UNIVERSITY OF CALIFORNIA — BERKELEY

RADIATION LABORATORY

DISCLAIMER

UCRL-2033 Rev.
Unclassified-Instrumentation Distribution

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

Contract No. W-7405-eng-48

INSTRUCTION MANUAL FOR DC PORTABLE VAPOR DETECTOR MODEL 3EPS

C. S. Presenz

June 1, 1953

Berkeley, California

INSTRUCTION MANUAL FOR DC PORTABLE VAPOR DETECTOR MODEL 3EPS

C. S. Presenz

Radiation Laboratory, Department of Physics
University of California, Berkeley, California

June 1, 1953

INTRODUCTION

Although mercury or quicksilver (Hg) has been used in one form or another for a great many years, only recently have industry and the research laboratory discovered the dangers of its vapor. The present consumption of this element not only exposes personnel to vapor poisoning but also involves management in untold expense created by costly apparatus contamination. With the general recognition of these facts it is obvious and imperative, from a point of view of safety and economy, that some dependable form of monitoring equipment be utilized.

Mercury vapor detection equipment in general use at the present time is based either on chemical or spectrum absorption principles.

Chemical absorption equipment, initially economical, suffers by its somewhat crude calibration and slow integration method of operation. Although accepted as a positive means of detection, this system measures only the accumulated effect of vapors penetrating an area, rather than the intensity of vapor at the instant.

Spectrum absorption equipment, being complicated in design, is considerably more expensive from an original cost viewpoint. In justification, however, this equipment provides a continuous monitoring action, and alerts an area to the immediate presence of mercury vapor. Likewise the instrument will show when the vicinity is free from contamination.

It is easy to see, the spectrum absorption method is to be desired inasmuch as it reveals the conditions at the moment rather than the hazards of the past.

Although the principle of spectrum absorption is generally considered superior, detection equipment based on it has frequently lacked many desirable features. Undoubtedly, as the result of minimum consumer demand, important and useful characteristics such as stability, portability, resolving time and normal working habit interference, have been neglected.

The problem was faced by the Radiation Laboratory, and as an outcome, an a.c. operated Portable Vapor Detector, Model 1EPS, came into being. The unit featured accuracy, sensitivity and area protection to a degree greatly exceeding demands. The instrument also incorporated an audio alarm circuit which eliminated the need for constant supervision by the operator. Since portability had been a prime factor in the design, the finished product was unsuited for continuous, 24 hour a day operation.

With constant duty in mind, a new design effort produced an a.c. Rack Mounted Vapor Detector, Model 2EPS. Contained in this unit are all the favorable points of the previous model with the exception of portability. In addition, Model 2EPS has greater mechanical and electrical stability, plus the added feature of automatic starting of the ultra-violet light source.

Upon completion of Model 2EPS, operators in the field expressed a strong desire for a portable detector which would be completely self-contained. Model 1EPS, it turned out, suffered from a serious disadvantage; namely, the manner in which the unit derived its power. Naturally, as an a.c. unit, it depended on the use of a power cord which created the following irritations:

1. The necessity of locating an a.c. outlet.
2. A restricted radius of operation because of the limited length of cable.
3. The winding and unwinding of cable with the consequent wear and raveling and exposure to dirt and possible contamination.

Since a self-contained portable unit necessitated the use of a battery or batteries for power, the project was studied and broken down into several interesting problems. The design request contained factors such as:

1. Equality of performance with previous models.
2. Minimum power drain.
3. Minimum weight.
4. A filter system which would allow the standardization of the detector to a fresh air base level when used in a contaminated area.

These criteria have been met in a practical manner with the manufacture of the D. C. Portable Vapor Detector, Model 3EPS, shown in Fig. 1.

THEORY OF OPERATION

All substances absorb light at some region of the spectrum. If a spectral region exists where a vapor has a high absorption and the diluent a high transmission, the concentration of the vapor can be measured in terms of light absorbed. The operation of this instrument is based on the Beer-Lambert law which states: "Light absorption depends on the distance traversed and the molar concentration of the light absorbent."

The Model 3EPS is specifically intended for use with vapors having a strong absorption in the 2537 Angstrom region of the spectrum.

The Vapor Detector is based on quantitative, not qualitative measurements and should not be considered in any sense an analytical type instrument. The unit reacts to vapors listed in the following section.

Since the prime purpose of the instrument is the detection of Hg vapor, to avoid confusion in what follows all reference, unless otherwise stated, will be based on Hg vapor concentrations.

DETECTABLE VAPORS

The Vapor Detector is sensitive to vapors of substances, listed below, in a descending order of magnitude.

Positive Deflection	Moderate Deflection	Slight Deflection
Isopropyl ether	Naptha	Carbon Tetrachloride
Tetraethyl lead	Xylene	Nitromethane
Pyridine	Benzyl alcohol	Tetraethyl gasoline
Benzene	Aniline	Dichloro benzene
Mercury*		T-butyl hydropentoxide
Diethyl acetal		Butyl bromide
Acetone		Carbolic acid
Toluene		Tetralin
Illuminating Gas		Turpentine

* See Fig. 2, for calibrated curve.

While undertaking vapor measurements in the field, extreme precautions should be taken to see the following conditions do not exist. If they are present, the operator should be cognizant of the fact inasmuch as this matter could have an appreciable effect upon vapor measurements being attempted. The conditions are the presence of:

Smoke
Dust
Fog
Ozone

TECHNICAL SUMMARY

Battery Complement

1	6 volt 40 ampere/hour Wet Cell	Willard ER-40-6

Tube Complement

1	Bridge Tube	RCA 5963
2	Photo Tube	RCA 935
1	Audio Control Tube	6C4
1	Germicidal Lamp 4W	GE-4 T 4/1

Vibrator Complement

1	6 volt Vibrator	Mallory 743

Filter Attachment

1	Hg Absorbing Filter	M. S. A. CR-40397

Mechanical Characteristics

Height	15 inches (Including Handle)
Depth	16 inches
Width	9 inches
Weight	37 pounds

Operational Characteristics

Fully Charged Battery (1270 Sp. Gr.)	14 Hours Cont. Operation
Allowable Unit Tilt	145 degrees max. recommended

Range Sensitivities - Metered and Audio Alarm

XI	Calibrated for Hg Vapor	0-3.2 mg./cu. Meter, (78 percent F.S.)
XI0	Calibrated for Hg Vapor	0-.1 mg./cu. Meter (F.S.)

GENERAL DESCRIPTION

A schematic diagram of the D. C. Portable Vapor Detector, Model 3EPS is given in Figure 7 and a photograph of the instrument in Figure 1.

Basic operation of the unit is centered around a 2537 Angstrom ultra-violet light source which controls a dual photocell balanced bridge circuit as shown in Figure 3. Since a mercury arc light source lacks stability, two phototubes are used. Phototube V4 acts as a standard; its function is to see the same source fluctuations in light intensity as V5 in the vapor sampling leg of the bridge. V4 being physically closer to the ultra-violet source requires the use of an iris to attenuate the light to the level of intensity as seen by V5. Presuming the bridge to be in a balanced state, the flow of an absorption type vapor into the sampling chamber will retard the light being sampled by V5 and cause an electrical unbalance. A VTVM circuit is used to measure the amount of this unbalance, and the net result can then be seen on the instrument meter, (the readings of which are a direct function of light absorbed in the sampling chamber).

RANGE SWITCH (C), Ref Fig. 4 — OFF - V - XI - XI0

A selector switch marked RANGE is provided with designations which perform the following functions:

OFF	Battery Disconnected
V (Green)	Battery Check
XI	Normal Sensitivity - (0-3.2 Milligrams Hg per cubic meter) (3.2 milligrams equals 78 percent of Full Scale, and is designated by the letters Hg on scale)

XI0 Ultra-Sensitivity - (0-0.1 milligrams Hg per cubic meter) (0.1 milligrams equals full scale deflection)

AUDIO ALARM, Ref. Fig. 4

The audio alarm may be adjusted to function at any portion of the meter scale by simply setting the knurled knob index adjustment (F) at the level desired. The accuracy of the contact mechanism is within plus or minus 1 percent.

NEON INDICATOR, Ref. Fig. 4

The neon acts as a high voltage indicator. When it is glowing the instrument will be operating in either the XI, or XI0 range.

CALIBRATE PUSH BUTTON, Ref. Fig. 4

The red push button (A) is used for calibrating the full scale deflection of the microammeter to the total absorption of the chamber light. This is used in conjunction with the adjustment knob marked CAL (B).

ZERO ADJUSTMENT, Ref. Fig. 4

The control marked ZERO (D) is used to null the microammeter which indicates a balanced condition of the REFERENCE and VAPOR SAMPLING legs of the bridge circuit.

OPERATION, Ref. Fig. 4

When placing the Vapor Detector in operation, first establish the condition of the battery. This is done by rotating RANGE switch (C) to V (Green letter). If the microammeter does not read within the GREEN AREA of the microammeter scale the detector should not be used, because the specific gravity of the battery is too low. This condition will make the unit either inoperative or erratic. Since the battery checking position while measuring the specific gravity places a heavy drain on the battery, care should be exercised not to prolong the test. Assuming the battery is charged, the RANGE switch (C) should be rotated to the XI position. The neon indicator (E) will then glow, signifying the presence of high voltage to the unit. It should be noted, unless this indicator lamp is energized the instrument will not function.

With the lamp lit, the unit should be allowed to run for approximately 5 minutes to allow the G - 4 T 4/1 U. V. lamp to gain some order of stability. Following this warm-up period the ZERO control (D) should be set for the bridge null (zero deflection of the microammeter). Following this adjustment depress the CAL pushbutton (A) and rotate CAL control (B) (Red lettering) until the microammeter reads full scale (100 on meter scale).

It is advisable to repeat the ZERO set and full scale CALIBRATE adjustments before using instrument. With these preliminary adjustments completed, the Vapor Detector is ready for vapor measurements.

CAUTION

If stored in a cold area do not use detector until the vapor sampling chamber has approximated operational ambient temperature.

If this precaution is not adhered to, condensation of Hg vapor may take place, thus contaminating the sampling chamber which in turn will produce inaccurate results.

IMPORTANT NOTE

All line up procedure must be done with range switch in XI position. When range switch is in XI0 position it is impossible to calibrate the detector.

The CAL button is intentionally bridged in the XI0 position to avoid damage to the microammeter movement.

CIRCUIT ANALYSIS AND MAINTENANCE

BATTERY

A 6 volt battery is used at the primary source of power for the detector, and when fully charged (1270 specific gravity) approximately 14 hours of continuous unit operation may be expected. The battery (Willard Type ER 40-6) is enclosed in a polystyrene NON-SPILL type container, with Fibrite plate insulation and built in specific gravity indicators. The detector is furnished with two fully charged batteries. Recommended normal practice will employ one battery in service while the other is being recharged. With system of battery alternation (one in service/one charging) the detector will be able to operate continuously (8 hours a day) without interruption.

The maximum and recommended standard rate of charge is 4 amperes. Owing to the aging properties of the specific gravity floats in the battery, it is advisable to ignore them completely and make electrolyte readings with an approved type battery hydrometer.

CAUTION

Replace evaporated battery water when required, and do not fill above level line on battery.

Although not recommended, the battery may be turned upside down without acid spillage.

VIBRATOR POWER SUPPLY, Ref. Fig. 5

This is a standard type synchronous vibrator power supply, and should not require further circuit discussion. A low frequency filter system is not used, since the ripple does not interfere with the operation of the associated detector circuits. If a slight jitter in the d. c. high voltage is observed it should be overlooked, for it appears to be an inherent characteristic of the vibrator, and is probably caused by the frequency hunting of the vibrating reed. The effect of the jitter is in the order of .5 percent of the micro-ammeter scale, and has no practical bearing on the accuracy of the measurements. For vibrator replacement data see "Technical Summary".

SAMPLING CHAMBER AND BLOWER ASSEMBLY, Ref. Fig. 6

Bakelite is used throughout the sectionalized construction of the vapor chamber/blower assembly for reasons of economy and weight. Every effort has been made to provide ease of adjustment and maintenance accessibility. The assembly encompasses a vapor sampling chamber, also the physical relationship of the ultra-violet light source with respect to the standard and the sampling phototube legs of the bridge circuit. Placed between the ultra-violet tube and the standard phototube is a built-in adjustable spring loaded iris. The structure also houses a centrifugal blower which is powered by a permanent magnet field blower motor (Diehl FD 6-27-2 armature voltage 12 volts d. c.). Although operated at 6 volts, the motor performs with satisfactory torque and speed for the application. The motor is bracket mounted to the chamber assembly and should be handled with care in order to preserve alignment. The chamber tube portion of the assembly is provided with optical quartz windows at each end, together with a set of neoprene gaskets which give a positive vapor seal. If at any time the chamber becomes contaminated, the tube section may easily be removed and replaced with a similar section of black bakelite tubing. If it is considered necessary to disassemble the chamber, care must be taken to replace the 6 baffle rings in the positions indicated in reference drawing. The rings are vital factors affecting both calibration and resolving time characteristics, the matter of correct placement should not be overlooked.

AUDIO ALARM

In order to reduce wear of the switching section in the indicating control meter movement to a bare minimum, a thyratron circuit has been incorporated to actuate a bell.

The circuit is conventional, and should not require further comment.

MICROAMMETER, Ref. Fig. 4

The Weston Model 1087, Contact Making Instrument (G), is not only an indicating device but also a means of circuit control. The movement is rated at 50 microamperes full scale, and is provided with an arbitrary calibration from 0-100 divisions. Accuracy of the indicating and contact portions of the instrument are plus or minus 1 percent of full scale. Contact accuracy preservation is directly dependent upon the care with which the index is set. Index control (F) is mounted on body of the case in the lower right corner.

When the detector is not set up for audio alarm operation, always set index to the right extremity (100 on scale).

This habit is necessary because the index position governs the maximum sweep of the meter pointer.

SCALE INSCRIPTIONS

With RANGE switch in XI position the letter T, inscribed opposite division 11 of meter scale, signifies the maximum Hg toxicity permitted in areas containing personnel.

With RANGE switch in XI position the letters Hg, inscribed opposite division 86 of meter scale, indicate the reading to be expected when calibrating the detector to the mercury standard, as outlined in the section entitled "Calibration".

With the RANGE switch in the V position, the green area of the meter is used for battery checking purposes. When the pointer reads within the green area the specific gravity may be considered sufficient for accurate and stable operation of the detector.

CAUTION:

This instrument is expensive - use operational, and maintenance techniques appropriate to apparatus of this type.

FILTER ATTACHMENT

A special filter accessory (MSA-Mersorb Respirator Cartridge) is supplied which allows the detector to be standardized to fresh air. The cartridge is housed in a two piece threaded container which is equipped with a sampling aperture and sampling hose nipple. If Hg contamination is suspected in the operating area, an ABSOLUTE ZERO CHECK (the filter absorbs Hg vapors) may be made by fitting the filter accessory to end of the sample hose.

CAUTION:

Since the filter cartridge absorbs Hg vapor, store units in vapor free atmosphere. Filter life is dependent on usage and may be readily established according to specific operating procedure.

BRIDGE CIRCUIT, Ref. Fig. 7 and Ref. Fig. 4

A standard Bridge type vacuum tube volt-meter circuit is used for quantitative measurements. If at any time it is necessary to replace the 5963 bridge tube, attention should be paid to the selection of balanced characteristics for each triode section. Bridge unbalance is measured in the cathode circuit. The Calibrate pushbutton (A), (Red) is used to calibrate the microammeter for maximum deflection. This is accomplished by setting RANGE switch (C) to XI sensitivity and adjusting Cal. Control (B), (Red index). The zero control, (D), of course, is used previously to zeroize the instrument correctly. Correct sequence is listed in the section entitled "Operation".

CALIBRATION OF XI AND XI0 RANGES, Ref. Fig. 4

Hg CALIBRATION XI

Hg calibration of the XI sensitivity range is not necessary under normal operating conditions. If an accuracy check is desired, the instrument should be placed in an area where the air is fresh and devoid of contaminating vapors, smoke, etc. A small, stoppered flask of Hg (temperature to be at twenty degrees centigrade), with neck of sufficient diameter to allow convenient insertion of the rubber sampling hose, should be readied. After routine adjustments (Zero and Full Scale Cal.) have been made, the actual Hg calibration on XI range may be performed. Upon releasing the stopper, the sampling hose should be held within one quarter inch of Hg surface. Following this procedure a reading of 86 (plus or minus one percent movement accuracy) should result. Do not allow the sampling hose to touch the Hg. If this is permitted a contaminated hose results, causing inaccurate measurements. In case of accidental contamination, the affected portion of the hose should be destroyed.

IRIS

The IRIS assembly is adjusted when the unit is tested. When the IRIS is correctly set, and with Range Switch on XI Scale, the ZERO knob should cause the meter needle to vary from below zero to above 10th division on meter scale, after 10 minute warm up period.

If the unit has not been in operation for some time, it may take more than 10 minutes before the ZERO control knob will operate normally.

CALIBRATION XI0, Ref. Fig. 4

Since the XI0 range is a sensitivity multiplier, no Hg calibration methods are necessary. Following routine adjustments (zero and full scale calibration, with the range switch in XI position), rotate Zero control (D) clockwise until the microammeter indicates a deflection of exactly ten divisions. Change Range switch to XI0 position, and a full scale deflection of the meter should result. If this reaction does not occur, rotate screwdrive - adjust R15 (marked XI0 calibration on chassis) to obtain it. Upon completion of XI0 sensitivity calibration, the RANGE switch should be restored to XI range and the microammeter restored to zero deflection.

STABILITY

Routine Checks

For routine checks the Vapor Detector should be subjected to a 10 minute warm-up period. This allows the U.V. G 4 T 4/1 and associated tubes to approach working stability. The unit may be put into service prior to this time; however, frequent adjustments of Zero and Calibration controls will be required due to the drift during the warm-up time.

FURTHER MODEL DEVELOPMENT

At the time of writing, an A.C. Combination Portable and Laboratory Vapor Detector, Model 4EPS is nearing completion. It incorporates all the refinements of the previous instruments as applicable for a.c. usage. This unit will make Model 1EPS obsolete. Drawings for Model 4EPS are as yet unassigned.

ACKNOWLEDGMENTS

An expression of thanks is directed to the following people for their cooperative efforts:

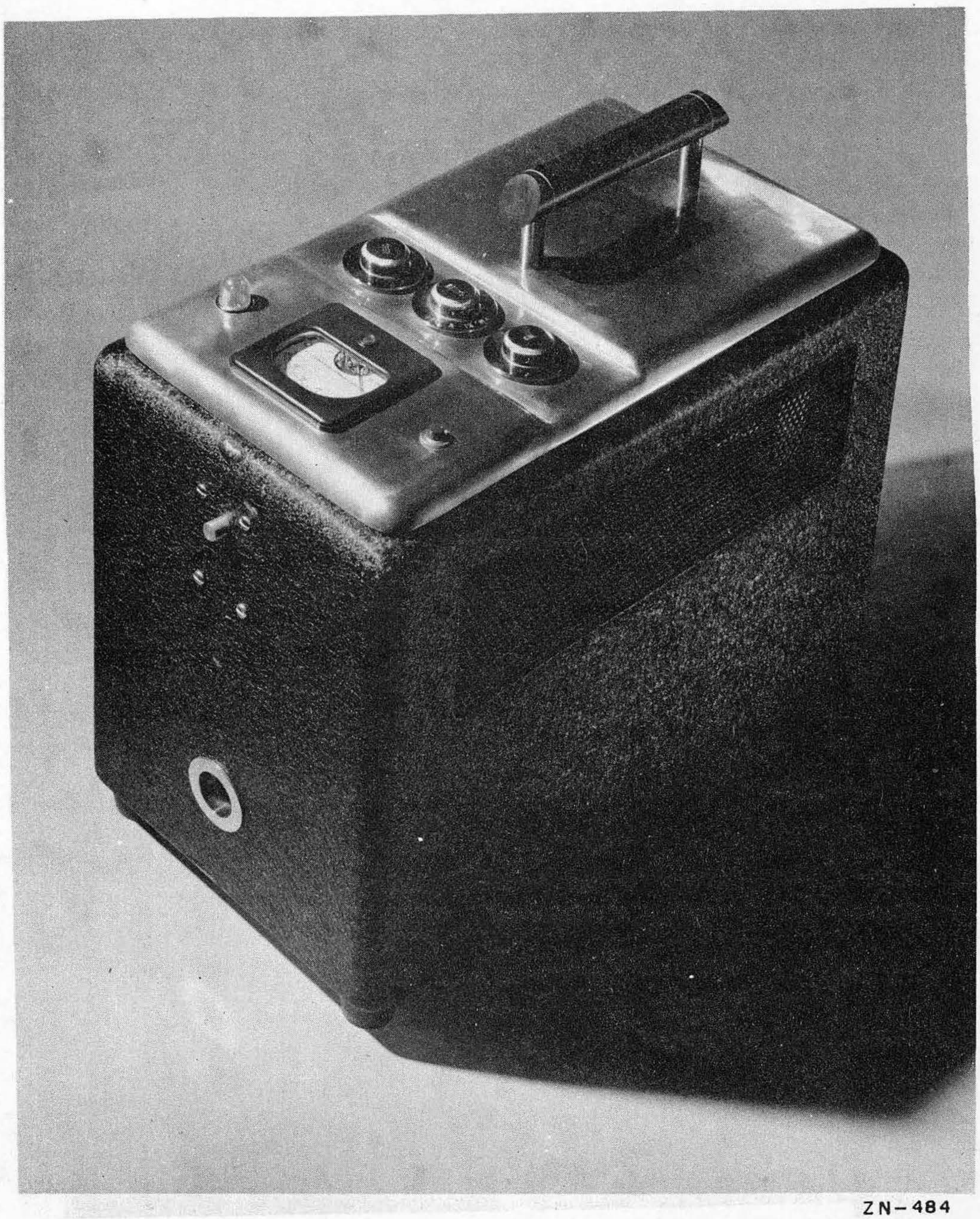
H. Gilbert	A.E.C. Safety Division, Washington, D.C.
L. L. Kelly	A.E.C. Safety Division, San Francisco
M. E. Thaxter	U.C.R.L. Health Chemistry Department
Entire Group	U.C.R.L. Electronic Production Department

REFERENCES

Cross reference of models and University of California, Radiation Laboratory Drawing numbers:

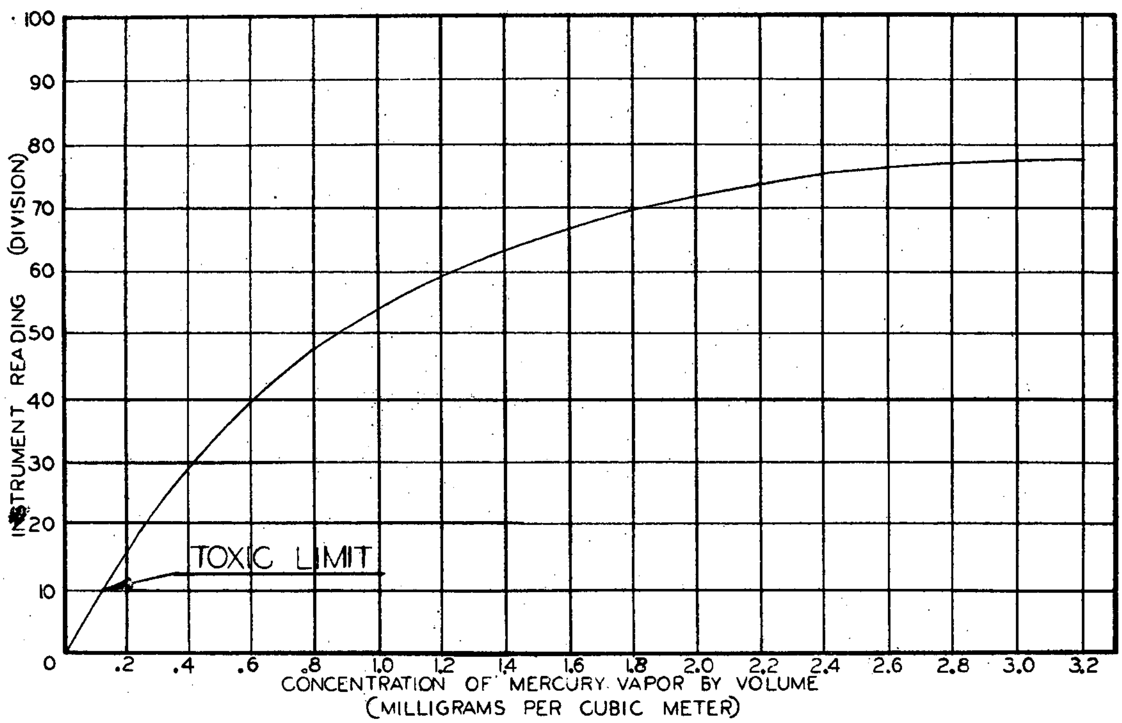
Model 1EPS	A.C. Portable Vapor Detector	5Z 7133
Model 2EPS	A.C. Rack Mounted Vapor Detector	5Z 7143
Model 3EPS	D.C. Portable Vapor Detector	5Z 4943

Information Division
6/9/53 pe



ZN-484

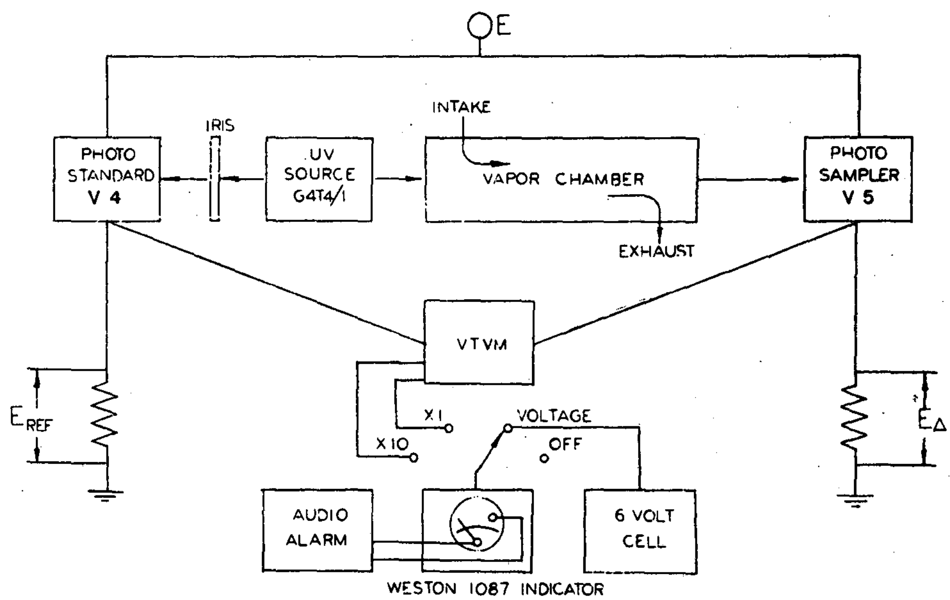
Fig. 1



MERCURY CURVE

MU-4494

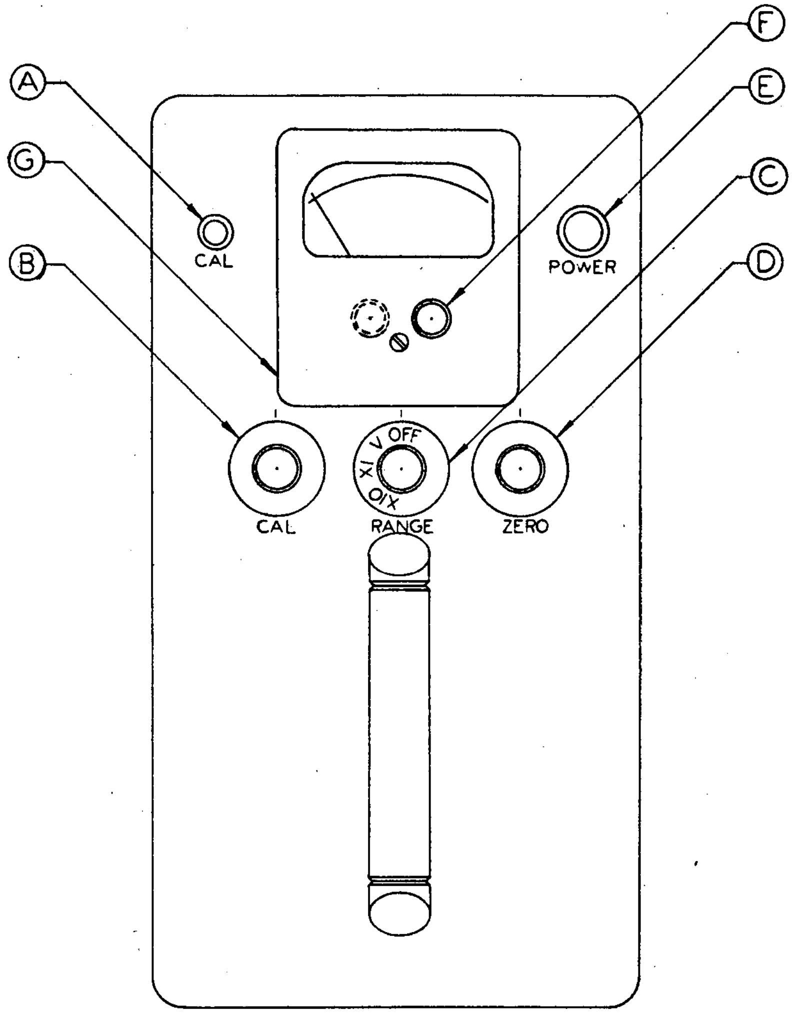
Fig. 2



FUNCTIONAL DIAGRAM

MU-4495

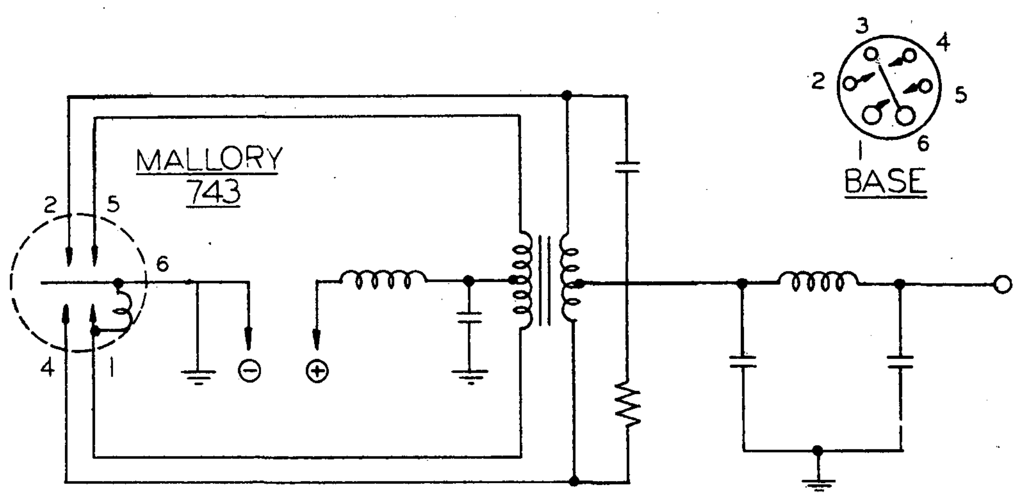
Fig. 3



CONTROL LAYOUT

MU-4496

Fig. 4



POWER SUPPLY UNIT

MU-4497

Fig. 5

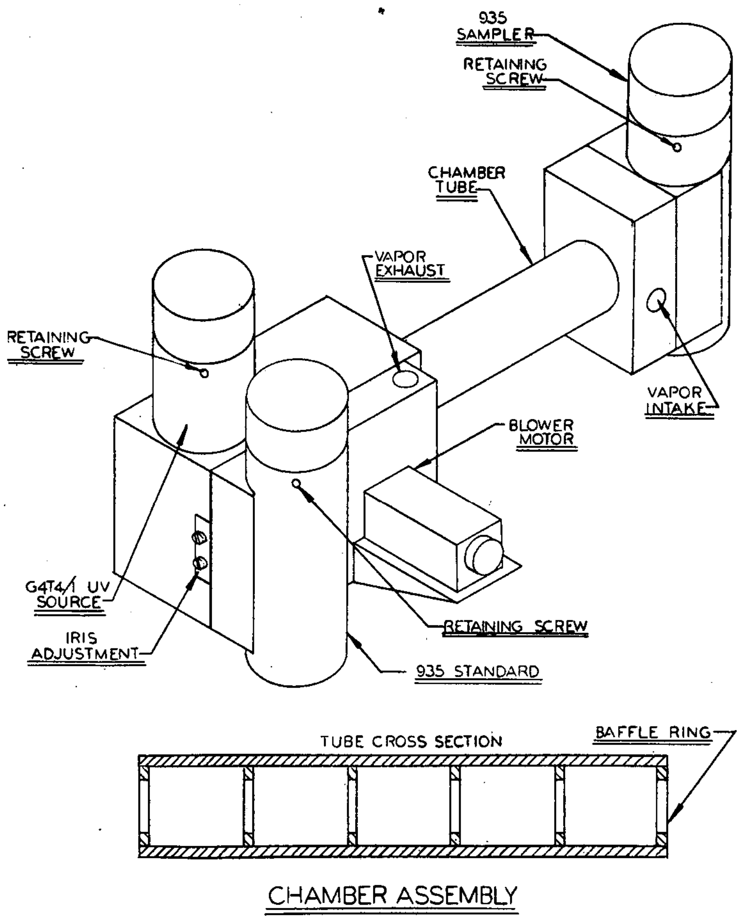
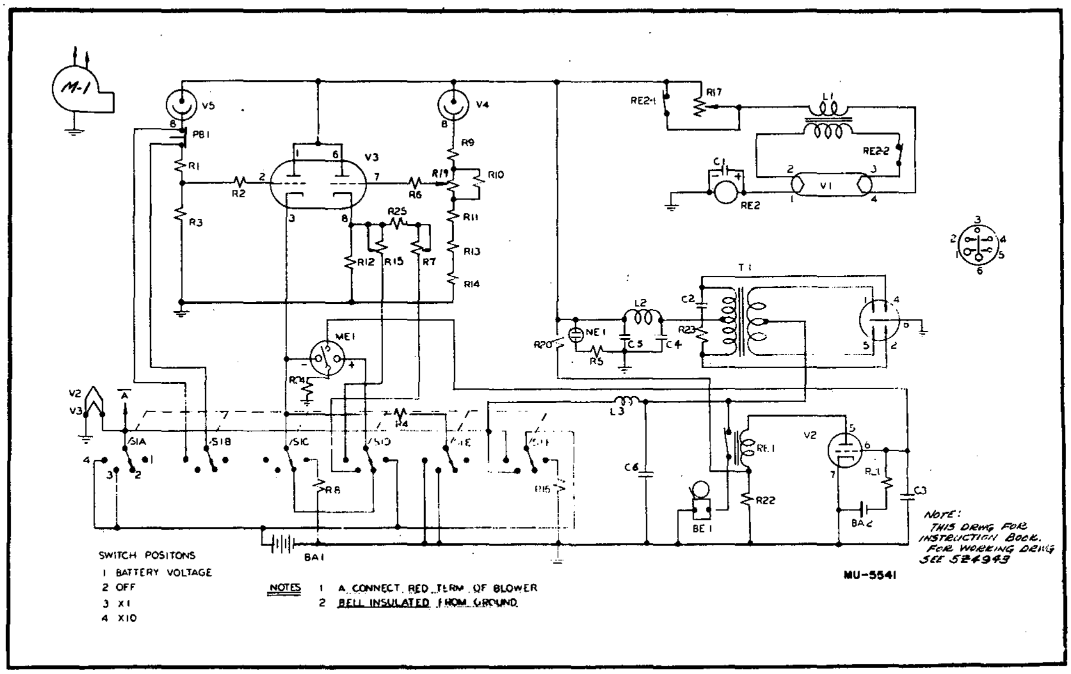

935
SAMPLER
RETAINING
SCREW
CHAMBER
TUBE
VAPOR
EXHAUST
RETAINING
SCREW
VAPOR
INTAKE
BLOWER
MOTOR
G4T4/1 UV
SOURCE
IRIS
ADJUSTMENT
RETAINING SCREW
935 STANDARD
TUBE CROSS SECTION
BAFFLE RING
CHAMBER ASSEMBLY
MU-5540

Fig. 6



M-1
V5
PB1
R1
R2
R3
V3
V4
R9
R19
R10
R6
R11
R25
R12
R15
R7
R13
R14
ME1
R4
RE2-1
R17
L1
RE2-2
C1
V1
RE2
T1
L2
C2
R23
NE1
R20
R5
C5
C4
L3
C6
RE1
V2
R22
BE1
BA2
C3
S1A
S1B
S1C
S1D
S1E
S1F
R8
R16
BA1
SWITCH POSITONS
1 BATTERY VOLTAGE
2 OFF
3 X1
4 X10
NOTES 1 A CONNECT RED TERM OF BLOWER
2 BELL INSULATED FROM GROUND
NOTE: THIS DRWG FOR INSTRUCTION BOOK. FOR WORKING DRWG SEE 524943
MU-5541

Fig. 7

PARTS LIST - Reference , Fig. 7

Desig.	Quan.	Specifications
BA-1	1	6V Wett Cell, Willard No. ER 40-6
BA-2	1	7 1/2V Dry Cell, Burgess W5BP
BE-1	1	6V D. C. Bell
C-1	1	50 MFD, 50V Electrolytic Capacitor
C-2, 4, 6	3	.01 MFD, 1600V, Paper Capacitor
C-3	1	.1 MFD, 200V, Paper Capacitor
C-5	1	8 MFD, 450V, Electrolytic Capacitor
L-1	1	GE 58G827 Ballast
L-2	1	2.5 MH R.F.C., Millen No. 34100
L-3	1	7MH R.F.C., 36 turns no. 16 enamel wire on lucite form - 2 layers.
ME-1	1	0-50 Microamps, Weston 1087 Meter/Relay
M-1	1	FD 6-27-2, 12VDC, Diehl Motor
NE-1	1	NE51 Neon Lamp
PB-1	1	4 NC 5-5P, Acro Pushbutton
R-1	1	500K, 1 watt, Precision Resistor
R-2	1	5.1 Megohm, 1 watt, Carbon Resistor
R-3	1	3 Megohm (3 x 1 Meg.), 1 watt, Precision Resistor
R-4	1	5K, 1 watt, Precision Resistor
R-5	1	100K, 1/2 watt, Carbon Resistor
R-6	1	5.1 Megohm, 1 watt, Carbon Resistor
R-7	1	70K, 4 watt, Wirewound Potentiometer
R-8	1	118K, 1 watt, Precision Resistor
R-9	1	250K, 1 watt, Precision Resistor
R-10	1	2 Megohm (2 x 1 Meg.) 1 watt, Precision Resistor
R-11	1	1 Megohm, 1 watt, Precision Resistor
R-12	1	5K, 1 watt, Precision Resistor
R-13	1	1 Megohm, 1 watt, Precision Resistor
R-14	1	750K, 1 watt, Precision Resistor
R-15	1	70K, 4 watt, Wirewound Potentiometer
R-16	1	2 ohm, 50 watt, Wirewound Resistor
R-17	1	2.2, 25 watt, Wirewound, Adjustable Resistor
R-19	1	2.5 Megohm, 2 watt, Potentiometer
R-20	1	56K, 2 watt, Carbon Resistor
R-21	1	1 Megohm, 1 watt, Carbon Resistor
R-22	1	43K, 2 watt, Carbon Resistor
R-23	1	47K, 1 watt, Carbon Resistor
R-24	1	100K, 1 watt, Carbon Resistor
R-25	1	30K, 1 watt, Precision Resistor

PARTS LIST (CON'T)

RE-1	1	250-44 Relay, Ward Leonard
RE-2	1	964B Relay, Advance
S-1	1	4 pos., 6 ckt., Mallory 2505 switch
T-1	1	Vibrator Transformer, Triad V1K
V-1	1	GE 4T/1 Germicidal Lamp, General Electric
V-2	1	6C4 Tube
V-3	1	5963 Tube
V-4, 5	2	935A Photo Tube