Victoreen®

943-25, 943-25A, 943-25B, 943-25T, 943-25TA, 943-25TB, 943-26, 943-26A, 943-26B, 943-26TT, 943-26TA, 943-26TB

Beta Detectors

Users Manual

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Section 1
Introduction

1.1 General Description

The 943 series beta detectors are designed to be sensitive to a beta radiation source.

Although the 943 series beta detectors are functionally identical, the detectors differ in the material used for the housing; the material used for the end window, and in the response ratio achieved through the scintillation disc area variations (refer to Section 1.2, Specifications).

Two end window materials are used for the 943 series beta detectors. The mylar end window is used for replacement of existing beta detectors with similar windows. The beta detectors with titanium end windows offer greater durability and ease of decontamination.

The beta detector has preamplifier circuitry located in the interior of the overall protective housing. The preamplifier provides pulse conditioning and cable driving capabilities to match the input characteristics of the Victoreen instruments used to monitor detector output. The detector is supplied with an eight (8) foot coaxial cable that normally terminates in a junction box located within a sampling system.

1.2 Application

The detector can be used with Victoreen ratemeters or Scaler Module 960SF. Ratemeters are used with beta detectors in small single channel analog monitoring systems while scaler modules and detectors are primarily used in multiple channel digital monitoring systems.

1.3 Specifications

Detector

Dimensions	9 x 2.5 in (22.9 x 6.4 cm)
Weight	3 lbs (1.4 kg), approximately
Housing	Stainless Steel 943-25, 943-25A, 943-25B, 943-25T, 943-25TA, 943-25TB
	Carbon Steel 943-26, 943-26A, 943-26B, 943-26T, 943-26TA, 943-26TB
Power	+2000 VDC @ 500 uA, +15 VDC @ 50 mA, -15 VDC @ 50 mA
Connector	MS 3106E 2427B
Operating Temperature	32° to 122°F (0° to 50°C)
Storage Temperature	32° to 104°F (0° to 40°C)
Relative Humidity	0 to 95% non-condensing

Response Ratio:	1:1	943-25, 943-26, 943-25T, 943-26T
	10:1	943-25A, 943-26A, 943-25TA, 943-26TA
	100:1	943-25B, 943-26B, 943-25TB, 943-26TB
End Window Material	Mylar	943-25, 943-25A, 943-25B, 943-26, 943-26A, 943-26B
	Titanium	943-25T, 943-25TA, 943-25TB, 943-26T, 943-26TA, 943-26TB

Preamplifier

Maximum Pressure (Face Exposure)	30 psi
Rise Time	< 60 ns
Input Impedance	> 50 kilohms
Output Coupling	AC
Voltage Gain	6 V/V
Configuration	Voltage sensitive
Output Polarity	Negative
Output Impedance	50 ohms
Maximum Cable Length	1500 ft
Maximum Pulse Amplitude @ Maximum Cable Length	-6 V
Dead Time	Approximately 10 us @ 8 ft cable length
Maximum Count Rate	10^7

The beta detectors have been assembled with parts selected for the reliability required in a nuclear application. Any unauthorized repairs made to the detectors utilized in nuclear applications will void the safety-related rating. Safety-related detectors must be returned to Fluke Biomedical, Radiation Management for authorized, qualified (ANSI 45.2.6, Skill Level II) service.

1.4 Functional Description

The Victoreen beta scintillation detector is shown in block diagram form in Figure 1-1. The detector consists of a scintillation disc, a photomultiplier tube, a preamplifier assembly, and various interconnecting cables connecting the detector, readout, and the detector power supply that is located at the ratemeter or scaler module.

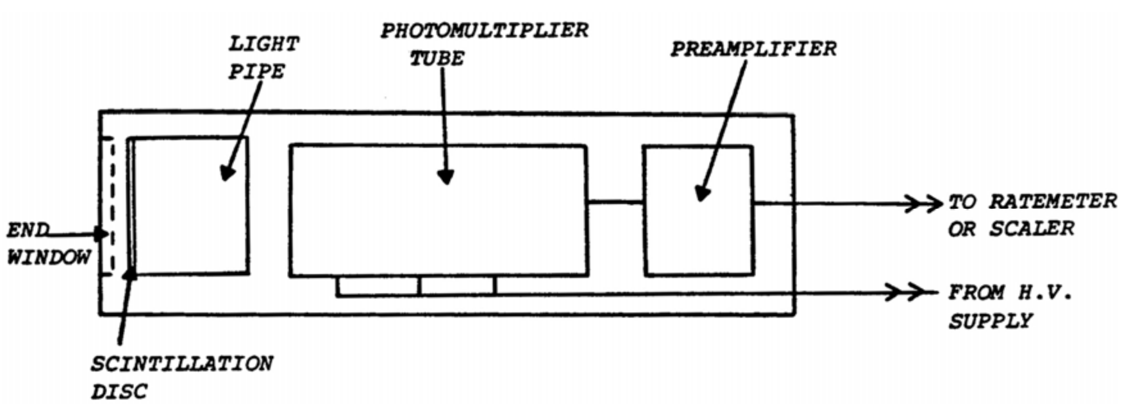

Figure 1-1. Block Diagram, 943 Series Beta Detector

Beta particles that have enough energy to penetrate the end window and impinge upon the disc will produce light pulses, proportional to the energy deposited in the disc. The disc is thin so that gamma rays will not have a high incidence of interaction with the disc. This yields a high rejection of gamma rays while still possessing good sensitivity to beta particles.

A photomultiplier tube, optically coupled to the scintillator disc, detects visible light emitted from the disc and converts this light to pulses of electrical energy whose voltage is proportional to the energy deposited by the beta particle. The electrical pulse is sent to a preamplifier in the detector housing.

The preamplifier circuit amplifies the pulses received from the photomultiplier tube/crystal assembly, providing a fixed gain of six (6). The current drive output of the preamplifier circuit will drive a 50-ohm transmission line up to 1500 feet without degradation of the signal.

Should a very high intensity beta source be detected, the photomultiplier tube may become saturated. That is, visible light from successive photon collisions within the scintillation disc may occur so often that they are essentially continuous. This would have the effect of holding the output voltage of the preamplifier at a relatively constant output voltage. Since the readout is designed to count pulses that represent individual beta particle collisions, a high intensity beta signal could be interpreted as a low or no radiation condition. An anti-jam circuit must be provided in the ratemeter or scaler to which the detector is connected to prevent misinterpretation of the existing radiation field.

1.5 Receiving Inspection

The single channel analyzer board can be supplied independently or as a component of a UDR. Once the SCA board has been received, unpack it from the shipping carton and inspect for damage.

1.6 Storage

Storage of Victoreen instruments shall comply with level B storage requirements as outlined in ANSI N45.2.2 (1972) Section 6.1.2(.2). The storage area shall comply with ANSI N45.2.2 (1972) Section 6.2 Storage Area, Paragraphs 6.2.1 through 6.2.5. Housekeeping shall conform to ANSI N45.2.3 (1972).

Level B components shall be stored within a fire resistant, tear resistant, weather tight, well-ventilated building or equivalent enclosure.

Storage of Victoreen instruments must comply with the following considerations.

1.6.1 Control of Items in Storage

Inspection and examination of items in storage shall be in accordance with ANSI N45.2.2 (1972) Section 6.4.1. Requirements for proper storage shall be documented, and written procedures or instructions shall be established.

1.6.2 In Case of Fire

Post-fire evaluation shall be in accordance with ANSI N45.2.2 (1972) Section 6.4.3.

1.6.3 Removal from Storage

Removal of items from storage shall be in accordance with ANSI N45.2.2 (1972) Sections 6.5 and 6.6.

1.7 Procedures, Warnings, and Cautions

The equipment described in this manual is intended to be used for the detection and measurement of ionizing radiation. It should be used only by persons who have been trained in the proper interpretation of its readings and the appropriate safety procedures to be followed in the presence of radiation.

Although the equipment described in this manual is designed and manufactured in compliance with all applicable safety standards, certain hazards are inherent in the use of electronic and radiometric equipment.

WARNINGS and **CAUTIONS** are presented throughout this document to alert the user to potentially hazardous situations. A **WARNING** is a precautionary message preceding an operation that has the potential to cause personal injury or death. A **CAUTION** is a precautionary message preceding an operation that has the potential to cause permanent damage to the equipment and/or loss of data. Failure to comply with **WARNINGS** and **CAUTIONS** is at the user's own risk and is sufficient cause to terminate the warranty agreement between Fluke Biomedical and the customer.

Adequate warnings are included in this manual and on the product itself to cover hazards that may be encountered in normal use and servicing of this equipment. No other procedures are warranted by Fluke Biomedical. It shall be the owner's or user's responsibility to see to it that the procedures described here are meticulously followed, and especially that WARNINGS and CAUTIONS are heeded. Failure on the part of the owner or user in any way to follow the prescribed procedures shall absolve Fluke Biomedical and its agents from any resulting liability.

Indicated battery and other operational tests must be performed prior to each use to assure that the instrument is functioning properly. If applicable, failure to conduct periodic performance tests in accordance with ANSI N323-1978 (R1983) Radiation Protection Instrumentation Test and Calibration, paragraphs 4.6 and 5.4, and to keep records thereof in accordance with paragraph 4.5 of the same standard, could result in erroneous readings or potential danger. ANSI N323-1978 becomes, by this reference, a part of this operating procedure.

Section 2
Operation

2.1 Installation

CAUTION

Do not apply voltage to the detector if the mylar/titanium cover is not on the disc. Even slight pinholes In the cover could admit enough light to seriously damage the detector. Failure to observe this precaution may destroy instrument calibration, or may even cause destruction of the instrument itself.

Install the detector into the sampler housing (refer to the sampler manual for specific mounting details).

Before connecting the detector to its readout, be sure channel power is turned off, and the high voltage potentiometer is at the lowest setting.

CAUTION

On digital systems, the power should be turned off before the detector cabling is connected to avoid a surge that might destroy electronic components. This is good practice with all systems, digital and analog.

Connect the appropriate cables between the detector and the readout.

CAUTION

Do NOT exceed 2000 V to the detector under any circumstances.

Operation of the detector during initial turn-on is dependent on whether the detector is supplied as part of a radiation-monitoring channel or as a replacement part.

2.2 Detector Operation

Turn on channel power at the readout and slowly increase the high voltage to the value indicated on the factory calibration sheet. This does not have to be an exact value because that value will be determined during the calibration process. A two to four hour warm-up is recommended prior to commencing calibration.

2.3 Detector Operation - Replacement Parts

Turn on channel power at the readout and slowly increase the high voltage until a count rate of approximately 100 cpm is achieved. This count rate assumes that the detector is in the open air and that the discriminator threshold is set at 0.2 VDC in the readout. If the detector is placed within a lead shield, the high voltage should be increased until a count rate of approximately 20 cpm is achieved. A two to four hour warm-up is recommended prior to commencing calibration.

Section 3
Theory of Operation

3.1 Scintillator and Photomultiplier Tube

When beta particles enter the scintillation disc, pulses of light are emitted. The light pulses striking the photocathode of the photomultiplier tube excite the electrons in the cathode to a high-energy state causing them to escape from the surface of the cathode. The freed electrons are attracted by a voltage potential to the first dynode of the photomultiplier tube. This starts a cascading effect where a charge is passed from dynode to dynode, increasing in size at each stage until a shower of electrons is passed on to the preamplifier.

3.2 Preamplifier

The schematic diagram for the preamplifier is located in Appendix A. The preamplifier provides amplification of the output from the photomultiplier tube and cable driving capabilities. Negative pulses derived from the photomultiplier tube are applied to the input of the preamplifier. Operational amplifier Z1 is configured as a non-inverting amplifier with a gain of approximately six (ratio of R6 + R7/R6). The amplified pulses are coupled to transistors Q1 and Q2.

Resistor R11 allows impedance matching of the preamplifier to the 50-ohm transmission line connected to the readout. The non-inverting input of Z1 (pin 3) is biased at +10 VDC potential. This enables the operational amplifier, in conjunction with transistor Q1 and Q2, to drive 1500 feet of cable and produce a 6 V pulse at the readout.

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Section 4
Maintenance, Calibration, and Troubleshooting

4.1 Maintenance

There is no periodic maintenance required for the detector. The following assembly/disassembly procedure is to be used if the detector requires repair. Refer to Section 4.5, Troubleshooting, for the troubleshooting procedure.

4.1.1 Detector Disassembly

Refer to the assembly drawings in Appendix A.

1. Remove the four screws from the base of the detector (connector end).
2. Take the assembly out using a pair of needle nose pliers, ensuring that it does not rotate during removal.

NOTE

The photomultiplier tube may separate from the socket and remain within the detector sleeve. If this occurs, pliers may be applied to the keyed plastic base extrusion of the tube and carefully pulled from within the detector sleeve with moderate vertical force.

3. The photomultiplier tube can be completely removed from its socket by disconnecting the tube shield wire.

4.1.2Detector Assembly

Refer to the assembly drawings in Appendix A.

1. Make sure the photomultiplier tube face (glass) is free of dust, fingerprints, etc. The tube can be cleaned with methyl alcohol.
2. Lubricate the o-ring, located at the detector base, with a light consistency grease using P/N MSJ-3306.
3. Connect the photomultiplier tube shield wire.

CAUTION

Rotating the assembly when fully installed inside the detector sleeve will damage the interface coupling. Align the base plate screw holes with the sleeve holes prior to full Insertion of the assembly into the sleeve.

4. Place the detector assembly inside the detector sleeve and press the baseplate into the sleeve, aligning the four screw holes.

5. Replace the four screws at the connector end of the detector.

4.2 Calibration

The beta scintillation detector is calibrated by adjusting the high voltage supply to the photomultiplier tube (adjusting detector sensitivity to the photons that impinge on the scintillation disc).

This family of beta scintillation detectors essentially provides a linear output for all levels of beta radiation until the disc starts to saturate. Setting the beta scintillation detector for the proper output count rate at any point in its operating range assures an accurate measurement of any other point.

The beta scintillation detector is factory calibrated. It is usually shipped as part of a monitoring system and the ratemeter or scaler module power supply is adjusted for an accurate reading over the entire operating range.

After initial installation, at regular intervals after installation, if the detector is replaced, or if the power supply output voltage changes, calibration should be repeated.

4.3 Calibration Where Calibration Data is Available

Calibration of the beta scintillation detector requires a standard button source of known beta activity for which a known count rate is recorded in a standard geometry. The standard geometry (test fixture, P/N 844-36) is used to position the detector and button source with respect to each other (Figure 4-1). The detector should be connected to the readout with all the cable that will be in place during normal operation since the high voltage setting is slightly cable dependent. At the readout, set the discriminator level to the level indicated on the data sheet (normally 0.2 VDC).

1. Insert the detector into the cavity provided in the standard geometry.
2. Place the ^{90}Sr button source, blank side up (P/N 844-36-14), on the slide in the standard geometry.
3. The expected count rate for the button source should be determined. It is recorded on the calibration data sheet. Correction must be made for decay. (The half-life of the source is 29.12 years.)
4. Adjust the high voltage power supply to the detector so that the net count rate corresponds to the expected count rate calculated in Step 3.

NOTE

The net count rate is the indicated count rate minus the background count rate.

5. The count rate will increase and decrease in conjunction with power supply voltage. If the high voltage reaches 2000 VDC without achieving the necessary count rate, suspect a defect in the detector, wiring, or readout device.

4.4 Calibration Where Detector Is a Replacement Part

Calibration of a replacement detector unit depends on the uniformity of response of the detector. The replacement detector should have the same size scintillation disc as the original detector in the system. The detector should be connected to the readout with all the cable that will be in place during normal operation since the high voltage setting is slightly cable dependent. At the readout, set the discriminator level to the level indicated on the data sheet (normally 0.2 VDC).

1. Insert the detector into the cavity provided in the standard geometry.
2. Place the ^{9O}Sr button source, blank side up (P/N 844-36-14), on the slide in the standard geometry (Figure 4-1).
3. The expected count rate for the button source should be determined. It is recorded on the calibration data sheet. Correction must be made for decay. (The half-life of the source is 29.12 years.)
4. Adjust the high voltage power supply to the detector so that the net count rate corresponds to the expected count rate calculated in Step 3.

NOTE

The net count rate is the indicated count rate minus the background count rate.

5. The count rate will increase and decrease in conjunction with power supply voltage. If the high voltage reaches 2000 VDC without achieving the necessary count rate, suspect a defect in the detector, wiring, or readout device.
6. If more than one button source is available, measure all the button sources. The lowest activity source should be used first. Record the high voltage values that reproduce the original count rates. Average the high voltages to determine the best value for all the button sources.

4.5 Troubleshooting

Troubleshooting is indicated for the detector when the measured output of the check source or some other beta source shows a marked change in the count rate observed at the readout while high voltage has remained constant.

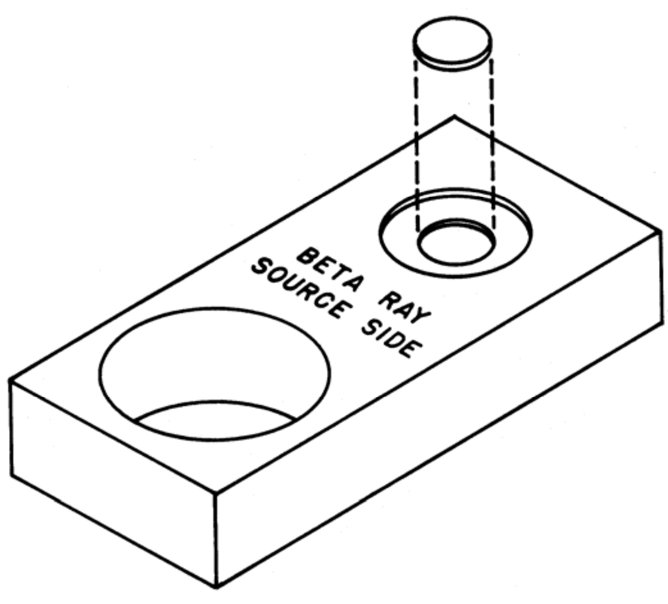

Figure 4-1. Standard Geometry Drawer Inverted to Show Recess for Beta Disk Sources

4.6 Safety Related Detectors

If the fault is isolated to the detector, repair can be performed by a technician rated to Skill level II as described in Section 1.3, Specifications.

Any fault that cannot be isolated to the detector must be in the wiring to the readout or in the readout itself. Consult the appropriate standard manual for the readout purchased so that the troubleshooting procedure for that readout can be used. Defective wiring is replaced using the schematic diagram and Table 4-1 as a guide.

Table 4-1. Cable Connector Pin Out

Pin	Function
A	High Voltage
B	High Voltage Shield
E	+15 VDC Supply
G	Power (± 15 V) Ground
F	-15 VDC
C	Signal (Negative Pulses)
D	Signal Ground

4.7 Commercial Detectors

If the fault has been isolated to the detector, the following procedure can be used to identify the faulty component. The schematic diagram in Appendix A can be used as a guide. Recommended test equipment is listed in Table 4-2.

4.7.1 Preliminary

1. Turn off channel power at the readout.
2. Disassemble the detector according to Section 4.1.1, Detector Disassembly.
3. Remove and inspect the photomultiplier tube for visible signs of damage (cracks, excessive rattling).

CAUTION

Do not replace the photomultiplier tube until troubleshooting has been completed and power is disconnected.

Table 4-2. Recommended Test Equipment

Feature	Specification
Pulse Generator (Square Wave)	
Pulse	± 0.1 to 5 V variable (into a 50 ohm load)
Rise Time	≤ 30 ns
Pulse Width	1.0 microsecond (variable)
Output Impedance	50 ohms
Maximum Repetition Rate	2 MHz
Digital Voltmeter	
Ranges	± 0 to 100 mV up to ± 0 to 1000 V (20% overrange)
Accuracy	± 0.1% of input +1 digit
Input Impedance	≥ 10 megohms
Oscilloscope (Dual Trace)	
Bandwidth	10 MHz @ 10 mV/div
Fastest Sweep Time	< 10 Microseconds/div
Electrostatic Voltmeter	
Range	0 to 2000 VDC
Precision	± 1%
Input Impedance	10^{12} ohms
Counter/Scaler	
Maximum Count Rate	10^5 cps
Minimum Pulse Width for Counting	40 ns
Preset Counting Time	0.1,1.0, and 10 minutes

4.7.2Dynode Test Measurement

CAUTION

Preamplifier input is easily damaged. Ground pin 3 of Z1 before applying power and measuring photomultiplier tube anode or dynode voltage.

1. Using an electrostatic voltmeter, measure the total DC resistance of the dynode string. The value should be 9.67 megohms ± 15%. If no reading is obtained, check dynode resistor interstage connections.
2. Connect the cable to the readout.
3. Turn on channel power and apply 900 V to the detector. Measure the anode resistor voltage (R13) using an electrostatic voltmeter. The value should be 900 V.
4. Remove channel power.

4.7.3Preamplifier Checkout

High voltage must be removed for this test.

1. Remove the grounding jumper from pin 3 of Z1.
2. Connect an oscilloscope to the input circuitry of the readout (50 ohms terminated).

3. Turn on channel power.
4. Using a pulse generator, inject negative pulses of -0.50 V amplitude, one microsecond pulse duration, at a frequency of 1 kHz to the node of R13 and C6 (+) and gnd (-).
5. Output pulses should be -1.6 V ± 20% amplitude. If pulses are not present, check Z1 and associated circuitry.

If the preamplifier and dynode tests are positive, the detector malfunction is probably in the photomultiplier tube. Remove all power, replace the photomultiplier tube and reassemble the detector according to the procedure in Section 4.1.2.

4.8 Replacement Parts

Drawing Number	Description
943-25	Beta Scintillation Detector, Mylar End Window,
943-26	1:1 Response Ratio
943-25A	Beta Scintillation Detector, Mylar End Window,
943-26A	10:1 Response Ratio
943-25B	Beta Scintillation Detector, Mylar End Window,
943-26B	100:1 Response Ratio
943-25T	Beta Scintillation Detector, Titanium End Window,
943-26T	1:1 Response Ratio
943-25TA	Beta Scintillation Detector, Titanium End Window,
943-26TB	10:1 Response Ratio
943-25TB	Beta Scintillation Detector, Titanium End Window,
943-26TB	100:1 Response Ratio

NOTE

Refer to the individual assembly drawings for a breakdown of individual components.

Appendix A
Applicable Drawings

A.1 Applicable Drawings

Detectors 943-25, 94-25T, 943-25A, 943-25B, 943-25TA, 943-25TB

Drawing Number	Description
943-25-5	Beta Scintillation Detector Assembly
943-25T-5	Beta Scintillation Detector Assembly
843-25-10	Preamplifier Circuit Board Assembly
843-25-3	Detector Schematic

Detectors 943-26, 943-26T, 943-26A, 943-26B, 943-26TA, 943-26TB

Drawing Number	Description
943-26-5	Beta Scintillation Detector Assembly
943-26T-5	Beta Scintillation Detector Assembly

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