663253

DP-1260

AEC RESEARCH AND DEVELOPMENT REPORT

AN IMPROVED AIR MONITOR IN A STANDARD NUCLEAR INSTRUMENT MODULE

W. J. WOODWARD

DU PONT
REG. U. S. PAT. OFF.

Savannah River Laboratory

Aiken, South Carolina

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.95

663253

DP-1260

Instruments
TID-4500, UC-37

AN IMPROVED AIR MONITOR IN A STANDARD NUCLEAR INSTRUMENT MODULE

by

William J. Woodward

Approved by

D. E. Waters, Manager
Laboratory Operations and Services Division

June 1971

E. I. DU PONT DE NEMOURS & COMPANY
SAVANNAH RIVER LABORATORY
AIKEN, S. C. 29801

CONTRACT AT(07-2)-1 WITH THE
UNITED STATES ATOMIC ENERGY COMMISSION

ABSTRACT

An instrument was developed for multichannel monitoring of airborne radioactive contaminants. Each channel is contained in a single-width nuclear instrument module (NIM), and consists of an amplifier, an integral discriminator, and a five-range count rate meter covering 0-300,000 counts/min. Up to ten monitoring channels and a high voltage power supply can be installed in any standard NIM bin.

CONTENTS

LIST OF FIGURES

INTRODUCTION

At the Savannah River Laboratory a vacuum system draws air continuously from rooms where radioactive materials are handled. Exit air from these rooms is passed through paper filters, and the particulate matter collected on the filters is monitored for radioactivity each time the filters are changed. To provide early warning of the presence of airborne radioactive contaminants, a series of monitors was developed, each capable of monitoring four filter locations.[1] As more locations required monitoring, more four-channel instruments were fabricated, which in turn required more space for the instruments as well as for the cables connecting them to the detectors.

A new monitor has been developed (Figure 1) to perform the same functions as the older four-channel units, with several improvements:

- A ten-channel monitor requires the same panel space as the four-channel instrument.
- Each detector probe is connected to the instrument through a single cable instead of three cables.
- Each monitoring channel is contained in a single-width NIM (nuclear instrument module) that plugs into a standard bin.[2]
- The high voltage power supply (developed to operate the new instruments) is contained in a double-width NIM, and is capable of supplying up to ten monitoring channels.
- Any number of NIM monitoring channels may be operated at a given location instead of multiples of four (Figure 2).
- The NIM units may be used along with other standard nuclear instruments in the same bin.
- The per-channel cost of the new monitors is lower than that of the older four-channel units.
- Spare parts inventory is reduced since one channel may be substituted in case of failure without disturbing the others in the same bin, and the high voltage supply may be substituted without disturbing the monitor units.

- Alarm reliability is improved in the new units because solid state circuits are used instead of contacting meters.

- The new design makes use of integrated circuits for improved reliability.

- Sockets are provided so that all active components plug in, including the individual alarm relays.

- Safety high voltage (SHV) connectors are used in the new design to eliminate shock hazards.

The improved monitor operates satisfactorily with cable lengths exceeding 500 ft between the NIM units and their associated scintillation detector probes.

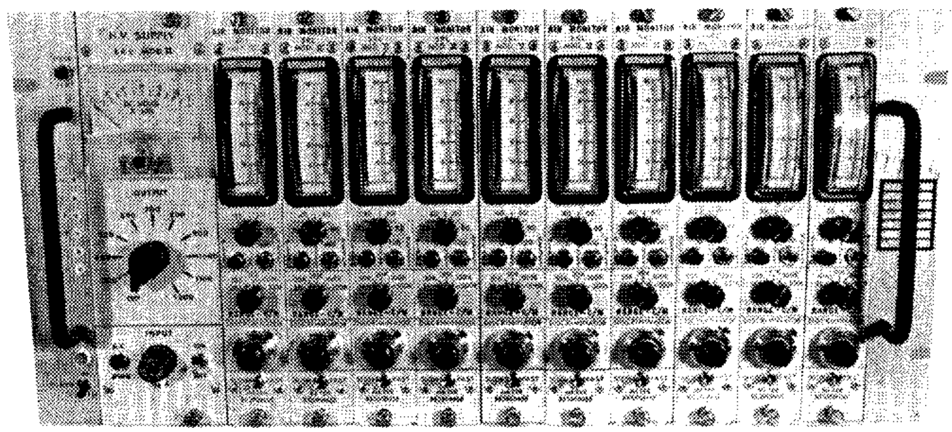


FIG. 1 TEN-CHANNEL NIM AIR MONITOR, COMPLETE WITH HIGH VOLTAGE POWER SUPPLY

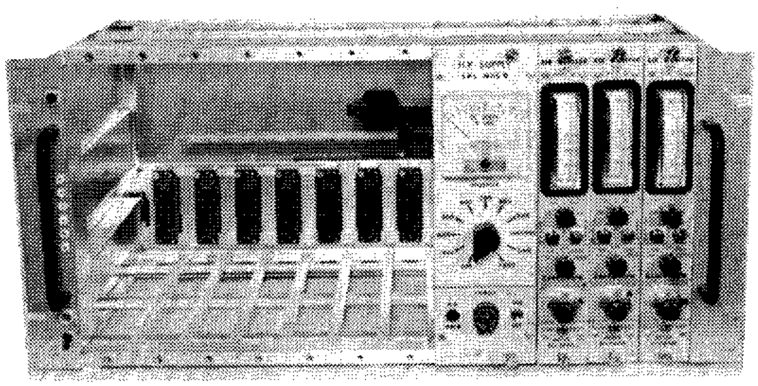


FIG. 2 THREE-CHANNEL MONITOR WITH ROOM FOR OTHER INSTRUMENTS IN BIN

DESIGN

DETECTOR

Each monitoring channel count rate meter (CRM) accepts signals from a scintillation detector probe. Each probe is mounted on a standard laboratory air sampler so that a 3-in. photomultiplier tube with its attached scintillator is about 1/4 in. from the upstream face of a paper filter. The probe assembly swings upward and away from the sampler to facilitate filter change. Air flows from the room through the filter and into a vacuum system at about 6 ft^3/min, depositing any airborne particulate matter onto the filter in front of the scintillator. Scintillations resulting from collected radioactive particles are converted to electrical impulses by the photomultiplier tube.

The photomultiplier signals are collected at the high impedance anode and processed by a stacked emitter-follower-preamplifier (Figure 3), the output of which is coupled at a low impedance to the interconnecting cable. Power for the transistors in the circuit is derived from voltage developed across a low voltage avalanche diode in series with the dynode divider resistors. When 600 volts or more is supplied to the probe, enough current is drawn through the diode to produce 5.6 volts for proper transistor operation. The dynode divider and anode supply are well bypassed by capacitors so that the output signals are developed across a single resistor that is ac grounded at its lower end. In this manner the detector signals and the high voltage supply to the photomultiplier are carried simultaneously on a single coaxial cable from the CRM unit.

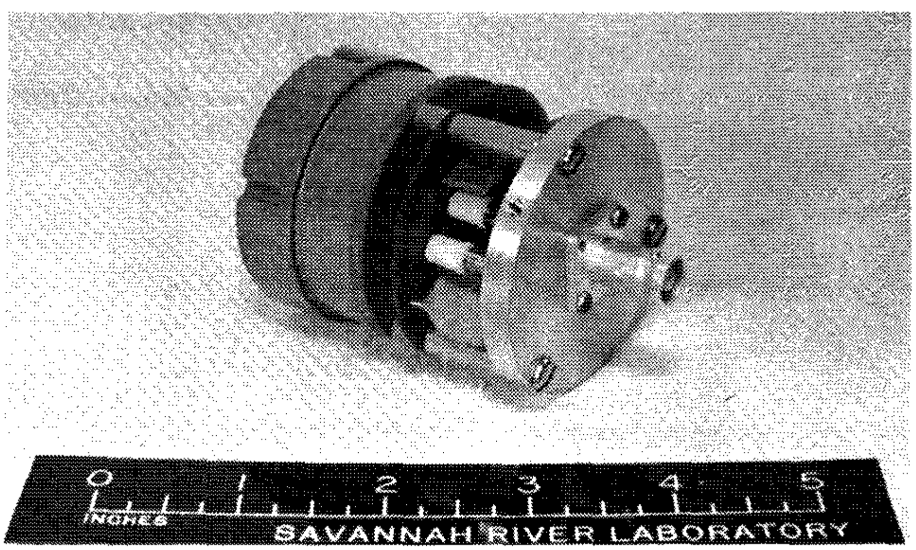


FIG. 3 PREAMPLIFIER MOUNTED ON PHOTOMULTIPLIER SOCKET

COUNT RATE METER UNIT

The cable connects at the rear panel of the CRM unit, which is constructed in a single-width NIM (Figure 4). High voltage is supplied to the CRM through another (identical) connector, also at the rear panel. A potentiometer, mounted between the connectors, is in series with the high voltage input so that it forms a voltage divider with the resistors in the detector probe. The potentiometer serves as a gain control because adjustment of the potentiometer changes the voltage to the photomultiplier over a range from that supplied to the CRM to approximately 25% lower. Input and output of the potentiometer are bypassed by capacitors to prevent cross-talk between units and to further reduce power supply ripple. An additional resistance in series with the potentiometer acts as the signal load, with its high end coupled to an integrated circuit amplifier and the other end ac grounded. Coupling to the amplifier is through a small capacitor that readily passes the fast-rising pulses from the detector but effectively blocks the last remaining bit of ripple from the high voltage supply.

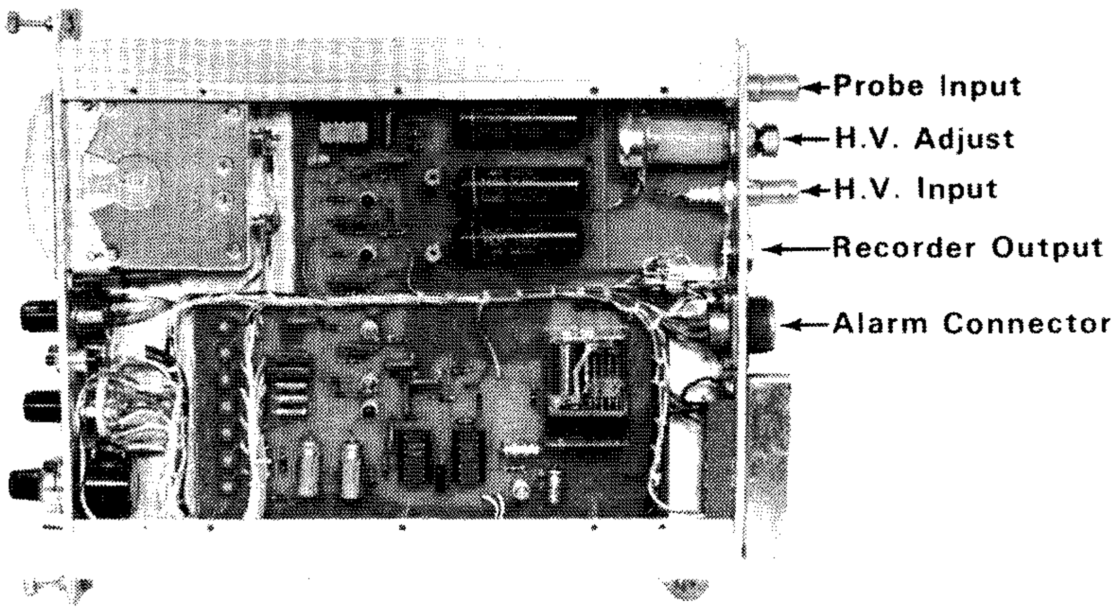


FIG. 4 COUNT RATE METER UNIT WITH COVER REMOVED

The amplifier is a three-stage video chip, compensated for the frequencies to be encountered and ac feedback controlled to yield a voltage gain of approximately 50. The amplifier I.C. plugs into a standard, 14-pin dual in-line socket.

Output signals from the amplifier are coupled to a discrete component Schmitt trigger that acts as an integral discriminator. Threshold level of the discriminator is adjusted by means of a 10-turn precision potentiometer at the front panel. Output pulses from the discriminator are differentiated, clipped, and applied to a monostable multivibrator.

The multivibrator produces square pulses of constant amplitude, but having widths determined by five timing capacitors selected one at a time by the "range" switch on the front panel. The multivibrator is direct-coupled to a constant current transistor that drives the readout meter. Current pulses to the meter circuit are integrated by a pair of capacitors shunting the meter and its calibrating resistance, which is one of five miniature potentiometers, also selected by the "range" switch. One of two integration time constants is selected by the "meter response" switch, marked "slow" and "fast" on the front panel.

A closed circuit telephone jack and a dummy resistance are wired in series with the meter so that a 0-100 microampere recorder can be connected at the rear panel. The dummy resistance is adjusted to the same value as that of the recorder to preserve calibration when the recorder is disconnected. (A millivolt recorder can be used by adding a voltage divider and suitable 100-microampere shunt to its input.)

The voltage developed across the meter circuit is also applied to an integrated circuit operational amplifier. Gain of the amplifier is fixed by feedback so that its output is sufficient to drive one input of a differential voltage comparator, also in I.C. form. The other input to the comparator is connected to a front panel potentiometer marked "alarm set" and calibrated to correspond to 0-100% of the meter reading. When the meter reading exceeds the value set by the potentiometer, the comparator switches states, causing a transistor to energize a small relay. Two sets of form "C" contacts on the relay are brought out to a rear panel "alarm" connector. Other contacts light a neon "alarm" indicator on the front panel and seal the relay on until a manual "reset" button, also on the front panel, is pressed. The relay and the two alarm circuit I.C.'s plug into sockets on the printed circuit board. Both I.C.'s are 14-pin dual in-line types.

All components of the CRM unit except those requiring panel mounting are on a single etched circuit board. All calibration adjustments are four-turn miniature potentiometers, and all are grouped for easy access. All transistors plug in for easy removal in trouble-shooting. High voltage components are covered with glass-epoxy board (Figure 5), and SHV connectors are used to minimize shock hazards. Internal circuits are protected against high voltage transients resulting from sudden connection or disconnection of the high voltage power supply. Module cover plates are marked to indicate the correct side to open for servicing. Standard NIM bin connectors are used, and power consumption is from voltages provided by any standard NIM bin and power supply.

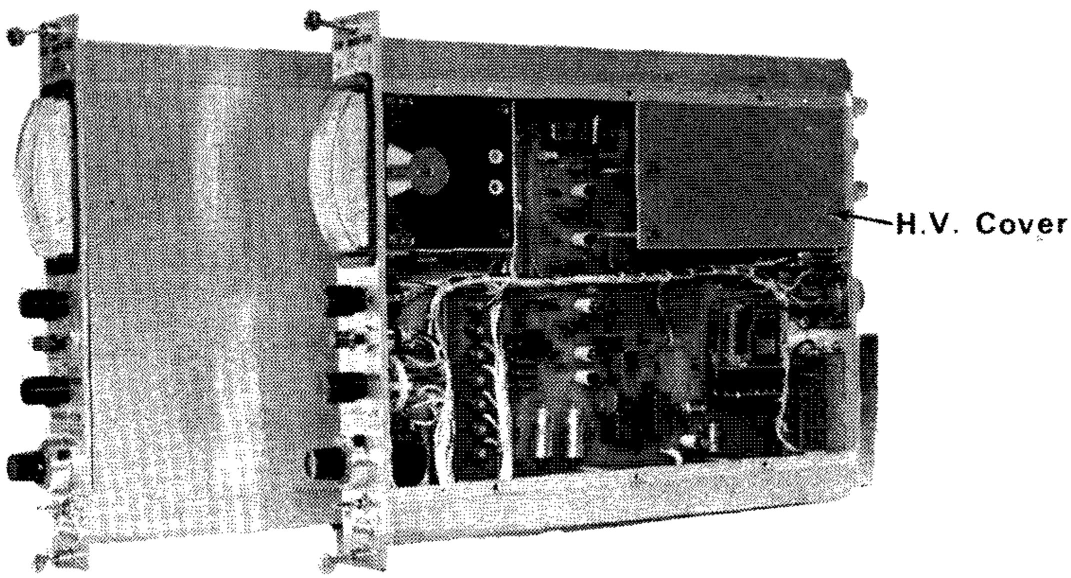


FIG. 5 COUNT RATE METER UNITS WITH HIGH VOLTAGE PROTECTIVE COVER INSTALLED

The CRM unit performs quite satisfactorily when operated with detector probes connected by 500 ft of RG-59/U cable or more. (Tests at Savannah River used 500 ft because no installation requiring a greater length is anticipated.) Ranges of the instrument are 0 to 0-3,000; 0-10,000; 0-30,000; 0-100,000; and 0-300,000 counts/min. A complete schematic diagram of the detector and CRM is shown in Figure 6.

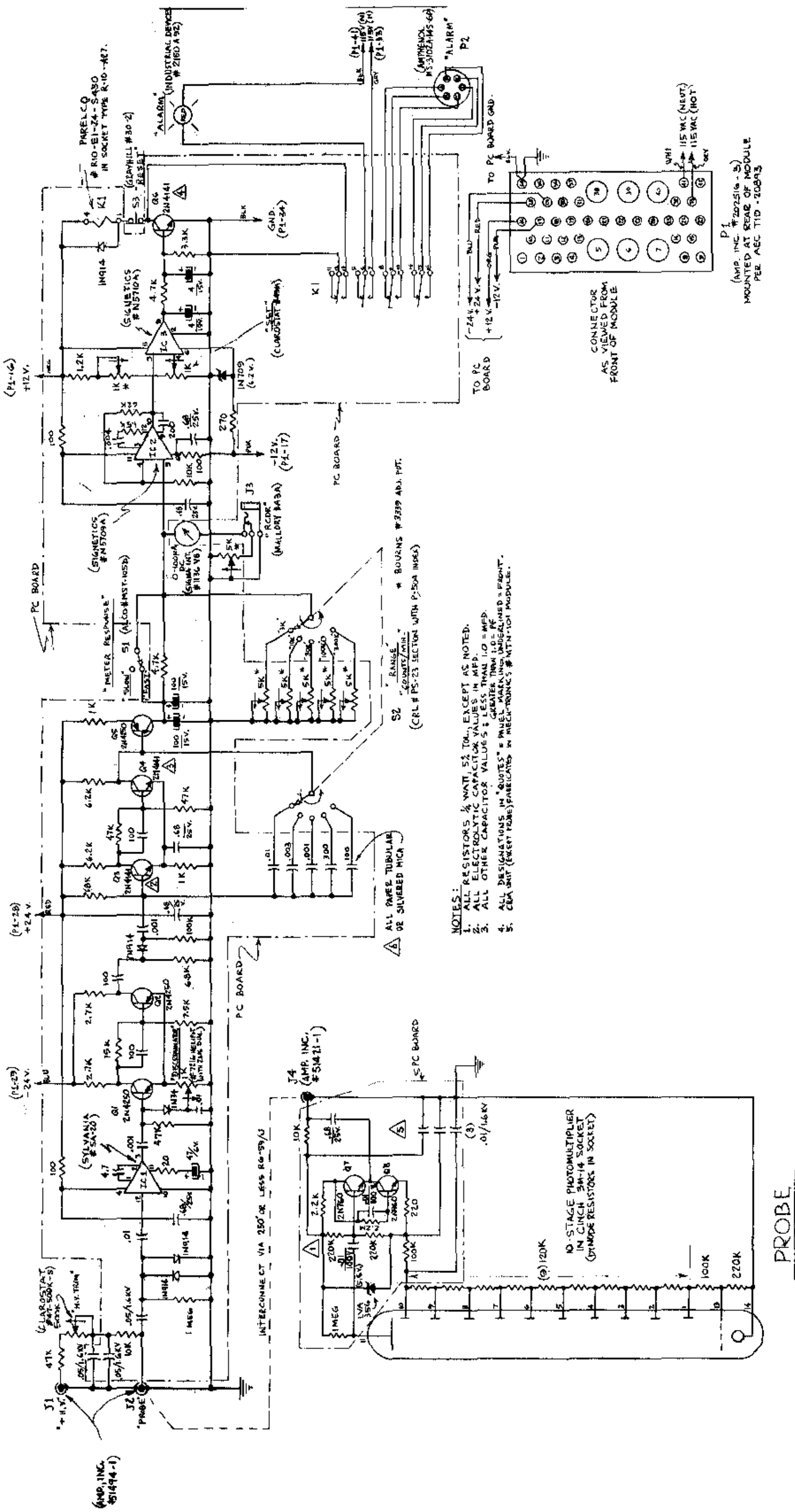


FIG. 6 SCHEMATIC DIAGRAM OF COUNT RATE METER AND DETECTOR PROBE

HIGH VOLTAGE SUPPLY

Positive regulated dc voltage is provided by the high voltage supply. The supply is contained in a standard double-width NIM (Figure 7), having 10 output SHV connectors on its rear panel. A selector switch on the front panel selects zero (ground), and 300 to 1200 volts, inclusive, in steps of 100 volts each. A small readout meter indicates proper operation of the supply, and ac power input to the module is switched, fused, and indicated at the front panel.

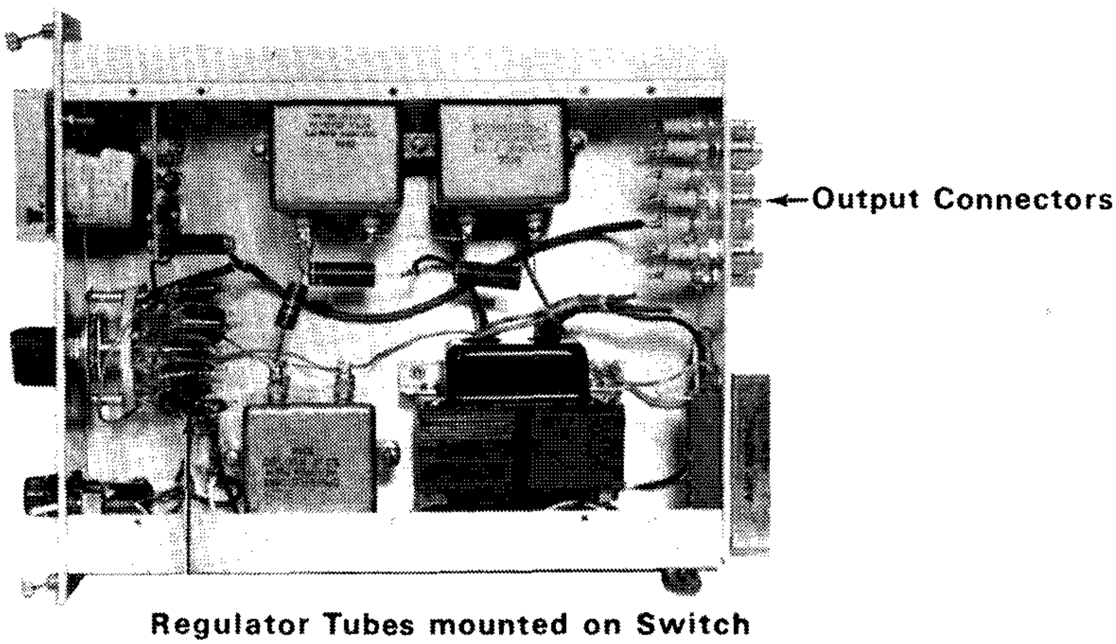
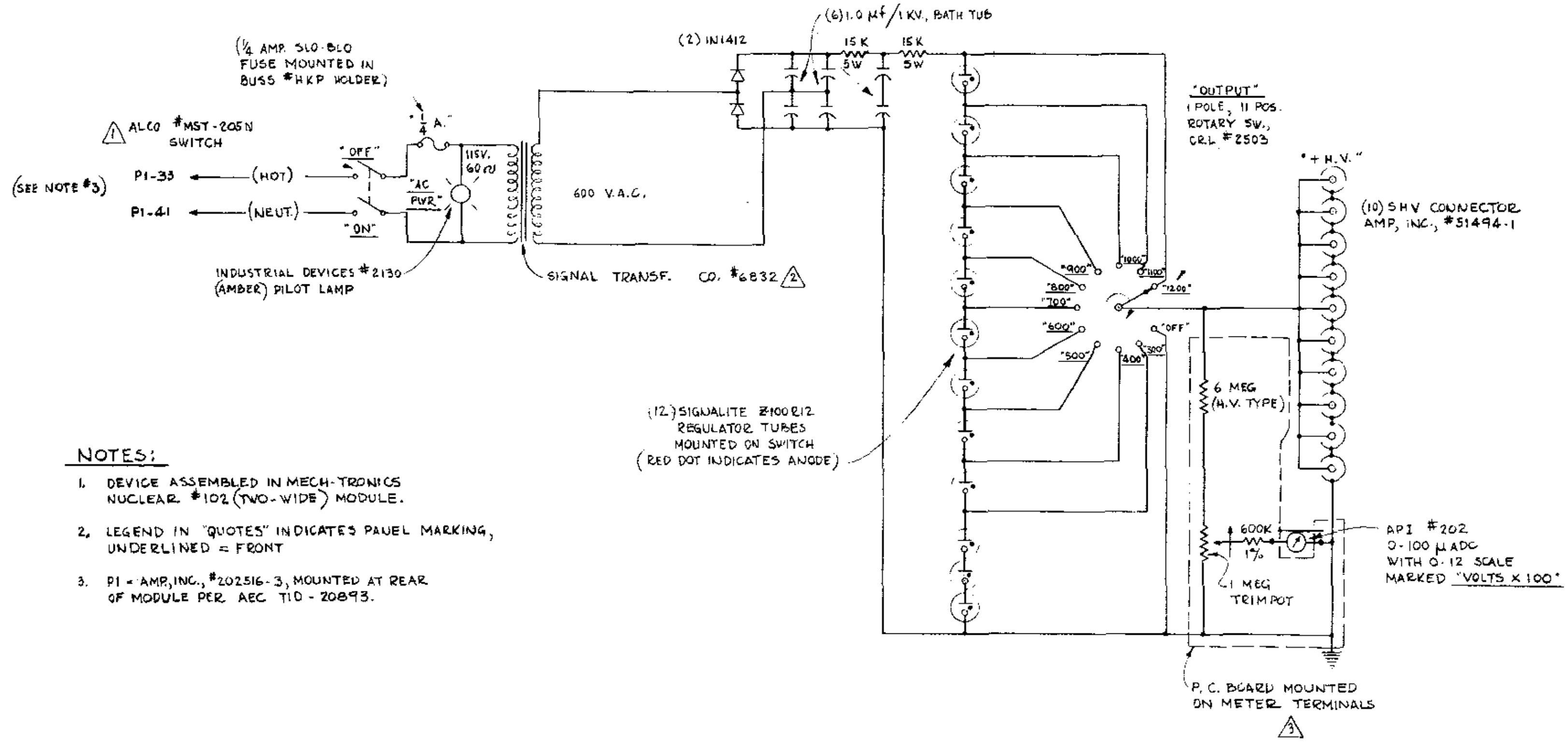


FIG. 7 HIGH VOLTAGE SUPPLY WITH COVER REMOVED

The supply consists of a transformer, voltage doubling rectifier, filter network, and a series combination of 12 miniature gas-tube regulators. Junctions between regulators are connected to the selector switch; the moving contact of this switch is connected to the output connectors and the meter circuit. Filter capacitors are oil-filled paper types for reliability. Because of the relatively low values of capacity in the filter system ripple is somewhat high, but additional bypassing in the CRM and probe units prevents this becoming a problem. A schematic diagram of the high voltage supply appears in Figure 8.

Output from the supply is adequate for ten complete count rate systems operating at maximum voltage.



NOTES:

1. DEVICE ASSEMBLED IN MECH-TRONICS NUCLEAR #102 (TWO-WIDE) MODULE.
2. LEGEND IN "QUOTES" INDICATES PANEL MARKING, UNDERLINED = FRONT
3. P1 = AMP, INC., #202516-3, MOUNTED AT REAR OF MODULE PER AEC TID-20893.

FIG. 8 SCHEMATIC DIAGRAM OF HIGH VOLTAGE SUPPLY

NIM BIN AND POWER SUPPLY

Specifications for the instrument bin and its power supply are contained in Reference 2. Several manufacturers of nuclear instruments offer the bins (complete with power supplies) and basic module kits according to these specifications. The bins chosen for this development were furnished by Mech-Tronics Nuclear Corporation, with line filters incorporated into the power supply, but the CRM units and the high voltage supply have been tested in bins made by other manufacturers. Similarly, other nuclear instrument modules, such as scalers, timers, and pulse amplifiers have been operated satisfactorily in the air monitor bins along with the CRM units and high voltage supply.

SERVICE HISTORY

The prototype monitor, consisting of ten CRM units and one high voltage supply in a single NIM bin, has operated satisfactorily for several months at Savannah River, having been used mostly for demonstration purposes. In this service it has been switched on and off many times, exhibiting negligible calibration shift from a "cold" start to weeks of continuous operation. A second monitor, with three CRM units and two high voltage supplies in a single bin, was used in an active radioactive display device to demonstrate neutron activation techniques at the American Society of Metals show in Cleveland, Ohio and at the Instrument Society of America show in Philadelphia, Pennsylvania in October of 1970. The monitor was also displayed at the American Chemical Society meeting in Houston and the Institute for Electrical and Electronics Engineers meeting in New York. No ill effects from shipping were observed, and the instrument operated satisfactorily at all times. Additional showings of the display are planned, including Geneva, Switzerland, with complete confidence in this part of the instrumentation.

REFERENCES

1. W. J. Woodward. *A Four-Channel Monitor for Airborne Radioactive Contaminants*. USAEC Report DP-1176, E. I. du Pont de Nemours & Co., Savannah River Laboratory, Aiken, S. C. (1968).

2. L. Costrell. *Standard Nuclear Instrument Modules*. USAEC Report TID-20893, National Bureau of Standards, Washington, D. C. (1969).