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A PORTABLE ALPHA SURVEY METER

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HEALTH PHYSICS DIVISION

A PORTABLE ALPHA SURVEY METER

by

W. M. Hurst
G. S. Hurst
W. B. McDonald

Date Issued: MAR 14 1950

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A PORTABLE ALPHA SURVEY METER

by

W. M. Hurst
G. S. Hurst, and
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Abstract

This article describes a portable alpha survey meter having a specific application to Health Physics survey work where the objective is detection and semi-quantitative measurement of alpha radiation. The total weight of the instrument is four pounds, and includes a proportional counter, amplifier with thyratron output tube, headphones for aural counting, and batteries to supply all the required voltages. The background count is approximately 1 count per minute, and an alpha source of 100 disintegrations per minute in an area appreciably less than the proportional counter window can be detected with approximately 15 c/m in the headphones. Lower values of contamination are detected proportionately. The proportional counter includes a desiccant whereby the instrument can be used in an ambient of 95% relative humidity.

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A PORTABLE ALPHA SURVEY METER

Introduction

Alpha particles are heavy, ionizing particles emitted from radioactive material with energies ranging from 2 Mev to approximately 9 Mev[1]. Although they produce a dense path of ion pairs throughout their entire range in matter alpha emitters are a health hazard only when ingested or otherwise placed within living tissue. The range in tissue of a 7 Mev alpha is about .065 mm which is less than the thickness of the human epidermis. However, because of the dense ion tracks they produce, alpha emitters when fixed in living tissue are extremely hazardous. In fact, for equal absorbtion of energy per gram of tissue, alpha particles have a Relative Biological Effectiveness of 20 on a scale where the beta-gamma-x-ray value is taken as unity[2].

Thus it is clear that the Health Physicist must be able to detect and measure low levels of alpha contamination where the possibility of ingestion exists. Where alpha contamination is detected, the problem of what to do about it depends among various considerations on the contamination activity which can be measured in terms of disintegrations per minute. Furthermore, these measurements must discriminate against the beta-gamma radiation which is often present.

Added requirements are imposed by the necessity of scanning a variety of objects under various weather conditions. Also, in order that very low activities of alpha contaminant may be measured, it is necessary that the instrument's background count be maintained as low as possible. (One count

(1) Seaborg, G. T., and Perlman, I., Rev. Mod. Phys., 20, 585 (1948)

(2) The Chalk River Conference for Establishing Radiation Tolerances, September 29, 30, 1949.

per minute is considered reasonable). Achievement of sensitivity with low background count means that a present technique of contamination measurement by the "smear" method can be modified by examining the smears in the field without recourse to a counting laboratory.

Proportional Counter Method

For the portable alpha survey meter application, proportional counters are better than pulse ionization chambers because the proportional counter pulses are many times larger than ionization chamber pulses, hence they provide a better signal-to-noise ratio and require less amplification.

The proportional counter used in this application has as the gas, air at the ambient atmospheric pressure. The disadvantages of using ambient air are many, particularly: (1) it is highly electronegative and, (2) the counter characteristics depend on the particular atmosphere in which it happens to be, thus a pressure change because of elevation differences (also normal barometric variations) changes the gas amplification factor. However, the advantage afforded by making it possible to use a very thin window for alpha entry compensates for these disadvantages.

No attempt is made here to discuss proportional counter theory. Standard references are Korff[3] and Corson and Wilson[4]. Air proportional counters have been treated by Borkowski[5] and Simpson[6], and have been

(3) Korff, S. A., Electron and Nuclear Counters, (D. Van Nostrand Co., Inc., New York, 1946).
(4) Corson, D. R. and Wilson, R. R., Rev. Sci. Inst., 19, 207 (1948)
(5) Borkowski, C. J., and Marsh, C. R., "Poppy-Pulse Type Detector for Alphas, Betas, Gammas and Neutrons, AECD-2410, Oak Ridge National Laboratory, 1945.
(6) Simpson, J., Jr., "Air Proportional Counters", MDDC-1315 (Technical Information Division, Oak Ridge, Tennessee, 1947).

used by Dandl[7] and others for portable alpha counters.

The instrument to be described here uses essentially the method of Dandl, which employs a pulse amplifier to magnify the pulses formed by the proportional counter to a level sufficient to fire a thyratron output circuit. Gamma discrimination is inherent in this method in that the pulses caused by gamma are of smaller height than the alpha pulses, hence the amplifier gain may be adjusted so that the gamma pulses are less than the "firing" potential of the thyratron. A desirable feature of the thyratron output is the uniform pulse size and shape which leaves no doubt in the mind of the operator as to whether a "click" in the headphones has been heard.

General Description

The complete instrument (See Figures 1 and 2) consists of three items, as follows:

A. Head phones (magnetic preferred, about 4,000 ohms) for aural counting connected to the battery box by a phone cord, plug and jack. Weight is about 6 ounces.

B. Battery box, containing 1.5 volt (Burgess number 2FBP), 3 volt(Burgess number B2BP), 45 volt (Burgess number XX30E), and 300 volt (Eveready number 493) batteries for amplifier filaments, thyratron bias, plate and screen, and proportional counter high voltage source, respectively. It is to be noted that the battery box contains only low impedance components. The total weight including a belt for strapping this unit to the waist of the surveyor is three pounds. The battery box is connected to the following hand unit (item C) by a shielded 6 conductor cable and cable clamp, tested to withstand a straight pull of 85 pounds.

C. The alpha detector hand unit, consisting of a proportional counter and dessicant, high voltage push-button switch and condenser assembly, and amplifier, is complete relative to containing all of the high impedance components and circuitry. Preliminary considerations given to the problem of (1) reducing the free flow of air into the dessicant and the high voltage switch compartments and, (2) maintaining an almost zero air pressure differential at the thin window of the probe, resulted

(7) Dandl, R. A. "Walkie Poppy - A Portable Battery Operated Proportional Type Alpha Survey Counter", MDDC-1331, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1945.

in the use of gasketing except for the push-button switch panel mounting which also functions as an air bleeder. The amplifier (See Figure 3) is connected to an off-on switch located at the battery box. The high voltage push-button switch providing a nominal 1,800 volts for the proportional counter is located on the rear panel of the hand unit. Depressing the push-button switch connects five condensers in parallel across the 300 volt battery, and releasing the switch reconnects the five condensers in series with the 300 volt battery. Charging the condensers every 10 minutes while in operation will be sufficient for most survey work. Adjustment of the high voltage is not provided for as the instrument will operate satisfactorily over a wide range of air pressure without voltage adjustment. (See Figure 4). Total weight of the hand unit is one pound.

Operation

Assuming that the operator has the battery box strapped to his waist, has (See Figure 2) headphones on, and is ready to survey an object for alpha contamination; the off-on switch at the battery box is turned on and the high voltage push-button switch at the hand unit is fully depressed and released. A click in the head phones will be heard as the high voltage switch is released. For normal survey work at this moment it is convenient to have a small alpha source, about 100 to 500 disintegrations per minute, to test for probe sensitivity and over-all operation of the instrument.

Where the operator desires to do semi-quantitative measurements it is necessary to have both a source of known activity and a timepiece to count minutes. Changes in atmospheric pressure (See Figure 4) and geometry so alter the counting efficiency even if moderately, as to require a background count and calibration at the time of measurement. Ambient temperature variations of as much as 20°C do not change the counting rate significantly.

Proportional Counter

In the probe the collector wire is .0005 inch diameter stainless steel;[8] this diameter permits proportional region operation at 1,800 volts (in air) and the

(8) Sigmund Cohn Corporation, 44 Gold Street, New York, N. Y.

material available is considerably smoother than our supply of tungsten, thereby providing a more uniform voltage field and a corresponding uniform sensitivity over the length of the probe. The wire may be replaced only by wire of the same diameter and material, from straight stock not previously deformed since a sharp bend or kink in the wire when straightened will leave microscopic projections which will seriously alter the electrostatic field, making the counter insensitive over most of the length. When brazing or spot welding the collector wire, the joint is to be finished smooth and free of sharp projections by painting with a conductor such as aquadag or neolube to form a smooth overcoating.

One end of the collector wire is held by a machined or molded fluorothene or polyethylene insulator (9), these materials having the desirable property of minimum contribution to background "noise" or spurious counts when subjected to high voltage and humidity. The effective insulation surfaces from the probe collector wire to ground must not be touched by hand. The parts thus affected are the ceramic coupling condenser and the fluorothene insulator, and they must be handled by clean tweezers, pliers, etc. Unplasticized polystyrene may be used with excellent results providing it is injection molded with unusual and particular care being given to highly polishing the molds. The insulator must have no scratches or fine lines, however small they may be, because of the difficulty of removal of water adsorption (10) in an interstice. Such a requirement does not appear to be so necessary in the case of fluorothene and polyethylene. If a polystyrene insulator is touched with uncovered hands, it should be discarded. Polyethylene and fluorothene may be repeatedly cleaned with appropriate solvents followed by distilled water and alcohol; however, an

(9) Glass, F. M., Rev. Sci. Inst., 20, 239 (1949).

(10) Ledoux, E., Vapor Adsorption, (Chem. Pub. Co., Inc., New York, 1945)

insulator is at its best when freshly machined or molded. The other end of the collector wire is attached, through a helical spring for compliance, to the H. V. blocking condenser made of ceramic and treated (9) for "noise" reduction. The blocking condenser is supported at the grid connection end so as not to add the leakage path of the support to the collector voltage.

A departure from conventional design is in the substitution of a stainless steel wire screen in place of solid material for the cylindrical electrode (stainless steel is a preferred metal because it is relatively low in natural alpha emission). Between the screen electrode and the solid sheet outer shell is space for 40 grams of screened (for uniform size) silica gel free of dust. This design permits the most rapid removal of water vapor from the counting region and the insulators, thereby permitting the operation of the proportional counter in a 95% R. H. ambient without spurious counts. The silica gel in the probe should be replaced every two months, or when the cobalt chloride coloring has changed from blue to pink. The silica gel should not be discarded, as it may be reactivated by baking at a temperature of 110°C until it has changed back to the blue color. In refilling the probe with dust-free fresh silica gel, care should be taken to completely fill in order that dust caused by mechanical abrasion of loose pellets rolling around may be avoided. Dust in the probe results in a higher background count and must therefore be guarded against.

The thin window, transparent to alpha radiation (absorption is roughly equivalent to 0.5 cm air) is 0.0002 inch thick rubber hydrochloride (pliofilm), weight about 0.66 mg/cm^2, and was chosen as the result of comparative tests of materials (pliofilm and nylon) relative to the diffusiveness of water vapor. The pliofilm surface inside of the counter is made conducting (this is not mandatory, since the counter will operate satisfactorily with a plain window) by brushing or spraying with aeolube (See Appendix A). The absorption factor of the graphite is offset by establishing

a normal field intensity at the probe window, resulting in slightly higher count sensitivity[6].

Amplifier

The amplifier (See Figure 5) consists of three RC coupled Raytheon type CK 512 AX subminiature pentodes, with the output of the final stage applied to a Raytheon type RK-61 subminiature thyratron. The pulse from the thyratron is sufficient to produce a loud click in a pair of earphones.

The coupling time constants between the stages are relatively short, being 1.8 microseconds. This serves a two fold purpose. By degrading the low frequency response of the amplifier, microphonic effects are greatly reduced since most of the microphonic signal energy is at frequencies well below the effective pass band of the amplifier. Secondly, the differentiating action of the fast time constant tends to prevent pulses due to beta or gamma radiation from "piling up" and producing a pulse large enough to trigger the thyratron. The pulse shape in the amplifier is a sharp rise, followed by an exponential decay. If a gamma (or beta) pulse follows a similar preceding pulse before the exponential decay has essentially been completed, the second pulse will add to the remaining level of the first pulse. This build up process can result in an overall pulse as large as that due to the alpha and therefore a spurious count if the gamma (or beta) level is so high that pulses are sufficiently closely spaced in time. The time constant used in this particular system will allow survey of alpha contamination in the presence of gamma fields of up to 0.1 r per hour without false counts due to the gamma.

The high frequency response of the system is limited by the normal consideration of required gain and tube complement. The upper half power point occurs at approximately 70 KC. The overall frequency response characteristic of the amplifier is shown in Figure 6.

The CK 512 AX filament requires 0.625 volts at 20 milliamperes, so that two in series should operate from a nominal source of 1.25 volts. From the standpoint of long time performance of battery with decreasing filament battery voltage, it was found best to use a 1.5 volt source, and connect two CK 512 AX's in series directly to the 1.5 volts rather than use a series dropping resistor (a variable resistor is considered to be an unnecessary added control) to bring the potential of a fresh 1.5 volt battery down to 1.25 volts. The third CK 512 AX is connected to the 1.5 volt source in series with a 33 ohm resistor. The RK-61, requiring a nominal filament supply of 1.4 volts is connected across the 1.5 volt line. The total filament drain is approximately 100 milliamperes. With these filament connections, the instrument can function as long as the potential of the filament source does not drop to less than 1.0 volt.

In order to minimize surface leakage and spurious counts, the input capacitor (Centralab type 850 NPO) which blocks the probe voltage from the first amplifier grid, must be specially processed [9].

High Voltage Supply

The high voltage necessary for the proportional counter is furnished by a special two position push-button operated switching mechanism, condensers, and a battery. When the push-button is fully depressed, five Fast [11] condensers (.01 mfd Number A7878DA) are placed in parallel across a 300 volt battery (Eveready number 493) charging each condenser to 300 volts. When the push-button is released the condensers are reconnected into series with the 300 volt battery to furnish approximately 1800 volts. (See Figure 7).

This switch includes a condenser mount made of fluorothene (See Figure 1) on

(11) J. E. Fast Company, 3123 North Pulaski Road, Chicago, Illinois

on which are placed the non-movable contacts connected to lugs which hold the five Fast Condensers. Slots between adjacent contacts increase the leakage path. A fluorothene slide, upon which spring contacts are mounted, fits into the condenser mount. A flat spring for restoring force holds the assembly with the condensers connected in a normal series relation.

Certain precautions (See Appendix B) should be taken during the machining and assembly operations involving the fluorothene. Particular care has been exercised in the design of this switch to keep leakage paths as long as possible with the result that the leakage rate of the system when charged to 1800 volts is something less than one volt per minute.

This unit will operate the instrument for extended periods of more than one hour without recharging the condensers. In field usage, however, it is recommended that the condensers be recharged at intervals of about 10 minutes.

Instrument Service and Repair Notes

Several field test models have been in use for five months by the Survey Monitoring Section in order that we could catalog the various reasons for instrument failure, and possibly make some desired corrections before quantity production of the survey meter was started.

The return of instruments for servicing or repair was as follows:

1. Filament and plate supply batteries needed replacing (3 returns).
2. Silica gel needed replacing to reduce background count (3 returns, 2 of which coincided with battery replacements).
3. Probe was contaminated, thereby causing a high background count (2 returns).
4. Probe window was broken (1 return).
5. Off-on switch was broken (1 return).

Failure of the CK 512 AX tubes or the RK-61 thyratron while in service has not occurred, as yet. However, it was noticed during the assembly and testing of these field instruments that some CK 512 AX tubes had broken filaments, shorted tube elements, or too high a gain.

If an amplifier strip has too high a gain (or too low) and at the same time has tubes within rated limits, the overall gain is easily adjusted by appropriate changes in the grid resistor value of tube No. 2 (see Figure 5).

Appendix A

Pliofilm Preparation

Note: The following procedure for preparing the rubber hydrochloride film and attaching it to the proportional counter should be carefully observed in detail.

1. Stretch pliofilm (.0002 inch thickness) lightly over a frame and backing such that the film is flat and free from wrinkles. The backing is required when the film surface is rubbed during processing.
2. Apply one even coating of Neolube (12) with a soft camel hair brush and let dry. Drying time is approximately two minutes and the coating will then appear dull.
3. When dry, rub off loose material with a clean cloth or paper toweling. After rubbing, the resistance will be about 20,000 to 30,000 ohms between two points spaced one cm apart. This is approximately 1/30th the resistance of the unrubbed coating. The coating will now appear glossy.
4. Apply a coating of aquadag (13) to the mating surface (do this in a high humidity ambient) of the proportional counter and clamp the pliofilm window in place with the Neolube coated surface against the probe.
5. After drying approximately two hours (in a low humidity ambient), trim off excess film and apply a coating of Pliobond adhesive to the contact edges of film and probe.

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(12) Huron Industries, Port Huron, Michigan.

(13) Acheson Colloids Corporation, Port Huron, Michigan.

Appendix B

Notes for Machining and Handling Fluorothene Insulators

The following precuations must be exercised in processing parts made of fluorothene:

1. Clean all cutting tools in a hot vapor degreaser.
2. Rinse in distilled water.
3. Rinse in ethyl alcohol.
4. Air dry (do not use air hose).
5. After cleaning, cutting surfaces of tools must not contact foreign material other than the fluorothene.
6. After machining and during assembly, fluorothene must not be touched with hands, but should be handled only with cotton gloves which have been:

   (a) washed with hot water and soap,

   (b) rinsed in distilled water,

   (c) rinsed in ethyl alcohol and

   (d) air dried.

CAPTIONS

Figure 1	Portable Alpha Survey Meter
Figure 2	Surveying a Laboratory Table for Contamination
Figure 3	Amplifier Strip
Figure 4	Counting Rate Variation with Air Pressure
Figure 5	Circuit Diagram for Alpha Survey Meter
Figure 6	Overall Frequency Response from Probe Electrode to Thyratron Grid
Figure 7	Schematic of High Voltage Switch

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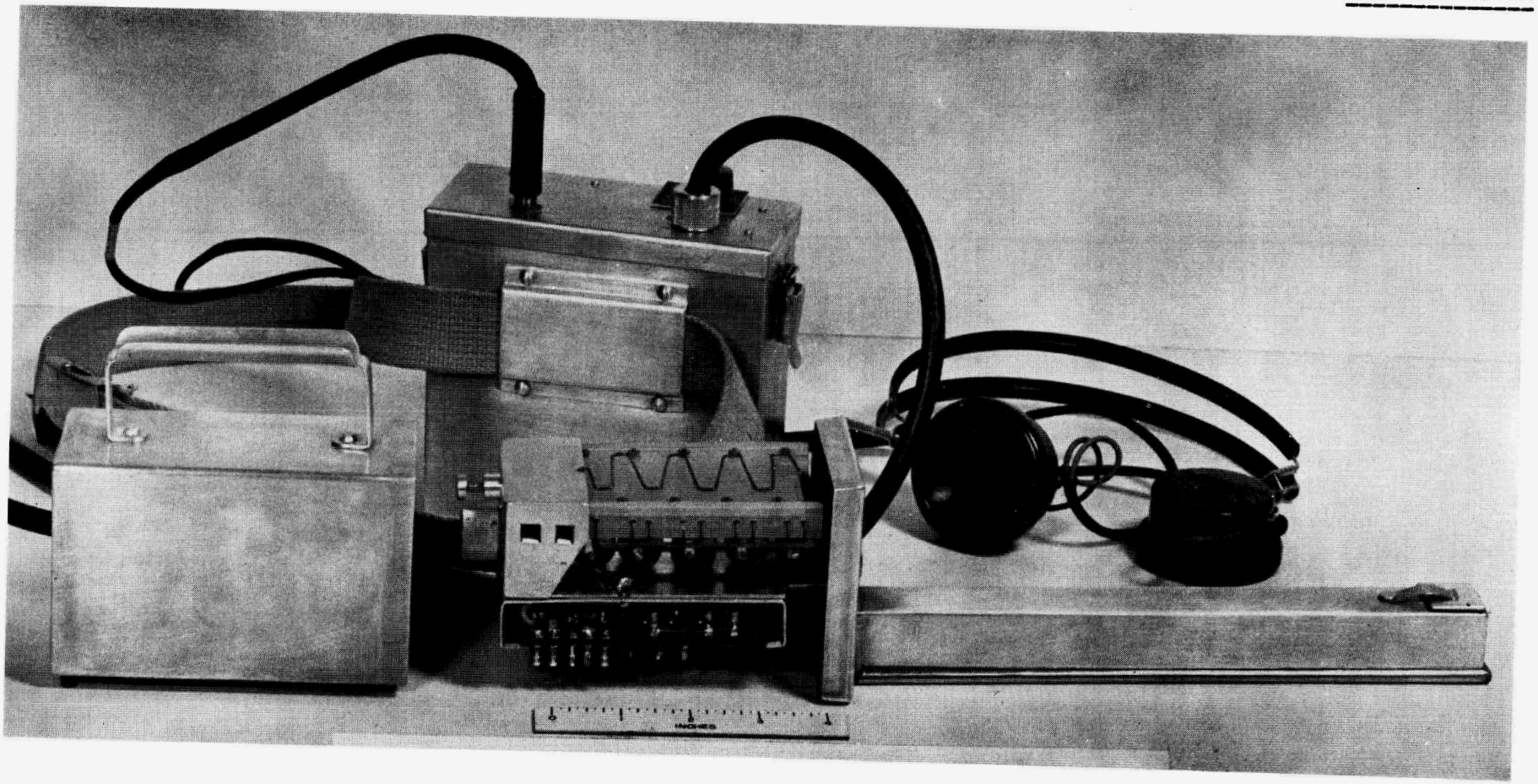

Figure 1
PORTABLE ALPHA SURVEY METER
(Case Removed to Show Amplifier
and High Voltage Switch Assembly)

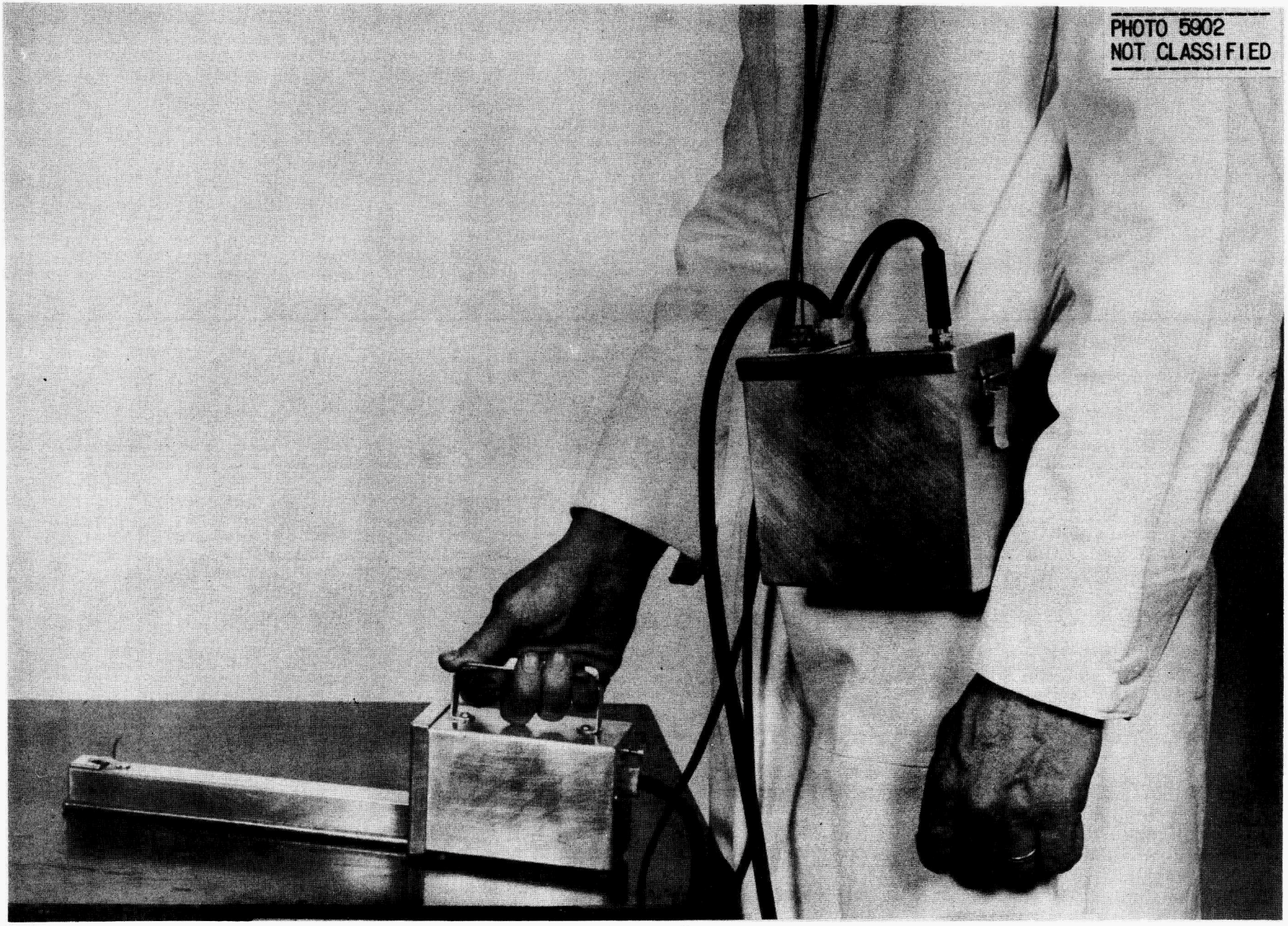

Figure 2
SURVEYING A LABORATORY TABLE FOR CONTAMINATION

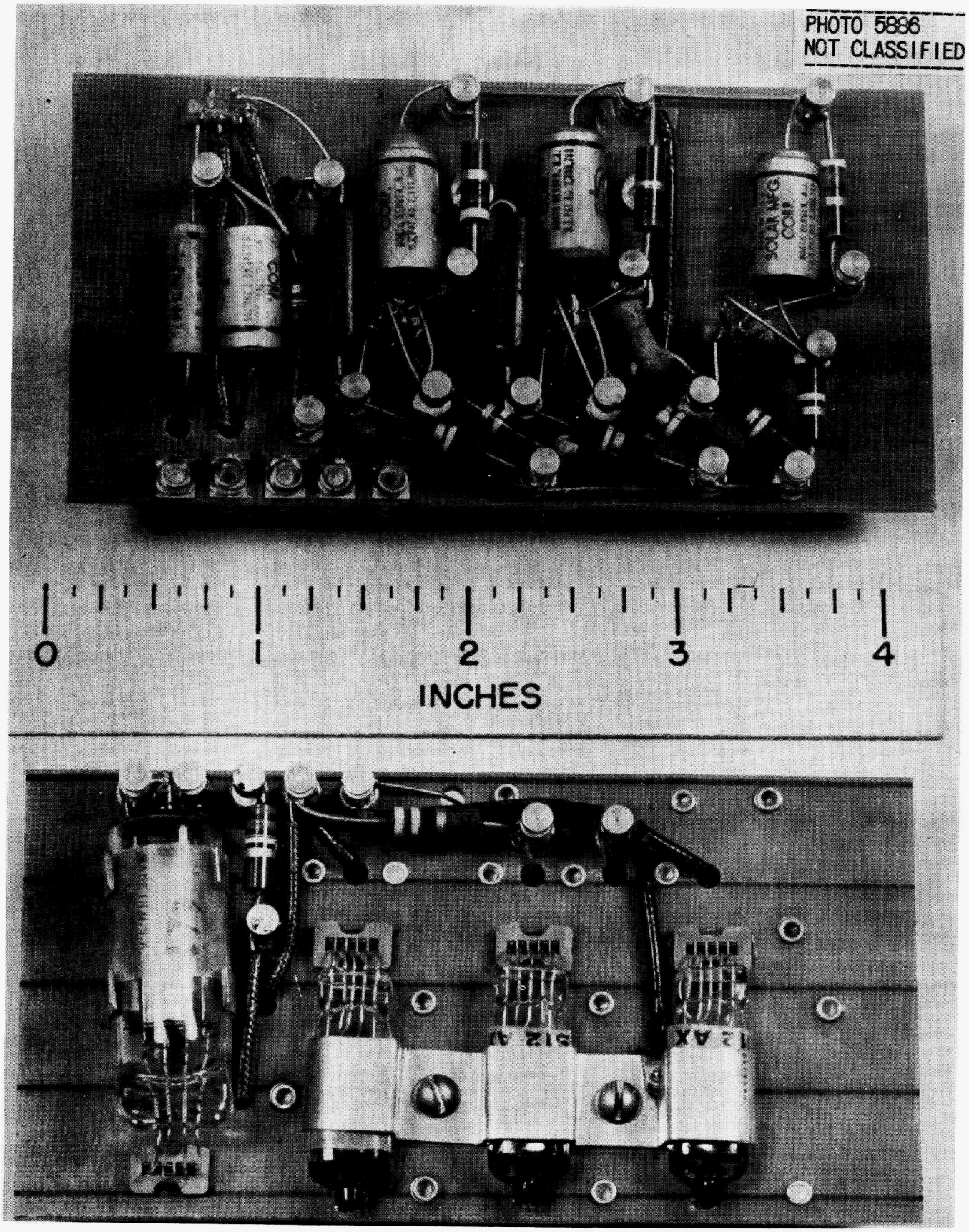

Figure 3
AMPLIFIER STRIP
(Showing Obverse and Reverse Sides)

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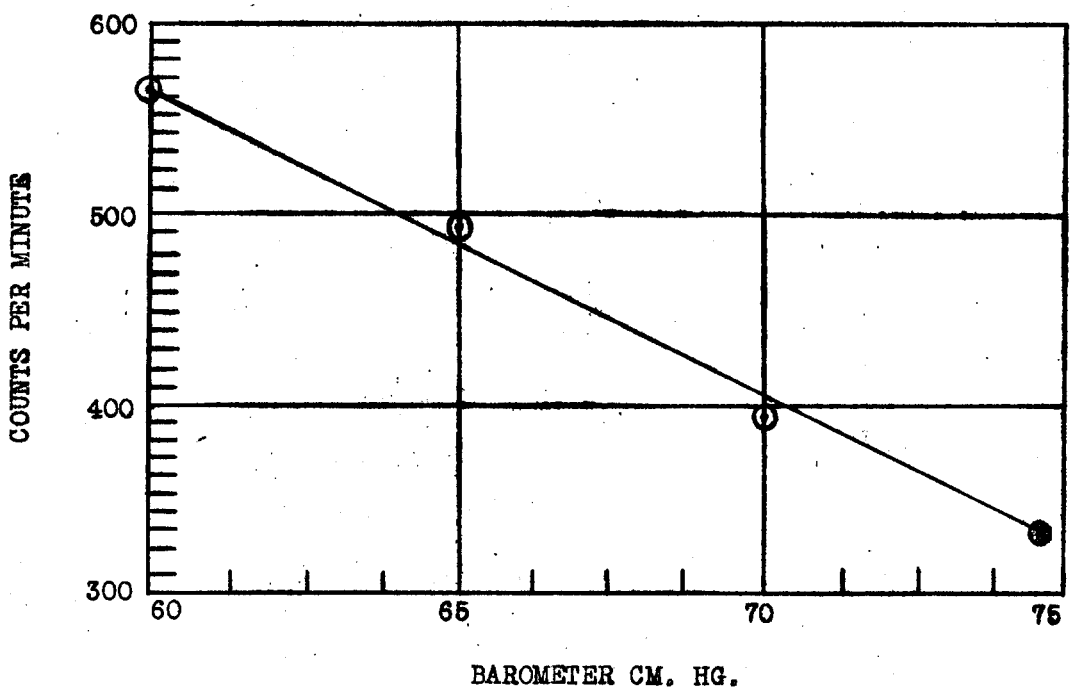

Figure 4

COUNTING RATE VARIATION WITH AIR PRESSURE

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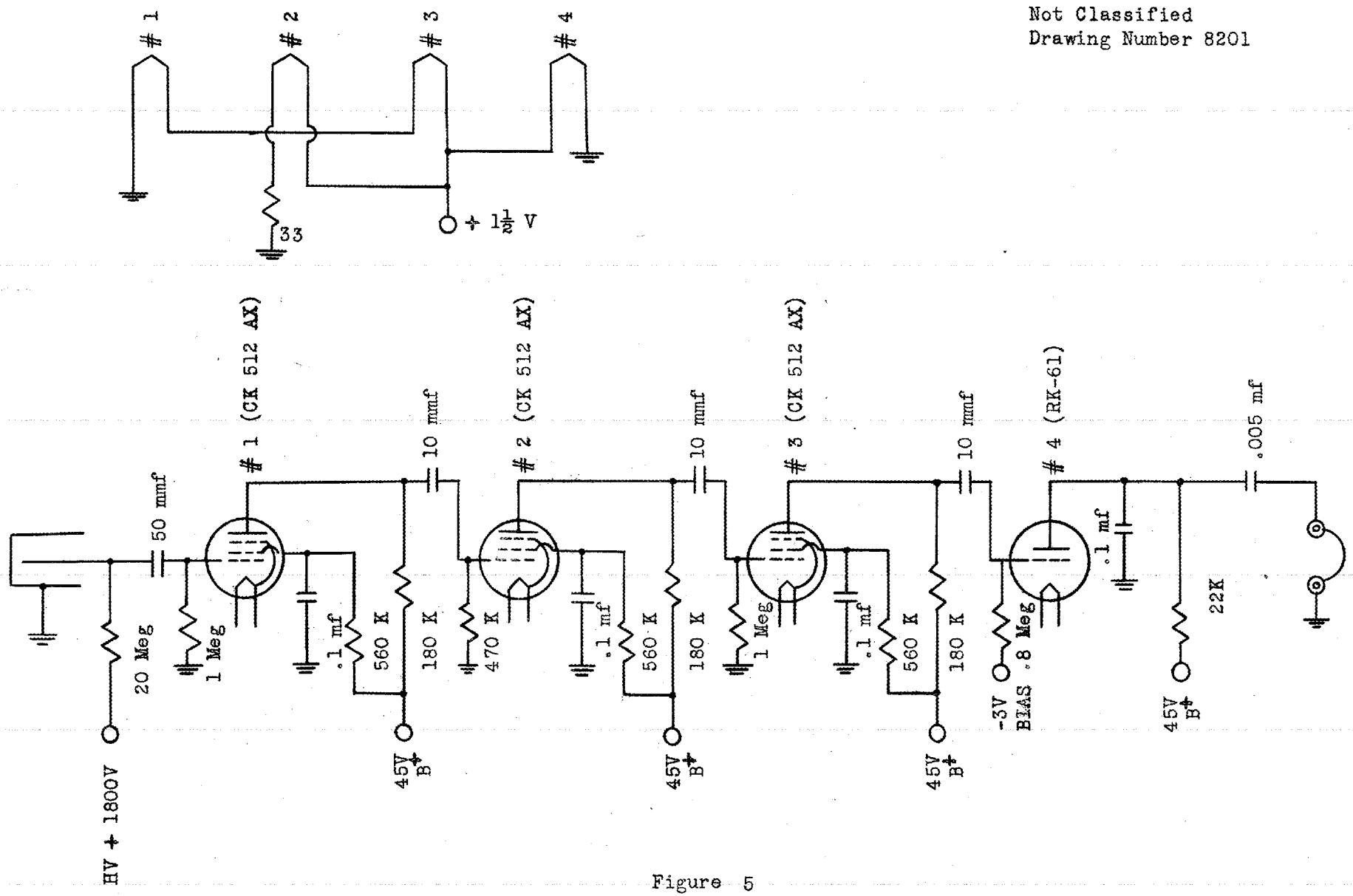

Figure 5

CIRCUIT DIAGRAM FOR ALPHA SURVEY METER

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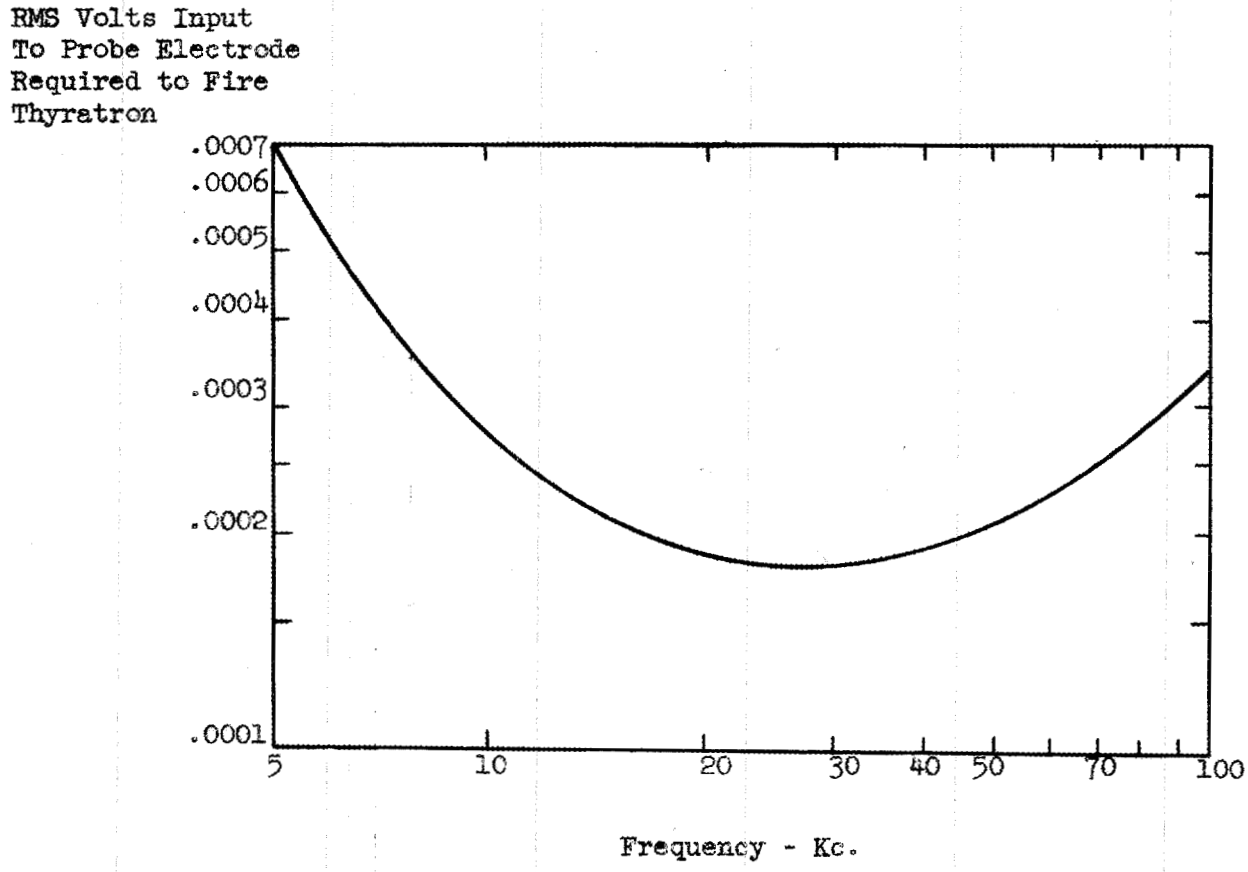

Figure 6

OVERALL FREQUENCY RESPONSE FROM PROBE ELECTRODE TO THYRATRON GRID

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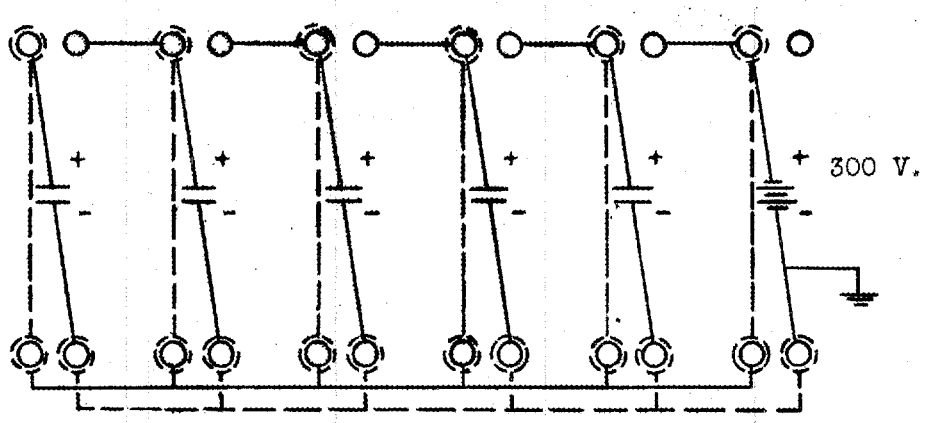
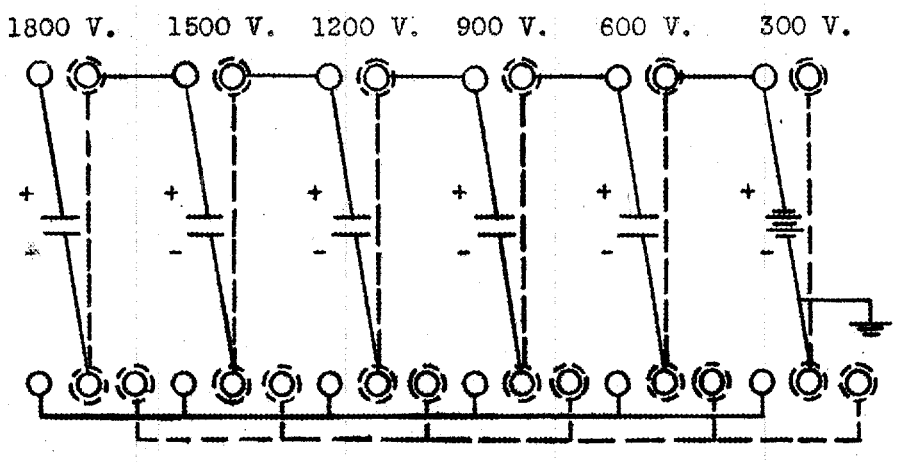


CHARGING POSITION



OPERATING POSITION

Legend

- ○ Stationary Contacts
- —— Conductor Between Stationary Contacts
- ◯ Sliding Contacts
- - - Conductor Between Sliding Contacts

Figure 7

SCHEMATIC OF HIGH VOLTAGE SWITCH