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On the Proportional Counter

By

Masateru Sonoda

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Introduction

When the cylindrical counter ordinarily used is operated under the threshold of the Geiger-Müller region, there is a certain range of voltage in which the charge accumulated on the central wire is proportional to the primary ionization. This is called the proportional counter and can discriminate the nature of the incident particles by the amount of ionization. It has recently been used widely because of its various advantages.

I. α-Proportional Counter

The cylindrical proportional counter was investigated by several workers,[1] but it had a serious disadvantage that the amplification factor is very sensitive to the small change of the applied voltage.[2] It was, however, found by Korff and Rose[3] that the amplification factor became a slowly changing function of the applied voltage when the comparatively large amount of methane or other complex gas was used and the proportional counter could be successfully used if the applied voltage was sufficiently stable.

This counter has the following advantages:

(1) It has a small pulse-width and accordingly a better resolving time than the ionization chamber of an ordinary Wynn-Williams type owing to its higher applied voltage.

(2) In the proportional counter, a certain amplification is performed in the counter itself and therefore the pulse height on the collector is greater than in the Wynn-Williams ionization chamber. Accordingly the large counter can be used without making the pulse height too small by its large capacity which is very convenient for the observation of very rare events.

(3) Furthermore, the amplifier can be simplified and that of four stage is sufficient.

We have investigated for these several years the various photonuclear effects by the γ-rays from the (Li–p) or (F–p) reactions.[4] In these cases, the very rare events must be counted under the intense γ-ray background. The large proportional counter was found suitable for such investigations and so its properties were investigated.

Construction

The details of the counter are shown in Fig. 1. The counter wall W is made of aluminium of 1 mm in thickness and has the inner diameter of 6.25 cm and the length of 26 cm. The collector C is a tungsten wire of 0.15 mm in diameter and is supported at both ends by the cupper poles P of 3 mm in diameter which jet out about 3 cm into the inner tube. S is an outer aluminium cylinder of 10 cm in diameter which is grounded to shield the counter from the outer electrical disturbances. There is the guard ring G between the central wire and the counter wall on which the negative high tension is applied so that the surface leakage from the counter wall may always be earthed not so as to reach the collecting wire. The other constituent parts are similar to those of the Geiger-Müller counter.

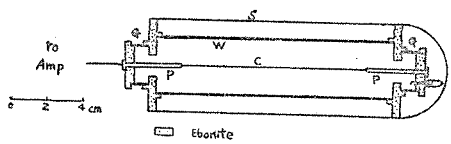

Fig. 1.

Amplifier Circuit

The amplifier adopted is a four stage resistance capacity coupling type and is shown in Fig. 2. It is a simplified form of the linear amplifier used with the ionization chamber.[5] The central wire of the counter is connected directly to the control grid of the first valve 6C6 or 6SJ7, which is earthed through a high resistance of the order of $10^8 \sim 10^9$ ohms and a small bias cell. The second and third valves are also 6C6 or 6SJ7 and the fourth one is a power valve UZ 42 or 6F6.

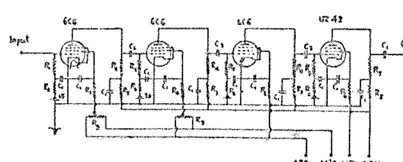

Fig. 2.

$R_2 = 10^6\,\Omega$	$R_8 = 1\,\mathrm{K}\Omega$
$R_3 = 20\,\mathrm{K}\Omega$	$R_9 = 10\,\mathrm{K}\Omega$ Potentiometer
$R_4 = 250\,\mathrm{K}\Omega$	
$R_5 = 500\,\mathrm{K}\Omega$	$C_1 = 2\,\mu\mathrm{F}$
$R_6 = 50\,\mathrm{K}\Omega$	$C_2 = 0.0001\,\mu\mathrm{F}$
$R_7 = 7\,\mathrm{K}\Omega$	$C_3 = 0.001\,\mu\mathrm{F}$

The amplification factor is controlled by the slight change of the screen grid potential of the first or second valve. It is desirable to control both potentials complementarily in order to avoid the unwanted disturbances of linearity.

Each stage of the amplifier is mounted in a separated iron case in order to eliminate the electric disturbances. The linearity of the amplifier was tested by the pulse of known voltage from a pulse generator.

The high voltage supply of an ordinary Gingrich type[6] was used which was capable of giving a very stable voltage up to 5000 volts.

Characteristic Curve

According to Rose and Korff,[3] it is necessary to adsorb the photo-quanta and suppress the photoelectric effect in the counter by filling it up with a certain amount of complex gas such as methane, in order to obtain a reliable proportional counter. We have adopted the mixture of methane and argon gas and investigated its counting properties for different mixing ratios and various values of total pressure under an intense γ-ray background.

As an α-ray source, we used a piece of pitchblende or active deposit from Tn placed at a given distance from the counter. The α-particles were introduced into the counter through a thin aluminium window of 2 mg/cm^2 in thickness. The intense γ-ray background was produced by a 5.4 mg Radium in a lead case of 6 mm in thickness placed at a distance of 7.1 cm from the center of the counter. The number of the incident γ-ray quanta was estimated to be of the order of 4×10^7 per sec.

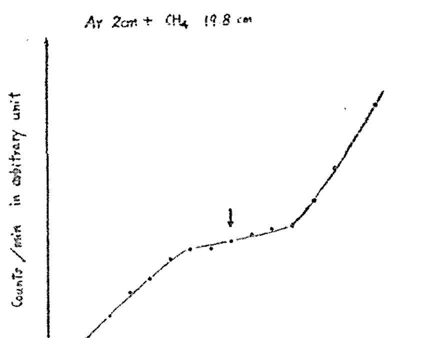

Fig. 3 a.

A typical characteristic curve was shown in Fig. 3 a for the case of Ar 2 cmHg + CH_4 19.8 cmHg. It is seen from the figure that the counting rate increases rather rapidly at first and then the rise becomes gradual in some region of applied voltage.* In this region, the rate of rise is about 15~20% and therefore the counter can be practically used,

* This region can be called "plateau" as in the case of the Geiger-Müller counter, although it is not so flat as that of the latter case.

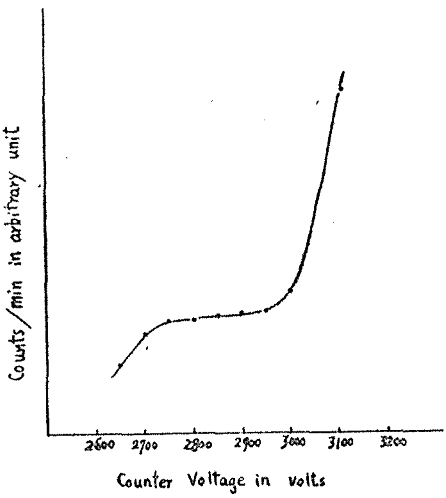

Fig. 3 b.

if the high tension supply is sufficiently stable. The arrow indicates the voltage at which the counter begins to become sensitive to the pile-up of the γ-ray quanta. We will call this point the γ-point hereafter.

The plateau is displaced as a whole to the higher voltage for the greater value of the total pressure. Argon is not always necessary. It seems, however, that the plateau region becomes wider and the operating voltage decreases when a small amount of argon is added. On the contrary, the amount of methane must be greater than a certain lower limit (about 2 cmHg).

These are shown in Figs. 4 and 5. Fig. 4 gives the relation between the plateau and the total pressure when the partial pressure of argon is maintained at 2 and 0 cmHg (no argon) respectively. Fig. 5 shows the plateau against the mixing ratio of both components at the total pressure of 10 and 7 cmHg. The γ-point is indicated as the cross and the dotted line in both figures. As is seen, the γ-point falls on the region of plateau for a high pressure and therefore the relatively smaller pressure is preferable to detect α-particles or protons under such intense γ-ray background.

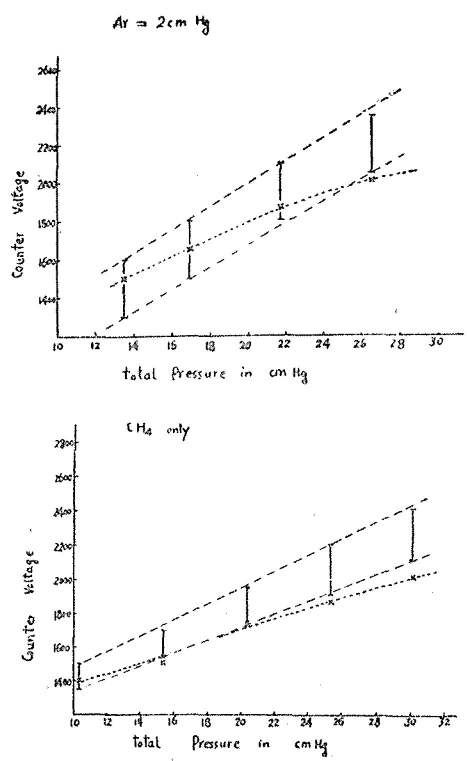

Fig. 4.

The methane gas can be replaced by the vapor of alcohol. Although similar characteristic curves are obtained in this case, alcohol vapor is not so convenient as methane gas, since its vapor pressure is very sensitive to the room temperature.

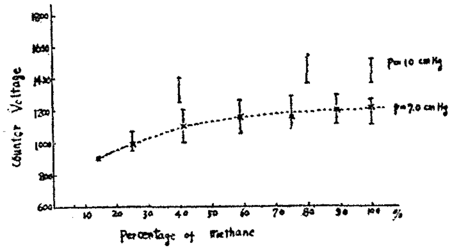

Fig. 5.

II. α–Proportional Counter of Flow Type

Recently J. A. Simpson[7] devised the α-proportional counter which operated at the atmospheric pressure, the methane gas having been flowed through the counter from the commercial bomb at the atmospheric pressure. Since it has no need of evacuation, it is convenient especially when the counter wall must be coated with various samples.

The properties of this counter were also investigated by us. The construction of the counter was similar to the one shown in Fig. 1, except that the gas inlet and outlet were provided in this case, through which the methane gas flowed into and out from the counter. The diameter of the central wire is smaller and namely 0.1 mm in order to diminish the operating voltage. The method of operation will be described in detail in the next section.

The characteristic curve is shown in Fig. 3 b. The rate of rise in the plateau is smaller than in the case of the ordinary type.

III. β–Proportional Counter of Flow Type

We have applied Simpson's method to the β-proportional counter and obtained the satisfactory results. This β-ray proportional counter of flow type has the various advantages. Since it has no need of evacuation, it can be used immediately after putting together. The window can be made extremely thin or, if necessary, can be removed entirely and the sample to be measured can be directly put on the aperture of the counter. Thus we can measure the β-particles of very low energies. The counter of this type will be very convenient for the tracer of low energy β-activity such as C^{14} or S^{35}.*

* The energies of β-rays are 0.15 and 0.16 MeV respectively.

Construction

The details of the counter are shown in Fig. 6. It is an end window type. A brass tube of 2 mm in thickness, 2 cm in diameter and 4 cm in length, is mounted by an ebonite insulator in an outer cylinder. The outer cylinder is 4.4 cm in diameter and 6 cm long, and is grounded in order to prevent the electrical disturbances from imposing on the central wire. The central wire used is so fine that we can diminish the operating voltage as possible and namely 0.075 mm in diameter. It is supported at one end by a small brass pole of about 3 mm in diameter which is put 1 cm into the inner tube. A small glass ball of about 0.5 mm in diameter was attached to the other end of the central wire to eliminate sparking and situated 3 mm beneath the end plane of inner tube to minimize the end effect of the electric field. This value was experimentally determined after several tests. The window is a thin collodion foil of 0.18 mg/cm^2 * and 3.5 cm in diameter, and 3 mm apart from the end plane of the inner cylinder.

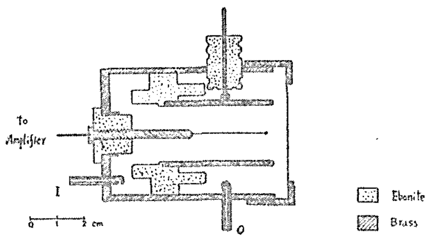

Fig. 6.

The ebonite insulator which supports the inner tube and the one through which the high tension lead is connected to the counter tube must have the large surfaces as possible in order to minimize the leakage. I and O are the gas inlet and the gas outlet respectively. The holes through which the gas flows into and out from the counter are situated on the sides of the inlet and outlet pipes to avoid the probable impairment of the ebonite surface caused by the direct impact of the stream of gases. Careful attentions were payed to every constituent part as described in the previous paper on the γ-ray counter.

Operation and Characteristics

The manner of operation is schematically shown in Fig. 7. The methane gas flows into the counter through the inlet I and out from the outlet O. F is a glass bottle filled with vacuum pump oil at the height of about 2 cm through which the methane gas is bubbled and serves as a simple flow meter which indicates the flow rate of the gas.

* This thickness corresponds to the β-ray energy of 7.6 KeV.

S is the same bottle as F, but contains more amount of oil, namely at the high of about 10 cm. C_1, C_2, C_3 and C_4 are the cocks. In the state of operation, all the cocks are opened and the methane flows through the counter and the flow meter. The bubbles are seen in the flow meter F but not in the bottle S, because the higher pressure is necessary to bubble through S. If the pressure of the methane gas rises suddenly by an accident, the gas will flow through S and the thin foil of the window will be protected from breaking. Namely, S is a simple safety valve. In the actual operation, the amount of oil in S and F must suitably be adjusted, taking account of the strength of the foil.

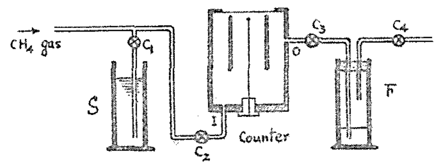

Fig. 7.

Before operating, the counter must be cleaned for about one hour by flowing methane gas so rapidly that the air in the counter may be prefectly removed. We see that the threshold voltage decreases gradually after the beginning of the flow and finally it becomes to a constant value. Then, during the operation the flow is diminished to a rate of 20 or 30 bubbles per minute through a hole of 1 mm in diameter.

The characteristic curve obtained is shown in Fig. 8, when 1 mg Radium source within a 6 mm lead shield was placed at the distance of 107 cm from the counter. It is not affected by the atmospheric conditions such as the pressure or the temperature. The curve rises at first more rapidly and then the rise becomes gradual in the voltage range from 3600 to 3800 volts in our case. In this range the rate of rise is about 15% and therefore the counter can be practically useful if the high voltage supply is sufficiently stable. The natural background is about 11.4/min at the middle of the plateau. The amplifier is the same as that shown in Fig. 2.

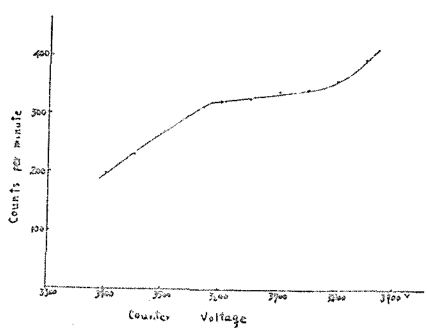

Fig. 8.

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Institute of Physics,
University of Kyoto