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AEC RESEARCH AND DEVELOPMENT REPORT

PLUTONIUM WOUND MONITOR

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Instruments
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PLUTONIUM WOUND MONITOR

by

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ABSTRACT

A portable, lightweight monitor was developed to measure plutonium in wounds. Two scintillation detectors were designed for use with this instrument: one detects 17-kev X-rays from plutonium with a minimum detection level of 0.3 nCi of ^{239}Pu under 1/4 inch of tissue; the other detector is sensitive to alpha particles and is used to locate plutonium on the skin, in or near the wound. Plug-in circuit cards facilitate repair of the monitor.

CONTENTS

LIST OF FIGURES

INTRODUCTION

Quantitative measurements of plutonium in wounds are necessary because therapy procedures are based on the amount of this toxic material present in the tissue. The plutonium wound monitor previously used at Savannah River was not portable because of bulky components and heavily shielded detectors. A portable monitor was developed for easy transport to plant medical facilities or off-plant sites.

SUMMARY

The portable plutonium wound monitor is light and compact. Two detectors are used: The first, a NaI crystal, detects the 17-kev X-rays from plutonium, and can measure 0.3 nCi of ^{239}Pu under 1/4 inch of tissue (background: 15 counts per minute). The second detector is for locating plutonium-alpha contamination on the skin, in or near the wound. It consists of a light pipe with a wedge-shaped tip sprayed with ZnS(Ag) and covered with two layers of aluminized "Mylar."* This detector has an alpha detection efficiency of approximately 10% [background: 5 counts per minute (c/m)]. It can be sterilized before placing it against a wound.

The circuits for the monitor are on transistorized plug-in circuit cards to facilitate servicing. The monitor is powered by self-contained batteries or 110-volt AC, requires no warmup period, and is unaffected by normal temperature changes. Its calibration remains constant over long periods.

DISCUSSION

WOUND MONITOR

The wound monitor (Fig. 1) weighs 14 lb and measures 7 in. x 8 in. x 10 in. The circuitry is contained on six plug-in circuit cards, for quick and easy repair. Silicon transistors are used to minimize temperature-dependence between 0 and 125°F.

Four flashlight batteries are used for the portable power source. The condition of the batteries can be determined with the battery check position on the selector switch. The selector switch also has positions for three count ranges (0-500, 0-5,000, and 0-50,000 c/m) and for a register integrator for low count rates. An audio output is also provided.

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* Trademark of Du Pont for polyester film.

DETECTORS

The first detector (Fig. 1) is designed to detect 17-kev X-rays from plutonium embedded in wounds. It consists of a one-inch-diameter photomultiplier tube, and a 1/16-inch-thick by one-inch annular lead-band shield around a 40-mil-thick NaI crystal with a 5-mil beryllium window. This shielding and the single-channel analyzer circuit reject all photons except those in the 17-kev region and reduce the background to approximately 15 c/m. With this background and a detection efficiency of 1% for 17-kev X-rays, approximately 0.3 nCi of ^{239}Pu can be detected under 1/4 inch of tissue. The single-channel analyzer "window" can be adjusted to accept other photon energies.

The alpha-particle detector is a small scintillation counter used to detect and locate plutonium on the skin surface, in or near a wound. The detector is a 7/32-inch-diameter, one-inch-long "Lucite"* light pipe coupled to a one-inch-diameter photomultiplier tube. The 60-mm^2 wedge-shaped tip of the pipe is sprayed with 10 mg/cm^2 of ZnS(Ag). The light pipe, except for the two ends, is in a 1/4-inch-diameter stainless steel cylinder. A lighttight covering is provided by two layers of 0.15-mil doubly aluminized "Mylar" around the light pipe. This covering can be easily sterilized before placing it in contact with a wound and is simple to replace. Background of the detector is 5 c/m, and its efficiency is approximately 10%.

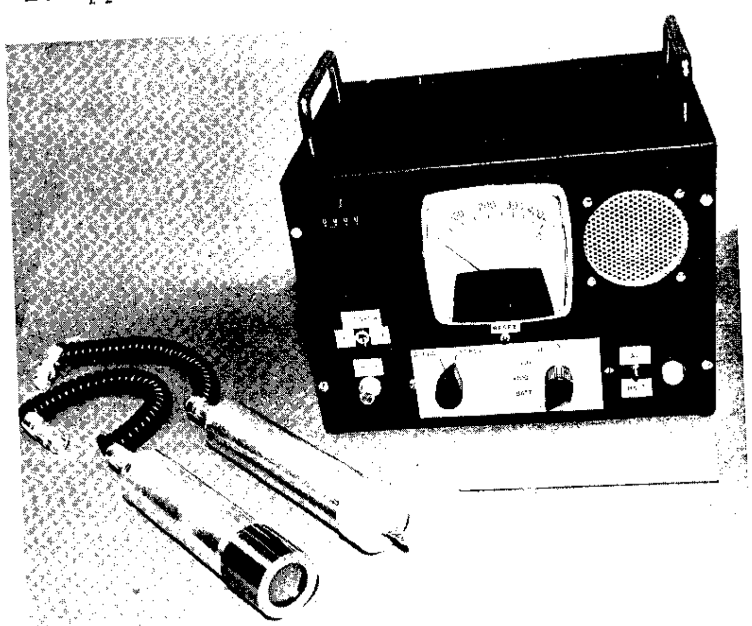
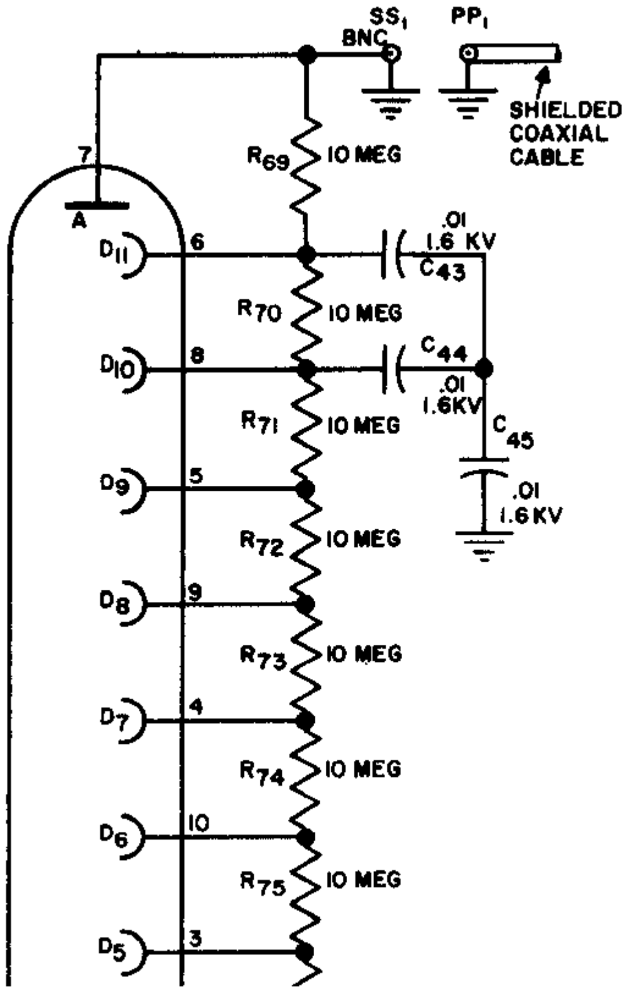


FIG. 1 PLUTONIUM WOUND MONITOR WITH DETECTORS

* Trademark of Du Pont for acrylic resin.



ELECTRONIC CIRCUITRY

EMI one-inch-diameter 9524B photomultiplier (PM) tubes, V_1 and V_2, and the high voltage-divider network, R_{69}-R_{80}, are contained in the two detachable probes (Fig. 2). Bypass capacitors, C_{43}, C_{44}, and C_{45}, in the last two dynode stages of the PM tube ensure peak currents from each scintillation which exceeds the average dynode string current.

The preamplifier plug-in card (Fig. 3) contains the signal developing resistor R_1, emitter-follower Q_1, and a complementary-pair amplifier Q_2, Q_3. D_1 prevents burnout of Q_1 by high voltage transients that are generated when the instrument is being turned off. The signal developed across the potentiometer R_4, used as the "gain" control, is fed to Q_2

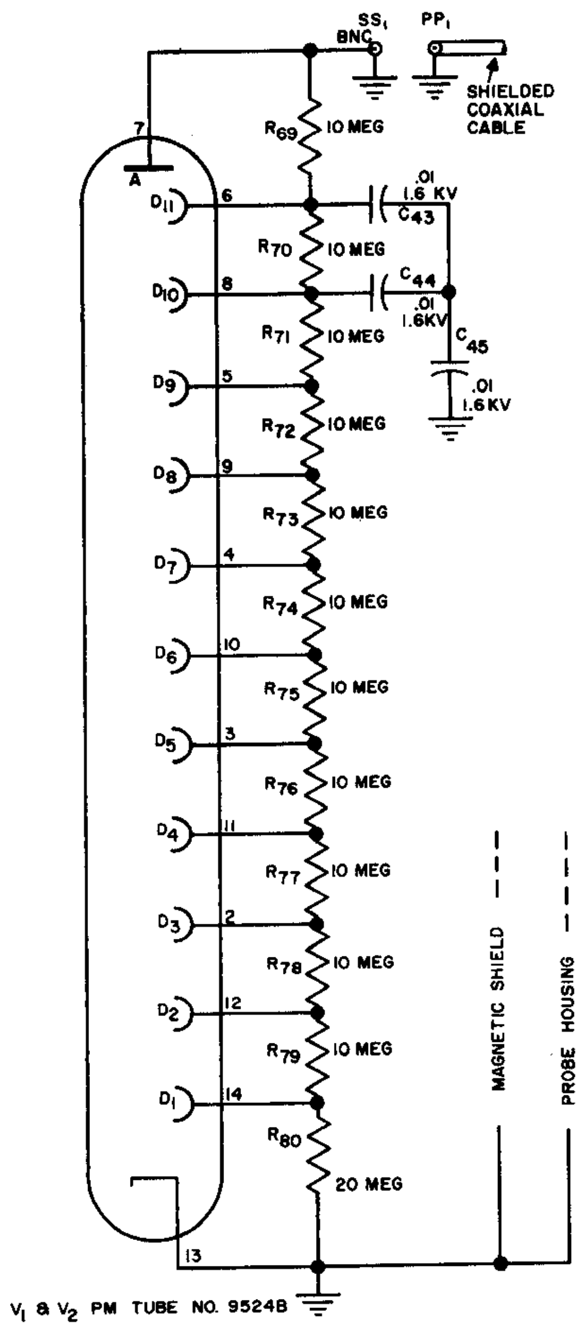


FIG. 2 PHOTOMULTIPLIER TUBE CIRCUIT

ELECTRONIC CIRCUITRY

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Potentiometer R_{12} (Fig. 3), used only when the monitor is switched in the "Alpha" detector mode, adjusts the output signal amplitude of the preamplifier to a level which will allow the preset trigger level of multivibrator $Q_{11}Q_{12}$ to reject smaller gamma and electronic noise pulses.

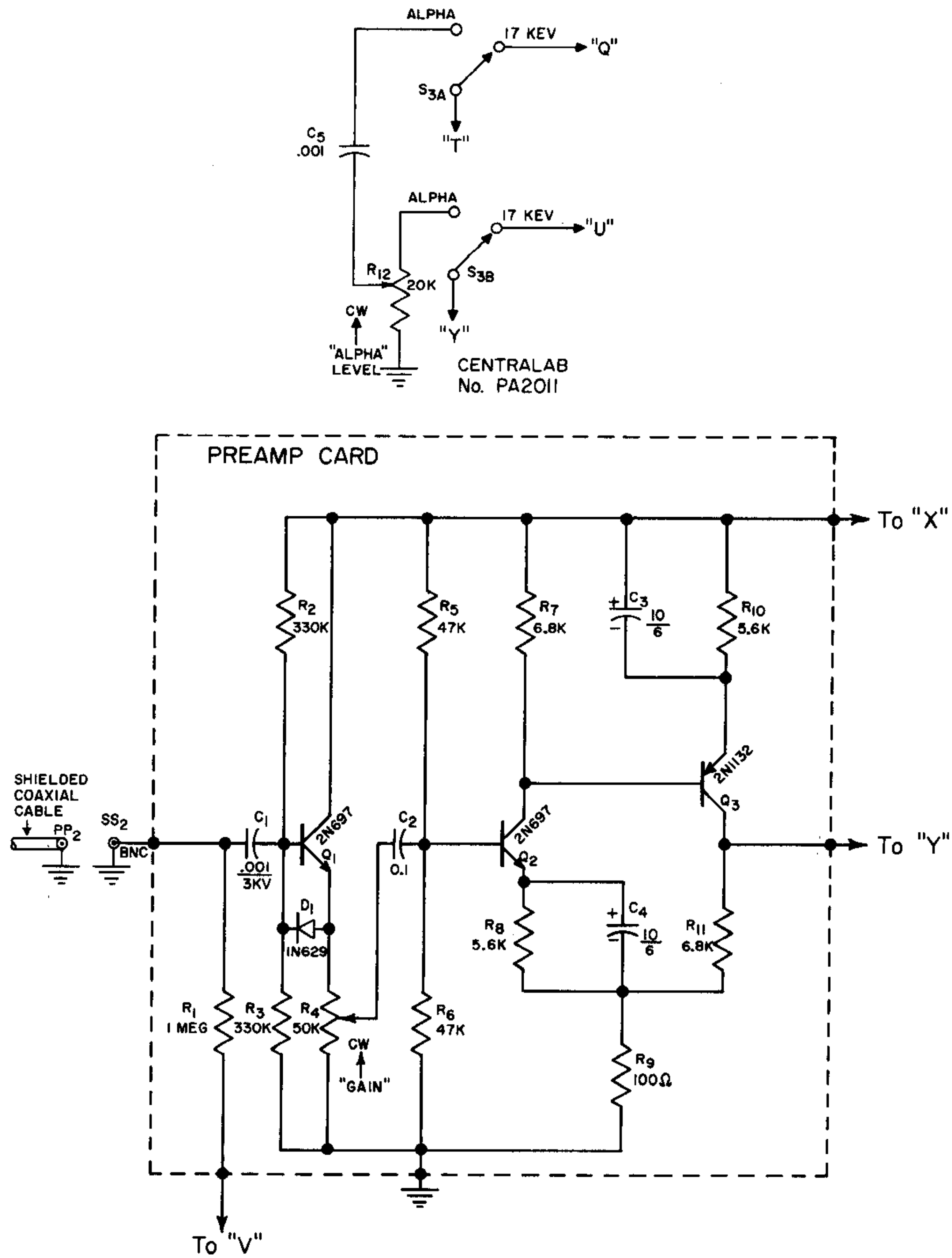

FIG. 3 SCHEMATIC OF PREAMPLIFIER CIRCUIT

The negative input signal to the single-channel analyzer plug-in card (Fig. 4) is coupled simultaneously to two emitter-followers, Q_4 and Q_8, to provide isolation stages and to prevent interference between the upper and lower gates. The negative polarity signal is coupled from the emitter-follower Q_4, to the lower gate multivibrator Q_5Q_6. In the monostable multivibrator, Q_5 is normally conducting and Q_6 is cut off. An incoming negative pulse above the fixed trigger level of the multivibrator cuts off conduction within Q_5 and cycles the monostable multivibrator. Potentiometer R_{15} in the emitter of the emitter-follower Q_4 provides a means of adjusting the lower gate pulse height to the desired level to trigger the multivibrator.

In the upper gate multivibrator, Q_9Q_{10}, R_{28} in the emitter of the emitter-follower Q_8 provides a means of adjusting the upper gate pulse height to the desired level to trigger the multivibrator.

If the amplitude of an incoming negative pulse is sufficient to cycle the lower gate multivibrator, Q_5Q_6, the negative pulse developed at the collector of Q_6 is coupled via C_{10} and R_{22} and developed across R_{25}. Potentiometer R_{25} allows the negative output pulses to be set at the desired amplitude for subsequent circuits.

When the amplitude of the incoming negative pulse is sufficient to simultaneously cycle the upper and lower gate multivibrators, a negative pulse is developed at the collector of Q_{10} and is coupled to the base of the anticoincident gating transistor, Q_7. (This is an anticoincident gate similar to that used by Reagan and Smith.[1]) The negative pulse to the base of Q_7 biases the transistor into conduction, and the negative pulse developed at the collector of Q_6 is effectively shorted to ground, and no output pulse develops across R_{25}. D_2 is across the input of the gating transistor, Q_7, to ensure a uniform input, and D_3 is across the output to provide a uniform output level.

The negative output pulse from the single-channel analyzer is sent to a count rate plug-in card (Fig. 5) which contains a

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1. J. B. Reagan and R. V. Smith. "Instrumentation for Space Radiation Measurements, Part I." IEEE Trans. Nucl. Sci. NS-10 (1), 172 (1963).

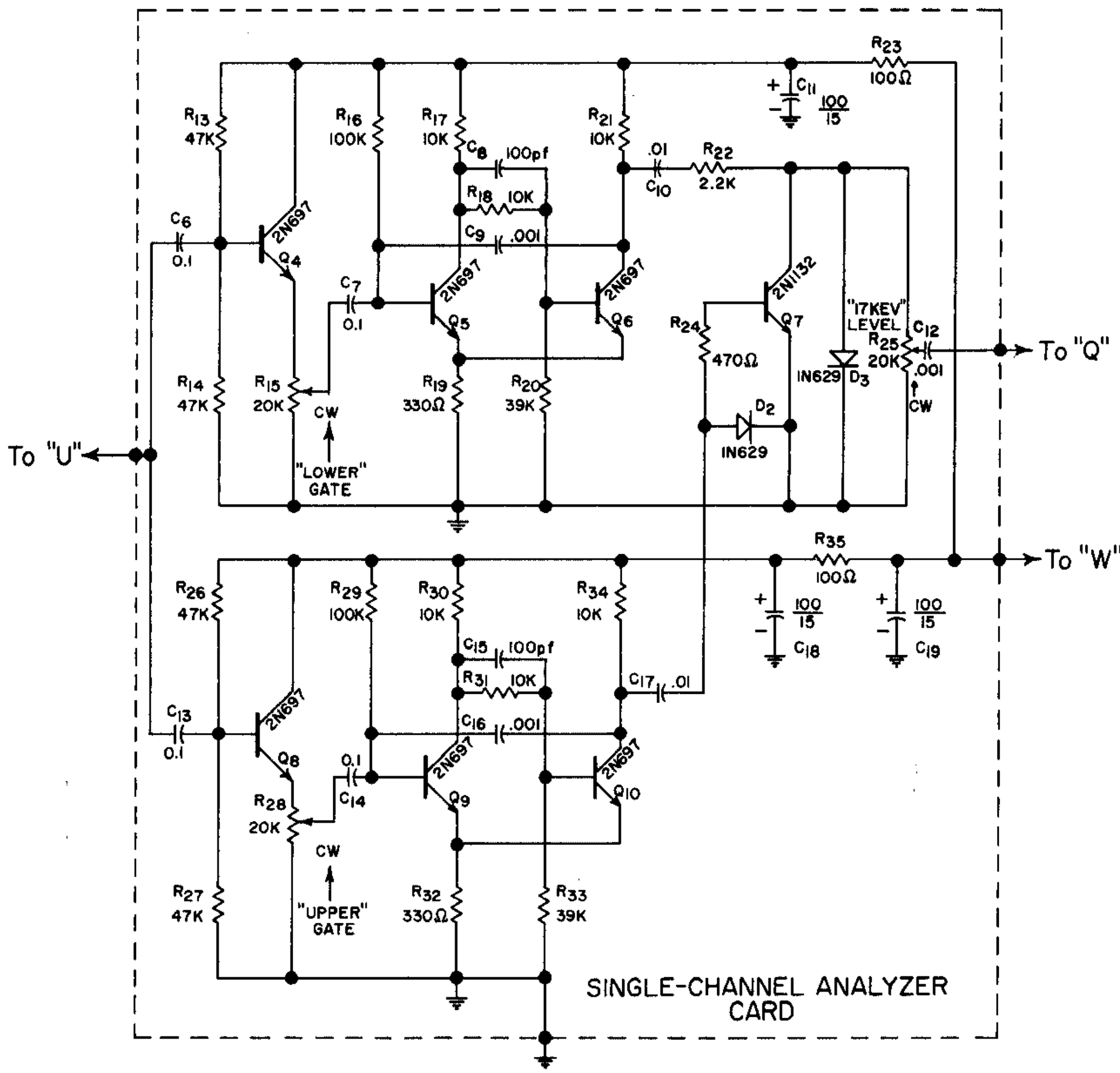

FIG. 4 SCHEMATIC OF SINGLE-CHANNEL ANALYZER CIRCUIT

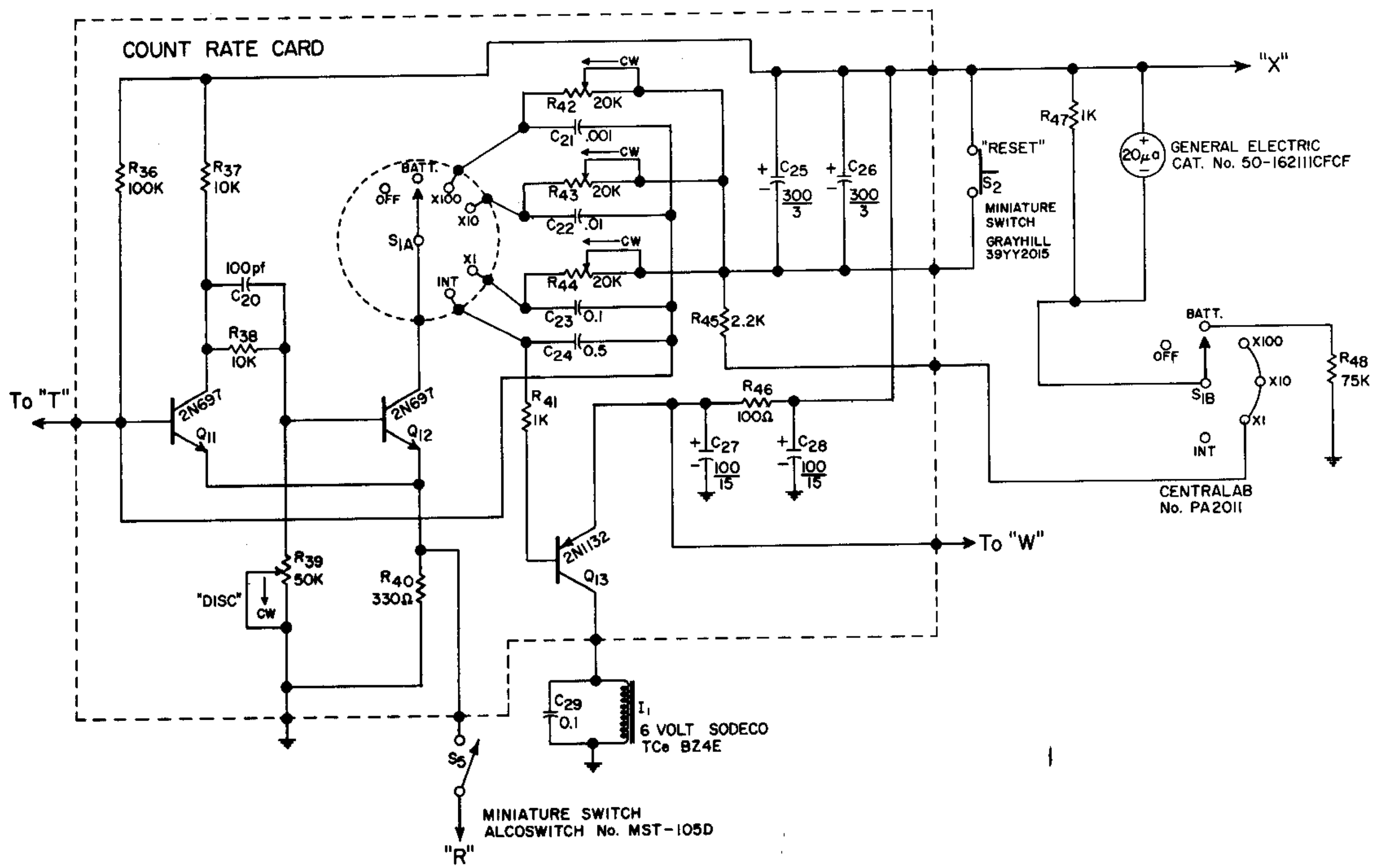

FIG. 5 SCHEMATIC OF COUNT RATE CIRCUIT

monostable multivibrator consisting of Q_{11}, Q_{12}, and a register driver, Q_{13}. The multivibrator $Q_{11}Q_{12}$ functions similar to that of the multivibrator Q_5Q_6. Potentiometer R_{39} is used as a pulse height discriminator control to allow the bias of Q_{12} to be adjusted to a point that will reject the smaller pulses and electronic noise. As a result of the multivibrator $Q_{11}Q_{12}$ being cycled for a scintillation pulse, a negative square wave voltage pulse is drawn through the meter circuit causing an up-scale reading. The meter deflection per pulse is determined by the value of the Q_{12} collector capacitor used to gate the multivibrator. For higher counting rates, a smaller value capacitor is used, reducing the conduction time of Q_{12} and, in turn, reducing the scale deflection per scintillation pulse. C_{25} and C_{26} smooth out the Q_{12} voltage pulses and provide a uniform meter deflection. Potentiometers R_{42}, R_{43}, and R_{44} are used to calibrate the rate meter scales. The reset switch S_2 discharges C_{25} and C_{26} and allows the meter to be quickly returned to zero after a high meter reading.

In the register integrate position, a PNP silicon transistor Q_{13} replaces the meter circuit in the collector circuit of Q_{12}. Conduction of Q_{12} as a result of a scintillation pulse also biases Q_{13} into conduction and cycles a Sodeco* register.

The high voltage plug-in card (Fig. 6) contains a DC to DC converter that develops 900 volts for the PM tube dynode string by a voltage doubler. Q_{14} is used in a blocking oscillator circuit that oscillates at approximately 800 cycles per second and draws approximately 15 ma. Potentiometer R_{54} is used to adjust the frequency of the oscillation and to provide the 900 volts across the 900-volt corona discharge tube, V_3. A second corona discharge tube, V_4 (Fig. 6), can be switched into the output of the high voltage circuit to regulate the high voltage at 700 volts.

A positive pulse is produced across the common emitter resistor R_{40} of Q_{11} and Q_{12} (see Fig. 5) for each cycling of the multivibrator and is coupled to a complementary amplifier, Q_{15} and Q_{16} (Fig. 7). The positive pulse is amplified in the complementary amplifier and is used to activate Q_{17} which is normally biased off. Q_{18}, which is in the collector circuit of Q_{17}, is also biased into condution and produces a voltage pulse across a 3.2-ohm speaker. The positive feedback circuit, R_{64} and C_{39} to the base of Q_{17}, produces a more suitable audible tone for each ionizing event.

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* Société des Compteurs de Genéve, Geneva (Switzerland).

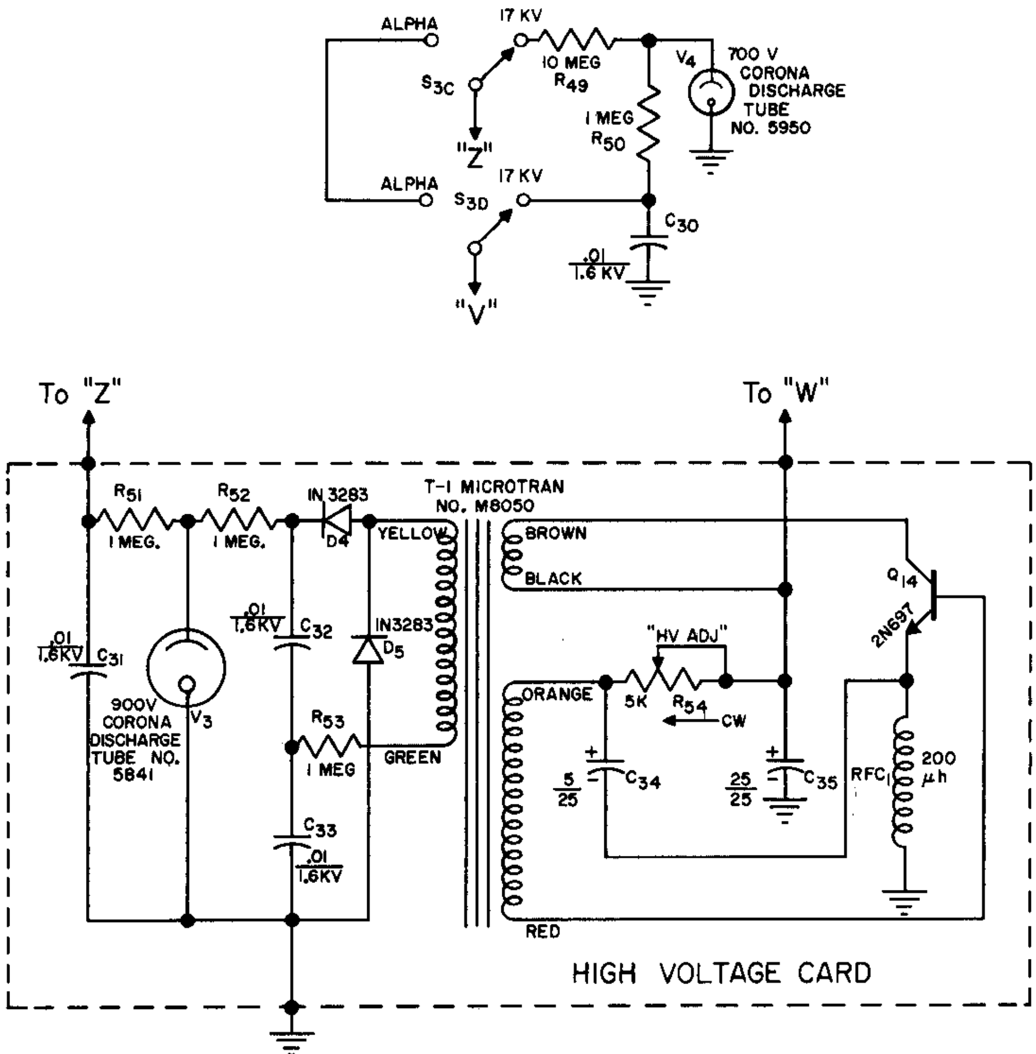

FIG. 6 SCHEMATIC OF HIGH VOLTAGE CIRCUIT

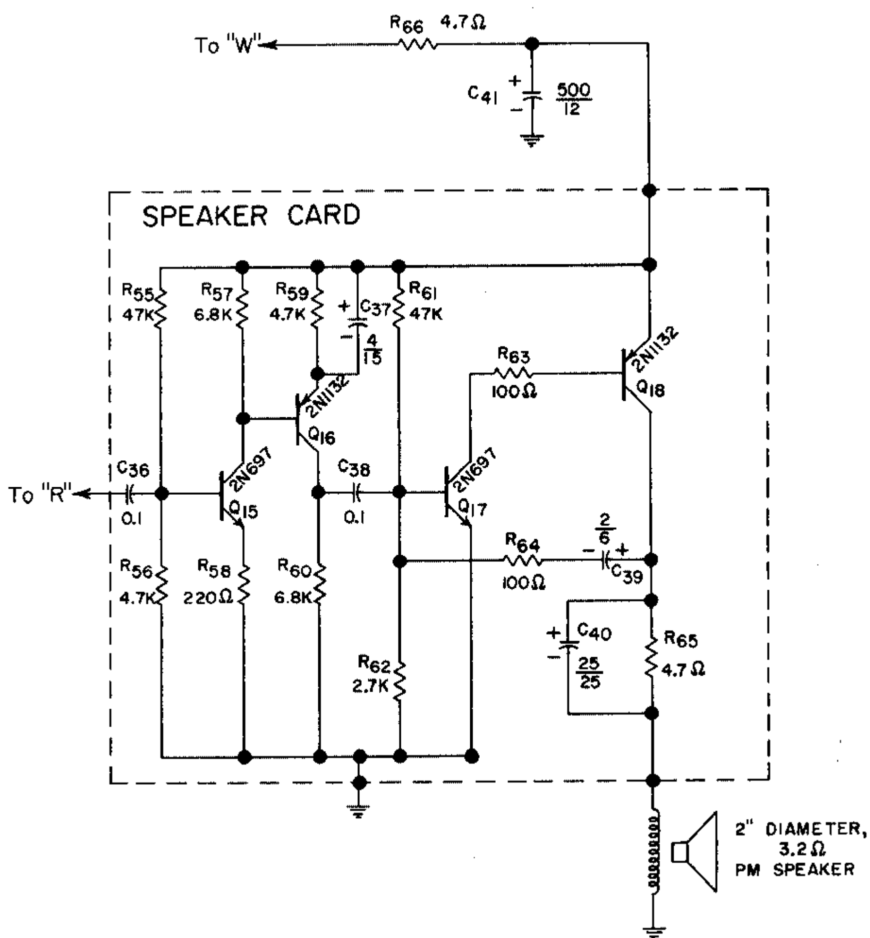

FIG. 7 SCHEMATIC OF SPEAKER CIRCUIT

The line-operated power supply (Fig. 8) consists of a full-wave rectifier, D_7 D_8, and a series voltage regulator, Q_{19}, that is referenced biased to 6.3 volts by the zener diode, D_6. The switch S_4 allows the monitor to be operated from the 110-volt AC line or from the self-contained flashlight batteries.

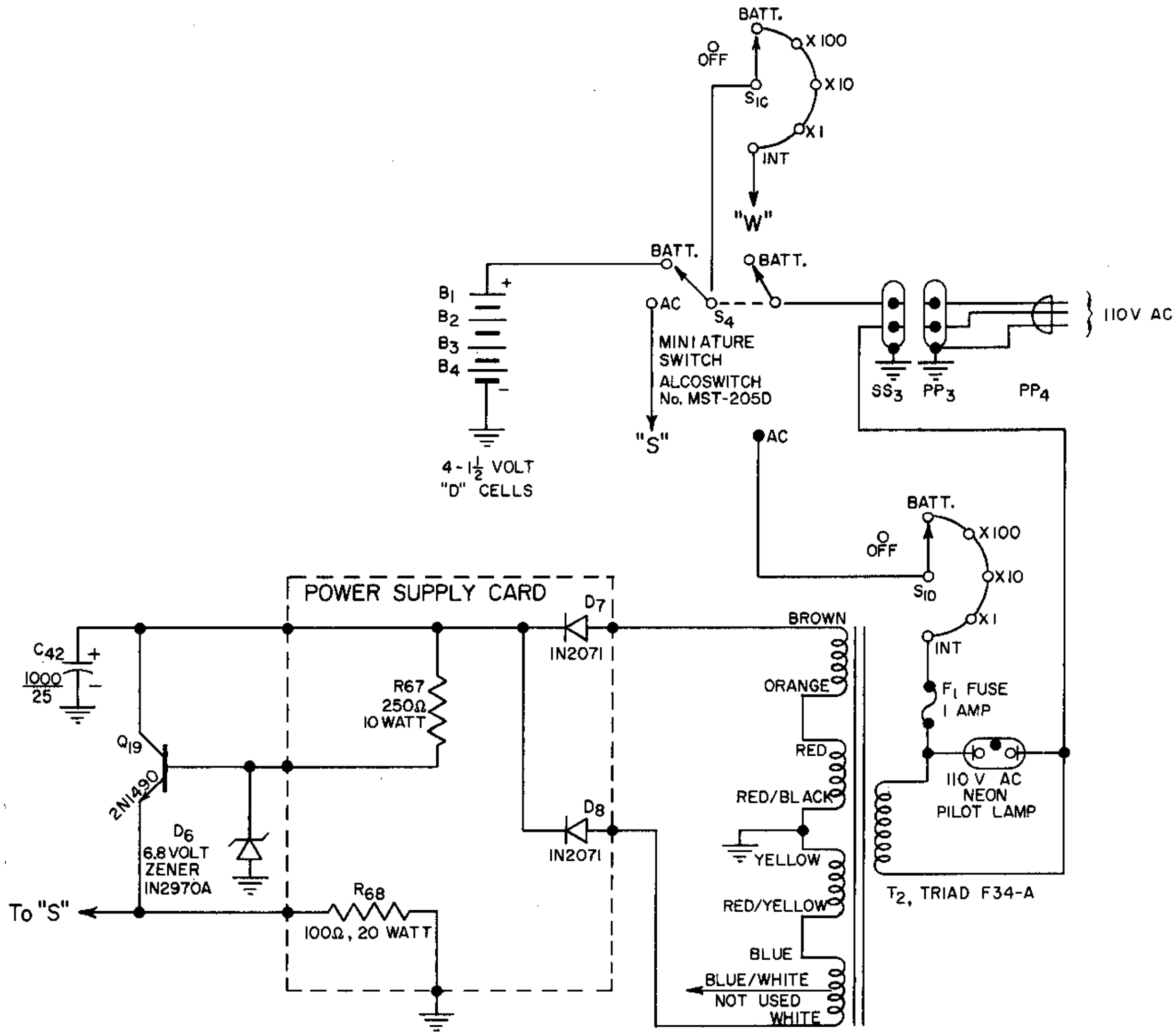

FIG. 8 SCHEMATIC OF POWER SUPPLY CIRCUIT