

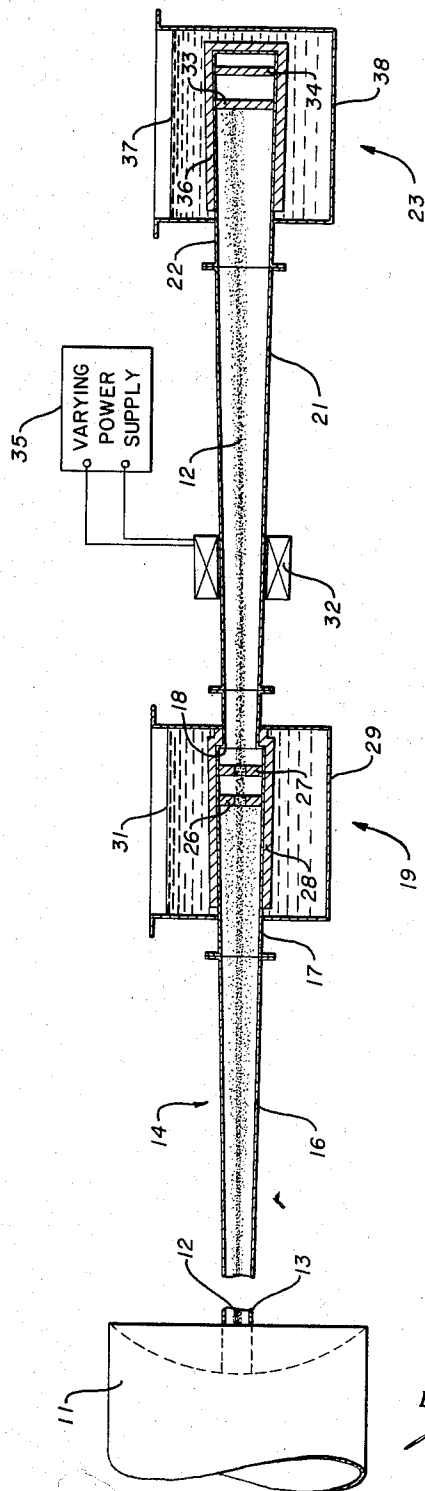
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TARGET ASSEMBLY

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TARGET ASSEMBLY

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The present invention relates to an improved two-stage target assembly for use with beams of high energy particles.

Recent advances in nuclear physics have proven the feasibility of large scale transmutation of elements and this may be exploited to produce in quantity certain elements occurring only rarely or not at all in the world today. One proven method of synthesizing elements is the bombardment of certain other elements with high energy beams of charged particles wherein desired physical reactions including the capture or release of atomic particles result. Devices have been designed and constructed to produce such bombardment transmutations, and for a detailed account of one such machine reference is made to the copending patent application of Ernest O. Lawrence, Edwin M. McMillan and Luis W. Alvarez, Serial No. 571,850, filed March 15, 1956, for Electro-nuclear Reactor, now abandoned.

The present invention is adapted for use with, although not limited to, devices of the type disclosed in the above-noted application. The efficient utilization of a very high energy beam of charged particles as may now be produced requires that a target to be bombarded thereby be capable of absorbing tremendous quantities of energy and of producing useful work therefrom. With the beam energies contemplated direct interception of the entire beam by a solid material is not possible for no known material could withstand the resultant temperatures without melting. As a solid material is necessary for, at least, a part of the target to maintain some desired configuration thereof, it is necessary to move the beam and target relative to each other so as to provide intermittent bombardment of individual target sections whereby the average energy received thereby is maintained below a critical maximum value.

As regards relative beam-target motion, the great size and weight of the target required to absorb the incident beam energy poses great difficulty in the way of target displacement so that beam deflection appears most feasible. Also, as a result of the naturally divergent nature of charged particle beams traveling in space, the free beam travel distance required in any beam deflection system results in a considerable beam cross section at the target and the beam at the target normally has a density variation from an intense center outward.

It is contemplated by the present invention that two targets shall be employed in displaced relation along the beam traverse with the first intercepting the outer cross section of the beam and the second being traversed by the remaining relatively intense beam core. Traversal of the second target may be accomplished by the establishment of rotating or moving magnetic fields in the beam path, preferably directly behind the first target wherein the beam density gradient is quite small radially of the beam.

As the required beam deflection at the second target is a function of the beam intensity or density at the

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beam center area regardless of the overall beam radius, it is desirable to have a beam of limited cross section to minimize the target area required to accommodate the traversing beam. In this invention this is accomplished by intercepting with a first target a desired outer annular beam cross sectional area.

It is an object of the present invention to provide an improved dual target arrangement for intercepting high energy beams of charged particles.

It is another object of the present invention to provide a two-stage bombardment target wherein the relatively low density portion of the beam cross section is intercepted at a first target and a second target is traversed by the continuously deflected remaining beam.

It is a further object of the present invention to provide a first annular target adapted to intercept a predetermined outer portion of a high energy beam of charged particles, a second target spaced from the first, and beam deflection means directing the beam passing the first target to follow a predetermined path over the surface of the second target.

Various other possible objects and advantages of the invention will become apparent to those skilled in the art from the following description taken together with the accompanying drawing wherein the sole figure is a longitudinal cross section of a target assembly embodying the features of the present invention.

The dual target assembly of the present invention includes a first apertured target through which the intense center or core of a beam is adapted to pass, with the outer beam portions intercepted at this first target. A second target is also provided with a larger area than the cross section of the incident beam with beam precessing means provided for sweeping the beam across the target surface to produce a relatively even bombardment thereof.

Considering now the details of the illustrated embodiment of the invention and referring to the drawing, there is shown the high energy end of a particle accelerator 11 adapted to produce a beam of charged particles and to accelerate same to a very high velocity. For the purposes of the present invention, it may be assumed, as is normally the case, that the accelerated beam 12 is very dense at the center with the beam density decreasing radially outward of the beam. Although the present invention may be employed with various types of particle accelerators, there is illustrated a linear accelerator having an axial exit tube 13 through which the beam 12 travels from the accelerator proper. Attached to and communicating with the accelerator tube 13 is a target beam envelope 14 axially aligned with the tube 13. The interior of the accelerator 11 is maintained under vacuum by means not shown and the target beam envelope, which must also be under vacuum, may be evacuated from the accelerator or by separate pumping means, not shown. All joints and connections of the target beam envelope are maintained vacuum tight by suitable sealing means to insure against air leaks to the interior thereof.

The target beam envelope 14 which is preferably formed of a metal such as stainless steel includes a first elongated conical section 16 attached at the small end to the accelerator tube 13 and at the large end to an expanding first target section 17 which has at the large end thereof a transverse wall 18 having a central aperture therethrough and disposed within a first target 19. The envelope further includes a second elongated conical section 21 connected at the small end thereof at the end wall 18 of the first target section and communicating therewith through the aperture in the end wall. A further expanding conical target section 22 connects axially

to section 21 and terminates with a second target structure 23.

Considering now the first target 19, same will be seen to include a primary target element 26 and a secondary target element 27 disposed in spaced relation normal to the beam axis immediately ahead of the transverse wall 18. The target elements 26 and 27 have small central apertures transversely therethrough so that the beam 12 is collimated in passing therethrough and emerges therefrom with a very small cross section which comprises the most intense beam core. The number and composition of target elements employed in the target are determined by the beam composition and energy as well as the reactions it is desired to promote by beam bombardment, and, for example, the two elements illustrated may be formed of helium cooled beds of appropriately sized pellets of uranium or thorium. The envelope section 17 about the target elements 26 and 27 is jacketed by a target lattice 28 which is in turn immersed in a tank 29 filled with a fluid 31, such as water, for cooling and shielding of the target 19. One possible arrangement of the target components is a primary target element producing high energy neutrons from beam bombardment, a secondary target element producing low energy neutrons from bombardment by high energy neutrons, and a lattice of material undergoing a desired reaction or transmutation upon bombardment with low energy neutrons.

It will be seen that the target 19 serves two functions in that the target elements thereof collimate the beam to pass only the small intense central core thereof while intercepting the outer beam portions which diffuse somewhat in traveling from the accelerator in relatively field free space along the elongated envelope section 16. Additionally, the primary element of the first target 19 serves as a regular bombardment target in intercepting a desired portion of the beam and reacting therewith in some desired fashion, as for example to transmute the target material to another element by nuclear transmutation reaction.

There emerges from the first target 19 an intense beam collimated to a small cross section and this beam is subjected to the influence of time varying magnetic fields produced by magnet windings 32 disposed about the envelope section 21 near the small end thereof. The windings are adapted for controlled and variable energization from a source 35, to produce a magnetic field generally parallel to the beam axis and varying in a predetermined manner to apply to the beam deflection forces of desired amplitude and direction, as noted in more detail below.

The beam 12 is finally completely intercepted at target 23 by means of primary and secondary target elements 33 and 34 thereof disposed transversely of the beam at the large end of the envelope section 22. A target lattice 36 surrounds the end of the envelope section 22 about the target elements 33 and 34 and the lattice 36 is immersed in a fluid 37, such as water, contained in a tank 38. As in the case of the first target 19, the second target 23 may be designed to produce neutrons in the primary and/or secondary target sections and to react same with material held in the lattice to the end of transmuting elements, for example.

With regard to the operation of the present invention, assume first that an intense beam of charged particles, such as protons or deuterons for example, are accelerated from the particle accelerator 11 axially through the exit tube 13. In the field free space between accelerator 11 and first target 19 the beam diverges somewhat, as illustrated, and the outer portion of the beam is intercepted by the primary target element 26 whereby the beam is collimated through the aperture therein. The secondary target element is likewise bombarded, possibly with certain of the beam directly around the aperture in this element, with beam particles piercing the primary element, as also by secondary particles produced in the primary target element. Secondary particles such as neutrons produced in the primary and secondary target elements

bombard the enveloping lattice 28 for producing desired and calculable physical reactions such as nuclear transmutation of the lattice material to an artificially produced material by neutron absorption reactions. The elements and lattice of the primary target are mounted in removable relation to the beam envelope 14 and tank 29 whereby same may be removed when, for example, a desired reaction is sufficiently progressed, i.e., when they have been sufficiently bombarded.

The collimated beam emerging from the first target 19 is acted upon by varying magnetic fields established in the path thereof by the energization of one or more windings 32. The lines of force of the field are generally parallel to the beam axis; however, the magnitude of the field and instantaneous location thereof is varied as by employing multiple windings with a predetermined frequency of voltage energization to apply varying deflecting forces upon the beam in a predetermined manner. By this means the beam is deflected in a pattern and in traversing the distance from magnet 32 to target 23 is displaced to trace a pattern upon the surface of the primary target element 33, as for example a circle or a triangle. In order to provide even target irradiation without burning thereof as at the target center the primary element is formed with a radius at least equal to the beam diameter at the target so that no overlapping of the irradiated surfaces occurs during the beam sweep.

In the second target 23 the primary element 33 is bombarded by the beam uniformly over the surface thereof as a result of beam sweeping and the secondary element 34 and lattice 36 are bombarded by beam particles piercing the primary element and those deflected therein, as well as by secondary particles such as neutrons freed in the bombardment of the primary element. Like the first target, the elements and lattice of the second target are removably mounted therein whereby same may be exchanged after a desired amount of target bombardment.

It will be seen from the foregoing that the present invention in accomplishment of the foregoing objects provides a first collimating target utilizing a portion of the beam energy while at the same time reducing beam diameter and, further, a second target intercepting the remainder of the beam which is swept thereover in a repetitious pattern by beam deflection means intermediate the targets. The number of elements provided in each target is dependent upon the beam energy and the desired target reactions, as well as target composition and numerous other factors, so that the embodiment of the invention herein described is illustrative only and is in no way limiting. For a precise definition of the scope of the invention reference is made to the appended claims.

What is claimed is:

1. A target assembly adapted to intercept a beam of charged particles and comprising a first target having a small transverse aperture therethrough for collimating a beam directed thereat and being of a material capable of undergoing and promoting physical reactions with the intercepted particles, a second target spaced from said first target along the beam path for intercepting all of the beam passing said first target and being of a material capable of undergoing and promoting physical reactions with the intercepted beam, and means establishing varying magnetic fields in the path of said beam on the exit side of said first target whereby the beam is deflected and swept over the surface of said second target.

2. An improved target assembly adapted to intercept and utilize a high energy beam of charged particles of singular charge polarity comprising a first target including at least one element disposed transverse to the beam in the path thereof with a small central aperture whereby the beam is collimated in passing therethrough, a second target disposed transversely of the beam in the path thereof for intercepting the beam at a distance from said first target in the direction of beam travel therefrom, said first and second targets being of a material

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capable of ejecting particles in response to beam bombardment, and magnetic deflection means producing a varying magnetic field and disposed adjacent the first target toward the second target therefrom whereby the collimated beam is constrained to sweep said second target.

3. An improved target assembly as claimed in claim 2 further defined by each of said first and second targets having a lattice enveloping the beam in the vicinity of beam interception for bombardment by particles ejected from the targets by beam bombardment thereof.

4. A target assembly adapted for connection to an accelerator producing a beam of charged particles comprising a vacuum-tight envelope, a first target disposed in said envelope with a collimating aperture therethrough substantially on the envelope axis and spaced from an open end of said envelope adapted for joinder to a particle accelerator, a second target disposed in said envelope in spaced relation to said first target axially of said envelope, a lattice enveloping each one of said targets, magnetic field producing means disposed adjacent said first target toward said second target therefrom for establishing a varying magnetic field in a limited length of said envelope and deflecting said beam, whereby said collimated beam is swept across said second target.

5. An improved target assembly comprising an elongated open-ended vacuum tight envelope adapted for connection at the open end thereof to a source of a high energy beam of charged particles, a first target disposed at a distance from the open end of said envelope and including at least one element extending transversely through said envelope with a central aperture therethrough for collimating a beam passing through the envelope and formed of a material producing free neutrons from intercepted peripheral beam portions, a second target disposed at the closed end of said envelope and including at least one element extending transversely of the envelope for intercepting a collimated beam of charged particles, said envelope and intercepting second target element having a radius transverse of the envelope axis at least equal to the diameter of a beam intercepted at the second target, and magnet windings about said envelope adjacent said first target on the sec-

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ond target side thereof for establishing a varying magnetic field through said envelope to deflect a particle beam therethrough whereby same sweeps over the surface of said second target element.

6. An improved target assembly comprising a first elongated vacuum tight conical envelope adapted for connection at the small end thereof to a source of a high energy beam of charged particles, a first target disposed at the large end of said envelope section and including at least one element extending transversely through the envelope thereat with a central aperture therethrough for collimating a beam passing through the envelope section and formed of a material producing free neutrons from intercepted peripheral beam portions, a lattice enveloping said first target for bombardment by the neutrons thereby produced, a tank of cooling and shielding fluid surrounding said lattice, a second elongated vacuum tight conical envelope section communicably connected in vacuum-tight relation at its small end to the large end of said first envelope section, a second target disposed at the large end of said second envelope section and including at least one element extending transversely of the envelope for intercepting a collimated beam of charged particles, said second target element being formed of a material producing free neutrons from the intercepted collimated beam, a second lattice enveloping said second target for bombardment by the neutrons thereby produced, a second tank filled with cooling and shielding fluid surrounding said second lattice, and magnet windings about said second envelope section intermediate said first and second targets for establishing a varying magnetic field through said second envelope section to deflect a particle beam therethrough whereby same sweeps over the surface of said second target element.

References Cited in the file of this patent

UNITED STATES PATENTS

2,500,455	Fisher	Mar. 14, 1950
2,543,859	Long	Mar. 6, 1951
2,576,600	Hanson	Nov. 27, 1951
2,672,559	Goodwin	Mar. 16, 1954