particle beam 12 is effected by controlling the energization supplied to the coil 29. Such energization is provided through leads 53 which are wrapped around the pivot axle 33 to avoid entangling with the mechanism and which are passed to a source of direct current 54 through a control switch 56. It is apparent that the latter elements, current supply 54 and control switch 56, may take a wide variety of forms according to the structure of the associated accelerator and are therefore here shown schematically. It will generally be found most satisfactory to key the switch 56 to some portion of the accelerator control system in order that the target 26 will be inserted and retracted from the beam at the optimum moments. The action of the switch 56 is such that at the desired portion of the beam accelerating cycle, generally when the beam has reached maximum energy, a current is supplied to the coil 29, the current being maintained for a desired interval and then reversed to retract the target.

The magnetic field of the energized coil 29 interacts with the magnetic field 35 of the accelerator to rotate the coil assembly through a ninety degree arc, further rotation of the assembly being limited by the vane 43 abutting against the stop 44. Rotation of the coil assembly 28 is transferred to the target arm 24 through the pivot axle 33, first crank arm 38, links 41, second crank arm 39, and shaft 22. Reversal of the coil current by the control switch 56 counter rotates the coil assembly 28 to the original position and through the described linkage, retracts the target arm 24.

Considering now the action of the damping vane 43 in smoothing the motion of the assembly and in minimizing vibration and whiplash, it may be seen that the vane rotates in a reverse manner from the rotation of the coil assembly 28, that is the vane moves from a horizontal position to a vertical one as the coil moves from vertical to horizontal. As the coil describes the latter motion, the torque force producing such movement, which torque is initially strong, decreases as a cosine function of the angle traversed. Concurrent with such action, the vane 43 cuts through the magnetic field of the accelerator at a rate which increases as a sine function of the angle traversed. As the vane 43 rotates, eddy currents are created which, through their associated magnetic fields, increasingly oppose further motion of the apparatus. Thus the vane 43, opposing the decreasing rotational forces acting on the coil assembly 28 provides an increasing damping influence which has a maximum effect in the last stage of the movement therefor tending to bring the apparatus gently to rest in the target up position. In practice, the action is prematurely stopped by the vane 43 coming into abutment against the stop block 44, whereupon the eddy currents in the vane are rapidly dissipated and the assemblage is held in position by the remaining rotational tendency of the coil assembly 28 which persists until current to the coil is stopped or reversed.

It will be apparent that interchangeable damping vanes 43 of varying sizes might be provided, and that the current strength supplied the coil 29 may be varied, to adjust for differences in the mass of various targets 26. Such adjustment may be particularly desirable when employing electrically conductive target substances as the target will then exhibit a damping influence analogous to that of the vane 43. To prevent further unwanted damping effects, as well as to minimize disturbance of the accelerator magnetic field, it will be found preferable to form all elements of the invention, with the exception of the damping vane 43 and the electrical components, of dielectric material.

In some instances it may be desirable to irradiate a target which is elongated in the direction of the beam and

5

must therefore remain horizontal while being raised and lowered. Referring now to Fig. 5 there is shown a modification of the described embodiment by which this may be accomplished. The elements of this apparatus are similar to those of the previous embodiment except as will now be described.

The second baseplate 18 must in this instance be widened so that the bearing block 23 and the shaft 22 are located centrally upon the plate. A second shaft 22', mounted by a second bearing block 23', is disposed over the baseplate 18 parallel with the first shaft 22. The second shaft 22' is provided with a radial crank arm 39', similar to the crank arm 39 on the first shaft. A link 58 pivotally connects the two crank arms 39 and 39' in order that the two shafts 22 and 22' will rotate in unison. The target arm 24' differs from that of the previous embodiment by having a right angled lower extremity 59, the point of connection with shaft 22 thus being offset from the axis of the arm for a purpose which will hereinafter be made clear. The target retaining platform 25' is elongated in the direction of the ion beam to support the long target 26' and is pivotally fastened at the inside edge to the upper extremity of the target arm 24' by a transverse pin 61.

To stabilize the target and hold it in a horizontal position at all times, a second target arm 62 projects radially from the second shaft 22', the second arm being parallel to the first arm 24' and having a right angled upper extremity 63 projecting in the direction of the first arm. A second pivot pin 61' attaches the angled extremity 63 of the second target arm to the target retaining platform 25'.

For the most satisfactory operation, the pivoted juncture 61 of the first target arm 24' with the target retaining platform 25' should be beneath the approximate center of gravity of the target 26', the second or stabilizing target arm 62 being more proximal to an extremity of the target. As may be seen, rotation of the crank arm 38, through the action of the coil assembly as previously described, will rotate the two target arms 24' and 62 lifting the target from a retracted position, as shown in phantom in Fig. 5, to the beam intercepting position. As may be observed, the effect of the angled extremities 59 and 63 of the target arms 24' and 62, respectively, is to allow the arms to nest together in the retracted position so that maximum lowering of the target may be achieved.

It will be apparent to those skilled in the art that numerous modifications, other than those herein disclosed, are possible within the spirit and scope of the invention and thus it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. In a target mounting for a fixed beam orbit charged particle accelerator, the combination comprising a base element secured within the vacuum chamber of said accelerator, an elongated target arm having a first extremity pivotally fastened to said base element, the second extremity of said arm being swingable in the direction of said beam orbit, said arm having provision for retaining a target substance on said second extremity thereof, an electrical winding movably mounted within the magnetic field of said accelerator, a controlled direct current source supplying energization to said winding, and means coupling motion of said winding to said arm whereby said target substance is swung in the direction of said beam orbit.

2. A target mounting as described in claim 1 and having a motion damping means comprising an electrically conducting member of substantial area pivotally mounted within said magnetic field and constrained to pivot across said field concurrent with motion of said arm.

3. A target mounting as described in claim 1 wherein said electrical winding comprises a closed loop mounted to rotate about a diameter thereof, and said motion coupling means comprises a crank arm secured to said loop and linked to said target arm.

6

4. In a target mounting as described in claim 2 wherein said provision for retaining a target substance to said arm comprises a flat platform pivotally mounted on the extremity of said arm, the further combination of a stabilizing arm having a first extremity pivotally fastened to said base element and a second opposite extremity pivotally fastened to said platform, said stabilizing arm being mounted parallel with said target arm.

5. In a target positioner for a fixed beam orbit electromagnetic particle accelerator, the combination comprising a base element mounted within the vacuum tank of said accelerator, a target arm having a first extremity pivotally affixed to said base element, the second extremity of said arm being swingable in the direction of said beam orbit, target securing means disposed on said second extremity of said arm, a movable electrical coil mounted within the magnetic field of said accelerator, a source of reversible direct current controllably supplying energization to said coil, means transferring motion of said coil to said target arm, an electrically conducting damping element of substantial area movably disposed within said magnetic field, and means linking motion of said damping element and said target arm obtaining simultaneous motion of the two elements.

6. An accelerator target positioner as described in claim 5 wherein said damping element is disposed within the plane defined by said target arm and the pivot axis thereof.

7. A target mounting for use within the vacuum vessel of a fixed beam orbit charged particle accelerator, comprising a base member secured within said vacuum vessel, an elongated target arm having one extremity pivotally fastened to said base member, the opposite extremity of said arm being positioned to pivot in the direction of said beam orbit and being provided with means for retaining a substance which is to be irradiated, an electrical winding positioned within the magnetic field of said accelerator, controlled current supply means exciting said winding, a conducting damping vane pivoted at one extremity, and linkage means simultaneously pivoting said target arm and said damping vane upon movement of said winding.

8. A target mounting substantially as described in claim 7 wherein said damping vane pivots through substantially a ninety-degree arc, said damping vane being positioned to be directed along said magnetic field when said target arm is closest to said beam orbit, and transverse to said magnetic field when said target arm is most removed from said beam orbit.

9. A target mounting for a charged particle accelerator comprising an elongated target arm disposed within the vacuum vessel of said accelerator and fastened to pivot about one extremity into and away from the beam orbit of said accelerator, an electrical winding in the form of a closed loop, at least one bearing element supporting said loop for rotation about a diameter thereof, a controllable current source supplying excitation to said winding, and linkage transferring rotation of said winding to said target arm.

10. A target mounting as described in claim 9 and further characterized by an electrically conducting damping vane pivotally mounted at one extremity within said magnetic field, said vane being constrained to rotate with said winding and being oriented substantially normal to the plane of said winding.

11. A particle accelerator internal target positioner comprising a rotatable shaft disposed within the beam chamber of said accelerator, an elongated target arm projecting radially from said shaft, the extremity of said target arm having provision for the attachment of a target substance, a conducting motion damping vane projecting radially from said shaft and having a substantial area within the plane defined by said target arm and said shaft, an electrical coil mounted to rotate in the magnetic field of said accelerator, linkage transferring rotation of said coil to said shaft and a controlled direct current supply energizing said coil.

7

12. A target positioner as described in claim 11 wherein said provision for the attachment of a target substance to said target arm comprises a platform pivotally secured to the extremity of said arm, and comprising the further combination of a second rotatable shaft disposed parallel to said first shaft and linked to said first shaft to rotate concurrently therewith, and a second elongated arm projecting radially from said second shaft and being pivotally fastened to said platform, said second arm being parallel to said first arm.

13. A target positioner for a charged particle accelerator comprising a rotatable shaft fixed within the vacuum chamber of said accelerator transverse to the beam orbit thereof and offset from said beam orbit, an elongated target arm projecting radially from said shaft at the extremity thereof most proximal to said beam orbit, said arm having provision for retaining a substance to be irradiated, an electrical winding, at least one bearing element mounting said winding for rotation about a diameter thereof, means linking rotation of said winding to said shaft, a current supply energizing said winding, and an electrically conducting damping vane projecting radially from said shaft, said vane lying in the plane defined by said shaft and said arm.

14. A target mounting for a charged particle accelerator comprising a rotatable shaft mounted within the beam chamber of said accelerator transverse to the beam orbit therein and offset from said beam orbit, an elongated target arm projecting radially from said shaft, the free extremity of said arm having provision for the attachment of a substance to be irradiated, a flat electrical winding having two journals affixed at diametrically opposed points thereon, a bearing mounting engaging said journals to support said winding for rotation in the magnetic field of said accelerator, linkage transferring rotation of said journals to said shaft, a motion damping vane projecting radially from said shaft at an azimuth similar to that of said arm, and a source of reversible direct current connected to said coil.

15. A target mounting for a charged particle accelerator as described in claim 14 wherein said linkage comprises a first crank arm projecting radially from one of said journals, a second crank arm projecting radially from said shaft and at least one rigid link having a first extremity pivotally secured to the free end of said first crank arm and a second extremity pivotally secured to the free end of said second crank arm.

8

16. A target mounting as described in claim 14 wherein said provision for the attachment of a substance to be irradiated to said arm comprises a platform the central portion thereof being pivotally fastened to the extremity of said arm, and comprising the further combination of a second rotatable shaft disposed parallel to said first shaft and linked to said first shaft for rotation in unison therewith, and a stabilizing arm projecting radially from said second shaft in parallel relationship with said target arm, said stabilizing arm being pivotally connected with said platform.

17. Apparatus for the time insertion of a target substance into the circulating beam of a charged particle accelerator comprising at least one flat base plate disposed on the floor of the beam accelerating envelope of said particle accelerator, an elongated horizontal shaft disposed immediately above said base member and aligned along a radius of said accelerator, a plurality of bearings spaced along said shaft securing said shaft to said base plate, a target mounting arm projecting radially from said shaft at a point thereon substantially beneath said circulating particle beam, a pair of upright posts secured to said base plate and spaced apart along a line paralleling said shaft, each said post having an aperture in the upper extremity thereof, a multi-turn electrical coil mounted between said upright posts by diametrically opposed journals seated in said apertures in said posts, a first crank arm radially projected from one of said journals, a second crank arm radially projected from said shaft, rigid link means pivotally connected at one extremity to said first crank arm and pivotally connected at the opposite extremity to said second crank arm, means supplying timed reversible direct current excitation to said coil, and a conducting damping vane projected radially from said shaft in the plane defined by said shaft and said arm.

18. Apparatus as described in claim 15 and comprising the further combination of stop means limiting rotation of said target mounting arm to a ninety-degree arc.

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