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LESSON 3:

X AND GAMMA RADIATION MONITORING

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X and Gamma Radiation Monitoring using Portable and installed instruments

1. Monitoring Technique
2. Instruments
3. Calibration and Testing
4. Practical measurements

X AND GAMMA RADIATION MONITORING INSTRUMENTS

Purpose:

1. To measure ambient dose equivalent rate, $H^{*}(10)$ at the points of interest.
2. To assess the intensity of radiation fields at workplace for regulatory compliance.
3. To apply the measurement values for controlling external exposures.

1. Monitoring Technique

The monitoring process generally involves placing the reference point of a suitable monitor.

It measures ambient dose equivalent rate, at the measurement point.

The reference point should be as close as possible to the intended measurement point.

In theory, there is no need to point the instrument in a particular direction but in practice no instrument is totally isotropic in its response.

In addition, the operator will produce considerable shielding for radiation behind the instrument. Hence, it is important to identify a direction for each monitoring point.

For this reason, area gamma monitors should be located at higher elevations.

1. Monitoring Technique

Searching:

- In areas where conditions are poorly understood
- Shielding weaknesses or source searches
- Highest dose rates on outside of package

Is easier as sensitivity of instrument increases.

Helped by using audio output.

Portable instruments are used.

1. Monitoring Technique

- Installed instruments continuously monitor.
- Alarms and remote indicators possible.

- Emphasis is on selection of best position for detectors
- Consider scenarios of potential dose rate
- Ensure instrument is not shielded and is located to measure point of interest
- Facility design basis may dictate locations

INSTRUMENTS

2. Instruments

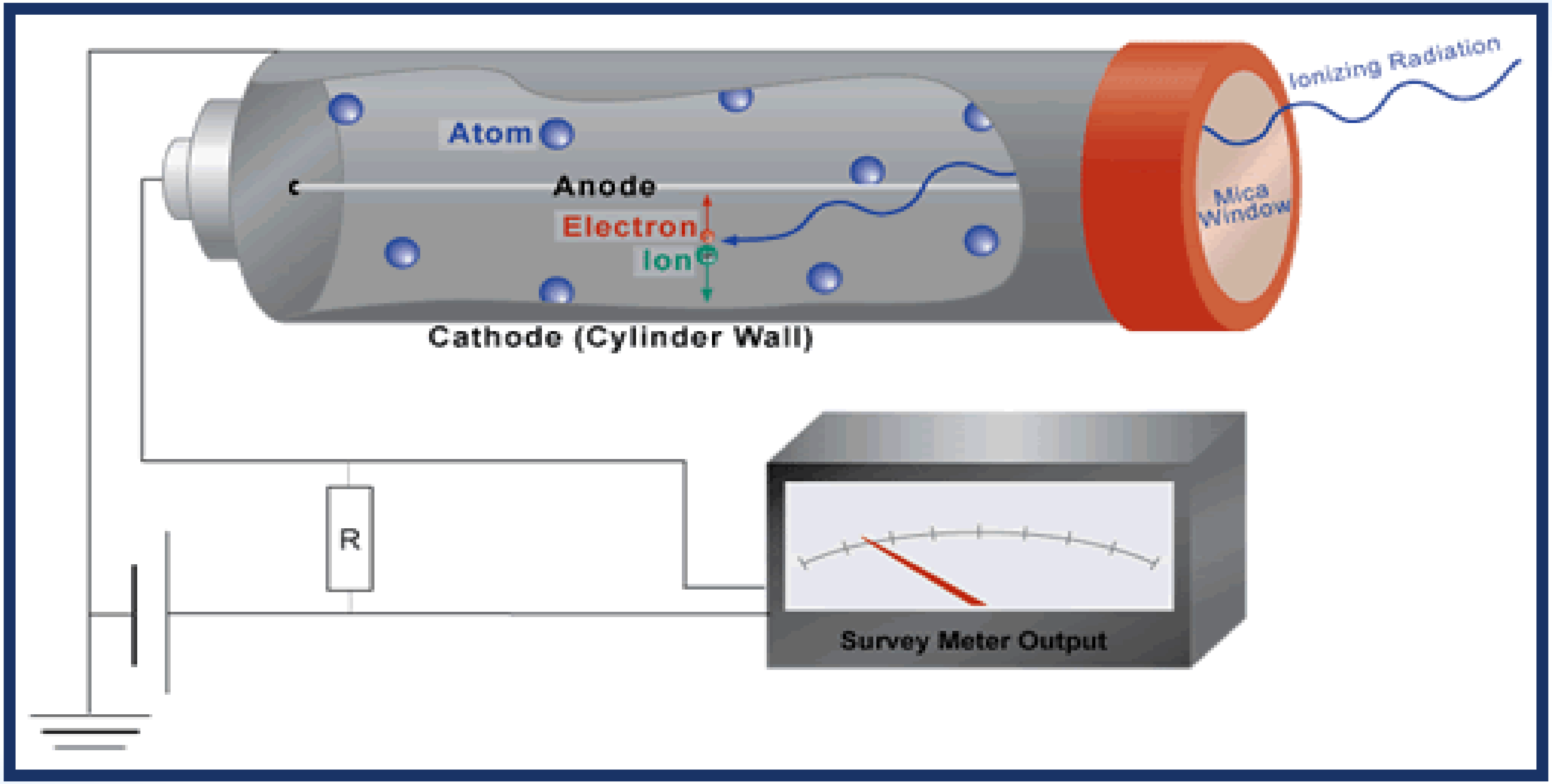
- The instrument required is determined mainly by the anticipated range of dose rates and whether relatively low energy radiation is present.
- It is important to choose equipment which has a desirable response at the lowest dose rate of interest.
- Another main point of consideration is whether the radiation field has a significant low energy component (below 60 keV) and the range of an instrument.

2. Instruments

The equipment that can be employed are:

- GM counters
- Ionisation chambers
- Proportional counters
- Plastic scintillation detectors
- Semiconductor detectors

Schematic diagram of gas filled detector



Sketch of functioning of a typical GM tube

GM Detectors in Workplace Monitoring

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End Window	Here radiation enters the sensitive volume of the detector through a very thin mica window (1.5 - 3 mg/cm^2). Protection of thin window is taken care by a mesh. End windows GM tubes can detect alpha, beta, and gamma.
Side Wall	This detector has a sliding sleeve. Beta particles (300keV and above) and gamma rays can be detected with the window open. By closing the window the beta contribution is removed.
Pancake	A pancake G-M is similar to the end window in that a very thin mica covering is used. Its design offers a greater detection area than the end window probe.

GM Counters - Merits

Higher sensitivity compared to ionisation chamber

Small size and volume is possible due to higher sensitivity.

Can be operated in ‘pulse’ mode or ‘current’ mode, depending on electronics.

Energy compensated instruments suitable for measuring ambient dose equivalent (H*10).

Relatively inexpensive.

GM Counters - Limitations

- Dead time is about 300 μsec
  - Dead time correction may be needed.
- Saturates at high dose rates.
- No energy discrimination is possible.
- Cannot be used to accurately measure the pulsed source of radiation from accelerators.
- Shows energy dependency, hence filters used.
- Slope of the plateau must be designed reasonably flat for reproducible results.

Energy Dependency of GM Tubes

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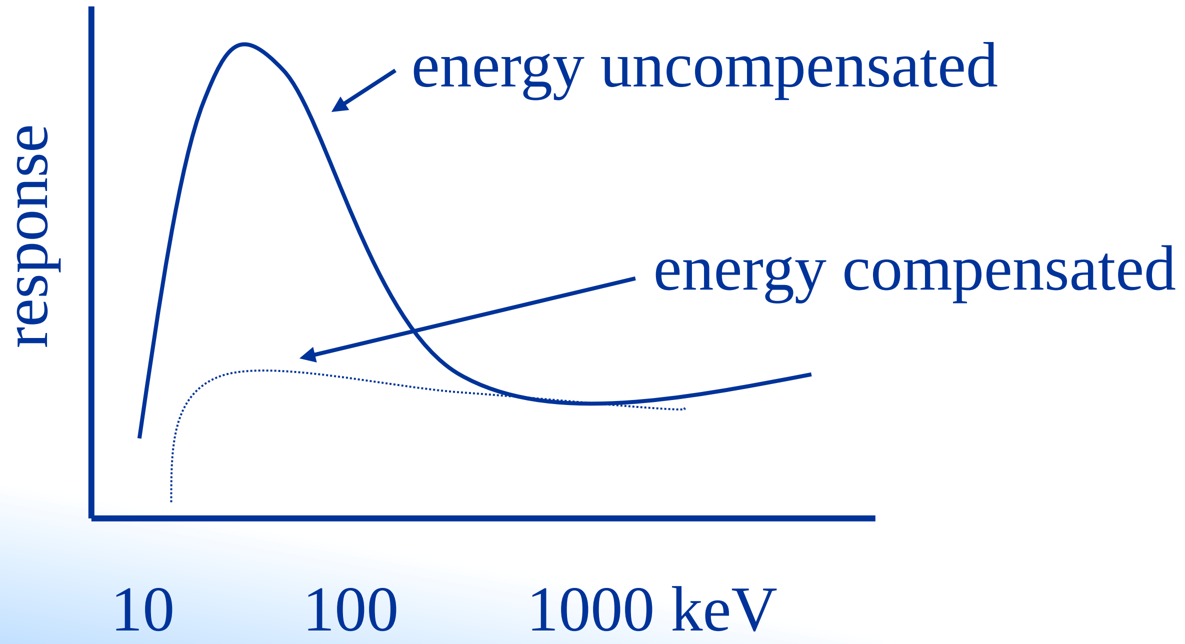
Energy compensation for X, gamma dose below 80 keV.

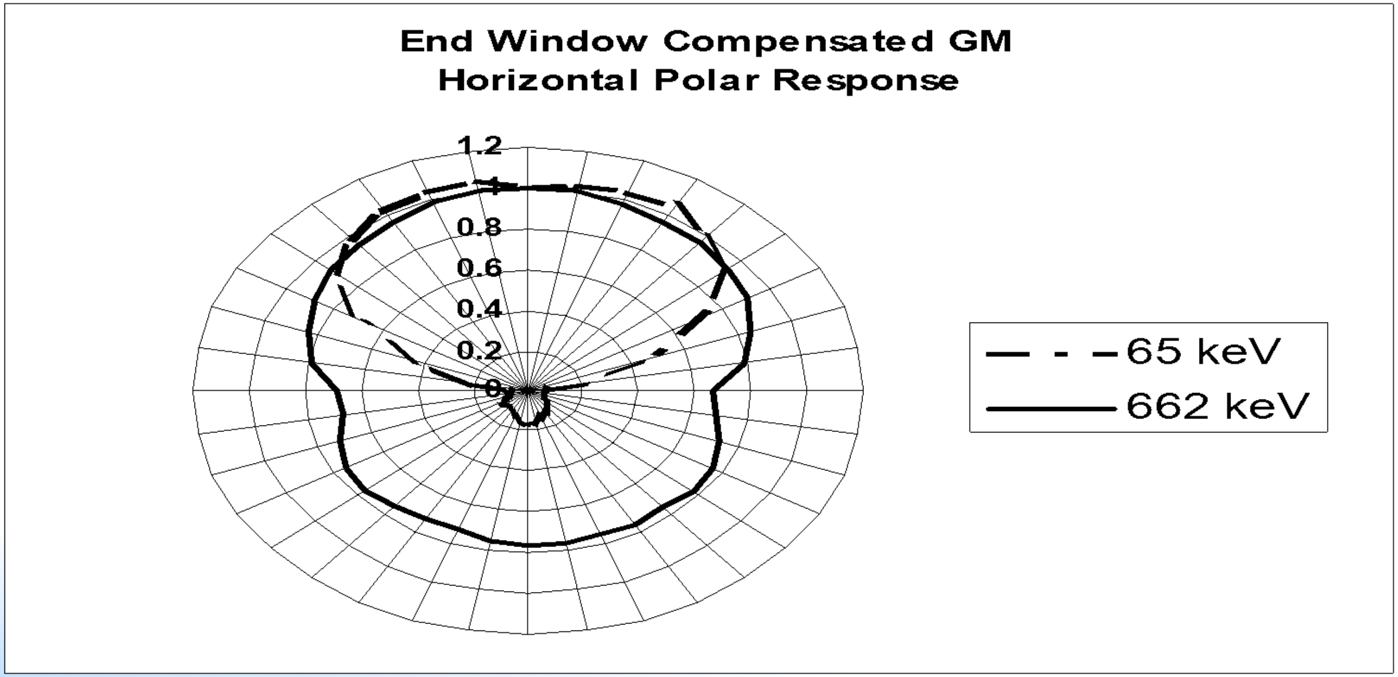
Bare detectors have an energy dependent response.



GM Survey Meter

Polar response of a typical cylindrical GM for X-Ray and Gamma Ambient Dose Equivalent Rates

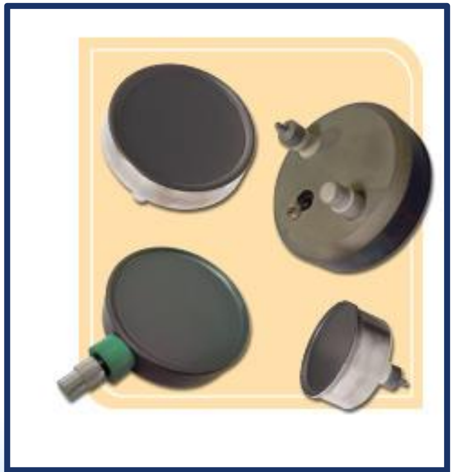
- Good polar response



Typical Examples GM Based Gas Detectors

Miniature GM tubes

End window GM tubes



Pancake GM tubes

Side wall GM tubes

Courtesy: Canberra

Proportional Counters as Survey Meters

Dose rate meters using proportional counters are uncommon, (with some exception).

They are more sensitive than ionisation chambers and suitable for measurements in low intensity radiation fields.

Although smaller than equivalent sensitivity ionization chambers they require highly stable power making them not suitable for workplace monitoring.

Typical Example of Proportional Counters

Proportional counters in various configurations.

Ion Chamber - Characteristics

Detector operates in current mode with air as fill gas.

No gas amplification is required for operation

Designed to measure x-ray and gamma rays

Ideal for exposure rate measurements; can measure very high radiation levels with virtually no dead time

Flat energy response above 100 keV

By increasing the pressure of fill gas the sensitivity can be enhanced

Ion Chamber - Strengths

1	Excellent X, gamma ambient dose equivalent and polar response
2	More reliable in case of high dose rate where GM tubes cannot be used due to overload effect.
3	Suitable for accident dose rate and therefore installed for the purpose of area monitoring.
4	Can be used in pulsed radiation fields
5	Can be used to measure accurately measure beta radiation if window slide provided.
6	Gold standard for exposure measurements.

Ion Chamber - Weaknesses

1. Detector operates in current mode with air as fill gas.
2. No gas amplification is required for operation
3. Designed to measure x-ray and gamma rays
4. Ideal for exposure rate measurements; can measure very high radiation levels with virtually no dead time
5. Flat energy response above 100 keV
6. By increasing the pressure of fill gas the sensitivity can be enhanced

Ionisation Chambers in Workplace Monitoring

Courtesy: Mirion

Portable Ionisation Chamber Survey Meter

Measuring: 1 μSv/h to 1Sv/h

Measure volume: 350 cm^3

Courtesy: Canberra

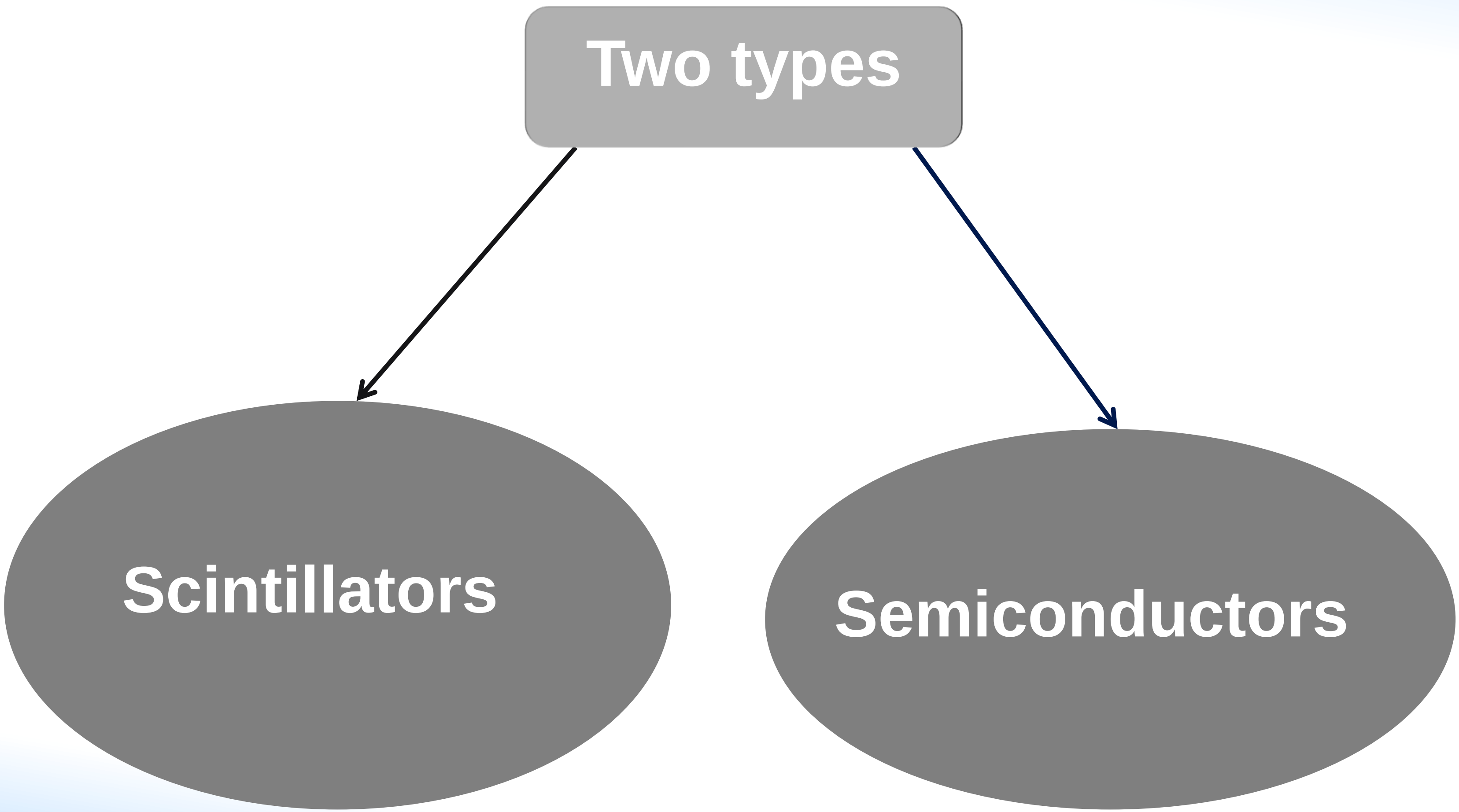
Area monitor

Range:1 μSv/h to 1Sv/h

Detector: Ionisation chamber probe

GAMMA AND X RAY DOSE RATE MEASUREMENT (SOLID STATE DETECTOR)

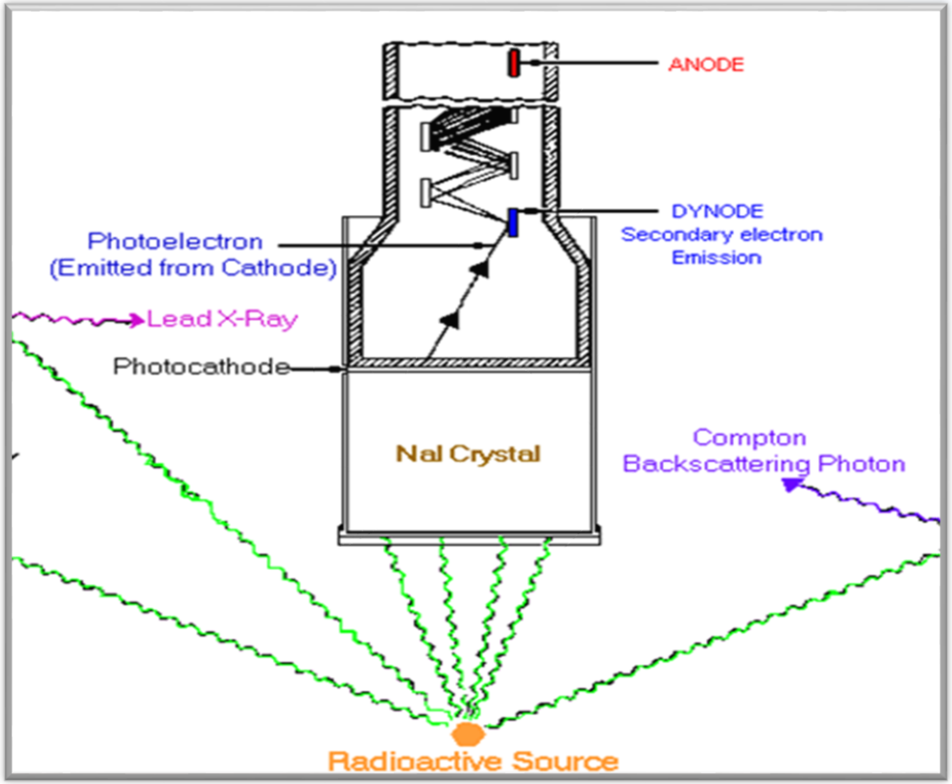
Solid State Detector



Scintillation-Phenomenon

- Scintillation is the process through which ionizing radiation is converted into visible light photons.
  - This type of luminescence called radio-luminescence.
- Scintillation can provide the energy information and hence can be useful in nuclear spectroscopy.
  - The size of the light pulse is determined by the amount of energy deposited in the event.
- It takes place in the time scale of nano seconds.
- Plastic scintillator, NaI(Tl), CsI(Tl) or LaBr:Ce^{3+} used.

Schematic diagram of scintillator



Interaction of gamma with NaI(Tl)

Scintillator - Characteristics

- High atomic number and hence high efficiency for gamma
- Sensitivity is 10^3 to 10^4 times higher than gas detectors depending on the material.
- Higher stopping power enhance the probability of energy deposition.
- Intensity of light is proportional to the energy.
- Can be operated at room temperature.

Scintillator as Survey Meters

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NaI(Tl) based scintillators are used both for as area monitors and portable as survey instruments.

Sleek plastic scintillator based instruments with a wide range of 0.01μSv/h to 10 Sv/h are also available.

Palm or credit card sized radiation dosimeters based on Si diode with a wide range of dose(1 μSv to 10 Sv) and dose rate (1mSv/h to 10Sv/h) have been introduced recently.

Some configurations also provide spectral information of radionuclide present.

Examples of Scintillators as Dose Rate Meters

Area Gamma Monitor:

Range: 0.1 μSv/h to 100 mSv/h

Courtesy: Canberra

Micro R survey meter:

Range: 0.01-100 mSv/hr

Courtesy: Nucleonix

Plastic scintillator: Survey meter

Range:1 nSv/h to 100 μSv/h.

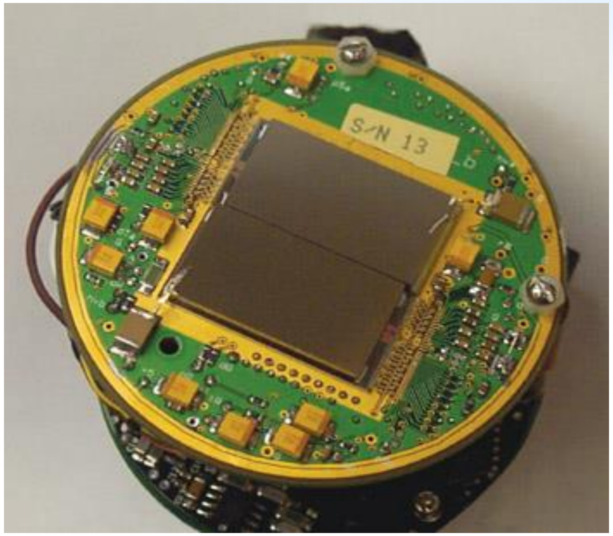
Semiconductor - Characteristics

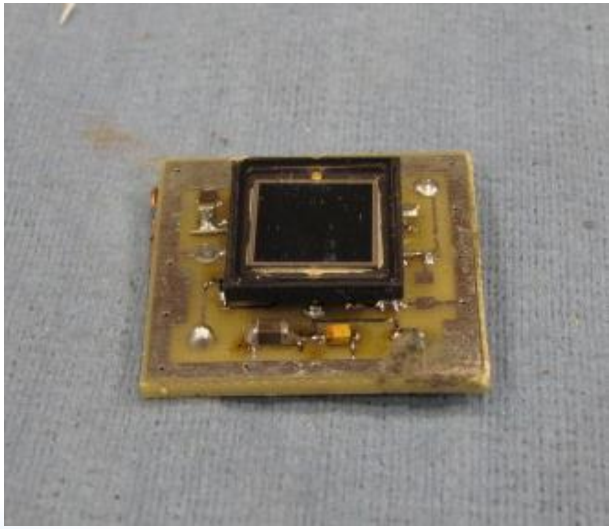
- Types
  - Si diode
  - Cadmium Zinc telluride (CdZnTe)
- Dimension- small in size
- High Energy resolution (HPGe) and therefore suitable for radiation spectroscopy.
- HPGe is available with higher efficiency (nearly 100 %) with along with high resolution.

Semiconductor - Examples

Courtesy: Fuji electric

X-Gamma Silicon Survey Meter
Range: 0.01µSv/h to 99.9 mSv/h





CALIBRATION AND TESTING

Calibration

Calibration is defined as the quantitative determination, under a controlled set of standard conditions, of the indication given by a radiation measuring instrument as a function of the value of the quantity the instrument is intended to measure.

Will typically include:

- Response to high dose rates
- Linearity
- Energy dependence
- Directional dependence

Calibration

- Calibration should use radiation qualities defined in (ISO 4037-3 – 662 keV of ^{137}Cs, ^{241}Am-60keV).
- Calibration is conducted at dose rates representing between 1/3 and 2/3 of each measurement scale.
- Calibration factor between ±1.2 is an acceptable calibration factor.
- Generally, the linearity should be determined using either ^{137}Cs or ^{60}Co gamma radiation over the range of dose rates for which the instrument will be used.

Calibration

- Any uncalibrated ranges should be identified on the instrument.
- Calibration should be made at least every year
- Calibration of installed monitors is performed by the manufacturer. After that, it is tested in-situ using a calibrated instrument or a source, including:
  - Function check
  - Background indication
  - Alarm check (including high & low dose rate response)
  - Response to high dose rates

Functional Testing

For an installed instrument, will typically include:

1 Functional check

- check indicator lights are functioning
- visual check of physical condition
- check alarm using the check function, if available.
- check display operates correctly

2 Background indication

Functional Testing

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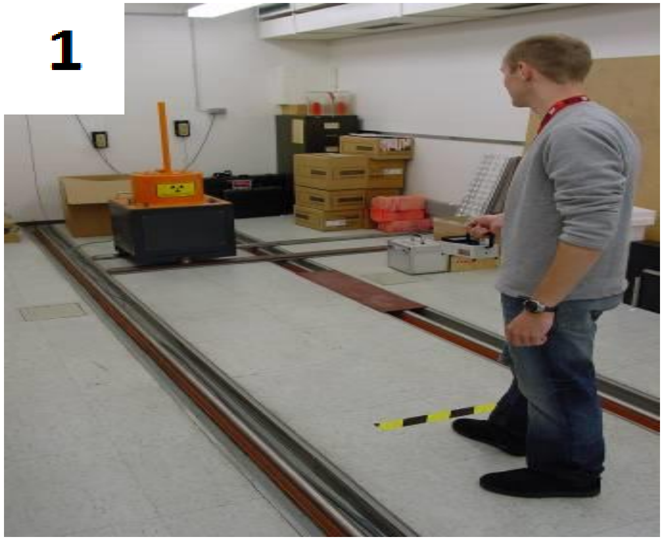
For a portable instrument, will typically include:

- Physical integrity of the detector, cable, probe
- Calibration validity
- Battery condition
- Background reading
- Check source reading within the expected range
- Alarm check

PRACTICAL DOSE RATE MONITORING

Practical Dose Rate Monitoring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1.High activity sealed source; keep distance.

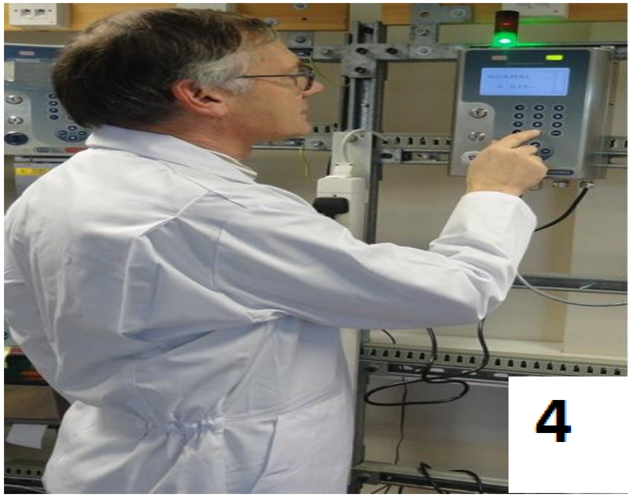
2.Searching for contamination


2


3

3.Gamma radiography with a high activity sealed source

4.Installed gamma monitoring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Practical Dose Rate Measurement(1)

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1. Choose the right equipment for the purpose.
2. Perform a functional test.
3. Check the calibration validity.
4. Set alarm signals for the task (dose rates and integrated doses).
5. Make a survey of the radiation field and point of interest.

Practical Dose Rate Measurement(2)

1. Direct the detector to the highest dose rate
2. Be aware of collimated beams
3. At unexpected high or low dose rate, act immediately
4. Use appropriate time constant for detector reading to stabilize
5. GM or proportional counters should not be used in pulsed beams

Practical Dose Rate Measurement(3)

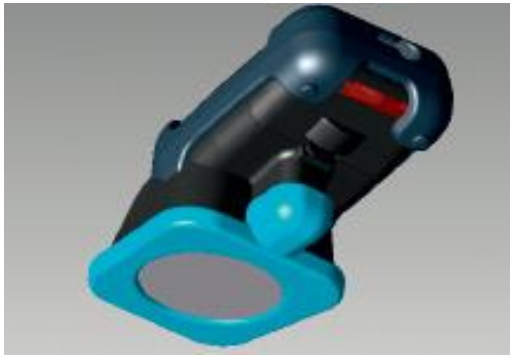
- Use telescopic detectors (or remote detectors for installed applications) for high dose rates source
- Use audio signal and/or rotating beacon
- Minimize the time spent in the radiation field
- Cover the probe with sleeve to avoid contaminating the equipment
- Turn the equipment off when not in use.
- Don’t hold the probe by the cable.

SPECIALIZED EQUIPMENT - EXAMPLES

Energy Compensated Pancake G-M

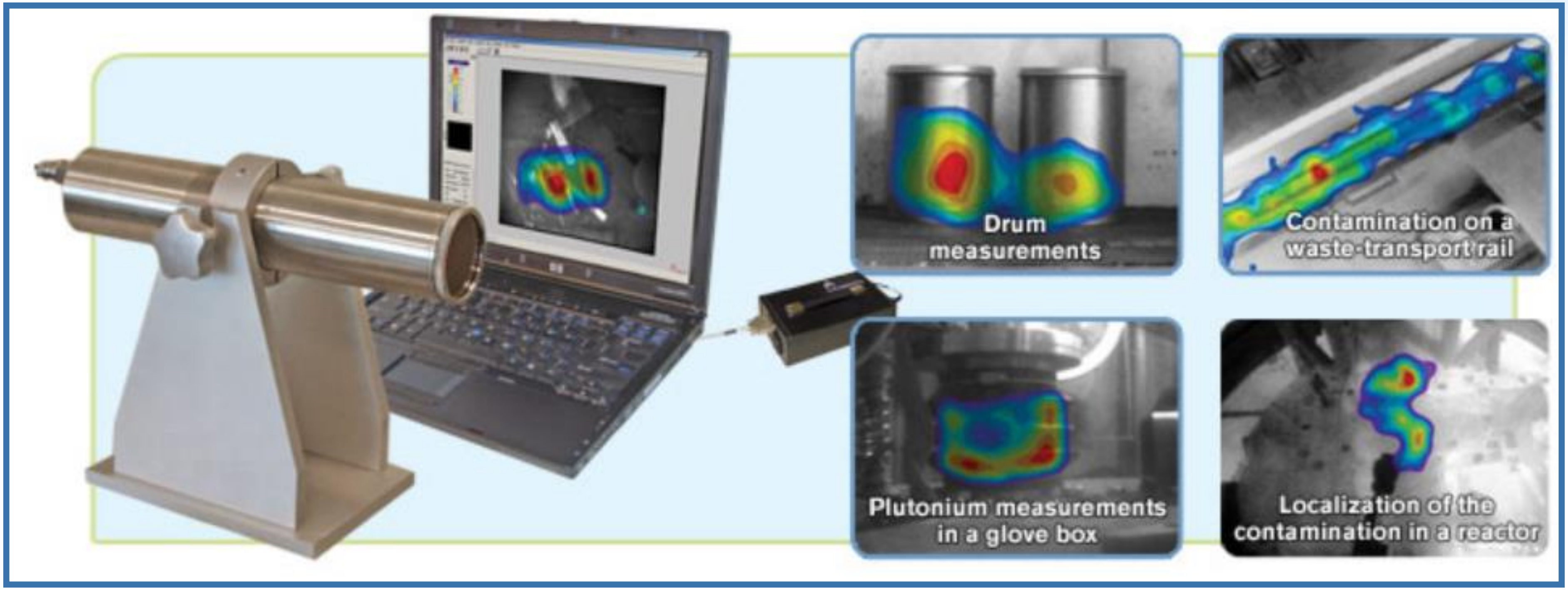
Features:

- 1.8 to 2.2 mg/cm^2 Ultra Thin Mica Window
- 28 or 45 mm effective diameter
- High alpha, beta and gamma efficiency
- Cost effective with unmatched quality/cost ratio
- Measurement range: less than 2 mSv/h
- Photon energy range:17 keV to 1.3 MeV



Courtesy: Thermo-Fisher

Gamma Camera

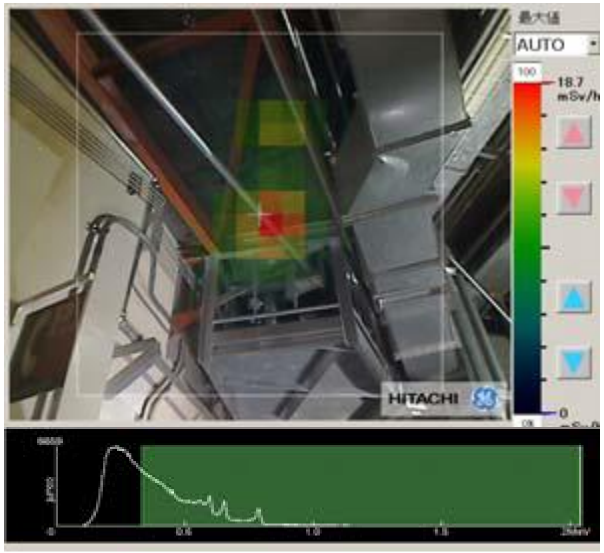


Gamma camera employed for detecting contamination in workplace monitoring

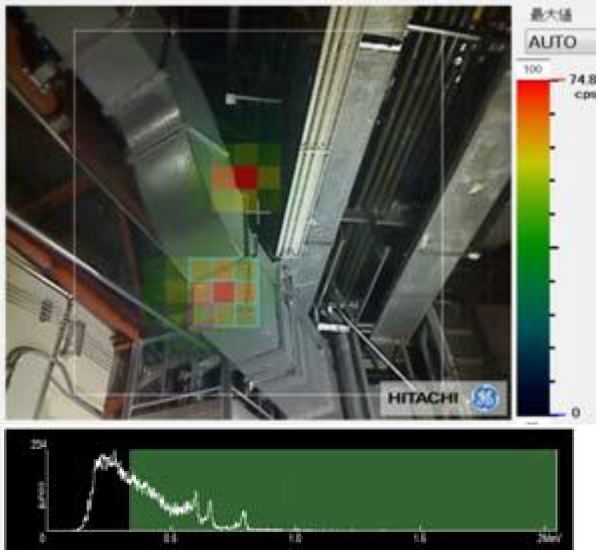
Gamma Camera Employed at Fukushima

Gamma Camera Employed at Fukushima Plant

P1A



P2A



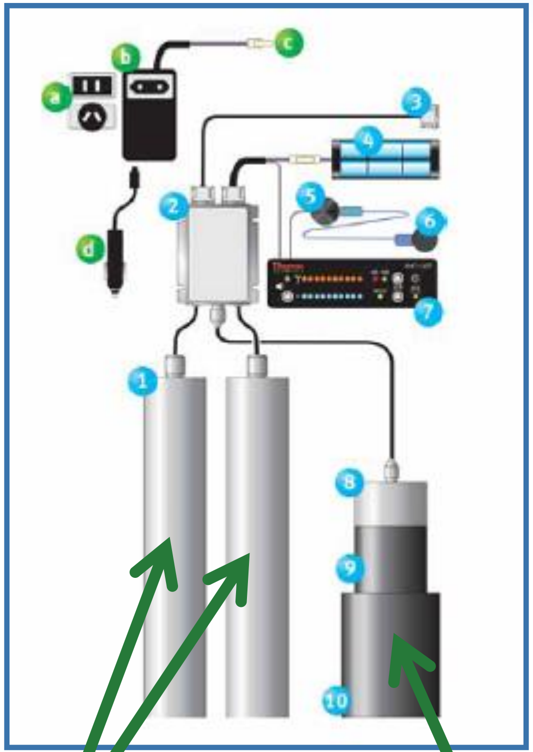
Visualization results in the reactor building of the Fukushima Dai-ichi nuclear power plant. P1-A and P2-A are images of the same penetration holes observed from different locations with the gamma camera built with CdZnTe.

Ref: ***Progress in Nuclear Science and Technology,*** **Volume 4 (2014) pp. 14-17**

Backpack for Searching of Sources

Alarm at +20% BG

Energy range: 50 keV to 3 MeV



BF_3 neutron detectors

Plastic scintillator for gamma

Novel Radiation Detectors

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Key Features

- • Pocket-sized gamma neutron pager
- • Very high neutron and gamma sensitivity
- • Immediate classification of gamma source
- (NORM/non-NORM)
- • Energy compensated gamma dose rate
- • Dual gamma/neutron display
- • No false neutron alarms for even intense
- gamma sources
- • Ideal for law enforcement officers
- and first responders
- • Gamma efficiency: 900 cps per µSv/h (Am-241)
- • Neutron efficiency: 4.3 cps/20,000 n/s Cf^{252}

Courtesy: Thermo fisher

Miniature Radiation Detectors

Miniaturisation results in novel and tiny radiation detectors

NaI scintillator

G-M watch

Mobile phone with app

Summary: Photon Dose Rate Measurement

Always execute measurements with great care

Never take the performance of the instrumentation for granted

Regularly check the equipment

Ensure periodic calibration

Protect yourself from unnecessary exposures