HIGH SENSITIVITY BF₃ PROPORTIONAL COUNTER TYPE WL-7087

The WL-7087 is a high sensitivity, multielement, proportional counter designed to detect thermal and intermediate speed neutrons in the flux range from 2.5 x 10⁻² to 2.5 x 10³ neutrons/cm²/second. The tube is provided with a 7 foot length of RG-149/U cable sealed into the case for electrical connections. The WL-7087 is hermetically sealed although it is not designed to withstand the galvanic erosion caused by water immersion. The WL-7087 is extremely rugged and will operate in any position and at temperatures not exceeding 175°F.

The WL-7087 consists of four proportional counter units surrounded by a polyethylene moderator block and enclosed by a heavy-walled aluminum cylinder. The elements are one inch in diameter and twenty-eight inches long and are located symmetrically in the case. Each counter employs BF₃ enriched to 96% in Boron-10 isotope as the neutron sensitive material resulting in an overall sensitivity for the WL-7087 of approximately 40 counts/neutron/cm² with an operating voltage of 2000 volts.

MECHANICAL:

Maximum Diameter ................. 5-7/8 Inches
Approx. Overall Length ............ 39-1/2 Inches
Approx. Sensitive Length .......... 26 Inches
Net Weight ....................... 36-3/4 Pounds
Approx. Shipping Weight .......... 100 Pounds

MATERIALS:

Body ................................ Aluminum
Center Electrodes of each Unit .... 0.001" Diameter Tungsten
Insulation .......................... Polyethylene & Alumina
Gas Filling ......................... BF₃ Enriched 96% B-10

MAXIMUM RATINGS:

Absolute Maximum Values
Voltage Between Electrodes  ...... 2500 Volts
Operating:
Thermal Neutron Flux ............. 2.5 x 10³ n/cm²/sec
Temperature ...................... 175 °F
Non-Operating:
Thermal Neutron Flux ............. 4 x 10² n/cm²/sec
Gamma Flux ....................... 10⁴ R/hr
Temperature ...................... 175 °F

TYPICAL OPERATING CHARACTERISTICS:
Voltage Between Electrodes  ...... 2000 Volts
Neutron Flux Range ............... 2.5 x 10⁻² to 2.5 x 10³ n/cm²/sec
Multiplication Factor ............. 500
Sensitivity ....................... 40 counts/n/cm²
Plateau Characteristics:
Length (Minimum) ................. 200 Volts
Overall Slope ................. (less than) 4 Per Cent
Output Pulse Characteristics:
Magnitude ....................... (more than) 10⁻⁹ Volts
Inherent Rise Time ........... (less than) 5 x 10⁻⁸ Seconds

* When in flux levels exceeding the recommended operating range, the tube should be shunted with a maximum resistance of 1.5 megohms, and the operating voltage removed.
† These characteristics will vary depending on associated circuitry. For application details, see page 3.
TYPICAL OPERATING CHARACTERISTICS

**Figure 1**
VOLTAGE CURVE FOR BF$_3$ COUNTER

**Figure 2**
INTEGRAL BIAS CURVE FOR BF$_3$ COUNTER

**Figure 3**
MULTIPLICATION CURVE FOR BF$_3$ COUNTER

**Figure 4**
NEUTRON RESPONSE OF BF$_3$ COUNTER UNDER CO$_{60}$ GAMMA IRRADIATION
BF₃ PROPORTIONAL COUNTER-INSTRUMENTATION

This section describes instrumentation associated with the proportional counter, which must provide
1. A method of applying the operating voltage
2. A method of removing the pulse and amplifying it to a useable level.

The output pulse from a proportional counter tube is of negative polarity and is formed by the external circuitry.

As the tube is normally located at a distance from the instrumentation, coaxial cable must be employed to transmit the pulse from the tube to the amplifier. For lengths of cable less than 25 feet, cable effects may be neglected. However, for lengths greater than 25 feet, capacitive effects become significant and must be cancelled. This will be discussed in detail later.

A block diagram indicating the general requirements of the BF₃ proportional counter is shown in CE-A1328.

The BF₃ proportional counter is operated with the center wire positive and the outer cylinder negative. As the outer cylinder is electrically part of the tube, it should be operated at ground potential.

Amplifier input circuitry will vary according to the application.

EFFECT OF AMPLIFIER INPUT CHARACTERISTICS ON PULSE SIZE AND SHAPE

The output of the BF₃ counter, is essentially a sharply rising waveform with rise time less than 5 x 10⁻⁶ seconds. The extremely high resistance of the counter tube permits the accumulated charge to remain, thus presenting to the external circuitry the appearance of a step. In a proportional counter the charge formation is local in nature, i.e., the discharge takes place in a limited area within the tube and, hence, a relatively small charge is formed. This can be contrasted with a Geiger counter where the discharge for a single particle is distributed along the length of the center wire and the output pulse may have heights as great as 200 volts. The height of this step voltage change in the BF₃ counter may be as low as 10⁻³ volts. Voltage steps will vary as a function of applied voltage even when the tube is operated on the plateau. The external circuit converts these step functions into pulses.

Gamma radiation causes secondary emission from the gas and metal parts of the tube. Pulses of a lower magnitude are formed and these must be considered in amplifier designs.

Under the following circuit conditions employing a length less than 25 feet of RG 149/U (C = 22 ufd/ft) pulse heights vary from one to six millivolts as the voltage applied to the tube is varied from 1950 to 2250 volts. Note that the high voltage is fed through a high impedance in CE-A1329.
SPECIAL CONSIDERATIONS

If cable lengths greater than 25 feet are required, cable capacity undesirably influences the pulse formation and transmission. Termination in a high impedance to obtain high magnitude pulses becomes difficult as the cable appears as a capacitive element across the tube. To minimize long cable effects, it is desirable to terminate the cable in its characteristic impedance to make the cable appear as a purely resistive element. Since the characteristic impedance is usually low, it becomes obvious that the pulse height is greatly reduced since it is now developed across a lower value of resistance. Additional amplifier gain is required to compensate for this reduced pulse amplitude which is on the order of 20:1. Gamma pulses will correspondingly decrease.

GENERAL AMPLIFIER REQUIREMENTS

The maximum count rate at which the tube will satisfactorily operate is about $3 \times 10^5$ counts per second. This is a mean frequency. The separation of pulses varies statistically, and generally speaking, an amplifier of 2 megacycle bandwidth will suffice for normal application of the BF$_3$ proportional counter.

In order to distinguish between neutron events, it is necessary to decay the pulse rapidly to prevent overlap. A 0.8 microsecond decay time is satisfactory for most applications and this decay is usually accomplished at the input of the linear amplifier. When high impedance terminations are employed (with short cables), it is customary to provide either a cathode follower or a preamplifier with a high impedance input and perform the differentiation at the output of the preamplifier or the input of the main amplifier. As differentiation is substantial when a low impedance termination is used, the wisdom of additional pulse shaping will depend upon the particular circuit employed.