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UNITED STATES ATOMIC ENERGY COMMISSION

HASL AERIAL SURVEY SYSTEM

By
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R. T. Graveson
H. D. LeVine

July 29, 1957

Health and Safety Laboratory
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ABSTRACT

Radioactive debris from nuclear detonations may fall out over an extensive area. A rapid evaluation of the distribution of such surface contamination can be obtained by an aircraft mounted detector. The gamma field measured in the aircraft can be related to the intensity on the ground.

The HASL "Top Hat" system measures the radiation intensity, in an aircraft, at any altitude up to 1500 feet. The data is continuously compensated to the reading that would be obtained if the measurements were taken at three feet from the ground surface. It will record the ground radiation field intensities from 0.01 mr/hr to 1000 r/hr. The Telepulse Coding Unit converts this information to a signal suitable for transmission to a plotting center via a standard voice radio transmitter. The transmitted signal is decoded by a Telepulse Receiving Unit and is automatically recorded on a strip chart. The radiation data must be correlated with the aircraft position to determine the location and intensity distribution of the contaminated area.

HASL AERIAL SURVEY SYSTEM

1. INTRODUCTION

The measurement of fall-out over extensive areas has become necessary in view of the increased yield of radioactive debris from the larger nuclear devices. The use of aircraft for long range radiation survey makes feasible a rapid determination of the distribution of fall-out debris. The limit of detectability depends on the sensitivity of the measuring instrument, the energy and intensity of the surface radioactivity and the absorption of the intervening layer of air. When the altitude is known, it is then possible to relate an aerial radiation measurement to the intensity at the surface.

The resolution, that is, the degree at which an area can be delineated is proportional to the aircraft altitude. The radius of the ground area in feet which is viewed by the detector is approximately equal to the aircraft altitude in feet. Since fall-out is distributed fairly uniformily over wide areas, the aircraft reading is directly related to the surface radiation field.

This aerial survey system uses a scintillation counter which is sensitive over a range extending from 0.005 mr/hr to 200 r/hr, as measured in the aircraft. A signal from the airplane radar altimeter corrects the aircraft radiation reading to a radiation intensity at three feet from the surface. This level is recorded and simultaneously converted to a time-modulated pulse-train by a "Telepulse" Coding Unit for radio transmission to a plot center. At this center, a "Telepulse" Receiving Unit decodes the information and presents the ground-level radiation intensity on a strip-chart [illegible] The [illegible] making data and is correlated [illegible] evaluate the [illegible] intensity [illegible] the [illegible] with this information. [illegible] of the system.

2. "TOP HAT" AIRBORNE [illegible]

2.1 General [illegible]

The "Top Hat" [illegible] Figure [illegible] battery [illegible] gamma [illegible] sity from [illegible] measured at the [illegible] that would [illegible].

2.1.1 [illegible]

[illegible] meters. [illegible] instrument [illegible] necessary to [illegible] ground [illegible] radiation [illegible]

[illegible] survey technique [illegible] the [illegible] delineate [illegible] for the [illegible] in [illegible] gamma ray [illegible]

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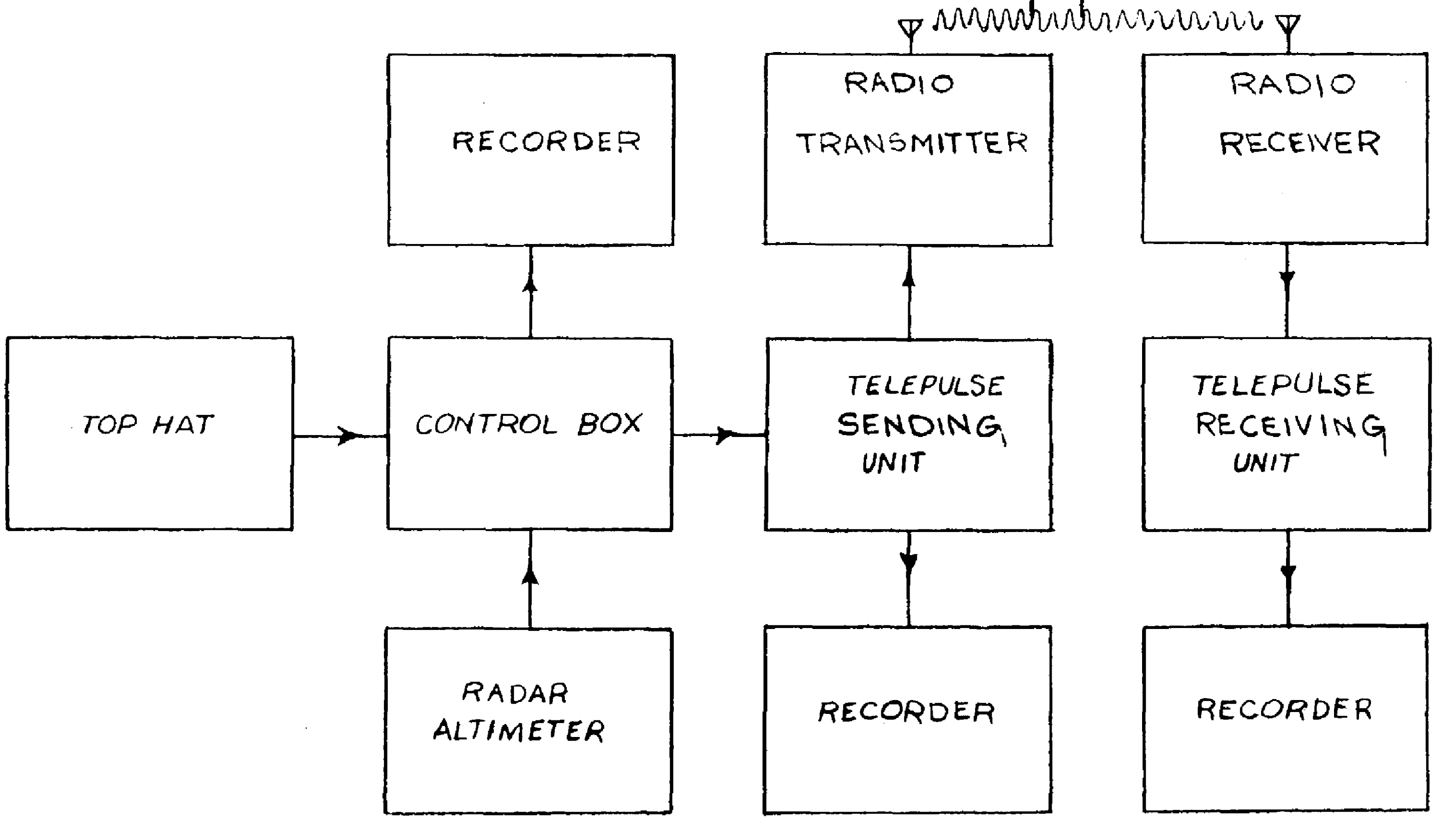

Figure 1--HASL Aerial Survey System Block Diagram

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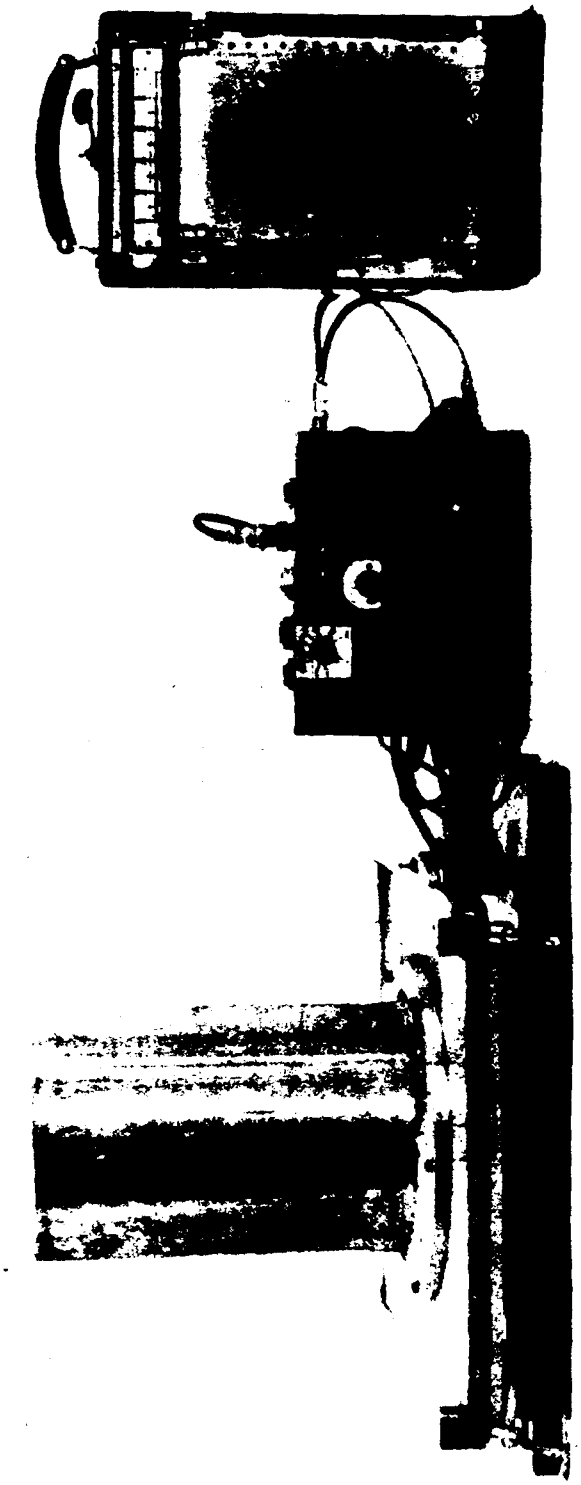

Figure 2--Top Hat Airborne Detector

second time constant and has a small standard air since the number of contributing gamma ray photons absorbed in the phosphor is large.

The plastic type phosphor was selected for the following reasons:

A. Its response to the gamma ray energies, Figure 3, is practically equivalent to that of air. The response of a thallium activated sodium iodide phosphor which is widely used for scintillation counters is included for comparison.

B. It is based on organic scintillators which have short decay factors. Thus, there is little residual light in the phosphor after incident radiation has been removed. Therefore, it is feasible to survey low intensity areas immediately after leaving a high intensity field.

C. The phosphor is strong and will not shatter from thermal or mechanical shock.

With a given phosphor size the photomultiplier tube is limited to the range over which it will operate without saturation. Therefore, two phosphors and photomultiplier tubes were used to extend the total range. The low radiation level detector responds from 0.005 mr/hr to 100 mr/hr and the high radiation level detector responds from 10 mr/hr to 200 r/hr.

In a single flight line, the radiation intensity change may span several decades. The D.C. amplifier was designed with a logarithmic response to present a large dynamic range on a single scale. The logarithmic response of this instrument is achieved by using the plate current-grid current characteristic of the D.C. amplifier tubes[1]. The two detectors have an overall range,

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1. LeVine, H. D., "Logarithmic D.C. Ratemeters for Scintillation Counters", Nucleonics, - Feb. 1954, pp 36-39

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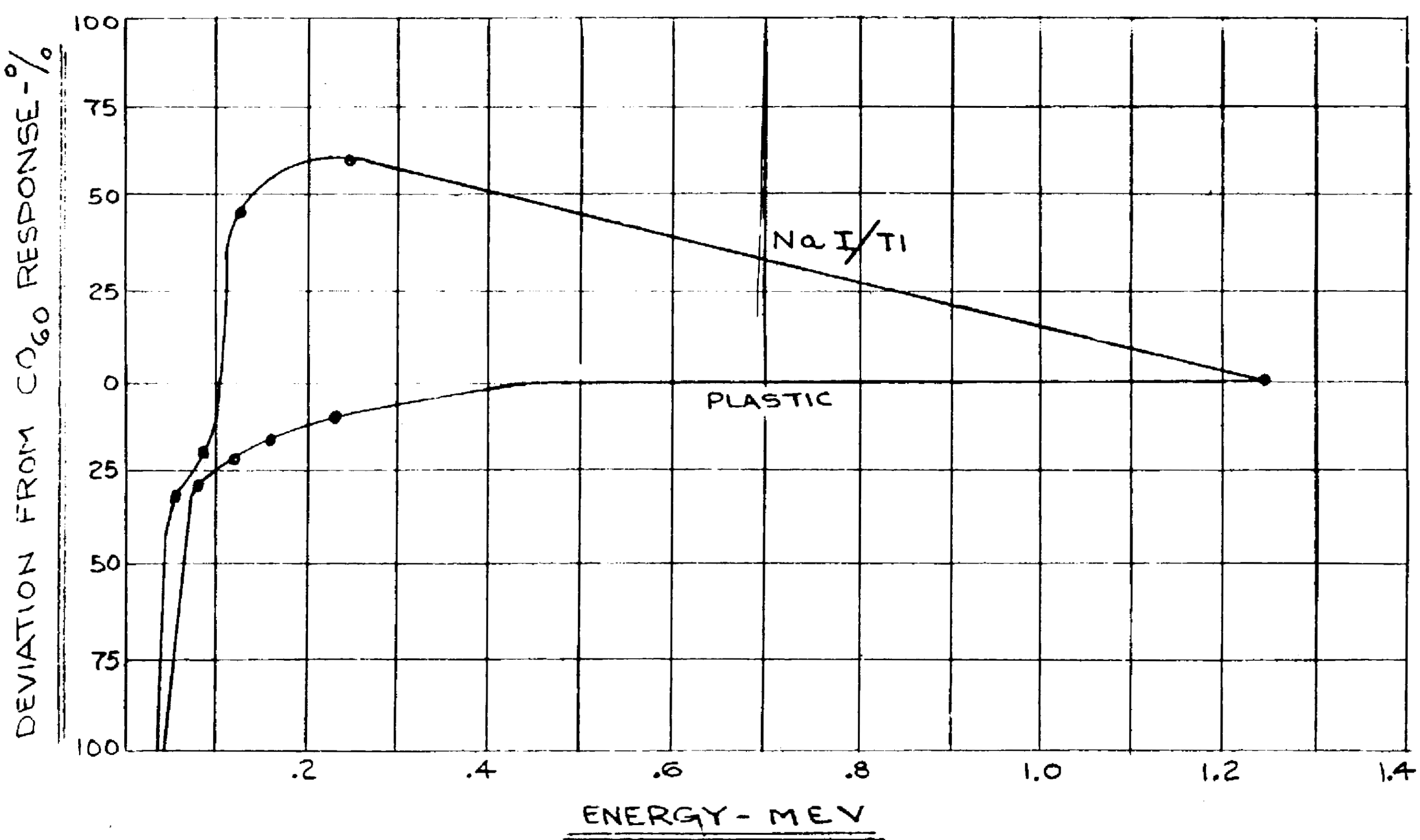

ENERGY RESPONSE OF PHOSPHORS

Figure 3--Energy Response of "Top Hat" Detector

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Figure 4, of approximately nine decades. This is divided into four scales of three decades each, Figure 5. Those scales are:

A. .005 - 1 mr/hr

B. 0.1 - 100 mr/hr

C. 10 to 10,000 mr/hr (0.01 to 10 r/hr)

D. 1,000 to 1,000,000 mr/hr (1 to 1,000 r/hr)

The low level detector covers the range of scales A and B, and the high level detector covers scales C and D. The three decade scale achieves a compromise between reading and telemetering accuracy with a minimum amount of scale switching. The upper limit of scale D (1000 r/hr) is extended beyond the maximum reading of the instrument (200 r/hr) to allow for the increase in reading due to the compensation of aircraft intensities to ground level readings. This will be fully discussed in Section 2.1.4 on altitude compensation.

2.1.2 Detector Circuit Description (Figure 6)

The detector consists of two plastic phosphors. One, 3" diameter by 4" high, is mounted on a 3" photomultiplier tube (DuMont type 6363), and measures the low radiation levels. The second, 1" in diameter by 1/4" high, is mounted on a $1\frac{1}{4}$" photomultiplier tube (DuMont type 6467) for measuring high radiation levels. The phosphor sizes were experimentally determined for the range of radiation intensities to be covered. The tenth dynode of each photomultiplier tube is connected to the grid of the amplifier, however, high voltage is applied only to the tube in use.

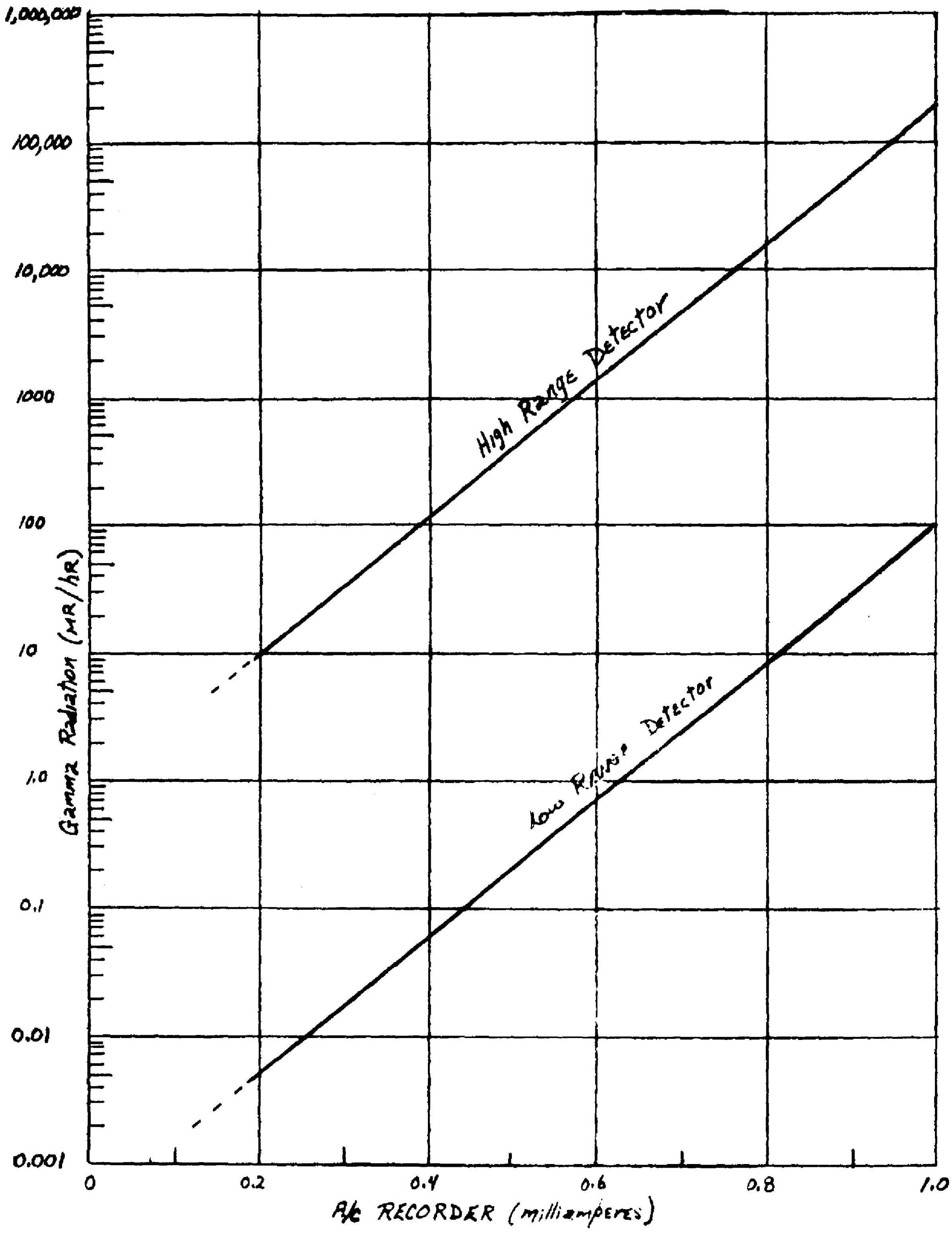

Figure 4 "Top Hat" Calibration

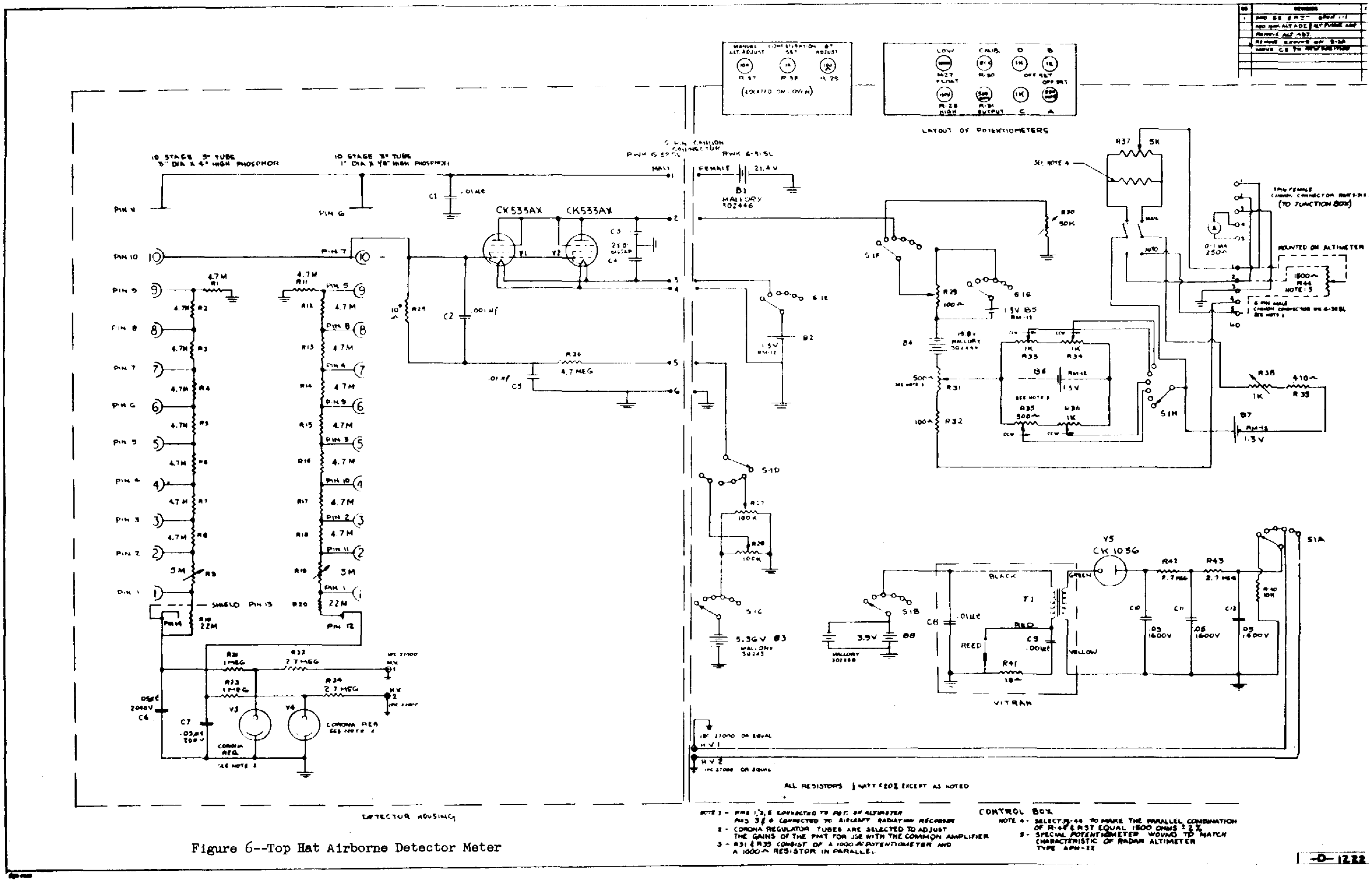

Figure 6--Top Hat Airborne Detector Meter

This arrangement eliminates switching of dynodes in the high impedance grid circuit. Voltage regulator tubes, V-3 and V-4 are selected, and the gain controls R-9 and R-19 adjusted, so that the gains of the individual photomultiplier tubes are matched into the single amplifier circuit.

Light excited in the phosphor by gamma radiation illuminates the photocathode of the photomultiplier tube which produces electrons that are multiplied by secondary emission of electrons from the dynodes. The electron current pulses appearing on dynode 10 are integrated by capacitor C-2 and averaged by the effective grid to cathode resistance of the amplifier tubes. The value of this RC product is kept small to keep the time constant of the instrument fast. The amplifier consists of two Raytheon CK-533AX tubes, which are connected in parallel to secure the power output necessary to drive a recorder. When these tubes are driven from a high-impedance current source, as provided by the dynode of a photomultiplier tube, the plate current is a logarithmic function of the input grid current. Individual tubes are selected for this characteristic. Since the electrical characteristics of photomultiplier tubes differ, individual bias adjustments are required. This bias is inserted under the grid resistor, R-25. Because of the 10^9 ohm value of R-25, the grid sees a constant current bias. The slope of the logarithmic characteristic (at the high end of the scale) is set by the gain controls. The bias controls are used to match this slope at the low end. Over a 4-1/2 decade range the plate current change is 180 microampers per decade of radiation. This current is measured by a recorder (Esterline-Angus Model AW), plotting radiation intensities from 0.005 to 100 mr/hr from the low-level photomultiplier tube, and from 10 mr/hr to 200 r/hr from the high-level photomultiplier tube.

Since only three decades of information are to be presented at a time, additional load resistance, R-31, R-32, are added in series with the internal resistance of the recorder. The R-31 is set at 1,850 ohm from arm to ground so that a change of one volt with respect to ground is equal to a radiation change of 3 decades. The three decade scales of the 4½ decade response, of each photomultiplier tube is selected by subtracting a fixed voltage in series with the output signal. The four voltages are provided by potentiometers R-35, 36, 37 and 38. They are consecutively selected by switch S-1 in positions A,B,C, and D. The switch also connects the proper grid bias, buck-out voltage and high voltage into the circuit for the selected scale. On any scale, the voltage at the output of the subtraction circuit will be zero volts for the minimum intensity and one volt for the maximum intensity.

In the OFF position of S-1, the batteries are disconnected. Those remaining in the circuit are utilized at negligible current drain. In the SET position, the recorder is used as a voltmeter to check the B plus voltage.

2.1.3 Altitude Compensation

Since the distance from the aircraft to the ground is continuously varying, the aircraft readings are useful only when referred to a standard distance from the surface. For the evaluation of dosage, the accepted level has been set at three feet above the ground.

The relationship between the intensity measured at the aircraft and the three foot intensity is proportional to (over an altitude range from 200 - 1000 ft.):

$$I_a = I_o E^{-u_a X} \text{ (See Figure 7)} \quad (1)$$

I_a = radiation intensity in aircraft

I_o = radiation intensity at ground level

u_a = linear absorption coefficient of air (ft^{-1})

X = altitude (ft)

Then

$$I_o = \frac{I_a}{E^{ux}} \quad (2)$$

And

$$f_a = \frac{I}{E^{ux}} \quad (3)$$

where fa = altitude correction factor

from (2) & (3), $I_o = f_a \times I_a$ (4)

and $\text{Log } I_o = \log f_a + \log I_a$ (5)

from (3) $f_a = \frac{I}{E^{-ux}} = E^{+ux}$ (6)

$$\log f_a = ux \text{ or } \frac{1}{u} \log f_a = X$$

Because the detector output is designed to provide a logarithmic response, it is only necessary to add the log f_a electrically to obtain log I_g. Also $\frac{1}{u}$ log f_a is directly proportional to altitude (equation 6) and thus may be derived from a radio altimeter.

It is not possible to maintain an aircraft in level flight and the changes of $\pm$ 50 feet which normally occur will create large changes in the radiation reading. Thus it is essential to

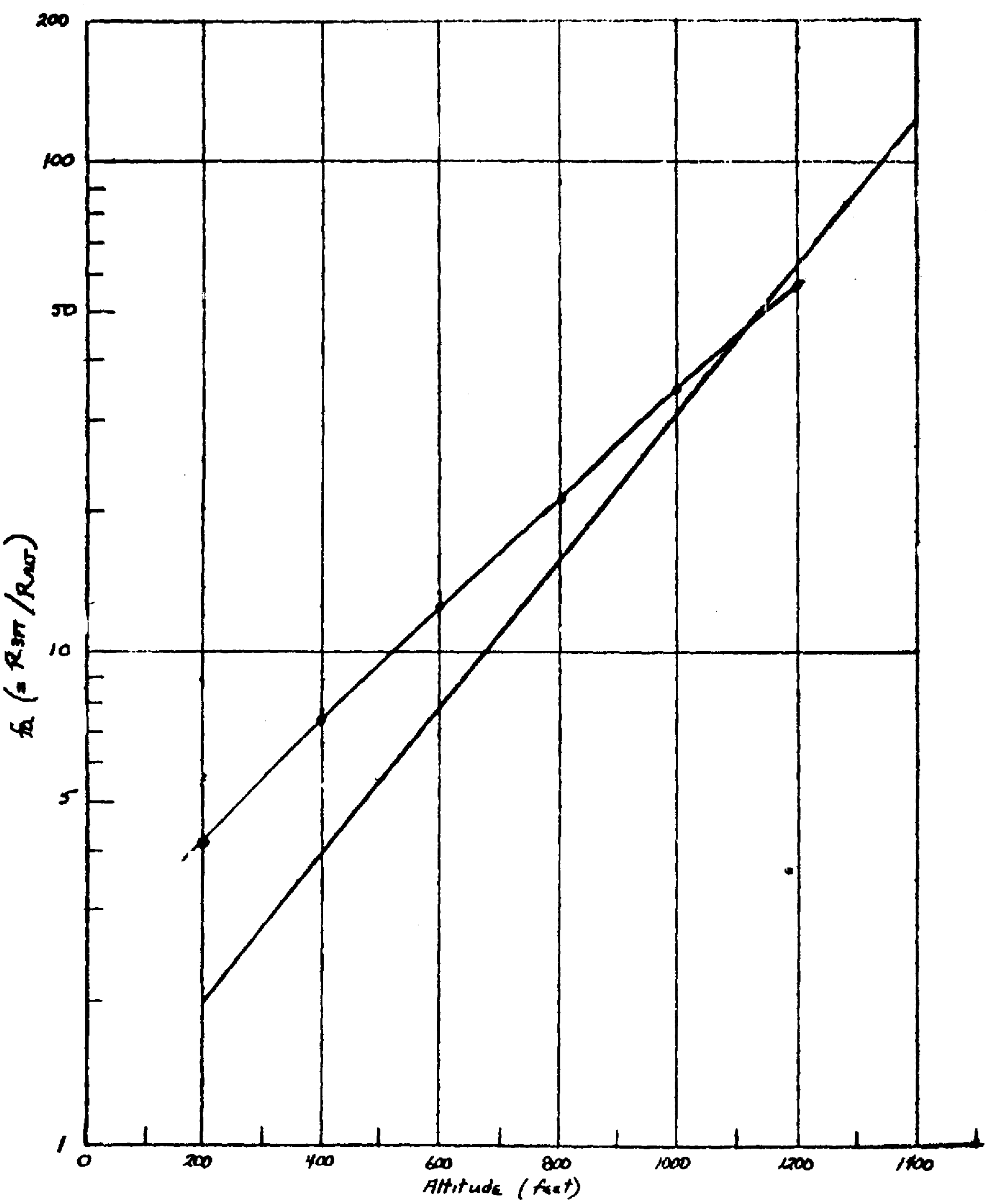

Figure 7

Altitude Correction Factor

continuously and automatically correct the aircraft reading to ground level.

The altitude compensation consists of a radio altimeter arranged to provide a voltage inversely proportional to the height above the ground. A potentiometer is coupled to the indicator shaft of a radar altimeter, Figure 8, to develop the required voltage for altitude correction. Barometric altimeters are unsuitable, since they indicate altitude from an arbitrary reference, usually sea level, and do not account for variation of the earth's surface. A radar altimeter gives the true altitude from the surface.

Manual altitude compensation is possible should the radar altimeter fail. Manual operation is useful only when the terrain is fairly level and when it is possible to closely estimate the distance from aircraft to ground. Then, by flying at a constant barometric altitude, ground level data can be obtained.

2.1.4 <u>Altitude Compensation Circuit Description</u>

The detector signal is coupled into the compensation circuit through switch, S-1H (Fig. 6). The altitude compensation voltage is developed by potentiometer R-44, in automatic operation, and by potentiometer R-37 in manual operation. It is added to the detector voltage to produce a signal proportional to the radiation intensity at ground level. This level is measured by a vacuum tube voltmeter circuit having a one volt full scale sensitivity. (Section 3.2.1).

A voltage corresponding to the maximum (1500 ft) altitude is developed across the altitude compensation potentiometer by battery B-7 through calibration resistor R-38. The potentiometer

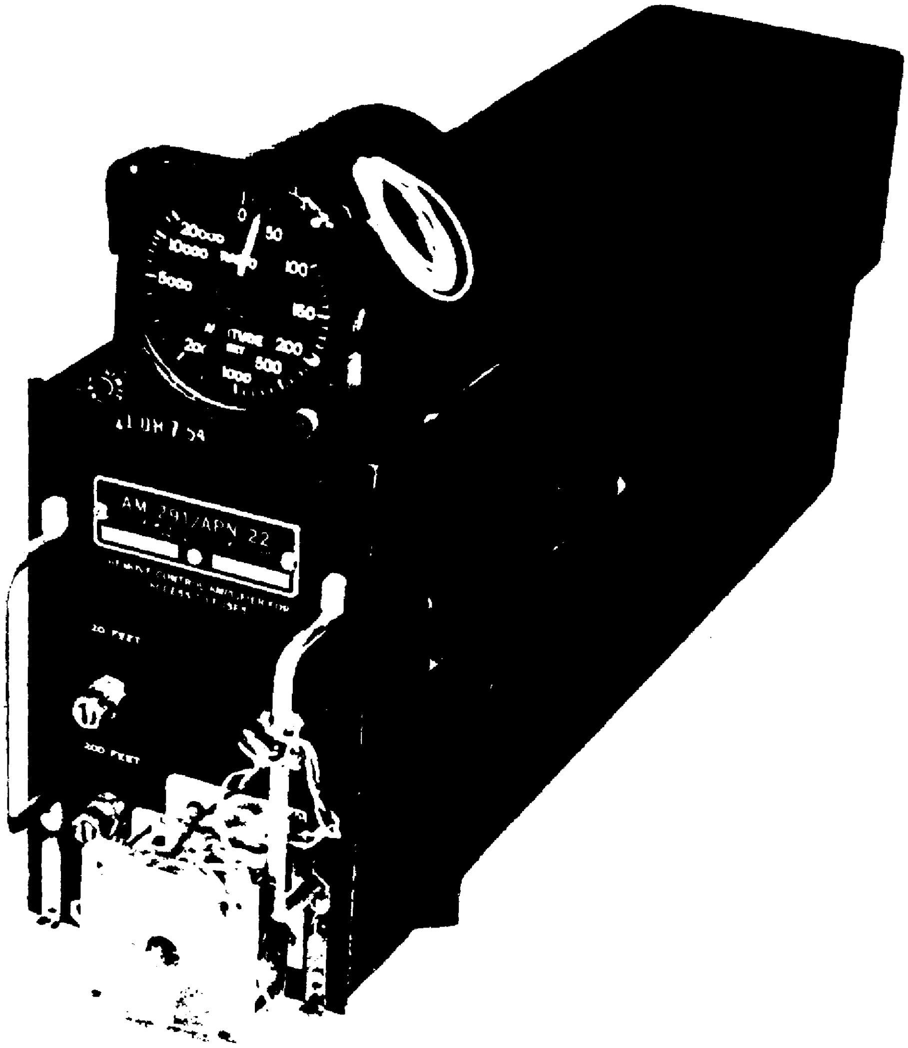

Figure 8--Radar Altimeter

output voltage is directly proportional to the altitude (Section 2.1.3 equation 6). Therefore, the compensation added to the radiation signal will be a logarithmic function of the altitude. The proper compensation voltage for an area contaminated with radioisotopes can be determined by taking two passes over a level section of the area, one at 500 and the second at 1000 feet. The ratio of the readings obtained at the two altitudes can be used to determine the voltage applied to the altitude compensation potentiometers. (See Section 2.4.4 for a full description of this procedure). Once the voltage has been determined and set, the instrument will properly compensate for any altitude over an area with a similar type of contamination. However where these values have previously been determined, the altitude compensation voltage may be set prior to operation.

Since the rotation of the indicator shaft of the radar altimeter (APN-22), which has been used with this instrument is not a linear function of altitude, the resistance of the automatice compensation potentiometer (R-44) was computed to produce a linear change with altitude. It has been reported that the newer models of the altimeter may have linear output characteristics available thus permitting the use of standard linear potentiometers.

2.1.5 Power Supply

All power for the "Top Hat" airborne detector is obtained from an internal supply of mercury cell batteries, which have been selected because of their flat voltage discharge characteristic and sharp voltage drop off at the end of useful life.

2.2 Mechanical Description

The instrument consists of two units, excluding recorders, the "Top Hat" detector and the Control Box. These are interconnected by cables. The "Top Hat" detector is housed in a 12" high by 8" diameter aluminum cylinder; closed at one end by a welded plated and hermetically sealed to an aluminum base plate at the other. The "Top Hat" housing provides a hermetic seal to prevent humidity from affecting the high impedance sections of the detector and amplifier circuits. The photomultiplier gain controls are brought through the base plate by sealed shafts. The voltage regulators for the photomultipliers, the dynode voltage divider networks, and the logarithmic amplifiers are within the housing with the unregulated high voltage fed through the base plate through hermetic seal connectors. The phosphor-photomultiplier assemblies are mounted perpendicularly to the base plate over thinned out sections of the plate (1/16" thickness to reduce attenuation of rays being measured). The phosphors are provided with 1" thick peripheral lead shields to minimize radiation effects should the plane become contaminated. The shielding also provides the characteristic of Figure 9. The control circuit is mounted in a water tight box, 9½" wide by 7" high by 3¼" deep.

The control box houses a high voltage vibrator supply, the batteries and all controls with the exception of the photomultiplier tube gain controls. The controls that are used during a survey are mounted on the cover of the control box. These are the RANGE switch, B PLUS set adjustment, altitude compensation, SET and the MANUAl ALTITUDE control.

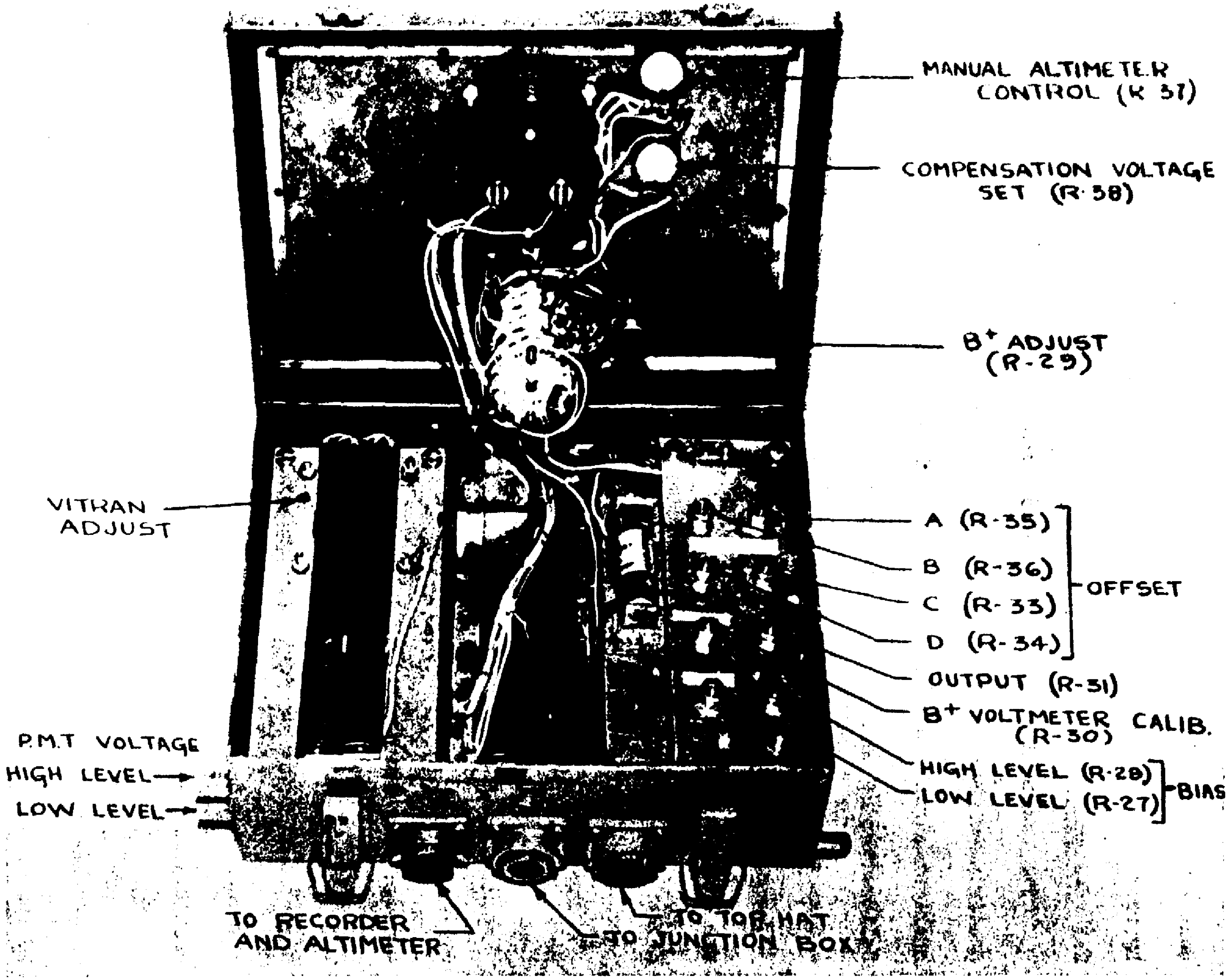

Figure 9--Calibration Controls Control Box

A meter is included on the cover of the control box to indicate ground level radiation intensity. The amplifier bias, scale buck-out and B plus voltmeter controls are mounted on a board within the control box, and adjusted only during calibration. Batteries are accessible by releasing the snap locks on each end of the potentiometer board.

2.3 Calibration

The calibration procedure is divided into four phases: 1) The preliminary power supply adjustments, 2) The "Top Hat" detector, 3) The buck-out ciruit setting and 4) the altitude compensation circuit. Calibration of this instrument requires a standard gamma radiation source such as radium or cobalt 60 of suitable size, a vacuum tube voltmeter and an ohmmeter. The locations of the internal controls are shown in Figure 10.

2.3.1 Preliminary Power Supply Adjustments

Connect the required cables between the "Top Hat", Control Box and the Aircraft Radiation Recorder.

High Voltage Supply - If the vibrator does not start, rotate the vitran contact two turns counter-clockwise. This control is reached through the hole in the high voltage battery board (See Figure 10). Set switch S-1 to position SET, turn the vitran contact clockwise until the reed is heard to just start to vibrate and then advance the contact 1/8 turn. When the switch is now turned from OFF to SET, the vitran should start without further adjustment.

B plus Supply - With the switch at SET position, adjust R-29 to produce the minimum B plus voltage. This point will be indicated by the minimum recorder deflection that can be obtained with this control.

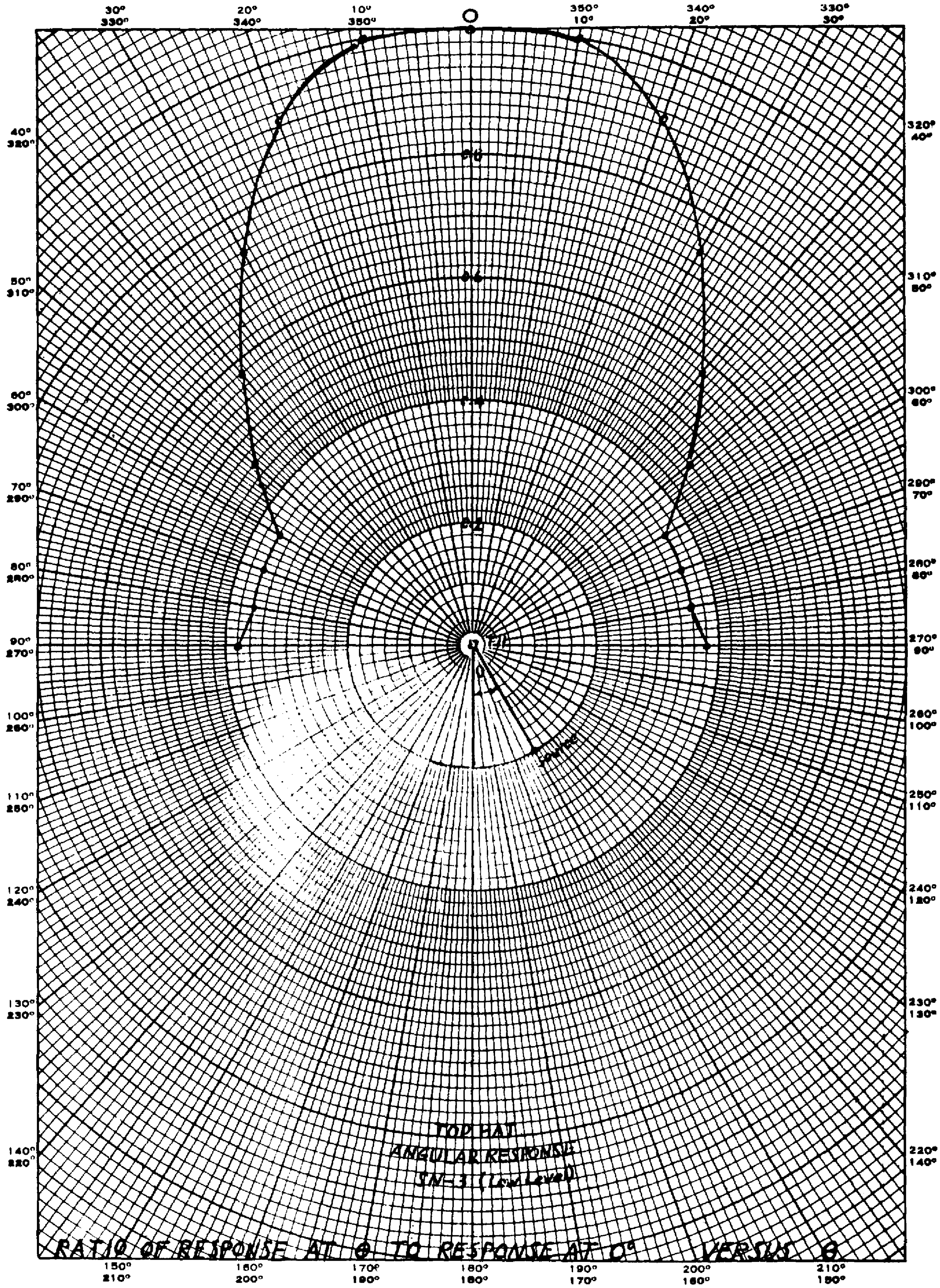
TOP HAT
ANGULAR RESPONSE
SN-3 (Low Level)
RATIO OF RESPONSE AT θ TO RESPONSE AT 0° VERSUS θ

Figure 10

Then adjust R-30 until the recorder reads 0.70 ma. When making any calibration adjustments, tap the recorder tape in front of the pen until the pen comes to its final reading.

2.3.2 "Top Hat" Detector Calibration

There are three mechanisms for obtaining the desired calibration curve, these are:

A. Adjustment of the gain of the photomultiplier tube to obtain the proper slope.

B. Adjustment of the bias control to set the low end of the calibration curve.

C. Adjustment of the amplifier plate voltage supply to bring the amplifier into the logarithmic portion of its characteristic.

The gain of the photomultiplier tubes is adjusted by selection of the voltage regulator tubes, and setting of the potentiometers R-9 and R-19. 1000 volt corona regulator tubes (V-3 and V-4) should be used as a first approximation to the proper value. With the range switch at position A, and the detector in a 10 mr/hr radiation field, adjust the low level photomultiplier gain control, R-9, until the recorder reads 0.82 ma. Should it be impossible to reach this current, the 1000 voltage regulator tube, VR-3, should be replaced with one regulating at a higher voltage. Then reduce the radiation field to 0.01 ma and set the amplifier grid bias control (float control) R-27 to produce a recorder indication of 0.275 ma. (If the recorder current cannot be brought down to this value the photomultiplier tube has too high a noise level and should be replaced). Check the current at 10 mr/hr and if it has changed read just R-9. Then check the 0.01 mr/hr point and make any necessary adjustment with R-27.

After these settings are made, it should be possible to reproduce the proper meter indications at 0.01 and 10 mr/hr without any further adjustment.

The instrument should then be calibrated over its full range by obtaining the recorder current for several values of radiation and plotting a curve which should match curve A shown in Figure 4. If there is a departure from linearity, compensate by readjusting the B plus set control, R-29, slightly. However, if this is done the switch should be then turned to the SET position and R-30 readjusted to produce a recorder current of 0.70 ma. Should there be a marked non-linearity in the calibration curve, it will be necessary to select new amplifier tubes, V-1 and V-2 until a pair is found which will give the required characteristics.

To calibrate the high level detector, set the range switch to position C and repeat the procedure for setting the photomultiplier tube gain control and the float control described above; however, use radiation values of 10 mr/hr and 10 r/hr to correspond to currents of 0.200 and 0.740 ma respectively. Selection of the proper photomultiplier tube, VR tube (V-4) and gain control adjustment (R-19) should bring the detector into proper calibration as shown by curve B in Figure 4, without any further change of B plus or amplifier tubes.

2.3.3 Buck-Out Circuit

Set the arm of R-31 at 1,850 ohms between it and ground as measured by an ohmmeter. The buck-out potentiometers are then adjusted to produce zero volts measured between the arm of switch S-1H and ground at the corresponding scales and radiation fields shown in the chart below.

Switch Position	Apply Radiation Intensity	Adjust Resistor
A	0.005 mr/hr	R-35
B	0.1 mr/hr	R-36
C	10 mr/hr	R-33
D	1000 mr/hr	R-34

2.3.4. Altitude Compensation Circuit

The proper compensation voltage for attenuation factors corresponding to a particular contaminated area can be determined and set while in flight by the following procedure.

A. Make passes over the same section of a contaminated area at 500' and 1000'.

B. Subtract the current reading on the aircraft radiation recorder obtained at 1000' from the one obtained at 500'.

C. Then using the curve shown in Figure 11, determine the voltage corresponding to the difference in current between the 500 and 1000 foot readings, adjust R-38 to obtain this voltage across the compensation potentiometer.

2.4 Operation

To assure minimum radiation absorption by the aircraft, the "Top Hat" detector is positioned so that only the skin of the aircraft separates it from the outside. The most suitable location is usually in the tail section. Also, the tail position is furthest removed from radioactive dial instruments in the pilot's compartment. The control box is located with the operator.

To set the unit in operation:

A. Set the altitude compensation toggle switch (S-2) to either "automatic" or "manual" depending on the type of operation desired. When using manual altitude compensation, the

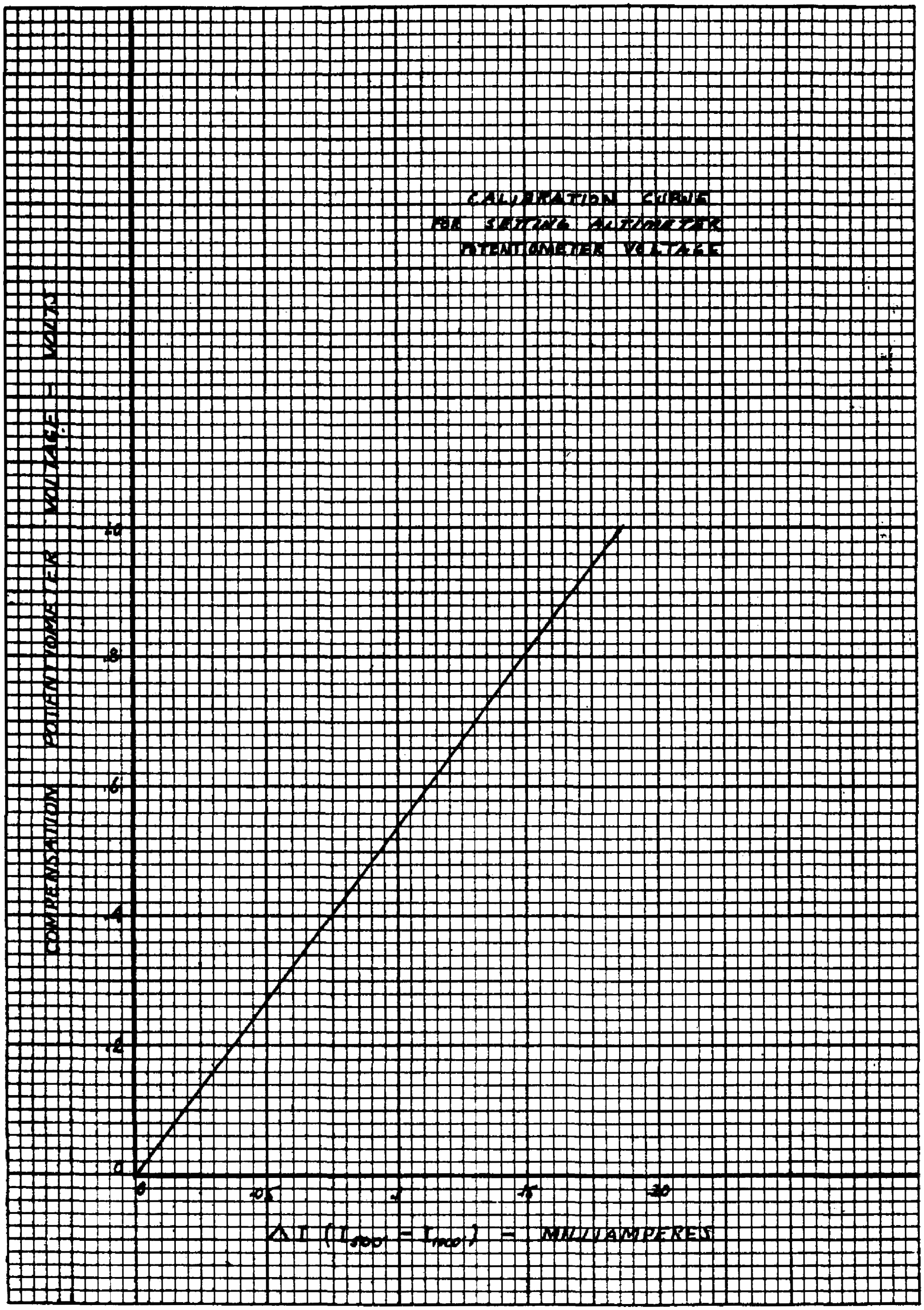
CALIBRATION CURVE
FOR SETTING ALTIMETER
POTENTIOMETER VOLTAGE
COMPENSATION POTENTIOMETER VOLTAGE - VOLTS
1.0
.8
.6
.4
.2
0
0
MILLIAMPERES

FIG. - 11

manual control must be continuously adjusted as the aircraft changes altitude.

B. Turn the range switch (S-1) from "OFF" to "SET". This connects the batteries and places the aircraft radiation recorder in the circuit as a voltmeter indicating the B plus voltage.

C. Adjust the "B + SET" control bringing the recorder reading to 0.70 ma. Since this setting is critical, the paper in front of the recorder pen should be tapped, to overcome pen friction which may cause erroneous readings.

D. Start the recorder chart drive.

E. Turn the range switch to a scale giving a convenient reading on the aircraft radiation recorder or control box meter. An external voltmeter circuit is required to drive the control box meter (See Section 3.2.1)

The ground-level radiation-intensity signal-voltage is a combination of the aircraft radiation signal and the altitude compensation voltage. Therefore it is possible to have a reading on scale even when measuring a radiation intensity which is less than the minimum value that can be measured on that particular scale. If there were no altitude compensation the recorder would read below scale, but at high altitudes there might be sufficient altitude voltage introduced to drive the recorder on scale. As an example, this condition would occur if the aircraft were flying at 500 ft. (fa-11.5) and the radiation intensity at the aircraft was 0.05 mr/hr. This corresponds to a three foot intensity of 0.58 mr/hr and would be indicated as such if the A scale is used. However, if the B scale is used the recorder will indicate 0.27 mr/hr (0.14 ma). To prevent this from occuring the operator should always check to make sure he is on the lowest range scale (A,B,C, or D) giving an on scale deflection on either the three foot level recorder or the meter on the control box.

3. TELEPULSE CODING UNIT

3.1 General Description

In the Telepulse Coding Unit, (Figure. 12) the ground level radiation intensity from the detector is measured by vacuum tube voltmeter bridge which drives a strip chart recorder and is also converted to a periodic, time-modulated, constant-amplitude pulse-train for radio transmission. This type of signal is suitable for transmission by both telephone lines and radio. The instrument is powered by 115 volts at 60 cycles.

An auxiliary unit, the Junction Box, contains a control to permit either voice communication or telemetering over the plane radio transmitter.

3.2 Circuit Description

The Unit is divided into four subsections: 1) Bridge, 2) Converter, 3) Comparator, and 4) Power Supply. The circuit diagram is shown in Figure 13.

3.2.1 Bridge

In the bridge section, the ground level radiation signal from the detector is amplified by a balanced D.C. amplifier, V-1 (a one volt full scale sensitivity). It drives a strip chart recorder (Esterline-Angus Model AW) and the meter on the control box of the "Top Hat" airborne detector. The radiation intensity corresponding to the current indicated it can be obtained from the calibration curves given in Figure 5 or three decade chart paper (Esterline Angus type 1273) may be used and the intensity read off directly. The voltage

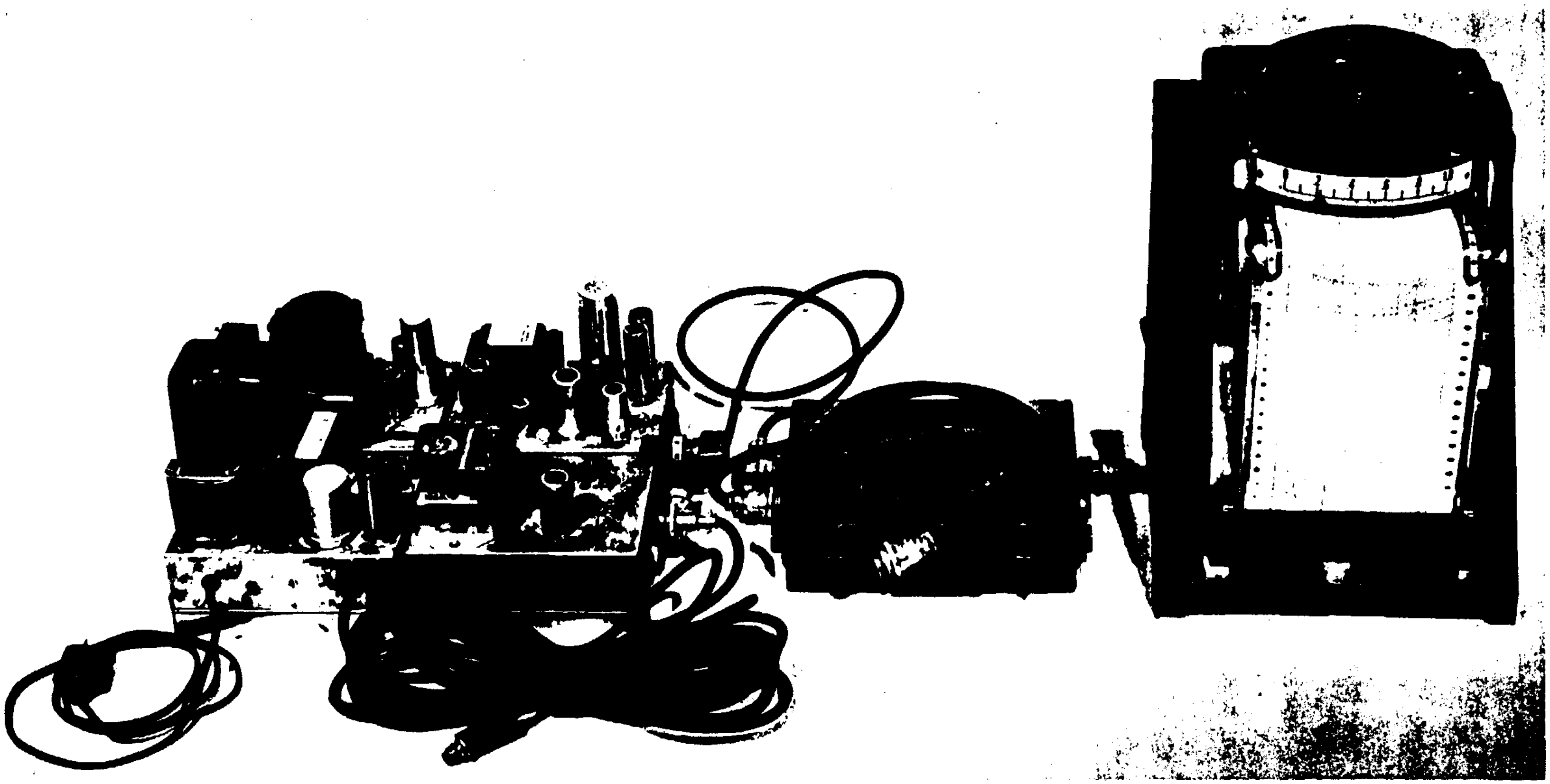

Figure 12--Telepulse Coding Unit - Picture

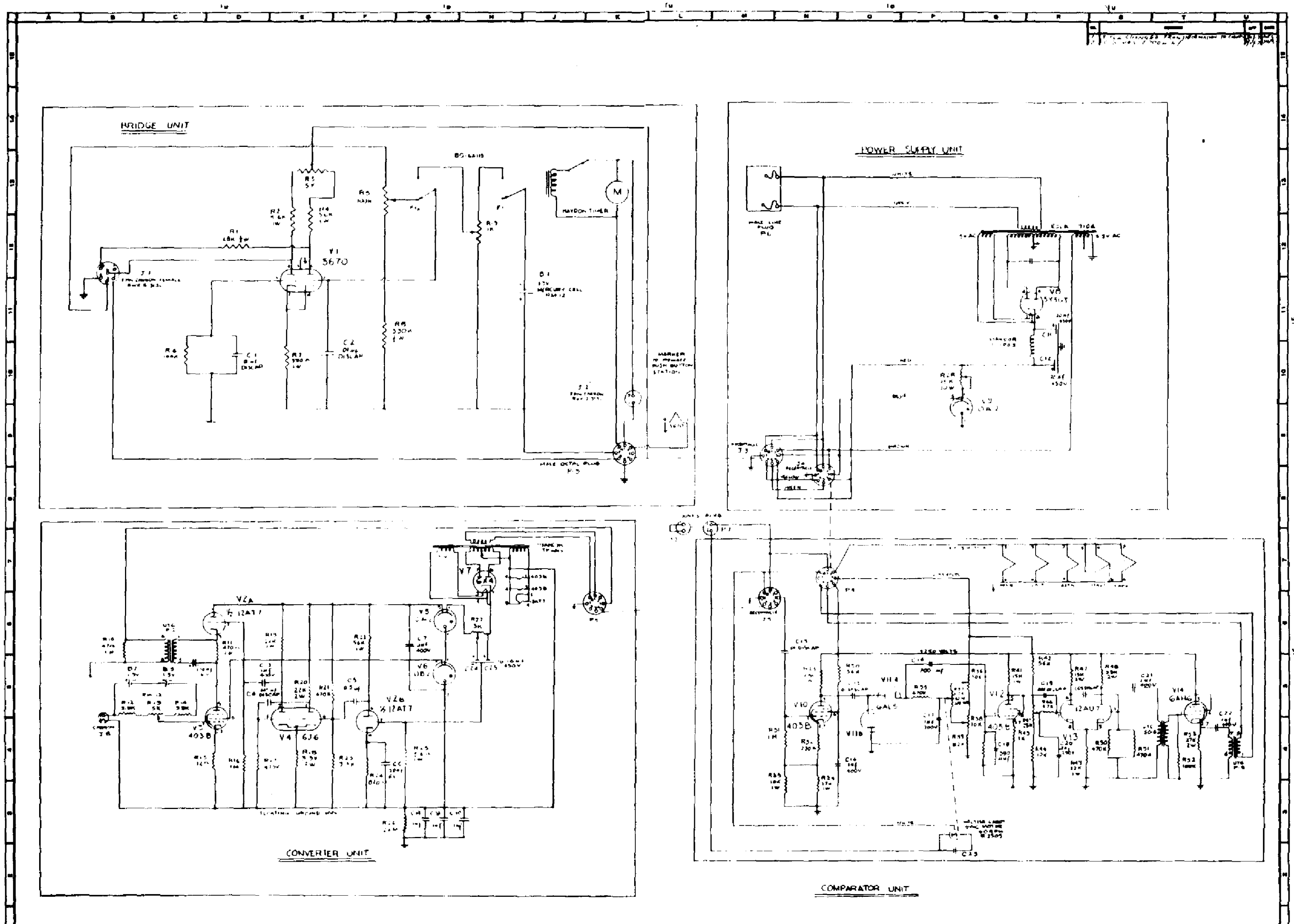

Figure 13--Telepulse Coding Station

fed to the converter unit is developed across a resistor (R-1) in the junction box, Figure 15, which is in series with these meters.

Identification markers may be injected during a survey by the circuit consisting of battery B-1, potentiometer R-9 and timer T-1. The input from the detector is disconnected and a voltage is supplied to the grid of the balanced amplifier to drive the output signal to full scale. The marker is initiated by an external push button. Its duration is determined by timer T-1 and its amplitude by R-9.

3.2.2 Converter

The converter section turns the D.C. voltage developed across R-1 into amplitude modulated pulses.

A small part of the full-wave rectified 60 cps line voltage appears across R-25 and is amplified by V-2B. The output of V-2B triggers a univibrator producing constant amplitude square waves (Figure 14a) at a 120 pps rate. These are fed to the grid of the upper converter tube V-2A. The signal from the bridge circuit is fed into the grid of tube V-3, which is in series with the cathode of V-2A. The detector signal determines the current through both V-3 and V-2A and hence the gain of V-2A. Therefore, the amplitude of the pulses appearing across R-11 (Fig. 14b) are proportional to the signal from the bridge. The pulses across R-11 are transformer coupled to the comparator unit.

Batteries, B-2 and 3, and resistors, R-12, 13 and 14, fix the bias of V-3 so that the tube operates over a linear portion of its characteristic. A floating ground is used since the signal from the bridge is at a potential above chassis ground. R-26 and C-8, 9 and 10 provide a filter from the floating ground bus to chassis ground.

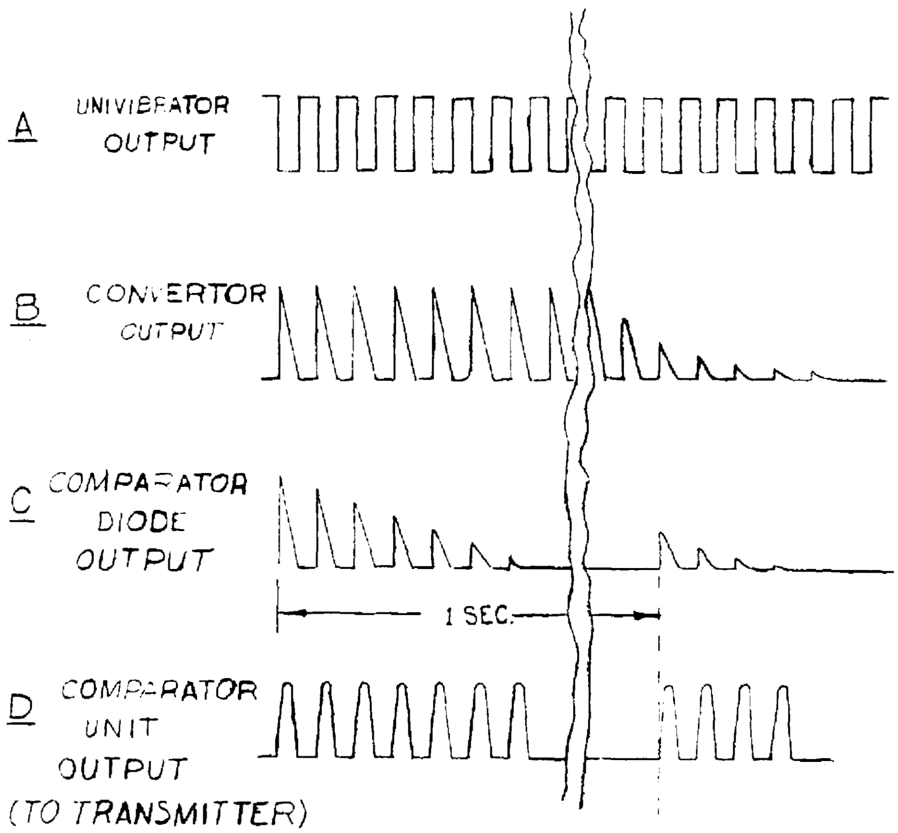

Figure 14--Circuit Wave Forms Information Station

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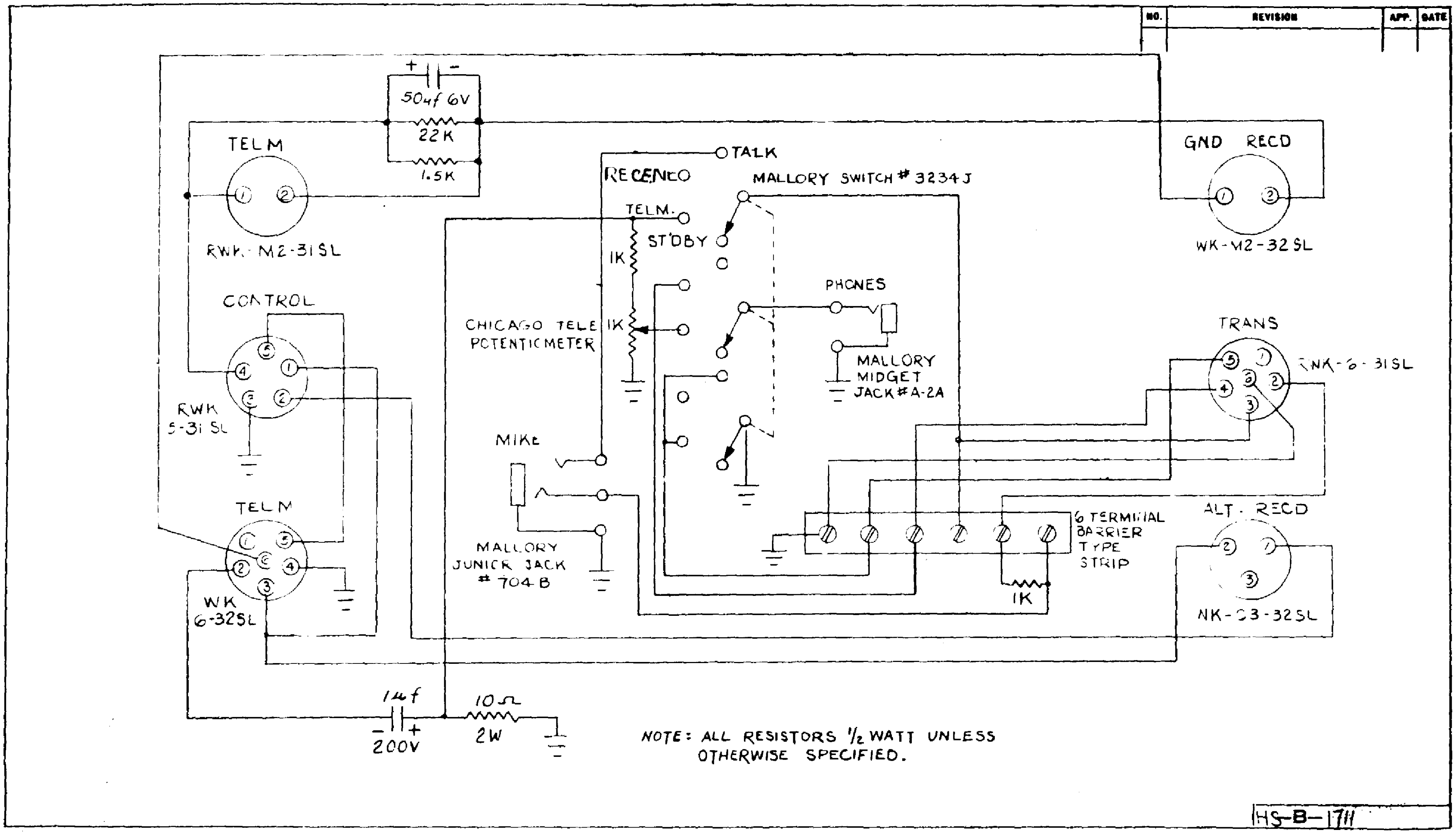


Figure 15--Telepulse Junction Box Circuit Diagram

3.2.3 Comparator

The comparator circuit changes the amplitude modulated pulses from the converter into a time-modulated pulse-train.

The output pulses of the converter are transformer coupled into the comparator unit, where they are amplified by V-10. The pulses out of this amplifier appear on the plate of the discriminator diode, V-11. The cathode potential of this diode is varied linearly from a minimum to a maximum voltage by R-37 whose shaft is motor driven at a rate of 1 cps. The limits of this variable voltage are set by R-36 and R-38. Only those pulses on the plate of V-11A larger in amplitude than the cathode potential pass through the diode. Therefore, each second a train of pulses of decreasing amplitude are produced (Fig. 14c). These are fed to an amplifier (V-12) which drives a univibrator (V-13), whose output is a constant amplitude pulse.

R-38 is adjusted so that at zero signal on the bridge results in the production of five pulses large enough to trigger the univibrator. With one volt on the bridge about 95 pulses are produced. Since the input rate is 120 pulses per second, no pulses are transmitted for at least one quarter of a second. A large sharp pulse is produced by the potentiometer as the wiper leaves the winding on the high end, therefore capacitor C-16 must be kept small so that it will discharge before the wiper again contacts the winding on the low end to beginning of the next cycle. C-18 acts as a by-pass for the residual spike and reduces its amplitude to a level which will not affect the pulse discriminators. The output of the univibrator, Figure 14d, is a constant-amplitude time modulated pulse train, whose length is proportional to the ground level radiation intensity. It is fed to a cathode follower (V-14) and then transformer coupled to the radio transmitter.

3.2.4 Power Supply

Power for the bridge and comparator units is developed in a power supply utilizing a Sola constant voltage transformer with B plus VR tube regulation. The converter unit, however, has its own power supply which is floated above chassis ground, using a standard transformer and VR tube regulation. The instrument is powered 110 volt, 60 cps through a fused plug.

3.3 Mechanical Description

The telepulse coding unit consists of four 5" x 7" unit chassis connected together by octal connectors, and mounted on a tray for mechanical rigidity. The overall dimensions are 14-1/8" long by 10-1/4" wide, by 7-3/4" high. The assembly fits into a standard aircraft shock mounted rack.

3.4 Junction Box

The junction box controls the radio communication equipment. A switch on the side of the box allows the operator to use the radio for voice transmission, voice reception or telemetering transmission. Jacks for connecting a microphone and earphone are provided on the same side of the box as the switch.

The junction box is 9½" wide by 7" high by 3¼" deep and also serves as an interconnecting point for the cables which join the units of the system. A circuit diagram is shown in Figure 15.

3.5 Operation

1. Allow the instrument to warm-up for approximately five minutes.

2. With zero signal into the bridge bring the ground level recorder to zero by adjusting R-3 (See Fig. 16)

3.6 Calibration

The calibration of the telepulse coding unit should be done in the following order: 1) bridge, 2) converter, 3) comparator. Figure 16 shows the positions of the controls.

3.6.1 Bridge:

1. With zero input, the bridge is balanced (R-3) to produce a zero reading on the recorder.
2. A negative one volt signal is applied to the input and the sensitivity control (R-5) adjusted for full scale on the recorder.
3. The marker push button is closed and the recorder brought to full scale by adjusting R-9.
4. The duration of the marker is set by adjusting timer T-1. The minimum period should be five seconds.

3.6.2 Converter:

1. With zero signal input, the bias of V-3 is adjusted to -1.45 volts. The amplitude of the converter output pulses, appearing across R-10, should be approximately 16 volts.
2. With 1.4 volts applied to the input of V-3, the amplitude of the pulses across R-10 should be approximately 30 volts.

3.6.3 Comparator:

1. Resistor R-45 in the comparator unit is adjusted so that the univibrator (V-13) is triggered reliably by ten volt input pulses.

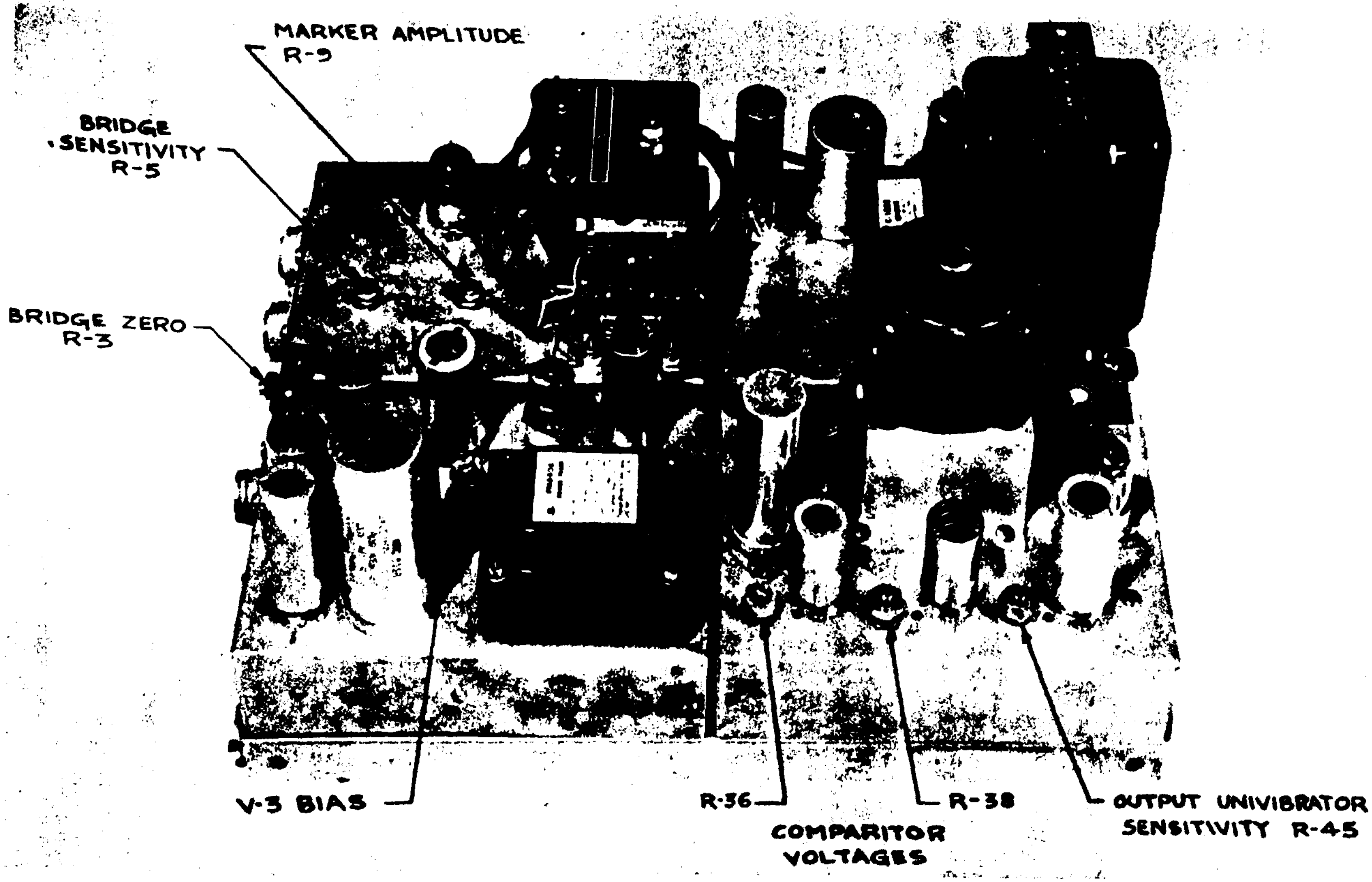


Figure 16--Calibration Controls Coding Station

2. Connect the output of the telepulse information unit to a scaler.

3. Place 0.20 volt on the input of the bridge (This should drive the recorder to 0.20 ma), and adjust R-38 until the scaler indicates an average count of 23 cps.

4. Increase the bridge input voltage to 0.80 volts. (the recorder should indicate at 0.80 ma), and adjust R-36 until the scaler indicates an average count of 77 cps.

5. Since the voltage drops across R-36 or R-38 are interdependent, steps 3 and 4 must be repeated until the scaler finally indicates the proper count for each of the input voltages after all adjustments are completed.

6. A linearity check is then made by introducing signals from zero to one volt on the bridge circuit. The scaler count for zero input should be approximately five cps, and for one volt input 95 cps. For intermediate points the proper count can be determined by:

$$C = 90 V_1 + 5$$

where C = counts per second

V_1 = input to bridge in volts.

If there is a calibrated Telepulse Receiving Station available, an alternate method of calibrating the coding station is:

Connect the telepulse coding station directly to the calibrated telepulse receiving station. A voltage is placed on the input of the bridge which drives the recorder to 0.20 ma. R-38 of the comparator unit is adjusted until the receiving station recorder reads 0.20 ma.

Then a signal producing an 0.80 ma deflection on the coding recorder is introduced and R-36 adjusted until the receiving recorder reads 0.80 ma. The signal producing 0.20 ma is injected again and R-38 readjusted to bring the receiving station to the .20 ma reading. Then the 0.80 signal is injected and R-36 adjusted to bring the receiving recorder to the proper level. This process is repeated until the Receiving Station recorder indicates the correct reading when the voltages are alternated. A linearity check is then made by introducing signals of various amplitudes from 0 to 1 volt on the bridge circuit. The coding and receiving station recorders should agree within 5% of full scale.

4. TELEPULSE RECEIVING STATION

4.1 General Description

The Receiving Station telepulse unit (Fig. 17) decodes the information transmitted from the aircraft and records a signal, proportional to the radiation intensity at ground level on a strip chart recorder. The number of pulses in each pulse train transmitted from the remote station are counted and converted to a signal suitable for driving the recorder. The unit operates on 110 volt 60 cycle power.

4.2 Circuit Description

Several sections of the telepulse receiving station circuit (Fig. 18) are used in a telephone telemetering system, which obtains data from fixed ground-monitoring stations. These will be described first to separate them from the circuit operation in the aerial system.

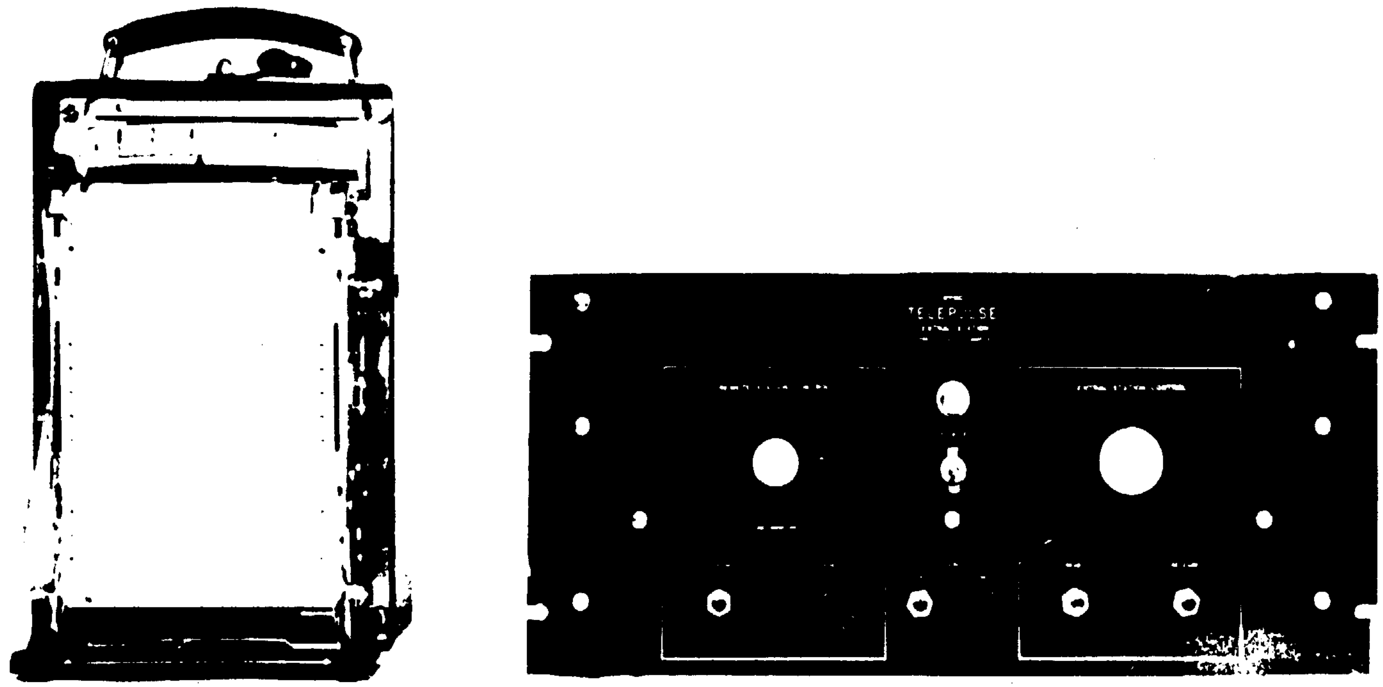
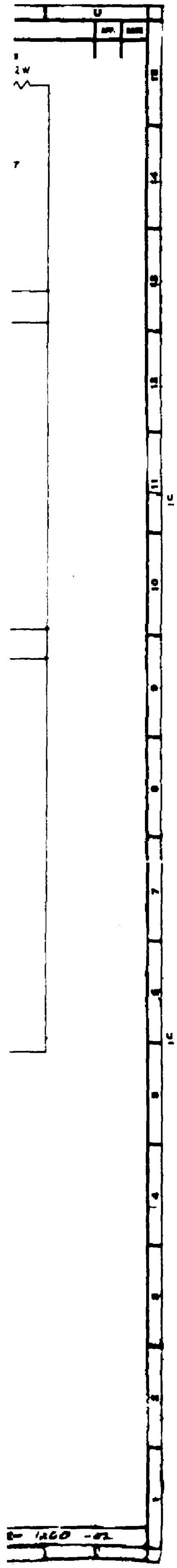


Figure 17--Telepulse Receiving Station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The lock-on circuit, consisting of oscillator (V-17), amplifier (V-16), the push button switch (S-), and relay (K-4) is used only with the telephone telemetering system. When a remote ground monitoring station is called, a timer holds the line for two minutes. If telemetering for a longer period is required, the lock-on button is pushed which places the 2400 cps tone generated by the oscillator (V-17) on the telephone line. This line actuates a latching relay at the monitoring station which will hold the line until the Receiving Station release switch is pressed.

The 2400 cps tone, its third harmonic (7200 cps) and 60 cps which is often picked up on telephone lines are attenuated by filters F-1,2 and 3 respectively. The filters prevent these signals from affecting the Receiving Station circuits. The filter circuits remain in the circuit for all types of operation although they are only necessary when using telephone lines and lock-on system. The circuit from this point on, is common to both aerial and ground telemetering.

Pulses from the radio receiver are amplified and shaped by V-1, V-2 and their associated circuitry, actuating Schmitt Trigger, V-3. For each input pulse (Fig. 19a) this stage delivers a uniform sized positive pulse, (Fig. 19b). This is fed through a cathode follower V-4B into a diode coupled (V-5B) step-charger, consisting of capacitors C-51 and C-52. While one of these capacitors is being charged by the pulses from the Schmitt trigger, the voltage of the other, developed by the previous pulse train, is read by a VTVM bridge (V-11 and V-12) whose output drives the strip chart recorder. Either three decade recorder chart paper can be used to read the intensity

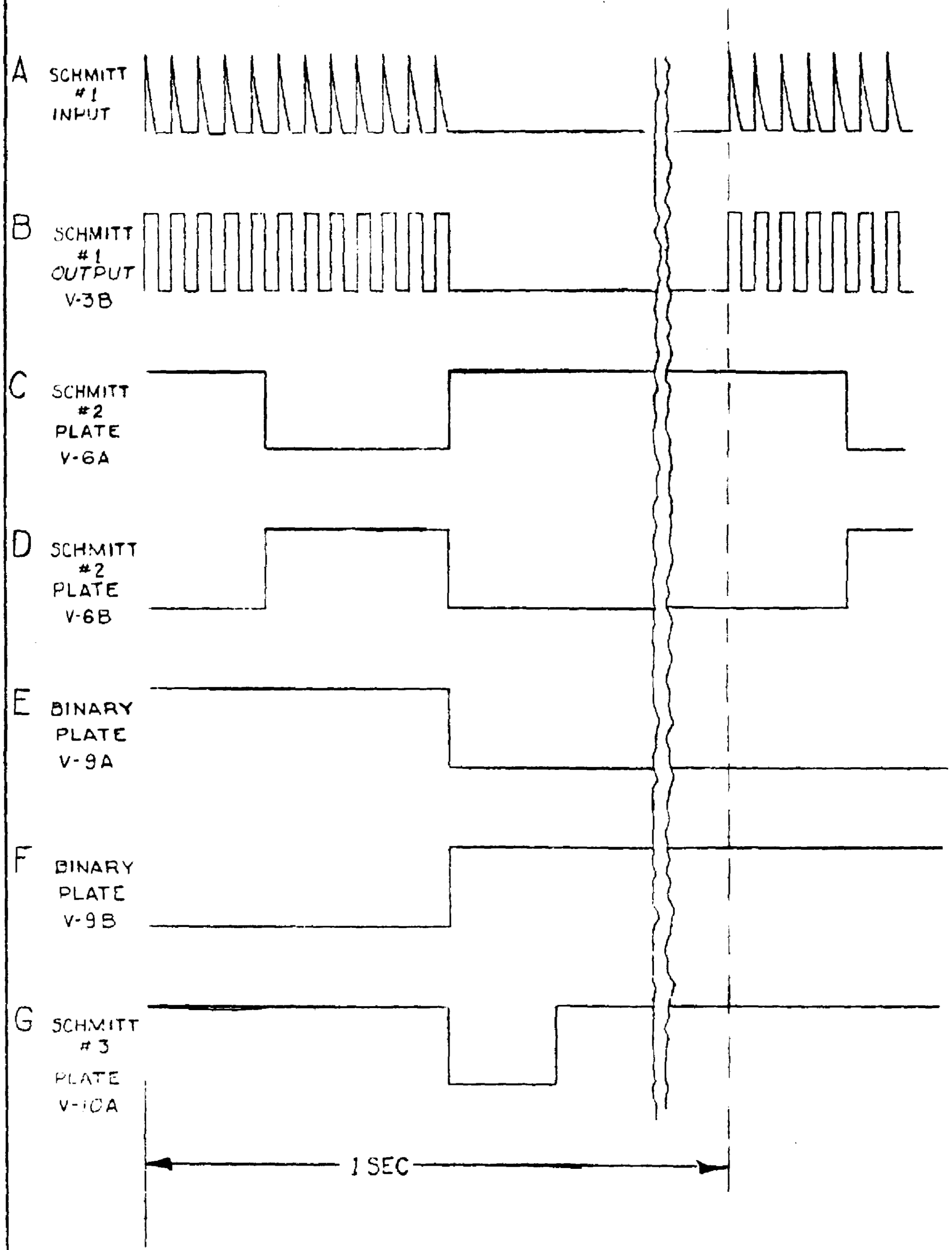

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Figure 19--Circuit Wave Forms Central Station

directly or the calibration curves given in Fig. 5 may be used to determine the intensity.

In order to alternate the capacitors in the charge and read positions, the positive pulses from the Schmitt trigger are also fed into integrating circuit, C-30 and R-32. The voltage developed across the integrating circuit causes the cathode potential of a cathode follower, V-4A, to rise, thus triggering the second Schmitt trigger, V-6. To prevent spurious pulses from actuating, V-6, R-32 is adjusted so that the integrating circuit will accept 5 pulses before the potential rises high enough to fire the Schmitt.

When the second Schmitt (V-6) is triggered, a negative pulse is produced at the plate of V-6A (Fig. 19c) which is applied to the third Schmitt trigger (V-10), and a positive pulse at the plate of V-6B (Fig. 19d) which is applied to a binary stage (V-9), the polarity of the pulses is such that these circuits are not affected. However, when the train of pulses stops, the cathode potential of V-4A drops the Schmitt trigger returns to its normal state producing a positive pulse on the plate of V-6A and a negative pulse on V-6B.

The negative pulse from V-6B triggers the binary stage (V-9). The relay K-2 in the plate circuit of V-9A is actuated or released, depending upon the previous condition of the binary, reversing the position of the step charger capacitors. The plate voltage variations are shown in Figures 19e and 19f. The positive pulse from V-6A fires the third Schmitt trigger (V-10), Figure 19g, actuating a relay (K-1) which discharges the capacitor just switched from the read to charge position, thus preparing it for charging by the next train of pulses.

A two microfarad capacitor C-46, is placed across the discharging relay K-1 delaying actuation until the switching relay has transferred the step charging capacitors. Since the maximum pulse train duration is 3/4 of a second, 1/4 of a second is allowed for switching and discharging of the capacitor.

To buck out the voltage developed across the step charger capacitors by the initial five pulses required for actuating the switching circuit, the capacitors are discharged to a small negative bias. The negative bias supply providing this voltage is also used to bias the diode(V-5C), which serves as a discharge path for coupling capacitor C-53.

The output bridge (V-11 and V-12) is a D.C. vacuum tube voltmeter capable of driving from 1 to 10 strip chart recorders should duplicate copies of the survey be desired. The recorder line card is plugged into J- so that the chart drive will run only when the read circuit is actuated. An oscilloscope is mounted on the front panel, displaying a portion of the input pulse train. A gain control (R-3) permits adjustment of the signal to an operating level which will reliably trigger the first Schmitt circuit.

Power Supply - The B plus supply is electronically regulated because of the wide variations in current required by the Schmitt triggers. All critical stages are decoupled to eliminate spurious counts.

4.3 Operation

The operational controls for the Telepulse Receiving Station are the bridge zero adjustment, the read and release push button switches, and the gain control. The lock-on control is only used for telephone telemetry. The horizontal and vertical position and intensity controls for the oscilloscope are located on the scope mounting plate. All of these controls are on the front panel (Fig. 17)

Procedure

1. Connect cables from the 110 volt 60 cps line, recorder and radio.
2. Turn line switch on and press the release button.
3. After five minutes warm-up, bring the recorder to zero by adjusting the zero set control (R-67). The zero test button is pressed to check the zero of the recorder when telemetering rather than the release switch, since it does not affect the counting and switching circuits. Therefore, the recorder will rise to the proper reading immediately after the release of the button.
4. Commence telemetering by pressing the read button and adjusting the level (gain) control (R-3) until the height of the pulses as observed on the oscilloscope is approximately 2/3 the height of the scope face. The switching relays will be heard if the circuit is operating properly.

Note: When the telemeter radio channel is used for voice communication, the release button should be pressed, otherwise the central station will be actuated by the voice signal resulting in erratic fluctuations of the recorder.

4.4 Calibration

The first part of this section covers the preliminary circuit adjustments used for setting-up a new unit or after major servicing, and the second part describes the calibration procedure which should be followed to check the instruments operation before a survey. Figure 20 shows the location of the controls.

4.4.1 Preliminary Adjustments

1. B supply - Adjust R-80 to obtain a B plus of 250 volts.
2. Filter circuit adjustments.
   a. Introduce a 2400 cps signal to the input (pin 6 of J-1). Capacitors C-6 and C-8 are adjusted to produce maximum attenuation to the 2400 cps signal as measured at the grid of V-1A. (Set the gain control (R-3) above minimum. A convenient way of obtaining a 2400 cps signal is to connect pins 5 and 6 of J-1 together, and then pressing the lock-on button.
   b. Place a 7200 cps signal on the input and adjust R-10 and R-13 until maximum attenuation is reached (measure at the grid of V-2A).
   c. Introduce a 60 cps signal and adjust R-15 and R-16 to produce maximum attenuation as measured on the grid of V-2A.
3. Connect the output of a Telepulse Receiving Station to the Telepulse Central Station input through a 100 to 1 attenuator.
4. First Schmitt trigger (V-3) sensitivity - Adjust the front panel control (R-3) until pulses of 10 volts amplitude appear

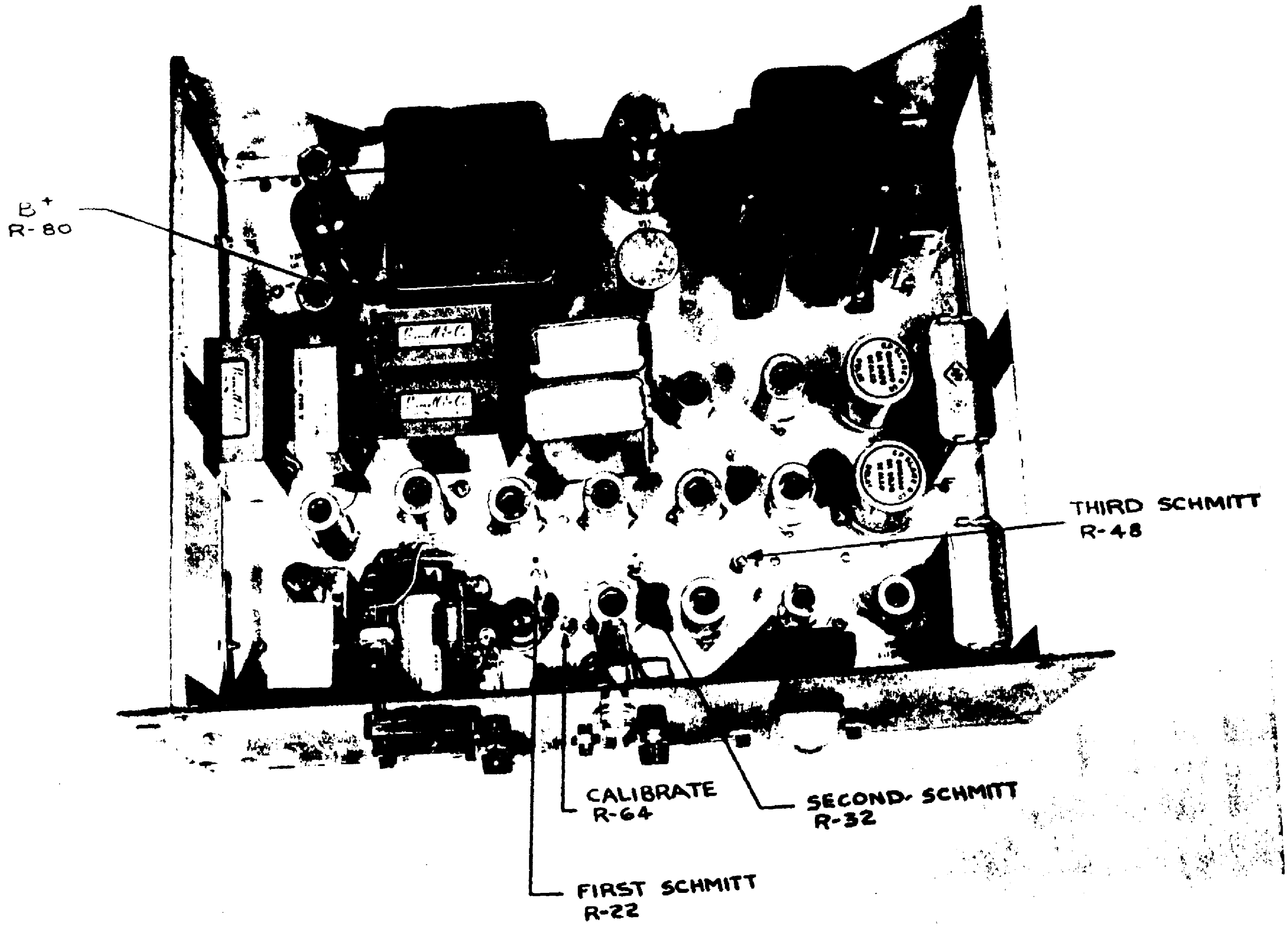

Figure 20--Calibration Controls Receiving Station

at the input (Grid of V-3A) of the first Schmitt Trigger. Then adjust R-23 until the Schmitt circuit just triggers.

5. Second Schmitt Trigger (V-6) - With five pulses per train from the information unit, adjust R-33 so that the second Schmitt triggers on the fifth pulse from the first Schmitt.

6. Third Schmitt trigger (V-10) sensitivity - R-48 gives a range of control from a point where the Schmitt cannot be fired to where the Schmitt fires more than once per period. R-48 should be adjusted to a point midway between these extremes to insure reliable operation of the grounding relay, K-1.

4.4.2 <u>Calibration Procedure</u>

1. Press the release button and zero the recorder with the zero "SET" control.

2. Set the arm of R-76 to zero volts. (This control is mounted on the rear of the chassis).

3. Feed a signal of 90 pulses per train (from the information station) to the input of the Receiving Station, and bring the recorder to full scale by adjusting R-64.

4. Reduce the number of pulses per train to five, and adjust R-76 until the recorder reads zero. This adjustment bucks out the potential developed across the integrating capacitors by the initial five pulses.

5. Several check points over the full range should be taken by introducing appropriate signals from the information unit.

5. APPLICATION

5.1 Fallout Studies

The HASL Aerial Survey System has been used successfully on Operation Wigwam. However, the data is classified and is not included here.

Field tests were conducted at the U. S. Atomic Energy Commission, Nevada Test Site during Operation Teapot, Figure 21 shows the aircraft installation at the operator's position used during these tests. In front of the operator's seat are the control box and the recorder, which indicates aircraft radiation intensities. The junction box is mounted on the left side of the operator. The recorder, which indicates ground level intensities, was mounted on the right side of the aircraft facing the operator. The Telepulse Coding Station is behind the control box and the radio equipment is in a rack behind the operator's seat. The "Top Hat" detector was mounted in the tail section of the aircraft, Figure 22, where it is most distant from radioactive instrument dials and "sees" only the thin skin of the aircraft between it and the ground.

Data obtained over Yucca Flat when flying south, parallel to the main access road, is shown in Figure 23. This data is typical of that which would be expected from a series of localized contaminated areas. The plane flew at an altitude of 500 feet and telemetered the data to a Central Station located at the Control Point (south) end of the Flat, and the chart shown was taken from the Central Station recorder.

While the basic aerial survey technique as developed by this Laboratory has applications to raw materials exploration, civil

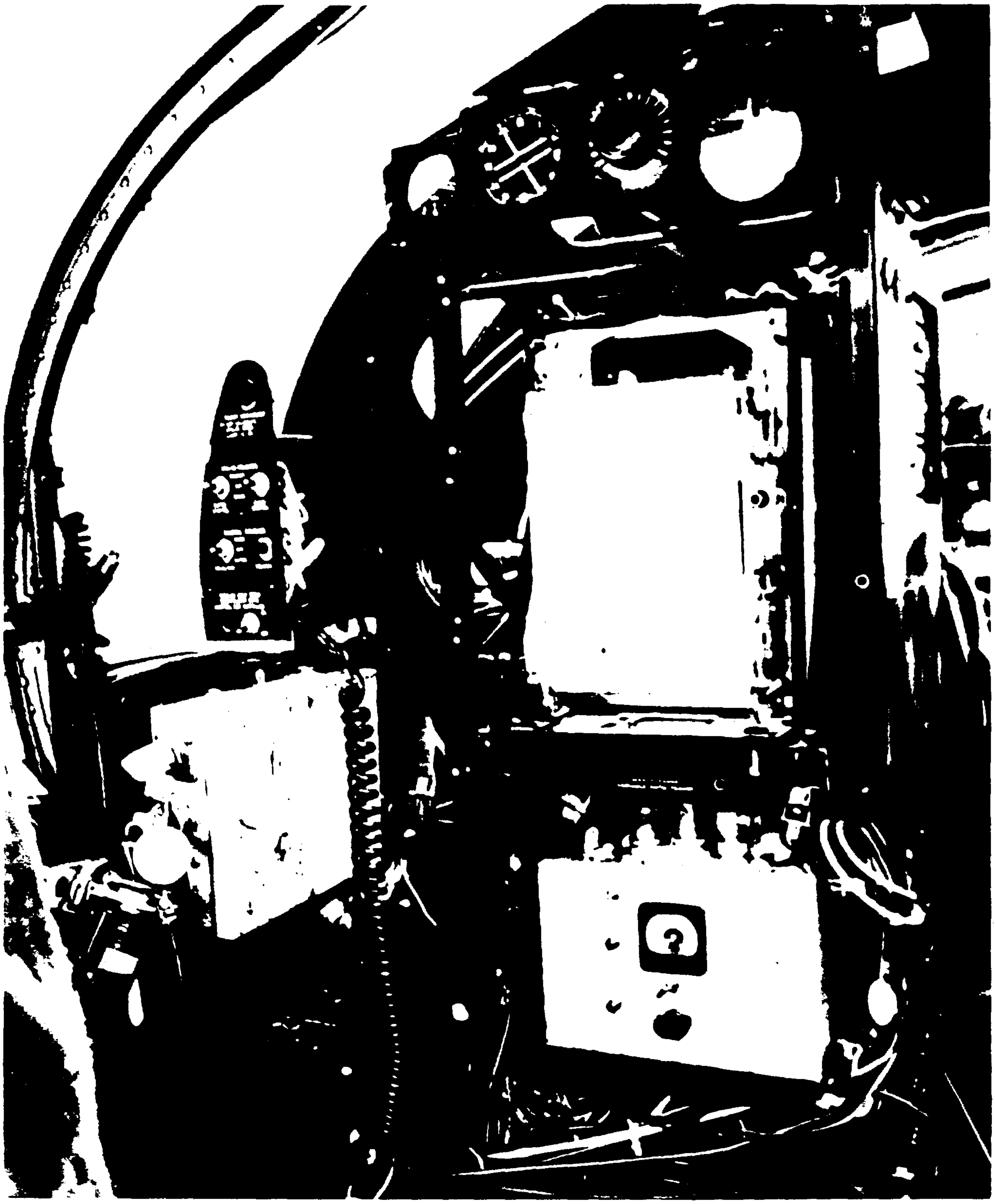

Figure 11--Picture of AD5-N Operator's Position

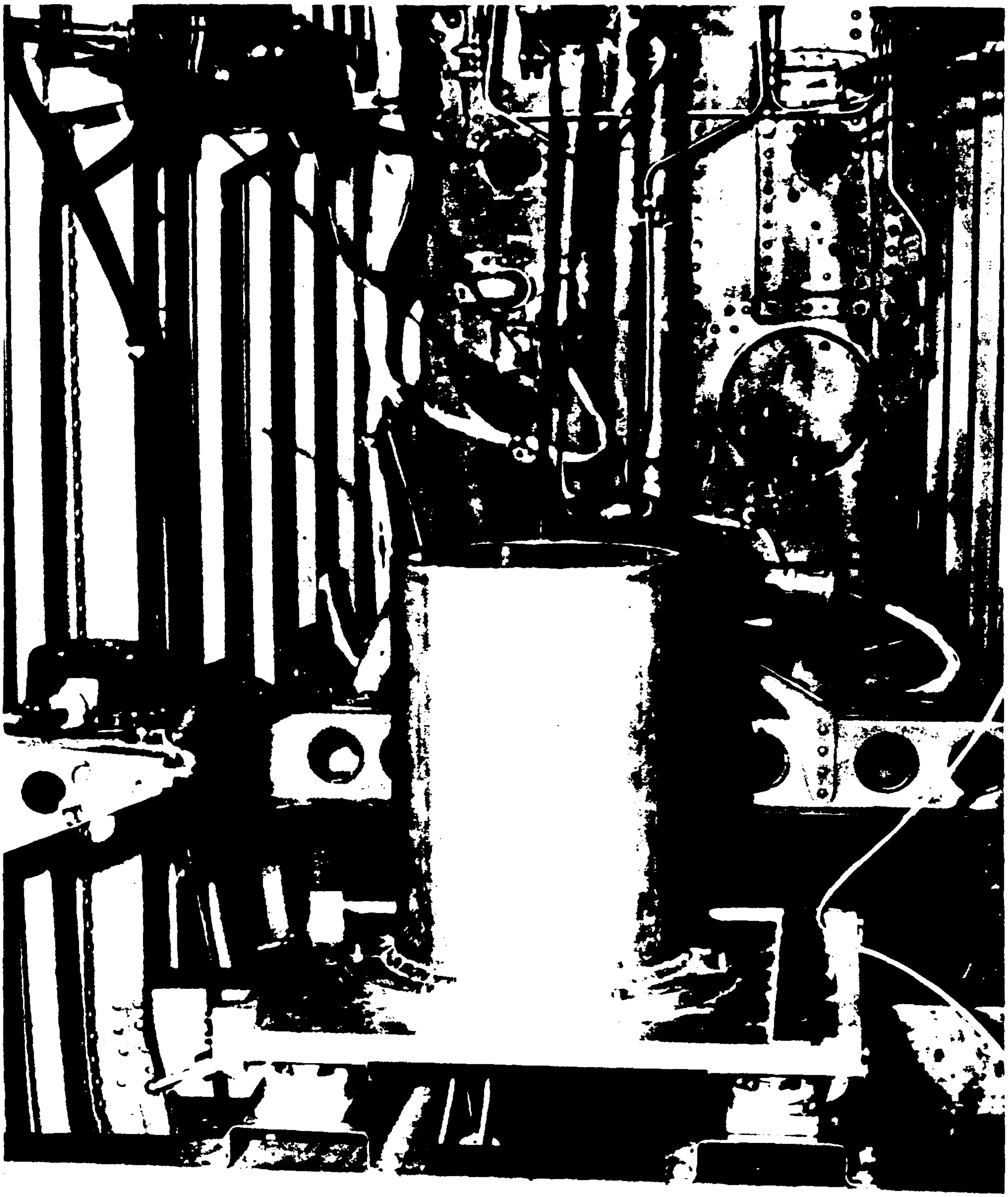

Figure 22--Picture of Top Hat Location

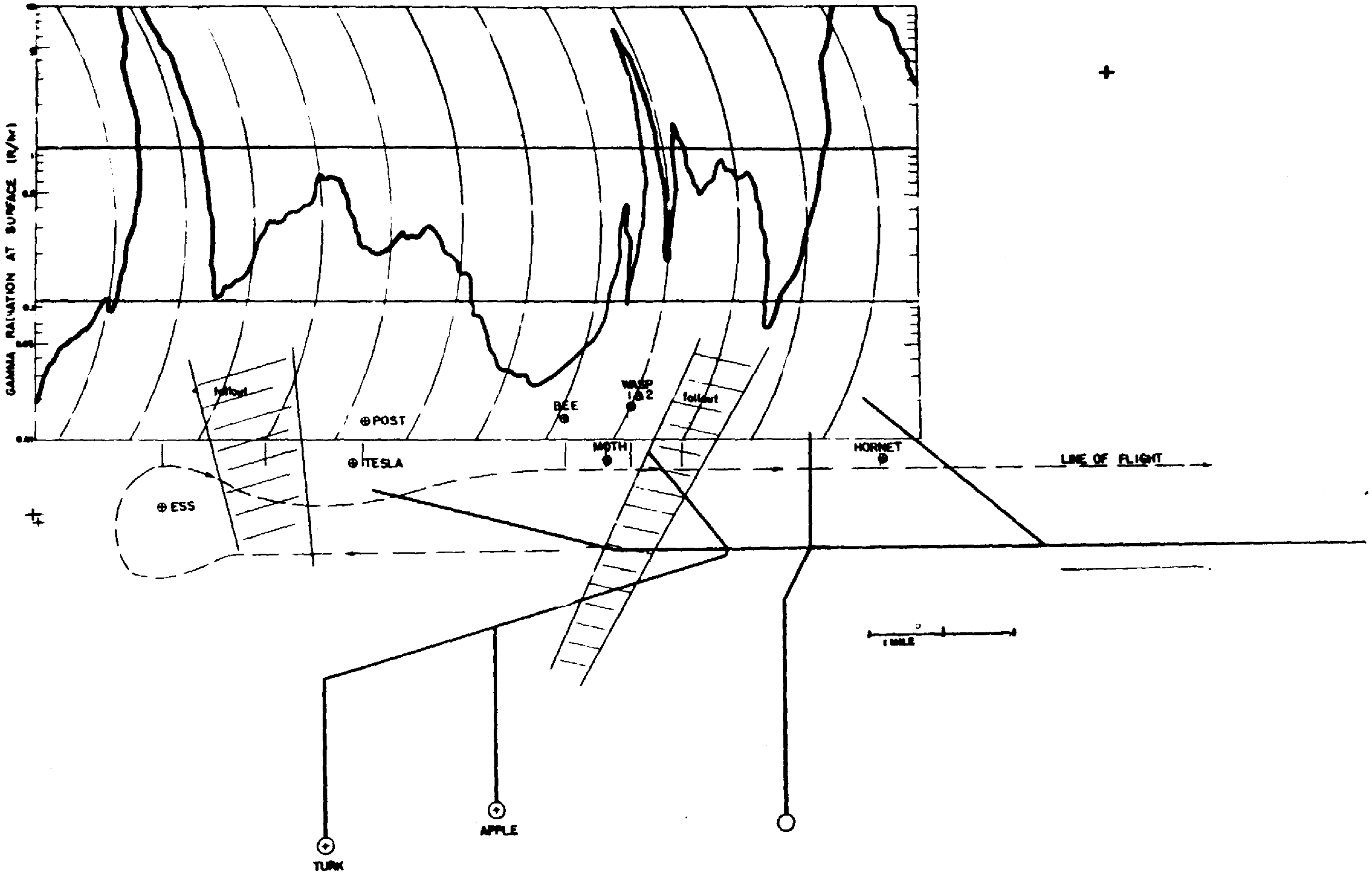

Figure 23--Yucca Trace

defense and other nuclear problems, it has also been utilized during nuclear weapons tests and the information obtained is in the classified category. With those readers who have access to this material, the attached list of reports contains these field applications and performance results.

The application of the aerial survey technique developed by this Laboratory during nuclear weapons tests is given in the following reports.

1. NYOO-4606 - Performance of HASL Instrumentation During Castle (Secret, RD)

2. NYOO-4618 - Radioactive Debris from Operation Castle-Aerial Survey of Open Sea Following Yankee-Nectar (Secret, RD)

3. ITR-1185 - Operation Teapot CETG 30.3 Preliminary Report (Confidential, RD - until reviewed for classification)

These reports include data from which the altitude compensation technique was derived, but due to classification they are available to authorized personnel only.