LEARNING OBJECTIVES:

2.17.01 List the factors which affects an RCT's selection of a portable contamination monitoring instrument.

☞ 2.17.02 Describe the following features and specifications for commonly used count rate meter probes used at your site for beta/gamma and/or alpha surveys:

a. Detector type
b. Detector shielding and window
c. Types of radiation detected/measured
d. Energy response for measured radiation
e. Specific limitations/characteristics.

☞ 2.17.03 Describe the following features and specifications for commonly used count rate instruments used at your site.

a. Types of detectors available for use
b. Operator-adjustable controls
c. Specific limitations/characteristics.

☞ 2.17.04 Describe the following features and specifications for commonly used personnel contamination monitors at your site.

a. Detector type
b. Detector shielding and housing
c. Types of radiation detected/measured
d. Scaler type uses
e. Scaler operator-adjustable controls
f. Specific procedures for source checks
g. Specific procedures for sample counts.

☞ 2.17.05 Describe the following features and specifications for commonly used contamination monitors used at your site (tool, bag, laundry monitors).

a. Detector type
b. Detector shielding and window
c. Types of radiation detected/measured
d. Energy response for measured radiation
e. Specific limitations/characteristics.

NOTE: ***Text is provided for some commonly used contamination monitoring instruments (except those included by Objective 5). The site may adjust text as necessary for instruments used at the site. Text added for specific instruments used at the site must, at a minimum, cover the material required by the objective.***

INTRODUCTION

This lesson covers contamination monitoring instruments in relation to types used, purpose for, radiation monitored, operational requirements, and specific limitations and characteristics. The RCT uses information from these monitoring instruments to identify and assess the hazards presented by contamination and establish protective requirements for work performed in contaminated areas.

General Discussion

Measurements using portable contamination monitoring (count rate) instruments provide the basis for assignment of practical contamination and internal exposure controls. To establish the proper controls, the contamination measurements must be an accurate representation of the actual conditions. Measurements using non-portable contamination monitors, such as an Eberline PCM-1B or PM-6, are used to identify personnel contamination prior to exiting controlled areas or facilities. Measurements using counter scalers to determine the levels of transferrable contamination on specific location samples are the basis for contamination postings and material releases from controlled areas.

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 radioactive gases, mixed radiation fields, humidity and temperature.

2.17.01 List the factors which affects an RCT's selection of a portable contamination monitoring instrument.

FACTORS AFFECTING INSTRUMENT SELECTION

The selection of the proper instrument is critical to ensure the data obtained is accurate and appropriate. Instrument selection is based on the characteristics and specifications for that instrument as compared to the required measurements.

Several factors should be considered when selecting the instrument.

- The type of radiation to be measured
- The energy of the radiation to be measured
- The intensity of the radiation (dose rate or activity levels)
- Interference from a mixed radiation field
- Background radiation conditions
- Environmental factors, such as radioactive gases or temperature, affecting instrument response
- Procedural requirements.

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.

2.17.02 *Describe the following features and specifications for commonly used count rate meter probes used at your site for beta/gamma and/or alpha surveys:*
a. Detector type
b. Detector shielding and window
c. Types of radiation detected/measured
d. Energy response for measured radiation
e. Specific limitations/characteristics.

COUNT RATE METER HAND PROBES

EBERLINE MODEL HP-210 AND VICTOREEN MODEL 110C

Models like the Eberline Model HP-210 or Victoreen Model 110C hand probes are sensitive beta detectors using a thin window "pancake" Geiger-Mueller (GM) detector. These detectors are designed for contamination surveys of personnel, table tops, floors, equipment, etc.

Detector responds to alpha, beta, gamma and X-ray radiation of minimum energies.

- alpha > 3 MeV

Detector must be close enough to the source of alpha particles to prevent alpha particle attenuation in the air between the source and the detector.

- beta > 40 keV

This precludes the detection of low energy beta particles, such as the beta particle from the decay of tritium (E_{max} = 18.6 keV).

- gamma > 6 keV

Photon radiation, such as gamma or X-ray, can interact in the detector walls and the fill gas to create a pulse. However, the probability of interaction is small due to the shallow depth of the detector and therefore the efficiency for photon radiation is small.

GM tube has mica window of 1.4 to 2.0 mg/cm^2 density

Gamma sensitivity is approximately 3,600 counts per minute (cpm) per mR/hr for Cs-137.

Available with either high-density tungsten or aluminum housings

- HP-210AL - aluminum housing with a low shielding factor for low background use

- HP-210T - tungsten shield covering the top and sides of the detector allows use in high background area

- Victoreen 110C - aluminum housing with a low shielding factor for low background use.

Victoreen 110C series hand probes are almost identical to the Eberline model HP-210AL.

Detector Type

The detector is sealed Geiger-Mueller (GM) "pancake" detector. A "pancake" detector has a radius or width that is much larger than the depth of the detector. The shielded hand probe contains the GM detector which has the mica window protected by a wire or stainless-steel etched screen. The fill gas in the GM tube is halogen-quenched argon.

The operating voltage for the GM detector is 900V $\pm$ 50V. The detector has a 50 µs resolving time which is defined as the minimum time that must elapse after the measurement of an ionizing particle before a second particle can be measured.

Detector Window and Shielding

The thin detector window is 1.4-2.0 mg/cm^2 mica and is protected by the screen which is 79% open. Mica windows must be used instead of Mylar, because the Mylar will react with the halogen quench gas. The window has an effective surface area of 2.4 inch^2 (15.5 cm^2).

Efficiencies for the detector are dependent on the type and energy of the radiation.

The detector is designed, calibrated and used to measure beta radiation

22% for Cs-137
16% for Co-60
32% for Sr-90 -Y-90
15% for Tc-99
6% for C-14

Typically, a conservative beta efficiency of 10% is assigned for these types of problems. Therefore, to convert the cpm reading to a dpm value, the meter reading is multiplied by ten (dpm = cpm x 10). Efficiencies for alpha and photon radiation are not typically quoted because the probes are not calibrated for either type of radiation. However, gamma efficiencies are low, about 1-2%, because of the shallow detector depth. Alpha efficiencies are highly dependent on the particle energy and distance from the source, but can be as high as 20%.

Specific Limitations and Characteristics

Generally, environmental conditions, such as humidity and temperature, do not affect the response of the detector because it is sealed at a pressure slightly less than atmospheric pressure.

Use of the hand probe at proper frisking speeds and distances is extremely important to ensure accurate results. The probe should be used at a distance of no more than 1/2 inch and at a speed of about 1 inch per second.

The mica window is extremely fragile and sufficient care must be taken to prevent any punctures which will ruin the detector.

The detector probe is not calibrated for alpha radiation; however, it may be used for indication of alpha emission from contamination, if used properly.

VICTOREEN MODEL 489-4 DETECTOR PROBE (THYAC)

The Model 489-4 detector probe is a cylindrical GM detector with a sliding beta shield and can be used for high count rate applications of contamination monitoring.

Detector Type

The detector is a sealed Geiger-Mueller (GM) cylindrical detector. The shielded probe contains the cylindrical GM tube which has a stainless steel wall surrounding the entire

detector volume. The fill gas in the GM tube is halogen-quenched argon. The operating voltage for the GM detector is 900V $\pm$ 50V.

Detector Window and Shielding

The detector "window" is the 30 mg/cm^2 stainless steel wall of the detector. Shielding provided by a 360° sliding steel shield.

The GM detector will detect any radiation that interacts within the sensitive volume of the detector.

Charged particle radiation must pass through the detector wall before an interaction can take place; therefore, the minimum sensitivity for charged particle radiation is based on the wall thickness and distance from the detector. The minimum sensitivity for beta particles is about 200 keV with the shield retracted, which precludes the measurement of most average-energy, fission-product beta particles. The detector will not detect beta radiation with the shield in place. Alpha particles can not be detected because all alpha particles would be stopped in the detector wall.

Photon radiation, such as gamma or X-ray, can interact in the detector walls and the fill gas to create a pulse. The minimum sensitivity for photon radiation is about 6 keV with the shield retracted and about 70 keV with the shield in place.

Specific Limitations and Characteristics

Generally, environmental conditions, such as humidity and temperature, do not affect the response of the detector because it is sealed at a pressure slightly less than atmospheric pressure. When used with a count rate meter, the meter reading (cpm) is converted to a dpm value by multiplying by thirty (dpm = cpm x 30). The detector probe is not calibrated and is not recommended for measurement of beta radiation due to the thickness of the detector wall.

EBERLINE MODEL AC-3 ALPHA HAND PROBE

The Model AC-3 is an alpha scintillation detector used to identify alpha-emitting contamination.

Detector Type

Scintillation detector using ZnS (Ag) powder embedded in tape. Active detector area is 9.1 inch^2 (59 cm^2) within a 5 3/4 x 2 inch sampling area. Low gamma sensitivity.

Detector Window and Shielding

Window is 1.5 mg/cm^2 aluminized plastic film. Total probe assembly is 11 1/2 inches long x 2 3/4 inches wide x 3 1/4 inches. Clear plastic probe cover is supplied for protecting the detector window. Weight of probe is 1 pound 6 ounces.

Efficiency

From a 1-inch diameter source or from 50 cm^2 of a large-area distributed Pu-239 source, 2 pi geometry. Minimum efficiency is 28%. Typical efficiency is 31%. Sensitivity to Pu-239 source is typically 2 x 10^7 cpm per microcurie/cm^2.

Specific Limitations and Characteristics

Probe is sensitive to gamma radiation. Not used in areas where gamma interference in mr/hr will indicate $\geq$300 cpm alpha. The mr/hr value is affixed to each instrument during routine calibration.

Detector window is very fragile. Puncture or damage to covering will cause detector to become sensitive to light.

Erratic meter movement can be due to electrical short in probe connection cable.

Detector is to be held 0.5 cm from the surface and moved at approximately 1-2 inches per second.

2.17.03 *Describe the following features and specifications for commonly used count rate instruments used at your site.*
a. Types of detectors available for use
b. Operator-adjustable controls
c. Specific limitations/characteristics.

COUNT RATE INSTRUMENTS

VICTOREEN MODEL 496

Victoreen Model 496 is an analog GM count rate meter.

Used in conjunction with GM probe assembles to measure beta and gamma radiation.

Victoreen 489-4
Victoreen 110-C
Eberline HP-210

Three operating ranges of 0-800, 0-8,000, and 0-80,000 cpm.

Response time of 10 seconds or less to 90% of the final reading.

Accuracy of ±10% normally.

Weight of 4 pounds.

Operation

Meter face readout of 0-800

Rotary for power and range functions

- Off - setting for non-operation
- Batt - initial selection for testing of battery strength, needle will identify battery strength
- x1 - establishes meter reading times 1 as the activity in cpm (0-800 range)
- x10 identifies meter reading times 10 as the activity in cpm (0-8,000 range)
- x100 - identifies meter reading times 100 as the activity in cpm (0-80,000 range).

Volume Control Rotary Switch

Audible indication of count rate by independently controlled speaker

Functions of off and on to control speaker

Correction factors for beta/gamma cpm to dpm reading based on type of detector attached

Thyac 489-4 - meter reading x 30

Pancake probes - meter reading x 10

LUDLUM MODEL 12

Ludlum Model 12 is an analog count rate meter

Electronic circuitry has potential for use of proportional, scintillation, and GM detectors

Available in three different detector configurations

Eberline HP-210 detector - used for beta-gamma measurement
Victoreen 110C - used for beta-gamma measurement
Eberline AC-3-7 Probe - used for alpha measurement

Operating ranges of 0-500, 0-50,000, and 0-500,000 cpm

Fast-Slow toggle switch provides for meter response time selection

- Slow - response time of 22 seconds for 90% of final reading
- Fast - response time of 4 seconds for 90% of final reading.

Operation

Meter face readout of 0-500

Range multiplier selector switch is a six-position switch

1. OFF
2. BAT
3. x1,000
4. x100
5. x10
6. x1

Audio on-off switch for operation of count rate speaker

Fast-Slow toggle switch to establish response time of 4 seconds (fast) or 22 seconds (slow)

RES button provides a rapid means to reset the meter to zero

HV Test Button displays the detector voltage on the meter when depressed

Operates on two standard "D" cell batteries or rechargeable cells

Weight of 3.0 pounds, less detector and batteries

LUDLUM MODEL 3-6

Ludlum Model 3-6 is an analog survey instrument

Electronic circuity has potential for use of proportional, scintillation, and GM detectors

Operating ranges of 0-500, 0-5,000, 0-50,000, and 0-500,000 cpm

Fast-Slow toggle switch provides for meter response time selection

- Fast - response time of 5 seconds for 90% of the final reading
- Slow - response time of 25 seconds for 90% of the final reading.

Operation

Meter face readout of 0-5,000

Range multiplier selector switch is a six-position switch

1. OFF
2. BAT
3. x100
4. x10
5. x1
6. x0.1

Audio on-off switch for operation of count rate speaker

Fast-Slow toggle switch to establish response time of 5 seconds (fast) or 25 seconds (slow)

RES button provides a rapid means to reset the meter to zero

Operates on two standard "D" cell batteries or rechargeable cells

Weight of 3.5 pounds, less detector

LUDLUM MODEL 177-2

Ludlum Model 177-2 count rate meter is placed at specific locations for personnel contamination monitoring

Electronic circuitry has potential for use of scintillation, and GM detectors

Available in conjunction with alpha, beta-gamma, and alpha-beta-gamma detection probes

Operating ranges of 0-500, 0-5,000, 0-50,000, and 0-500,000 cpm
Fast-Slow toggle switch provides for meter response time selection

- Slow - response time of 22 seconds for 90% of final reading
- Fast - response time of 2.2 seconds for 90% of final reading.

Operation

Meter face readout of 0-500

Range multiplier selector switch is a six position switch

1. OFF
2. x1
3. x10
4. x100
5. x1,000

Audible click per radiation incident volume control adjustment

Operates on 115 V AC only and does not contain battery pack

RES Button provide a rapid means to reset the meter to zero

Alarm Set Selector Switch is 11 position switch used to select a predetermined alarm threshold (0.5 to 500) at 100 cpm over background

Weight of 4.2 pounds, less detector.

2.17.04 Describe the following features and specifications for commonly used personnel contamination monitors at your site.
a. Detector type
b. Detector shielding and housing
c. Types of radiation detected/measured
d. Scaler type uses
e. Scaler operator-adjustable controls
f. Specific procedures for source checks
g. Specific procedures for sample counts.

PERSONNEL CONTAMINATION MONITORS

PERSONNEL CONTAMINATION MONITOR PCM-1B

Eberline Personnel Contamination Monitor, Model PCM-1B is a microprocessor-based radiation detection system

Performs quick indication of beta-gamma contamination, with option of alpha capabilities

PCM-1B has fifteen (15) independent gas-flow proportional detectors

Control processing unit (CPU) includes an Intel 8085 microprocessor, memory, and input-output lines

Performs two-part personnel whole body survey by performing a right side then lift, personnel body survey.

Operation mode

Monitor measure and stores background values for all detectors

Checks for high background alarm levels

Checks for low or high count failures

Checks for low gas pressure conditions

Ultrasonic motion sensor detects movement of person toward monitor

Background check is suspended

Display reads - "STEP UP - INSERT RIGHT ARM"

Placement of arm in arm cavity initiates personnel monitoring routine

Display reads - "COUNTING RIGHT SIDE"

Counting continues for duration of specific counting time

If no alarm levels detected, unit beeps and displays clearance

Display reads - "RIGHT SIDE OK -- INSERT LEFT ARM"

Placement of left arm in cavity initiates monitoring

Display reads - "COUNTING LEFT SIDE"

Counting continues for duration of specific counting time

If no alarm levels detected, unit beeps and displays clearance

Display reads - "COUNT COMPLETE, YOU MAY PASS"

Display accompanied by chime and the LED extinguishes.

Alarm modes

Premature arm withdrawal

Arm withdrawn prior to preset count time completion

Alarm alert sounds

Display reads - "COUNT INCOMPLETE**RECOUNT**"

Reinsertion of arm restarts count

Contamination detection

Activity in excess of alarm levels detected in either right or left side count

Alarm alert sounds at end of count time

Appropriate display appears - "ALARM: ZONE 1 - ZONE 2 - ZONE 3," etc.

Alarm and display continue for specified alarm hold time

Alarm stops and display reads - "CONTAMINATED -- PLEASE STEP OUT."

Troubleshooting

PCM-1B message display will illuminate the trouble or diagnostic lights to identify various monitor malfunctions. Description of basic malfunction conditions listed below:

High background - Background count rate in any zone(s) has increased above selected limit.

Alarm light, high background light, sonalert, and "Channel Designation (i.e., 'Zone 1 ft): High Background" message are activated.

Area should be checked for radioactive sources and/or detector checked for dirt, moisture or radioactive contamination.

High count fail

- Alarm light, trouble light, sonalert, and channel designation message are activated.
- Count capacity in any zone has been exceeded and PM Group to be contacted for troubleshooting.

Low count fail or low sensitivity fail

- Alarm light, trouble light, sonalert, and channel designation message are activated.

May be the result of component failure or decrease/loss of decrease/loss of counting gas. Detector identified should be checked for leak in mylar. Leak in mylar can be sealed with scotch tape.

Contaminated detector

Contaminated detector light is activated along with contaminated detector message. Operation will continue with detector light on.

Detector to be checked for contamination and decon around detector performed with masslin cloth.

Loss of gas pressure

Two cylinders used but cylinder No. 1 used until empty. When empty, "Bottle No. 1 Empty" light activated and No. 2 put in use automatically.

If both cylinders fail (empty) the trouble light, "Bottle No. 2 Empty," and display with indicate "Failure**Out of Gas" message will be activated.

PCM-1B must not be used to monitor personnel with any trouble light illuminated. Monitor placed in "Out of Service" mode until cause corrected.

EBERLINE PM-6

Microprocessor based radiation monitor using gas-flow proportional detectors for whole body contamination scans.

Two basic types of PM-6s are typically used.

PM-6A

Uses eleven gas-flow counters to detect beta-gamma contamination.

Same basic operating characteristics as PCM-1B.

Source checked daily using beta-gamma source.

PM-6A-2

Uses fifteen gas-flow counters to detect alpha or beta-gamma contamination.

Four additional detectors used in hand pods to increase ability to detect hand contamination.

Hand and foot detectors sensitive to alpha as well as beta-gamma contamination.

Source checked daily using alpha and beta-gamma sources for both hand and foot detectors. Beta-gamma source is used on body detectors.

Source checks and troubleshooting PM-6 is same as PCM-1B.

OTHER CONTAMINATION MONITORS

2.17.05 *Describe the following features and specifications for commonly used contamination monitors used at your site (tool, bag, laundry monitors).*
a. Detector type
b. Detector shielding and window
c. Types of radiation detected/measured
d. Energy response for measured radiation
e. Specific limitations/characteristics.

(Site must add material based on other contamination monitors, such as tool, bag or laundry monitors, used at the site. text add must cover the material required by the objective.)

SUMMARY

In this lesson, we have covered contamination monitoring instruments in relation to types used, purpose for, radiation monitored, operational requirements, and specific limitations/characteristics for use. The RCT uses this information to identify and assess the hazards presented by contamination and establish protective requirements for work performed in contaminated areas.

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