palmRAD 907

Nuclear Radiation Monitor

Operating Manual

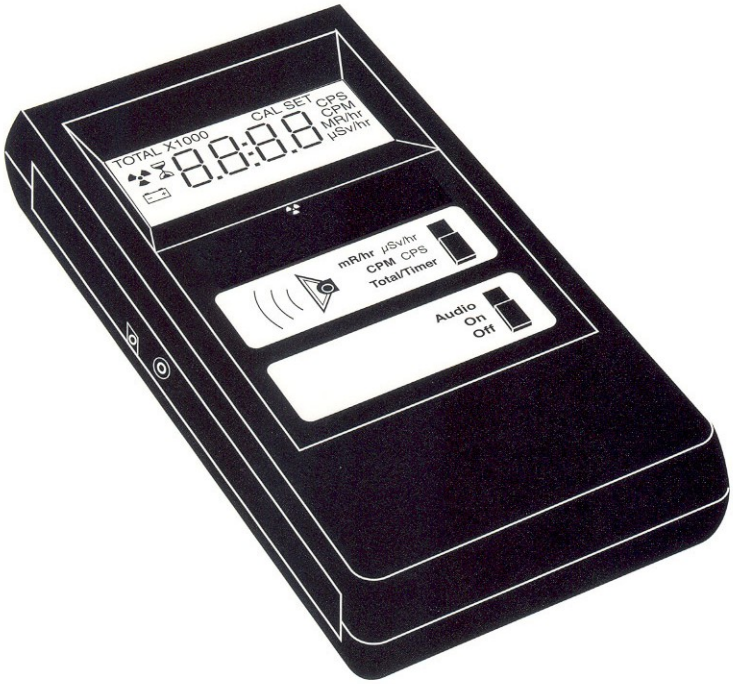
Revision: September 2005

Contents

1 Introduction

The palmRAD 907 is a health and safety instrument that is optimized to detect low levels of radiation. It measures alpha, beta, and gamma radiation. Its applications include:

- Detecting and measuring surface contamination
- Monitoring possible radiation exposure while working with radionuclides
- Alerting you with an audible alarm if the radiation goes above the an alert level that you set
- Screening for environmental contamination
- Detecting noble gases and low energy radionuclides



How the palmRAD 907 Detects Radiation

The palmRAD 907 uses a Geiger-Mueller tube to detect radiation. The Geiger tube generates a pulse of electrical current each time radiation passes through the tube and causes ionization. Each pulse is electronically detected and registers as a count. The palmRAD 907 displays the counts in the mode you choose: counts per minute (CPM), milliroentgens per hour (mR/hr), or total counts. In SI units, counts per second (CPS) and microsieverts per hour (µSv/hr) are used.

The number of counts detected by the palmRAD 907 varies from reading to reading due to the random nature of radioactivity. A reading is expressed more accurately as an

average over time, and the average is more accurate over a longer time period. For more information, see “Operating in Total/ Timer Mode” in Chapter 3.

Precautions

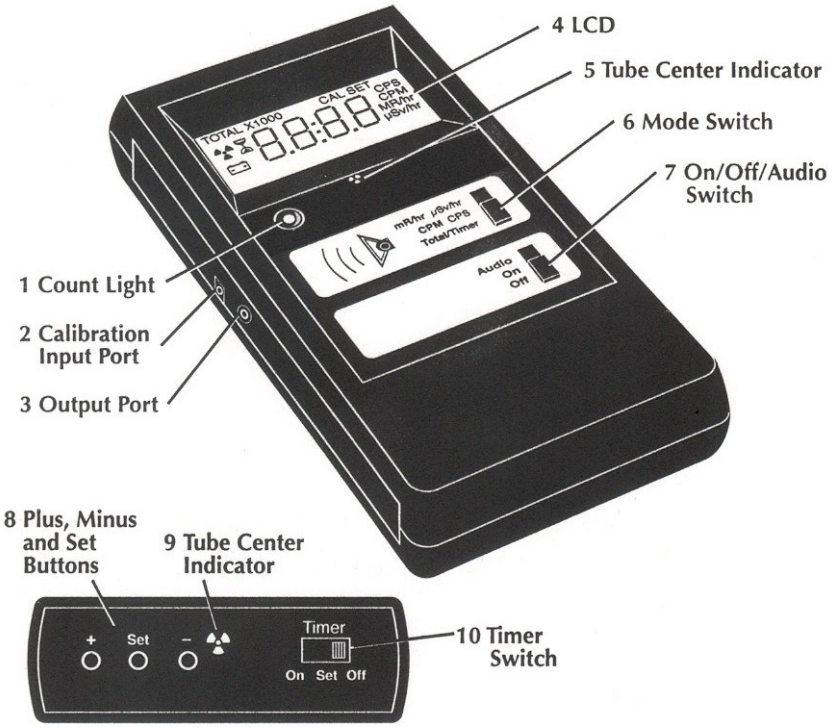
To keep the palmRAD 907 in good condition, handle it with care, and observe the following precautions:

- Do not contaminate the palmRAD 907 by touching it to radioactive surfaces or materials. If contamination is suspected, you can replace the rubber strips above and below the rear label with the extra strips supplied with the palmRAD 907.
- Do not leave the palmRAD 907 in temperatures over 122° F (50° C) or in direct sunlight for extended periods of time.
- Do not get the palmRAD 907 wet. Water can damage the circuitry and the coating of the mica surface of the Geiger tube.
- Avoid making measurements with the detector window in direct sunlight; this could affect the readings if the coating of the mica surface of the Geiger tube has been damaged by moisture or abrasion.
- Do not put the palmRAD 907 in a microwave oven. It cannot measure microwaves, and you may damage it or the oven.
- If you expect to not use the palmRAD 907 for longer than one month, remove the battery to avoid damage from battery corrosion.
- Change the battery promptly when the battery indicator appears on the display.

2 Features

The palmRAD 907 measures alpha, beta, gamma, and x-ray radiation. It is optimized to detect small changes in radiation levels and to have high sensitivity to many common radionuclides. For more information, see Appendix A, "Technical Specifications."

This chapter briefly describes the palmRAD 907's functions. For more information on how to use the palmRAD 907, see Chapter 3, "Operation."

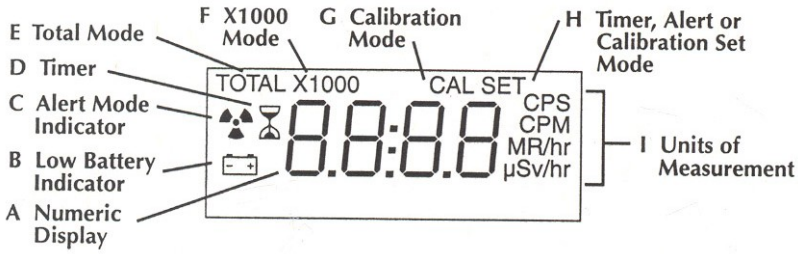


The palmRAD 907 counts ionizing events and displays the results on the liquid crystal display (LCD) (4). You control which unit of measurement is shown by using the mode switch.

Whenever the palmRAD 907 is operating, the red count light (1) flashes each time a count (an ionizing event) is detected.

The Display

Several indicators on the LCD show information about the mode setting, the current function, and the battery condition.



- The numeric display (A) shows the current radiation level in the unit specified by the mode switch setting.
- A small battery (B) appears to the left of the numeric display to indicate low battery voltage.
- A radiation symbol (C) appears when the Alert feature is on.
- An hourglass (D) appears during a timed count.
- TOTAL (E) appears when the palmRAD 907 is in Total/Timer mode.
- X1000 (F) appears when the radiation level is displayed in X1000 mode.
- MENU (not shown) appears when you are in the Utility menu.
- CAL (G) appears while you are calibrating the palmRAD 907.
- SET (H) appears when you are setting the timer, the Alert level, and the calibration factor, or working in the Utility menu (the numeric display shows the setting you are adjusting instead of the current radiation level).
- The current unit of measurement (I)--CPM, CPS, mR/hr or µSv/hr--is displayed to the right of the numeric display.

The Switches

The palmRAD 907 has two switches on the front, and one switch and three buttons on the end panel. Each switch has three settings, which are described below.

On/Off/Audio Switch (7)

Audio. The palmRAD 907 is on, and it makes a clicking sound for each radiation event detected.

On. The palmRAD 907 is operating, but audio is off.

Off. The palmRAD 907 is not operating.

Mode Switch (6)

mR/hr µSv/hr. The numeric display shows the current radiation level in milliroentgens per hour from .001 to 100. When SI units are used, it shows the current radiation level in microseiverts per hour, from .01 to 1000.

CPM CPS. The display shows the current radiation level in counts per minute from 0 to 350,000. When X1000 is shown, multiply the numeric reading by 1000 to get the complete reading. When SI units are used, the display shows the current radiation level in counts per second from 0 to 5000.

Total/Timer. The display shows the accumulated total of counts starting when the switch is turned to this position, from 0 to 9,999,000. When X1000 is shown, multiply the numeric reading by 1000 to get the complete reading.

Timer Switch (10)

Off. The timer is not operating.

Set. You can now set the length of the timed period using the + and - buttons. If the timer is already operating, the display shows the time remaining in the timed period.

On. The timer is operating, and the display shows the total counts so far in the timed period.

+, -, and SET Buttons (8)

These buttons are used for setting the alert level and the timer. They are also used for calibration and for using the Utility Menu. For more information, see "Taking a Timed Count," "Using the Alert," and "The Utility Menu" in Chapter 3 and "Calibration" in Chapter 5.

The Detector

CAUTION: The mica surface of the Geiger tube is fragile. Be careful not to let anything penetrate the screen.

Internal—For palmRAD 907 Only

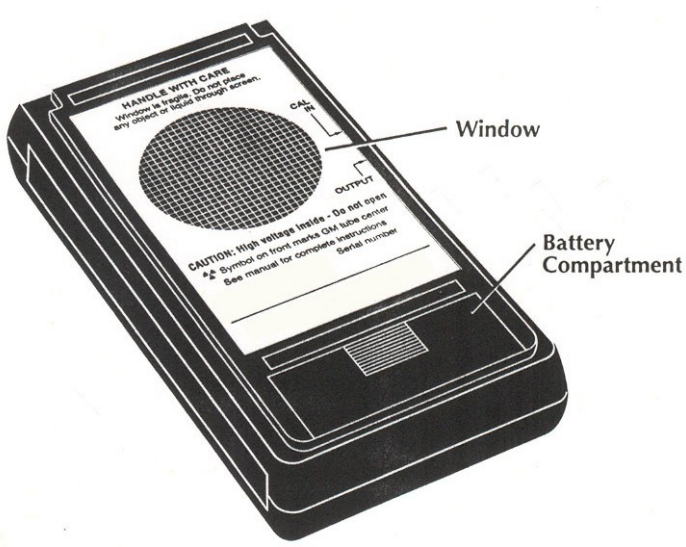
The palmRAD 907 uses a two-inch round Geiger tube, commonly called a "pancake tube." The screen on the back of the palmRAD 907 is called the window. It allows alpha and low-energy beta and gamma radiation, which cannot get through the plastic case and the stainless steel detector body, to penetrate the mica surface of the tube. The small radiation symbols on the front label (5) and the end label (9) indicate the center of the Geiger tube.

External—For palmRAD 907 EXP Only

The palmRAD 907 EXP has the pancake detector in an external probe instead of inside the instrument. To connect the probe, plug one end of the cable into the connector on the end of the palmRAD 907 EXP and the other end to the probe.

CAUTION: The connectors are directional. Be sure to line them up properly before fitting them together. If the probe is not connected when you turn the palmRAD 907 EXP on, the instrument will not function properly.

CAUTION: Do not remove the probe while the instrument is on.



The Input/Output Ports

There are two ports on the left side of the palmRAD 907. The palmRAD 907 has a third port on the end panel.

The calibration input port (2) is used for calibrating electronically using a pulse generator. For more information, see "Calibrating Electronically" in Chapter 5.

The output port **(3)** below the calibration input port allows you to interface the palmRAD 907 to a computer, data logger, or other device using a 3.5 mm stereo plug. For more information, see "Interfacing to an External Device" in Chapter 3.

The probe port on the end panel of the palmRAD 907 EXP allows you to plug the external probe into the instrument.

3 Operation

The guidelines in this chapter describe how to use the palmRAD 907.

Units of Measurement

The palmRAD 907 is designed both for users of conventional units (milliroentgens per hour and counts per minute) and for users of SI units (microsieverts per hour and counts per second). To switch between conventional and SI units, use the Utility Menu. See "The Utility Menu" in this chapter.

Starting the palmRAD 907

Be sure that a standard 9-volt alkaline battery is installed in the battery compartment in the lower rear of the palmRAD 907. Note: When installing the battery, place the battery wires along the side of the battery and not under it.

Before you start the palmRAD 907, make sure the timer switch on the end panel is set to Off.

To start the palmRAD 907, set the top switch to the mode you want, and set the bottom switch to On or Audio. The palmRAD 907 then does a four-second system check, displaying all the indicators and numbers.

After the system check, the radiation level is displayed in the selected mode. Thirty seconds after you start the palmRAD 907, a short beep indicates that enough information has been collected to ensure statistical validity.

When using the palmRAD 907, always be sure there is no obstruction between the detector window and the source you are surveying or monitoring.

Operating in the Dose Rate Modes

When the mode switch is set to mR/hr µSv/hr or CPM CPS, the numeric display is updated every three seconds. At low count rates, significant changes in the radiation level displayed can take up to 30 seconds to stabilize. See "Operating Ranges and Response Times" in this chapter for more information.

CPM (or CPS) and total counts are the most direct methods of measurement; mR/hr (or µSv/hr) is calculated using a conversion factor optimized for Cesium-137, so this mode is less accurate for other radionuclides, unless you have calibrated the palmRAD 907 for a specific radionuclide using an appropriate source. It is more appropriate to measure alpha and beta activity using CPM than using mR/hr. Conversion for alpha and beta emitters is calculated differently, and the palmRAD 907's reading in mR/hr may not be accurate.

The most immediate indicators of the radiation level are the count light, the audio beep, and the alert. It takes three seconds before an increase is shown on the numeric display in the dose rate modes.

Operating in Total/Timer Mode

When the mode switch is set to Total/Timer, the palmRAD 907 starts totaling the counts it registers, and the numeric display is updated every second.

Taking a Timed Count

When a timed count is taken over a longer period, the average count per minute is more accurate, and any small increase is more significant. For example, if one 10-minute average is one count higher than another 10-minute average, the increase may be due to normal variation. But over 12 hours, a one-count increase over the 12-hour background average may be statistically significant.

The palmRAD 907 can give you a total count for a timed period of from one minute to 24 hours. Follow these steps:

1. With the palmRAD 907 operating, set the Mode switch to Total/Timer. The display shows TOTAL.
2. Set the Timer switch on the end panel to Set. The display shows SET, the hourglass, and the most recent timing period used. The first time you use the timer, the setting is 00:01, which means one minute.
3. Use the + and – buttons to set the timing period. The timed period can be for 1 to 10 minutes in one-minute increments, for 10 to 50 minutes in ten-minute increments, or for 1 to 24 hours in one-hour increments.
4. Set the Timer switch to On. The palmRAD 907 beeps three times and starts counting. The hourglass indicator flashes during the timed period.

   If you want to see how many minutes remain, set the Timer switch to Set. The display counts down from the time setting in hours and minutes to zero. For example, if the display says 00:21, 21 minutes remain. Be sure to set the switch back to On to see the total count when the timed period is finished.
5. At the end of the timed period, the palmRAD 907 beeps three times, and repeats the beeping several times. The number displayed is the total count.
6. To find the average dose rate for the timed period in counts per minute, divide the total by the number of minutes.
7. Set the Timer switch to Off to return to normal operation.

As long as the Timer switch is set to On, the timer mode is active in the background even when the Mode switch is set to one of the dose rate modes. For example, during and after the timed period, you can switch back and forth between Total/Timer and mR/hr; when the timed period is over, the total is displayed whenever you switch back to Total/Timer. The hourglass indicator is shown on the display in any mode setting; it is blinking while the timer is totaling counts.

Taking a Total Count

The timer can take timed counts of up to twenty-four hours. In certain situations, you may want to take a total count without the timer; for example, taking a count for longer than twenty-four hours. Follow these steps:

1. Place the palmRAD 907 in the location where you plan to take the count.
2. Note the time.
3. Immediately when you note the time, set the mode switch to Total/Timer.
4. At the end of the time period, note the time and the total on the numeric display.
5. Subtract the starting time from the ending time to determine the exact number of minutes in the timing period.
6. To get the average count, divide the total reading by the number of minutes in the timing period.

Operating Ranges and Response Times

In some modes, when radiation levels increase over certain preset levels, the palmRAD 907 uses autoranging, automatically changing to the X1000 scale. Whenever X1000 is shown above the numeric display, multiply the displayed reading by 1000 to determine the radiation level. The following table shows the radiation levels the palmRAD 907 measures in each mode and how they are displayed.

Mode	Regular Range	X1000 Range
mR/hr	.001-110	NA
μSv/hr	.01-1100	NA
CPM	0-9999	10,000-350,000 (displayed as 10.00-350, with X1000 indicator)
CPS	0-5000	NA
Total/Timer	0-9999	10,000-9,999,000 (displayed as 10.00-9999, with X1000 indicator)

Maximum level. When the maximum level for the current mode is reached, the palmRAD 907 beeps for three seconds, pauses for three seconds, and repeats that pattern. The numeric display flashes. The beeping pattern and the flashing continue until the level decreases or the palmRAD 907 is turned off.

Display update and response time. In Total/Timer mode, the numeric display is updated each second. In the dose rate modes, the numeric display is updated every three seconds. When the radiation level is less than 6,000 CPM, the reading in any of the dose rate modes is based on the radiation detected in the immediately previous 30 seconds. In order to give a quicker response to changes, when the radiation level exceeds 6,000 CPM in any 30-second period, the reading is based on the previous 6 seconds, and

when it exceeds 12,000 CPM, the reading is based on the previous 3 seconds, as shown in the following table. This automatic change in response time is called auto averaging.

Radiation level	Basis for reading (after first 30 seconds)
< 6000 CPM or < 1.75 mR/hr (< 100 CPS)	30 seconds
6000-12000 CPM or 1.75-3.6 mR/hr (100-200-CPS)	6 seconds
> 12000 CPM or > 3.6 mR/hr (> 200 CPS)	3 seconds

Note: You can set the response time to 3 seconds at all radiation levels using the Utility Menu; see "The Utility Menu" in this chapter.

Using the Alert

The palmRAD 907 can sound an audible alert whenever the radiation reading reaches a certain level. The +, -, and Set buttons on the end of the palmRAD 907 allow you to turn Alert mode on and off and to set the alert levels.

To use Alert mode, follow these steps:

1. Press the Set button on the end panel. The current alert level is displayed. It is in CPM, CPS, mR/hr, or μSv/hr, depending on the palmRAD 907's current settings. The radiation symbol and SET icon are displayed.
2. If you want to change the displayed alert level, use the + and – buttons to adjust the level up or down.
3. When the desired alert level is displayed, press the Set button again to save the new level and continue in Alert mode.

   The radiation symbol is displayed to show that the palmRAD 907 is in Alert mode.
4. If you want to reset the alert level while you are in Alert mode, press the Set button twice (Off, then Set).
5. To turn off Alert mode, press the Set button once.

When you start Alert mode, the palmRAD 907 restarts counting, and beeps after 30 seconds to show that the reading is statistically valid.

When you first start the palmRAD 907, the alert levels are preset at .10 mR/hr, and the equivalent in CPM, μSv, and CPS. If you set the alert level in one mode, the settings for the other modes are automatically updated to the equivalent values.

The best alert level is one that rarely gives a false alarm, yet warns you when the radiation is higher than normal.

The Utility Menu

The Utility Menu allows you to change the default settings for several operating parameters. When you change a setting, it remains in effect after you turn off the palmRAD 907 and until you change it again.

To activate the Utility Menu, hold down the + button on the end panel while you turn on the palmRAD 907. The word MENU appears at the bottom right of the numeric display, and the display shows 1 for menu option 1. To scroll through the menu, push the plus (+) and minus (–) buttons. To select an option, push the Set button. Once an option is selected, use the + and – buttons to scroll among settings. After you choose the setting you want, select option 0 to exit the Utility Menu.

The options are:

0 Resume normal operation.

1 Auto Averaging. on (the default) selects Auto averaging; oFF selects 3-second (fast response) averaging at all radiation levels.

2 Units of measurement. CPM mR/hr selects counts per minute and milliroentgens per hour; CPS µSv/hr selects counts per second and microseiverts per hour.

3 Cal 100 Reset. Selecting this option automatically resets the calibration factor to 100 and restarts the instrument.

4, 5, 6 Reserved for future options.

7 Cal Factor Adjust. Displays the current calibration factor, which you then adjust to the new factor you want. See "Calibration" in Chapter 5.

8 Factory Default Reset. Selecting this option automatically resets the items 1, 2, and 3 to Auto averaging, CPM and mR/hr, and 100, and restarts the instrument

9 Revision #. Displays the software version number.

Interfacing to an External Device

The lower output jack on the left side of the palmRAD 907 is a dual miniature jack that provides a data output that can be used to drive a CMOS or TTL device. You can use it to record the counts on a computer, data logger, or accumulating counter. Use a 3.5 mm stereo plug to access this port. The output at the tip of the plug provides a positive (3.3 volt) pulse each time the Geiger tube detects a count. A cable with an RS-232 connector for an IBM PC-compatible computer serial port and accompanying software are available from Berkeley Nucleonics Corporation.

4 Common Procedures

The following sections give instructions for several commonly-used procedures. With any procedure, the user must determine the suitability of the instrument or procedure for that application.

Establishing the Background Count

Normal background radiation levels vary at different locations, even in different areas of the same room. To accurately interpret the readings you get on the palmRAD 907, it is a good idea to establish the normal background radiation level for each area you plan to monitor. You can do this with a timed count. Use the following steps to get a ten-minute average.

1. With the palmRAD 907 operating, set the Mode switch to Total/Timer.
2. Set the Timer switch on the end panel to Set. Unless you have previously changed it, the display reads 00:01, which means one minute.
3. Press the + button nine times. The display should read 00:10, for ten minutes.
4. Set the Timer switch to On. The palmRAD 907 beeps three times and starts counting.

   If you want to see how much of the ten minutes remains, set the Timer switch to Set. The display counts down from ten minutes to zero. For example, if the display says 00:03, seven minutes have passed and three minutes remain. Reset the switch to On to return to the radiation level display.
5. At the end of the ten minutes, the palmRAD 907 beeps three times, and repeats the beeping several times. Note the total reading.
6. To find the average counts per minute, divide the total by ten (the number of minutes).

A ten-minute average is moderately accurate. You can repeat it several times and see how close the averages are. To establish a more accurate average, take a one-hour timed count. If you need to determine whether there is prior contamination, take averages in several locations and compare the averages.

For more information on using the timer, see "Taking a Timed Count" in Chapter 3.

Environmental Area Monitoring

You can keep the palmRAD 907 in CPM or mR/hr mode whenever you want to monitor the ambient radiation, and look at it from time to time to check for elevated readings. You can also use Alert mode to warn you if the radiation increases above the alert level.

If you suspect an increase in ambient radiation, use the timer to take a five or ten minute count, and compare the average to your average background count. If you suspect an increase that is too small to detect with a short timed reading, you can take a longer count (for example 6, 12, or 24 hours).

Checking for Surface Contamination

To check a surface, hold the palmRAD 907 with the alpha window facing and close to the surface. If you want to find out if a surface is slightly radioactive, place the palmRAD 907 next to it and take a timed count or a longer accumulated count.

CAUTION: Never touch the palmRAD 907 to a surface that may be contaminated. You may contaminate the instrument. The rubber strips on the back can be replaced if they become contaminated. Replacement strips are supplied with the palmRAD 907.

5 Maintenance

The palmRAD 907 should be handled with care and can be calibrated as necessary to comply with regulations. Use the following guidelines to maintain the palmRAD 907 properly.

Calibration

The palmRAD 907 should be calibrated as often as your regulations require. The best way to calibrate is using a calibrated source. If no source is available, it is possible to calibrate electronically using a pulse generator.

The standard radionuclide for calibration is Cesium-137. A certified calibration source should be used. To calibrate the palmRAD 907 for another radionuclide, you must use a calibrated source for that radionuclide or the appropriate conversion factor referenced to Cs-137.

CAUTION: In calibration mode, the smallest increment that can be adjusted is .010, which prevents fine adjustment of the calibration factor. Thus, errors can occur if you use a low-level source or background to set the calibration factor.

Calibrating Using a Source

Before you calibrate the palmRAD 907, make sure the distance between the palmRAD 907 and the source is correct to produce the appropriate dose rate. Follow these steps:

1. Start with the palmRAD 907 turned off and the Mode switch set to mR/hr µSv/hr.
2. Hold down the – button on the end panel while you turn the On/Off/Audio switch to On. (Don't use the Audio setting.)

   The display shows CAL, and the palmRAD 907 counts down for 15 seconds, beeping each second. This delay gives you a chance to move out of the field and then expose the source. At the end of the 15 seconds, the palmRAD 907 beeps several times.
3. The palmRAD 907 collects data for 30 seconds, beeping as it does so, with CAL and the hourglass indicator flashing. At the end of the 30 seconds, it beeps several times. The display shows CAL and SET. You can now seal or close the source.
4. Press the + and - buttons to adjust the reading to what it should be. When the reading is correct, press the Set button. The new calibration factor is automatically calculated from the adjustment you make.
5. The new calibration factor is displayed for several seconds, then the palmRAD 907 beeps and resumes regular operation.

The calibration factor is set to 100 (percent) at the factory. If you change the reading, for example, to 20%higher than the factory reading, the new calibration factor would be 120. The current calibration factor is displayed during the system check when the palmRAD 907 is first turned on.

Calibrating Electronically

You can calibrate electronically using a pulse or function generator. Electronic calibration requires a cable with a 2.5 mm plug, with the tip carrying the signal. Follow these steps:

1. Set the signal height to 3.3 volts (positive pulse) and the pulse width to 80 microseconds.

   CAUTION: Do not inject a pulse when the palmRAD 907 is turned off. Do not exceed 5 volts.

2. Plug the cable into the upper jack.

3. Start with the palmRAD 907 turned off and the Mode switch set to mR/hr µSv/hr. Hold down the – button on the end panel while you turn the On/Off/Audio switch to On. (Don't use the Audio setting.)

   The display shows CAL, and the palmRAD 907 counts down for 15 seconds, chirping each second. At the end of the 15 seconds, the palmRAD 907 beeps several times.

4. The palmRAD 907 collects data for 30 seconds, beeping as it does so, with CAL and the hourglass indicator flashing. At the end of the 30 seconds, it beeps several times. The display shows CAL and SET.

5. Use the following table to check the palmRAD 907's accuracy. The table shows appropriate pulse generator count rates to calibrate for Cs137. If the accuracy is not within desired limits, follow steps 5-7. Note that the palmRAD 907 automatically compensates for lost counts due to GM tube dead time. Thus, the display reading in CPM mode does not equal the input frequency. You can display uncompensated counts in CPM mode by continuously holding down the – (minus) button; the reading now corresponds to the input frequency.

Pulse Generator Input (PPM)	CPM	mR/hr	µSv/hr	CPS
31,423	33,400	10	100	557
59,335	66,800	20	200	1,113
127,043	166,999	50	500	2,783
177,752	267,200	80	800	4,453
205,031	334,031	100	1,000	5,567

6. Press the + and - buttons to adjust the reading to what it should be. When the reading is correct, press the Set button. The new calibration factor is automatically calculated from the adjustment you make.

7. The new calibration factor is displayed for several seconds, then the palmRAD 907 beeps and resumes regular operation.

Troubleshooting

The palmRAD 907 is a highly reliable instrument. If it does not seem to be working properly, look through the following chart to see if you can identify the problem.

Problem	Possible Cause	What To Check
Display is blank	no battery, dead battery, poor battery connection	make sure a new 9-volt battery is firmly connected
	broken LCD	if the count light and audio work, the LCD may need to be replaced
Display works, but no counts are registered	damaged Geiger tube	look through the window to check the mica surface of the tube; if it is wrinkled or a break is visible, it needs to be replaced
	bad cable connection (EXP only)	check to make sure the cable is connected correctly
Reading is high, but another instrument has a normal reading in the same location	contamination	check the palmRAD 907 with another instrument; clean the instrument with a damp cloth with mild detergent and replace the rubber strips on the back of the instrument
	photosensitivity	remove from direct sunlight and ultraviolet sources; if the high count drops, the mica window coating may have washed off the Geiger tube due to getting wet; the tube will need to be replaced
	moisture	the circuit board may be wet; dry the instrument in a warm dry place; if it still has a problem, it requires factory service
	continuous discharge	replace the Geiger tube
	electromagnetic field	move the instrument away from possible sources of electromagnetic or radio frequency radiation

Service

If the palmRAD 907 requires servicing, please contact the manufacturer:

Berkeley Nucleonics Corporation
415-453-9955, fax 415-453-9956
http://www.berkeleynucleonics.com

Do not attempt to repair the palmRAD 907; it contains no user-serviceable parts and you could void your warranty.

CAUTION: Do not send a contaminated instrument for repair or calibration under any circumstances.

6 Basics of Radiation and Its Measurement

This chapter briefly tells what radiation is and how it is measured. This information is provided for users who are not already familiar with the subject. It is helpful in understanding how the palmRAD 907 works and in interpreting your readings.

Ionizing Radiation

Ionizing radiation is radiation that changes the structure of individual atoms by ionizing them. The ions produced in turn ionize more atoms. Substances that produce ionizing radiation are called radioactive.

Radioactivity is a natural phenomenon. Nuclear reactions take place continuously on the sun and all other stars. The emitted radiation travels through space, and a small fraction reaches the Earth. Natural sources of ionizing radiation also exist in the ground. The most common of these are uranium and its decay products.

Ionizing radiation is categorized into four types:

X-rays are manmade radiation produced by bombarding a metallic target with electrons at a high speed in a vacuum. X-rays are electromagnetic radiation of the same nature as light waves and radio waves, but at extremely short wavelength, less than 0.1 billionth of a centimeter. They are also called photons. The energy of X-rays is millions of times greater than that of light and radio waves. Because of this high energy level, X-rays penetrate a variety of materials, including body tissue.

Gamma rays occur in nature and are almost identical to X-rays. Gamma rays generally have a shorter wavelength than X-rays. Gamma rays are very penetrating; thick lead shielding is generally required to stop them.

Beta radiation. A beta particle consists of an electron emitted from an atom. It has more mass and less energy than a gamma ray, so it doesn't penetrate matter as deeply as gamma and X-rays.

Alpha radiation. An alpha particle consists of two protons and two neutrons, the same as the nucleus of a helium atom. It generally can travel no more than 1 to 3 inches in air before stopping, and can be stopped by a piece of paper.

When an atom emits an alpha or beta particle or a gamma ray, it becomes a different type of atom. Radioactive substances may go through several stages of decay before they change into a stable, or non-ionizing, form.

An element may have several forms, or isotopes. A radioactive form of an element is called a radioisotope or radionuclide. Each radionuclude has a half-life, which is the time required for half of a quantity of the material to decay.

The following chart shows the complete decay chain for Uranium 238, which ends with a stable isotope of lead. Notice that the half-lives of the radionuclides in the chain range from 164 microseconds to 4.5 billion years.

Isotope	Emits	Half-life	Product	
U-238	alpha	4.5 billion years	Th-234	Thorium
Th-234	beta	24.1 days	Pa-234	Proactinium
Pa-234	beta	1.17 minutes	U-234	Uranium
U-234	alpha	250,000 years	Th-230	Thorium
Th-230	alpha	80,000 years	Ra-226	Radium
Ra-226	alpha	1,602 years	Rn-222	Radon
Rn-222	alpha	3.8 days	Po-218	Polonium
Po-218	alpha	3 minutes	Pb-214	Lead
Pb-214	beta	26.8 minutes	Bi-214	Bismuth
Bi-214	beta	19.7 minutes	Po-214	Polonium
Po-214	alpha	164 microseconds	Pb-210	Lead
Pb-210	beta	21 years	Bi-210	Bismuth
Bi-210	beta	5 days	Po-210	Polonium
Po-210	alpha	138 days	Pb-206	Lead

Radiation Measurement Units

Several different units are used to measure radiation, exposure to it, and dosage.

A roentgen is the amount of X-radiation or gamma radiation that produces one electrostatic unit of charge in one cc of dry air at 0° C and 760 mm of mercury atmospheric pressure. The palmRAD 907 displays readings in milliroentgens per hour (mR/hr).

A rad is the unit of exposure to ionizing radiation equal to an energy of 100 ergs per gram of irradiated material. This is approximately equal to 1.07 roentgen.

A rem is the dosage received from exposure to a rad. It is the number of rads multiplied by the quality factor of the particular source of radiation. The rem and millirem are the most commonly-used measurement units of radiation dose in the U.S. In most cases, one rem equals one rad.

A sievert is the standard international measurement of dose. One sievert is equivalent to one hundred rems. A microsievert (μSv) is one millionth of a sievert.

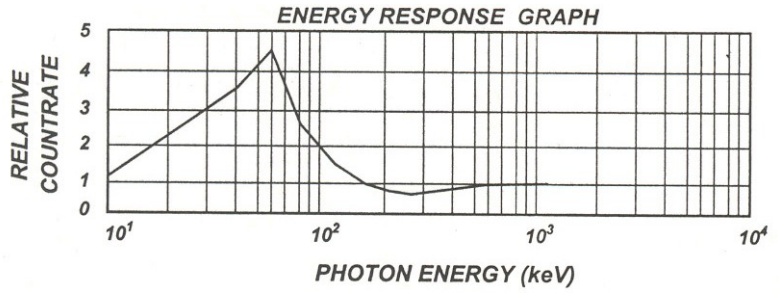
A curie is the amount of radioactive material that decays at the rate of 37 billion disintegrations per second, approximately the decay rate of one gram of radium. Microcuries (millionths of a curie) and picocuries (trillionths of a curie) are also often used as units of measurement.

A bequerel (Bq) is equivalent to one disintegration per second.

Appendix A
Technical Specifications

Detector:	Halogen-quenched Geiger-Mueller tube. Effective diameter 1.75" (45 mm). Mica window density 1.5-2.0 mg/cm^2.
	EXP only: Same detector in anodized aluminum housing with black vinyl grip. 500 volt power supply is located in the probe head. Amphenol Tucal connectors.
Display:	4-digit liquid crystal display including mode indicators
Operating Range:	mR/hr: .001 to 100.0 CPM: 0 to 350,000 Total: 1 to 9,999,000 counts µSv/hr: .01 to 1,000 CPS: 0 to 5,000
Gamma Sensitivity:	3500 CPM/mR/hr referenced to Cs-137 Smallest detectable level for I-125 is .02 mCi at contact.
Efficiency:	For 4 pi at contact:

Isotope	Energy	Efficiency
Beta		
C-14	49 keV avg. 156 keV max.	5.3%
Bi-210	390 keV avg. 1.2 MeV max.	32%
Sr-90	546 keV and 2.3 MeV	38%
P-32	693 keV avg. 1.7 MeV max.	33%
Alpha		
Am-241	5.5 MeV	18%



Averaging Periods: Display updates every 3 seconds, showing the average for the past 30-second time period at normal levels. The averaging period decreases as the radiation level increases.

Timer:	Can set 1-10 minute sampling periods in one-minute increments, 10-50 minute sampling periods in 10-minute increments, and 1-24 hour sampling periods in 1-hour increments
Alert	Beeper sounds the alert
Accuracy:	mR/hr: ±15%up to 50 mR/hr ±20%up to 100 mR/hr CPM: ±15%up to 130,000 CPM ±20%from 130,000 to 350,000 CPM
Anti-Saturation:	Readout holds at full scale in fields up to 100 times the maximum reading
Temperature Range:	-20° to +50° C , -4° to +122° F
Power:	One 9-volt alkaline battery; battery life is average 2160 hours at normal background, average 625 hours at 1 mR/hr with beeper off
Size:	150 x 80 x 30 mm (5.9" x 3.2" x 1.2")
Weight:	323 grams (11.4 oz) including battery

Appendix B

Technical Update

Date: August 11, 2005
Firmware revision: 0.81
Instrument: Inspector Alert / Inspector EXP

The above named instrument has been found to have an issue with the Alert setting if the user does either of the following:

- Selects Utility Menu item 8, Factory Reset, while the unit is in µSv/hr or CPS mode.
- Changes the units of measurement between mR/hr CPM and µSv/hr CPS mode using Utility Menu item 2.

The alert level does not convert correctly to the equivalent alert level. The problem is resolved by simply manually changing the Alert setting in any mode to the desired setting.

If you would like to have the corrected revision of firmware installed, please return the unit to a factory authorized service center for reprogramming.

Warranty

Berkeley Nucleonics Corporation warrants all instruments, including component parts, to be free from defects in material and workmanship, under normal use and service for a period of one year. If repairs are required during the warranty period, contact the factory for component replacement or shipping instructions. Include serial number of the instrument. This warranty is void if the unit is repaired or altered by others than those authorized by Berkeley Nucleonics Corporation.

Warranty does not cover any instrument

- once the warranty period has expired;
- if evidence of opening the instrument by the user is apparent; or
- in the event of mechanical damage if the requirements of operation were not satisfied.

Warranty does not cover battery replacement.

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