

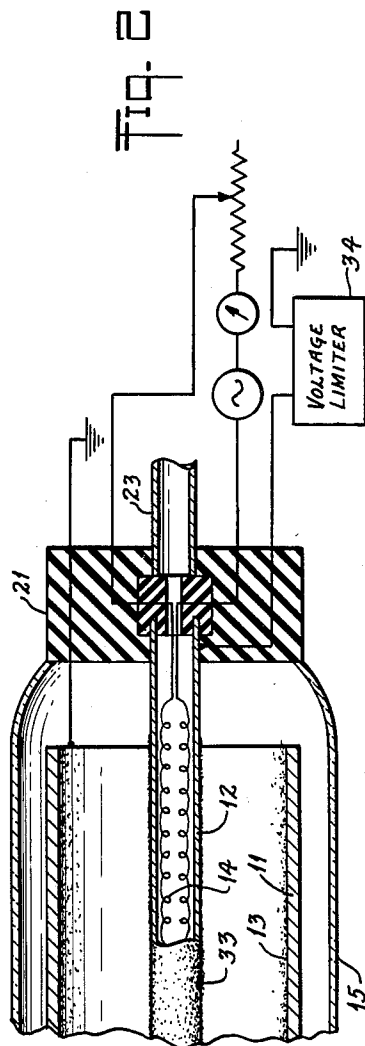
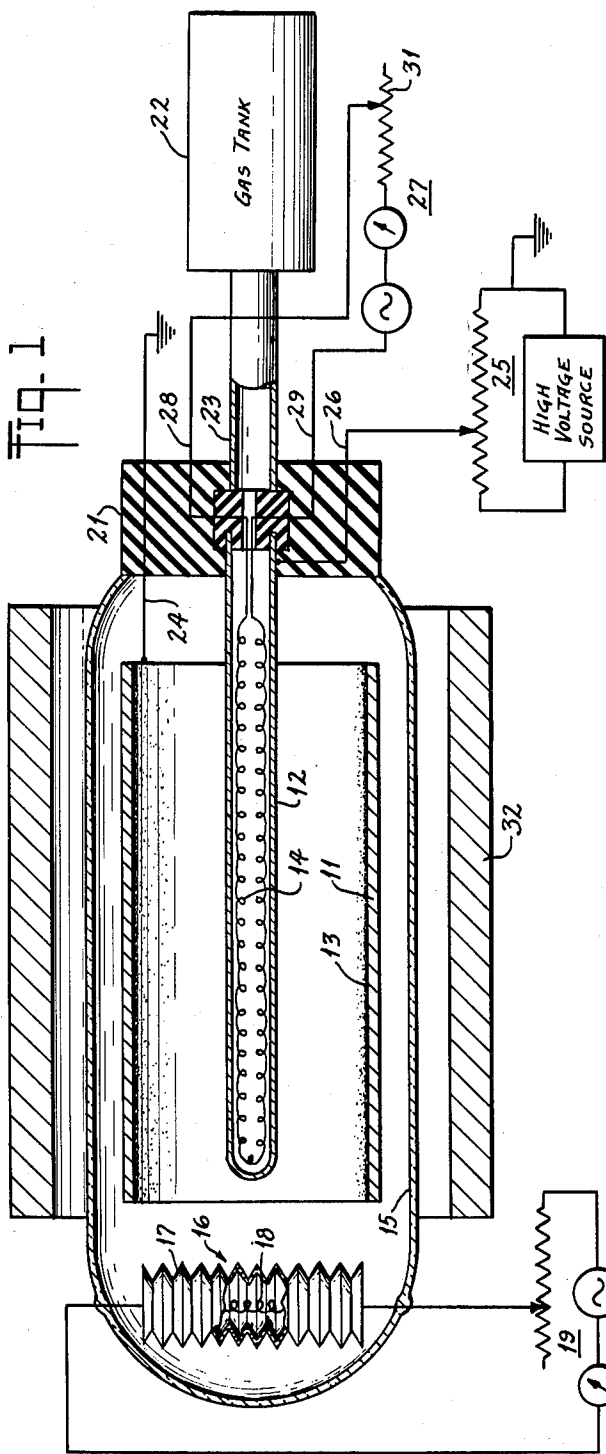
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J. T. DEWAN ET AL

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PARTICLE ACCELERATOR

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INVENTORS.
JOHN T. DEWAN
CLARK GOODMAN
BY
Campbell, Brumbaugh, Free & Groves
THEIR ATTORNEYS

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PARTICLE ACCELERATOR

John T. Dewan, Houston, Tex., and Clark Goodman, Boston, Mass., assignors to Schlumberger Well Surveying Corporation, Houston, Tex., a corporation of Delaware

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The present invention relates to particle accelerators and, more particularly, to novel apparatus for generating electrically-charged particles and for accelerating the particles to a desired velocity in a predetermined direction.

Particle accelerators have found varied laboratory and industrial applications, particularly in the field of nuclear physics. For example, particle accelerators may be employed in the production of high-energy neutrons or other nuclear radiation. However, the utility of such accelerators has heretofore been very limited because their extreme bulkiness, cost, and complexity have substantially prohibited their use for many laboratory and industrial applications where a small, relatively inexpensive accelerator would be highly desirable.

It is, accordingly, an object of the present invention to provide novel, compact apparatus for generating charged particles and for accelerating the particles to a desired velocity in a predetermined direction.

Prior to the present invention, particle accelerators generally comprised a relatively complex source of charged particles, an accelerator tube into which the particles may pass, a source of relatively high potential associated with said tube for creating an electrical potential gradient to accelerate the particles to a desired velocity, and a target upon which the accelerated particles may impinge.

In accordance with the present invention, a novel, compact structure is provided in which the number and complexity of the components required by the prior accelerators are reduced and simplified by means of a group of elements performing, as a unit, the combined functions of the previously separate accelerator components.

In one embodiment of the invention a hollow cylindrical cathode is provided which is maintained at a negative potential relative to an elongated anode passing coaxially therethrough. The space between the anode and the cathode is evacuated, whereby electrons emitted by said cathode will impinge upon the anode. The anode is so constructed that a desired gas will be continuously emitted thereby and will be ionized by the electrons impinging thereupon. The ions, which are positively-charged particles will then be accelerated in the direction of the cathode which will act as a target. The inner surface of the cathode is coated with any material giving a predetermined nuclear reaction with the charged particles. Accordingly, this structure acts as a combined charged-particle source, accelerator and target, and thus occupies an extremely small space.

An axial magnetic field may be provided through the cathode in order that the electrons may have greater efficiency in producing charged particles.

In a modified form of the invention a high-intensity beta particle emitter is coated on the outer surface of the anode. The beta particles cross the evacuated space between the anode and the cathode and create the desired potential difference between these electrodes. Thus a compact high-voltage source, particle source, accel-

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erator and target are provided in one integrated structure.

In order that the invention may be more fully understood, it will now be described in detail with reference to the accompanying drawings, wherein:

Fig. 1 is a longitudinal sectional view of a typical embodiment of the invention showing the associated circuits schematically, and

Fig. 2 is a longitudinal sectional view of a modified portion of the structure of Fig. 1.

In Fig. 1, there is provided a hollow, open-ended cylindrical cathode 11, which may be constructed from any one of a number of metals, such as, for example, nickel, tantalum, or tungsten, but is preferably constructed of outgassed zirconium or uranium. Passing coaxially through the interior of the cathode 11 is a small-diameter, enclosed tubular anode 12, the walls of which are very thin and are constructed of palladium or platinum through which the heavier isotopes of hydrogen, that is, deuterium or tritium, can diffuse when the anode 12 is heated. On the inner surface of the cathode 11 is deposited or plated a coating of target material 13, which contains the elements or compounds upon which it is desired to impinge relatively high-velocity charged particles. For example, the target material 13 may contain deuterium or tritium bound in zirconium or tantalum.

In the interior of the tubular anode 12 there is maintained at a relatively constant pressure the gas which it is desired to ionize into charged particles. This gas may, for example, be deuterium or tritium. Upon heating the anode 12 to the desired temperature, for example, by means of a heating coil 14 extending along its interior, the deuterium or tritium will leak slowly through the anode wall into the space between the anode 12 and the cathode 11. This space is maintained at a relatively low pressure, for example, in the range of 10^{-4} to 10^{-6} millimeters of mercury. The anode 12 is maintained at a desired high positive potential with respect to the cathode 11.

One mode of operating this device can be described on the assumption that deuterium gas is contained inside the palladium or platinum tubular anode 12 and that tritium is contained in the target coating 13. The anode 12 is maintained at a positive potential of from 20 to 100 kilovolts with respect to the cathode 11. The heating coil 14 is energized with just enough current to heat the anode 12 sufficiently to allow a slow radial leakage of deuterium through the palladium or platinum anode wall. As this gas escapes from the surface of the anode 12, it is bombarded by electrons of from 20 to 100 kilovolt energy, which electrons have been released from the cathode 11 by cold emission, for example. The electron bombardment of the gas produces a significant yield of deuterons (positively charged deuterium ions) since the electron current density is relatively large because of the small diameter of the anode 12. The resulting deuterons are accelerated by the electric field between anode 12 and the cathode 11 and arrive at the cathode 11 with energies of from 20 to 100 kilovolts. These energies are sufficient to cause the deuterons to react nuclearly with the tritium contained in the coating 13 to produce high-energy, mono-energetic neutrons.

Such neutron sources have a considerable application in laboratories, in hospitals and in industry. For example, conventional neutron well logging of the earth's formations traversed by a borehole and the novel neutron logging methods described in copending application Serial No. 275,932, filed March 11, 1952, for "Neutron Well Logging" by Clark Goodman may employ such devices.

The space between the cathode 11 and the anode 12 may be maintained substantially evacuated by means of

a suitable container 15, manufactured, for example, from outgassed glass. Since all of the gas leaking from the anode 12 will not be ionized, the pressure in the container 15 may tend to increase to a value such that the free movement of the charged particles is hindered. However, the cathode 11 will become heated during the operation, and if it is constructed of uranium or zirconium as preferred, the cathode 11 will perform the additional function of a getter of the non-ionized gas escaping, thus maintaining the desired low pressure. If required, one or more additional getter apparatus 16 may be included within the container 15. Such getter may comprise a corrugated cylinder 17 constructed of zirconium or uranium and heated by means of a coil 18 controllably energized by current from a source 19.

The container 15 may be sealed from the atmosphere by means of a conventional base 21. The desired gas may be supplied from a high-pressure tank 22 connected to the interior of the anode 12 through an insulated coupling 23. The cathode 11 may be grounded by means of an insulated conductor 24 passing through the base 21. The high potential for the anode 12 may be supplied by any conventional high-voltage source 25 connected to the anode 12 by an insulated conductor 26 passing through the base 21. The amount of gas leaking through the cylindrical wall of the anode 12 depends upon the intensity of the current heating the coil 14. The heating current is supplied from a source 27 over conductors 28 and 29 and is controlled by a device 31, such as a rheostat.

An axial magnetic field may be provided in the space between the cathode 11 and the anode 12 by a coaxial solenoid or cylindrical permanent magnet 32. This magnetic field has no substantial effect on the relatively heavy ions traveling from the anode 12 to the cathode 11 but increases the path length of the electrons moving in the other direction. In particular, it causes the electrons to strike the anode 12 at an oblique angle rather than perpendicularly, thus increasing the production of positive ions near the anode surface.

Fig. 2 shows the altered portions of a modified particle accelerator which requires no external high-voltage source. A high-intensity beta particle emitter 33 is embedded or coated on the surface of the anode 12. The beta particles therefrom cross the substantially evacuated space without appreciable loss in energy and strike the cylindrical cathode 11. A difference of potential is thus established between the anode 12 and the cathode 11. The high-voltage source 25 is not employed and is preferably replaced by a voltage limiter 34 of the corona-discharge type. The accelerator of Fig. 2 may in other respects be similar to that illustrated in Fig. 1. This mode of high-voltage generation and the control of the resulting potential are more fully described in copending application Serial No. 282,143, filed April 14, 1952, for "High-Voltage Generators" by Hugh B. Frey. This third embodiment provides an integrated structure comprising a source of high potential, a source of positive ions, a target containing a substance capable of nuclearly reacting with high-energy ions, and means for accelerating the ions to a sufficient energy toward the target to produce nuclear radiation therefrom.

The cathode 11 and the anode 12 may be any desired length, depending on the total amount of neutron radiation desired. The diameter of the cathode 11 may, for example, range from 10 to 100 times the diameter of the anode 12. For example, with a 10 centimeter inner diameter of the cathode 11, the anode 12 may have an outer diameter of from 0.1 to 0.2 centimeter.

Since the particle accelerator may take various forms not specifically illustrated, it is to be understood that the invention is limited only by the language of the appended claims.

We claim:

1. A particle accelerator comprising a hollow anode

containing ionizable gas, a cathode at least partially surrounding said anode, means for establishing a positive potential gradient between said cathode and said anode and for projecting electrons between said cathode and said anode, means for gradually emitting molecules of said gas from said anode whereby said electrons tend to ionize said gas molecules, and a substance on the inner surface of said cathode for nuclearly reacting with positive ions drawn thereto by said potential gradient.

2. A particle accelerator according to claim 1 wherein the means for establishing the positive potential gradient is a beta particle emitter on the outside surface of said anode.

3. A particle accelerator comprising a tubular anode containing deuterium gas, a cathode at least partially surrounding said anode, means for establishing a positive potential gradient between said cathode and said anode and for projecting electrons between said cathode and said anode, means for gradually emitting said deuterium from said anode whereby said electrons tend to ionize said deuterium to form deuterons, and tritium on the inner surface of said cathode for nuclearly reacting with said deuterons drawn thereto by said potential gradient to produce neutron radiation.

4. A particle accelerator comprising a hollow, open-ended cylindrical cathode, a hollow, enclosed anode having a thin cylindrical wall coaxially mounted within said cathode and containing ionizable gas, means for maintaining a potential gradient for accelerating electrons from said cathode toward said anode, means for heating said anode to controllably diffuse said gas through the cylindrical wall thereof, whereby said electrons tend to ionize said gas molecules, and a substance on the inner surface of said cathode for nuclearly reacting with positive ions impinging thereon.

5. A particle accelerator according to claim 4 further provided with means for generating an axial magnetic field substantially coaxial with the cylindrical cathode whereby the electrons approach the anode at an oblique angle and thereby increase the production of ions.

6. A particle accelerator comprising a hollow, open-ended cylindrical cathode, a hollow, enclosed anode having a thin cylindrical wall coaxially mounted within said cathode and containing deuterium gas, means for establishing a potential gradient between said cathode and said anode and for accelerating electrons therebetween, means for heating said anode to controllably diffuse said deuterium through said cylindrical wall, whereby said electrons tend to ionize said deuterium to form deuterons, and tritium on the inner surface of said cathode for nuclearly reacting with said deuterons drawn thereto by said potential gradient to produce neutron radiation.

7. A particle accelerator comprising a hollow cylindrical cathode, an enclosed tubular anode coaxially mounted within said cathode and containing ionizable gas, means for maintaining a potential gradient to accelerate electrons from said cathode toward said anode, means for controllably diffusing the gas from the interior to the exterior of said anode whereby said electrons tend to ionize said gas molecules, and a substance on the inner surface of said cathode for nuclearly reacting with positive ions impinging thereon.

8. A particle accelerator according to claim 7 further provided with means for generating an axial magnetic field substantially coaxial with the cylindrical cathode whereby the electrons approach the anode at an oblique angle and thereby increase the production of ions.

9. A particle accelerator comprising a hollow cylindrical cathode containing a substance that absorbs hydrogen gas, an elongated anode within said cathode formed with thin walls enclosing deuterium gas and through which molecules of deuterium may be diffused, means for maintaining said cathode at a negative potential relative to said anode to accelerate electrons from said cathode toward said anode whereby said electrons tend to ionize

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said deuterium gas to produce deuterons which are accelerated toward said cathode, and a coating containing tritium on the inner surface of said cathode whereby neutrons are produced by the reaction of said deuterons with said tritium.

10. A particle accelerator according to claim 9 further provided with means for generating an axial magnetic field substantially coaxial with the cylindrical cathode whereby the electrons approach the anode at an oblique angle and thereby increase the production of deuterons.

11. A particle accelerator comprising a hollow cylindrical cathode, a cylindrical anode formed with a thin tubular wall enclosing an ionizable gas capable of diffusing through said wall and coaxially mounted within said cathode, a beta particle emitter contained on the external surface of said anode for creating a positive potential difference be-

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tween said anode and said cathode for ionizing the gas that diffuses through said anode wall, and a substance on the inner surface of said cathode for nuclearly reacting with positive ions impinging thereon to generate a nuclear radiation.

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