Our work has consisted mainly of thermal analyses, since the system had been previously unreported, and thorough knowledge of the phase relations was deemed necessary before proceeding to the measurement of magnetic and other properties. In most cases, two or three breaks were observed in the cooling curves during solidification; however, in one, namely, for the alloy of composition corresponding to Cu_2MnIn, only one break could be found. The plateau that followed was at about 617°C and probably indicates a compound or an eutetic mixture at this composition.

Further thermal measurements are in progress, and it is intended to supplement them with microscopic examinations of the properly heat-treated alloys. By means of these data, it should be possible to determine whether a single phase is responsible for the magnetism, and if so, to determine its composition and temperature limits. However, in view of the large range of composition which exhibits ferromagnetism, it would not be surprising to find more than one magnetic phase in this system.

[1] Hames and Eppelsheimer, Nature **162**, 968 (1948).
[2] S. Valentiner, Naturwiss. **4**, 123 (1947).

Discharge of a Geiger Counter at Voltages above the Plateau

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WHEN a voltage higher than that corresponding to the upper end of the plateau is applied to a Geiger counter, a discharge occurs which is spoken of as continuous, but which, in fact, is a very rapid succession of pulses. I have been interested in trying to learn something about the mechanism by which a counter first breaks into such a discharge and the mechanism by which succeeding pulses are produced. It is difficult to see how the existence of the electric field can, of itself, produce the first electron or ion in order to initiate the breakdown. The onset of field emission from the cathode surface surely would not be expected to occur at the potential gradients dealt with in Geiger counters, and other mechanisms, for instance the pulling apart of atoms in the gas, also seem to be out of the question because of the magnitude of the field which would be required.

Experiments I made some time ago seemed to substantiate the idea that high voltage alone cannot initiate the discharge. After allowing a counter to remain at its plateau or below for a few minutes, the voltage was suddenly raised to several hundred volts above the plateau. The first count after raising the voltage occurred substantially no sooner than it would have occurred under normal operation on the plateau. After the first count, further discharges came in rapid succession, as is normally observed above the plateau.

Lately I have carried the experiment somewhat further. By means of a system of relays, timers, etc., a counter was put through the following cycle: voltage raised to some high value (above plateau); time measured to first discharge; voltage dropped back to one-half the high value immediately after first discharge; resting period allowed at half-voltage; voltage again raised to high value. Precautions were taken to prevent any surges produced by the relay contacts from reaching the counter. The apparatus ran automatically, and at least 300 cycles were recorded at each setting of the time and voltage. The average time between the raising of the voltage and the first discharge is plotted in the two graphs (see Fig. 1); the first showing the time as a function of voltage with constant resting period and the second showing the time as a function of resting period with constant voltage. Data on the counter tube used are: wire, 10-mil tungsten; cathode, brass ¾-inch diameter; gas, 9-cm argon, 1-cm alcohol vapor. A

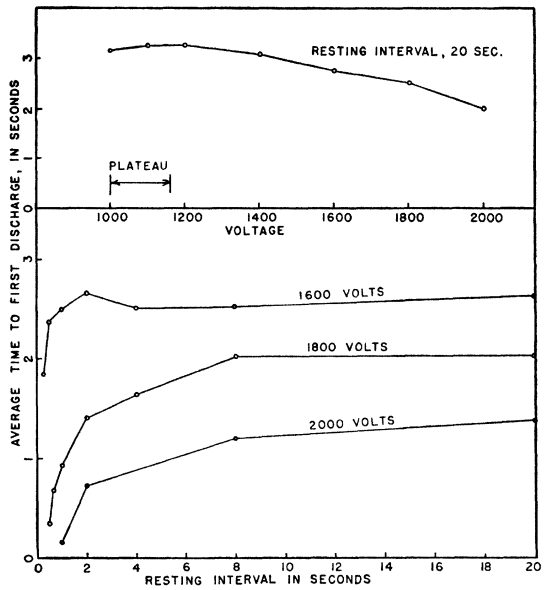

FIG. 1. Average time between raising of the voltage and the first discharge of a Geiger counter. Upper curve for constant resting period; lower curve for different resting periods and various constant voltages. Correction: The three curves in the lower part of the figure should have been labeled 1600, 2000, and 2300 volts, respectively.

Neher-Harper quench circuit was used. The plateau extended from 1000 to 1160 volts. The counter was housed in 2 inches of lead and was subject only to natural radiation background, which gave 20 counts per minute. This agreed with the average time for firing found with the relay scheme, when the voltage applied was within the plateau range.

The results make it reasonable to suppose that in the region above the plateau, spurious discharges may be initiated by an after-emission of electrons or photons, due to activation of the surfaces or gas produced by the *previous* discharge, rather than by ionization produced directly by the application of the high voltage. Since the curves show that in some cases it requires seconds for the after-emission to die away, it does not seem possible to account for the effect on the basis simply of gas ions which fail to be collected during the resting period. Activation of the metal or gas would be expected to depend strongly upon the kinds of materials present and to increase with increasing intensity of discharge. It appears to decay in a way similar to radioactive decay, as is indicated by the second set of curves. It would not be sensible, however, to try to derive the decay law of the after-emission from the curves because of the complexity of materials in the counter.

It should not be assumed that meager results presented here are representative of all counters, since only one example was used, but the measurements do indicate a line of investigation which well might lead to methods of increasing the width of the Geiger counter plateau.

I am grateful to Professors W. C. Parkinson, M. L. Wiedenbeck, R. W. Pidd, and L. Madansky for helpful discussions.

High Multiplication Proportional Counters for Energy Measurements

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DEVELOPMENTS have been reported recently in the application of proportional counters to the detection[1] of electrons and to the measurement[2] of electron or β-ray

TABLE I. Typical counters used.

	Counter *I*	Counter *II*
Effective length	30 cm	20 cm
Cathode diameter	2.5 cm	5 cm
Wire diameter	0.01 cm	0.01 cm
"Xenon" filling (cm Hg)	50 cm Xe, 10 cm CH_4	26 cm Xe, 14 cm A, 10 cm CH_4
"Argon" filling (cm Hg)	40 cm A, 12 cm CH_4	40 cm A, 12 cm CH_4

TABLE II. Experimental results from counter *I*.

Radiation energy (ev) E	Estimated mean number of ion pairs released by radiation, n	Observed standard deviation (% of pulse size)
17,400	700	$(4.0\pm0.2)\%$
2800	110	$(8.8^{+0.3}_{-0.1})\%$
~250	~10	$(36\pm4)\%$

energies particularly in the low energy range (200 to about 50,000 ev). We describe here the essentials of the technique used in the investigation of L-capture[3] in A^{37} and the H^3 spectrum,[4] and discuss the problems of linearity and "linewidth." It is concluded that the energy resolution is better than predicted by current theories.

Counters are connected to a fast, stable, linear amplifier feeding a 30-channel pulse analyzer.[5] A signal generator feeds pulses of known size into the counter through a small capacity, enabling the multiplication factor to be measured. All energy measurements are made in terms of signal generator output: this avoids the effects of any amplifier non-linearity, and, further, facilitates the use of a biased amplifier to obtain an expanded view of any part of a spectrum.

Two typical counters used are described in Table I.

Two calibrating radiations were used: Mo$K\alpha$-x-rays (17.4 kev) from a crystal spectrometer, and, from the decay of A^{37} by K-capture, radiation of energy 2.8 kev (the Cl K ionization potential). Another line at about 250 ev (the Cl L ionization potential) was also available[3] from the A^{37} decay. (See Fig. 1.)

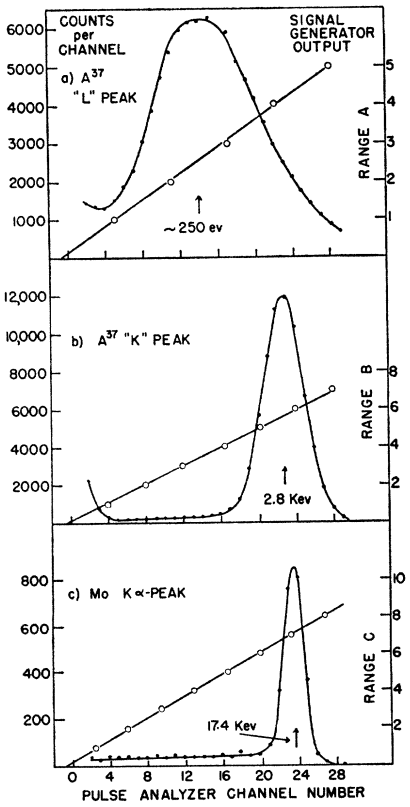

FIG. 1. Peaks produced by ~250-ev, 2.8-kev, and 17.4-kev radiations showing the decrease in percent width with increasing energy. The straight lines refer to the signal generator calibration. Precise measurements of widths, however, were made using a biased amplifier to spread the 2.8-kev and 17.4-kev peaks over many channels of the pulse analyzer.

The linearity of gas amplification was established within the experimental accuracy of 2 percent, by measuring (in counter *II*) the ratio of the mean pulse sizes produced by the 17.4- and 2.8-kev radiations. Further, the widths of the peaks were found to be independent of the gas multiplication M up to a critical value M_c, which is a function of the radiation energy E, where the widths suddenly increased. For $M>M_c$ lack of linearity was apparent. These facts strongly suggest that proportionality is maintained up to that multiplication factor which produces a certain total output pulse, that is $E\times M_c=$constant, which in this counter was about 10^8 ev.* It follows, and may be specially noted, that for low energy measurements correspondingly large multiplication factors may be used.

Correcting for the low energy tail, the shape of the peaks produced by the 17.4- and 2.8-kev radiations was found to be Gaussian, at least over an energy range (±3 standard deviations) where background fluctuations do not disturb the measurements.

Since this spread is due not only to statistical fluctuations, but also to instrumental causes (such as irregularities in wire diameter), we cannot conclude that the "ideal" peaks (i.e., peaks with a spread due to statistical causes only) would be Gaussian. However, it seems almost certain** that the observed value of the standard deviation obtained by fitting the experimental data to a Gaussian distribution will give an upper limit to the standard deviation of the corresponding "ideal" peak.

The theories of Snyder and Frisch[6] give a mean square deviation at the output, referred back to the initial number of ions, n, equal to $(n/K)+n$. K is a constant discussed by Fano[7] and may be about 3. The first and second terms represent, respectively, the fluctuation in the initial number of ions and the contribution added by the statistics of the multiplication process.

The experimental results from counter *I*, which is one of our counters giving the least spread, are presented in Table II.

The results are most consistent with a mean square deviation of n. Since K is unlikely to be very great,*** and in any case the observed values represent lower limits for the mean square deviation, our results show definitely that the gas amplification introduces less spread than predicted. An attempt to formulate a more accurate theory of the process is being made in this Laboratory.

[1] Bruce B. Benson, Rev. Sci. Inst. **17**, 533 (1946); C. J. Borkowski and E. Fairstein, Phys. Rev. **74**, 1243 (1948); these authors also mention the possibility of measuring β-particle energies.
[2] D. H. W. Kirkwood, B. Pontecorvo, and G. C. Hanna, Phys. Rev. **74**, 497 (1948); S. C. Curran, J. Angus, and A. L. Cockcroft, Nature **162**, 302 (1948).
[3] B. Pontecorvo, D. H. W. Kirkwood, and G. C. Hanna, Phys. Rev. **75**, 982 (1949).
[4] G. C. Hanna and B. Pontecorvo, Phys. Rev. **75**, 983 (1949).
[5] C. H. Westcott and G. C. Hanna, Rev. Sci. Inst. **20**, 181 (1949).
* The condition is certainly less stringent than this when the original ionization is spread over a large distance.
** In principle this conclusion is not certain because the "ideal" distribution might be a pointed curve with extremely long tails which would evade detection.
[6] Hartland S. Snyder, Phys. Rev. **72**, 181 (1947); O. R. Frisch, *The Statistics of Multiplicative Processes*, as yet unpublished.
[7] Ugo Fano, Phys. Rev. **72**, 26 (1947).
*** Previously (see reference 2) we obtained a value for K of at least 2.4, assuming the validity of the Snyder formula. This might have been in good agreement with Fano's estimate. Our better accuracy would now yield impossibly high values for K.