

**FLUKE®**

**Biomedical**

**Victoreen®**  
**943-35, 943-36**  
**943-36H, 943-37**  
**943-237A**  
**Gamma Scintillation Detector**

**Operators Manual**

March 2005  
Manual No. 943-35-1 Rev. 2  
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**Fluke Biomedical  
Radiation Management Services**

6045 Cochran Road  
Cleveland, Ohio 44139  
440.498.2564

[www.flukebiomedical.com/rms](http://www.flukebiomedical.com/rms)

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# Section 1

## Introduction

### 1.1 General Description

The 943 series Gamma Scintillation Detectors consist of an integral gamma sensitive NaI crystal, a photomultiplier tube, a preamplifier assembly, and various interconnecting cables for connecting the detector, readout, and power supply. Refer to Figure 1-1 for a general view or to Appendix A for each specific detector. All are functionally identical. The size of the crystal employed, the housing material, and whether or not an Americium source is included in the assembly are the only differences. All photomultiplier tube/crystal assemblies are an integral line construction.

The 943 series Gamma Scintillation Detectors are designed to be sensitive to gamma radiation. The Gamma Scintillation material photomultiplier tube and preamplifier are contained within a cylindrical housing. This assembly provides protection from the environment, and provides a mechanism for installation without damaging the detector assembly.

When gamma or x-rays enter the scintillation crystal, pulses of light are emitted. The light pulses striking the photocathode of the photomultiplier tube excites 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.

The preamplifier provides pulse conditioning and cable driving capabilities to match the input characteristics of the Victoreen Universal Digital Ratemeter or the 960 Digital Radiation Monitoring System (DRMS), used to monitor the detector output. The detector is supplied with an 8-foot coaxial cable that normally terminates in a junction box supplied as a part of a complete monitoring channel.

### 1.2 Applications

The 943 series Gamma Scintillation Detectors may be used with Victoreen digital ratemeters or with the 960 Digital Radiation Monitoring System (DRMS). Ratemeters are used in systems where individual control room readouts are employed, while the 960 DRMS is used when a complete digital system is supplied.

### 1.3 Detector Variations

#### **Model 943-35**

The 943-35 Gamma Scintillation Detector Consists of an integral 1.5 inch diameter by 1.0 inch thick sodium iodine (NaI) crystal/photomultiplier tube assembly and preamplifier, enclosed in a stainless steel housing. The stainless steel housing completely encloses the scintillator and is used where direct contact with the process is required. The response of the detector is slightly less than the 943-36 detector, due to the 0.045 inch thick housing.

### **Model 943-36**

The 943-36 Gamma Scintillation Detector consists of an integral 1.5 inch diameter by 1.0 inch thick sodium iodine (NaI) crystal/photomultiplier tube assembly and preamplifier, enclosed in a stainless steel, housing. The aluminum crystal housing protrudes through the process end of the detector for maximum efficiency. The detector is normally used for monitoring of radioactive iodine, or in liquid process monitors, where the detector is protected from the process by a stainless steel well that is part of the detector shield assembly. The well is provided separately.

### **Model 943-36H**

The 943-36H is similar in construction to the 943-36, and is modified to operate at process temperatures of up to 160°F with less than a 10% decrease in output at low photon energies (below 662 keV), and less than a 5% decrease in output at high energies (662 keV and above). This detector is recommended for use in applications where the process temperature is above 120°F.

### **Model 943-37**

The 943-37 Gamma Scintillation Detector consists of an integral 2.0 inch diameter by 2.0 inch thick sodium iodine (NaI) crystal/photomultiplier tube assembly and preamplifier, enclosed in a stainless steel housing. The stainless steel housing completely encloses the scintillator and is used where direct contact with the process is required. The 2 inch crystal provides more sensitivity to both ambient and process radiation than the 943-35 or 943-36 detectors, and is used in applications where low ambient background radiation is anticipated.

### **Model 943-237**

The 943-237A Americium Detector contains a small capsule of Americium 241, which is inserted in the sodium iodine (NaI) crystal. The function of the Americium is to provide a high-energy pulse output for regulation of the high voltage power supply under conditions where fluctuations in the process temperature are expected, or where pulse height spectrometry is desired. The americium-doped detectors are designed to be used in conjunction with the 960AM series Americium Regulator Module or the 942-200-90 SCA/Americium Regulator board for dynamic regulation of the detector high voltage.

Americium 241 is selected as the source of calibrating energy for the regulated detector, because the equivalent energy level of the pulse (approximately 5.4 MeV) is relatively distant from that of the isotopes normally being monitored.

## **1.4 Specifications**

The 943 series Gamma Scintillation Detectors have been assembled with parts selected for the high reliability required in nuclear applications. Unauthorized repairs made to the detector will void the warranty and may affect the nuclear qualification. The detectors should be returned to Fluke Biomedical for authorized, qualified (ANSI 45.2.6, Skill Level II) service or repair.

**NOTE**

The following detector models are no longer manufactured, and may be replaced as shown below.

<b>Obsolete Model</b>	<b>Description</b>	<b>Replacement</b>
943-38	2 x 2 in crystal, carbon steel housing	943-37
943-238A	2 x 2 in crystal, carbon steel housing, with Americium	943-237A

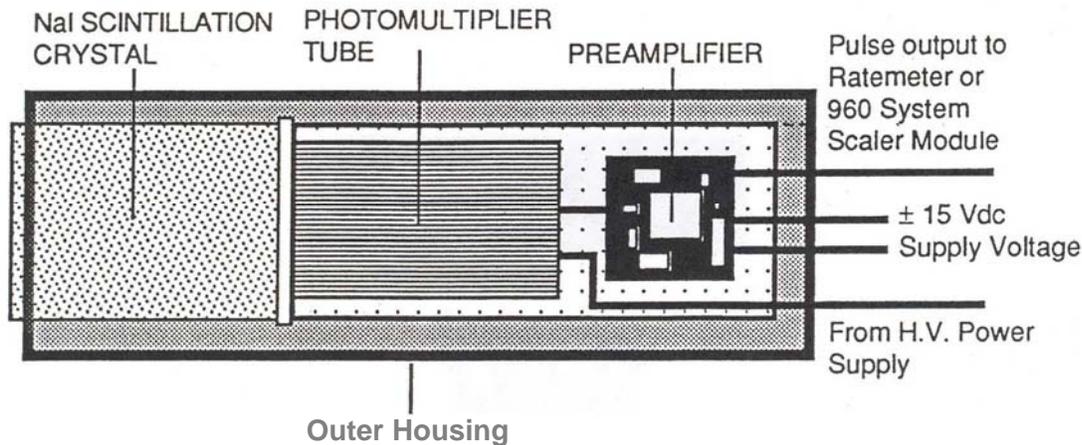
## Detector

<b>Dimensions</b>	<b>943-35:</b> 9.5 x 2.5 in (24.1 x 6.4 cm) <b>943-36, 943-36H:</b> 9.5 x 2.5 in (24.1 x 6.4 cm) <b>943-37, 943-237A:</b> 10.5 x 2.5 in (26.7 x 6.4 cm)
<b>Weight</b>	Approximately 3 lbs (1.4 kg)
<b>Housing Material</b>	Stainless Steel
<b>End Window Material</b>	<b>943-36, 943-36H:</b> Aluminum <b>943-35,943-37, 943-237A:</b> Stainless Steel
<b>Photomultiplier Tube</b>	2 inch photocathode, 10-stage, integral crystal
<b>Crystal Size</b>	<b>943-35, 36, 36H:</b> 1.5 in diameter x 1 in thick <b>943-37,943-237A:</b> 2 in diameter x 2 in thick
<b>Crystal Material</b>	<b>943-3X:</b> Sodium Iodine (NaI) <b>943-23X:</b> Sodium Iodine (NaI) with Americium
<b>Power Requirement</b>	+1000 VDC @ 500, +15 VDC @ 15 mA, -15 VDC @ 50 mA
<b>Connector</b>	MS3106E 2427B (supplied with detector)
<b>Detector Cable Length</b>	8 feet (2.4 meters) (supplied with detector)
<b>Cable Type</b>	50-111: (two 50 ohm coax and two #18 AWG)
<b>Interconnecting Cable</b>	50-100: (one 50 ohm coax, one 75 ohm coax, two #18 AWG, four #18 AWG twisted pairs)
<b>Operating Temperature</b>	32° to 122°F (0° to 50°C), (160°F for 943-36H)
<b>Storage Temperature</b>	32° to 122°F (0° to 50°C), (160°F for 943-36H)
<b>Relative Humidity</b>	0 to 95% non-condensing
<b>Maximum Pressure</b>	15 psig (without well)
<b>Preamplifier</b>	
<b>Rise Time</b>	< 250 ns
<b>Input Impedance</b>	> 50 kilo ohms
<b>Output Coupling</b>	AC
<b>Voltage Gain</b>	6.1 V/V
<b>Configuration</b>	Voltage Sensitive
<b>Current Polarity</b>	Negative
<b>Output Impedance</b>	50 Ohms
<b>Maximum Cable Length</b>	1500 Feet
<b>Max. Pulse Amplitude @ Max. Cable Length</b>	-6 VDC

<b>Max. Count Rate</b>	2E7 CPM
<b>Operating Temperature</b>	32° to 122°F (0° to 50°C), (160°F for 943-36H)
<b>Storage Temperature</b>	32° to 122°F (0° to 50°C), (160°F for 943-36H)
<b>Relative Humidity</b>	0 to 95% non-condensing

## 1.5 Functional Description

Refer to Figure 1-1 for aid in understanding the functional description.



*Figure 1-1. Typical Model 943-36 Series Gamma Scintillation Detector (Not Drawn To Scale)*

Gamma or x-rays that have enough energy to penetrate the crystal or outer housing and interact with the NaI crystal scintillator, will produce light pulses proportional to the energy deposited in the scintillator. A photomultiplier tube, optically coupled to the scintillator detects visible light emitted and converts this light into pulses of electrical energy, whose voltage is proportional to the energy deposited. The electrical pulses are sent to the preamplifier in the detector housing.

The preamplifier circuit amplifies the pulses received from the photomultiplier tube/scintillator assembly with 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 radiation source be detected, the photomultiplier tube may become saturated. That is, visible light from successive photon collisions within the scintillator may occur so often that they are essentially continuous. This would have the effect of holding the output voltage of the preamplifier at a relative constant output voltage. Since the readout is designed to count pulses that represent individual particle collisions, a high intensity signal could be interpreted as a low or no radiation condition. The readout device should include an overrange setpoint of 2E7 CPM that will result in the display of an overrange error message instead of a radiation value. Although the actual radiation value will not be displayed under this extreme condition, it will prevent misrepresentation of the radiation value during overrange conditions.

### **Integral Sodium Iodine (NaI) Crystal/Photomultiplier Tube**

The NaI crystal and photomultiplier tube are supplied as an integral assembly within the detector housing.

The NaI crystals used in the detector are single crystal elements. They are hermetically sealed into a metal can with an optical window on one end of the can to permit the light pulses to escape the crystal. The interior of the can is lined with a highly reflective media to enhance the collection of light.

The NaI crystal is optically coupled to the photomultiplier tube so that light pulses occurring in the crystal are visible to the photocathode of the photomultiplier tube. The electrons in the photocathode become excited by the light, resulting in emission of electrons from the surface of the photocathode. The voltage potential differences in the dynode network start a cascade of electrons, which, upon reaching the anode, become a pulse of current. The anode collects this pulse and makes it available to the preamplifier.

### **Preamplifier**

The preamplifier provides amplification of the output from the photomultiplier tube and cable driving capabilities. Operational amplifier Z1 is configured to provide a voltage gain of 6 for the output of the photomultiplier tube. Transistors Q1 and Q2 provide cable-driving capability for up to 1500 feet of cable.

Using the detector as typically set up by the Fluke Biomedical calibration process, the output of the photomultiplier tube produces a negative pulse from approximately 200 millivolts to 6 Volts, corresponding to an 80 keV to 2 MeV photon energy range. This signal is amplified to a 12 Volt negative pulse at the emitter of Q2, which is coupled to the cable by capacitor C6.

The combination of impedance matching resistor R11 and the termination resistor in the readout (ideally 50 ohms) results in a received pulse with a pulse height proportional to incident energy.

## **1.6 Receiving Inspection**

Upon receipt of the package:

1. Inspect the cartons (s) and contents for damage. If damage is evident, file a claim with the carrier and notify Fluke Biomedical, Radiation Management Services at 440.248.9300.
2. Carefully remove the contents from the packing material. The crystal end is fragile.
3. Verify that all items listed on the packing list have been received and are in good order.

NOTE
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If any of the listed items are missing or damaged,  
notify Fluke Biomedical.

## **1.7 Storage**

Instruments storage must 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 enclosure, in a well-ventilated building or equivalent.

Instrument storage must comply with the following:

1. Inspection and examination of items in storage must be in accordance with ANSI N45.2.2 (1972) Section 6.4.1.
2. Requirements for proper storage must be documented and written procedures or instructions must be established.
3. In the event of fire, post-fire evaluation must be in accordance with ANSI N45.2.2 (1972), Section 6.4.3.
4. Removal of items from storage must be in accordance with ANSI N45.2.2 (1972), Sections 6.5 and 6.6.

## **1.8 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**

Ensure all power is removed prior to installing the 943 Series Detector.

**NOTE**

If the detector is used in a process monitoring system, refer to the applicable system manual for all applicable system drawings and special mounting instructions. Electrical and mechanical drawings for the detector are provided in Appendix A.

The detector is designed for use in a number of process monitoring configurations in a number of Victoreen sampler assemblies. Installation is system dependent. Installation will generally consist of mounting the detector in the desired configuration, performing electrical interconnections, and performing any system testing which may be required. Refer to the applicable system manual for installation instructions for the sampler assembly supplied.

1. Install the detector into the desired mounting location (refer to the Appendix A, the readout manual, or the system manual for specific mounting details).
2. Set the high voltage potentiometer to its lowest setting (not required if the detector and readout were factory calibrated prior to shipment).
3. Connect the appropriate cables between the detector and the readout.

**CAUTION**

Do not exceed 1200 VDC @ 500  $\mu$ A to the detector under any circumstances. Failure to comply will result in damage to the detector.

4. If the detector is part of a radiation monitoring system, turn on channel power and verify the high voltage is set to the value indicated on the factory calibration sheet. If the detector is a replacement part, turn on channel power and slowly increase the high voltage until a count rate of approximately 3000 CPM is achieved (this count rate assumes that the detector is in 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 100 CPM is achieved.
5. Allow a one-hour warm-up before proceeding to calibration.

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## Section 3

# Theory of Operation

### 3.1 Introduction

A brief review of gamma radiation is necessary to understand the absorption processes that are inherent to the operation in the spectrometer mode. This consideration is necessary because in practical applications, not all of the energy of the incident photon is given up in every case. There are three absorption processes: Compton scatter, pair production, and photoelectric process.

Compton scatter is a process where penetrating photons are scattered by the electrons that are in the crystal. In this process, part of the energy is given up to the electron and part is retained by the photon. The ratio of retained energy to that given off is dependent on the angle of collision. The electron will give rise to secondary ionization of somewhat less total energy than the energy of the incident photon. The lower energy output is generally referred to as Compton smear or scatter, most common at intermediate photon energies.

Pair production is a process where the photon gives up energy to create an electron-positron pair. This requires minimum energy of 1.02 MeV since it is a transformation of kinetic energy into mass. Photo energy in excess of 1.02 MeV appears as kinetic energy of the electron and positron. The energy is absorbed by the NaI crystal through ionization. The positron, being unstable in the presence of electrons, will annihilate, causing two photons with 0.51 MeV each. Either of these photons may be absorbed through the photoelectric process, through Compton scatter, or escape the crystal. In practice, pair production becomes evident with incident photons above 2 MeV.

In the photoelectric process, all of the photon's energy is given up to one electron within the NaI crystal. The charged electron will have a short ionization path within the crystal resulting in a light output that is directly proportional to the incident radiation energy. This process permits using the detector to identify the energy level of the incident gamma ray. With many isotopes, isotopic identification can be performed using information derived from the gamma ray.

Photons derived from various sources, whether radioactive or visible light, impinge on the metal shield at the front of the detector. Any photons containing energy less than a specific value (approximately 20 keV) are highly attenuated by the shield. The remaining high-energy photons penetrate the shield and interact with the NaI crystal, causing a pulse of light to be produced. The amount of light emitted is proportional to the energy of the absorbed photon. The crystal is optically coupled to a 10-stage photomultiplier tube (PMT). The light produced from the crystal is seen by the photocathode in the PMT. The cathode is excited by the light and emits electrons from its surface. A string of 10 Dynodes in the PMT, at sequentially increasing potentials, causes a cascade effect that delivers a shower of electrons at the anode of the PMT. This appears as a negative pulse, proportional to the energy of the original photon. By varying the PMT high voltage, the gain of the detector and output pulse height may be set to achieve a specific output, based upon the isotope and activity of the incident radiation.

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## Section 4

# Maintenance, Calibration and Troubleshooting

### 4.1 Maintenance

The 943 series Gamma Scintillation Detector requires no routine maintenance. Periodic verification of the high voltage and discriminator setting supplied by the readout device, however, is recommended. If the detector requires repair, the following assembly/disassembly procedure is to be used.

CAUTION

Ensure all power is removed prior to disassembly of the 943 Series Detector.

#### Detector Disassembly

NOTE

If additional information is required, refer to the assembly drawing in Appendix A.

1. Disconnect the cable from the readout device.
2. Remove the four flat head hex screws from the detector sleeve (connector end).
3. For the 943-35, 943-37, and 943-237A detectors, using the detector cable, gently pull the detector end plate, preamp, and photomultiplier/crystal assembly out from the detector sleeve. The photomultiplier/crystal assembly may then be removed from its socket for replacement and/or the preamplifier circuit board may be repaired.
4. For the 943-36 and 943-36H detectors, the crystal assembly must be separated from its socket while removing the detector end plate. This may be accomplished by applying a slight rocking motion while gently pulling on the detector cable.

To remove the photomultiplier/crystal assembly, the RTV used to seal the front end of the detector must be removed to expose and remove the 38-34 outer retaining ring. Next, the 38-35 crystal retaining ring and 843-36-51 crystal mounting with o-ring may be removed, followed by the 38-34 inner retaining ring. The photomultiplier/crystal assembly may then be removed for replacement.

CAUTION

Use extreme care when removing the detector preamplifier and photomultiplier assembly to prevent damage to these delicate components.

5. The o-rings in the assembly may be removed with a small screwdriver, using care not to damage the o-ring.

## Detector Assembly

NOTE
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If additional information is required, refer to the assembly drawing in Appendix A.

1. Prior to assembly, inspect the following parts for damage:
  - All
    - P/N 46-35 Detector end plate o-ring
    - P/N 843-133-4 Detector crystal cushion
  - 943-35
    - P/N 843-35-6 PMT alignment spacer
    - P/N 46-20 o-ring
  - 943-36 & 943-36H
    - P/N 38-34 Inner/outer mounting rings
    - P/N 38-35 Crystal retaining ring
    - P/N 843-36-51 Crystal alignment mounting ring
    - P/N 46-73 o-ring
2. Lightly lubricate the 46-35 rear end plate o-ring with o-ring grease (MST-3306 or equivalent) and install on end plate.
3. For the 943-36, 943-36H, 943-37, and 943-237A detectors install the PMT/crystal assembly into the socket and insert the PMT/crystal and preamplifier assembly into the sleeve, ensuring the four screw holes on the sleeve are aligned with the end plate holes.
4. For the 943-35 detector, install the PMT/crystal assembly into the socket assembly. Re-install the P/N 843-35-6 PMT alignment spacer over the crystal, sliding it up to the PMT housing. Lightly grease the P/N 46-20 o-ring and install in the groove provided on the crystal housing. This will ensure proper alignment of the PMT/crystal assembly in the sleeve. Insert the PMT/crystal and preamplifier assembly into the sleeve, ensuring the four screw holes on the sleeve are aligned with the end plate holes. Press fit the unit together with moderate hand pressure.
5. Re-install the four screws on the base of the detector.
6. For the 943-36 and 943-36H detectors only the crystal retainers at the front of the detector must be re-installed. First, re-install the P/N 38-34 inner retaining ring in the groove provided on the detector sleeve to retain the PMT. Next, lightly grease P/N 46-73 o-ring and install in the groove provided on the P/N 843-36-51 crystal alignment mounting ring. The P/N 38-35 retaining ring is then installed in the groove provided on the crystal housing to properly position the crystal in the mounting ring. The P/N 38-34 outer retaining ring is then installed in the outer sleeve groove to properly position the complete assembly. The assembly is completed by filling in the entire area between the crystal and the sleeve with RTV (MST-4341, GE #167, or equivalent) to prevent ambient air leakage path through the detector.
7. Reconnect the detector cable to the readout device.
8. Detector is now ready for calibration.

## 4.2 Calibration

The 943 series Gamma Scintillation Detector is factory calibrated and is shipped with a calibration data sheet. It is usually shipped as part of a monitoring system and the ratemeter or scaler (960 DRMS) module high voltage supply, upper and low discriminator are adjusted for a specific response over the entire operating range. With the factory calibration, a dead time correction factor (Tau) is also provided.

At regular intervals after initial installation of the detector, if the detector is replaced, if a dramatic change in detector output is noticed, or if the power supply output voltage changes, calibration should be repeated.

NOTE

The count rate will increase and decrease in conjunction with detector and pulse height voltage. If the high voltage reaches 1000 VDC without achieving the necessary <sup>137</sup>Cs pulse height, suspect a defect in the detector, wiring, or readout device.

The 943-series Gamma Scintillation Detectors are calibrated by adjusting the high voltage supply to the photomultiplier tube (adjusting photomultiplier tube gain based on the photons that impinge on the NaI scintillator).

The detector provides a linear output for all levels of gamma radiation. Although the output is essentially linear, at high counting rates the dead time of the crystal and preamplifier combination causes pulses that are produced at the same time or very nearly the same time to appear as one pulse, reducing the actual pulse output of the detector. Linearity can be improved by using a dead time correction. In digital systems, an algorithm automatically compensates for dead time based on an operator-entered constant. Setting the detector for the proper output count rate at any point in its operating range assures an accurate measurement at any other point.

Victoreen detectors are factory calibrated to provide a fixed output count rate and pulse height over an energy range of 60 keV to over 2 MeV. All Victoreen Primary calibrations are based on detectors that are set-up to provide the same gain, using a master set of button sources and a standard geometry fixture retained permanently at Fluke Biomedical. This permits the use of secondary, or transfer button sources, to reset the high voltage (i.e. re-calibrate) in the field to obtain the same detector efficiency used in the original detector/sampling geometry primary isotopic calibrations. Transfer button sources and standard geometry fixtures are normally provided with Victoreen radiation monitoring systems. The factory calibration procedure is contained in the each applicable system manual.

### Calibration Where Calibration Data and Button Sources are Available

Calibration of the gamma scintillation detector requires a standard button source (s) of known gamma activity and P/N 844-36 standard geometry. The button source is used to reproduce a known count rate using the standard geometry.

The standard geometry is used to consistently position the detector and button source with respect to each other. The detector should be connected to the readout device with the cable that will be in place during normal operation (high voltage setting is slightly cable dependent). At the readout device set the discriminator level to the level indicated on the calibration data sheet (normally 0.2 VDC).

1. Insert the detector into the cavity provided in the standard geometry. Allow detector to warm up for approximately 1 hour.
2. Determine the background count rate by allowing the detector readout device to run for ten minutes. Record this rate on the calibration data sheet. The following Max count rates should be displayed on the readout device (detector dependent):

943-35, 943-36, 943-36H 200 CPM  
943-37 400 CPM  
943-237A 3000 CPM

3. Place a  $^{133}\text{Ba}$  button source (P/N 844-36-15), blank side up in the slide drawer of the standard geometry, and insert drawer into geometry.
4. The expected count rate for the button source should be determined. It is recorded on the factory calibration data sheet. Correction must be made for decay. (The half-life of the source is 10.74 years).
5. Run a 2-minute count (10,000 CPM minimum), using the  $^{133}\text{Ba}$  source.
6. Adjust the high voltage power supply to the detector so that the net count rate corresponds to the expected count rate calculated in step 4. (Net count rate is indicated count rate minus background count rate). A  $\pm 2\%$  tolerance is acceptable.
7. The count rate will increase and decrease in conjunction with the high voltage setting. If the high voltage reaches the maximum allowable setting without achieving the necessary count rate, suspect a defect in the detector, wiring or readout device.
8. If additional button sources were provided, repeat step 5 for each source. A 6% tolerance is acceptable.
9. If the above sources are not within  $\pm 6\%$ , the gain may be incorrectly set on the 356 keV  $^{133}\text{Ba}$  photopeak and not on the 80 keV  $^{133}\text{Ba}$  photopeak. Using a  $^{137}\text{Cs}$  source and an oscilloscope, verify and adjust the high voltage so that the  $^{137}\text{Cs}$  photopeak is at approximately 2.3 Volt average (1.65 Volts for Americium regulated detectors). Step 6 should then be repeated being sure to adjust the high voltage in the negative direction only.

### **Calibration Without Transfer Button Sources**

In the event secondary transfer sources are not available, the detector high voltage may be set to the value stated on the calibration data sheet by using a  $^{137}\text{Cs}$  source and an oscilloscope. The average height of the  $^{137}\text{Cs}$  photopeak is approximately 2.3 Volts, at the high voltage stated on the calibration data sheet, and may be checked to determine proper detector alignment. Without a set of secondary sources, however, the overall detector response in terms of counts per minute,  $\mu\text{Ci per cm}^3$  must be determined by the user's primary calibration.

## **4.3 Troubleshooting**

### **WARNING**

Extreme care must be used when troubleshooting a system that has power applied. All standard troubleshooting precautions apply.

### **WARNING**

Extreme care must be used when troubleshooting in close proximity to the high voltage output.

### **WARNING**

Once a problem has been located, remove all power before continuing with the repair.

**CAUTION**

Personnel performing the following procedure must be familiar with the operation of the monitoring system and the location of each piece of equipment used in the system.

Troubleshooting is indicated for the detector when the measured output of the check source or other gamma source shows a marked increase or decrease in the number of counts observed at the readout while high voltage has remained constant. Check for any visible signs of malfunction. To troubleshoot the system, refer to the applicable drawings located in Appendix A. Insure that all electrical connections are correct. If necessary, refer to the wiring diagrams for electrical connections.

Verify  $\pm 15$  VDC and detector high voltage are present at the detector cable termination point. If the above voltages are present, and no output pulse exists, a failure in the detector preamplifier or photomultiplier tube is suspected. Any fault that cannot be isolated to the detector must be in the wiring to the readout or the readout itself. Consult the readout manual for troubleshooting procedures pertaining to the readout.

Refer to cable connector pin outputs below for pin and function:

Pin	Function
A	High Voltage
B	High Voltage Shield
C	Signal (negative pulses)
D	Signal Shield
E	+15 VDC Supply
F	-15 VDC Supply
G	Power $\pm 15$ VDC Ground

If the detector is determined to be at fault, it must be sent back to Fluke Biomedical for repair or repaired by a technician qualified to ANSI 45.2.6, 1978, Skill Level 2.

**NOTE**

If a problem cannot be resolved by applying the calibration or troubleshooting procedures described above, contact Fluke Biomedical at 440.248.9300 for assistance.

**Dynode Test Measurement**

**NOTE**

The photomultiplier tube must be removed from the detector tube socket during this test.

1. Turn off channel power at the readout device.
2. Disassemble the detector according to the instructions provided in "Detector Disassembly".

CAUTION

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

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

NOTE

If the "Preamplifier Check-out" is to be performed, omit step 7.

7. Reassemble the detector according to the instructions provided in "Detector Assembly".

### Preamplifier Checkout

CAUTION

The high voltage must be removed for this test.

NOTE

If the "Dynode Test Measurement" was performed, omit steps 1 and 2.

1. Turn off channel power at the readout device.
2. Disassemble the detector according to the instructions provided in "Detector Disassembly".
3. Remove the grounding jumper from pin 3 of Z1.
4. Connect an oscilloscope to the input circuitry of the readout (50 ohms terminated).
5. Turn on channel power.
6. Using a pulse generator, inject negative pulses of 0.50 Volts amplitude, 1  $\mu$ s pulse duration, at a frequency of 1 kHz, to the node of R13 and C6 (+) and ground (-).
7. Output pulses should be -1.6 VDC  $\pm$  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 instructions provided in "Detector Assembly".

## **Appendix A**

# **Applicable Drawings and Bill of Materials**

### **A.1 Applicable Drawings**

<u>Drawing Number</u>	<u>Description</u>
943-35-5	Gamma Scintillation Detector Assembly
943-36-5	Gamma Scintillation Detector Assembly
943-36H-5	Gamma Scintillation Detector Assembly
943-37-5	Gamma Scintillation Detector Assembly
943-237A-5	Gamma Scintillation Detector Assembly
943-25-25	Preamplifier Assembly
843-25-10	Preamplifier Assembly, PC Board
843-25-3	Schematic Diagram
50-100	Cable
50-111	Cable

### **A.2 Applicable Bill of Materials**

<u>Document Number</u>	<u>Description</u>
943-35-5	Gamma Scintillation Detector Assembly
943-36-5	Gamma Scintillation Detector Assembly
943-36H-5	Gamma Scintillation Detector Assembly
943-37-5	Gamma Scintillation Detector Assembly
943-237A-5	Gamma Scintillation Detector Assembly
943-25-25	Preamplifier Assembly
843-25-10	Preamplifier Assembly PC Board

**Fluke Biomedical  
Radiation Management Services**

6045 Cochran Road  
Cleveland, Ohio 44139  
440.498.2564

[www.flukebiomedical.com/rms](http://www.flukebiomedical.com/rms)