This invention relates to radiation detectors, and in particular to proportional counter radiation detectors. One object of the invention is to provide a proportional counter capable of counting at high rates.

Another object of the invention is to provide a proportional counter tube construction which will afford excellent linearity between the incident radiation to be detected and the output voltage pulses.

Another object of the invention is to provide a proportional counter tube construction which has a high sensitivity.

A further object of the invention is a proportional counter tube construction which is simple to manufacture.

A still further object of the invention is a proportional counter wherein the width of the voltage pulse height distribution approaches the theoretical limit.

Still a further object of the invention is to provide a proportional counter tube construction which will respond to low-energy X-radiation.

These and other objects of the invention will be best understood from the following description, which should be read in connection with the accompanying drawing in which:

Fig. 1 is a front elevational view of a proportional counter in accordance with the invention;

Fig. 2 is a cross-sectional view along line 2—2 of the tube shown in Fig. 1.

Referring now to the drawing, a proportional counter tube in accordance with the invention comprises a generally elongated cylindrical shell 1 constituted of a metal capable of being sealed to glass. Such a metal is, for example, copper or stainless steel. The shell 1 is substantially opaque to low and medium energy X-radiation. The inner surface of the shell 1, which serves as the cathode of the tube, defines a perfectly cylindrical, symmetrical, electric field region 2. Opposite ends of the cylindrical shell 1 are closed off by a pair of electrically-insulating plates 3, e.g., mica, which are sealed in recesses 4 formed at the ends of the shell 1. Each of the insulating plates 3 has a central aperture 6 for receiving supporting end-pieces 7, 8, which serve to center and support an anode wire 10. The supporting plates 3 are powder-glass-sealed 11 to the shell 1 and the end-pieces 7, 8.

In order to achieve true proportionality between the energy content of the incident radiation and the amplitude of the output voltage pulses of the counter tube, it is essential that there be a perfectly symmetrical electric field between the central anode wire and the surrounding cathode shell. To accomplish this, the anode wire in the tube must be exactly centered with respect to the surrounding cathode shell. Production-wise, this presents an obstacle since the tube is usually assembled by unskilled labor.

One of the features of the present invention resides in the end-piece-supporting-plate construction by which mere assembly of the components making up the tube insures that the anode wire will be perfectly centered relative to the surrounding cathode wall. This is accomplished in the following manner.

Since the cathode shell 1 is symmetrical at both ends, the mica supporting plates 3 are identical and may be simultaneously stamped out from a double-layer mica sheet. At the same time, the central aperture 6 is formed in the mica plates 3. When these plates 3 are placed at opposite ends of the shell 1 in the receiving recesses 4, the centers of their respective apertures 6 will be accurately located on the longitudinal axis of the cathode shell 1. The end-piece 7 in the right half of the tube is also symmetrical about its longitudinal axis. It consists of a hollow metal cylinder having a substantially, centrally-located, radially-extending shoulder 15 for engagement with the inner surface of the plate 3. The outer end of the end-piece 7 is open and bevelled to facilitate sealing thereto of a glass tube. The diameter of the cylindrical body of the end-piece is chosen to correspond to the diameter of the aperture 6 so that the end-piece 7 fits rather tightly in the aperture. The inner end of the hollow end-piece 7 is closed off by a curved or rounded end 16 pierced through by a tiny central aperture 17. The rounded end 16 of the end-piece, which is located within the electrode region 2, serves to maintain a symmetrical field distribution at the discontinuity presented by the presence of the end-piece and avoids a high field intensity thereat. The aperture 17 is, of course, located on the longitudinal axis of the shell 1.

The opposite end-piece 8 is somewhat similar to its counterpart 7. It comprises a symmetrical, hollow, cylindrical body having an inner cylindrical member 20 closed off by a curved or rounded end 21 in the same manner as the end-piece 7. The rounded end 21 is pierced by a central aperture 22. Opposite sides of the cylindrical member 20 are also provided with apertures 23 and 24 for exhausting purposes, as will be explained in greater detail hereinafter. The end-piece 8 is provided with a shoulder 25 which abuts the outer side of the mica plate 3. Extending from the shoulder 25 in an axial direction is a cylindrical portion 26 which serves as the means for exhausting and filling the interior of the tube.

The anode wire 10 is preferably constituted by a refractory metal which is non-oxidizable at medium elevated temperatures of the order of 600° C., easily welded to other metals, and easily sealed to glass. Such a metal is, for example, platinum. The wire 10 extends through the apertures 17 and 22 of the end-pieces 7 and 8, respectively. The end of the wire 10 in the end-piece 7 is welded to a compression spring 30, for example, of tungsten, which abuts an inner flat surface 31 on the inside of the cylindrical member 20. The other end of the wire 10 passes entirely through the end-piece 7 and serves as the external terminal connection for applying a suitable potential thereto.

Entrance of the radiation to be detected into the electric field region 2 within the tube is afforded by a rectangular window 35 provided on a side wall of the shell 1 equidistant from both ends thereof. The window 35 must fulfill the dual requirements of affording a tight sealing of the tube and absorbing the smallest possible quantity of radiation impinging thereon. These requirements are fulfilled by the window shown, which is produced by milling a rectangular opening 36 in the side wall of the shell 1 and a pair of aligned rectangular recesses 37, 38 in the wall itself. The innermost recess 38 is provided to support a thin beryllium foil 39, whereas the outer recess 38 supports a thin mica member 40 which is powder-glass-sealed 41 along its periphery to the surrounding portions of the shell 1. The depths of the beryllium-and-mica foil containing recesses 37, 38 are adjusted so that when the tube is exhausted, the respective difference tends to bend the foils inwardly to an extent at which the inside surface of the beryllium defines a substantially continuous surface with the inner surface of
the cathode shell 1 in order to minimize any electric field distortions which may exist in that area. The beryllium foil is present as a conductive member to maintain the desired field distributions. However, to avoid excessive absorption of low energy radiation, it is made as thin as possible, for example, about 0.001 inch; with this thickness, the beryllium foil may be porous and not vacuum-tight. Also, production tolerances on beryllium may be difficult to seal. Consequently, the mica member is employed for vacuum-tight sealing of the window, mica itself having relatively low absorption to low energy radiation. Alternatively, a single mica member may be employed which is coated on its inner surface with a thin conductive coating of, for example, gold. Of course, if one has available thin, vacuum-tight beryllium which may be sealed to metal tubes, a thin foil of that material alone will provide a useful construction.

The window dimensions are chosen in accordance with the application of the counter. The rectangular window construction shown, in which the long sides of the rectangle are parallel to the longitudinal axis of the tube, was designed for receiving a rectangular-shaped X-ray beam having a corresponding cross-section. For other applications, the rectangle could be arranged such that the longer sides are perpendicular to the anode wire. Such a construction would enable a material reduction in the length of the tube, and would afford the additional advantage of a narrow pulse height distribution due to absorption of the radiation in a more uniform electric field. The overall length of the tube is chosen such that the discharges resulting from the incident radiation passing through the window 35 and absorbed by the gas-filling are confined to a region within the electric field region 2 spaced from the tube ends and which has an electric field that is cylindrically symmetrical and uniform in the axial direction of the tube when a potential is applied between the cathode and anode electrodes. This region resides mainly in the vicinity of the window 35 and spaced from the ends of the counter.

A second window 45 is disposed on the opposite wall of the counter shell 1. As shown in the drawing, the second window 45 is positioned diametrically opposite to the first window 35 and in alignment with the central anode wire 10. However, this need not be the case since the windows could be located opposite each other on the ends of a chord slightly displaced from a diameter parallel to the chord to prevent incident radiation from impinging directly on the anode wire 16. The second window 45 is constructed in the identical manner with the first window 35, except that its dimensions are slightly longer. That is, the rectangular opening 36A in the shell wall for the second window 45 is slightly longer and wider than the corresponding opening 36 in the first window 35. The reason for this is that the second window permits the escape of wedge-shaped incident radiation from the tube which is not absorbed in the electric field region 2. If only a single entrance window were employed, radiation not absorbed in the electric field region would impinge upon the cathode wall and may release electrons or create photons thereby causing a discharge within the electric field region 2. However, the amplitude of the voltage pulse resulting from such a discharge would not be proportional to the energy content of the incoming radiation. The second window is provided to avoid the foregoing. Radiation not absorbed within the electric field region 2 will pass out of the tube through the exit window 45. Since the X-ray beam diverges slightly from its source, usually the focal spot of an anode in an X-ray tube, a wedge-shaped X-ray beam is produced. The slightly larger exit window enables the escape of this wedge-shaped beam without the beam striking the walls of the tube. Both windows are, of course, located centrally between opposite ends of the shell 1 to maintain the symmetry of the tube and are spaced from the shell ends. The second window may not necessarily be required if one is more interested in an application in which fast counting is desired rather than perfect proportionality.

The tube shown in the drawing may be manufactured in the following manner. An elongated glass tube is sealed to each of the outer ends of the end-pieces 7 and 8. The anode wire 10 is threaded through the shell 1, the aperture 17 of the end-piece 7 and a supporting plate 3. The end-piece 7 and plate 3 are then assembled and inserted into position in a recess 4 at one end of the shell 1. Powder-glass, a slightly-adhesive pasty substance, is spread 11 over the inner surface of the plate 3 and the shoulder 15 of the end-piece 7. Similarly, the mica supporter-member 12 is located centrally between opposite ends of the shell 1 at the opposite end of the shell 1 are assembled, except here, the powder glass paste 11 is applied to the outer side of the mica. The shell 1 is disposed in a vertical position, the left-hand side up, and the bottom mica plate 3 held in position by a clamping member (not shown).

The windows 35, 45 are then simply assembled by placing the thin beryllium foil 39 in the inner recess 37 and placing the mica foil 40 in the outer recess 38. The powder-glass paste 41 is then spread along the periphery of the mica spacer and along the side-walls of the recess 38. The slightly adhesive powder-glass paste maintains the parts in their proper positions.

The thus-prepared tube is thereafter placed in an oven and baked at a temperature and for a time interval sufficient to fuse the powder-glass, during which all of the apertures or openings in the shell, with the exception of the glass tubules on the end-pieces 7, 8 have been vacuum-tight sealed in a single heat processing operation. Moreover, the anode wire 10 is perfectly concentric with respect to the surrounding cathode surface of the shell 1.

Next, the spring 39 is welded to one end of the anode wire 10 and inserted within the end-piece 8. The anode wire 10 extending out of the glass tube is attached to the end-piece 7, still pulled taut, slightly compressing the spring 39, and the tube is collapsed 50 and sealed to the wire 10. Alternatively, the end-piece 7 can be filled with powder glass paste after the spring 39 has been placed in the end-piece 8 and the anode wire 10 inserted through the tube and end-piece 7 and held taut by a clamp. Thereafter, baking of the tube to seal the windows and ends will also seal and fix the anode wire in the tube, thereby eliminating the step of separately sealing a glass tubule to the wire. The sealed-off glass 50 may be enclosed by a metal cap (not shown) welded to the anode wire 10, and serves as the high-voltage terminal connection. The tube sealed to the opposite end-piece 8 is utilized for evacuating the tube and introducing the proper gas-filling, which occurs via the apertures 23 in the side walls of the cylindrical member 20. After the tube has been properly filled, that tube is also collapsed and sealed-off, as shown at 51 in the drawing.

The tube may be filled with any of the well-known gas-fillings for proportional counters or Geiger-Mueller tubes, depending upon its particular application. For X-ray diffraction and spectroscopic work, suitable gas-fillings are the combination of a rare gas, such as neon, argon, krypton or xenon, with an organic quench, such as methane or ethylene.

A particularly useful gas-filling is the one described and claimed in a co-pending application, Serial No. 402,846 filed January 6, 1954, consisting essentially of argon and methanol in the ratio of 79 to 3% and a trace of methylene bromide.

To illustrate operation of the tube of the invention for the detection of low-energy X-radiation, the tube shown in the drawing was filled to a pressure of about 300 mm. of Hg with a gas-filling of about 90% of xenon and 10% of ethylene. A potential of about 1800 volts was applied between the anode wire and the cathode shell. Upon
excitation by copper K-α radiation, of about eight keV, there resulted about a ten millivolt electrical pulse for each absorption event.

The tube construction described above offers the following advantages. It produces voltage pulses in response to incident radiation with a pulse-height discrimination having a half-width approaching the theoretical limit as determined by statistical processes of gas absorption and gas amplification. This indicates that the distribution is not broadened by additional fluctuations caused by poor tube geometry, as is so common in the known tubes. Moreover, the tube is adapted for very fast counting, limited only by the speed of the electrical counter, since it is operated in the proportional region of its discharge characteristic (below the Geiger threshold region) with no dead and recovery time. Still further, this is attained without the use of a highly stabilized power supply, which was heretofore thought necessary for the operation of proportional counters. Stated otherwise, the tube of the invention is less voltage dependent than the known tubes.

A further advantage is that the tube has a long shelf and counting life, as well as being compact, relatively rugged, electrically stable and very reliable. Moreover, as indicated above, its manufacture is relatively simple and rapid, requiring only a single heating operation to practically complete the entire tube; at the same time, perfect concentricity of the cathode and anode, an essential condition of a good proportional counter, is insured. The tube, still further, is excellently adapted for detecting low and medium energy X-radiation, such as found in conventional X-ray spectroscopic and diffraction equipment. In this application, it exhibits excellent linearity and high sensitivity, thereby eliminating the need for expensive and carefully regulated amplifying accessories. While we have described our invention in connection with specific embodiments and applications, other modifications thereof will be readily apparent to those skilled in this art without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A radiation detector comprising an elongated, cylindrical, metal, low and medium energy X-radiation-opaque shell having recesses at opposite ends and an inner cylindrical surface serving as a cathode, a pair of insulating members each seated in a recess at one end of the shell and vacuum-tight sealed thereto, said insulating members having central apertures aligned with each other and with the longitudinal axis of the shell, a pair of end-pieces each seated in an aperture of one of said insulating members and sealed thereto, each end-piece comprising a hollow, elongated, metal member having a shoulder in engagement with the insulating member and a portion inside said shell having a rounded end and a central aperture, an anode wire supported by said end-pieces and passing through the apertures in the rounded ends, and a X-radiation-permeable window for the radiation to be detected located in a side wall of the metal shell, the ends of said window being spaced distances from the adjacent end-pieces at which incoming radiation is confined to a region within the shell exhibiting an electric field which is cylindrically symmetrical and uniform in the axial direction of the shell when a potential is applied between cathode and anode, said window including a metal conductive member positioned so as to define a substantially continuous surface with said cathode surface to maintain the field symmetry within the tube.

2. A radiation detector comprising an elongated, cylindrical, metal, low and medium energy X-radiation-opaque shell having recesses at opposite ends and an inner cylindrical surface serving as a cathode, a pair of insulating members each seated in a recess at one end of the shell and vacuum-tight sealed thereto, said insulating members having central apertures aligned with each other and with the longitudinal axis of the shell, a pair of end-pieces each seated in an aperture of one of said insulating members and sealed thereto, each end-piece comprising a hollow, elongated, metal member having a shoulder in engagement with the insulating member and a portion inside said shell having a rounded end and a central aperture, and uniform in the axial direction of the shell when a potential is applied between cathode and anode, said window including a metal conductive member positioned so as to define a substantially continuous surface with said cathode surface to maintain the field symmetry within the tube.

3. A radiation detector comprising an elongated, cylindrical, metal, low and medium energy X-radiation-opaque shell having recesses at opposite ends and an inner cylindrical surface serving as a cathode, a pair of insulating members each seated in a recess at one end of the shell and vacuum-tight sealed thereto, said insulating members having central apertures aligned with each other and with the longitudinal axis of the shell, a pair of end-pieces each seated in an aperture of one of said insulating members and powder-glass sealed thereto, each end-piece comprising a hollow, elongated, metal member having a shoulder in engagement with the insulating member and a portion inside said shell having a rounded end and a central aperture, a tantalum wire supported by said end-pieces and passing through the apertures in the rounded ends, and a X-radiation-permeable window for the radiation to be detected located in a side wall of the metal shell and powder-glass sealed thereto, the ends of said window being spaced distances from the adjacent end-pieces at which incoming radiation is confined to a region within the shell exhibiting an electric field which is cylindrically symmetrical and uniform in the axial direction of the shell when a potential is applied between cathode and anode, said window including a metal conductive member positioned so as to define a substantially continuous surface with said cathode surface to maintain the field symmetry within the tube.
including a conductive member positioned so as to define a substantially continuous surface with said cathode surface to maintain the field symmetry within the tube.

5. A radiation detector as claimed in claim 4 in which the insulating members and the window are powder-glass sealed to the shell.

6. A radiation detector comprising an elongated, cylindrical, metal, low and medium energy X-radiation-opaque shell having recesses at opposite ends and an inner cylindrical surface serving as a cathode, a pair of insulating members each seated in a recess at one end of the shell and vacuum-tight sealed thereto, said insulating members having central apertures aligned with each other and with the longitudinal axis of the shell, a pair of end-pieces each seated in an aperture of one of said insulating members and sealed thereto, each end-piece comprising a hollow, elongated, metal member having a substantially centrally-located shoulder in engagement with the insulating member and defining a first portion inside said shell and an adjoining conductive member positioned so as to define a substantially continuous surface with said cathode surface to maintain the field symmetry within the tube.

7. A radiation detector comprising an elongated, cylindrical, metal, low and medium energy X-radiation-opaque shell having recesses at opposite ends and an inner cylindrical surface serving as a cathode, a pair of insulating members each seated in a recess at one end of the shell and vacuum-tight sealed thereto, said insulating members having central apertures aligned with each other and with the longitudinal axis of the shell, a pair of end-pieces each seated in an aperture of one of said insulating members and sealed thereto, each end-piece comprising a hollow, elongated, metal member having a substantially centrally-located shoulder in engagement with the insulating member and defining a first portion inside said shell and an adjoining conductive member positioned so as to define a substantially continuous surface with said cathode surface to maintain the field symmetry within the tube.

8. A radiation detector comprising an elongated, cylindrical, metal, low and medium energy X-radiation-opaque shell having recesses at opposite ends and an inner cylindrical surface serving as a cathode, a pair of insulating members each seated in a recess at one end of the shell and vacuum-tight sealed thereto, said insulating members having central apertures aligned with each other and with the longitudinal axis of the shell, a pair of end-pieces each seated in an aperture of one of said insulating members and sealed thereto, each end-piece comprising a hollow, elongated, metal member having a substantially centrally-located shoulder in engagement with the insulating member and defining a first portion inside said shell and an adjoining conductive member positioned so as to define a substantially continuous surface with said cathode surface to maintain the field symmetry within the tube.
surface to maintain the field symmetry within the tube.

11. A radiation detector as claimed in claim 10 in which the conductive member is beryllium.

12. A radiation detector comprising an elongated, cylindrical, chrome-iron metal, low and medium energy X-radiation-opaque shell having recesses at opposite ends and an inner cylindrical surface serving as a cathode, a pair of mica insulating members each seated in a recess at one end of the shell and vacuum-tight sealed thereto, said insulating members having central apertures aligned with each other and with the longitudinal axis of the shell, a pair of end-pieces each seated in an aperture of one of said insulating members and sealed thereto, each end-piece comprising a hollow, elongated, metal member having a substantially centrally-located shoulder in engagement with the insulating member and defining a first portion inside said shell having a rounded end and a central aperture and a second portion outside said shell, a platinum anode wire supported by said end-pieces and passing through the apertures in the rounded ends, and a pair of diametrically-opposed X-radiation-permeable windows for the radiation to be detected substantially centrally located in side walls of the metal shell, the ends of said windows being spaced distances from the adjacent end-pieces at which incoming radiation is confined to a region within the shell exhibiting an electric field which is cylindrically symmetrical and uniform in the axial direction of the shell when a potential is applied between cathode and anode, each of said windows including a mica member sealed to the shell and a beryllium conductive member positioned so as to define a substantially continuous surface with said cathode surface to maintain the field symmetry within the tube.

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