Aim:

To Validate the calibration of radiation survey instruments and Pocket Dosimeters.

Apparatus required:

1. Radiation Survey Meter
2. Digital Contamination Monitor
3. Micro Digital Pocket Dosimeter
4. Cs-137 source with Lead Shield
5. Calibration Bench and other accessories

Theory:

Radiation Survey meters and Contamination Monitors are hand-held ionizing radiation measuring instruments used to check the radiation level in an environment containing radioactive sources or radiation-generating equipment. These instruments use gas-filled radiation detectors, semiconductor radiation detectors, or scintillation detectors. Out of these three, Gas-filled radiation detectors are very commonly used. Gas-filled detectors have three types: the Ionization chamber, the Proportional counter, and the Geiger - Muller (G.M.) counter. They all work in their respective voltage region.

G.M based instruments

Geiger-Muller radiation counter tubes (G.M. tubes) are intended to detect alpha particles, beta particles, gamma, or X-radiation. A G.M. tube is a gas-filled device that reacts to individual ionizing events, thus enabling them to be counted. A G.M. Tube consists of an electrode at a positive potential (anode) surrounded by a metal cylinder at a negative potential (cathode). The cathode forms part of the envelope or is enclosed in a glass envelope. Ionizing events are initiated by quanta or particles entering the tube through the window or the cathode and colliding with the gas molecules. The gas filling consists of a mixture of one or more rare gasses and a quenching agent. Quenching is the termination of the ionization current pulse in a G.M. tube. Effective quenching in the G.M. tube is determined by the combination of the quenching gas properties and the value of the anode resistor.

Radiation survey meter [Model: RM701N]

Radiation Survey Meter (micro) RM701N is a G.M. Detector-based, battery-powered, hand-held, ruggedized general-purpose radiation survey meter used for radiation survey, area monitoring, and ambient radiation monitoring. It uses a thick-walled G. M. Tube with Energy energy-compensated filter to detect X-ray and gamma radiation above energies of about 60 keV to 1.3 MeV. It has an overall wall thickness of about 1-2 mm chrome steel. It can measure radiation levels in the range of 0 -10 R/hr.

Fig.1. Radiation Survey Meter   Fig.2 Thick-walled G. M. Tube Detector

Digital contamination monitor [Model: CM710N]

Digital Contamination Monitor CM710N is a microcontroller-based unit that essentially serves as a low-level alarming survey meter cum beta contamination monitor to measure the contamination of personnel, work areas, flooring, contamination of source housings, ports of therapy machines, industrial sources, etc. It can measure contamination in CPS or CPM mode and low-level gamma dose rate in mR/hr or µSv/h. It consists of a Pancake GM detector housed inside a cylindrical housing with a handle. The contamination probe is fixed into a clamp on one side of the instrument. The probe has a cap for Beta/Gamma selection and can measure dose rate in the range of 0 – 200 mR/hr.

Fig.3 Digital Contamination Monitor   Fig.4 Pancake GM detector

Micro-digital Pocket Dosimeter **[Model: MPD-1501]**

Pocket dosimeters are an integrating device that measures immediate cumulative exposure dose by x-rays and gamma rays. The pulses from the detector are counted in a counter that reads in every 5-second interval. It is based on semiconductor detectors and used in the range of 1μSv to 1Sv. The detector mostly used is a Silicon (Si) rectifier diode operating at a low reverse bias voltage of 4V. A charge-sensitive amplifier based on a low-power CMOS IC amplifies the pulses from the detector. The detector and the amplifier circuits are provided with an energy compensation filter, which also acts as electromagnetic shielding and is enclosed in an anti-vibration polyurethane compound to reduce sound wave interference. The pulses from the amplifier are fed to a discriminator with a threshold voltage adjusted to cut off the noise.

The pulses at the output of the discriminator are fed to a programmable divider circuit to calibrate the dosimeter so that one count corresponds to 1μSv (137Cs gamma). It provides a continuous digital readout of X and Gamma radiation dose displayed in a 6-digit counter-LCD-display.

Fig.5 Micro Digital Pocket Dosimeter.

Calibration of Radiation Instruments

Calibration is defined as the quantitative determination of a parameter given by a radiation measuring instrument as a function of the value of the quantity the instrument is intended to measure under a controlled set of standard conditions. The primary objective of calibration is to ensure that the instrument is working properly and, hence, can be used for monitoring purposes. Calibration also helps to find the deviation of the measuring quantity from its actual value, and if needed, the calibration factor can be adjusted based on the overall measurement accuracy.

All the radiation survey and measuring instruments should be calibrated periodically to ensure that they are giving correct/valid readings and it is also a regulatory requirement. A convincing method to calibrate these instruments is to place them in a radiation field of a known dose rate (produced by radioactive elements) and compare their response with the dose rate. Different calibration factors are used for β and γ radiations. The known dose rate can be calculated from the exposure rate constant of the given radionuclide (Calculation shown below).

<u>Procedure</u>

In this experiment, we will validate the calibration of the Radiation Survey meter, Contamination Monitor, and Pocket Dosimeter. Here, we will use Cs-137 (activity 3.7MBq) as a reference source. We will place the instruments at a specific distance from the source (as shown in the table).

1. Calculate the Radiation exposure rate at the fixed distance theoretically from the exposure rate constant. This is the reference value (True value).
2. Tabulate the readings shown by the Radiation Survey Meter and Contamination Monitor. (As shown below)
3. Place the Micro Digital Dosimeter at a given distance from the source for a fixed amount of time. A stopwatch can be used to set the time. (As shown in Table)
4. Tabulate the readings shown by the Micro Digital Dosimeter.

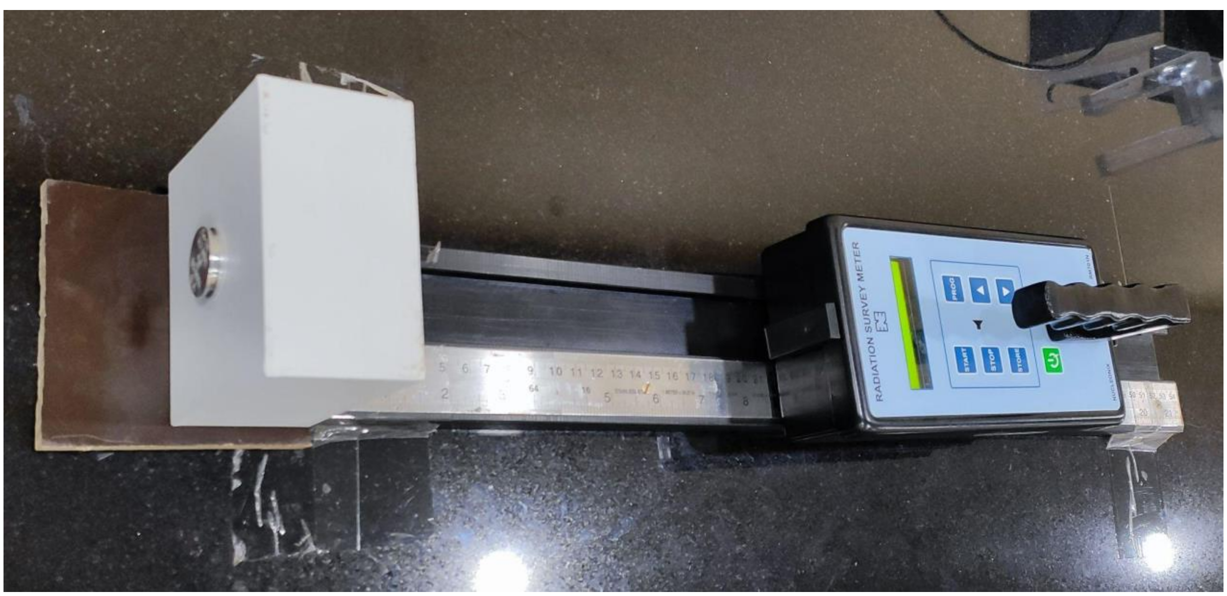

Fig. 6 Setup for Radiation Survey Meter

Fig.7 Setup for Contamination Monitor

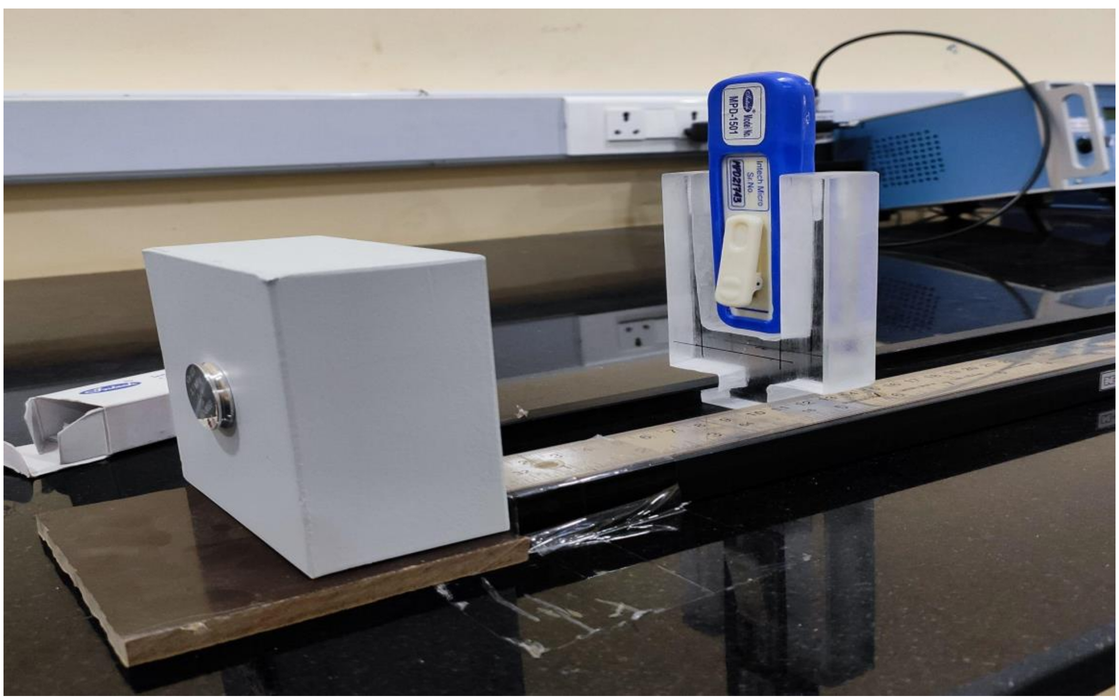

Fig. 8 Setup for Micro Digital Pocket Dosimeter

Tabulation

Response for Contamination Monitor									
Source: Cs - 137		Activity: 3.7MBq						Distance: 50cm	
Background Counts (**B**) = $\frac{B1+B2+B3+B4+B5}{5} = \frac{0.01+0.02+0.01+0.01+0.02}{5}$ = 0.014									
Sr. No.	True Dose Rate	Observed Dose Rate						Corrected Dose Rate	Uncertainty (%)
	(mR/h)	1	2	3	4	5	Avg	(X_c)	
1	0.153	0.160	0.150	0.155	0.169	0.169	0.161	0.147	3.9

Response for Survey Meter									
Source: Cs - 137		Activity: 3.7MBq						Distance: 50cm	
Background Counts(**B**) = $\frac{B1+B2+B3+B4+B5}{5} = \frac{0.01+0.02+0.01+0.02+0.01}{5}$ = 0.014									
Sr. No.	True Dose Rate	Observed Dose Rate						Corrected Dose Rate	Uncertainty (%)
	(mR/h)	1	2	3	4	5	Avg	(X_c)	
1	0.153	0.150	0.145	0.150	0.150	0.160	0.146	0.151	1.3

Micro Digital Pocket Dosimeter						
Source: Cs - 137		Activity: 3.7MBq			Distance: 10cm	
Sr. No.	Time (min)	True Dose Rate (µSv) (D)	Observed Dose (µSv)		Uncertainty (%)	
			MDD-1 (Sr. No. 742)	MDD-2 (Sr. No. 743)	MDD-1	MDD-2
1	10	6.4	7	8	9	25
2	20	12.8	11	14	14	9

Calculation

1. True Dose Rate (R) = $\frac{R\,.\,A}{d^2}$ (R/hr)

   k is the exposure rate constant (for Cs-137, k=0.3818).

   A is the Activity of Radionuclide in Ci at the of experiment

   d is the distance between the source and detector.

2. True Dose (D) = $R' \times t$ (μSv)

   Where, R' is True dose rate in μSv/min. And **t** is time in minutes

   Note: The uncertainty percentage should be ≤ ±15%, as per instrument manufacturing company.

Conclusion: