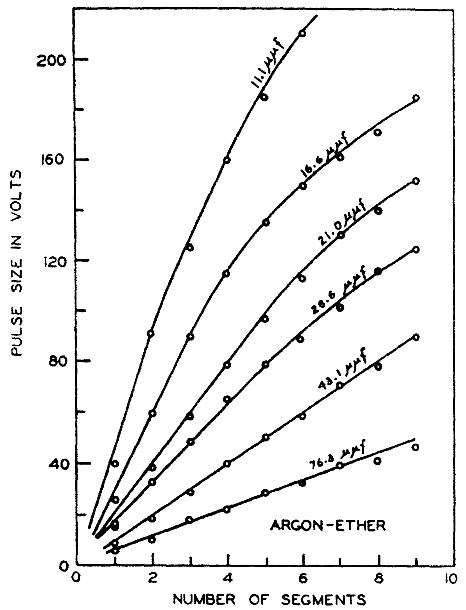

FIG. 1. Pulse size *vs.* length and capacity of counter.

the positive ion sheath which surrounds the counter wire during the discharge.

Figure 1 displays a family of curves showing the dependence of pulse size upon length and capacity while Table I gives the values of α as calculated from the slopes of the separate curves at $l=0$. For small c and large l a departure from the simple relation indicated is observed and corresponds to that found in the non-self-quenching mixture where c is small and l is large. It has been previously shown[1] that the voltage pulse can be represented best by the expression $(l/c)[\alpha-(\beta l/c)]$, where $\beta l/c$ is negligible except for a long counter with a small total wire capacity. For both types of gases the departure is to be expected if a time of the order of magnitude of 10^{-7} second is required for the discharge to spread the entire length of the tube. Such a time delay permits the potential of the wire to change while the positive ion sheath is being established in certain portions of the counter. For this reason the positive charge in the sheath is not constant over the wire length and the average value decreases as we decrease c and increase l. The theory has, with justification, assumed

TABLE I. Values of α, the charge per unit length in the positive ion sheath.

Capacity $\mu\mu$f	Volts/Segment	α in coulombs
11.1	40	4.4×10^{-10}
16.6	26	4.3×10^{-10}
21.0	19.5	4.1×10^{-10}
26.6	16.2	4.3×10^{-10}
32.1	13.0	4.2×10^{-10}
43.1	10.0	4.3×10^{-10}
54.2	8.2	4.4×10^{-10}
65.2	6.5	4.2×10^{-10}
76.3	5.5	4.2×10^{-10}

that, following the passage of the original ionizing particle, photons from the first electron avalanches create discharge centers throughout the counter in extremely short times. It has, therefore, naturally invoked the assumption that, for its purpose, the ionization starts instantaneously at all points along the wire. That this is not strictly true follows from the fact that the spreading process depends upon electrons moving appreciable distances through the gas. Therefore the absence, rather than the appearance, of a small correction term would occasion some surprise.

Figure 2 of reference 1 is a diagram of the counter used. In order to vary the effective counter length *without* changing the wire capacity the cylinder is made to consist of nine separately insulated segments whose voltages may be independently assigned. The number of segments at a fixed value above the starting potential determines the effective counter length. All other segments are at a given voltage well below the Geiger counter threshold. The total capacity of the wire system was varied by adding capacitors between wire and ground. The pulses were observed on an electron tube oscillograph under conditions which gave more than adequate time for the complete collection of the charge involved in the discharge process.

[1] W. E. Ramsey and Wayne L. Lees, Phys. Rev. **60**, 411 (1941).
[2] C. G. Montgomery and D. D. Montgomery, Phys. Rev. **57**, 1030 (1940).

Directional Properties of Self-Quenching Counters

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H. G. STEVER[1] has recently reported a very interesting way in which to endow a Geiger-Mueller counter with directional properties. He finds that small beads of glass mounted on the wire of a counter filled with a self-quenching mixture effectively confines the discharge to those sections of the tube traversed by the original ionizing ray. Thus the pulse size from the wire is proportional to the number of segments traversed and is an indication of the path taken by this ray.

The ability to limit the discharge in self-quenching counters in this way is a consequence of the fact that in these counters not only is the active discharge confined to the immediate vicinity of the wire, as in all counter action, but also to the fact that no photoelectrons are formed in remote parts of the counter as a consequence of photons originating in this region. Emmett L. Hudspeth, using an arrangement employed by the author for studying the distribution of photons in time during the discharge in a non-self-quenching mixture,[2] found this absence of photoelectrons in the case of the self-quenching gas. Thus in the self-quenching mixture the ***entire*** ionization process is confined to the vicinity of the wire.* Started at a point (or a few points) by the passage of the ionizing ray, it must spread along the wire from this point to another very close to it. It is clear that the discharge may be confined to a desired section of the counter *by any procedure which*

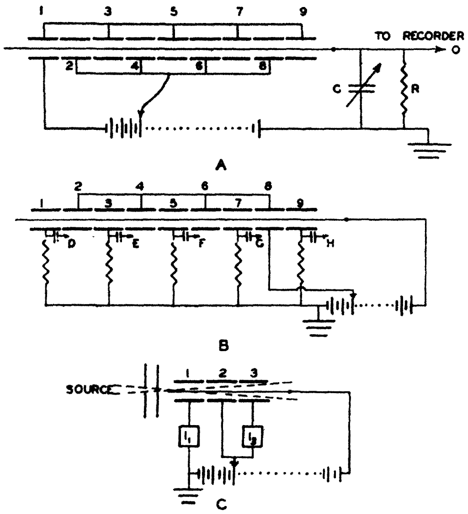

FIG. 1. Counter cylinder composed of separately insulated segments whose potentials may be independently assigned. Filled with a mixture of argon-ether.

interferes with this step-by-step process of propagation at the boundaries of the section.

In one such procedure, and one rich in possible applications, the electric field is reduced at points where it is desired to interrupt the discharge. This has been demonstrated by utilizing the segmented counter employed for other studies.[3,4] Reducing the potential of certain segments (Fig. 1*A*) below the starting potential (say for example 2, 4, 6, 8) we arbitrarily divide the counter into a series of lengths (1, 3, 5, 7, 9) which may be used in coincidence in precisely the manner described by Stever. The pulse sizes observed at 0 are proportional to the number of segments (of the group 1, 3, 5, 7, 9) traversed by the rays passing down the axis of the counter tube. The assignment of active and inactive segments is of course quite arbitrary, and one may divide the same counter into many different coincident groups.

The greatest flexibility is achieved, however, as a result of the fact that voltage pulses (Fig. 1*B*), or charges (Fig. 1*C*) may be taken from the separate segment units. Space does not permit an elucidation of these applications but Figs. 1*B*, 1*C* are suggestive. In 1*B* voltage pulses are taken from the cylinder segments (say *D*, *E*, *F*, *G*, *H*) and applied in any desired manner to the recording circuits. In 1*C* only currents (or total charges) are measured. Here, in segment 1, working in the Geiger counter region, the current to the segment is proportional to the number of ionizing particles which pass through it, while the current to segment 3, working in the proportional region, varies linearly with the product of the number of particles and the specific ionization of the particles involved. Therefore I_3/I_1 is a measure of the specific ionization of the particles of the beam. This procedure, or some obvious modification of it, can provide us with a rugged method for measuring changes of specific ionization of the particles in a beam under conditions where the number of particles does not remain constant. We may thus count particles and simultaneously measure their ionizing capacity *within the same counter.*

[1] H. G. Stever, Phys. Rev. **59**, 765 (1941).
[2] W. E. Ramsey, Phys. Rev. **58**, 476 (1940).
[3] W. E. Ramsey, Emmett L. Hudspeth, and Wayne L. Lees, Phys. Rev. **59**, 685 (1941).
[4] W. E. Ramsey, and Wayne L. Lees, Phys. Rev. **60**, 411 (1941).
* It is essential to adjust the gas mixture until each discharge, as observed on an oscillograph, consists of one single pulse. Failure to break into a continuous discharge with low resistance is not sufficient.

A Suggestion on the Detection of the Neutrino

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It is known that the presence of the neutrino cannot be detected by its own ionization effect. It appears that the only hope of getting evidence of its existence is by measuring the recoil energy or momentum of the radioactive atom. Crane and Halpern[1] have, by measuring the momentum and energy of the emitted β-ray and the recoil atom with a cloud chamber, obtained evidence pointing toward the existence of the neutrino. However, owing to the smallness of the ionization effect of the recoil atom, it seems worth while to consider a different method of detecting it.

When a β^+-radioactive atom captures a K electron instead of emitting a positron, the recoil energy and momentum of the resulting atom will depend *solely* upon the emitted neutrino, the effect of the extra-nuclear electron being negligible. It would then be relatively simple to find the mass and energy of the emitted neutrino, by measuring the recoil energy and momentum of the resulting atom *alone*. Moreover, this recoil is now of the same amount for all atoms, since no continuous β-rays are emitted. We take for example the element Be^7 which decays in 43 days with K capture in two different processes:[2]

$$Be^7+e_K\rightarrow Li^7+\eta+(1\text{ Mev})$$

and

$$Be^7+e_K\rightarrow (Li^7)^*+\eta+(0.55\text{ Mev}),$$
$$(Li^7)^*\rightarrow Li^7+h\nu+0.45\text{ Mev}.$$

The first process is relatively large, about 10 to 1 in comparison with the second process. The recoil energy of the first process is, by assuming the mass of neutrino to be zero, about 77 ev while that of the second process is about one-third of that amount. This recoil energy would have to be detected and measured in some way, and a correction would have to be made for the disturbances due to the γ-rays and the soft x-rays (originating from the replacement of the K electrons by outer electrons). The recoil energy of certain K-capture atoms, particularly those having isomeric properties so that the K capture is followed by an α-decay, may also be possibly detected by chemical means. In this case, if the radioactive substance is prepared to form some suitable compound of non-polar type, the recoil energy of the resulting atom will break the bond and thus be detected.

[1] H. R. Crane and J. Halpern, Phys. Rev. **53**, 789 (1938); Phys. Rev. **56**, 232 (1939).
[2] R. B. Roberts, N. P. Heydenburg, and G. L. Locher, Phys. Rev. **53**, 1016 (1938); L. H. Rumbaugh, R. B. Roberts, and L. R. Hafstad, Phys. Rev. **54**, 657 (1938).