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Gorka, Jr.

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[54] **MAGAZINE FOR HANDLING STRIPPING FOILS IN A PARTICLE ACCELERATOR**

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[73] Assignee: **The United States of America as represented by the United States Atomic Energy Commission,** Washington, D.C.

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[21] Appl. No.: **474,550**

[52] **U.S. Cl.** **328/233,** 313/152, 313/359

[51] **Int. Cl.** **H05h 7/00**

[58] **Field of Search** 328/228, 233; 313/359, 313/363, 146, 152

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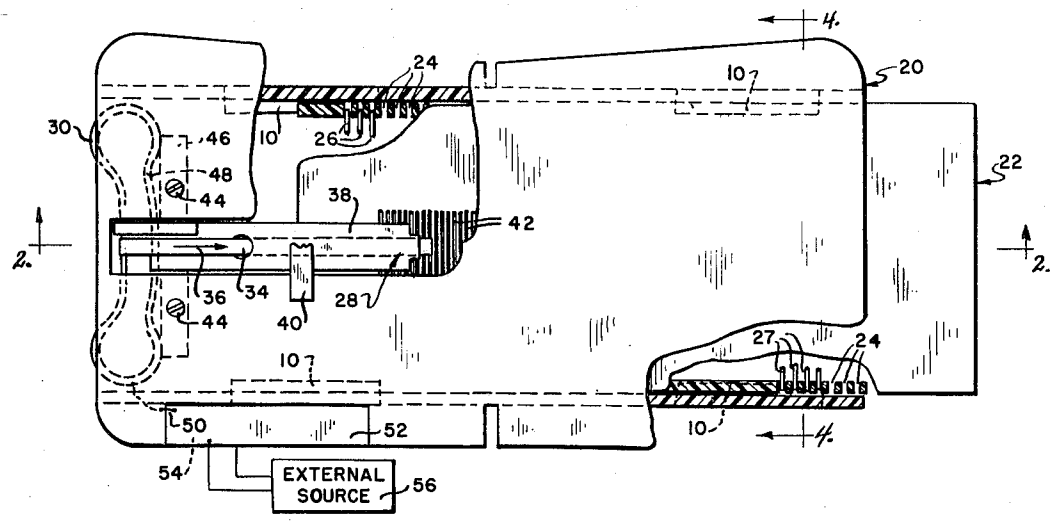
Primary Examiner—Palmer C. Demeo

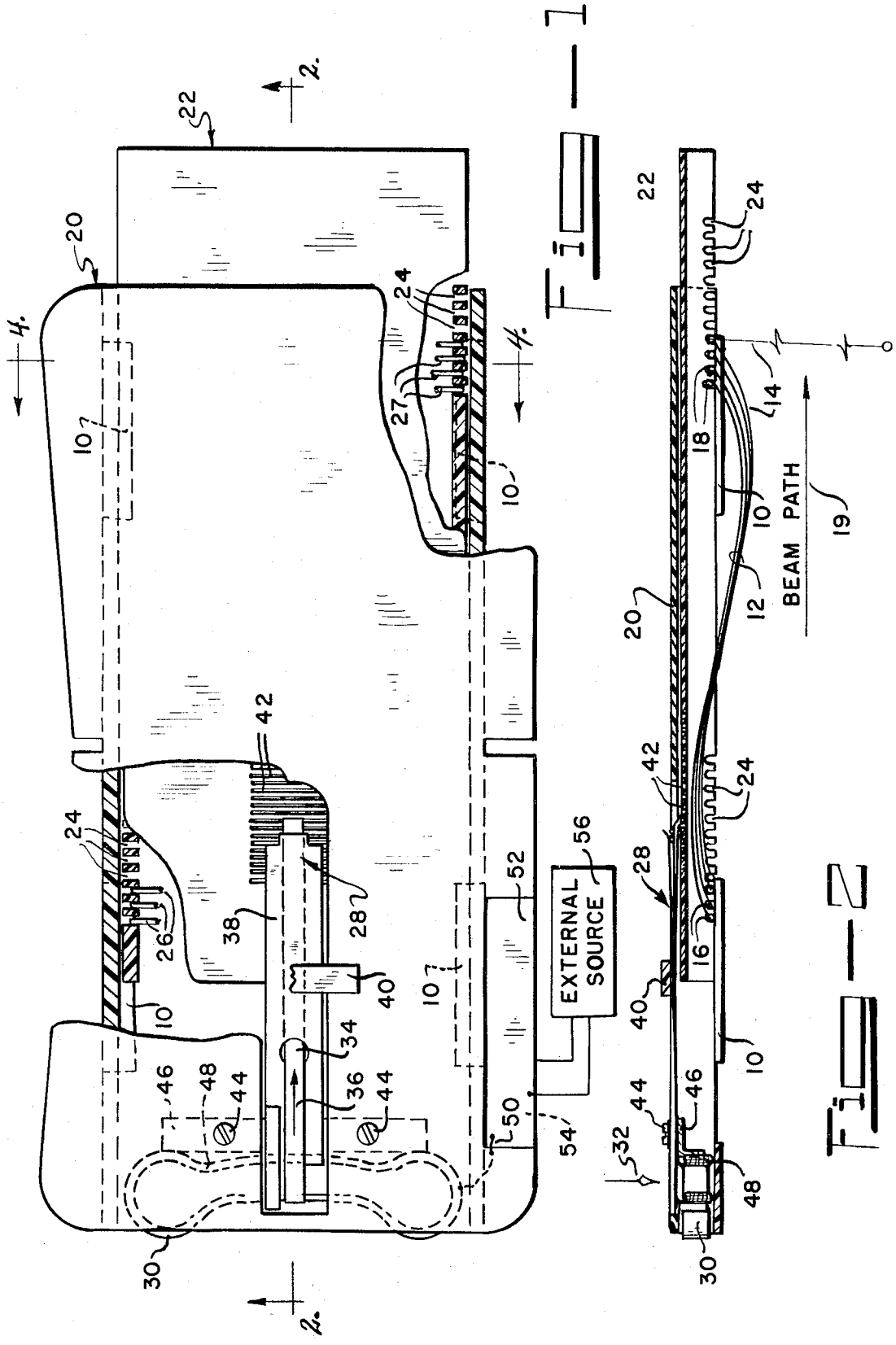
Attorney, Agent, or Firm—John A. Horan; Arthur A. Churm; Donald P. Reynolds

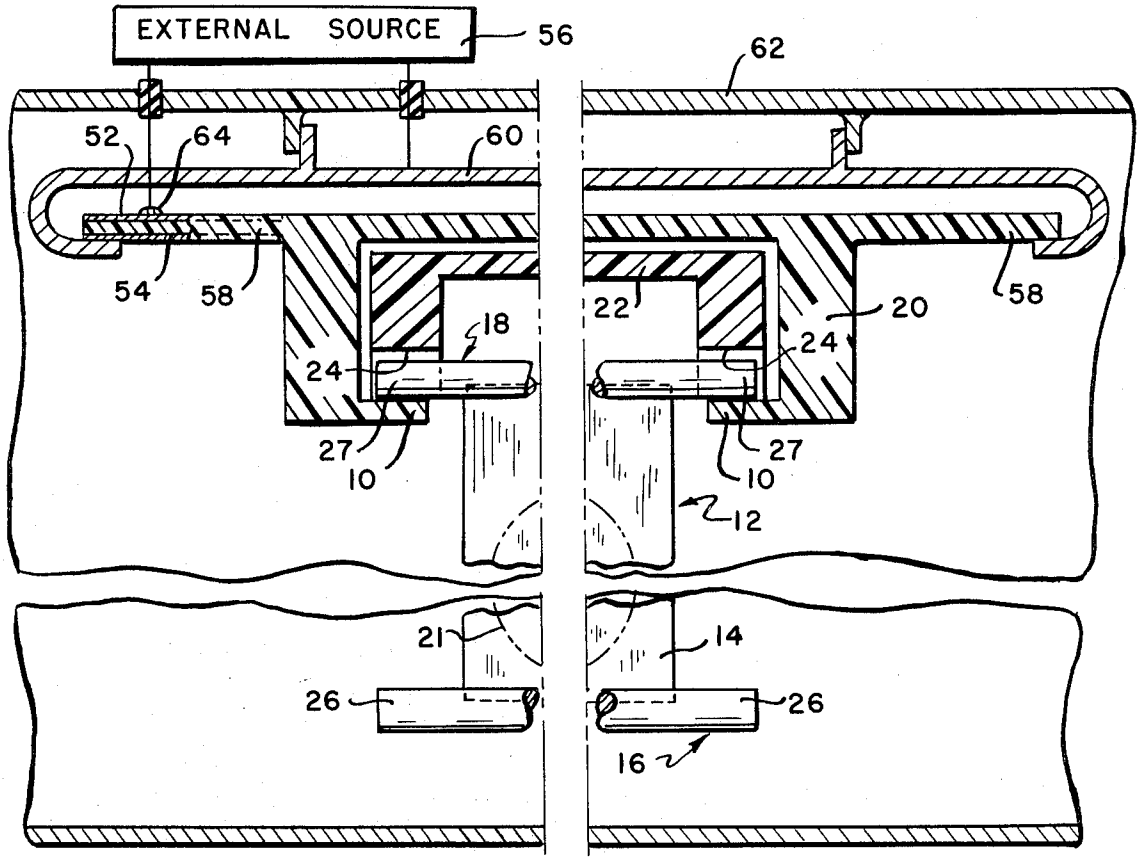
[57] **ABSTRACT**

Thin foils for stripping a particle beam are stored in a magazine that is operable remotely to display an individual foil, release it when it is spent, and repeat this process. The magazine is operable in the high-vacuum, high-radiation environment in the interior of a particle accelerator, and it uses the magnetic field of the accelerator to operate the display and dropping mechanism.

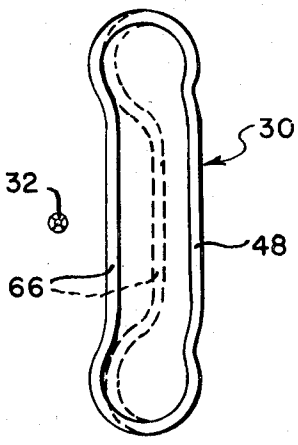
12 Claims, 7 Drawing Figures




EXTERNAL SOURCE
BEAM PATH


EXTERNAL SOURCE
56
62
52
64
60
54
58
18
24
22
20
58
24
27
10
27
10
12
21
14
26
26
16

Fig—4


30
32
48
66

Fig—3

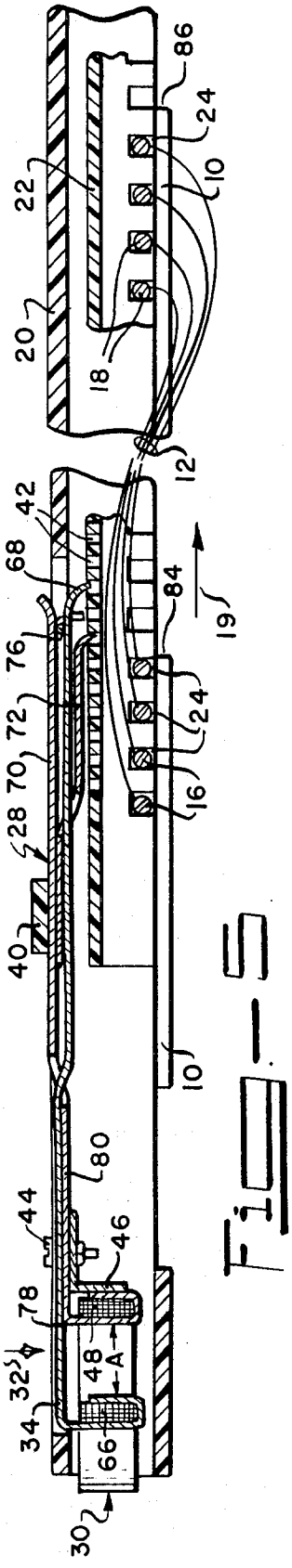


FIG. 5

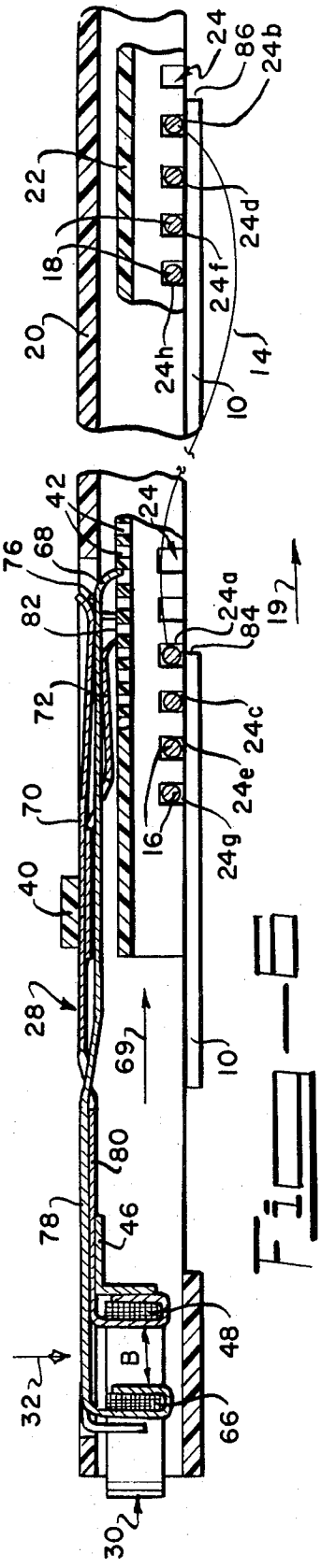


FIG. 6

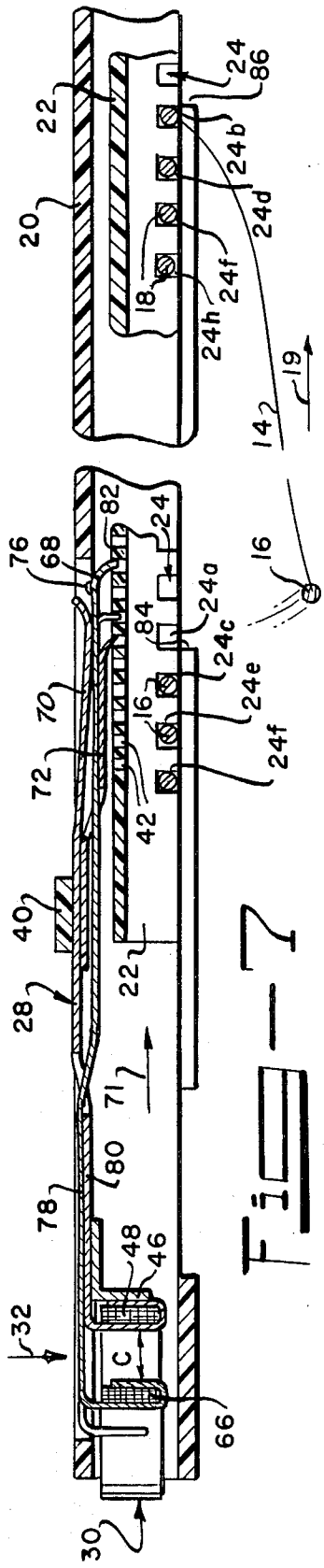


FIG. 7

MAGAZINE FOR HANDLING STRIPPING FOILS IN A PARTICLE ACCELERATOR

CONTRACTUAL ORIGIN OF THE INVENTION

The invention described herein was made in the course of, or under, a contract with the UNITED STATES ATOMIC ENERGY COMMISSION.

BACKGROUND OF THE INVENTION

This invention relates to the means of charge exchange known as stripping. It provides improved operation of various kinds of accelerators of charged particles.

Stripping is a well-known technique in the field of charged-particle accelerators. As a part of the process of acceleration, it is often desirable to change the state of charge of the particles in a beam. This is done by causing the particles to collide with other particles. One way of stripping is to introduce molecules of gas into the path of the beam. Another way is to place a thin foil in the path of the beam. The objective is to assure that a high percentage of the number of particles in the beam makes a predetermined number of collisions with stripping molecules, and that a small percentage collides with a different number of stripping molecules. The latter objective requires that, if a foil is used, it be very thin.

Various materials are used to strip. In an example of the instant invention, the stripping atom is carbon which is disposed in the beam path as a very thin foil of an organic polymer. The particular foil used in the practice of the present invention is a thermally stabilized polymer of p-xylene, approximately 5800 A in thickness, formed by vapor deposition. Criteria for its selection included the following. A material for stripping should comprise atoms of low atomic numbers, preferably at and below the atomic number of carbon. Such a material must withstand the energy of the beam without melting or decomposing. It myst have sufficient tensile strength to support itself in pieces that span a cross-section larger than the cross section of the beam to be stripped. It must maintain this tensile strength long enough to provide a reasonable period of accelerator operation, of the order of at least an hour, before requiring replacement. It must be self-supporting without a backing and without a framework at all edges. It must withstand the vacuum environment in the interior of a particle accelerator and it must not produce or release particles to comprise a virtual leak.

The stripping foil must be disposed in the beam for stripping at a predetermined time and the means of disposing the foil must permit remote operation. There must be a way to remove and replace foil that has been damaged by radiation, and this way should minimize accelerator downtime. The means for disposing foils must be unaffected by radiation, high vacuum, and the magnetic field of the accelerator.

It is an object of the present invention to provide an improved means of stripping a beam of charged particles.

It is a further object of the present invention to provide a means of disposing a thin film of poly-paraxylylene in a beam of charged particles to effect charge exchange.

It is a further object of the present invention to provide a remotely operable means of placing and replacing stripping foils in a particle beam.

It is a further object of the present invention to provide a means of placing stripping foils in a particle beam under conditions of radiation, high vacuum, and high magnetic field.

SUMMARY OF THE INVENTION

A remotely operable magazine stores, displays, and releases thin foils of poly-paraxylylene to effect charge exchange in a particle beam. Each foil is connected at each of two opposite sides to a rod which projects beyond the sides of the foil. The projecting portions of the rods are held in notches in the magazine, which stores a plurality of such foils. Operation comprises indexing the magazine to release one rod, dangling the foil by the other rod to place the foil in the beam. A second indexing step releases the second rod to drop the foil. Successive indexing steps repeat the process to display and remove a plurality of foils, one at a time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial sectional top view of the magazine of the present invention.

FIG. 2 is a sectional side view of the magazine of FIG. 1, taken along section lines 2—2.

FIG. 3 is a top view of the coil of FIGS. 1 and 2.

FIG. 4 is a sectional view of the magazine of FIG. 1, taken along section lines 4—4, showing a dangling foil.

FIGS. 5, 6, and 7 are expansions of the sectional side view of FIG. 2 showing three successive states of the sequence of operation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a partial sectional top view of the magazine of the present invention, and FIG. 2 is a sectional view of the magazine from the side, taken along section line 2—2. In FIGS. 1 and 2, shelves 10 support a plurality of foil assemblies 12. Each such foil assembly 12 comprises a foil 14 which is attached to a first rod 16 and to a second rod 18. Shelves 10 support foil assemblies 12 by their first rods 16 and second rods 18. Shelves 10 comprise parts of support frame 20, and notched indexing frame 22 is supported on shelves 10. The notches 24 in indexing frame 22 engage the projecting ends 26 and 27 of first rods 16 and second rods 18 so as successively to (1) hold first rods 16 and second rods 18 on shelves 10; (2) upon once moving, drop a first rod 16 from a shelf 10 to dangle a foil 14 from a second rod 18 into beam path 19; and (3) upon moving again, to drop the second rod 18 from a shelf 10, thus dropping the foil assembly 12. This cycle is repeated to supply new foils 14, one at a time.

To move indexing frame 22 with respect to support frame 20, ratchet mechanism 28 is actuated by applying a pulse of electric current to coil 30. This generates a magnetic field that interacts with the accelerator magnetic field 32 to produce a magnetic force. This magnetic force squeezes coil 30, moving ratchet drive rod 34 in the direction of arrow 36. Removal of either or both of the current in coil 30 and the accelerator magnetic field 32 relaxes the magnetic force on coil 30, which returns under its own elasticity to its original position. Fixed spring 38 is placed under support 40 to maintain contact of ratchet mechanism 28 with ratchet slots 42. Screws 44 affix a bracket 46 that maintains the near side 48 of coil 30 in a fixed position with respect to support frame 20. Electric current is supplied to coil

30 through wires 50, which connect to upper sliding contact 52 and lower sliding contact 54, which in turn are connected to external source 56.

The position of coil 30 is shown diagrammatically in two views in FIG. 3, which is a top view of coil 30. In FIG. 3, near side 48 is in a fixed position, and far side 66 is free to move under the influence of the magnetic force between current flowing in coil 30 and the accelerator magnetic field 32, here shown as the conventional view of an arrow directed into the paper. The solid lines indicate coil 30 in a relaxed position; the dotted lines show coil 30 squeezed. The motion associated with the change from the solid line to the dotted line actuates ratchet mechanism 28.

Further understanding of the invention may be had from FIG. 4, which is a sectional view of the magazine of FIG. 1 taken along section lines 4—4. In FIG. 4, two shelves 10 are seen to support a foil assembly 12 by ends 27 of a second rod 18. First rod 16 has been dropped previously, allowing foil 14 to dangle from second rod 18 in beam track 21. FIG. 4 is taken through the center of a notch 24 in indexing frame 22. FIG. 4 also shows that support frame 20 is itself held in position by projections 58, which rest on a carrier 60. In operation, the carrier 60 is attached to the vacuum wall 62 of a particle accelerator. Upper fixed contact 64 engages upper sliding contact 52, and lower sliding contact 54 is engaged by carrier 60. Upper fixed contact 64 and carrier 60 are connected electrically to external source 56 to effect an electrical connection from outside the vacuum wall 62.

Further understanding of the present invention may be had from FIGS. 5, 6, and 7, which are expanded views of portions of the sectional view of FIG. 2 showing successive steps in the sequence of operation. FIG. 5 is the standby condition. Four foil assemblies 12 are shown loaded in the magazine, held in place by notches 24 on shelves 10. These notches are further labeled *a* through *h* to indicate alphabetically the sequential order in which foil assemblies 12 will be dangled and dropped. Each foil assembly 12 is supported by a first rod 16 and a second rod 18, which rest on shelves 10. Indexing frame 22 is moved with respect to support frame 20 by ratchet mechanism 28. Coil 30 is capable of carrying an electric current that generates a magnetic field to interact with accelerator magnetic field 32, actuating ratchet mechanism 28. In FIG. 5, coil 30 carries no current, and as a result near side 48 and far side 66 are separated by an equilibrium distance A. In FIGS. 6 and 7, coil 30 is energized with electric current flowing in a direction that, together with the direction of accelerator magnetic field 32, squeezes near side 48 and far side 66 together. In FIG. 6, near side 48 and far side 66 are separated by a distance B, which is less than A. This represents partial actuation. Full actuation is shown in FIG. 7, in which near side 48 and far side 66 are separated by a distance C which is less than B.

Referring to FIG. 5, ratchet mechanism 28 can be seen to have three parts, a driving leaf 68, a stopping dog 70 and a forward leaf 72. Spring tension of all three parts is maintained by support 40 which tends to hold them into ratchet slots 42 in indexing frame 22. In FIG. 5, driving leaf 68 and forward leaf 72 engage two different ratchet slots 42. However, stopping dog 70 is kept from engaging a ratchet slot 42 by cam 76, which is attached to and moves with driving leaf 68. Cam 76 raises stopping dog 70 to clear ratchet slot 42. This is evident from FIGS. 6 and 7 in which ratchet mechanism 28 is operating. In FIGS. 5, 6, and 7, driving leaf 68 is connected by arm 78 to far side 66 of coil 30 and moves with far side 66. Stopping dog 70 and forward leaf 72 are both connected by arm 80 to support frame 20, and maintain their position with respect to support frame 20. The beginning of such motion appears in FIG. 6, in which driving leaf 68 has been moved in the direction of the arrow 69, driving indexing frame 22 with it. Stopping dog 70 is being held up by a land 82 between two ratchet slots 42. Forward leaf 72 is bent to permit motion of indexing frame 22 in the direction of the arrow but to catch in a ratchet slot 42 and prevent motion in the direction opposite to the arrow.

The completion of one cycle of motion of indexing frame 22 is shown in FIG. 7, in which driving leaf 68 has reached its maximum extension in the direction of the arrow 71. Further motion in this direction is prevented by stopping dog 70, which has dropped into a ratchet slot 42. Forward leaf 72 has also dropped into a ratchet slot 42, and will hold indexing frame 22 from moving in the direction opposite to the arrow when the current in coil 30 is removed and driving leaf 68 returns to the position shown in FIG. 5. If it is necessary or desired, the return of driving leaf 68 and hence indexing frame 22 to the equilibrium separation distance A can be assured by applying to coil 30 a restoring electric current in a direction opposite to the direction that actuated the ratchet mechanism 28.

The motion of indexing frame 22 relative to support frame 20 moves notches 24 successively past a first edge 84, then a second edge 86, of shelves 10, first dangling a foil assembly 12, then dropping it. In FIG. 5, four foil assemblies 12 are stored in a ready position. The actuation of coil 30, already described, has produced in FIG. 6 some motion of frame 22 that has half uncovered notch 24*a*. Notch 24*b* and all higher lettered notches are still fully covered. Operation of ratchet mechanism 28 has resulted in FIG. 7 in completion of the motion of frame 22, and notch 24*a* is fully uncovered. This has released a first rod 16 from notch 24*a*, and the foil assembly 12 dangles from its second rod 18 in notch 24*b*. This foil assembly 24 will strip a particle beam passed through it along beam path 19 until radiation damage or any other reason causes one to want to replace it. Ratchet mechanism 28 is then actuated again, causing notch 24*b* to be uncovered. The foil assembly 12 that was hanging from notch 24*b* drops from the magazine. Another actuation of ratchet mechanism 28 uncovers notch 24*c*, dangling a fresh foil. This cycle is repeated until all the foils are used, at which time a fresh magazine is introduced.

The present invention has been built to strip negative hydrogen ions to improve injection into the Zero Gradient Synchroton at Argonne National Laboratory. Foils were prepared by vapor deposition of poly-p-xylylene to a thickness of the order of 5800 A. These were trimmed to rectangular sheets approximately 4½ × 2½inches. The short ends were attached to nonferrous rods, specifically 3 inch pieces of 16 gauge copper wire, to make the foil assemblies of the present invention. The copper wire was attached to the foil at the short sides by adhesion to clean surfaces, using heat. The magazine of the present invention was designed to store and display 12 foils at a time. Both the support frame and the indexing frame were made of an epoxy-filled glass fiber material selected for its radiation resis-

tance, its ability to withstand vacuum, and its nonmagnetic properties. This material also does not tend to cohere in vacuum, so that the two frames slide with respect to one another in the vacuum environment of the interior of a particle accelerator.

The ratchet mechanism comprised driving pieces made of thin strips of nonmagnetic stainless steel attached to an actuating coil of about 100 turns of No. 32 wire insulated with Formvar, a trade name for a vinyl acetal resin varnish insulator. The magnetic field set up by a current flowing in this coil interacted with the magnetic field used for synchrotron acceleration in the Zero Gradient Synchrotron to operate the ratchet mechanism. When this apparatus was used, the spring action of the coil was sufficient to reset the ratchet. In operation it might be desirable to provide a positive return of the ratchet. This could easily be done by applying a pulse of current in the opposite direction to the actuating coil.

The apparatus disclosed herein met the requirements for stripping, earlier mentioned as including the use of a very thin foil to provide single atomic collisions with light atoms in limited numbers. The desire for single collisions necessitated a thin foil which contributed to the handling problems solved by the present invention. Foils as disclosed herein have operating lifetimes of the order of an hour or more, and the time necessary to change foils using the present invention is less than 10 seconds. This provides excellent stripping operation with acceptable amounts of accelerator downtime. Each magazine is capable of providing stripping foils over a period of the order of at least 12 hours. This is adequate for many types of operation. A transport system designed in association with the apparatus of the present invention but not claimed therewith provides remotely controllable supplies of a plurality of such magazines which extends the possibility of operation to an indefinite period of time. The transport system supplies a magazine from outside the accelerator, positions it above the beam in external electrical contact with the current supply for the ratchet mechanism, and thus provides for the operation disclosed herein. When all 12 foil assemblies have been spent and dropped, the transport system has provisions for dropping a magazine to the bottom of the accelerator tube, removing the used magazine for reloading and reuse, removing the spent foils for disposal, and placing a new magazine to continue the cycle.

It should be evident from the illustrations of the operation of the magazine shown in FIGS. **4, 5** and **6** that the choice of suspending shelf is made when the magazine is loaded. If each individual foil rod is moved one notch toward the coil in FIGS. **4** through **6**, the rod at the end farther from the actuating coil will be dropped first and the foil will dangle from the shelf closer to the coil. The next actuation of the coil will drop the foil as earlier described and the operation will proceed cyclically through the use of a full magazine of foils dangled from the other shelf. This variation is a matter of choice in loading the foils and is significant only insofar as use of one shelf or the other may change the location of dangled foils with respect to the position of the beam.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A foil assembly for insertion into a beam of charged particles to effect charge exchange in said beam, said foil assembly comprising:

a foil formed of a thin film of an organic polymer, said foil having an area greater than the cross-sectional area of said beam;

a first rod connected to said foil at a first edge thereof, said first rod being longer than said first edge and projecting beyond said foil at each end of said first edge to form a pair of first supporting projections; and

a second rod connected to said foil at a second edge thereof opposite to said first edge, said second rod being longer than said second edge and projecting beyond said foil at each end of said second edge to form a pair of second supporting projections.

2. The foil assembly of claim **1** wherein said foil is a thermally stabilized sheet of polymerized p-xylene (poly-paraxylylene) having a thickness of 5800 A.

3. The foil assembly of claim **1** wherein said first and second supporting rods are nonferrous metal.

4. A magazine for storing and displaying a plurality of the foil assemblies of claim **1** in a particle accelerator comprising:

a support frame;

a pair of first shelves disposed in a plane and connected to the support frame to support said first rod, said pair of first shelves including a first edge;

a pair of second shelves disposed in the plane of the first shelves and connected to the support frame to support said second rod of said stripping foil assembly, said pair of second shelves including a second edge parallel to said first edge;

an indexing frame disposed in sliding engagement with said pairs of first and second shelves, said indexing frame including a plurality of notches forming with said pairs of first and second shelves a plurality of enclosures for stripping foil assemblies, said notches grouped into a first group and a second group, corresponding notches of said first and second groups being spaced relative to each other a distance differing from the distance between said first and second shelf edges by the width of a notch;

a ratchet mechanism connected to said support frame and said indexing frame for moving said indexing frame by one-half the width of a notch with respect to said support frame; and

remotely operated actuating means connected to said ratchet mechanism for operating said ratchet mechanism from a location remote from said magazine.

5. The magazine of claim **4** wherein said support frame and said indexing frame are made of epoxy bonded glass fibers.

6. The magazine of claim **4** wherein said remote actuating means comprise:

a coil of wire having two ends and disposed to produce a vertically directed magnetic field on the passage of an electric current therethrough; and

a pair of electrical contacts connected one to each of said two ends and adaptable to connect said coil to an external electrical source.

7. An apparatus for inserting a stripping foil into the particle beam of an accelerator having a vertically directed component of accelerating magnetic field, the apparatus comprising:

a thin foil of an organic polymer sized to cover a cross-section of the particle beam;

a first rod connected to the foil at a side thereof, the ends of said first rod projecting beyond the foil to form a first pair of supporting projections;

a second rod connected to the foil at a side opposite to the side of the first rod, the ends of said second rod projecting beyond the foil to form a second pair of supporting projections;

a support frame including a first pair of shelves separated from each other by a distance less than the length of said first rod and adapted to support said first rod by said projecting ends of said first rod, said support frame further including a second pair of shelves separated from each other by a distance less than the length of said second rod and adapted to support said second rod by said projecting ends of said second rod, said support frame disposed adjacent to and above said particle beam;

means for sequentially moving said first and second rod with respect to said support frame first to move said first rod off said first pair of shelves to dangle said thin foil in said particle beam, and secondly to move said second rod off said second pair of shelves to drop said thin foil out of said particle beam.

8. The apparatus of claim **7** wherein the means for sequentially moving said first and second support rod comprise:

an indexing frame including a first notch sized to receive one of said projecting ends of said first rod and disposed to open on one shelf of said first pair of shelves to form therewith an enclosure for said one of said projecting ends of said first rod, said indexing frame further including a second notch alinged on a first axis with said first notch, sized to receive the other of said projecting ends of said first rod and disposed to open on the other shelf of said first pair of shelves to form therewith an enclosure for said other of said projecting ends of said first rod, said indexing frame further including a third notch sized to receive one of said projecting ends of said second rod and disposed to open on one shelf of said second pair of shelves to form therewith an enclosure for said one of said projecting ends of said second rod, said indexing frame further including a fourth notch aligned on a second axis with said third notch and sized to receive the other of said projecting ends of said second rod and disposed to open on the other shelf of said second pair of shelves to form therewith an enclosure for said other of said projecting ends of said second rod, said first and second axes being parallel to each other and separated by a distance that differs from the separation of said first and second pairs of shelves by the width of said first notch; and

driving means for producing relative motion of one notch width between said indexing frame and said support frame, whereby operation of said driving means when a foil is supported on said first and second pair of shelves drops one rod from one of said pairs of shelves to dangel the foil in the particle beam to effect stripping thereof.

9. The apparatus of claim **8** wherein said driving means comprise:

a coil of wire connected to said support frame and said indexing frame and squeezably deformable to produce relative motion therebetween, said coil disposed to produce a vertically directed magnetic field on the passage of an electric current therethrough;

a source of electrical energy connectable to said coil to pass an electric current therethrough;

means for connecting said source to said coil; a ratchet mechanism for controlling the amount and direction of relative motion between said support frame and said indexing frame,

whereby connecting said source to said coil establishes a magnetic field therein to interact with the vertically directed component of the accelerator magnetic field to produce squeezed deformation of said coil and hence relative motion between said support frame and said indexing frame.

10. The apparatus of claim **8** wherein said support frame and said indexing frame are epoxy-bonded glass fibers.

11. The apparatus of claim **7** wherein said thin foil is formed of polymerized para-xylene (poly-p-xylylene) having a thickness less than 6000 Angstroms.

12. The apparatus of claim **7** wherein said support frame is epoxy-bonded glass fibers.

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