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Characteristics of a boron-coated proportional neutron counter in the corona zone

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Characteristics are given for a boron-coated, argon-filled counter for thermal neutron detection which is operated proportionally in the corona zone. Application of short signal clipping times (2 μsec) and the use of high-valued anode load resistors (~100 megohms) result in counting plateaux extending 2 kv above corona threshold with mean slope less than 0·5% per 100 v.

1. Introduction

Operation of coaxial wire-cylinder argon counters in the corona zone as proportional detectors of α- and β-particles has been described previously by Colli *et al.* (1952). It is found that in the region of stable, self-sustained corona discharge, which commences at some tens of volts beyond the upper limit of the Geiger plateau, constant gas multiplication factor exists over a range of several microamps of corona current; the corresponding variation in anode–cathode potential difference is of the order of several hundred volts. The condition for maintenance of the corona is given by

$$\gamma M \geqslant 1 \qquad (1)$$

where M is the gas multiplication factor for electrons and γ is the probability per avalanche electron that a secondary electron will be produced at the cathode by the action of photons and positive ions generated in each avalanche.

Constancy of multiplication factor with increasing corona current has been explained qualitatively by Loeb (1953). It is considered that the electric field in the electron-multiplying region close to the anode wire is held constant by positive ion space charge neutralization of over-potential beyond corona onset. Colli *et al.* (1954) have theoretically investigated the dynamic behaviour of the corona discharge following α-particle ionization and have obtained experimental confirmation.

Proportional counting in the corona zone is attractive since operation at maximum gas gain, independent of variation in counter e.h.t. voltage, is available. In such a counter, however, the minimum amount of particle ionization that can be detected in practice is limited by the amplitude of fluctuations in corona current (background corona noise). Again, the very good α-particle pulse-height distributions obtained by Colli *et al.* (1952) for their detectors were from well-collimated paraxial tracks. In practical applications, uncollimated α-particles emitted from coated cathodes can be expected to give inferior amplitude distributions for reasons of cathode curvature and space charge saturation effects which reduce gas multiplication for the more radial tracks.

The characteristics of an argon-filled corona-proportional counter developed for thermal neutron detection by the reaction $^{10}_{5}B(n,\alpha)^{7}_{3}Li$ are given in §2. Signal-to-noise ratio for the detector is high and collimation is such that $^{7}_{3}Li$- and α-particle pulses are resolvable.

2. Counter characteristics

A counter was constructed with a nickel cathode cylinder (2·2 cm in diameter, 24 cm long) and tungsten wire anode (0·2 mm in diameter) mounted coaxially in a soda-glass envelope. A thin layer of unenriched elemental boron was deposited previously on the cathode by thermal decomposition of diborane gas (Hurd 1952). The counter was filled with welding-grade argon containing 0·1% nitrogen to a pressure of 725 mmHg after outgassing at 420° C for several hours under vacuum. Thermal neutrons were provided by a 10 mc Ra–Be source set in paraffin wax moderator. γ-radiation from radium was attenuated by lead shielding.

Oscillograms of typical negative-polarity anode pulses due to α-particles are shown at various corona currents in figure 1

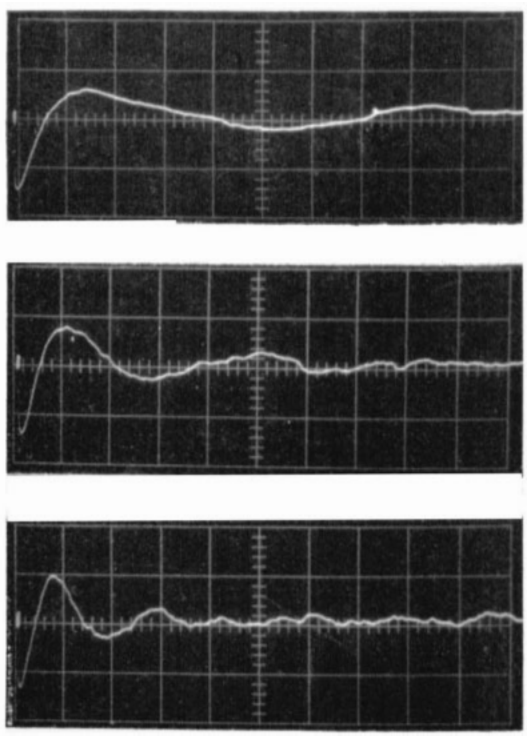

Figure 1. Oscillograms of α-particle pulses from $^{10}_{5}B(n,\alpha)^{7}_{3}Li$ at the anode of a corona-proportional counter at various corona currents (upper 1 μA, middle 5 μA, lower 10 μA). Time scale 50 μsec cm^{-1}, amplitude sensitivity 15 mv cm^{-1}. Pulses have been RC clipped at 5 μsec time constant.

(an anode load resistor of 110 megohms was used in this and all subsequent measurements). These pulses were subject to RC clipping at 5 μsec time constant prior to display. It is seen that a low-frequency transient oscillation accompanies each pulse, and that the frequency of oscillation increases with corona current. This is a characteristic of corona counters and arises from the regenerative nature of the corona discharge (Colli *et al.* 1954); the corona plasma is shocked into current oscillations by the rapid build-up of charge at the anode which follows α-particle ionization of the counting volume.

Figure 2 shows plots of integral neutron count against pulse-height discriminator bias voltage at 1, 5 and 10 μA

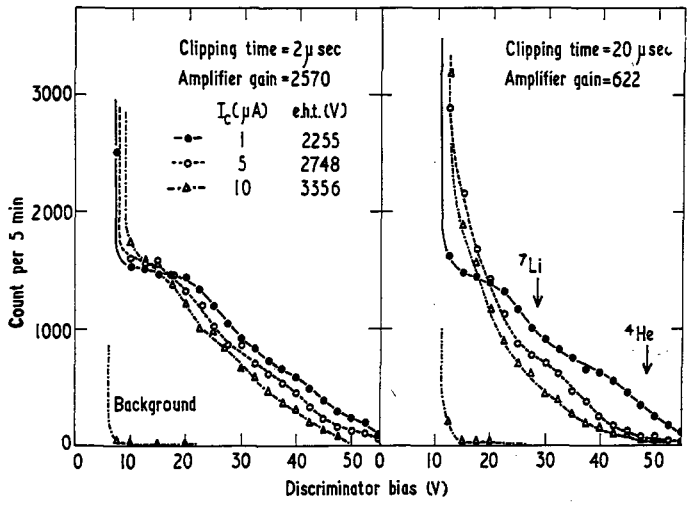

Figure 2. Neutron count rate against pulse-height discriminator bias at various corona currents. RC clipping of counter pulses at short time constant improves the stability of the count-bias plateau with changing corona current.

corona current. Pulses were RC clipped at the counter anode prior to amplification and count-bias plots at 2 and 20 μsec clipping time constant were taken. At longer time constant (20 μsec) the shape of the count-bias plateau degenerates with increasing current due to spurious counting of oscillations. As the corona current increases, the oscillatory signal is less attenuated by the RC clipping network and count rate increases, particularly at low bias settings. True count rate was registered when a dead-time of 200 μsec was inserted in the count recorder unit. For 2 μsec clipping time constant (of the order of the rise time of the fast initial step in the anode pulse) the count-bias plateau is more stable, although there is some decrease in mean pulse height at higher corona current indicating a lower gas multiplication factor.

Figure 3 shows the variation of neutron count rate (discriminator bias setting = 15 v, see figure 2) and corona current with counter e.h.t. supply voltage. The improved plateau slope which results from hard RC clipping is obvious. The count plateau at 2 μsec clipping time constant is 2 kv long with a mean slope less than 0·5% per 100 v.

In the application of corona-proportional counters it is best to use the highest practical value for the anode resistor R_L in order to take advantage of the corona-stabilizer action of anode–cathode potential which arises from this mode of counter operation. Since the differential corona resistance R_C is nearly constant with corona current, any increase in counter e.h.t. supply voltage, ΔV_S say, will be diminished to $\Delta V_S R_C/(R_L + R_C)$ at the anode. The range of e.h.t. supply voltage over which the gas multiplication factor is constant can therefore be increased by making $R_L \gg R_C$. For the counter studied here, $R_C \simeq 10$ megohms and $R_L = 110$ megohms.

It was found that oxidation of the cathode surface in the present counter raised the threshold for corona ignition from 2150 v to 2400 v. This was due to a decrease in efficiency of secondary electron emission by positive ions at the cathode; the factor γ of equation (1) was reduced and M as a consequence increased. At higher M values the rise of the anode

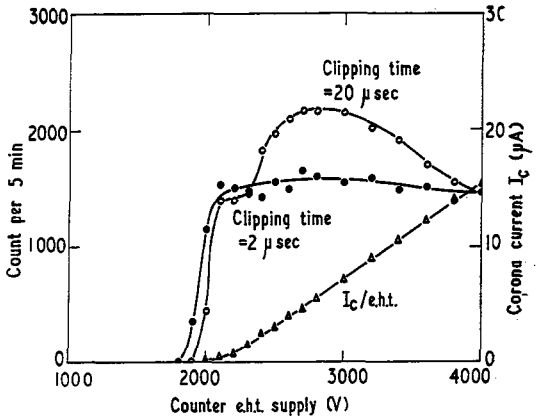

Figure 3. Variation of neutron count rate and corona current with counter e.h.t. supply voltage. Discriminator bias set at 15 v (see figure 2).

pulse was no longer smooth but had a repetitive signal superposed on it. This signal arose from the regenerative feedback of avalanche photons to the cathode and showed a periodicity which corresponded to the time for photoelectrons to transit from cathode to anode ($\simeq 2$ μsec).

3. Conclusions

The operation of an argon-filled proportional counter in the corona zone for the detection of neutrons by the reaction $^{10}_{5}B(n,\alpha)^{7}_{3}Li$ is feasible. Signals are discrete from corona current noise and very long count against e.h.t. plateaux at low slope are displayed.

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Notes and news

Institute of British Photographers

The Medical Group of the Institute of British Photographers will hold their 12th Annual Conference from 20th–22nd September 1962 at the Royal College of Surgeons, Lincoln's Inn Fields, London, W.C.2.

The conference is open to all interested, whether members or not of the Institute, and will cover the uses of photography in the medical, biological and veterinary fields.

A suggested title and a 20-word precis are required in the first instance for any papers which may be submitted. These should be sent to the Conference Convenor, Mr. N. K. Harrison, 38 Bedford Square, London, W.C.1, from whom further information about the conference can also be obtained.

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We have received notice from the International Nickel Company (Mond) Limited that they have produced two new publications featuring educational services now available.

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This is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., price 50 cents.

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We have recently received notice of the following new publications of the British Standards Institution:

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B.S. 1613: 1961—*Method of determining the resolving power of lenses for cameras.* 5*s.* B.S. 3403: 1961—*Indicating tachometers for general use.* 6*s.* B.S. 3406: Part 1: 1961—*Methods for the determination of particle size of powders, Sub-division of gross sample down to* 0·2 *ml.* 6*s.* B.S. 3425: 1961—*Measurement of noise emitted by motor vehicles.* 3*s.*

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