The Preparation and Efficiency of the Fast Geiger-Müller Counter

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The dependence of the efficiency of the fast Geiger-Müller counter upon the partial pressures of argon and alcohol is investigated. No change in the efficiency of an argon-alcohol counter is found when the pressure of the argon is changed from 11 cm to 74.5 cm; furthermore a change exceeding 0.5 percent is incompatible with the results.

I. INTRODUCTION

IN the course of a recent investigation[1] we had occasion to use a large number of Geiger-Müller counters in anticoincidence. The use of many counters required that a simple method of preparation should be employed, and their use in anticoincidence required that they should have efficiencies as nearly as possible one hundred percent. The present paper describes briefly the preparation of the counters and the measurement of their efficiencies. The result of the work is to show that the argon-alcohol counter filled without careful chemical treatment of the counter sheath is as efficient as any other type of counter.

II. THE PREPARATION AND PROPERTIES OF THE COUNTERS

Nearly 100 counters were used and they were all of the copper-in-glass type[2] with the cathode a bright copper sheath or 0.1-mm thickness and the anode a tungsten wire of 0.1-mm diameter. The sheath was cleaned by rubbing over with a rag soaked in benzene. The counters varied in diameter from 3.0 to 3.5 cm and in length from 20 to 80 cm. They were filled immediately they came from the glass blower with a mixture of argon (11 cm) and alcohol (1.5 cm) and then sealed off, the whole operation for each counter taking only one quarter of an hour. Counters so prepared had the following properties:

1. Efficiency: 99.5 percent (see Section III).
2. Starting potential: 1000 volts.
3. Length of plateau: 300 volts.
4. Anode-cathode resistance could be as low as 20,000Ω.

Counters of this type were in continuous use for two years without appreciable changes in their properties. Trost,[3] the discoverer of the argon-alcohol counter, was the first to use the simple method of preparation we have adopted but his method seems subsequently not to have been followed except by Curran and Petrzilka.[4] Other workers in this field, notably Neher,[2] Shonka,[5,6] Locher,[7] Loeb,[8] and Collie[9] recommend methods involving the careful cleaning of the counters with acid, frequent rinsings with water and baking on the pump or in the presence of gases rich in oxygen. Many of these more elaborate procedures result in reliable counters but it would appear from our experience that most of the chemical treatment is unnecessary.

III. THE MEASUREMENT OF THE EFFICIENCY OF A COUNTER

There are two reasons why an ionizing particle may pass through a counter without being recorded.

1. The particle may not produce an ion because of fluctuation. An ionizing particle produces about 40 ion pairs per cm path in air at N.T.P. or approximately 5 ion pairs per cm in the gas of a counter filled at 10-cm pressure. Thus the path of a particle through the sensitive volume of a counter must exceed several millimeters in length or there is an appreciable chance of no ion being produced. This effect was

[1] L. Jánossy and G. D. Rochester, Nature **148**, 531 (1941); Proc. Roy. Soc., in press.
[2] J. Strong, *Modern Physical Laboratory Practice* (Blackie & Son Ltd., London, 1940), chapter VII, p. 268, fig. 9.
[3] A. Trost, Zeits. f. Physik **105**, 399 (1937).
[4] S. C. Curran and V. Petrzilka, Proc. Camb. Phil. Soc. **35**, 309 (1939).
[5] Quoted by J. Barton Hoag, *Electrons and Nuclear Physics* (Chapman & Hall Ltd., 1938), p. 432.
[6] F. R. Shonka, Phys. Rev. **55**, 24 (1939).
[7] G. L. Locher, Phys. Rev. **55**, 675 (1939).
[8] L. Loeb, *Fundamental Processes of Electrical Discharges in Gases* (John Wiley & Sons, New York, 1939), p. 500.
[9] C. H. Collie and D. Roaf, Proc. Phys. Soc. **52**, 186 (1941).

first observed by Danforth and Ramsey.[10] The decrease in the efficiency of a counter with decrease in pressure reported in Section V (see Table II) is due to this cause.

2. The counter is insensitive to ionizing particles for a definite time after each discharge. This insensitive time is of the order of 10^{-3} sec. for an argon-alcohol counter.

The most important cause of lack of efficiency is (2). The efficiency of a counter is defined as the probability of the counter responding to an ionizing particle crossing the sensitive volume and it has been measured by many observers.[6, 11–13] In the present instance the efficiency was measured by the apparatus illustrated diagrammatically in Fig. 1. The counter under test, A', was placed between C and D of a threefold coincidence set BCD. Counters B, C, and D were 20 cm long and A' and A 40 cm long. The coincidence set BCD was shielded from side-showers by a bank of 14 counters, A, connected with A' to an anticoincidence set. The anode-cathode resistance for A' and A was 20,000Ω and the coupling condenser 100μf. The pulses from the anticoincidence counters were amplified by a three-stage, resistance-capacity amplifier, mixed with the pulses from BCD and then passed on to a Rossi anticoincidence set[14] which had an efficiency of 100 percent. Since every ionizing

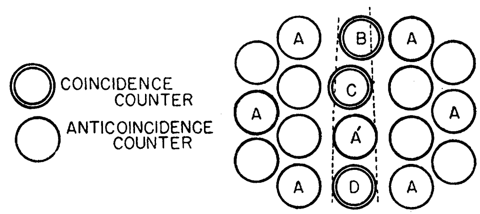

FIG. 1. Arrangement of counters.

particle crossing BCD had also to cross A', every coincidence BCD should have been accompanied by a discharge in A' if A' was 100 percent efficient and no anticoincidence $BCDA'$ should have been recorded. Thus the efficiency of the counter was given by

$$\epsilon = [1-(BCDA'/BCD)]\ 100 \text{ percent},$$

where $BCDA'$ was the rate of anticoincidences and BCD the rate of the coincidences.

In a detailed experiment the efficiency of one counter was found to be 99.3±0.1 percent after correcting for casual coincidences B, C, D which simulate anticoincidences. All other counters used in the investigation were tested and nearly all had efficiencies exceeding 99 percent.

TABLE I. Counter data.

Observer and reference	Type	Dimensions d (cm)	l (cm)	Filling	Total pressure (cm Hg)	ϵ %
Street and Woodward[11]	Copper in glass	3.8	13.0	Air	8	95*
Ehmert and Trost[12]	Brass in glass	4.5	14.2	Argon-Alcohol (90%–10%)	10	100 ±0.3*
Shonka[6]	Copper in glass	4.1	38.0	Air or H_2	7–10	98*
Neher[2]	Copper in glass	7.0	?	Argon-Xylene (95%–5%)	6–10	100 ±1†
Rose and Ramsey[13]	Copper in glass	1.0	15.0	Argon-Oxygen (94%–6%)	9	97
Rochester and Janossy	Copper in glass	3.0	40.0	Argon-Alcohol (90%–10%)	12.5	99.3 ±0.1*

* Corrected for accidentals and side showers.
† Not stated if corrected for accidentals and side showers.

IV. COMPARISON OF THE EFFICIENCIES OF DIFFERENT TYPES OF COUNTERS

The efficiencies of different types of counters are given in Table I from which it is seen that the argon-alcohol counter has the highest efficiency; it is therefore the most suitable counter for use in anticoincidence experiments. The slight differences in the results for different argon-alcohol counters are probably due to the differences in the dimensions of the counters and the different conditions under which the efficiencies have been measured.

V. THE DEPENDENCE OF THE EFFICIENCY OF THE ARGON-ALCOHOL COUNTER ON THE PARTIAL PRESSURES OF ARGON AND ALCOHOL

Five counters ($l=40$ cm, $d=3$ cm) were placed one above the other in a vertical plane. The counters had a common exhausting tube by which the pressure could be changed easily. If the efficiency of a counter filled at a pressure p was $\epsilon(p)$ and the rate of fivefold coincidences at p was $R(p)$ the ratios of the efficiencies at two

[10] W. E. Danforth and W. E. Ramsey, Phys. Rev. **49**, 854 (1936).
[11] J. C. Street and M. H. Woodward, Phys. Rev. **46**, 1029 (1934).
[12] A. Ehmert and A. Trost, Zeits. f. Physik **100**, 553 (1936).
[13] M. E. Rose and W. E. Ramsey, Phys. Rev. **59**, 616 (1941).
[14] B. Rossi, L. Jánossy, G. D. Rochester, and M. Bound, Phys. Rev. **58**, 761 (1940).

pressures p and P were

$$\epsilon(p)/\epsilon(P)=[R(p)/R(P)]^{1/5}.$$

Putting

$$\epsilon(P)=100,\quad \epsilon(p)=[R(p)/R(P)]^{1/5}\,100.$$

A rough survey was first made of the change in efficiency of a counter with the pressure of argon or alcohol. The results are given in Table II, the efficiencies recorded in the last column being relative to the maximum efficiency.

A comparison of the efficiencies of counters filled with (*a*) argon at 11 cm and alcohol vapor at 1.5 cm and (*b*) argon at 74.5 cm and alcohol vapor at 1.5 cm was then made. Alternate readings were taken for several days with the fivefold set first filled with the mixture (*a*) and then with the mixture (*b*).

Fluctuations in the intensity of the cosmic beam due to changes in barometric pressure, etc., during the course of the experiment were compensated for by setting up near the fivefold set a threefold set of sealed counters, and comparing the ratio of the fivefold to the threefold ratio at the two argon pressures. The results are given in Table III from which it is seen that the efficiency does not change when the pressure of argon is

TABLE II. Dependence of efficiency on pressure.

Pressure of alcohol vapor (cm)	Pressure of argon (cm)	Pressure of air (cm)	Count	Fivefold rate (c. per min.)	Relative, efficiencies % ($\epsilon(p)$)
0.25			very short plateau, unstable		
1.00			1044	7.8±0.2	91
2.00			1157	11.7±0.3	98
3.00			very short plateau, counter unstable		
4.00					
1.0	1.8		215	10.3±0.7	96
1.0	11.0		434	12.7±0.6	100
2.0	11.0		483	12.7±0.6	100
2.5	10.5		3920	12.8±0.2	100
2.5	50.0		7270	12.6±0.2	100
4.0	10.0		very short plateau, counter unstable		
2.5		1.0	1694	12.2±0.3	99

TABLE III. Efficiency dependence on argon pressure.

Pressure of alcohol (cm)	Pressure of argon (cm)	Counts Fivefold	Counts Threefold	Ratio: Fivefold: Threefold
1.5	11.0	71426	62645	1.140±0.0054
1.5	74.5	50480	44243	1.141±0.0065
			Difference	0.001±0.008

increased from 11.0 cm to 74.5 cm. Excluding fluctuations which exceed four times the standard deviation it is concluded that a change in the efficiency of the fivefold set by more than $4\times 0.008=3$ percent, or a change of 0.6 percent in the efficiency of an individual counter, is incompatible with the observations. This result is not in agreement with the results of Stever,[15] who in a recent paper predicts theoretically the direct proportionality of the insensitive time of a counter and the pressure. Since the insensitive time σ is related to the efficiency by the formula

$$\epsilon=(1-n\sigma)100,$$

where n is the rate of discharges in the counter, it follows that the change in the efficiency $\delta\epsilon$ resulting from a change in the insensitive time of $\delta\sigma$ is

$$\delta\epsilon=-n\delta\sigma\,100.$$

Stever finds that a change in the pressure of 6.4 cm (13.4–7.0) results in a change in σ of 2×10^{-4} sec. for a counter filled with an argon-xylol mixture. Since $n\sim 6$ c. per sec.

$$\delta\epsilon=-6\times 2\times 10^{-4}\times 100=-0.12 \text{ percent}.$$

Assuming that the insensitive time is directly proportional to pressure the change in efficiency of a counter when the pressure is changed from 11.0 to 74.5 cm should be 1.2 percent. The change in the fivefold rate should therefore be 6 percent. As no change in efficiency of this magnitude has been found one must conclude that the insensitive time is not directly proportional to pressure in the range 11.0 to 74.5 cm.

[15] H. G. Stever, Phys. Rev. **61**, 38 (1942).