Dec. 13, 1960 K. F. STONE ET AL 2,964,710

ACCELERATOR TARGET POSITIONER AND CONTROL CIRCUIT THEREFOR

Filed Dec. 16, 1959 2 Sheets-Sheet 1

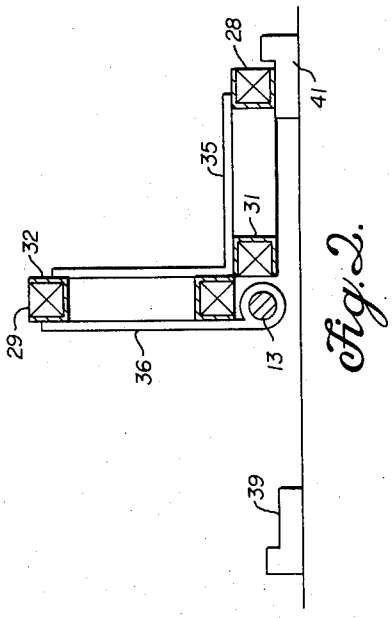


Fig. 2.

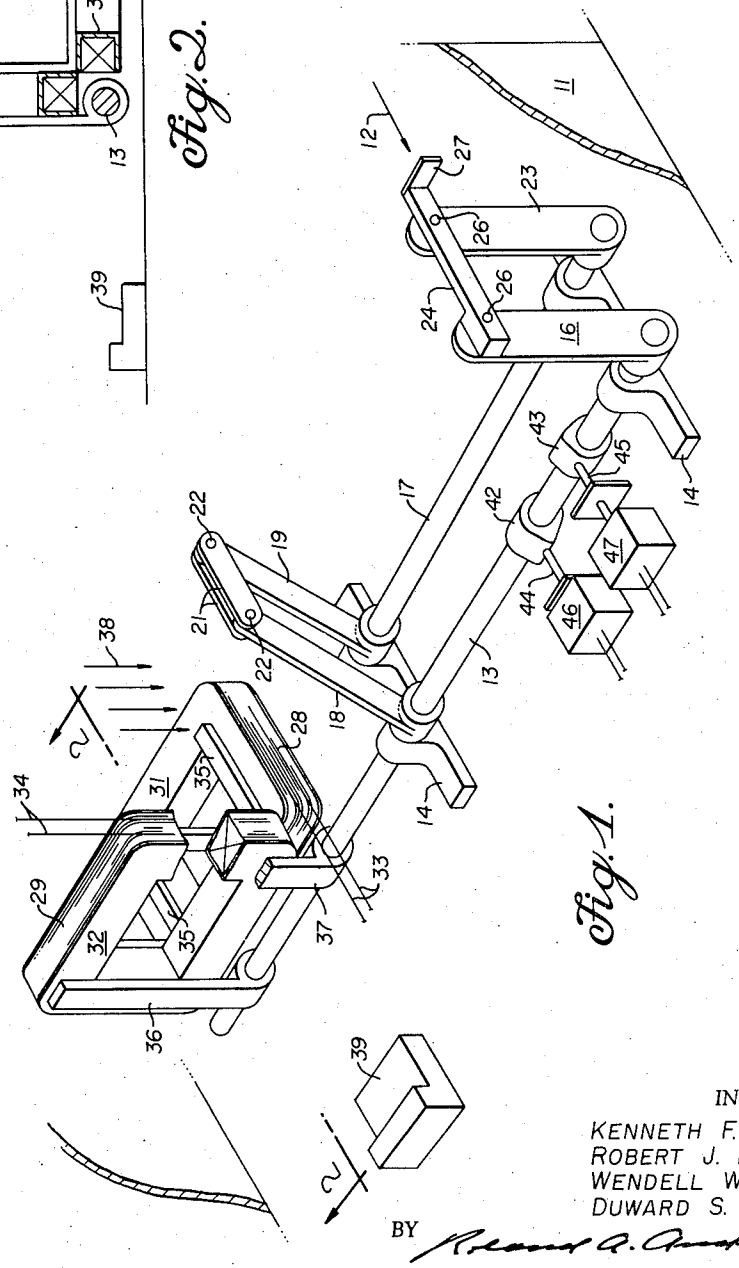


Fig. 1.

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Filed Dec. 16, 1959 2 Sheets-Sheet 2

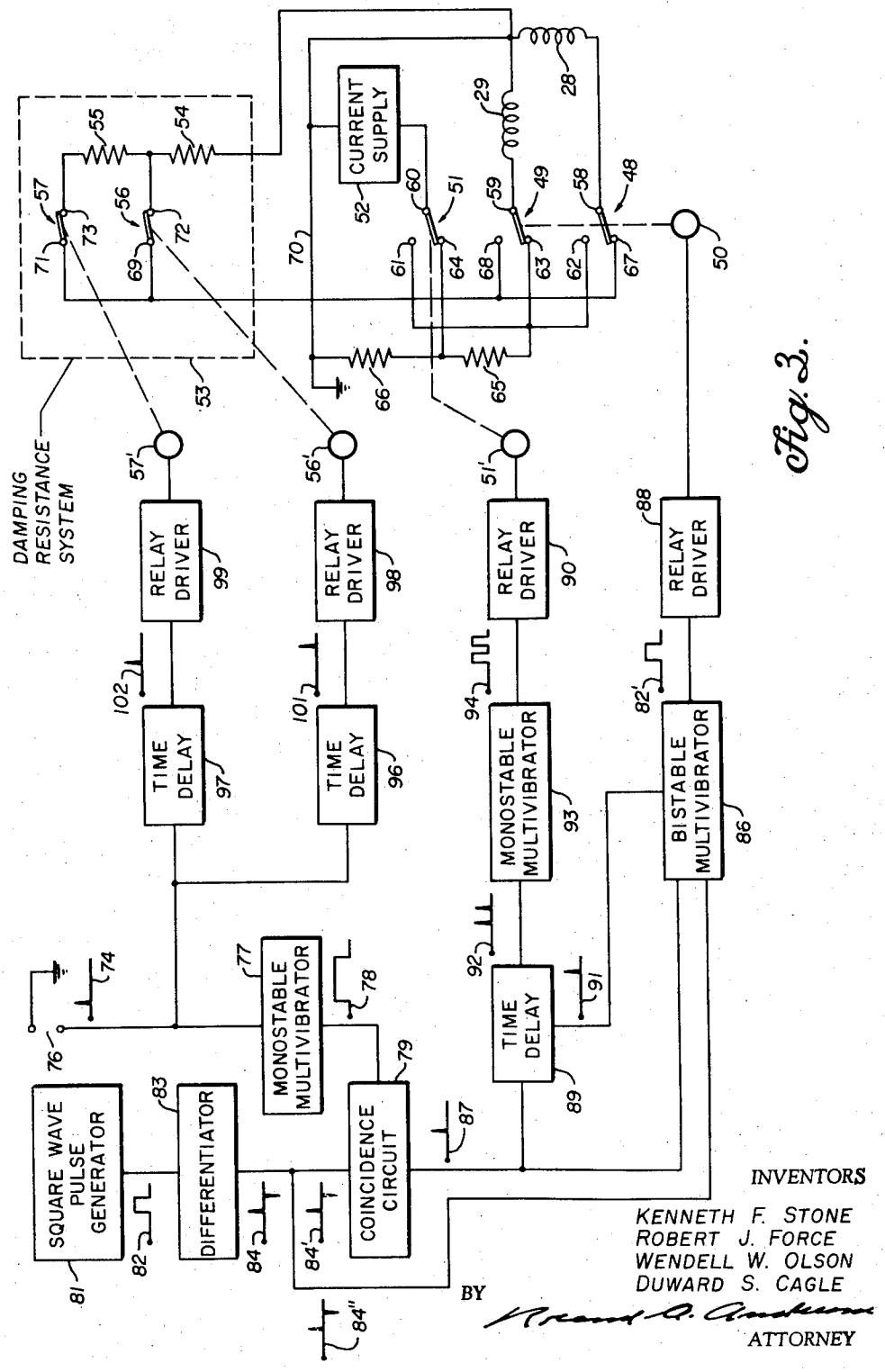


Fig. 3.

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ACCELERATOR TARGET POSITIONER AND CONTROL CIRCUIT THEREFOR

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14 Claims. (Cl. 328—235)

The present invention relates to charged particle accelerators and more particularly to means for controlling the motion, timing and positioning of target materials with respect to the particle beam within such accelerators.

The primary beam of high energy particle accelerators of the proton synchrotron class cannot be extracted from the accelerating region without very serious losses in beam intensity. Accordingly, an external beam is usually produced by inserting a target within the accelerator, into the circulating primary beam, whereby secondary beams are produced by interaction of the primary beam with target material which secondary beams may leave the accelerator through a thin metal window suitably located in the vacuum wall thereof. To insert a target into the beam for this purpose requires a positioning apparatus which will not interfere with the beam during the injection and early acceleration period thereof, or interfere with the accelerator magnetic field, but which will move the target rapidly into the beam at an appropriate instant.

In many proton synchrotron experiments, such as those in which the secondary beam is directed to a detection instrument of the bubble chamber type, only a short duration pulse is needed with respect to the duration of primary accelerator pulse. It is therefore desirable to produce more than one secondary pulse from a single primary beam pulse in order that a corresponding number of separate experiments may be performed concurrently and more efficient use of the synchrotron beam will result. In order to produce several secondary pulses in this manner, it is necessary to rapidly move a first target into a beam intercepting position and intercept a fraction of the circulating beam. This first target must then be quickly removed from the region of the beam and a second target moved into a second beam intercepting position to intercept a different fraction of the same beam pulse.

Since the life of an individual beam pulse is short, of the order of one and three-quarter seconds for full energy in the University of California Bevatron, and the desired particle energies occur at only particular periods within this pulse, it can be seen that the target motion into and out of the circulating beam must take place at very high speed and the target must come to rest within the beam and out of the beam without whiplash or oscillation.

A type of internal target positioner used with high energy proton synchrotrons is described in U.S. Patent No. 2,798,178, issued to H. G. Heard et al., July 2, 1957, for Accelerator Target Positioner. Such target positioner is contained within the accelerator and inserts the target into the beam orbit by means of a rotatable arm which normally rests retracted at a distance below the orbit. Torque to raise the target to the beam orbit is imparted to the target arm through a connecting shaft by applying a current to a magnetic coil coupled thereto which coil is disposed in and interacts with the magnetic field of the accelerator. Braking of the target arm to prevent vibration and whiplash is accomplished by a damping vane

projecting radially from the connecting shaft to interact with the accelerator magnetic field. Rotation of the shaft causes the vane to cut through the accelerator magnetic field, producing eddy currents within the vane. For target raising, the magnetic fields associated with these eddy currents interact with the accelerator magnetic field and produce a torque which increasingly opposes the direction of rotation. The motion is finally stopped by the vane coming into abutment with a resilient stop whereupon the eddy currents are no longer generated and the target is held in place by the continued rotational tendency of the energized coil.

Although the damping vane in the foregoing apparatus provides satisfactory braking and brings the target to a precise stop at the beam intercepting position, it can be seen that the method is effective in only one direction. For target raising, the vane initially lies in a plane perpendicular to the direction of the accelerator magnetic field. Rotation causes the vane to cut through the field at a rate which increases as the sine function of the angle traversed, resulting in the maximum braking torque at 90°, i.e., when the target is in the beam. However in lowering the target, the effect of the vane is to strongly retard the initial downward motion and produce almost no braking as the target is brought to rest in the down position. Due to this lack of final braking, the target must be lowered at relatively slow speeds in order to avoid damaging the target mechanism. Consequently, the overall operating speed of the described target positioner is reduced, forestalling the possibility of raising a second target within the duration of the same beam pulse in the manner heretofore discussed.

A further characteristic of the described positioner is that any particular vane is not adaptable to a variety of target masses or different magnetic field intensities. Vanes of various sizes are needed to meet these conditions, thereby requiring a new vane to be installed for each occurrence of a different operating condition.

To achieve the previously discussed increased efficiency of accelerator operation and experimentation, whereby a succession of targets may clip fractions of an individual beam pulse, the overall operating speed of the target positioner must be increased. This requires that the slow drive-down and one way braking limitations of the damping vane arrangement be overcome and that a more convenient means of adapting the target positioning mechanism to various operating conditions be devised.

Accordingly, the present invention provides an improved means of controlling the motion of an accelerator target positioner of the general type discussed above whereby two electrically independent coils, disposed at 90° to each other, are mounted directly to the connecting shaft within the accelerator magnetic field and, through the use of novel control circuitry, interchangeably produce the driving and damping forces which operate the target arm.

At either stationary position of the target there is always one coil in the plane of the accelerator magnetic field and one coil in a plane transverse to the field. By applying a current to that coil which is transverse to the field, a magnetic field is produced which interacts with the accelerator field to cause a rotation of the assembly through a 90° arc. The torque producing this rotation decreases as the cosine function of the angle traversed. Concurrent with this, the second coil is short-circuited and is cutting through the accelerator field acquiring induced currents which in turn are creating a magnetic field interacting with that of the accelerator to produce a torque opposing the rotation. This opposing torque increases as the sine function of the angle traversed. Thus, during

the pivoting of the target carrier arm through a ninety degree arc, the resultant torque causes a rapid increase in angular velocity as the target rotates to 45° followed by a rapid decrease in angular velocity (approaching zero) as the target rotates to 90° and is brought to rest in the new position. With the target in the new position, the coils have interchanged the planes in which they lie and by reversing the electrical connections thereto they will have interchanged functions for the return motion. In this way, maximum damping is always provided at the last stage of the motion, regardless of the direction of rotation. With this effective braking available the target positioner is suited to greatly increased operating speed while the target is brought to position smoothly and accurately. In addition, the mechanism provides easy accommodation of the target motion for different target masses and accelerator field intensities by adjusting the current applied to the driving coil and varying the shorting resistance of the damping coil. These adjustments are available from the control circuitry to the coils, which circuitry forms an important feature of the invention.

It is therefore an object of the invention to provide an improved means for controlling the motion of a target into, and away from, the beam of a high energy charged particle accelerator.

It is an object of this invention to provide a means to facilitate the irradiation of a succession of target substances with a single charged particle beam pulse within a high energy accelerator.

It is a further object of the invention to provide a target positioner for use with accelerators which positioner is capable of moving a target into and away from the path of the charged particle beam at very high speed.

It is a still further object of the invention to provide a particle accelerator target positioner capable of rapidly moving a target to a rest position without whiplash or oscillation.

It is still another object of this invention to provide a target positioner for a charged particle accelerator, which target positioner causes a minimum disturbance of the accelerator magnetic field.

It is a principal object of the present invention to provide a means for the timed programming of a plurality of target insertions into a high energy particle beam pulse in an accelerator.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in conjunction with the accompanying drawing, of which:

Figure 1 is a perspective view showing the mechanical structure of the invention;

Figure 2 is a section view taken along line 2—2 of Fig. 1, and further illustrating structural features of the invention; and

Figure 3 is a schematic diagram of electrical control circuitry associated with the structure shown in Figs. 1 and 2.

Referring now to the drawing and, more particularly, to Fig. 1 thereof, there is shown a portion of the vacuum tank 11 of a particle accelerator. The tank 11 encloses the charged particle beam orbit here indicated by arrow 12 and in this example has a rectangular cross section. The target positioner is disposed on the floor of the tank 11, radially inward from the region occupied by the circulating beam 12 in this embodiment; however, it will be apparent that other positions are possible, particularly in accelerators of different configuration.

A rotatable drive shaft 13 is mounted on the floor of tank 11 by two spaced bearings 14. Shaft 13 extends radially inward from a point beneath the path of the particle beam 12, toward the side of the tank 11, whereby the majority of the elements of the positioner are removed from the immediate region of the beam 12. On the end of shaft 13, adjacent the beam orbit 12, is a target carrier

arm 16 projecting at right angles from the shaft. The arm 16 is rigidly fixed to shaft 13 and adapted to swing a target 27 from a position adjacent the floor of the tank 11 to a position where the beam 12 is intercepted.

A second shaft 17, shorter than drive shaft 13, is similarly mounted on the tank floor, and is disposed parallel to drive shaft 13, in this instance on the side thereof toward the oncoming beam. The second shaft 17 is used to provide a means for stabilizing the target motion and is coupled at one end to drive shaft 13 at a point radially inward from the beam orbit. To effect this coupling, radial crank arms 18 and 19 are rigidly secured to shafts 13 and 17, respectively. To transfer rotary movement of drive shaft 13 to the second shaft 17, the crank arms 18 and 19 are connected by a pair of parallel rigid links 21 secured to the extremities of the arms by transverse pivot pins 22. The second shaft 17 extends from the coupling point and terminates near the beam orbit 12 at a point slightly beyond the termination of drive shaft 13. A second target carrier arm 23, identical to target carrier arm 16, similarly projects from shaft 17 at this end. The difference in the termination points of shafts 13 and 17 is determined by the clearance necessary for the two target carrier arms 16 and 23 to nest together when in a horizontal position in order that maximum lowering of the target may be obtained. A target mounting bar 24 connects the target carrier arms 16 and 23, and is attached to the free ends of arms 16 and 23 by transverse pivot pins 26. In this way the target mounting bar 24 maintains a horizontal position throughout the various movements of the apparatus. The substance to be irradiated, the target 27, is affixed to the target mounting bar 24 at the end thereof which faces the oncoming beam, and at right angles thereto. Owing to the above-described action of the stabilizing mechanism, the plane of the target 27 is perpendicular to the beam 12 at all times.

Means for producing rotation of the drive shaft 13, and thus rotation of the target carrier arms 16 and 23, comprises two similar multiple turn wire coils 28 and 29, wound in essentially rectangular configuration around coil frames 31 and 32, respectively. In order that the coils may interchange functions as driver and damper, each is electrically independent of the other and each is provided with terminals 33 and 34 which connect to the controlling circuitry. As best shown in Fig. 2, the coils 28 and 29 are disposed at right angles to each other and are secured together at one edge by angle braces 35 which fasten to the coil frames. The coil combination is positioned with the apex of the angle formed by the two coils adjacent drive shaft 13 and is mounted on the shaft by means of two spaced supporting arms 36 and 37 against which the coil 29 is secured, the arms being rigidly secured to the shaft and extending in the plane defined by the target carrier arm 16 and the drive shaft 13. Thus, when the target 27 is in either of the rest positions one coil is aligned with the accelerator magnetic field, shown in Fig. 1 by field lines 38, and one coil is in a plane transverse to the field. Rotation of shaft 13 in either direction is limited to 90° by the abutment of the coils with on of a pair of resilient stops 39 and 41, which stops are mounted on the floor of tank 11.

Referring again to Fig. 1, a pair of spaced eccentric cams 42 and 43 are fixed to connecting shaft 13 near the target arm to provide a remotely viewable indication of the target position. The apogees of cams 42 and 43 are oriented to correspond respectively to the two limits of rotation of shaft 13, at which points contact is made with one of the actuator buttons 44 and 45 of a pair of microswitches 46 and 47 which switches are mounted on the tank floor. Microswitches 46 and 47 may be connected to suitable conventional indicator circuitry for indicating whether the target 27 is retracted or in the beam intercepting position, and target rise time position with respect to the accelerator beam energy markers.

Referring now to Fig. 3 there is shown a diagram o

the circuitry for energizing coils 28 and 29 to controllably raise and lower the target at selected energy levels during the primary beam pulse. In order that coils 28 and 29 may interchange functions as driver and damper, three similar relays 48, 49, and 51, which relays act as single-pole double-throw switches and the first two of which are ganged, are used to alternately connect each of the coils to a driving current supply 52 and to a damping resistance system 53 as will be described in detail, whereby when one coil is energized by supply 52 the other coil is short circuited through the damping resistance system 53. The damping resistance system 53 comprises a pair of series resistances 54 and 55, separately connectable to the circuit by a pair of relays 56 and 57, which relays act as single-pole single-throw switches. In this way, the amount of resistance may be decreased during the target motion to progressively increase the damping effect to reduce shock loads and thereby permit faster target motion speeds and the damping circuit may be opened at the end of the target motion to dissipate all current in the damping system. While the damping resistance system 53 shown in the figure includes only the two resistors 54 and 55, it should be realized that the system may be extended with additional resistors, similarly connected with associated relays, to provide increased variability to the damping resistance during the target motion. In such cases, programming circuitry is required for each additional relay similar to that which is hereinafter described for each of the shown relays 56 and 57.

Considering now the detailed connections of the above-discussed circuitry, the input to coil 28 is connected to the common terminal 58 of relay 48 and the input to coil 29 is connected to the common terminal 59 of relay 49. Coils 28 and 29 are joined at their outputs to the ground line 70 of the circuit. A third relay 51 has a common terminal 60 connected to the output of a regulated current supply 52 and the normally uncontacted terminal 61 of relay 51, the normally uncontacted terminal 62 of relay 48, and the normally contacted terminal 63 of relay 49 are connected together. The normally contacted terminal 64 of relay 51 is connected to terminals 61, 62 and 63 through an isolation resistor 65 and is also connected to ground through a grounding resistor 66. These connections of relays 48 and 49 allow the current supply 52 to be applied to either of coils 28 and 29, which energized coil then acts as driver to the target motion. The described connections of relay 51 allow current supply 52 to be isolated from both coils during the switching operation of relays 48 and 49 to prevent possible arcing across the relay contacts. To provide damping resistance to that coil which is unenergized, the normally contacted terminal 67 of relay 48, the normally uncontacted terminal 68 of relay 49, and terminals 69 and 71 of the damping resistance relays 56 and 57 respectively are connected together. Resistor 55 is connected from terminal 73 of relay 57 to terminal 72 of relay 56, the resistor 54 is connected from terminal 72 of relay 56 to the output junction of coils 28 and 29. With these connections, the sequential activation of relays 57 and 56 will remove resistor 55 from the damping resistance and then open the circuit of the damping resistance system. Thus it can be seen that relay 51 in the energized position and relays 48 and 49 in the unenergized positions, coil 29 is coupled to the current supply 52 and coil 28 is coupled to the damping resistance system 53 whereby the target is in the drive-down position. Reversing the positions of relays 48 and 49 will reverse the coil connections in the circuit and drive the target up. The activation of relays 48, 49, and 51 to direct the target motion and of relays 56 and 57 to vary the damping resistance is programmed by the control circuitry, shown in block form.

The starting signal for the apparatus is a current pip 74 generated by the accelerator at an appropriate time in the beam pulse to synchronize the target positioning operation with the desired energy level of the beam. Circuitry for generating such marker signals is commonly employed on accelerators and is well understood within the art. This signal is applied to the circuit at terminals 76 and is directed to a monostable multivibrator 77 which expands pip 74 into an extended square wave pulse 78. The pulse 78 provides a first input signal to a coincidence circuit 79 of the type producing an output signal upon the simultaneous occurrence of two input signals. The second input signal to coincidence circuit 79 originates from a controllable square wave pulse generator 81. The rise and fall of the pulse 82 from generator 81 will initiate the target drive-up and drive-down, respectively, thus, the pulse length is selected for the positioning time required and the pulse timing is synchronized with the accelerator cycle to expose the target at the desired instant. This square wave pulse 82 is differentiated in a differentiator 83, producing a positive and negative peaked output signal 84, corresponding to the rise and fall of pulse 82. The output of differentiator 83 is coupled to a bistable multivibrator 86 through coincidence circuit 79, and also coupled directly to a second input to the multivibrator. Coincidence circuit 79 responds to the positive peak of signal 84 from the differentiator, as indicated in the figure by signal 84' in which the negative portion of the wave form is shown in phantom. This peak, in coincidence with the extended square wave pulse 78, produces an output signal 87 to trigger multivibrator 86. It can be seen that in the event the accelerator has not attained the prescribed energy level, signal 78 will be absent from the coincidence circuit and upon the input of signal 84' no output signal will occur to energize the remaining circuitry. In this way, the possibility of exposing the target to the beam at erroneous energy levels is prevented.

The output of multivibrator 86, triggered by the signal 87 from the coincidence circuit, is cut off by the negative peak of the signal 84 as shown in the figure by signal 84'' and which is received by the second input of the multivibrator. The output signal 82' of bistable multivibrator 86 is, thus, a square wave of the same duration as the original square wave 82. This signal is applied through a relay driver 88 to an energizing coil 50 of ganged relays 48 and 49, whereby the actuation of these relays to interchange the connections of coils 28 and 29 will always occur simultaneously. In order that relay 51 does not couple the current supply 52 to the driving coil before the coil connections are completed, a time delay 89 has a first input coupled to the coincidence circuit 79 output to receive trigger signal 87, corresponding to the rise of wave 82', and which initiates the target drive-up. A second input to time delay 89 receives a trigger signal 91 from multivibrator 86 at the cut-off time, corresponding to the fall of wave 82', and which initiates the target drive-down. Time delay 89 holds each of these signals for the switching time of the coil relays 48 and 49. The double-peaked output signal 92 of time delay 89 is applied to a second monostable multivibrator 93, producing output pulses 94 therefrom of duration equal to actual driving time of the target positioning means. This signal is applied through a second relay driver 90 to the energizing coil 51' of relay 51. In this way the coil acting as the driving coil is energized only from the time the coil connection is complete until the target arrives in the new position.

To vary the resistance of the damping resistance system 53 during the operation, a connection from input terminals 76 applies the starting signal 74 to each of a pair of resistor controlling time delays 96 and 97. The output of time delay 97 is connected through a third relay driver 99 to the energizing coil 57' of relay 57. The output signal 102 from delay 97 occurs when the target drive-down is initiated, whereby relay 57 is energized and resistor 55 is removed from the damping re-

sistance for the drive-down. The output of time delay 96 is similarly coupled through a fourth relay driver 98 to the energizing coil 56' of relay 56. When the target has returned to the down position, signal 101 from time delay 96 energizes relay 56 and the damping circuit is opened to dissipate currents in that coil which was acting as the damping coil.

Considering now the operation of the invention, and with reference to Figs. 1, 2, and 3, assume a charged particle beam 12 circulating in the vacuum tank 11. In the initial condition the target carrier arms 16 and 23 are retracted whereby the target 27 is maintained out of the beam, thus coil 28 is disposed in the vertical plane and coil 29 is in the horizontal plane. All relays of the circuit of coils 28 and 29 are in the unenergized positions. The starting signal 74, generated by the accelerator, is applied to the circuit at terminals 76 at an appropriate time in the beam pulse and applied to the resistance controlling time delays 96 and 97, which delays will later actuate the damping resistance system relays 56 and 57. The starting signal is also received by monostable multivibrator 77, triggering the extended square wave output signal 78 therefrom, which signal supplies a first input to coincidence circuit 79. Within the duration of signal 78, the target actuating square wave 82 from pulse generator 81 is differentiated in differentiator 83, producing a positively and negatively peaked output signal 84, corresponding to the rise and fall of square wave 82. Coincidence circuit 79, responding to the positive peak of this signal in coincidence with signal 78, produces output pulse 87. Pulse 87 is applied to bistable multivibrator 86, triggering output signal 82' therefrom, which signal energizes relay coil 50 through relay driver 88. The contacts of relays 48 and 49 will now switch from the normally closed terminals to the normally open terminals whereby coils 28 and 29 will interchange circuit connections. Through the branched output of coincidence circuit 79, pulse 87 is also delayed for this switching period in time delay 89 and applied to monostable multivibrator 93, triggering output signal 94 therefrom. Signal 94 energizes relay coil 51' through relay driver 90 and relay 51 connects current supply 52 to coil 28, energizing coil 28 for the target drive-up. When the vertical coil 28 receives the current from supply 52, the magnetic flux created by the current interacts with the flux of the accelerator field 38 producing a torque which causes coil 28 to rotate to a horizontal plane. At the same time, the initially horizontal coil 29, coupled to the damping resistance system 53, is rotating toward a vertical plane and produces a torque opposing that of coil 28. Due to the rigid connection of the coils to connecting shaft 13, the resultant of the torque of coils 28 and 29 is transferred to shaft 13. This rotation of shaft 13, and of the second shaft 17 through their mutual coupling, simultaneously raises target carrier arms 16 and 23 from their retracted positions, bringing the target 27 into the orbit of the particle beam 12. The apparatus is brought to rest with the target in the up position upon the abutment of coil 28 with the stop 41 and the fall of signal 94 from monostable multivibrator 93 de-energizes relay 51, isolating current supply 52 from the coil circuit.

The target remains in the beam intercepting position until bistable multivibrator 86 is cut-off by the negative peak of signal 84 from differentiator 83, thereby de-energizing relays 48 and 49 and returning coils 28 and 29 to the original connections. Simultaneously with this cut-off, multivibrator 86 applies signal 91 to time delay 89. Time delay 89 again holds the signal for the switching time of relays 48 and 49 before triggering monostable multivibrator 93. The output signal of the multivibrator, energizing relay coil 51' will actuate relay 51 to couple current supply 52 to the circuit for the drive-down. Coil 29 will now receive the driving current and coil 28 will be connected to the damping resistance system 53. At this time, the output of resistance controlling time delay 97 applies the delayed starting signal 102 to relay driver 99, energizing relay coil 57' of relay 57, whereby resistor 55 is disconnected from the damping resistance. This reduced damping resistance optimizes the braking during the latter portion of the movement, permitting high drive-down speeds. With these coil connections, a torque is created which rotates shaft 13 in the opposite direction and the target is returned to the retracted position. The apparatus is now brought to rest by the abutment of coil 29 with stop 39 and the fall of signal 94 from monostable multivibrator 93 de-energizes relay 51 to isolate the current supply from the circuit. The output of resistance controlling time delay 96 will now apply the further delayed starting signal 101 to relay driver 98, energizing coil 56' of relay 56, whereby the damping resistance circuit 53 will be opened and any remaining currents in the damping coil will be dissipated. The target has now been completely removed from the beam orbit in sufficient time for a second target, operated by a second target positioner, to be exposed to the remaining portion of the beam.

Thus, it can be seen that the double coil arrangement, by virtue of its symmetry, makes it possible to effectively control the positioning of the target in both directions, allowing for more rapid drive-down and increased operating speed than has heretofore been available. It can also be seen that by adjustment of the timing controls to the relays in the circuit and regulation of the current to the driving coil, the apparatus may be easily adapted to various operating conditions of the accelerator.

While the invention has been described with respect to a particular embodiment thereof, it will be apparent to those skilled in the art that numerous variations and modifications 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. An internal target positioner for use in a charged particle accelerator of the class having a magnetic field defining a closed beam orbit, comprising a rotatable shaft positioned adjacent said beam orbit of said accelerator, a target carrying arm projecting radially from said shaft and having provision at the free end for the attachment of a target substance whereby rotation of said shaft moves said target substance into said beam orbit, a first electrical coil disposed in said magnetic field and coupled to said shaft for effecting rotation thereof, a second electrical coil disposed in said magnetic field transverse to said first coil and coupled to said shaft for effecting rotation thereof, and a current source for alternately energizing said first electrical coil and said second electrical coil to control the motion of said target substance with respect to said beam orbit.

2. A target positioner for use in a particle accelerator which accelerator has a magnetically defined curvilinear beam orbit, said target positioner comprising a rotatable drive shaft positioned transverse to said beam orbit and spaced apart therefrom, a target mounting arm extending radially from said shaft and having provision at the free end for the attachment of a target substance thereto whereby rotation of said shaft swings said target substance into said beam orbit, a first electrical winding disposed in the magnetic field of said accelerator and linked to said drive shaft, the axis of said first winding being normal to the plane defined by said shaft and said arm, a second electrical winding disposed in said magnetic field and linked to said drive shaft, the axis of said second winding being substantially at right angles to the axis of said first winding, a current source selectively connectable with said first electrical winding to rotate said shaft in a first direction through interaction with said magnetic field and alternately connectable with said second electrical winding to rotate said shaft in an opposing direction.

3. An internal target positioner for use within the

magnetic field of a charged particle accelerator of the type having a substantially fixed beam orbit, said target positioner comprising a rotatable connecting shaft mounted within said magnetic field adjacent said beam orbit and at right angles thereto, an arm secured to said shaft and extending radially therefrom, a target retaining platform affixed to the free end of said arm whereby rotation of said shaft swings said platform adjacent said beam orbit and a target substance retained thereby intercepts said beam orbit, a first flat electrical winding secured to said shaft and disposed in a plane which includes said shaft, a second flat electrical winding secured to said shaft and disposed transverse to said first electrical winding, a current source, a first switching means connected between said current source and said electrical windings and energizing said first electrical winding to produce rotation of said shaft in a first direction and alternately energizing said second electrical winding to produce rotation of said shaft in an opposing direction.

4. A target positioner for use within a charged particle accelerator of the type having a curvilinear beam orbit defined by a magnetic field, comprising a rotatable shaft positioned adjacent said beam orbit of said accelerator, a target carrying arm projecting radially from said shaft and having provision at the free end for affixing a target substance thereto whereby rotation of said shaft positions said target substance in said beam orbit, a first electrical coil disposed in said magnetic field and coupled to said shaft for effecting rotation thereof, a second electrical coil disposed in said magnetic field transverse to said first coil and coupled to said shaft for effecting rotation thereof, a current source alternately energizing said first electrical coil and said second electrical coil to rotate said shaft, and means for alternately varying the electrical resistance of each of said coils.

5. In apparatus for positioning a target substance in the charged particle beam of a high energy accelerator of the class having a magnetic fie'd establishing a generally circular beam orbit, the combination comprising a rotatable shaft disposed adjacent said beam orbit, a radial arm extending from said shaft, a target holder affixed to the extremity of said arm whereby a target substance held thereby intercepts said beam upon rotation of said shaft, a first electrical coil coupled to said shaft and disposed within said magnetic field, a second electrical coil coupled to said shaft and aligned in a plane transverse to that of said first electrical coil and being disposed within said magnetic field, a current source, at least one electrical resistor, and switching means having a first position connecting said first electrical coil to said current source to rotate said shaft in a first direction and connecting said second electrical coil to a resistor to brake the rotation of said shaft, said switching means having a second position connecting said second electrical coil to said current source to rotate said shaft in an opposing direction and connecting said first electrical coil to said electrical resistor to brake said rotation.

6. Apparatus for positioning a target material in the circulating beam of a charged particle accelerator of the class having a magnetically established curvilinear beam orbit comprising, in combination, a rotatable shaft disposed in proximity to said beam orbit, an arm extending radially from said shaft, a target retainer mounted on the extremity of said arm whereby said retainer is moved adjacent said beam orbit upon rotation of said shaft, a first electrical coil disposed in said magnetic field and coupled to said shaft, a second electrical coil disposed in said magnetic field at right angles to said first electrical coil and coupled to said shaft, a current source, a resistance unit having a plurality of electrical resistors, relay means having a first operating condition connecting said first electrical coil to said current source to rotate said shaft in a first direction and connecting said second electrical coil to said resistance unit, said relay means having a second operating condition connecting said second electrical coil to said current source to rotate said shaft in an opposite direction and connecting said first electrical coil to said resistance unit, and switching means progressively disconnecting said resistors within said resistance unit during said rotation of said shaft thereby progressively decreasing the resistance of said electrical coil coupled thereto during the rotation of said shaft and producing an increasing torque opposing said rotation.

7. In target positioning apparatus for use within a charged particle accelerator of the class having a particle beam circulating within a magnetic field, the combination comprising a rotatable shaft spaced from the orbit of said beam, an arm projecting radially from said shaft, a target retainer mounted on the extremity of said arm whereby rotation of said shaft swings said target retainer to intercept said beam orbit, a first electrical coil linked to said shaft to rotate said shaft, a second electrical coil disposed transverse to said first electrical coil and linked to said shaft to rotate said shaft, a current source, an electrical resistor, a signal generator producing selectably timed control signals, a first relay acting in response to said control signal to connect said first electrical coil to said current source to rotate said shaft in a first direction and acting upon the cessation of said control signal to connect said first electrical coil to said electrical resistor, and a second relay acting in response to said control signal to connect said second electrical coil to said electrical resistor and acting upon the cessation of said control signal to connect said second electrical coil to said current source whereby said shaft is rotated in an opposite sense.

8. In apparatus for the timed insertion of a target substance into the beam of a charged particle accelerator of the type having a magnetic field constraining said beam to circulate in a closed orbit and which accelerator produces a reference signal at particular energy levels of said beam, the combination comprising a rotatable shaft spaced from said beam orbit, an arm projecting radially from said shaft and having provision for retaining a target substance on the extremity thereof whereby rotation of said shaft positions said target substance into said beam orbit, a first rotatable electrical coil disposed in said magnetic field and mechanically linked to said shaft, a second rotatable electrical coil disposed in said magnetic field transverse to said first coil and mechanically linked to said shaft, a current source, an electrical resistor, a signal generator producing selectably timed control signals, a coincidence circuit receiving said control signal at a first input and receiving said accelerator reference signal at a second input and producing an output signal upon the concurrent receipt of said control signal and said reference signal, a first relay acting in response to said output signal to connect said first electrical coil to said current source to rotate said shaft in a first direction and acting upon the cessation of said output signal to connect said first electrical coil to said resistor, and a second relay acting in response to said output signal to connect said second electrical coil to said electrical resistor and acting upon cessation of said output signal to connect said second electrical coil to said current source whereby said shaft is rotated in an opposite direction.

9. Apparatus as described in claim 8 and further comprising a monostable multivibrator having an input receiving said accelerator reference signal and producing a time extended reference signal at an output terminal which output terminal is connected with said second input to said coincidence circuit whereby the coincidence time of said coincidence circuit is extended.

10. In target positioning apparatus for use within a circulating beam charged particle accelerator of the type having a magnetically created beam orbit and of the type providing energy level marker signals during the accel-

eration period of said beam, the combination comprising a rotatable shaft adjacent said beam, a radial arm projecting from said shaft, a target retainer affixed to the extremity of said arm whereby rotation of said shaft swings said target retainer into a position adjacent said beam, a first electrical coil disposed in said magnetic field and mechanically linked to said shaft whereby energization of said coil rotates said shaft in a first direction, a second electrical coil disposed in said magnetic field at right angles to said first coil and mechanically linked to said shaft whereby energization of said second coil rotates said shaft in an opposite direction, a coil energizing current source, an electrical resistor, a first relay having a first setting connecting said first coil with said current source and having a second setting connecting said first coil with said resistor, a second relay having a first and second setting synchronized with said first and second setting of said first relay, said second relay connecting said second coil with said resistor at said first setting thereof and connecting said second coil with said current source at said second setting thereof, a square wave generator producing controllably timed output signals, a differentiator coupled to the output of said generator and producing a trigger pulse corresponding to the rise of said square wave signal and a cut-off pulse corresponding to the fall of said square wave signal, a monostable multivibrator receiving a selected one of said energy marker signals and producing a time extended output signal, a coincidence circuit receiving said time extended signal at a first input and having a second input coupled to said differentiator and producing an output pulse upon the simultaneous presence of said trigger pulse at said second input, a bistable multivibrator energized by said trigger pulse from said coincidence circuit and de-energized by said cut-off pulse from said differentiator, and a relay driver actuating said first relay and said second relay to switch the settings thereof in response to the output signal of said bistable multivibrator.

11. Apparatus for positioning a target material in the circulating beam of a charged particle accelerator which accelerator has a magnetically defined beam orbit of substantially constant radius and which accelerator generates reference signals at particular energy levels of said beam, said apparatus comprising a rotatable shaft disposed adjacent said beam orbit, a radial arm secured to said shaft and having provision at the free end for affixing a target substance to intercept said beam orbit upon rotation of said shaft, a first electrical coil disposed in the magnetic field of said accelerator and mechanically coupled to said shaft to effect rotation thereof, a second electrical coil disposed in said magnetic field transverse to said first coil and mechanically coupled to said shaft to effect opposite rotation thereof, a coil energizing current source, a coil impedance resistor, pulse generator means producing a controllably timed trigger signal and cut-off signal, a coincidence circuit receiving said accelerator reference signal at a first input and said trigger signal at a second input and producing a second trigger signal at the output upon the simultaneous presence of said reference signal and said trigger signal, a bistable multivibrator having a first input connected to said coincidence circuit output and a second input connected to said pulse generator and producing a control signal of duration determined by said second trigger signal and said cut-off signal, a first relay acting in response to said control signal to connect said first electrical coil to said current source, said first relay acting upon the cessation of said control signal to connect said first electrical coil to said impedance resistor, a second relay acting in response to said control signal to connect said second electrical coil to said impedance resistor, said second relay acting upon the cessation of said signal to connect said second electrical coil to said current source, and switching means actuating said current source upon the respective connection of said current source to said first electrical coil and said second electrical coil.

12. Apparatus as described in claim 11 wherein said switching means comprises a time delay having a first input receiving said second trigger signal from said coincidence circuit and having a second input receiving said cut-off signal from said pulse generator and producing correspondingly delayed output signals thereof, a monostable multivibrator coupled to the output of said time delay and extending the time duration of said signals therefrom, and a third relay coupled to the output of said monostable multivibrator and actuating said coil energizing current source in response to said time extended second trigger signal and said time extended cut-off signal respectively.

13. Apparatus as described in claim 11 and further comprising means varying the resistance of said coil impedance resistor to controllably retard said rotation of said shaft.

14. In apparatus for the controlled positioning of a target material with respect to the beam of a charged particle accelerator of the class having a magnetic field providing a generally curvilinear beam orbit and which accelerator generates reference signals at particular energy levels during the accelerating period of said beam, the combination comprising, a rotatable shaft disposed in proximity to said beam, a radial arm projecting from said shaft and adapted at the free end to hold said target material whereby rotation of said shaft moves said target material into said beam orbit, a first electrical coil coupled to said shaft and disposed in said magnetic field whereby energization of said first coil rotates said shaft in a first direction, a second electrical coil coupled to said shaft and disposed in said magnetic field whereby energization of said second coil rotates said shaft in a second direction, a coil energizing current source, a plurality of coil impedance resistors, a like plurality of resistor connecting relays, a pulse generator producing selectably timed control signals, a coincidence circuit receiving said control signals at a first input and said accelerator reference signal at a second input and producing an output signal upon the simultaneous presence of said control signal and said reference signal, a first relay responding to said output signal to connect said first electrical coil to said current source and responding to the cessation of said signal to connect said first coil to said plurality of resistors, a second relay responding to said output signal to connect said second electrical coil to said plurality of resistors and responding to the cessation of said signal to connect said second coil to said current source, and a plurality of time delay means each transmitting said accelerator reference signal to one of said plurality of resistor connecting relays to decrease the resistance of said electrical coil coupled thereto and increasingly retard the rotation of said shaft produced by the other of said coils.

No references cited.