TIME DELAYS IN ARGON–PROPANE PROPORTIONAL AND GEIGER COUNTERS*

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As part of an investigation of the properties of argon–propane mixtures for use in counters, we have measured the time intervals between the release of electrons from the cathode and the subsequent appearance of a pulse in a counter operated in the proportional and Geiger regions.

The method used consisted of allowing the u.v. light from a short duration spark (approximately 10 nsec) to release photoelectrons from the cathode of the counter. An oscilloscope method was used to measure the time delays between the sparks and the counter pulses. This method has been used by several investigators (e.g. Laufer 1950). The device for producing the spark is based on a design due to Andreev and Vanyukov (1961).

The cylindrical counter had an effective length of 15 cm and was 2·3 cm in diameter. The central anode was 0·0025 cm diameter tungsten wire and the cathode was of copper. The counter was filled with argon containing 9% of commercial grade propane.‡ For most of the measurements the pressure was 75·1 cmHg. This mixture and pressure were chosen because it had been shown previously in this laboratory by Ivanovich (1964) that the mixture possessed some suitable properties for use in gas-flow proportional counters. With the pressure of 75·1 cmHg the Geiger threshold for this counter was at 1700 V.

A series of measurements was made in which it is estimated, from statistical considerations, that about 80% of the counter pulses were due to single electrons released from the cathode. Such measurements were made at several counter operating voltages, and the results obtained at 1750 V are shown in Figure 1 for a total of 750 counter pulses. In this case the most probable delay was about 0·25 μsec and the shortest delay was 0·2 μsec. However, 9·2% of the delays were longer than 1 μsec and delays up to 3 μsec occurred. Similar results were obtained at both lower and higher voltages. Delays of up to several hundred microseconds were searched for but none were seen.

At present we have no explanation for the delays longer than about 0·5 μsec. One possibility that has been considered is that capture of the electron by an electronegative molecule occurs near the anode, with consequent increase of the transit time. However, for this explanation to be valid, the cross section for attachment would have to exceed the known values for most gases.

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‡ Obtained from the Shell Oil Co. under the name "Porta-Gas". A typical analysis, supplied by the company, states that besides propane (C_3H_8) there is about 15% by weight of propene (C_3H_6) and 1% of other hydrocarbons in this product.

Another series of measurements was made in which it is estimated that an average of 35 photoelectrons were released from the cathode per spark. This number is of the same order as would be produced by a minimum-ionization singly charged particle in travelling 1 cm through this gas. The results are summarized in Table 1.

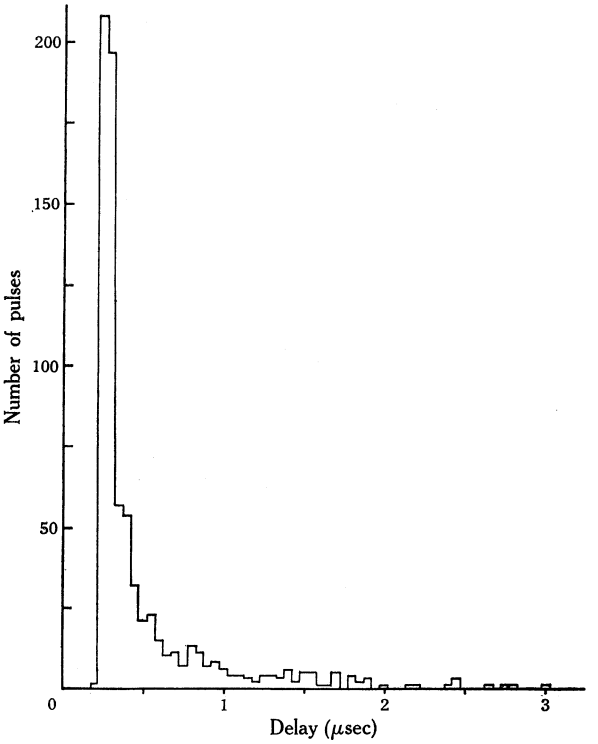

Fig. 1.—Distribution of time delays for counter pulses initiated by single photoelectrons from the cathode, with a counter operating voltage of 1750 V.

As might be expected, the shortest delays were approximately the same as observed in the case where the pulses were produced by single electrons. The long delays ($\geqslant$ 1 μsec) were not observed in this experiment. This is also in accord with expectations, since most of the electrons in the single-electron experiment suffered little delay.

A commonly used gas mixture for counters in which short delays are required is argon–methane. We therefore performed similar measurements (in rather less detail) in which our counter was filled to atmospheric pressure with this mixture (10% methane). The shortest delays were again about 0·25 μsec and the distributions were similar to those for the argon–propane mixture.

From the practical point of view, our results suggest that the argon–propane mixture is as suitable for use in fast counting arrangements as the argon–methane mixture. The long delays ($\geqslant$ 1 μsec) should not lead to any undesirable consequences, because in normal use there would almost always be many primary electrons and

our experiments show that the majority of these will suffer little delay. Thus in beta–gamma coincidence measurements, where a gas-flow counter for instance is used to detect the beta-particles and a scintillator to detect the gamma-rays, short resolving time circuits could be used. Electrons arriving late at the anode would not usually produce a new pulse because, according to our results, they would almost certainly arrive within the dead time of the circuitry. It should be remarked, however, that these results apply to a counter of cylindrical geometry, which is very different from that of a common type of gas-flow counter in which there is a wire loop anode and a hemispherical cathode. Possible effects on time delays due to geometrical factors will not be discussed further in the present paper.

TABLE 1

TIME DELAYS FOR AN AVERAGE OF 35 PHOTOELECTRONS PER SPARK

Counter Operating Voltage (V)	Shortest Observed Delay (μsec)	Longest Observed Delay (μsec)	Mean Delay (μsec)	R.M.S. Deviation (μsec)
1400	0·34	0·68	0·441	0·054
1450	0·32	0·54	0·387	0·041
1500	0·29	0·36	0·320	0·017
1550	0·27	0·35	0·295	0·012
1600	0·26	0·37	0·284	0·012
1650	0·25	0·32	0·272	0·010
1700	0·25	0·29	0·270	0·009
1750	0·24	0·30	0·264	0·010
1800	0·22	0·28	0·260	0·007
1850	0·23	0·29	0·260	0·012
1900	0·24	0·29	0·258	0·012

The actual delays in any particular counter will, of course, depend upon the size of the counter and, presumably, upon the E/p values it employs (E being the electric field strength and p the gas pressure). It is therefore of interest to obtain what information we can from our results about the electron drift velocity as a function of E/p for the argon–propane mixture. One method is simply to obtain the average speed of the electrons by dividing the distance between the cathode and anode by the shortest observed delay. (The shortest delay, rather than the average, is used because we believe the results so obtained can be realistically compared with those from the usual methods of measuring drift velocity as a function of E/p, in which swarms of electrons are often used.) The results are listed in Table 2.

Since the value of E/p for this counter is less than average for about 90% of the distance between the cathode and anode, and since it would be expected that the electrons would spend most of their transit time in this first 90% of the distance, the values listed in Table 2 are believed to give the average drift velocity of electrons in the argon–propane mixture for the E/p range 0·24–2·2 V cm^{-1} torr^{-1}. There appear to be no detailed results with which to compare ours, but several authors (e.g. English and Hanna 1953; Bortner, Hurst, and Stone 1957) have given such results for many other gas mixtures. Over approximately the E/p range referred to above, these authors find higher average drift velocities only in mixtures containing methane.

In principle, it should be possible to obtain further information on the drift velocity as a function of E/p from our results by using a method due to Hamers *et al.* (1957). This method gives the value of the mobility at the cathode. In fact, a reasonable value of the mobility constant was obtained by this method for the atmospheric-pressure data. However, measurements at 30 and 10 cmHg in the same counter with the same gas mixture led to conflicting results. Although we hope to re-examine this problem in the future, we have thought it worth reporting at this stage on the present results.

TABLE 2

DRIFT VELOCITY AS A FUNCTION OF E/p

Operating Voltage (V)	Av. Drift Velocity (cm/μsec)	Av. E/p (V cm^{-1} torr^{-1})	E/p at Cathode (V cm^{-1} torr^{-1})
1400	3·4	1·62	0·237
1450	3·6	1·68	0·245
1500	4·0	1·74	0·253
1550	4·3	1·79	0·262
1600	4·4	1·85	0·270
1650	4·6	1·91	0·279
1700	4·6	1·97	0·287
1750	4·8	2·03	0·296
1800	4·8	2·08	0·304
1850	5·0	2·14	0·313
1900	4·8	2·20	0·321

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