FLUKE®
Biomedical

Victoreen® 6000-529

Mammographic Ion Chamber

Users Manual

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Fluke Biomedical
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Section 1
General Information

1.1 Introduction

The Model 6000-529 Mammographic Ion Chamber is an ion chamber especially designed to measure low energy x-ray exposure as encountered in mammography.

1.2 Application

The Model 6000-529 Mammographic Ion Chamber is specifically designed for measurement of exposure rate from the output of mammographic x-ray tubes.

1.3 Specifications

Volume	3.3 cm^3
Size	41 mm x 14 mm high
Window Material	Polycarbonate
Window Thickness	9.5 mg/cm^2
Sensitivity	1 nC/R, nominal (0.087 nC/Gy)
Energy Dependence	Within ± 5% from 0.2 mm Al HVL to 5.0 mm Al
Angular Response	± 2% for radiation incidence of up to 30° from normal
Max. Exposure Rate	13 R/min at 300 V bias for 99% collection efficiency
Accessories	Custom carrying case and detachable acrylic stem
Cable Length	10 meters
Cable Termination	BNC signal and banana HV or BNC Triax
Weight	128 g

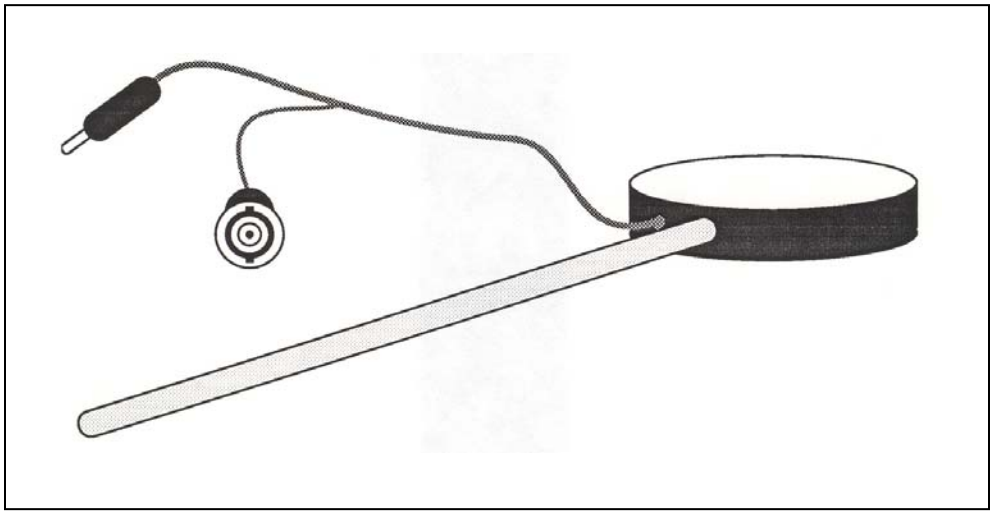

Figure 1-1. Model 6000-529 Ion Chamber (shown with handle attached)

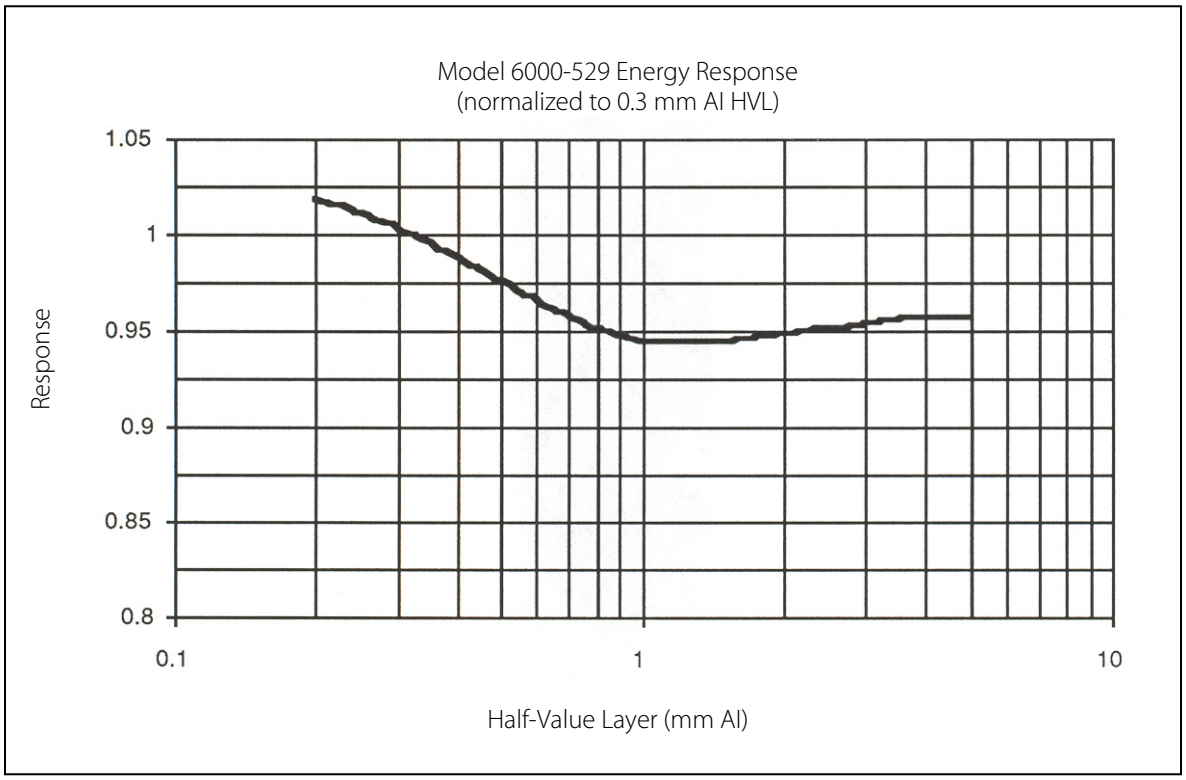

Figure 1-2. Model 6000-529 Energy Response

1.4 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. Remove the contents from the packing material.
3. Verify that all items listed on the packing list have been received and are in good order.

1.5 Storage

The storage requirements for this instrument are listed below.

1. The instrument shall be stored in a cool, dry location.
2. If the instrument is taken from its current location and is to be placed in a new location with a different ambient temperature, allow the instrument to reach the new location's ambient temperature before applying power.

1.6 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 ionizing 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, Radiation Management Services 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.

1.7 Installation

CAUTION

Ensure all power is removed prior to installing the Model 6000-529 Ion Chamber.

Installation of the Model 6000-529 consists of connecting the ion chamber to a Model 4000M+, 4000+, 6000B, 6000M, RAD-CHECK® Plus, or any medical grade electrometer.

The Model 6000-529 may also be used with the Model 6000-531 preamplifier for interfacing with the 4000 or 6000 series of instruments. Refer to the 6000-531 manual for interface details.

A handle is also included with the ion chamber for supporting the ion chamber for in-air measurements.

1.8 Electrical Interface

Final electrical interface connections between the preamplifier, the Ion Chamber, and the host instrument are listed in Table 2-1.

Table 2-1. Electrical Interface Connections

Connector	**Description**
BNC	Ion Chamber Output
HV (BIAS)	Ion Chamber High Voltage

1.9 Setup

Because the Model 6000-529 Ion Chamber may be used with many commercially available electrometers and dosimeters, please refer to the applicable instrument manual for set up and calibration.

Section 2
Theory of Operation

2.1 Theory of Operation

An ionization chamber consists of a defined volume of air in which ions produced by radiation passing through the chamber can be collected and measured. The Model 6000-529 is a parallel plate ion chamber, consisting of a guarded center electrode placed near a conductive plate that serves as a window as well as an electrode. A potential difference in the range of approximately 200 - 300 volts is placed across the plates of the ion chamber (the high voltage applied to the ion chamber will depend on the host instrument used). When ionizing radiation passes through the chamber, ion pairs are produced, each pair consisting of one positive and one negative ion. Under the influence of the electric field produced by the potential between the plates, the ions move toward their oppositely charged plate. Upon arrival, they are neutralized by the free charges on the plates, taking an electron from the negative plate and adding an electron to the positive plate. This causes a current to flow through the external electronics connected to the plates, the magnitude of which is proportional to the rate of exposure to radiation.

The sensitivity of an ion chamber depends on the number of air molecules in the chamber, in fact these quantities are directly proportional. The number of molecules is a function of volume, temperature, and pressure. The volume of air in the chamber is fixed, but since it communicates with the atmosphere, temperature and pressure will vary. The chambers are calibrated at Fluke Biomedical at a temperature of 22°C and a pressure of 760 mmHg. A correction factor should be applied to the reading given by the ion chamber, based on the ambient temperature and barometric pressure at the time the measurement is made. For diagnostic x-ray use, this is usually unnecessary since the errors are on the order of 0.3% per degree Celsius and 0.1% per mmHg. However, if you are using the 6000-529 at an elevation greatly different than sea level, the error could be significant. The correction factor is calculated by the following expression:

$$cf = \frac{760}{P} \times \frac{T + 273.16}{295.16}$$

Where T is the temperature in degrees Celsius and P is the pressure in mmHg.

2.2 Sample Applications

Beam Quality Measurements

Beam quality is an indication of the penetrating ability of diagnostic x-rays. The quantity being measured is the half-value layer (HVL) and is reported is units of millimeters of aluminum. The HVL is defined as the thickness of an absorbing material (aluminum in this case) required to reduce the intensity of the x-ray beam to one half its unattenuated intensity. Also, by definition of the HVL, radiation scatted by the absorber must not be included in the measurement, thereby necessitating care to be taken in setting up the measurement geometry.

To perform a beam quality measurement, one makes several exposure (or air kerma) measurements with the Model 6000-529 ionization chamber, while increasing the thickness of an absorbing material from zero to a sufficient quantity to reduce the reading to less than one half the reading measured with no absorber. A logarithmic interpolation formula is then used to interpolate between the measurement made

with enough aluminum to give a reading just below one-half the unattenuated reading and that made with aluminum to give a reading just greater than one-half the unattenuated reading.

When making beam quality measurements at mammographic energies, it is recommended that you use 99% pure aluminum. Alloy 1100 aluminum has been used, however studies show that an error as great as 7.5% may result.

To perform a beam quality test, follow these steps:

1. Raise the compression paddle to its highest position. Mount the 6000-529 ionization chamber on a ring stand so there is approximately 5 cm of space between the bottom of the chamber and table. The chamber should be centered in the beam laterally, and approximately 4 cm from the chest wall.
2. Collimate the beam, using the light field, so that the entire chamber is included in the beam. The field should be approximately 6 cm x 6 cm. If necessary, relocate the chamber such that it is centered in the field.
3. Set the kVp selector at a kVp setting that is frequently used for making mammograms. Set manual timing, and set the mAs to provide an exposure reading of at least 500 mR. Refer to the instruction manual for the electrometer or other instrument used to measure charge generated in the 6000-529 chamber.
4. Make an exposure. Note the reading and label it X_0. If you are using an electrometer that reads in nC or some other instrument that would normally require the application of a correction factor, you may note the raw reading without corrections. This is so because all subsequent readings are normalized to X_0.
5. Place a sheet of aluminum 0.2 mm thick on the compression paddle. Using the collimator light, be sure the entire ionization chamber is in the shadow of the aluminum sheet. Make an exposure. Record the reading and label it X_1; also record the thickness of aluminum used to make the exposure. Label it t_1.
6. Place an additional 0.01 mm of aluminum on top of the aluminum absorber(s) already in place. Make an exposure. Record the reading, labeling it with sequential indices. Also, record the total thickness of aluminum used in making the measurement, labeling it as t_N where N is the total number of filtered exposures taken so far. If X_N is less than one half of X_0 proceed to step 7, otherwise, repeat step 6.
7. It is now assumed that you have compiled a list of data pairs, labeled "t_i" and "X_i"- If N is the total number of filtered exposures, then the half-value layer may then be calculated using the following formula:

$$HVL = \frac{t_N \ln\left(\frac{2X_N - 1}{X_0}\right) - t_{N-1} \ln\left(\frac{2X_N}{X_0}\right)}{\ln\left(\frac{X_{N-1}}{X_N}\right)}$$

It is recommended that the HVL be in the following range:

$$V \times 0.001 \frac{mmAl}{kV} \leq HVL < V \times 0.01 \frac{mmAl}{kV} + 0.1 mmAl$$

If your calculated HVL is lower than this range, you may be in violation of Federal or State regulation. For more information, see American College of Radiology Medical Physicist's Manual.

Measuring Breast Entrance Exposure and Mean Glandular Dose

Breast entrance exposure is the radiation exposure that would be measured at the point of radiation entry to the breast, free-in-air with the breast removed from the beam. Mean glandular dose is the dose to glandular tissue in a typical 50-50 adipose-glandular composition breast, compressed to a thickness of 4.5 cm, and averaged over the extent of the glandular tissue.

To measure entrance exposure, follow these recommended steps:

1. Set up the x-ray machine for a typical mammographic technique. Place a loaded cassette in the cassette holder, of the size and type consistent with the examination being simulated. Set the machine in the AEC mode and set the density control to the position most commonly used for the examination.

2. Place a mammographic phantom on the cassette holder assembly at the position normally occupied by the breast. Be sure the phantom completely covers the AEC sensor. Now, place the Model 6000-529 ionization chamber just to the side of the phantom. The entrance window of the ion chamber should be flush with the top of the phantom, and the chamber should be placed as close as possible to the chest wall edge of the x-ray field being sure that the entire chamber is in the field and that it does not shadow the AEC sensor. Now, lower the compression paddle until it contacts the phantom and chamber. Take care not to put any mechanical stress on the chamber.
3. Connect the chamber cable to an electrometer, NERO, 4000M+ or other charge-measuring instrument. Follow the instructions accompanying the instrument for details of instrument operation.
4. Make an exposure. Record the reading from the electrometer or other instrument. Apply whatever corrections are necessary to yield an accurate exposure reading. If you are using the Model 6000-531 preamplifier, and have set it up according to the instructions, the only correction that may be necessary would be air density correction (see section page 2-1). If you are using a charge-reading electrometer, you should multiply the electrometer reading (in nanocoulombs) by the calibration factor (in Roentgens per nanocoulombs) listed on the calibration report that accompanied the chamber. Record the result.
5. Repeat step 4 three more times. Average all four results. The final result is the breast entrance exposure. You should now repeat the procedure for all other clinically used techniques.
6. To compute mean glandular dose, refer to Table 2-1. In the column labeled "HVL", locate the value closest to the half-value-layer you measured in step 4 for the kVp setting used in making the entrance exposure measurement. Now, for Mo/Mo tubes, find the column labeled by the same kVp. Alternatively for W/Al tubes, locate the column labeled “W/Al." The number located at the intersection of the column thus located and the row designated by the proper HVL should be noted. This number, when multiplied by the entrance exposure in Roentgens will give mean glandular dose in millirads.

Table 4-1. Glandular Dose for 4.5 cm Breast Thickness - 50% Adipose/50% Glandular Breast Tissue (in mrad/R)

Mo/Mo Target-Filter X-Ray Tube Voltage (kVp)

HVL	23	24	25	26	27	28	29	30	31	32	33	W/Al Target-Filter
												Combination
0.23	109											
0.24	113	116										
0.25	117	120	122									
0.26	121	124	126	128								
0.27	126	128	130	132	134							
0.28	130	132	134	136	138	139						
0.29	135	137	139	141	142	143	144					
0.30	139	141	143	145	146	147	148	149				170
0.31	144	146	147	149	150	151	152	153	154			175
0.32	148	150	151	153	154	155	156	158	159	160	160	180
0.33	153	154	155	157	158	159	160	162	163	164	164	185
0.34	157	159	160	161	162	163	164	166	167	168	168	190
0.35		163	164	166	167	168	169	170	171	172	172	194
0.36			168	170	171	172	173	174	175	176	176	199
0.37				174	175	176	177	178	178	179	180	204
0.38					179	180	181	182	182	183	184	208
0.39						184	185	186	186	187	188	213
0.40							189	190	191	192	192	217
0.41								194	195	196	196	221
0.42										200	200	225
0.43											204	230
0.44												234
0.45												238

Section 3
Maintenance, Calibration and Troubleshooting

3.1 Maintenance

The Model 6000-529 Ion Chamber requires no routine maintenance, other than routine inspection of the chamber for damage.

3.2 Calibration

The Model 6000-529 Ion Chamber is accompanied by the chamber's sensitivity on the calibration report. If this report is not available, the ion chamber may be returned to Fluke Biomedical so that a new sensitivity factor may be obtained, or by the customer by intercomparison with a know ion chamber.

NOTE

Obtain the value of chamber sensitivity in dimensions of exposure per unit charge or air Kerma per unit charge (see the calibration report which accompanied the chamber), and the charge calibration factor for the host instrument in dimensions of charge per displayed exposure unit, prior to referring to the applicable preamplifier manual.

3.3 Troubleshooting

WARNING

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

WARNING

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

CAUTION

Personnel performing the troubleshooting must be familiar with the operation of the system and the location of each piece of equipment used.

Troubleshooting consists of checking the wiring and verifying inputs/outputs are present on all connectors. If a problem develops with the Ion Chamber, return the chamber to Fluke Biomedical.

NOTE

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

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