AEC
RESEARCH
and
DEVELOPMENT
REPORT

ADVANCED ALPHA-BETA-GAMMA
HAND AND SHOE
CONTAMINATION MONITOR

E. M. SHEEN, C. A. RATCLIFFE
and
L. V. ZUERNER

BNWL-250

2-

BATTELLE-NORTHWEST

BATTELLE MEMORIAL INSTITUTE / PACIFIC NORTHWEST LABORATORY

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON

operated by

BATTELLE MEMORIAL INSTITUTE

for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

PRINTED BY/ FOR THE U. S. ATOMIC ENERGY COMMISSION

3 3679 00060 2526

BNWL-250
UC-37, Instruments

ADVANCED ALPHA-BETA-GAMMA HAND
AND
SHOE CONTAMINATION MONITOR

By

E. M. Sheen, C. A. Ratcliffe

and

L. V. Zuerner

Process Instrumentation Section
Applied Physics and Electronics Department

August 1966

FIRST UNRESTRICTED
DISTRIBUTION DATE

AUG 3 0'66

PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON

Printed in USA. Price \$1.00. Available from the Clearinghouse
for Federal Scientific and Technical Information,
National Bureau of Standards
U.S. Department of Commerce, Springfield, Virginia

ADVANCED ALPHA-BETA-GAMMA HAND AND SHOE CONTAMINATION MONITOR

INTRODUCTION

Two major problems encountered in the detection of radionuclide contamination on the hands and shoes of personnel are the marginal counting signal to background ratio and the considerable cost of the instrumentation required to perform the measurement in a rapid and efficient manner. Another problem is the general lack of reliability of the detectors and circuits employed.

These problems prompted the development of an advanced-model monitor that incorporates design features applicable for alpha-beta-gamma, for beta-gamma, and for alpha-only monitoring in a reliable and efficient manner.

SUMMARY

The developed combination alpha-beta-gamma hand and shoe contamination monitor incorporates low-noise multiplier phototubes, special light pipes, probe-contained preamplifiers to provide a satisfactory signal-to-noise ratio, and all solid state circuitry with no relays. The main chassis contains power supplies, indicating registers, all circuitry except that used in the probes, and adjustment controls that are incorporated in a printed circuit card file. Solid state circuits were developed and fabricated on printed circuit cards that were size-compatible with available, commercial card files. These circuits, combined with commercially available logic units,

provided an instrument that reduced both capital and maintenance costs. The basic design is that of a combination alpha-beta-gamma contamination monitor; however, the general design features are directly applicable to the manufacture of single-purpose instruments, as for beta-gamma only or for alpha-only monitors.

DISCUSSION

Figures 1 and 2 show the completed instrument in front and rear views, respectively. Figure 3 illustrates the printed circuit card file, electro-mechanical register, and the power supplies.

The block diagram of the electronics portion of the monitor, shown in Figure 4, indicates that many of the circuits are used in several channels; thus, in many cases, the circuits were assembled with two per printed circuit board with separation achieved by function and by channel to simplify calibration, adjustment, and maintenance effort.

Probe Description

The scintillation detection probes, shown in Figure 5, are similar to those described by Spear.⁽¹⁾ These probes, which contain Lucite light pipes, were modified by the substitution of low-noise multiplier phototubes (EMI 9536B), by the addition of solid state preamplifiers (voltage gain of 25), and by addition to each probe of a gain control to permit simplified adjustment and balancing.

Neg. 0653179-8

FIGURE 1. Front View

Neg. 0653179-7

FIGURE 2. Rear View

Neg. 0653179-6

FIGURE 3. *Circuit Card File and Top
of Chassis*

FIGURE 4. Block Diagram

Neg. 0653179-2

FIGURE 5. Hand Probes

For beta-gamma-only probes, the light-tight cover consists of three layers of double aluminized Mylar. Each layer has a density thickness of about 1 mg/cm^2 . The alpha-beta-gamma and alpha-only probes have one layer of the aluminized Mylar covering two layers of 0.2 mg/cm^2 aluminum "Dutch Leaf." The leaf serves to cover any small light leaks (pinholes) in the aluminum film on the Mylar. This three-layer, light-tight cover allows about a 16% counting efficiency for Pu^{239} alpha detection.

The alpha-detection scintillator consists of silver-activated zinc sulfide that is purchased in sheets and is applied like a decal directly to the plastic light pipe. For the alpha beta-gamma probes, the alpha scintillator is attached to the upper side of the beta-gamma scintillator, and the bottom side of the beta-gamma scintillator is cemented to the light pipe. The alpha-to-beta-gamma pulse height ratio is approximately two; this permits simple amplitude discrimination to separate the pulses into alpha-only and alpha plus beta-gamma channels.

The beta-gamma scintillator is a 0.02 in. thick sheet of NE-102* plastic which consists of terphenyl in polyvinyl-toluene. This thickness provides a nearly optimum ratio of beta-gamma contamination response to background. The NE-102 is cemented to the light pipe using NE-580* epoxy cement which insures a reliable bond and good optical coupling. For beta-gamma only probes, the NE-102 scintillator is used alone.

The light pipes are made of ultra-violet-absorber-free Lucite. A reflective aluminum foil is employed to cover the surfaces of the light pipe that are not attached to the scintillator. The foil is not glued to the light pipe but only taped at the top edges, as the small air gap between the light pipe and the aluminum foil increases the internal reflectivity of the assembly.

The multiplier phototubes are sealed into light-pipe sockets with Dow-Corning "Sylgard" No. 184 resin to provide a satisfactory mechanical and optical attachment. The glass envelope of each multiplier phototube and the foil-covered portion of the light pipe is covered with black plastic electrical tape for light shielding. Occasionally, light leaks may appear in the scintillator cover and may cause an annoying increase in the apparent background counting rate. Such light leaks can be located through use of a prefocused light bulb (scanning the probe surface) and an oscilloscope; light falling upon the pinhole is revealed by a considerable increase in the observed signal. The located pinhole is easily repaired with a small spot of black acetate drawing ink or silver paint.

Electronic System Description

Refer to Figures 6 through 9, following page 14.

The monitoring channel for the right hand comprises one probe for the back of the hand, one for the palm of the hand (with gain controls and preamplifiers in each probe), and main chassis electronics. The preamplifier outputs are wired to inputs of the Dual Alpha Amplifier and Discriminator circuit board. On this board, the input signals are amplified using adjustable-gain, inverting

* Nuclear Enterprises Ltd., Winnipeg, Canada

amplifiers, and the output signals are directed to the discriminator.

The dual-input discriminator has a common threshold-level adjustment and a single output, from which a signal is obtained if either applied pulse exceeds the threshold level. The discriminator output is connected to one portion of the Alpha Register Driver circuit board, where the second portion is used in the channel for the other hand. The output of the register driver operates the register marked Right Hand Alpha on the monitor panel.

Output signals from the amplifiers also pass through gain controls marked Beta-Gamma Gain on the board and are directed to the Dual Beta-Gamma Amplifier and Discriminator Board. The signals are amplified by 20 and directed to another adjustable-threshold, dual-input discriminator (as before). The discriminator output is scaled down by a factor of 32 (minor rewiring may change this to 16, 8, 4, or 2 if desired), and the scaler output signal is connected to the Right Hand Beta-Gamma Register Driver to drive the Right Hand Beta-Gamma register on the front panel.

The channels for monitoring the left hand are identical to those described above; however, the alpha register drivers for the right and left hands are on a common board, as are the beta-gamma register drivers for both hands.

Each shoe monitoring channel is similar to the hand channels, but has one probe per shoe, and uses the amplifiers and discriminator as described previously. Since the shoes are not monitored for alpha particles, the alpha discriminator portion is not used and the

alpha register driver and register are omitted.

Capability for incorporation of external monitoring (clothing, etc.) probes is included. Such probes⁽²⁾ may be fabricated for either alpha or beta-gamma detection, and they operate from positive high voltage and contain no preamplifiers. The External Probe channel includes an amplifier (External Probe Preamplifier), another adjustable-gain amplifier, a discriminator, and a gated oscillator (board marked External Probe Annunciator.) Aural output signals are provided by a small speaker.

The Counting Interval Timer controls the counting by removing cutoff bias on the discriminators during the counting interval. The phototubes and amplifiers remain energized and operating at all times. A switch is provided (rear of chassis) to bypass the timer, allowing continuous counting if desired during adjustment and maintenance work. Ordinary timer operation and counting is initiated by inserting the hands into the hand probes; this action operates the Start microswitch and energizes the Count neon lamp. When the counting interval is completed, the Count lamp extinguishes and the Reset lamp is energized. The count cycle cannot be re-initiated until the circuitry has been reset (extinguishing the Reset lamp). The lamps are not energized when the timer bypass switch is used.

Preamplifier and External Amplifier Boards

Refer to Figures 8 and 9, following page 14. The basic form of the circuits is that of a complementary feedback doublet, and with the values shown the circuit has a typical noninverting voltage

gain of about 26. A design feature of the preamplifiers is the use of a silicon input transistor (2N2219) and large-value bias resistors. These resistances may be used since the leakage current (I_{CO}) of the 2N2219 is negligible under the anticipated operating conditions. Because of the large amount of feedback used in the amplifier, the high input impedance prevents clipping of the wide, slow risetime pulses resulting from alpha-caused scintillations. The circuits are decoupled from the power supply by an R-C filter. Amplifiers on the External Amplifier board use germanium transistors (2N1308 and 2N1309) and a negative supply voltage; the bias resistors are of smaller value than used in the preamplifier.

These circuits may be tested by applying fast risetime, exponentially decaying ($>0.5 \mu\text{sec}$), negative-going pulses of up to 0.1 V at the input. A range of voltage gain from 22 to 30 is acceptable, as the gain is dependent on the actual value including tolerances, of the Q_2 collector load resistor (4.7 k Ω) and the feedback resistor (180 Ω).

Dual Alpha Amplifier and Discriminator Board

Refer to Figure 8, following page 14.

As may be seen from the block diagram, the Alpha Amplifier follows the preamplifier. The preamplifier output is connected to the input of the Alpha Amplifier, which provides a voltage gain from base to collector of

$$A_V \approx \frac{-R_L}{R_E}$$

where

R_E is variable, so the gain may be adjusted between two and ten.

After amplification, the (now) positive-going alpha-caused pulses are presented to a discriminator to provide rejection of the much smaller beta-gamma- and noise-caused pulses. The discriminator emits a pulse whenever the input signal exceeds the predetermined threshold level. In practice, the amplifier gain and the alpha discriminator threshold level are set so output pulses occur only when the scintillator is exposed to alpha particles.

The basis of the discriminator is a difference amplifier, made up of transistors Q_4 and Q_6 and associated components (on the Dual Alpha Amplifier board). The base voltage of Q_6 is set to a fixed positive voltage (typically 2 V dc) by the potentiometer and divider resistance network, and the quiescent base voltage of Q_4 is referenced to ground. Since the emitters are connected, Q_6 is normally conducting and Q_4 is normally biased off. When a pulse arrives from Q_1 , it will be positive-going and thus tend to reduce the reverse bias on Q_4 . If the pulse magnitude exceeds the voltage set on the potentiometer, Q_4 will conduct and Q_6 will become biased off. When Q_4 conducts, some of its collector current flows from the base of amplifier Q_3 , turning it on and producing a positive pulse at output terminal K.

When the input pulse magnitude falls below the threshold voltage level, Q_4 turns off and the circuit returns to its normal state. Transistor Q_3 also turns off, and the output pulse terminates. Diode D_1 is used with Q_3 to assure that Q_3 does not start to turn on because of

an increase in collector leakage current at higher temperatures. Transistor Q_6 is used with the Threshold Adjusting Control (instead of using the control alone) since the Q_6 emitter-to-base voltage tends to vary in the same manner as that of Q_4 and provides compensation for temperature-caused changes. The threshold voltage level at which an incoming pulse will cause an output is thus relatively independent of temperature.

The foregoing section has described the action of the discriminator accepting pulses at Input No. 1. Pulses arriving at Input No. 2 are treated in a similar manner in a discriminator made up of Q_5 and Q_6 . Transistor Q_6 acts as before, and Q_5 serves a function similar to that of Q_4 . The output from Q_5 also causes an output pulse at terminal K through transistor Q_3 as before. A positive control voltage (applied at Pin X) biases off transistors Q_4 and Q_5 , in the same manner as Q_6 did, to prevent counting. A significant difference, however, is that the magnitude of the control voltage is about + 11 V dc instead of only + 2 V dc. This large voltage also cuts off Q_6 . When the control voltage is zero (or negative), diode D_2 is reverse biased, and the control voltage has no effect. The control voltage is obtained from the Timer board and is - 1 V dc during the counting interval and + 11 V dc otherwise. In this manner, the gain channels are always operating, and control is exercised only on the discriminator output.

As there is but one threshold control, the two channels may be adjusted by setting the gain of either channel and the threshold control of the dis-

criminator such that proper counting is obtained. The discriminator threshold is then left fixed and the gain of the other channel is adjusted for proper counting.

The voltage gain provided by Q_1 and Q_2 for the alpha detection portion is also used in the beta-gamma portion. The gain controls for the beta-gamma portion are located on the Alpha Amplifier board and connected as the collector load resistors for Q_1 and Q_2 . The output signals, which appear at terminals H and T for Channels 1 and 2, respectively, are positive-going, and the magnitude for each channel depends on the settings of both the alpha and beta-gamma gain controls. The maximum amount of gain is as described before for alpha gain, and the beta-gamma gain control allows a fraction (from 0 to 100%) of the alpha amplifier gain to be used as required.

The board may be tested by applying (to the inputs E and V) negative pulses from 0.1 to 1 V in height. With the beta-gamma controls fully CW and the control terminal X open circuited, the output pulses observed at terminals H and T will be positive and 2 to 11 times larger than was in the input pulse. Maximum pulse height obtainable is about 5 V. With output pulses from 1 to 5 V, one can observe the presence or absence of pulses at the discriminator output (terminal K) depending on the setting of the discriminator threshold control. A typical setting might be 1 V dc at the base of Q_6 , so that pulses greater than about 1 V presented to the discriminator will cause an output at terminal K.

Dual Beta-Gamma Amplifier and Discriminator Board

Refer to Figure 8, following page 14.

This board follows the Alpha Amplifier and provides the voltage gain necessary to prepare the beta-gamma pulses for discrimination.

The amplifier for each channel is a complementary feedback doublet circuit, similar to that used in the described preamplifier. Typical voltage gain is about 20. Channel gain is adjusted by controls on the Alpha Amplifier board and was described in the preceding section.

The positive output pulses from the amplifier are presented to a discriminator as before. The discriminator is a dual unit and is the same as used on the Alpha Amplifier board. The discriminator output pulses have a positive-going leading edge with rise time of 0.3 μ sec or less, suitable for driving the subsequent binary counters (scalars).

To test this board, positive pulses should be applied to the inputs (E and V) of from 10 to 100 mV in height. Observation at the collectors of Q_2 and Q_4 should show a replica of the input pulse, but some 20 times larger. The discriminator threshold adjustment may be varied, as described in the portion on adjustment of the Alpha Discriminator, and the output observed at terminal K.

Binary Counters (Scalars)

Refer to Figures 7 and 8, following page 14.

These counters are commercial units.* Each board contains four resettable,

counting flip-flops or binaries, each of which divides the incoming pulse rate by 2. Five of these binaries are used in tandem in each hand and shoe channel, dividing the input pulse rate by (2^5) or 32 times. The scale factor may be changed from a scale of 32, as shown by the drawings, to a scale of 16, 8, 4, 2, or 1 by a simple wiring change. The binaries and mechanical registers are all reset to an initial state by the reset button.

Dual Register Driver Board

Refer to Figure 8, following page 14.

This board contains two circuits for driving the front panel registers. One pair of circuits is for the left and right hand Alpha Registers, one pair is for the left and right hand Beta-Gamma Registers, and one circuit is for the shoes Beta-Gamma Register.

Each circuit contains a 40 msec, monostable multivibrator which is followed by saturating driver stage. The driving stage connects to the register, a diode, and a neon lamp. The diode is connected across the register, normally nonconducting, to serve as a path for decay of register current after the exciting pulse. If the diode were not present, the collector voltage would become destructively large at the trailing edge of the driving pulse. The neon lamp is excited in parallel with the register. As increasing amounts of contamination are presented to the probes, the register driving rate will become faster than the register can follow and it will "jam." However, the neon lamp will remain lighted during the counting interval.

* *Circuit Boards Type 4XC-RP, Wyle Manufacturing Co., El Segundo, California*

External Probe Annunciator Board

Refer to Figure 8, following page 14.

The board contains a variable gain amplifier, a discriminator, and a gated oscillator. The original probe shell design was retained. The amplifier is of the same type as described in the section on the Alpha Amplifiers. Its output is directed to a discriminator transistor Q_2 which is off-biased by the 4.7 and 22 k Ω resistors to about 2.5 V dc. If the positive waveform at the collector of Q_1 exceeds the 2.5 V off-bias, transistor Q_2 will turn on, thereby turning on Q_3 , which produces a fast-rise pulse at the collector of Q_3 . This positive-going discriminator output pulse is directed to a monostable multivibrator (Q_4 and Q_5) of the same type described in the foregoing section. The collector load impedance for Q_5 consists of a 10 k Ω resistor in parallel with an astable multivibrator. When Q_5 conducts and the control switch contacts are closed (Pin R connected to Pin P by external switch or jumper), Q_6 and Q_7 oscillate and deliver power to the collector load of Q_7 . This collector load is a transistor switch driving a sound-powered telephone speaker that is resonated with a 0.05 μ F capacitor.

Timer Board

Refer to Figure 8, following page 14.

The function of this board is to provide an electronically controlled timing control voltage and to provide control for lamps indicating the timing sequence.

In operation, a switch contact closure between Pins T and V starts the

timing cycle. The control voltage or output at Pin C changes from about + 11 V dc to about -10 V dc and remains at this value during the timing interval. At the end of the interval, the control voltage reverts to + 11 V dc. Also, a panel neon lamp labeled Count (connected between Pin X and common) will be energized during the counting interval and extinguished otherwise. A second panel neon lamp, labeled Reset, is energized after the count interval and is extinguished when the timer is reset.

The circuitry consists of an R-C network, a comparator which compares the output voltage of the R-C network to a reference, and two storage flip-flops whose state depends on the voltage of the R-C network. Two neon lamp driver circuits are included so the state of the flip-flops may be displayed.

In the quiescent (normal) state, the Count flip-flop (Q_7 and Q_8) is off, with Q_7 off and Q_8 conducting. The collector current of Q_8 turns on Q_9 , which shunts the Count lamp causing it to be extinguished. Since Q_7 is not conducting, its collector voltage is near + 12 V dc, as is the emitter of Q_1 . Transistor Q_1 "emitter-follows" the output of Q_7 , and the Q_1 output is the control voltage output of the timer board. The Reset flip-flop is also off, with Q_5 conducting and Q_4 not conducting. As Q_5 is on, the Q_5 collector voltage is essentially the same as the emitter voltage, namely + 12 V dc. The collector of Q_4 tends to rise toward - 95 V dc, but is stopped by the emitter-base diode of Q_6 , turning it on. As Q_6 is on, it shunts the "Reset" neon

lamp, extinguishing it. An 18 μ F paper timing capacitor is connected (externally) from Pin E to -10 V dc on Pin Z of board 26. This capacitor is shunted by Q_2 , which is turned on by the output of Q_1 (see above). The timing capacitor, the 470 k Ω resistor, and the 1 M Ω rheostat form the R-C time base circuit. The output of this timing circuit is normally shunted to -10 V dc by Q_2 (except during timing) and the output voltage is compared against ground voltage by a comparator consisting of Q_3 , D_1 , D_2 , and the 10 k Ω resistor.

To start the timing action, a contact closure is made between Pins T and V. Recalling that Pin V (connected to the collector of Q_5) normally is at +12 V dc, it is seen that a positive transition occurs at Pin T. This transition is differentiated by the 0.01 μ F capacitor, and the positive pulse of current is directed to the base of Q_7 , turning it on. This last action turns off Q_8 which turns off Q_9 , allowing the Count lamp to be energized. As Q_7 is on, its collector voltage (and consequently the emitter voltage of Q_1) is at about -10 V dc. Thus Q_2 becomes turned off, presenting essentially an open circuit to the R-C timer circuit. As Q_2 no longer shunts the timing capacitor, the voltage rises toward +12 V dc, and Q_3 conducts when the base voltage is slightly positive. The current into the collector of Q_3 sets binary Q_4 - Q_5 such that Q_4 is conducting. The collector voltage of Q_4 is now at about +12 Vdc, turning off Q_6 , and energizing the Reset lamp. When Q_4 turned on, its collector moved from the 0 V (ground) to +12 V dc (a 12 V positive transition). This transition is differentiated by the 0.1 μ F capacitor,

and the positive current pulse is directed through the 10 k Ω resistor and D_3 to the base of Q_8 , turning it on. When Q_8 turns on, it turns on Q_9 , extinguishing the Count lamp, and turns off Q_7 . The collector of Q_7 and the emitter and base of Q_1 then rise to +12 V dc, turning on Q_2 , which discharges the timing capacitor back to -10 V dc. The base of Q_3 is now at about -10 V dc, turning it off and stopping the current flow from the base of Q_4 . At this point, further counting is stopped and the Reset button must be used to reset the system.

When the Reset button is pressed, -95 V dc is connected through Pin K and differentiated by the 0.01 μ F capacitor. The negative pulse of current is passed through the 100 k Ω resistor to the base of Q_5 , turning it on. When the reset voltage disappears, diode D_4 shunts away the positive recharge current from the 0.01 μ F capacitor, preventing destruction of the emitter-base junction of Q_5 . When Q_5 turns on, it turns off Q_4 which turns on Q_6 , extinguishing the Reset lamp. The whole circuit has now returned to its original quiescent state, as the Count flip-flop (Q_7 and Q_8) returned to normal at the end of the timing interval.

Hand and Shoe Probe Wiring

Refer to Figure 9, following page 14.

The circuitry inside the hand and shoe probes consists of a voltage divider arrangement for the multiplier phototube, a gain control, and a pulse amplifier.

The phototube dynode voltage divider uses a positive high voltage to insure the absence of voltage stress at the

photocathode. The amount of high voltage applied to the tube is controlled by the 10 M Ω rheostat connected between the tube cathode and circuit common. As the phototube gain is strongly dependent on the applied voltage, this rheostat serves as a gain control. In moving the rheostat from full CW to CCW, one can expect a gain reduction of 70%. This control, as well as the two controls on the Alpha Amplifier board, permit the equalization of gains between the two probes for each hand or between the two shoe probes. The high voltage is filtered by 1 M Ω and 0.1 μ F before being applied to the phototube. A cable from each probe to the main chassis delivers both the signal and preamplifier power. High voltage is supplied on separate cables, looped in tandem from the main chassis to each succeeding probe; thus, the high voltage supplied to each probe is constant, but is separately adjustable for each phototube.

Main Chassis Circuitry

Refer to Figures 6, 7, and 10, following page 14.

The main chassis circuitry consists of power supplies, registers, indicator lamps, interconnecting wiring between circuit boards, and other items.

There are three power supply units on the chassis. The unit* supplying +12 V dc is made from commercial circuit boards and is located in the card file. The unit supplying high voltage for the multiplier phototubes is fabricated on the chassis and consists of a step-up transformer, rectifier, filter, and corona-type voltage regulator.

* Type UPS and 12-PR Circuit Boards, Wyle Manufacturing Co., El Segundo, Calif.

It is fused at 0.25 A. The unit supplying the -95 V dc for registers consists of a transformer, rectifier, filter, and voltage regulator. This regulator is an emitter follower and the output voltage is set by the voltage of a Zener diode connected to the base of the emitter-follower transistor. Unregulated -160 V dc (used for reset) is taken from the above supply before the regulator.

The readout registers are mounted on the front panel and connected to the -95 V dc power supply and to the register driver circuit boards. Damping diodes are connected in parallel with the registers to prevent destruction of the driver transistors.

A register is incorporated (rear of the main chassis) to indicate the number of users of the monitor. The counting coil of this register is connected to the reset bus, thus advancing the register count for each resetting of the instrument. The Reset coil of the register is not connected, to prevent inadvertent destruction of the data.

The high voltage adjustment for the external probe is also on the main chassis. It is an 11-position switch, permitting step adjustments of gain. Fine adjustments may be made on the external probe circuit board.

RESULTS AND CONCLUSIONS

Prototypes of the various circuits were fabricated and tested satisfactorily for operation and counting efficiency. Sensitivities of the probes are easily adjusted to be equal as described. On the hand probes, alpha particles (from a 500

dis/min Pu^{239} source, for example) may be detected with a counting efficiency of from 9 to 27% (averaging 16%) depending on the position of the source relative to the probe detection surface. Counting efficiency for Pu^{239} at the "finger end" of the probe averages about 20%. For beta particles (as from Pm^{147}), detection efficiency averages about 7%.

For certain applications, it may be desirable to have an instrument for measurement of alpha contamination only. For this case, the shoe probes, the beta-gamma scintillator on the hand probes, several of the registers, and several circuit boards may be omitted (as noted in Figure 7).

The accumulated experience with these instruments is about six instrument-years. After initial postmanufacture check out, the electronic portions operated without failure. During this period, approximately four failures occurred due to light leaks in the probe light shield covering. This type of failure is indicated by

high noise count rate, and is easily repaired by the method discussed.

During the first several checkouts, it was found necessary to reroute and shield some wires and make three minor circuit modifications. The circuit diagrams in this report incorporate the above changes.

ACKNOWLEDGEMENT

The authors thank J. I. Forsberg for layout of the printed circuit boards, F. L. Rising for tests and reviews conducted, J. Mateo for making the engineering drawings, and D. P. Brown for providing suggestions and minor circuit modifications during the authors' absence. The method of coupling the multiplier phototube to the light pipe is due to C. D. Boyne.

REFERENCES

1. W. G. Spear. Method for Beta-Gamma Hand and Shoe Counting Under Varying Background Conditions. HW-78956. October 1963.
2. W. G. Spear. Transistorized Line-Operated Radiation Detection Instrumentation. HW-65553. January 1961.

FIGURE 7. Instrumentation Contamination Monitor Elementary Diagram

FIGURE 8. *Instrumentation Contamination Monitor Printed Circuit Boards Elementary and Block Diagram*

H-4-39279 - Sheet 5

APPENDIX

Details for this instrument are given by the following drawings.

Print No. Number	Sheet Number	Revision Number	
H-4-39197	1	3	Models K-3 and K-4 Probes Casting Patterns (Cavities)
H-4-39198	1	4	Models K-3 and K-4 Alpha or Beta-Gamma Scintillation Probe
H-4-39270	1	3	Hand Probe Assembly, Plastic Light Pipe Type
H-4-39270	2	1	Hand Probe Assembly, Plastic Light Pipe Type
H-4-39270	3	2	Hand Probe Assembly, Plastic Light Pipe Type
H-4-39270	4	1	Hand Probe Assembly, Plastic Light Pipe Type
H-4-39271	1	2	Shoe Probe Assembly, Plastic Light Pipe Type
H-4-39271	2	2	Shoe Probe Assembly, Plastic Light Pipe Type
H-4-39271	3	1	Shoe Probe Assembly, Plastic Light Pipe Type
H-4-39271	4	2	Shoe Probe Assembly, Plastic Light Pipe Type
H-4-39271	5	1	Shoe Probe Assembly, Plastic Light Pipe Type
H-4-39279	1	3	Instrumentation, Contamination Monitor, Arrangement
H-4-39279	2	4	Instrumentation, Contamination Monitor, Elementary Diagram
H-4-39279	3	3	Instrumentation, Contamination Monitor, Printed Circuit Boards, Elementary and Block Diagram
H-4-39279	4	3	Instrumentation, Contamination Monitor, Printed Circuit Boards
H-4-39279	5	2	Instrumentation, Contamination Monitor, Assembly
H-4-39279	6	0	Instrumentation, Contamination Monitor, Hand and Shoe Probes, Light Pipe Assembly
H-4-39279	7	0	Instrumentation, Contamination Monitor, Hand and Shoe Probes, Light Pipe Assembly

DISTRIBUTION

<u>Number of Copies</u>		<u>Number of Copies</u>	
438	<u>Division of Technical Information Extension</u>	50	<u>Battelle Northwest</u>
5	<u>Douglas United Nuclear</u>		E. A. Berreth
	H. C. Copeland		C. D. Boyne
	P. C. Jerman		D. P. Brown
	J. E. Kaveckis		A. C. Case
	M. L. Smith		L. J. Chockie
	J. H. Soehnlein		G. M. Dalen
1	<u>General Electric Company</u>		W. L. Fisher
	G. R. Klingler		J. I. Forsberg
1	<u>Hanford Occupational Health Foundation Inc.</u>		G. C. Fullmer
	F. E. Adley		J. J. Fuquay
4	<u>Isochem Inc</u>		W. R. Keplinger (3)
	G. E. Cunningham		J. Mateo
	J. C. Glover		H. A. Meloeny
	L. M. Knights		M. G. Peterson
	M. T. Slind		N. S. Porter
5	<u>Richland Operations Office</u>		C. A. Ratcliffe (2)
	C. D. Corbit		F. L. Rising
	W. P. Foote		G. M. Rolph
	H. G. Hicks		H. G. Ruppert
	R. K. Sharp		R. H. Scott
	Technical Informa- Library		E. M. Sheen (12)
			C. C. Simons
			W. G. Spear (2)
			C. M. Unruh
			E. E. Utz
			D. C. Worlton
			L. V. Zuerner (2)
			Technical Inform- ation Files (5)
			Technical Publica- tions (2)