IAEA
International Atomic Energy Agency

# LESSON 11:

# NOBLE GAS MONITORING

# Noble Gas Monitoring

- Techniques
- Equipment
- Examples of Noble gas Monitors
- Calibration and Testing
- Factors Influencing Volumetric Activity

# Noble Gas Monitoring

- Some of the important radioactive noble gases, which are produced in the nuclear reactors, are;
  - Activation product $^{41}Ar$,
  - Fission product $^{85}Kr$, $^{85m}Kr$, $^{87}Kr$, $^{88}Kr$ and $^{133}Xe$, $^{133m}Xe$, $^{135}Xe$ and $^{138}Xe$.

- A release of noble gases into the working atmosphere indicates a breach of containment including possible clad rupture.

- Noble gases are inert and insoluble deliver;
  - external dose due to immersion
  - lung dose

- Detecting the Fission Product Noble Gases (FPNG) limits and reduce the risk of exposures.

# Techniques

Noble gases cannot be trapped by filters.

By special techniques such as cryogenic techniques they can be collected on suitable medium.

They are monitored either in real time or by taking a grab sample which is subsequently counted by an appropriate detector in the laboratory.

In real time monitoring the sampled air passes through a measurement cell.

The measurement cell may be the detector itself, for example an ionization chamber, or a proportional counter of flow through type, or a sampling cell equipped with a plastic scintillator.

# Techniques

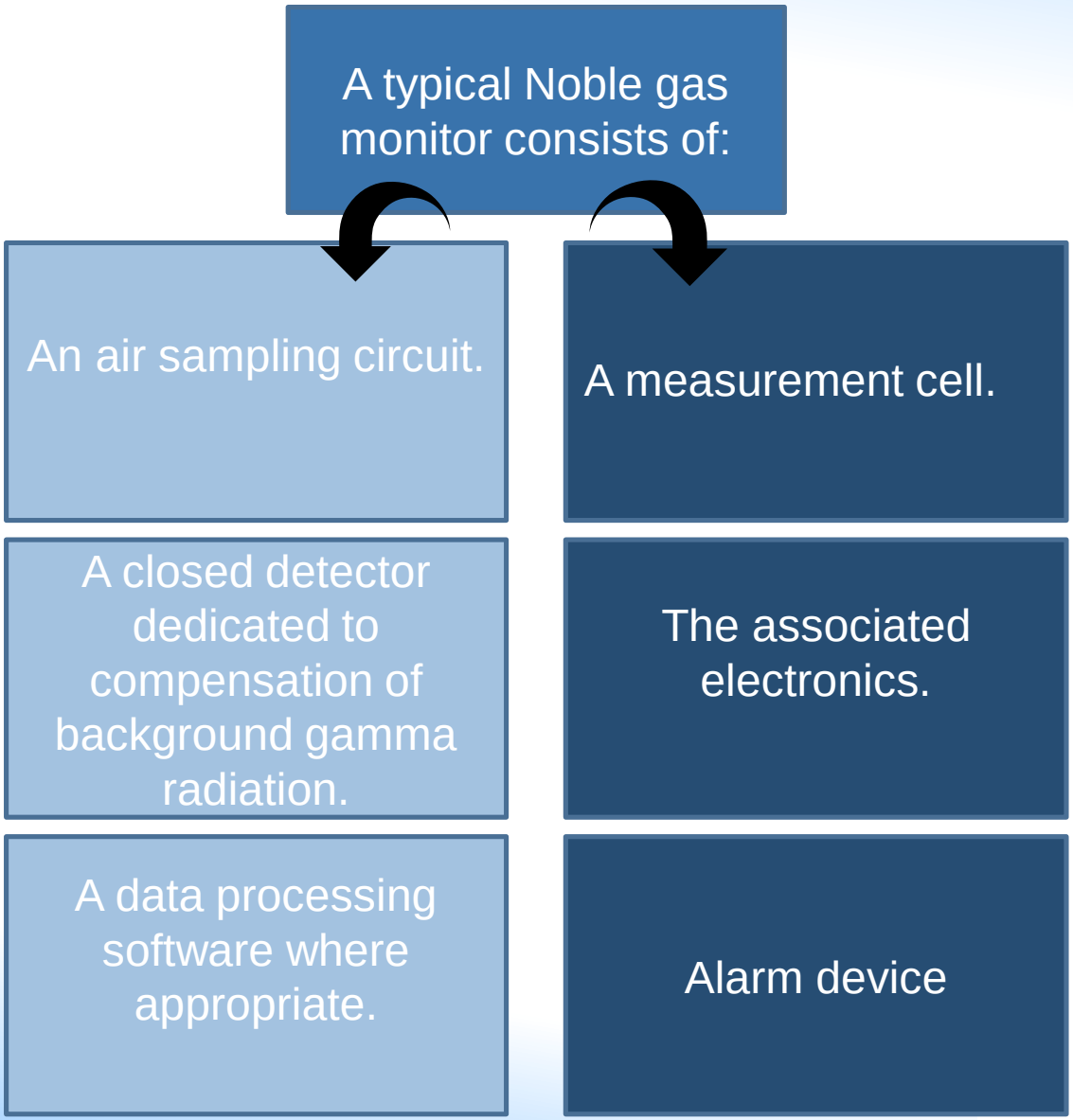
Gamma radiation background in the vicinity is compensated by a sealed identical detector as used for the flow cell.

The reading may be either direct or after software treatment to compensate for the activity of the radon and to improve the detection limit of the instrument.

The readings have to be provided in derived units (e.g. $Bq/m^3$).

# EQUIPMENT

# Equipment


A typical Noble gas monitor consists of:
An air sampling circuit.
A measurement cell.
A closed detector dedicated to compensation of background gamma radiation.
The associated electronics.
A data processing software where appropriate.
Alarm device

# Points to consider for Equipment

- In order to avoid error in the gas measurement the sampling line should include upstream of the detector:
  - A humidity trap (e.g. desiccant)
  - A pre-filter in order to trap particulates
    - The pre-filter should not decrease the flow rate or the pressure inside the measurement cell over the limits specified by the manufacturer.
  - A charcoal filter
    - if iodine is suspected to be present in the area. Iodine isotopes are decay precursors of noble gas (Xe) so trapping the iodine should not result in a false indication of the noble gas measurement.

# Points to consider for Equipment

- The measurement cell should be equipped with a pressure measurement device in order to verify that the pressure is in the normal range of operation.
- The instrument should be chosen depending on its detection limit and the response time required for each particular case.

# Location of Sampling Head

The most important criterion in selecting the location of sampling head is the representativeness of the sample.

The most appropriate location for the sampling head may be selected by the determination of transfer coefficient using a gaseous tracer like helium.

# Sampling Line

If the detector is not directly installed in the area of interest, the gas may be sampled and drawn from the controlled area to the measurement cell.

In this case, the time delay between the sampling point and the measurement cell should be taken into account due to the short half lives of the isotopes.

Noble gases are not subject to trapping on the wall of the sample line.

# EXAMPLES OF MONITORS

# Measurement Cell Equipped with Silicon Diode or Scintillation Detector

Good points:

- Small size monitor.
- Good detection limit: a chamber of 100 ml has a detection limit similar to an ionisation chamber of 10 Litre.
- Usable with high gamma ray background due to the small size and possibility of efficient shielding without significant excessive weight.
- Low influence on sensitivity of the variation of temperature.

# Measurement Cell Equipped with Silicon Diode or Scintillation Detector

- ✓ Insensitive to humidity.
- ✓ Low cost.
- ✓ Low maintenance cost.

Weakness:

- ✗ Sensitive to pressure: the response is proportional to the pressure inside the measurement chamber.
- ✗ Interference of gamma. So the detector should be shielded.

# Measurement Cell Equipped with Silicon Diode or Scintillation Detector

Check for:

- Detection efficiency.
- Calibration of the pressure measurement device.
- Clogging of the inlet filter.

# Ionization Chamber

Good point:

- Low maintenance cost.
- Continuous monitoring of Noble gases in workplace


Courtesy:Doza

Weaknesses:

- Detector larger than measurement cell equipped with silicon diode.

# Ionization Chamber

- Poor detection limit with reasonable size.
- Usable where gamma radiation background is low.
- Due to the size of the detector it is quite difficult to install a shielding.
- Sensitive to temperature.

# Ionization Chamber

- Sensitive to pressure: the response is proportional to the square of the pressure.
- Very sensitive to humidity: it is necessary to include a humidity trap at the inlet of the monitor.
- Sensitive to electromagnetic field: the large chambers should be well screened electrically.

# Ionization Chamber

Check for:

- Detection efficiency.
- Calibration of the pressure measurement device.
- Clogging of the inlet filter.
- Saturation of the water trap.

# Flow through Proportional Counter

Good points:

- Small detector.
- Due to the small size detector can be well shielded.
- Low maintenance cost.

Weaknesses:

- Poor detection limit.
- Sensitive to temperature.
- Sensitive to pressure: the response is proportional to the square of the pressure.
- Sensitive to humidity.

Proportional counter for WPM.

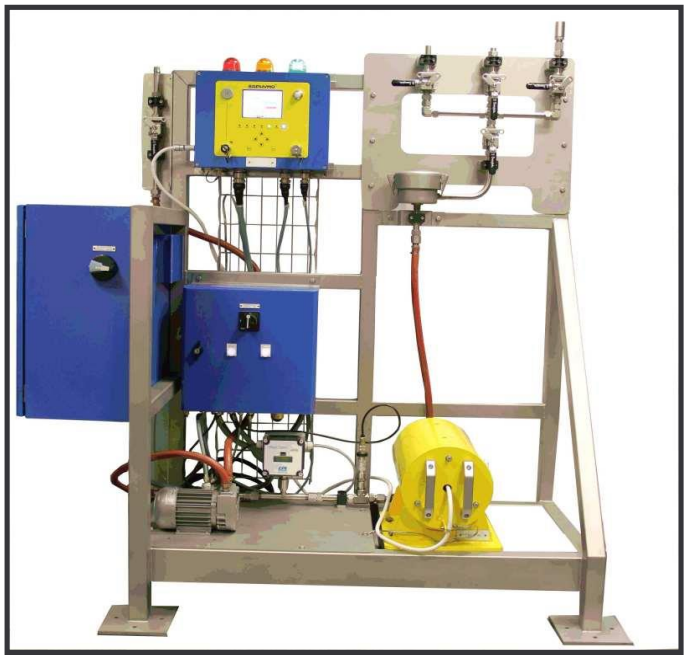
Courtesy: Thermo scientific

# Flow through Proportional Counter

Check for:

- Detection efficiency.
- Calibration of the pressure device.
- Clogging of the inlet filter.
- Saturation of the water trap.

# Examples of Modern Noble Gas Monitors



Detector: HPGe detector

Detector: Flow through ionisation chamber

# EXAMPLES OF MONITORS

# Type Test Report and Certificate

As per IEC 60761-1, the manufacturer shall provide, with each equipment, a certificate giving the following information:

- radioactive noble gas or gases for which the assembly is designed;
- detector type and general characteristics;
- response as a function of the volumetric activity per unit under reference conditions;
- response to the check source;
- response to the other radioactive gases;
- response to interfering gases of concern.

# Calibration and Functional Testing

- Each air monitoring instrument is required to have a valid calibration certificate before use
- Functional testing should be defined by the manufacturer and usually includes testing the detection efficiency with a radioactive source at regular intervals.
- The detection efficiency measured with a checking source is only an equipment functional check.
- Unless otherwise indicated by the manufacturer, this value should not be used as a calibration factor.
- The pressure measurement device should be verified at regular time intervals by comparing with a calibrated pressure measuring instrument

# FACTORS INFLUENCING VOLUMETRIC ACTIVITY

# Factors Influencing Activity Concentration

Determination of the volumetric activity of the noble gas may be influenced by three parameters:

- The energy of the radionuclide detected.
- The pressure of the gas inside the measurement cell.
- The presence of natural radioactive gas such as radon.

# Energy of Radionuclide Measured

The detection efficiency is affected by the radiation type and energy of the radionuclide measured.

The response of the instrument to different energies should be measured during type testing and provided by the manufacturer.

# Pressure of the Gas Measured

- The volumetric activity is normally indicated for temperature and pressure of the gas at the inlet of the assembly.
  - The manufacturer should identify if any correction is required and the method to address this.
- The manufacturer should indicate the influence of other radioactive gases such as radon on the indication of the monitor.