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METHOD AND APPARATUS FOR GENERATING NEUTRONS

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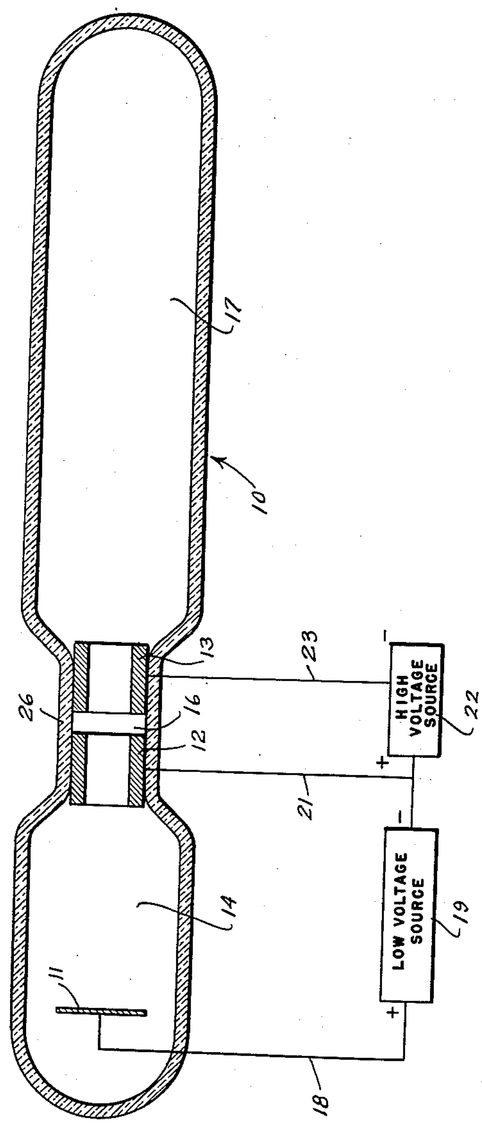

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METHOD AND APPARATUS FOR GENERATING NEUTRONS

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The present invention is directed to an improved method and apparatus for providing a source of mono-energetic neutrons.

In the past few years, considerable work has been done on exothermic nuclear reactions initiated by deuteron bombardment of the light elements. These reactions proceed on the basis that if the deuterons and the light elements are given a sufficiently high relative velocity to overcome the electrostatic repulsion which normally exists between the similarly charged nuclei, the deuterons will react with the light elements to liberate neutrons. To achieve the relatively high potentials required to overcome this repulsion, generators of various descriptions have been employed. One of the most common is the Cockroft-Walton machine which employs a series of electrical capacitances which are progressively charged by the action of a vacuum tube switching circuit to potentials on the order of several hundred kilovolts. The deuterons are accelerated by these high potentials in an evacuated accelerating space and are directed toward a target containing the light element.

However, machines of this type are extremely complex and expensive and require continuous differential pumping of an evacuated accelerating column, precise control or a rather critical ion source and extractor mechanism, and frequently require cooling and special target structures.

Electrostatic machines of the Van de Graaff type have also been employed to initiate such reactions but the complexities incident to the operation of electrostatic machines of this type provide a distinct drawback to their extensive use.

Still other systems and methods for generation of neutrons have been suggested in the past. In many cases, such systems and methods have not been altogether successful because they involved extremely low efficiencies since there was a severe current drain on the high voltage source which produced electrode heating problems when large ion currents were desired. Many of these prior systems employed magnetic fields to produce a strong discharge current. Such systems almost invariably operated at extremely low pressures on the order of one micron of mecury or less thereby further adding to the difficulties in maintaining the conditions required for efficient neutron generation.

With the foregoing in mind, an object of the present invention is to provide an improved method for liberating neutrons at a higher level of efficiency than has previously occurred in neutron generating systems employing glow discharge chambers.

Another object of the present invention is to provide a simplified apparatus for generating mono-energetic neutrons without the use of magnetic fields.

Still another object of the invention is to provide a method for generating neutrons at pressure conditions which are much easier to achieve and maintain than the pressure conditions which were required in systems of the past.

Generally speaking, the method of the present invention involves the establishing of an electrical discharge zone between a pair of relatively widely spaced electrodes, ionizing an isotope of hydrogen in the discharge area and then accelerating the ions thus produced through an accelerating zone maintained of the same pressure conditions as the discharge zone. The accelerating zone is short enough so that its length is of the order of the mean free path for the ions under the prevaling conditions. Finally, the accelerated ions are directed at a target capable of liberating neutrons by reaction with the ions. In a preferred embodiment of the invention, the electrical discharge, the acceleration, and the reaction take place in separate zones of the same vessel, the vessel containing an atmosphere of deuterium, tritium, or mixtures of the two hydrogen isotopes. The isotope thereby serves the dual function of providing the source of the ions and providing the "target" for producting neutrons by the reaction between the accelerated ions and the unionized isotopes.

A further description of the present invention will be made in conjunction with the attached sheet of drawings which illustrate an apparatus embodying the principles of the present invention.

In the attached drawing, reference numeral **10** indicates generally an envelope composed of glass or other suitable dielectric material. Disposed within the envelope **10** is an ionizing electrode **11**, and a pair of relatively closely spaced accelerating electrodes **12** and **13**. The electrodes divide the envelope **10** into three distinct zones—an ionizing zone **14** occurring between the ionizing electrode **11** and the accelerating electrode **12**, an accelerating zone **16** existing between the pair of relatively closely spaced accelerating electrodes **12** and **13**, and a target area **17** beyond the accelerating zone **16**.

The ionizing electrode **11** is maintained at a relatively low potential by means of a conductor **18** which connects the electrode **11** to a source of relatively low voltage **19**. A conductor **21** connects the opposite side of the low voltage source **19** to the accelerating electrode **12**.

The accelerating voltage between the electrode **12** and **13** is provided by a high voltage source **22** which has its negative terminal connected to the accelerating electrode **13** by means of a conductor **23** and its positive terminal connected to the conductor **21**.

In any gaseous discharge tube, if the breakdown potential is plotted against the product of the gas pressure and the distance between the electrodes, a curve results which exhibits a minimum breakdown potential at an intermediate pressure-distance product. This plot is known as the Paschen's law curve for gaseous breakdown. Thus, in a gaseous discharge tube, it is possible to have a discharge occur between two points of relatively low potential without a discharge occurring between two points in the same tube at a relatively high potential by suitably selecting the operating point on the curve, that is, by properly selecting the spacing, the pressure, and the respective voltages. This condition exists in the gaseous discharge tube shown in the drawings. The electrical discharge occurs between the ionizing electrode **11** and the accelerating electrode **12** even though the potential difference between the two electrodes is substantially less than the potential difference existing between the accelerating electrodes **12** and **13**. While the voltage for any given system may vary, a typical example of such a system for ionizing deuterium into deuterons might employ a potential of about 1 kilovolt for the low voltage source **19**, and a potential of about 50 kilovolts for the high voltage source **22**.

In order to prevent an electrical discharge occurring between the outer extremities of the electrodes **12** and **13**, the envelope **10** is necked down as indicated at numeral **26** so that no gas paths exist to the outer extremities of the electrodes.

With the systems shown, a reasonably high pressure of gas can be employed in the envelope **10** for the reaction. I prefer to operate at a pressure on the order of 50 to 100 microns of mercury absolute but reasonable efficiencies can also be obtained at lower pressures on the order of 10 microns or pressure up to 1000 microns.

At the given pressure conditions existing in the system, the spacing between the electrode **11** and the accelerating electrode **12** is adjusted so that a glow discharge will occur between the electrodes at the potential difference applied between the electrodes. At the same time, the spacing between the electrodes **12** and **13** is so chosen that the voltage between these electrodes is not conducive for establishing an area of electrical breakdown between the electrodes **12** and **13** under the pressure conditions existing. The entire envelope **10** is filled with a gaseous isotope of hydrogen, which may be deuterium, tritium, or a mixture of the two. The gas is ionized in the ionizing space **14** to produce deuterons or tritons or both, and the ionized particles are then accelerated by passage through the accelerating space **16**. After leaving the accelerating space **16**, the accelerated ionized particles enter the target area **17** where they undergo a neutron liberating reaction by collisions with other ions present according to the normal D,D reaction or the D,T reaction.

One of the advantages of the described system is the fact that electrons which are also formed in the ionized space along with the ions are formed at a low voltage condition, and for the most part do not appear in the accelerating space. Hence, only the useful ions are accelerated by the high potential so that all of the current in the voltage zone is useful, thereby improving the efficiency of the overall neutron generating process without constituting a severe current drain on the high voltage source.

For an electrode spacing of five millimeters and a mean free path of one millimeter, the probability of an ion traversing the accelerating gap with no collisions is e^{-5} or 7×10^{-3}. Since in the apparatus shown, only the useful ions enter the accelerating space, there would be 7×10^{-3} millamperes of fast deuterons per millampere of total current in the discharge tube. At an applied voltage of seventy kilovolts, these deuterons arrive at the target area with an energy of 35 kev.

It has been estimated that about 4.9×10^5 neutrons can be expected per microcoulomb of incident deuterons with certain types of targets. Hence, under the previously described conditions, there will be approximately 3.5×10^6 neutrons per second per milliampere from the discharge tube.

This application is a continuation-in-part-of my copending application Serial No. 506,851, entitled "Neutron Discharge Tube," filed May 9, 1955, now U.S. Patent No. 2,983,834.

It will be evident that various modifications can be made to the described embodiment without departing from the scope of the present invention.

I claim as my invention:

1. An apparatus for generating neutrons comprising a closed envelope containing an atmosphere of an isotope of hydrogen, an ionizing electrode contained within said envelope, a pair of spaced accelerating electrodes within said envelope spaced from said ionizing electrode, means for applying a relatively low potential between said ionizing electrode and one of said accelerating electrodes, means for applying a relatively higher potential between said accelerating electrodes, the spacing between said ionizing electrode and said one accelerating electrode being sufficiently large to create an electrical discharge zone therebetween under the pressure conditions existing within said envelope, and the spacing between said accelerating electrodes being sufficiently small to preclude an electrical discharge therebetween under said existing pressure conditions, said envelope also defining a reaction zone beyond said accelerating electrodes in direct line with the direction in which the ions are accelerated for reacting ions accelerated by said accelerating electrodes with the gas contained within said reaction zone.

2. The apparatus of claim 1 in which said atmosphere is an atmosphere of deuterium.

3. The apparatus of claim 1 in which said atmosphere is an atmosphere of tritium.

4. The apparatus of claim 1 in which said atmosphere is a mixture of deuterium and tritium.

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