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An Experimental Investigation of the Dead Time of Geiger-Mueller Counters

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Jessner — The Dead Time of Geiger - Mueller Counters

AN EXPERIMENTAL INVESTIGATION OF THE DEAD TIME OF GEIGER-MUELLER COUNTERS

By

Peter H. Jessner

A Thesis
In partial fulfillment of the
Requirements for the Degree of
Master of Science in Physics

The University of New Mexico

1951

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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CHAIRMAN

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CHAPTER I

INTRODUCTION

As ever more sensitive and precise experiments are being performed with Geiger Counters, especially in cosmic ray research, the resolving power of these instruments assumes an ever increasing importance. With the present perfection of electronic circuitry, this resolving time has become largely a function of the dead time of the Geiger counter tube itself. It was therefore proposed to investigate methods of reducing this dead time. Only self-quenching counter tubes had to be considered in this connection since the dead time of all other types of Geiger counters is inherently longer.

1. CAUSE OF DEAD TIME

After the passage of any ionizing particle causing a pulse in a Geiger counter tube, the tube will not produce another pulse, however small, until a certain amount of time, the dead time, has elapsed. This dead time is of the order of 10^2 to 10^3 microseconds for counter tubes of the usual dimensions. After the end of the dead time, pulses of increasing magnitude may be produced until the counter tube has completely recovered. Then pulses of normal size appear again. The dead time is due to the fact that during the discharge electrons are rapidly collected on the positive central wire of the counter tube; this removal of electrons from the gas leaves behind a sheath of positive ions around the

central wire where most of the ionization occurs. This sheath modifies the electric field inside the counter and prevents any further pulse. Since the mobility of the positive ions is very much smaller than that of the electrons, this sheath drifts comparatively slowly toward the cathode. Only when this sheath reaches a certain critical distance from the central wire, a new pulse becomes possible, and since the field inside the tube has not yet returned to normal, only a small pulse can be produced. After the field returns to normal, pulses of full size may again be produced. However, with high gain amplifiers even very small pulses can be registered so that the recovery time is comparatively unimportant in determining the resolving time of the counter tube.

2. METHODS OF REDUCING THE DEAD TIME

This qualitative picture of Geiger Counter operation suggests two possible ways of reducing the dead time of the counter tube, one electronic and the other mechanical.

Electronically it is possible to use the steep leading edge of the pulse from the counter to actuate some device which will reverse the electric field inside the tube. This causes the positive ion collection to take place on the central wire. Since most positive ions are formed very close to the central wire, this method of collection is very much more rapid than collection by the wall of the tube. An electronic circuit for this purpose, with an effective dead time of 10 microseconds, has been described by Simpson.[1] For an arrangement of this type the

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[1] J. A. Simpson, "Reduction of the Natural Insensitive Time in G-M Counters," Physical Review, August 1 and 15, 1944, Vol. 66, Nos. 3 and 4, pp. 39-47.

control wire where any of the [illegible] [illegible]. This [illegible] that the electric field inside the [illegible] [illegible] [illegible] [illegible]. Since the [illegible] of the [illegible] [illegible] [illegible] [illegible] [illegible] of the [illegible], this [illegible] [illegible] [illegible] [illegible] the cathode. Only when [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] and the control wire, [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] side the tube. [illegible] [illegible] produced. After the field [illegible] to [illegible], [illegible] of [illegible] again be produced. However, [illegible] [illegible] [illegible] [illegible] pulses can be [illegible] so that the [illegible] [illegible] [illegible] important in determining the [illegible] [illegible] of the counter tube.

[illegible] OF [illegible] THE [illegible]

This qualitative picture of [illegible] [illegible] [illegible] the possible ways of [illegible] of [illegible] [illegible] [illegible] tronic and the other [illegible].

Electronically, [illegible] [illegible] [illegible] [illegible] pulse from the [illegible] [illegible] [illegible] [illegible] [illegible] electric field inside the tube. This [illegible] [illegible] [illegible] to take place on the control wire. [illegible] [illegible] [illegible] [illegible] very close to the [illegible], [illegible] [illegible] [illegible] [illegible] more rapid [illegible] [illegible] [illegible] [illegible] of the tube. [illegible] cuit for this [illegible], with [illegible] [illegible] [illegible] has been [illegible] by [illegible].[1] [illegible] [illegible] of this [illegible]

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[1] [illegible], "[illegible] [illegible] [illegible] [illegible] [illegible] Counters," *Physical Review*, [illegible] pp. [illegible].

dead time becomes largely a function of the electronic circuits. However these circuits are quite complicated and the reversal of the field in the counter tube may cause new complications.

The dead time can be shortened mechanically either by reducing the physical dimensions of the counter tube, or by decreasing the gas pressure in the tube. It is to be expected that a decrease in the diameter of the counter tube, by shortening the distance the ion sheath has to move, will result in a decrease of the dead time. Reducing the gas pressure on the other hand increases the average speed of the positive ions and should thus have a similar effect.

To investigate these two effects, three counter tubes of different diameters but identical in all other respects were constructed . The dead time of each of these at varying gas pressures was then measured by the method developed by Stever.[2] The results were expected to provide an indication as to the desirability of using any particular size of counter tube for a given experiment.

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[2] H. G. Stever, "The Discharge Mechanism of Fast G-M Counters from the Dead Time Experiment," Physical Review, January 1 and 15, 1942, Vol. 61, Nos. 1 and 2, pp. 38-52.

dead time between large pulses. [illegible] How- ever these circuits are quite complicated and a reversal of the field in the counter tube may cause bad spurious counts.

The dead time can be shortened most readily either by reducing the physical dimensions of the counter tube, or by increasing the gas pressure in the tube. It is to be expected that a decrease in the diameter of the counter tube, by shortening the distance the positive ions have to move, will result in a decrease of the dead time. Increasing the gas pressure on the other hand increases the average speed of the positive ions and should thus have a similar effect.

To investigate these two effects, three counter tubes of different diameters but identical in all other respects were constructed. The dead time of each of these at varying gas pressures was then measured by the method developed by Stever.[7] This research was intended to provide an indication as to the optimum size of the tube and pressure of counter gas for a given experiment.

---

[7] H. G. Stever, "The Discharge Mechanism of Fast G-M Counters from the Dead Time Experiment," Physical Review, January 1 and 15, 1942, Vol. 61, Nos. 1 and 2, pp. 38-52.

CHAPTER II

THEORY

The theory of Geiger-Mueller counter operation has been described fairly completely by several writers.[3,4,5] No attempt will be made here to give a complete quantitative analysis of Geiger counter operation. Much of this analysis is based on the theory of electrical discharges in gases discussed in detail by Loeb. Many of the constants involved, such as ion and electron mobilities, are either not known or depend so critically on the presence of slight amounts of impurities, that such an analysis does not permit the prediction of the operation of any particular Geiger counter. However, a more thorough qualitative discussion of Geiger counter operation, as well as a quantitative development of formulas relating the dead time to variables of the counter tube will be given.

1. GEIGER COUNTER OPERATION

The characteristic which distinguishes the Geiger-Mueller counter from other electric counters, such as ionization chambers or proportional

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[3] C. G. Montgomery and D. D. Montgomery, "The Discharge Mechanism of Geiger-Mueller Counters," Physical Review, 1 June 1940, Vol. 57, No. 11, pp. 1030-1040.

[4] H. G. Stever, loc. cit.

[5] D. H. Wilkinson, Ionization Chambers and Counters, Cambridge, Eng., Cambridge University Press, 1950, pp. 170-246.

[6] L. B. Loeb, Fundamental Processes of Electrical Discharge in Gases, New York: John Wiley and Sons, Inc., 1939.

CHAPTER [illegible]

[illegible]

The theory of [illegible] counter operation has been [illegible] fairly completely [illegible] [illegible] here to give a [illegible] tion. Much of [illegible] charges in [illegible] involved, such as [illegible] depend on [illegible] that much [illegible] of any particular [illegible] development of [illegible] counter tube will be given.

A. [illegible] Counter Operation

The [illegible] from [illegible] electric [illegible]

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6. [illegible] Montgomery, [illegible] "[illegible]," [illegible], pp. 1030-1040.

7. [illegible], loc. cit.

8. [illegible] Cambridge University Press, 1939, pp. [illegible]

9. [illegible] New York: John Wiley and Sons, [illegible]

counters, is the fact that, at least theoretically, every time an ionizing particle produces as much as a single ion pair anywhere within the sensitive volume of the counter tube, a pulse of the same amplitude will be produced.

For the production of a pulse, both a process of multiplication and one of limiting the number of ions produced in the counter must exist. The multiplication of the number of ions takes place through ionization of the counter tube gas by collision with electrons accelerated by the electric field which exists in the counter tube. Since for the usual cylindrical geometry the field is strongest near the central wire, most of the ionization takes place in a comparatively small part of the counter tube surrounding the central wire. The production of one avalanche is however not sufficient to explain the Geiger counter action since it produces a pulse proportional to the initial ionization, like the pulse in a proportional counter. Some other mechanism which permits ions in one avalanche to generate other avalanches must exist.

In self-quenching counter tubes photons produced by the highly energetic electrons in collisions with the gas near the counter tube wire cause the emission of photoelectrons probably by the polyatomic molecules of the quenching gas. These photoelectrons start new avalanches and cause the discharge to spread all along the central wire. The existence of this phenomenon and the fact that it is confined to a space very close to the central wire are best shown by Stever's experiments with counter tubes bearing small glass beads on the central wire.[7]

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[7] H. G. Stever, loc. cit.

These beads localize the discharge to any given section of the counter tube even though the diameter of the beads is only a few times that of the central wire.

What limits the total ionization produced in the counter tube and prevents a continuous discharge through the tube is the reduction of the electric field by the positive ion sheath near the counter wire to a value lower than that necessary for the production of avalanches of ions. Since the mobility of electrons is so much larger than that of the positive ions, the positive ion sheath can be considered as stationary during the collection of the electrons by the central wire. The positive ion sheath then drifts to the cathode. In non-self-quenching counters the arrival of the positive ions at the cathode will cause the ejection of electrons from the cathode and thus produce a new discharge pulse unless this is prevented by some external mechanism.

In self-quenching counters electron emission at the cathode is prevented by the presence of polyatomic gas molecules. Charge exchange takes place between noble gas ions and polyatomic gas molecules inside the counter, so that the ions reaching the counter tube wall are all polyatomic gas ions. These ions predissociate on arrival at the cathode rather than causing electron emission. This quenching action has been thoroughly discussed by Korff and Present.[8]

While this dissociation thus prevents a continuous discharge of the counter tube, it also limits its useful life since the quenching agent is continuously being used up.

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[8] S. A. Korff and R. D. Present, "On the Role of Polyatomic Gases in Fast Counters," Physical Review, 1 and 15 May 1944, Vol. 65, Nos. 9 and 10, pp. 274-282.

These beams lead the discharge to the [illegible] of the counter tube even though the discharge [illegible] a few ions [illegible] in the central wire.

That limits the spread [illegible] produced in the counter tube and prevents a continuous discharge [illegible] is the [illegible] of the electric field [illegible] positive [illegible] is a value less than that necessary for the [illegible] of the [illegible] of ions. Since the mobility of electrons is [illegible] than that of the positive ions, the positive [illegible] can be considered as stationary during the collection of the electrons by the central wire. The positive ion sheath then drifts to the cathode. In a self-quenching counter the arrival of the positive ions at the cathode [illegible] the ejection of electrons from the cathode and thus causes a [illegible] pulse unless [illegible] by the external [illegible].

In self-quenching counters [illegible] of the [illegible] is prevented by the presence of polyatomic gas molecules. These molecules take [illegible] charge [illegible] collision with the counter gas [illegible] polyatomic gas [illegible] dissociate [illegible] at the cathode rather than causing electron emission. This quenching condition has been thoroughly discussed by Korff and Present.[9]

While this [illegible] a continuous discharge of the counter tube, it also limits the useful life [illegible] quenching agent is continuously being used up.

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[9] S. A. Korff and R. D. Present, "On the Role of Polyatomic Gases in Fast Counters," Physical Review, [illegible] 1944, Vol. 65, Nos. 9 and 10, pp. 274-282.

DEAD TIME

To derive an expression for the variation of the dead time with counter tube variables, a basic expression for the behavior of the positive ion sheath must first be developed.[9] We assume that the potential of the central wire remains substantially constant during the discharge. If we consider a counter tube of radius b with a central wire of radius a which is initially charged to a charge per unit length Q_o, containing a positive ion sheath of charge q per unit length at a distance x from the central wire, the effective charge Q on the central wire will be given by the expression

$$Q = Q_o - q\left(\frac{\log b/x}{\log b/a}\right) \qquad (1)$$

and the ion sheath is in a field

$$X = \frac{2}{x}\left\{Q_o - q\left(\frac{\log b/x}{\log b/a}\right)\right\} + \frac{q}{x} \qquad (2)$$

where the last term is the self-force of the ion sheath. From this expression we can derive an expression for the time t(x) which the ion sheath will need to reach a distance x from the central wire, assuming that all the positive ions have the same mobility K. The expression for t(x) is quite complicated but can be simplified by assuming that x is many times larger than a, the wire radius. t(x) then becomes

$$t(x) = \frac{(x^2 - a^2)\log b/a}{2\ KV\left(1 + \frac{1}{2}m\right)} \qquad (3)$$

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[9] D. H. Wilkinson, *op. cit.*, pp. 206-207

where V is the potential applied to the counter tube and *m* stands for the ratio q/Q_o. For Geiger counter action to take place at the wire, the field at the wire must be as large as that produced by the threshold potential for Geiger counter action V_s. Therefore the charge per unit length on the wire must be

$$\frac{V_s}{2 \log b/a} \tag{4}$$

By combining expressions (1) and (4) we can find an equation for the dead time t_d.

$$Q_o - q \frac{\log b/x_d}{\log b/a} = \frac{V_s}{2 \log b/a} \tag{5}$$

$$x_d = b\, e^{-\left[(V - V_s)/mV\right] \log b/a} \tag{6}$$

$$t_d = \frac{b^2 e^{-\left[(2V - 2V_s)/mV\right] \log b/a}}{2\,KV \; (1 + \frac{1}{2}m)} \tag{7}$$

Experimentally it was found that[10]

$$m = \frac{V - V_s}{100}\, C \tag{8}$$

where C is a constant characteristic of each counter tube and V must be smaller than V_b an experimentally determinable voltage above which the expression for *m* changes. Therefore at potentials slightly above V_s, substituting (8) into (7),

$$t_d = \frac{b^2 e^{-(200/VC)\log b/a}}{2\,KV \; (1 \;\; \frac{V - V}{200})} \quad \log b/a, \tag{9}$$

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[10] D. G. Wilkinson, *op. cit.*, p. 182.

where V is the potential applied to the counter with respect to the cathode, θ_c. The Geiger discharge is able to take place as the field at the wire [illegible] is so large as that [illegible] potential applied, or greater than V_s. [illegible] length on the wire equal to

$$\frac{V_s}{2\log b/a}$$

By combining expressions (4) and (5) we can derive equations for the dead time t_d:

$$\rho_c = a\,\frac{\log b/a}{\log b/a} = \frac{V_s}{2\log b/a} \qquad (4)$$

$$r_f = b\,e^{-\left[V - V_s/V\right]\log b/a} \qquad (5)$$

$$t_d = \frac{b^2 e^{-\left[2V - 2V_s/mV\right]\log b/a}}{2\,mV\,(1 + m)} \qquad (6)$$

Experimentally it was found that[10]

$$m = \frac{V - V_s}{100}\,C$$

where C is a constant characteristic of each counter. When V is smaller than V_s at approximately [illegible] the expression for t_d changes. Therefore [illegible] substituting (...) into (...),

$$t_d = \frac{b^2 e^{-(2V/C)\log b/a}}{2\,V\,\left(1 + \frac{V - V_s}{C}\right)} \qquad (7)$$

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[10] S. G. Wilkinson, op. cit., p. 182.

and at the threshold potential V_s the dead time t_{do} becomes

$$t_{do} = \frac{b^2 e^{-(200/V_s C)\log b/a}}{2KV_s} \log b/a \qquad (10)$$

The dead time at any potential will vary with the counter variables in a manner similar to t_{do}. Since the dead time varies inversely as K, which in turn varies inversely as the pressure, the dead time may be lowered by reducing the counter gas pressure. However, this effect is counteracted by the decrease of V_s with pressure, although this effect is smaller. The b^2 in the numerator of (10) shows that the dead time may be substantially reduced by a decrease in the counter tube diameter also the exponential increases slightly as b decreases so that t_d does not decrease as rapidly as b^2.

The preceding discussion assumes that each pulse terminates completely before the next pulse starts. For very high counting rates this may not be true, and we may then have several different positive ion sheaths moving across the counter tube at the same time. This will result in a reduction of the dead time as was first shown by Muelhause and Friedman.[11] However this effect becomes important only at very high counting rates and does not interfere with the comparison of the dead times of various counter tubes at similar counting rates.

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[11] C. O. Muelhause and H. Friedman, "Measurements of High Intensities with the Geiger-Mueller Counter," Review of Scientific Instruments, November 1946, Vol. 17, No. 11, pp. 506-510.

and at the threshold potential V_s the dead time t_{ds} becomes

$$t_{ds} = \frac{b^2 - (a^2/V_s)\text{[illegible]}}{2K_s} \ln(b/a) \qquad (23)$$

The dead time at any potential will vary with the counter variables in a manner similar to t_{ds}. Since the dead time varies inversely as K, which in turn varies inversely as the pressure, the dead time may be lowered by reducing the counter gas pressure. However, this effect is counteracted by the decrease of V_s which accompanies it so that the effect is smaller. The b^2 in the numerator of (23) shows that the dead time may be substantially reduced by a decrease in the cathode diameter since also the exponential factor [illegible] and [illegible] decrease, V_s does not decrease as rapidly as b^2.

The preceding discussion assumes that each pulse terminates completely before the next pulse starts. For very high counting rates this may not be true, and an ion sheath may be formed before the positive ion sheath arrives near the cathode [illegible] of the preceding. This will result in a reduction of the dead time as was first shown by Mühlhauser and Friedman.[11] However this effect becomes important only at very high counting rates and does not interfere with the measurement of the dead times of various counter tubes at average counting rates.

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[11] O. G. Mühlhauser and [illegible], "[illegible] Intensities with the Self-quenching Counter," Review of Scientific Instruments, November 1945, Vol. 16, No. 11, pp. 316-[illegible].

CHAPTER III

EXPERIMENTAL PROCEDURE

1. TUBE CONSTRUCTION

Three counter tubes, $\frac{1}{4}$ inch, $\frac{1}{2}$ inch, and 1 inch in diameter, respectively, and 12 inches in length were used in this investigation. They all had .005-inch diameter Kovar central wire and were essentially of the all-metal construction described by V. Regener.[12] Due to the small diameter of these counter tubes separate exhausting tubes were impracticable. Instead a single Kovar-glass seal with a glass branch tube for exhausting was used. On the other end of the tube the central wire was sealed directly to a Kovar-glass seal without the use of a spring. Tautness of the central wire was insured by clamping the counter tubes vertically and stretching the central wire by means of a weight while it was being sealed to the glass seal.

To permit a study of the variation of the dead time with changes in the filling mixture, the counter tubes were never sealed off completely but left connected to the vacuum system by rubber tubing. After each filling, the rubber tubing was closed by a pinch clamp. Since all measurements were made within a twelve hour period after filling the tube, no serious leakage of air into the tube could take place during this time. For each tube, mixtures of 10mm of argon with

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[12] V. Regener, "All-Metal Fast Geiger Counters for Cosmic Ray Research," Review of Scientific Instruments, May 1947, Vol. 18, No. 5, pp. 267-270.

CHAPTER III

PRELIMINARY PROCEDURE

1. TUBE PREPARATION

Three copper tubes, ¼, ⅜, and ½ inch diameter, respectively, and 12 inches in length were used in this investigation. They all had .003 inch diameter tungsten central wire and were essentially of the all-metal construction described by V. Regener.[17] Due to the small diameter of these copper tubes separate connecting tubes were impracticable. Instead a single Kovar-glass seal with a glass exhaust tube for exhausting was used. On the other end of the tube the central wire was sealed directly to a Kovar-glass seal without the use of a spring. In none of the counters were the [illegible] to [illegible] the counter being vertically and [illegible], the central wire by means of a weight while it was being sealed to the glass seal.

To permit a study of the variation of response with pressure and in the filling mixture, the counter tubes were never sealed off completely but left connected to the vacuum system by rubber tubing. After each filling, the rubber tubing was closed by a pinch clamp. Since all measurements were made within a relatively short time after filling the tube, no serious leakage of air into the tube could take place during this time. For each tube, a mixture of 10cm of argon and

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[17] V. Regener, "All-Metal Counter Tubes for Cosmic Ray Research," Review of Scientific Instruments, May 1943, Vol. 14, No. 5, pp. 367-375.

90mm of alcohol, 11mm of argon with 103mm of alcohol, 12mm of argon with 115mm of alcohol, 13mm of argon with 127mm of alcohol, and 14mm of argon with 140mm of alcohol were used.

2. ELECTRONIC CIRCUITS

To measure the dead time of the counter tubes under various conditions the method developed by Stever[13] was used. This method consists in disconnecting the normal internal synchronization of an oscilloscope and using the pulse from the counter tube to trigger the oscilloscope sweep. This insures the coincidence of the beginning of each counter tube pulse with the beginning of the sweep and thus causes the superposition of the irregularly occuring pulses on the oscilloscope screen. Since in the Geiger region all pulses occuring after the recovery time of the counter tube are of approximately the same amplitude a bright sharp picture of the counter tube pulses is obtained. One can clearly determine visually the moment at which it is possible for new pulses, however small, to occur in the counter tube after the beginning of the original pulse. By using a ruled oscilloscope screen and calibrating this ruling with a sine wave of known frequency, the dead time of the counter may be found.

Instead of modifying an ordinary oscilloscope to provide the synchronization of the oscilloscope sweep with the counter tube pulses, a Western Electric TS-34/AP oscilloscope was used. This instrument provides the necessary mechanism for triggering the sweep by means of the

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[13] H. G. Steever, loc. cit.

50m of alcohol, 12m of sugar with [illegible] of alcohol, [illegible] and 125m of alcohol, [illegible] with [illegible] and [illegible] with [illegible] of alcohol [illegible].

[illegible]

To measure the [illegible] of the [illegible] the author developed [illegible] in [illegible] [illegible]. This [illegible] take [illegible] with the [illegible] position of the [illegible]. Since [illegible] of the [illegible] every [illegible] determine [illegible] however small, [illegible] original [illegible] this [illegible] counter [illegible].

Instead of [illegible] [illegible] Renton [illegible] vides the [illegible]

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[1] [illegible]

incoming pulse. A 100,000 ohm load resistance was used with the counter tube, and the counter tube was coupled to the oscilloscope by means of a 50-micromicrofarad coupling condenser. The sweep of the oscilloscope was calibrated with a Hewlett Packard Audio Oscillator.

3. MEASUREMENTS

For every tube filling, the plateau for Geiger counting was first determined. Measurements of the pulse height and of the dead time were taken at an overvoltage of fifty volts. By using the same overvoltage throughout, the effect of the dependence of the dead time on the overvoltage was eliminated. It was also found that the operating characteristics of the tubes changed within the first few hours after filling, an effect previously mentioned by Regener.[14] However, no appreciable changes in the dead time occured after the first few hours. All of the measurements were made at least three hours after filling the counter tube.

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[14] V. Regener, loc. cit.

CHAPTER IV

RESULTS

Although the theoretical considerations given in Chapter III involve many approximations, the results of the experiment tend to bear them out. Table 1 and Graphs 1 and 2 show the results.

Graph 1 shows the variation of the dead time of each counter tube with the total gas pressure in the tube. All of the curves on Graph 1 show that the almost linear relationship predicted by the theory is followed in practice. Only as the pressure is decreased very considerably does the dead time begin to decrease somewhat more slowly. In view of this fact and the increased instability of the counter tubes at lower pressures, there is probably little benefit to be derived from reducing the pressure below 100mm.

TABLE I

TUBE I : Tube diameter 1 inch

alcohol pressure	argon pressure	starting voltage	discharge voltage	pulse height	dead time
10 mm	90 mm	1210 v	1360 v	9.8 v	110 μs
11 mm	102 mm	1230 v	1370 v	9.8 v	117½ μs
12 mm	115 mm	1290 v	1420 v	9.8 v	125 μs
13 mm	127 mm	1350 v	1520 v	9.8 v	140 μs
14 mm	140mm	1430 v	1570 v	9.2 v	155 μs

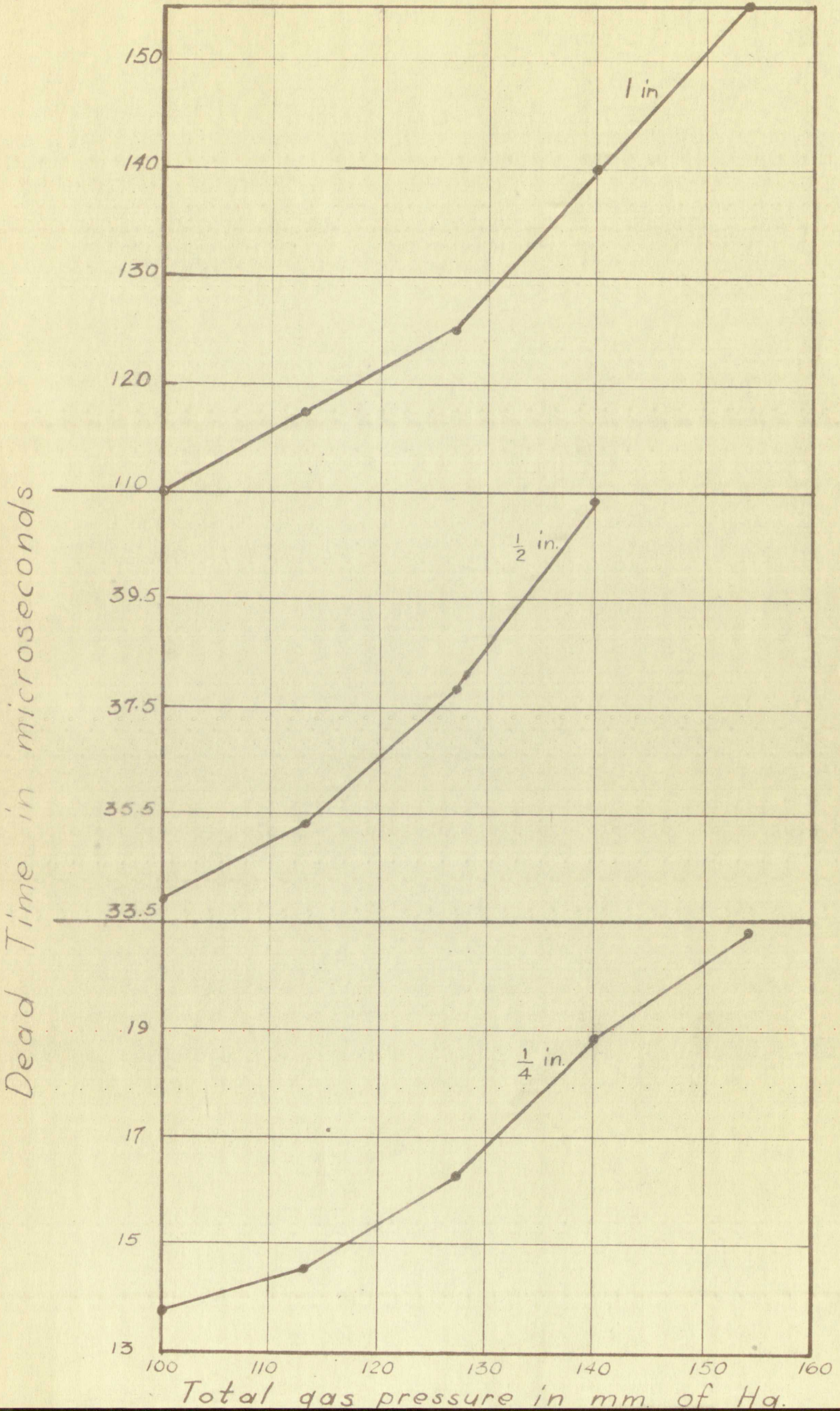
Tube II : Tube diameter ½ inch

alcohol pressure	argon pressure	starting voltage	discharge voltage	pulse height	dead time
10 mm	90 mm	980 v	1060 v	9.8 v	33.9 μs
11 mm	102 mm	1040 v	1120 v	10.2 v	35.3 μs
12 mm	115 mm	1080 v	1170 v	10.2 v	37.8 μs
13 mm	127 mm	1080 v	1170 v	10.2 v	41.3 μs
14 mm	140 mm	1240 v	1330 v	10.2 v	55 μs

TUBE III : Tube diameter ¼ inch

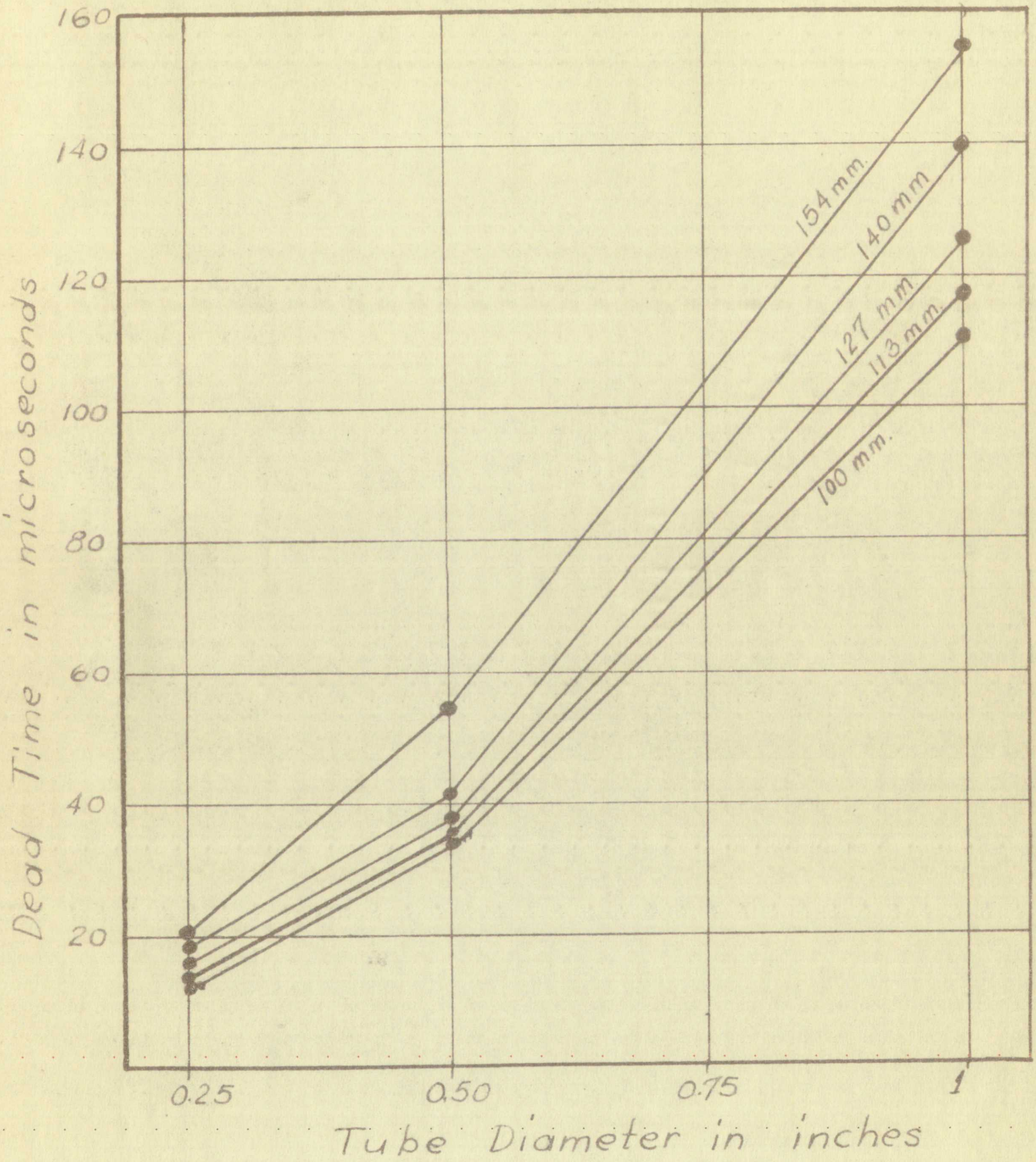
alcohol pressure	argon pressure	starting voltage	discharge voltage	pulse height	dead time
10 mm	90 mm	900 v	970 v	10.2 v	13.8 μs
11 mm	102 mm	970 v	1050 v	10.2 v	14.6 μs
12 mm	115 mm	1040 v	1120 v	10.2 v	16.3 μs
13 mm	127 mm	1075 v	1150 v	10.2 v	18.9 μs
14 mm	140 mm	1110 v	1190 v	10.2 v	20.7 μs

Graph I. Dead Time versus Pressure



Graph 2 gives the relationship between the dead time and the counter tube diameter for various gas pressures. These curves are of substantially the same form regardless of the filling mixture. The relationship between the dead time and the counter tube diameter comes closer to being linear than the theoretical equation predicts. It is difficult to deduce much from these graphs as the various parameters cannot be varied individually to permit an accurate examination of the influence of each of them.

Graph 2. Dead Time versus Diameter



As the results show, substantial reductions in the dead time can be achieved by the reduction of the tube diameter. However, the data on the plateaus of the various counter tubes given in Table 1 show that as the diameter is reduced the plateau of the counter becomes dangerously small. Very stable power supplies would be required to operate a $\frac{1}{4}$ inch diameter counter tube satisfactorily. It may, on the other hand, be possible to improve the operating characteristics of such a small tube by using a thinner central wire.

It must also be considered that when banks of smaller diameter tubes are used to replace one large diameter tube, the resolving time of the combination is automatically lower than the dead time of the individual tubes. The number of counts for each tube is smaller and the statistical probability of two successive incoming particles traversing the same counter tube is slight. Thus the resolving time is simultaneously reduced by two factors, and very large improvements may be obtained.

CHAPTER V

SUMMARY AND CONCLUSIONS

1. SUMMARY

The need for a reduction in the resolving time of the Geiger-Mueller counters led to a theoretical examination into the possibilities of reducing the dead time of Geiger counter tubes. Two of these possibilities, the reduction of the dead time by decrease in the counter gas pressure or by decrease of the counter tube diameter were investigated by means of three Geiger counters. These were identical except in diameter and were filled with various gas mixtures. Using the triggered oscilloscope method of measuring the dead time, data on the performance of these counter tubes at various pressures were obtained. The experimental data obtained checked to within the approximations made with the theoretical predictions.

2. CONCLUSIONS

For experiments in which the resolving time of the Geiger-Mueller counter is of critical importance, the two investigated methods of reducing the dead time of the counter tube were shown to produce good results. The pressure can be reduced up to a certain point with only a slight loss of stability.

Even larger reductions in the dead time may be obtained by reducing the counter tube diameter. However, in this case there are several disadvantages such as the added cost of the larger number of smaller counter tubes and the shorter plateaus of the smaller counter tubes.

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