Elton Smith

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PHOTOMULTIPLIER TUBE

principle to application

PHOTON is OUR BUSINESS

HAMAMATSU

In high-energy physics applications such as proton decay experiments and cosmic ray detection, photomultiplier tubes are sometimes operated while underwater or in the sea. In this case, a pressure higher than one atmosphere is applied to the photomultiplier tube. The breaking pressure depends on the configuration, size and bulb material of the photomultiplier tube. In most cases, smaller tubes can withstand a higher pressure. However, large diameter (8 to 20 inches) photomultiplier tubes, specifically developed for high energy physics experiments, have a hemispherical shape capable of withstanding a high pressure. For example, 8-inch diameter tubes can withstand up to 7 atmospheres and 20-inch diameter tubes up to 6 atmospheres.

As for the bulb materials, photomultiplier tubes using a silica bulb provide lower pressure-resistance due to the graded seal. There are various shapes of input windows used for head-on photomultiplier tubes, including a plano-plano type (both the faceplate and photocathode are flat), a plano-concave type (the faceplate is flat but the photocathode is concave) and a convex-concave type (the faceplate is convex but the photocathode is concave). Compared to the plano-plano type, the plano-concave and convex-concave types offer higher pressure-resistance.

8. 8 Effects of External Electric Potential

Glass scintillation occurs upon exposure to radioactive rays or UV light, as explained in Section 8.6.2 of Chapter 8. It also occurs when a strong electric field is inside the glass. These glass scintillations cause the dark current to increase.

8. 8. 1 Experiment

Figure 8-15 shows the dark current variations of a photomultiplier tube whose side bulb is coated with conductive paint, measured while changing the electric potential of this coating with respect to the cathode potential.

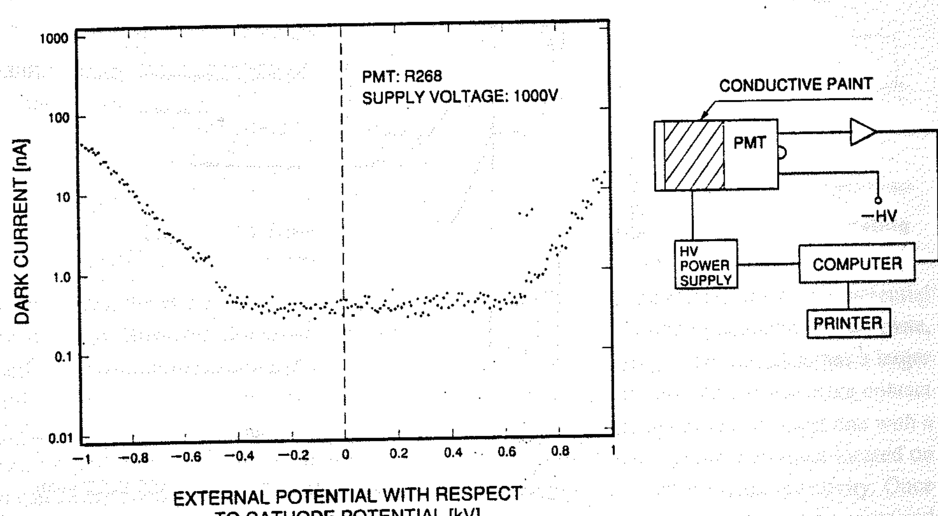
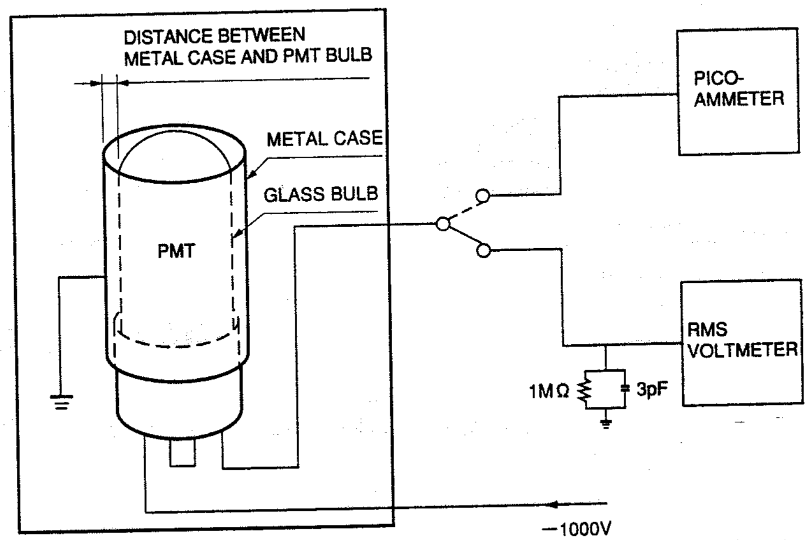


Figure 8-15: Dark current vs. external electric potential

It is clear that the larger the potential difference with respect to the cathode, the higher the dark current. The reason for this effect is that the inner surface of the bulb near the cathode is aluminum-coated and maintained at the cathode potential as explained in Chapter 2, and if the outside of the bulb has a large potential difference with respect to the cathode, glass scintillation occurs there. This scintillation light is reflected into the photocathode, causing an increase in the dark current.

The housing in which the photomultiplier tube is installed is usually grounded. If the photomultiplier tube is operated in the anode grounding scheme with the cathode at a negative high voltage and is installed close to the wall of the housing, the dark current may increase for the same reason. This problem can be solved by allowing an adequate distance between the photomultiplier tube and the inside of the housing. Figure 8-16 shows the dark current variations while the distance between the photomultiplier tube and the grounded case is changed, proving that there is no increase in the dark current when the separation ≧ 4 millimeters.



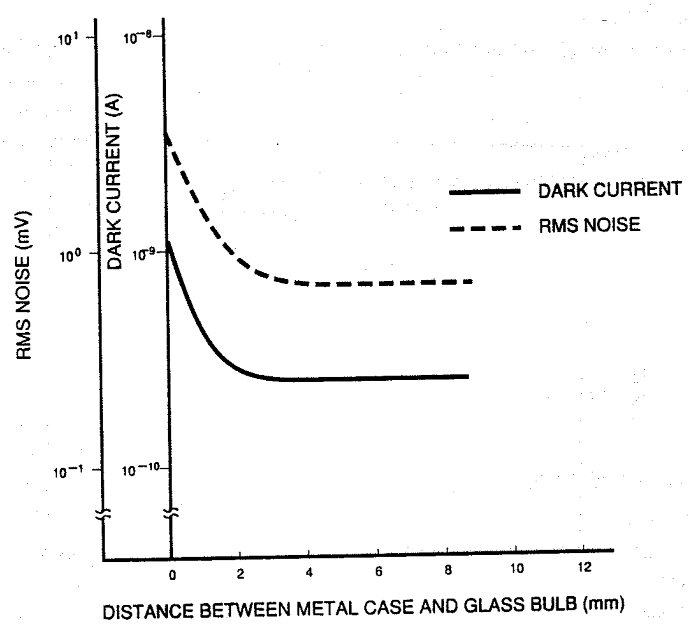


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Figure 8-16: Dark current vs. distance to the grounded case

8. 8. 2 Taking corrective action

The above effects of external electric potential can be eliminated by use of the cathode grounding scheme with the anode at a positive high voltage, but photomultiplier tubes are frequently operated in the anode grounding scheme with the cathode at a negative high voltage. In this case, a technique of applying a conductive paint around the outside of the bulb and connecting it to the cathode potential can be used , as illustrated in Figure 8-17[13].

This technique is called "HA coating" by Hamamatsu Photonics and, since a negative high voltage is applied to the outside of the bulb, the whole bulb is covered with an insulating cover (heat-shrinkable tube) for safety. The noise problem caused by the external electric potential can be minimized by use of an HA coating. Even so, in cases where a metal foil at ground potential is wrapped around the tube, minute amounts of noise may still occur. This effect can be observed using a setup like that shown in Figure 8-18. This noise is probably caused by a small discharge which may sometimes occur due to dielectric breakdown in the insulating cover, which then produces a glass scintillation reaching the photocathode. This problem can be reduced by shifting the metal foil wrapped around the HA coating away from the photocathode toward the bulb stem.

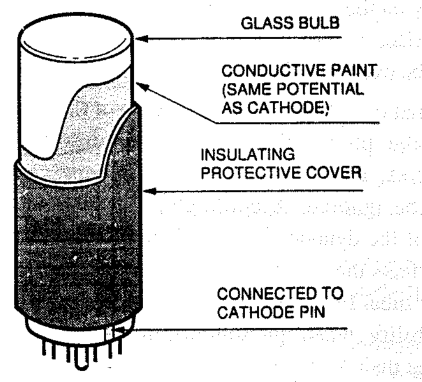

Figure 8-17: HA coating

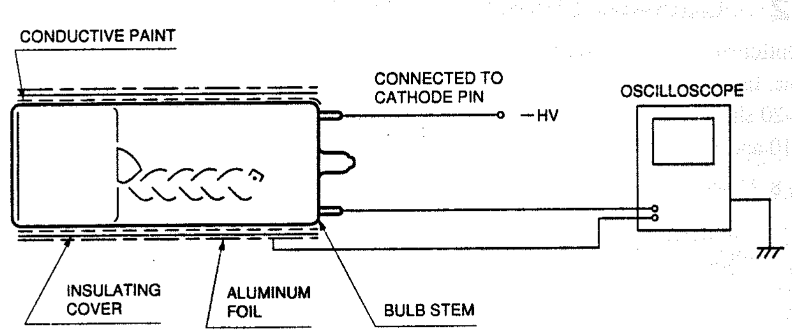

Figure 8-18: Observing the effect of external electric potential on HA coating

As mentioned above, the HA coating can be effectively used to eliminate the effects of external potential on the side of the bulb. However, if a grounded conductive object is located on the photocathode faceplate, there are no effective countermeasures and what is worse, scintillation occurring in the faceplate has a larger influence on the noise. Therefore, any grounded object, even insulating materials, should not make contact with the faceplate. If such a object must make contact with the faceplate, it is necessary to select one with a high insulating properties such as teflon. Another point to be observed is that a grounded object located on the faceplate can cause not only a noise increase but also deterioration of the photocathode sensitivity. Once deteriorated, the sensitivity will never recover to the original level. Thus, particular care must be exercised with regard to the mounting method of the photomultiplier tube.

Taking account of the above effects of external electric potential it is recommended, if possible, that the photomultiplier tube be operated in the cathode grounding scheme with the anode at a positive high voltage.