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PHOTOELECTRIC SHIELD INCLUDING A DIELECTRIC SHEET SANDWICHED BETWEEN TWO METAL SHEETS

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FIG. 1

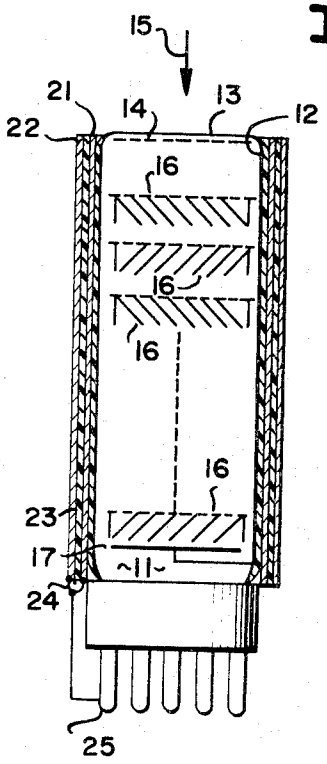


FIG. 2

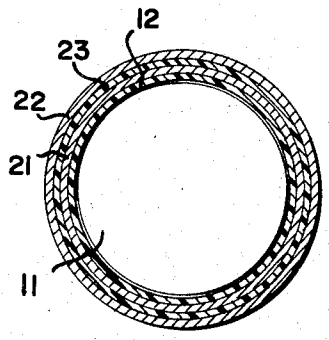
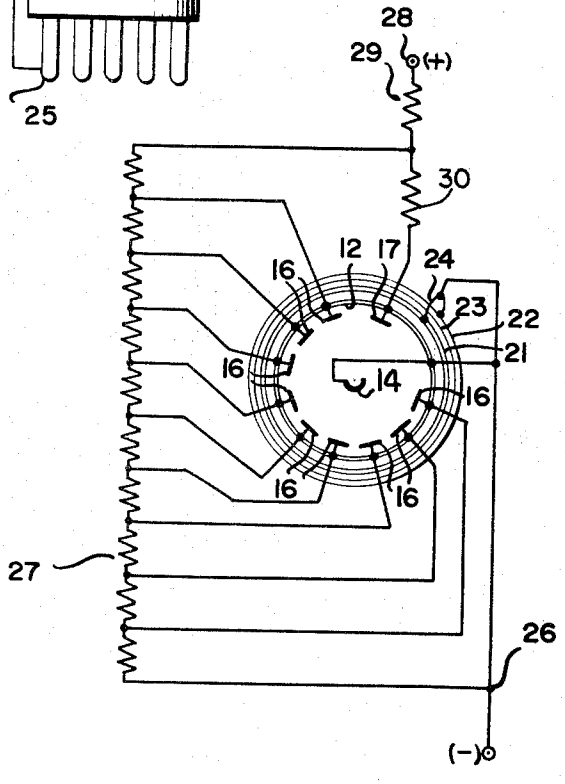


FIG. 3



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PHOTOELECTRIC SHIELD INCLUDING A DIELECTRIC SHEET SANDWICHED BETWEEN TWO METAL SHEETS

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ABSTRACT OF THE DISCLOSURE

A shield for a photomultiplier tube, characterized by a pair of confronting electrically conductive sheets separated by a dielectric, the sheets and separating dielectric encompassing the glass envelope of the photomultiplier tube except for a portion through which the cathode of the photomultiplier is exposed to light. The sheets are electrically connected to one another and to the cathode such that all are at the same electrical potential when the tube is operated, the sheet immediately adjacent the glass envelope acting as a buffer to prevent any leakoff or discharge of electrons next to the glass or through the glass, which might otherwise cause "fluorescence" of the glass and consequent incidence of spurious light flashes on the cathode.

The present invention relates generally to shields for photomultiplier tubes, and more particularly to a shield employing a layer of dielectric material sandwiched between a pair of metal sheets.

It is well known that one of the problems attendant with the use of photomultiplier tubes resides in their high noise level at ambient, room temperatures. The poor signal to noise ratio occurs because the cathode is usually maintained at an extremely large potential difference from equipment surrounding the tube configuration. Because of this extreme potential difference, with the cathode usually maintained at a high negative potential, electrostatic discharge between the cathode and surrounding equipment, generally at ground potential, frequently occurs. In response to electrostatic discharge between the cathode and surrounding equipment, light energy is produced on the surface of the photocathode. This light energy is frequently of greater intensity than the source being sensed so that shot noise occurs in the phototube output.

An attempt to relieve this dilemma has been advanced by employing a single shield, maintained at the same potential as the cathode, and surrounding the tube configuration. It has been found, however, that when the single shield leaks electrons in response to electrostatic discharge to the surrounding equipment, the glass tube envelope fluoresces. In response to fluoresences of the glass tube envelope, light spots are coupled into the photomultiplier structure and result in the derivation of a signal having a poor signal to noise ratio.

Another approach to the problem has been to surround the sides of the photomultiplier tube envelope with a liquid nitrogen refrigeration system. Since shot noise is an increasing function of temperature, it has been found that tolerable signal to noise ratios are achieved by maintaining the tube envelope at approximately zero degrees centigrade. While for many purposes refrigeration achieves a quite satisfactory result, it is always expensive and cumbersome. For many uses, such as for portable equipment, it is completely out of the question. It has been found that the single metal shield, referred to supra, is not sufficiently reliable for most applications unless it is utilized with a refrigeration system.

According to the present invention, a new and improved shield for photomultiplier tubes is provided by employing

a dielectric sheet sandwiched between a pair of metal sheets that serve as electrostatic shields. Both metal sheets are connected to the cathode of the photomultiplier structure, hence to the negative voltage supply for the cathode. The entire shield configuration is placed, in a preferred embodiment, over the tube glass envelope walls so that the inner metal shield serves as a buffer betwen the glass tube envelope and the surrounding equipment. Any electron leakage due to electrostatic fields between the shield and the surrounding equipment is supplied by the outer metal shield rather than the inner shield. Thus, any electrostatic discharge between the outer shield and the surrounding equipment is supplied by the negative DC potential source for the cathode.

In response to electrostatic discharge, any electrostatic field given off by the outer shield, inwardly towards the tube envelope, must pass through the dielectric material separating the inner and outer shields. The field is generally so weak when it reaches the second shield that there is virtually no possibility of its passing through to the tube envelope. In consequence, the problem of glass fluorescing of the tube envelope is obviated. I have found, through experimentation, that the shield of the present invention makes it possible to operate photomultiplier tubes under ambient conditions, rather than under refrigeration at a maximum temperature of zero degrees centigrade.

It is, accordingly, an object of the present invention to provide a new and improved apparatus for maintaining the signal to noise ratio of a photomultiplier at a minimum level.

It is another object of the present invention to provide a new and improved shield for photomultiplier tubes.

It is still another object of the present invention to provide a shield that effectively prevents shot noise from effecting photomultiplier tubes under ambient temperature conditions, and for temperature conditions up to 70 degrees centigrade.

It is still another object of the present invention to provide a new and improved apparatus for maintaining signal to noise ratio of a photomultiplier tube output at an extremely high level without the need for expensive and cumbersome equipment.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a side sectional view illustrating a preferred embodiment of the present invention in combination with a photomultiplier tube;

FIGURE 2 is a top view of the configuration shown in FIGURE 1; and

FIGURE 3 is a schematic diagram illustrating the manner in which the invention is connected with the photomultiplier tube.

Reference is now made to FIGURES 1 and 2 of the drawings wherein there is illustrated a conventional photomultiplier tube **11**, such as manufactured by Mullard. Tube **11** includes a cylindrical glass envelope **12** having a transparent top section **13**, directly beneath which is positioned photocathode **14**. Photocathode **14** is responsive to light, indicated by arrow **15**, directed longitudinally to the axis of tube **11**, to emit electrons. Electrons deriving from photocathode **14** are detected and amplified by the dynode structure **16** which is arranged longitudinally of tube **11**. In a typical photomultiplier tube, nine dynode electrodes **16** are provided, and collector or anode **17** is responsive to the electrons emitted by the secondary emissive dynode most proximate to it.

According to the present invention, the longitudinal

sides of glass envelope 12 are surrounded by a shield structure including cylindrical metal shields 21 and 22 between which is sandwiched a cylindrical dielectric layer 23. Layers 21–23 are bonded together to form a unitary structure having a tubular configuration that in a typical arrangement has a thickness on the order of one eighth of an inch. The thicknesses of metal sheets 21 and 22 are not critical but dielectric sheet 23, which is preferably formed from a high dielectric material such as tetrafluoroethylene (commonly known by the trademark Teflon), nylon, or polyester film (commonly known by the trademark Mylar), must be at least 0.010 inch thick. Metal sheets 21 and 22 may be of any suitable highly conductive metal, such as aluminum or copper. In the alternative, sheets 21 and 22 may be electromagnetic as well as electrostatic shields by being formed of a high permeability material, such as Mumetal. The use of a high permeability shield, to prevent coupling of magnetic fields to the interior of tube 11, is employed in photomultiplier tubes having crossed magnetic and electrostatic fields.

To maintain shields 21 and 22 at the same potential as photocathode 14, the shields are connected to each other at adjacent points by wire 24 that is also connected to pin 25, which extends internally of tube 11 to photocathode 14. It is to be understood, that metal parts 21 and 22 of the shield, as well as wire 24 must be carefully insulated from the remainder of the metal parts on tube 11 so that the various dynode structures 16 and anode 17 are not short circuited to photocathode 14.

Reference is now made to the schematic circuit diagram of FIGURE 3 which illustrates the manner in which the shield of the present invention is connected with the photocathode and the negative DC biasing source employed in a photomultiplier. Photocathode 14 is negatively biased, to a voltage on the order of −1000 volts, by the DC power supply connected to terminal 26. The negative voltage at terminal 26 is also connected to shield members 21 and 22 via the connection through lead 24. Biasing for the nine elements comprising dynode structure 16 is established by connecting voltage divider 27 between terminal 26 and the low positive DC voltage (on the order of 100 volts) at terminal 28. The connection at the low voltage end of voltage divider 27 is made through resistors 29 and 30 to terminal 28 and anode 17 of photomultiplier tube 11. A low voltage signal output, dependent upon the light intensity impinging upon cathode 14, is derived at the junction between anode 17 and resistor 30. This voltage may be amplified, if necessary, or supplied directly to a load that is to be controlled.

In operation, at ambient or room temperatures, there is a tendency for electrostatic discharge of the large negative voltage at cathode 14 to surrounding equipment, that is generally maintained at ground potential. In response to such discharge, light energy impinges upon the photocathode 14 and appears in the output signal of the photomultiplier tube, at anode 17, as shot noise.

According to the present invention, this tendency is virtually obviated for all temperatures up to 70° centigrade. It is obviated because of the double shield configuration employed in the present invention. Instead of electrons discharging between photocathode 14 and the surrounding equipment in the present invention, such discharge occurs from the negative voltage at terminal 26 through outer shield 22 to the surrounding equipment. The electrostatic field produced by outer shield 22 inwardly towards the center of photomultiplier 11, that occurs in response to electrostatic discharge to the surrounding equipment, must penetrate dielectric layer 23 before reaching shield 21. When the electrostatic field impinges upon the outer surface of shield 21 its intensity is quite weak and cannot penerate the second shield from its outer to its inner surface. In consequence, glass envelope 12 does not fluoresce and no shot noise is coupled to photocathode 14. Thereby, the output signal at anode 17 is virtually

devoid of shot noise and a high signal to noise ratio is achieved.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variation of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. A shield for encircling the longitudinal surface of a photomultiplier tube having a photocathode disposed at one end thereof to receive light energy, said shield comprising a pair of metal sheets having sandwiched between them a layer of di-electric material, and means for electrically connecting said two metal sheets together and to said photocathode.

2. The shield of claim 1 wherein at least one of said metal sheets is comprised of a metal having a relatively high magnetic permeability.

3. The shield of claim 1 wherein said dielectric layer is at least 0.010 inch thick.

4. In combination, a photomultiplier tube having a glass envelope and a photocathode disposed within said envelope at one of its ends, a shielding structure encircling a surface of said glass envelope leaving a portion of the envelope unobstructed to expose said photocathode to ambient light, said shielding structure comprising: a pair of metal layers, a dielectric layer sandwiched between said pair of metal layers, and means for electrically connecting both of said metal shielding layers and said photocathode together.

5. The combination according to claim 4 wherein at least one of said metal shielding layers is a high magnetic permeability metal.

6. The combination according to claim 4 wherein said dielectric layer is at least 0.010 inch thick.

7. A shield for preventing electrostatic discharge and shot noise from the photocathode of a photomultiplier tube to surrounding equipment maintained at a potential considerably less than the photocathode, wherein said photocathode is disposed at one end of said photomultiplier tube having a circular glass envelope, said shield comprising a tubular sleeve having three substantially parallel layers, the inner diameter of said sleeve being proportioned to contact the outer edge of the glass envelope without contacting any of the electrodes or terminals of said photomultiplier tube, said sleeve including a pair of metal layers having sandwiched between them a dielectric layer having a thickness of approximately 0.010 inch and means connecting said pair of metal layers and said photocathode to be at substantially the same potential.

8. An electrostatic shield for a photomultiplier tube having a glass envelope and a plurality of electrodes within said envelope, said electrodes adapted to be biased at differing voltage levels, at least one of said electrodes disposed within said envelope for response to incident light energy for emission of electrons to impinge on others of said electrodes, whereby to produce multiple secondary emissions from the others of said electrodes, said shield comprising a pair of coextensive confronting electrically conductive sheets, a dielectric sheet separating said conductive sheets, one of said sheets disposed immediately adjacent and encompassing the exterior surface of said glass envelope except for a region sufficient to permit exposure of said light energy-responsive electrode to ambient light, means electrically connecting said conductive sheets to each other and to said light energy-responsive electrode, said one of said sheets acting as a buffer to prevent electrical discharge adjacent said envelope.

9. The invention according claim 8 wherein said envelope is substantially cylindrical, and said shield has an internal surface conforming to the exterior surface of said envelope.

10. The invention according to claim 8 wherein said dielectric sheet is approximately 0.01 inch thick.

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