Sept. 6, 1960 C. GOODMAN 2,951,945

RENEWABLE TARGET

Filed May 26, 1954

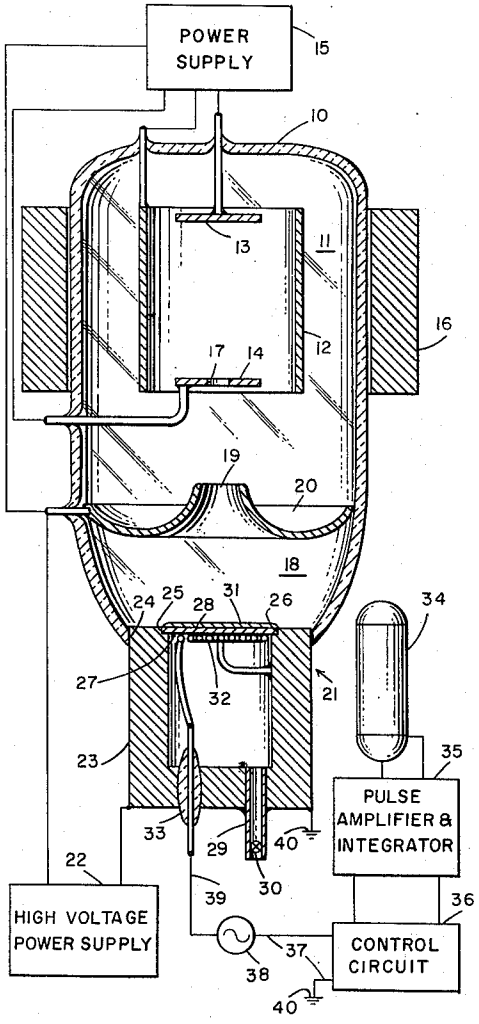


FIG. 1

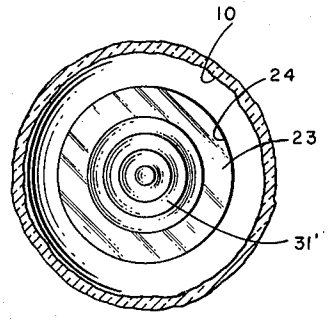


FIG. 3

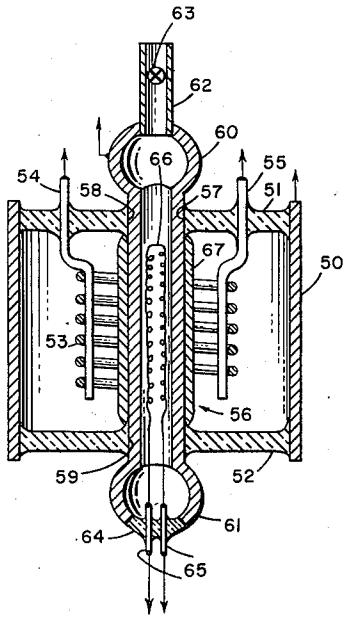


FIG. 4

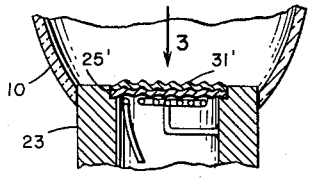


FIG. 2

INVENTOR.
CLARK GOODMAN
BY Robert Hockfield
HIS ATTORNEY

United States Patent Office 2,951,945
Patented Sept. 6, 1960

2,951,945

RENEWABLE TARGET

Clark Goodman, Boston, Mass., assignor, by mesne assignments, to Schlumberger Well Surveying Corporation, Houston, Tex., a corporation of Texas

Filed May 26, 1954, Ser. No. 432,345

9 Claims. (Cl. 250—84.5)

This invention relates to radiation generators of the type wherein particles are accelerated toward a target and, more particularly, pertains to a new and improved target assembly for a particle accelerator.

A target assembly embodying the present invention may have utility in a variety of particle accelerators. However, it is ideally suited for use in a particle accelerator intended for the generation of neutrons through reactions between highly accelerated deuterium ions and a target material, such as deuterium or tritium. For convenience, it will be described in this connection.

Experience with neutron generators of the foregoing type has indicated that the neutron yield may not always be maintained at a desired high level at accelerating potentials in the neighborhood of 100 kilovolts. This deficiency is often attributable to depletion of the target; i.e., the amount of deuterium or tritium, as the case may be, within the penetration range of accelerated deuterium ions is reduced with operation of the generator.

It is, therefore, an object of the present invention to provide a new and improved target assembly for a particle accelerator which is not subject to this deficiency of certain prior arrangements.

Another object of the present invention is to provide a new and improved target assembly for a particle accelerator wherein a target material may be replenished, either continuously or intermittently, as required.

Yet another object of the present invention is to provide a new and improved target assembly for a particle accelerator wherein replenishment of a target material may be accomplished without the necessity of disassembling the accelerator.

A target assembly constructed in accordance with the present invention may be utilized in a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected substance. The target assembly comprises a sheet-like control valve adjustably permeable to the selected substance in a direction from one surface to the other surface thereof. Means are provided for introducing the selected substance to the aforesaid one surface of the control valve and a storage layer is connected to and covers the other surface of the control valve, at least in part. The storage layer is composed of a material absorbent to the selected substance and adapted to permit accelerated particles to react with the substance. The target assembly further comprises means for selectively operating the control valve.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

Fig. 1 is a view in longitudinal cross section of a particle accelerator provided with a target assembly embodying the present invention;

Fig. 2 represents a modification which may be made to the target assembly of Fig. 1;

Fig. 3 is a plan view of a portion of Fig. 2 taken in the direction of arrow 3; and

Fig. 4 is a view in longitudinal cross section of another type of particle accelerator wherein the target assembly of the present invention may be utilized.

As shown in Fig. 1 of the drawing, a target assembly constructed in accordance with the present invention is embodied in a particle accelerator which comprises an evacuated envelope 10 composed of an electrical insulating material, such as out-gassed glass. Envelope 10 is filled, after evacuation, with an ionizable gas, such as an isotope of hydrogen known as deuterium, at a selected pressure.

To derive ions of the gas within envelope 10, there is provided an ion source 11 including a tubular or cylindrical anode 12 and a pair of cathode plates 13 and 14 supported at opposite ends of cylinder 12. Connections from a medium-voltage power supply 15 to elements 12—14 of ion source 11 are completed over leads which are suitably sealed in respective openings in envelope 10 in a known manner. A cylindrical magnet 16 receives envelope 10 and is essentially coextensive with anode cylinder 12. The ion source just described is disclosed in the copending application of John T. Dewan, filed April 9, 1952, bearing the Serial Number 281,378 and assigned to the same assignee as the present invention.

Some of the ions which are derived in source 11 may pass through an opening 17 in cathode plate 14 and are thereby introduced to an accelerating gap 18 via an opening 19 of a probe electrode 20 included in the accelerating gap. Also included in accelerating gap 18 is a target assembly 21 embodying the present invention, and the accelerating gap is energized by a high voltage power supply 22. The spacing between the electrodes of accelerating gap 18 is selected in a known manner, in view of the voltage supplied by source 22, so that no ionization occurs within the accelerating gap, while particles are accelerated to a velocity sufficient to react with a selected target substance to produce neutrons, as will be more apparent from the discussion to follow.

Target assembly 21 comprises a cylindrical container or reservoir 23, constructed of a metal having good thermal conductivity such as copper, suitably fused or sealed to the periphery of an opening 24 in the lower end of envelope 10. The upper end of cylinder 23 is closed by a sheet-like control member 25 seated in an annular recess 26 and suitably attached thereto to provide a vacuum type seal, such as by silver soldering techniques. Control member 25 is constructed of a material, such as a palladium sheet approximately 1 to 10 mils in thickness, which is adjustably permeable to a selected substance in a direction from its lower surface 27 toward its upper surface 28. For example, if the particle accelerator is intended to generate neutrons as a result of deuterium-tritium reactions, the isotope of hydrogen, tritium is employed. This gas is introduced to reservoir 23, after evacuation, via a supply tube 29 provided with a valve 30.

Of course, if desired, deuterium may be employed in place of tritium in applications where neutrons are desired as the result of deuterium-deuterium reactions.

It is evident that reservoir 23 provides the means for introducing tritium to lower surface 27 of control member 25 and, as is well-known, at a selected temperature palladium member 25 is permeable to this gas. Accordingly, tritium may pass in a direction from lower surface 27 to upper surface 28 and thus to a storage layer 31 which preferably covers surface 27 in its entirety so that leakage of tritium into envelope 10 is minimized.

Layer **31** may be composed of a material absorbent to tritium, such as zirconium and is sufficiently thin to permit accelerated particles to react with tritium gas which may be absorbed thereby. For example, layer **31** may be 1 to 10 microns in thickness. Preferably, layer **31** should be adapted to form a stable hydride at a temperature somewhat in excess of that at which valve layer **25** is permeable to the selected hydrogen isotope and it should be fusible to the metal of member **25**. Moreover, it should not flake off when hydrided with the selected isotope, and it must retain the deuterium or tritium, as the case may be, under bombardment when present in a layer of the order of 10 to 50 kilovolts thick for deuterons which are accelerated through a potential of 100,000 electron volts during operation.

In associating layer **31** with control member **25**, it is desirable that the resulting interface be permeable to the selected substance, tritium. This may be achieved, for example, by the following technique: After cylindrical container **23** has been closed at the upper end by control member **25**, it is sealed to envelope **10** by means of conventional metal-to-glass seal **24**. Envelope **10** is then cracked off around the periphery a few centimeters above seal **24**. This assembly is placed in an evaporator and outgassed. A thin, uniform layer **31** of zirconium, or other suitable metal, is then evaporated in vacuum onto surface **28** of control member **25**. Excess metal deposited on the inner surface of the lower part of envelope **10** is removed by chemical means before resealing to the upper section of envelope **10**. During this resealing operation, excessive heating of container **23** and layer **31** can be avoided by cooling the lower end of container **23** with solid carbon dioxide (Dry Ice).

In order to operate control valve **25** selectively, a heater coil **32** is suitably located adjacent to, but electrically insulated from, surface **27** of member **25**. For example, coil **32** may be a flat spiral separated from surface **27** by means of a thin mica disk. One end of coil **32** is connected to the inner surface of cylinder **23** and its other end extends through an insulating seal **33** at the lower end of cylinder **23**.

An automatic control system is provided for supplying energy to heater **32** of a magnitude responsive to the output of the particle accelerator. To this end, a radiation-responsive device **34** is positioned adjacent the target portion of accelerating gap **18**. Device **34** may be of conventional construction, or may be of a specific type disclosed in the copending application of Clark Goodman, entitled "Radiation-Responsive Apparatus," filed May 17, 1954, bearing the Serial Number 430,139, now Patent No. 2,842,695, and assigned to the same assignee as the present invention. As there disclosed, device **34** derives pulses representative of the neutron output of the particle accelerator and these pulses are supplied to a pulse amplifier and integrator unit **35**, in turn, coupled to a control circuit **36**. Control circuit **36** may be of conventional construction adapted to compare the potential supplied by unit **35** with a reference potential to derive a control effect. This control effect may be the value of impedance exhibited at its output leads **37**. In other words, the impedance exhibited at leads **37** is dependent upon the potential supplied by unit **35**. One of output leads **37** is grounded at **40** and the other is connected to one terminal of a source **38** of electrical energy. The remaining terminal of source **38** is connected by a lead **39** to the lead which extends from heater **32** through insulator **33**. The heater circuit is completed by a connection from reservoir **23** to ground **40**.

To condition the neutron-generating particle accelerator illustrated in Fig. 1 for operation, reservoir **23** is evacuated and a desired amount of tritium gas is introduced via tube **29** before valve **30** is closed; for example, a pressure of one to two atmospheres may be employed.

Thus, the gas pressure in reservoir **23** is considerably higher than the relatively low gas pressure in envelope **10**, which may be of the order of 10 microns of mercury. A variable resistor (not shown) may be temporarily connected between leads **37** so that heater **32** may be energized and valve layer **25** heated to a temperature at which tritium is supplied to layer **31**. Thereafter, the resistor is removed and power supplies **15** and **22** are energized.

Ion source **11** operates in the manner described in the above-mentioned Dewan application and the deuterium gas within the ion source is ionized. Some of the derived positive ions drift toward cathode **14** and pass through opening **17**. Since probe **20** is slightly negative relative to cathode **14**, ions are attracted toward the probe. Some pass through opening **17** and are thus exposed to the high accelerating potential applied between probe **20** and target layer **31** in which tritium is absorbed. Accordingly, highly accelerated deuterium ions react with tritium in target layer **31** to produce neutrons having an energy level in the neighborhood of 14 million electron volts.

As the particle accelerator continues to operate and deplete the tritium contained by layer **31**, the neutron yield falls off. Since detector **34** is exposed to the neutron output of the particle accelerator, a decrease in the number of pulses supplied to unit **35** accompanies such a reduction in neutron yield. Thus, the potential derived by pulse amplifier and integrating unit **35** decreases and the value of the impedance exhibited between leads **37** of control circuit **36** is reduced. Inasmuch as the amount of power supplied to heater **32** is inversely related to the value of this impedance, an increase in temperature is exhibited by heater **32**. The temperature of control valve **25** is thereby increased to a value in the neighborhood of 250 degrees centigrade at which the tritium gas under pressure within reservoir **23** may pass through surfaces **27** and **28** into storage layer **31**. Layer **31**, of course, absorbs the tritium admitted from valve member **25** and it does not permit the tritium to escape into the region of accelerating gap **18**.

As the tritium in layer **31** is replenished, the neutron output of the particle accelerator increases with an attendant increase in the pulse output of detector **34**. Accordingly, the voltage developed by unit **35** increases thereby increasing the impedance which appears across leads **37** of control circuit **36** and the voltage to heater **32** is reduced. The resupply of tritium to layer **31** thus is brought to a halt.

It is, therefore, evident that layer **31** may be replenished many times during the continuous operation of the particle accelerator, and a target assembly constructed in accordance with the present invention overcomes the deficiencies of prior arrangements. The action of replenishment may be continuous or intermittent, and manifestly may be achieved without the necessity of disassembling the particle accelerator.

This desirable feature permits the accelerator tube to be sealed off and mounted within apparatus intended for operation remote from control equipment, as may be required in apparatus adapted to traverse a borehole, for example, as described in detail in the copending application of Clark Goodman, entitled "Neutron Well Logging," filed March 11, 1952, bearing the Serial Number 275,932 and assigned to the same assignee as the present invention. In such an environment, long continuous operation at constant neutron intensity is desirable and thus an accelerator tube incorporating a target assembly constructed in accordance with the present invention is ideally suited for logging service.

If desired, the surface portion of reservoir **23** which is exposed to the gas within envelope **10** may be coated with an insulating material such as glass to minimize recombinations of ions with electrons. Alternatively,

absorbent layer **31** may be enlarged so as to cover this portion.

Although an automatic control system has been illustrated, obviously, manual control may be provided for replenishment of layer **31**. To this end, elements **34**, **35** and **36** may be eliminated and a variable resistor (not shown) may be shunted across leads **37**.

Alternative materials may, of course, be employed for members **25** and **31**. For example, the control valve member **25** may be constructed of platinum, rather than palladium. In place of zirconium in absorbent layer **31**, tantalum may be utilized.

If desired, an alternative construction shown in Fig. 2 may be employed for the absorptive layer and the valve member wherein these elements, designated **25'** and **31'** respectively, are of corrugated form. This may be best observed in the plan view of Fig. 3, illustrating corrugation of concentric disposition. By utilizing a corrugated form, as shown, cracking and/or flaking of the absorptive layer **31'** under the stresses imposed by changes in temperature may be minimized.

In Fig. 4 of the drawing, a modified type of target assembly embodying the present invention is shown in connection with another form of particle accelerator. This accelerator comprises a metallic cylindrical housing **50** provided with upper and lower closures **51** and **52** of electrical insulating material, such as out-gassed glass. An electrode **53**, in the form of a helix, is supported coaxially within housing **50** by a pair of leads **54** and **55** which extend through suitably sealed openings in upper closure **51**.

A target assembly **56** constructed in accordance with the present invention is comprised of a reservoir including a cylindrical portion **57** extending through and peripherally sealed to respective openings **58** and **59** of closures **51** and **52**. Portion **57** extends within helical electrode **53** in coaxial relation with housing **50**. The reservoir further comprises upper and lower integral, spherical terminations **60** and **61** which have diameters larger than that of cylinder **57**. A tube **62** is connected to upper portion **60** and is provided with a valve **63**, while a sealed insulator **64** is associated with lower portion **61**. Thus, sealed leads **65** may be introduced to a heater **66** supported within cylindrical portion **57** of the reservoir.

The reservoir, including portions **57**, **60** and **61**, may be constructed of palladium and the exterior surface of cylindrical portion **57** is coated with a layer of hydrogen-absorbing material **67**, such as zirconium.

Connections between housing **50** and lead **55** with power supply **15** (Fig. 1) provide the means for energizing the portion of the illustrated particle accelerator which functions as the means for ionizing deuterium gas contained by housing **50**. Acceleration potential from a power supply, such as the one designated **22** in Fig. 1, is supplied over lead **54** and a lead which extends to upper termination **60**. Accordingly, ions which are produced in the space defined by the inner surface of housing **50** and helical electrode **53** may be accelerated by the potential existing between helical electrode **53** and target layer **67** wherein deuterium-tritium reactions may occur with the resulting production of high energy neutrons.

As in the embodiment of the invention illustrated in Fig. 1, tritium gas at a pressure of one to two atmospheres is introduced to the reservoir via tube **62** after the reservoir is evacuated. An adjustable source of electrical energy (not shown) may be connected to heater leads **65** so that the permeability to tritium of the portion **57** of the palladium reservoir may be controlled. In this way, the amount of tritium which is supplied to target layer **67** may be adjusted in the manner ascribed to the embodiment shown in Fig. 1.

As in the arrangement of Fig. 1, it may be desirable that layer **67** cover and hence seal the outer surface of

valve element **57** in order to prevent leakage of gas into the accelerating gap portion of the particle accelerator.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and therefore the aim of the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected substance comprising a sheet-like control valve adjustably permeable to said substance in a direction from one surface to the other surface thereof, means for introducing said substance to said one surface of said control valve, a storage layer connected to and covering said other surface of said control valve, at least in part, and being composed of a material absorbent to said substance and adapted to permit accelerated particles to react with said substance, and means for selectively operating said control valve.

2. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected substance comprising a sheet-like control valve having a permeability to said substance in a direction from one surface to the other surface thereof dependent upon temperature, means for introducing said substance to said one surface of said control valve, a storage layer connected to and covering said other surface of said control valve, at least in part, and being composed of a material absorbent to said substance and adapted to permit accelerated particles to react with said substance, and means for adjusting the temperature of said control valve selectively to control the quantity of said substance supplied to said storage layer.

3. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected substance comprising a sheet-like control valve having a permeability to said substance in a direction from one surface to the other surface thereof dependent upon temperature, means for introducing said substance to said one surface of said control valve, a storage layer connected to and covering said other surface of said control valve, at least in part, and being composed of a material absorbent to said substance and adapted to permit accelerated particles to react with said substance, a heater element associated with said control valve for controlling the temperature thereof, a source of electrical energy coupled to said heater element, and means for adjusting the electrical energy supplied by said source to said heater element to regulate the temperature of said control valve and thereby control the quantity of said substance supplied to said storage layer.

4. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected gaseous substance comprising a sheet-like control valve adjustably permeable to said substance in a direction from one surface to the other surface thereof, a chamber containing said substance in communication with said one surface of said control valve for introducing said substance thereto at a selected pressure, a storage layer connected to and covering said other surface of said control valve, at least in part, and being composed of a material absorbent to said substance and adapted to permit accelerated particles to react with said substance, and means for operating said control valve so that said substance at said selected pressure may selectively pass through said one surface of said control valve, traverse said control valve and pass through said other surface thereof into said storage layer.

5. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected gas comprising a sheet-like control valve having a permeability to said gas in a direction from one

surface to the other surface thereof dependent upon temperature, a chamber containing said gas in communication with said one surface of said control valve for introducing said gas thereto at a selected pressure, a storage layer connected to and covering said other surface of said control valve, at least in part, and being composed of a material absorbent to said gas and adapted to permit accelerated particles to react with said gas, and means for adjusting the temperature of said control valve selectively to control the quantity of said gas at said selected pressure passing through said one surface of said control valve and thereby control the quantity of said gas passing through said other surface into said storage layer.

6. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected substance comprising a sheet-like control valve adjustably permeable to said substance in a direction from one surface to the other surface thereof, means for introducing said substance to said one surface of said control valve, a storage layer connected to and covering said other surface of said control valve, at least in part, and being composed of a material absorbent to said substance and adapted to permit accelerated particles to react with said substance, and means for automatically operating said control valve in response to a predetermined operating characteristic of said particle accelerator.

7. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected isotope of hydrogen comprising a sheet-like control member of palladium adjustably permeable to said isotope of hydrogen in a direction from one surface to the other surface thereof, means for introducing said isotope of hydrogen to said one surface of said control member, a thin storage layer of zirconium connected to and covering said other surface of said control member, at least in part, absorbent to said isotope of hydrogen and adapted to permit accelerated particles

to react with said isotope of hydrogen, and means for selectively operating said control valve.

8. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected substance comprising a sheet-like control valve of corrugated form adjustably permeable to said substance in a direction from one surface to the other surface thereof, means for introducing said substance to said one surface of said control valve, a storage layer connected to and covering said other surface of said control valve, at least in part, having a corrugated form conforming to said corrugated form of said control valve, and being composed of a material absorbent to said substance and adapted to permit accelerated particles to react with said substance, and means for selectively operating said control valve.

9. A target assembly for a particle accelerator wherein particles are accelerated to a velocity sufficient to react with a selected substance comprising a sheet-like control valve permeable to said substance in a direction from one surface to the other surface thereof, means for introducing said substance to said one surface of said control valve, a storage layer covering said other surface of said control valve, at least in part, and being composed of a material absorbent to said substance, and means for operating said control valve.

References Cited in the file of this patent

UNITED STATES PATENTS

2,189,998	Schenk	Feb. 13, 1940
2,211,668	Penning	Aug. 13, 1940
2,251,190	Kallman	July 29, 1941
2,489,436	Salisbury	Nov. 29, 1949
2,528,547	Reilly et al.	Nov. 7, 1950
2,576,600	Hanson	Nov. 27, 1951
2,582,282	Rothstein	Jan. 15, 1952