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Stark

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[54] **NEUTRON GENERATORS**

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[52] **U.S. Cl.** ..... **313/61 S,** 331/7

[51] **Int. Cl.** **H01j 39/00**

[58] **Field of Search** ..... 313/61 R, 61 S

[56] **References Cited**

UNITED STATES PATENTS

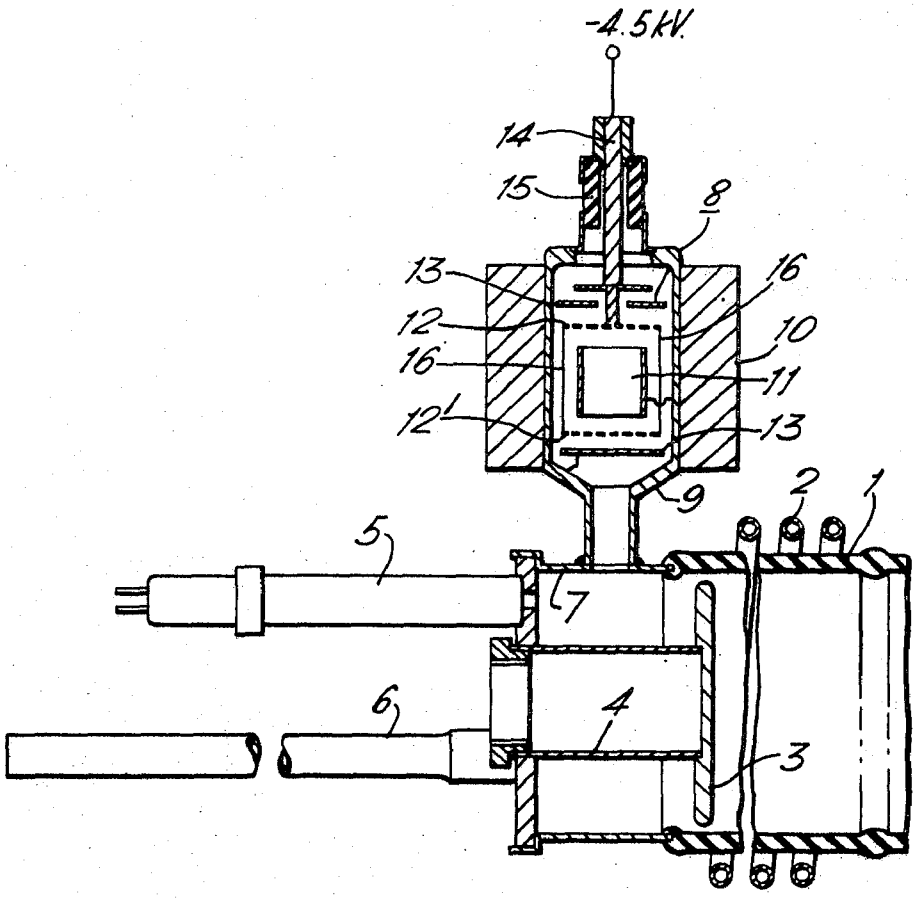
2,964,665 12/1960 Brinkerhoff et al. 313/61

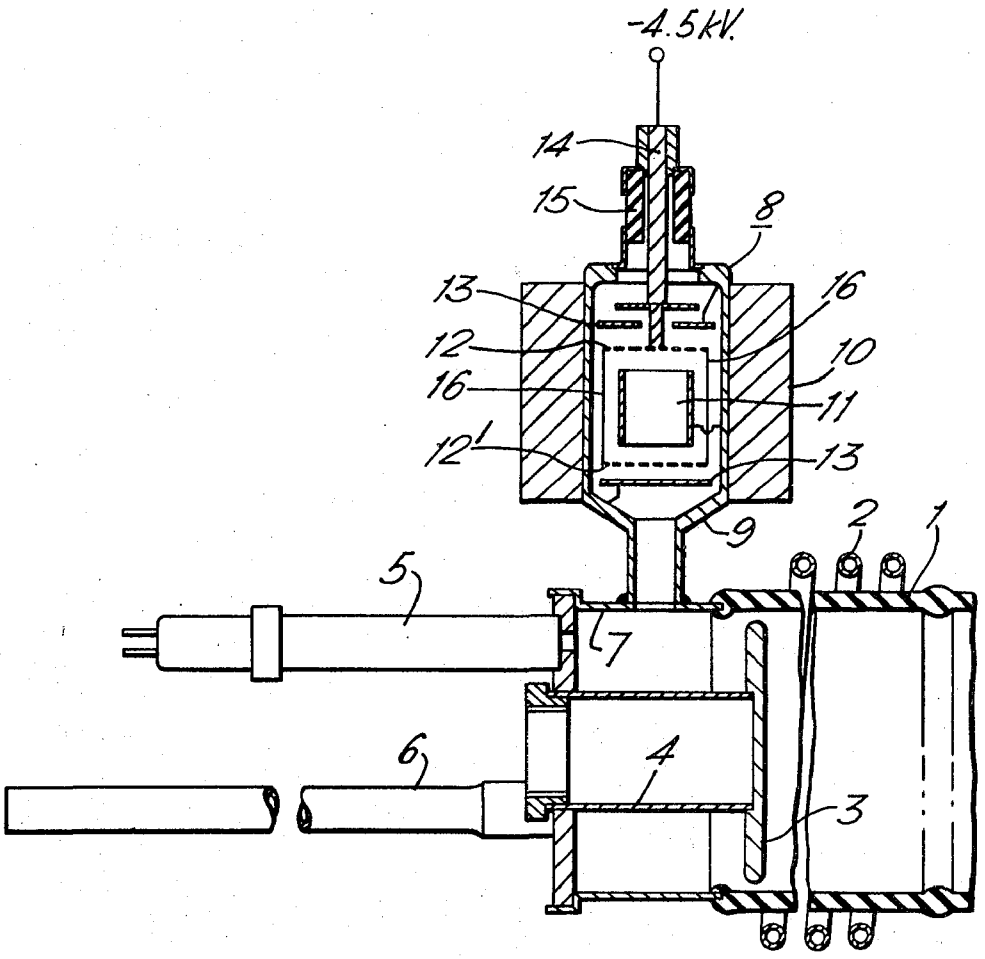
Primary Examiner—Roy Lake
Assistant Examiner—Darwin R. Hostetter
Attorney, Agent, or Firm—Larson, Taylor & Hinds

[57] **ABSTRACT**

In a sealed-off neutron generator containing tritium, for the production of neutrons by the D-T reaction, helium-3 gas accumulates owing to radioactive decay of the tritium and interferes with the proper operation of the generator. In the present generator a sputter-ion pump is sealed to the generator to remove the helium-3 from the envelope prior to admitting hydrogen isotope gas from the usual replenisher before use. The pump is adapted to remove only the unwanted helium-3 and not the wanted D and T, by having its sputterable cathodes made of, or coated with, a metal which has a low chemical affinity for hydrogen but is readily sputtered by helium, such as copper.

8 Claims, 1 Drawing Figure

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NEUTRON GENERATORS

BACKGROUND OF THE INVENTION

This invention relates to neutron generators and relates particularly to generators comprising a sealed-off envelope or tube in which deuterium and/or tritium ions from an ion source are accelerated to strike a target containing deuterium and/or tritium to produce neutrons by the D-D and/or D-T reactions. A generator of this type is described, for example, in U.K. Specification No. 1,088,088 and corresponding U.S. Pat. No. 3,448,314.

In the latter type of sealed-off generator, a low pressure (e.g., about 0.02 mTorr) of deuterium and/or tritium is present throughout the tube during operation. This is obtained from a gas replenisher containing a hydrogen-occluding metal (such as titanium) in which deuterium and/or tritium gas has been previously absorbed. The desired pressure in the tube is maintained by controlling the temperature of the replenisher. When the replenisher is switched off the gas is reabsorbed by the replenisher and the pressure should fall to approximately zero.

In generators which contain tritium, for producing neutrons by the D-T reaction, a problem arises from the fact that tritium decays radioactively (with a half-life of about 12.3 years) to helium-3 (He-3). Thus a continuously increasing concentration of He-3 atoms builds up in all parts of the tube where tritium is held, (for example the target, gas replenisher and ion source walls into which tritium is driven by the radiofrequency discharge which, as in the aforementioned generator, is frequently used to ionize the gas).

Since He-3 is a chemically inert atom, it is not chemically bonded to the target, replenisher and walls in the same way as its parent tritium atom. There is thus a gradual release of He-3 atoms, which build up a gas pressure in the free space within the tube.

This free He-3 gas can cause reduction of neutron output in several ways:

i. The He-3 gas within the ion source is ionized so that the pressure within the ion source is incorrect and the extracted deuterium and/or tritium ions are contaminated with He-3 ions.

ii. The deuterium and/or tritium ions, during their acceleration towards the target, undergo various electronic interactions with the neutral He-3 atoms, which, in general, reduce their velocity of impact on the target.

iii. An excessive He-3 pressure in the ion source can prevent the striking of an ionizing discharge in the ion source.

iv. The voltage which can be applied between electrodes without breakdown is reduced.

It is an object of the present invention to provide a neutron generator in which the problem of He-3 accumulation is alleviated.

SUMMARY OF THE INVENTION

According to the present invention, in a sealed-off neutron generator which contains tritium and which includes a replenisher for providing hydrogen isotope gas, there is provided a pump in continuous communication with the generator envelope for removing helium from the envelope, said pump being adapted to pump gas from the envelope when the pump is operated, and substantially not to absorb hydrogen gas from the envelope when the pump is not operated.

The pump is preferably a sputter-ion pump having sputterable electrode means whereof the sputterable metal has a low chemical affinity for hydrogen.

Preferably the sputterable metal has a high sputtering coefficient for helium ions.

The sputter-ion pump is preferably of the triode type, the sputterable electrode means comprising at least one multi-apertured, eg grid or mesh, cathode located between an anode and a further electrode on to which, in operation, metal is sputtered from the cathode. The pump may be external to the envelope and permanently sealed thereto.

Sputterable metals suitable for the sputterable electrode include copper, silver and gold. The sputterable metal may be a deposit on a stronger metal such as stainless steel, monel or molybdenum, eg, plated on to a grid or mesh of such metals.

The sputter-ion pump serves to remove the accumulated gaseous He-3 periodically. Before switching on the hydrogen-isotope replenisher, the pressure in the tube is checked. A reading other than zero indicates the presence of He-3 gas and the He-3 pump is operated until a zero indication is obtained. The pump is then switched off, and the replenisher operated to give the working hydrogen isotope pressure.

As will be hereinafter explained, conventional sputter-ion pumps are unsuitable for use in the present invention because such pumps comprise metals, such as titanium, which have a high chemical affinity for hydrogen and which would therefore remove the wanted D and T as well as the unwanted He-3.

DESCRIPTION OF THE DRAWING

To enable the nature of the present invention to be more readily understood, attention is directed, by way of example, to the accompanying drawing, which is a sectional elevation of part of a neutron generator tube embodying the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The drawing shows the ion-source end of a neutron generator tube of the kind described in U.K. Specification No. 1,088,088. It comprises a glass tube or envelope **1** surrounded by a radiofrequency exciting winding **2**. Within the tube an aluminum-coated copper electron-stopper **3** is supported on a metal tube **4**. Attached to the tube **1** are a gas replenisher **5**, a sealing-off tube **6** and a Pirani pressure gauge, the latter being hidden behind sealing-off tube **6**.

The envelope **1** includes a metal portion **7** to which, in accordance with the present invention, there is sealed a triode-type of sputter-ion pump **8** (sometimes called a getter-ion pump). Pump **8** comprises an envelope **9** of non-magnetic stainless steel surrounded by hollow cylindrical permanent magnet **10** to provide an axial magnetic field. Within the envelope **9** are mounted a cylindrical anode **11**, a pair of mesh cathodes **12** and a pair of further elecrodes formed as end-discs **13**. The anode and the end-discs are earthed to the envelope **9** and are also of stainless steel. The mesh cathodes **12** and **12'** are mounted on a lead-through connection **14** sealed to an insulating bush **15**, and in use are connected to a negative potential, suitably about - 4.5 kV.

In the present example the upper mesh cathode **12** is made of stainless steel wire 0.0148 inch in diameter with 20 wires per inch, and is plated with copper to a thickness of 0.002 inch. The lower mesh cathode **12'** is made of copper wire 0.0124 inch in diameter with 24 wires per inch. The use of plated stainless steel wire for cathode **12** prevents it distorting under the weight of cathode **12'**, which is suspended from it by the narrow flat strips **16.** Anode **11** and discs **13** are mounted on envelope **9** by further narrow flat strips (omitted for clarity) in a conventional manner.

The operation of a conventional sputter-ion source will be familiar to those skilled in the vacuum art, but briefly electrons emitted from the mesh cathodes are accelerated towards the anode and oscillate to and fro between the two cathodes before eventually arriving at the anode. The electron path length is increased by spiralling in the magnetic field. The electrons produce ionization of the gas molecules by collision, and the ionized gas molecules are accelerated away from the anode. Some strike the mesh cathodes and cause sputtering of metal from the cathode on to the end-discs. Other ions, together with excited atoms, pass through the cathode meshes and reach the end-discs with just enough energy to cause their sorption. These loosely held ions and atoms are then sealed into the end-discs by burial under further sputtered metal from the cathodes, and are thus permanently pumped. In conventional sputter-ion sources the sputterable mesh cathode is usually made of titanium.

The above type of pumping action takes place for both inert gases like He-3 and for chemically active gases like hydrogen and its isotopes since it depends only on ionization and electronic excitation processes. However, for chemically active gases there is an additional, much faster process by which pumping takes place. This is due to the chemical affinity between the gas and the titanium film continuously sputtered on to the end-discs. Neutral molecules of hydrogen, for example, strike the end-discs by normal gas-kinetic processes, and being chemically active, they have a finite probability of becoming bonded to the titanium film and hence pumped.

In the present invention it is essential that the pump should not pump or absorb gaseous D or T which are present during operation of the generator. Otherwise (a) it would tend to empty the gas replenisher, and (b) its pumping action for He-3 would be impaired by saturation effects. It has been found that such a conventional sputter-ion pump will continue to absorb hydrogen even when the cathode voltage is switched off. This is because, once the titanium film has been deposited, its chemical sorption action does not depend on the presence of electrical voltages.

In accordance with the present invention the hydrogen absorption problem is alleviated by making the cathode meshes of a metal which does not readily react chemically with hydrogen. Hence the film sputtered over the end-discs is relatively chemically inactive and the pumping action substantially ceases immediately the voltage applied to the cathodes is switched off. Preferably the cathode meshes are made of a metal having a high sputtering coefficient for helium ions. In this way, maximum He-3 pumping speeds can be obtained and, because of the deeper burial of ions and excited atoms, the re-emission of pumped He-3 is minimised. Examples of high-sputtering metals which do not readily react with hydrogen are copper, silver and gold. As meshes made of such metals tend to soften when the generator is vacuum-baked during manufacture, these metals can advantageously be deposited, e.g., by plating, on meshes made of stronger metals such as stainless steel, monel and molybdenum.

As will be known, there exists a diode type of sputter-ion or getter-ion pump whose pumping mechanism is similar to that of the triode type, except that ion pumping takes place at the same electrodes as are being sputtered. This can result in a re-emission of gas already pumped, which is particularly serious for inert gases, which are not chemically pumped. It is therefore preferred to use the triode type of pump in the present invention, where the pumping and retention of inert He-3 are the requirements.

The accompanying drawing is approximately to scale, the external diameter of envelope **9** at its widest being about 1 inch.

The suitability of the above-described pump for the present requirement is indicated by the following typical performance data, using an axial magnetic field of about 900 oersteds and about - 4 kV applied to the cathodes.

i. The pump operates satisfactorily at 180 mTorr helium pressure.

ii. It pumps down from this pressure to zero in approximately 7 hours and from 50 mTorr in 1½ hours, in a volume of about 1 litre.

iii. It pumps 1600 litre mTorr of helium without reduction of pumping speed and with no indication of saturation.

iv. After pumping 1600 litre.mTorr of helium, the pump releases helium gas at the low rate of 6 litre.mTorr in the first week and at 3.5 litre.mTorr per week thereafter.

v. Despite the cathode sputtering which accompanies the pumping of 1600 litre.mTorr of helium, the pump does not absorb hydrogen gas at a measurable rate when the cathode voltage is switched off thereafter.

I claim:

1. A sealed-off neutron generator which contains tritium and which includes a replenisher for providing hydrogen isotope gas, wherein there is provided a pump in continuous communication with the generator envelope for removing free helium gas from the envelope, said pump being adapted to pump gas from the envelope when the pump is operated, and substantially not to absorb hydrogen gas from the envelope when the pump is not operated.

2. A neutron generator as claimed in claim **1** wherein said pump is a sputter-ion pump having sputterable electrode means whereof the sputterable metal has a low chemical affinity for hydrogen.

3. A neutron generator as claimed in claim **2** wherein the sputterable metal has a high sputtering coefficient for helium ions.

4. A neutron generator as claimed in claim **3** wherein the sputter-ion pump is of the triode type, the sputterable electrode means comprising at least one multi-apertured cathode located between an anode and a further electrode on to which, in operation, metal is sputtered from the cathode.

5. A neutron generator as claimed in claim **3** wherein the sputterable metal is selected from copper, silver and gold.

6. A neutron generator as claimed in claim 3 wherein the sputterable metal is a deposit on a stronger metal.

7. A neutron generator as claimed in claim 1 wherein the pump is external to said envelope and sealed thereto.

8. A method of operating a neutron generator as claimed in claim 1 comprising operating said pump to remove helium from the envelope before admitting hydrogen isotope gas from the replenisher.

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