A GEIGER MUELLER COUNTING CIRCUIT FOR X-RAY INTENSITY MEASUREMENTS

by

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Submitted in Partial Fulfillment of the
Requirements for the Degree of Bachelor
of Science from
The Massachusetts Institute of Technology
April 14, 1942.

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ACKNOWLEDGEMENT

I wish to express my gratitude to Professor G.G. Harvey for the suggestion of this problem and for his helpful advice and encouragement.

CONTENTS

Introduction

The purpose of this thesis was to construct a Geiger Mueller counting circuit that would be able to measure the intensity of X-Rays and thus be readily adapted to use in an X-Ray spectrograph. Two aims in the construction were to gain experience in constructing electronic equipment and to understand more thoroughly the mechanism of scaling circuits. Since the complete construction and testing were not able to be carried out in the time allotted, there is still room for another thesis to be performed on the continuation of this problem.

Most of the time was spent on construction of equipment; all apparatus was made except for a low voltage stabilized supply. Because of the shortage of this last piece of equipment and the absence of the Cenco message register, testing at this date has not been completed as there is still some undiscovered trouble in units B,C, and D of the scaling circuit.

The first part of the thesis will deal with various types of scaling circuits and their respective advantages in solving the problems encountered. The second part will deal with the problem of constructing a Geiger Mueller counter for the measurement of X-Ray intensities.

Extinguishing Circuits

The problem of extinguishing the arc produced in a Geiger Counter discharge is indeed vital for the proper functioning of the circuit. A condition for stability is that the duration of the lowering of the voltage be long enough to permit the removal of the ions produced in the discharge. The standard proceedure has been to use a resistance in series with the tube sufficiently large (10^8 to 10^{10} ohms) to produce the necessary drop. The relatively slow recovery is insured by the time needed to charge up the counter through so large a resistance. However, this becomes inefficient at high counting rates due to its long recovery time. The use of such high resistances makes it necessary to take precautions to minimize circuit leakage and in many applications of Geiger Counters these precautions are difficult to carry out.

One type of recovery circuit is that shown in the diagram IV A. It employs a multivibrator so biased that it cannot oscillate. The circuit possesses the novel feature that the length of the pulse is limited by the vacuum tube circuit and not by the counter. The mechanism may be described by stating that the counter momentarily upsets the stability of the circuit by varying the voltage on one of the grids of the multivibrator so that one pulse takes place. Alternatively the action may be described as follows: the passage of the ionizing particle causes a sudden lowering of the voltage on the wire electrode and hence the grid of the first tube. The change is twice amplified, and the amplified pulse of correct phase is fed back to the counter producing a regenerative effect. Whereas the initial lowering of the grid, resulting from the counter current through the meg ohm resistor, would not have been sufficient to extinguish the arc, the regenerative effect of the coupling through the entire available voltage drop of the vacuum tube circuit on the wire electrode is sufficient. The recovery of the circuit is fixed by the resistance and capacitance of the circuit, compared to which the capacity of the counter is negligible. The shape of the pulse is rectangular, the wave shape being fixed by the multivibrator.

The statistics of this counter are entirely different from those of previous circuits. Here the maximum counting rate is the oscillation frequency of the multivibrator, independent of the Geiger Counter. The passage of an ionizing particle while the wire is on the crest of the rectangular pulse has no appreciable effect because the counter is below its critical voltage and because the grid of the first tube is already so negative that the first tube cannot respond to any further small pulses, were they forthcoming. With constants shown the circuit will count as many as 2,000 random counts per second and with small counters the pulse has been reduced to 10^{-4} seconds.

The advantages of this circuit are the following: the highest resistor ever needed is 10^6 ohms; the outside electrode of the counter is insensitive to pickup as it is connected directly to the high potential; different counters may be used without altering the resolving time of the circuit; all tubes are used within the manufacturers ratings; the pulse on the counter wire can be studied with an oscilloscope by connecting it directly through a reasonably large condenser; and either sign pulses may be taken off by connecting either to the first or second tube. A disadvantage of the circuit is that the high potential must be turned on rapidly to prevent continuous discharge. This results from the condenser coupling between the tubes of the multivibrator.

[2]The Neher Harper extinguishing circuit is that shown in diagram IV E. The virtue of this circuit is mainly realized in its application to high speed counting, but the convenience afforded in the use of a low extinguishing resistance (10^6 to 10^7)makes it useful in many applications.

Under normal conditions the voltage Eg maintains the control grid of the 57 tube sufficiently negative to prevent the flow of appreciable plate current through Rp. The potential Ep is adjusted to such a value that the effective voltage across the counter tube is above its threshold, that is, the counter is assumed to be in a sensitive state. The passage of an ionizing particle through the counter initiates a discharge between its electrodes. This discharge causes the potential of the control grid to become less negative, thereby increasing the plate current flowing through Rp. If the change in grid potential is of sufficient magnitude, the voltage drop in Rp will result in the effective counter voltage dropping below the threshold value. Thus the counter discharge is extinguished and the circuit recovers to normal conditions in a period determined by the time constant. The amplifying action of the 57 tube permits satisfactory counter operation with a total circuit resistance far below the value ordinarily employed in Geiger counters. It is also quite apparent that there is an optimum value for Eg---if too negative the counter will not be able to affect the plate current by an amount sufficient to cause extinction of the discharge;---if too positive the plate current may be increased to the point where the voltage drop in Rp will bring the effective counter voltage below the necessary threshold value. Even before these extremes are reached a loss in counting efficiency is noted.

Some advantages of this type of circuit are the following: it will respond to at least 2×10^5 particles per minute; easily obtainable resistances of not more than a few million ohms are used; consistency of operation is obtained since surface leakage and surface charges are unimportant; the circuit will operate equally well with very small or very large counting tubes, and at either low or high counting rates; the counts are independent of the voltage on the counter over a wide range; a large pulse is obtained which makes possible the use of low values of resistance and capacity to the mixing tube in case several counters are used to count coincidents; the circuit is simple, inexpensive to make, and has given satisfactory performance on several different research problems.

[3]A third type of extinguishing circuit is that of Fig. IV B. This circuit consists of any heater type tube with the heater grounded and the counter wire connected directly to the cathode. The other elements of the tube (plate, screen grid, control grid, etc.) are all either connected to ground or to a fixed positive potential of 20 to 100 volts, according to whether the tube has a direct current or alternating current type of heater. Under rapid counting conditions tests showed that this circuit behaves about as well as the Neher Harper circuit.

The advantages of this circuit are that the counter wire can be kept at ground potential as in most counter circuits used prior to the Neher Harper circuit, and that there are no critical adjustments of the tube potential to be made. Apparently the action of the tube is due to the cathode's electron emission to the grounded heater being increased by the decrease in potential caused by the collection of electrons on the counter wire during each count. The recovery time is short because the capacitance of the counter wire cathode system is low.

Extinction Circuits for Message Registers

In many branches of physics small gas filled triodes are used as relays to operate electromagnetic counters and similar devices. This type of relay has two well known advantages, namely: (1) it can control large amounts of power with a very small input power, and (2) it can be triggered by very short impulses and then extinguished at any later time. The one disadvantage of such a relay is the requirement of some means of stopping the current once it has been established. Ordinarily this is accomplished by contacts on the moving arm of the counting mechanism. Such an arrangement is convenient in that the current can be broken at the required instant, but it is undesirable, particularly at fast counting rates to have to rely on such mechanical means of clearing the circuit.

4 A circuit having an advantage over those employing the usual type of mechanical clearing is that of Fig. IV D. In this another relay is used with contacts which make, but do not break, the main current through the counter. When the tube becomes conducting, the small current necessary to operate the relay is established. The resistance R2 is adjusted to keep this to the minimum. When the relay contacts close, a surge passes through the counter and causes it to operate. The voltage across the counter rapidly falls to almost zero because of its low impedance,

and finally becomes too low to maintain the arc in the tube and hence the relay is released. As a general rule the operation of the circuit will be governed by the speed of the relay. This, of course, must not be too high or the counter will not operate properly.

Advantages of this circuit are that the relay contacts do not break the comparatively heavy surge current through the counter; and the gas triode does not have to handle the full current necessary to operate the counter but only the small current necessary for the relay. However, there is still the disadvantage that it relies on mechanical means to clear the circuit.

A circuit proposed to avoid this difficulty is that shown in Fig. IV F. The operation depends on the resistance R being of such magnitude that the steady current through the tube will not maintain the arc. The capacity C supplies the large momentary current necessary to operate the counter. In practice this means that, for a counter such as the Cenco Impulse Counter, C is about $\frac{1}{2}$ micro farad while R must usually be larger than 10^{5} ohms. Thus the resolving time is about one tenth of a second and fast counting rates are out of the question. For slower rates, or for the operation of very sensitive counters the circuit is quite satisfactory.

The circuit of Fig. IV C has the advantage of a fast recovery time and no moving contacts or auxilliary relays. The basic principle underlying its operation is that if the grid of a gas tube is strongly negative with respect to the cathode, and if the current through the tube is small, the grid will regain control and extinguish the arc. In operation the grid receives a positive pulse. An arc is established and a current flows through the counter, the resistance R, and the condenser C. This flows long enough to operate the counter. The condenser C now becomes charged to practically the full plate voltage and the arc current drops to a value determined by R1, R2, and the resistance of the counter. The cathode is now at a high positive potential with respect to the grid, and thus we have the condition for extinction of the arc. After this occurs, the condenser C discharges through R2 and the circuit is ready to operate again. Circuit constants depend upon the type of counter used. The maximum counting rate for the circuit with the constants shown is better than sixty evenly spaced counts per second which is short enough so that most counters will operate near their maximum speed.

5 High Speed Mechanical Recorders

The fastest commercial recorder has a reaction time of 10^{-2} seconds. This means that if accuracy is an important factor, random counting rates should be limited to one or two per second with a recorder of this type. A description of a recorder made and tested and having a reaction time of $.8 \times 10^{-3}$ seconds follows. This takes the place of a scaling circuit of 8 or 16 and thus replaces 12 radio tubes.

For such a circuit electrical and mechanical systems should be matched, that is, the electrical period should be as short as the mechanical period. The electrical period is determined by the L/R value. An additional requirement is that the mechanical and electrical parts each be nearly critically damped. The recorder to be described employs a ratchet rotated by an arm upon which is mounted an armature which in turn is caused to move with an electric magnet. Two methods are available for transmitting the motion to the ratchet. Either it can be moved while the armature is being attracted to the magnets, or it can be moved on the return of the armature to its normal position. In the former case the accelerations increase as the motion takes place until the movable arm either strikes a stop or the armature strikes the faces of the pole pieces. The tendency is for the ratchet to continue its motion beyond the point where it is actually moved by the arm. On the other hand, if the ratchet is made to move when the arm returns to its normal position, the accelerations are large at first because of the restoring forces and die to zero gradually as the normal position is approached. There should therefore be less tendency to count double with this construction. The ratchet was prevented from turning backward by a pawl. It was necessary to apply some friction to the ratchet by pushing the pawl against the ratchet to keep the recorder from counting double. Details of the exact construction can be found under the article stated in the bibliography.

Direct Reading Impulse Frequency Meter Suitable for High Speed Recording

A modified two tube thyratron inverter is employed to deliver an invariant current pulse to an indicating instrument each time the polarity of the input signal reverses. The average current in the indicator is strictly proportional to the frequency of the input signal below 7000 cycles per second and approximately so for higher frequencies. The current may be varied to permit a standard current instrument to be used as a direct frequency indicator. The readings of the instrument are independent of the amplitude or wave form of the input signal over a wide range. When the frequency of the input signal is not constant, either an accurate indication of the average frequency can be obtained or the output circuit of the instrument can be modified to permit the frequency to be recorded as a function of time.

The operation of the circuit (Fig. IV G) may be described by beginning with tube B non conducting and tube A carrying its normal plate current. Under these conditions the condenser Cm associated with tube A and the condenser C each become charged to a voltage Er equal to the drop across the load resistance R in the cathode return of tube A, while the other condenser Cm is uncharged. When the input signal, introduced through the transformer with center-tapped secondary, varies in such a way that the grid of the thyratron B is carried sufficiently positive, the arc discharge in B will be initiated and the potential of the cathode of tube B will be raised abruptly to a value Er equal to that of the plate supply less the tube drop in B. Inasmuch as the voltage across the condenser C cannot alter instantaneously, the cathode of tube A will momentarily be carried positive with respect to its anode by a voltage equal to Er less the tube drop across A. Since the grid of tube A is at the same time negative with respect to the cathode, the arc in A will be extinguished, provided the deionization time of the thyratron is not greater than the time required for C to discharge through R. In a similar manner, since the voltages existing across Cm cannot alter instantaneously, both anodes of the double diode will be raised momentarily to a positive voltage Er and a current pulse will be delivered to the indicating instrument. If the time constant of the metering circuits (RmCm) is made somewhat less than the time constant of the commutating circuit (RC) the current pulse delivered to the meter will always be completed within the time required to extinguish the arc in tube A. Using the circuit constants shown, the entire sequence of events takes place in fifty micro seconds. Thus the average current is proportional to the number of pulses delivered per second. Mercury vapor thyratrons are not in general satisfactory for this type of service on account of their large temperature coefficients of tube drop and starting potential. The type 885 Argon filled thyratron, on the other hand, shows no temperature effects under average conditions and appears to be entirely satisfactory.

7 Trigger Circuits

The basis of most counting circuits is a trigger circuit in which when one tube conducts the other becomes non conducting. The most common of these is the Eccles Jordan trigger circuit, (Fig. V B). The action of the circuit depends upon the fact that current flows through only one tube at a time. Suppose that equal currents could flow in both tubes. Any small increase of plate voltage or decrease of negative grid voltage of tube 1 increases the plate current in tube 1 and thus increases the voltage drop in Rb1. This makes the grid of tube 2 more negative, which decreases the plate current of tube 2 and the voltage drop through Rb2 and thus makes the grid of tube 1 less negative. The action is cumulative and results in an abrupt increase of ib1 and cessation of ib2. The current can be caused to transfer from tube 1 to tube 2 by introducing additional negative voltages in the grid or plate circuit of tube 1 or positive voltages in the grid or plate circuit of tube 2. If these voltages are applied gradually, they have no effect until critical values are reached, at which the current transfers abruptly. Transfer from tube 1 to tube 2 can also be effected by decreasing Rb1. For specific values of plate and grid supply voltages there is a critical value of Rb1 at which transfer takes place.

Pentode trigger circuits work on a similar principle. The advantage of this type of circuit is that while it is very sensitive to a negative pulse on the grid or change of control grid voltage of less than $\frac{1}{2}$ volt, it is very insensitive to a positive pulse or change of control grid voltage. The screen grids are employed in the usual manner, and the suppressors and plates are connected in the manner of the plates and control grids of a triode trigger circuit. The circuit is tripped by increasing the negative control grid voltage of the tube that is passing plate current. The functions of the suppressor and control grids may be interchanged; but the circuit is then responsive to voltage pulses of either polarity, and a greater tripping voltage is required. In either circuit the grid to plate resistors should be shorted by condensers of approximately 50 micro micro farads.

By taking advantage of the peculiar characteristic which causes the plate current to jump abruptly from one critical value to another as the grid voltage goes through a critical value, we can have a trigger circuit using only one pentode as in Fig. V D. In this circuit the resistors R1, R2, and R3 form a voltage divider which causes the suppressor voltage to vary with the screen voltage in the desired manner. The combination of resistors also forms the screen load resistance. Under proper operating conditions the suppressor voltage corresponding to the upper values of screen current is so negative that the plate current is zero. The plate current corresponding to the lower values of screen current depends upon the circuit constants and operating voltages. With a type 57 tube it may be made several milliamperes. The plate current may be turned on and off abruptly by small changes in screen current. The most satisfactory method of voltage control is to introduce the control voltages in series with the suppressor or the control grid. The control grid is the more sensitive, but in order to obtain sufficiently high plate current, particularly when resistance is used in the plate circuit, it may be necessary to use positive control grid voltage. This causes the flow of control grid current which may be objectionable. Values for resistances and voltages shown in the circuit are not very critical.

The fact that the plate characteristic of a tetrode has a portion that may be cut in three points by the load line indicates that this type of tube can also be used as a trigger amplifier by the use of sufficiently high load resistance in the plate circuit. The objection to tetrodes is the variation of secondary emission during the life of the tube. Excellent results have been obtained with the old 2A4 tubes, but the more recent tetrodes have rather critical adjustments.

[7] High Speed Thyratron Counting Circuits

The frequency at which a mechanical counter can respond is limited by the inertia of moving parts. For high speed counting it is necessary to design circuits in which the relay operates once in a relatively large number of impulses. Two electron tube counting circuits developed by [8]Wynn-Williams are based upon the parallel thyratron switch.

A typical example is the scale of eight counter shown in Fig. V E. It consists of two or more parallel circuits in tandem. The impulses to be counted are applied simultaneously to the grids of the first parallel circuit. The anode voltage of one tube of this first parallel circuit is applied to the grids of the following parallel circuit, which has a counting relay in series with one anode. The grids are biased sufficiently to prevent firing without the application of an impulse to the input. Because of slight differences between tubes the first impulse will cause one of the tubes of the first stage to fire. The next impulse fires the second tube and extinguishes the first in the following manner. When tube 1 is conducting, the condenser charges to such polarity that the terminal connected to the anode of that tube is negative with respect to the other terminal. Firing of tube 2 by a positive grid impulse applies a negative voltage to the anode of tube 1 causing it to be extinguished. Firing of tube 2 reduces the negative grid voltages of the tube in the second stage, causing one of them, say tube 3, to fire. The third impulse fires tube 1 and extinguishes tube 2. The fourth impulse fires tubes 2 and 4, closing the relay and extinguishes tubes 1 and 3. The addition of another stage allows the relay to count every eighth impulse. With n stages of two tubes each the relay need operate only each 2^n th impulse.

The second type of counter developed by[9] Wynn-Williams is known as the ring circuit (Fig. V C). It consists of three or more grid controlled arc discharge tubes. The impulses to be counted are applied simultaneously to all the grids. Suppose that one tube, say tube 1, has fired. The IR drop resulting from the flow of current through the cathode resistor R1 accomplishes two results. It reduces the negative grid bias of tube 2, so that the next impulse applied to the grids will cause tube 2 to fire; and it charges the condenser C1,so that,when tube 2 fires, the anode of tube 1 is made negative relative to the cathode causing tube 1 to extinguish. Similarly till we get to tube 3, the firing of which charges C3 so that the third impulse will again fire tube 1 and extinguish tube 3. As many tubes as desired may be connected in this manner. The counting relay is operated either directly by the anode current of one tube or by an auxillary high vacuum or arc tube Tr which is controlled by the voltage drop in one of the cathode resistors in the ring circuit.

Counting Circuits Based upon High Vacuum Tube Trigger Circuits

[7]A number of scaling circuits have also been devised in which high vacuum trigger circuits have been adapted. In these circuits the voltage pulses are applied simultaneously and in the same polarity to both tubes of an Eccles Jordan trigger circuit. Each pulse transfers the current from one tube to the other. The abrupt change in current in either plate resistor is used to produce a voltage pulse which is applied to the grids of the next stage. By the use of n similar stages, the final one of which controls an electromagnetic counter, the rate at which the counter must operate is reduced in the ratio of 2^n. Circuits of this type are more rapid in operation than thyratron circuits but require input pulses of very steep wave front. Two examples of these circuits are shown in Figs. V F and V G.

Another type of scaling[10] circuit has been devised by Stevenson and Getting which differs from the Wynn-Williams type in using vacuum tubes instead of thyratrons. Its short resolving time (better than 1/50,000th of a second), its stability, and its durability over extended periods of operation recommend it for accurate recording of high speed Geiger counter discharges. Since this circuit, shown in Fig. V A, is similar to that which was built, a detailed explanation of its performance will follow.

It is possible to apply the principle of retroaction to two vacuum tubes in such a way that there are two conditions of stability. In one position one tube has a low impedance and its mate a high impedance. In the other position the situation is reversed. It is necessary that at each incident pulse the circuit shall be tripped from one equilibrium state to the other. Two additional vacuum tubes for input and condensers for cross coupling solve the problem. Consider the drop in potential along the two sets of symmetrically parallel resistors across which is applied a combination positive plate supply Eb and a negative grid bias Eg. Assume that the grid of the tube T1 is approximately at ground potential, and R1 is of such value that the tube at this bias has a low impedance compared to R1. The plate and the point A will not be far above ground potential. If R2 and R3 are suitably chosen, the drop in potential across R2 can be made large enough to hold the point B and the grid of T2 at a negative bias sufficient to make the tube have an effective resistance greater than R1. The plate of T2 and the point D will therefore be at a positive potential so large that the drop across R2' will not lower the grid of T1 to a potential below ground. Hence a stable condition exists in which the tube on the left is conducting; that on the right, non conducting; with the positive potentials at A and D low and high respectively.

Now suppose a positive pulse is applied to the input, to the grids of the two tubes T3 and T4, which are normally biased so far negatively that they are essentially non conducting. Because of the plate to plate connection of T3 and T1 and the low impedance of the latter tube, the input pulse is completely quenched on this side. However, the potential of the plates T2 and T4 is high initially, and lowering of the impedance of the latter by the input pulse causes a sudden fall of potential at D. This amplified negative pulse is fed through C2' to the grid of T1 shutting off the tube; and it produces an amplified positive pulse which is applied through C2 to the grid of T3 turning it on. Since the potential at A has risen and that at D fallen, T1 and T2 are held at a new condition of stability in which T1 is now non conducting and T2 is conducting. The next input pulse enters through T3 and trips the pair T1 and T2 back to their original position. Output pulses may be taken from A or D and fed to another scaling stage or to a recording circuit, the input tubes of which respond to only positive kicks. A 1/10th watt neon lamp N will glow only while the corresponding tube T1 is donducting. Likewise N' glows only while T2 is conducting. Hence N and N' may be used for interpolation in multistage units.

The circuit cannot respond to long pulses applied directly to the grids of T3 and T4 because during the input pulse these tubes have low impedance and will quench cross pulses. Hence recovery time of the input condenser C4 must be made less than the recovery time of the condensers C2 and C2'. Empirically it was found that R2C2 greater than 5R4C4 gave a stable circuit. If short resolving time is desired R4C4 must be correspondingly small. The use of vacuum tubes insures constant characteristics and dependability over long periods of time.

As the circuit is sensitive to only positive pulses, successive stages can be connected in series; C4 of the second stage being connected to the output of the first, etc. The output pulse of the first stage is limited in steepness by the constants of the first stage and in magnitude by the plate supply. In order to successfully trip the second stage with a plate supply of 200 volts, it has been found necessary to increase the R4C4 value of the second stage by a factor of 2. It is more convenient to increase C4 rather than R4 in order to keep the voltage operative region the same for all stages. The R4C4 value of the third stage must be twice that of the 2nd, etc. This in no way reduces the efficiency of the unit as a whole inasmuch as the first stage output pulses cannot be closer together than twice the initial resolving time. Two condensers may be used to replace the vacuum tubes T3 and T4. However, the circuit is not as stable nor as fast. Also separating amplifiers must be used between stages to prevent feedback.

Construction of a Geiger Mueller Counting Circuit for X-Ray Intensity Measurements

The construction of the counter and extinguishing circuit is shown in Figs. I A and I B. The corresponding pictures will also help to illustrate how this was built. The entire apparatus, consisting of the counter, #57 tube, resistors and condensers, was mounted in a brass tube about 12" long and 2½" in diameter. The mounting was done by means of amphenol discs which were turned on a lathe to fit the inside diameter of the tube. The ends of the tube were covered by circular brass face-plates which fitted snugly into the ends of the tube. A window 3/4" in diameter was cut in the front face-plate to permit the entering of X-Rays into the counter. This was to be covered with Aluminum foil to keep the humidity inside the tube constant and thus keep leakage conditions constant. The supporting discs were connected to one another and to the rear face-plate by means of amphenol cylinders that had been drilled and tapped. Thus by removing the rear face-plate the complete mechanism could be removed from the brass shielding tube. Due to this semi-rigid arrangement it was also easy to reinstall the mechanism within the tube.

Both the high voltage and output leads consisted of shielded cable, and entered through separate openings in the rear face-plate. All other leads entered through a multi-wire shielded cable through the center of the rear face-plate. Although this apparatus is completed it has not as yet been tested.

The rest of the equipment was constructed on 17" by 13" chassis with paneled fronts so that when completed the entire apparatus might be mounted in the usual panel arrangement.

On the first chassis was constructed the amplifier with its power supply (Fig. I E). The amplifier consisted of a three-stage high-gain resistance-capacitance coupled amplifier (Fig. I D), but built to run at a rather high plate bias of 450 volts. The power supply consists of a well filtered (3 stage choke input) 450 volt supply with constants as shown in Fig. I C. At this time the power supply has been performing properly but as yet complete tests have not been made on the amplifier.

On the second chassis was constructed the high voltage regulated supply (Figs. III A and C) and the output stage to the message register Fig. III B. The output stage has a resolving time determined by the leakage of the pulse through the 10^6 ohm grid resistor. The high voltage supply works in the following manner: various voltages are tapped off a resistance potentiometer arrangement by means of a selector switch. The 2X2 is a half wave rectifier tube capable of handling the high voltages put out by the neon sign transformer. The condenser filtering arrangement is quite adequate in the case of light loads, as is the case in the present arrangement. The 6C5G and 6C6 serve as a voltage regulator in the following manner. When there is a voltage increase, the grid of the 6C6 is made more positive. This permits more current to flow through the 6C6 and thus increases the voltage drop across R11 which is an extremely high resistor (for purposes of amplification). This causes the grid of the 6C5 to become more negative, thus increasing the tube drop across the 6C5, and thus reducing the voltage. Similarly, a reverse effect takes place when there is a drop in voltage. Ordinarily the grid of the 6C5 runs from a few volts to 25 volts negative with respect to the cathode while the tube drop may vary from a hundred to six hundred volts. The grid of the 6C6 is generally a few volts negative while the tube drop is about one hundred volts. In measuring these drops great care must be taken, since in many instances the resistances are too large to give accurate voltage measurements. At the time of completion this part of the apparatus was working perfectly, and to get the required regulated voltage of 780 volts the dials should be set in the following manner: selector switch on tap three, grid bias dial on 75, and high voltage vernier dial on 83. Settings of the two dials are not too critical and can be made when the apparatus is in use.

On the third chassis was constructed the four units of the scaling circuit with their filament transformer as shown in Figs. II. The perspective view is not correct in that a few of the switches are interchanged and a filament transformer is placed in the front-center of the chassis between the scaling circuits. The four sections are arranged around the chassis in a counter clockwise manner with the A unit in the rear left-hand corner. An accurate description of the mechanism of this type of scaling circuit is heretofore given by Stevenson and Getting. At the time of completion only the A unit was in proper working order. A suggested change for future research on the project is the shifting of the neon bulbs to a panel front so that more accurate readings of the number of counts may be made. It might also be advisable to construct a direct reading impulse frequency meter such as that described in the previous part of the thesis inorder to get faster measurements of the X-Ray intensities.

In conclusion, much remains that will provide a suitable project for a Bachelor's thesis. This consists of the building of the low voltage regulated supply (it may be found necessary to build more than one.); the testing of the individual units; testing of the units as a whole when the Cenco high impedance counter arrives; calibrating the resolving time and accuracy of the circuit; and the making of actual X-Ray intensity measurements in conjunction with the X-Ray spectrograph.

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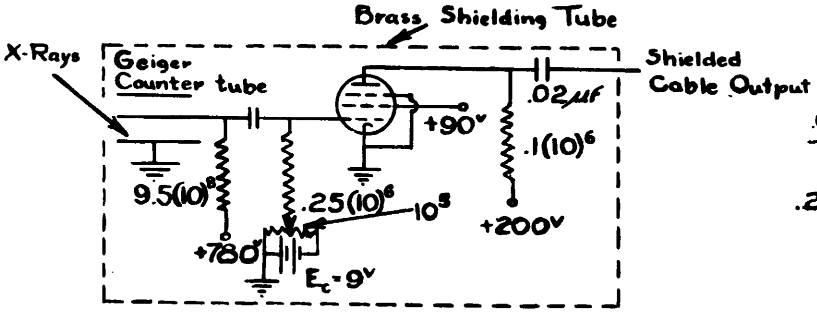
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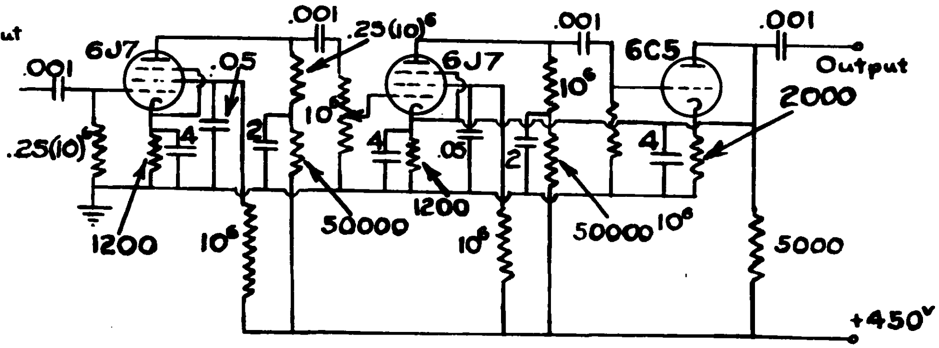
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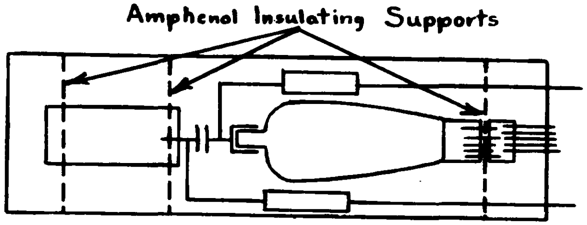
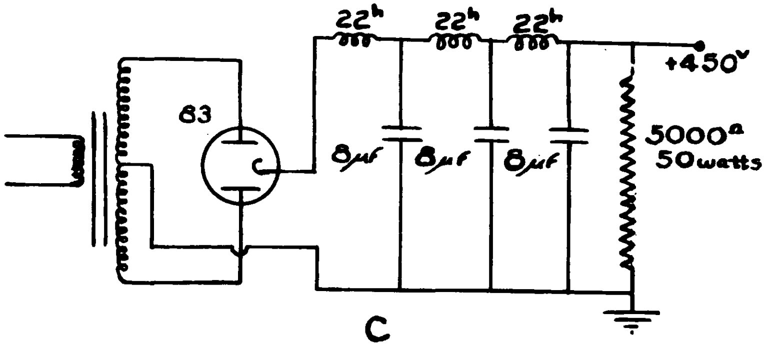
.05
1200
2
106
106
50000
6C5
.001
Output
2000
4
106
5000
+450v

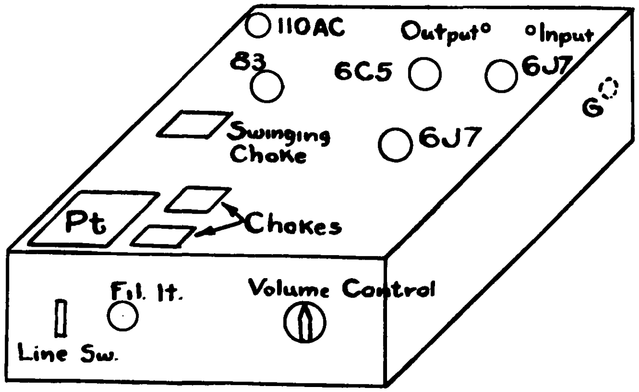
D


Amphenol Insulating Supports

B

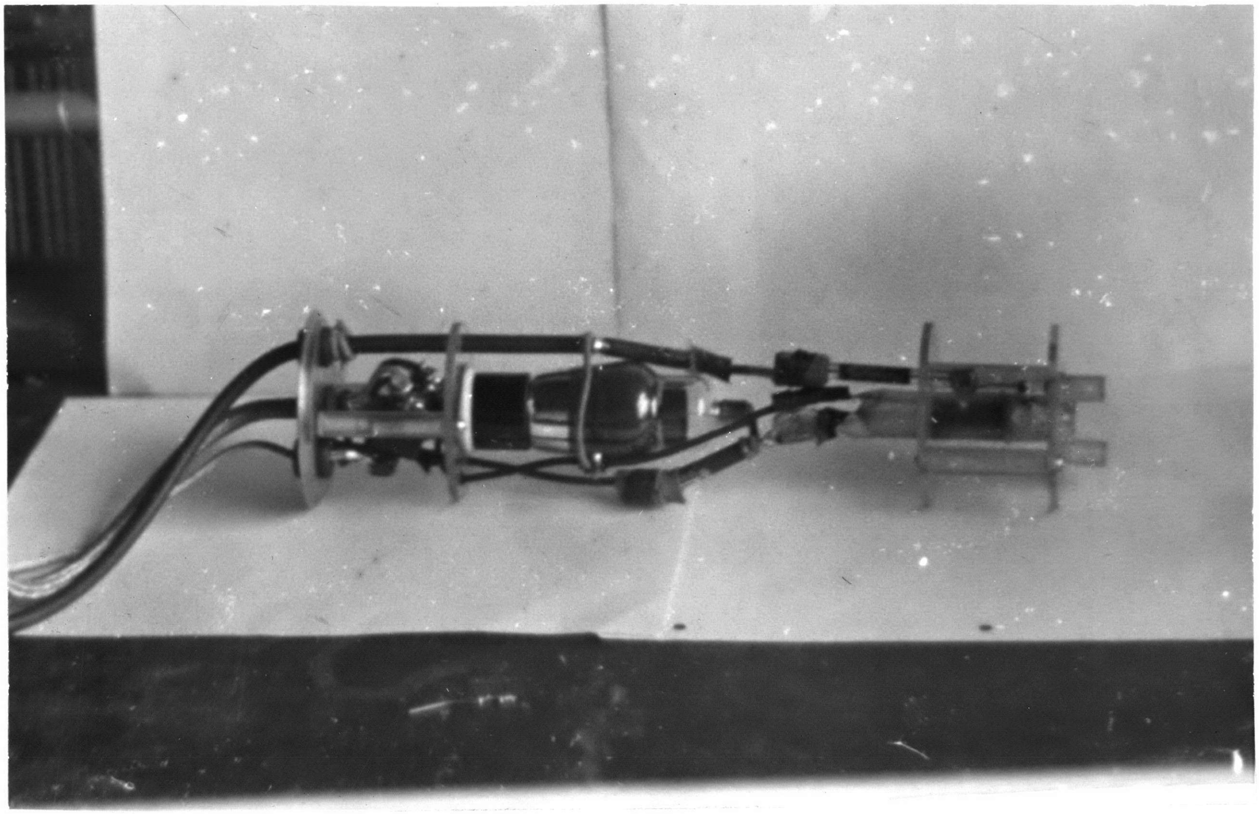

22h
22h
22h
+450v
83
8µf
8µf
8µf
5000Ω
50watts

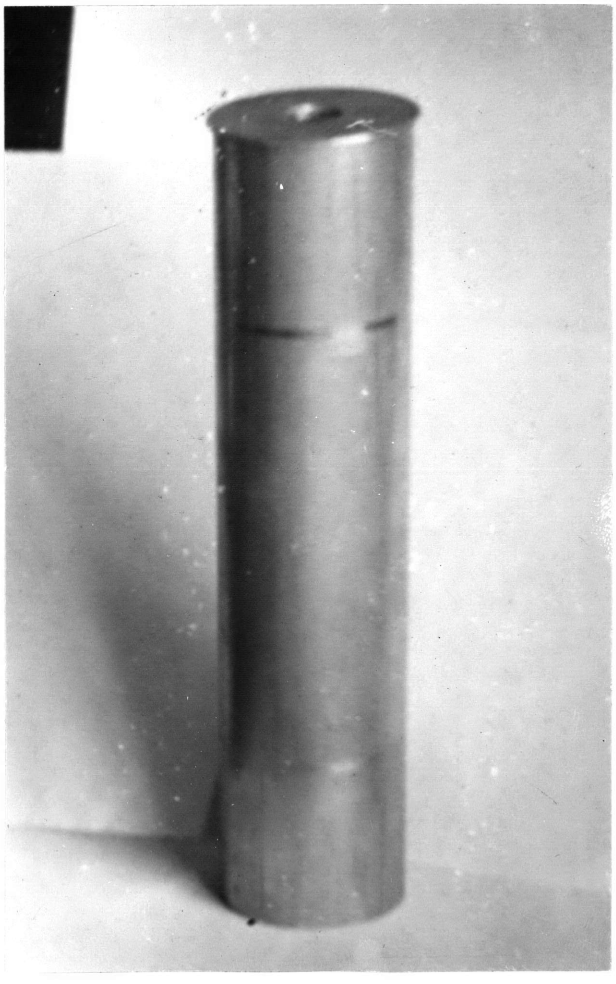
C


110AC
Output
Input
83
6C5
6J7
G
Swinging Choke
6J7
Pt
Chokes
Fil. lt.
Volume Control
Line Sw.

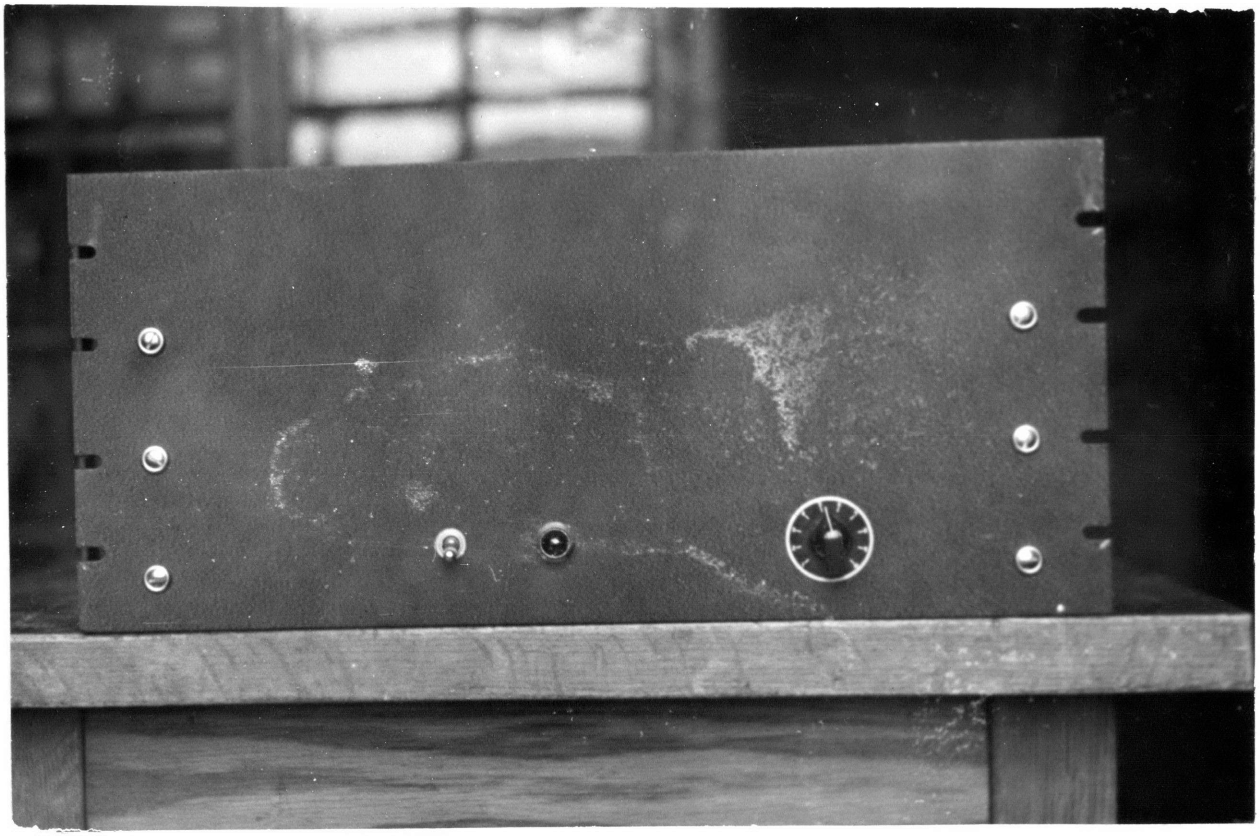
E

I

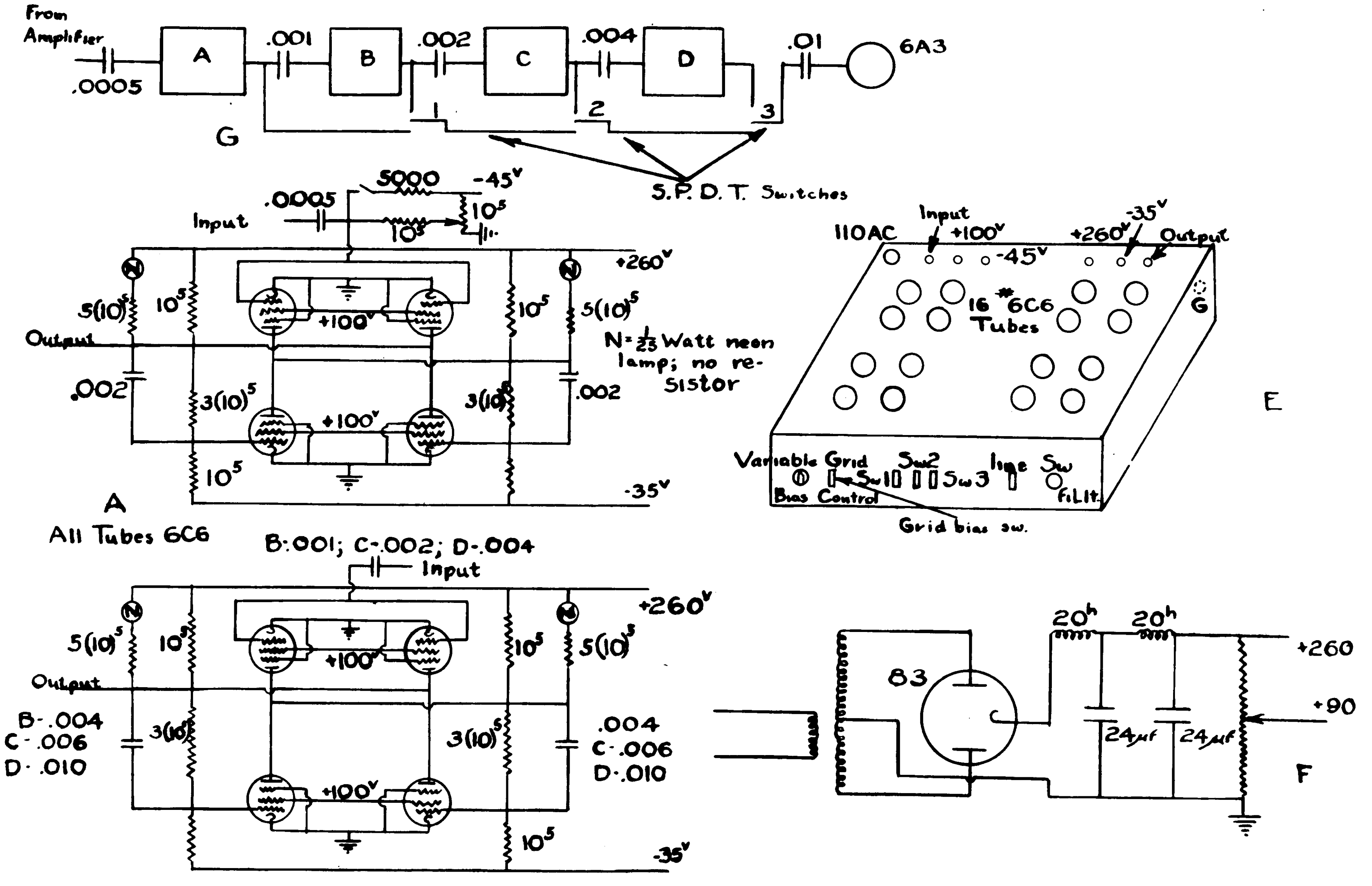




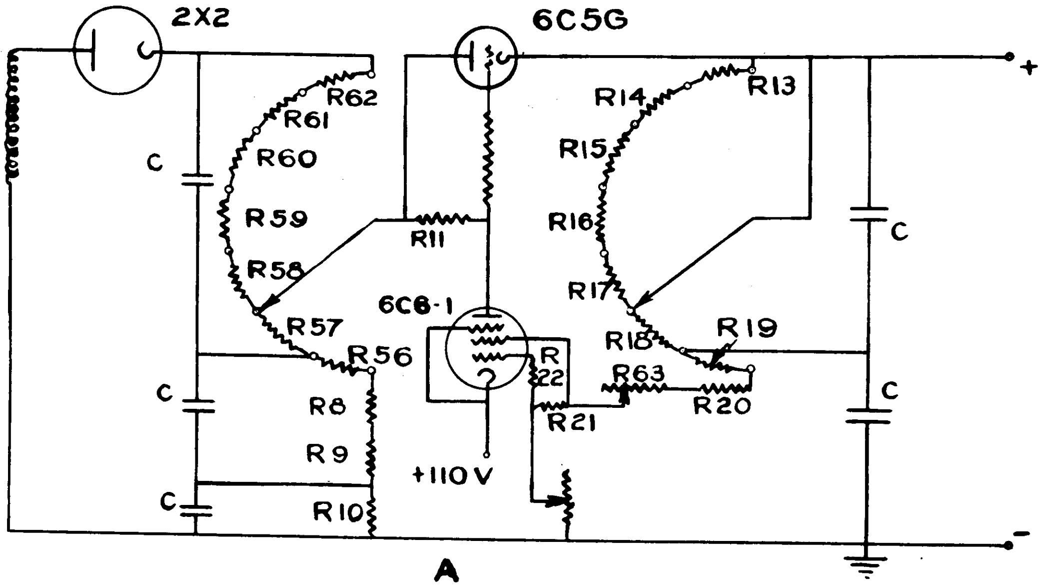
I A + B



I c, D, E

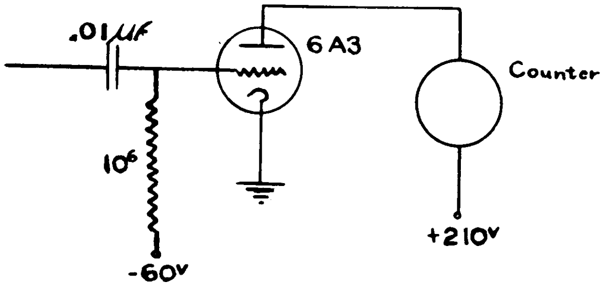

From Amplifier
.0005
A
.001
B
.002
C
.004
D
.01
6A3
1
2
3
G
S.P.D.T. Switches
.0005
5000
-45ᵛ
10⁵
10⁵
Input
+260ᵛ
5(10)⁵
10⁵
+100ᵛ
10⁵
5(10)⁵
Output
N = 1/25 Watt neon lamp; no resistor
.002
3(10)⁵
+100ᵛ
3(10)⁵
.002
10⁵
-35ᵛ
A
All Tubes 6C6
110AC
Input
+100ᵛ
-45ᵛ
+260ᵛ
-35ᵛ
Output
16 #6C6 Tubes
G
E
Variable Grid
Bias Control
Sw1
Sw2
Sw3
line Sw
Fil. lt.
Grid bias sw.
B-.001; C-.002; D-.004
Input
+260ᵛ
5(10)⁵
10⁵
+100ᵛ
10⁵
5(10)⁵
Output
B-.004
C-.006
D-.010
3(10)⁵
+100ᵛ
3(10)⁵
.004
C-.006
D-.010
10⁵
-35ᵛ
B,C,D
20ʰ
20ʰ
83
24μf
24μf
+260
+90
F

II

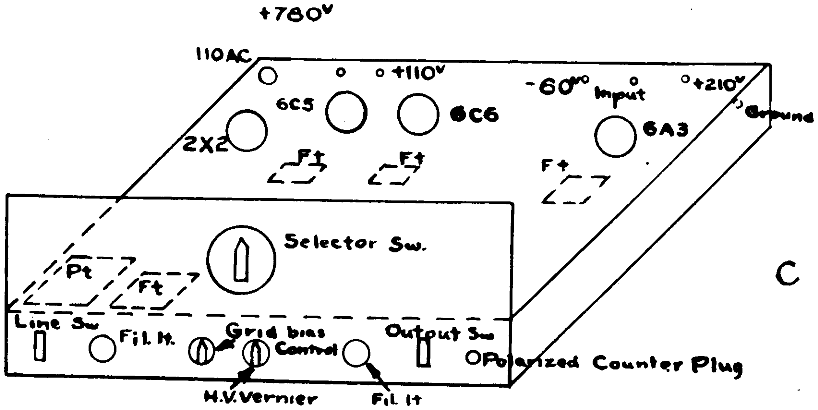


A

0.1 Meg. - R62
0.2 Meg. - R61
0.25 Meg. - R 8, 56, 57, 58
0.3 Meg. - R59, 60
0.5 Meg. - R 21
0.75 Meg. - R 13-19
1.0 Meg. - R 20, 22, 9, 10
1.0 Meg. var. - R63, 64
10.0 Meg. - R 12
100 Meg. - R11
Pt. - 2000V Neon Sign Trans.
Ft. - Fil. Trans.

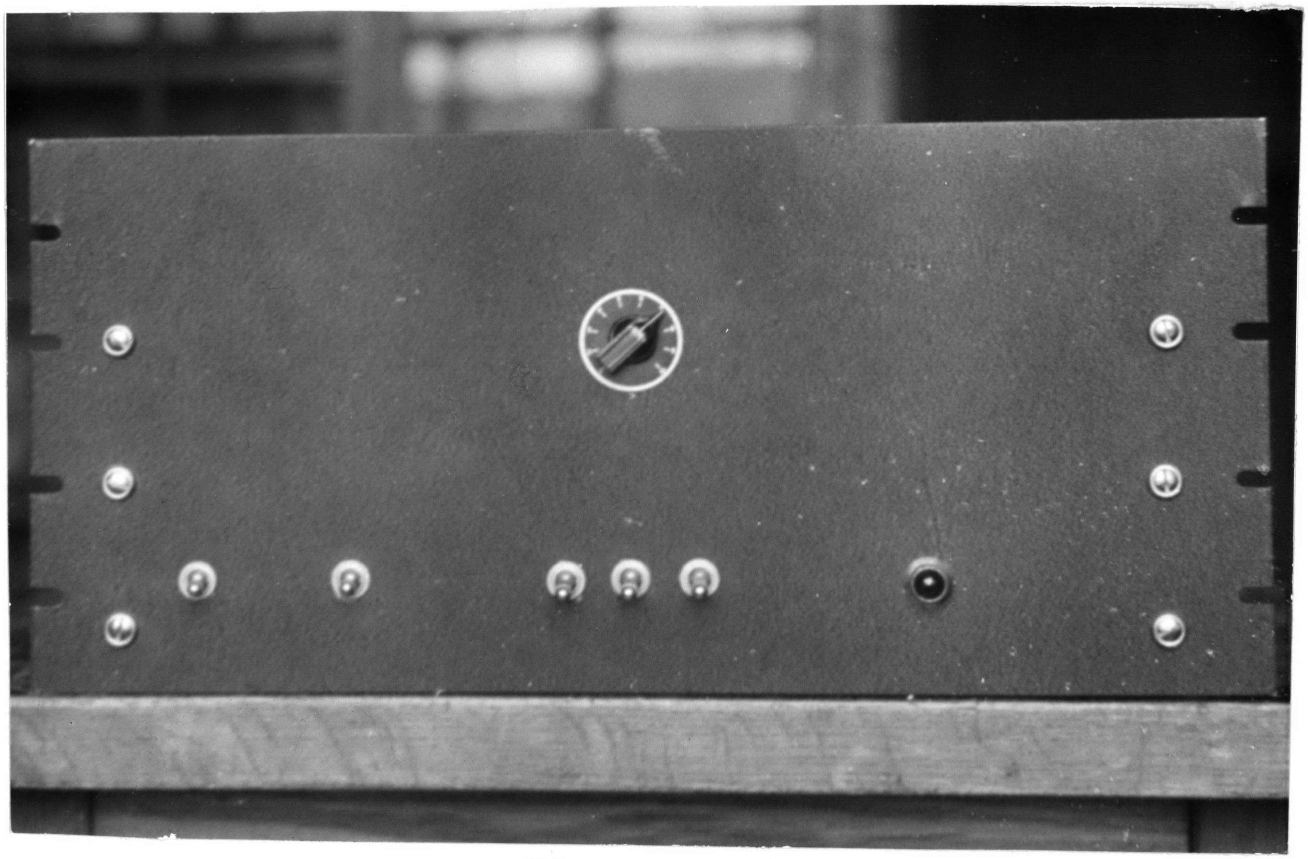


B



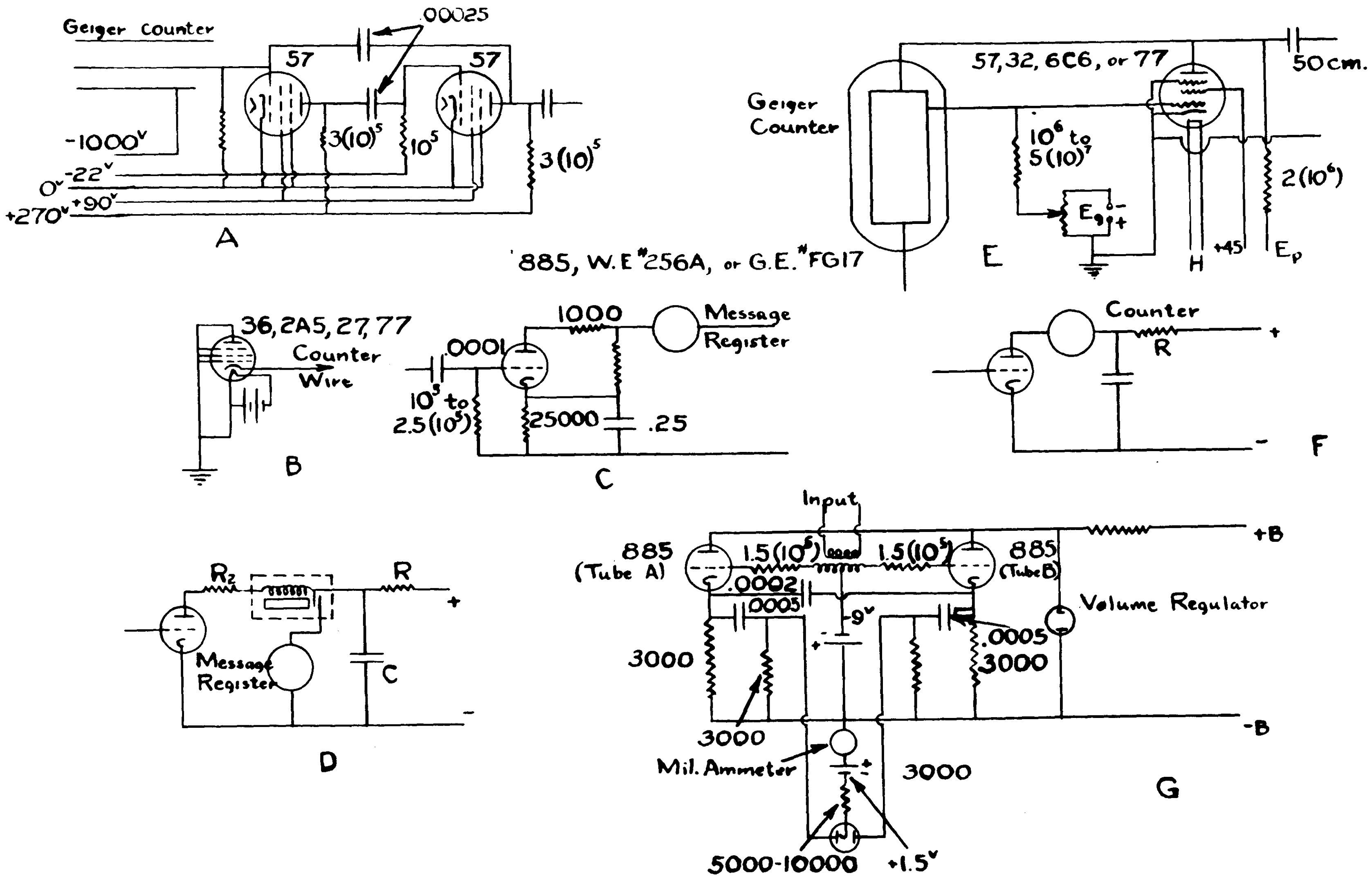
C

III

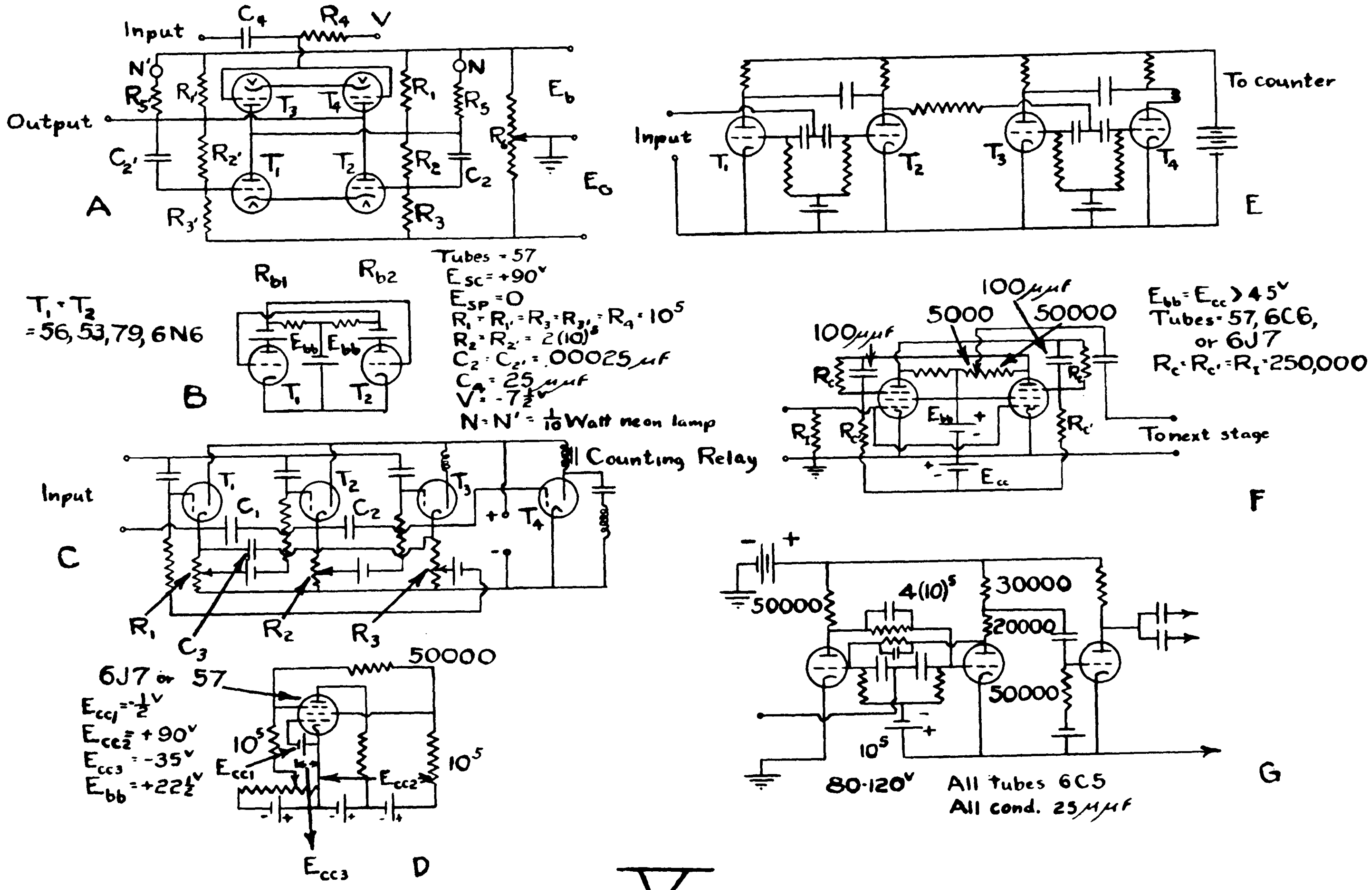


II

III


Geiger counter
.00025
57
57
-1000v
0v
-22v
+90v
+270v
3(10)^5
10^5
3(10)^5
A
Geiger Counter
57,32, 6C6, or 77
50cm.
10^6 to 5(10)^7
Eg
2(10^6)
+45
H
Ep
E
885, W.E.#256A, or G.E.#FG17
36, 2A5, 27, 77
Counter Wire
B
1000
Message Register
.0001
10^5 to 2.5(10^5)
25000
.25
C
Counter
R
+
-
F
R2
R
+
Message Register
C
-
D
Input
885 (Tube A)
1.5(10^5)
1.5(10^5)
885 (Tube B)
+B
.0002
.0005
9v
.0005
Volume Regulator
3000
3000
3000
-B
3000
Mil. Ammeter
3000
5000-10000
+1.5v
G

IV


Input
C4
R4
V
N'
N
R5
R1'
T3
T4
R1
R5
Eb
Output
R6
C2'
R2'
T1
T2
R2
C2
Eo
A
R3'
R3
T1 = T2
= 56, 53, 79, 6N6
Rb1
Rb2
Ebb
Ebb
T1
T2
B
Tubes = 57
Esc = +90v
Esp = 0
R1 = R1' = R3 = R3' = R4 = 10^5
R2 = R2' = 2(10)^8
C2 = C2' = .00025 μf
C4 = 25 μμf
V = -7½v
N = N' = 1/10 Watt neon lamp
Counting Relay
Input
T1
C1
T2
C2
T3
T4
+
-
C
R1
C3
R2
R3
6J7 or 57
50000
Ecc1 = -½v
Ecc2 = +90v
Ecc3 = -35v
Ebb = +22½v
10^5
Ecc1
Ecc2
10^5
Ecc3
D
To counter
Input
T1
T2
T3
T4
E
100 μμf
5000
50000
100 μμf
Rc
Rc
R1
Rc
Ebb
Rc'
Ecc
To next stage
Ebb = Ecc > 45v
Tubes = 57, 6C6,
or 6J7
Rc = Rc' = R1 = 250,000
F
-
+
50000
4(10)^5
30000
20000
50000
10^5
80-120v
All tubes 6C5
All cond. 25 μμf
G

V