

LEARNING OBJECTIVES:

- 2.19.01 Describe the features and specifications for commonly used laboratory counters or scalers:
- a. Detector type
 - b. Detector shielding
 - c. Detector window
 - d. Types of radiation detected and measured
 - e. Controls/Indicators
 - f. Precautions/Limitations
 - g. Typical efficiency
 - h. Check sources
- 2.19.02 Describe the features and specifications for low-background automatic counting systems:
- a. Detector type
 - b. Detector shielding
 - c. Detector window
 - d. Types of radiation detected and measured
 - e. Controls/Indicators
 - f. Precautions/Limitations
 - g. Typical efficiency
 - h. Check sources
- 2.19.03 Describe the following features and specifications for commonly used gamma spectroscopy systems.
- a. Detector type
 - b. Detector shielding
 - c. Detector window
 - d. Types of radiation measured

INTRODUCTION

An overview of counters, scalers and associated equipment will describe the basic functions of counting equipment used to detect radiation activity. The RCT uses information from these counting instruments to identify and assess the hazards presented by contamination and airborne radioactivity, establish protective requirements for work performed in radiological areas, or identify and assess internal/external personnel contamination. Stand-alone counters or scalers measure gross activity while spectroscopy systems perform spectral analysis to identify and quantify activity from specific nuclides. The common uses of counting room equipment in various facilities will be discussed.

A variety of counting equipment is used depending on facility and needs. There are both manual and automated counting systems. There is shielded equipment to measure radioactivity just above background levels. There is equipment to measure gross counts of alpha, beta and gamma to determine if surface contamination limits are met. There is equipment to measure the energy spectrum for alpha and gamma radiation so that individual isotopes can be identified and quantified (e.g. to determine if an alpha emitter is a plutonium isotope, a uranium isotope or a radon daughter).

The counting systems use various types of detectors, including gas proportional counters for alpha and beta radiation; sodium iodide, scintillation detectors for gamma spectroscopy; zinc sulfide (ZnS) scintillation detectors for alpha radiation; liquid scintillation for tritium and carbon 14; surface barrier (semiconductor) detectors for alpha spectroscopy, lithium drifted germanium (GeLi semiconductor) detectors for gamma spectroscopy, and high purity, germanium (HPGe semiconductor) detectors for gamma spectroscopy.

The most common uses of the equipment are to count smears, swipes and air filters. Nasal swipes are also counted as one way to test if an individual has been exposed to airborne radioactive contamination. Both workplace and stack emission air filters are counted to measure the concentration of specific radionuclides (e.g. plutonium, and uranium) and classes of radionuclides (e.g. mixed fission products).

GENERAL PRINCIPLES

A variety of counting room systems are used. The principles of these systems will be discussed in general and then specific systems will be described.

Detector Type

When looking for low levels of radioactivity from alpha emitters (e.g. U, Pu, etc.) it is important to minimize the background contribution from beta and gamma radiation. The

principles used to accomplish this are typically a combination of pulse height discrimination and detector design.

Alpha detectors are generally gas proportional counters, ZnS scintillators, or silicon semiconductors.

Gamma spectroscopy requires good resolution to distinguish the different energy peaks. GeLi or HPGe semiconductors give the best resolution, though NaI scintillators are also used.

Detector Shielding

To reduce the background, shielding is often used. Betas can be shielded with aluminum or plastic, while typical gamma shielding is a few inches of lead or steel.

Detector Window

Since alphas have a short range the windows are thin, typically 1 mg/cm^2 (or 0.25 mil plastic). Some detectors have no window between the sample and the detector; in this case there is a gas purge system for gas proportional counters, or a light tight housing for scintillators. The alpha range is so short that self-shielding is often significant, e.g. an alpha emitter buried in a filter may be shielded from the detector by the fibers.

Types of Radiation

Some of the detectors discussed in objectives 1 and 2 are designed for alphas, some for betas, some count both. Gamma spectroscopy is discussed with objective 3. Most nuclides emit more than one type of radiation; beware of exceptions (ex: Be-7 or C-14).

Beta background is greater than alpha, so alpha detectors use typically a combination of pulse height discrimination and detector design to discriminate between alpha/beta/gamma. Alpha detectors are thin (typically 1 mg/cm^2) and this design is used to distinguish alpha from beta or gamma. Different alpha energies are distinguished by the use of pulse height discrimination.

Some gammas may be detected in these detectors, but thin detectors have low gamma efficiency, and shielding helps to reduce the gamma background still further.

Operator Adjustable Controls

Counting room systems usually have a timer to allow the operator to measure the number of counts per minute (cpm). The most common count time is 1 minute, but the count time can be selected by the operator based on the required MDA needed for the analysis.

Sources

National Institute of Standards and Technology (NIST) traceable sources are used to check the systems. Common sources are Pu-239 for alpha counters, Sr-90 for beta counters, and mixed nuclide sources for gamma spectroscopy systems.

Procedures

Procedures generally include:

- Performing a background count
- Performing a source check
- Counting a sample
- Performing background subtraction
- Dividing by time to get cpm
- Correcting to 4 pi efficiency to get dpm
- Recording the data
- Maintaining and updating QC charts

LABORATORY COUNTERS OR SCALERS

- | | |
|---------|--|
| 2.19.01 | Describe the features and specifications for commonly used laboratory counters or scalers: |
| a. | Detector type |
| b. | Detector shielding |
| c. | Detector window |
| d. | Types of radiation detected and measured |
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| f. | Precautions/Limitations |
| g. | Typical efficiency |
| h. | Check sources |

EBERLINE MS-2 AND MS-3 MINISCALERS (*Figures 1 & 2*)

The MS-2 and MS-3 miniscalers are complete counting systems (less detector). Each unit contains a variable high voltage power supply, charge sensitive input amplifier, six decade scaler, and timer. The MS-2 also includes a single channel pulse analyzer and a four range linear rate meter which is very good for alpha energy discrimination. These miniscalers are designed for use with a variety of scintillation, Geiger Mueller, or proportional detectors. Both units have LED readouts and may be operated without line voltage by using an optional battery pack that connects to the rear panel.

The high voltage power supply develops high voltage for the detector. When radiation reacts in the detector, negative pulses are generated. These pulses are applied to a pulse height discriminator. The output of the discriminator is applied to a scaler (ratemeter or scaler for MS-2) which is controlled either manually or by the timer.

Miniscalers are used to analyze air, smear, and evaporated liquid samples when the required/desired sensitivity is lower than that provided by portable instruments.



Figure 1 – Eberline MS-2

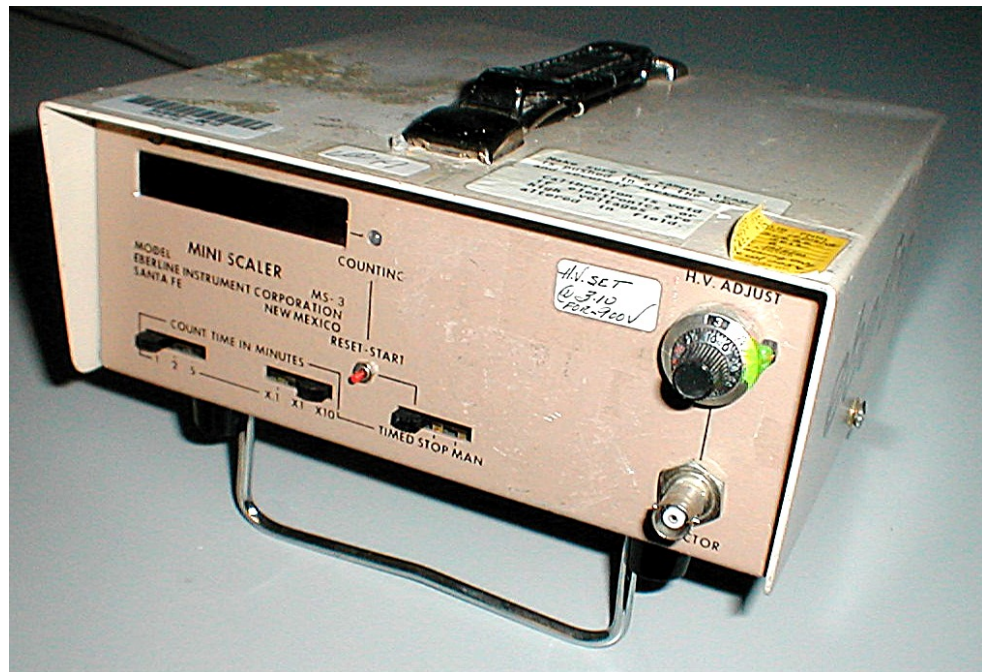


Figure 2 – Eberline MS-3

Physical Description

Common Features (MS-2 and MS-3)

H. V. Adjust: The high voltage adjust potentiometer varies the detector voltage from 200 volts to approximately 2500 volts.

Detector: The detector jack accommodates an MHV coaxial connector.

Timer Mode: This three way slide switch establishes either **TIMED**, **STOP**, or **MAN** timing. In the **TIMED** mode, the count automatically stops after the preset counting interval. In the **STOP** mode, the instrument will not count. The **MAN** mode initiates continuous counting.

Reset-Start: Resets the scaler and timer to zero and initiates counting.

Count Time in Minutes: Two slide switches are used to set the count time (in minutes). The first slide switch sets the count time to 1, 2, or 5 minutes. The second slide switch is a multiplier with options of x 0.1, 1, and 10.

MS-2 Additions

Threshold: Adjustable by a calibrated ten turn potentiometer from 0 to 1.0 volt. The threshold establishes the base line, or "low end", sensitivity of the instrument. The actual threshold setting is determined at calibration and is dependent upon the isotope(s) of concern and the type of detector used.

Window: Adjustable by a calibrated ten turn potentiometer from 0 to 1.0 volt, above the threshold setting. The window establishes the range of pulse height (energy) to be counted by the system. The actual window setting is determined at calibration and is dependent upon the isotope(s) of concern and the type of detector used.

In-Out: This two position toggle switch disables/enables the window setting. Placing the switch in the **OUT** position disables the window and permits gross counting.

Test-On: This two position toggle switch engages/disengages the timer oscillator frequency. **TEST** inserts the timer oscillator frequency (3600 cpm test signal) into the scaler and rate meter.

Response: This dial controls the response time of the rate meter.

Range: This four position switch (x1, x10, x100, x1000) establishes the upper limit of the analog rate meter (i.e. 500, 5000, 50,000, 500,000).

Reset: This switch returns the count rate meter reading rapidly to zero when depressed.

Detectors

Ludlum 43-10 Probe

The 43-10 probe is a windowless ZnS(Ag) coated lucite light pipe. The crystal connects to a 5.08 cm (2 in) diameter, photomultiplier tube, housed in a metal casing attached to a two-inch sample drawer. This probe responds to alpha energies above 3 MeV. The average efficiency is roughly 34% for Pu²³⁹.

Eberline HP-210 Probe

Three types of HP-210 detectors may be used at the Hanford Site, the HP-210AL which has a 1:1 window to background ratio the HP-210T which has a tungsten shield providing a 4:1 shielding ratio, and the HP-210L which has a lead shield providing a 4:1 shielding ratio. All three detectors use a "pancake" GM tube with a thin mica window. The mica window is approximately 1.4 to 2.0 mg/cm² thick and has an active area of 15.5 cm². The thin mica window of the probe is very fragile and is protected by a fine mesh copper-beryllium screen. These detectors operate at a high voltage of about 900 V. Typical efficiency is approximately 25% for Sr-Y⁹⁰.

General Counting Operation

To count a smear, air filter, or evaporated liquid in a planchet, open the sample drawer and place the sample in the holder. Planchets should be used for holding smear and air samples to minimize handling and the potential for cross contamination.

Set the desired counting time, then press the **RESET-START** button to initiate counting. After the count is complete, the display registers the total number of counts measured during the counting interval, **NOT** the counts per minute measured from the sample. Only when the count time is one minute will the display be in units of cpm. In general, the display value is divided by the count time (in minutes) to obtain the count rate in cpm.

Upon completing the analysis, disposition the sample according to facility protocols (e.g., hold for decay, send for isotopic analysis, dispose).

Precautions

The MS-2 (miniscaler mode) and the MS-3, with attached detectors, are intended for counting dry technical smears, air sample filters, and evaporated liquid samples. Placement of other types of materials into the sample tray may result in contamination of the instrument or inaccurate measurements.

Evaporating liquids can produce unacceptable levels of solid material (e.g., salts) which in turn can produce self-absorption. Evaporating liquid samples should only be performed at the direction and guidance of facility technical staff.

The sample drawer should be cleaned with a cotton swab (or equivalent) as needed to remove any residual contamination.

Technical smears and air sample filters that are bent require extra care since they may easily lodge inside the sample drawer. A thin layer of adhesive between the sample and its planchet may help bent samples lie flat.

The potential for significant instrument contamination increases with the activity of the sample. Highly radioactive samples may contaminate counting instruments and should be handled with extreme care. Portable survey instruments may be used to survey samples before placing them into a sample tray.

Samples that are wet or that will break apart, such as soils or powders, should not be counted.

Use the efficiency values determined during calibration, unless the radionuclide and counting efficiency for another radionuclide of concern is known.

Sample counting times may vary to obtain desired minimum detectable activity (MDA) or minimum detectable concentration (MDC) values. The longer a sample is counted, the lower the MDA/MDC value. Sample count times must be long enough to yield the required sensitivity (MDA/MDC). See HNF-13536, 5.2.7 (FH), *Analyzing Air and Smear Samples* or RPP-5779, RCI-08 (CHG) *Analyzing Air and Smear Samples for Alpha and Beta Emissions* for additional information.

For information relating to periodic testing of miniscalers refer to Section 2.03, *Counting Errors and Statistics*.

Sample Holder SH-4 with HP210 and ESP

One problem with using the HP210 for quantitative measurements (e.g. to satisfy release criteria) is one of ensuring a precise geometry. The SH-4 sample holder solves this problem by holding the sample in a fixed position directly under the HP210 detector.

EBERLINE BC-4 BETA COUNTER (*Figure 3*)**Description**

The Eberline BC-4 Beta Counter used at the Hanford Site consists of a single unit containing a 2-inch pancake type Geiger Mueller (GM) detector, high voltage power supply, pulse amplifier, timer, and six-decade LED readout. The instrument is intended for stationary use.

The detector is a standard pancake GM tube identical to those used with portable beta-gamma contamination survey instruments (HP-260, HP-210) with a 4.4 cm (1 3/4 in) diameter window. The window has a density-thickness of 1.4 to 2.0 mg/cm².



Figure 3 - Eberline BC-4 Beta Counter

Total window density is increased to approximately 7 mg/cm² when the calibration facility adds a 0.002 inch thick mylar window. The detector is shielded on the top and sides by a minimum of 2.2 cm (7/8 in) lead shielding.

Samples up to 5.2 cm (2 in.) in diameter and 1.0 cm (3/8 in.) thick can be placed in the sample drawer on the front of the instrument. The sample holder in the drawer can be adjusted to compensate for different sample thicknesses. The sample holder's height is set during the calibration and must be maintained to use the calibration efficiency.

Sample holders should not be moved unless directed by facility technical staff. Facilities are responsible for documenting drawer movements and instrument operation for drawer positions that are different from the calibrated position.

Instrument Controls

Reset-Start - Resets the timer and scaler to zero and starts a timed count.

Count Mode - The **TIMED** position automatically stops the count at the preset time. The **MANUAL** position counts continuously. The **STOP** position does not count.

Count Time in Minutes - Two slide switches are used to set the count time (in minutes). The first slide switch sets the count time to 1, 2, or 5 minutes. The second slide switch is a multiplier with the options of x0.1, x1, and x10.

External/Internal Sources

The BC-4 has no internal radioactive sources, but typically utilizes a 47 mm electroplated Sr- 90 disc source for routine source checks.

Radiation and Energy Response

The BC-4 is a beta counting instrument. The BC-4 is calibrated to a minimum efficiency of 24% for Sr 90 (Y) and 4% for Tc 99 . Actual efficiencies for calibrated instruments average 30% for Sr 90 (Y) and 9% for Tc 99 . The detector will detect alpha, beta, and gamma radiation. Gamma can be corrected for by background subtraction, however, any alpha interference is seen as beta during the count.

Operation

To count a contamination smear or air sample filter, open the sample drawer and place the sample in the holder. Planchets should be used to hold samples (minimizing handling and the potential for cross contamination).

Set the desired counting time then press the **RESET-START** button to start the count cycle.

The same general precautions apply as were discussed for the MS-2 and MS-3 miniscaler counting systems.

The required checks and tests are discussed in Section 2.03, *Counting Errors and*

Statistics.

EBERLINE SCINTILLATION ALPHA COUNTER (SAC-4) (Figure 4)

The Eberline SAC-4 is a scintillation alpha counter. The scintillation phosphor is ZnS powder on a plastic light pipe. The system is a self contained unit with the detector and associated electronics housed in a single unshielded box. The detector and sample are both in a light tight can, so no window is required between the ZnS detector and the sample.

The system will accept samples up to 2 inches in diameter by 3/8 inches thick. (Self shielding would be a major problem with samples this thick.) The sample holder in the slide drawer is adjustable. It can be moved closer to the detector for thin samples. However, the SAC-4 is calibrated with the sample holder in a certain position, so if the sample holder is moved, the calibration is no longer valid.



Figure 4 - Eberline SAC-4 Alpha Counter

The electronic package consists of the high voltage power supply used to power the photomultiplier tube and determine its amplification, and a linear amplifier. The linear amplifier output provides a 0 to 10 volt pulse signal to the discriminator that is set to 1.25V above the base line. Only pulses with amplitudes above 1.25V will be counted. This will discriminate against betas because they will produce smaller pulses.

The output from the discriminator is counted by a six decade light emitting diode (LED) readout. The timing circuit is synchronized to the line frequency (60 Hz) and provides preset counting times from 0.1 to 50 minutes controlled by front panel switches. This scaler can also be operated in a manual mode which will continue to count until reset by the operator.

A Pu-239 source is used to check the system each day. Background counts are conducted as a part of the performance check and to check for detector contamination. The detector and sample drawer are easily removed for decontamination if required.

The gross count rate is obtained by dividing total counts by the time in minutes. Background counts (typically 0.3 cpm) are subtracted from gross counts to obtain net counts per minute (cpm). The net count rate (cpm) is corrected for efficiency (as described in lesson 2.03) to convert cpm to disintegrations per minute (dpm).

This counting system is used to obtain total activity and the procedures are followed as described in the SAC-4 manual. Each background, source count, and sample count is documented and kept on file.

LUDLUM MODEL 2929 ALPHA/BETA MINISCALER (*Figure 5*)

Instrument Description and Theory of Operation

The Ludlum 2929 is an AC powered, two-channel, scaler that can be equipped to detect and measure alpha and beta radiation. The model 2929 measures a sample (e.g., air filter or technical smear) for gross alpha and beta activity with a single sample count. Three detectors are currently used with the 2929 at Hanford, the Ludlum 43-1-1, 43-10-1, and 43-78-5. All detectors are ZnS(Ag) scintillators, accommodating 2" (43-10-1) or 4" (43-1-1, 43-78-5) sample diameters respectively. All these detectors provide a sample drawer to ensure consistent and reproducible geometry. The 2929 is most commonly connected to the 43-10-1 alpha/beta detector. The Ludlum 2929 can be equipped with an optional printer (Ludlum Model 264), providing hard copy printouts of sample results.

Physical Description

The Ludlum 2929 weighs 5.7 kg (12.6 lb), including an attached 43-10-1. It measures 22 cm (8.5 in.) high by 37 cm (14.5 in.) wide by 23 cm (9 in.) deep, including the 43-10-1. The front panel includes a dial denoting the applied detector voltage, HV adjustment potentiometer, two-digit count time dial, four-position count time range dial (X.1, X1, X10, external), power switch, two six digit LED scaler displays (one for each channel), count and hold pushbuttons, red light indicating counting status, and a single MHV connection. The rear panel includes a 1 Amp fuse, Amp out connector, and 15-pin connectors for alpha and beta data output. Internal controls, used during calibration, include amplifier gain, alpha and beta discriminators, and beta window potentiometers.

The 43-10-1 detector itself weighs 1.9 kg (4.1 lb) and measures 24 cm (9.3 in.) high by 11 cm (4.5 in.) wide by 24 cm (9.3 in.) long. The 43-10-1 uses ZnS(Ag) plated on a plastic scintillation disc, 2" in diameter and 0.01" thick. The 43-78-5 detector weighs 36 kg (80 lb) and measures 17 cm (6.5 in.) in diameter and 29 cm (11.4 in.) high (see Figure 17.2). Increased weight is the result of integral lead shielding. The 43-78-5 uses ZnS(Ag) plated on a plastic scintillation disc, 4.125" in diameter and 0.01" thick. The associated PMT is 3" in diameter with a 14-pin base and 10-pin dynode structure.



Figure 5 - Ludlum Model 2929 with a model 43-10-1 detector

Radiation and Energy Response

These detectors will respond to alpha radiation above ~ 3 MeV. Alpha response may be energy dependent but should be relatively consistent for Am-241 and Pu-239. Ludlum states that the energy response of the 43-10-1 is flat from 4 to 5.2 MeV. The 43-10-1 average Pu-239 efficiency is 36%. The 43-78-5 average Pu-239 efficiency is 40% (2" source) and 37% (4" source). These detectors respond to beta radiation above ~ 100 keV. Beta response is energy dependent. The 43-10-1 average efficiencies are, 23%

(⁹⁹Tc), 31% (¹³⁷Cs), and 43% (⁹⁰Sr/Y). The 43-78-5 average efficiencies are comparable for 2" sources. The 4" ⁹⁰Sr/Y average efficiency is 37%. Based on detector type, neutron and gamma response should be slight at best.

Sources

The Ludlum 2929 and 43-10-1/43-78-5 have no integral sources. Source checks are typically performed using 47 mm electroplated Pu-239 (plutonium), and Sr-90 (strontium) disc sources.

Operation

To count a technical swipe or air sample filter:

- rotate the sample drawer locking knob counter-clockwise
- pull the sample drawer out, and place the sample in the tray
- Slide the sample holder back beneath the detector and lock the slide in position by rotating the locking knob clockwise
- Set the desired count time, and then press the COUNT button to start the count cycle. Count times between 0.1 minutes (6 seconds) and 990 minutes (16.5 hours) are possible

General Precautions

- Planchets should be used to hold samples (minimizing handling and the potential for cross contamination)
- The sample holder must be pushed completely in to trip a microswitch, enabling the detector voltage.
- The 2929 is intended for counting dry technical smears and air sample filters. Placement of other types of materials into the counters may result in contamination of the instrument, inaccurate measurements, and/or detector damage.
- The sample drawer should be maintained clean. A cotton swab may be used to remove any residual debris.

- Bent technical smears and air sample filters require extra care as they may easily lodge inside the sample drawer. A thin layer of adhesive between the sample and its planchet, may help bent samples lie flat.
- The potential for significant instrument contamination increases with the activity of the sample. Highly radioactive samples may contaminate counting instruments and should be handled with extreme care.
- Portable survey instruments should be used to survey samples before placing them into the sample drawer.
- Contact facility technical staff if questions arise regarding sample activity limitations.
- Samples that are wet or that will break apart should not be counted.
- The 2929 cannot discriminate radon or radon progeny.
- Use the efficiency values determined during calibration (normally ^{239}Pu and $^{90}\text{Sr}/\text{Y}$), unless the radionuclide and the counting efficiency for another radionuclide of concern is known. Contact the calibration laboratory to request specific isotopic efficiency values.
- Sample counting times will vary to obtain desired minimum detectable activity (MDA) or minimum detectable concentration (MDC) values. The longer a sample is counted, the lower the MDA/MDC value. Sample count times should be long enough to yield the required sensitivity (MDA/MDC).
- Sample count times should be less than or equal to the background count time.
- The 43-10-1 detector includes a sample holder, approximately 1 cm (3/8 in.) thick. This holder must be used for accurate analysis results.
- When counting 2" sample media on a 43-78-5, a jig should be used to ensure the sample is centered beneath the detector.

Instrument Specifications and Limitations

Temperature

The Ludlum 2929 is intended for use indoors. It has not been tested for proper operation in conditions other than controlled environments (indoors). Ludlum states a temperatures range between -20C (4°F) and 50C (122°F) for the 2929 and 43-10.1. No temperature data is available for the 43-78-5.

LOW-BACKGROUND AUTOMATIC SYSTEMS

2.19.02 Describe the features and specifications for low-background automatic counting systems:

- a. Detector type
- b. Detector shielding
- c. Detector window
- d. Types of radiation detected and measured
- e. Controls/Indicators
- f. Precautions/Limitations
- g. Typical efficiency
- h. Check sources

In this section, several automatic counting systems are discussed (objective 2). The principles are the same as in the first section. The essential differences between the systems in sections 1 and 2 are:

- complexity of electronics
- number of detectors or automated sample changing
- shielding to reduce background

Tennelec LB 5100-W (2")

The Tennelec LB 5100-W is a low background automatic counting system. The primary detector is a gas flow proportional counter with a 2.25 inch diameter with a very thin ($80 \mu\text{g}/\text{cm}^2$) mylar window, used to count both alpha and beta activity. A second larger gas flow proportional counter, the guard detector, is used to count gamma background. The gas used is P-10 (90% argon and 10% methane).

The sample detectors are surrounded by 4 inches of lead shielding to reduce background.

The Tennelec LB 5100-W is used primarily to count smears or air filters. Gross counts for each sample are processed in the computer and converted to dpm or other appropriate units ($\mu\text{Ci/cc}$, etc.). High count rate samples ($> 15,000$ cpm) should not be counted in this instrument due to the probability of instrument contamination. Since this instrument is used to monitor very low levels of radioactivity, any instrument contamination can greatly affect its ability to see these low levels.

Performance checks (background and efficiency), are performed daily or prior to system use. Recommended sources are 47 mm electroplated Pu-239 (plutonium), and Sr-90 (strontium) disc sources. Typical efficiencies are approximately 33% for Pu-239 and approximately 51% for SrY-90.

The system is controlled by a desktop computer and the associated software. The system has an automatic sample changer with a dual stack that can typically handle up to 50 samples. One stack holds the samples to be counted and the other stack stores the samples that have been counted.

Liquid Scintillation Counters, LSC e.g. Packard 2550

Tritium and C-14 emit such low energy betas that even a thin layer of air would stop the betas. To detect this radiation, the sample must be in intimate contact with the detection medium. This is achieved with a liquid scintillation system.

A liquid scintillation counting system uses a "cocktail" that immerses the sample in the scintillating medium to maximize the detection efficiency for low energy beta emitters. This liquid scintillator material converts the energy deposited by low energy betas into light photons, which are then counted by the instrument using photomultipliers.

The sample chamber, containing the sample vial and photomultiplier tubes, is light tight. Since stray electrons can be spontaneously emitted from the photocathode, or by the dynodes in the photomultiplier tube, two or more tubes are used with coincidence circuitry to reduce this source of noise called "dark current". Typical background for beta is 20 cpm.

The LSC system is typically used to count tritium samples from swipes, water samples, and oil samples (vacuum pumps).

To calibrate the system, a series of cocktails with known amounts of tritium and varying levels water for “Quenching” are prepared. These sources are loaded into the first sample holder (a tray of 10 sample vials). The computer program calculates the detector efficiency for each calibration source and generates a calibration curve that is subsequently used for sample analysis.

GAMMA SPECTROSCOPY

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|---------|--|
| 2.19.03 | Describe the following features and specifications for commonly used gamma spectroscopy systems. |
| a. | Detector type |
| b. | Detector shielding |
| c. | Detector window |
| d. | Types of radiation measured |

The instruments discussed in objectives 1 and 2 are designed to detect alphas and/or betas, and make a gross count of total alpha and beta activity. In order to identify specific radionuclides, the unique spectrum of energies particular to each radionuclide is used. This technique is known as spectroscopy.

Alpha emitters (e.g. Th, U, Pu, Am and their daughters) have characteristic alpha energies, but alpha spectroscopy, detecting the alphas directly, is not optimal, because the energy loss of alpha particles between the sample and the detector smears the energy spectrum (see lesson 2.18.03). Gamma spectroscopy, looking for the characteristic spectrum of gammas from the radioactive decay, is discussed in this section.

Gamma spectroscopy usually uses germanium detectors (GeLi or HPGe) because the good resolution obtained with these detectors enables gammas with nearly the same energy to be distinguished or resolved.

Gamma Spectroscopy System

A Gamma Spectroscopy system uses an HPGe coaxial photon detector to perform gamma and x-ray spectroscopy in the energy range from 3 keV to 10 MeV. GeLi detectors are not routinely used anymore due to the advantages of HPGe detectors over GeLi detectors. Manufacturers no longer service or manufacture GeLi detectors if the crystal loses its Lithium drift.

Detector Type

The detector is made of n-type high purity germanium semiconductor (HPGe). A 30 liter dewar of liquid nitrogen (LN₂) is used to cool the detector. A HPGe detector does not need to be cooled when not in use (high voltage not applied).

Detector Shielding

These detectors are typically shielded by several inches of steel or a equivalent amount of lead (Pb). Since these systems measure small amounts of radioactivity, the best shielding uses steel or lead (Pb) manufactured prior to World War II. This material was manufactured before radioactive fallout (artificial radioactivity, lesson 1.06.03) from nuclear weapons appeared in trace quantities. The cost of the shielding is based on the level of background radioactivity in the shield. A sample holder inside the shield allows the sample to be positioned at distances from less than 1 cm up to 40 cm from the detector end cap.

Detector Window

Most HPGe detectors do not have a detector window. The detector crystal is sealed in a stainless steel or Aluminum can. Some low energy HPGe detectors will have a thin Beryllium window, which will allow accurate gamma energy identification down to approximately 17 KeV.

Types of Radiation Measured

The gamma spectrometer is designed to detect gammas and x-rays from alpha emitting nuclides, and sort the data in a multi channel analyzer to produce a spectrum that is characteristic of the nuclide. The peaks in the spectrum are close together, so excellent resolution is required to distinguish the peaks. Typical resolution from a germanium semiconductor detector (HPGe or GeLi) is better than 1%, which means that if the photon energy is 100 keV, the width of the peak is less than 1 keV. Photons from two different nuclides that are 1 keV apart will be seen as two distinct peaks.

Procedures

Energy and efficiency calibrations are obtained using two different sources that are NIST traceable. These are mixed sources that contain several gamma emitting nuclides. One source contains isotopes of americium (Am), antimony (Sb), and

Europium (Eu). The second mixed source contains isotopes of cadmium (Cd), cerium (Ce), cobalt (Co), strontium (Sr), tin (Sn), cesium (Cs), and yttrium (Y). The energy and efficiency calibration values are then used by the analysis software.

Specific procedures are written to direct the operator through the sample and computer setup, and the computer analysis. The original copy of the results are kept on file for 1 year and then archived for 75 years as a radiological record.

SUMMARY

This lesson has discussed the detector, shielding, window, types of radiation detected, and procedures for counting room equipment. This knowledge is important to ensure accurate and consistent counting room data for the assignment of proper radiological controls.

EQUIPMENT CHARACTERISTICS

MS-2 & MS-3

Laboratory Counter

Detector type: GM (HP-210 or Ludlum 43-10) (external)
Detector shield: Tungsten, Al or Pb (GM) or none (Ludlum)
Detector window: mica 1.4 to 2 mg/cm² (GM); none (Ludlum)
Radiation detected: beta or alpha
Controls: timer
Source check: NIST traceable Sr-90 or Pu-90

BC-4

Laboratory Counter

Detector type: GM (internal)
Detector shield: Lead
Detector window: mica 1.4 to 2 mg/cm²
Radiation detected: alpha/beta/gamma
Radiation measured: beta w/ alpha interference
Controls: timer
Source check: NIST traceable Sr-90

Eberline SAC-4 Laboratory Counter

Detector type: ZnS(Ag) scintillator
Detector shield: None
Detector window: None
Radiation detected: alpha
Controls: Timer: 0.1 to 50 minutes
Source check: NIST traceable Pu-239 source

Ludlum Model 2929 Laboratory Counter

Detector type: ZnS(Ag) scintillator
Detector shield: 43-10-1:None; 43-78-5: Lead (Pb)
Detector window: None
Radiation detected: alpha/beta
Controls: Timer: 0.1 to 990 minutes
Source check: NIST traceable Pu-239 and SrY-90 sources

Tennelec LB 5100-W Low Background Automatic

Detector type: Gas flow proportional (P-10 gas)
 Larger guard detector for background
Detector shield 4 inches lead
Detector window 80 $\mu\text{g}/\text{cm}^2$ mylar
Radiation detected alpha and beta
Source checks Pu-239 and Sr-90

Liquid Scintillation Counter**Packard 2550 Low-Background Automatic**

Detector type: Liquid scintillation
Detector shield: none
Detector window: none (Light tight housing)
Radiation detected: Low energy beta from Tritium (or C-14)
Source checks: Set of 10 tritium calibration sources, with water as quench agent.

Gamma Spectroscopy System

Detector type:	HPGe (high purity germanium)
Detector shield:	Several inches of steel or a equivalent amount of lead (Pb).
Detector window:	usually none; 0.5 mm thick Beryllium window for low energy analysis
Radiation detected:	gamma and x-ray photons from 17 keV to 4MeV
Source checks:	NIST traceable, mixed nuclide gamma sources

GLOSSARY:

cocktail: mixture of liquid scintillation chemicals and sample

discriminator: electronic device that discriminates against small pulses, e.g. to distinguish alphas from betas.

gamma spectroscopy: the use of gamma spectra to identify radionuclides by their characteristic gamma emissions.

multi channel analyzer (MCA): combination of many SCAs, each connected to a scaler channel, to produce a spectrum

resolution: measure of the ability of a system to separate nearby peaks in a spectrum; measure of the widths of the peaks.

single channel analyzer (SCA): combination of a lower level discriminator and an upper level discriminator to select only pulses between the two levels (e.g. to select betas but reject small pulse height noise and large pulse height alphas).

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