Cesiom 137

INSTRUCTION MANUAL mic Rocunits (10)

FOR

MODEL 493-1 GM SURVEY METER

Serial No. 693 Thru___

Probe 493-50 CS-137 Gamma

Part No. 493-1-1A

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1 General Description

1.1 Purpose of Equipment - The VICTOREEN Model 493 is a low-cost, general purpose portable GM Survey Instrument which may be used to measure low levels of radiation in a wide variety of field and laboratory applications. The VICTOREEN line of optional detector probes permits the instrument to be used as a gamma, beta-gamma, or alpha-beta-gamma survey meter.

Reliability and accuracy under rough field usage are assured by the solid-state design and rugged construction.

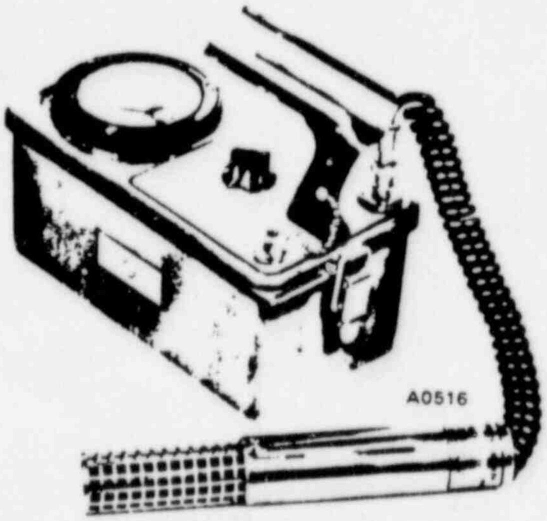

FIGURE 1. Model 493 GM Survey Meter

1.2 Physical Description - The Model 493 is a portable, self-contained instrument housed in a two-piece splashproof metal case. The accessory GM tube detector is contained in a probe on the end of a coiled cable. A clamp on the carrying handle provides convenient storage for the probe.

The single operating control, located on the case top under the handle, turns the instrument on and off, checks the batteries and selects the sensitivity ranges.

The batteries are retained in a high-impact resistant plastic battery compartment which cannot be corroded by battery leakage fluids. The battery contacts are readily replaceable without tools to facilitate cleaning or replacement.

A phone jack is provided for the connection of a Model 490-50 Portable Loudspeaker or 490-4 Headphone to allow aural monitoring.

Also included with the instrument is an operational check source. A vinyl carrying strap is optional.

1.3 <u>Specifications</u> - The electrical and mechanical specifications for the instrument are listed in Table I.

TABLE I: SPECIFICATIONS FOR MODEL 493 GM SURVEY METER

Feature	Specification
Ranges:	0-0.5, 0-5, 0-50 mR/h in three linear ranges. Corresponds to 300, 3000, and 30,000 cpm when used with 491-40 probe, calibrated with ^{137}Cs.
Accuracy	+20% of full scale on all ranges when calibrated with ^{137}Cs.
Response Time	(10% - 90%): 10 seconds nominal
Temperature Range:	-20° F to 120° F (-29° C to 49° C), excluding batteries. Alkaline batteries are recommended at temperatures below 32° F (0° C).
Battery Complement:	Two D size cells, NEDA Type 13 or 813.
Battery Life:	150 hours at 4 hours/day with standard carbon-zinc batteries.
Energy Dependence:	Instrument normally calibrated with ^{137}Cs
Dimensions:	4-1/2 in. (11.4 cm) wide x 8-3/4 in. (22.2 cm) long x 6-5/8 in. (16.8 cm) high (including handle)
Net Weight:	3.5 lb (1.6 kg), excluding probe.
Construction	Splash-proof, shock-proof, two-piece all-metal case.
Control	Single 5-position selector switch.
Probe Connector	Type UG-931/U (MHV).
Pulse Output Connector:	Amphenol #75-PC1M.
Accessory Supplied:	Operational check source.

Optional Equipment: Choice of detector probes (see paragraph 2.6), Model 490-50, Portable Loudspeaker attachment, Model 490-4 Headphone Set, and 772-17 Carrying Strap with two 710-44 strap buckles.

2 Operation

2.1 Installation

2.1.1 Batteries - Snap open the pull catches at each end of the case and remove the case bottom. This will expose the circuit board assembly and the battery compartment.

Squeeze the battery retainer clamp to remove it from the compartment. Install standard D size flashlight cells in the openings provided, observing the proper polarity. Replace the retainer clamp and the case bottom.

If operation below 32^0 F is contemplated, use alkaline batteries.

To check the batteries, turn the selector switch to the BAT position. If the meter does not read within the check band, the batteries must be replaced. The battery test may be performed at any time, whether the instrument is in a radiation field or not.

Remove all batteries if the instrument is to be stored for any extended period of time.

2.1.2 Detector Probes - Turn the instrument off and insert the probe connector on the probe cable into the coaxial receptacle to the right of the handle post. Press down, turn clockwise for about 1/4 turn and then release to lock the bayonet catches on their mating connector pins.

2.2 Meter Readings - The meter scale is calibrated in milliroentgens per hour (mR/h) when used with the standard Model 491-40 probe on ^{137}Cs gammas, or if the probe being used is not the MOdel 491-40, appropriate standardization factors for the mR/h scale (not the c/m scale) are required. Energy response curves for the VICTOREEN GM detector probes are shown in section 2.6, Figures 3 through 6. Divide the meter reading by the ratio of indicated-to-true exposure rate (given in Figures 3 through 6) for the particular probe and energy to determine the true exposure rate.

2.3 Use of Portable Loudspeaker or Headphone - The phone connector mates with the VICTOREEN Model 490-50 Portable Loudspeaker attachment or Model 490-4 Headphone Set. Each GM tube pulse results in a distinctly audible click in the loudspeaker or phones.

The rapid changes in exposure rate normally encountered in survey work are often more noticeable with the loudspeaker than with the indicating meter. Thus, concentrations of radiation, such as spills or X-ray leaks, may be located without constantly watching the meter.

Due to the random nature of ionizing radiation, the clicks are randomly spaced in time. When measuring low radiation levels, one may wait for several seconds before any click is observed, and then there may be two or three in rapid succession. Accurate measurements of background and other low-level radiation can be made by counting loudspeaker clicks, and timing with a watch which has a second hand. The procedure is to count a given number of counts and observe the time required to obtain these counts. The radiation rate in counts-per-minute is the number of counts divided by the time in minutes.

The following table gives the number of counts that are required to provide a given percentage error, where standard error is defined as that error for whic, in 68 cases out of 100, the true error will not exceed the given percentage error. The nine-tenth error is that error for which the true reading is no different from the observed reading within the given percentage limits for 90 cases out of 100.

TABLE II: BACKGROUND COUNT, STATISTICAL ERROR

Percent Error	Number of Counts Required For: Standard Error	Nine-Tenths Error
1%	10,000 Counts	27,000 Counts
3%	1,000 Counts	3,000 Counts
10%	100 Counts	271 Counts

2.4 Operability Check - A low-intensity uranium beta check source, Part No. 700-115 (nominal activity: 0.013 μCi), is fastened to the side of the case bottom. This may be used in conjunction with any of the GM probes connected to the instrument in order to verify operability and to check the constancy of calibration.

For the Model 491-40, 491-30, and 489-4 beta-gamma probes, the beta shield should be retracted to expose the perforated Geiger tube guard. One of the square openings in the perforated guard near the center of the GM tube should be placed directly over the 3/8" diameter circle on the operational check source, under which the beta source is located. This check must be carried out without the presence of any additional appreciable radiation fields from other sources.

If the counting rate obtained on a specific combination of probe and instrument is retained, a periodic repeat of this procedure will check the constancy of calibration of the instrument and probe combination.

The Model 489-35 end window probe can be checked in a similar manner by removing the plastic alpha and beta cap from the end of the probe and placing the mica window end of this geiger tube probe on the operational check source directly over the circle identifying the location of the source.

2.5 Use of Carrying Strap - A vinyl, easy de-contaminable carrying strap with its attaching strap buckles is provided. The strap anchors are arranged in such a way that the meter is unobstructed when the instrument is carried from the shoulder. Refer to Figure 2.

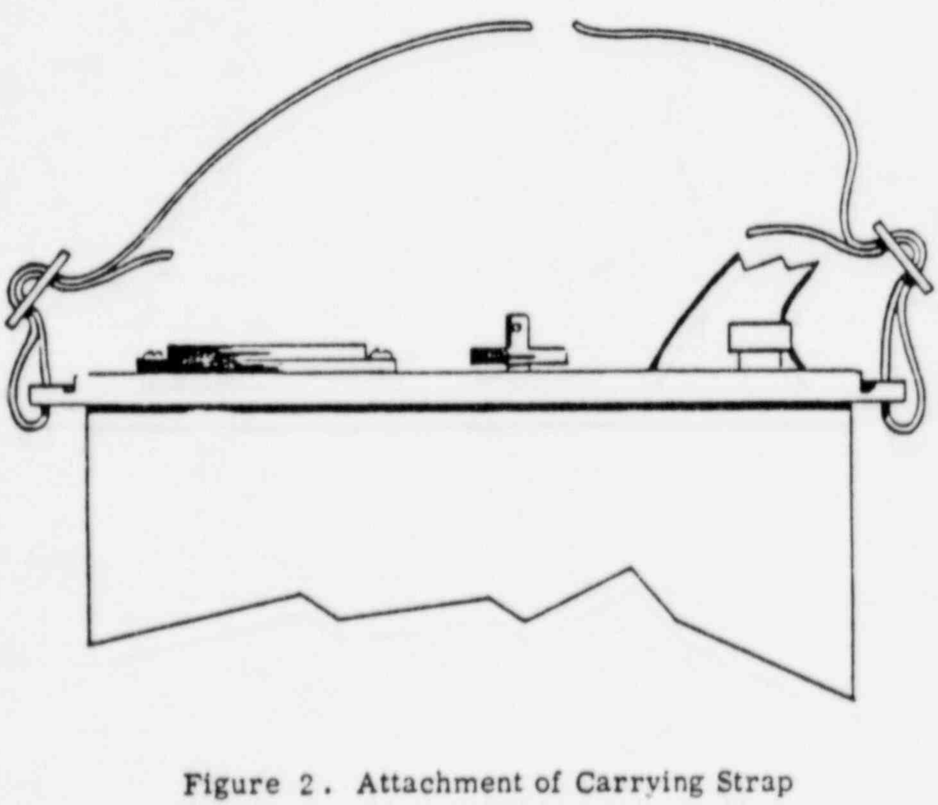

Figure 2. Attachment of Carrying Strap

2.6 Detector Probes - Four different GM probe options are available with the Model 493. The standard probe, the model 491-40, provides direct readings on the mR/h scale for ^{137}CS gamma radiation.

The features of the four probes are shown in Table III. Figures 3 through 6 describe their energy response when used with the Model 493.

TABLE III: DETECTOR PROBES

Probe	Features
491-40	Standard probe, provides direct readings on ^{137}Cs. 30 mg/cm^2 stainless steel wall GM tube. Beta and Gamma detection.
491-30	Increased sensitivity (approx. 2.3X for ^{137}Cs). 30 mg/cm^2 stainless steel wall GM tube. Beta and Gamma detection.
489-4	Increased sensitivity (approx. 5.3X for ^{137}Cs). 30 mg/cm^2 aluminum wall GM tube for good low-energy response. Beta and Gamma detection.
489-35	Increased sensitivity (approx. 5.1X for ^{137}Cs). 1.4-2.0 mg/cm^2 mica end window GM tube for good low-energy response. Alpha, Beta, and Gamma detection.

3 Theory of Operation

3.1 General - The overall operation of the Model 493 can best be understood by referring to the schematic circuit diagram, Figure 7. The GM tube detector is supplied with a regulated high voltage from the power supply, via R1. When the detector is energized by a photon of radiation, the current through R1 increases briefly, causing a negative pulse to appear at C1. This pulse is coupled via C1 to the pulse shaping circuit which amplifies and shapes the pulse. The shaped pulse supplies current for readout to the meter and its associated response time circuit, and the headphone output.

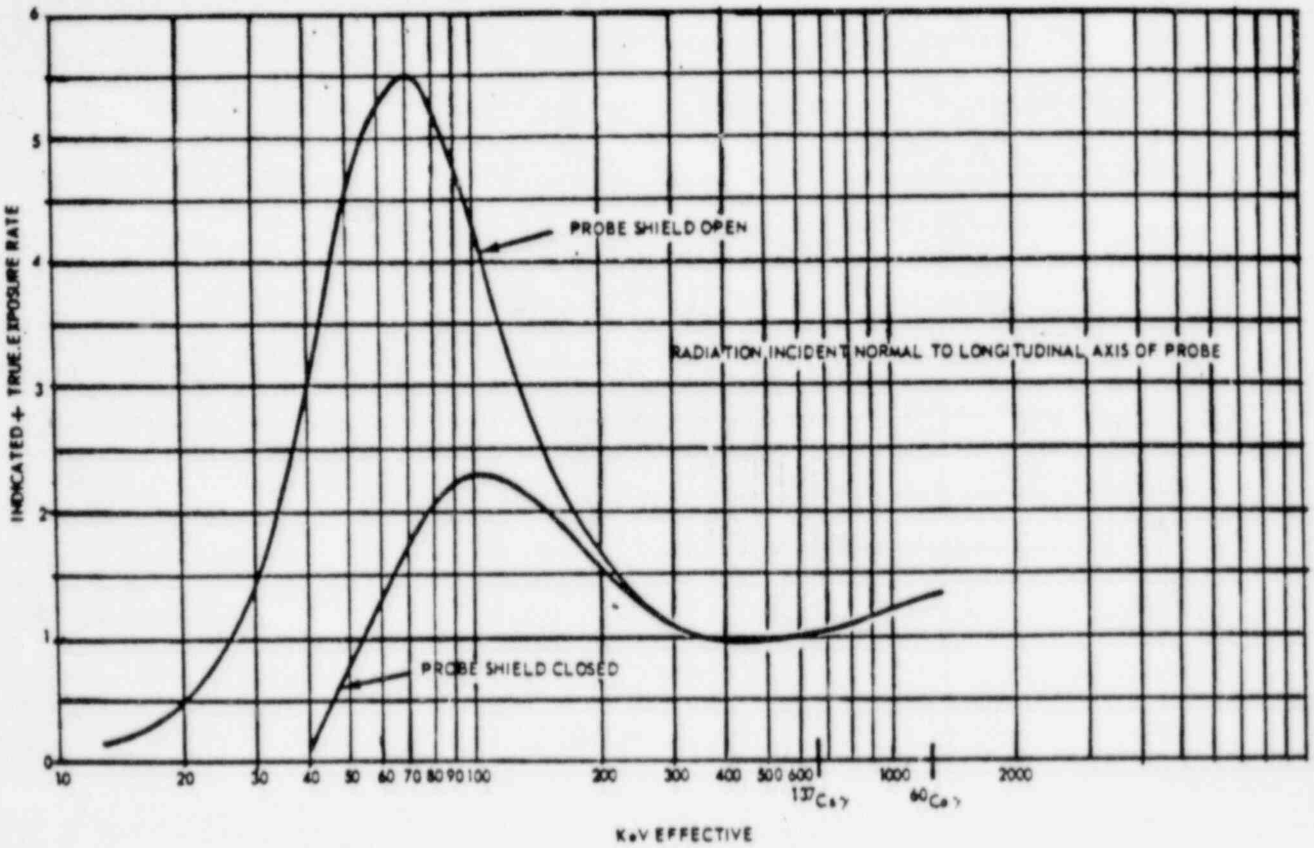

FIGURE 3. Energy Response, Model 491-40 Probe

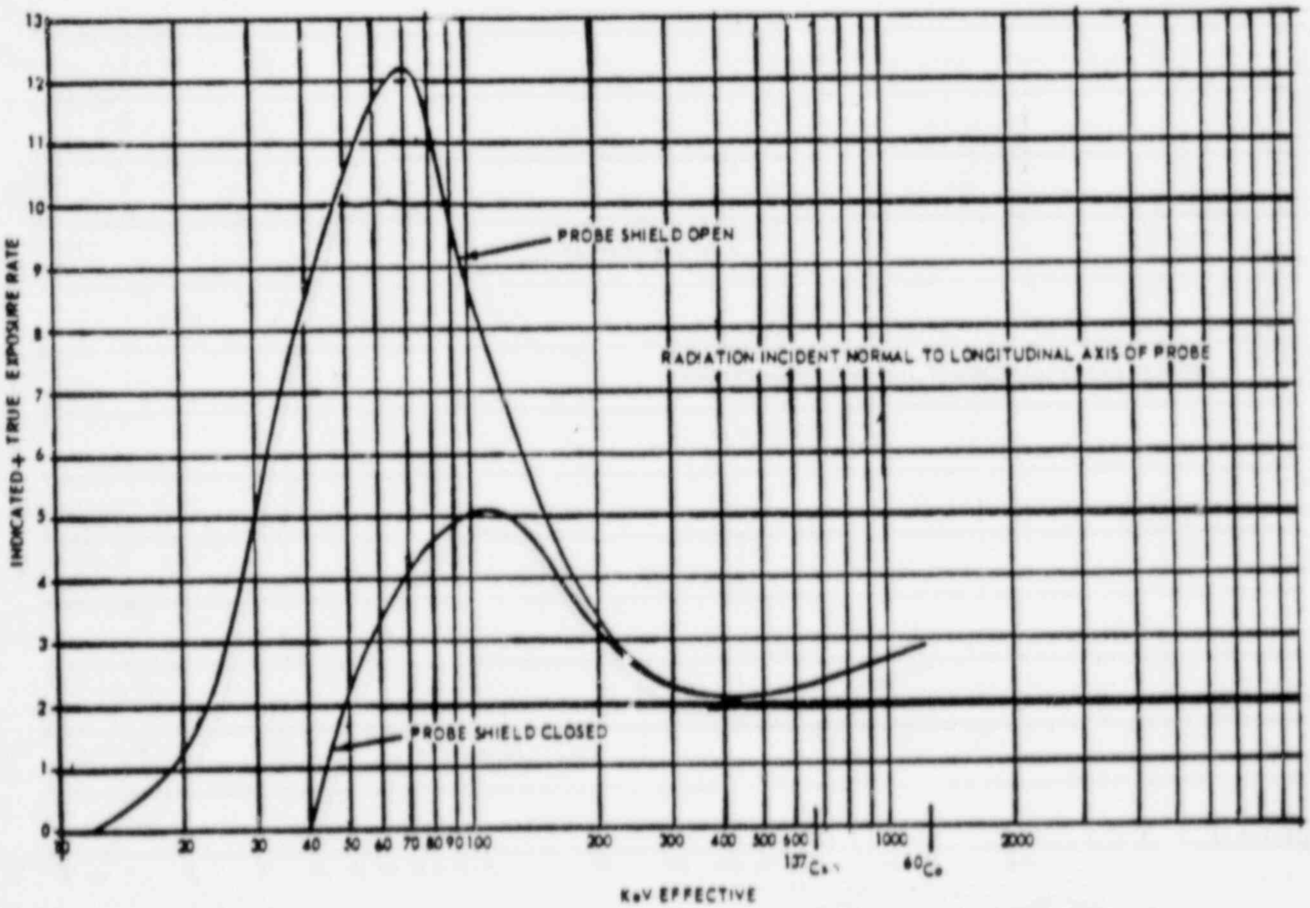

FIGURE 4. Energy Response, Model 491-30 Probe

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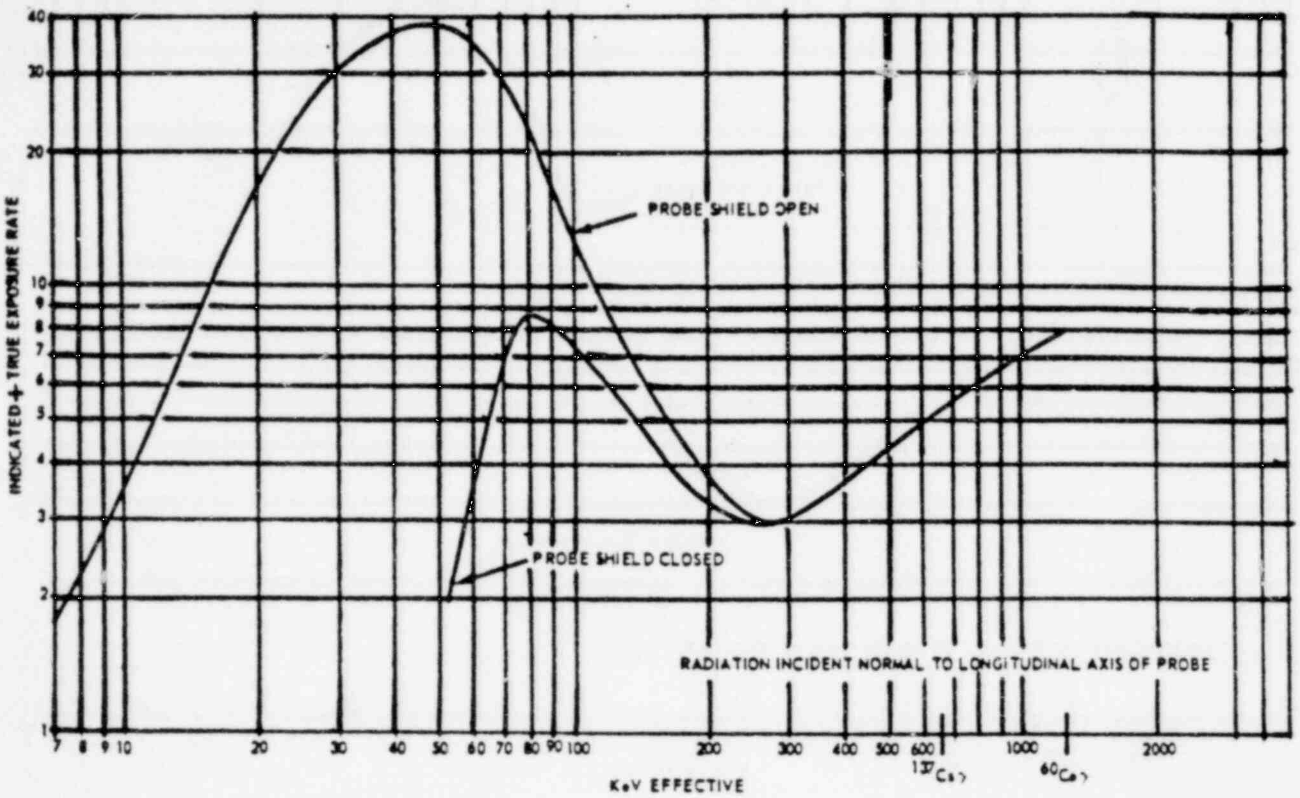

FIGURE 5. Energy Response, Model 489-4 Probe

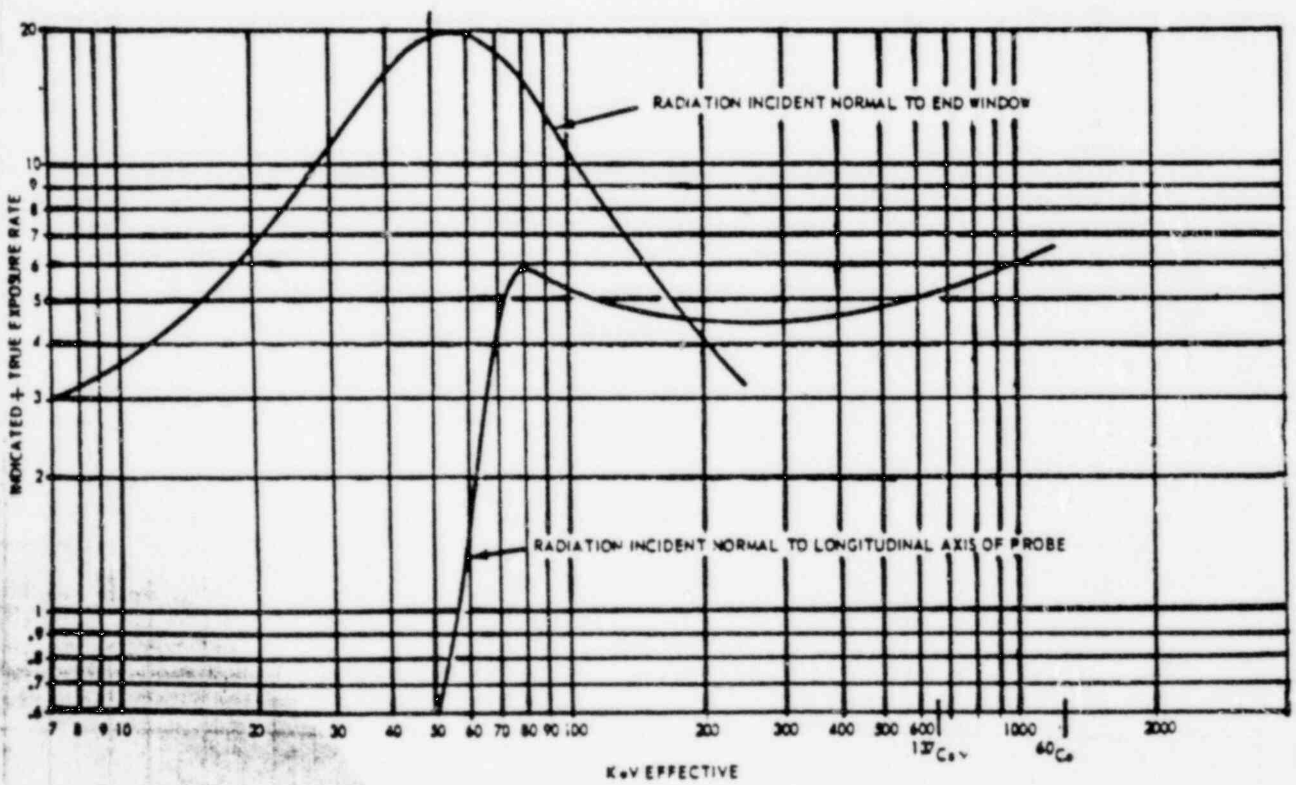

FIGURE 6. Energy Response, Model 489-35 Probe

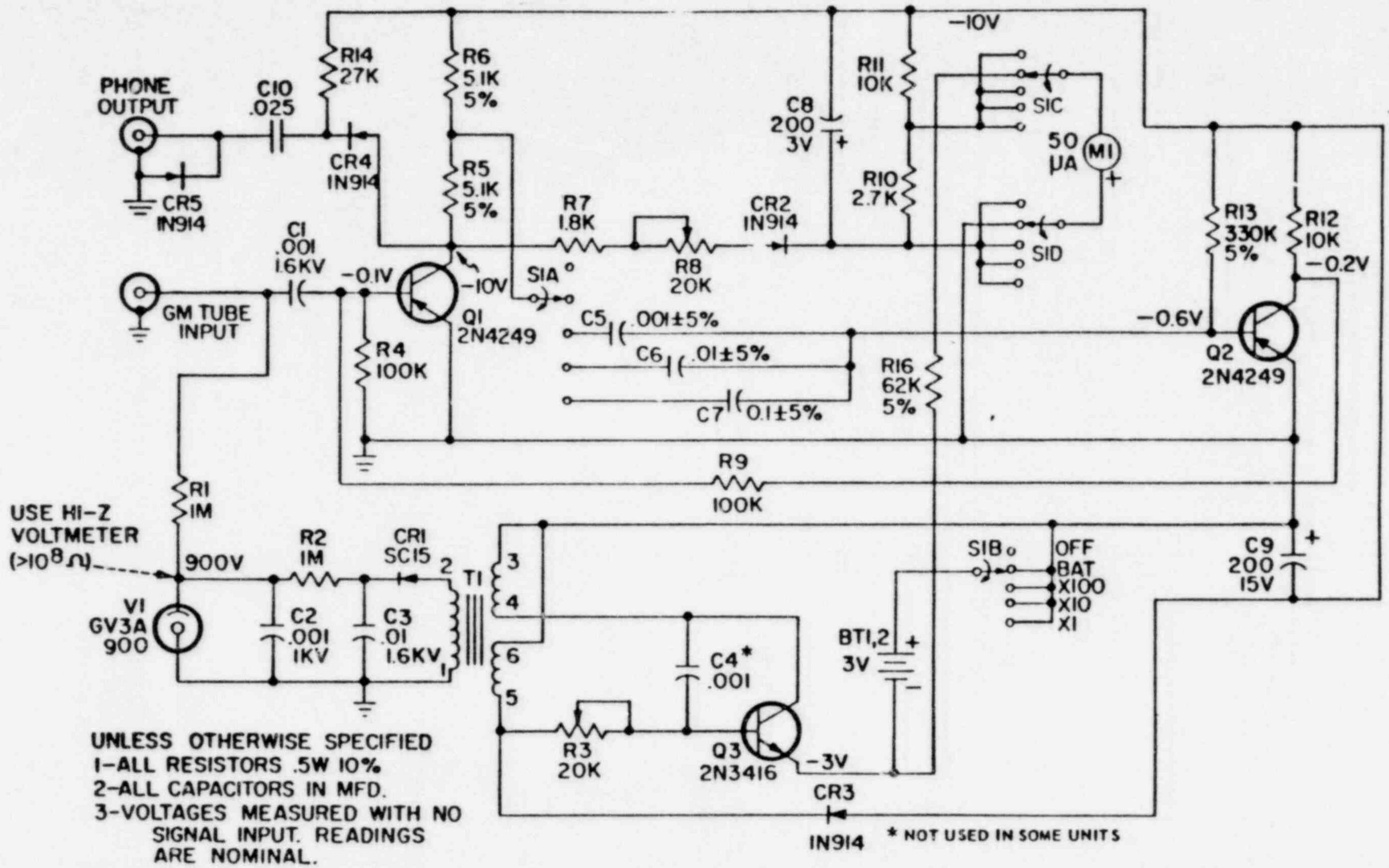

FIGURE 7. Schematic Circuit Diagram

3.2 Geiger Tube - The detecting element in each of the GM probes used with this instrument is a Geiger-Mueller tube. Although each tube had different operating characteristics, the theory of operation is the same.

The Geiger tube consists of a thin cylindrical shell which is the cathode, a fine wire anode suspended along the longitudinal axis of the shell, and an inert gas into which a small amount of a halogen or organic gas is inserted to act as a quenching agent.

A potential of approximately 900 volts is maintained between the two electrodes with the anode always positive. This voltage is slightly less than that required to produce a discharge in the gas. When a nuclear particle or ray of sufficient energy enters the Geiger tube, it ionizes a molecule of the inert gas. Because of the high voltage maintained between the electrodes, the positive ions are attracted to the cathode and the electrons are attracted to the anode. In their movement toward the electrodes, these charged particles trigger the ionization of additional gas molecules, resulting in an avalanche of ions flowing between the electrodes. The gas discharge thus created is similar to the glow of a neon lamp. The tube conducts as long as the gas is in the ionized state.

The small amount of halogen gas or organic gas in the gas mixture quenches the flow of ions, suppressing further electron avalanches until another nuclear particle or ray enters the tube. This glowing and quenching results in a rapid pulse or surge of current in the external circuit. When amplified through a headphone, this pulse is heard as one click in the headphone; the more radiation present, the more clicks per minute. The meter, suitably connected to the tube, indicates the number of pulses per minute on a calibrated scale.

3.3 Power Supply - All of the GM probes used with the Model 493 are powered by the same power supply, which has a regulated output of 900 volts. This supply also provides a regulated low voltage of approximately 10 volts to power the pulse shaping circuit. These voltages are provided by a blocking oscillator operated in the flyback mode.

The blocking oscillator portion of the circuit consists of transistor Q3, windings 3-4 and 5-6 of transformer T1, resistor R3, and the batteries. C4 serves only to suppress high frequency parasitic oscillations caused by the transistor parameters.

The high voltage power supply portion of the circuit consists of winding 1-2 of F1, diode CR1, the associated resistors and capacitors, and the corona discharge tube V1. The low voltage section is comprised of winding 5-6 of T1, diode CR3 and capacitor C9.

The operation of the power supply is as follows: When the instrument is turned on, Q3 conducts and an increasing current flows through winding 3-4 and the collector of Q3. This current induces a voltage in winding 5-6 of such polarity as to sustain and increase the conduction of Q3. The collector current continues to increase until Q3 becomes saturated, at which time the current through Q3 and winding 3-4 reaches a constant value. Because the current in winding 3-4 is constant, the induced voltage in winding 5-6 falls to zero, causing the base current to drop. This, in turn, causes the current in the collector and winding 3-4 to drop. This decreasing current induces a voltage in winding 5-6 of such polarity as to turn off the transistor. When the induced voltage at the base reaches zero, the transistor conducts again and the cycle repeats. Potentiometer R3 controls the rate of repetition.

As a result of the flyback action of the circuit, large voltage pulses appear on all the transformer windings. The voltage present is proportional to the number of turns on the winding.

The voltage at winding 1-2 is rectified by CR1, filtered by C3, R2, and C2, and regulated by the corona regulator tube V1. This provides 900 volts for the GM tube. At winding 5-6, the pulses are rectified and filtered by CR3 and C9. The regulating action of V1, reflected back through the transformer, maintains the output of the low voltage supply at a constant level.

3.4 Pulse Shaping Circuit - The pulse shaping circuit, consisting of transistors Q1 and Q2 and their associated components, is a monostable or one-shot multivibrator. Its function is to provide a uniform current pulse output for each pulse input, regardless of the shape or magnitude of the input pulse.

With no pulse input, Q2 is saturated due to the large base current supplied through R13. Because the transistor is saturated, the voltage across its collector to emitter is about 0.2 volts. This voltage is dropped to about 0.1 volt through R9 and R4, and applied to the base of Q1. This effectively maintains Q1 cut off, placing its collector at the supply voltage. Because there is no current through Q1, and thus through R5 and R6, the supply voltage also appears at the junction of R5 and R6. Whichever timing capacitor (C5 through C7) is connected in the circuit thus has a voltage drop across it equal to the difference between the supply voltage and the base voltage on Q2.

When a pulse appears at the base of Q1 of sufficient magnitude to forward bias it, collector current begins to flow. This drops the voltage at the junction of R5 and R6 to one-half the supply voltage. The change

in voltage is coupled to the base of Q2 through the timing capacitor and appears as a positive voltage at the base. This reverse biases Q2, the collector current drops, and the collector voltage rises. The rise is coupled to the base of Q1 via R9 and causes Q1 to conduct even harder. This results in a regenerative action which causes a rapid change of state, with Q2 now turned off and Q1 in saturation.

Because the voltage across a capacitor cannot change instantaneously, and the end of the timing capacitor which was at the supply voltage is instantaneously reduced to one-half the supply voltage (as Q1 becomes saturated), the end which connects to the base of Q2 must be at a positive voltage, equal in magnitude to one-half the supply voltage. This positive voltage keeps Q2 off, which, in turn, keeps Q1 in saturation. The base does not stay positive, however, as it is tied to the negative supply voltage via R13, and thus the capacitor charges toward the supply voltage at an exponential rate determined by the values of R13, R5, R6, and the timing capacitors. When this voltage reaches a slightly negative value, Q2 begins to conduct and, through the regenerative action, the circuit returns to its normal state with Q1 cut off and Q2 saturated.

Range switching is accomplished by switching timing capacitors in decade steps. This changes the charge per pulse available to the metering circuit by factors of ten. The nominal pulse duration for a given range is given in Table IV.

TABLE IV: PULSE WIDTH VS. RANGE SWITCH POSITON

mR/H	c/m	PULSE DURATION Microseconds
0-0.5	0-300	15,000
0-5	0-3000	1500
0-50	0-30,000	150

The determining factor on the pulse duration is the resolving time or dead time of the GM tube, which may be as high as 150 microseconds. During this dead time, the tube is incapable of responding to ionizing events. Because of the random nature of these events, it is statistically predictable that a certain percentage will not be counted during this dead time. If the dead time is 150 μsec and the count rate is 30,000 cpm, the resolution loss will be 7.5%. The resolution loss

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is proportionally less for lower count rates. In order for the instrument to respond accurately to all rates the meter scale is designed to compensate for the resolution loss.

To allow the use of a common scale for all ranges, the resolution loss is maintained on all ranged. Thus the pulse duration increases by a factor of ten from the X100 to X10 ranges, and again by a factor of ten on the X1 range.

3.5 Metering Circuit - The metering circuit consists of the meter, diode CR2, capacitor C8, and resistors R7, R8, R10, and R11. The series resistors R7 and R8 determine the amount of charge that is placed on C8 during the pulse period of the multivibrator. The charge on the capacitor is discharged by themeter, R10, and R11, causing the meter to deflect. The amount of deflection is proportional to the amount of charge which, in turn, is proportional to the average current through Q1. Thus the meter reading is proportional to the pulse rate and width. R7 and R8 are used for calibration.

3.6 Audio Circuit - Aural monitoring is achieved by diode coupling and a headphone. Each pulse counted by the pulse shaping circuit develops a positive pulse at the collector of Q1. This pulse is coupled to the headphone jack by CR4 and differentiated by capacitor C10. When the headphone is connected at the jack, a pulse of approximately 10 volts is developed across the headphone resulting in a clear audible click.

4 Maintenance

4.1 Battery Replacement - The best preventive maintenance that can be recommended is to keep the instrument turned off when it is not in use, to remove the batteries during extended periods of storage, and to be sure that fresh batteries are used.

The batteries may be checked by turning the selector switch to BAT and observing the meter indication. Battery life is about 150 hours with carbon-zinc cells when operated at an average rate of four hours per day.

4.2 Power Supply Adjustment - The operating point of the power supply oscillator is adjusted by means of potentiometer R3, located inside the case on the right when the instrument is viewed from a normal operating angle. The adjustment provides for optimum battery life and voltage regulation. Check the setting before calibration, and after any components have been replaced.

To check the operating point, insert a 0-100 mA meter in series with a fresh set of batteries. With the instrument turned on, the current should be 33 mA with carbon-zinc batteries and 30 mA with alkaline batteries.

If the current is within ± 2 mA of the correct value, no adjustment is required. If not, turn the POWER control, R3, counterclockwise, then clockwise until the correct value is obtained.

4.3 Calibration - The instrument is factory-calibrated using the Model 491-40 probe on Cesium-137 gamma radiation. The accuracy specification in paragraph 1.3 refers to this combination.

1. Install a new set of batteries and check the Power Supply Adjustment according to section 4.2 before proceeding with calibration.
2. Place the probe in a radiation field which will read in the upper half of the scale on the X10 or X100 range.
3. Switch the instrument to the proper range and adjust the calibration control for a correct meter reading. The calibration control R8, is located inside the case, on the left side of the instrument as viewed from the normal operating position.

Other probes and/or isotopes may be used for calibration purposes, but in that case the calibration must be performed in accordance with the energy response of the GM tube. For example, the ratio of indicated-to-true exposure rate for the Model 491-30 probe on ^{60}Co gammas is 2.9 (see Figure 4). To calibrate the instrument with this combination of probe and source material, adjust the instrument to read 2.9 times the true exposure rate. The accuracy specification in 1.3 will then be correct for this particular combination of isotope and probe.

4.4 Checking Pulse Shaping and Metering Circuit - After it has been determined that the power supply is operating properly and after voltage and resistance checks have been made as indicated on the schematic, the monostable multivibrator may be checked with an oscilloscope.

1. Connect a detector probe to the instrument as outlined in section 2.1.2 and expose it to the Operational Check Source on the side cf the case.
2. Set the instrument on the X10 range.
3. Check for waveforms as follows:
   (1) Q1 Collector: Positive 10 volt square wave.
   (2) Q2 base: Positive 5 volt pulse, rising sharply and decaying exponentially.
   (3) Q2 collector: Negative 10 volt square wave.

The pulses should vary in width by factors of ten on the respective ranges. Refer to Table IV for the nominal values.