

Course Title: Radiological Control Technician
Module Title: Radiation Survey Instrumentation
Module Number: 2.16

Objectives:

- 2.16.01 List the factors which affect an RCT's selection of a portable radiation survey instrument, and identify appropriate instruments for external radiation surveys.
- ☞ 2.16.02 Identify the following features and specifications for ion chamber instruments used at your facility:
- Detector type
 - Instrument operating range
 - Detector shielding
 - Detector window
 - Types of radiation detected/measured
 - Operator-adjustable controls
 - Markings for detector effective center
 - Specific limitations/characteristics
- ☞ 2.16.03 Identify the following features and specifications for high range instruments used at your facility:
- Detector type
 - Instrument operating range
 - Detector shielding
 - Detector window
 - Types of radiation detected/measured
 - Operator-adjustable controls
 - Markings for detector effective center
 - Specific limitations/characteristics
- ☞ 2.16.04 Identify the following features and specifications for neutron detection and measurement instruments used at your facility:
- Detector type
 - Instrument operating range
 - Types of radiation detected/measured
 - Energy response
 - Operator-adjustable controls
 - Specific limitations/characteristics

INTRODUCTION

External exposure controls used to minimize the dose equivalent to personnel are based on the data taken with portable radiation survey instruments. An understanding of these instruments is important to ensure the data obtained are accurate and appropriate for the source of radiation. This lesson contains information about widely used portable radiation survey instruments.

Many factors can affect how well the measurement reflects the actual conditions, such as:

- Selection of the appropriate instrument based on type and energy of radiation, radiation intensity, and other factors.
- Correct operation of the instrument based on the instrument operating characteristics and limitations.
- Calibration of the instrument to a known radiation field similar in type, energy and intensity to the radiation field to be measured.
- Other radiological and non-radiological factors that affect the instrument response, such as RF fields, radioactive gases, mixed radiation fields, humidity and temperature.

References:

1. Radiation Detection and Measurement, Glenn F. Knoll
2. Basic Radiation Protection Technology, Daniel A. Gollnick
3. Operational Health Physics, Harold J. Moe
4. ANSI N323A

NOTE: *The text is provided for some commonly used instruments. The facility must adjust text as necessary for instruments used at each site. Text added for specific instruments used at the facility must, at a minimum, cover material required by the objectives.*

2.16.01 *List the factors which affect an RCT's selection of a portable radiation survey instrument, and identify appropriate instruments for external radiation surveys.*

FACTORS AFFECTING INSTRUMENT SELECTION

As discussed, the selection of the proper instrument is critical to ensure the data obtained are accurate and appropriate. The instrument is selected based on the characteristics and specifications for that instrument as compared to the required measurements. Several factors should be considered when selecting the instrument.

- **Type of Data Required**

Distinguish clearly between external radiation surveys (lesson 2.16) and contamination monitoring (lesson 2.17). External radiation surveys require an instrument that reads R/hr, mR/hr, rem/hr, mrem/hr, etc., rather than counts per minute, etc.

- **Measurement of the True Dose Equivalent**

Ion chambers (which read current instead of counting pulses) have the flattest energy response. Ion chambers are closest to being tissue equivalent. Generally, the best choice for external beta-gamma surveys is an ion chamber.

- **Type of Radiation to be Measured**

Ion chambers measure beta and gamma. For neutrons, choose a rem ball (NRD). Alphas are not measured in an external radiation survey, since they do not penetrate the skin (7 mg/cm^2 , see lesson 1.07.10).

- **Intensity of the Radiation (exposure or dose rate)**

For high radiation fields ($>5 \text{ R/hr}$) use an extendible instrument (Teletector) if this is "reasonably achievable" (ALARA).

- **Energy of the Radiation to be Measured**

Low energy radiation will not penetrate either the skin or the window of most external radiation instruments. GM detectors over-respond to low energy gammas. Most instruments under-respond to high energy neutrons.

- **Environmental Factors**

Ion chambers are usually vented to air, so radioactive gases or high humidity affect the instrument response.

- **Procedures**

If all else fails, read the instructions!

Preoperational Check

Once the proper type of instrument has been identified, a pre-operational check is essential and must be performed in accordance with appropriate procedures.

- **Physical Damage**

Perform a physical inspection of the instrument by checking for obvious physical defects or damage, especially of the probe, and replace the probe or cable if necessary.

- **Calibration Sticker**

Verify the instrument is calibrated and has not exceeded the calibration due date.

- **Battery**

Perform a battery check to verify the battery condition is within the acceptable range. Change the batteries if necessary.

- **Zero**

Perform a zero adjustment for the meter needle, if applicable (e.g. for ion chambers).

- **Source Check**

Perform a source response check as required by the procedures.

Instrument Selection General Principles

To ensure the proper selection and operation of instruments, the instrument operator must understand the operating characteristics and limitations of each instrument available for use.

There are general principles which apply to the specific instruments described in the following sections.

- **Detector Type**

Ion chambers have the flattest energy response. Ion chambers are closest to being tissue equivalent.

GM detectors over-respond to low energy gammas

Special detectors are used for neutrons

- **Instrument Operating Range**

External radiation measuring instruments read in R/hr, rad/hr, or rem/hr. In contrast, instruments designed for measuring contamination read in cpm.

Extendible instruments are generally appropriate for high radiation fields.

- **Detector Shielding**

Large amounts of shielding are not practical with a portable instrument, but some probes incorporate a small amount of shielding to reduce the background. Many external radiation survey instruments incorporate a sliding "beta shield". Note that this also shields low energy gammas.

- **Detector Window**

External radiation instruments generally have windows that are about as thick as human skin (7 mg/cm^2). The reason for this is: if the radiation does not penetrate this window then it does not penetrate skin, and so it does not contribute any external dose. In contrast, contamination monitoring instruments have thinner windows.

- **Types of Radiation Detected/Measured**

Ion chambers have a flat energy response for gammas. Ion chambers are closest to being tissue equivalent. They are also good for betas, but a correction factor may be needed.

Tube shaped GM detectors are designed so that the walls are close to the detector gas. Gamma interactions in the walls are important. A well designed detector wall can partially compensate for the over-response to low energy gammas. They are designed primarily for gammas, and also measure betas if the window is not too thick.

Pancake shaped GM detectors have side walls separated from the gas. They are good for betas, but have a low efficiency for gammas because very few gammas hit the side walls.

Gas proportional detectors distinguish between alphas and betas. They often discriminate against (reject) betas and gammas.

ZnS scintillation detectors only detect alphas.

NaI scintillation detectors are generally used for gammas.

Neutron detectors are very specialized.

- **Operator Adjustable Controls**

Portable instruments generally have a battery check.

Ion chambers generally have a zero adjustment.

- **Markings for Effective Detector Center**

External radiation surveys are generally taken at 30 cm (except for transportation, see lesson 2.12). It is not always obvious what point on the detector should be 30 cm from the source, so most detectors mark the effective center.

The effective center of the detector, as defined in ANSI N323, is the point within the detector that produces, for a given set of irradiation conditions, an instrument response equivalent to that which would be produced if the entire detector were located at that point. The effective center can be thought of as the point in the detector where the measurement of the radiation intensity is taken. Portable radiation survey instruments are calibrated in a uniform field of radiation larger than the volume of the detector, so that the same radiation intensity is seen throughout the detector. Therefore, the reading "taken" at the effective center represents the rate value in all portions of the detector. If the radiation field over the whole detector is not uniform, the exposure rate will not be uniform over the entire detector volume. For non-uniformly irradiated detectors, the displayed value, as "taken" at the effective center, will not reflect the actual exposure rate value and a correction factor may be appropriate.

- 2.16.02 Identify the following features and specifications for ion chamber instruments used at your facility:*
- a. Detector type*
 - b. Instrument operating range*
 - c. Detector shielding*
 - d. Detector window*
 - e. Types of radiation detected/measured*
 - f. Operator-adjustable controls*
 - g. Markings for detector effective center*
 - h. Specific limitations/characteristics*

EBERLINE RO-2 and RO-3

The Eberline RO-2, RO-3 series of instruments are portable, air-vented ion chamber instruments used to detect and measure gamma, X-ray, and beta radiation. Technical specifications for the RO3 are similar to the RO2.

Detector Type

The ion chamber is a phenolic, or plastic cylinder of 3 in. diameter and 12.7in³ (208cm³) volume, with one end covered by a Mylar window. The fill gas is air, vented to atmosphere through a desiccant pack.

The ion chamber detector is closer to tissue-equivalent than most types, allowing the instrument to assess the exposure rate to human tissue. The detector is approximately tissue equivalent because the materials used for construction have an effective atomic number *Z* close to that of tissue at 7.5. "Tissue equivalent" means that the detector responds the same as human soft tissue. No detector is perfectly tissue equivalent, but a well designed ion chamber is close enough for most work.

Although the detector is not as sensitive as a GM, it is the detector of choice for assessing exposure because of its close correlation to the energy deposited in human tissue by radiation.

The RO-2 series instruments are operated in the current mode, which is the mode that averages the individual pulse heights per unit time. Individual pulse information is lost; therefore, the electrical signal will not supply information about the type and energy of the individual radiation interactions. However, small pulses, which would be lost in the pulse mode, are averaged along with the other interactions.

Instrument Operating Ranges

The instrument range of the Model RO-2 is 0 - 5000 mR/hr. The readings are expressed in roentgen, since the measurement is made in air.

The settings are as follows:

| RO-2 Ranges |
|---------------|
| 0-5 mR/hr |
| 0-50 mR/hr |
| 0-500 mR/hr |
| 0-5,000 mR/hr |

Detector Shielding

The sliding beta shield is made of phenolic as follows:

- RO-2 shield: 400mg/cm² (1/8 in. thick) mounted on the case.

The active volume of the detector is shielded from the side by the detector wall and the instrument case, and from the bottom by the movable beta shield and two layers of window. The detector wall is 200mg/cm² and the 0.13 cm aluminum case is about 345-mg/cm².

Detector Window

The materials and density-thickness value of the two windows, one on the case and one on the detector, for the Model RO-2 and RO3 are as follows:

- RO-2 windows: 7mg/cm² total; two Mylar windows 3.5mg/cm² (1 mil) each.
- RO-3 window: 3.5mg/cm² total; one window of 1 mil Mylar.

Types of Radiation Detected/Measured

The RO-2 instrument is designed to measure gamma, X-ray, and beta radiation but will respond to (not measure) neutron radiation. Although an ionization chamber would respond to alpha radiation, the Mylar windows and the air gap between the two windows eliminates any possibility of an alpha response.

The RO-2 measures photon radiation within $\pm 20\%$ for photon energies from 12keV to 7-MeV (beta shield open). The minimum energy increases to 25keV if the shield is closed, and to about 40keV through the side of the instrument. Because of the thinner window, the RO-3 measures photons from 8-keV.

The RO-2 measures beta radiation $>70\text{keV}$ with the beta shield open. A beta correction factor may be appropriate in some situations.

Operator-Adjustable Controls

RO-2 range switch with OFF, ZERO, and BATT checking positions.

ZERO position works in conjunction with ZERO knob to electronically zero the meter. BAT1 and BAT2 positions check the two batteries used to power the instrument circuitry.

Markings for Detector Effective Center

The Effective Center markings on the RO-2 are the "dimples" or depressions on the sides and front of the instrument case.

Specific Limitations\Characteristics

The response time for the RO-2 series of instruments is 5 seconds to reach 90% of the full value.

High humidity or moisture can cause leakage currents in the detector and cause erratic meter readings. The detector is vented through a silica gel desiccant, or drying medium, contained in a plastic box. The desiccant can become saturated and will need replacement if the crystals start to turn clear or pink instead of the normal blue color.

The detector is vented to atmosphere; therefore, any change in atmospheric density changes the air density in the detector. An increase in atmospheric pressure will cause an increase in air density in the detector and cause a higher response. If the RO2 is calibrated in Los Alamos (7000 ft) and then used at sea level, the response will be 30% high. A change in response of about 10% will occur if the instrument was calibrated at room temperature and used in an environment that is different by about 50 °F.

Because the detector is vented to atmosphere, radioactive gases could enter the detector and cause a reading.

BICRON RSO-50 AND RSO-500 INSTRUMENTS

The Bicron RSO-50 and RSO-500 instruments are portable air-vented ion chamber instruments used to detect and measure gamma, X-ray and beta radiation. The Bicron

RSO series of instruments are very similar in design and construction to the Eberline RO-2 series of instruments.

Detector Type (identical for both models)

- Operated as an ionization chamber.
- A phenolic, or plastic, cylinder of 3 in. diameter and 12.7 in³ (208 cm³) volume with one end open but covered by a Mylar window.
- Fill gas - air (vented to atmosphere through a silica gel desiccant pack).

The Bicron RSO series instruments are operated in the current mode, or the mode that averages the individual pulse heights per unit time.

Instrument Operating Range

The instrument ranges of the two models are as follows:

| RSO-500 Ranges |
|----------------|
| 0-0.5 R/hr |
| 0-5 R/hr |
| 0-50 R/hr |
| 0-500 R/hr |

| RSO-50 Ranges |
|---------------|
| 0-50 mR/hr |
| 0-500 mR/hr |
| 0-5 R/hr |
| 0-50 R/hr |

Detector Shielding

The active volume of the detector is shielded from the side by the detector wall and the instrument case and from the bottom by the movable beta shield and two layers of window. Detector wall is 200 mg/cm² and the 0.13 cm aluminum case is about 345 mg/cm.

Detector Window

The materials and density-thickness value of the two windows, one on the case and one on the detector, are the same for both models.

- RSO windows - 7 mg/cm² total, both windows are Mylar of 5 mg/cm² each.

The sliding beta shield is made of phenolic and the density-thickness value is the same for both models.

- RSO shield - 400 mg/cm^2 (1/8 in. thick) and is mounted externally on the case.

Types of Radiation Detected/Measured

The Bicron RSO series of instruments are designed to measure gamma, X-ray and beta radiation but will detect (not measure) fast neutron radiation. The instruments will read approximately 10%, in mR/hr, of the true neutron field, in mrem/hr. Like the Eberline RO-2, the Bicron RSO series instruments will not respond to alpha radiation because the alpha particles are shielded before they reach the detector. The energy response of the two models is identical. Both models measure photon radiation within $\pm 20\%$ for photon energies from 12 keV to 7 MeV (beta shield open). The minimum energy increases to 25 keV if the shield is closed, and to about 40 keV through the side of the instrument. Both models measure beta radiation $>70 \text{ keV}$.

Operator-Adjustable Controls

RSO-500 range switch with OFF, ZERO, and BATT positions.

- Switch ranges labeled as 0.5, 5, 50, and 500 R/hr.
- ZERO position works in conjunction with ZERO knob to electronically zero the meter.
- BAT position checks the two batteries used to power the instrument circuitry and detector bias.
- OFF position turns the instrument off.

RSO-50 range switch is the same but is labeled 50 and 500 mR/hr and 5 and 50 R/hr.

Markings for Detector Effective Center

The effective center markings on both Bicron models are the stamped circles with a plus sign in the circle and are located on the sides and front of the instrument case. If the radiation field over the whole detector is not uniform (such as from surface contamination, radiation streaming, or from a small point source) the displayed value may need to be corrected.

Specific Limitations/Characteristics

The response time varies between the two models of Bicron instruments available.

RSO-500 - approximately 10 sec from 0-90% of the final reading.

RSO-50 - approximately 5 sec from 0-90% of the final reading.

Correction factors may be needed when the radiation field is not uniform over the entire detector. High humidity or moisture can cause leakage currents in the detector and cause erratic meter readings.

- The detector is vented through a desiccant, or drying medium, contained in a plastic box.
- The desiccant can become saturated and will need replacement if the crystals start to turn clear or pink.

Like the Eberline RO-2, the detector is vented to atmosphere; therefore, any change in atmospheric density changes the air density in the detector.

- An increase in temperature will lower the air density in the detector and cause a lower response.
- An increase in atmospheric pressure will cause an increase in air density in the detector and cause a higher response.
- Tables are provided in the technical manuals for correcting the instrument response due to changes in pressure or temperature.
- A change in response of about 10% will occur if the instrument was calibrated at room temperature and used in an environment that is different by about 50 °F.

Because the detector is vented to atmosphere, radioactive gases can enter the detector and cause a reading.

VICTOREEN MODEL 450B

The Victoreen 450B is a portable, general purpose, ion chamber survey instrument which uses microprocessor and LCD (liquid crystal display) technology.

Detector Type

Operated as an ionization chamber. A Bakelite, or plastic, cylinder of 200 cm³ volume with one end open but covered by a Mylar window. The fill gas is air (vented to atmosphere through a desiccant pack). The ion chamber detector is designed as tissue-equivalent, allowing the instrument to accurately assess the exposure rate to human tissue. The Victoreen 450B is operated in the current mode as are most ion chambers.

Instrument Operating Ranges

- Overall range is 0-50 R/hr.

The instrument is autoranging, or automatically changes scales as required for the instrument reading, and has the following scales:

| 450B Scales |
|-------------|
| 0-5 mR/hr |
| 0-50 mR/hr |
| 0-500 mR/hr |
| 0-5 R/hr |
| 0-50 R/hr |

Detector Shielding

The active volume of the detector is shielded from the side by the detector wall and the instrument case and from the bottom by the movable beta shield and windows. The detector wall is 200 mg/cm. The sliding beta shield is made of Bakelite, which is a type of plastic and the density-thickness value is 440 mg/cm.

Detector Window

The two detector windows, one on the detector and one on the case, are made of 1.7 mil Mylar for a total of 3.4 mg/cm².

Type of Radiation Detected/Measured

The 450B instrument is designed to measure gamma, X-ray, beta and alpha radiation but will detect (not measure) fast neutron radiation. The instruments will read approximately 10%, in mR/hr, of the true neutron field, in mrem/hr.

Energy response. Photon energy response ($\pm 20\%$) is about 20 keV for slide open, 40 keV for slide closed, and 50 keV from the side. Beta energies >32 keV can be measure. The alpha response is limited to energies >4 MeV and only if the detector to source distance is less than the alpha range in air.

Operator-Adjustable Controls

Only three external controls are available on the 450B: the ON/OFF switch, the MODE switch and the meter light button. The Mode switch is used during calibration and is not enabled for operator use. The ON/OFF switch turns the instrument on and off. The instrument is autoranging and will change the bar graph, digital value and scale markings as appropriate for the exposure rate value. The instrument has an "autozero" feature that eliminates any need for an external zero control. If the batteries are low, then the instrument will display a LOW BAT message. A button switch is provided in the handle for turning the meter face light on and off.

Markings for Detector Effective Center

The effective center markings on the 450B are the painted-white depressions in the plastic case and are located in the front and on the sides.

Specific Limitations/Characteristics

The response times to 90% of the final value for the 450B instrument are as follows, assuming that a step increase or decrease in the rate does not cause a range change:

| 450B Response Times | |
|---------------------|-------|
| 0-5 mR/hr | 8 sec |
| 0-50 mR/hr | 5 sec |
| 0-500 mR/hr | 2 sec |
| 0-5 R/hr | 2 sec |
| 0-50 R/hr | 2 sec |

Geotropism, or the effect of gravity on the instrument, causes no greater than a $\pm 1\%$ of full scale change from the actual value. Correction factors must be applied when the radiation field is not uniform over the entire detector, such as for surface contamination beta dose rates. High humidity or moisture could cause leakage currents in the detector and cause erratic meter readings. The detector is vented through a desiccant, or drying medium, contained in a plastic cylinder. The desiccant could become saturated and will need replacement if the crystals start to turn clear or pink. The atmospheric vent on the case has a rubber bladder to allow for changes in temperature and pressure but prevents the free flow of air into and out of the detector casing. The rubber bladder minimizes the effects of high humidity environments and radioactive gases. The detector is vented to atmosphere; therefore, any change in atmospheric density changes the air density in the detector. An increase in temperature will lower the air density in the detector and cause a lower response. An increase in atmospheric pressure will cause an increase in air density

in the detector and cause a higher response. The value of the changes due to temperature and pressure are similar to those of other air-vented ion chambers.

- 2.16.03** *Identify the following features and specifications for high range instruments used at your facility:*
- a. Detector type*
 - b. Instrument operating range*
 - c. Detector shielding*
 - d. Detector window*
 - e. Types of radiation detected/measured*
 - f. Operator-adjustable controls*
 - g. Markings for detector effective center*
 - h. Specific limitations/characteristics*

EBERLINE TELETECTOR

The Eberline Teletector is an extendible, telescoping-rod instrument designed with two Geiger-Mueller (GM) detectors for the measurement of photon exposure rates and detection of beta radiation.

Detector Types

Both detectors are sealed GM tubes with halogen-quenched argon fill gas contained in an energy compensating case. Energy compensation is required in GM detectors to reduce the over response to low energy photons.

The low range detector is the largest of the two detectors and is located at the end of the detector housing. The low range detector is used for the three lowest ranges on the instrument.

The high range detector is the small cylinder in the detector housing, and is used for the upper two scales.

The GM detectors are very sensitive; however, they lack the direct correlation to energy deposited and are not as accurate as ion chamber instruments for assessing exposure rates.

The Teletector instrument is operated in the pulse mode, or the mode that counts each individual pulse. Since any ionization in a GM tube causes the same large pulse, any radiation interaction in the detector will be counted. All the pulses are of the same large size regardless of the energy or type of radiation; therefore, all information on the type and energy of the radiation is lost.

Instrument Operating Ranges

The instrument range is 0 - 1000 R/hr.

The analog Teletector has five settings. The three lower settings utilize the large GM detector and the two upper settings utilize the smaller GM detector.

| Teletector Settings |
|---------------------|
| 0-2 mR/hr |
| 0-50 mR/hr |
| 0-2 R/hr |
| 0-50 R/hr |
| 0-1000 R/hr |

Detector Shielding

The two detectors are shielded by layers of lead and fiber to compensate for the GM over-response to low-energy photons. The high-range detector is partially shielded by the low-range detector.

Detector Window

The low-range detector has a 30mg/cm² mica window and a rubber cap to protect the window.

Types of Radiation Detected/Measured

The Eberline Teletector will measure gamma and X-ray radiation and responds to (but does not measure) beta radiation. According to the manufacturer, beta response is not accurate. Alpha response is eliminated by the thicker window and casing. Neutron response is insignificant due to the lower probability of interaction in the small detectors.

The Teletector measures photon radiation >80 keV. Lower energy photons are attenuated in the detector window. Beta particles >160 keV can be detected but not measured.

Operator-Adjustable Controls

The only control is the range switch with OFF and B (battery check) positions.

Detector Effective Center Markings

The effective center of both detectors is indicated by the machined grooves in the detector housing, with the groove closest to the beta window indicating the low-range detector.

Specific Characteristics and Limitations

Response time for the instrument is approximately 1 second to 90% of full scale.

The sealed detectors do not require correction factors for temperature or pressure. The sealed detectors do not experience problems with humidity or radioactive gases entering the detector.

Audible indication is available only through the speaker jack; no internal speaker is installed.

For GM detectors, the possibility exists that the detectors become saturated in very high radiation fields. Some GM detector instruments will read zero if the detector becomes saturated. The manufacturer states (on the title page of the 6112B brochure) that the Eberline Teletector will not saturate, up to 30,000 R/hr (which is larger than the maximum range).

It is easy to damage the instrument by bending the extendible tube.

EBERLINE RO-7

The RO-7 series instrument provides remote monitoring in high range beta and gamma radiation fields. The RO-7 consists of a basic digital readout instrument, three interchangeable detectors, and various interconnecting devices. The detectors may be interconnected to the instrument by flexible cables of different lengths, by rigid extensions of different lengths or by use of an underwater housing.

Detector Types

All three detectors are air-vented ion chambers contained in a plastic-lined (phenolic) aluminum housing. The detector fill gas is air. The detector housing also contains other electronics, such as an operational amplifier and detector identification circuitry.

The three available detectors are as follows:

- The RO-7-LD is a low-range, gamma-only detector with an active volume of about 50 cm³ and dimensions of 2.5 cm diameter and 10.2 cm long.

- The RO-7-BM is a mid-range, beta/gamma detector, with beta window, that has an active volume of about 7 cm³ and dimensions of 2.5 cm diameter and 5 cm long.
- The RO-7-BH is a high-range, beta/gamma detector, with beta window, that has an active volume of about 7 cm³ and dimensions of 2.5 cm diameter and 5 cm long.

Each detector is labeled at the connector end of the detector.

- NOTE: Two small screws on the label are marked ZERO and CAL. These should only be adjusted at calibration and must not be adjusted by the operator.

The RO-7 instrument is operated in the current mode of operation.

Instrument Operating Ranges

The operating range of the instrument is dependent on the detector that is connected to the instrument.

- The range of the RO-7-LD detector is 0-2 R/hr.
- The range of the RO-7-BM detector is 0-200 R/hr.
- The range of the RO-7-BH detector is 0-20 kR/hr (20,000 R/hr).

Detector Shielding

All three detectors have a phenolic liner and aluminum housing.

Detector Window

The RO-7-BM and RO-7-BH detectors each have a 7 mg/cm² Mylar window. The Lucite cap for the beta window is 100 mg/cm².

Types of Radiation Detected/Measured

As previously mentioned, the RO-7-LD detector measures only gamma and X-ray radiation. Both beta and alpha radiation are shielded by the detector housing. The neutron radiation response is insignificant due to the small size of the detector. The actual detectors in the RO-7-BM and RO-7-BH detector assemblies are identical. Both detect and measure gamma, X-ray and beta radiation. Alpha response is eliminated by the 7 mg/cm² window (same density thickness as the outer layer of skin). Neutron radiation response is even smaller than the RO-7-LD due to the smaller detector volume.

The energy response for the three detectors is as follows:

The RO-7-LD responds to photon radiation between 50 keV and 1.3 MeV ($\pm 20\%$). The RO-7-BM and RO-7-BH detectors respond to photon radiation differently depending on orientation and whether the Lucite cover is in place.

- Lucite cover off - 10 keV to 1.3 MeV ($\pm 20\%$)
- Lucite over on - 25 keV to 1.3 MeV ($\pm 20\%$)
- Shield on, from the side - 50 keV to 1.3 MeV ($\pm 20\%$)
- The beta response for the RO-7-BM and RO-7-BH detectors is for beta energies >70 keV.

Operator-Adjustable Controls

The ON/OFF switch is the only range control because the instrument identifies the detector model and adjusts the readout accordingly. A low battery condition is indicated by a "colon" under the battery mark on the meter. The ZERO knob will zero the LCD readout. A meter face light is turned on/off by the small switch in front of the pistol grip.

Detector Effective Center

No markings are provided for the detector effective center.

Specific Limitations/Characteristics

The response time of the basic instrument is 2.5 seconds to 90% of the final reading. The correction factor for the true beta measurement is 1.5 as recommended by the manufacturer.

Since the detector is air-vented, atmospheric temperature and pressure changes affect the instrument reading. The instrument response will remain within $\pm 10\%$ for the temperature range of -20° to 160° F. A correction table is available in the technical manual for pressure changes. The detectors are air-vented but do not have a desiccant pack. The detector should be kept dry and out of high humidity environments to prevent leakage currents. Each detector has associated electronics designed for that particular range. Overranging a detector may cause damage to the detector electronics. If the instrument is not calibrated with the underwater housing and the housing is used, the response will be about 5% low. The instrument reading should be multiplied by 1.05 to obtain the corrected response.

Interconnecting devices from the detector to the instrument that are available from the manufacturer are the:

- 15 ft flexible cable
- 60 ft flexible cable
- 2 ft rigid extension
- 5 ft rigid extension
- Stainless-steel underwater housing with 60 ft of cable.

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 - f. Specific limitations/characteristics*

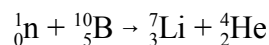
NEUTRON DETECTORS

EBERLINE NRD NEUTRON SPHERE

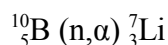
The Eberline Neutron Rem Detector (NRD) sphere is a portable instrument for the detection and measurement of the dose equivalent rate from neutron radiation.

Detector Types

The detector is the Eberline NRD (Neutron Rem Detector) sphere, which may be connected to a PNR-4 (Portable Neutron Rem) or to an ESP (Eberline Smart Portable) instrument by a coaxial cable. The NRD sphere is a 9 inch diameter, cadmium loaded, polyethylene sphere with a BF₃ proportional tube in the center of the sphere. The BF₃ (boron trifluoride) detector design allows the detection of neutrons only, and the rejection of other radiation. The thermal neutron capture reaction with the ¹⁰B results in gas ionization pulses caused by the alpha particle from the reaction:



or



The 9 inch diameter polyethylene sphere is used to moderate the neutrons. The polyethylene has a high percentage of hydrogen which thermalizes the fast and intermediate energy neutrons. Those neutrons that are thermalized in the sphere can be detected in the BF₃ tube. The cadmium loading is a thin sheet of cadmium placed at a radius of about 7 cm inside the polyethylene sphere to help reduce the over response to lower energy neutrons.

Instrument Operating Ranges

When the NRD is connected to the PNR-4 readout, there are two needles. One needle covers the range up to 50 mrem/hr; above 50 mrem/hr, the second needle takes over and covers the range up to 5000 mrem/hr. The NRD may also be connected to an Eberline Smart Portable, ESP, which is discussed in lesson 2.17.

Types of Radiation Detected/Measured

Neutrons are measured. Alpha and beta radiation are not detected because they do not penetrate the detector shielding. Gamma radiation passes through the detector shielding but is rejected by the BF₃ proportional chamber up to 500 R/hr (dependent on high voltage setting and desired rejection level).

Since the BF₃ detector is operated in the proportional region, the pulses from the alpha particles are larger than pulses from other interactions and trigger a pulse height discriminator in the instrument circuitry. The mode of operation for the instrument is the pulse mode so that individual pulses can be discriminated and counted. Pulses from gammas are rejected. Alpha and beta particles do not penetrate the polyethylene sphere.

Energy Response

The energy response curve for the instrument shows the relative response of the instrument as compared to the theoretical dose equivalent. This instrument over-responds to intermediate energy neutrons, and under-responds to relativistic neutrons.

Operator-Adjustable Controls

The only operator-adjustable control on the PNR4 is the OFF/ON/BAT switch which turns the instrument on and off and allows a check of the battery.

No markings are provided for the detector effective center as the active volume of the detector is centered in the sphere.

Specific Characteristics and Limitations

The response time depends on which decade of the scale is appropriate.

| Response Times | |
|----------------|---------|
| First Decade | 12 sec |
| Second Decade | 6 sec |
| Third Decade | 1.5 sec |
| Fourth Decade | 0.3 sec |

The detector is a sealed pressurized cylinder and is not affected by changes in humidity, radioactive gases or changes in atmospheric density.

EBERLINE ASP-1 WITH NRD SPHERE

The Eberline ASP-1 with the NRD sphere is a microcomputer-based, analog-display, portable neutron radiation survey instrument. The detector (Eberline NRD sphere) is identical to the detector used with the PNR-4 readout packages. The mode of operation is the pulse mode.

Instrument Operating Ranges

The overall range is 0-100 rem/hr and has a useable range of 1 mrem/hr - 60 rem/hr.

| ASP-1 Ranges |
|-------------------|
| 0-1 mrem/hr |
| 0-10 mrem/hr |
| 0-100 mrem/hr |
| 0-1,000 mrem/hr |
| 0-10,000 mrem/hr |
| 0-100,000 mrem/hr |

Detector shielding is the same as previously mentioned for the NRD sphere. The energy response is the same as previously mentioned for the NRD sphere.

Operator-Adjustable Controls

The OFF/BAT/HV/range switch has the following functions:

- The OFF position turns the instrument off.

- The BAT position checks the instrument battery power supply.
- The HV position checks the applied high voltage to the detector and should match the value listed on the special label on the instrument case.

The range markings are X1, X10, X100, X1K, X10K, and X100K with a meter scale of 0-1.0.

The INTEGRATE/FAST/SLOW switch is a three position toggle switch with the following functions:

- In the INTEGRATE position, the instrument will show the total dose equivalent accumulated since the last time the instrument was reset to zero or turned off.
- In the FAST position, the response time selected by the microcomputer is for typical survey work.
- In the SLOW position, the response is slower but with greater accuracy than the FAST position.

The LIGHT/RESET switch is a three-position, spring-loaded toggle switch with the following functions:

- The LIGHT position illuminates the meter face
- The RESET position will zero the meter reading for the current mode (INTEGRATE/FAST/SLOW) setting of the instrument.

The RESET switch will cause the "standard current" value to be displayed if held for 5 seconds while in the FAST or SLOW mode. The SPEAKER is a two-position toggle switch for turning the external speaker on and off. Acoustic (airline-type) head phones can be plugged into the speaker cover on the top of the instrument. As previously mentioned, the NRD sphere has no effective center markings.

Specific Limitations/Characteristics

The response time of the instrument is controlled by the microcomputer and is based on the input count rate and whether the mode switch is in FAST or SLOW. In the FAST position, the instrument response time varies between one and ten seconds. In the SLOW position, the instrument response time will vary up to a maximum of 29 seconds. No correction factors are required to correct the displayed value. The sealed detector is not affected by changes in atmospheric density, humidity or radioactive gases. The instrument has a microcomputer controlled "overrange" indication. When the radiation rate exceeds the useful range of the detector, the computer will cause an overrange alarm.

When the instrument alarms, the meter needle will sweep back and forth and an interrupted tone will sweep in the speaker.

SUMMARY

This lesson has covered the specifications, features and limitations for the portable radiation survey instruments that may frequently be used by the RCT. This knowledge should be used to properly select and operate the instruments to ensure that the data obtained is accurate and appropriate. The appropriate, accurate data is then used to properly assign external exposure controls.