SHORT NOTE

Characteristics of a Proportional Counter Provided with Multiple Cathode Wires

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1. Introduction

A proportional counter is a radiation detector utilizing gas multiplication, so that large pulse-height can be obtained from radiations of low energy. At the present time, this type of counter is the only detector that permits measurement of pulse-height distributions due to an ion pair.

As is commonly known, the factors that limit the pulse-height resolution of the counter are (1) fluctuations of primary ion pairs in ionizing processes, and (2) fluctuations in the size of the avalanches produced by individual primary electrons near the collector electrode. The latter can be evaluated through measurements of pulse-height distribution due to single electrons released in a sensitive volume of the counter. And the distribution thus determined may be utilized for studies of the fundamental characteristics of a proportional counter.

In the present study, the pulse-height distribution due to single electrons were measured on a counter provided with multiple cathode wires arranged symmetrically to the collector electrode instead of the usual co-axial cylindrical cathode, and the relation between the distribution and the mean gas multiplication factor was examined. The relation between pulse-height resolution and energy was also studied by varying the thickness of the collector electrode and the number of cathode wires. Such practical data are not abundantly available at present.

2. Experimental and Results

A cut-away view of the counter and a block diagram of the measuring system are given in Figs. 1 and 2, respectively. The window of the counter was covered with thin aluminized mylar sheet 12 µ thick. A mixture of 90% Ar and 10% CH₄ (P-10 gas) was used as counting gas under atmospheric pressure. Single electrons generated by a low-pressure mercury lamp and introduced into the counter through an aluminized mylar window. To attract the electrons toward the sensitive part of the counter, an electric potential of 18 V was applied to the cathode wires and the outer case was grounded. Counting rates between 50 and 10 cps (counts per second) were set.

Fig. 1 Cut-away view of proportional counter provided with multiple cathode wires

Fig. 2 Block diagram of measuring system

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were chosen so as to diminish the pile-up effect of the signal pulses.

The pulse-height distributions due to single electrons were measured on counters with various thicknesses of collector electrode (electrode diameter $d_c=30, 50$ and $100\mu$) and the number of cathode wires ($n_c=4$ and 16). The distance $r_{ac}$ between the collector electrode and the cathode wires was fixed at $6\,\text{mm}$ throughout the experiments. Some representative results were given in Fig. 3-(a) and -(b). In the figure, the abscissa represents the number of electrons collected on the central electrode.

The mean gas multiplication factor was also measured by means of a low energy X-ray source ($^{55}\text{Fe}$) and a precision mercury pulser. The results of these measurements were compared with the mean electron number derived from the distribu-

![Fig. 3 Pulse-height distribution due to single electrons](image-url)
The pulse-height resolution in the region of low energy was measured for the same parameters as above. The X- and γ-ray sources used were $^3$H-Zr (Zr-LX: 2.04 keV), $^3$H-Ti (Ti-KX: 4.51 keV), $^{55}$Fe (Mn-KX: 5.98 keV), $^{57}$Co (Fe-KX: 6.49 keV, γ-ray: 14.4 keV), and $^{109}$Cd (Ag-KX: 22.1 keV). The results are given in Fig. 4. In this figure, the dotted curves represent the familiar relation, $R \propto E^{-1/2}$ (R denotes pulse-height resolution, and E the energy in keV).

### Table 1

<table>
<thead>
<tr>
<th>$n_c$</th>
<th>$d_c$</th>
<th>$V_{cent}$ (V)</th>
<th>$M_{ef}$</th>
<th>$M_{ef}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>30μ</td>
<td>1.750</td>
<td>0.64 (×10⁵)</td>
<td>0.99 (×10⁵)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.900</td>
<td>2.8</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>50μ</td>
<td>1.940</td>
<td>0.67</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.000</td>
<td>1.2</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>100μ</td>
<td>2.285</td>
<td>0.66</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.355</td>
<td>1.05</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1.840</td>
<td>0.92</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.880</td>
<td>1.5</td>
<td>0.70</td>
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<tr>
<td></td>
<td></td>
<td>1.930</td>
<td>1.5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

3. Discussion and Conclusion

The probability that a single electron was introduced into the sensitive volume of the counter during the multiplication process triggered by the preceding one was estimated below 1% considering the maximum pulse width and counting rate. It is seen from Figs. 3-(a) and -(b) that, in the case of P-10 gas, the distribution did not possess the maximum reported by several investigators. As the applied voltage was increased, the distribution did not change in form similarly in the two cases, and the curve was deformed at large pulse-heights. In other words, the shape of the distribution showed a tendency to vary with gas multiplication factor. The average electron number of the distribution may determine the gas multiplication factor $M_{ef}$. The values of $M_{ef}$ calculated from the distributions are given in the line 4 of Table 1. The corresponding values of $M_{ef}$, estimated by using a $^{55}$Fe source and a precision mercury pulser are also given in the line 5. The two data agree with each other fairly well. The present results prove that a large multiplication factor can easily be obtained with thinner collector electrode and by increasing the number of cathode wires. The relation between pulse-height resolution and energy shows large deviation from $E^{-1/2}$ in the case of 4 cathode wires, but fair coincidence with $E^{-1/2}$ in the case of 16. In the latter case, no significant difference was found from a counter provided with co-axial cylindrical cathode in so far as concerns practical performance. Similar results were also found for the case of 8 cathode wires. It can be expected that, in the case of $r_{ce}=6$ mm, counters with 8 cathode wires or more would possess characteristics common with counters provided with co-axial cylindrical cathode. It is clear from the Fig. 4 that differences in the thickness of the collector electrode did not influence the relation between pulse-height resolution and energy.

Gas multiplication may be influenced by the deviations from radial homogeneity of the electric field near a collector electrode. The sources of such non homogeneity to be considered include (1) the deviation of electric field due to use of multiple cathode wires, (2) that due to displacement of the collector electrode, (3) that due to displacement of cathode wires, (4) that due to surface roughness of the collector electrode. Ana-
Analytical calculations indicated that the first and the second sources would contribute errors of at most $10^{-5}$ and $10^{-2}\%$, respectively. The third source was found liable to cause $0.85\%$ deviation for a displacement of $1\text{mm}$. Quantitative estimation of the last-mentioned source of deviation could not be made in the present experiment, but microscopic examination indicated an error of several percent. In the measurement of low energy radiation, the last source is serious, and is probably the largest factor influencing gas multiplication.

--- REFERENCES ---


