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ORNL 332

PHYSICS-INSTRUMENTATION

HEALTH PHYSICS DIVISION

INSTRUMENT MANUAL

BY

D.M. DAVIS

OAK RIDGE NATIONAL LABORATORY

OPERATED BY
CARBIDE AND CARBON CHEMICALS CORPORATION
FOR THE
ATOMIC ENERGY COMMISSION
POST OFFICE BOX P
OAK RIDGE, TENNESSEE

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ORNL-332
Physics-Instrumentation

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PREFACE

The purpose of this manual is to give the apprentice surveyor a working knowledge of the types of radiation encountered at Oak Ridge National Laboratory, tolerances for different types of radiation, instruments used to measure the various types of radiation, brief calibration procedures, what the instruments are designed to do, some of the common malfunctions of the instruments, and methods used in counting air and smear samples. It does not purport to give complete definitions, descriptions, and diagrams, and for such the reader should consult the proper authorities.

It is not the purpose of this manual to endorse any specific type of instrument for radiation survey work.

Grateful acknowledgement is made to F. A. Markli for his assistance on circuits and descriptions of operation of instruments; to J. T. Sutherland for the procedure for processing air and smear samples; and to G. C. Warlick for his work with photographs.

The writer wishes to thank R. S. Thackeray and his staff for editing and proofing this manual.

OUTLINE OF CONTENTS

This manual is concerned with the types of portable survey instruments used at Oak Ridge National Laboratory and what they are designed to do. However, before presenting the instruments, we would like to discuss briefly the types of radiation with which we are concerned, some of the terms involved, and the tolerances for the different types of radiation.

I. Types of Radiation with which we are mainly concerned.

A. Alpha

Alpha rays are particles that carry positive charges and have been identified as the nuclei of helium atoms, or two protons and two neutrons hold together extremely tightly. The alpha particle has a mass four times that of the hydrogen atom and a charge equal to but electrically opposite that of two electrons. Alpha particles may have velocities ranging from nearly 0 to the order of 2×10^9 cm per sec. As they move through air they produce ionization by knocking electrons out of atoms. Each successive collision reduces the speed of the particle until it is no longer able to produce ions.[1] Alpha particles have definite ranges, the range depending upon the energy of the particle. For example, in air under normal conditions, an alpha particle of 0.2 Mev has a range of 0.17 cm. An alpha particle with an energy of 5.0 Mev has a range of 3.48 cm.[2]

B. Beta

Beta rays are particles that carry negative charges, and are in reality high speed electrons. They have velocities ranging up to 0.99 that of light. Beta rays are much more penetrating than alpha particles. More than the alpha particle, the beta particle (due to its lighter mass) deviates from its path with each collision.[1] Beta particles are emitted from a given isotope with energies ranging continuously from near 0 to a maximum energy characteristic of the isotope. There is a fairly definite path length associated with each energy of beta ray. Since most of the paths are not straight and only a few rays are emitted with the maximum energy, very few particles will reach the theoretical maximum range for the source in question. As the beta particle slows down, more ionization is produced per unit path length until it reaches a point at which it is no longer capable of producing ionization. In air, under normal conditions, a beta particle of maximum energy 0.2 Mev has a range of 37 cm. A beta particle of maximum energy 2.0 Mev has a range of 840 cm. in air, under normal conditions.[2]

C. Gamma

Gamma rays are electromagnetic radiations of the same character as x-rays but extend to much higher frequencies.[1] The frequency of the gamma rays is so high that they are best understood by considering them as quanta of energy. The gamma ray (a ray of quanta) has three types of interaction with matter which makes its detection relatively simple.[3] The three types of interaction are:

1. Photoelectric effect - the quantum transfers all of its energy to an electron of an atom, detaches it completely, and gives the electron kinetic energy equal the energy of the quantum less the binding energy of the electron in the atom.(3) The ionization produced by the photoelectron is detectable.
2. Compton effect - when the quantum of energy collides with an electron it will project the electron in the general direction of the quantum according to the ordinary rules of impact, and deflect a new quantum of lower energy. In this way the recoil electron can acquire enough energy to ionize and be detected.
3. Pair production - the gamma quantum is transformed into a pair of particles, the particles having the same mass but opposite charges (electron, positron). It is the ionization caused by these particles that may be measured. (See Atomic Physics by Semat for discussion of pair production). Pair production accounts for only a small part of the energy loss of low energy (none below 1.2 Mev) gamma rays.

A beam of gamma rays loses intensity exponentially along its path and so is not considered to have a limit or range. However, one frequently considers its half-thickness which is the thickness of the medium required to reduce the intensity to one-half.

D. Neutron

The neutron is an uncharged particle with a mass slightly greater than that of a proton - atomic weight 1.0089. The fast neutron does not produce primary ionization but may be detected when it collides with nuclei and imparts energy to them. These moving nuclei, provided they have sufficient energy, secondarily produce ionization which is detectable. A fast neutron may give up one-half (this is the average) its energy to a hydrogen nucleus, giving rise to a proton whose range will measure the energy of the original neutron. Slow neutrons may cause nuclear reactions which give rise to fast moving protons, alpha particles, or gamma rays. These secondary radiations can then be measured in the appropriate way and this data will furnish considerable information about the slow neutron flux. A beam of neutrons loses energy exponentially along its path and so is not considered to have a limit to its range. As with the gamma ray, the half range is frequently used. Neutrons are grouped into three categories according to their energy. These are: slow neutrons 1/40 ev - 10 ev; medium, 10 ev - 0.5 mev; fast neutrons, 0.5 mev - up.

II. Inverse Square Law

Since a point source emits gamma rays equally in all directions, frequent use is made of the inverse square law. The law, neglecting absorption, is that the radiation at any distance from the source is inversely proportional to the square of the distance from the source. For example, if a gamma source produces a radiation of 10 mr/hr at 4 feet, at one foot there would be an intensity of 160 mr/hr.

II. Inverse Square Law (cont'd)

Problem: A gamma source reads 40 mr/hr at 8 feet. What should be the intensity at 2 feet?

Solution: $40 : x :: 2^2 : 8^2$

$4x = 2560$

$x = 640$ mr/hr intensity at 2 feet.

In taking measurements with an instrument, such as the Cutie Pie, it should be noted that the effective center of the chamber is not always the same as the geometrical center of the chamber. The effective center is somewhere between the central electrode and the outside of the chamber nearest the source. This effect is insignificant unless the source is within several chamber diameters distance.

III. Some Terms Commonly Used in Radiation Survey Work

A. Curie

The curie was originally defined as the amount of radon in equilibrium with one gram of radium. Since it is difficult to isolate a given mass of radium or radon, and since the term has been applied to elements other than radon, a more practical definition of the curie has been established. This definition states that a curie is that amount of substance which gives a rate of 3.7×10^{10} disintegrations of a given kind per second.

B. Roentgen

The roentgen is the quantity of X or gamma radiation such that the associated corpuscular emission (secondary electron radiation) per 0.001293 grams of air produces, in air, ions carrying one esu of quantity of electricity of either sign.(4)

III. Some Terms Commonly Used in Radiation Survey Work (cont'd)

C. Rep

The rep (roentgen equivalent physical) may be defined as the dose of radiation which will result in the dissipation of 83 ergs per gram of tissue.(4)

D. Rem

The rem (roentgen equivalent man) is that amount of radiation which will produce the same damage to man as a roentgen of X or gamma radiation.

IV. Tolerance (Maximum Permissible Exposure)

The tolerance levels established at Oak Ridge National Laboratory are as follows:(5)

Type Radiation	Roentgens	Rem	Rep
X-ray	0.1	0.1	0.1
Gamma	0.1	0.1	0.1
Beta		0.1	0.1
Fast Neutron		0.1	0.02
Thermal Neutron		0.1	0.02 to 0.1
Alpha*		0.1	0.01

*NOTE: Alpha considered from standpoint of internal effects only. The maximum permissible level for alpha emitters in the atmosphere has been tentatively set at 3×10^{-11} μc/cc. The maximum permissible level for beta-gamma (without mask) is considered to be the level equivalent to 10^{-8} μc/cc of air. The tolerances given are the maximum permissible and each individual should strive to keep his exposure to a minimum.

V. Radium Standards

Radium, in equilibrium with its short-lived decay products, is used as a standard in the calibration of portable survey instruments at Oak Ridge National Laboratory. The sources used at present are enclosed in one mm of platinum. To determine the strength of the source the following equation is used:

$$S = 8.98 (1 - 0.13 t) M, \text{ where}$$

S is the source strength, measured in roentgens per hour at one cm,
t is the thickness of the platinum filter, measured in mm, and
M is the mass of radium, measured in milligrams.

For one mm of platinum filter (6)

$$S = 7.8 M.$$

VI. Detection of Radioactive Materials

The following is a list of the portable survey instruments used at present at Oak Ridge National Laboratory and the type of radiation each will measure or detect.

Cutie Pie - measures beta and gamma.

Zeus - measures alpha, beta, and gamma.

Zeuto - measures alpha.

Fish Pole Probe - measures beta-gamma of high intensities.

Lauritsen Electroscope - measures beta and gamma.

Landsverk Electroscope - measures alpha, beta and gamma.

Walkie Squawkie - detects beta and gamma.

Walkie Talkie - detects beta and gamma.

Walkie Poppy - detects alpha.

Victoreen 263 - detects and measures beta and gamma of low intensities.

Beckman - measures beta and gamma.

VI. Detection of Radioactive Materials (cont'd)

Boron Coated Electroscope - measures thermal neutrons.

Chang and Eng - measures fast neutrons.

NOTE: The measurements for alpha and beta are for ionization current only. None of the portable instruments will give us values of alpha and beta in rep/hr.

References

1. Physics - Hausmann - Slack
2. Lecture III - Units and Instruments for Measuring Radiation - K. Z. Morgan
3. Applied Nuclear Physics - Pollard and Davidson
4. Lecture VII - Health Physics - K. Z. Morgan
5. Health Physics and You - (Health Physics Handbook)
6. Data on Radium Sources - F. Western

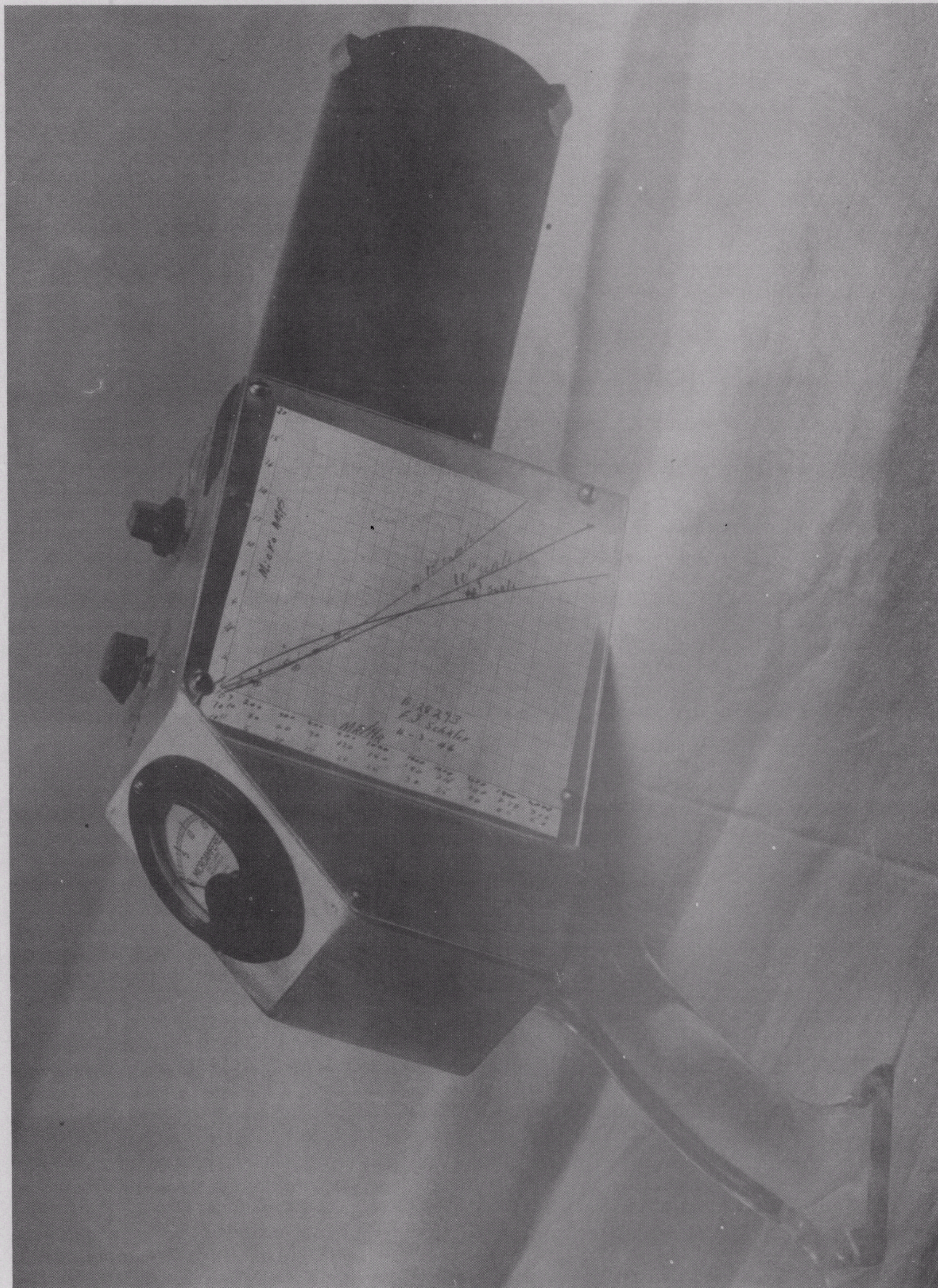
PORTABLE SURVEY INSTRUMENTS - CALIBRATION AND USE

1. Cutie Pie
2. Fish Pole Probe
3. Zeus (α, β, γ survey meter)
4. Zeuto (α survey meter)
5. Beckman
6. Lauritsen Electroscope
7. Landsverk Electroscope
8. Walkie Talkie
9. Walkie Squawkie
10. Victoreen 263
11. Walkie Poppy
12. Chang and Eng
13. Proteximeter

Even the casual reader will notice the oddity of names for many of the above instruments. There is no technical significance attached to these names. During the early period of the atomic energy program, meaningless names were given to the instruments for security reasons. Although the instruments are no longer classified, they still are known by their original names.

CUTIE PIE

The Cutie Pie is a small, lightweight, portable, gamma measuring, beta indicating, survey instrument with an ionization chamber coupled to a balanced bridge circuit utilizing an electrometer tube (VX32) as one arm of the bridge. The radiation through the chamber causes an ionization current to flow through several high value resistances. By means of a selector switch, the voltage drop across one of these is applied to the grid of an electrometer tube, unbalancing the bridge and thusly producing a current in a micro-ammeter.


Micro AMPS
MICROAMPERES

CUTIE PIE

I. Use of Instrument

A. What the instrument is designed to do.

1. Measure, within 10%, hard gamma radiation (no beta present) between the intensities of ~5 mr/hr and ~10 r/hr.

2. Measure the ionization current due to soft gamma and/or beta radiation. In general, the accuracy of the beta ionization measurement will increase as the energy level of the betas increases.

NOTE: The purpose of the "open window" reading is to determine whether or not beta radiation is present.

B. What the instrument is not designed to do.

1. Accurately measure radiations of intensities < 5 mr/hr or > 10 r/hr.

2. Measure rep's of beta radiation. (Different instruments will show a wide variation in beta sensitivity.)

3. Measure alpha radiation.

C. Factors affecting proper use and interpretation.

1. Proper warm-up time. (30 sec.)

2. Proper zero setting.

3. Proper distance of instrument from source.

4. Type of radiation being measured.

5. Low sensitivity to orientation.

II. Calibration

A. Sources - 27.03 mg Ra source
700 mc Co source

B. Calibration cycle - three weeks

C. Pre-calibration check list

1. Check for radioactive contamination.

2. Check dial functions.

3. Check batteries.

4. Check for other possible faults.

II. Calibration (cont'd)

D. Procedure

1. Zero on "zero set" and do not zero on any of the sensitivity positions.

2. Set on 10^9 position, which is least sensitive, and proceed toward source, starting at the 100 mr/hr position. Record mr/hr and microampere data for range of scale.

3. Set on 10^{10} position, starting at the 5 mr/hr position and proceed as above.

4. Set on 10^{11} position, starting at the 5 mr/hr position and proceed as above.

E. Salient Factors

1. Turn instrument on five minutes before calibration to allow plenty of "warm-up" time.

2. Plot <u>at least</u> three points on each of the sensitivity positions.

3. Always calibrate with instrument oriented to give the maximum reading.

SOME POSSIBLE MALFUNCTIONS OF THE CUTIE PIE WITH PROBABLE CAUSES

1. Will not zero

   Causes:

   a. $7\frac{1}{2}$ V. batteries do not have same voltage.

   b. Resistors on both sides of zero potentiometer not balanced.

   c. $22\frac{1}{2}$ V. battery down.

   d. Filament battery down.

2. Needle fluctuates

   Causes:

   a. Insulator in back of ionization chamber dusty or dirty.

   b. A bad connection anywhere.

   c. A high value resistor open.

   d. Resistor dirty or tube dirty.

   e. Burned wax.

3. Reads off scale

   Causes:

   a. Stud mounting ion chamber grounded to case.

   b. Corroded or dirty connection.

   c. One of resistors bad.

   d. Bad switch on potentiometer.

4. Will not zero on sensitivity scales.

   Causes:

   a. High value resistors bad.

CUTIE PIE (CONT'D)

b. Tube base may be bad.

c. Dirty insulator at end of ion chamber.

5. Needle goes below zero

Cause:

a. Tube burned out.

6. Indicates reading when no radiation is present

Causes:

a. Contamination of instrument.

b. Light getting into chamber.

c. Mechanical balance of meter.

7. Reading is less than known radiation.

Causes:

a. Instrument grounded at wrong place.

b. Chamber and box giving signals of opposite polarities.

c. Needle on meter sticks.

8. Change of zero set in changing position of instrument from horizontal to verticle

Cause:

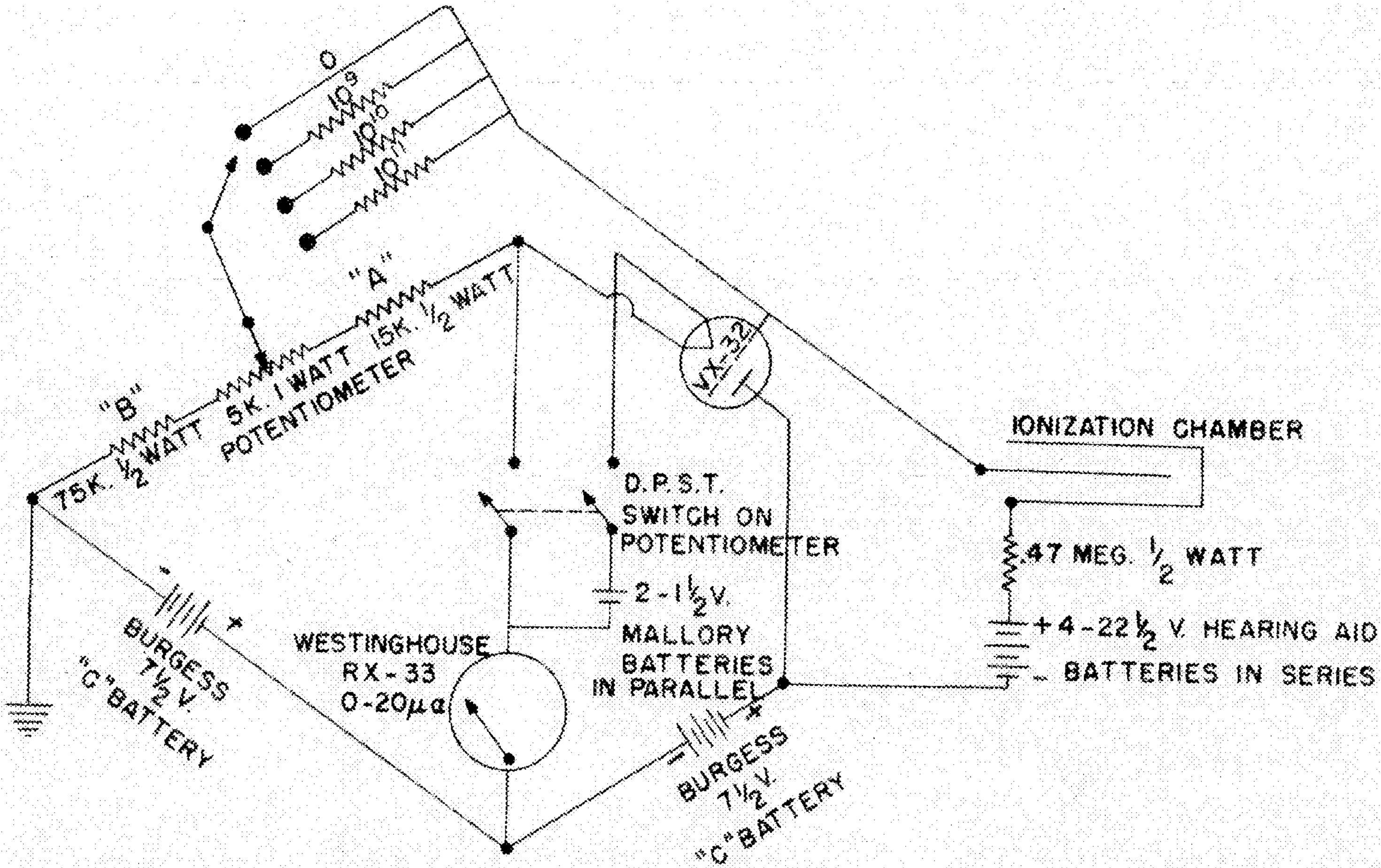
a. Mechanical balance of meter.

9. Needle drifting

Cause:

a. Batteries getting low.

The Cutie Pie is convenient to use to obtain the relative magnitude of radiation. It is not as accurate as the Electroscope under normal conditions.

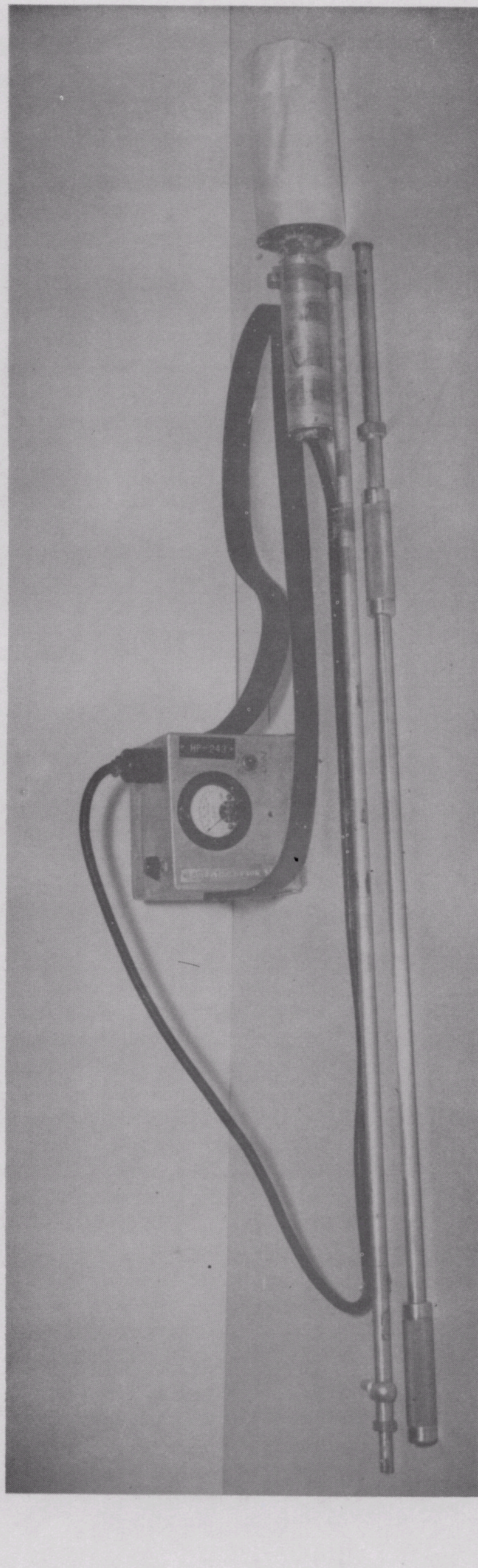


NOTE: VALUES OF RESISTORS "A" & "B" VARY WITH INDIVIDUAL CIRCUITS AND MAY HAVE TO BE CHANGED WHEN INSTRUMENT IS TESTED.

WIRING DIAGRAM

FISH POLE PROBE

The Fish Pole Probe is similar to the Cutie Pie, except that the Fish Pole Probe has the chamber at the end of a pole, or rod, and reads much higher intensities than does the Cutie Pie.



FISH POLE PROBE

I. Use of Instrument

A. What the instrument is designed to do.

1. Measure, in order of magnitude, hard gamma radiation between 5 r/hr and 20 to 100 r/hr depending on sensitivity of instrument used.

2. Measure ionization current due to soft gamma and/or beta radiation.

B. What the instrument is not designed to do.

1. Accurately measure radiations of intensities less than 5 r/hr.

2. Measure rep/hr of beta radiation.

3. Measure alpha radiation.

C. Factors affecting proper use and interpretation.

1. Proper warm-up time. (30 seconds)

2. Proper zero setting.

3. Proper distance of instrument from source.

4. Type of radiation being measured. This instrument does not have a window to help differentiate between beta and gamma radiation.

5. Low sensitivity to orientation.

II. Calibration

A. Source - 2 g Ra source.

B. Calibration cycle - three weeks.

C. Pre-calibration check list.

1. Check for radioactive contamination.

2. Check batteries.

3. Check dial functions.

4. Check cord connections.

5. Check for any other discrepancies.

D. Procedure

1. Zero outside of any field of radiation. Instrument has only one sensitivity position.

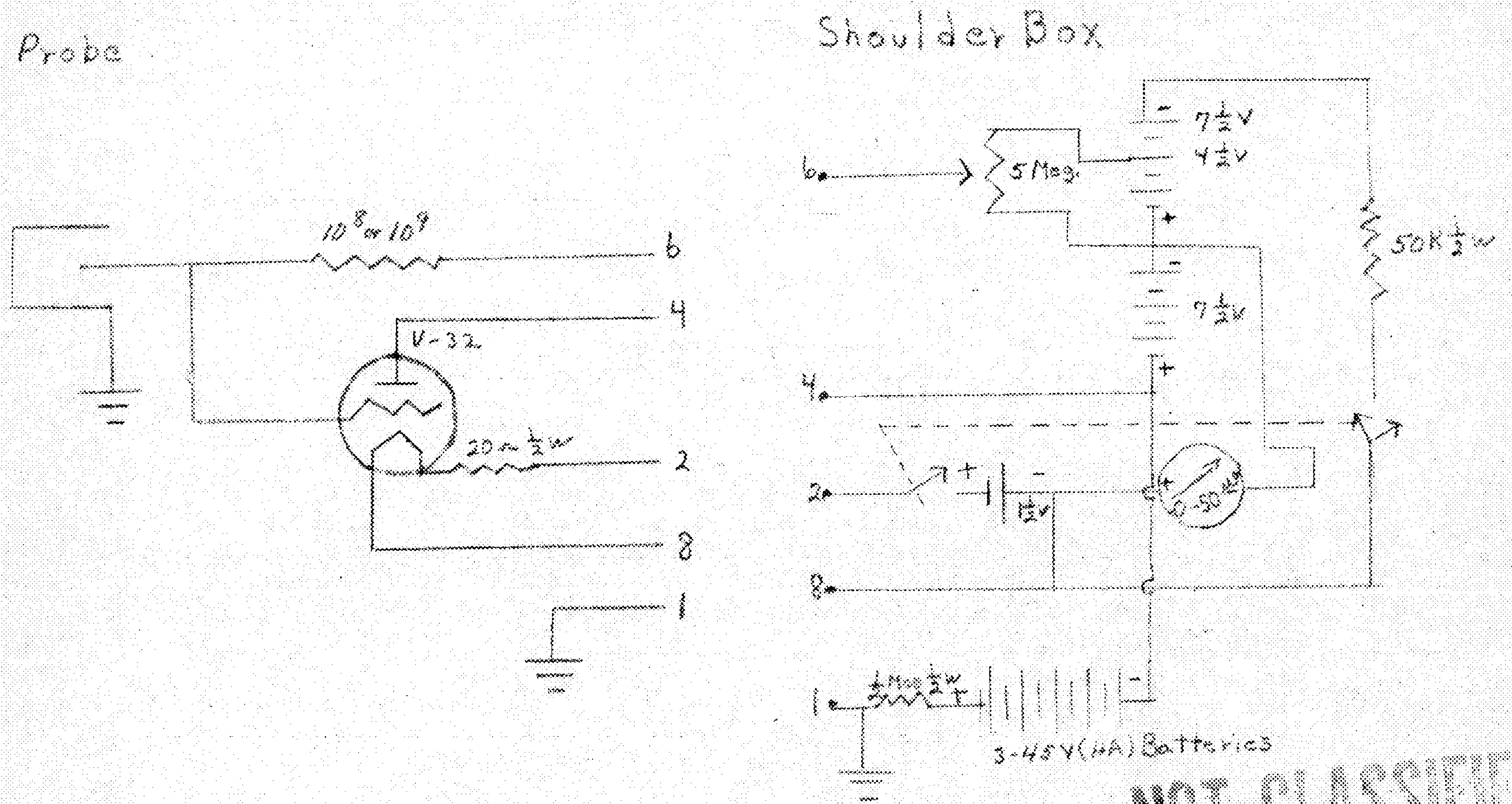
2. Start at the 5 r/hr position and proceed toward the radium source until an "off-scale" reading is obtained.

E. Salient Factors

1. Turn instrument on five minutes before calibration to allow plenty of "warm-up" time.

2. Plot at least three points on the graph.

3. Always calibrate with instrument oriented to give the maximum reading.



NOT CLASSIFIED

INSTRUMENT SHOP - BLDG 717B
CLINTON LABORATORIES

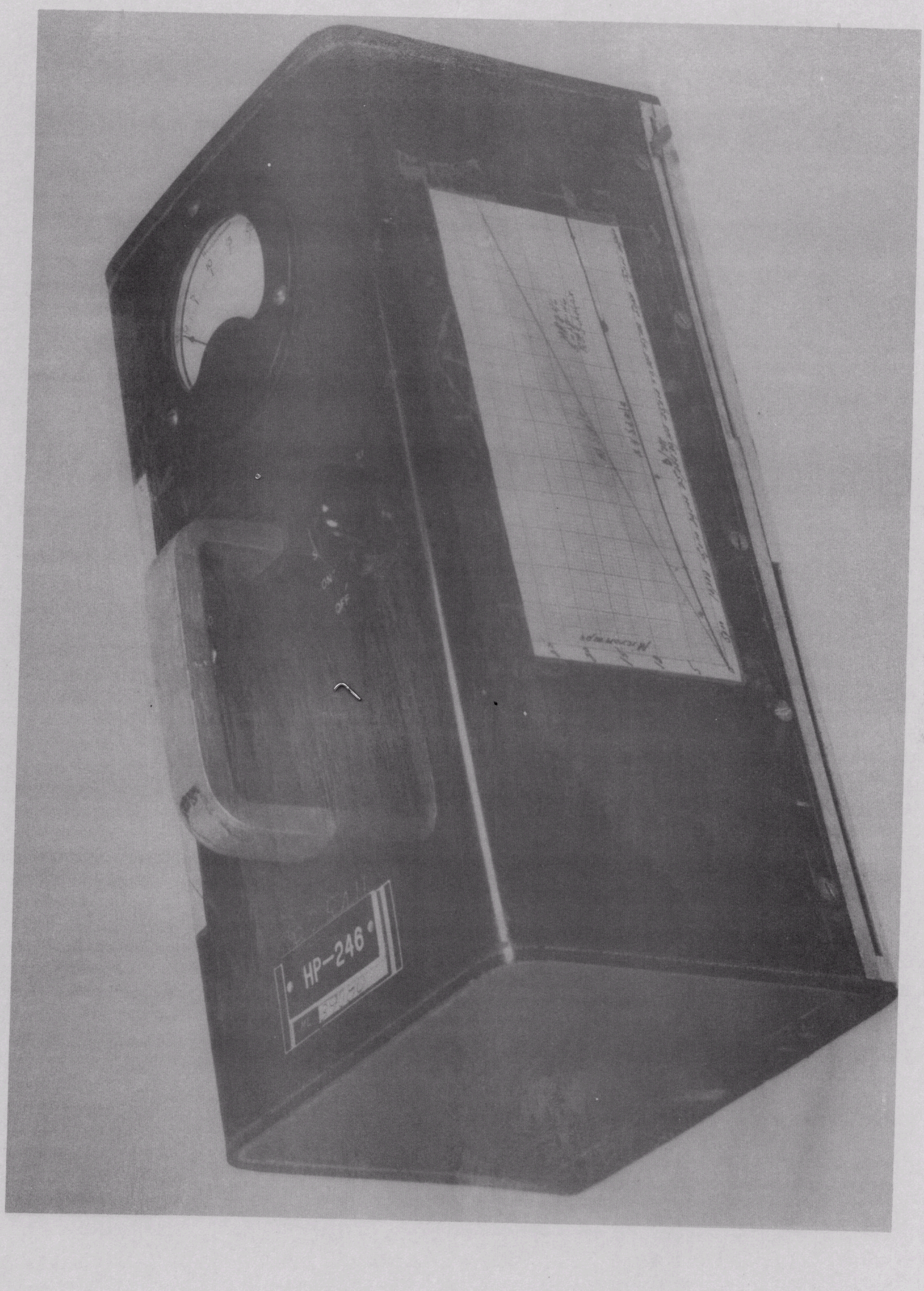
Revised Fish Pole

SCALE: None	DATE: 7/18/45
CH'K'D / D'WN	APP'D
SKETCH NO Q	BLDG. NO 717-B

RETURN TO
717-B FILES

ZEUS

The Zeus is a medium sized lightweight portable survey instrument utilizing an ionization chamber with a thin nylon diaphragm forming one side of the chamber. The ionization chamber is coupled to a grid of one or two electrometer tubes (CK 570 AX) forming two arms of a bridge. Radiation entering the chamber causes an ionization current to flow through one of several high value resistors, the voltage drop across which causes an unbalance in the bridge which is indicated on the microammeter. The instrument is equipped with a plastic shield over the window for filtering out beta radiation and a thin aluminum screen for screening out alpha radiation.


HP-246
ON
OFF

I. Use of Instrument

A. What the instrument is designed to do.

1. Measure, within 10%, hard gamma radiation between the intensities of 5 mr/hr and ~2 r/hr.

2. Measure ionization current due to soft gamma and/or beta radiation. (Reading for beta and soft gamma made with plastic window open.)

3. Measure ionization current due to alpha radiation. (Reading for alpha made with both windows open.)

B. What the instrument is not designed to do.

1. Measure radiations accurately of intensities less than 5 mr/hr or greater than ~2,000 mr/hr.

2. Measure mreps of beta radiation. Different instruments will show wide variation in beta sensitivity.

C. Factors affecting proper use and interpretation.

1. Proper warm-up time. (30 seconds)

2. Proper zero setting.

3. Proper distance of instrument from source.

4. Type of radiation being measured.

5. Proper position of windows for each type measurement.

II. Calibration

A. Sources - 27.03 mg Ra source
700 mc Co
Alpha Sources

1. 4,000 d/m	4. 42,128 d/m
2. 13,180 d/m	5. 85,000 d/m
3. 22,306 d/m	6. 169,000 d/m

B. Calibration cycle - three weeks

C. Pre-calibration check

1. Check for contamination.

2. Check batteries.

3. Check dial functions.

4. Check for any other discrepancies.

D. Procedure

1. For gamma - Ra and Co sources

a. Zero on "zero set" and do not zero on any of the sensitivity positions.

b. Set on X100 position, which is least sensitive, and proceed toward source, starting at the 100 mr/hr position.

c. Set on X4, the next sensitive position, and proceed toward radium source, starting at the 5 mr/hr position.

d. Set on X1, the most sensitive position, and proceed toward radium source, starting at the 5 mr/hr position.

2. For alpha - Alpha sources

a. Zero on "zero set" and do not zero on any of the sensitivity scales.

b. Set on X1 scale and read in succession the above alpha sources.

c. Set on X4 and read in succession the above alpha sources.

E. Salient Factors

1. Turn instrument on five minutes prior to calibration to allow plenty of warm-up time.

E. Salient Factors (cont'd)

2. Plot at least 3 points on each of the sensitivity positions.

3. Always calibrate with instrument oriented to give the maximum reading.

4. Take gamma readings with both windows closed.

III. References

A. MDDC-118

SOME POSSIBLE MALFUNCTIONS OF THE ZEUS

WITH PROBABLE CAUSES

1. Will not zero

   Causes:

   a. Battery is down - 13½ volt potential between grid of one tube and plate of another.

   b. Dirt on high value resistor.

   c. Dust on switch deck in tube housing box.

   d. Contamination of instrument.

2. Needle fluctuates

   Causes:

   a. Open high value resistor.

   b. Dust or dirt on insulator.

3. Reads off scale

   Causes:

   a. Tube burned out.

   b. Battery shorted.

   c. Possible high contamination.

4. Zero on "zero set" but not on sensitivity scales

   Causes:

   a. Low battery.

   b. High value resistor bad.

   c. Insulator bad.

5. Readings less than known radiation

   Causes:

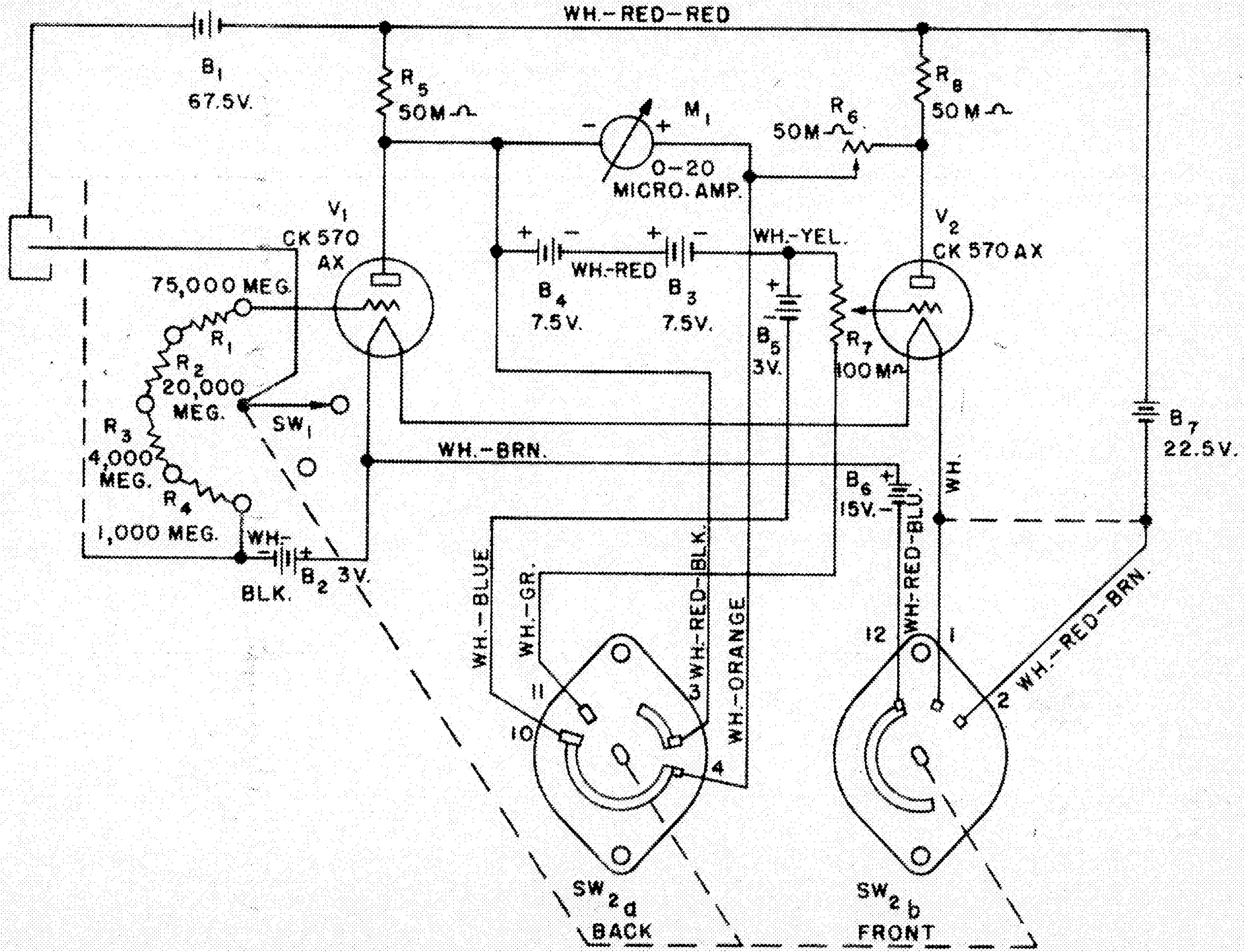
   a. Bad tubes.

   b. Battery low.

6. Will not move off zero

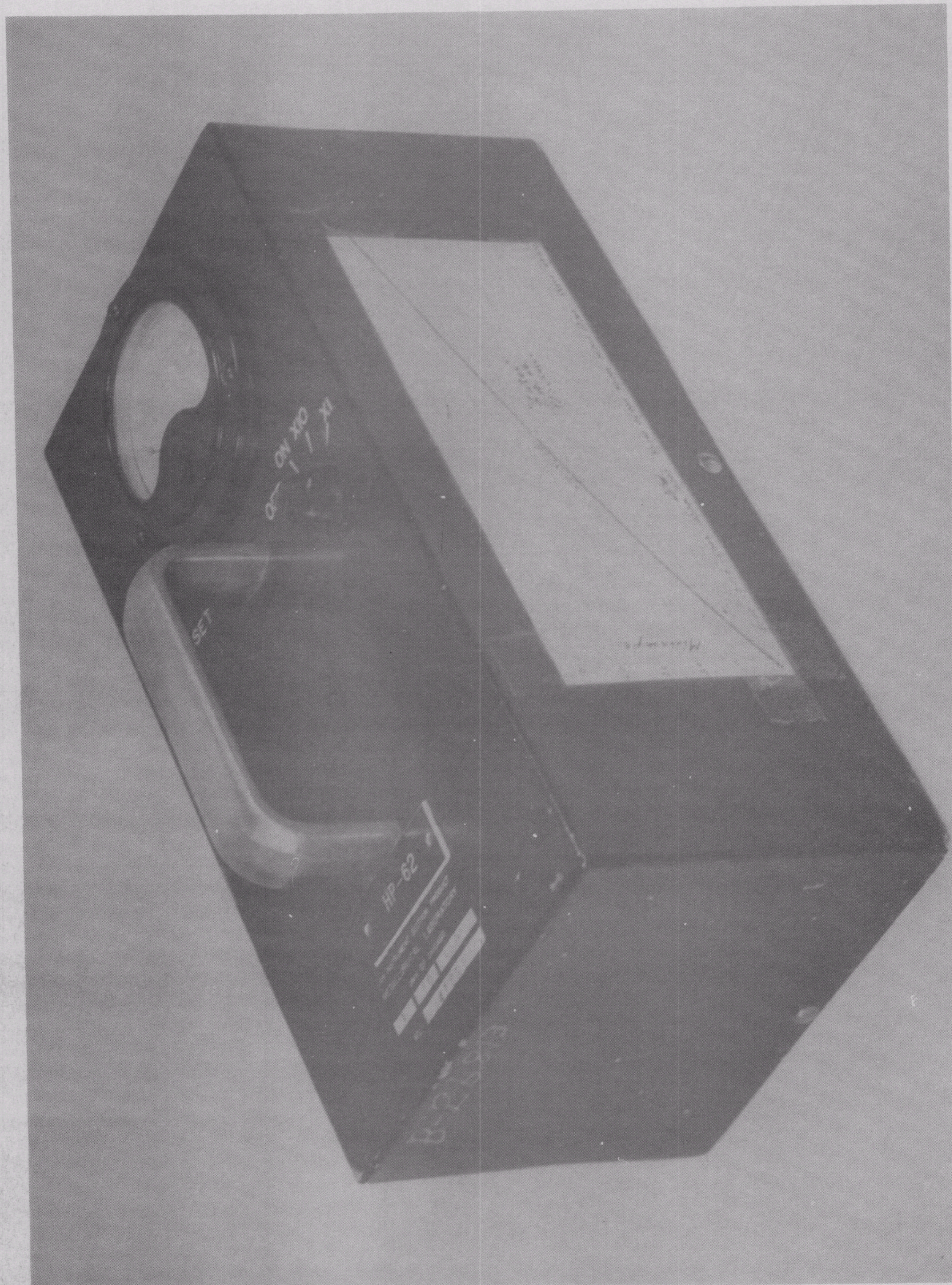
Cause:

a. Both tubes are bad.


WH.–RED–RED
B1
67.5V.
R5
50M Ω
M1
0–20
MICRO. AMP.
R6
50M Ω
R8
50M Ω
V1
CK 570
AX
V2
CK 570 AX
75,000 MEG.
R1
R2
20,000
MEG.
R3
4,000
MEG.
R4
1,000 MEG.
SW1
WH.–RED
B4
7.5V.
B3
7.5V.
WH.–YEL.
B5
3V.
R7
100M Ω
WH.–BRN.
B6
15V.
B7
22.5V.
WH.
WH.–
BLK.
B2
3V.
WH.–BLUE
WH.–GR.
WH.–RED–BLK.
WH.–ORANGE
WH.–RED–BLU.
WH.–RED–BRN.
11
10
3
4
12
1
2
SW2a
BACK
SW2b
FRONT

ZEUTO

The Zeuto is essentially the same type instrument as the Zeus. The Zeus is calibrated for alpha and gamma; the Zeuto is calibrated for alpha only.


HP-62
SET
OFF
ON
X10
X1

ZEUTO

I. Use of Instrument

A. What the instrument is designed to do.

1. Measure ionization current due to alpha radiation.

2. Give readings which are reproducible within 10%.

B. What the instrument is not designed to do.

1. Measure beta and gamma radiation. The instrument will give readings in presence of beta or gamma radiation but this is an undesirable feature. It is not calibrated for these measurements.

2. Measure accurately alpha emitters below ~300 d/m or greater than 80,000 d/m.

C. Factors affecting proper use and interpretation.

1. Proper warm-up time. (90 seconds)

2. Proper zero setting.

3. Proper distance from source being measured.

4. Type of radiation being measured.

5. Distribution of active material being measured.

II. Calibration

A. Sources - alpha emitters

1. 4,000 d/m

2. 13,180 d/m

3. 22,306 d/m

4. 42,128 d/m

5. 85,000 d/m

6. 169,000 d/m

B. Calibration cycle - three weeks

C. Pre-calibration check

1. Check for contamination.

2. Check batteries.

3. Check dial functions.

4. Check for any other discrepancies.

D. Procedure

1. Zero on "on" position, and do not zero on sensitivity positions.

2. Set on X1 position and read in succession the above alpha sources.

3. Set on X4 position and read in succession the above alpha sources.

E. Salient Factors

1. Turn instrument on five minutes prior to calibration to allow plenty of "warm-up" time.

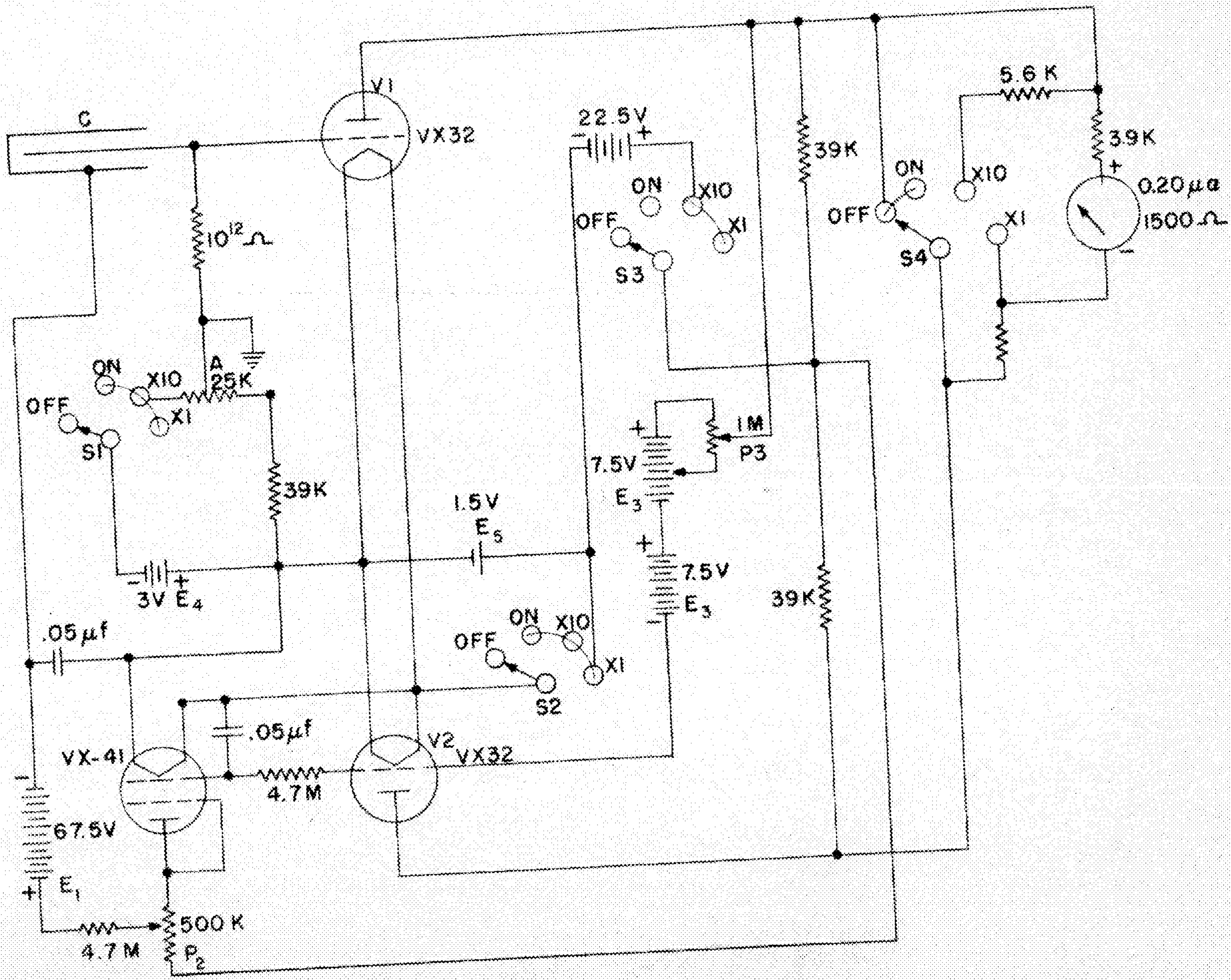
2. Plot at least three points on each of the sensitivity positions.

3. Always take readings with minimum distance between instrument and source.

III. References

A. MDDC - 117

The circuit of the Zeuto is very similar to that of the Zeus. Common malfunctions are observable. The Zeuto has only two ranges: X^1 (0 to 8,000 d/m), X^{10} (0 to 80,000 d/m).



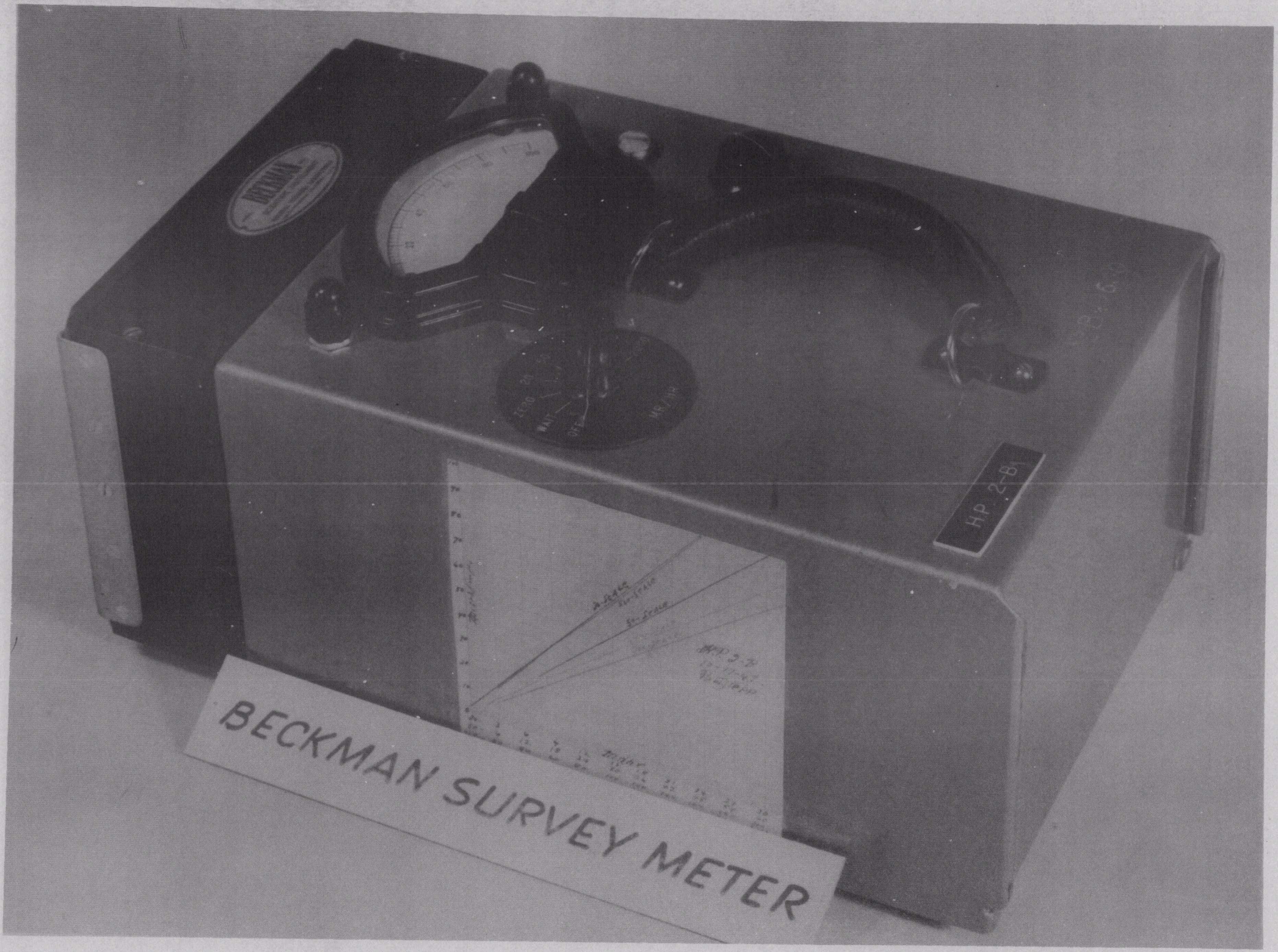
SCHEMATIC

MODEL 356 PORTABLE ALPHA METER

SER. NOS. 121 & UP

BECKMAN SURVEY METER

The circuit and operation of the Beckman Survey Meter is similar to the Zeus. The Beckman is not calibrated for alpha radiation.


HP 2-B1
BECKMAN SURVEY METER

BECKMAN SURVEY METER

I. Use of Instrument

A. What the instrument is designed to do.

1. Measure, within 3%, hard gamma radiation between the intensities of less than 1 mr/hr and 2,000 mr/hr.

2. Measure ionization current due to soft gamma and/or beta radiation.

NOTE: Provides window to aid in determining type of radiation being measured.

B. What the instrument is not designed to do.

1. Measure radiations of intensities greater than 2,000 mr/hr.

2. It is not calibrated to measure rep/hr of beta radiation and different instruments will show wide variation in beta sensitivity.

3. Measure alpha radiation.

C. Factors affecting proper use and interpretation.

1. Proper warm-up time. (30 seconds)

2. Proper zero setting.

3. Proper distance of instrument from source.

4. Type of radiation being measured.

II. Calibration

A. Sources - 27.03 mg Ra source
700 mc Co

B. Calibration cycle - 3 weeks.

C. Pre-calibration check.

1. Check for contamination.

2. Check batteries.

C. Pre-calibration check (cont'd)

3. Check dial functions.

4. Check for any other discrepancies.

D. Procedure

1. Turn selector switch to "wait" for 20 seconds.

2. Turn selector switch to zero and adjust needle until it stands at zero.

3. Set on "2,000" position, the least sensitive, and proceed toward source, starting at 100 mr/hr position.

4. Set on "500" position, the second sensitive scale, and proceed toward radium source, starting at the 100 mr/hr position.

5. Set on "200" position, the third sensitivity scale, and proceed toward radium source, starting at the 5 mr/hr position.

6. Set on "50" position, the fourth sensitivity scale, and proceed toward radium source, starting at 5 mr/hr position.

7. Set on "20" position, the fifth sensitivity scale, and proceed toward radium source, starting at 5 mr/hr position.

E. Salient Factors

1. Turn selector switch to wait position at least one minute before calibration with source is begun.

2. Where possible, calibrate at temperature at which the instrument is to be used.

3. Allow at least 15 seconds for needle to settle before recording reading.

4. Plot at least 3 points on each of the sensitivity scales.

5. Always calibrate with instrument oriented to give the maximum reading.

III. References

A. Beckman Bulletin 177, "Instructions for Beckman Model MX-2 Radiation Meter".

BECKMAN SURVEY METER

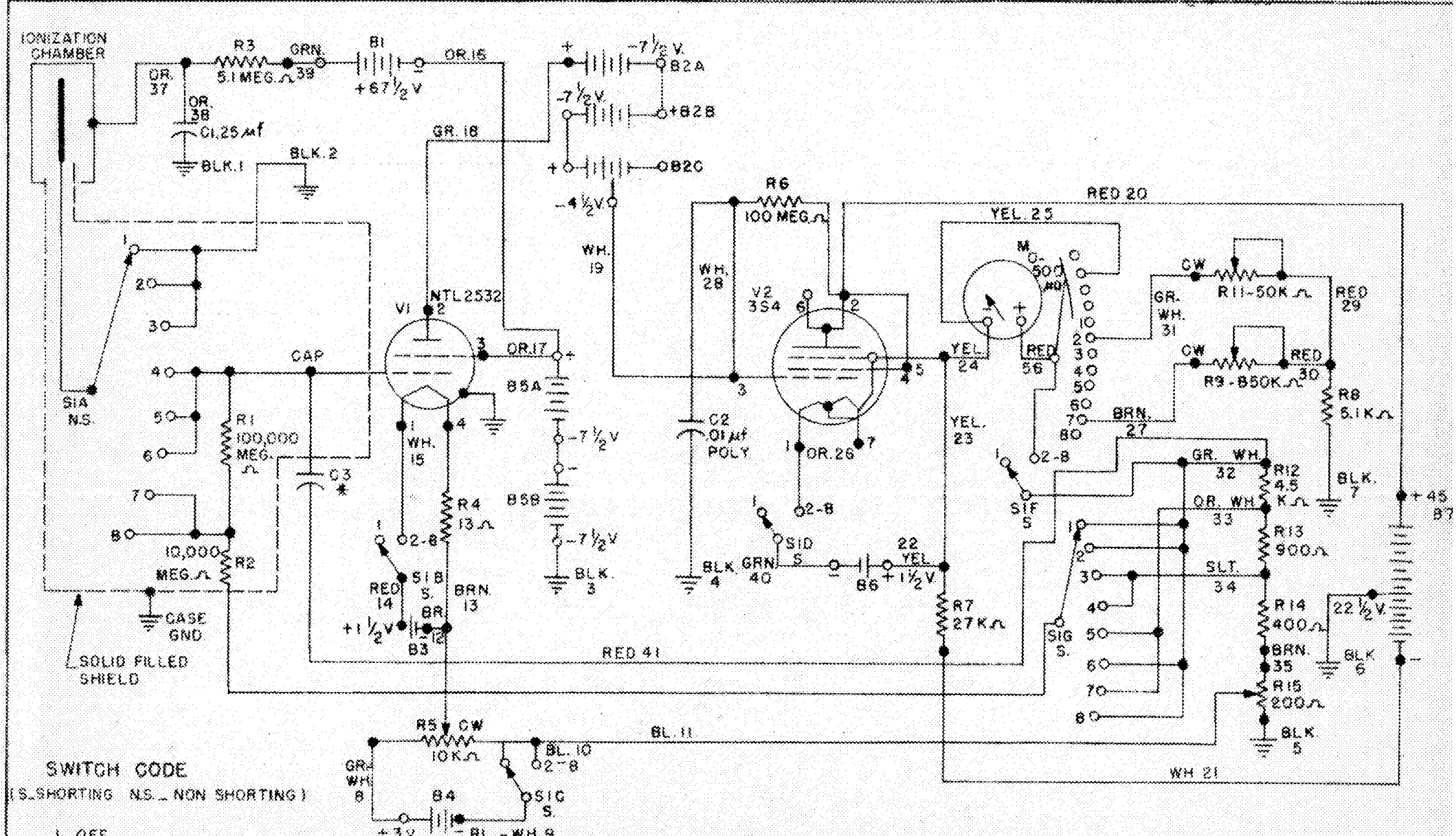
Scales:

1. 0 to 20.0 mr/hr
2. 0 to 50.0 mr/hr
3. 0 to 200.0 mr/hr
4. 0 to 1,000.0 mr/hr
5. 0 to 2,000.0 mr/hr

Instrument is similar to Zeus except not calibrated to read alpha.

NOTE: Reaction time is very slow. Allow a minimum of 30 seconds to warm up. In reading wait 15 seconds before taking reading.

UNCLASSIFIED Drawing # 2153



SWITCH CODE

(S._SHORTING N.S._NON SHORTING)

1 OFF
2 WAIT
3 ZERO
4 20
5 50
6 200 } MR/HR FULL SCALE
7 500
8 2000

NOTE-(1) SWITCH WIRING HAS TWO GR.-WH. WIRES AND TWO RED WIRES.

*(2) C3 IS A SHORT PIECE OF SHIELDING AROUND THE GRID LEAD CABLE.

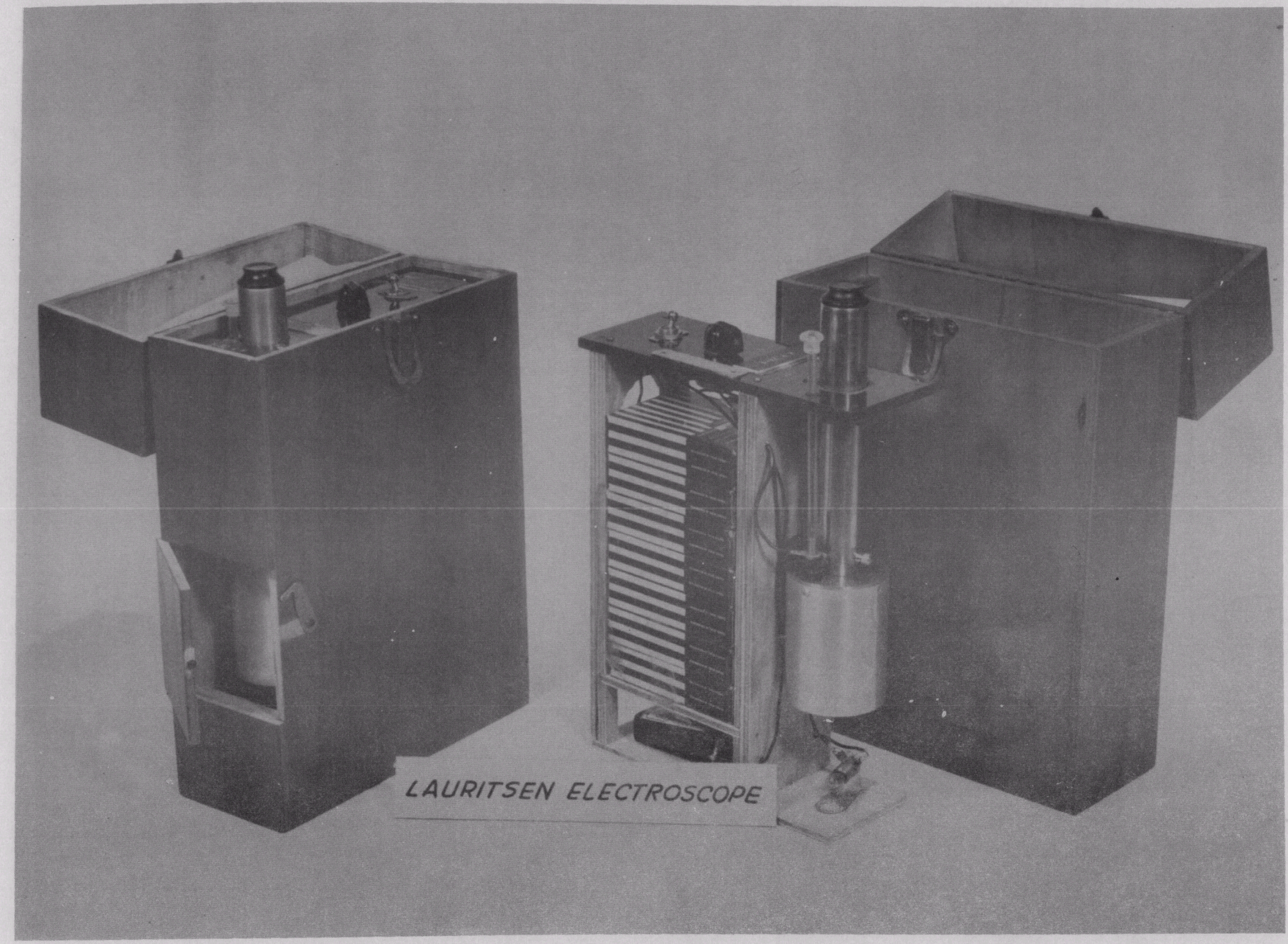
(3) POTENTIOMETER R15 IS ACCESSIBLE ONLY WITH CASE BOTTOM PLATE REMOVED.

(4) ROTOR BLADE OF SWITCH SECTION S1E COVERS 5 CONTACTS AND IS SHOWN IN POSITION 1

CIRCUIT DIAGRAM BECKMAN MODEL MX-2 RADIATION METER

ELECTROSCOPE - LAURITSEN

The Lauritsen Electroscope is a medium sized portable gamma measuring, beta indicating survey instrument. The instrument utilizes a quartz fiber, plated with a conducting material, suspended in an ionization chamber and observed through a microscope with scale mounted in the eyepiece. The fiber is charged through a battery and potentiometer after which all circuit connections are removed. The passage of radiation through the chamber discharges fiber due to ionization current and fiber tends to return to its uncharged position. The rate of return to the normal position is an indication of the intensity of the radiation. A stop watch is necessary to determine this rate of drift.


LAURITSEN ELECTROSCOPE

LAURITSEN ELECTROSCOPE

I. Use of Instrument

A. What the instrument is designed to do.

1. Measure, within less than 1%, hard gamma radiation between the intensities of less than 1 mr/hr and 1,000 mr/hr.

2. Measure ionization current due to beta radiation.

B. What the instrument is not designed to do.

1. Measure radiations of intensities greater than 1,000 mr/hr.

2. Measure beta activity in rep/hr.

3. Measure alpha activity.

C. Factors affecting proper interpretation.

1. Proper zero setting - fiber should be charged back to the zero point on the scale.

2. Proper distance of instrument from source.

3. Type of radiation being measured.

4. Use of proper portion of scale.

5. Requires no warm-up period.

6. Proper orientation of instrument to source.

II. Calibration

A. Source - 27.03 mg Ra

B. Calibration cycle - 3 weeks

C. Pre-calibration check

1. Check for contamination.

2. Check batteries.

3. Check fiber movement.

4. Check relations of fiber and scale.

5. Check background of instrument.

6. Check for any other discrepancies.

D. Procedure

1. On the 2 mr/hr position, record the time required for fiber to move from 1 to 2 on scale (10 div.).

2. On the 10 mr/hr position, record the time required for the fiber to move from 1 to 2 on the scale, and also from 1 to 6 (50 div.).

3. On the 100 mr/hr position, record the time required for the fiber to move from 1 to 2 on the scale, and also from 1 to 6.

4. On the 1,000 mr/hr position, record the time required for the fiber to move from 1 to 6 on the scale.

5. On a sheet of log-log graph paper plot the readings vs. time.

E. Salient Factors

1. Background on instrument should not exceed 10 divisions for a 30 minute period.

2. Instrument should not be moved while readings are being taken.

3. Three readings at each position should be averaged and these should not vary more than 0.4 seconds, except in the very low ranges.

4. Calibrations are made with windows closed.

5. Calibrate instrument with window toward source.

III. References

A. Information sheet, Model 1, Lauritsen Electroscope, Fred C. Henson Company.

SOME POSSIBLE MALFUNCTIONS OF THE LAURITSEN

WITH PROBABLE CAUSES

1. Scale is Dark

Causes:

a. Battery is burned out.

b. Bulb burned out.

2. Will not zero

Causes:

a. Battery is dead or weak.

b. Plating flaked off of fiber.

c. Voltage too low.

3. Fiber drifts

Causes:

a. Dirty insulator.

b. Dirty fiber.

c. Plating flaked from fiber.

d. Instrument contaminated.

4. Scale is blurred or fiber is not seen clearly

Causes:

a. Lens of electroscope not properly focused.

b. Dirty lens.

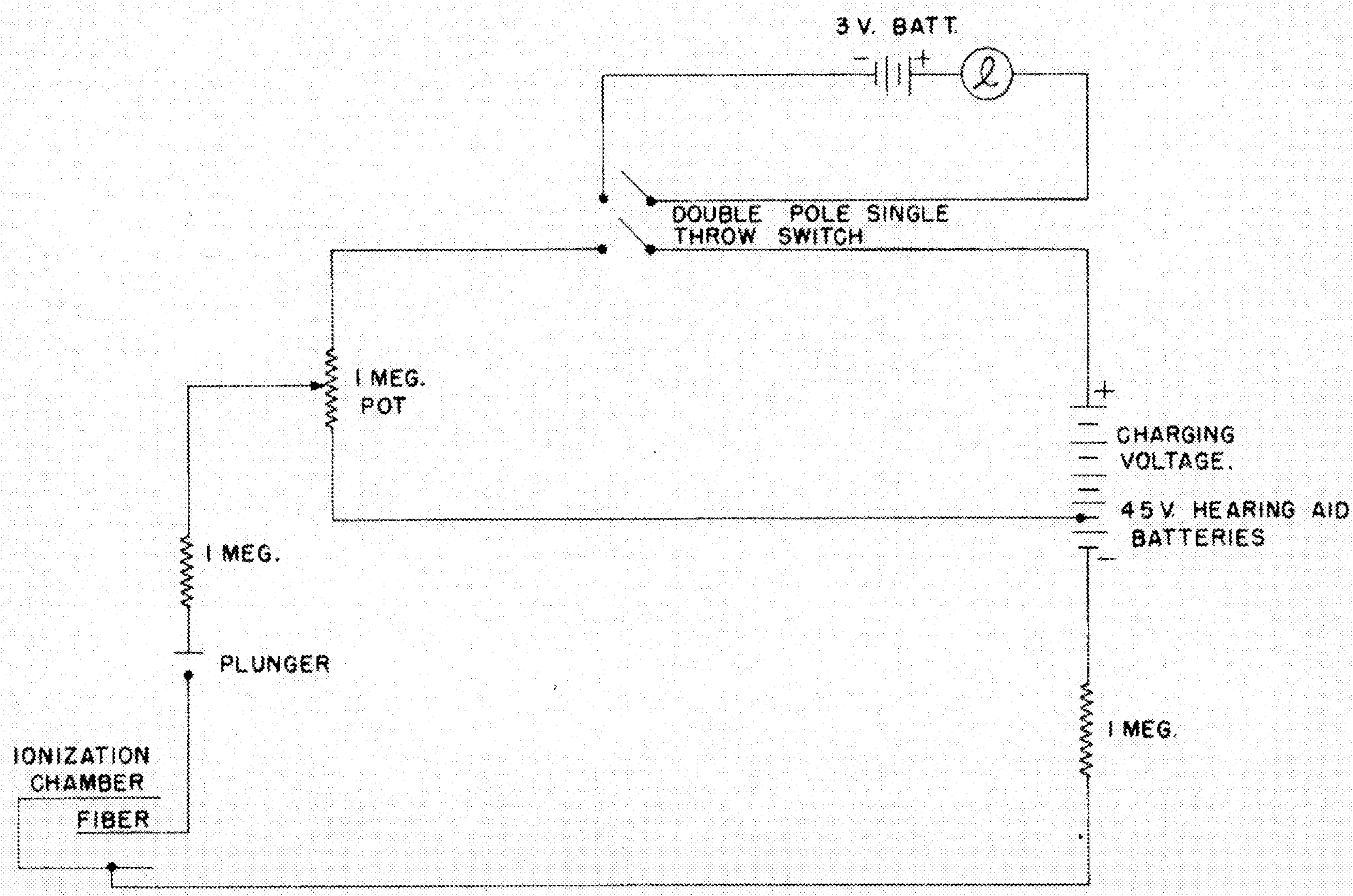
5. Fiber is off vertically

Causes:

a. Scale in electroscope has moved.

b. Small arm which holds the fiber may have slipped.

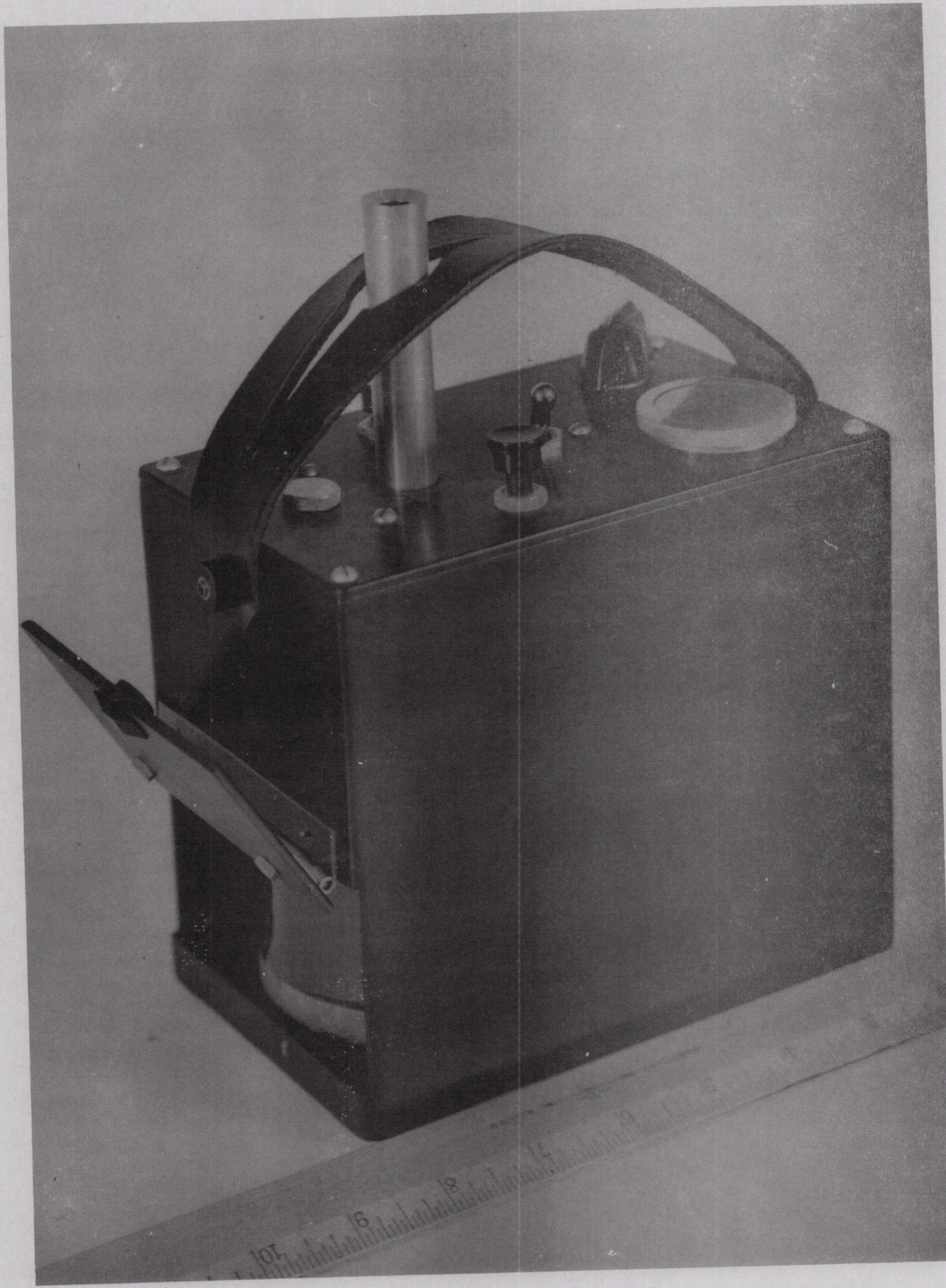
Precaution: Never remove ion chamber in the field.



LAURITSEN ELECTROSCOPE

ELECTROSCOPE - LANDSVERK

The Landsverk Electroscope is a medium sized portable gamma measuring, alpha and beta indicating survey instrument. The instrument utilizes a quartz fiber, plated with a conducting material, suspended in an ionization chamber and observed through a microscope with scale mounted in the eyepiece. The fiber is kept charged through a battery and potentiometer. When all circuit connections are removed the passage of radiation through the chamber discharges fiber due to ionization current and the fiber tends to return to its uncharged position. The rate of return to the normal position is an indication of the intensity of the radiation. The Landsverk employs an automatic flashing light timer, therefore, a stop watch is not essential.



ELECTROSCOPE, LANDSVERK

I. Use of Instrument

A. What the instrument is designed to do.

1. Measure, within less than 1%, gamma radiation between the intensities of background level and 1,000 mr/hr.

2. Measure ionization current due to beta radiation.

3. Measure ionization produced by alpha particles.

B. What the instrument is not designed to do.

1. Measure radiation of intensities greater than 1,000 mr/hr.

NOTE: Because of the great dependence of alpha and beta ray measurements on the condition under which they are made and the energy of the particles, no calibration is furnished for such measurements. If the proper calibration chart is prepared, this instrument may be used in the same manner as a Lauritsen Electroscope.

C. Factors affecting proper interpretation.

1. Proper zero setting.

2. Proper distance of instrument from source.

3. Type of radiation being measured.

4. Proper position of window for radiation being measured.

II. Calibration

A. Sources - 27.03 mg Ra source
Alpha emitters

1. 4,000 d/m
2. 13,180 d/m
3. 22,306 d/m
4. 42,128 d/m
5. 85,000 d/m
6. 169,000 d/m

B. Calibration cycle - three weeks

C. Pre-calibration check list

1. Check for contamination.

2. Check neon lamp.

3. Check fiber control and voltage release.

4. Check batteries.

5. Check for other possible faults.

D. Procedure

1. Illuminate the microscope field by pressing the toggle switch to the right.

2. Set the electrometer fiber image to zero of the microscope scale by adjusting the electrometer potential control potentiometer at the rear right side of the meter.

3. Place the instrument at the 50 mr/hr position.

4. Depress fully and hold down the electrometer release push button at right center of meter. This frees the electrometer of battery voltage and starts the automatic timer. An initial neon lamp signal flash will be observed directly over the microscope scale just as the push button is depressed. The next signal flash should occur at the instant the fiber image indicates 50 mr/hr on the microscope scale. Should the fiber fail to be at the 50 mr/hr mark on the scale, adjust timer to the desired position.

E. Salient Factors

1. This instrument requires no "warm-up" period.

2. The high range polystyrene insulated capacitor is charged only when it is in use. If it has been discharged for a period of time before use, it will not hold its voltage satisfactorily for about a minute after it has been recharged. For this reason it is good practice to depress the high range push button switch when the meter is to be used at intervals during use. This operation charges the condenser and permits it to become saturated at the operating potential of the electrometer.

III. References

A. Instructions for the L-100 Alpha-Beta-Gamma Survey Meter.

SOME POSSIBLE MALFUNCTIONS OF LANDSVERK ELECTROMETER

WITH PROBABLE CAUSES

1. Scale does not light up when switched to <u>on</u> position.

   Causes:

   a. Batteries burned out.

   b. Light burned out.

   c. Dirty contact on light circuit.

2. Neon lamp fails to flash.

   Causes:

   a. Push button switch fails to connect the charged condenser.

   b. Vacuum seal of neon lamp is broken.

   c. Neon lamp holder not properly grounded.

3. Meter gives incorrect reading.

   Causes:

   a. Atmospheric conditions.

   b. Timer out of adjustment.

4. Will not zero.

   Causes:

   a. Low voltage.

   b. Fiber stuck to electrode.

5. Fiber out of control.

   Causes:

   a. Short circuit.

   b. One of contact wires stuck.

6. Fiber moves erratically.

Causes:

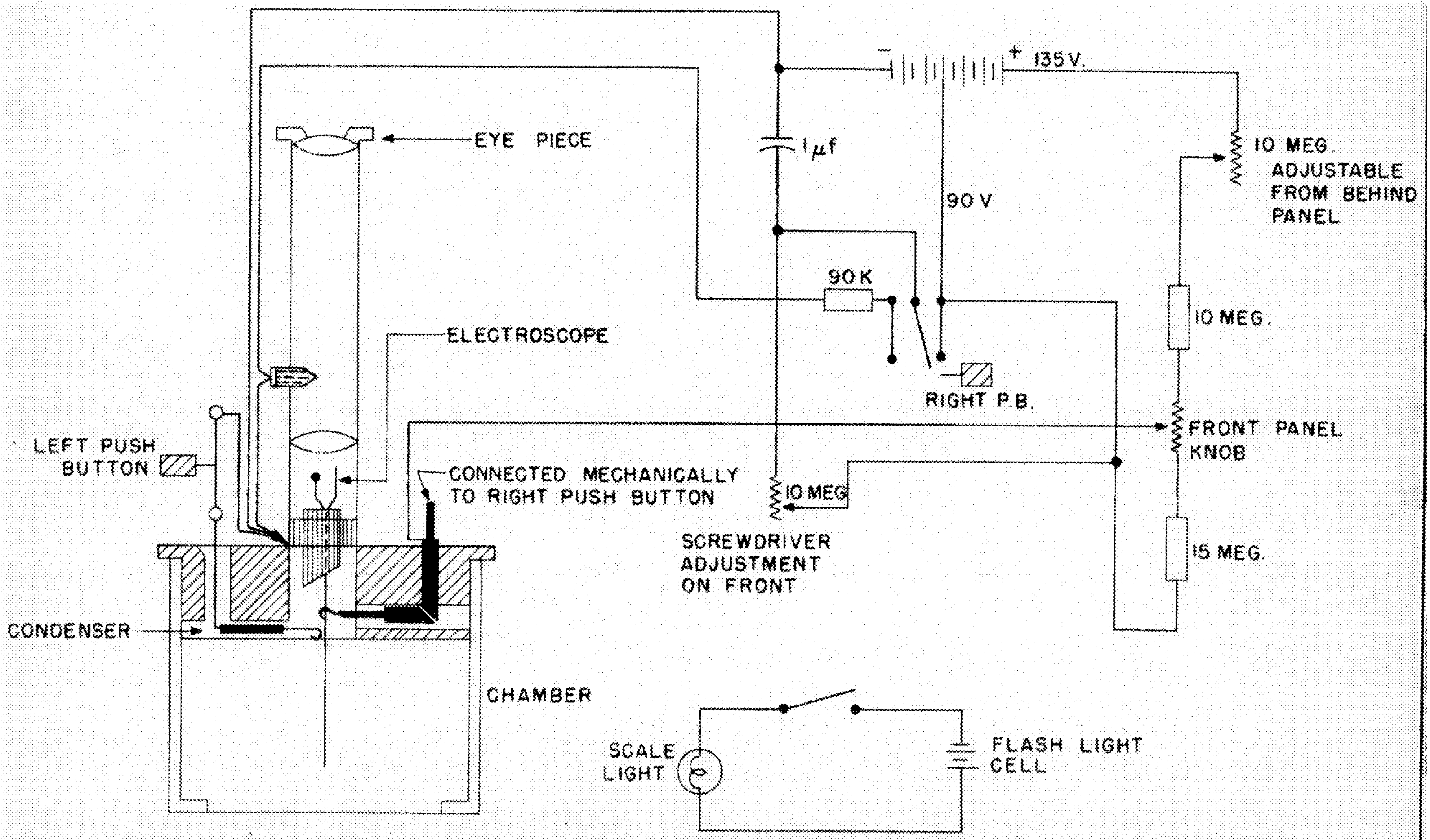
a. Dust on fiber.

b. Bad connection in circuit.

7. Fiber image not clear.

Cause:

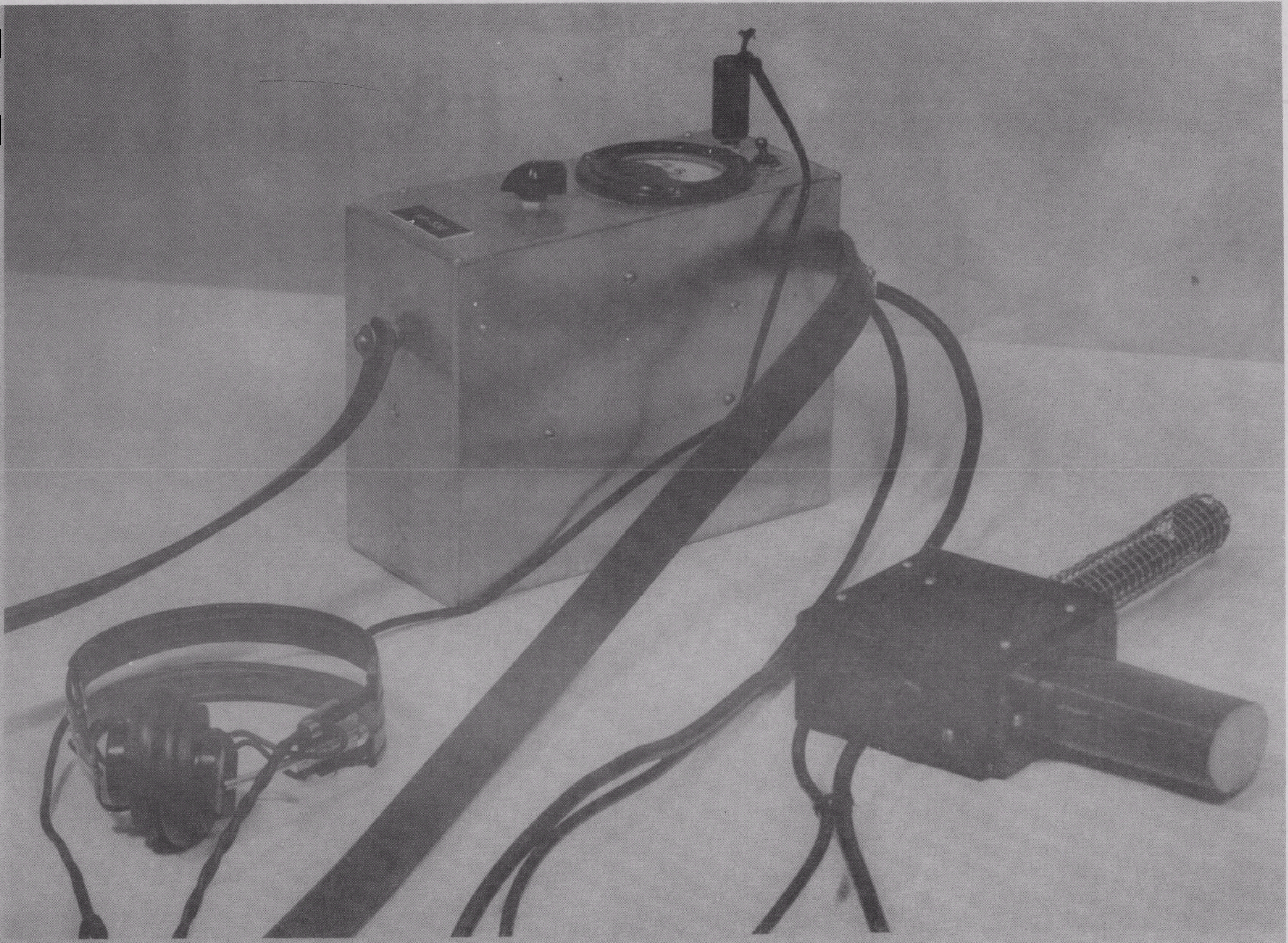
a. Lens of electroscope is out of focus.



LANDSVERK ELECTROSCOPE

WALKIE TALKIE

The Walkie Talkie is a medium weight, portable, beta-gamma detecting survey instrument, utilizing a G-M tube probe supplied with high voltage from a vacuum tube, oscillator and rectifier circuit. The output from the G-M tube is fed through a single amplifier stage to a pair of headphones.



WALKIE TALKIE

I. Use of Instrument

A. What the instrument is designed to do.

1. Indicate presence of beta or gamma by audio signal.

B. What the instrument is not designed to do.

1. Measure quantitatively any type of radiation.

2. Give audio signal for alpha radiation.

C. Factors affecting proper use of instrument.

1. Proper voltage adjustment.

2. Proper warm-up time. (10 seconds)

II. Calibration

A. Pre-calibration check list.

1. Check for contamination.

2. Check batteries.

3. Check dial functions.

4. Check for any other discrepancies.

B. Procedure

1. With a source, check the proper operating voltage and record on instrument.

SOME POSSIBLE MALFUNCTIONS OF THE WALKIE TALKIE

WITH PROBABLE CAUSES

1. Voltage is up but no signal or pops.

   Cause:

   a. Bad GM Tube.

2. No background at all.

   Cause:

   a. Burned out tube.

3. High background outside radiation field.

   Causes:

   a. Low batteries.

   b. Bad tube.

   c. Contamination on instrument.

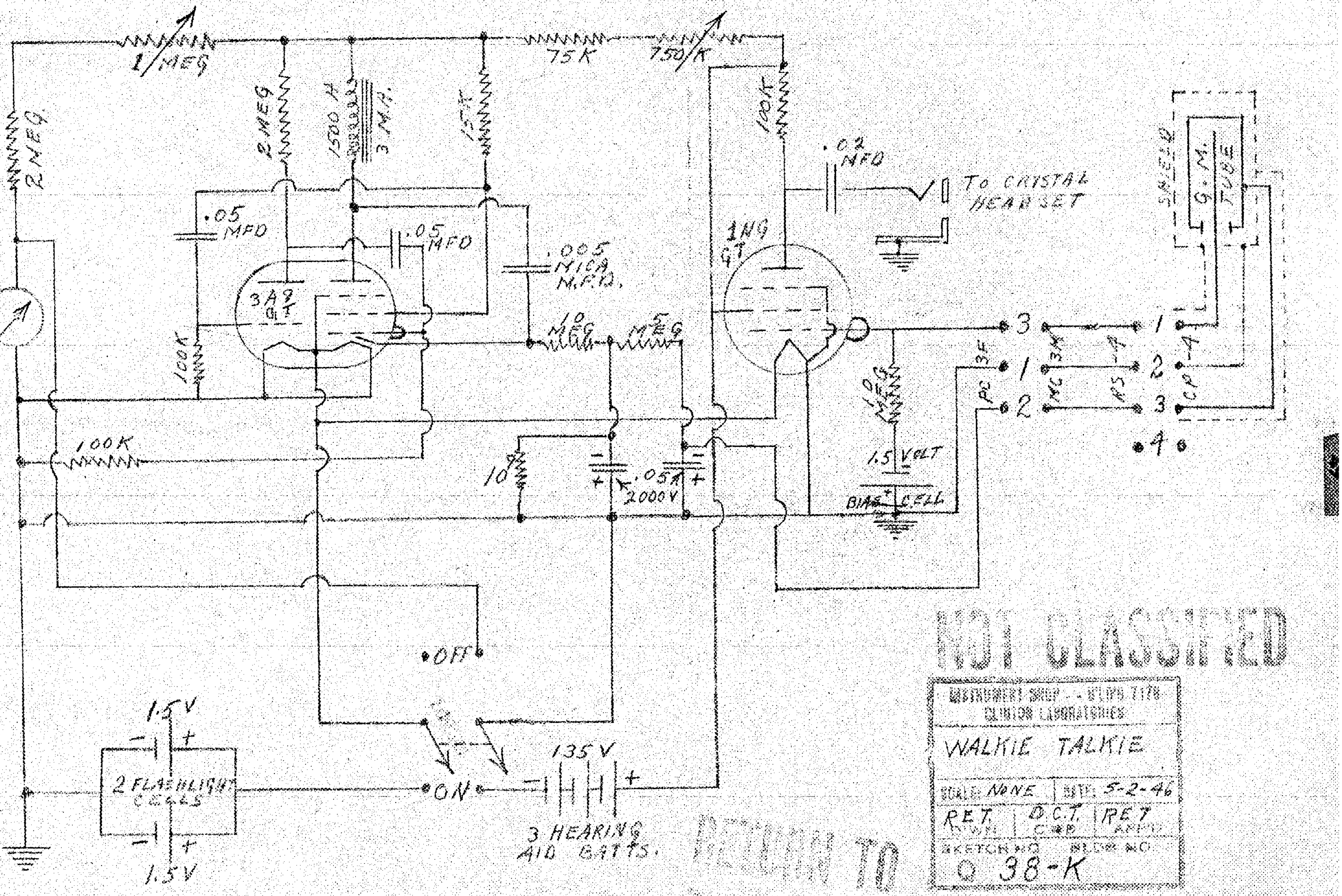
4. Intermittent Operations.

   Cause:

   a. Bad cable connections.

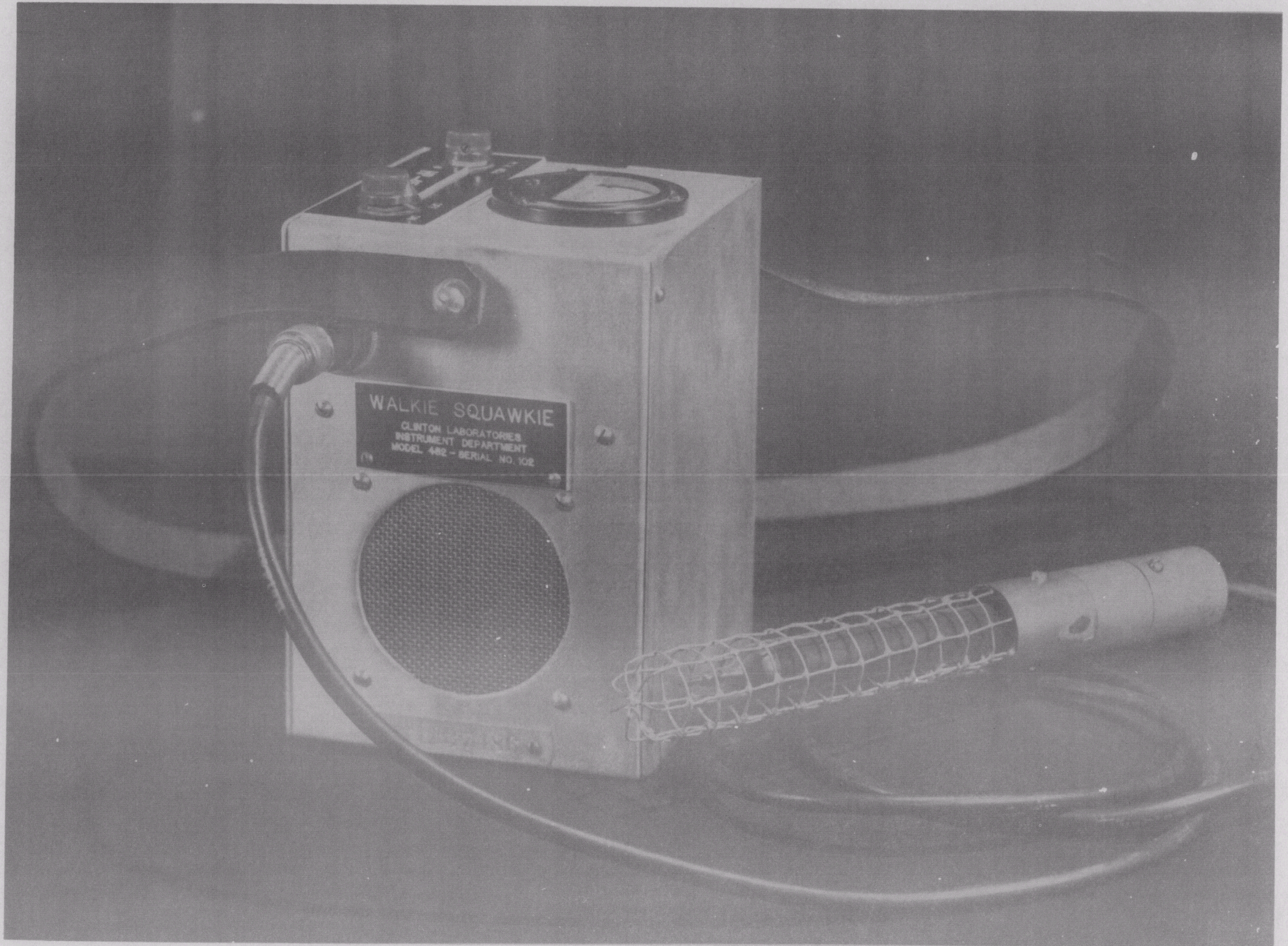
Precaution:

1. Never operate GM Tube at too high voltage.


1 MEG
75 K
750 K
2 MEG
2 MEG
1500 Ω
3 M.A.
15 K
100 K
.02 MFD
TO CRISTAL HEADSET
0-50 μAMMETER
.05 MFD
.05 MFD
.005 MICA M.F.D.
3A8 GT
1N6 GT
10 MEG
5 MEG
100 K
100 K
1.0 MEG
10
.05 μ
2000 V
1.5 VOLT
BIAS CELL
SHIELD
G. M. TUBE
3F
PC
3A
MC
RS
CP
OFF
ON
1.5 V
2 FLASHLIGHT CELLS
1.5 V
135 V
3 HEARING AID BATTS.
CLINTON LABORATORIES
WALKIE TALKIE
SCALE: NONE
DATE: 5-2-46
R.E.T. DWN
D.C.T. CHK
R.E.T. APPD
SKETCH NO
BLDG NO
Q 38-K

WALKIE SQUAWKIE

The Walkie Squawkie is the same type instrument as the Walkie Talkie. The only difference is that a Walkie Talkie uses headphones while the Squawkie is arranged to utilize a loud-speaker.


WALKIE SQUAWKIE
CLINTON LABORATORIES
INSTRUMENT DEPARTMENT

I. Use of Instrument

A. What the instrument is designed to do.

1. Indicate presence of beta or gamma by audio signal.

B. What the instrument is not designed to do.

1. Measure quantitatively any type of radiation.

2. Give audio signal for alpha radiation.

C. Factors affecting proper use of instrument.

1. Proper voltage adjustment.

2. Proper warm-up time. (10 seconds)

II. Calibration

A. Pre-calibration check list.

1. Check for contamination.

2. Check batteries.

3. Check dial functions.

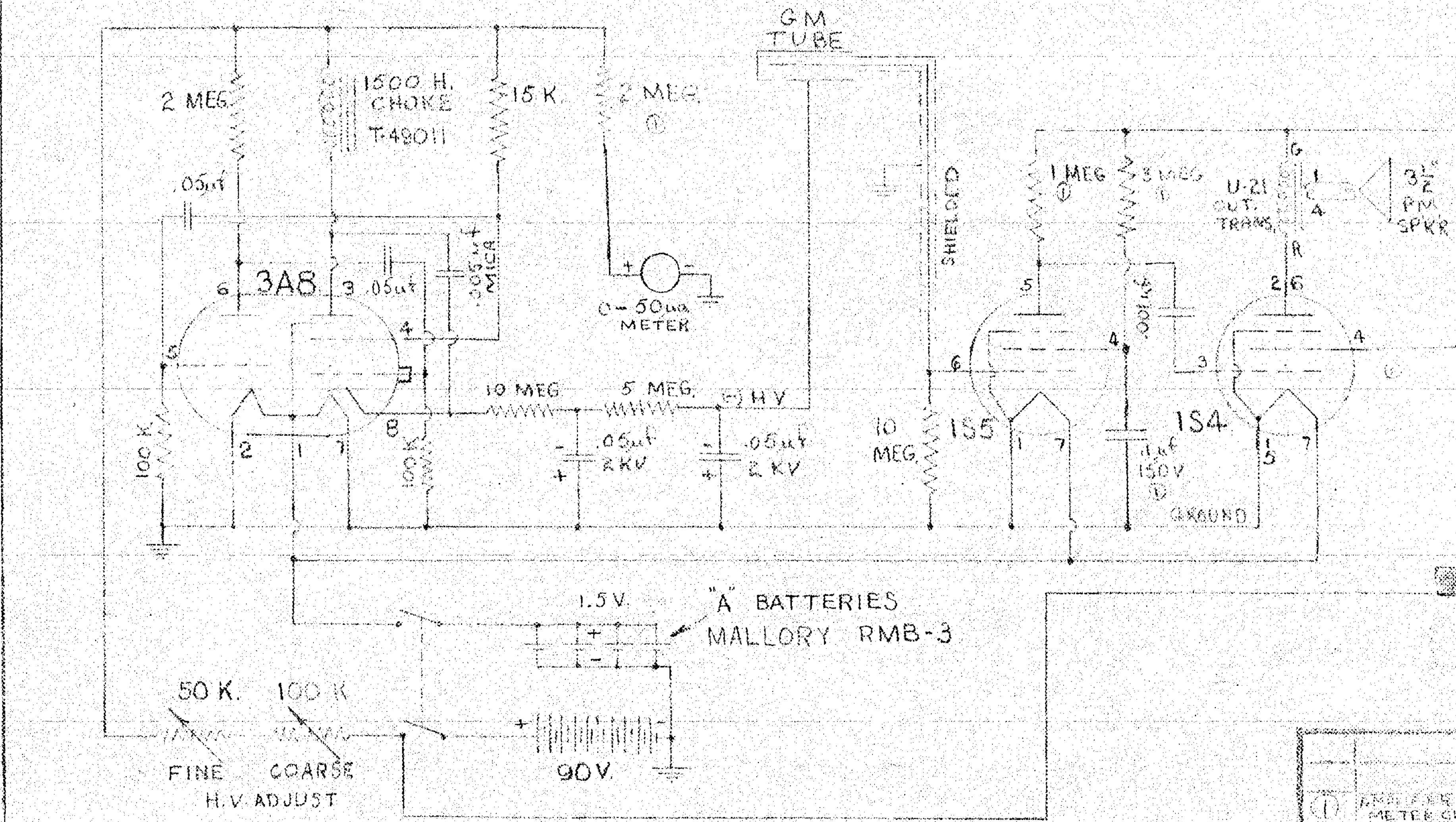
4. Check for any other discrepancies.

B. Procedure

1. With a source, check the proper operating voltage and record on instrument.

SOME POSSIBLE MALFUNCTIONS OF THE WALKIE SQUAWKIE WITH PROBABLE CAUSES

1. Malfunctions of the Walkie Talkie are also common to the Walkie Squawkie. (The Talkie utilizes headphones while the Squawkie makes use of a speaker.)



1. COARSE H.V. ADJ. POT. TO BE MOUNTED ON BACK OF FINE CONTROL INSIDE CASE.
2. "A" BAT. CASE SHOWN ON Q-479 A & B.
3. ALL RESISTORS TO BE ½ WATT
4. 400V COND. UNLESS OTHERWISE SHOWN.

717-B FILES

NOT CLASSIFIED

1	AMPLIFIER AND METER CIRCUIT
REV. NO.	REVISIONS

MONSANTO CHEMICAL CO.
CLINTON LABORATORIES
INSTRUMENT UNIT

WALKIE-SQUAWKIE

K.N.F. K.N.F.

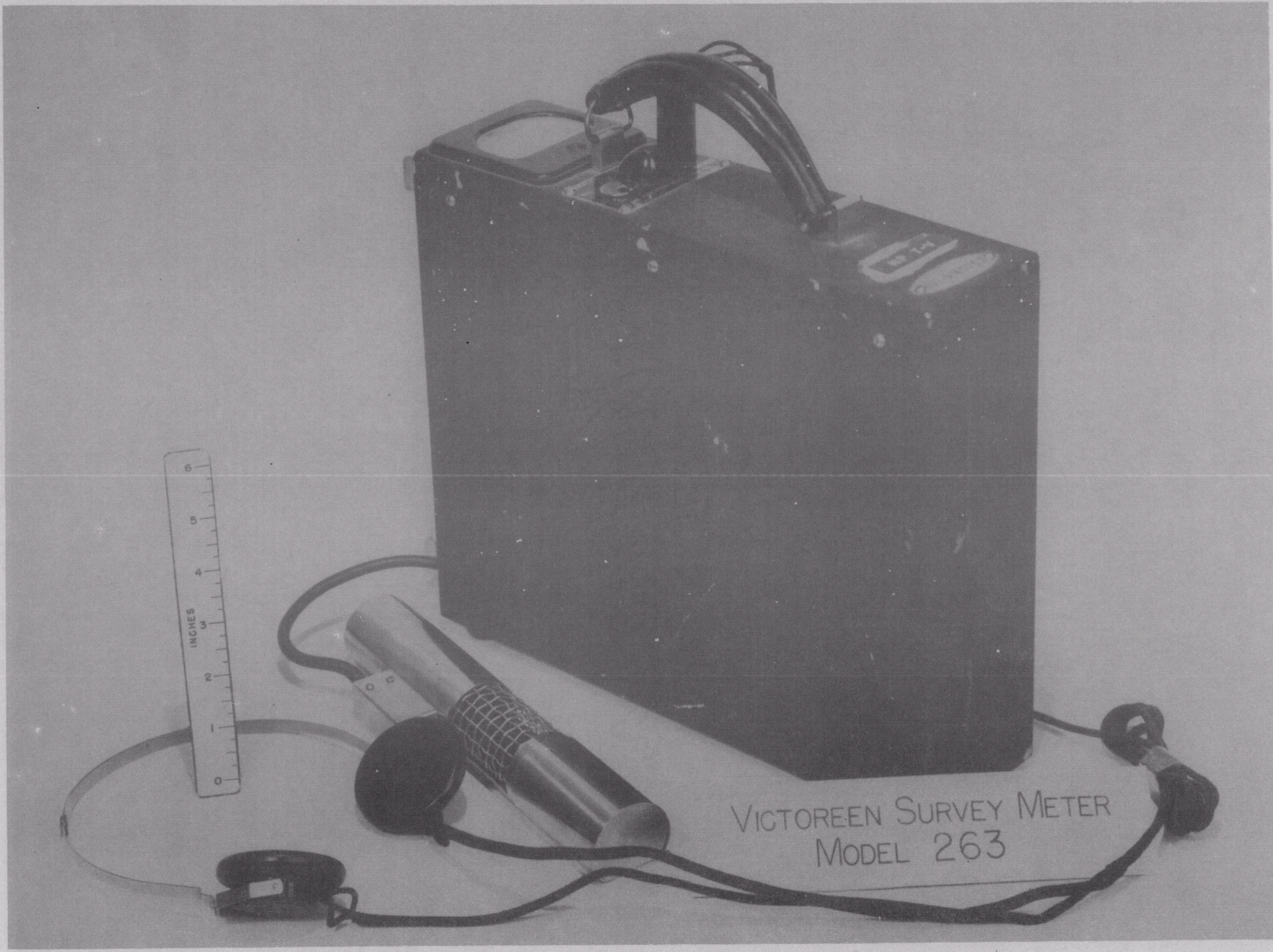
DATE 10-11-46 NONE

SHEET 1 OF 1

SKETCH Q-482A

VICTOREEN 263

The Victoreen 263 is a medium weight portable beta-gamma indicating survey instrument utilizing a GM Tube supplied by a high voltage battery. The pulses from the tube are amplified by a two stage vacuum tube amplifier which feeds into a pair of headphones for audio detection. This instrument is also equipped with a rate meter comprised of a microammeter, condensor, resistor combination in the plate circuit of the final amplifier tube.


INCHES
0
1
2
3
4
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6
VICTOREEN SURVEY METER
MODEL 263

I. Use of Instrument

A. What the instrument is designed to do.

1. Indicate roughly the magnitude of beta and gamma radiation between the intensities of less than .2 mr/hr and 20 mr/hr.

2. By use of a shield, to determine whether activity being measured is largely gamma or beta.

NOTE: The instrument is most often used as a detection instrument rather than a quantitative measuring instrument.

B. What the instrument is not designed to do.

1. Measure intensities greater than 20 mr/hr.

2. Measure rep/hr of beta radiation.

3. Measure alpha radiation.

C. Factors affecting proper use and interpretation.

1. Proper warm-up time. (15 seconds)

2. Proper zero setting.

3. Proper distance of instrument from source.

4. Type of radiation being measured.

II. Calibration

A. Sources - 0.96 Ra source
27.03 mg Ra source

B. Calibration cycle

1. Calibrated upon request.

C. Pre-calibration check

1. Check for contamination.

2. Check batteries.

3. Check dial functions.

4. Check cord connections.

5. Check for any other discrepancies.

D. Procedure

1. Zero on the most sensitive position and do not zero on any of the other positions.

2. Set on #3 which is the most sensitive position and proceed toward radium source, starting at the .1 mr/hr position.

3. Set on #2 which is the next most sensitive position and proceed toward radium source, starting at the .5 mr/hr position.

4. Set on #1, the least sensitive position, and proceed toward radium source, starting at 5 mr/hr position.

E. Salient Factors

1. Turn instrument on five minutes before calibration to allow plenty of "warm-up" time.

2. Plot <u>at least</u> three points on each of the sensitivity positions.

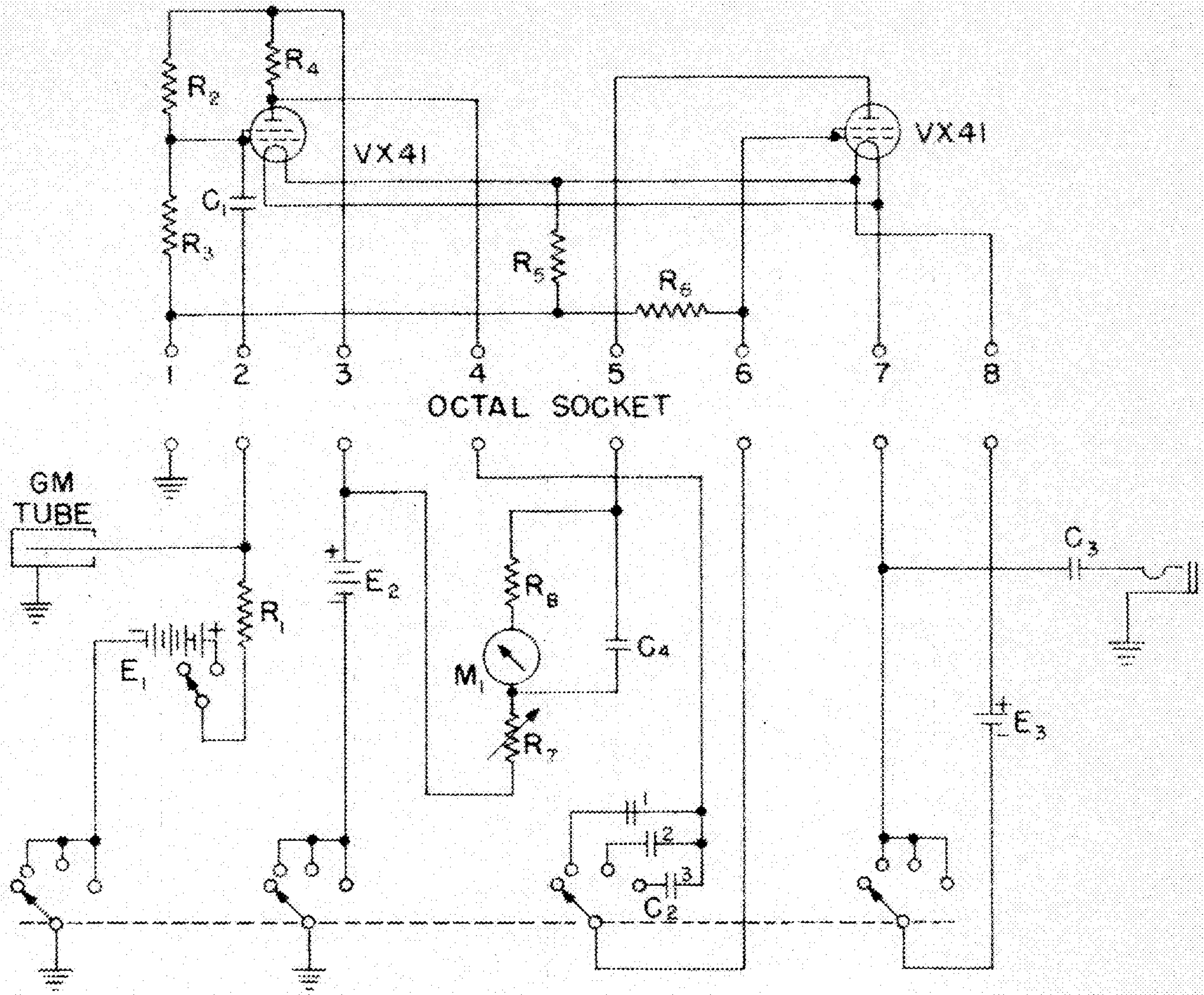
3. Calibrate with instrument oriented to give the maximum reading with shield over GM Tube.

VICTOREEN 263

Ranges: three scales

1. 0 to 0.2 mr/hr
2. 0 to 2.0 mr/hr
3. 0 to 20.0 mr/hr

The Victoreen 263 is the same type instrument as the Walkie Talkie.



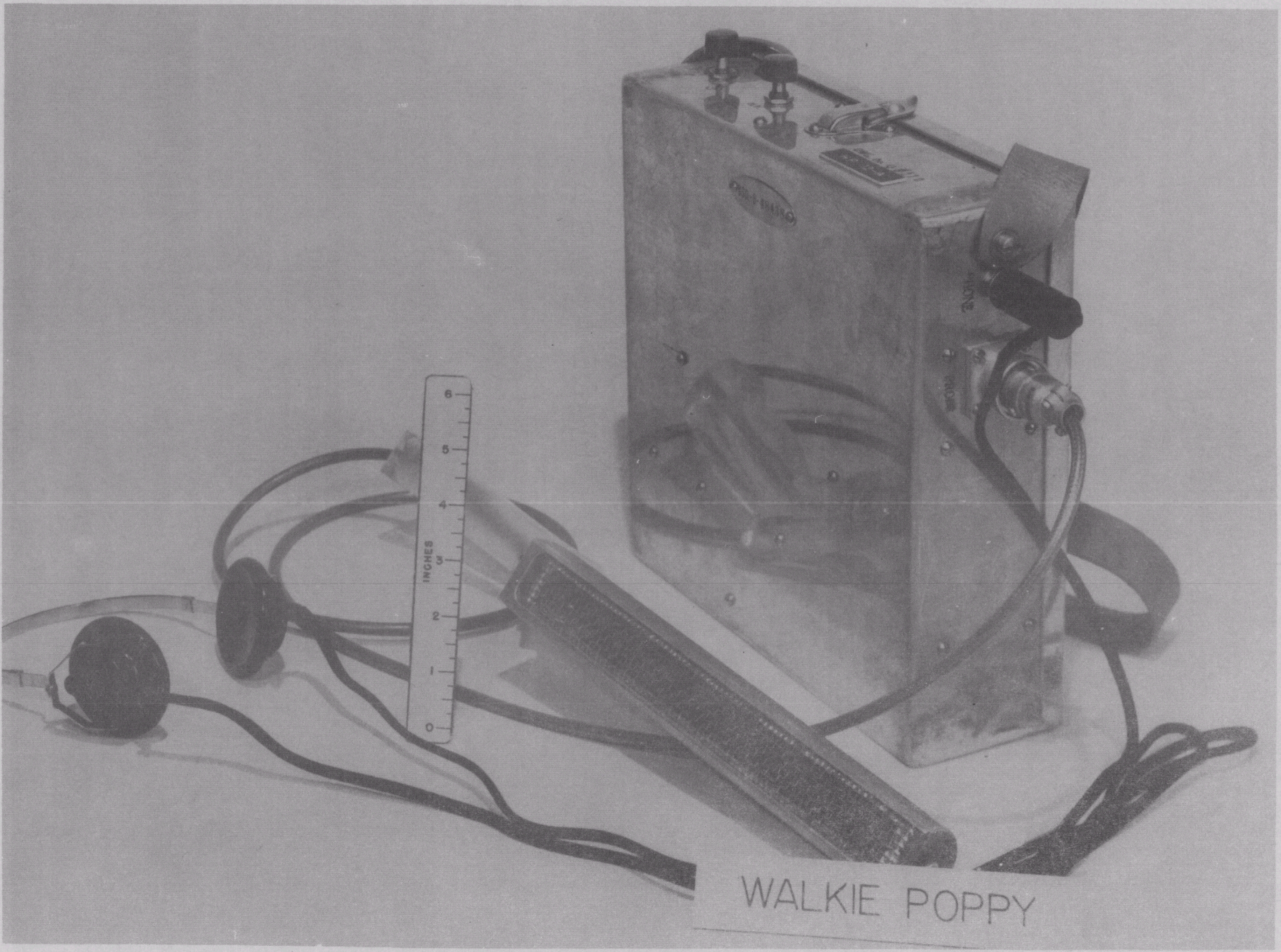
R_1	300 K	C_1	75 μμfd 1000 V
R_2	10 MEG	C_2	RANGE 1 - 20 MR 227 μμfd
R_3	MEG		RANGE 2 - 2 MR 1700 μμfd
R_4	100 K		RANGE 3 - 0.2 MR 13000 μμfd
R_5	24 K	C_3	0.0025 μfd (MAY BE SMALLER FOR
R_6	1 MEG		REDUCED VOL. IN HEADPHONES
R_7	25 K POT.	E_1	840-960V EVEREADY X 591
R_8	20 K	E_2	67 1/2 V BA-1 BURGESS XX45
	ALL RESISTORS - 0.5 WATT	E_3	1 1/2 V BA-30 BURGESS NO. 2
M_1	0-50 MICROAMMETER 0-20		USE HIGH IMPEDANCE HEADPHONES
		C_4	100 μfd

IPS NO. D-1 TRACED BY A.E.C. 1/20/49

VICTOREEN SURVEY METER ____________ MODEL 263

WALKIE POPPY

The Walkie Poppy is a medium weight portable alpha detecting survey instrument utilizing a special probe-type air filled chamber, with an aluminum wall and longitudinal nylon window protected by a bronze screen. The chamber is supplied with high voltage by a vacuum tube oscillator and rectifier circuit. A signal from the probe is fed through a three stage amplifier, the output from which is used to trigger a miniature thyatron tube, which in turn produces audible impulses in a pair of headphones. This instrument makes use of a high gain amplifier and is therefore more critical to use than most of the portable instruments.


WALKIE POPPY
INCHES

WALKIE POPPY

I. Use of Instrument

A. What the instrument is designed to do.

1. Indicate presence of alpha radiation by audio signal.

B. What the instrument is not designed to do.

1. Measure quantitatively alpha radiation.

2. Give audio signal for beta or gamma radiation.

C. Factors affecting proper use of instrument.

1. Proper voltage adjustment.

2. Proper warm-up time. (50 seconds)

II. Calibration Procedure - The only calibration is a check with an alpha source to insure proper operation of instrument.

A. Pre-calibration check list

1. Check for contamination.

2. Check batteries.

3. Check cable connections.

4. Check for any other discrepancies.

B. Procedure

1. With an alpha source, check the proper operating voltage and record same on instrument.

SOME POSSIBLE MALFUNCTIONS OF THE WALKIE POPPY WITH PROBABLE CAUSES

1. Majority of troubles due to batteries.

2. High background noise.

   Causes:

   a. Leakage in high voltage.

   b. Bad bias cells of amplified section supply.

3. No noise or pops.

   Causes:

   a. Tube burned out in amplifier section.

   b. High voltage failure.

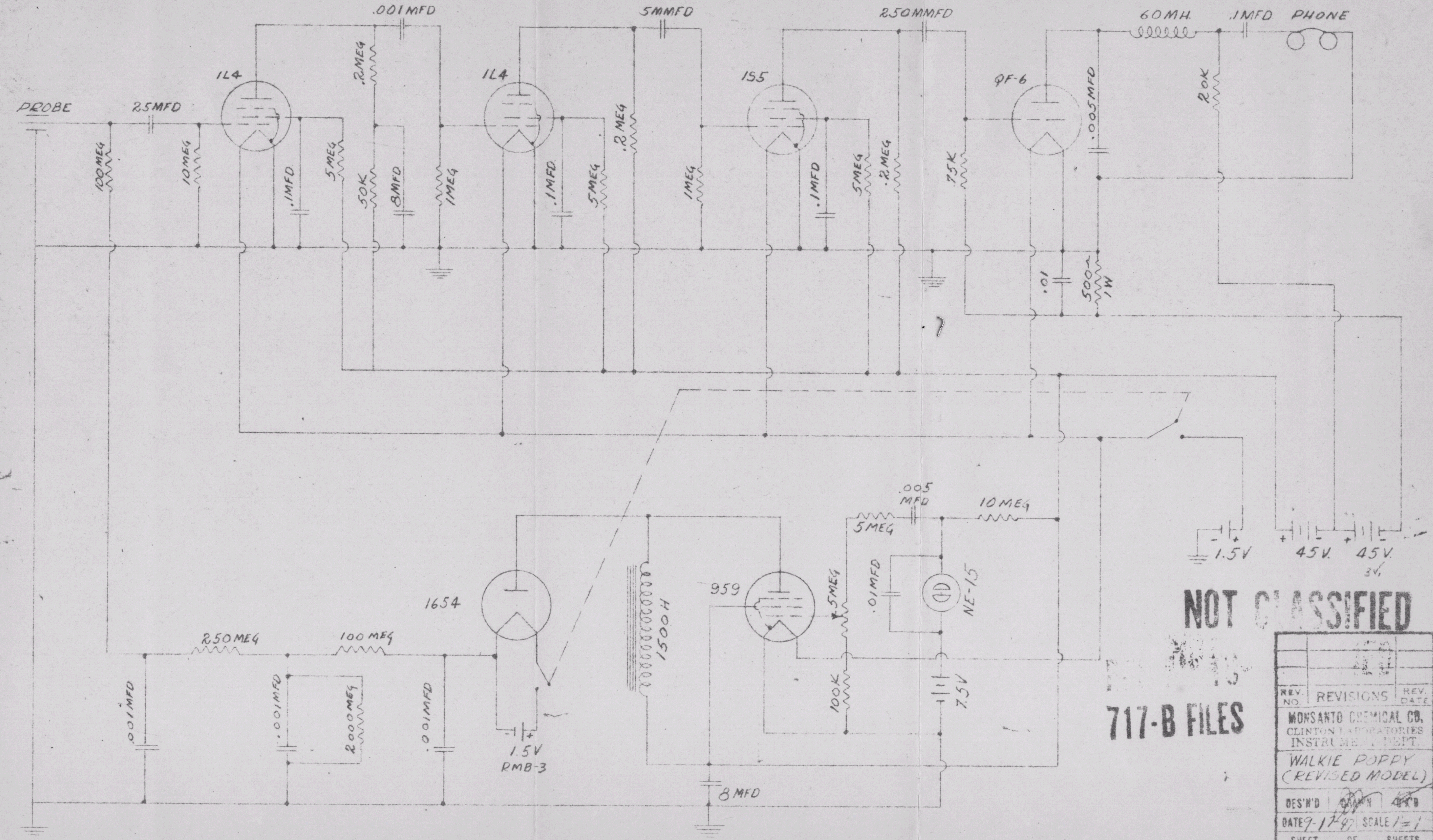
4. Intermittent Operation.

   Cause:

   a. Bad cable connection.

NOTE: The filament batteries must be changed quite frequently. High voltage lags behind the adjustment. Operating point is very critical.

78



NOT CLASSIFIED

717-B FILES

REV. NO.	REVISIONS	REV. DATE

MONSANTO CHEMICAL CO.
CLINTON LABORATORIES
INSTRUMENT DEPT.

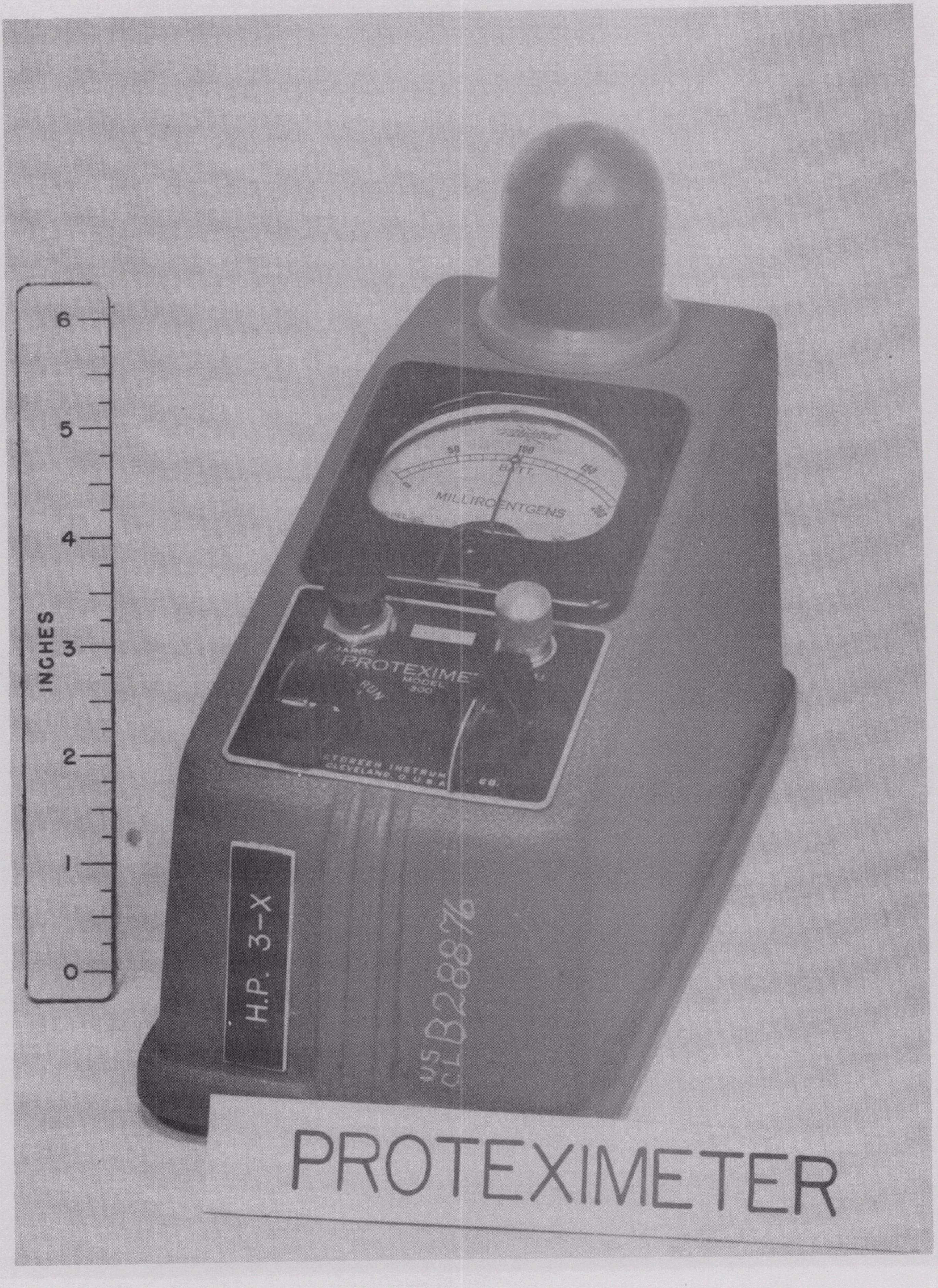
WALKIE POPPY
(REVISED MODEL)

DES'N'D	DRAWN	CH'K'D
DATE 9-17-47	SCALE 1=1	
SHEET	OF	SHEETS

SKETCH Q-327D

PROTEXIMETER

The Proteximeter reads total accumulated dosage of beta and gamma radiation. The instrument makes use of a complex type of polyethelene ionization chamber which is charged by a battery and potentiometer and then disconnected from same, the charge of the chamber forming the negative bias on the grid of the electrometer tube such that a microammeter in the plate circuit reads zero. Radiation passing through the chamber causes this charge to leak off making the grid progressively less negative and consequently the plate current progressively greater. The reading at any time is an indication of the total amount of charge which has leaked off and, therefore, an indication of the radiation dosage.


INCHES
6
5
4
3
2
1
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MILLIROENTGENS
BATT.
PROTEXIME
MODEL
300
RUN
CLEVELAND, O. U.S.A.
H.P. 3-X
US
CL
B28876
PROTEXIMETER

PROTEXIMETER

I. Use of Instrument

A. What the instrument is designed to do.

1. Measure accumulated gamma radiation up to 200 mr with an accuracy of less than 10%.

2. Measure accumulated beta radiation.

B. What the instrument is not designed to do.

1. Distinguish between beta, x-ray, or gamma radiations.

2. Measure alpha radiation.

3. Measure dosage rate.

C. Factors affecting proper use of instrument.

1. Voltage adjustment.

2. Zero setting.

3. Position of instrument. Instrument will not operate in inverted position.

II. Calibration

A. Source - 27.03 mg Ra source.

B. Calibration Cycle - as requested.

C. Pre-calibration check list.

1. Check for contamination.

2. Check batteries.

3. Check dial functions.

4. Check zero set.

PROTEXIMETER (CONT'D)

D. Procedure

1. Set instrument with chamber on 100 mr/hr position.

2. Zero instrument.

3. Leave at this position for one hour.

4. Record number of divisions the instrument has accumulated on front of instrument.

E. Salient Factors

1. If the instrument will not read up to "100" when the switch is on "battery", the batteries must be replaced.

SOME POSSIBLE MALFUNCTIONS OF THE PROTEXIMETER

WITH PROBABLE CAUSES

1. Will not zero.

    a. Adjust charger adjustment.

2. No reading in radiation.

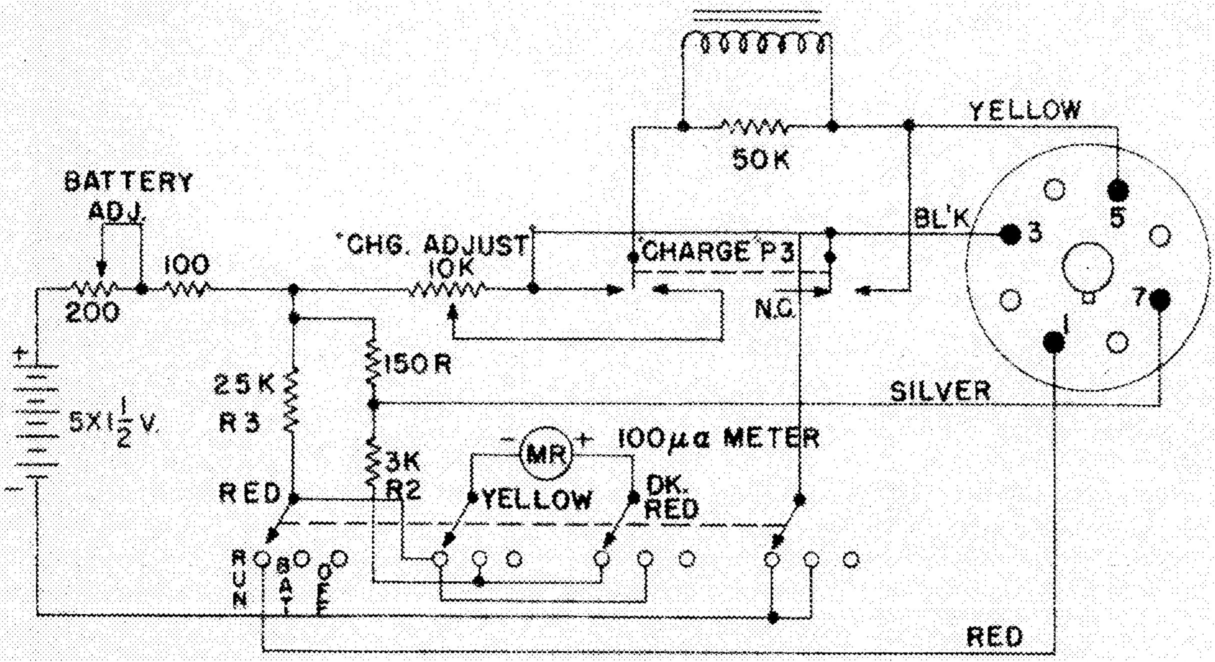
    a. Bad tube.

3. Erratic reading.

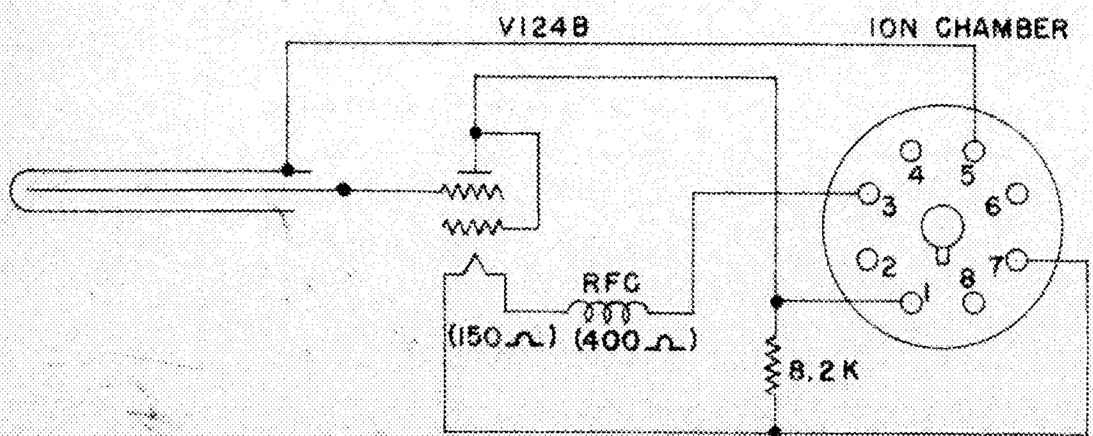
    a. Bad connections.

    b. Bad tubes.

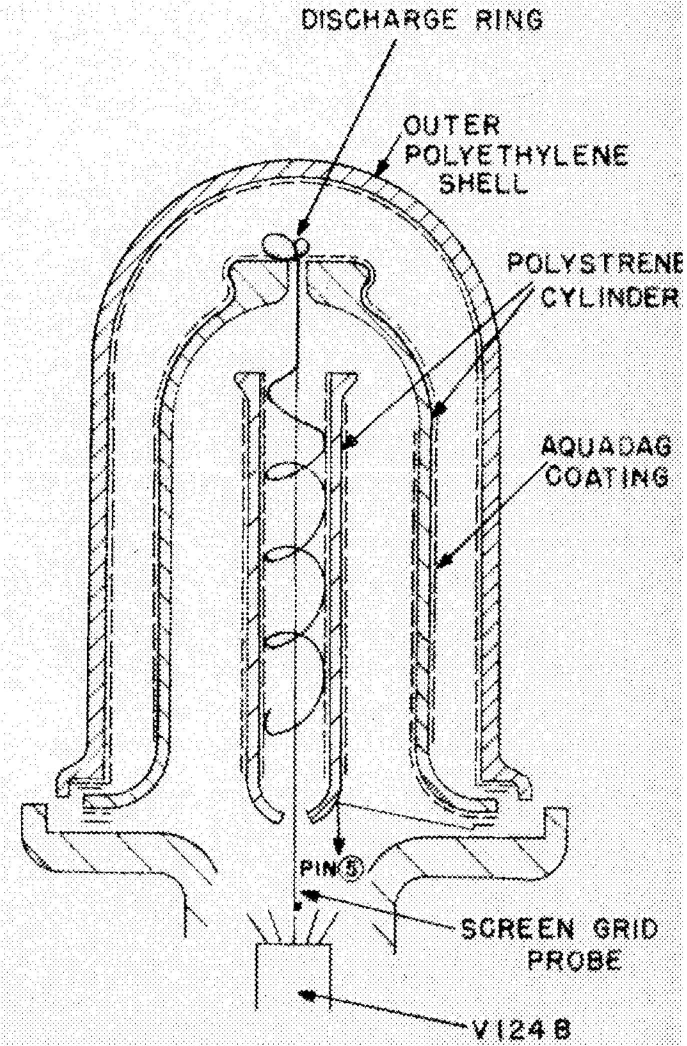
NOTE: Tube is very delicate and must be handled with care.



VICTOREEN PROTEXIMETER - SCHEMATIC (INST. #143)

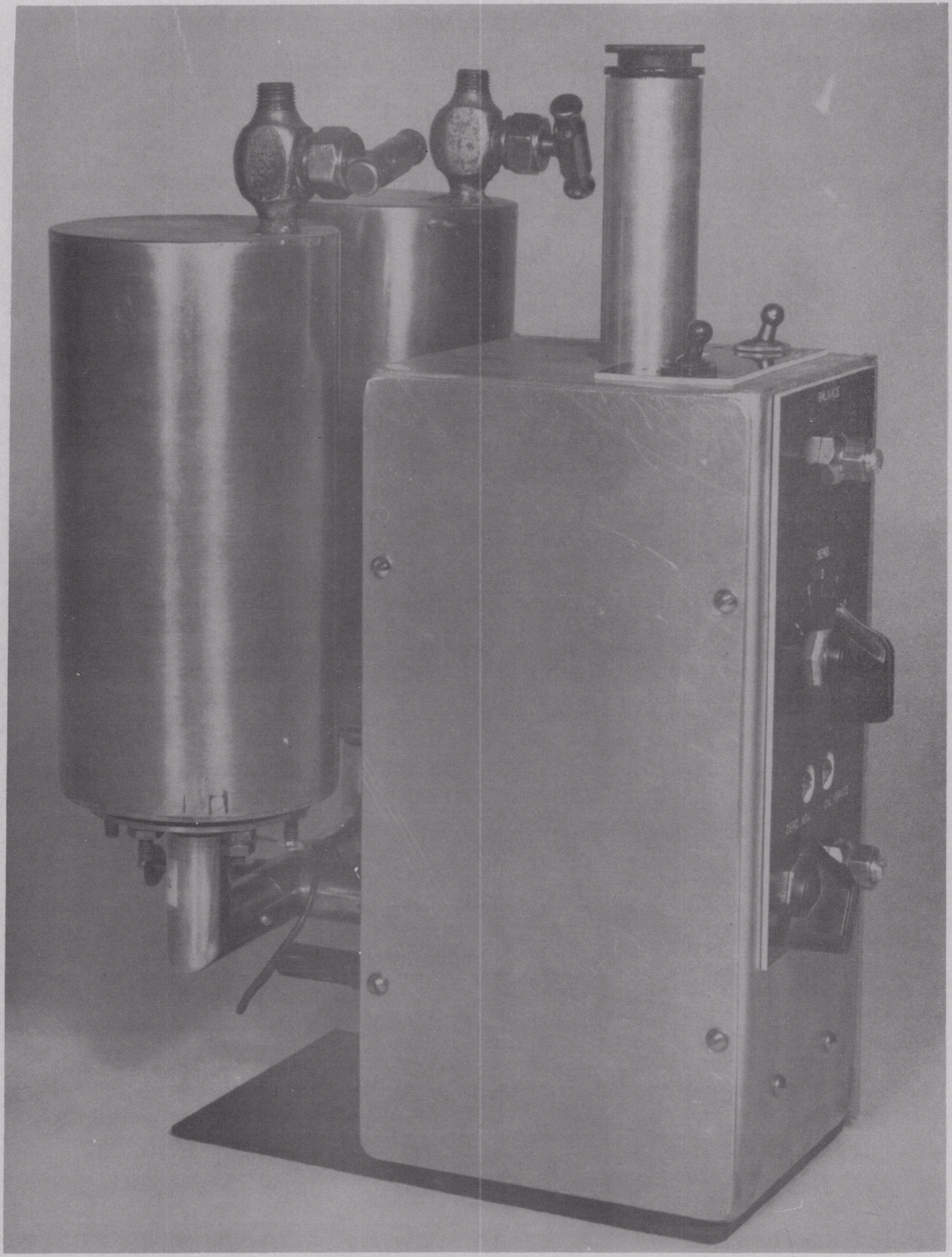


PROTEXIMETER ION CHAMBER - SCHEMATIC



CHANG AND ENG

The Chang and Eng, as a portable survey instrument for Health Physics, was designed to measure the "reps" of fast neutrons in the presence of gamma radiation. The simplicity of the instrument is limited by the type of radiation it is designed to measure. The Chang and Eng consists of two ionization chambers, connected in parallel, with a Lindemann type electrometer to measure the difference of the ionization current in the two chambers. One of the chambers is filled with argon at about 30 pounds per square inch pressure, and the other chamber is lined with paraffin about one mm thick and is filled with butane at 20 pounds per square inch pressure. The relative pressures in the two chambers are adjusted so that the ionization currents are equal when both chambers are irradiated with gamma rays only. When placed in a fast neutron beam, recoil protons from the paraffin and butane produce greater ionization in the butane chamber. The difference in the ionization current is an indication of the "rep" value of the fast neutron exposure, as the ionization currents due to the presence of gamma are equal and opposite and cancel out.


BALANCE
SENS

I. Use of instrument

A. What the instrument is designed to do.

1. Measures fast neutron exposure (rep) in a field of gamma radiation.

B. What the instrument is not designed to do.

1. Measure alpha, beta, gamma or thermal neutron radiation.

2. Measure fast neutron flux in a field of gamma of different energies to that used for calibration.

C. Factors affecting proper interpretation.

1. Electrometer balance.

2. Pressure balance.

3. Geometry of source.

4. Gamma radiation energy balance.

II. Calibration

A. Sources - 27.03 mg Ra source
5 curie Po Be source

The value of these sources is not critical.

B. Calibration cycle - if in constant use, should be calibrated every two weeks.

C. Pre-calibration check

1. Check for contamination.

2. Check batteries.

3. Check electrometer.

4. Check for leakage of gas in cylinder.

5. Check for any other discrepancies.

D. Procedure

1. Electrometer Calibration - Remove shaft lock from sensitivity adjustment pot. With both chambers removed, adjust the sensitivity until the desired deflection is obtained when a known potential is applied to the electrometer. A sensitivity of 400 - 500 div/volt is recommended for the highest sensitivity scale. This adjustment is to be made with the selector switch in the No. 1 position. This procedure adjusts the sensitivity for all other positions on the selector switch at the same time.

2. Pressure balancing

   a. Fill butane chamber to 20 psi of butane; fill argon chamber to about 35 psi of argon.

   b. Insert chambers into proper position in yoke assembly and connect electrical leads.

   c. Turn on high voltage switch. (It is recommended that the instrument be allowed to stand in this condition for about an hour before attempting to balance pressure.)

   d. With a gamma source placed such that it is equidistant from both chambers, allow enough argon to leak out until the rate of drift of the electrometer is reduced to zero. The gamma ray energy of the source used for balancing should approximate the gamma ray energies anticipated in operation.

3. Calibration in known neutron field.

   a. Place a neutron source of known strength at a known distance from the center of the butane chamber.

   b. Record the time it takes the electrometer fiber to move 20 scale divisions.

   c. Determine the N_k (neutron constant) from the following formula:

$$N_k = \frac{NT}{d}$$

N_k = number of neutrons per cm^2 per second required to deflect the electrometer one division.

N = number of neutrons per/cm/sec.

d = total number of divisions deflected (20 div.).

T = time in seconds for deflection.

d. The neutron flux in an unknown field will be $N = \frac{N_k d}{T}$

e. A separate N_k will be determined for each of the sensitivity scales.

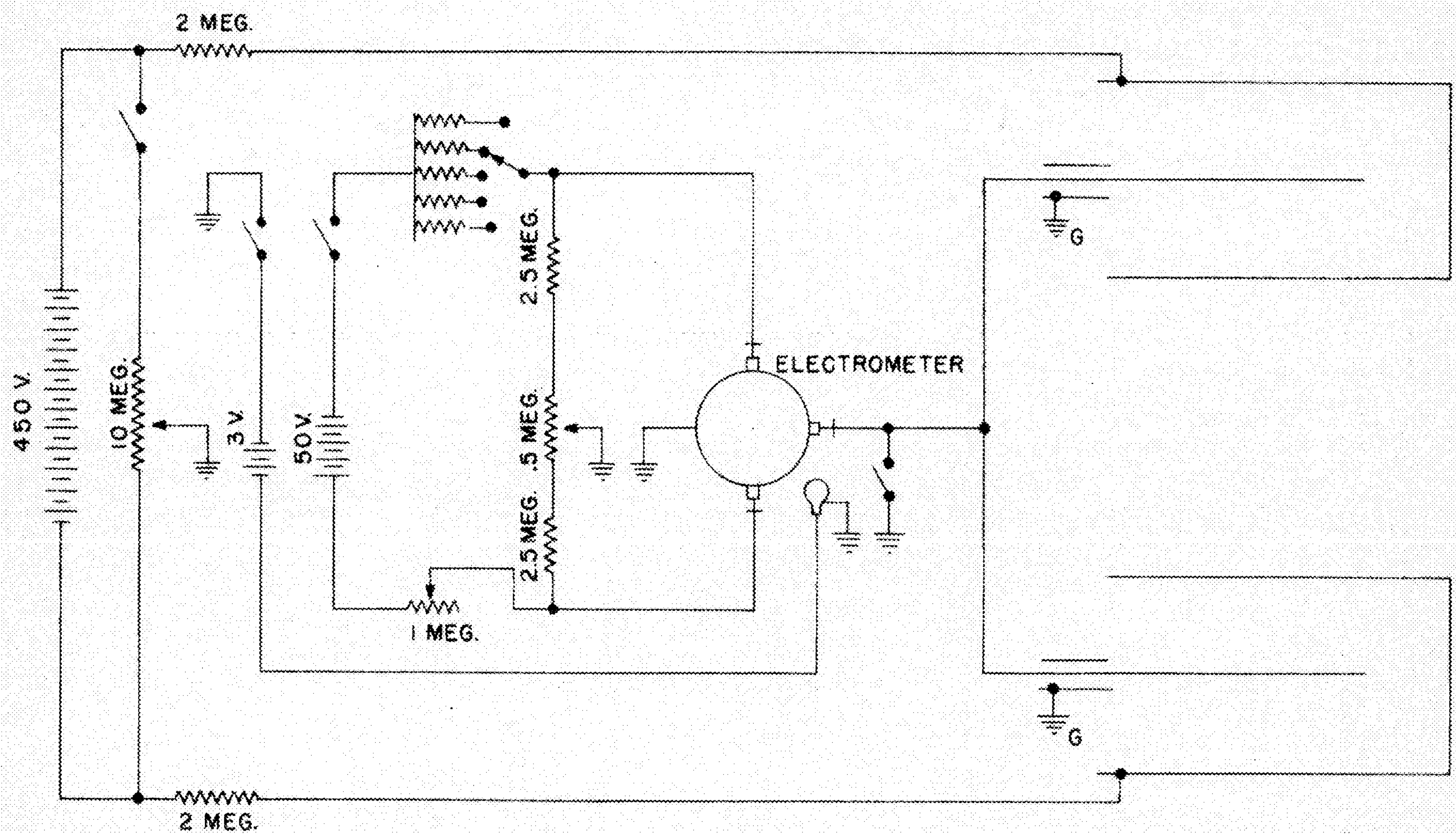
E. Salient Factors

1. Electrometer scale is not linear, the same portion of scale must always be used.

2. Geometrical errors are inherent in the instrument because of the separation of the two chambers. Care must be exercised in placing the instrument so that this effect is a minimum.

3. The gamma ray energy for balancing should approximate the gamma ray energies anticipated in operation.

4. Where scattered gamma rays are present, two argon chambers may be used to determine the orientation to balance out the gamma radiation.



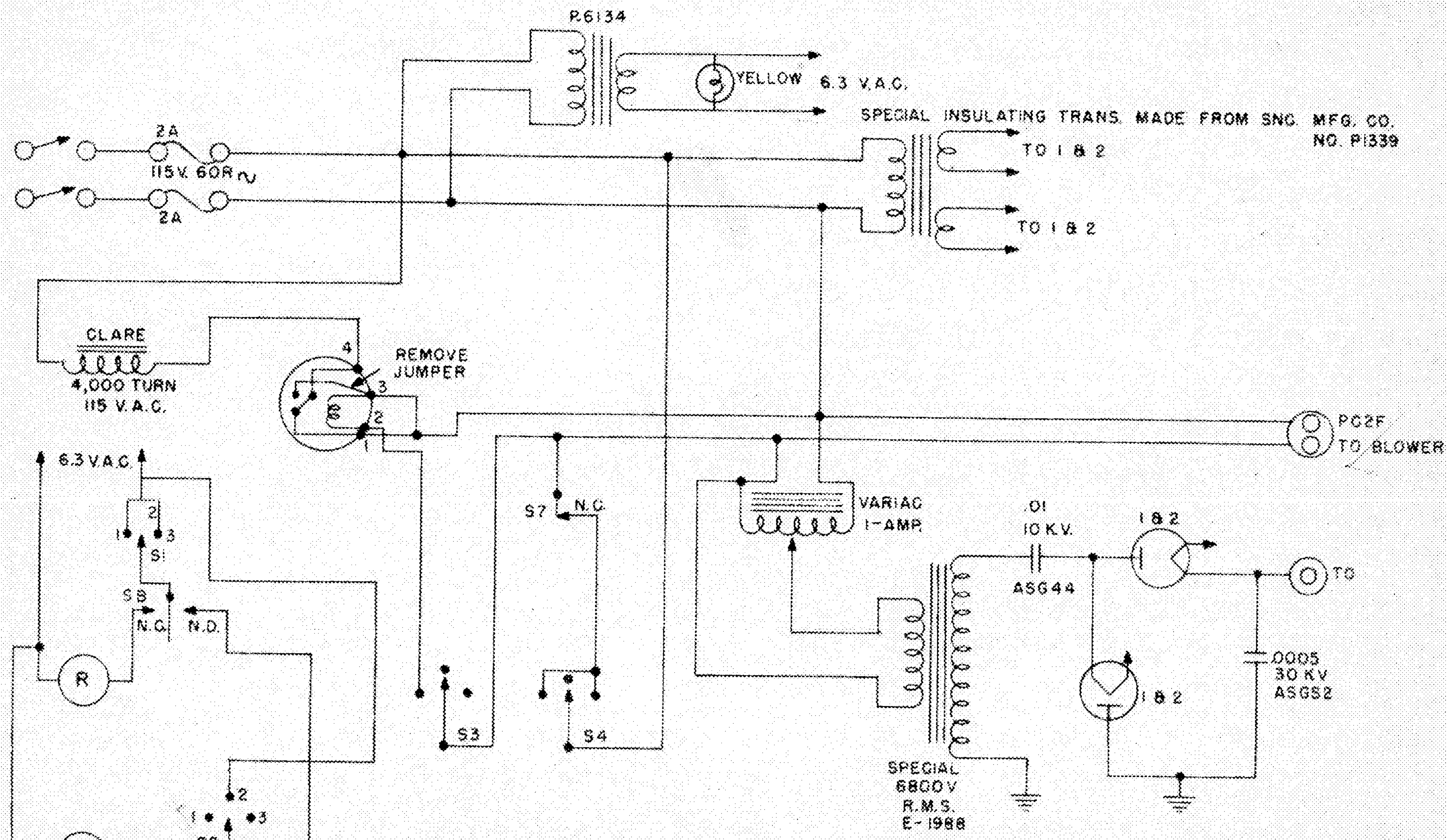
R	75 K
R	100 K
R	0.5 MEG.
R	3 MEG.
R	20 MEG.
G	GUARD RING

PRECIPITATOR

The "Precipitator" consists of a high voltage supply and motor with blower. The precipitator ionizes a stream of air by a corona discharge as it is drawn through an aluminum cylinder. The radioactive dust which has become charged is deposited on aluminum foil just inside the aluminum cylinder under the influence of an electrostatic field. Under proper operating conditions, air flow of 3 cu. ft./min. or less and voltage of eleven KV or greater, the instrument is over 99% efficient.

110 Volts.

10,000 Volts.



S1, S2, S3, S4, — 4 POLE 3 POS. SELECTOR SWITCH

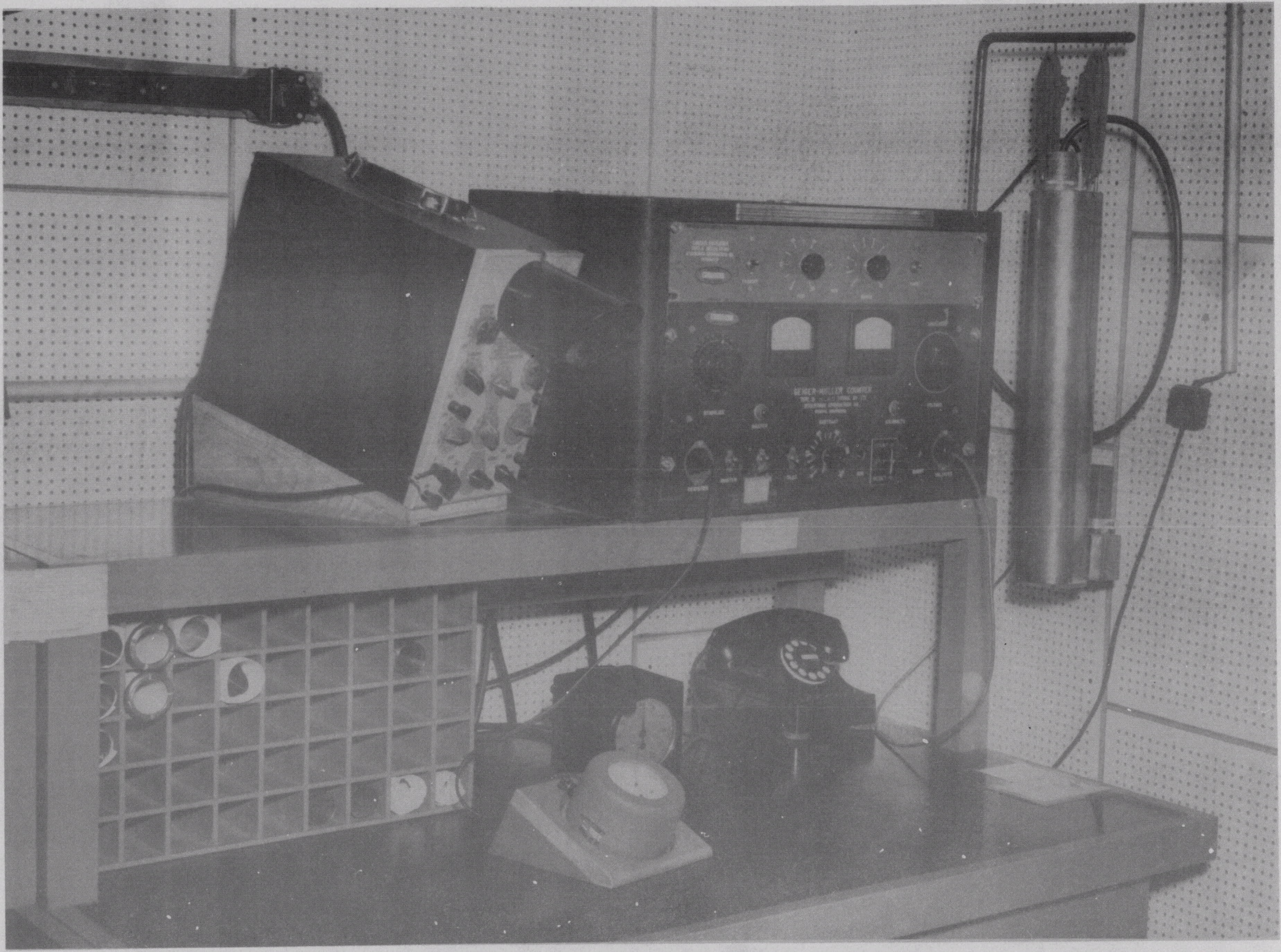
S5, — SWITCH ON TIMER

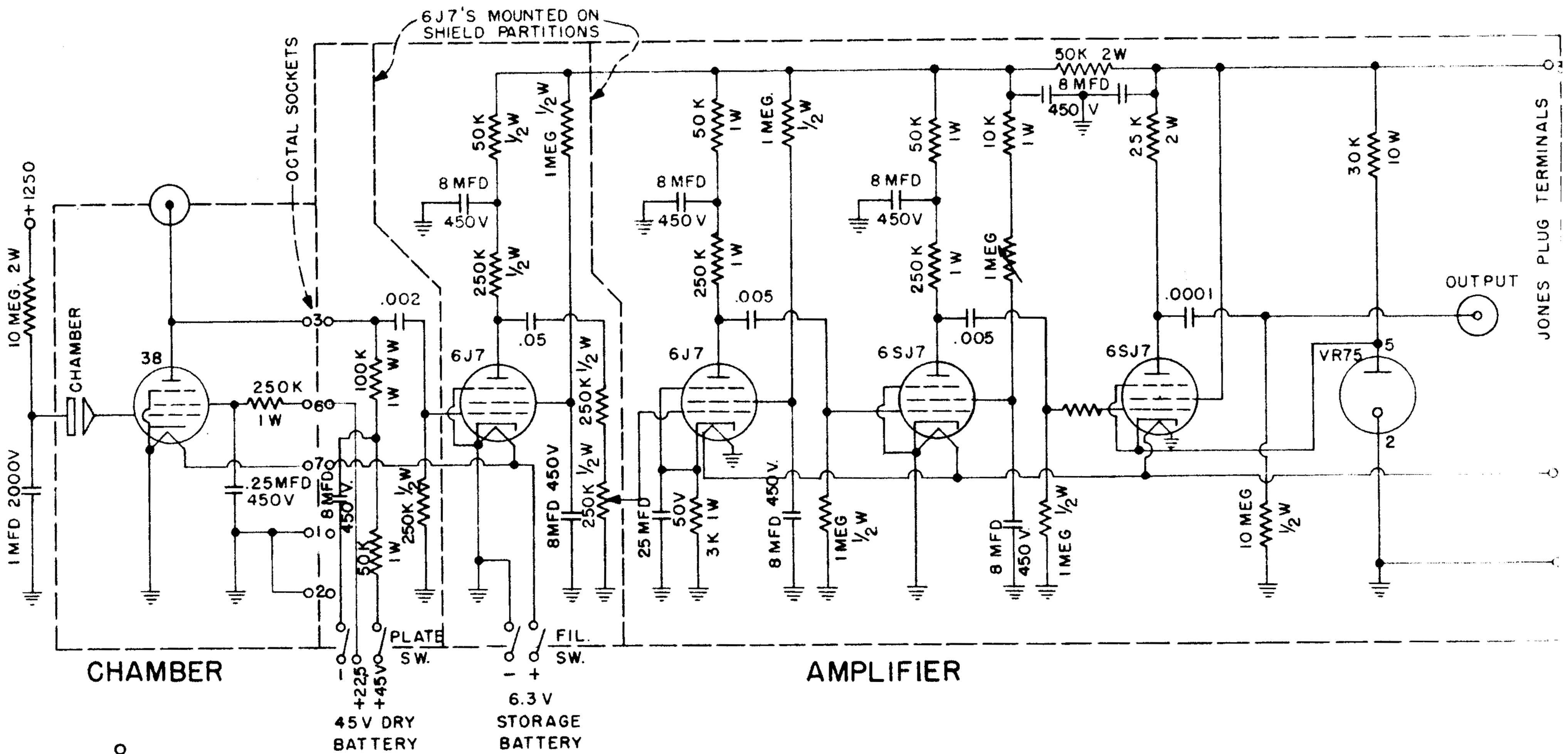
S6, S7 — MICRO SWITCHES ON CLARE RELAY

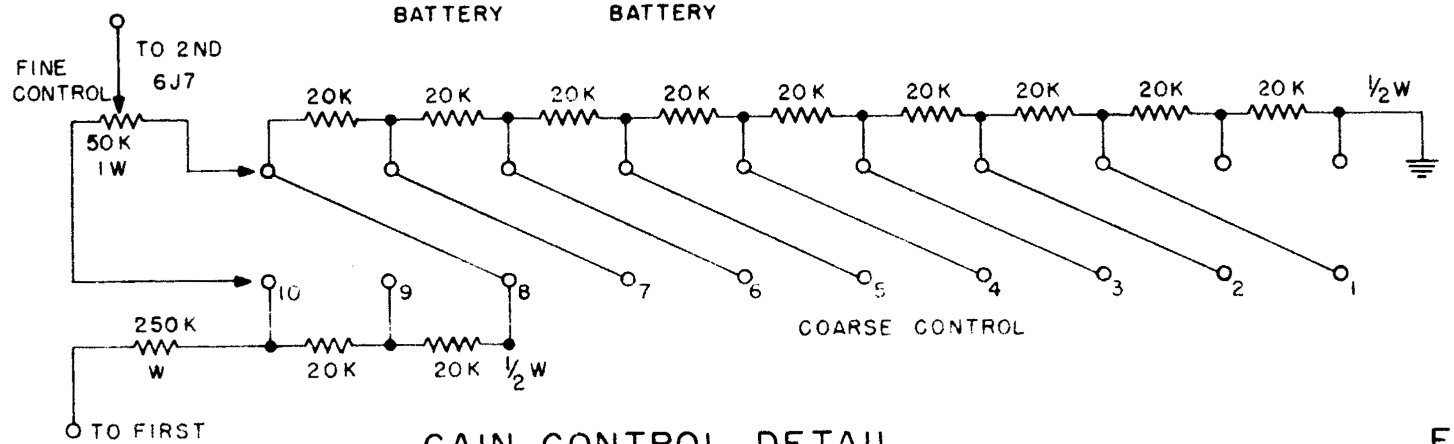
PRECIPITRON POWER SUPPLY

ALPHA AMPLIFIER

The alpha amplifier is a high gain linear amplifier for use in conjunction with the alpha counter and pre-amplifier for operating a scaler for alpha counting. This amplifier must be a high quality amplifier capable of amplifying very steep rise time and very short duration pulses. It must also be constructed and shielded in such a manner to render it non-microphonic and to eliminate stray pick-up as far as is possible.


GEIGER-MULLER COUNTER





GAIN CONTROL DETAIL

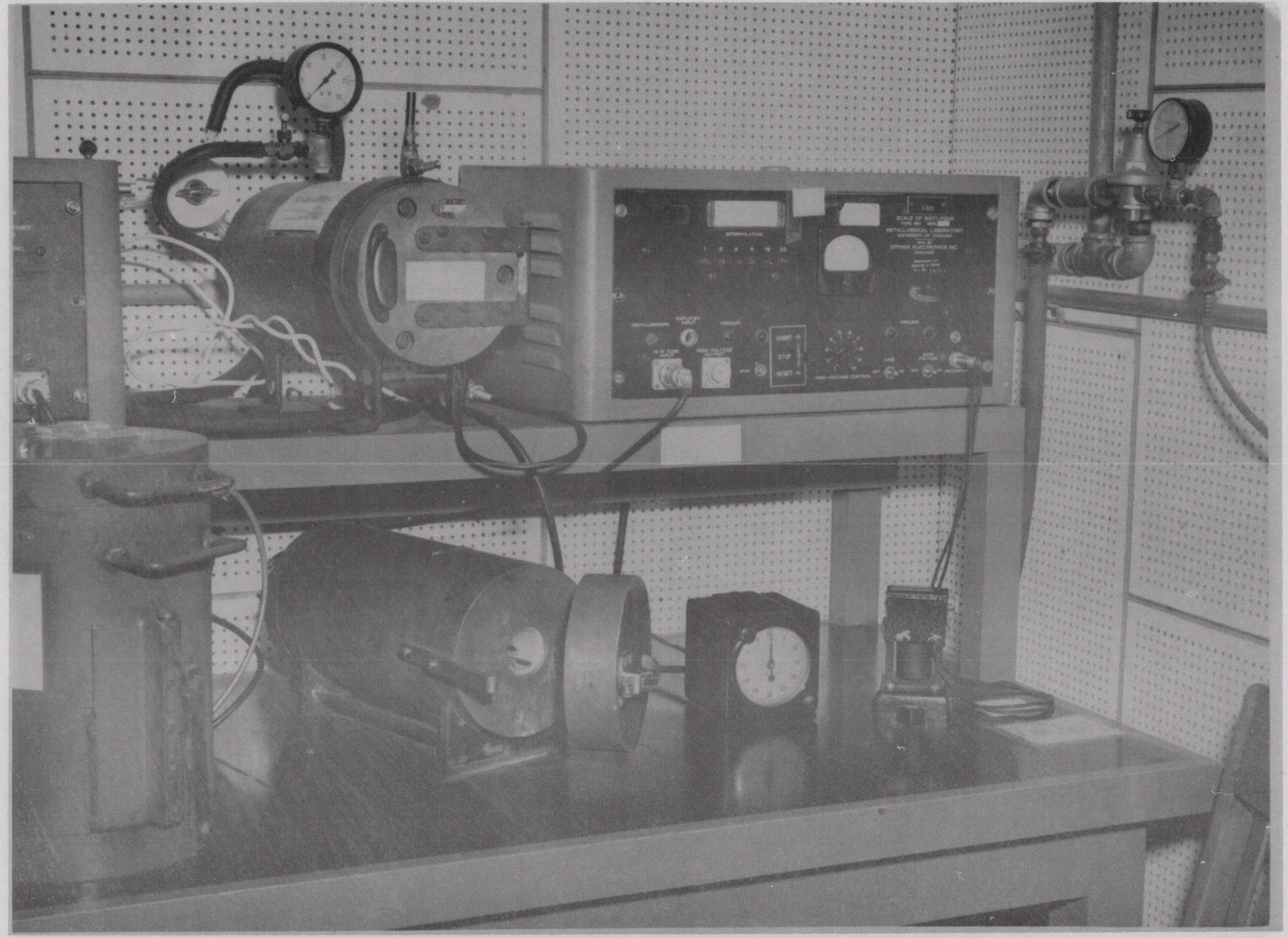
ALPHA AMPLIFIER FOR OFFNER SCALER

SCALER

The "Scaler" is an electronic circuit designed to receive pulses from a Geiger, or other counter device, at a rapid rate and scale them down or divide the total number received by a fixed or easily selected divisor, so that the total pulses rate at the output of the Scaler will be a known fraction of the input. It may readily be seen then, that by driving a mechanical register from the output of a scaler with a properly selected ratio of input to output, the combination will register accurately pulses arriving at such a rapid rate that the mechanical register alone would be jammed and totally incapable of recording them.

Scalers used at Oak Ridge National Laboratory usually consist of three, five, six, or seven scale of two stages cascaded into each other to give scale factors of 8, 32, 64, or 128 respectively. The Scaler stages usually consist of two triode tubes arranged in a "flip-flop" circuit such that a pulse causes one tube to conduct, blocking the second tube. The next pulse will make the second tube conduct and pass a pulse along to the next stage and at the same time block the first tube making it ready to take the next pulse. Thus the process continues, each scaler stage passing along to the following stage each second pulse that it receives. Scalers are multi-tube devices themselves and so they nearly always have a high voltage supply for the Geiger tube and other auxiliary circuits contained in the same chassis. They are usually rather heavy and bulky and not very well adapted to portable use.

There is a variety of scalers produced commercially at the present time.


COUNT
STOP
RESET

EQUIPMENT AND PROCEDURE FOR PROCESSING AIR AND SMEAR SAMPLES

This section is concerned with the equipment needed in a counting room (air and smear samples) and the steps in processing samples.

Equipment Needed for Processing Air and Smear Samples for Alpha, Beta and Gamma

I. Air Samples

A. Beta, Gamma

1. Scaler (scale of 64) Obtained commercially from I.D.L., Tracer Lab.,etc.
2. Wizard Recorder (230V DC - Production Instrument Co., Chicago, Illinois
3. Timer - Standard Electric Time Company, Springfield, Mass.
4. G.M. tube (7" sensitive area) Oak Ridge National Laboratory
5. Lead shield - cylindrical
6. Cylinder for inserting and removing G.M. tube from lead shield - Oak Ridge National Laboratory.
7. Plastic cylindrical sample holder - Oak Ridge National Laboratory

B. Alpha

1. Alpha counter of good design
2. Alpha ionization chamber - Oak Ridge National Laboratory
3. Cathode - Ray Oscillograph - Allen B. DuMont Laboratories, Passaic, N.J.
4. Cyclotron recorder - Cyclotron Specialties Company, Moraga, Cal.
5. Timer (see above #3)

II. Disc Samples

A. Beta, Gamma

1. Scaler (see #1 under air samples - Beta, Gamma)
2. Wizard Recorder (see above)
3. Timer (see above)
4. Micro-window G.M. tube - Oak Ridge National Laboratory

5. Vertical lead chamber - Oak Ridge National Laboratory

6. Plastic sample holder - Oak Ridge National Laboratory

7. Set of Al absorbers - Oak Ridge National Laboratory

   Range of 10 to 1600 mg/cm^2, with step ups of 20 mg/cm^2.

B. Alpha

1. Alpha counter of good design (see above)

2. Alpha ionization chamber - parallel plate type - Oak Ridge National Laboratory

3. Cathode - Ray Oscillograph (see above)

4. Cyclotron recorder (see above)

5. Timer (see above)

If precision counting of samples with low counting rate is desirable, would suggest an instrument that makes counting for a predetermined number of counts easy and practical. Several companies make such an instrument - Tracer Lab., I.D.L., Auto Scaler, etc.

The Simpson type counter seems to work well for counting disc samples for alpha. An oscillograph is not needed with this type counter.

COUNTING OF AIR SAMPLES

Air samples are submitted to the Health Physics Counting Room still inside the aluminum sample holder, wrapped in a standardized form (B-1133), with thorough identification and with services desired clearly indicated. (See services available at Health Physics Counting Room).

The Counter Operator, using tweezers, removes the foil sample from the aluminum sample holder and inserts it in the horizontal lead cylindrical chamber, carefully adjusting it with relation to the seven inch sensitive portion of the long size G.M. tube inside.

The operator proceeds to take a beta - gamma count as follows: clears interpolater lights on scaler, zeros Wizard recorder, zero-setts clock, turns switch to "operate" position, and counts for a total count of at least 500 counts (this will limit Probable Error to approximately $\pm$ 3% provided the sample counting rate is 5 x background counting rate), stops count on the minute. The operator computes the count by: multiplying Wizard recorder results by scaling factor, add scaler interpolation, divide by counting period in minutes, and subtract background.

Then the operator converts the results in counts per minute to μ curies per sample by substituting in the following formula:

(1)* μ curies/sample = $2.17 \times c/m \times 10^{-6}$

In order to determine the long-lived, C_{LL}, beta-gamma activity, the operator takes a second count (in the same manner as described above) after a time interval of $>$ 20 hours and substitutes in the following formula:

(2)** $C_{LL} = \dfrac{C_2 - C_1 T}{1 - T}$

This will be the long-lived beta - gamma activity in counts per minute. Substitute in (1) to convert to μ curies per sample.

To determine the alpha activity, the operator places the foil sample in the alpha ionization chamber which is cylindrical in shape and hangs vertically from a metal elbow mounted to the top of the case of the California-type scaler.[1]

The operator clears the interpolator, zero sets clock, records on work sheet the reading on the cyclotron recorder, turns switch to "operate" position, and counts for a total count of at least 500 counts, and stops count on the minute. The operator computes the count by: subtract reading previously taken from cyclotron recorder from reading on cyclotron recorder at the end of the count, multiply by scaling factor, add scaler interpolation, divide by counting period in minutes, and subtract background.

This result, in counts per minute, is converted to μ curies per sample by substituting in the following formula:

(3)* μ curies/sample = $.9 \times c/m \times 10^{-6}$

To determine the long-lived, C_{LL}, alpha activity the operator takes another count, called C_1, four hours later (in same manner as described above) and another count, called C_2, at least 16 hours after C_1 was taken (in same manner as described above) and substitutes in (2).

This will be the long-lived alpha activity in counts per minute. Substitute in (3) to convert to μ curies per sample.

NOTE: [1]This is the type scaler used at Oak Ridge National Laboratories.

DISC SAMPLES

Disc samples submitted to the Health Physics Counting Room must be less than 2 inches in diameter with contamination on one side only. Generally, disc samples submitted to the counting room are either isotope carrier smears or room smears on No. 50 filter paper discs approximately 1 3/4 inches in diameter.

Upon receiving a disc sample the counter operator, handling it with tweezers, places it in a plastic sample holder, contaminated side up and fits the holder containing the sample into one of the four shelves (usually the second shelf) found inside the vertical lead chamber that houses the micro-window tube.

The operator closes the door of the lead chamber and proceeds with beta-gamma count as follows: clears interpolater lights on scaler, zeros Wizard recorder, zero-sets clock, turns switch to "operate" position, counts for a specific number of counts if a count to a specified per cent of probable error has been requested, and stops count on the minute.

The operator computes the count by: multiply Wizard recorder results by scaling factor, add scaler interpolation, divide by counting period in minutes, subtract background.

This result is in counts per minute at the shelf geometry which varies slightly with each micro-window tube. The operator converts this result to counts per minute at 10% geometry and reports results in this form to the requestor, unless the requestor has specified that he desires the result in μ curies per sample.

If it has been specified that results are desired in μ curies per sample, the operator converts the result in counts per minute at 10% geometry to μ curies per sample by substituting in the following formula:

(4)* μ curies/sample = $4.5 \times c/m \times 10^{-6}$

To determine the alpha activity on a disc sample, the operator places the sample inside the alpha ionization chamber, parallel plate type, which is cylindrical in shape and hangs vertically from a metal elbow mounted to the top of the case of the California-type scaler.

The operator clears the interpolator, zero-sets the clock, records on work sheet the reading on the cyclotron recorder, turns switch to "operate" position, counts for a specific number of counts if a count to a specified per cent of probable error has been requested, and stops count on the minute. The operator computes the count by: subtract reading previously taken from cyclotron recorder from reading on cyclotron recorder at the end of the count, multiply by scaling factor, add scaler interpolation, divide by counting period in minutes, and subtract background.

The result is in counts per minute at 52% geometry and it is reported to the requestor in this form unless the requestor has specified that he desires the result in μ curies per sample. If it has been specified that results are desired in μ curies per sample, the operator converts the result in counts per minute at 52% geometry to μ curies per sample by substituting in the following formula:

(5)* μ curies/sample = $.88 \times c/m \times 10^{-6}$

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* Formulae taken from report, "Determination of Particulate Airborne Long-Lived Activity", by G. Koval to K.Z. Morgan, dated 6-22-45 and simplified in this manner:

$$\mu \text{ curies/sample} = \frac{c/m}{\underset{\text{(called 1)}}{\text{Counter Eff.}} \times \underset{\text{(varied with type counter)}}{\text{Counter Geom.}} \times \underset{\text{(d/sec/curie)}}{3.7 \times 10^{10}} \times \underset{\text{(sec/min convert to min)}}{60} \times \underset{\text{(convert to } \mu \text{ curies)}}{10^{-6}}}$$

$$= \frac{c/m}{\text{Geom} \times 2.2 \times 10^{12} \times 10^{-6}} = \frac{1}{\text{Geom.} \times 2.2} \times c/m \times 10^{-6}$$

Geometry of Alpha Counter (cylinder)------------50%

Geometry of Beta-gamma Counter (cylinder)-------21%

Geometry of Alpha Counter (disc)----------------52%

Geometry of Beta-gamma Counter (disc)-----------10% (regardless of the shelf used of the geometry of that shelf - conversion always made to 10%)

**Formula taken from same report as (*)

C_{LL} = count due to long-lived activity (as used here long-lived activity means any activity that has a half-life greater than the radon and thoron decay products normally found in the atmosphere)

C_1 = first count

C_2 = second count (at least 16 hours after C_1; 24 hours is convenient time lapse)

$T = e^{-\lambda \Delta t}$ where $\lambda = .0655$ (from half-life of Thorium B)

$\Delta t = t_2 - t_1$ in hours

Catalogue of Services Available at Health Physics Counting Room, Oak Ridge National Laboratories

The following counting services are available at the H. P. Counting Room, Oak Ridge National Laboratories. These services are catalogued by number and use of these numbers will be explained in subsequent paragraphs. The services offered are as follows:

I. Immediate Alpha Count (Cylinder)

II. Long-life Alpha Count (Cylinder)

III. Immediate Alpha Count (Disc)

IV. Decay Curve of Alpha Activity (Cylinder)

V. Immediate Beta Count (Cylinder)

VI. Long-life Beta Count (Cylinder)

VII. Immediate Beta Count (Disc)

VIII. Decay Curve of Beta Activity (Cylinder)

IX. Decay Curve of Beta Activity (Disc)

X. Beta Count of Radioactive Gas

XI. Beta Decay Curve of Radioactive Gas

XII. Gamma Count of a Liquid Sample

The following is a more detailed description of the kind of radiation to be measured, form of sample to be submitted, results to be reported, and probable errors to be ascertained.

I. *Immediate Alpha Count (Cylinder)

Alpha counting of activity deposited within a cylinder of maximum outside diameter of $1\frac{1}{2}$" and maximum length of 7". Report will indicate μ curies at the time the sample is first counted. Probable error $\pm$ 3% unless otherwise requested.

II. Long-lived Alpha Count (Cylinder)

Alpha counting of activity deposited within a cylinder of maximum outside diameter of $1\frac{1}{2}$" and maximum length of 7". Report will indicate μ curies of long-lived activity excluding Radon and Thoron decay products by computing

$$C = \frac{C_2 - C_1 \epsilon^{-.0655\,(t_2 - t_1)}}{1 - \epsilon^{-.0655\,(t_2 - t_1)}} \qquad \text{for}$$

two counts where $t_1 > 4$ hrs. Probable counting error $\pm$ 3% unless otherwise requested.

III. *Immediate Alpha Count (Disc)

Alpha counting of activity deposited on a flat disc $\leq 1\frac{1}{2}$" diameter, activity on one surface only. Report will indicate μ curies at the time the sample is first counted. Probable error $\pm$ 3% unless otherwise requested.

IV. Decay Curve of Alpha Activity (Cylinder)

The report will be a semi-log graph and table of values of the decay of the activity in μ curies vs. time of activity deposited within a cylinder of maximum outside diameter of 1½" and maximum length of 7". The period to be covered by the decay data and the frequency of counting are to be specified by the requestor. Probable counting error ± 3% unless otherwise requested.

V. *Immediate Beta Count (Cylinder)

Beta counting of activity deposited within a cylinder of maximum outside diameter of 1½" and maximum length of 7". This is Beta counting of activity that will penetrate .007" of aluminum. Report will indicate μ curies at the time the sample is first counted. Probable counting error ± 3% unless otherwise requested.

VI. Long-Lived Beta Count (Cylinder)

Beta counting of activity deposited within a cylinder of maximum outside diameter of $1\frac{1}{2}$" and maximum length of 7". This is Beta counting of activity that will penetrate .007" of aluminum. Report will indicate µ curies of long-lived Beta activity excluding Radon and Thoron decay products by computing

$$C = \frac{C_2 - C_1 \epsilon^{-.0655 (t_2 - t_1)}}{1 - \epsilon^{-.0655 (t_2 - t_1)}}$$

For two counts were $t_1 > 4$ hrs. Probable counting error ± 3% unless otherwise requested.

VII. *Immediate Beta Count (Disc)

Beta counting of activity deposited on a flat disc $< 1\frac{1}{2}$" in diameter, activity on one surface only. This is beta counting of activity that will penetrate a window thickness of 3.8 m gm cm^2. This service will include flat mud samples in dishes. Report will indicate µ curies at the time the sample is first counted. Probable counting error ± 3% unless otherwise requested.

VIII. Decay Curve of Beta Activity (Cylinder)

The report will be a semi-log graph and table of values of the decay of the activity in μ curies vs. time of activity deposited within a cylinder of maximum outside diameter of $1\frac{1}{2}$" and maximum length of 7". The period to be covered by the decay data and the frequency of counting are to be specified by the requestor. Probable counting error $\pm$3% unless otherwise requested.

IX. Decay Curve of Beta Activity (Disc)

This report will be a semi-log graph and table of values of the decay of the activity in μ curies vs. time of activity deposited on a flat disc 1" in diameter. Activity to be on one surface only. The period to be covered by the decay data and the frequency of counting are to be specified by the requestor. Probable counting error $\pm$ 3% unless otherwise requested.

X. Beta Count of Radioactive Gas

Beta counting of radioactive gas. Sample to be submitted in a gas tight container of volume $>$ 700 cc. with provisions for connecting a small rubber tube. Evacuated cylinders for collecting gas samples are available. (For Cylinders, contact H. P. Counting Supervisor). The report will indicate μ curies per cc of gas collected. Probable counting error $\pm$ 3% unless otherwise requested.

XI. Beta Decay Curve of Radioactive Gas

Beta counting as in number X above except result will be a semi-log graph and table of values of the decay of activity in μ curies per cc vs. time. The period of activity covered by the decay data and the frequency of counting are to be specified by the requestor.

XII. Gamma Count of a Liquid Sample

Not less than five gallons of a sample should be submitted in easy pouring containers. Report to indicate mr/hr at a point in an infinate volume of the liquid counted. (Counting to be two vessel method as described in CH-2565.). Probable counting error ± 3% unless otherwise requested.

XIII. Decay Curve of Alpha Activity (Disc)

The report will be a semi-log graph and table of values of the decay of the activity in μ curies vs. time of activity deposited on a flat disc ≤ 1½" diameter, activity on one surface only. The period to be covered by the decay data and the frequency of counting are to be specified by the requestor. Probable counting error ± 3% unless otherwise requested.

XIV. Absorption Curve of Beta Activity (Disc)

The report will be a semi-log graph and table of values of the absorption of the beta activity in counts per minute vs. mg/cm^2 Al activity deposited on a flat disc ≤ 1½" diameter, activity on one surface only. Probable error ±3% unless otherwise requested.

*Immediate count indicates that sample will be counted within 30 minutes after receipt of sample. Samples arriving on 4-12 and/or 12-8 shifts or on Saturdays, Sundays, or holidays will be counted on the next regular work day.

The following information given in order as shown below should accompany each sample:

1. Data and time sample taken
2. Requestor's name, address and telephone number
3. Catalogue number of types of service requested
4. Remarks (if any)

In submitting samples every precaution should be taken to prevent spread of contamination. Where practical, samples should be wrapped to prevent loss of radioactive material, but not so that the wrapping can erode away the specimen.

The standardized values for Probable Error will be ± 3%. However, if the nature of the work permits a greater Probable Error, we would greatly appreciate the requestor stating the permissible Probable Error under "Remarks" on the sample sheet. Also, if due to nature of the work, a smaller Probable Error is desired then the requestor should state that information under "Remarks" on the sample sheet.

Due to present facilities, only a minimum number of beta decay curves of radioactive gas can be obtained. For special problems concerning counting and counting operations consult the Health Physics Counting Supervisor.