FLUKE®
Biomedical

Nuclear Associates 06-526 & 06-526-2200

RAD-CHECK™ PLUS

Operators Manual

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Section 1
General Information

1.1 Product Description

The RAD-CHECK™ PLUS (see Figure 1-1) is a battery operated, portable unit which measures the output radiation of diagnostic x-ray equipment. The exposure is displayed on a 3 1/2 digit liquid crystal display (LCD) as either:

1. Exposure, in Roentgens (0.001 to 1.999 R) or SI units of milligrays (0.01 to 19.99 mGy).
2. Rate, in Roentgens per minute (0.01 to 19.99 R/min) or Si units of milligrays per minute (0.1 to 199.9 mGy/min).

Radiation is detected with an internal ionization chamber, or with an optional remote ionization chamber (part number 6000-528 or 6000-529).

The optional detectors consist of an ionization chamber and a 15-foot cable assembly. They are designed to be used with the RAD-CHECK PLUS for measuring dose and dose rates from diagnostic x-ray machines. They can also be used with any properly configured charge measuring electrometer.

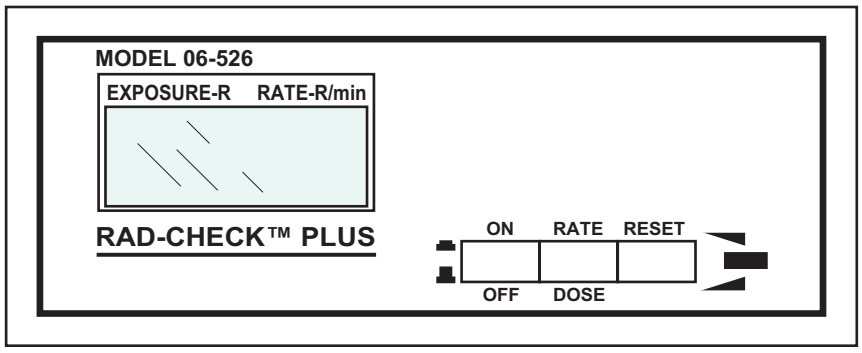

Figure 1-1. RAD-CHECK PLUS X-ray Exposure Meter

1.2 Specifications

RAD-CHECK PLUS

Range Dose	0.001 to 1.999 R (.01 to 19.99 mGy)
Range Rate	0.01 to 19.99 R/min (0.1 to 199.9 mGy/min)
Measurement Area	18.3 cm^2 (4.8 in Ø) effective
Standard Calibration	5% at 75 kVp with 4 mm Al filtration at 22° C (72° F) and one atmosphere - 760 mm of Hg
Chamber Bias Supply	270 V
Reproducibility	Short term within 1% of full scale
Energy Response	5% from 30 kVp to 150 kVp
Electrometer Drift	< 1 mR/min
Maximum Instantaneous Exposure Rate	20 R/sec
Reset Switch	±1 mR of zero
Power Supply	9 V alkaline battery (Duracell type MN 1604 or equivalent). 50 hour operation in manual or external mode; 100 hour operation in auto mode
Display	3 1/2 digit LCD; 1/2 inch high digits; low battery indication
Operating Conditions	10° to 40° C (50° to 104° F)
Relative Humidity	90%, non-condensing
Dimensions	6 (w) x 6.3 (d) x 2.5 in (h) (154 x 160 x 64 mm)
Weight	1.1 lbs (500 g)

Optional External Detectors (Part No. 6000-528 (30 cc) & 6000-529 (3 cc Mammo))

Radiation	**Model 6000-528:** x-rays from 30 to 150 kVp
Measurement	**Model 6000-529:** x-rays from 16 to 90 kVp
Nominal Sensitivity	**Model 6000-528:** 9 nC/R **Model 6000-529:** 1 nC/R
Volume	**Model 6000-528:** nominal 30 cc **Model 6000-529:** nominal 3 cc
Energy Response	**Model 6000-528:** 30 to 150 kVp, within 7% **Model 6000-529:** 16 to 90 kVp, within 7%
Wall	0.031 inch phenolic
Termination	Signal; coaxial, fully guarded BNC HV; recessed banana plug
Cable Length	15 feet
Dimensions	**Model 6000-528:** 4 (w) x .54 (d) x 4 in (h) (101.6 x 13.7 x 101.6 mm) **Model 6000-529:** 1.57 inch Ø x .54 inch deep (40 mm x 15 mm)

** Specifications are subject to change without notice.*

1.3 Manual Addenda

Any improvements or changes concerning the instrument or manual will be explained in an addenda included with the manual. Be sure to note these changes and incorporate them into the manual.

1.4 Customer Service / Technical Assistance

Should you require operation or application assistance or service of your instrument, contact Fluke Biomedical, Radiation Management Services at 440.248.9300.

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Section 2
Operation

WARNING

Extreme caution should be used when making connections with the chamber and rear panel connectors.

WARNING

An electrical shock hazard exists between the ion chamber bias connector and ground (HV Out).

2.1 Exposure Mode

1. Turn the power switch to the ON position.

NOTE

RAD-CHECK PLUS performs to the specifications immediately on application of power. However, a five-minute warm-up period is suggested to minimize the drift associated with surface charge distribution.

   a. If **LOW BAT** appears in the upper left corner of the display, the battery voltage is low. Refer to the Battery Voltage section for battery replacement procedures.
   b. If no display is present, the battery may be fully discharged. Refer to the Battery Voltage section for battery replacement procedures.
2. Set the front panel selector switch to **DOSE**.
3. Set the rear panel switch to the desired position, refer to Figure 2-1:
   a. Select the manual (MAN) position if automatic reset is not desired or x-ray intensity is too low for auto reset.

NOTE

When the rear panel switch is set to the manual position, the display must be reset, using the front panel button, after each exposure.

   b. Select the (AUTO) position if automatic reset of the electronic circuit is desired after each exposure. Minimum operating parameters are discussed later in this section.

c. Select the external detector (EX DET) position if using the remote ion chamber (part number 6000-528). (Other ion chambers may be read if the proper connection is made. The RAD-CHECK PLUS provides a 270 V chamber bias for this purpose.)

NOTE

When the rear panel switch is set to the EX DET position, the display must be reset, using the front panel button, after each exposure. The internal ion chamber is still connected when the switch is set to the EX DET position. Be sure to keep the internal ion chamber out of the radiation beam when using an external chamber.

4. Using the collimator light field, adjust the field size to 6 inch (15 cm) in diameter (i.e. the size of the RAD-CHECK PLUS case).
5. Position the instrument so that the primary beam is centered on, and perpendicular to, the detector (represented by the black disk on top of the unit). For under-table tubes, invert the RAD-CHECK PLUS so that the detector faces the x-ray tube.
6. Press the RESET button to zero the display; make the x-ray exposure.

NOTE

It is not necessary to press the RESET button when the rear panel switch is in the AUTO position.

7. Read the exposure in roentgens (R). To minimize drift effects, readings should be recorded immediately.

CAUTION

If the display does not update, and the unit is in the AUTO mode, press the front panel RESET button. Select a higher kVp or mA, or use the manual reset mode, and make another exposure.

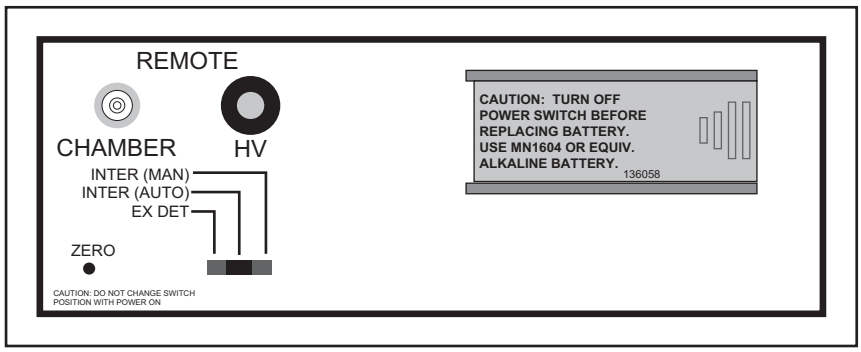

Figure 2-1. Rear Panel

2.2 Exposure Rate Mode

1. Turn the power switch to the ON position.

NOTE

RAD-CHECK PLUS performs to the specifications immediately on application of power. However, a five-minute warm-up period is suggested to minimize the drift associated with surface charge distribution.

   a. If **LOW BAT** appears in the upper left corner of the display, the battery voltage is low. Refer to the Battery Voltage section for battery replacement procedures.
   b. If no display is present, the battery may be fully discharged. Refer to the Battery Voltage section for battery replacement procedures.
2. Set the front panel selector switch to **RATE**.
3. Set the rear panel switch to either the MAN or EX DET position. The AUTO position is not used in the rate mode.

NOTE

When operating in the exposure rate mode, pressing the RESET button is not necessary. Be sure to keep the internal ion chamber out of the radiation beam when using an external chamber.

4. Using the collimator light field, adjust the field size to 6 inch (15 cm) in diameter (i.e. the size of the RAD-CHECK PLUS case).
5. Position the instrument so that the primary beam is centered on, and perpendicular to, the detector (represented by the black disk on top of the unit). For under-table tubes, invert the RAD-CHECK PLUS so that the detector faces the x-ray tube.
6. Energize the x-ray equipment.
7. Read the exposure rate in roentgens per minute (R/min). To minimize drift effects, readings should be recorded immediately.

2.3 Optional Remote Detector Operation

To use the remote detector:

1. Connect the remote cable to the rear panel connectors.
   a. The coaxial BNC on the chamber body is the signal input.
   b. The recessed banana plug is the high voltage connection for the chamber bias.
   c. The middle receptacle is threaded with a standard 1/4-20 thread for accessory mounting.
2. Set the rear panel selector to EX DET.
3. Turn the unit ON.

NOTE

Be sure not to pinch or crush the cable as this may cause an error in the readings. Keep the internal chamber out of the radiation beam. Internal chamber is still connected to the electrometer.

4. Using the collimator light field, adjust the field size to 15 cm (6 in) in diameter (i.e. the size of the RAD-CHECK PLUS case).
5. Position the instrument so that the primary beam is centered on, and perpendicular to, the detector (represented by the black disk on top of the unit). For under-table tubes, invert the RAD-CHECK PLUS so that the detector faces the x-ray tube.
6. Press the RESET button to zero the display; make the x-ray exposure.
7. Read the exposure roentgens (R) or the exposure rate (R/min). To minimize drift effects, readings should be recorded immediately.

WARNING

When finished, turn the unit OFF before disconnecting the cables to the remote detector.

2.4 Applications

RAD-CHECK PLUS can be used to measure radiation output as required by quality assurance procedures. Several applications are discussed in the following paragraphs.

In each of these applications, it is important that all data pertaining to tests performed be recorded for later comparison. Records should include the date, technique factor used, and readings obtained.

2.5 Radiographic Output (mR/mAs) Dose Measurements

1. Set up the x-ray field as follows:
   a. Using the collimator light field, adjust the field size to 6 x 6 inch (15 x 15 cm). This adjustment is equal to the size of the RAD-CHECK PLUS case.
   b. Position the instrument so that the primary beam is centered on, and perpendicular to the detector (represented by the black disk on top of the unit).
2. Select the desired x-ray technique (kVp, mA, and time).
3. Make the exposure.
4. Record the mR reading.
5. Calculate the mR/mAs value.
6. Record the value calculated in Step 5 and the technique factors selected in Step 2 (for reference at a later date).

2.6 Determining Minimum Filtration Requirements (Beam Quality - HVL)

1. Select a tube potential which is commonly used and is in the highest kVp range of the x-ray machine. Refer to Table 2-1.
2. Position the x-ray tube and the RAD-CHECK PLUS.
3. With no added filtration in the beam, make an exposure and record the reading.
4. Using the optional Half-Value Layer Kit (or equivalent), tape the increments of filtration to the face of the collimator.
5. Make an exposure and record the reading for each total thickness of filtration as indicated in Table 2-1.

NOTE

The information contained in Table 2-1 was extracted from DHEW Publications (FDA) 76-8014 "Suggested Optimum Survey Procedures for Diagnostic X-Ray Equipment."

6. Plot the exposure reading (log Scale) verses the total added filtration thickness on semilog paper.
7. Determine the exposure value which is 50% of the radiation recorded in Step 3. The corresponding thickness is the HVL value. Refer to Table 2-1 for the minimum HVL values required for that particular kVp.

To check the minimum filtration requirement at a particulate kVp:

1. At a pre-selected kVp, record an exposure reading with no filtration.
2. Record an exposure reading with the minimum filtration requirement taped to the collimator.

The minimum filtration required has been met if the second exposure is less than or equal to one-half of the first reading.

Table 2-1.Minimum Filtration Requirements

kVp Range	Total added filtration steps (mm Al)	kVp Measured	HVL (mm Al)
Below 50	0.5, 1.0, 1.5, 2.0	30	0.3
		40	0.4
		49	0.5
50 to 70	1.0, 1.5, 2.5, 3.5	50	1.2
		60	1.3
		70	1.5
Above 70	1.5, 2.5, 3.5, 4.5	71	2.1
		80	2.3
		90	2.5
		100	2.7
		110	3
		120	3.2

		130	3.5
		140	3.8
		150	4.1

2.7 MAS Reciprocity

At any given kVp, combinations of time and mA that yield equal mAs values should produce equal exposure (output) values.

1. Make an exposure at each mA station, varying the time to maintain mAs constant. Do not adjust kVp.
2. Record the exposure value obtained.

Variations exceeding the 10% average value may indicate the need for equipment re-calibration.

2.8 Fluoroscopic Exposure Rate

1. Position the RAD-CHECK PLUS with the detector circle facing the x-ray tube (inverted for under-table tubes).
2. Using the optional 07-706 Patient Phantom (or equivalent), place two 3/4 inch aluminum attenuators between the RAD-CHECK PLUS and the image intensifier.
3. Center the detector in the fluoroscopic beam as follows:
   a. Turn on the x-ray beam at a low mA setting.
   b. Use the image intensifier to view the RAD-CHECK PLUS image.
   c. Press the RATE button on the RAD-CHECK PLUS front panel.
   d. Turn the fluoroscope on and read the display.

CAUTION

To prevent damage to the image intensifier, the aluminum attenuators must be in place while making an exposure.

4. Place a 1/8 inch lead beam stop plate (also included in the 07-706 Patient Phantom) or equivalent (folded lead apron) between the RAD-CHECK PLUS and the image intensifier tube. This drives the automatic brightness control to maximum output.

NOTE

On equipment without automatic brightness controls, select maximum output settings. 21CFR1020 requires that the maximum exposure rate be less than 10 R/min (Cg/min).

2.9 Accuracy Considerations

2.9.1 Electrometer Drift

Each instrument has a constant drift which can be measured in a zero radiation field. Drift is expressed as mR/min and has a typical value of 1 mR/min or less. By recording the drift rate, this error can be corrected. Refer to Table 2-2. Drift of the internal chamber can only be measured in the manual mode.

2.9.2 Air Density Corrections

Temperature and pressure have a definite effect on the response from the ion chamber; they determine the number and density of molecules present for ionization. Figure 2-2 shows the correction factors used for changes in temperature and altitude (from 22°C and sea level). To achieve maximum accuracy, use the following equation:

Corrected Exposure =

(Measured Exposure - Drift x Exposure Time) (CF_T) (CF_P)

Where CTT and CFP are the correction factors for temperature and pressure respectively. Note that no more than 2% errors result over the temperature range of 60° to 82°F (16° to 28°C), so that the temperature correction can normally be disregarded.

In the above equation, CF_T and CF_P can be calculated (rather than approximating using Figure 2-2).

$$CF_T = \frac{T(°C) + 273}{295}$$

$$CF_P = \frac{760}{P(\text{mm Hg})}$$

Where:

T(°C) = temperature measured in degrees C, and

P (mm Hg) = pressure measured in mm Hg

Table 2-2. Periodic Drift Rate Record

Date	Drift (mR)	Time (Min)	Rate (mR/Min)
* / /			

* The first reading is performed at the factory for future references over the life of the instrument.

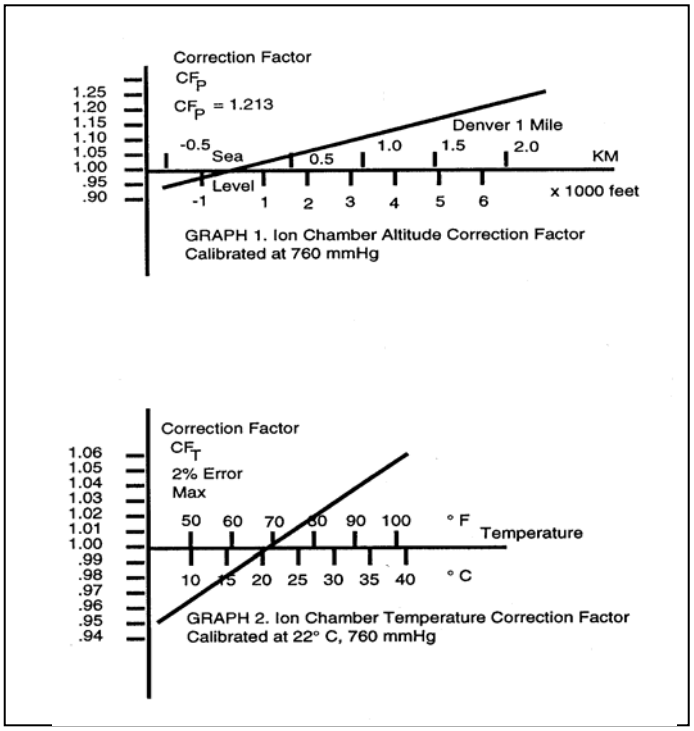

Figure 2-2. Temperature Altitude Correction Graphs

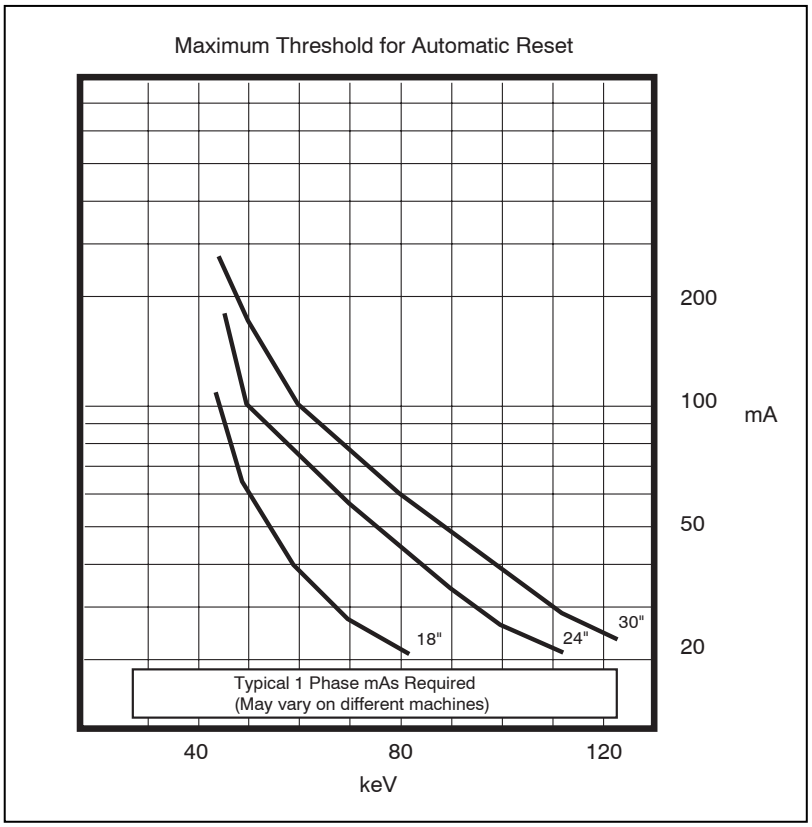

Figure 2-3. Auto Reset Technique Requirements

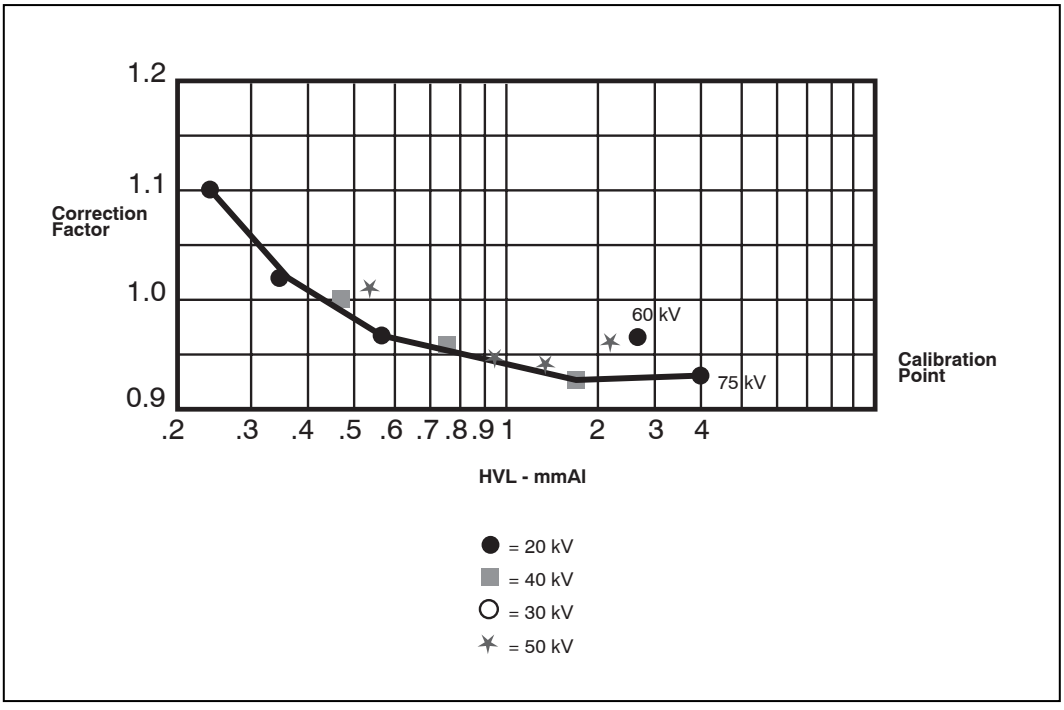

Figure 2-4. Energy Dependence

2.10 Sources of error

If an incorrect measurement is suspected, check the items listed below as they are potential sources of error:

1. Low battery voltage.
2. Failure to properly zero the unit before/between measurements.
3. Uncorrected drift error over long exposure times.
4. Unusual atmospheric conditions requiring a correction factor.
5. External low energy backscatter.
6. Capacitive effects (see precautions).
7. Static discharge (see precautions).
8. If using the remote detector, a damaged cable or connector.
9. Operating the unit beyond specified limits of temperature, x-ray energy, etc.

2.11 Precautions

CAUTION

Due to the high voltage inside the ion chamber and its delicate nature, puncturing or removing the chamber cover may result in damage to the unit or a change in calibration.

CAUTION

If a large amount of static electricity is present, small to moderate absolute errors may occur as a result of touching the exposed window. This is most likely to occur when the ambient humidity is very low.

CAUTION

Because of the highly sensitive nature of the electrometer input circuit, changing the position of the instrument can cause small changes in the reading due to capacitive effects. This is a reversible error and can be corrected by returning the unit to its original position or manually resetting the unit.

CAUTION

Exposures in the AUTO mode which do not trigger the reset will accumulate in the electrometer until a reset occurs either from a proper exposure or manually. If exposure reset occurs, the display will include the most recent exposure and the accumulated exposures which did not reset.

2.12 Operational Checks

Regular monitoring of the instrument's performance is necessary to achieve maximum accuracy.

2.13 Drift Rate

Periodic measurements of the drift rate should be recorded for reference when long exposure periods are used. Refer to Table 2-2.

2.14 Battery Voltage

Correct battery voltage is important for proper operation of the unit. Installation and replacement of the battery requires the removal of the rear access panel. Refer to Figure 2-1. A MN1604 alkaline battery (P/N 16-29 or equivalent) is recommended. However, any standard 9 V transistor battery will work, but with shorter life. The battery should be replaced after a maximum of one year's use.

WARNING

Turn the unit off before replacing the battery.

2.15 Zero Set

Due to aging of circuit components, small changes in the zero reading can be expected over the lifetime of the unit. A Zero adjustment, located on the rear panel, is provided to permit field adjustment as follows:

1. Turn the unit ON.
2. Wait five minutes.
3. Set the front panel switch to DOSE.
4. Set the rear panel switch to MAN.
5. Press RESET.
6. Adjust ZERO if necessary so that the display shows 0.000.

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Section 3
Maintenance

3.1 Introduction

The RAD-CHECK PLUS contains three functional elements: the ion chamber, the electrometer circuit, and the Voltage Ratio Module (VRM).

The ion chamber consists of electricity charged plates enclosing a constant volume. Under manual operation (no radiation), no free ions exist in this volume. When exposed to an ionization source, ions are created in direct relationship to the field strength. The ions are collected, producing an output current.

3.2 Cleaning the Instrument

Do not immerse the Model 06-526, 06-526-2200. The unit is not waterproof. Liquid could damage the circuits. The unit 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.

3.3 Circuit Description (General)

The electrometer circuit is either a charge integration circuit or a current to voltage circuit depending on the selection of DOSE or RATE respectively.

The DOSE or RATE mode is selectable using the front panel switch. When operating in the DOSE mode, the electrometer circuit is a charge integration circuit. When operating in the RATE mode, the electrometer circuit is a current to voltage converter.

WARNING

Use care 270 VDC is present inside the unit

3.4 Auto Reset (DOSE Mode)

When the rear panel switch is placed in the AUTO RESET position, diode D8 is active; radiation causes a current to flow through D8. This current produces a voltage which is input to voltage a comparator. When the threshold is exceeded, the comparator changes its output state causing comparator U1B to change state. U1B turns on transistor Q1 which closes relay RR2. RR2 remains closed as long as radiation is present.

When radiation is removed, RR2 opens and one-shot multivibrator U2A/U2B pulses RR2 to discharge C11. This sets up the integrator for the next shot. In manual or external modes, D6 and R13 bypass the auto reset and RR2 remains closed.

The high voltage utilized by the ion chamber is generated by the blocking oscillator circuit comprised of Q4 and associated components. Zener diode CR3 determines the output voltage thus enabling the circuit to be less sensitive to changes in input voltage.

The electrometer and the blocking oscillator operate from an internal +5 V supply generated by U5.

Transistor Q3 detects low battery voltage and turns on the LOW BAT display through R36.

U3 is a buffer for C13 that retains the last output of U4 through R32. The output of U3 is displayed on the VRM through selection of the DOSE switch position (SW2B). R33 is the zero (offset) adjustment for U4. CR1 provides a 1.2 V reference for the digital display VRM (at pin 7).

3.5 VRM Display

The voltage ratio module consists of an auto-zeroing, dual-slope analog to digital converter and a 3 1/2 digit liquid crystal display (LCD). The VRM converts two independent voltages into a display reading representing the ratio of the two voltages:

$$\text{Display} = \frac{(\text{IN HI} - \text{IN LOW})}{(\text{RFH-RFL})}$$

Because of the compact nature of the VRM board, it should be completely replaced if defective, rather than attempting repairs.

3.6 Calibration and Adjustments

This instrument has been calibrated to ± 5% at 75 kVp with 4 mm Al filtration at 72°F (22°C) and 760 mm of Hg (one atmosphere).

NOTE

The user should be aware that changes in altitude and temperature will affect the reading (refer to Air Density Corrections in Section 2).

The voltages listed below should be checked before continuing with adjustments or calibrations.

1. TP6 - TP8 = + 7 to + 9 V
2. TP6 - TP9 = + 5 V ± 0.5
3. TP12 - TP10 = - 270 V ± 10% (use an electrostatic voltmeter)
3. TP6 - TP4 = 1.1 V ± 0.2 V (see the adjustment for R19 for information)

The control functions are discussed in the following paragraphs. Refer to the internal circuit board for component locations.

3.7 Zero (R33)

This adjustment eliminates offset and aging errors common to operational amplifiers.

1. With the cover on the unit, set the front panel switch to DOSE.
2. Set the rear panel switch to MAN.
3. Reset the display, observe for several minutes, and adjust R33 as required.

3.8 Offset (R30, U4)

1. Set the front panel switch to DOSE.
2. Set the rear panel switch to AUTO-RESET.
3. Press the RESET button on the front panel. The display should read 0.00.
4. If necessary, adjust R30 to display a 0.00 reading.

NOTE

Use a voltmeter between TP4 and TP9 for accuracy.

3.9 Rate Calibration (R25)

Adjust the rate calibration using a known source.

3.10 Auto-Reset (R9)

Adjust the Auto Reset for 175 mV U1-6, TP13 to GND (TP12).

3.11 Remote Detector Calibration

Calibration of the external detectors can be performed by the user as follows:

1. Set the x-ray machine to 100 kV, 300 mA, 0.5 sec.

CAUTION

Do not exceed tube-rating limit.

2. Position RAD-CHECK PLUS at 40 inches.
3. Measure 5 exposures. Record the average as "True." All five should be within 3%.
4. Connect the external chamber.
5. Set the rear panel selector switch to EX DET.
6. Position the external chamber in the same position and same height (tops of chambers) as the RAD-CHECK PLUS. Keep internal chamber out of the radiation beam.
7. Move the RAD-CHECK PLUS to the control booth.

8. Measure 5 exposures. Record the average as "Measured." All five should be within 3%.
9. Calculate correction factor (cf):

   $$cf = \frac{\text{True}}{\text{Measured}}$$

10. Reposition RAD-CHECK PLUS and measure 1 exposure to verify that the x-ray machine did not change.

All readings on the RAD-CHECK PLUS using the external chamber should be multiplied by the correction factor. (**HINT:** Write the correction factor on a small sticker and put it on the chamber.)

3.12 Troubleshooting

WARNING

Extreme caution should be used when making connections with the chambers and rear panel connectors.

WARNING

An electrical shock hazard exists between the ion chamber bias connector and ground (HV Out).

When there is a problem with the unit, refer to the table below for possible causes and corrective action.

Symptom	**Possible Cause**	**Correction Action**
No display & No reset light	Dead battery Broken battery snap lead Defective ON/OFF switch	Replace battery Replace lead Replace switch
Display ON; No reading	Rear panel selector switch positioned incorrectly	Check and correct switch position
Inaccurate readings	Exposure level too low (see Figure 2-3)	Position rear panel selector switch to MAN reset position
	Does not zero	Adjust rear panel zero (see Zero Set)
	Low battery voltage	Replace battery
	Defective/damaged ion chamber	Recalibrate chamber Return unit to factory for chamber repair/replacement

3.13 Replacement Parts

Unless otherwise noted, resistors are .25 W, 5% carbon film; non-polarized capacitors are ceramic disk type, 20% tolerance, 100 VDC; and capacitors marked "FILM" are 10% tolerance, 100 VDC. Non-limited parts are standard components and should be available through local suppliers.

If it is necessary to order replacement parts, contact Fluke Biomedical at 440.248.9300.

3.14 Return Authorization

Upon receipt of the unit:

1. Check the shipping cartons(s) and their contents for in-shipment damage. If damage is evident, file a claim with the carrier and contact Fluke Biomedical at 440.248.9300 immediately.
2. Check that all items listed on the packing slip are present and in good condition. If any items are missing or damaged, contact Fluke Biomedical at 440.248.9300 immediately.

3.15 Protecting Your Warranty

Should your instrument require warranty service, contact Fluke Biomedical at 440.248.9300.

Fluke Biomedical
Radiation Management Services

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www.flukebiomedical.com/rms