

**RADIOLOGICAL MONITORING,  
METHOD, INSTRUMENTATION AND  
TECHNIQUES:  
PERSONNEL MONITORING**

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# Introduction

- Atomic Energy Licensing Regulations (BSS) 2010 (Act 304) require monitoring to be carried out on all personnel who work in controlled areas (and selectively in supervised areas).
- Occupational exposure can be delivered to personnel either by sources outside the body in the form of external radiation or by intake of radioactive contaminants.
- Atomic Energy Licensing Regulations (BSS) 2010 (Act 304) require the radiation exposures both from external and internal sources be evaluated to represent an individual dose in a year.
- A devices that is accepted by the AELB are required by all personnel to measure the radiation dose received while working with radiation sources or working in classified areas.

# Objective of Personnel Monitoring

- To provide information on radiation dose received by workers.
- To observe the trends of exposure histories of individuals or groups of workers in order to assess the need for improved standards of radiation protection.
- To provide information in the event of accidental over exposure.
- To provide information about the condition of radiation level at workplace.
- To improve the workers attitudes toward radiation protection in order to reduce future exposures as a results of information given to them.
- To demonstrate the adequacy of supervision, training and engineering standards.
- To provide a record of information which may be needed for legal or epidemiological purposes.

# Personal monitoring

## External monitoring

*(the measurement of dose due to sources outside the body)*

### Whole body monitoring

1. Film badge
2. TLD badge
3. Direct reading dosimeter
4. Others (OSL/RPL)

### Partial body (extremity) monitoring

TLD ring

## Internal monitoring

*(the measurement of dose due to sources inside the body)*

1. Whole body Counter (WBC)
2. Partial Body Counter

Bioassay

# Personal Dosimeters

(External Radiation)



# Film dosimeter @ film badge

- ❑ **One of the oldest detectors of ionizing radiation.**
- ❑ **Film badge consists of two components ;**
  - **A holder (usually made of plastic and incorporating filters of various material e.g. copper and lead filters for PTW-type film holder).**
  - **A film pack (e.g. Agfa-Geveart Film – use two pieces of film of differing sensitivity wrapped in a light tight paper and mounted in water and light tight plastic envelope)**
    - **A sensitive film for normal exposure (low dose)**
    - **Less sensitive film for abnormal exposure (high doses of up to 1Sv or 1000 mSv).**

# Personnel Monitoring Instrument for External Radiation – Film Dosimeter



The PTW film holder for personal dosimetry type 8621

# Film Dosimeter

- The emulsion consists of microscopic grains or crystal of silver bromide (AgBr) dispersed in a gelatin layer on either one or both sides of film base (cellulose acetate).
- Grains size  $\approx 0.1 \mu\text{m}$  (less sensitive film) –  $1 \mu\text{m}$  (sensitive film).
- The radiation absorbed by individual silver crystal will cause a latent image which appear as dark image after chemical processing ( convert  $\text{Ag}^+$  ions to Ag atom).
- The darkening of the film is proportional to the amount of radiation and depending on the type of radiation quality.
- The darkening of the film can be measured by using densitometer.
- Dose to the film is determine by measurement of optical density (O.D.).

# Film Dosimeter



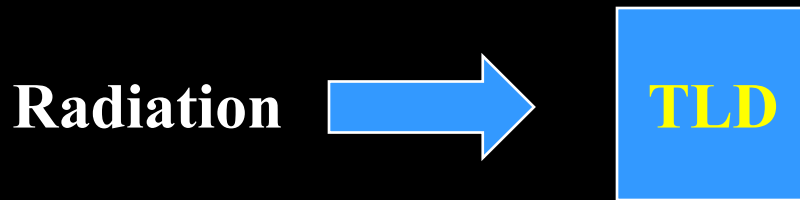
Chemical process – to convert the invisible latent image into a visible image with a range of densities.

# Thermoluminescence Dosimeter (TLD)

- A small device used to measure radiation by measuring the amount of visible light emitted from a crystal in the detector when exposed to ionizing radiation.
- The amount of light emitted is proportional to the amount of radiation absorbed (dose) by the TL material.

# Thermoluminescence Process

Stage 1 : Energy absorbed.



Stage 2 : Energy released.



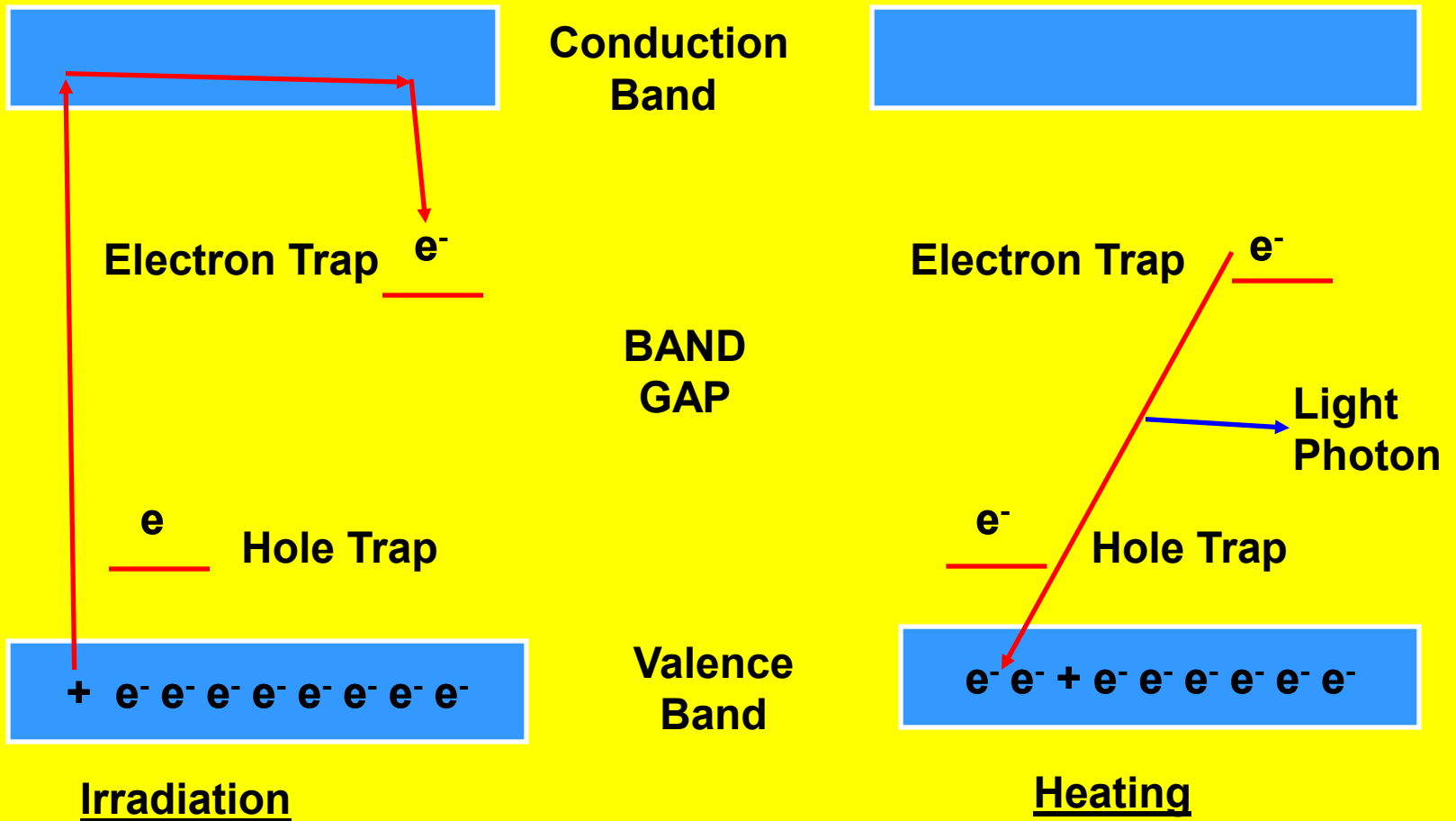
## Personnel Monitoring Instrument for External Radiation – TLD

- The process involve of excited electrons get trapped in a higher energy state.
- When heating at a specific temperature the trapped electrons return to their normal or ground state, release energy in the form of visible light or photons.
- The amount of light released is proportional to the exposure received by the crystal.

# Schematic Diagram of Thermoluminescence Process

Electron promoted to conduction band moves to trap

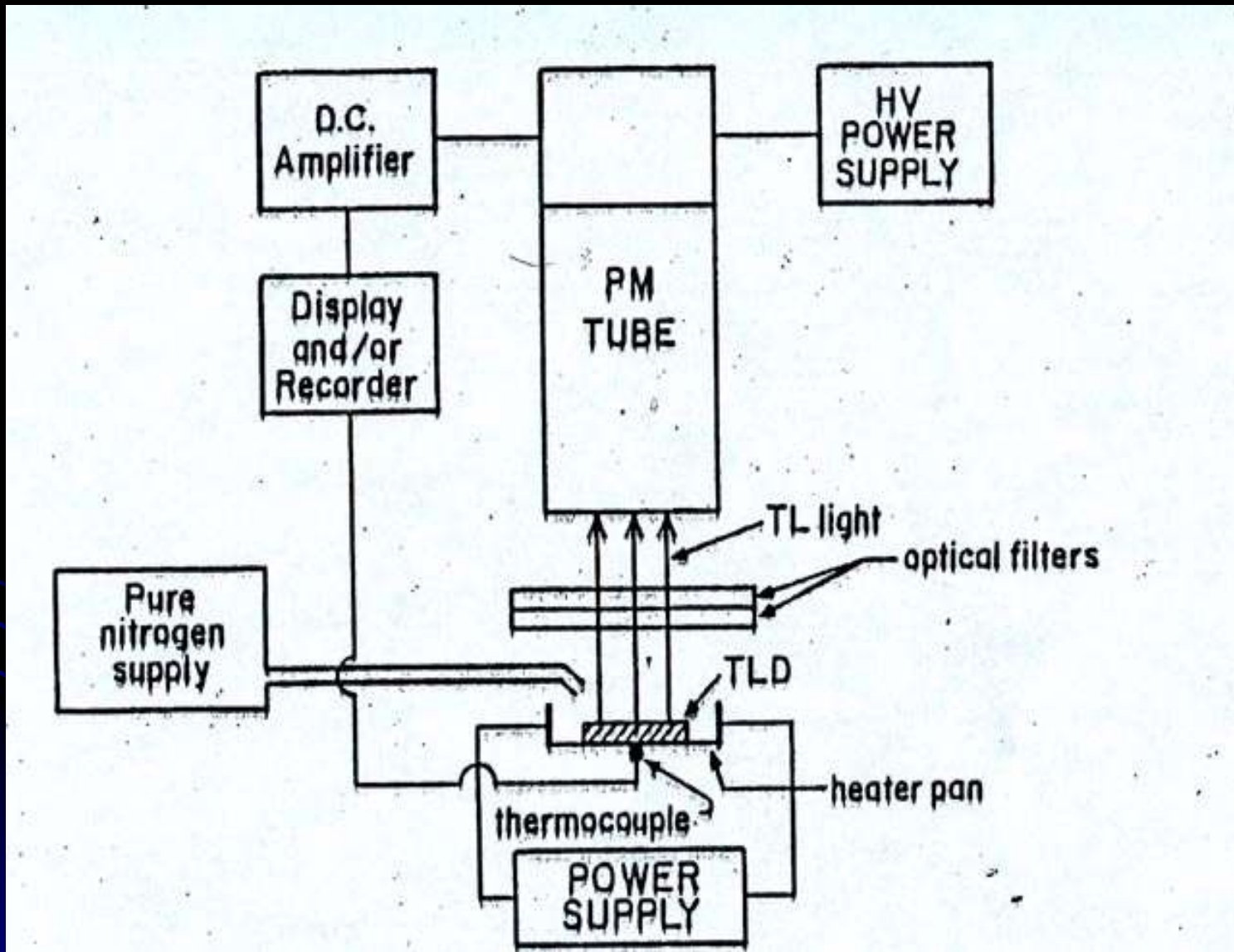
Electron falls to valence band causing luminescence



# TLD Reader

- A TLD reader is the instrument used to heat the TL crystal and to measure and record the light intensity during the heating cycle.
- The output display of such a reader can take the form of the luminescent light output versus temperature graph is called a “*glow curve*”.
- The area under the glow curve is used as a measure of dose.
- The shape of glow curve depends on the type and amount of impurities in the material.

# Schematic diagram of a typical TLD reader



# Typical Glow Curve

Selected

10/14/1999 15:35:31 11 01 CaReader

6.439 nC

ROI1

ROI2

ROI3

ROI4

0.9810 EDC

RCF

2 nA

0 .. 0

0 .. 0

0 .. 0

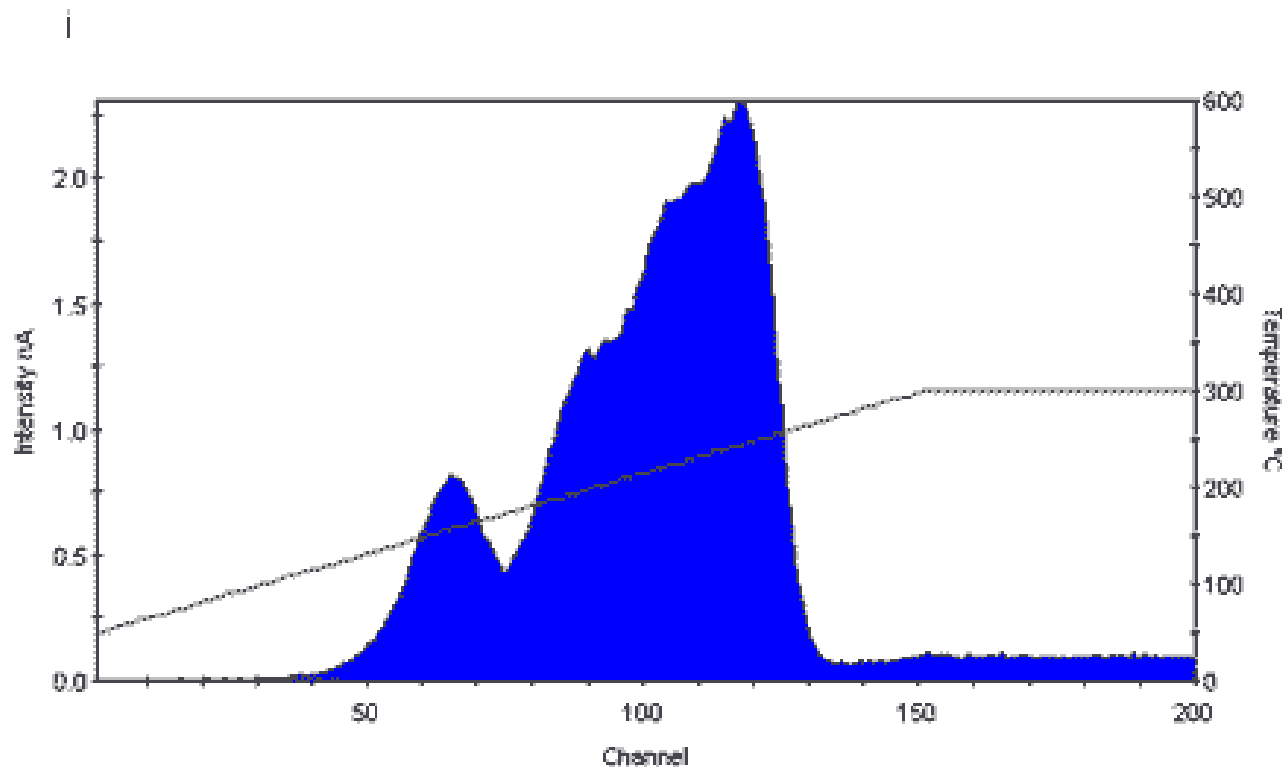
0 .. 0

Channel

Intensity

Temperature

Time



TO SET ROIs, Press appropriate key, left click mouse button, drag, release.

ROI1 (Green)-None ROI2 (Orange)-SHIFT ROI3 (Hot Pink)-CTRL ROI4 (Yellow)-ALT

# Personnel Monitoring Instrument for External Radiation – TLD Dosimeter



➤ The materials that normally used for personal monitoring is Lithium Fluoride (LiF)

➤ In form of TLD badge for whole body dose monitoring & TLD ring for extremity dose



# TLD Badge

The filter configuration of TLD badge is designed to agree with International Commission on Radiation Units and Measurements (ICRU)  $H_p(10)$ ,  $H_p(3)$  and  $H_p(0.07)$  recommendations.

# Personal dose equivalent : $H_p(d)$

## *Definition :*

- The dose equivalent in soft tissue below a specified point on the body at an appropriate depth,  $d$ .
- This quantity is used for the measurement of both strongly and weakly penetrating radiation with personal dosimeters.

## Cont'd

- Depths of  $d = 10$  mm for strongly penetrating radiation and  $d = 0.07$  mm for weakly penetrating radiation are recommended.
- The personal dose equivalent at 10 mm depth,  $H_p(10)$ , is used to provide an estimate of effective dose.
- The sensitive cells of the skin are considered to be between 0.05 and 0.1 mm below the skin surface, and therefore  $H_p(0.07)$  is used to estimate the equivalent dose to skin.

# Personnel Monitoring Instrument for External Radiation

## TLD Badge for Personal Monitoring



Position	Purpose	Filter
1	Energy discrimination	240mgcm <sup>-2</sup> ABS + 91mgcm <sup>-2</sup> Copper equiv. 333 mg.cm <sup>-2</sup>
2	Deep dose @ H <sub>p</sub> (10)	107mgcm <sup>-2</sup> ABS + 893mgcm <sup>-2</sup> PTFE equiv.1000 mg.cm <sup>2</sup>
3	Skin dose @ H <sub>p</sub> (0.07)	Mylar 17 mg.cm <sup>-2</sup>
4	Len of the eye dose H <sub>p</sub> (3)	ABS : 300 mg.cm <sup>-2</sup>

6.8cm



4.1cm

*Acrylonitile-butadien-styrene (ABS)*  
*Poly-tetra-fluoro-ethylene (PTFE)*

# Comparison between film badge and TLD

<b>Film badge</b>	<b>TLD badge</b>
Permanent image record	No image recorded, only recorded the glow curve
Not reusable	Reuseability (manufacturer spec. 500-1000 times)
Direction of radiation incident and presence of radioactive contamination can be detected.	Not possible
Less accuracy ( $\pm 30\%$ )	High accuracy ( $\pm 5\%$ )
Minimum detectable $\approx 200 \mu\text{Sv}$	Minimum detectable dose $\approx 10 \mu\text{Sv}$ .
Measurement of Dose Equivalent only	For depth dose (dose equivalent), skin dose & lens of the eye dose
Maximum of two years storage.	No limitation period.

## Cont'd

<b>Film badge</b>	<b>TLD badge</b>
Sensitive to light	Not sensitive to light
Sensitive to environment (temperature & humidity).	Less sensitive to environment
Not tissue equivalent material	Certain TLD is tissue equivalent material (Ex. LiF and LiBO <sub>4</sub> )
Relatively low cost	High cost

# General rules for using personal dosimeters

1. The user must wear dosimeter all the time when working in controlled area.
2. The dosimeter should be placed at the body location i.e. between the waist and neck level.
3. The dosimeter must be worn *only by the person whom it is issued* .
4. The personnel should used the film dosimeter with the same identification number for the whole working life time or otherwise notified.
5. Never use dosimeter badge/holder other than recommended by the Nuclear Malaysia.
6. Never use a dosimeter without its holder.
7. Never use a dosimeter holder without a complete set of a filter.
8. Never allow any objects to shield the front of the dosimeter.

## Cont'd

9. Dosimeters must not be worn during non-occupational exposure, such as during treatments with medical x-ray.
10. Dosimeter should be protected against damage by heat, moisture, pressure and contamination.
11. Dosimeters not in use should be stored in clean area (ex. administration office).
12. Dosimeters shall be changed on a *monthly* basis or on a duration as permitted by the authority.
13. Use the old dosimeters until the new one received. Change the old with the new dosimeter at the beginning of the month. Return the used dosimeters to the service center for dose analysis.

### **Note:**

- Films returned over 1 (one) year beyond their expiry date will not be processed.
- Finger dosimeter should also be used if hands are likely to receive higher radiation exposure than other parts of body.
- In cases of radiation accident or a higher dose is suspected, return the relevance dosimeter immediately to Nuclear Malaysia.

# Personnel Monitoring Instrument for External Radiation – Pocket Dosimeter

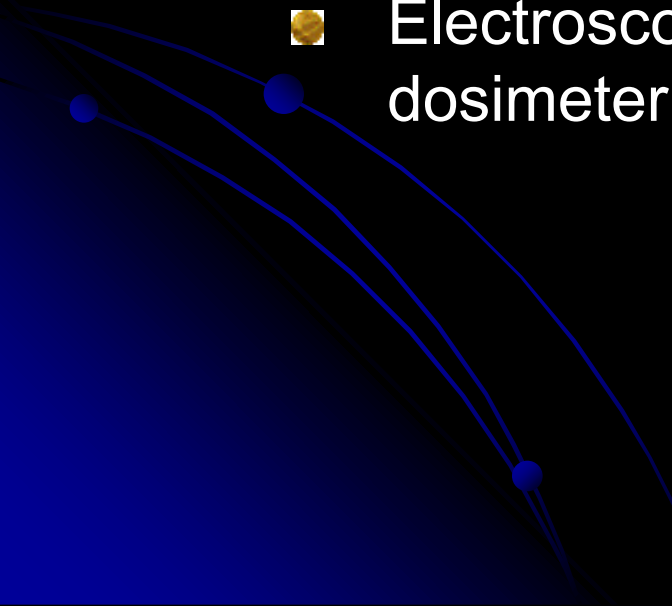
The direct-reading dosimeter **should be treated as an additional or a supplementary** to the approved type of personnel monitoring device.

*Pocket dosimeters are used whenever:*

- ❑ Film/TLD dosimeter is inadequate in the RPO judgments
- ❑ The radiation field is high and to prevent over exposure.
- ❑ A person is temporarily exposed to radiation and only needs to be monitored for a few days for example visitors

# Personnel Monitoring Instrument for External Radiation – Pocket Dosimeter

## *Types of Pocket Dosimeter*

- Electronic personal dosimeter.
  - Electroscope personal dosimeter (pen/pocket dosimeter)
- 

# Direct-Reading Dosimeter

Electronic Personal Dosimeter

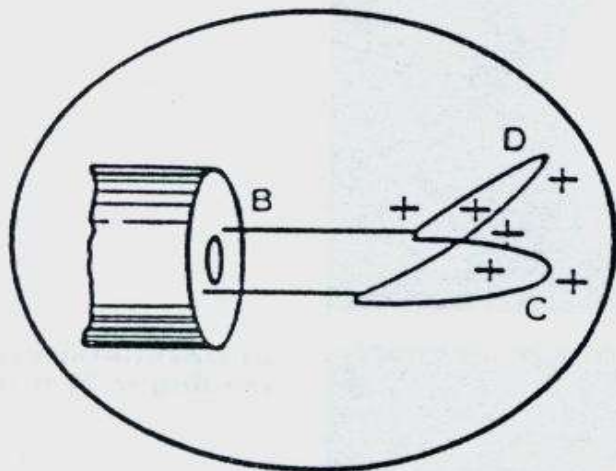
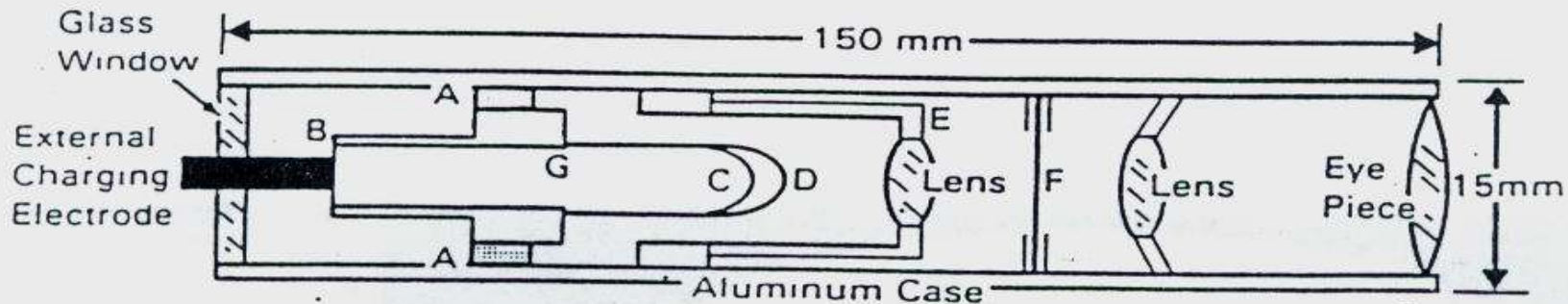


Silicon diode detector for X-ray & gamma ( 60keV – 3 MeV )

Electroscope Personal Dosimeter with charger (pen dosimeter)



# Pocket / Quartz Fiber Dosimeter



Enlarged View of Electrodes

- A - Insulating ring
- B - Charging rod (hollow to admit light from window)
- C - Fixed metal-coated quartz fiber
- D - Movable metal-coated quartz fiber
- E - Metal cylinder
- F - Transparent scale
- G - Metal support for fibers

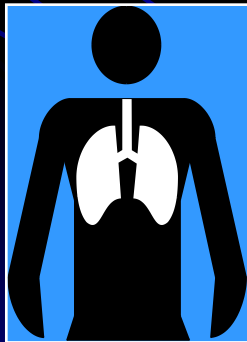
Schematic of construction of pocket ionization chamber

# Personnel Monitoring Instrument for Internal Radiation

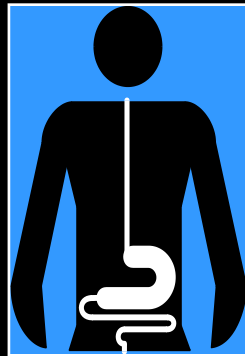
## Monitoring for internal contamination

- Required to be carried out on personnel who work with open or unsealed radioactive sources or in places where contamination is confirmed to be present.
- Radioactive materials can enter the body through:

**Inhalation**



**Ingestion**



**Absorption through  
skin/cut/injury/openings**



# Personnel Monitoring Instrument for Internal Radiation

Monitoring for internal contamination.

- There are two common methods used to determine the internal contamination namely:
  - bioassay; and
  - whole body/partial body counting

# Personnel Monitoring Instrument for Internal Radiation

## Bioassay

- Indirect method used to assess intake of radioactive materials into body.
- Common method used to assess intake of alpha, beta and low energy gamma emitters, e.g. radium-226, strontium-90, phosphorus-32, tritium and iodine-125.
- Examples of bioassay material, urine, feaces and sweat.

# Personnel Monitoring Instrument for Internal Radiation

*Cont.*

Measure radionuclide concentration in Becquerel than convert to radiation dose using standard table given in Atomic Energy Regulation (BSS) 2010.

The measured radionuclide concentration can be traced back to the actual amount at the time of intake using the standard excretion rate of human beings. This estimated amount of intake is compared with the allowable Annual Limit of Intake (ALI) stipulated in the Basic Safety Standard.

# Personnel Monitoring Instrument for Internal Radiation

## Whole body counting

- Direct method of measuring intake of radioactive materials into the body.
- whole-body counting system and is designed primarily to detect penetrating radiation emitted by radionuclides that have been taken into the body
- These systems use spectrometry-quality detectors, such as sodium iodide or sometimes germanium, in conjunction with multichannel analyzers.
- The systems usually incorporate software to quantify the amount(s) of specific radionuclides detected under the assumptions of certain predetermined counting efficiencies.
- System is made sensitive enough to detect and measure weak transmitted gamma radiation emitted by radionuclides deposited in a particular organ in body.

## Conts

- Whole body detector scan along the entire length of the body or with stationary detectors and a movable bed. One type of popular whole-body counting system uses large stationary sodium iodide (NaI) or hyper pure germanium (HPGe) detectors.



New WBC –Nuclear Malaysia  
Hyper pure germanium (HPGe) detector

# Personnel Monitoring Instrument for Internal Radiation

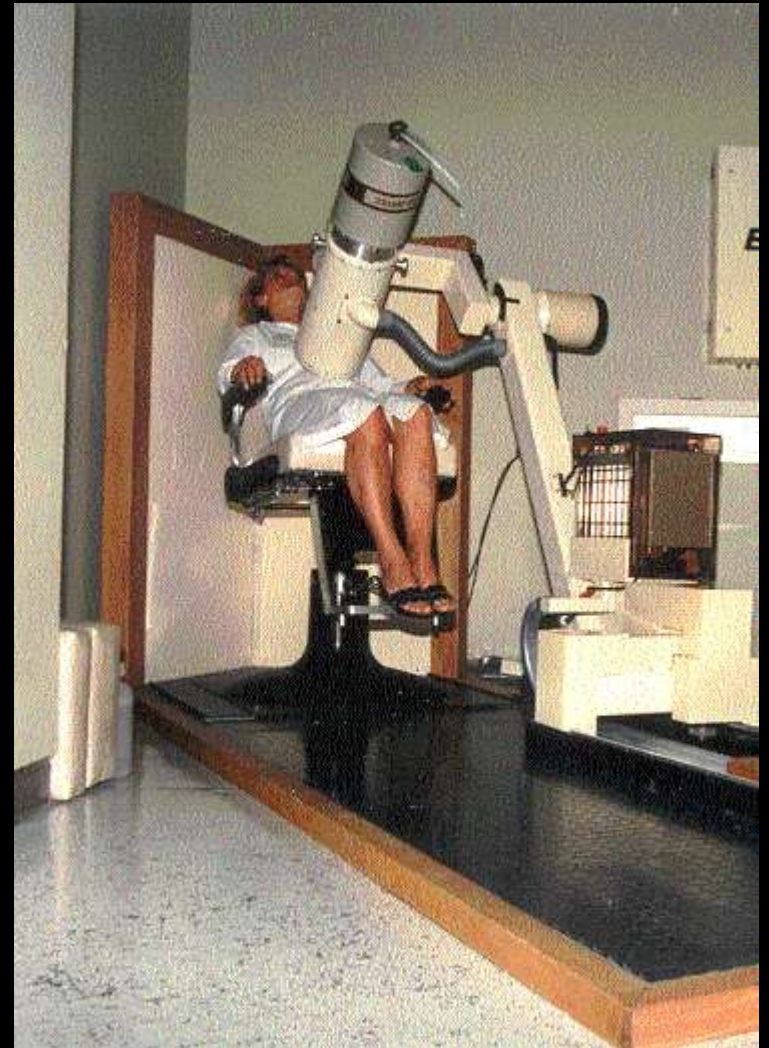
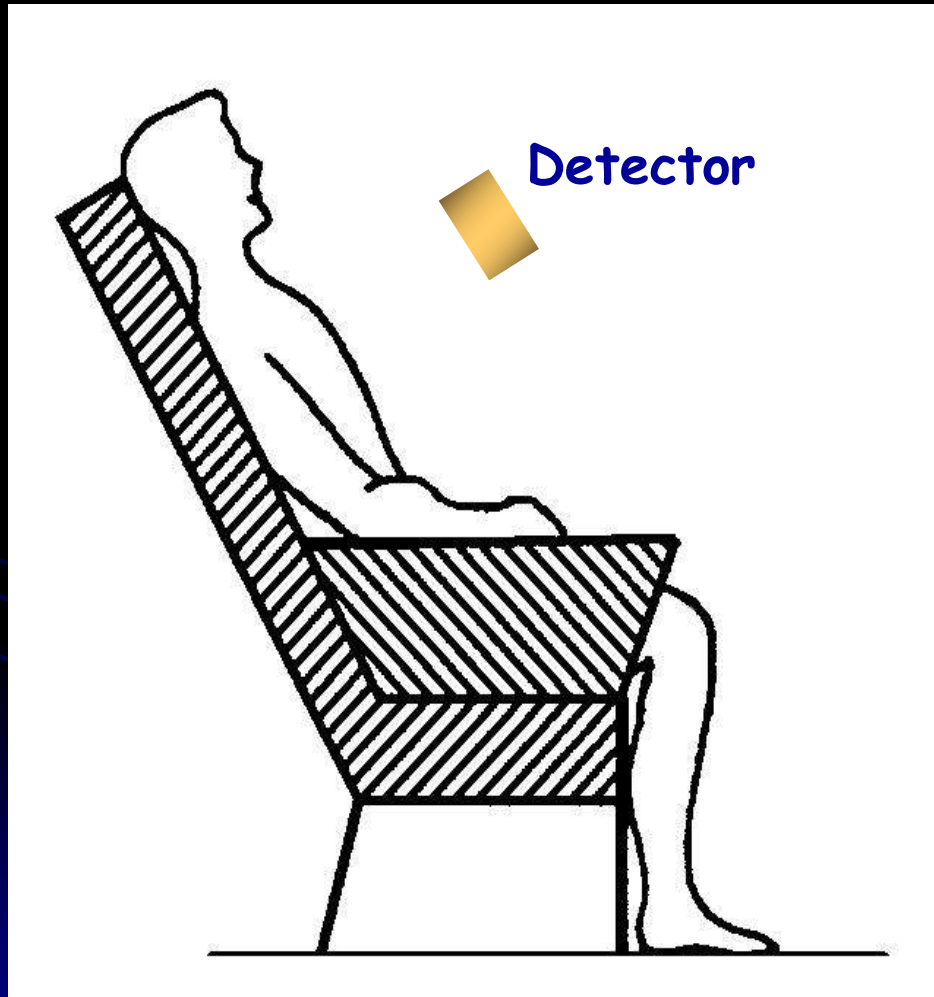
## *Partial body counter -Chair Type*

- Shape of a chair with three detectors positioned in the directions that allow for optimum measurement of radionuclides deposited in three critical organs, namely lung, stomach and thyroid.

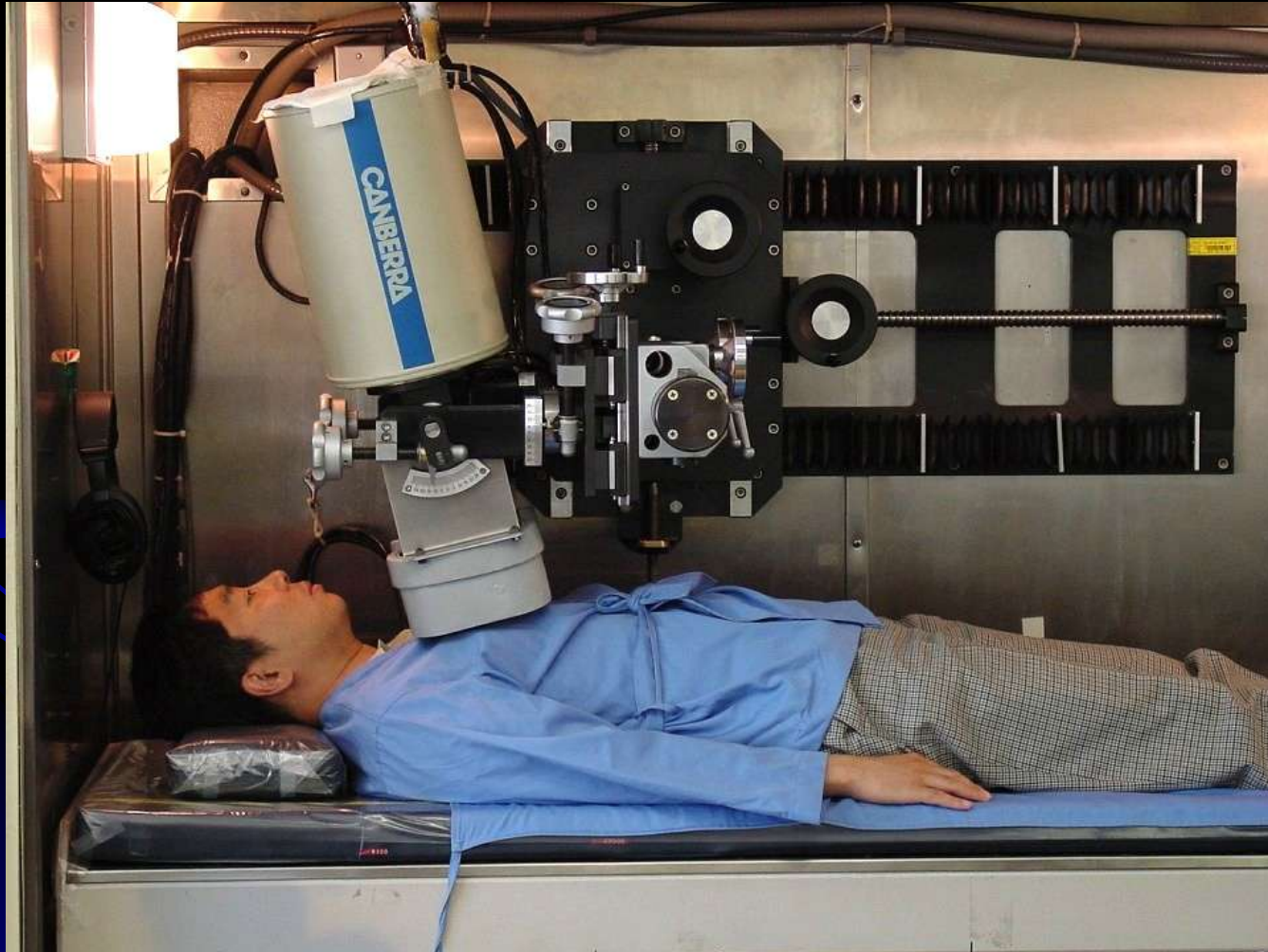
- To minimize interference from the background radiation, the system is normally provided with adequate thickness of shielding material on both the detectors and the subject to be measured.



# Chair geometry



# Measurement of radioactivity in the lung



# Personnel Monitoring Instrument for External Radiation Contamination

## Personnel Contamination Monitoring

- which is primarily intended to detect radionuclide contamination on the external surface of the body or clothing.
- Personnel contaminated externally is monitored using a portable radiation monitor or a fixed monitor called hand and foot monitor.
- All personnel working in radioactive work places must check for contamination on their clothes, tools and body and to ensure that they are clean before leaving the areas.
- Example: Hand & foot monitor (*unit Bq*)



- Scintillation counter for surface contamination and body part that prone to contamination



The second types of **whole-body contamination monitors** intended for external surface contamination detection are most often of the stand-in or walk-through types that use large area detectors to provide high sensitivity.

Unlike whole-body counters for internal radioactivity assessment, these systems attempt to look at the body surfaces, often with accommodations specifically for the hands and feet, body parts that are most prone to contamination in many work environments. The detectors used in many of these systems may be **scintillation types or gas-filled detectors** and may be sensitive to beta radiation as well as gamma radiation.



# Calibration and Quality Control

- All dosimeter are characterized by the manufacturer at the time of production.
- It is compulsory that the dosimeter be calibrated periodically as stipulated by the appropriate authority.
- Purpose of the calibration:
  - Film dosimeter and TL dosimeter are not absolute dosimeter and do not provide direct reading.
  - Film sensitivity decreases with storage time due to environmental exposure therefore recalibration is required for every six months.
  - Sensitivity of TLD may decreases with the number of use, it may due to the mishandling of the TLD material (TLD chip) –surface scratch, deterioration of teflon (TLD binder) in TLD card. Recalibration is recommended for every 6 months
  - to adjust or determine the response or reading of a dosimeter relative to a standard or to a series of conventionally true values. (pocket dosimeter)

# Calibration and Quality Control

## Calibration facilities of Film/TLD Dosimeter



Expose to gamma sources



Expose to  $^{60}\text{Co}$  source.



Expose to  $^{90}\text{Sr}/^{90}\text{Y}$  source

# Uncertainty of Measurements

**For routine individual monitoring of external radiation, results are subjected to uncertainties:**

- Between  $-50\%$  and  $+100\%$  at the 95% confidence level, for annual dose equivalents in the range of one-fifth of the derived limit.
- should not exceed  $-33\%$  and  $+50\%$  at the 95% confidence level, for values in the order of annual dose limits

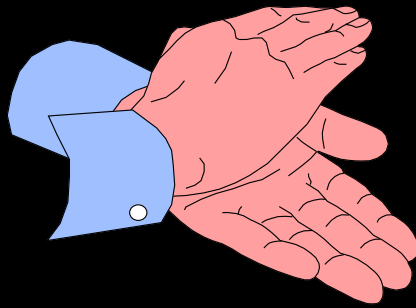
*\*(Reference: Basic Principles for Occupational Radiation Monitoring, Safety Series No. 84, IAEA, Vienna, 1987).*

# Record keeping

- The processed films will be kept for at least 5 years.
- The dose report, LPTA/BM/5 (Section B) shall be kept for 30 years, effective from the date of the last data entry.
- Radiation workers should have access to their own records at all times.
- Dose record for individual is usually provided to radiation workers when they transfer from one place of employment to another or submitted to appropriate authority for retention.

# Summary

- Objective of Personnel Monitoring
- Personnel Monitoring Instrument for External Radiation
  - ⊕ Film badges,
  - ⊕ Thermoluminescent Dosimeters (TLDs) badges and
  - ⊕ Direct-reading dosimeters.
- Personnel Monitoring Instrument for Internal radiation
  - ⊕ Bioassay Method
  - ⊕ Wholebody Counting
- Calibration and Quality Control



**Thank You**  
*for your attention*