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Experiments on the Life of Self-Quenching Geiger Mueller Counters

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Opperman — Self-Quenching Geiger Mueller Counters

EXPERIMENTS ON THE LIFE OF SELF-QUENCHING GEIGER MUELLER COUNTERS

By

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DATE

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INTRODUCTION

A. Self-quenching Counters

Whenever a Geiger counter is operated in the plateau region,[1] pulses are initially quenched by the formation of a positive ion sheath around the center wire which reduces the electric intensity in the vicinity of the wire. If the filling gas consists entirely of monatomic or diatomic molecules, extra counts will in general be initiated by the liberation of electrons from the cathode by the positive ions.

A quenching mechanism must be introduced to prevent these extra pulses in a counter. Self-quenching counters employ an internal quenching process. This is usually accomplished by including a small percentage of polyatomic molecules with the filling mixture. Tubes filled partially or entirely with an organic vapor have been used extensively as self-quenching counters. These fillings generally result in counters which have comparatively large pulses with a low percentage of spurious counts and a relatively long plateau. Unfortunately, the useful life of organic vapor counters is usually limited to about 10^8 or 10^9 counts, compared to lives of more than 10^{10} counts for counters using an inorganic

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[1] A list of definitions is given in the following section.

CHAPTER II

INTRODUCTION

A. Self-quenching Counters

Whenever a Geiger counter is operated in the Plateau region,[1] pulses are initially triggered by the formation of a positive ion sheath around the center wire which reduces the electric intensity in the vicinity of the wire. If the filling gas consists entirely of monatomic or diatomic molecules, extra counts will be produced at a later time by the liberation of electrons from the cathode by the positive ions.

A quenching mechanism must be introduced to prevent these extra pulses in a counter. Self-quenching counters employ an internal quenching process. This is usually accomplished by including a small percentage of polyatomic molecules with the filling mixture. Counters filled partially or entirely with an organic vapor have been generally referred to as self-quenching counters. These fillings usually result in counters which have comparatively large plateau slopes and a low percentage of spurious counts [illegible]. Unfortunately, the useful life of organic vapor counters is usually limited to about 10^8 or 10^9 counts; some counters have lives of more than 10^{10} counts [illegible]

[1] A list of definitions is given in the appendix section.

quenching gas. Some experiments to determine the relative importance of the factors limiting the life of alcohol-argon filled counters will be described in this thesis.

Counters in which an inorganic gas is used as the quenching gas generally have a shorter plateau than those employing an organic vapor. However, the lives of counters using an inorganic quenching gas may be considerably longer for some mixtures than those found for organic vapor counters. Experiments on the life of counters filled with ammonia and argon are described.

B. Notation and Terminology

The following is a list of definitions of terms used in this thesis:

V The potential difference applied across a counter.

V_s The lowest potential at which counts are observed with the equipment employed. In these experiments the starting potential was determined by visual observation on an oscillograph with constant amplification.

V_g The lowest potential at which all pulses are of equal size regardless of the number of ions produced by the primary ionizing particle.

V_c The potantial at which the counter gives continuous or self-sustaining counts.

V_u The overvoltage which is equal to V minus V_g.

Plateau The Potential region in which the counting rate in nearly independent of the applied voltage.

Plateau Slope The change in counting rate for one hundred volts change in supply voltage while the counter is operated in the plateau region.

Geiger Region The Potential region of Geiger counting action, i.e., Vc minus Vg.

C. Definition of Counter Tube Life

The life of a Geiger-Mueller counter is the number of events which can be counted without changing certain characteristics of the counter in such a way as to make it useless. These characteristics are the length and slope of the plateau, the normal operating voltage and the background counting rate.

Some causes of counter failure are common both to externally and to internally quenched counters, for example, pitting of the center wire. However, the changes in counter characteristics discussed in this thesis, will in general apply only to the self-quenching type since most of these changes are connected with the dissociation of the quenching gas used.

The amount and rate of change which can be tolerated in any of the listed characteristics depends on the application of the counter. If the length of the plateau decreases with use of the counter it eventually becomes impractical to

Plateau The potential range in which the counting rate is nearly independent of the applied voltage.

Plateau Slope The change in counting rate per one hundred volts change in applied voltage when the counter is operated in the plateau region.

Geiger Region The potential region of Geiger counting action, i.e., [illegible].

C. Definition of Geiger Tube Life

The life of a Geiger-Mueller counter is the number of events which can be counted without changing certain characteristics of the counter to such a degree as to make it unusable. These characteristics are the length and slope of the plateau, the normal operating voltage and the background counting rate.

Some causes of counter failure are chance opens in externally and internally connected components, [illegible] pitting of the center wire. However, any changes in counter characteristics discussed in this report will be meant to apply only to the self-quenching type where most of these changes are connected with the dissociation of the quenching gas used.

The amount and rate of change [illegible] in any of the listed characteristics [illegible] of the counter. [illegible] with use of the counter is eventually [illegible] regulate the voltage applied across the tube so as to remain in the plateau region. This constitutes the end of the useful life for such a counter. Increase in plateau slope or fluctuation in background counting rate will also limit the useful life.

D. Purpose of Experiment

Because of the several superior properties of counters containing organic vapor as a quenching agent, it is desirable to extend the life of such counters. It is, therefore, of interest to determine the relative importance of factors which limit their useful life. It is also worthwhile to further the investigation of counters containing an inorganic gas as the quenching agent.

In these experiments life tests were conducted with counters filled with different percentages of alcohol vapor. One counter was given a life test while supplied with a constant alcohol vapor pressure. In some cases, counters were refilled and in other cases new center wires were installed to determine the major factors limiting counter life. Tests were also conducted to determine the useful life of counters filled with ammonia and argon.

CHAPTER II

THEORY AND PRESENT STATE OF EXPERIMENTAL EXPERIENCE

A. General

A. Ehmert and A. Trost[1] in 1936 and A. Trost[2] in 1937 described experiments concerning vapor-quenched counters and proposed a theory of the counting mechanism. C. G. Montgomery and D. D. Montgomery[3] in 1940 and H. G. Stever[4] in 1942 extended this theory for nonself-quenching and self-quenching counters respectively. Korff and Present[5] (1944) described the role played by the polyatomic molecules in a self-quenching counter.

As explained by Korff and Present, the process of self-quenching must involve the dissociation of polyatomic molecules. The initial avalanche, after spreading along the entire sensitive portion of the counter in the Geiger counting region, is stopped by the action of the positive ion sheath which is formed during the avalanche. Ions of a monatomic or diatomic gas upon reaching the cathode liberate electrons and thus initiate extra counts. Polyatomic molecules, on the other hand, have a large probability of predissociation, i.e., dissociation before radiation, and thus have a small probability of liberating electrons from the cathode after being neutralized. In a filling

CHAPTER II

THEORY AND [illegible]

OF EXPERIMENTAL [illegible]

A. [illegible]

A. [illegible] and A. Trost[1] in 1936 and [illegible] in 1937 described experiments concerning [illegible] counters and proposed a theory of the [illegible] mechanism. C. G. Montgomery and D. D. Montgomery[3] in 1940 and [illegible] in 1942 extended this theory for [illegible] counters respectively. [illegible] (1944) described the role [illegible] by the [illegible] of a self-quenching counter.

As explained by [illegible], the [illegible] of self-quenching was [illegible] the [illegible] of [illegible] molecules. The initial [illegible] the entire sensitive portion of the [illegible] counting region, is [illegible] by the action of the positive ion sheath which is formed [illegible]. [illegible] a monatomic or diatomic gas upon [illegible] the cathode liberate electrons and thus [illegible]. Poly-atomic molecules, on the other hand, have a large probability of predissociation, i.e., dissociation before [illegible], and thus have a small probability of liberating electrons from the cathode after being [illegible].

mixture composed of about ten percent polyatomic molecules, the monatomic or diatomic ions produced in a discharge are neutralized by collision before reaching the cathode provided the ionization potential of the polyatomic gas is lower than that of the other gases present. The polyatomic ions are neutralized at the cathode and dissociate so that the counting action ceases.

A property of the quenching gas which is essential for proportional counters is the absorption of ultraviolet photons emitted by the gas molecules during an avalanche. Such an absorption prevents the initial avalanche from spreading throughout the entire volume of the counter for an appreciable range of applied voltages. The absorption of these photons results in additional dissociation of the polyatomic molecules.

B. Life of Self-quenching Counters

Dissociation of the polyatomic molecules sets a limit on the life of self-quenching counters, assuming no recombination of those molecules. Korff and Present[5] calculated a life of about 10^{10} counts for a counter containing ten percent alcohol vapor as limited by dissociation.

When an organic vapor is used as the quenching agent the dissociation products form a deposit on the electrodes. When ammonia is used as the quenching agent the dissociation

products are gases only. In either type counter, the continuous potential will be lowered if the center wire becomes pitted with use.

Korff and Krumbein[6] report recombination of the molecules in a counter filled entirely with ammonia. However, these authors report an increase in the background counting rate with use of this counter.

CHAPTER III

DESCRIPTION OF EXPERIMENTAL APPARATUS

The Geiger tubes used for these experiments were designed for cosmic-ray research. The cathodes were of two-inch diameter brass tubing with 1/32 inch walls. The anodes were of 0.005 inch Kovar wire. The tubes had an overall length of twenty-four inches and a sensitive volume of about nineteen inches in length. Complete details of the construction of these counters and of the filling procedure are given in an article by Regener.[7]

The equipment used for measuring counter characteristics during the life tests is indicated in Figure 1. A source of Gamma radiation supplies a constant high rate of counts. The oscillograph was used to determine the values of Vs and Vc and to make visual observations of multiple counts. The scaling circuits were used to measure the slope of the plateau during the life tests of some of the counters.

The potential measurements are limited to an accuracy of about two percent by the measuring equipment. However, the value of Vc is somewhat arbitrary since multiple counts, high background and the characteristic of breaking in and out of a self-sustaining discharge make it difficult to repeat readings.

The Gamma source was calibrated at a large distance

CHAPTER [illegible]

DESCRIPTION OF [illegible] APPARATUS

The Geiger tubes used for [illegible]

signed for cosmic-ray research. [illegible]

inch diameter brass tubing with [illegible]

were of 0.005 inch [illegible] wire. [illegible]

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struction of these counters and of the [illegible] are

given in an article by [illegible].[9]

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counts. The [illegible]

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high background [illegible]

out of a self-sustaining [illegible]

repeat readings.

The Geiger counter was [illegible]

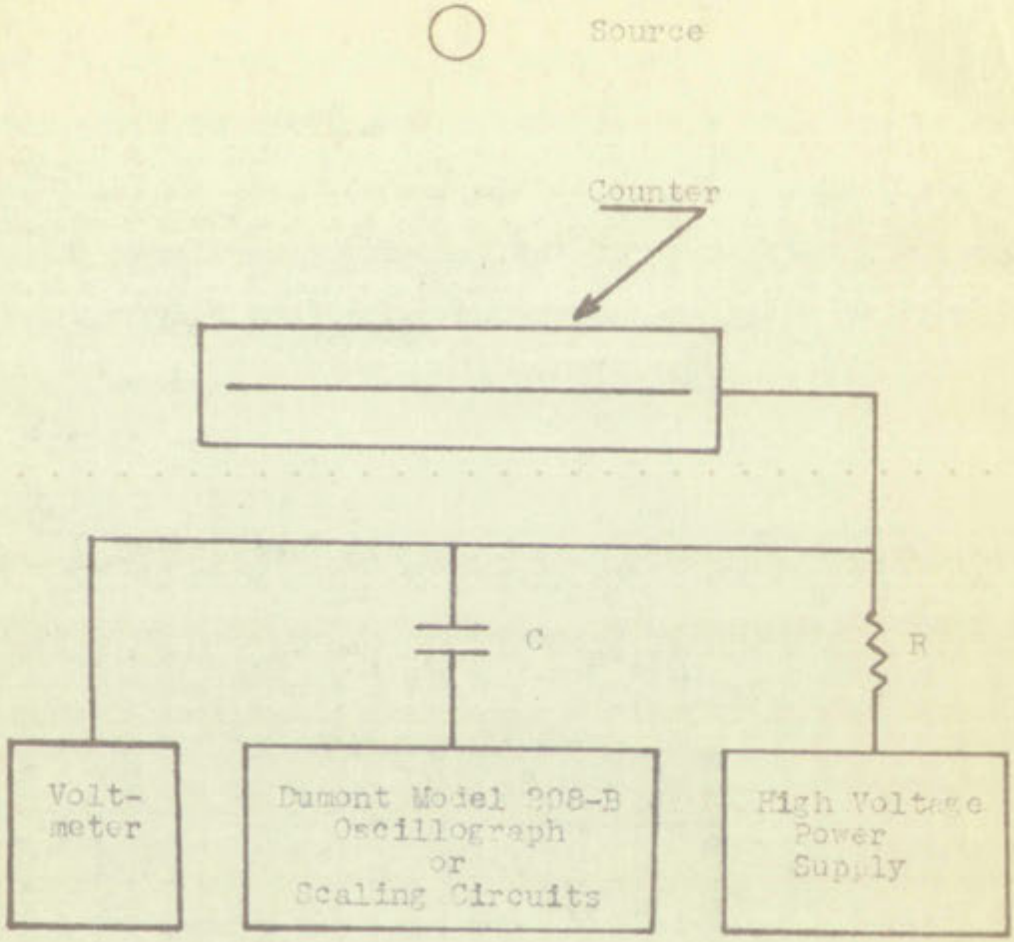

Fig. 1. Diagram of Experimental Apparatus. R is a one megohm resistor, C a 0.0005 Mfd. capacitor.

from the counter with the aid of scaling circuits and a mechanical recorder. The solid angle subtended by a Geiger counter at the Gamma source was calculated for the smallest distance actually used[1] and an estimate was made of the dead time of the counter. The calculated counting rate for the separation used throughout the life tests was 500 per second. These experiments were intended to compare lives of different fillings rather than to measure absolute life times accurately.

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[1] A calculation of the solid angle subtended by a Geiger counter at a point source is given in the appendix.

from the counter with the aid of suitable circuits and a mechanical recorder. [illegible] counter at the [illegible] distance actually used, and an [illegible] time of the counter. [illegible] counting rate for the apparatus used [illegible]. These experiments were [illegible] of different fillings rather than to measure [illegible] rately.

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[1] A calculation of [illegible] Geiger counter at a [illegible] is given in the Appendix.

CHAPTER IV

EXPERIMENTAL PROCEDURE AND RESULTS

A. General Procedure

Three sets of experiments will be described in this chapter. (1) Starting and continuous potentials were measured for different mixtures of gases. (2) Starting and continuous potentials were measured during the life of several counters. Measurements were made of the counting rate versus supply voltage during the life test of some of these counters. (3) A variation in starting potential with supply voltage was measured for "used" counters.

All tubes used were first cleaned, and a new center assembly was installed. The cathode surface was ground, polished, and cleaned with ethyl alcohol. After having been filled the tubes were given about a day for their characteristics to reach a constant value before beginning a life test. The initial values of starting and continuous potential were recorded and a visual check was made for multiple counts. In some cases the counting rate with respect to the supply voltage was recorded using the scaling circuits. The counter was then exposed to a counting rate of about five hundred per second by placing the Gamma source at a distance of 15 cm from the center line of the tube. The testing procedure described above was repeated at intervals

CHAPTER [illegible]

EXPERIMENTAL PROCEDURE AND RESULTS

A. General Procedure

Three sets of experiments will be described in this chapter. (1) Starting and continuous [illegible] were measured for different mixtures of gases. (2) Starting and continuous potentials were measured during the life of several counters. Measurements were made of the [illegible] supply voltage during the life [illegible] of these counters. (3) A variation in starting potential with supply voltage was measured for large counters.

All tubes used were [illegible] assembly was installed. The cathode surface was [illegible] polished, and cleaned [illegible] alcohol. [illegible] been filled the tubes were [illegible] characteristics to [illegible] a life test. The initial [illegible] potential were recorded and [illegible] multiple counts. In [illegible] respect to the supply [illegible] circuits. The [illegible] of about five hundred [illegible] at a distance of 15 [illegible] The testing procedure [illegible] of 20 hours or 0.36×10^8 counts during the life test. The average pulse height observed on the oscillograph was kept about the same for all the tests by adjusting the supply voltage. The average pulse had an amplitude of eight volts with the equipment used.

The starting and continuous potentials have been defined in Chapter I. After a counter has been "used" however, these potentials become somewhat arbitrary. The continuous potential will be further specified for the data recorded in this thesis as the potential at which pulses are seen along the entire oscillograph trace. In some cases this condition persists only momentarily at intervals of about a second. It may be necessary to increase the potential by as much as one hundred volts before the condition of continuous counting becomes permanent. The starting potential was observed in most cases after a counter had been counting at its background rate for a few minutes at the same potential at which the test was being conducted.

Some measurements were made of starting and continuous potentials for different percentages of quenching gas. Final readings were taken about forty-five minutes after filling since further changes in characteristics with time were about three percent as observed for several fillings. Measurements of starting and of continuous potentials were made for mixtures of alcohol with argon, ammonia with argon, of 20 hours or 0.3 × 10⁸ counts during the life test. The average pulse height observed at the [illegible] was about the same for all the tubes [illegible] the same voltage. The average [illegible] with the equipment used.

The starting and [illegible] potentials were [illegible] fined in Chapter I. [illegible] these potentials [illegible]. The [illegible] potential will be further [illegible] in this thesis [illegible] along the entire [illegible]. [illegible] condition [illegible] a second. It may be [illegible] by as much as [illegible] tinuous counting [illegible]. The starting potential was observed [illegible] at its background rate [illegible] tial at which the [illegible].

Some measurements were made [illegible] ous potentials for different [illegible]. Final readings were taken [illegible] filling since [illegible] were about three [illegible]. Measurements of [illegible] ents for mixtures [illegible] with [illegible], and ammonia with nitrogen. The observed values of these potentials together with the gas pressures are listed in Tables I, II and III.

B. Tests With Alcohol-Argon Fillings

Two counters, each filled with pressures of 10 mm Hg of alcohol vapor and 90 mm Hg of argon were given life tests as described in the preceding section. Values of Vs and Vc versus total number of counts for one of these counters are plotted in Figure 2. The other counter gave essentially the same results with some values differing by a few volts from those plotted. Figure 3 shows the corresponding curves for a counter filled with pressures of 15 mm Hg of alcohol and 85 mm Hg of argon.

The values circled in Figures 2 and 3 were taken at the end of the tests after the counters had been disconnected from the supply voltage for a few days. In subsequent life tests the counters were given "rest" periods of one day during which the values of Vs and Vc were checked several times. The value of Vs generally increased and that of Vc generally decreased during these "rest" periods becoming nearly constant with time after one day.

Immediately after counting for some time at a normal background rate with an overvoltage of about one hundred volts, the measured starting potential was higher than after

TABLE I

STARTING AND CONTINUOUS POTENTIALS

FOR COUNTERS FILLED WITH MIXTURES OF ALCOHOL AND ARGON

Alcohol Vapor Pressure (mm Hg)	Argon Pressure (mm Hg)	Starting Potential Vs (Volts)	Continuous Potential Vc (Volts)	Vc Minus Vs (Volts)
5	95	800	1125	325
10	90	1025	1500	475
15	85	1190	1800	610
20	80	1310	2000	690
5	145	850	1150	300
15	135	1275	1975	700

TABLE II

INITIAL STARTING AND CONTINUOUS POTENTIALS

FOR COUNTERS FILLED WITH MIXTURES OF AMMONIA AND ARGON

Ammonia Pressure (mm Hg)	Argon Pressure (mm Hg)	Starting Potential (Volts)	Continuous Potential (Volts)	Vc Minus Vs (Volts)
100	0	2100	2240	140
60	40	1525	1715	190
50	50	1445	1635	190
40	60	1330	1525	195
30	70	1245	1440	195
20	80	1105	1325	220
10	90	875	960	85
100	50	1715	1960	245
30	120	1310	1545	235
20	130	1150	1430	280
20	180	1175	1485	310

TABLE III

STARTING AND CONTINUOUS POTENTIALS FOR

COUNTERS FILLED WITH MIXTURES OF AMMONIA AND NITROGEN

Ammonia Pressure (mm Hg)	Nitrogen Pressure (mm Hg)	Starting Potential (Volts)	Continuous Potential (Volts)	Vc Minus Vs (Volts)
90	10	1400	1435	35
80	20	1430	1500	70
60	40	1485	1555	70
50	50	1510	1575	65
20	80	1715	1790	75
130	20	1715	1780	65

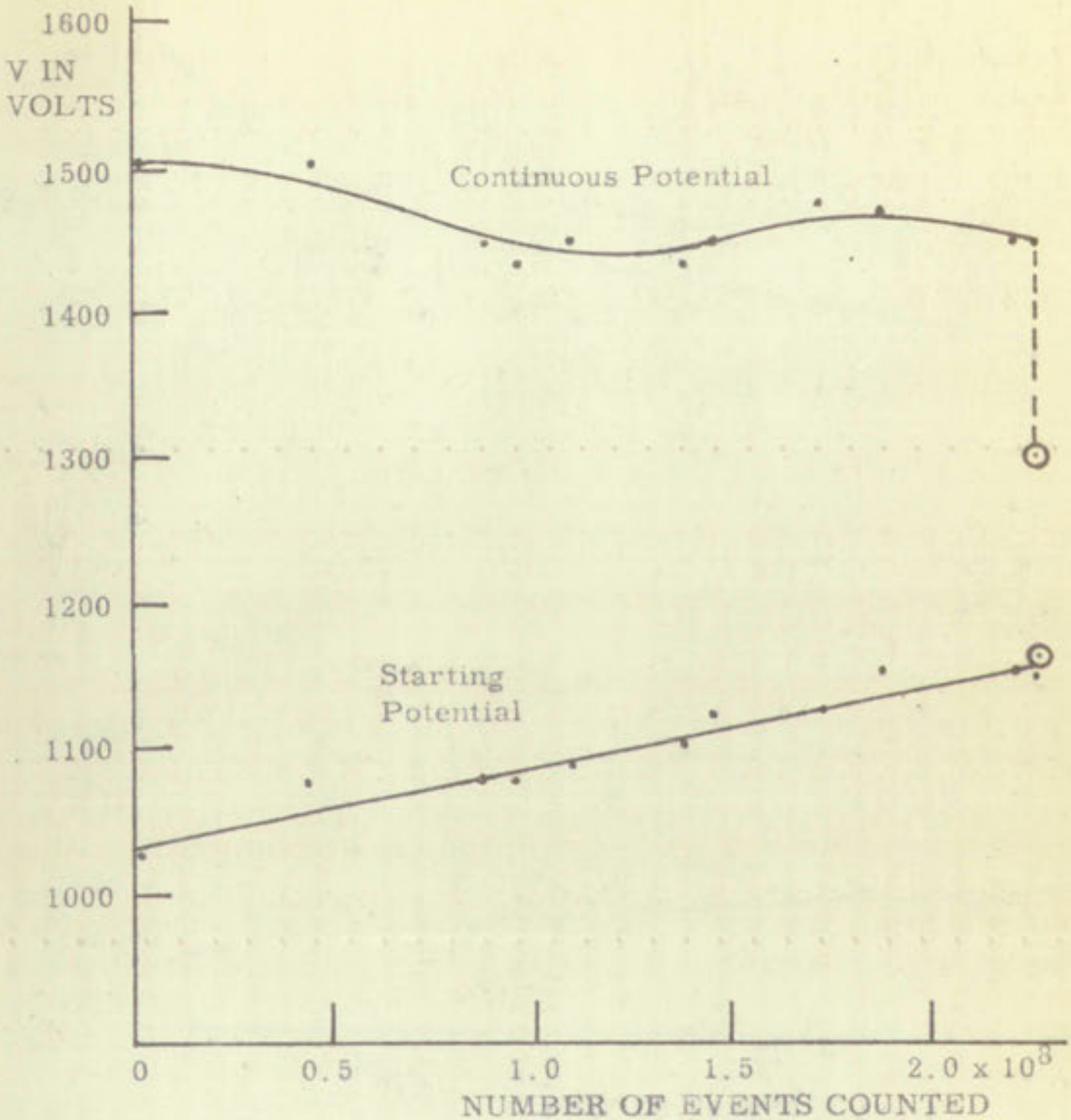

Fig. 2. Starting and continuous potentials during the life test of a counter filled with 10 mm Hg of alcohol and 90 mm Hg of argon. Circled values were taken after a few days rest.

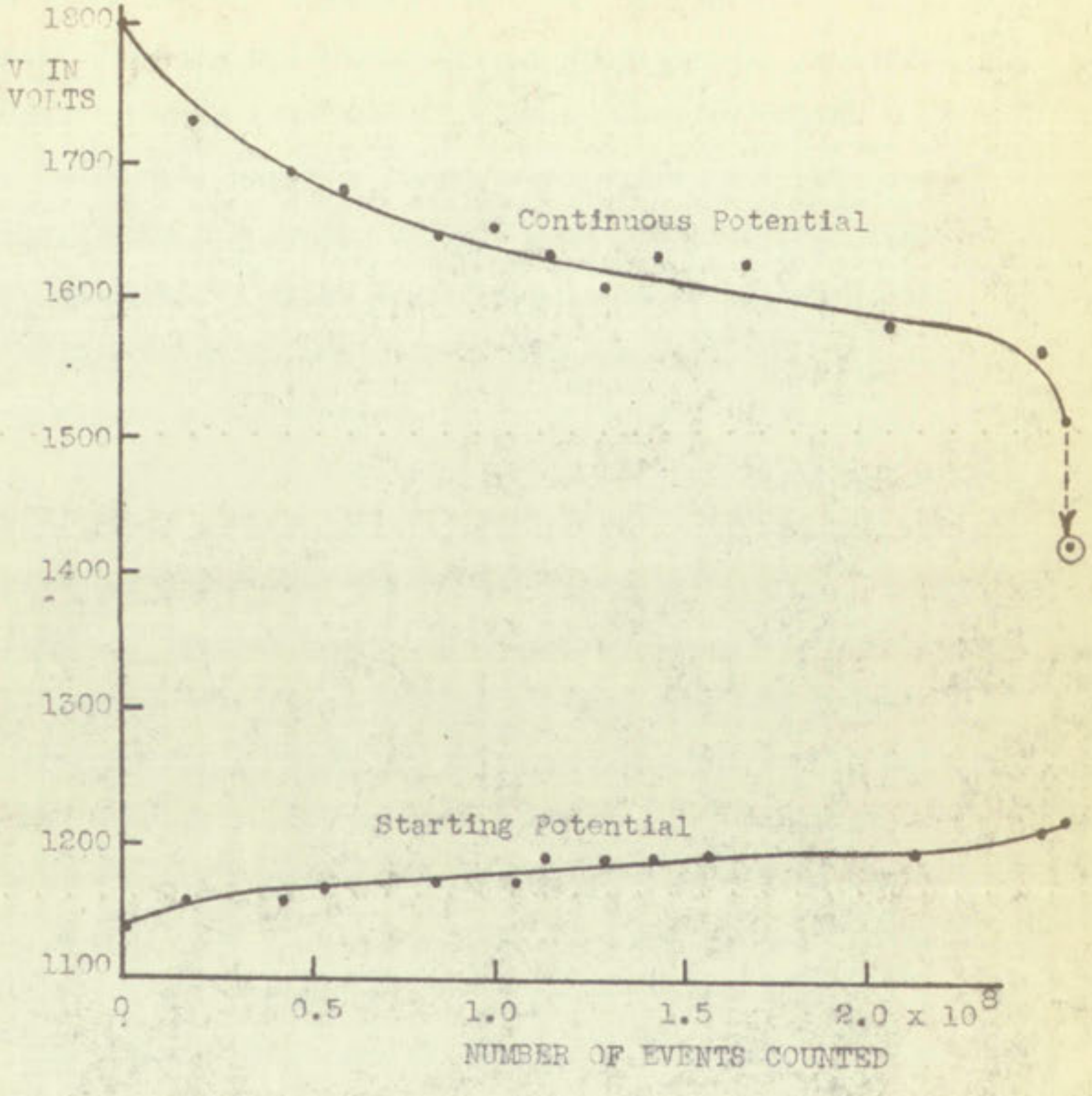

Fig. 3. Starting and continuous potentials during the life test of a counter filled with 15 mm Hg of alcohol and 85 mm Hg of argon.

a subsequent rest of only a few minutes. This rapid variation in Vs was not observed for "new" counters. It increased with the age of the alcohol counters to about one hundred volts in some cases. Several counters which had been "worn out" while counting cosmic rays gave the same result. When the supply voltage was increased from zero to about one hundred volts overvoltage, the amplitude of the pulses decreased to about fifty percent of their initial value within a few minutes.

Figure 4 is a plot of starting potential versus supply voltage for a counter filled with 10 mm Hg of alcohol and 90 mm Hg of argon which had counted 2×10^8 counts. After a "rest" of several hours, the supply voltage was increased until counts were first observed. This gave the lowest value of starting potential in Figure 4. The supply voltage (V) was then increased to 1150 volts and left constant for two minutes. V was then quickly lowered and again increased until counts were first observed. The new value of starting potential thus obtained was plotted above the supply voltage V = 1150 volts. The same procedure was repeated for V = 1200 to V = 1300 volts.

The values plotted for Vs in subsequent tests were taken after a counter had counted at its normal background rate for a few minutes with the same overvoltage as that being used in the life test. This procedure greatly reduced a subsequent rest of only a few minutes. [illegible] tion in V_s was not observed [illegible] however. It increased with the age of the counter [illegible] one hundred volts in some cases. Several counters which had been "worn out" while [illegible] showed the same result. When the supply voltage was increased [illegible] about one hundred volts [illegible], the amplitude of the pulses decreased to about [illegible] of their original value within a few minutes.

Figure 4 is a plot of starting potential versus [illegible] voltage for a counter filled with 10 mm Hg of alcohol and 90 mm Hg of argon which had counted [illegible] counts. After a "rest" of several hours, the supply voltage was increased until counts were first observed. This gave the lowest value of starting potential in Figure 4. The supply voltage (V) was then increased to [illegible] volts and [illegible] for two minutes. V was then quickly lowered and again increased until counts were first observed. The new value of starting potential thus obtained was plotted against the supply voltage V = 1150 volts. The same procedure was then repeated from V = 1200 to V = 1300 volts.

The values plotted for V_s in subsequent figures are taken after a counter was counting at the normal operating rate for a few minutes [illegible] being used in the same work. [illegible]

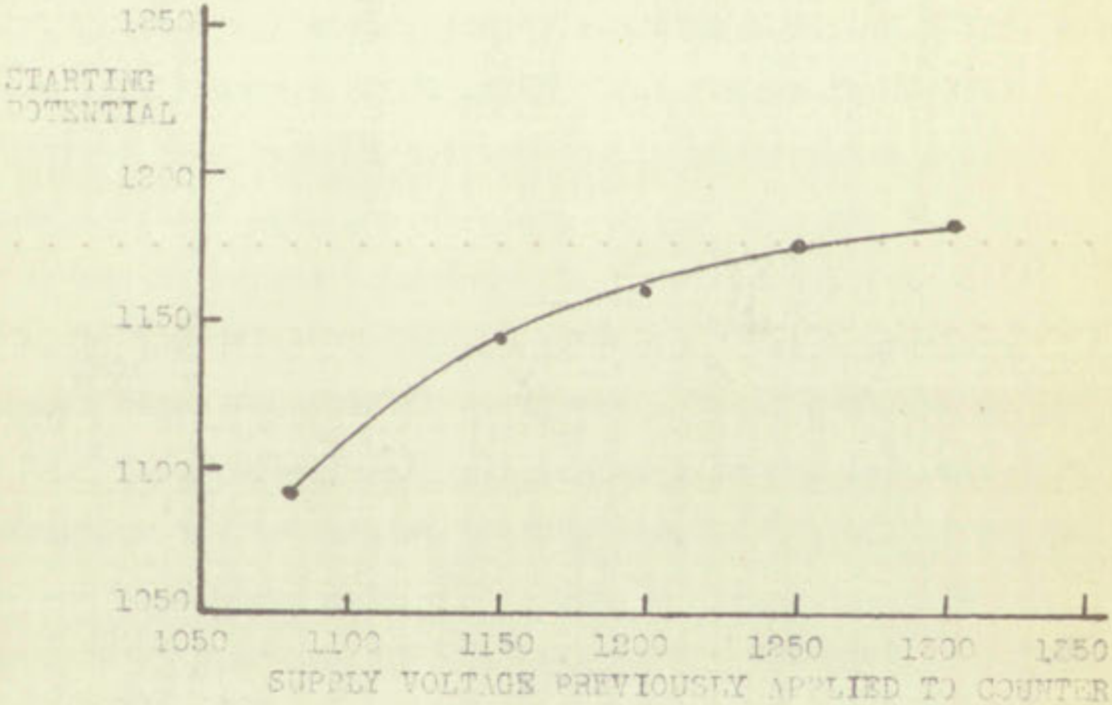

Fig. 4. Starting potential versus supply voltage for a counter filled with 10 mm Hg of alcohol and 90 mm Hg of argon after a total of 8×10^8 counts.

the fluctuation in successive readings of Vs for a counter.

A counter was supplied with a constant alcohol vapor pressure equal to 12.2 mm Hg by connecting the counter to a reservoir of liquid alcohol as indicated in Figure 5. The reservoir of alcohol was submerged in a bath of dry ice and ethyl alcohol while the counter was evacuated and filled with argon to a pressure of 88 mm Hg. The reservoir was then submerged in a bath of cracked ice in water while alcohol vapor diffused into the counter. After 48 hours the values of Vs and Vc became constant with time and approximately equal to the values indicated in Table I for a pressure of alcohol vapor equal to 12 mm Hg and a total pressure of 100 mm Hg. The alcohol reservoir was kept in the ice bath throughout the subsequent testing period. Values of starting and continuous potential observed during the life test for this counter are given in Figure 6. The circled values indicate readings taken after one day's "rest" following the life test. No further change in these potentials was observed after an additional day.

The changes in physical properties of a counter with use listed in Chapter II, Section B can be classified as changes in the filling mixture and changes in the condition of the electrode surfaces. In the experiment just described, the pressures of the major filling components remained constant throughout the life test. Further tests were performed the fluctuation in [illegible].

A counter was [illegible] with [illegible] alcohol vapor pressure equal to 1[illegible] mm Hg [illegible] counter [illegible] reservoir of liquid [illegible] indicated in Figure [illegible] reservoir of alcohol was [illegible] ethyl alcohol while the counter was [illegible] argon to a pressure of [illegible] mm Hg. [illegible] submerged in a bath of [illegible] vapor diffused into the counter. [illegible] of Va and Vo became [illegible] equal to the value [illegible] alcohol vapor equal to 1[illegible] mm Hg [illegible] pressure of [illegible] mm Hg. The alcohol [illegible] throughout the [illegible]. Values of start-ing and continuous [illegible] for this counter [illegible] Figure [illegible] indicate readings [illegible] the life test. [illegible] observed after [illegible].

The changes in [illegible] was listed in [illegible] changes in the [illegible] of the electrode surfaces. [illegible] the pressure [illegible] slowly throughout the life test. [illegible]

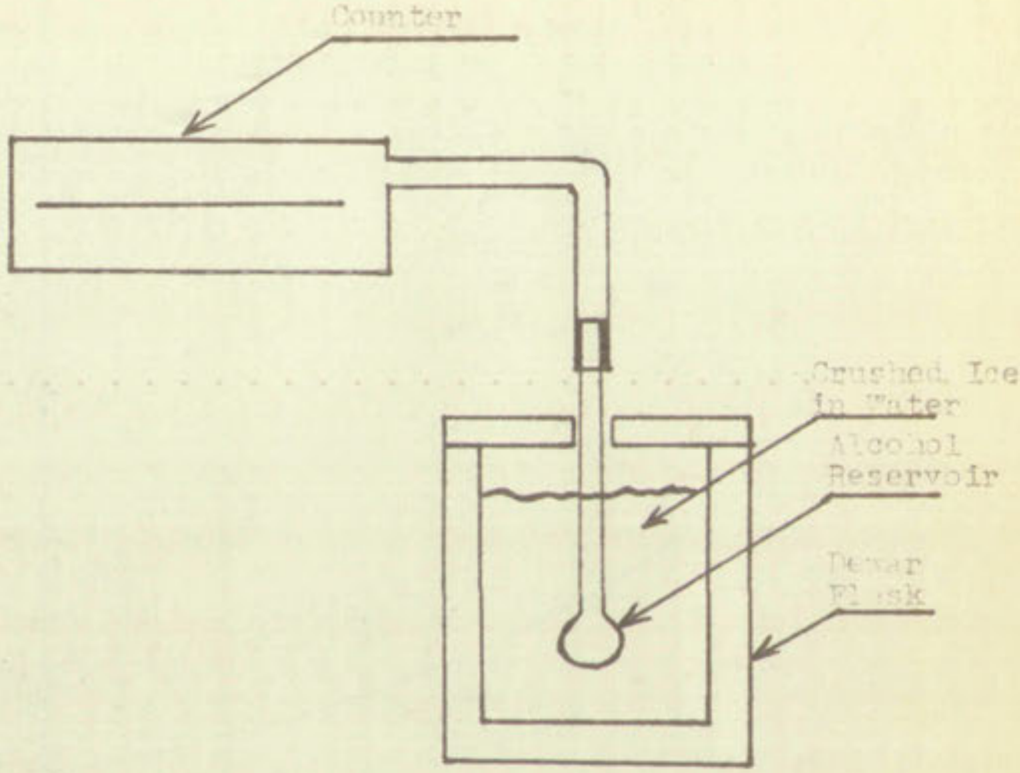

Fig. 5. Diagram of counter supplied with a constant alcohol vapor pressure.

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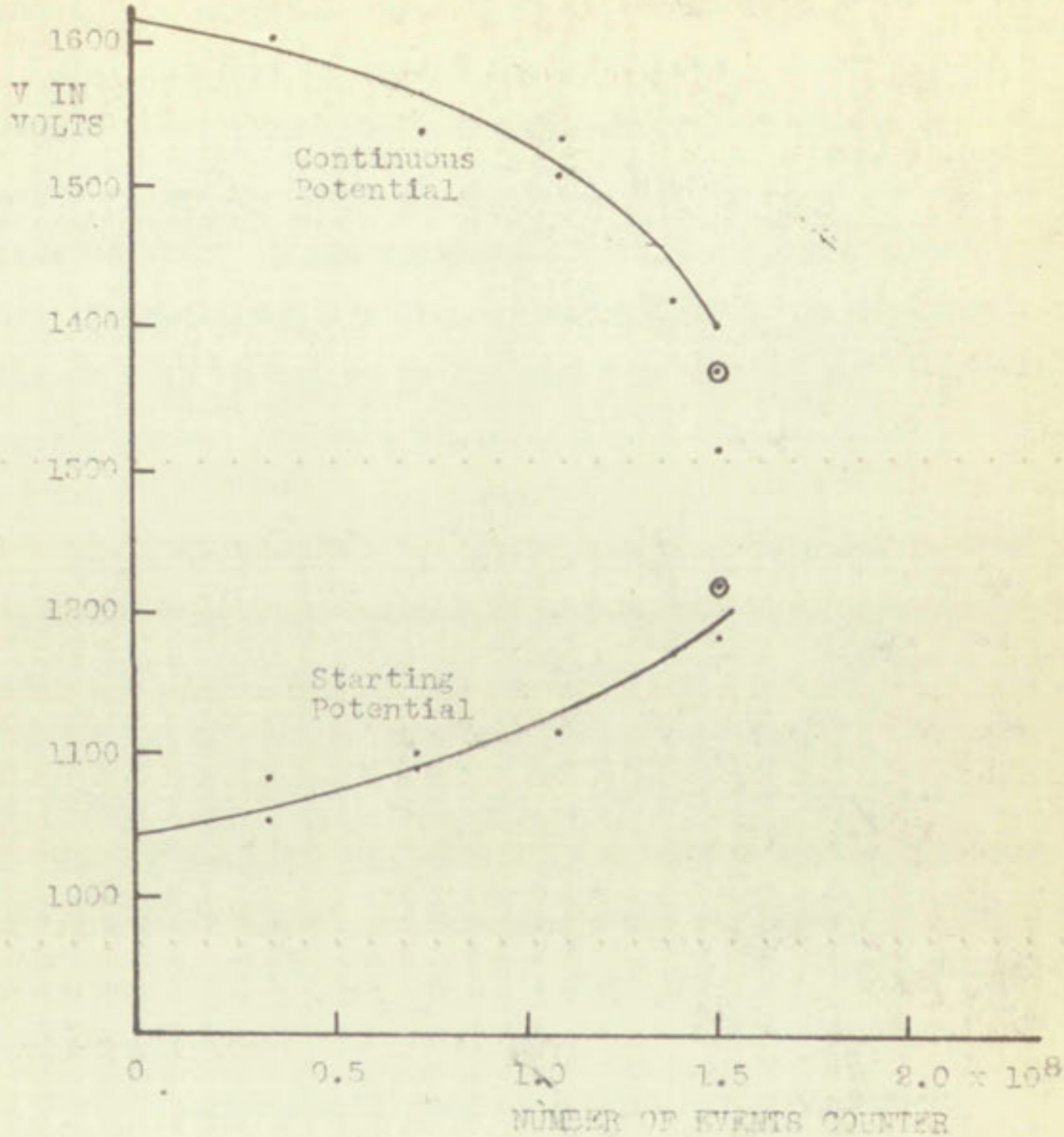

Fig. 6. Starting and continuous potentials during the life test of a counter supplied with a constant vapor pressure of alcohol equal to 12.2 mm Hg. Total pressure of argon and alcohol equal to 100 mm Hg.

to determine the relation between physical changes and the changes in electrical characteristics observed.

Two counters which had counted about 2×10^8 counts, Figure 2, were evacuated and refilled with 10 mm Hg of alcohol vapor and 90 mm Hg of argon. Table IV gives the values of starting and continuous potentials before and after the refilling. A drop of approximately thirty-five volts in both Vs and Vc is indicated as due to the change in composition and pressure of the filling mixture during the life test.

New center assemblies were installed in these two counters. They were again filled with the same mixture of gases. The resulting values of Vs and Vc were nearly equal to the original values when the tubes were "new." The number of spurious counts was also comparable to that found for "new" counters. The values of Vs and Vc during the life test of one of these counters are shown in Figure 7. The values observed for the other counter were the same within experimental error.

Two counters which had been worn out at a normal cosmic-ray and background counting rate gave comparable results when new center wires were installed. Figure 8 gives values of Vs and Vc during the life test of one of these counters after refilling. The history of these two counters was not known except that they had been filled to determine the relation between [illegible] changes in electrical [illegible] counters.

Two counters which had [illegible] Figure 2, were investigated [illegible] alcohol vapor and [illegible] values of starting [illegible] after the refilling. [illegible] volts in [illegible] composition and pressure [illegible] life test.

New center [illegible] counters. They were [illegible] gases. The resulting [illegible] to the original values [illegible] ber of spurious counts was also [illegible] for new counters. [illegible] test of one of [illegible] values observed for [illegible] experimental error.

The counters which [illegible] counts-[illegible] and [illegible] results when new [illegible] gives values of [illegible] these counters after [illegible] counters was not [illegible]

TABLE IV

VALUES OF STARTING AND CONTINUOUS

POTENTIAL FOR TWO COUNTERS BEFORE AND AFTER

REFILLING WITH 10 MM HG OF ALCOHOL AND 90 MM HG OF ARGON

Counter	Starting Potential (Volts)		Continuous Potential (Volts)	
	Before Refilling	After Refilling	Before Refilling	After Refilling
1	1120	1070	1260	1225
2	1155	1120	1295	1260

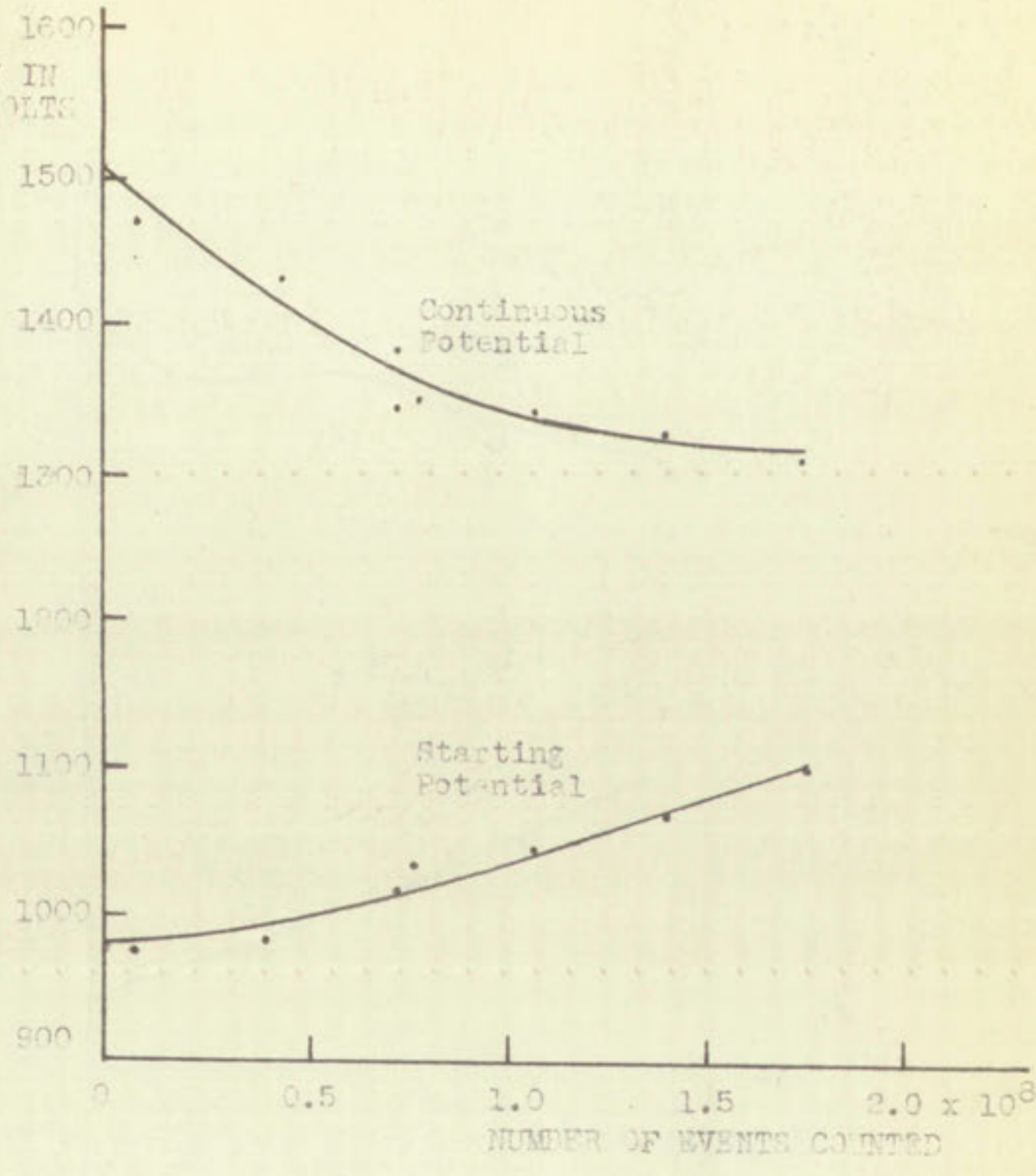

Fig. 7. Starting and continuous potentials during the life test of a used counter with a new center wire. Counter refilled with 10 mm Hg of alcohol and 90 mm Hg of argon.

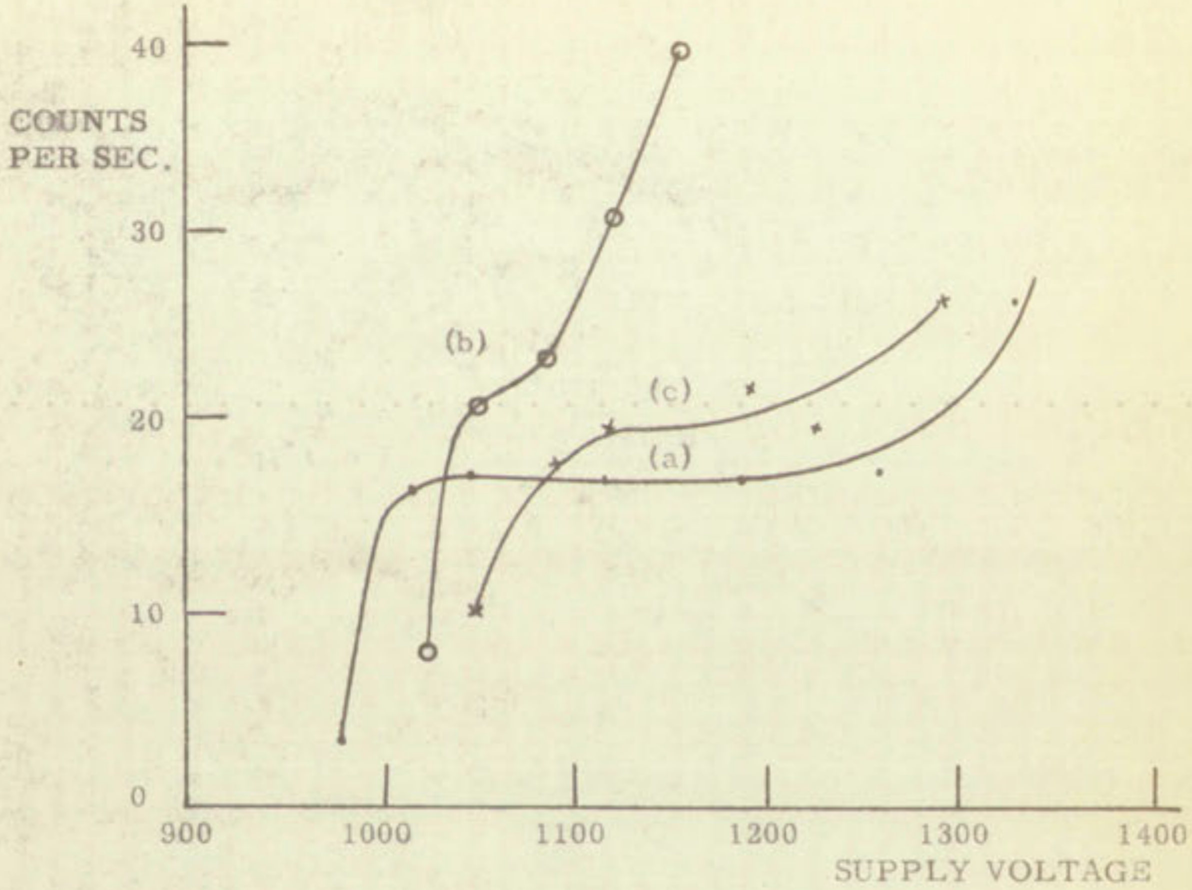

Fig. 9. Plateau curves taken during the life test of a counter filled with 10 mm Hg of alcohol and 90 mm Hg of argon. Curve (a) was taken after a life of 0.4 x 10^8 counts. Curves (b) and (c) were taken after a life of 1.4 x 10^8 counts. Curve (b) was taken immediately after exposing the counter to a high counting rate. Curve (c) was taken after a "rest" of one day.

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2.6×10^8 counts the plateau had disappeared due to the high background count. No significant recovery was observed after several days "rest."

The third ammonia-argon counter tested showed an increase in both starting and continuous potentials of about forty volts per 10^8 counts. This increase was apparently due to an air leak since the potentials continued to increase at the same time rate with no counts being recorded. Although this counter counted a total of 3.2×10^8 counts, there was no noticable increase in its random background counting rate. There was an increase in the number of multiple counts toward the end of the test. An increase in multiple counts was observed whenever a few mm Hg pressure of air or oxygen was added to the filling mixture of a counter.

D. Discussion of Results

(1) Alcohol-Argon Fillings

All the alcohol-argon fillings tested had a useful life of approximately 2×10^8 counts. The slightly longer lives indicated by Figures 2 and 3 were primarily due to the method of measuring the starting potential for those counters and because no rest periods were given during the life tests. Since no substantial difference in life was found for the counter supplied with constant alcohol vapor

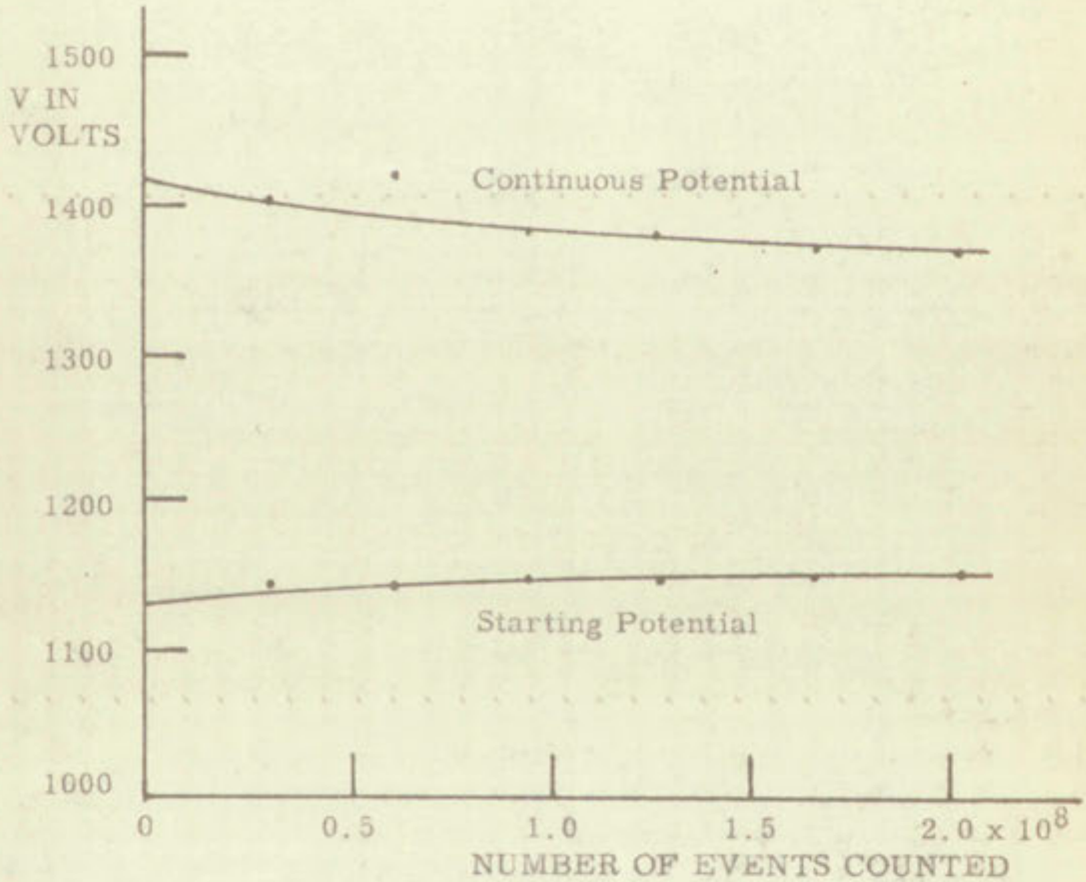

Fig. 10. Starting and continuous potentials during the life test of a counter filled with 20 mm Hg of ammonia and 130 mm Hg of argon.

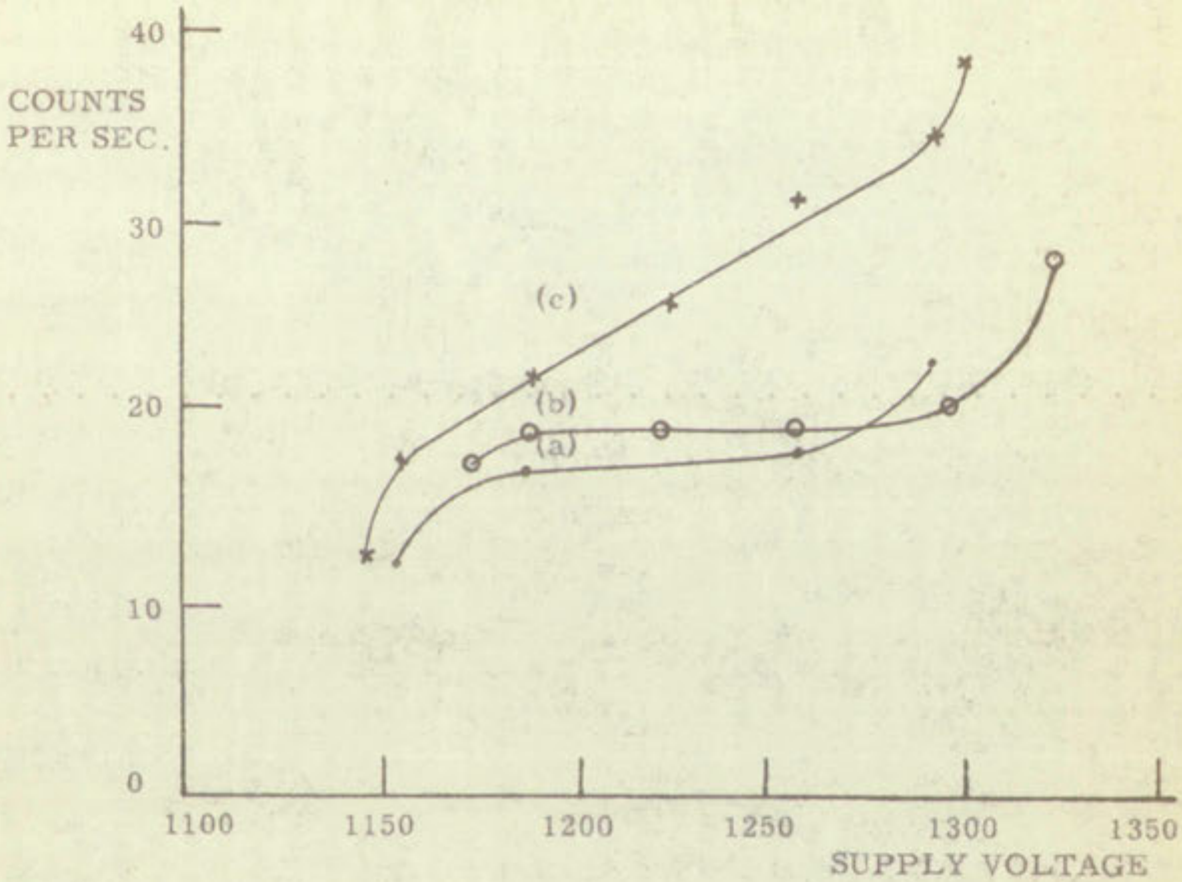

Fig. 11. Plateau curves taken during the life test of a counter filled with 20 mm Hg of ammonia and 130 mm Hg of argon. Curve (a) taken after 0.94×10^8 counts, curve (b) after 1.6×10^8 counts and curve (c) after 2×10^8 counts.

2.6×10^8 counts the plateau had disappeared due to the high background count. No significant recovery was observed after several days "rest."

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2.6 x 10^8 counts, the [illegible] had [illegible] due to [illegible]
background count. [illegible]
several days [illegible].

The [illegible] counter [illegible] crease in both [illegible] of about forty volts per 10^8 counts. This [illegible] due to an air leak [illegible] the [illegible] crease at the same time [illegible]. Although this [illegible] there was no noticeable [illegible] counting rate. [illegible] an increase in the [illegible] multiple counts [illegible] in multiple counts [illegible] sure of air or oxygen [illegible] a counter.

B. [illegible]

(1) Alcohol-argon [illegible]

All the alcohol-argon [illegible] life of approximately [illegible] x 10^9 counts. [illegible] lives [illegible] the method of [illegible] counters and [illegible] life tests. [illegible] found for the [illegible] pressure, the decrease in plateau for these alcohol-argon counters was not primarily due to the normal decrease in number of alcohol molecules.

The result of refilling two counters with the same mixture of gases as they contained originally was a decrease both in starting and in continuous potentials so that the length of the plateau remained nearly the same. This result indicates an increase in total pressure with use as observed by Spatz.[8]

The results found upon replacing the center wire show its condition to be a major life factor for the tubes tested in these experiments. These last results agree with those reported by Hagen and Loughridge[9] who used the same filling mixtures and tube construction. Shepard[10] reported nearly original characteristics for some "used" counters after electrically glowing the center wire for ten seconds. These counters contained a tungsten center wire in an atmosphere of alcohol and argon.

The increase of the starting potential after an increase in the supply voltage could be due to an insulating deposit on the electrodes as mentioned briefly by Loeb.[11] Korff and Present[5] list a hydrocarbon deposit on the electrodes as a cause for failure of organic vapor counters. It is difficult, however, to trace the decrease in continuous potential to the same cause. A more plausible explanation

for the decrease in the continuous potential would be pitting of the center wire due to overvoltage.

Spatz[8] reports lives of 10^9 to 10^{10} counts in a series of life tests on alcohol-argon counters. He used an overvoltage of sixty volts. Thus the lives found in these experiments are low by a factor of ten or more from the values predicted by Spatz. This discrepancy could be due to pitting of the center wire at the overvoltage (150 volts) used in these experiments. Also, the counters were operated at their continuous potentials for a few seconds while Vc was measured.

(2) Ammonia-Argon Fillings

The ammonia-argon filled counters showed an essentially constant starting potential for at least 2×10^8 counts. The continuous potential was also nearly constant but showed more fluctuation between readings. The overvoltage used during the tests was about one hundred volts. Values of Vc were initially lower and the total pressure higher than for the alcohol counters, so that one would expect less damage to the center wire during the life test.

These counters showed an increase in background counting rate beginning after about 2×10^8 counts. No substantial decrease in this background rate was observed after a rest as observed by Korff and Krumbein[6] for ammonia filled counters.

A counter which had a small leak did not show a noticable increase in random background counting rate after 3.2×10^8 counts. It did show an increase in multiple counts, apparently due to the contamination with air.

CHAPTER V

SUMMARY OF THESIS AND CONCLUSIONS

Measured values of starting and continuous potentials for several mixtures of argon with alcohol, argon with ammonia, and nitrogen with ammonia are listed.

Graphs of starting and continuous potentials recorded during the life tests of counters filled with argon and alcohol, and with argon and ammonia are given. Graphs are also plotted which show changes in the plateau with use of the counters.

The similar life characteristics obtained with the counter supplied with a constant pressure of alcohol vapor compared with those filled in the normal way shows that the major factor limiting the life of these counters is not a lack of quenching vapor. Tests in which "used" tubes were refilled and tests in which new center assemblies were installed indicate that the condition of the center wire is a major factor resulting in the failure of alcohol-argon counters.

Replacement of the center wire after 2×10^8 counts in four counters resulted in characteristics comparable to new tubes. It seems probable that the worn out condition was due largely to a deposit of hydrocarbons on the electrodes and to pitting of the center electrode. It

cannot be concluded from these limited data that replacing the center wire would result in counters with uniform characteristics. However, the length of the plateau can be substantially increased by replacing the center wire and the gas mixture. The condition of the cathode had a minor effect on counter characteristics after a few times 10^8 counts. These conclusions assume no contamination of the cathode surface while replacing the center wire.

A longer life can probably be obtained by using as low an overvoltage as possible and avoiding potentials as high as Vc.

The ammonia-argon fillings tested became useless because of an increase in background counting rate.

In conclusion I wish to acknowledge the advice and assistance received from Dr. V. H. Regener during the course of these experiments. Valuable aid was also given by Mr. Munson Thorpe in the preparation and filling of the counters.

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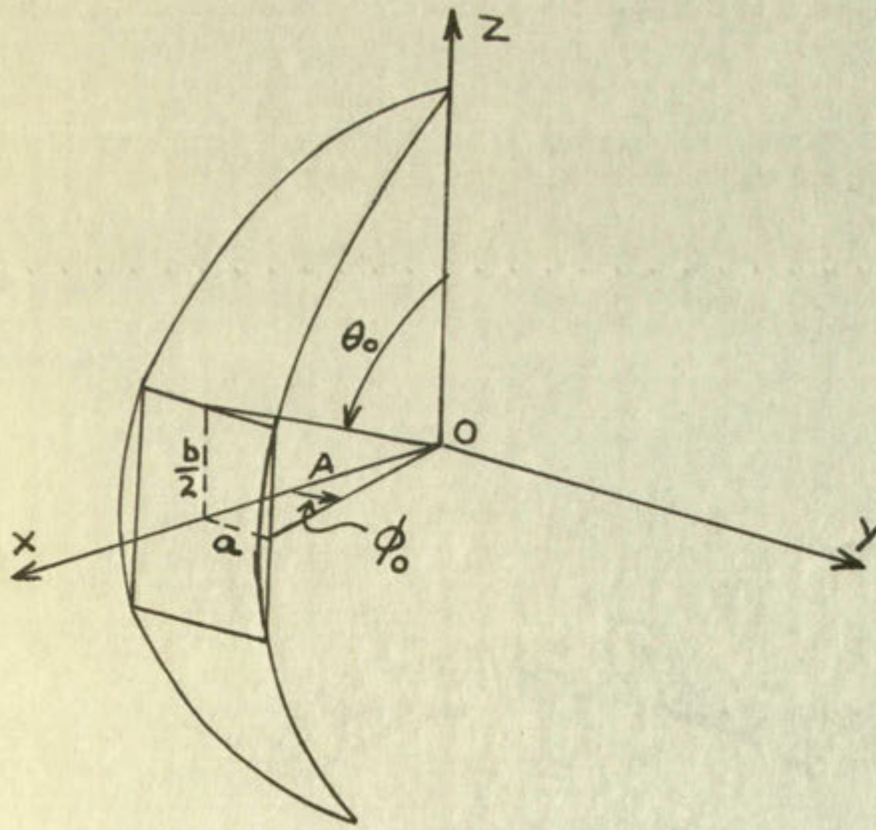
APPENDIX

APPENDIX

The solid angle subtended by a Geiger counter at a point source was calculated using spherical polar coordinates. The solid angle subtended by the cylindrical counter is approximately equal to that subtended by a rectangle of area 2ab where a is the radius and b the length of the sensitive volume.

As indicated in the following diagram, the rectangle is oriented perpendicular to the x axis. The source is located at the origin. The distance from the origin to the center of the rectangle is A.



The expression

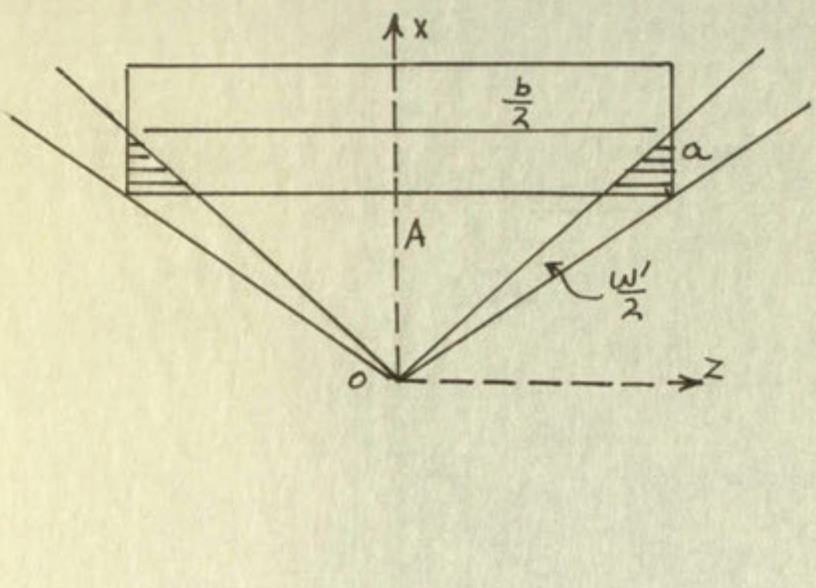
$$\omega = 4\int_0^{\phi_0} d\phi \int_{\theta_0}^{\frac{\pi}{2}} d\theta \, \sin\theta \qquad (1)$$

where $\cos\theta_0 = \frac{b}{2R} = \frac{b}{2\sqrt{\frac{b^2}{4}+A^2}}$ and $\tan\phi_0 = \frac{a}{A}$

gives the solid angle subtended by the rectangle within 0.5 percent for the values of a, b and A in the present experiments. Using the above values for θ_0 and ϕ_0 in equation (1) gives for the solid angle subtended by the rectangle at the origin:

$$\omega = \frac{2b}{\sqrt{A^2+\frac{b^2}{4}}} \tan^{-1}\frac{a}{A} \qquad (2)$$

The sensitive volume of a counter extends beyond the ends of the rectangle as indicated in the following diagram where the counter is drawn as a cylinder.



The solid angle subtended by the shaded volume is very nearly:

$$\omega' = \frac{\pi a^2 b}{2\left(A^2 + \frac{b^2}{4}\right)^{\frac{3}{2}}}$$

This correction is approximately 5 percent of the total solid angle.

The final expression for ω is

$$\omega_f = \frac{2b}{\sqrt{A^2 + \frac{b^2}{4}}} \operatorname{Tan}^{-1}\frac{a}{A} + \frac{\pi a^2 b}{2\left(A^2 + \frac{b^2}{4}\right)^{\frac{3}{2}}}$$

This is within one percent of the correct value for a = one inch, b = 19 inches and A = 15 cm.