ET Enterprises electron tubes

technical reprint

R/P084

integral Mumetal[1] shields

Integral Mu-Metal Shields

for reducing photomultiplier sensitivity to magnetic fields

Introduction

The integral, mu-metal shield is an option offered for end window photomultipliers up to 52mm (2 inch), with the following benefits -

- Reduced sensitivity to external magnetic fields
- Minimal dark counts and dark current

It is highly recommended for portable instrumentation operating in the laboratory environment. For equipment manufacturers it eliminates the need for a separate mu-metal shield in all but the most severe environments.

To order this option add suffix S after the type number, e.g. 9924SB or 9924QSA

The Integral Mu-metal Shield

Figure 1 shows the construction of the integral shield. First, a graphite coating is applied to the envelope of the photomultiplier and connected to the cathode pin. Then, a mu-metal shield is wrapped around making electrical contact with the graphite coating. Finally, a protective sleeve of insulating material is fitted over the mu-metal shield for safety reasons. This unobtrusive technique adds less than 1.175 mm to the diameter of a bare photomultiplier (or 0.375 mm to those normally supplied or ordered graphite coated and sleeved).

Figure 2 shows that the dark counts of a photomultiplier are at a minimum when the envelope is held at cathode potential. Any conductor in contact with the envelope of the photomultiplier must be maintained at cathode potential*. This long-standing recommendation from is satisfied in the design of the integral shield.

Reduced Sensitivity to Magnetic Fields

The integral mu-metal shield is sufficient to eliminate the variation in output due to changing the orientation of the photomultiplier in the Earth's field. It also significantly reduces variation due to static and low frequency fields from other sources including transformers, motors, switches and permanent magnets.

In applications where the photomultiplier orientation can vary, the direction of greatest magnetic sensitivity dominates the behaviour. Usually this is where the field is aligned across the length of the first dynode. The sensitivity of the photomultiplier to external fields can be reduced with a cylindrical shield as shown in Figure 3.

This data supercedes that published in the 1993 photomultipliers and accessories catalogue, PMC/93.

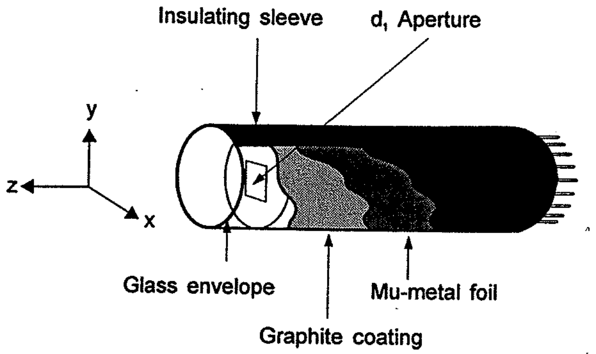

Figure 1

Cut away section illustrating the construction of the integral mu-metal shield. The co-ordinate axes adopted for the photomultiplier are also shown.

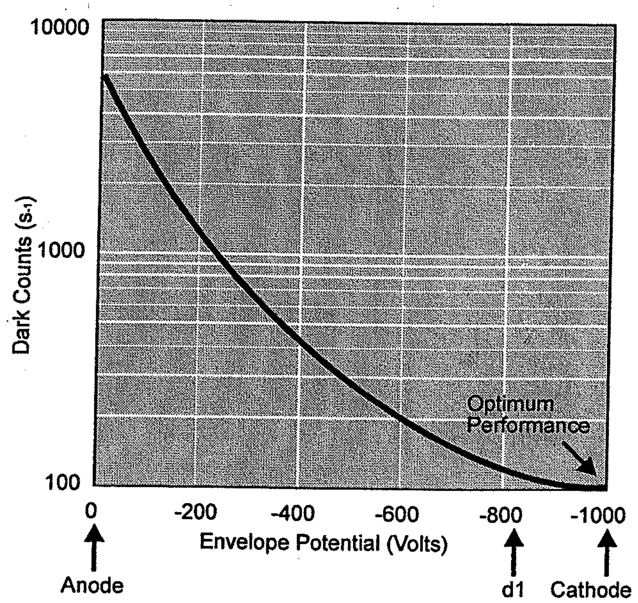

Figure 2

Effect of envelope potential on the dark counts of a 9924 photomultiplier.

* This rule also applies to the window of the photomultiplier,which is particularly relevant when operating the cathode at negative high voltage. Then unstable, high dark counts can often be traced to poor insulation between the window and ground potential. Only PTFE is recommended as an electrical insulator when in contact with the photomultiplier window.

To illustrate the benefits, Figure 4 shows the effect of an integral mu-metal shield for type 9106, typical of the 30 mm diameter linear focused range. The relative output of the photomultiplier is shown as a function of external magnetic field with and without the integral shield. The data are presented with the external field aligned in turn with each of the three mutually orthogonal axes defined in Figure 1.

Before shielding, a field of 0.8 Gauss aligned along the dynodes (y direction) results in a 10 % loss of output. After shielding, the most sensitive direction is axial (z) but the magnitude of the external field causing a 10% loss of output is much greater at 7 to 8 Gauss.

The shielding factor is defined in figure 3. Integral shields are 0.125 mm thick and have a typical relative permeability of 5,000 after wrapping. For a 30 mm diameter photomultiplier the shielding factor is typically 10, in agreement with measurement, as shown in Figure 4 (Y - Axis).

Severe Environments

In regions of high magnetic field, the combination of the integral shield with our range of formed mu-metal shields is recommended. The formed shield, isolated from the photomultiplier by the insulating sleeve may be grounded regardless of the potential of the cathode.

Formed shields are 0.5 mm thick and have a typical relative permeability of 30,000 due to annealing. For a 30 mm diameter cylinder the shielding factor is typically 250.

ET Enterprises also offer non-standard integral or formed shields in volume applications, tailored to specific requirements.

Note** This rule also applies to the window of the photomultiplier particularly relevant when operating the cathode at negative high voltage. Then unstable, high dark counts can often be traced to poor insulation between the window and ground potential. Only PTFE (Teflon) is recommended as an electrical insulator when in contact with the photomultiplier window.

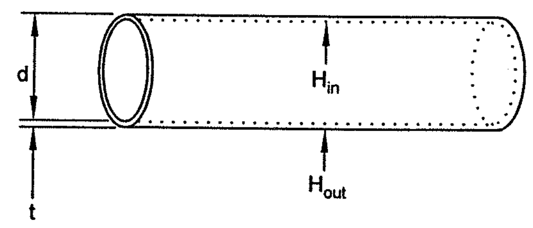

Figure 3

The transverse component of the magnetic field inside a mu-metal cylinder (H_{in}) is a fraction of the external field (H_{out}). For a cylinder of diameter d, wall thickness t and relative permeability μ, the shielding factor is $H_{out} / H_{in} = \mu t / 2d$

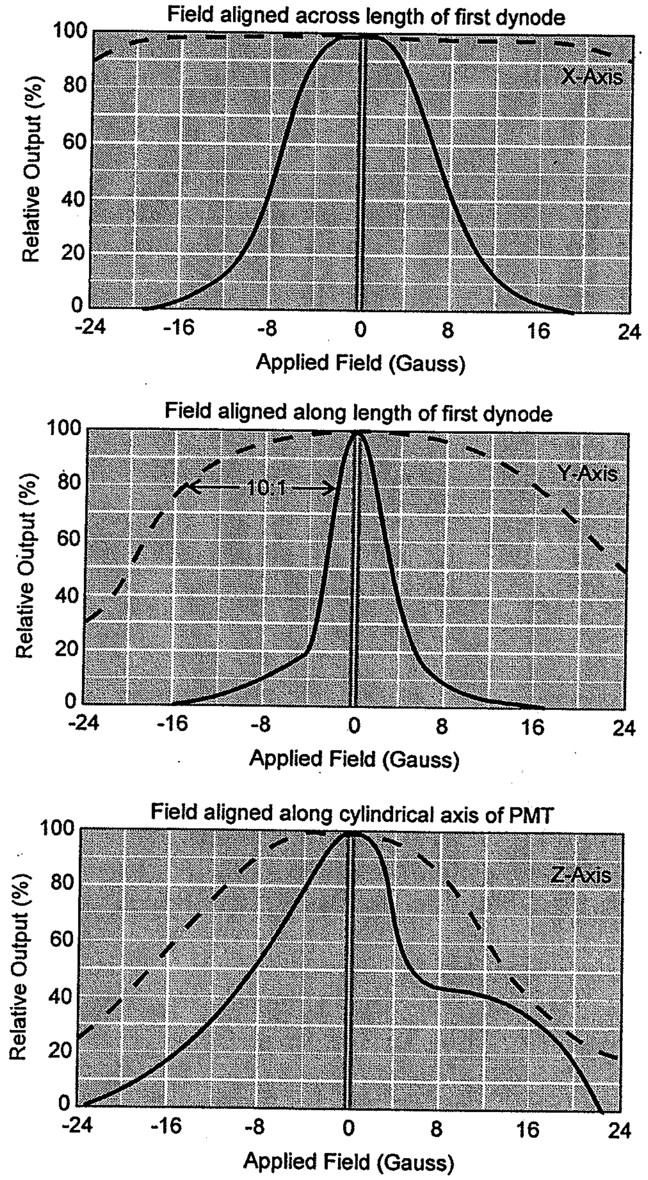

Figure 4

Demonstrating how a wrapped mu-metal shield reduces the sensitivity of a 9106 photomultiplier to external magnetic fields:
—— unshielded; – – – wrapped shield; ▒ +/- earth's field.

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