Nuclear Associates 30-471

VeriDose® Solid-State Diode Detectors

Operators Manual

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Fluke Biomedical
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Table Of Contents

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Section 1
General Information

WARNING

This device is intended for use only by persons who have been trained in the proper interpretation of its readings and in the appropriate safety procedures to be followed in the presence of radiation.

CAUTION

These detectors are not designed, nor are they recommended for use in primary calibration.

1.1 Introduction

The VeriDose Detectors, Models 30-471 through 30-475 and 30-471-8000 through 30-475-8000, are n-type diodes utilizing a p-n junction and are designed for use as radiation detection devices. These diodes are encased within a FDA approved polystyrene material. A low noise coaxial cable is used to connect the diode to an electrometer. In this configuration, these diodes provide enhanced sensitivity, instantaneous response time and are very rugged. With advantages such as large signal and fast response, these diodes are ideal for relative measurements in areas of steep dose gradients and relative absorbed dose in electron beam fields.

The Solid State Radiation Detector Diodes are constructed using a "parallel plate" geometry with planar electrodes opposing each other at a given spacing. This configuration has many advantages over the commonly used coaxial cylindrical geometry which have the electrodes being inner and outer shells.

The most obvious advantage is its superior construction and ease of orientation to the radiation beam. Unlike the cylindrical style diodes where the alignment of the diode's sensitive volume is critical in relationship to the radiation beam, the sensitive volume of the VeriDose Diode is the entire diode, which allows for a less stringent alignment to the radiation beam. The hemispherical shape also allows for easier attachment to the patient. The ideal orientation of the diode within the radiation beam is to have the beam perpendicular to the diode's horizontal axis. As long as the beam is wider than the diode, full collection of all ionization produced will occur regardless of the exact position in the active region. However, for ease of alignment within a radiation beam a raised X has been placed on top of the diode.

Figure 1-1. General View of the VeriDose Diode

1.2 Specifications

Sensitivity:	1.5 nC/cGy
Diameter:	Phonton: 12 mm Diameter Electron: 11 mm Diameter
Cable Length:	2 meters
Output Polarity:	pos/neg
Weight:	42 gm
Sensitive Volume:	0.25 mm^3
Linearity:	2.25%
Reproducibility:	0.2%
Temp. Dependence:	< 0.5% /°C
Angular Dependence:	Refer to the graphs on page 18 - 25
Rad Damage @10 kGy:	< 15%
Operating Temp.:	10° C to 40° C (50° F to 104° F)
Relative Humidity:	5 to 95%, non-condensing

1.3 Accessories

Part Number	**Description**
VeriDose QC (37-705-5000)	Dual purpose acrylic phantom, daily QA, flatness/symmetry & depth dose
Diode Detector Holder (37-492-1000)	Acrylic, 5-slot, wall mount
Calibration Fixture (37-705-4000)	Acrylic, 5-slot
Extension Cable (88-490)	10 meter low noise coaxial cable

1.4 Calibration Technique

The VeriDose diode detectors are part of a dose monitoring system. In order to obtain accurate results, the detectors must be used with a suitable patient dose-monitoring device. The VeriDose V, available from Fluke Biomedical, Radiation Management Services is a 5-channel dose monitor designed specifically for use with this type of detector. A calibration fixture is available to hold the detectors in a fixed, reproducible geometry during the calibration process. For optimum performance, the detector must be used within the energy range for which it was designed. Since the detectors are designed with an internal build-up cap, additional build-up is not required.

It is recommended that the system be calibrated under clinical conditions at which the detectors will be normally used. Since the calibration process will associate a particular detector to a specific channel on the dose-monitoring device, it is necessary to exercise caution when reconnecting the detectors for subsequent measurements. Each detector must be connected to the channel to which it was calibrated.

The detectors must be positioned in close proximity to the isocenter using the optional calibration fixture or an alternative method to obtain a uniform dose. A typical exposure of 100-200 cGy at a dose rate of 100-300 cGy/min is adequate for calibration. Refer to the calibration section of the appropriate operator's manual for the dose-monitoring device for a complete description of the adjustment procedure. Upon completion of the calibration process, several additional exposures should be made in the normal measurement mode of the dose monitor in order to verify the calibration.

1.5 Receiving Inspection

Upon receipt of the diodes:

1. Inspect the carton(s) and contents for damage. If damage is evident, file a claim with the carrier and contact Fluke Biomedical, Radiation Management Services at 440.248.9300.
2. Remove the contents from the packing material and visually inspect the unit for damage.
3. Verify that all items on the packing list have been received and are in good condition.

1.6 Storage

If the diodes are to be stored prior to use, pack them in the original container, if possible, and store in an environment free of corrosive materials, fluctuations in temperature and humidity, and vibration and shock.

1.7 Routine Cleaning

The VeriDose diodes should be kept clean and free from dirt and contamination. The unit may be cleaned by wiping with a damp cloth, using any commercially available cleaning or decontaminating agent.

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 which has the potential to cause personal injury or death. A **CAUTION** is a precautionary message preceding an operation which 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-l978 (R1983) Radiation Detection 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 Operation

The solid-state detectors are p-n junction style diodes that are operated with zero applied bias voltage. This mode of operation is known as the photovoltaic mode. In this mode the diode becomes a self-generating device, not requiring a power supply. When the diode's sensitive region is introduced to radiation, it produces a current output. Based on the internal construction of the detector, this output current is either positive or negative.

Within these detectors a silicon conductor chip is utilized. By using this chip, it minimizes the detectors leakage current. Since the leakage current has been reduced and due to the detectors great resistance, a stable output is achieved. This output is exceptionally linear throughout the specified range of the detector. With radiation fields that cover the specified range of the appropriate diode detector, the detector's reproducibility is better than 0.2%. This output remains constant as long as the dose and diode position remain constant. Changes in this output only become noticeable when the source to detector distance (SDD) is altered.

The isotropic characteristics of these detectors allows for measurements to be made with little consideration of the detectors orientation within the radiation field. The reason for this is that the detector's sensitive area always faces the radiation field regardless of the detectors position. This characteristic allows for an excellent geometric response. However, ideally the detector should be placed in the radiation field so that the field totally encompasses the detector. A raised cross hair has been placed on top of the detector to allow for ease of alignment. They can be applied to the patient with tape, and the rugged waterproof housing allows ease of cleaning with no degradation to the detector.

The sensitivity variation with temperature (SVWT) coefficient which is taken into account for thermal transfer from the patient is < 0.5% per degree Celsius. The semiconductor material within the detector is influenced by temperature. The effect of temperature is to introduce or remove more thermoenergy to the system. More energy bounces more charge carriers out of the centers, and thus increases the signals. The rate of change in sensitivity with temperature depends on the number of generation-recombination centers.

2.2 Photon Detectors

These detectors are used in the measurement of radiation in the range of 1 MV to 25 MV. They are available with a negative or positive output. They have been color coded for ease of identification. Following is a list of the detectors, polarity, color codes, and range.

Model Number	Range	Polarity	Color
30-471	1-4 MV Photon	Positive	Blue
30-471-8000	1-4 MV Photon	Negative	Blue
30-472	5-11 MV Photon	Positive	Yellow
30-472-8000	5-11 MV Photon	Negative	Yellow
30-473	12-17 MV Photon	Positive	Red
30-473-8000	12-17 MV Photon	Negative	Red
30-474	18-25 MV Photon	Positive	Green
30-474-8000	18-25 MV Photon	Negative	Green
30-475	5-25 MeV Electron	Positive	Gray
30-475-8000	5-25 MeV Electron	Negative	Gray

Build-up shields are utilized in their design to provide equilibrium and filtering of low energy radiation. These build-up shields also increase the detector's stability along with increasing the sensitivity in their respective ranges. The output of a typical detector is 1.2 nano coulombs/RAD (1.2 nC/cGy).

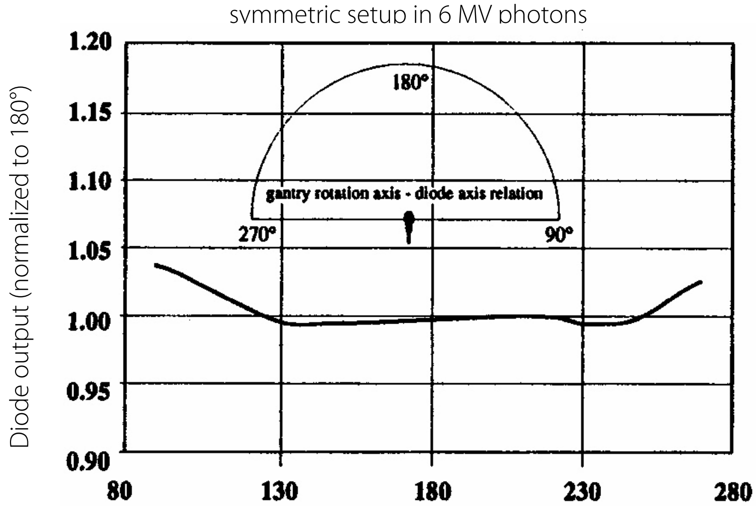
The semiconducting material in these diodes is planar and the diodes as a whole is hemispherical in shape, thus they have a preferred direction. Following are typical angular dependence of these photon detectors.

Angular Dependence

1-4 MV Diodes

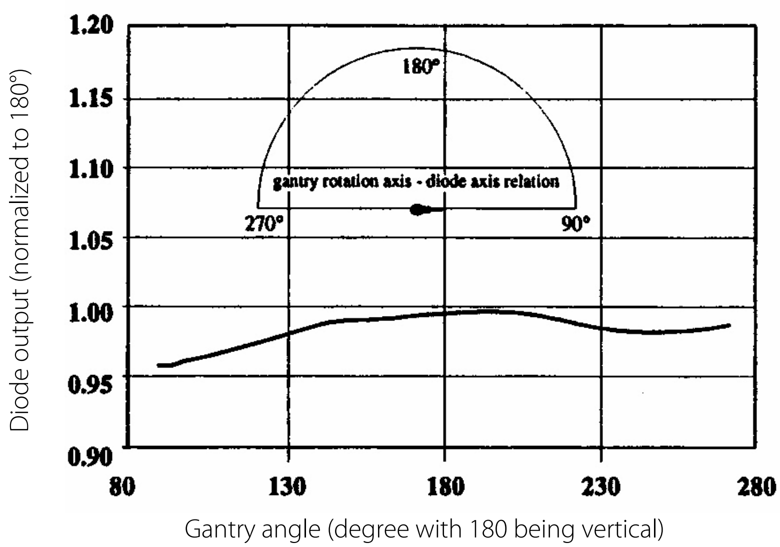
The following figures show the results for incident angles rotation along the diode cable axis and along the axis perpendicular to diode cable axis. For angle deflections less than 50 degrees from the diodes preferred direction, 180 degrees, the diode output changed by less than 1%.

Diode (type 471 [1–4 MV rated]) output vs. incident angle;
symmetric setup in 6 MV photons



Gantry angle (degree with 180 being vertical)

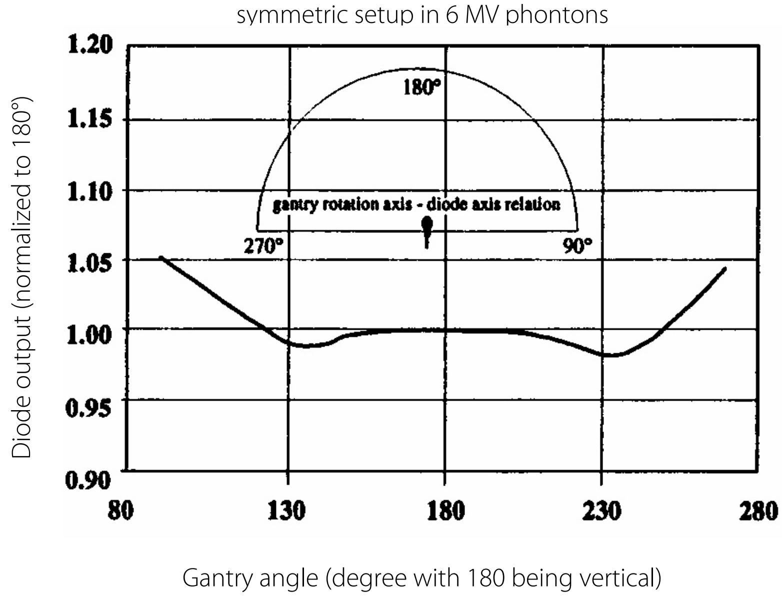
Diode (type 471 [1–4 MV rated]) output vs. incident angle;
asymmetric setup cable faces collimator when at 90 degrees



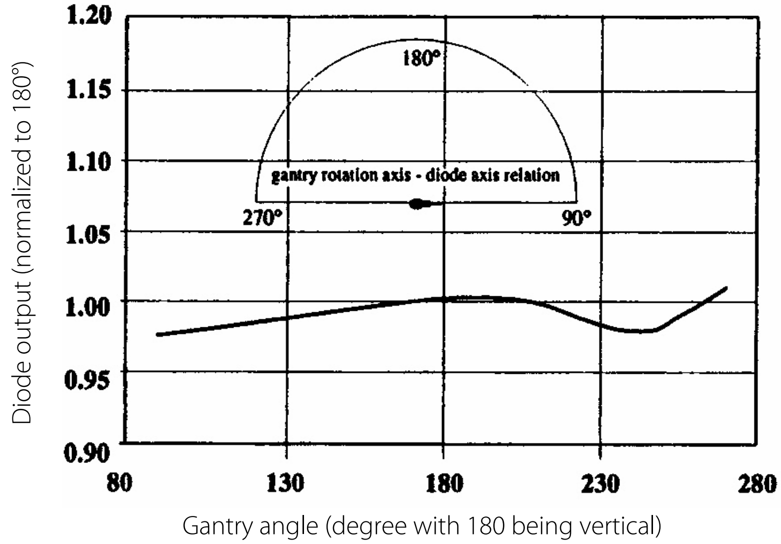
5–11 MV Diodes

Similar results are shown in the following figures for 5-11 MV diodes, although the output changes by less than 1% for a slightly smaller range of angles. That range being 35-40 degrees from 180 for both planes of rotation.

Diode (type 472 [5–11 MV rated]) output vs. incident angle;
symmetric setup in 6 MV phontons



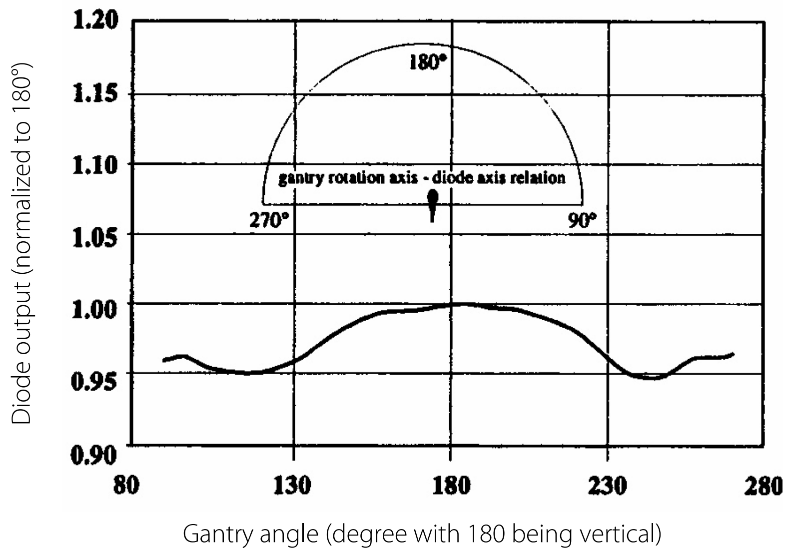
Diode (type 472 [5–11 MV rated]) output vs. incident angle;
asymmetric setup in 6 MV photons



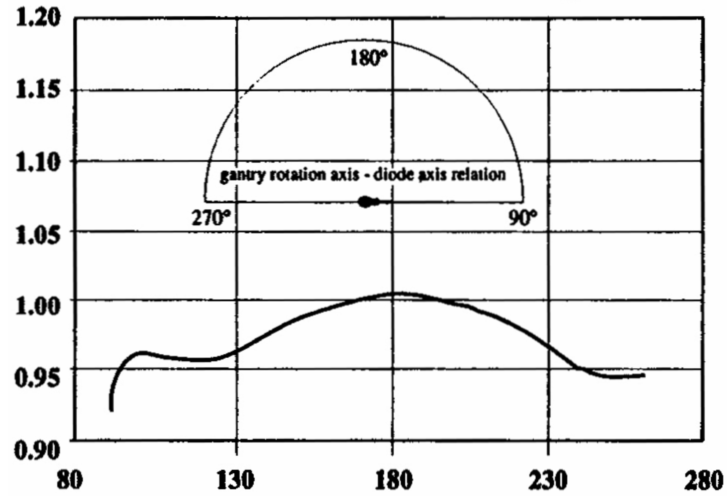
12-17 MV Diodes

As seen in the following figures, the results are good for angle variations in the plane perpendicular to the direction of the cable. Again, there is a small (less than 1%) variation extending to ± 30-35 degrees off center. Along the plane that includes the cable there is a 3% - 4% variation over the same angular range.

Diode (type 473 [12–17 MV rated]) output vs. incident angle;
symmetric setup in 6 MV photons



Diode (type 473 [12–17 MV rated]) output vs. incident angle;
asymmetric setup cable faces collimator when at 90 degrees



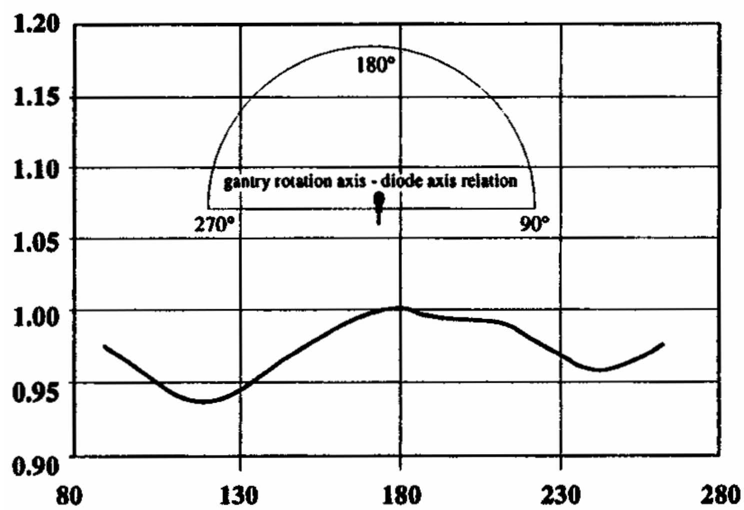
Diode output (normalized to 180°)

Gantry angle (degree with 180 being vertical)

18–25 MV Diodes

As seen in the following figure, the results are good for angle variations in the plane perpendicular to the direction of the cable.

Diode (type 474 [18–25 MV rated]) output vs. incident angle;
symmetric setup in 6 MV photons



Diode output (normalized to 180°)

Gantry angle (degree with 180 being vertical)

2.3 Electron Detectors

These detectors are used in the measurement of radiation in the range of 5 MeV to 25 MeV. They are available with a negative or positive output. They are color coded for ease of identification. Following is a list of the detectors, polarity, color codes, and range.

Model Number	Range	Polarity	Color
30-475	5-25 MeV Electron	Positive	Gray
30-475-8000	5-25 MeV Electron	Negative	Gray

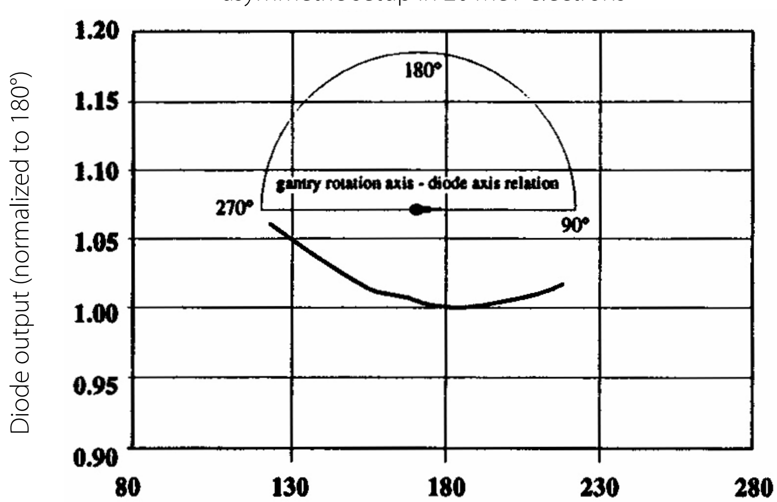
The semiconducting material in these diodes is planar and the diode as a whole is hemispherical in shape, thus they have a preferred direction. Following are typical graphs of the angular dependence of these electron detectors.

The output of a typical detector is 1.00 nano coulombs/RAD (1.00 nC/cGy).

Angular Dependence

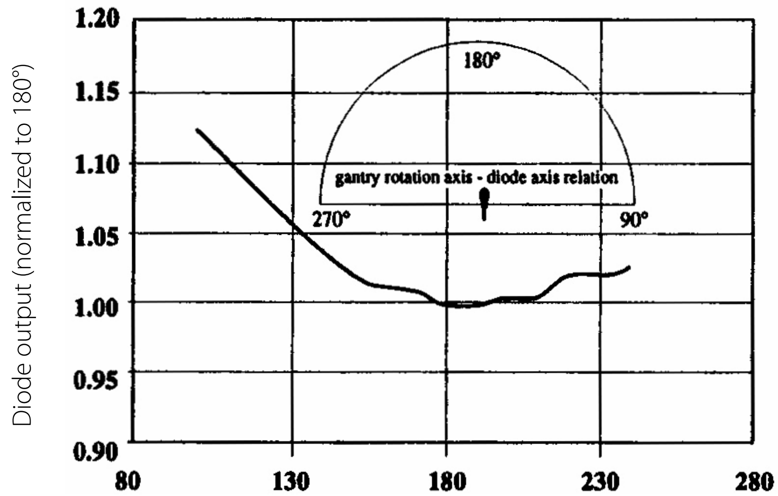
The electron diodes in a 20 MeV electron beam, shown in the following two figures have a I % change after a 30 degrees deflection, in both planes from 180.

Diode (type 475 [electron diode]) output vs. incident angle;
asymmetric setup in 20 MeV electrons



Gantry angle (degree with 180 being vertical)

Diode (type 475 [electron diode]) output vs. incident angle;
symmetric setup in 20 MeV electrons



Gantry angle (degree with 180 being vertical)

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Section 3
Theory of Operation

3.1 Theory of Operation

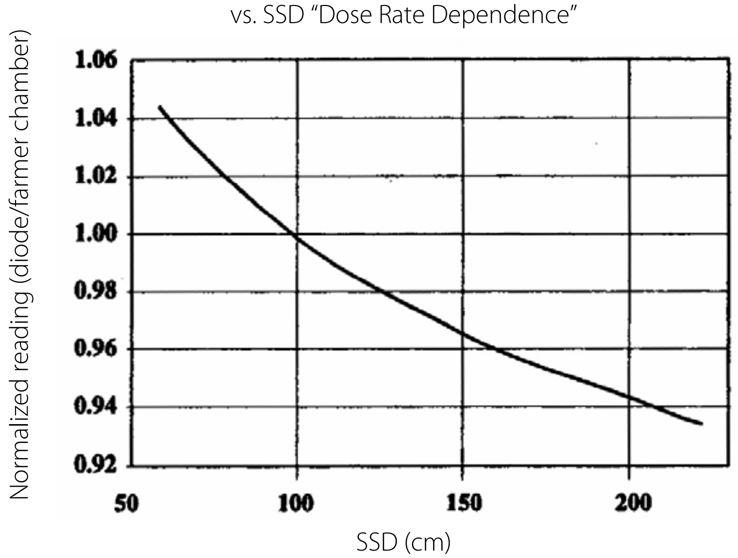
Semiconductors have been actively used as a solid medium for radiation monitoring since the 1960's. Early versions of semiconductor detectors were referred to as crystal counters. Today they are known as diode detectors or solid-state detectors.

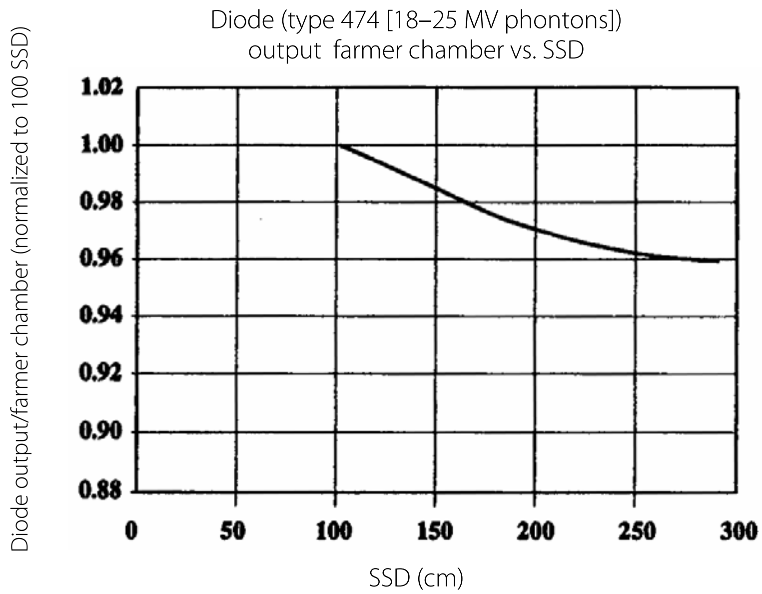
The main advantage of using a semiconductor for a radiation detector is its ability to generate a large number of information carriers for a given incident radiation event. The information carriers that we are concerned with are the electron-hole pairs created by the impinging radiation through the detector. When a charged particle passes through the semiconductor it generates electron-hole pairs along its path. The amount of charge collected by this event is related to the energy loss of the charged particles passing through the semiconductor.

It is the charge carriers' interaction with the generator-recombination centers that cause variations with dose rate. At low dose rates, electrons and holes recombine and are ejected from the centers at some rate. As the dose rate becomes high, the center starts to become saturated by electrons or holes. The carriers are then able to proceed farther then they were previously. Increasing the path length of the carriers in effect increases the sensitivity of the detector.

By placing a detector, along with a farmer chamber, at different distances from a radiation source, the determination of variation with dose rate can be accomplished. Any variations of the detector with respect to the farmer chamber reflects that detector's variation with dose rate. It was determined that the farmer chamber accurately recorded the relative change in dose with distance. Both sets of measurements were normalized to 100 SSD. The following graphs show the results to the measurement made.

Diode (type 472 [5–11 MV phontons]) output farmer chamber vs. SSD "Dose Rate Dependence"





Based on the characteristics of these detectors, they are used for specific applications such as exit dose measurements, intracavitary measurements and also with radiation therapy. Given the quick response of these detectors, they are very useful for verifying the patient's dose delivered during therapy and also as a safeguard against misadministered radiation treatments.

With various types of integral filters and build-up shields these detectors can measure radiation exposures as low as 1 MeV and as high as 25 MV. They are also available with a negative or positive polarity output. The various types of detectors have been color coded to identify them with a specific energy range. This allows for ease of identification and avoidance of misuse. Following is a list of diodes and their associated part numbers that are available.

Model Number	Range	Polarity	Color
30-471	1-4 MV Phonton	Positive	Blue
30-471-8000	1-4 MV Phonton	Negative	Blue
30-472	5-11 MV Phonton	Positive	Yellow
30-472-8000	5-11 MV Phonton	Negative	Yellow
30-473	12-17 MV Phonton	Positive	Red
30-473-8000	12-17 MV Phonton	Negative	Red
30-474	18-25 MV Phonton	Positive	Green
30-474-8000	18-25 MV Phonton	Negative	Green
30-475	5-25 MeV Electron	Positive	Gray
30-475-8000	5-25 MeV Electron	Negative	Gray

Section 4
Maintenance, Calibration and Troubleshooting

4.1 Maintenance

Due to the rugged construction of these detectors, periodic maintenance is not required.

4.2 Calibration

Over time, the amount of exposures the detector is subject to may result in damage to the detector. The effect these exposures have is a reduction in the detectors original response.

In light of this characteristic of these detectors, they provide a high degree of reproducibility in their outputs, even after a substantial accumulation of doses. When a significant change in the detector's response occurs, a calibration should be performed.

4.3 Troubleshooting

There are no troubleshooting procedures for the detector.

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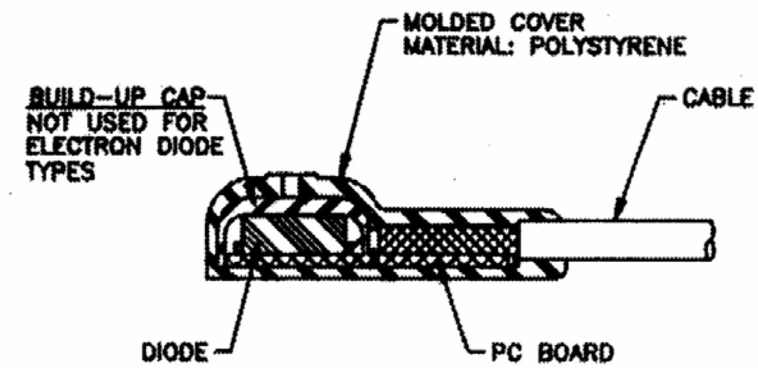
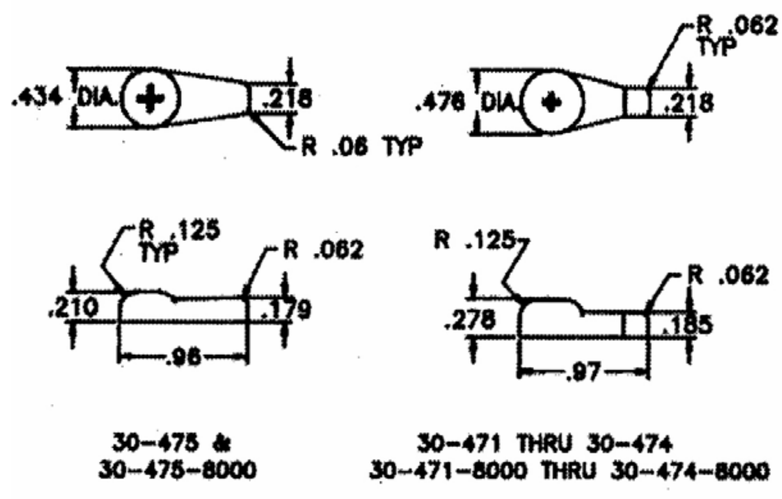
Appendix A
Drawings

A.1 Drawings





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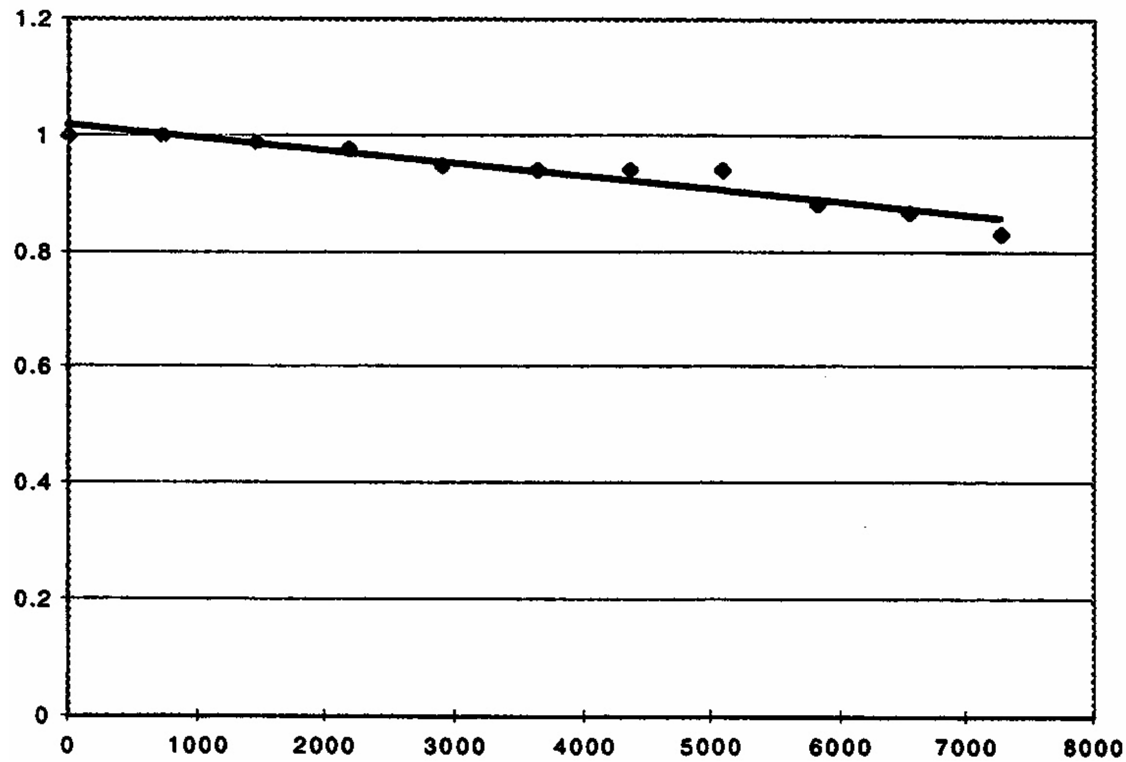
Appendix B
Radiation Damage

B.1 Radiation Damage

Radiation Damage in Diodes as delivered from Fluke Biomedical.
(Irradiated with 15 MV phontons)

Sensitivity (normalized to zero dose)



Number of Treatments
1 Treatment = 200 cGy

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