Localization of the Discharge in G-M Counters

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(Received September 26, 1942)

The discharge in fast counters has been localized by numerous devices. The reduction of the field in the counter by surface charges accumulated on an insulator has been shown to interrupt the spread of the discharge. This implies strong photon absorption in the gas of the fast counter. The efficiency of localization has been investigated as a function of the concentration of alcohol in an argon-alcohol filling. It is shown that localization is more complete at low values of overvoltage. The effectiveness of various gas fillings is given, among which are a number of inorganic gases which show both localization and fast counter action.

PREVIOUS studies of fast G-M counter action have indicated that the discharge initiated by an ionizing particle spreads very rapidly along the length of the counter wire. Stever[1] has recently shown that the discharge can be constrained by placing a glass bead on the wire. The same effect has been accomplished by Ramsey[2] by separation of the cathode into segments. This localization of the discharge has increased the versatility of the G-M counter, and a number of applications immediately suggest themselves; the determination of particle direction and range are perhaps the most important. For if the constraining device is completely effective in localizing the discharge, then a primary ionizing particle must produce ions in each section of a segmented counter which shows a discharge.

The present paper reports on some of the properties of this localization phenomenon. The values given apply only to the particular tube used by the authors. Since G-M counter properties depend upon many factors, the data should perhaps be considered a guide as to what may be expected with other tubes.

APPARATUS

The tube used in most of these experiments was designed to permit direct visual observation of the wire and to lend itself easily to internal changes. The cathode was made of ordinary copper wire screen. The inside of this screen cylinder was painted with a heavy coat of Aquadag and the edges were rolled outward in order to reduce the background rate. Other details of its construction are shown in Fig. 1, Tube A. The position of the quartz disk in the figure is typical of other devices used.

The means used to determine whether or not localization took place were (1) direct visual observation of the wire, and (2) the pulse sizes on the oscilloscope screen. It was possible to observe corona flashes along the wire for an individual pulse only when the tube had such a filling as to yield a slow counter. When operating as a fast counter, the corona was visible only when a high counting rate was attained. A small gamma-ray source held near one end of the tube produced a seemingly continuous glow in the segment nearest it when fairly complete localization was

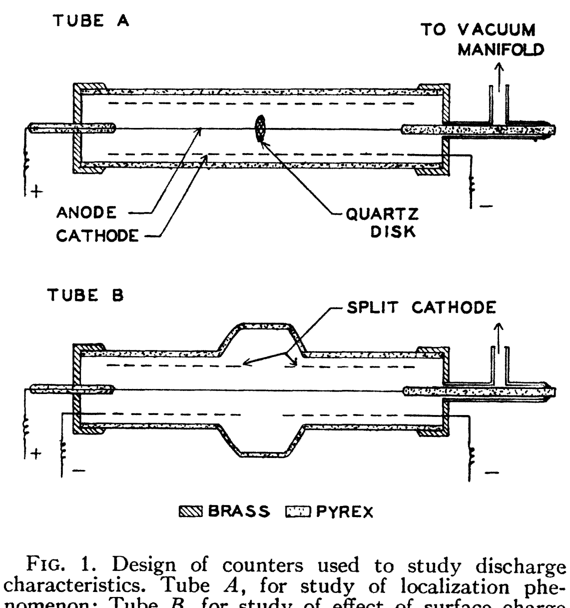

FIG. 1. Design of counters used to study discharge characteristics. Tube A, for study of localization phenomenon; Tube B, for study of effect of surface charge collected on walls of tube.

[1] H. G. Stever, Phys. Rev. **61**, 38 (1942).
[2] W. E. Ramsey, Phys. Rev. **61**, 96 (1942).

TABLE I. Effects of objects on spread of discharge in fast and slow counters.

No.	Object	Dimensions	Mounting	Percent localization Vapor filling	Pure argon
1	Quartz disk	25-mm diam., 2 mm thick	Through small hole in center	97	0
2	Plicene disk	20-mm diam., 2 mm thick	Rigidly at center of wire	95	0
3	Quartz tubing	1 cm long,4 mm i.d. 6 mm o.d.	Slung on wire at mid point	95	0
4	Quartz tubing	1 cm long, 1 mm i.d. 2 mm o.d.	Slung on wire at mid point	96	0
5	Bakelite ring	8 mm thick, 9 mm i.d. 30 mm o.d.	Fitted on inside of cathode	90	–
6	Bakelite ring	8 mm thick, 15 mm i.d. 30 mm o.d.	Fitted on inside of cathode	87	–
7	Bakelite ring	8 mm thick, 19 mm i.d. 30 mm o.d.	Fitted on inside of cathode	70	0
8	Brass ring	8 mm thick, 19 mm i.d. 30 mm o.d.	Fitted on inside of cathode	0	0
9	Split cathode	1-cm separation	Cathode cut perpendicular to its axis at midpoint	0	0
10	Split cathode	2-cm separation	Cathode cut perpendicular to its axis at midpoint	65	0

taking place. This was helpful in the ambiguous case when only one pulse height was observed on the oscilloscope screen. It may be interesting to note that the glow produced by the gamma-ray source in the fast counter was of uniform intensity over the part of the wire that is covered. If each pulse did not spread the full length of the glow, an inverse square law of illumination might have been expected.

The size of the pulses viewed on the oscilloscope furnished the more direct means of finding the extent of spread of a discharge along the wire. This is true because the total charge in a single pulse is directly proportional to the effective length of the counter. Hence, if a localizing device separated the counter into unequal parts, separate pulse sizes identified each segment and a third size, approximately equal to the sum of the other two, indicated complete spreading.

TABLE II. Comparison of localization due to a split cathode in an ordinary and an extended wall counter. Cathode separation, 2 cm. Overvoltage 100 volts.

Alcohol vapor concentration	Percent localization Straight wall	Extended wall
100%	95	85
40%	90	75
20%	85	15
15%	65	3
10%	35	3
5%	20	2
2%	8	0

LOCALIZING DEVICES

The effects of a number of devices on the localization of the discharge are shown in Table I. Each was used with a filling of 9 cm argon and 1 cm ethyl alcohol, or with pure argon. When complete spreading or complete localization did not occur, the percentage of single sized pulses as observed on the oscilloscope was used to measure the effectiveness of the localizing device. These percentages were found to be a critical function of the overvoltage, the voltage above threshold at which the tube was operated. Therefore in this experiment the overvoltage was kept constant at 140 volts. Table I shows that localization occurs only when a fast counter filling is used. The previously mentioned corona glow test always indicated complete spreading when pure argon was used.

It is possible to explain the localizing action in fast counters on the basis of a reduction in field strength over a part of the length of the counter, even though in some cases the opacity of the object to radiation may have been effective. In the case of the split cathode, reduction in field intensity comes about in an obvious way. When any insulator is placed in the counter it acquires a surface charge which acts to reduce the field intensity in the active part of the counter. A ring slipped into the cathode acquires positive charge, and a bead on the anode acquires negative charge. The brass ring slipped into the cathode, similar

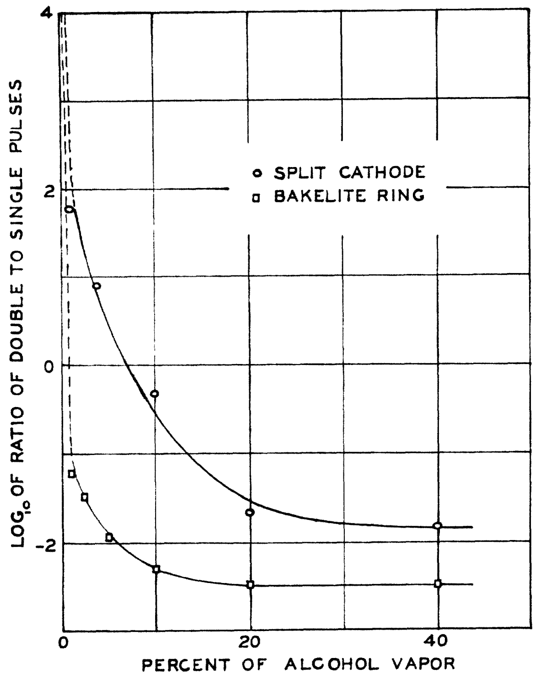

FIG. 2. Curves showing effectiveness of a Bakelite ring (No. 7, Table I) and a split cathode (No. 10) on localization of counter discharge for various mixtures of alcohol and argon.

in dimension to one of the insulating rings, had no localizing effect. It may be important for a variety of experiments that so simple a device as an insulating ring, which does not obstruct the body of the counter, serves well to segment the tube.

Even in the case of the split cathode, surface charge on the uncovered glass wall plays an important role. A tube constructed with an extended glass wall (Fig. 1, Tube *B*) so as to reduce the influence of surface charges gave markedly different results than the ordinary tube with straight walls (Fig. 1, Tube *A*). Table II shows that localization is consistently more complete in the ordinary tube for various concentrations of ethyl alcohol in argon. These data were taken at constant overvoltage.

Figure 2 compares the effectiveness of a Bakelite ring (No. 7, Table I) and a split cathode in an ordinary tube (No. 10) in producing localization. The Bakelite ring, whose surface charges are nearer the central wire, is the more effective. The differences between the curves are in degree rather than kind. The particular coordinates chosen lend themselves most easily to reading data from the curves. Since pulses of double height indicate the spreading of the discharge through the reduced field region, it is a low value of double to single height pulses that indicates a high degree of localization.

If reduction of field intensity over a part of the length of the counter is effective in interrupting the step by step mechanism which spreads the discharge along the wire, it implies that the "mean free path" of the agent responsible for the spreading is of the order of magnitude of the length of the reduced field region. Photons[3] are considered responsible for the propagation of the discharge. They undoubtedly produce abundant electrons or ions to build up the discharge until it is quenched by the positive ion space charge.[4] The localization phenomenon apparently depends upon a strong photon absorption by the added vapor or gas. Localization fails to occur when photons penetrate the reduced field region and reestablish the discharge. Since the new ions are formed in the gas by a strong photon absorption, they are undoubtedly far more abundant than in the case of the slow counter. For a certain dis-

TABLE III. Type of counter action produced by different gases and vapors.

Base gas Pressure 9 cm	Vapor or gas added Pressure 1 cm	Formula	Type of counter action produced	Percent localization
argon	alcohol	C_2H_5OH	fast	95
argon	acetylene	C_2H_2	fast	93
argon	ethylene	C_2H_4	fast	96
argon	methane	CH_4	fast	50
argon	alcohol oxygen	C_2H_5OH O_2	fast	95
argon	water vapor	H_2O	fast	50
argon	carbon dioxide	CO_2	fast	2
argon	carbon disulfide	CS_2	fast	99
argon	carbon tetrachloride	CCl_4	fast	99
air	alcohol	C_2H_5OH	fast	90
oxygen	alcohol	C_2H_5OH	fast	98
hydrogen	alcohol	C_2H_5OH	fast	96
carbon dioxide	—	CO_2	fast	10
argon	oxygen	O_2	slow	0
argon	bromine	Br_2	slow	0
argon	—	A	slow	0
oxygen	—	O_2	slow	0
hydrogen	—	H_2	slow	0
air	—		slow	0

[3] W. E. Ramsey and E. L. Hudspeth, Phys. Rev. **61**, 95 (1942).
[4] C. G. Montgomery and D. D. Montgomery, Phys. Rev. **57**, 1030 (1940).

charge current, each new ion or electron produces a smaller total number of ions by collision since there are more new ions formed in the fast counter than in the slow counter. This may account for the lower voltage at which the fast counter operates and the fact that the space charge is able to extinguish it.

EFFECT OF COUNTER FILLING AND OVERVOLTAGE

The above considerations suggest several properties that the localization phenomenon should show. Unless the reduced field region is very long compared to the photon half-value length, some photons should penetrate this region and localization should not occur for every discharge. The length of the region reduced below threshold field values, and consequently the efficiency of localization, should depend upon the overvoltage. The range of the photons should depend upon the nature and the concentration of the added vapor or gas.

Figure 3 shows at the same time the effect of alcohol concentration and overvoltage. The coordinates are the same as used in Fig. 2. The extent of localization changes extremely rapidly at the lower alcohol concentrations. At the higher concentrations it is nearly 100 percent and depends only very slightly upon concentration. It is also apparent that the localizer is most effective at low overvoltage.

Table III ennumerates the results obtained with a variety of counter filling combinations. These data were taken at voltages representing the middle of the plateau in each case, and the localizer used was the Bakelite ring (No. 7, Table I). The criterion for a fast counter was the existence of a usable plateau with one megohm in series with the counter. It is interesting to note that several inorganic gases show fast counter action. The experiment with carbon dioxide indicates that fast counters are obtainable even though there is only a small tendency to produce localization. However, localization was observed in all the fast counters. The shortest plateaus were about 40 volts with argon-water and argon-

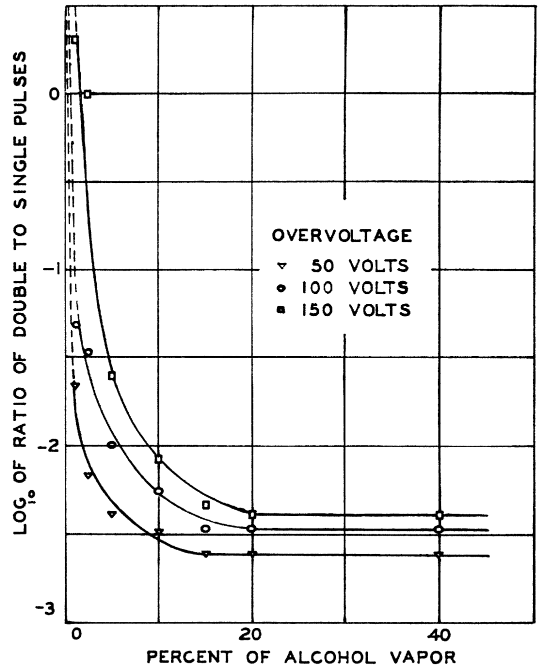

FIG. 3. Dependence of localization on the overvoltage at which the counter is operated.

carbon dioxide fillings, and about 60 volts with the argon-carbon disulphide filling.

Of the gases used, only monatomic and diatomic gases and their mixtures showed slow counter action. Gases whose molecules contain three or more atoms and at least two different atomic species gave fast counters. For example, air, pure argon, and argon-oxygen mixtures gave slow counters, while pure alcohol, carbon dioxide, and mixtures of these with argon gave fast counters. Bromine showed slow counter action, so molecular weight alone is apparently not sufficient to produce a fast counter. Presumably the larger number of degrees of freedom and the lack of atomic symmetry in the polyatomic molecules permit more abundant rotational and vibrational levels in these molecules and may account for their greater photon absorption. However, attempts to correlate any detailed photo-ionization mechanism with our results were completely unsuccessful.