A STUDY OF THE OPERATION OF G-M COUNTERS AT LOW TEMPERATURES

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INTRODUCTION

The present investigation is a sequel to an earlier report on the temperature dependence of G-M counter characteristics (Part I) by Puri and Gill (1956), where it was shown qualitatively that the operation of a self-quenching argon-petroleum ether filled internal counter remains substantially the same in the range of 16°C. to −21·5°C. The change in the characteristics of an argon-alcohol filled Maze type counter below −7°C. was attributed to the condensation of the polyatomic constituent. Below −11·5°C., the electrical resistance of the glass envelope becomes too high with the consequence that certain anomalies in the functioning of the counter set in.

With a view to get a quantitative confirmation of the above conclusions, the operation of the counter at low temperatures was analysed by studying the time distribution of pulses by the method of delayed coincidences. The time correlation between the ionizing events in the tube gives conclusive information regarding the origin of spurious pulses, which are always time correlated to the genuine ones. This study also helps to determine whether the temperature has any bearing on the dead and transit times of the counter.

EXPERIMENTAL ARRANGEMENT

Two counters of the self-quenching type, but with different quenching vapours, were employed. Counter No. 1 was the same as described in Part I. The other counter was 20 cm. in length and 1 cm. in diameter, filled with 86% argon and 14% butane at a total pressure of 12 cm. of Hg. It was designated as counter No. 2.

The temperatures were lowered by a thermostatically controlled cooling cabinet and still lower temperatures were secured by using eutectic mixtures, which were replenished twice or thrice during an operation. These modes of cooling ensured constancy of temperature over several hours of operation. The time interval analyser (Puri and Gill, 1955) was made use of for analysing the operation.

OBSERVATIONS AND RESULTS

An interval of two to three hours was allowed to elapse after embedding the counter in the eutectic mixture before the time distribution study of pulses was resorted to. This precaution secured the static conditions of temperature. Three sets of observations were taken in each case keeping the overvoltage the same in all the three cases and only varying the temperature.

The curves of Fig. 1 give the delayed coincidence rate *v.* delay time for counter No. 1 at temperatures of 6·66°C., −15·4°C. and −21·5°C. respectively, whereas those of Fig. 2 are for the counter No. 2 at temperatures of 18·6°C., 2·3°C. and −15·4°C.

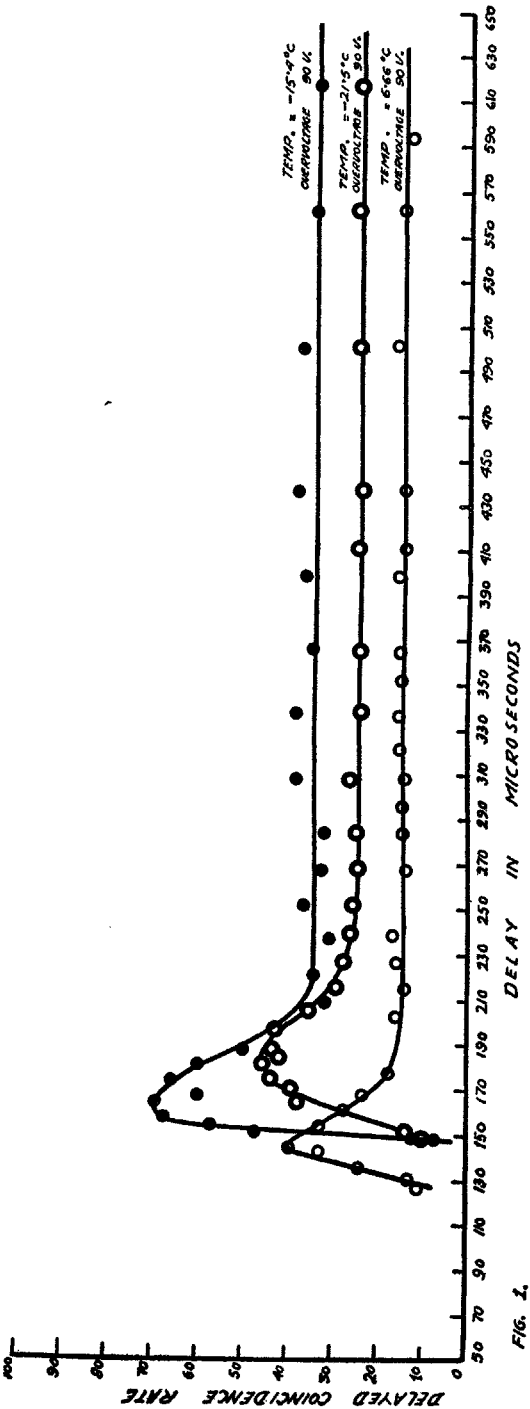

FIG. 1.

DELAYED COINCIDENCE RATE VS DELAY TIME FOR INTERNAL PETROLEUM ETHER FILLED COUNTER

The values of dead and transit times and those of the coefficient of secondary emission are tabulated in Table 1 for both the counters. The coefficients of secondary emission were calculated from the curves of Figs. 1 and 2, making use of the formula (Puri and Gill, 1955)

$$\frac{A_1}{r_c} = \frac{k}{n_1[1-k-k^2+k^3]}.$$

TABLE 1

COUNTER	Temp	T_d	T_r	n_1	A_1	γ_c	K
PETROLEUM-ETHER FILLED	6·66 °C	125	145	7478·1	$291\times2\times10^{-6}$	15·0	0·2155
	−15·4 °C	148	164	10630·3	$606\times2\times10^{-6}$	34·5	0·2550
	−21·5 °C	142	182	9590·7	$444\times2\times10^{-6}$	24·0	0·2465
BUTANE FILLED	18·6 °C	74	101	8776·35	$546\times2\times10^{-6}$	22·0	0·2787
	2·3 °C	84	106	8568·3	$297\times2\times10^{-6}$	19·0	0·2037
	−15·4 °C	81	106	8461·3	$732\times2\times10^{-6}$	25·5	0·2980

Where k is the probability that a discharge creates an after discharge. Here it pertains to secondary emission, since there is only one peak at the transit time of the positive ions.

A_1 is the area of first peak superimposing the background, r_c the rate of background coincidences, and n_1 is the rate of counting from the direct channel. This is observed from the output of the shaping circuit No. 1 in direct channel. The above data show that:—

(i) The dead and transit times increase exponentially with the decrease of temperature in case of counter No. 1, Fig. 3.

(ii) The dead and transit times are the same within experimental errors in case of counter No. 2.

(iii) The values of the coefficient of secondary emission remain the same, within experimental errors, with the decrease of temperature.

(iv) The threshold voltage of counters Nos. 1 and 2 remains unaffected up to the lowest temperature encountered as reported earlier by Puri and Gill (Part I, 1956).

Discussion

The critical radius R_c, defined as the distance to which the positive ions must move before the field at the wire recovers to threshold, is related to the overvoltage $v-vs$, where vs is the threshold voltage, the cylinder radius b, and charge q per unit length of the ion sheath and was given by Stever (1942)

$$R_c = b\, e^{\frac{-(v-vs)}{2q}}.$$

The value of R_c increases and consequently the dead and transit times if either of the following two possibilities or both come into play by lowering the temperature.

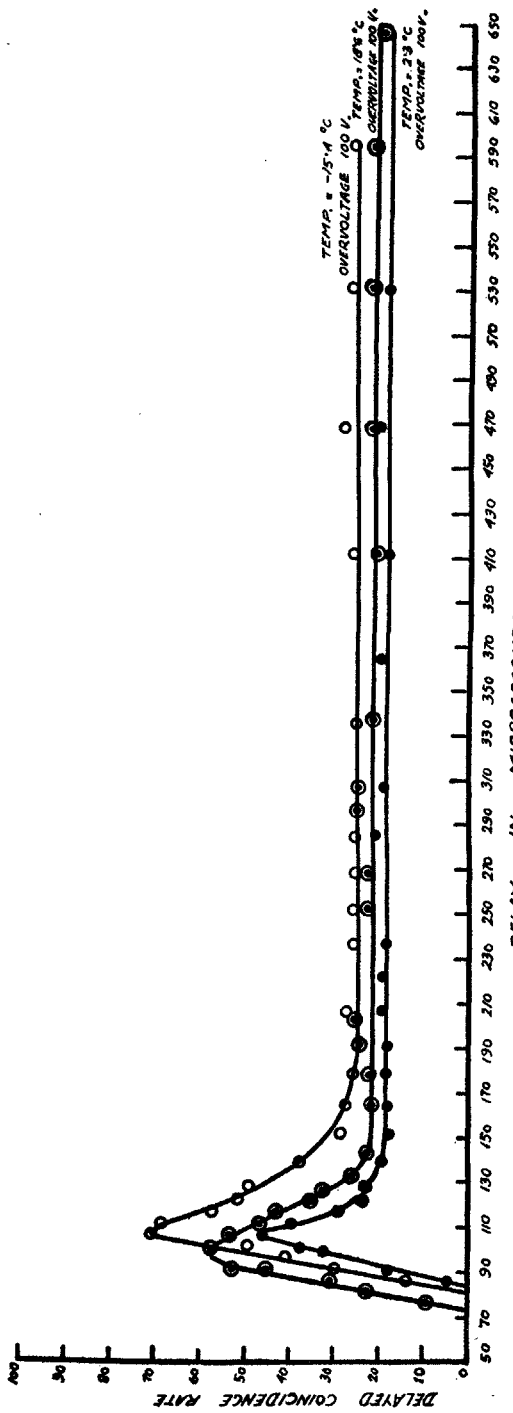

FIG. 2.

DELAYED COINCIDENCE RATE VS DELAY TIME FOR INTERNAL ARGON BUTANE FILLED COUNTER

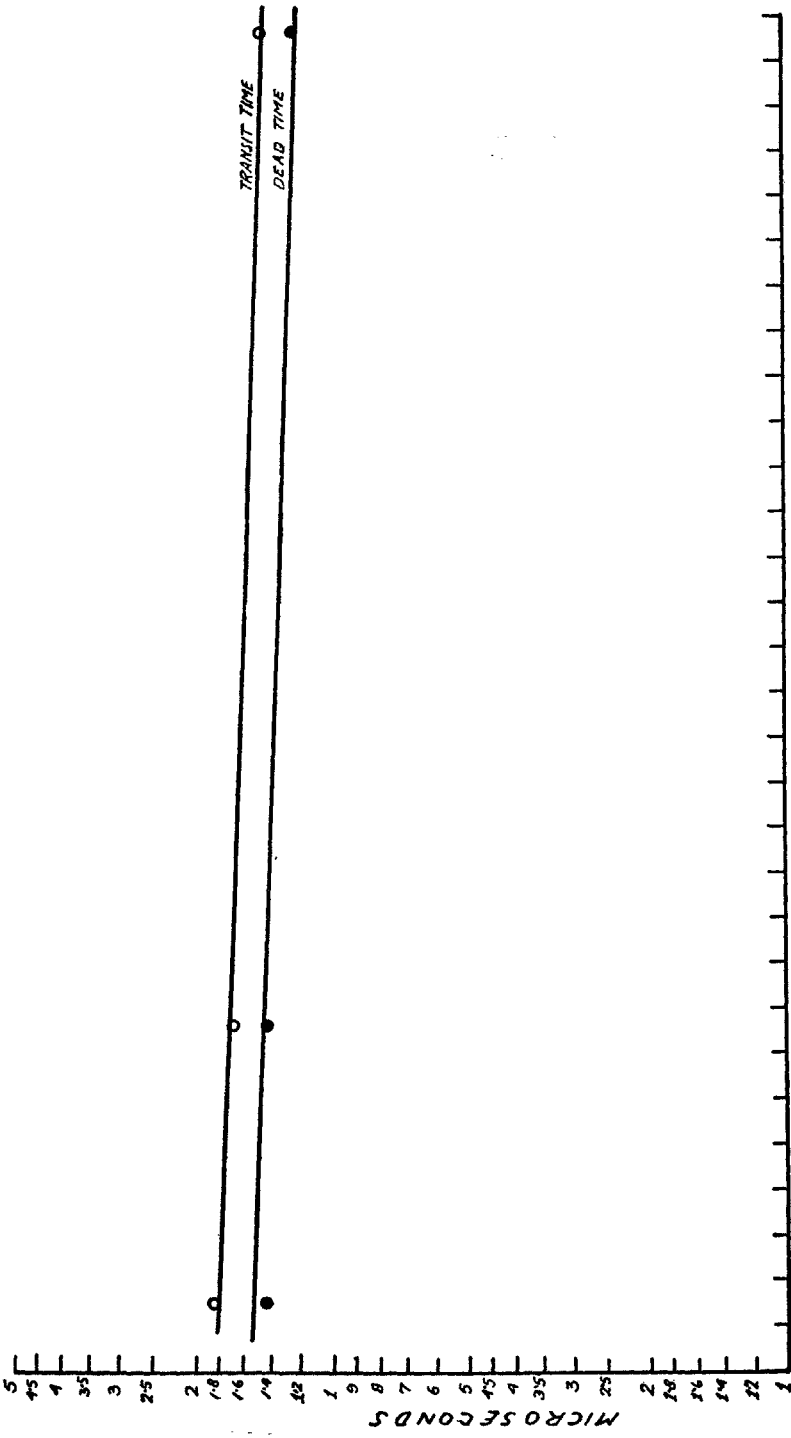

FIG. 3.

DEAD AND TRANSIT TIMES VS TEMPERATURE FOR THE PETROLEUM-ETHER FILLED COUNTER

(*a*) The rise of the threshold, leading to the reduction of overvoltage, will result in the exponential increase of dead and transit times (Puri and Gill, 1956).

(*b*) Increase in the value of the charge per unit length of the ion sheath. These two eventualities are contrary to the observations, since the threshold voltage remains unaffected up to the lowest temperature and pulse size retains the same value throughout the range of temperature investigated (Puri and Gill, 1956). The explanation of the increase of dead and transit times with temperature may lie in decreased mobility of the positive ions, as a result of the increase of the degree of saturation with the decrease of the temperature. The molecules may become massive by the coalescing of a few molecules together. The mobility, being inversely proportional to the square of the molecular weight, will decrease at the same overvoltage, and consequently the dead and transit times of the positive ions will decrease. But no such cluster formation is expected in the case of counter No. 2, since butane (B.P. $-0{\cdot}5$°C.) is unsaturated at the temperatures employed. The dead and transit times for this counter, therefore, remain the same throughout.

These minute clusters of molecules, even when multipli-charged during a count, will get neutralized by pulling the requisite number of electrons from the cathode and dispose of the excess energy through the process of predissociation. Thus the normal procedure of quenching the discharge will remain unimpaired by the lowering of temperature.

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Abstract

The operation of two self-quenching G-M counters is analysed at low temperatures by studying the time distribution of pulses by the method of delayed coincidences. The results indicated that :—

(*i*) The dead and transit times increase exponentially with the decrease of temperature in case of an argon-petroleum ether filled counter whereas these are substantially the same in case of argon-butane filled counter.

(*ii*) The values of the coefficient of spuriousness due to secondary emission remain constant with temperature.

The explanation of the increase in dead and transit times seems to be in the cluster formation at lower temperatures due to a certain degree of saturation of the polyatomic constituent. However, no such effect is expected in case of counter No. 2, since butane (B.P.$-0{\cdot}5$°C.) remains unsaturated throughout the range investigated.

References

Puri, Satya Pal, and Gill, P. S. (1955). Analysis of G-M counter impulses by the method of delayed coincidences. *Ind. J. Phys.*, **29**, 2, 95.

Puri, Satya Pal, and Gill, P. S. (1956). The temperature dependence of Geiger-Muller counter characteristics (Part I). *Ind. J. Phys.*, **30**, 2, 62–69.

Stever, H. G. (1942). The discharge mechanism of fast G-M counters from the dead time experiment. *Phys. Rev.*, **61**, 38–52.

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