

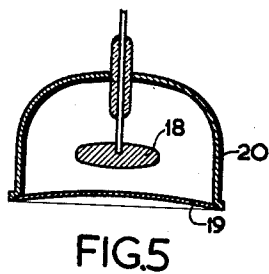
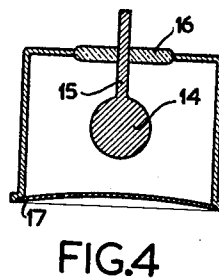
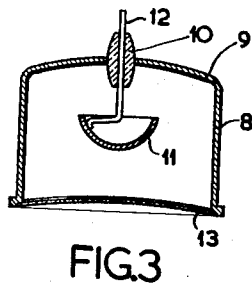
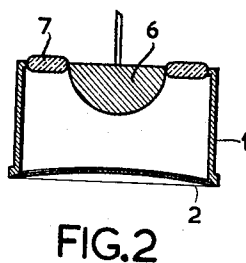
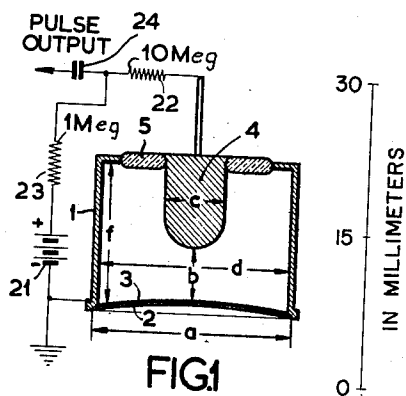
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BETA RAY DETECTORS

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BETA RAY DETECTORS

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This invention relates to Geiger-Muller counters for the detection of beta rays.

Counting tubes of the aforesaid kind, which are usually of the end-window type, comprise a cylindrical cathode, which constitutes part of the tube wall or envelope, and a wire-shaped anode mounted along the axis of the cathode cylinder. In order to enable the beta rays to enter the active counting space, the cathode is closed off at one end by a flat, thin window, e.g. of mica. Such counting tubes may be filled with a mixture of a rare gas and a small quantity of halogen quench. Such tubes have the disadvantage of a high background counting rate and of an unsatisfactory configuration of the electric field in the region near the window. Specifically, the field is attenuated at the end of the wire-shaped anode opposite the window and is even weaker at the area of the transition of the window into the cathode. Hence the efficiency of the beta ray counting is fairly low because much electron attachment occurs in the areas immediately behind the window, i.e., between the window and the anode. The electrons that become attached to halogen atoms and molecules are lost for the multiplication process. Therefore part of the incoming β -rays are not counted. Moreover electrical surface charges may develop on the inside of an insulating window producing fluctuations in the counting efficiency and in the counter's plateau characteristic, which is very undesirable particularly at low counting rates of a few counts per minute, which exist in determinations concerning radioactive fall-out.

In order to improve such counting tubes, it has been proposed to shape the anode not in the form of a wire but in that of an elongated rod and to round-off its end opposite the window. Since such a rounding-off with an insulating window would bring about a fairly large dead space, in which no discharge can take place between anode and window, it has been suggested also to make the window conductive, for example by metallizing and to provide the same potential at it as at the cathode, for example, by connecting the metal coating directly to the cathode. While a counting tube thus constructed exhibits improved efficiency for beta rays, it still has the disadvantage of a high background rate and a very small solid angle of collection, which renders such tubes essentially useless for counting low level activities, such as derive from fall-out.

The invention has for its main object to provide an improved counting tube for detecting beta rays in which the foregoing disadvantages are eliminated, while additional advantages are obtained, as will be described hereinafter.

A Geiger-Muller counter according to the invention comprises a cathode which forms part of the envelope wall, an anode arranged inside thereof, and a substantially flat window to allow beta rays to enter the active volume. The tube is filled with a beta ray ionizable gas containing at least 0.005% by volume of a halogen quench. The anode is a conductive body, which is substantially spherical at least on the side facing the window and has in a plane parallel to the window a maximum dimension between 0.15 and 0.75 times the largest dimension of the cathode in a plane parallel to the window. The window is conductive on the inner side and electrically connected

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to the cathode. The largest height of the discharge space, measured at right angles to the window, is between 0.25 and 1.5 times the largest dimension of the window, and the smallest distance of the anode from the window is between 0.1 and 0.5 times the largest dimension of the window. It has been found that a counter according to the invention has a very low background counting rate combined with very good β -ray counting efficiency. The low background may be accounted for as follows. The sample emitting the beta rays is, of course, always arranged as near the window as possible. The primary ionization produced by this radiation in the counter therefore takes place mainly in that portion of the gas-filled space which is located directly behind the window. The portion of the counter further removed from the window does not substantially contribute to the efficiency of the counter. However, the background of the counter is mainly produced by gamma radiation and cosmic radiation. The primary ionization produced by these radiations will be distributed substantially uniformly over the counter. By providing a short dimension of the discharge space of the counter in a direction at right angles to the window, i.e., its height, the efficiency for the beta radiation to be measured is substantially not affected, but the background is materially reduced.

The known counter described in the introduction, which comprised a cylindrical cathode, a rod-shaped anode and a conductive window, had a very great length, which was presumably required by the use of an organic quench. In this case, a large discharge space is advantageous, because during the operation of the tube, the organic quench decomposes and is also adsorbed. Hence, the larger the discharge space and the internal gas volume, the longer the tube can be satisfactorily employed. This is avoided through the use of the halogen quench.

Moreover, by providing on the side facing the flat or slightly curved window a substantially spherical shape of the anode whose dimensions and spacing to the window are related in the foregoing manner, and by rendering the inner side of the window conductive and by connecting it to the cathode, a uniform field distribution, which is very advantageous for counting beta rays, is obtained behind substantially the whole window. With counters containing halogen as the quench, it is highly important for the detection of beta radiation that the electrical field should be as homogeneous and as intense or strong as possible in that portion where the beta radiation produces ionization, i.e. behind the whole window. With this uniform field, in which the major electrical lines of force extend at right angles to the cathode surface, primary electrons produced by ionization are fully utilized. The intense field is necessary to prevent the occurrence of electron attachment, because of the strong electro-negative character of the halogen atoms. These results, which are not obtained in the known counter, are achieved in the inventive device, and a particularly favorable field distribution is established when the ratio between the largest dimension of the anode in a plane parallel to the window and the largest dimension of the cathode in a plane parallel to the window lies between 0.25 and 0.50. Further, the spherical shape of the anode should not be understood in only a strictly mathematical sense. The anode may, for example, be an ellipsoid of revolution or part thereof or, as an alternative, a cylinder with a strongly rounded-off rim.

Since the anode is not wire-shaped, its external connection involves difficulties. If, for example, the anode is a hemisphere with a short cylindrical portion secured thereto, this short cylinder must be sealed through the tube wall so as to be insulated therefrom. Although, from a technical point of view, the sealing of a fairly thick cylinder through an insulator of, for example, glass is

quite feasible, it is materially simpler to seal through a thin wire. In the case of a thick lead-in the stray capacitance of the counter is, moreover, increased, which affects adversely its satisfactory operation as a counting device. Moreover, in the case of a thick anode lead-in, the volume of the insulator is large. It has been found that this is also disadvantageous because a larger insulator involves a greater number of spurious discharges, i.e. uncontrollable discharges occurring at any instant, than a smaller insulator. This may be due to the fact that the insulator is charged by electrons or ions from the gas discharge.

The disadvantages of a thick anode lead-in may be mitigated by securing, in a particular embodiment of a counter according to the invention, the anode on the side remote from the window to a supporting wire, which is at the same time a current supply wire, of which the diameter, at least inside the discharge space, is smaller than one tenth of the largest dimension of a section of the cathode parallel to the window.

The supporting wire of the anode requires a greater height of the gas-filled space than without this wire, but with a choice of the thickness of the supporting wire as indicated above, it is possible to avoid the possibility that the gas-filled space portion between the supporting wire and the cathode becomes sensitive to gamma radiation and cosmic radiation, since the starting voltage in the said portion, owing to the choice of the wire diameter, will be materially higher than in the remaining portion of the discharge space. The supply voltage for the counter can then be chosen such that the portion behind the anode body is inactive, i.e., does substantially not count. The thin wire can be sealed through a small insulator, which will give rise to spurious discharges to a smaller extent.

The window may be made of different insulating materials, for example mica or glass; on the inner side such a window may be made conductive by applying, for example by evaporation, a thin metal layer, for example, of chromium. As an alternative, particularly with a glass window, conductivity may be obtained by means of a coating of conductive tin oxide. Instead of using an insulating window which is rendered conductive, the window may be made of a thin metal foil, for example, of chrome-iron.

Although, as a rule, use will be made of a cathode which is cylindrical throughout its length, it is advantageous, in order to obtain a homogeneous field distribution, to round-off slightly the cathode end remote from the window.

The invention will now be described more fully with reference to the drawing which shows several different embodiments of a counter according to the invention, which are drawn to scale with the dimensions derivable from the scale to the right of FIG. 1, with the exception of the thicknesses of the windows, which are shown on an enlarged scale for clarity's sake. In the drawing:

FIG. 1 is a cross-section of one embodiment of a counter according to the invention, in which the anode consists of a solid hemisphere with a solid, short cylinder connected therewith;

FIG. 2 is a cross-sectional view of one embodiment of a counter according to the invention comprising a solid, hemispherical anode;

FIG. 3 is a cross-sectional view of one embodiment of a counter according to the invention comprising a non-solid anode hemisphere, supported by a thin wire;

FIG. 4 is a cross-sectional view of one embodiment of a counter according to the invention comprising a solid spherical anode, supported by a thin wire;

FIG. 5 is a sectional view of one embodiment of a counter according to the invention comprising a solid anode shaped in the form of an ellipsoid, supported by a thin wire.

As shown in FIG. 1, the cathode of the counter is formed by a cylindrical wall 1, which may be made of

chrome-iron (75% iron—25% chromium by weight). On one side this wall is closed off by a mica window 2, which is coated on its inner side with a conductive layer 3, for example, of chromium, connected to the cathode 1. An anode 4 is constituted by a solid body, for example, of chrome-iron; as shown in this figure, this body 4 consists of a hemispherical portion at the bottom and a cylindrical portion connected therewith at the top. The cylindrical portion is secured in the wall 1 by means of an annular insulator 5, for example, of glass. The window 2, wall 1, insulator 5 and anode 4 constitute a sealed envelope, whose interior is filled with a beta ray ionizable medium, such as a rare gas, and a small amount of a halogen quench.

The aforesaid conditions relating to the dimensions of the various component parts of the counter according to the invention are clarified by designating by a the diameter of the window 2, by b the minimum distance of the anode 4 from the window 2, by c the largest dimension of the anode in a plane parallel to the window, by d the largest dimension of the cathode in a plane parallel to the window (in the embodiment shown in FIG. 1 d is equal to a , which, however, is not always necessary) and by f the largest height of the discharge space. The aforesaid conditions can thus be represented as follows:

$$0.15d < c < 0.75d$$

$$0.25a < f < 1.5a$$

$$0.1a < b < 0.5a$$

A specific example of a suitable geometry, which is not to be considered as limiting, follows below:

$$a=20; b=5; c=6; d=a; f=14$$

the gas filling is a mixture of neon and argon with 0.05 volume percent of bromine at a combined pressure of 100 mms. of mercury. The operating voltage is about 450 volts.

In FIG. 1 a battery is referred to by reference numeral 21 which provides the voltage for operating the tube. With reference numerals 22 and 23 resistors are indicated placed in the supply circuit. The output pulses are taken from the capacitor 24.

FIG. 2 shows another embodiment of a counter according to the invention, which is substantially identical to the embodiment shown in FIG. 1. The anode 6, however, is a hemisphere and sealed directly to the insulator 7 in turn sealed to the cathode 1.

As shown in FIG. 3, the cathode 8 may be rounded off spherically on the side remote from the window by means of a portion 9. In this portion 9 the insulator 10, for example, of glass, is secured in a gastight manner. The anode is a hollow hemisphere 11, which is secured in the insulator 10 in a gastight manner by means of a thin wire 12. The window, as in the embodiments shown in FIGS. 1 and 2, consists of a metal-plated mica foil 13, of which the thickness is about 0.01 mm.

In the embodiment shown in FIG. 4, the anode consists of a solid sphere 14, which is secured in a gastight manner with the aid of a thin wire 15 in the insulator 16, for example, of glass. The window of this embodiment consists of a chrome-iron foil 17, the thickness of which is about 0.02 mm. The diameter of the wire portion 15 inside the discharge space, in accordance with the aforesaid conditions, is smaller than $0.1d$ (FIG. 1).

FIG. 5 shows a counter in which the anode 18 is an ellipsoid of revolution. This shape furnishes a still better field homogeneity at the area of connection of the window 19 and the cathode 20.

Beta ray detectors in accordance with the invention have proved extremely suitable for low-level work, because of their extremely low background and their high counting efficiency. Moreover, the plateau are excellent, being about 300 volts or larger and having a slope of 2% per 100 volts or less. This illustrates the excellent characteristics of the tube (as is known, the tube is

generally operated at a voltage at about the center of the plateau, which is the horizontal portion of the counting rate-voltage discharge characteristic). Moreover, short dead times are experienced.

What is claimed is:

1. A Geiger-Muller counting tube for the detection of beta rays, comprising an envelope including a short cylindrical conductive surface serving as a cathode and a substantially flat, thin, beta radiation-transparent window portion having a conductive inner surface connected to the cathode and filled with an ionizable medium containing at least 0.005% by volume of a halogen quench, and a conductive anode within the cathode and having a substantially spherical surface opposed to the window and defining a discharge space with the cathode, the longest dimension of the anode in a plane parallel to the window being between 0.15 and 0.75 times the longest dimension of the cathode in a plane parallel to the window, the height of the discharge space measured at right angles to the window being between 0.25 and 1.5 times the longest dimension of the window, and the shortest distance between any point on the anode and the window being between 0.1 and 0.5 times the said longest dimension of the window, whereby the counting tube exhibits high efficiency together with low background.
2. A counting tube as set forth in claim 1 wherein the window comprises an internally-conductively-coated mica foil.
3. A counting tube as set forth in claim 2 wherein the conductive coating is conductive tin oxide.
4. A counting tube as set forth in claim 1, wherein the window comprises a thin metal foil of chrome-iron.
5. A Geiger-Muller counting tube for low level beta ray detection comprising an envelope including a short cylindrical conductive surface serving as a cathode and a substantially flat, thin, beta radiation-transparent window portion having a conductive inner surface connected to the cathode and closing-off the cathode and filled with an ionizable medium containing at least 0.005% by volume of a halogen quench, a conductive anode within the cathode and having a substantially spherical surface of substantial surface area opposed to the window and defining a discharge space with the cathode, the longest dimension of the anode in a plane parallel to the window being between 0.25 and 0.50 times the longest dimension of the cathode in a plane parallel to the window, the height

- of the discharge space measured at right angles to the window being between 0.25 and 1.5 times the longest dimension of the window, and the shortest distance between any point on the anode and the window being between 0.1 and 0.5 times the said longest dimension of the window, and means for applying a potential to the cathode and anode at which the tube operates in the Geiger-plateau region of its counting rate-voltage discharge characteristic, whereby the counting tube exhibits high efficiency together with low background.
6. A counting tube as set forth in claim 5 wherein the anode is supported on its side remote from the window by a wire whose diameter within the discharge space is less than 0.1 times the said longest dimension of the cathode.
7. A counting tube as set forth in claim 5 wherein the anode is a sphere.
8. A counting tube as set forth in claim 5 wherein the anode is a hemisphere whose convex side faces the window.
9. A counting tube as set forth in claim 5 wherein the anode is an ellipsoid of revolution whose major axis is parallel to the window.
10. A counting tube as set forth in claim 5 wherein the end of the cathode remote from the window is curved.

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