U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

HRTD
Human Resources
Training & Development

Chapter 5:

Instrumentation

Objectives:

- Summarize the advantages and disadvantages of the different types of devices used to monitor individuals for radiation exposure.
- Describe the principal advantages and disadvantages of air ionization chamber type survey instruments.
- Describe the principal advantages and disadvantages of Geiger-Müller (GM) type survey instruments.

Objectives:

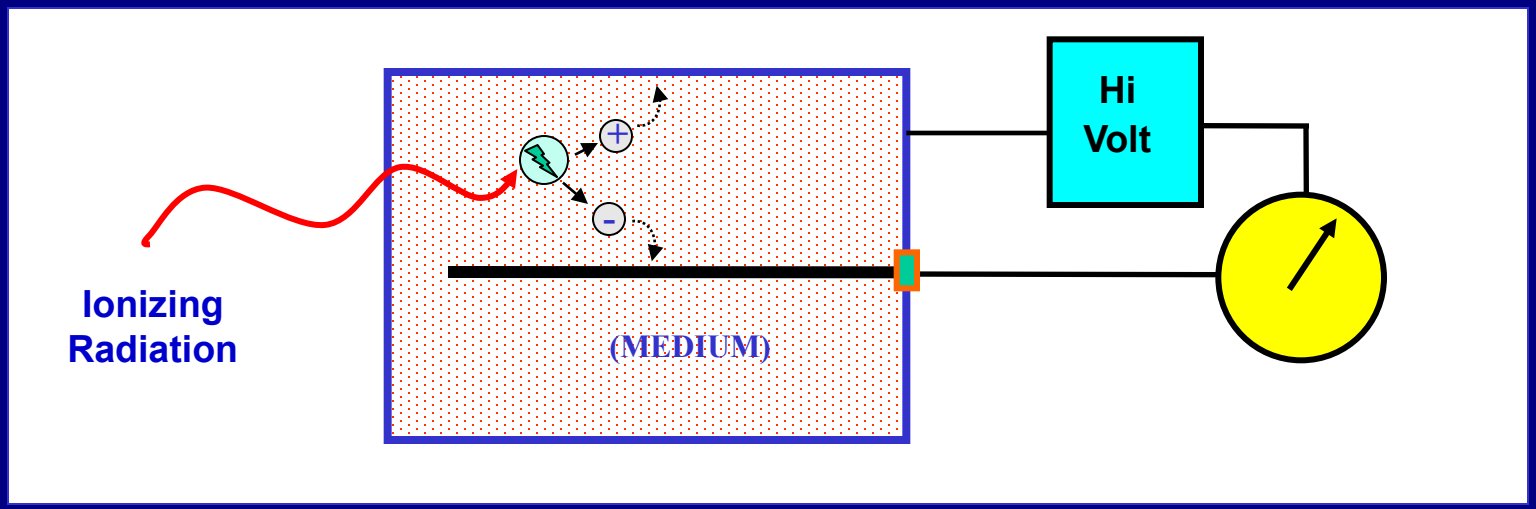
- Describe the important characteristics of any radiation monitoring instrument and why these characteristics are important for obtaining accurate results.
- Select the appropriate survey instrument for a task, and be able to ensure its proper operation and be able to interpret the results obtained.

Overview:

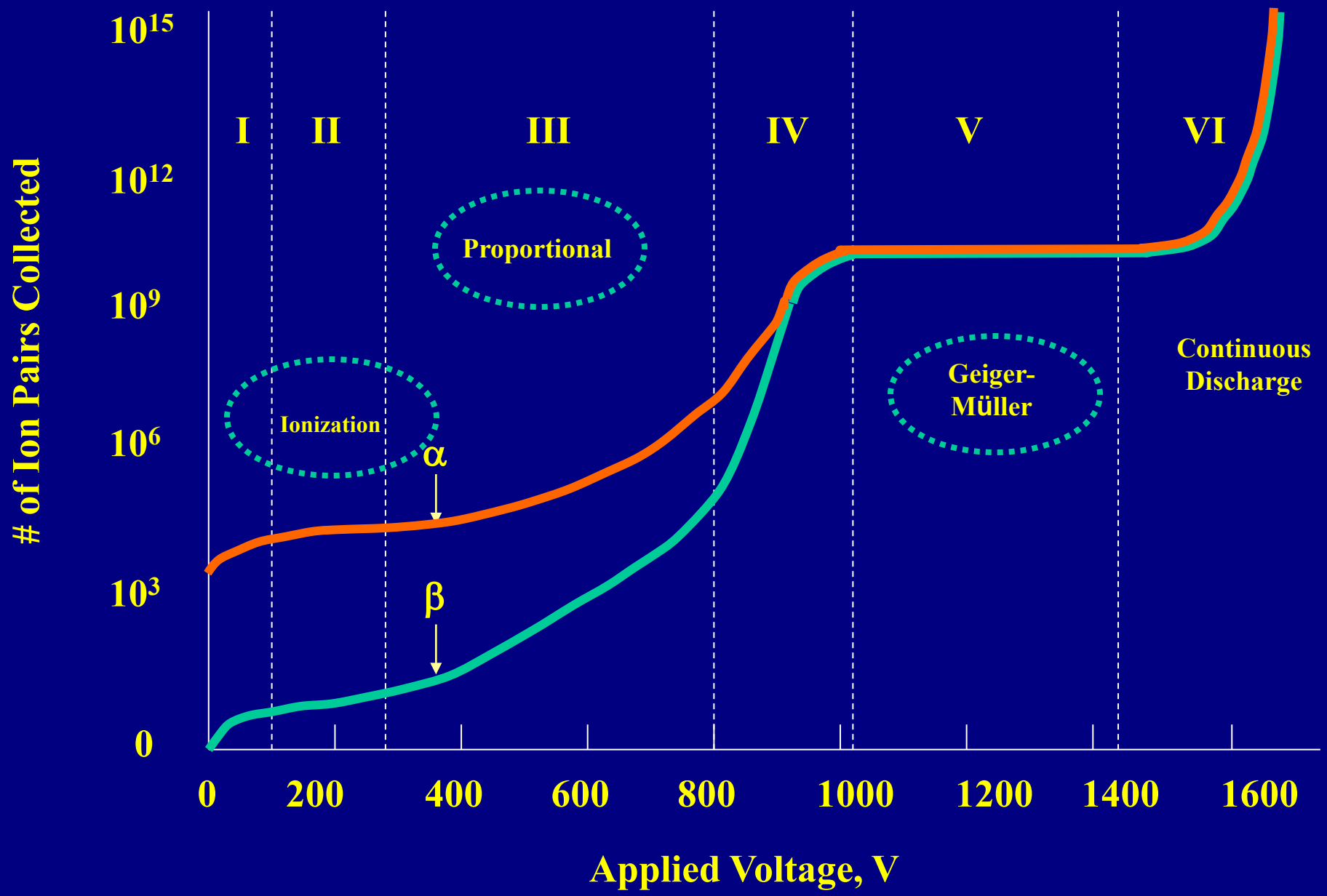
- Humans cannot detect ionizing radiation with any of our senses. But, we need to know:
  - Is ionizing radiation present?
  - Are we receiving dose from ionizing radiation?
  - How much dose have we received (mrem)?
  - Is there contamination present?
- We use instruments which respond to ionizing radiation. The type of instrument needed depends on the type and levels of radiation that are present.
- Radiation detectors respond to ionizations or excitations created by radiation interaction with the detector media. Detectors can either be gas-filled or solid materials.

Instrumentation

Gas-filled instruments for detecting ionizing radiation utilize the concept that radiation interaction with atoms can cause ionizations. The ions are collected and measured. This is used to provide information on the presence of radioactive material (contamination) or the dose rate in an area.



IONIZATION CURVE



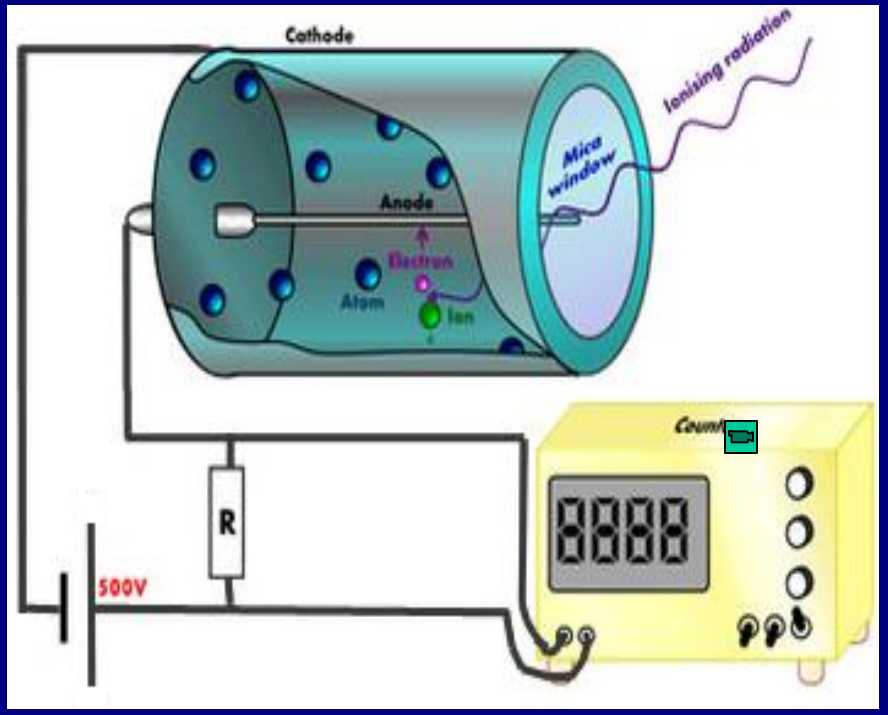
Ionization Chamber

Ionization chambers measure the ionization of air. Most ionization chamber instruments are open to air (are unsealed). Pressurized ion chambers are more efficient and widely used in the industry. Both types of ion chambers are useful in determining dose rates from gamma radiation.

Many detectors in open-air ion chambers have removable shields to allow the measure of dose rates from beta radiation (with use of a correction factor).

Geiger-Müller (GM) Detectors

GM instrument probes are available in a variety of sizes and uses - from measuring dose rates to determining contamination levels.



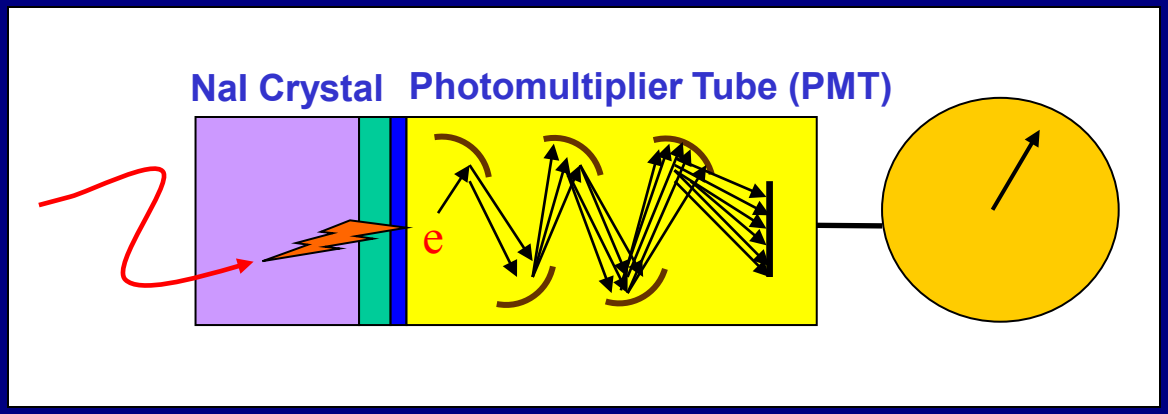
GM tubes are generally filled with a low pressure gas mixture of an inert gas (e.g., Xenon, Argon) and an organic vapor or halon gas.

GM detectors are not able to determine the type or energy level of the radiation.

An “audio” response is a common feature.

Radiation Detectors

Scintillation Detectors

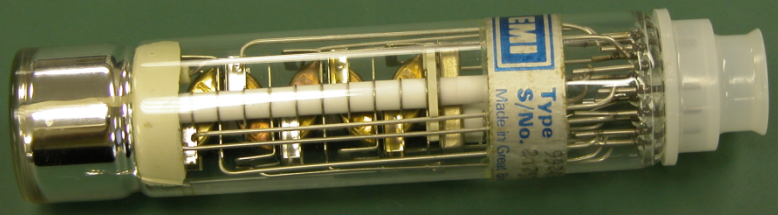


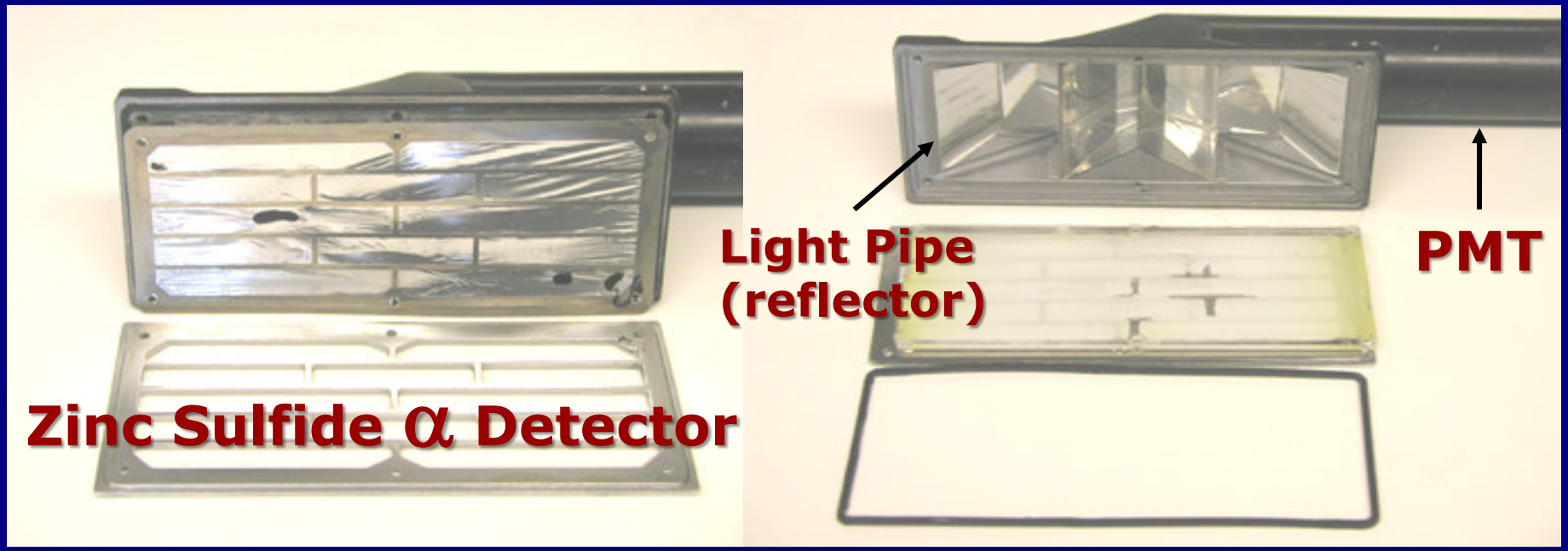
- Scintillation detection systems use some type of substance (usually solid crystal, but can be gaseous or liquid) in which ionizing radiation causes excitation and ionization and results in emission of light. A photo-cathode converts the light to electrons. The PMT then multiplies the number of electrons to create a pulse, or count.

- Crystal detectors are very sensitive to gamma radiation, measuring dose rates in the μrem/hr range. There are probes that can detect alphas, betas, and neutrons as well.

NaI Crystal

Photo-Multiplier Tube





Neutron Monitoring

Some neutron survey meters have a sphere of hydrogenous material which slows down neutrons to allow them to interact more readily with the gas inside the detector, BF_3. The neutron interacts with the boron atom causing an alpha particle to be produced. The alpha particle is detected, and the number of alpha particles is dependent on the number of neutrons interacting with the detector.

The reaction is abbreviated as:

$$^{10}B(n,\alpha)^{7}Li$$

Instrumentation Calibration

Be sure to verify that the instrument calibration is current.

Instrument calibrations do not ensure that the instrument is working properly when used! It only means that the instrument was operating properly at the time it was calibrated.

Instruments should also be source checked (usually daily) to verify proper operation.

Instrumentation Variability

Survey instruments are required to be calibrated (usually annually), but the accuracy is limited to about ±20%.

For this reason your survey instrument may not provide the same reading as another instrument of identical type and make.

Instrumentation Selection Considerations

What type of radiation is present?

What are the levels of radiation?

What do you want to measure - dose rate or contamination?

Is previous survey information available to help with your selection?

What type of detector to use?

Attribute	Geiger – Müller (GM) Tube	Ion Chamber	Scintillation	Neutron Ball
Detects	α, β, γ	β, γ	α, β, or γ	n
Medium	Gas	Gas	Solid/Liquid	Gas
Ranges	.04 mR/hr to 500 mR/hr	1 microR/hr to 10^4 mR/hr	up to 800,000 cpm	up to 500,000 cpm
Use	• Low dose rate • Frisking • Area monitor	• Low to High dose surveys • Area monitoring	• Low level contamination surveys	• Neutron surveys
Advantages	• Rapid response • Large output signal • Moderate sensitivity	• Low energy dependence • Simple to use • Wide dose range	• High sensitivity • Rapid response • Energy resolution	• Rapid response • γ discrimination
Disadvantages	• Long dead time • Energy dependent	• Slow response • Low sensitivity	• Fragile • Expensive	• Requires Hi Volt • Hi maintenance

Instrumentation Use:

- Check that calibration is current. A calibration tells you the instrument was working properly when calibrated.
- Familiarize yourself with the instrument readout "scale," is it in μR/hr; mR/hr; μSv/hr; cpm; KCPM?
- Check the battery (go to Batt Check), but don't leave the instrument on battery check!
- Check the multiplier scale - start on the highest scale and turn it lower until you get a reading. If it is "offscale," LEAVE THE AREA!
- If there is an audio function, make sure it is ON.
- Variability of 10-20% between instruments can be expected.
- Make sure that there has been a radiation response (source) check - does the detector & instrument system respond properly?

Area Monitors - Various Probes

- In addition to portable instruments, you will encounter “area monitors” that monitor radiological conditions in areas of the plant.
- Area monitors can measure dose rate (rem/hr) by using ionization chamber, GM, solid state detector or neutron instruments.
- They may have a light or other alarm associated with them. If they are alarming, leave the area immediately.

Summary

- Instruments respond to ionizing radiation interactions.
- Selection of instrument depends on type and levels of radiation.
- Familiarize yourself with the instrument.
- Check the battery, calibration date, and response check to radiation before using an instrument.
- Start on high scale setting and move to lower until you get a reading.

Summary

- If an instrument “goes off scale” warn others and get out of the area.
- GM (gas filled) and sodium-iodide (solid state) detectors are more sensitive.
- Ionization chamber (air filled) are used for higher dose rates than GM.
- Variation of 10% to 20% is expected when using an instrument.