UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PRELIMINARY REPORT

ON

FIELD MEASUREMENT OF RADIOACTIVITY

by

Frank W. Stead

May 1945

Trace Elements Investigations -- Report No. 13

Contents

Illustrations

Appendix
(at end of report)

Preliminary report on field measurement of radioactivity

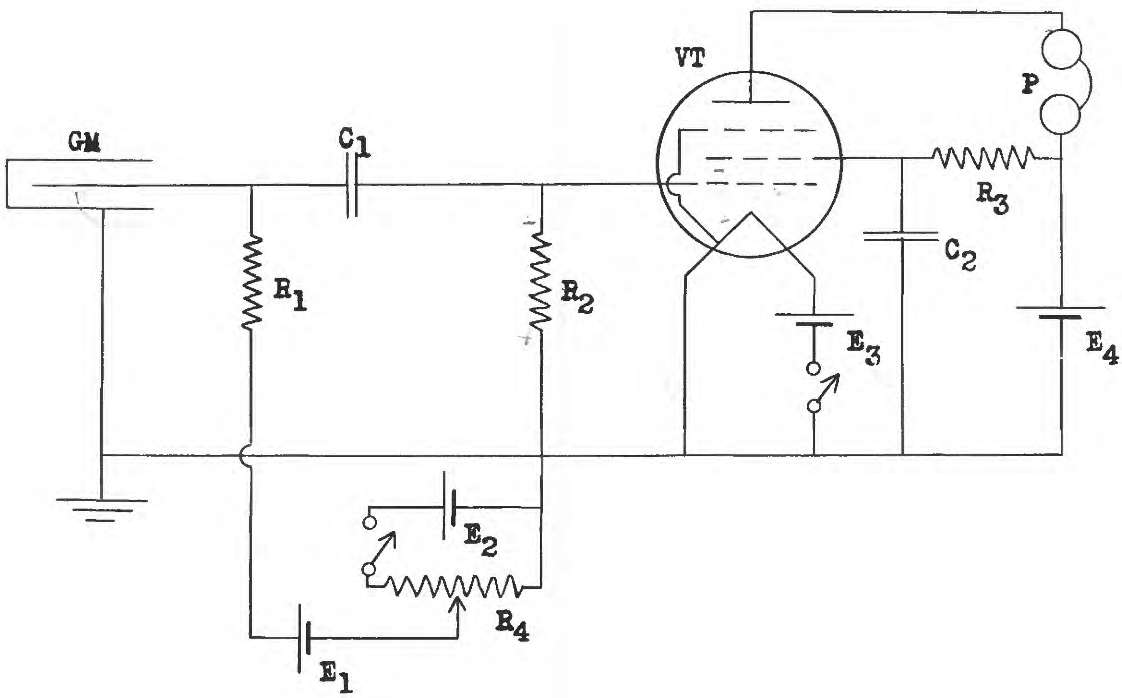
Introduction

The field measurements of radioactivity herein described are essentially screening processes to select samples for further measurements in the physics and chemistry laboratory of the Geological Survey. The arbitrary cut-off grade for this screening process is an activity equivalent to 0.005 percent of uranium in equilibrium with its disintegration products. The laboratory measurements of radioactivity will be described in a later report.

Equipment

The portable detectors used by the Geological Survey measure gamma radiations with a Geiger-Mueller counter tube, each discharge of the tube being heard as a click in earphones. Two models of detectors, originally designed by the Geophysical Instrument Company and by the Geotechnical Corporation respectively, are in service. In both models the amplifier and the battery supply are enclosed in a metal cabinet. The dimensions, weight, and circuit diagram for each model are given in figures 1 and 2. The instructions for use of the detectors are attached as Appendix I.

The Geiger-Mueller counter tubes enclosed in a cylindrical metal housing, are connected to the case by a 2-foot flexible coaxial cable. Three types of counter tubes of the self-quenching variety are in service. The first type, supplied by the Geophysical Instrument Company, has a counting rate on background of one to two counts per minute. The second type, constructed to specifications of the Geological Survey, has a counting rate on background of seven to nine counts per minute. The third type, a Herbach and Rademan No. CLC-10R,

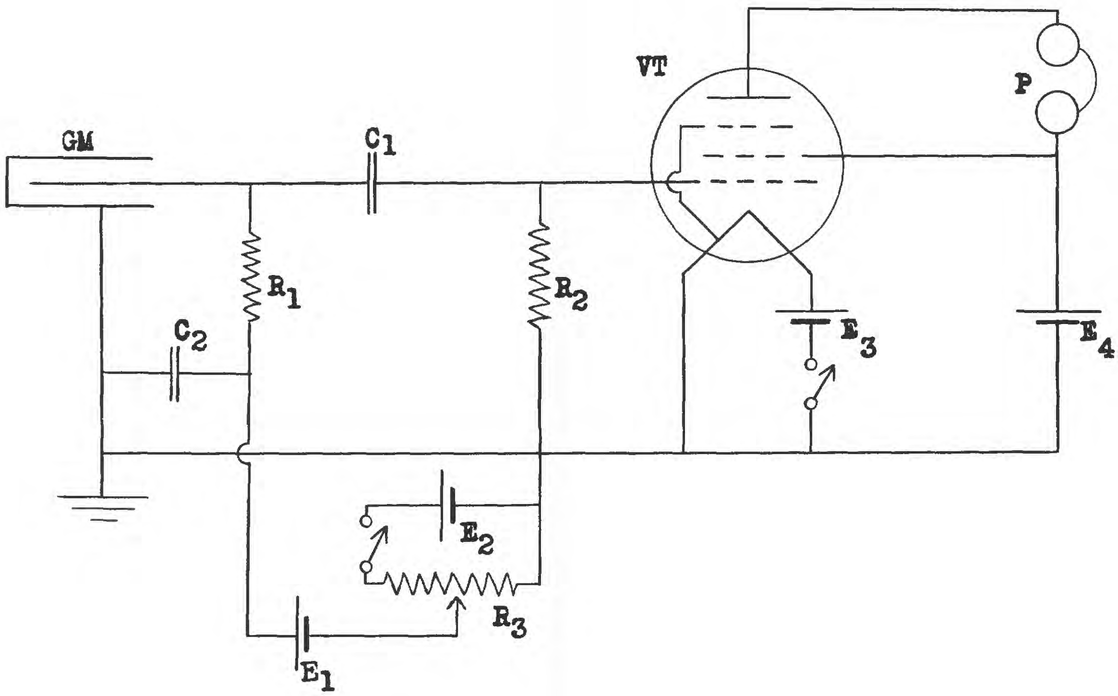


C_1	- .0001 mfd	E_1	- 810 volts (12 No. 467 Eveready)
C_2	- .005 mfd	E_2	- 67 1/2 volts (No. 467 Eveready)
R_1	- 10 megohms	E_3	- 1 1/2 volts (No. 742 Eveready)
R_2	- 1 megohm	E_4	- 67 1/2 volts (No. 467 Eveready)
R_3	- 50,000 ohms	P	- Earphones 2,000 ohms
R_4	- 1 megohm	GM	- Geiger-Mueller tube
VT	- No. 1D8GT		

Dimensions: 7 X 9 X 9½ in.

Weight: 18 pounds.

Figure 1. Circuit diagram of portable detector, Series G.
(Original design by Geophysical Instrument Company.)



C_1 - .0003 mfd	E_3 - 1 1/2 volts (No. 742 Eveready)
C_2 - .001 mfd	E_4 - 45 volts (No. 738 Eveready)
VT - No. 1T4	R_1 - 20 megohms
P - Earphones 2,000 ohms	R_2 - 1 megohm
E_1 - 945 volts (14 No. 467 Ever'dy)	R_3 - 1 megohm
E_2 - 67 1/2 volts (No. 467 Ever'dy)	GM - Geiger-Mueller tube

Dimensions: $4\frac{1}{2}$ X $9\frac{1}{2}$ X $9\frac{1}{2}$ in.

Weight: 18 pounds

Figure 2. Circuit diagram of portable detector, Series GS. (Original design by Geotechnical Corporation)

has a counting rate on background of nine to eleven counts per minute. As some of the tubes are markedly sensitive to light, the foregoing counting rates on background are for tubes enclosed in cylindrical metal housings.

Annular sample containers, designed to fit snugly around the housing of the counter tube, hold a volume of approximately 450 cc. of crushed sample for the field laboratory measurement of radioactivity. The sample containers are made either of brass or of vinylite plastic.

Procedure

Counter tubes always exhibit a natural counting rate, termed background, which is due in part to cosmic rays and the secondary rays they produce and in part to gamma radiations from the immediate environment. Thus, the average background for a particular area must be established by counting for a definite time, usually 5-minute periods, at several stations throughout the area. A counting rate greater than the average background can then be assumed to indicate the proximity of material more highly radioactive than normal for that area.

The portable detector is used in two distinct ways: a) in the field, for qualitative measurement on outcrops and in mines; b) in the field laboratory, for rough quantitative measurement on crushed samples.

Field: The detector as used on outcrops and in mines indicates only that at certain stations the observed counting rate is greater than expected from background. This method of use is essentially qualitative and does not yield a quantitative value. In practice, the detector is carried across the outcrop or through the mine with the counter tube clamped to the side of the case. Where for any reason a counting rate greater than background is suspected, the detector is placed on the ground so that a 5-minute measurement of the activity can be made. If this measurement indicates sufficient activity, samples are taken for further measurement in the field laboratory. Additional 5-minute measurements are also made at regularly-spaced stations when traversing an outcrop or mine, regardless of whether or not a counting rate greater than background is observed. Such stations serve the twofold purpose of checking the background as a norm for further measurement and of checking an above-average counting rate which might not be observed while the detector is being carried. Field data on the background counting rate in different areas are now sufficiently comprehensive so that the possibility of missing a locality of high radioactivity is small.

Field laboratory: The detector as used on crushed samples in the field laboratory yields an approximate quantitative value in terms of equivalent uranium content. The counting procedures used by Geological Survey field parties have differed considerably dependent in large part upon the particular counter tube in service. No rigid procedure is followed but the essential steps in field laboratory measurements may be summarized as follows:

1. Rock sample is crushed to pass a 4-mesh screen.
2. Crushed sample is quartered to approximately 450-cc. charge for filling the annular sample container.
3. Activities of the background, the sample, and the field standard are measured by counting for 5-minute periods in the following order: (a) background, (b) sample, (c) field standard, (d) sample, (e) background.

   Note: In determining the effective background, a container filled with anhydrous sodium sulphate known to have a very low radioactivity is used so that the mass of material shielding the counter tube from the natural background activity is approximately the same for all measurements.

4. Activities of the background, the sample, and the field standard are expressed as counts per minute by dividing the total counts by the number of minutes for that particular determination.

5. Counts per minute of the sample are converted to an equivalent uranium content by the following equations:

   (a) c/m sample - c/m background = net c/m sample

   (b) c/m field standard - c/m background = net c/m field standard

   (c) $\frac{\text{net c/m sample}}{\text{net c/m field standard}} = \frac{\text{equivalent U content sample}}{\text{U content field standard}}$

   Where: c/m is the average counts per minute obtained from measurements for 5 or more minutes.

   Note: It is assumed that the net counts per minute of a sample are due entirely to the activity of uranium and the disintegration products with which it is in equilibrium. In the Geological Survey laboratories further measurements, both chemical and physical, indicate the contribution to the total activity of a sample made by some of the individual radioactive elements in the uranium, thorium, and potassium series.

Accuracy of measurements

The field laboratory measurements of radioactivity have variability due to random causes and to assignable causes. As long as the variability in the measurements is due only to random causes, the measurements will follow the laws of chance associated with the causes. When an assignable cause of variability enters the system, it will superimpose an additional variation upon the chance variation, thereby causing measurements to exceed the probable limits.

The variability in field measurements due to assignable causes may be attributed to instrumental fluctuations and to the physical state of the samples.

Instrumental fluctuations causing a change in the counting rate of the counter tube are due to temperature and voltage variations which cannot be completely eliminated in portable equipment. The physical state of the samples also modifies the counting rate of the counter tube because the degree of crushing affects both the retention of radioactive gases (radon, actinon, and thoron) and the degree of compaction in the sample container. Inasmuch as the values of equivalent uranium calculated from the counts per minute are predicated upon the presence of uranium in radioactive equilibrium with its disintegration products, the loss of radioactive gases from a sample would give an erroneously low value of the equivalent uranium content. Even though containers are filled to the same volume, the effective density may vary between samples, background blank sample, and field standard sample. This density is a function of the intrinsic density of the rock itself, the size distribution of the ground sample, and the degree of compaction of constituent particles. Where the effective density (mass/bulk volume) of a sample exceeds that of the field standard sample, the value obtained by the comparison of the respective activities will be too high unless corrected for the mass difference; similarly, a sample of less effective density than the field standard will have too low a value unless corrected for mass difference.

In view of the variability due to assignable causes, a rigorous statistical comparison of the field laboratory measurements with the controlled measurements of the physics laboratory is not warranted. A simple comparison of the two sets of measurements totalling roughly 300 pairs of observations shows that the field laboratory measurements are on the average of the same order of magnitude as the physics laboratory measurements, and that only a relatively small number of the individual field laboratory measurements depart from the correspending physics laboratory measurements by more than one half the value of the physics laboratory measurements. This comparison between the field and physics laboratory measurements is deemed sufficiently good to warrant the assumption that samples with a radioactive content much above the out-off value will not be discarded in the field.

APPENDIX I.

INSTRUCTIONS FOR PORTABLE DETECTOR, SERIES GS

Construction

The portable detector consists essentially of a Geiger-Mueller counter tube, its associated amplifier, and a pair of earphones. The counter tube is mounted inside the brass housing and is connected by the coaxial cable and associated fittings to the metal cabinet containing the batteries and the amplifier. All controls for the amplifier and high voltage supply are mounted on the front panel of the cabinet. The amplifier tube is mounted in a socket on the rear of the front panel and is reached by removing the right panel of the cabinet (when facing the control panel).

Operation (see cut-a-way diagram of detector)

Remove the right panel of the cabinet. Insert the 1T4 amplifier tube in the socket. Connect the potentiometer lead from the right panel switch to the positive terminal of the potentiometer battery. Replace the right panel of the cabinet. CAUTION: DO NOT USE LONG SCREWS WHERE SUCH SCREWS MIGHT PENETRATE BATTERY INSULATION. SHORT SCREWS ARE PROVIDED FOR SCREW HOLES AGAINST WHICH BATTERIES ARE TIGHTLY PACKED.

Remove left panel of the cabinet. Connect the high voltage lead from the left hand panel switch to the positive end of the high voltage series of batteries. CAUTION: DO NOT TOUCH ANY PART OF THE CABINET WHILE CONNECTING HIGH VOLTAGE LEAD TO BATTERIES. Replace the left panel of the cabinet.

Throw both switches to ON position. Turn volume control, the bottom center knob on the front panel, to the maximum position in the clockwise direction. When the earphone plug is inserted and withdrawn from the phone jack, the amplifier should respond immediately by giving a sharp click in the earphones. If this does not happen, check the amplifier tube, the "A" and "B" batteries, and the earphones.

Turn potentiometer, the center knob on the front panel immediately below the meter, to the minimum position in the counter-clockwise direction. Attach counter tube to the fitting on the end of the cable. When active material is brought near the counter tube, clicks should immediately be heard in the earphones. If the amplifier operates satisfactorily but no clicks are heard with active material near the counter tube, increase the voltage by means of the potentiometer until clicks are heard. When full increase of the potentiometer does not provide sufficient voltage, the potentiometer should be turned to the minimum (counter-clockwise) and the spare battery in the high voltage set connected to the series. (Notes: When received, only 13 of the 14 batteries will be connected in series; one battery is provided as a means of increasing the high voltage supply.) Further adjustment of the potentiometer can then be made until the proper operating voltage for the counter tube is obtained.

Batteries

The amplifier requires one 1½ volt "A" battery such as Eveready No. 742 or its equivalent and one 45 volt "B" battery such as Eveready No. 738 or its equivalent. A new "A" battery should give 200-250 hours of service at 4 hours per day. A new "B" battery should give 150-180 hours of service at 4 hours per day. An "A" battery below 1.2 volts should be replaced; a "B" battery below 38 volts should be replaced.

The high voltage for the counter tube is obtained chiefly from a set of fourteen 67½ volt batteries connected in series. As the drain on the high voltage batteries is very small, the service life will be practically the shelf life of the batteries and replacement may not be necessary for about one year.

The $67\frac{1}{2}$ volt potentiometer battery is connected in series with the potentiometer. This battery should have a service life approximating the shelf life of the battery.

The meter which reads 100 volts for full scale deflection has both terminals mounted on the front panel. The red pin jack is positive; the black pin jack is negative. The negative test lead is provided with a clamp so that a firm connection can be made to the negative terminal of the 45 or $67\frac{1}{2}$ volt battery to be tested. The positive test lead should be pressed against the positive terminal of the battery being tested for no more than the time necessary to obtain a meter reading. Voltage measurements should be made no more than is necessary. CAUTION: THE METER IS DESIGNED FOR A MAXIMUM OF 100 VOLTS. DO NOT ATTEMPT TO TEST MORE THAN ONE $67\frac{1}{2}$ VOLT BATTERY.

<u>High voltage</u>

High voltage is used to actuate the Geiger-Mueller counter tube, the total voltage of all batteries being a maximum of 1,000 volts. A protective resistor has been inserted about every 250 volts of batteries to limit the current on accidental short circuits. This will reduce any harmful effects from accidentally touching the high voltage leads or from accidentally short-circuiting them. Nevertheless, caution should be used whenever the panels are removed to avoid touching the high voltage leads or having any of the battery leads come in contact with anything which might cause a short circuit. Whenever it becomes necessary to replace batteries, the protective resistors should be replaced in the same position in order to secure the proper protective effect.

Counter tubes

Two general types of Geiger-Mueller counter tubes may be distinguished: one type which requires an external circuit to extinguish a discharge and a second type, usually containing an organic gas, which is "self-quenching," i.e., the discharge in the tube is in large part extinguished internally. All counter tubes used by the Geological Survey are of the "self-quenching" type.

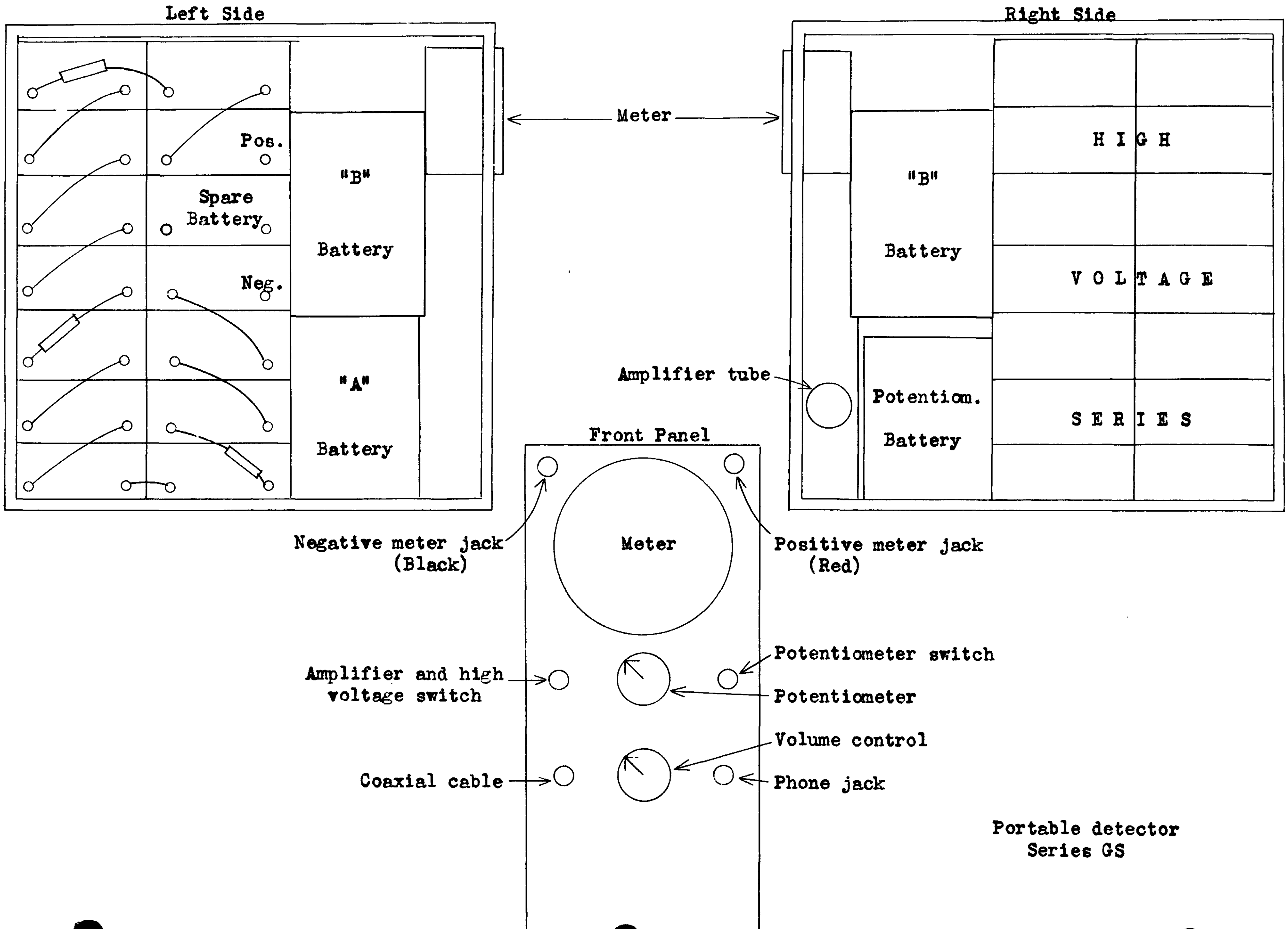
A counter tube is essentially a sealed tube containing a gas or mixture of gases at a very low pressure, a cylindrical cathode, and an electrode centrally located with respect to the cathode. A high potential difference (voltage) is maintained between the cathode and electrode: the cathode being negative and the electrode positive. This applied voltage is such that any ionization within the cathode-electrode volume of the tube (sensitive portion) due to radiations from an external active source will cause an electrical discharge or current flow between the cathode and the electrode. Such a current flow can be amplified and recorded by an appropriate circuit. In the portable detectors this current flow in the counter tube is amplified and recorded as a click in earphones.

A minimum potential difference must be applied to a counter tube before a current flow will be initiated by ionization within the sensitive portion of the tube. This minimum potential is commonly termed the starting potential of the tube. As the potential difference between the cathode and the electrode is gradually increased, the current flow initiated by ionization increases in proportion to the amount of original ionization until a potential difference is reached where any amount of ionization will cause a current flow (or pulse in the amplifier) of uniform size. The range of potential difference over which the current flow or pulse is of uniform size and is not proportional to the amount of original ionization is termed the Geiger-Muller or plateau region of tube. The counter tubes supplied with the portable detectors should always be operated within this region which can be recognized by the equal-volume clicks in the earphones. The range of potential difference for the plateau region of the counter tubes supplied with the detectors varies with individual tubes but should exceed 67½ volts, the maximum voltage adjustment of the potentiometer. As the potential difference is increased beyond the plateau region, the current flow no longer is of uniform size due partly to self-excitation, i.e., a discharge or current flow is initiated internally without ionization caused by the entrance of radiations from an external active source. Further increase in potential will finally result in a steady, self-maintained current or continuous discharge between the cathode and the electrode. Continuous discharge almost invariably will destroy the usefulness of a counter tube. Care should be exercised to prevent a counter tube from going into continuous discharge.

Laboratory testing of the counter tubes supplied with the detectors shows that: 1) the starting potential is roughly 880 volts; 2) the plateau region starts at roughly 910 volts and extends to 1080 volts; 3) continuous discharge is not probable at less than 1100 volts. Testing also shows that the background counting rate when the tube is in the brass housing and surrounded by the background blank sample ranges from 6 to 14 counts per minute (average counting rate for 5 minutes or more), the counting rate increasing with the applied voltage over the voltage range of the plateau region. For the particular field standard sample supplied to the field parties, the applied voltage should be adjusted so that the average background counting rate is roughly 7 counts per minute. At this voltage the field standard sample should give roughly 40 counts per minute.

30

80



Portable detector
Series GS