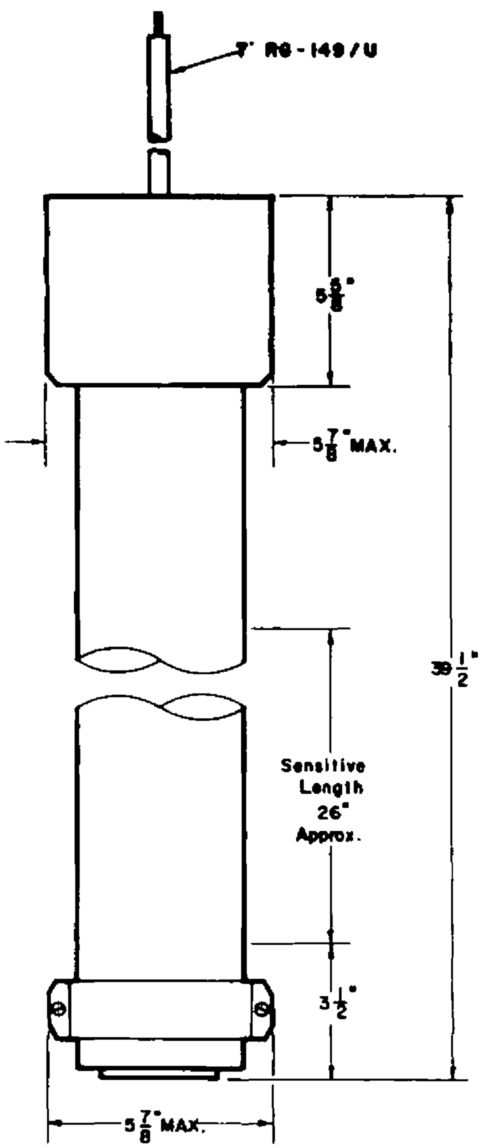
October 1, 1957

HIGH SENSITIVITY BF_3 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 2.5×10^{-2} to 2.5×10^{3} neutrons/cm^2/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 symetrically in the case. Each counter employs BF_3 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/cm^2 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	BF_3 Enriched 96% B-10

MAXIMUM RATINGS:

Absolute Maximum Values

Voltage Between Electrodes	2500	Volts
Operating:		
Thermal Neutron Flux	2.5×10^3	n/cm^2/sec
Temperature	175	°F
Non-Operating: ⊕		
Thermal Neutron Flux	4×10^9	n/cm^2/sec
Gamma Flux	10^4	R/hr
Temperature	175	°F

TYPICAL OPERATING CHARACTERISTICS:†

Voltage Between Electrodes	2000	Volts
Neutron Flux Range	2.5×10^{-2} to 2.5×10^{3}	n/cm^2/sec
Multiplication Factor	500	
Sensitivity	40	counts/n/cm^2
Plateau Characteristics:		
Length (Minimum)	200	Volts
Overall Slope (less than)	4	Per Cent
Output Pulse Characteristics:		
Magnitude (more than)	10^{-3}	Volts
Inherent Rise Time (less than)	5×10^{-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.

from JETEC release #2028, Oct. 28, 1957

TYPICAL OPERATING CHARACTERISTICS

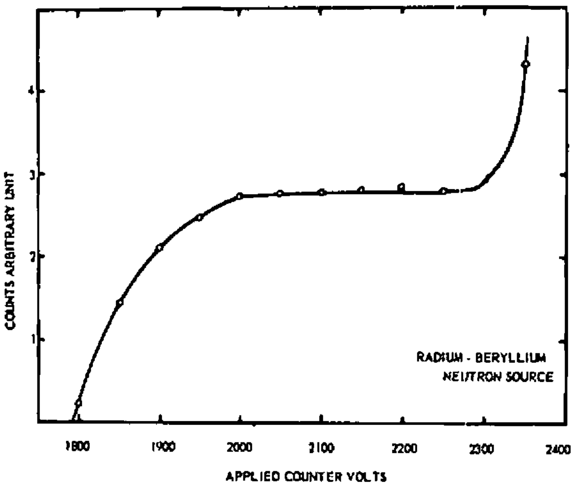


Figure 1
VOLTAGE CURVE FOR BF_3 COUNTER

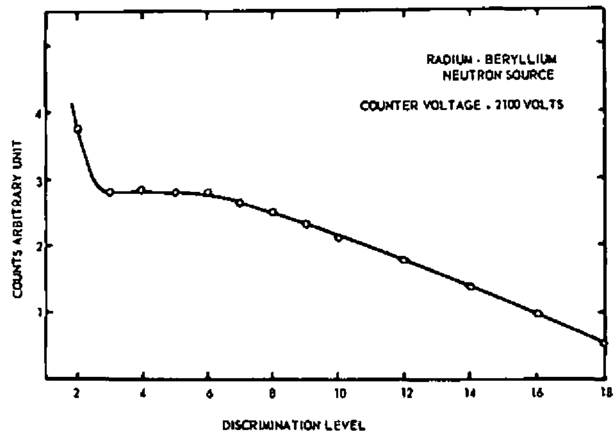


Figure 2
INTEGRAL BIAS CURVE FOR BF_3 COUNTER

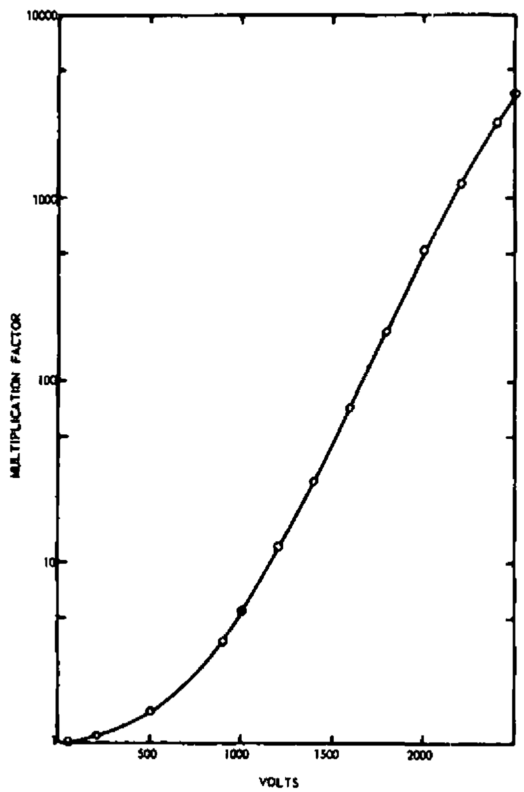


Figure 3
MULTIPLICATION CURVE FOR BF_3 COUNTER

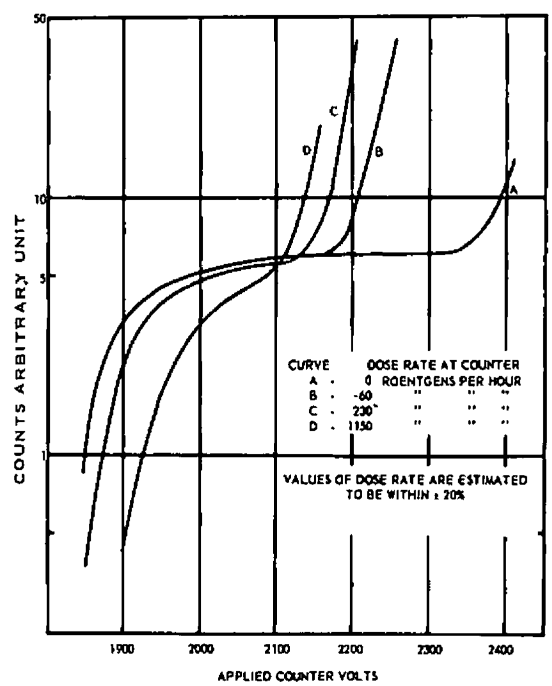


Figure 4
NEUTRON RESPONSE OF BF_3 COUNTER UNDER CO^{60} GAMMA IRRADIATION

BF_3 PROPORTIONAL COUNTER-INSTRUMENTATION

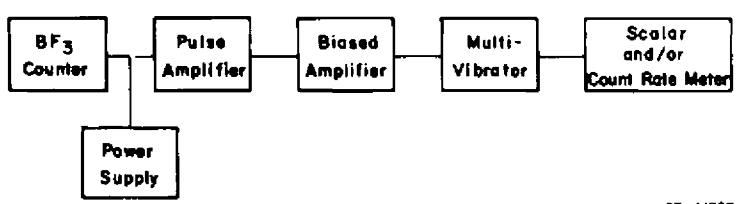
This section describes instrumentation associated with the proportional counter, which must provide -

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 BF_3 proportional counter is shown in CE-A1328.



CE-A1328

The BF_3 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.

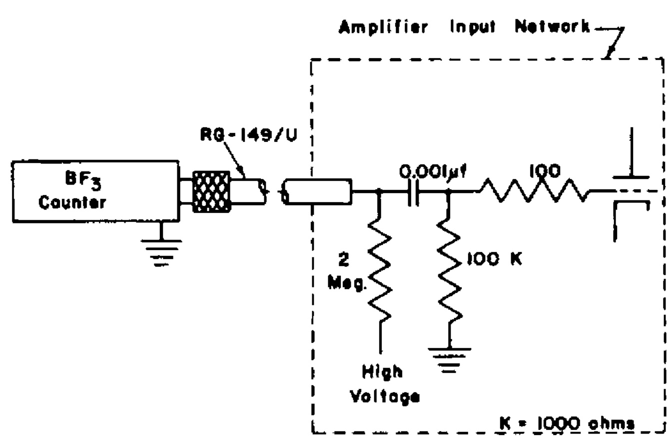
Amplifier input circuitry will vary according to the application.

EFFECT OF AMPLIFIER INPUT CHARACTERISTICS ON PULSE SIZE AND SHAPE

The output of the BF_3 counter, is essentially a sharply rising waveform with rise time less than 5×10^{-8} 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 BF_3 counter may be as low as 10^{-4} 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.

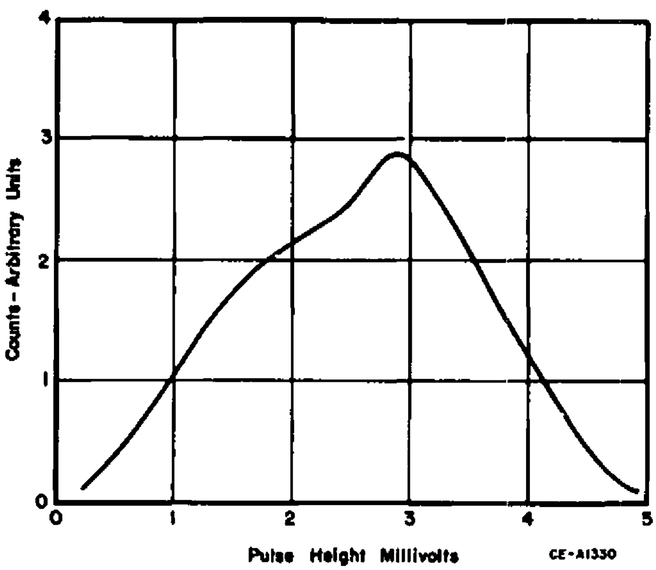
Gamma radiation causes secondary emission from the gas and metal parts of the tube. Pulses of a lower magnitude are formed and these must be considered in amplifier designs.

Under the following circuit conditions employing a length less than 25 feet of RG 149/U (C = 22 uuf/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.



CE-A1329

PULSE HEIGHT DISTRIBUTION

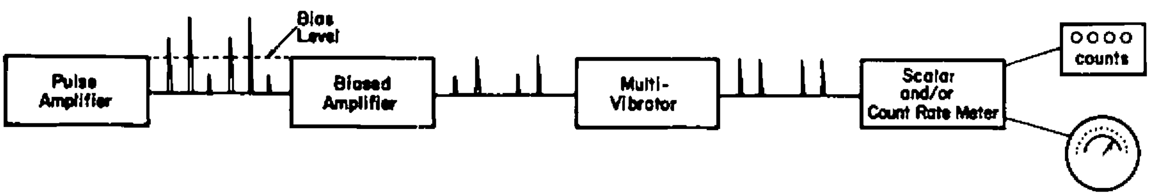


CE-A1330

The pulse height will not only vary as the applied voltage, but while operating at a specific voltage, say 2000 volts, the pulse height will be distributed over a range. At 2000 volts the pulse height distribution will vary from approximately .5 mv to 3.5 mv as shown in CE-A1330.

Pulses due to gamma radiation will increase in approximately the same fashion, but are about 1/20 the size of the average pulses due to neutron events.

In typical circuitry, gamma pulses are discriminated in a biased amplifier stage which will amplify only pulses greater than the selected bias value. This discriminator circuit drives a one shot multivibrator whose output is a pulse of constant magnitude. The bias of the discriminator circuit is adjusted so that only the high magnitude pulses are selected to drive the multivibrator. The multivibrator output pulses drive a scalar and/or count rate meter as shown in CE-A1331.



CE A1331

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 3×10^5 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 .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.