# Sri Aurobindo College of Dentistry

## Indore, Madhya Pradesh

## INDIA

# MODULE PLAN

- TOPIC :RADIATION PROTECTION
- SUBJECT: OMDR
- TARGET GROUP: UNDERGRADUATE DENTISTRY
- MODE: POWERPOINT – WEBINAR
- PLATFORM: INSTITUTIONAL LMS
- PRESENTER: DR.NAVDEEP JOHAR

# Contents

- Introduction
- Sources of radiation exposure
- Sources of Radiation in a Dental Radiology Department
- Radiation Protection for the

1. Operator,
2. Patient &
3. Environment

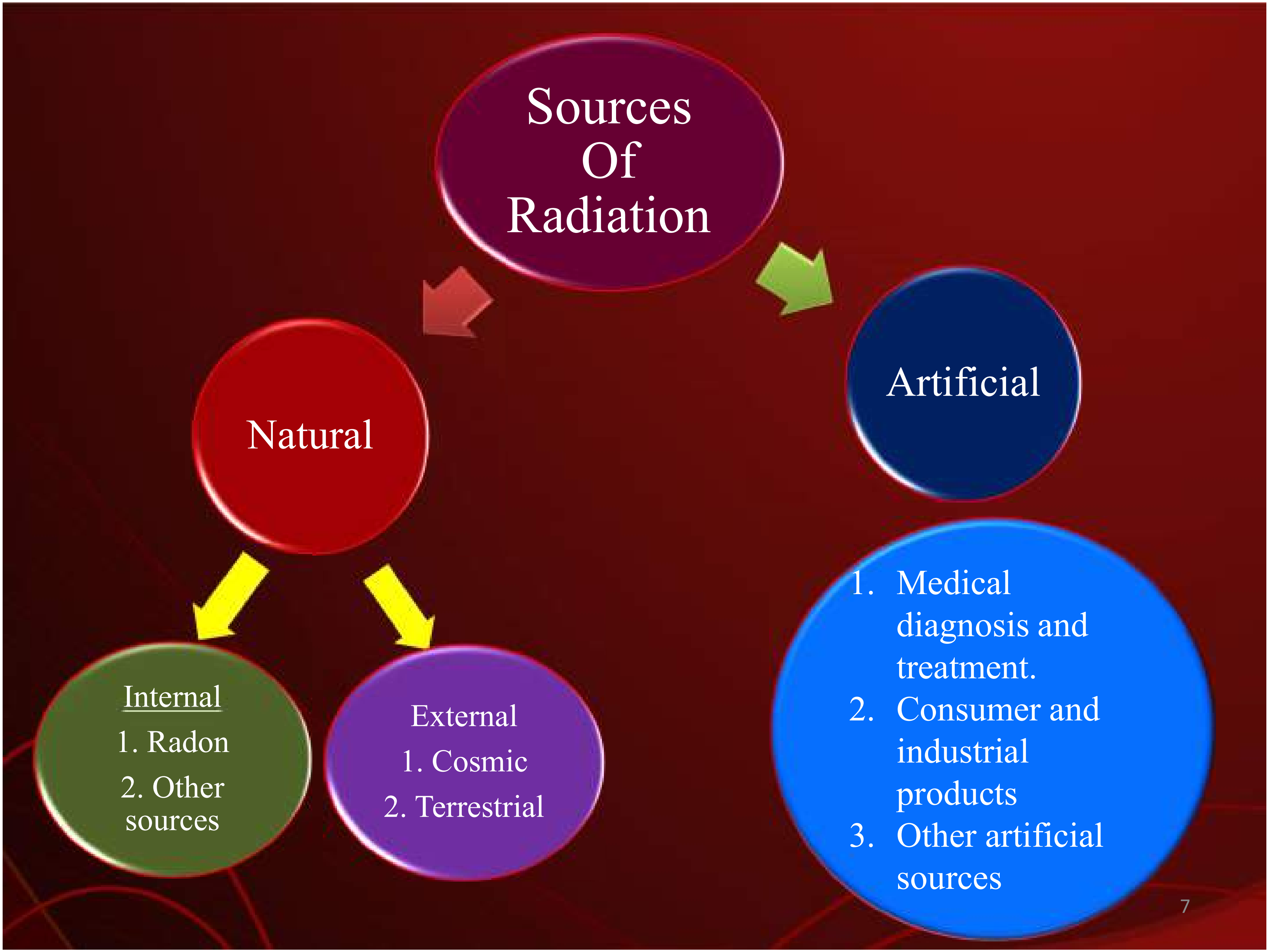
- X ray room layout

- X Rays were discovered by Roentgen in 1895.
- Within one year i.e., in January 1896, Emil Grubbe, a Chicago vacuum tube manufacture, was seen by his physician to have x-ray induced dermatitis of the hand.
- By 1922, it was estimated that more than 100 of the pioneers in radiology had died of cancer caused by their occupational exposure to ionizing radiation.

- Consequently, since the early years of radiology there has been an awareness of the hazards involved with the use of x-rays, which has resulted in a continuing effort to define and establish radiation protection standards of occupationally exposed individuals and radiation protection guides for the general population

- He proposed that “the x-ray light should be in a non radiable box from which no x-ray light can escape except the smallest cone of rays which will cover the area to be examined and the patient should be covered with a non-radiable material, exposing only the necessary area”.

- He formulated the first tolerance


Sources Of Radiation
Natural
Artificial
Internal
1. Radon
2. Other sources
External
1. Cosmic
2. Terrestrial
1. Medical diagnosis and treatment.
2. Consumer and industrial products
3. Other artificial sources

- Internal sources:

Sources of internal radiation include radionuclides that are taken up from the external environment by ingestion and inhalation. Accounts for 67% (2.4 mSv) of the radiation exposure of the population.

- Radon:

It is a decay product in the uranium series. It is estimated to be responsible for approximately 56% of the radiation exposure and is the largest single contributor to natural radiation.

Radon decays to form solid products that emit $\alpha$ particles. These decay products (Polonium, Lead and Bismuth) get attached to dust particles that can be deposited in the respiratory tract – contributing to an average annual equivalent dose to the bronchial

- Other internal sources:

Ingestion of food and water that contain radionuclides accounts for the second largest source of natural radiation.The average annual exposure due to the presence of uranium or thorium and their decay products is estimated at 0.4 mSv/yr with contribution from carbonyl, rubidium 87 and tritium.

Cosmic radiation → $2^0$

→ $1^0$

- Includes energetic subatomic particles, photons of extra terrestrial origin that reach the earth ($1^0$ cosmic radiation) and to a lesser extent the particles and photons ($2^0$ cosmic radiation) generated by the interactions of $1^0$ cosmic radiation with atoms and molecules of the earth's atmosphere.
- With an increase in altitude there is an accompanying increase in ED, almost double with each 2000 meter increase

- Therefore at sea level – exposure from cosmic radiation would be about 0.24mSv/yr. At an elevation of 1600 m – 0.50mSv/yr and an elevation of 3200m-1.25mSv/yr.
- Cosmic radiation is also greater at higher latitudes because charged particles from space are deflected toward the poles by the earth's magnetic field.
- Cosmic radiation also includes exposure resulting from airline travel.
- Thus in total cosmic radiation accounts for 0.27 mSv or about 8% of the average annual exposure(E).

## Terrestrial radiation:

- Radioactive nuclides in the soil account for exposure from terrestrial sources.
- Extent of exposure varies with the type of soil and the content of naturally occurring radionuclides Potassium – 40 and radioactive decay products of Uranium 238 and Thorium 232.
- Most $\gamma$ radiation from these sources comes from the top 20$\mu$m of soil; with only a small contribution by air borne radon and its decay products.



- Terrestrial exposure rate in India is as

# Artificial radiation ~ 17% (0.6mSv/yr):

Medical diagnosis and treatment:

Diagnostic and therapeutic radiation is the single largest component of artificial radiation to which the population is exposed, second only to radon as a source.

Diagnostic x-ray exposure is the largest contributor with an average annual E of about 0.39 mSv.

The average annual E from dental x-ray examination is 0.3% of the total average annual E (0.01 mSv)

Consumer and industrial products:

Are minor contributions to the average annual E (3%), this includes:

Domestic water supply (10-60 μSv)

Combustible fuels (1.0 – 6.0 μSv)

Dental porcelain (0.1 μSv)

Television receivers (< 10 μSv)

Pocket watches (1.0 – 5.0 x $10^{-2}$ μSv)

Smoke alarms (< 1.0 x $10^{-2}$ μSv)

Airport inspection system. (< 1.0 x $10^{-2}$ μSv)

Exposure rate of lung to tobacco products in a smoker is about 13 mSv.

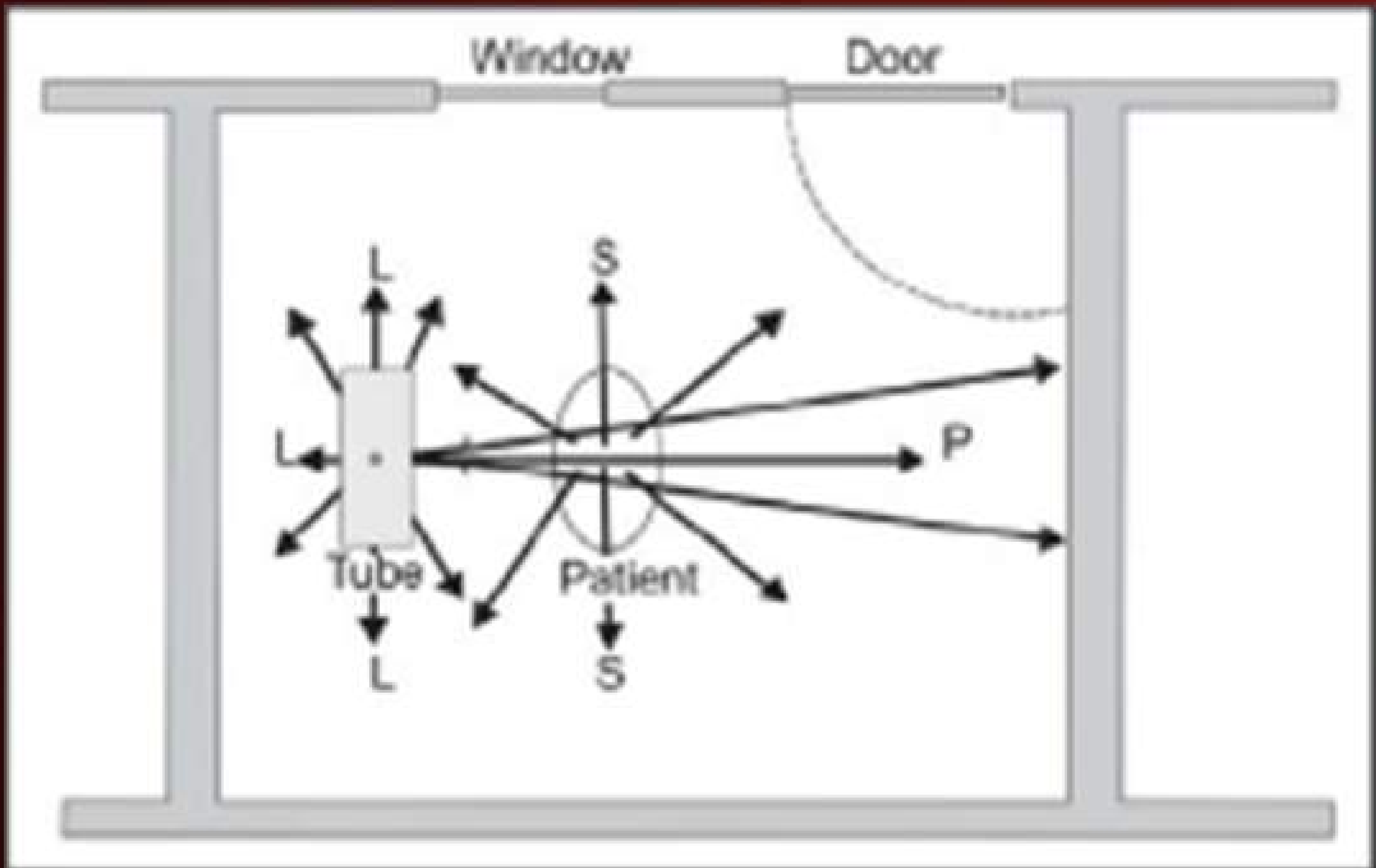
- Other artificial sources:

These include products of nuclear weapons testing that have been released into the environment. Fission products of nuclear testing have reached the human body through normal food chains.

- Strontium 90 and Iodine 131 are the most important. Strontium 90 $\alpha$ $\beta$ emitter is chemically similar to calcium – is readily assimilated in teeth and bones in children and young adults. Concentration in these areas is a matter of concern because of its long half life (928.8 yrs) and slow turnover rate (effective half life in bone – 17.5 yrs) Iodine 131 accumulates in the thyroid gland.

# Sources Of Radiation In Dental Radiology

- Radiation originating from the focal spot (Primary beam)
- Radiation originating from the irradiated tissues of the patient (Scattered or secondary radiation )
- Radiation from the X-ray tube head housing.
- Radiation from filters and cones.
- Radiation coming from the objects




Primary (P), Scattered (S) and Leakage (L) radiation during an X-ray exposure

# Methods Of Exposure And Dose Reduction:

- The guiding principle for use of diagnostic radiology in dentistry is to enhance the diagnostic benefits of dental radiographs and minimize the associate radiation risks to patients and staff.
- The overriding principle behind reducing radiation risk is to use exposure that are as low as reasonably achievable is the ALARA principle.

The means of protection can be divided into:

A. Protection for the operator.

B. Protection for the patient.

C. Protection for the environment.

## Protection for the operator.

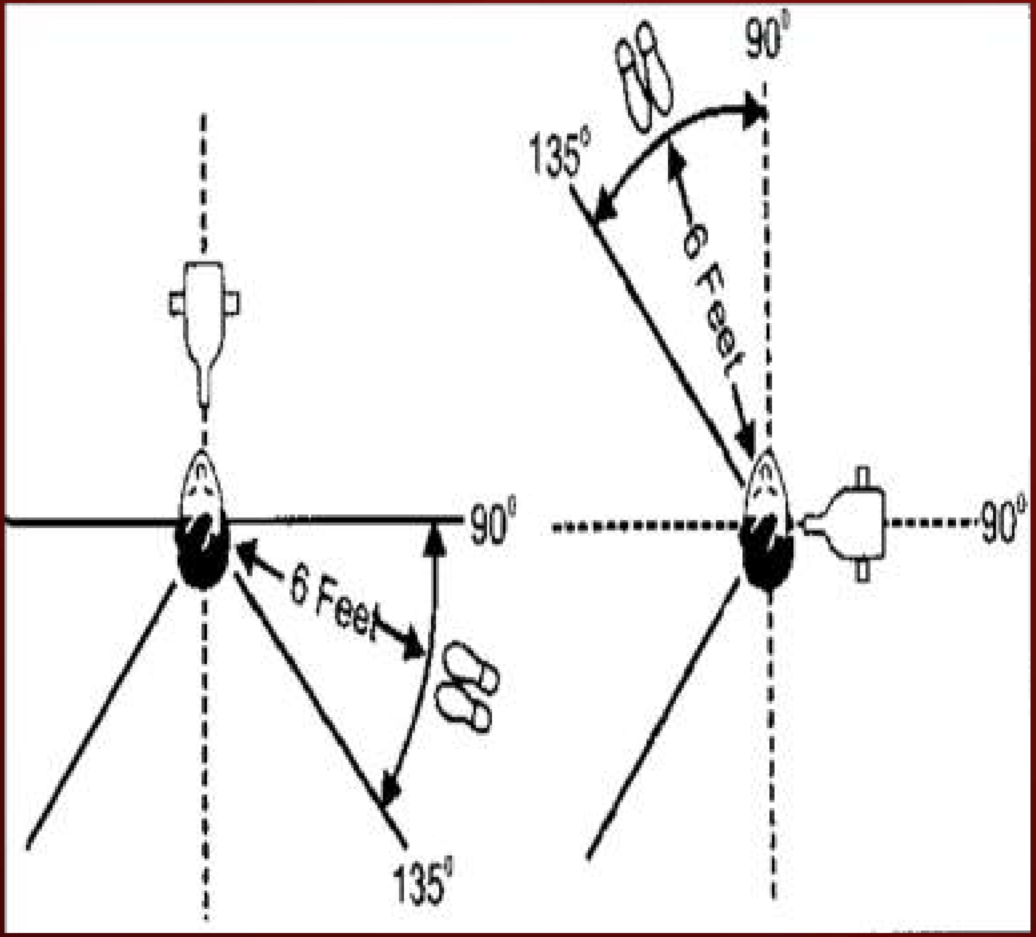
- Protection against primary beam:

Primary beam: It is defined as radiation emitted by the focal spot of the target

i. Effort must be made so that the operator can leave the room or take a suitable position behind a barrier or wall during exposure.

ii. Dental Operatory should be

- iii) Position Distance Rule- which states that the operator should stand at least six feet away the source of radiation or the operator should be at an angle of 90° to 135°, with respect to the direction of the central ray.



iv) A BARRIER, made of suitable material should be used.

- The most commonly used material is Lead. It has

Higher atomic number.

Higher density.

Higher linear coefficient of attenuation.

Lead can be used in form of:

v. If there is no shield or barrier, the operator should use a lead apron.

vi. The film and x ray tube head of the machine should never be held by the operator.

Ideally film holding devices should be used. If correct retention & placement is still not possible a parent or any other individual responsible for the patient must hold the film in position.

vii. There should be no use of fluorescent mirrors in the oral cavity at the time of radiation.

## Protection against leakage radiation

i. Neither the tube housing nor the cone should be hand held during exposure.

ii. The machine should be periodically checked for leakage.

## Protection from secondary & scattered radiation

- Use of high speed films.
- Replace the short plastic cone with an open ended lead lined cone.
- Adequate filtration of the primary beam.
- Use of collimator, to reduce the diameter of the beam.
- Use of film badge/TLD badge/ Pocket Dosimeter, for personal radiation monitoring, to avoid accumulated over exposure.

# Protection for the patient

- Patient dose from dental radiography is usually reported as the amount of radiation received by the target organs.
- One of the most common measurements is the skin or surface exposure.
- Other target organs commonly reported include the bone marrow, thyroid & gonads.

# Surface Exposure:

It is a measure of the intensity of radiation at the patients skin surface in Roentgens rather than a measure of the amount of energy absorbed by the tissues in grays.

- In intraoral radiography the per single dental film is:
  - 360 mR for periapical

# Mean Active Bone Marrow Dose
:

- The mean active bone marrow dose is that dose of radiation averaged over the entire active bone marrow.
- The mean active bone marrow dose resulting from an intraoral full mouth survey of 21 films exposed with round collimation is 0.142mSv;

# Thyroid dose:

- The proximity of the thyroid gland to the X-ray beam is of crucial importance in determining the magnitude of dose received.
- A radiographic examination of the cervical spine may consist of four separate exposures that in total are responsible for a dose to the thyroid of about 5.5 mg. During this examination, the thyroid gland is directly in the centre of the radiation

# Gonad dose:

- Radiographs of the abdomen result in the highest dose to the gonads; those involving the head, neck and extremities is the lowest.
- Radiographs of the kidneys, ureters and bladders deliver gonad doses of 1.07 mGy.
- Radiograph of the skull delivers a gonadal dose of less than 0.005mGy.
- A full mouth radiographic

# Tolerance dose of different organs

| Organ | App. tolerance dose |
|---|---|
| • Skin | 60 Gy / 5 weeks (in 30 sittings) |
| • Epiphysis (condyles) | 5 Gy / 3 weeks. |
| • Brain, liver, kidney, lungs | 40 Gy / 3 weeks. |
| • Eyes: | not more than 50 Gy / 3 weeks. |
| • Gonads: | not more than 4 Gy in a single dose. |
| i. Male gonads | 0.003 Gy |
| ii. Female gonads | 0.005 Gy |

Patient protection can be categorized as follows:

A) **Patient selection:** High yield or referral criteria, which is the clinical or historical findings that identify patients for whom a high probability exists that a radiographic examination will provide information affecting their treatment & prognosis.

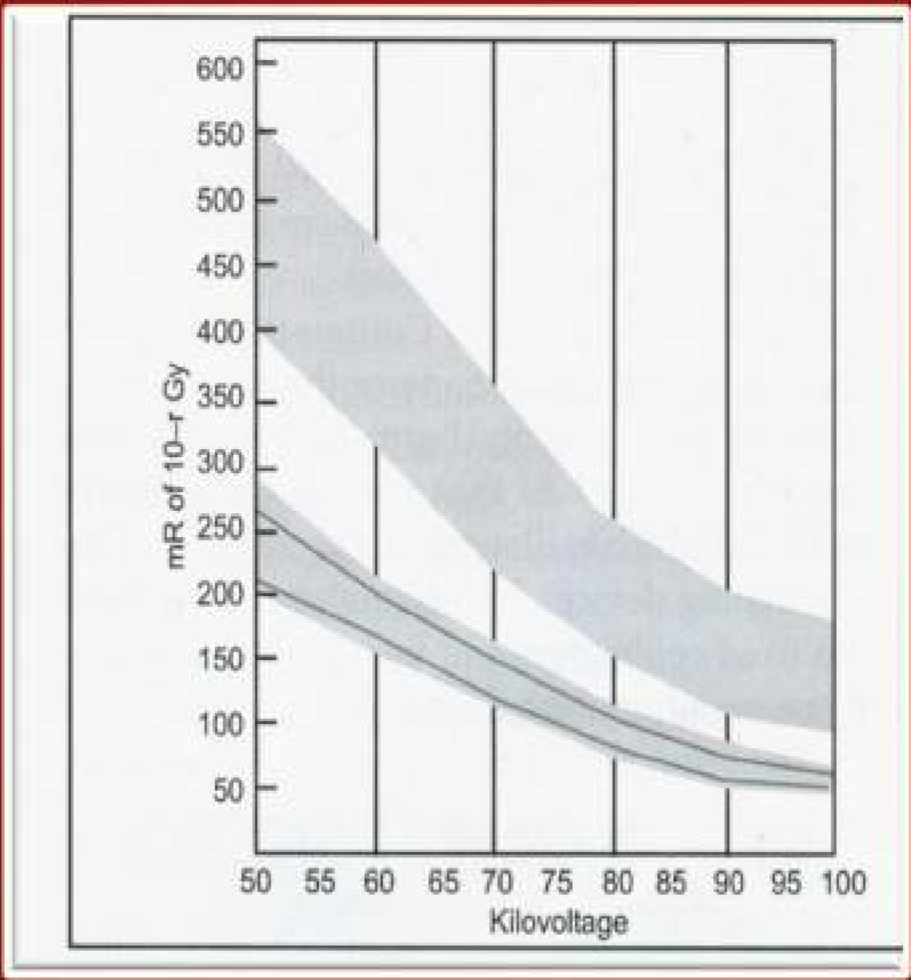
## i ) Selection of the image receptor :

- a. Use of high speed films, which will help to reduce the exposure time. Although the image quality may be compromised. E speed films are

**Table 6.5: Milliampere-seconds required to expose speed group D and E intraoral radiographic film to diagnostic density at a focal spot-to-film distance (FSFD) of 16 inches**

| Operating *kilovoltage** | Milliampere-seconds** *D* | | | *E* | | |
|---|---|---|---|---|---|---|
| | *Low* | *High* | *Mean* | *Low* | *High* | *Mean* |
| 70 | 6.7 | 10.9 | 8.8 | 3.6 | 4.8 | 4.2 |
| 90 | 3.1 | 6.0 | 4.6 | 1.7 | 2.6 | 2.2 |

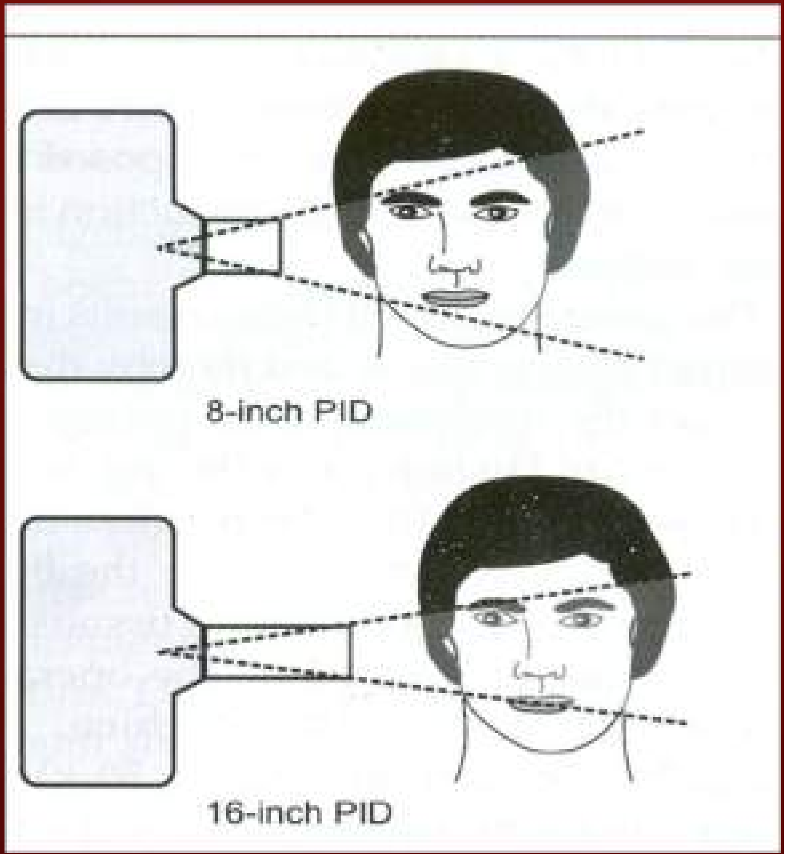
b. Use of screen films, the use of intensifying screens also helps reduce exposure time to the patient, but the diagnostic result of non screen films are far superior.




Relationship of surface exposure delivered to a patient by exposure of group D, E, F intraoral films & diagnostic density at

## ii. Focal Spot Film Distance :

- As x-rays are less divergent at a longer distance, there is decrease in the volume of the patient exposed. Longer FSFD results in 32% reduction in exposed tissue volume.

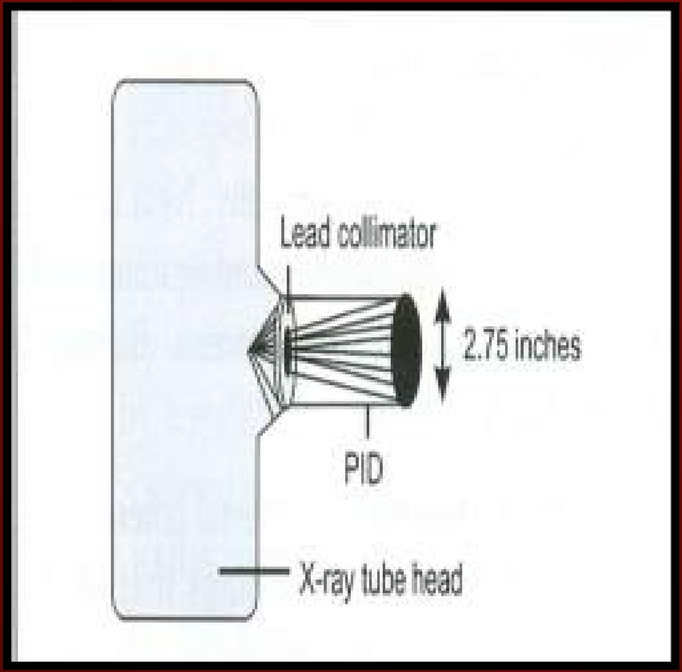


- Source Skin distance ( SSD): As the SSD is increased, the collimation must be correspondingly increased to reduce the beam size, thereby reducing the volume of tissue irradiated, thus reducing the patient dose.

- The operating SSD depends on the kvp of the machine.
- Equipments operating below 50 kvp should have a minimum distance of 10 cm (4”) from the end of the PID to the focal spot.
- Equipment operating above 50 kvp have a minimum distance of 18 cm (7”) from the end of PID to the focal spot.

## iii. Collimation of the Beam:

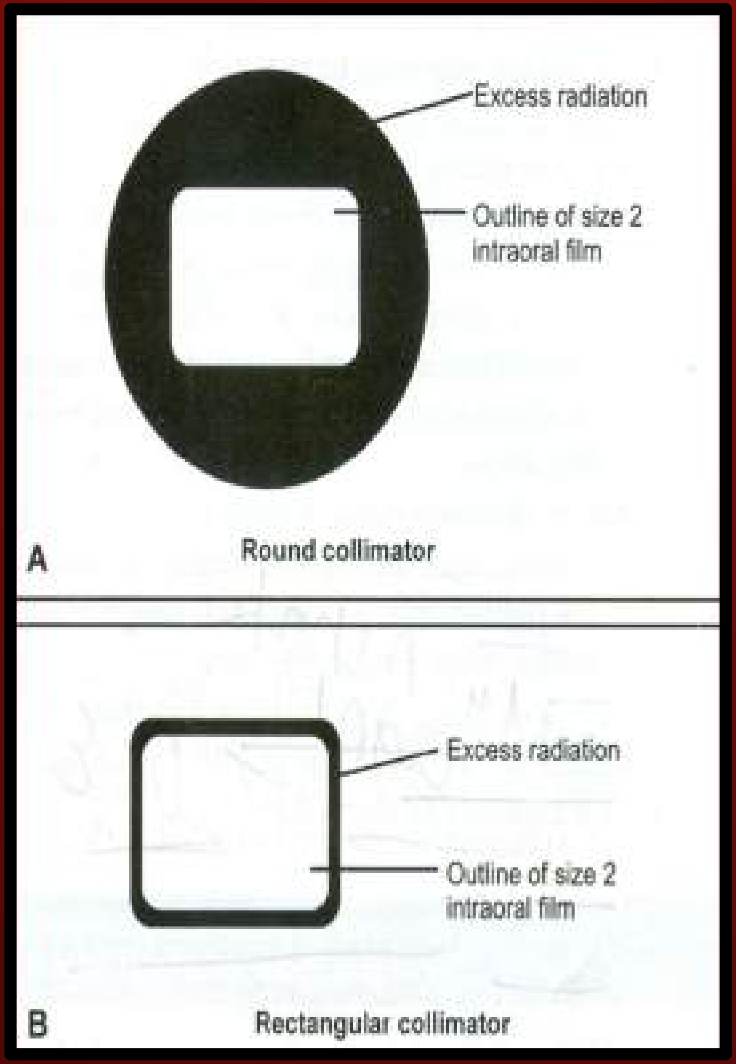
It helps to control the size & shape of the X-ray beam, allowing only the useful beam to emerge.




- It decreases the risk of radiation, minimizes scattered

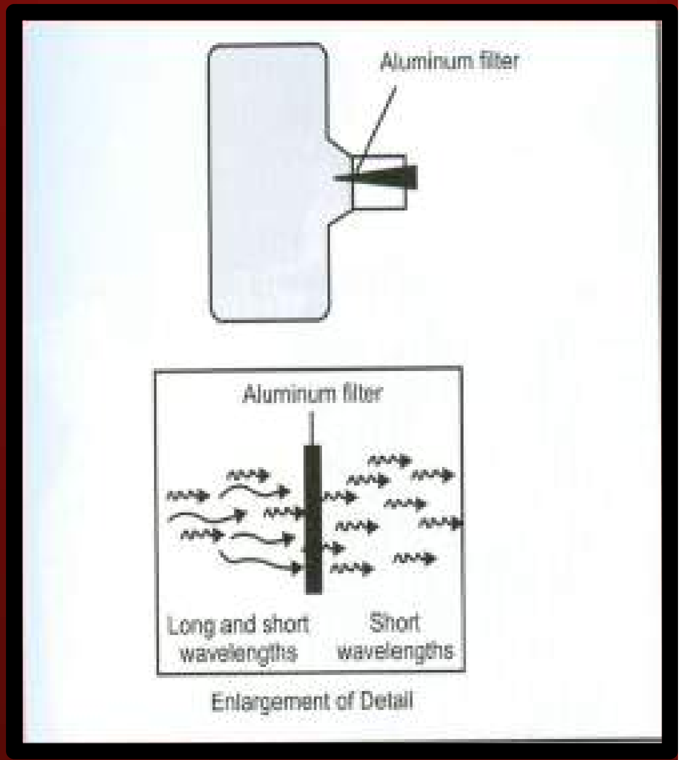
- In intraoral machines there are fixed collimators & in extra oral machines there are adjustable collimators.

- The beam should be limited to as small as an area possible for a particular radiographic examination



## iv. Filtration :

- Filtration preferentially absorbs low energy photons which are undesirable as they add to the patient's skin dose but do not have enough energy to penetrate the tissue & bring about image formation.
- Aluminium is the



The amount of filtration should be in accordance with the machine's operating range;

Below 50 kvp; 0.3 to 0.5mm of aluminum

50-70 kvp 1.2- 1.5 mm of aluminum

Above 70 kvp 2.1-4.1 mm of aluminum

## v. Use of high kvp:

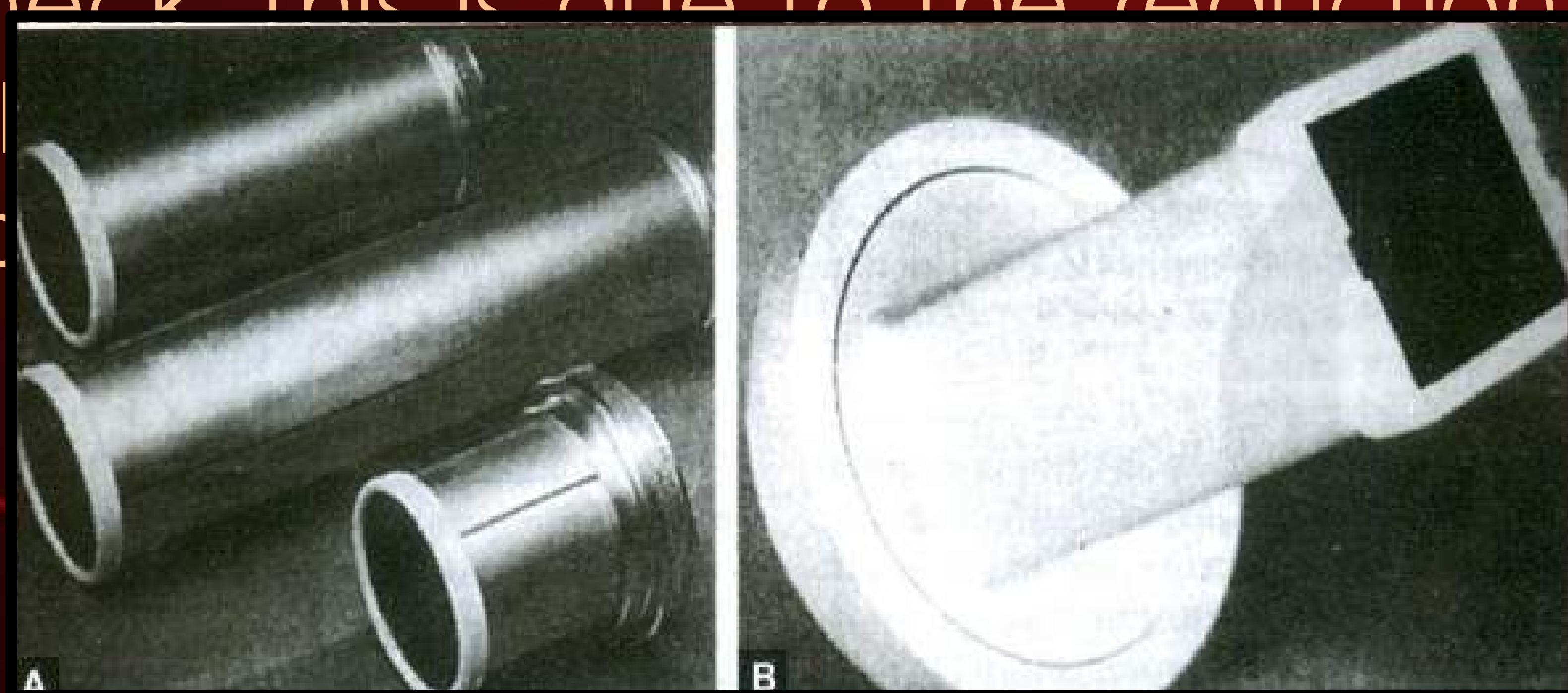
- Higher kvp is used to keep the incident skin dosage acceptable. The equipment should be capable of operating 60 kvp or higher.

## vi. Use of positioning indicating devices (PID):

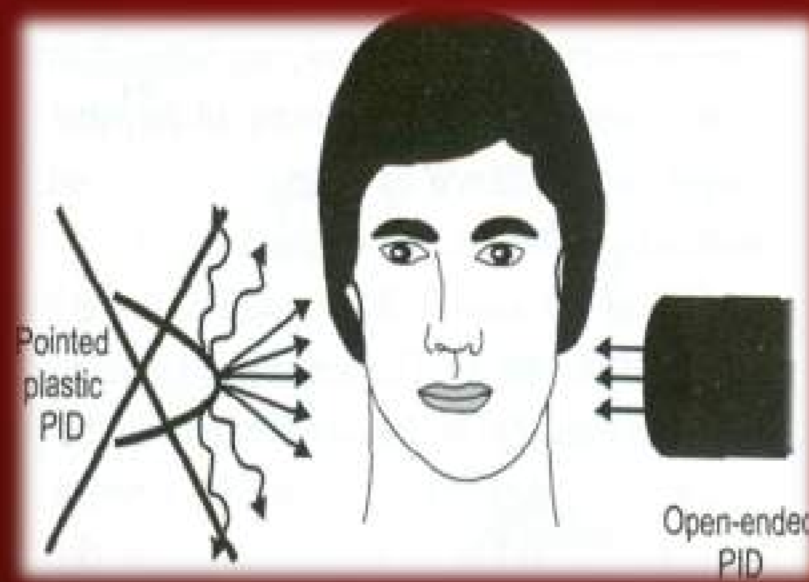
- These help to minimize the volume of tissue irradiated in intraoral radiography, it is necessary to increase the target film distance by using longer PID to direct x-ray beam.

- One of the most widely used PID is the long open ended cylinder. The instrument reduces the more divergent rays that are inherent in the use of short target film distance

- As a result the diagnostic quality of the image is markedly improved & significantly smaller doses of radiation are delivered to the head & neck, this is due to the reduction of th… & c… he s…



- If a change is made in the technique from long cone to short cone, it is important to simultaneously reduce the size of the collimator aperture.

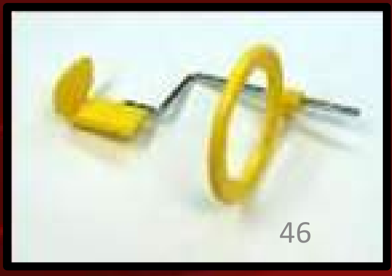



A plastic pointed PID produces scattered radiation & should be replaced by the open ended lead lined PID

- The use of open

vii. Film holding devices: These offer protection to the patient, because

- Their use often reduces frequency of retakes, as the film can be positioned more accurately in the patient's mouth.
- They also provide an external guide to indicate the film position.
- The possibility of misaligning the x-ray tube & partially missing the film (cone cut) is reduced.
- The exposure to the patient's fingers is also reduced, as he/she does not have to hold the film.



## viii. Grids:

- These are devices which reduce the amount of scattered radiation reaching the film whilst still allowing the patterns containing the primary beam to reach the film.

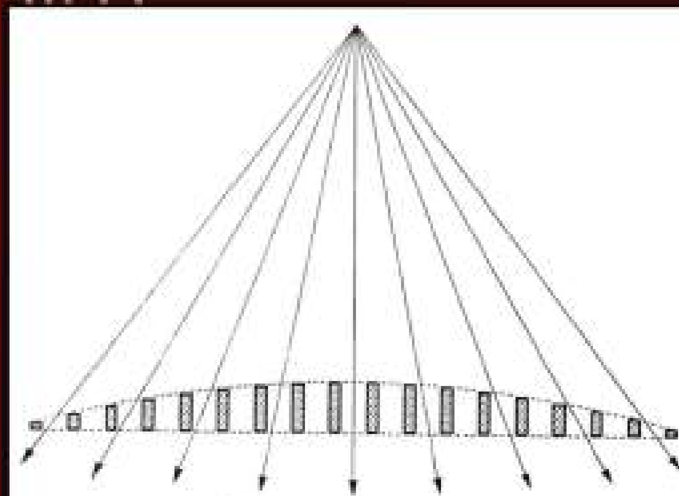


Fig. 183.—A pseudo-focused grid.

# ix. Timers:

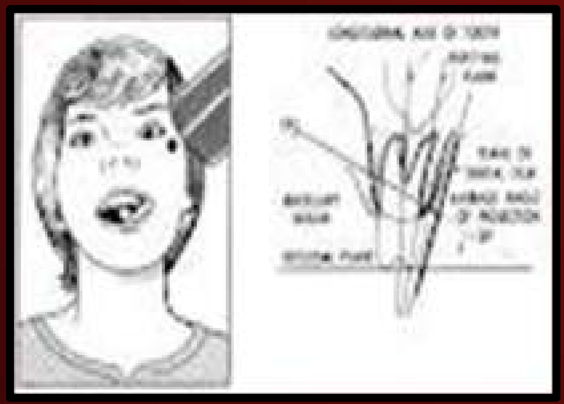
- Most equipments are provided with the dead man timers. This timer requires a continuous pressure on the button (switch) during the exposure cycle in order to continue the operation of x-ray machine.

## X. Use of protective barriers:

- Leaded aprons should be used to protect the patient.
- When used the lead apron should have a protective equivalent of ¼ th mm of lead.
- Use of lead thyroid shields, is recommended.

- It should be remembered that lead aprons are a secondary measure to protect the patient & should not be substituted for fast films, lead collimation & aluminum filtration, which are primary means of reducing exposure to the patient.

## xi. Use of proper technique:



## xii. Processing the image :

If films are not processed properly, retakes are required, increasing the patient exposure & cost.

## xiii. Interpretation of the image:

- The radiographs should be viewed under proper conditions with an illuminated viewer.
- Proper interpretation precludes the

# Protection for the environment

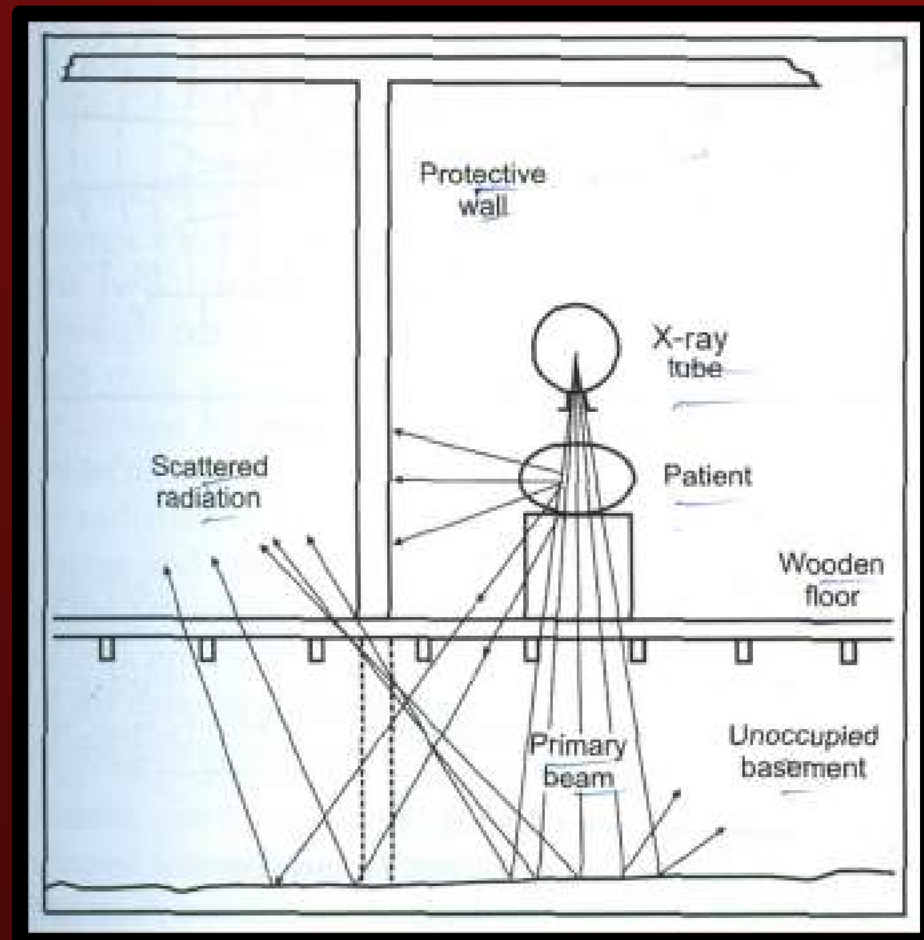
- The surrounding environment must be protected from the radiation to avoid exposure to persons in the environment.

- i. Primary beam should never be directed at any other than the patient.

ii. Patient should be positioned in such a way that x-ray beam is aimed at the wall of the room & not through a door or opening where people may be located.

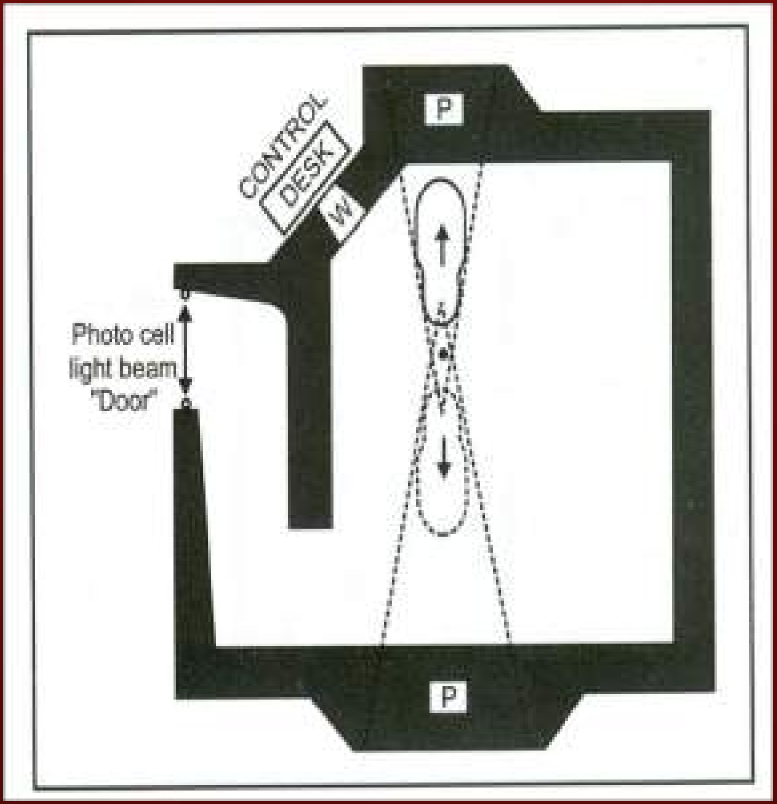
iii. Walls made of 3" of concrete, 3"x16" of steel or 1 mm of lead will be sufficient to protect adjacent rooms, even the workload in radiology is high.

iv. Primary barrier should be incorporated in any part of the floor or ceiling of the room at which beam is fired.




v. Secondary barrier in the walls, provide

iv. Windows: It is necessary for the operator to see the patient as he is being irradiated, so a window is provided. This window should be situated such that primary beam is not directed on it. Lead glass should be used.



vi Quality assurance may be defined as any planned activity to ensure that a dental office will consistently produce high quality images with minimum exposures to patients & personnel.

vii. Continuing education: Practioners should stay informed of new information on radiation safety issues as well as developments in equipment, materials & techniques & adopt appropriate items to improve radiographic practice.

viii. Regular radiation surveys, should be performed at regular intervals as the amount of exposure is dependent on many factors, such as:

A. The machine kilo voltage.

B. The work load of the x-ray machine.

C. The x-ray absorbing ability of the walls (by using radiation

## vi. Radiation monitoring:

- It is measuring of the x-ray exposure of operators or associated personnel as a protective measure.

# X-ray Room Lay Out

## Location of X-ray Installation

- The rooms housing the diagnostic x-ray units & equipment should be located as far away as feasible from areas of high occupancy & general traffic, such as maternity & pediatric wards.

- The walls of the room where the primary x-ray falls should not be less

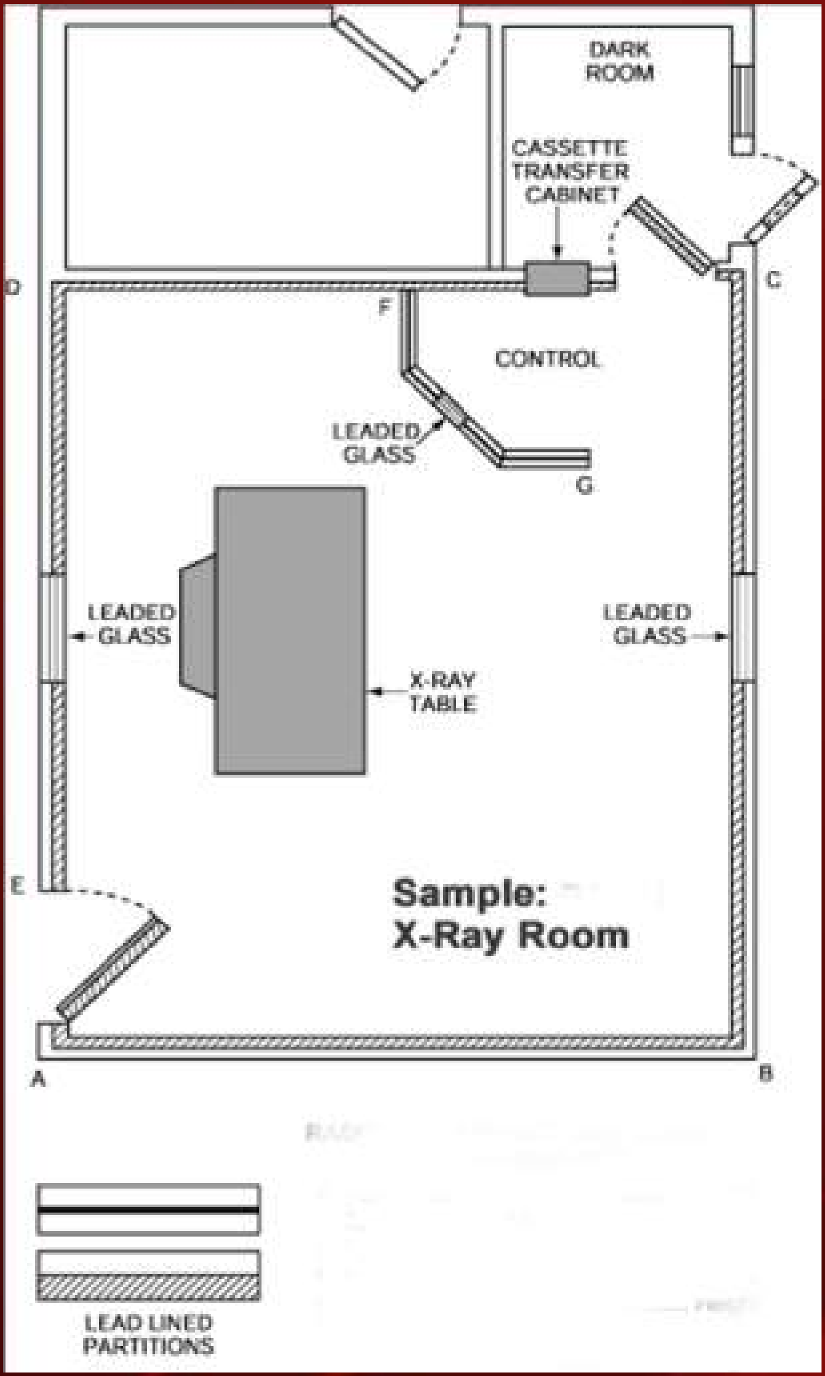
- Walls of the X-ray room on which scattered X-ray fall should not be less than 23 cm thick brick or equivalent.

- There should be shielding equivalent to at least 23 cm thick brick or 1.7 mm lead in front of doors & windows of the X-ray room.

# Layout

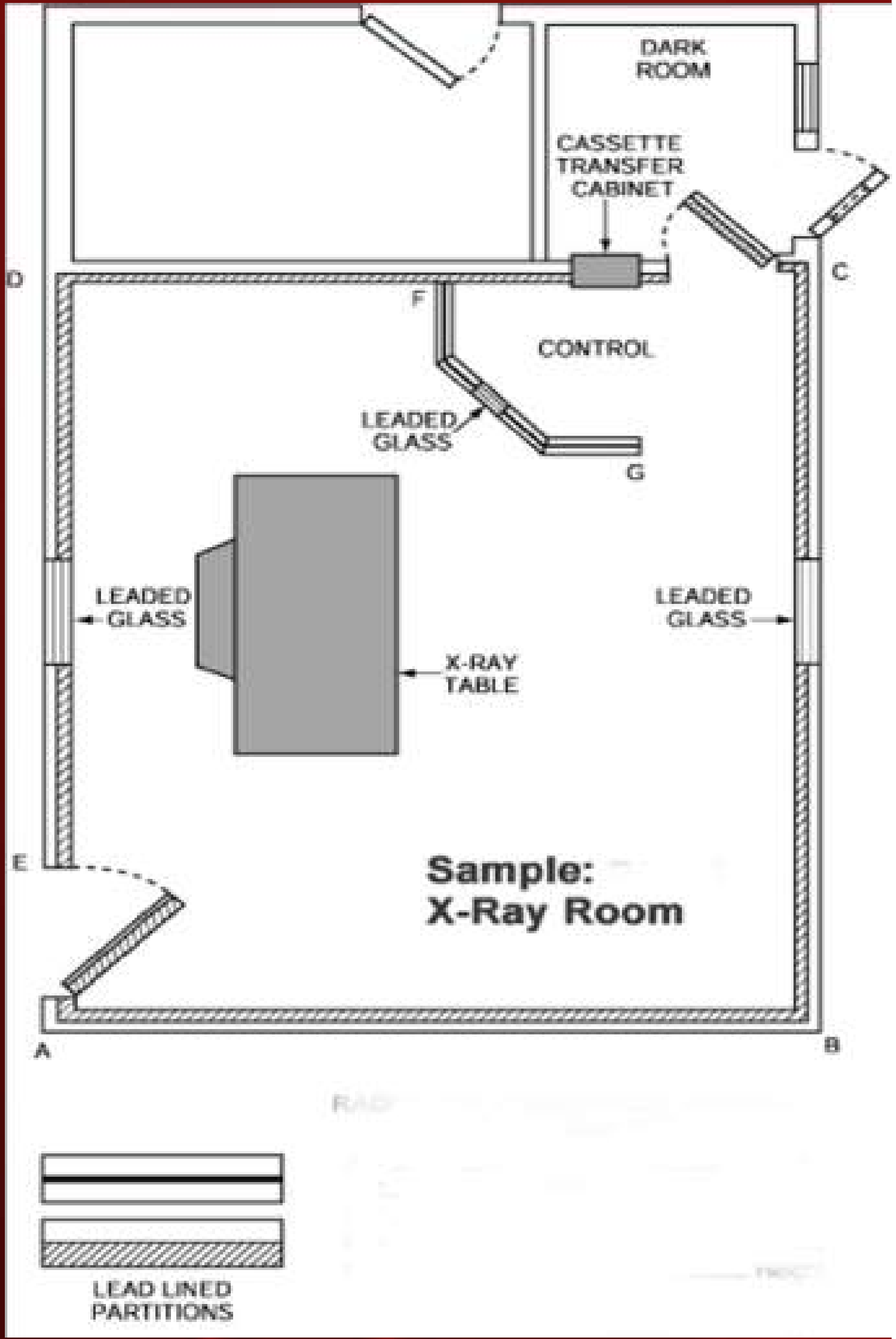
- Layout should aim at providing integrating facilities so that handling of equipment & related operations can be performed with adequate protection.

- The number of doors for entry to the room should be minimum.



- Doors & passages leading to instillation should permit safe & easy transport of equipment & patients.

- Dark room should be so located that the primary beam cannot be



# Room size

- Must be spacious.
- For dental radiography & area of 150 sq feet should be minimum ( or 18 $m^2$).
- For gantry of the CT unit the area should not be less than 25 $m^2$.
- One unit in one room . No room

# Shielding

- Appropriate structural shielding should be provided for wall, ceiling & floor, so that the MPD i.e. 50 mSv for occupational workers & 1 mSv for public should not be exceeded.
- A nine inch brick wall is recommended.
- Typically, the rooms should be shielded with sheets of lead.

- When lead is used, it usually is glued on the backside of the sheets of drywall that make the room walls (the lead sheets overlap to prevent gaps in the shielding).
- For doors, the lead is usually "sandwiched" on both sides by wood.
- In addition, small pieces of lead are placed behind outlet boxes and over screws that hold the drywall up.

- It is usually difficult to tell if a room is shielded just by looking at it. The best place to see it is along the door edges if the door contains a sheet of lead.

- Lead is not the only choice for x-ray room shielding, but it is the most commonly used due to cost and minimal thickness to achieve the amount of shielding desired. Some facilities use concrete , cinder block or fiber glass

## Paint used on walls of x-ray room

- Metallic lead sheathing has been used in X ray rooms to keep the rays in, but this is costly and the heavy metal requires special strengthening of building walls.
- Another option is Toch's method which advocates the use of a barium compound in the plaster or paint on

## Flooring used in X-ray room

- It is assumed that flooring has at least 150 mm thick, made of concrete and has a density of 2350 $kgm^{-3}$.

- Some buildings have floors constructed with ribs supporting thinner areas of concrete (often called waffle slabs).

## Opening & ventilations

- Unshielded opening if provided if an X-ray room for ventilation or natural light, etc., must be located above a height of six feet (or 2m) above finished floor outside the x-ray room.

# Equipment layout

- It should be installed in a way that in normal use the useful beam is not directed towards the control panel, doors, windows or areas of high occupancy.

- 1 mm of lead sheet protection for the entrance door.

- 1.5 mm lead barrier should be used.

- Vertical barriers must extend from the floor to a minimum height of 7 feet.

- If it is necessary to add additional shielding to the ceiling of the room then the

- Lead glass should be used for windows.

- The lead glass viewing window should have an area of at least 1 square foot.

- At least 1 square foot of the viewing window should be centered no less than 2 feet from the open edge of the booth and be centered 5 feet from the floor.

<u>Control Panel</u>

- It should be contiguous.
- A stretchable cable with length of at least 2 meter should be provided.
- For higher than 125 kvp, control panel should be in a separate room.

<u>Waiting area</u>

Should be outside the X-ray room.

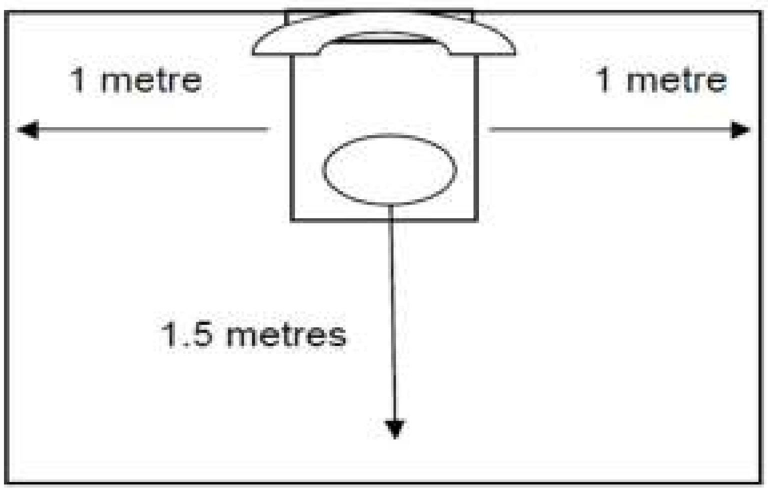
## Warning Light & Placard

- Warning signal (red light) should be placed at an conspicuous place outside the X-ray room which should go on when the exposure button is pressed, or a placard should be placed signal that the process o taking in progress.

# <u>Shielding plan for extraoral radiographic installations</u>

Dental extraoral equipment requires shielding of the primary

**Layout of a low-use panoramic X-ray room design showing the minimum distance from the radiation source to walls and other occupied spaces**




**Note:** Most standard dental exam rooms are likely to exceed these dimensions. The requirement for shielding may be alleviated by repositioning the chair.

- These equipment requires primary beam shielding along with a fixed operator's barrier with an exposure switch in a location at least arms length from the line of scatter.

- Floors need to use minimum thickness of about 3"-4.5" concrete floor. Need to know density of concrete (147 $lbs/ft^3$ standard)

# References


- Oral Radiology : Principles And Interpretations : White And Pharroh.
- Textbook Of Dental And Maxillofacial Radiology : Frenny P Karjodkar.
- Essentials Of Oral Radiology : Eric Whaites


Good morning….
Keefers

# DOSIMETRY

# Contents

- The initial interaction between ionizing radiation and matter occurs at the level of the electron within the first 10-13 second after exposure.
- These changes result in modification of biologic molecules within the ensuing seconds to hours.
- In turn, the molecular changes may lead to alterations in cells and

1). Deterministic or Non-Stochastic Effects :

Those effects in which the severity of response is proportional to the dose. These effects have a dose threshold below which the response is not seen

Example are - Oral changes after Radiation therapy, Cell death after Radiation exposure

2) Stochastic effects

Those for which the probability of the occurrence of a change, is dose

- Dosimetry is the determination of the quantity of radiation exposure or dose.

- Radiation dosimetry: Deals with the measurement of the absorbed dose or dose as resulting from the interaction of ionizing radiation with matter & particularly in different tissues of the body.

- Dose:- It is amount of radiation at a given point or amount of energy absorbed per unit mass at the site of interest.
- Exposure:- It is a measure of radiation quantity, the capacity of radiation to ionize air.
- Erythema Dose:- It is dose which produces in one sitting a reversible reddening of the skin (3-4 Gy).
- The SI unit of exposure in air is kerma (Kinetic Energy Released in Matter).

- Kerma – measures the kinetic energy transferred from photons to electrons & is expressed in units of dose gray (Gy).

- Kerma is the sum of the initial kinetic energies of all the changed particles liberated by uncharged ionizing radiation (neutrons & photons) in a sample of matter, divided by the mass of the sample.

- It has replaced Roentgen, the traditional unit of radiation exposure measured in air.

- This is because Roentgen was not acceptable for biological tissues since it was measured in air & different unit was needed for the tissues , since tissues are more dense than air & also vary in density amongst themselves & therefore their ionization differs from air.

- <u>Roentgen :</u> It is quantity of X ray or $\gamma$ radiation such that the associated corpuscular emission through 0.00123 gm of air at $0^{\circ}C$ or 760 mm of Hg produces in air ions carrying 1 electrostatic unit of electric charge of either positive or negative charge.

- Absorbed dose:- It is measurement of the energy absorbed by any type of ionizing radiation per unit mass of any type of matter.

$$\frac{Ed}{m}$$

- Ed is the energy imparted by an ionizing radiation to the matter in a volume of element
- m is mass of matter in volume of element.

- In 1975 , the SI unit Gray was introduced which replaced the traditional unit Rad.

- It is the production of 100 ergs of energy in 1 gram of tissue by any form of ionizing radiation.

- 1 Gray = 1 joule/ kg= 100 rad

- Equivalent dose ($H_T$):- It is used to compare the biologic effects of different types of radiation to a tissue or organ.

- It is sum of products of the absorbed dose ($D_T$ ) averaged over a tissue or organ & the radiation weighting factor ($W_R$).

- $H_T = \Sigma W_R \times D_T$

- Equivalent dose is expressed as the sum to allow the possibility that the tissue or organ is exposed to more than one type of radiation.

- The radiation weighting factor is chosen for the type & energy of the radiation involved.

- Thus high LET radiations have a corresponding higher $W_R$.

The unit of Equivalent dose is Sievert (Sv).

For diagnostic radiology 1Sv= 1 Gy

The traditional unit was ‘rem’.

Rem (Rad equivalent Mammal): It is the unit of dose equivalent. This unit is used to facilitate comparison between biological effects of exposure & various types of radiations.

1 Sievert = 100 Rem

- Effective Dose ( E ) :- It is used to estimate the risk in humans. It is the sum of the products of the equivalent dose to each organ or tissue (HT) & tissue weight factor (WT)

$$E = \Sigma H_T \ X \ W_T$$

The unit is Sievert (Sv).

Quality Factor (QF):- It relates all radiation to biologic systems in terms of its biologic effects relative to standard exposure of x-rays.

- For radiations used in dental radiology,

  1 R (exposure)= 1 Rad (absorbed dose)= 1 Rem(dose equivalent )

Thus, In diagnostic radiology : 1R = 1 r = 1 rem

- An exception is in the case of the bony structures of the head

- Relative biological Effectiveness: It is the unit of measuring radioactivity of a substance. Its application is only in the laboratory investigations & studies.

- It corresponds to 3.7 × $10^{10}$ disintegrations per second, the activity of 1 gram of radium, which was called Curie (Ci)]

- It is now replaced by Becquerel.

# Summary of radiation quantities and units

| Quantity | SI unit | Traditional unit | Conversion |
|---|---|---|---|
| Exposure | Air Kerma | Roentgen (R) | 1 Gy = 100 rad<br>1 rad = 0.01 Gy (1cGy) |
| Absorbed dose | Gray | Rad | 1 Gy = 100 rad<br>1 rad = 0.01 Gy (1cGy) |
| Equivalent dose | Sievert (Sv) | Rem | 1 Sv = 100 rem<br>1 rem = 0.01 Sv (1cSv) |
| Effective dose | Sievert (Sv) | | |
| Radioactivity | Becqueral (Bq) | Curie (C) | 1 Bq = $2.7 \times 10^{-11}$ Ci<br>1 Ci = $3.7 \times 10^{10}$ Bq |

# Maximum Permissible Dose (MPD)

- MPD is equal to .05 Sv/yr.

1. Average weekly exposure for either patient or operator is .001 Sv.

2. A maximum of 13 week exposure is .05 Sv.

- For the general public the MPD is

# Operator Accumulated Dose (OAD)

- This is equal to 5 (N-18) where N= the age of the patient

- OAD is also called MAD or Maximum accumulated dose.

- This indicates that the higher limits permitted for occupationally exposed persons do not pertain to

# Effective dose, equivalent natural exposure, and probability of stochastic effects from diagnostic dental radiographic examinations

| Survey | E (μSv) | Days of equivalent natural exposure | Probability of stochastic effects ($10^{-6}$) |
|---|---|---|---|
| **Intra oral** Round collimation D speed film | | | |
| Periapical 15 films | 111 | 13.9 | 8.1 |
| Interproximal l4 films | 38 | 4.8 | 2.8 |
| Complete mouth survey 20 films | 150 | 18.8 | 11.0 |
| Rectangular collimation, E speed film | | | |
| Complete mouth survey 20 films | 33 | 4.1 | 2.4 |
| Panoramic | 26 | 3.3 | 1.9 |

## Recommendations on annual limits for human exposure to ionizing radiation

| Recommendation | NCRP | ICRP |
|---|---|---|
| **Occupational dose limits** | | |
| Relative to stochastic effects | 50 mSv annual effective dose limit and [10mSv][age(yr)] cumulative effective dose limit | 50 mSv annual effective dose limit and 100 mSv in 5 years cumulative effective dose limit |
| Relative to deterministic effects | 150 mSv annual equivalent dose limit to lens of eye and 500 mSv annual equivalent dose limit to skin and extremities | 150 mSv equivalent dose limit to lens of eye and 500 mSv annual equivalent dose limit to skin and extremities |

## Recommendations on annual limits for human exposure to ionizing radiation

| Recommendation | NCRP | ICRP |
|---|---|---|
| **Non Occupational (public) dose limits** | | |
| Relative to stochastic effects | 5 mSv annual effective dose limit for infrequent exposure and 1 mSv annual effective dose limit for continuous exposure | 1 mSv annual effective dose limit and, if higher, not to exceed annual average of 1 mSv over 5 years |
| Relative to deterministic effects | 50 mSv annual equivalent dose limit to lens of eye, skin, and extremities | 15mSv annual equivalent dose limit to lens of eye and 50 mSv annual equivalent dose limit to lens of eye, skin, and extremities |

## Recommendations on annual limits for human exposure to ionizing radiation

| Recommendation | NCRP | ICRP |
|---|---|---|
| Embryo-fetus | 0.5 mSv equivalent dose limit per month after pregnancy is known | 2 mSv equivalent dose limit after the pregnancy has been declared |
| Negligible individual dose* | 0.01 mSv annual effective dose | None established |

# Radiation monitoring devices

1. Electrical

- ✓Ionization chamber
- ✓Thimble chamber
- ✓Proportional counter
- ✓Geiger counter

2.Chemical

3.Light

- ✓Scintillation counter
- ✓Gerenkoy counter

4. Thermoluminescence

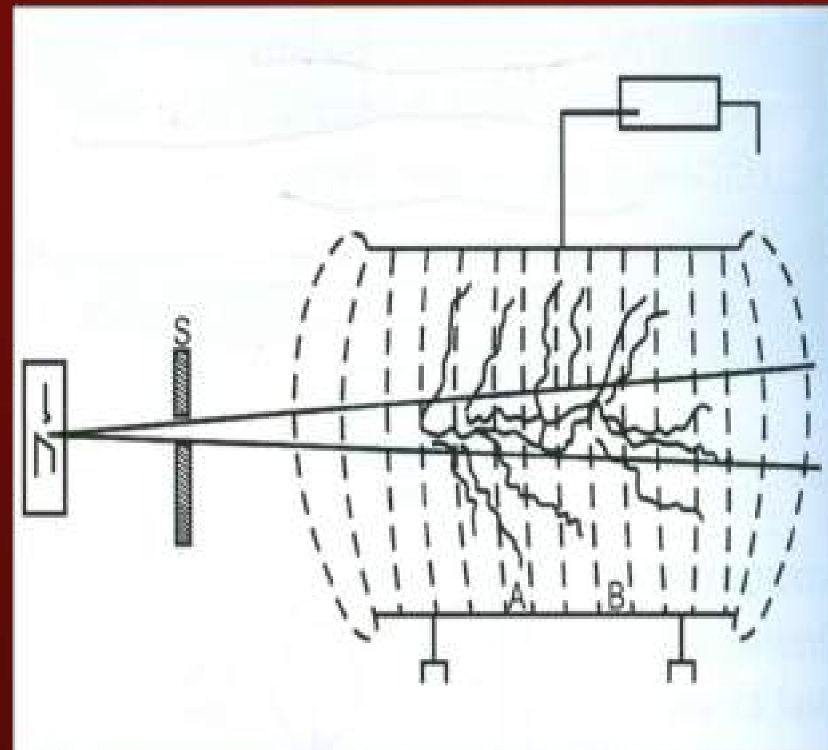
- ✓ Thermoluminescen

# Ionizing chamber:

- This chamber consists of a pair of collecting plates each with an opposite charge separated by a standard volume of air.

- The plates are

- Prior to use a standard charge is applied to the two plates.
- When an x-ray beam is directed through the air in the chamber, ion pairs (electrons & positively charged atoms) are



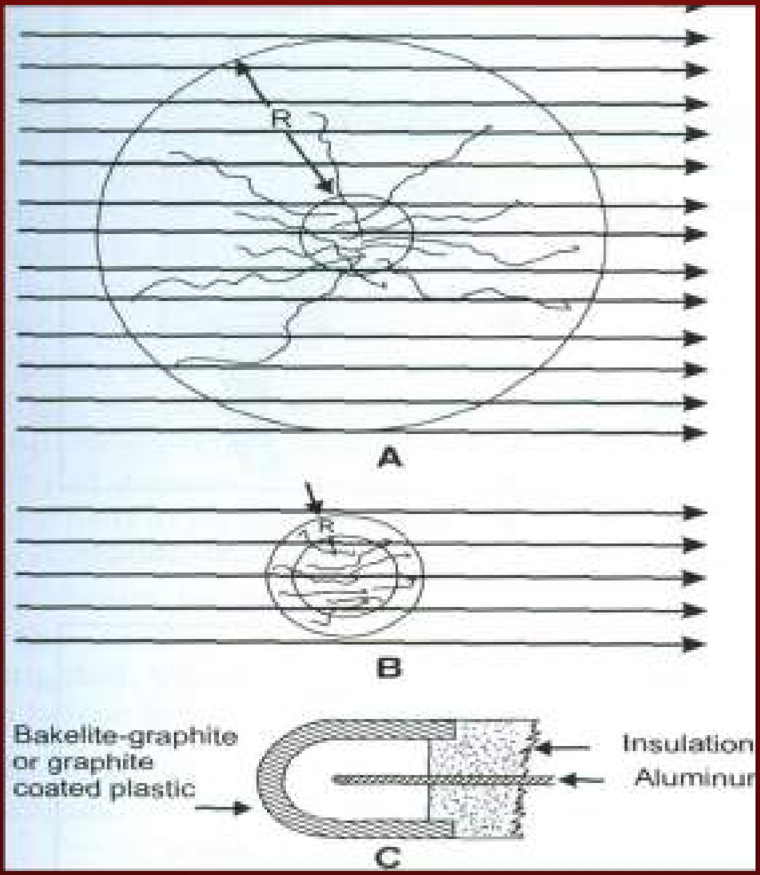

Ionization chamber

- The positive & negative ions produced by radiation will be attracted to the plates of opposite charge & cause partial discharge.

- The magnitude of the x-ray exposure is thus a function of number of ions produced & is measured by the magnitude of the drop in potential between the collecting plates of galvanometer.

# Thimble chamber

- It consists of a small thimble shaped ionization chamber filled with an inert gas argon.
- A positively charged metal plate is placed in the center & the walls are



- <u>Advantages of Ionizing chambers</u>

✓Most accurate method of measuring radiation dose.

✓Direct read out gives immediate information.

- Disadvantages of Ionizing chambers

✓They give out no permanent record of exposure.

✓No indication of type of energy used of the radiation.

✓Personal ionization monitors are very sensitive to low energy radiation.

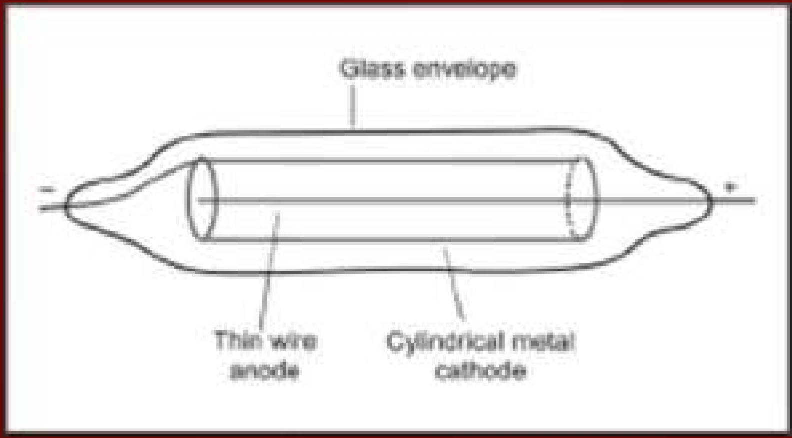
## Rate meter :

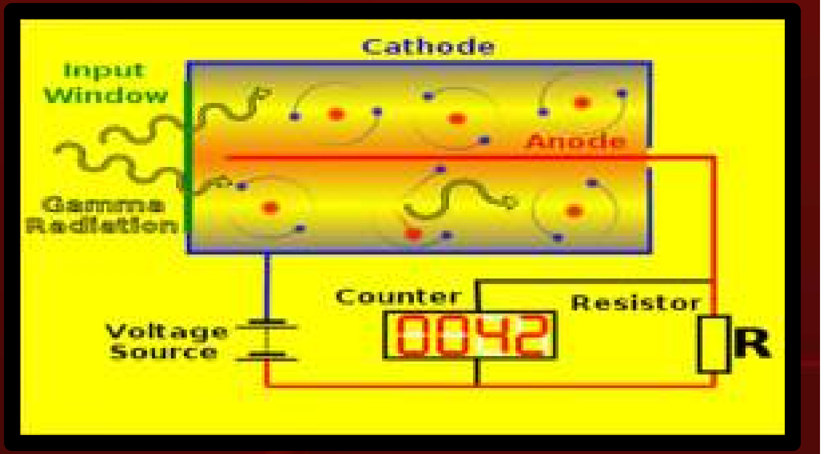
- It has an ion collecting chamber that is continually being charged by a battery. This instrument constantly measures the amount of ionization taking place in the air within the chamber.

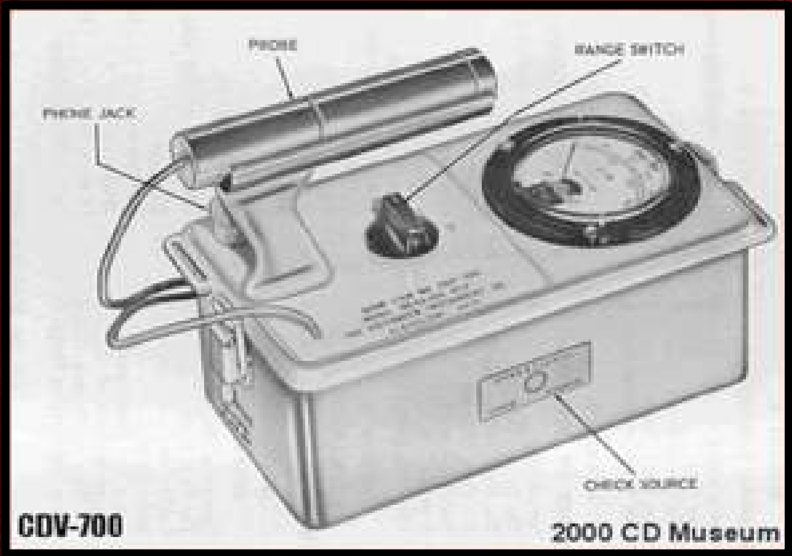
# Geiger Counter

- This works on the principle of **'ionization by collision'.**

It is used to detect & record much smaller amounts of ionization than the ionization in thimble chamber, e.g. ionization caused by radioactive decay.

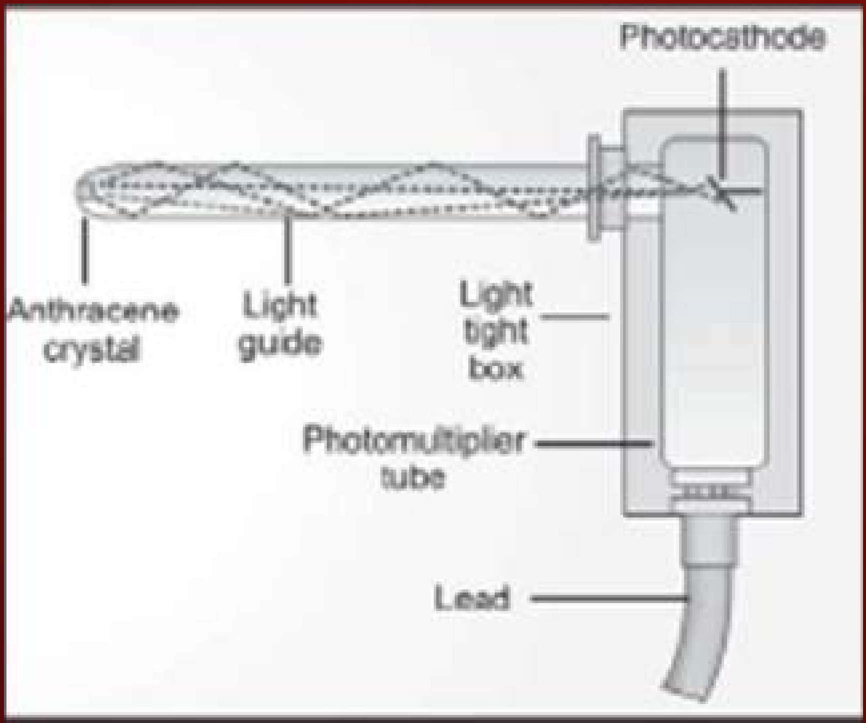



PROBE
RANGE SWITCH
PHONE JACK
CHECK SOURCE
CDV-700
2000 CD Museum

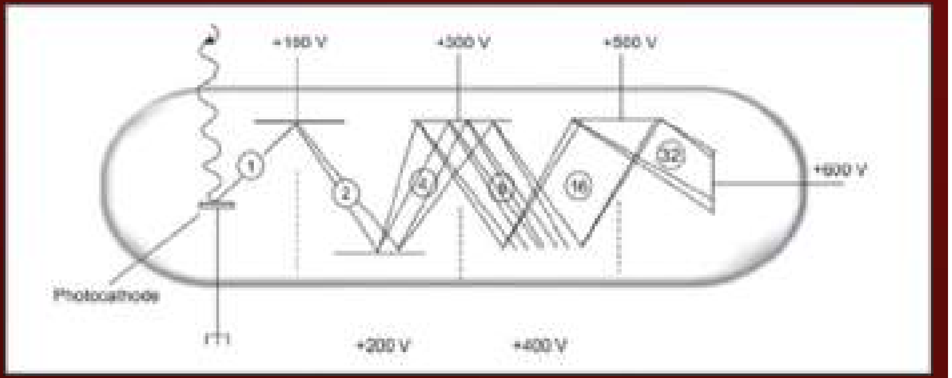
# Scintillation counter

- X-rays are incident on a phosphorescence substance which releases visible light proportional to amount of x-ray incident on it & this is reflected




The dotted line indicate the reflection of light along the internally polished guide on to the photo cathode

- This light when it leaves the chamber gives rise to an impulse.
- The number of impulses generated are proportional to




The number in the circles indicate the amplification being produced at each stage.

- Potentiometer: A potentiometer, using an aluminum can be used to determine the amount of radiation exposure.

- Personal monitoring devices: -

1. Pocket dosimeter
2. Digital electronic dosimeter
3. Film badge
4. Thermoluminscent dosimeter

# DOSIMETER / ELECTROMETER

- Has 2 electrodes which are charged through an external connection. Since they are of the same charge, they repel each other.

- As an ionizing radiation passes between the electrodes & the electrically conductive case, the charge on the electrodes

- When the charge reduces, an electrode moves away from the zero calibration.
- The magnifier displays this motion against a scale.
- The charger is a small box, usually powered by a battery.

- The box has a fixture that requires one to press the end of the dosimeter on the charging electrode.

- Some chargers include a light to illuminate measurement electrode, so the measurement, logging & recharging can occur with one routine motion.

- Are made in different ranges.



Peacetime occupational exposure

# TYPES OF DOSIMETERS

- ACTIVE
- PASSIVE DOSIMETERS.

- All passive dosimeters integrate the dose over the measurement time.

- Well-known examples are film badges, glass dosimeters and thermo luminescence dosimeters.

- As long as the maximum allowed dose is not exceeded, they are suitable to measure the dose in pulsed radiation fields.

- The main disadvantage of passive dosimeters is that dose rates are not measured.
- Therefore an alarm function is not available.
- Furthermore, usually a special readout is mandatory, which does not allow reading the personal dose obtained in real time.

- An active dosimeter, combines a detector with an electronic readout and is usually able to display the current dose rate.

- The detector either consists of a Geiger-Müller (GM) counter or a PIN-diode.

- Because of size limitations for active personal dosimeters, PIN diodes are preferred

# Dosimeter placement

- Interpretation of the measured dose depend on the placement of the dosimeter.

- All personnel must wear their dosimeters correctly.

Indications where dosimeters are to be worn: -

1. Film Badge with an TLD badge: wear

2. **Film badge with a TLD badge :** Wear the film badge under the lead apron & TLD above the apron at collar level.

3. **Ring Dosimeter:** Wear ring dosimeters so that employee's name faces outwards.

- Do not expose personnel monitoring devices to extreme heat or humidity.

- If any dosimeter has received a dose higher than the values shown below, the employee will be notified & the reason for high reading will be investigated.

- Measures will be taken to keep radiation doses below these limits where ever possible.

Whole body 125 mrem/

# Pocket dosimeter

- Pocket dosimeters are used to provide the wearer with an immediate reading of his or her exposure to x-rays & gamma rays.

- As the name implies, they are commonly worn in the pocket. There are different types:

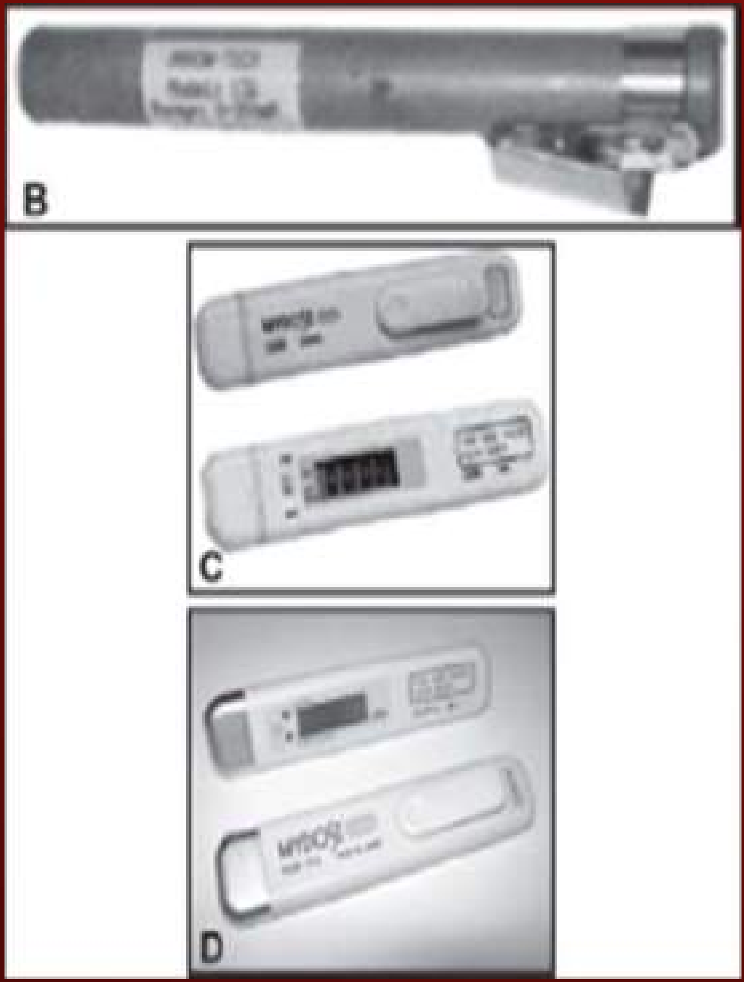
## (i) Minometer or the Condensor type or the indirect reading type:

- It is an ion chamber which has a voltage potential placed on it by insertion into a charger.

- Radiation penetrating the chamber causes the current to leak off in proportion

- By reinserting the dosimeter into the charge reader at the end of day, the resulting voltage is calibrated in milli roentegen.

- Usually two dosimeters are worn at a time with the lower of two readings taken as



## ii. Direct Reading Pocket Dosimeter:

- A direct reading pocket ionization dosimeter is generally of the same size & shape of a fountain pen.

- The dosimeter contains a small ionization chamber with a small volume of approximately 2 mm.

- When the anode is charged to a positive potential, the charge is distributed between wire anode.


- Electrostatic repulsion deflects the quartz fiber & the greater the charge, the greater the deflection of the quartz fiber.

- The electrons produced by ionization are attracted to & collected by the positively charged central anode.

- This collection of electrons reduces the net positive charge & allows quartz fiber to return in the direction of the original position.

- The amount of movement is directly proportional to amount of ionization which occurs.

- By pointing the instrument at a light source, the position of fiber may be observed through a system of built –in lenses.

- The fiber is viewed on a translucent scale which is graduated in units of exposure.

- Typical industrial

- During this shift , the dosimeter reading should be checked frequently.

- The measured exposure should be recorded at the end of each shift.

## Advantages

➢ The principal advantage of a pocket dosimeter is its ability to provide the wearer an immediate reading of

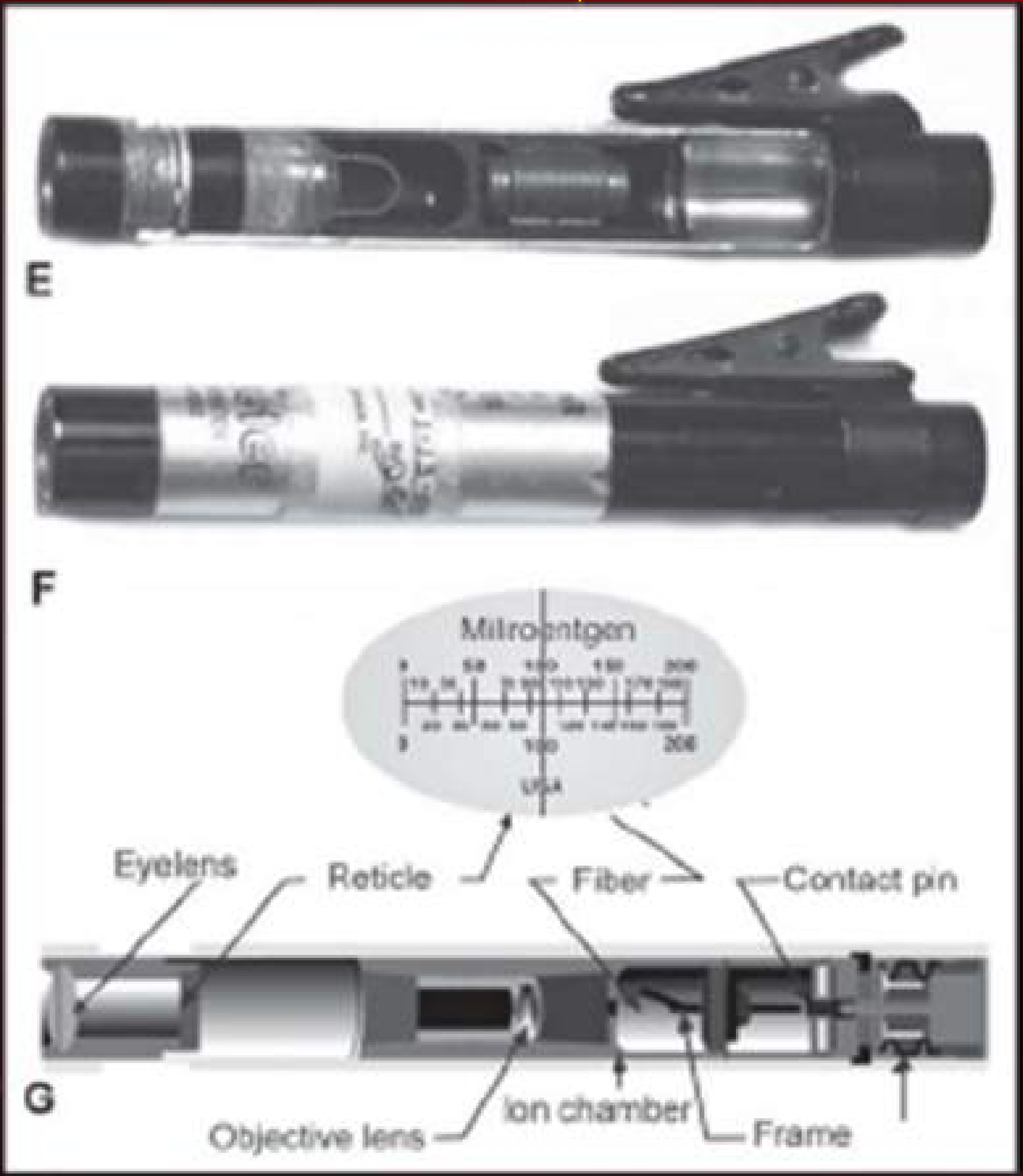
## Disadvantages

- ➢Limited range.
- ➢Inability to provide a permanent record.
- ➢Potential for discharging & reading loss due to dropping or bumping.

The dosimeters must be recharged & recorded at the start of each working shift.

- Charge leakage or drift can also affect the reading of a dosimeter .
- Leakage should be no greater than 2 %

# Direct reading pocket dosimeter



## b. Digital Electronic Dosimeter

- These dosimeters record dose information & dose rate.
- These dosimeters most often use Geiger-Muller counters.
- The output of the radiation detector is collected & when a predetermined exposure

- Some digital electronic dosimeters include an audible alarm feature which emits an audible signal or chirp with each recorded increment of exposure.



- Some models can also be set to

- This format helps to minimize the reading errors associated with direct reading pocket ionization chamber dosimeters & allows the instrument to achieve a higher maximum read out before resetting is necessary.

- The electronic dosimeter is 5 to 200 times more sensitive than a TLD.

# Arrow –Tech dosimeters

- These are rugged, precision instruments about the size of a pocket fountain pen, which are used to measure accumulative doses or quantities of γ & x-ray radiation.


- It is pocket size, conductive fiber electroscope with an ion chamber for detecting & indication integrated exposure to Υ & x-ray radiation.


- It has a thin wall which permits the penetration & detection of radiation.

# Personal alarm dosimeter

- The active element of a track etch dosimeter is a piece of CR-39 plastic ( from Columbia resin 39), made by polymerization of allyl diglycol carbonate.

- When a high energy charged particle such as

- The material is subsequently exposed to a suitable etchant such as NaOH & damage sites are preferentially etched, leaving pits which can be observed & counted under a microscope.

- The operation of the Bubble detector dosimeter is based on the change to gas bubbles of superheated liquid (at a temperature above its boiling point) triggered by fast neutron interactions.

- A commercial bubble detector personal neutron dosimeter consists of a clear plastic tube with an aluminum fitting at one end, about the size of large pen.

- It holds about 8 cm3 (.5 in.3) of clear solid elastic polymer containing about 10,000 superheated liquid droplets.

- On exposure to fast neutrons, small uniform sized bubbles form.
- The bubbles are counted visually & a fast neutron dose calculated using a calibration factor determined for that dosimeter.
- A similar device, used with the same charger, is a rate meter.
- This is an inexpensive method for civil defense persons to measure radiation rates.

- One measures the rate of change of the rate meter for a timed exposure after charging the rate meter.
- Usually one measures after charging fall out of 32 second period, & a light fall out over a 10 min period.
- The rate meter has 2 internal scales that read the radiation flux directs in rems of period.

# Film badges:

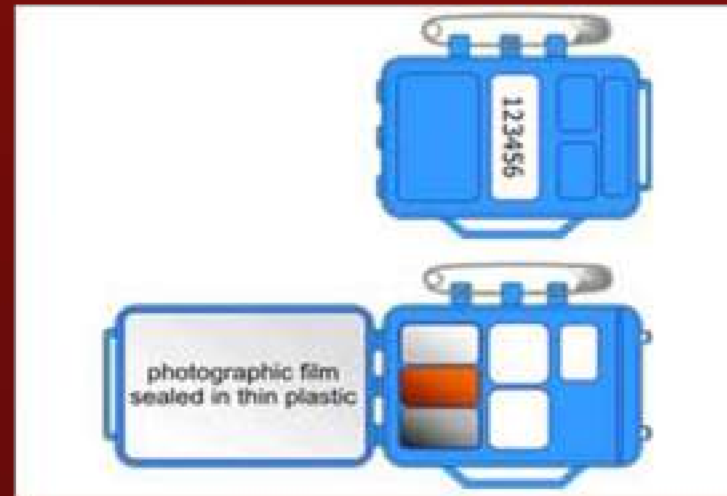
- The housing of film badge dosimeter is of plastic or metal, typically 50 mm2(2inch) by 12 mm (.5 inches) thick & equipped with a clip for attaching to clothing.


It contains one or

- The film is developed in a standardized procedure & optical density is measured & correlated to exposure, greater exposure being darker.

- The side of the badge housing is equipped with one or more filters of lead, aluminum, copper, silver or cadmium which cover different

- These filters modify the response of different areas of film & thereby provide more information to correct the response to approximate that of tissue.




- The blackening of a plane film does not alone give reliable indication of the exposure to which the film has been subjected.

- If, however , the film is ‘sandwiched’ between two thin sheets of tin of each about 1 mm thick, the blackening per unit

- The tin has practically no effect on the high energy radiation, thus the blackening per unit exposure is practically unaffected by the presence of tin.

- However, low energy radiation is considerably attenuated by the tin, so the blackening it produces is reduced.

- The degree of blackening produced on the film by the radiation is measured by 'densitometer' & when adequately calibrated , it gives the amount of radiation to which wearer

- In each badge there is a part of the film which is not covered by any filter.
- This ‘open’ part of the system has an important role.
- Taking a simpler badge as an example, the ratio of the blackening (fog) in the open part of the film to that of the region under the tin filter gives an indication of the quality of radiation to which badge has been exposed.

- If both portions are almost equally blackened, 'hard' Y or high energy x-rays would likely be the cause.

- If the blackening in the open part is four times as great as under the tin , then low energy x –rays may have been involved.

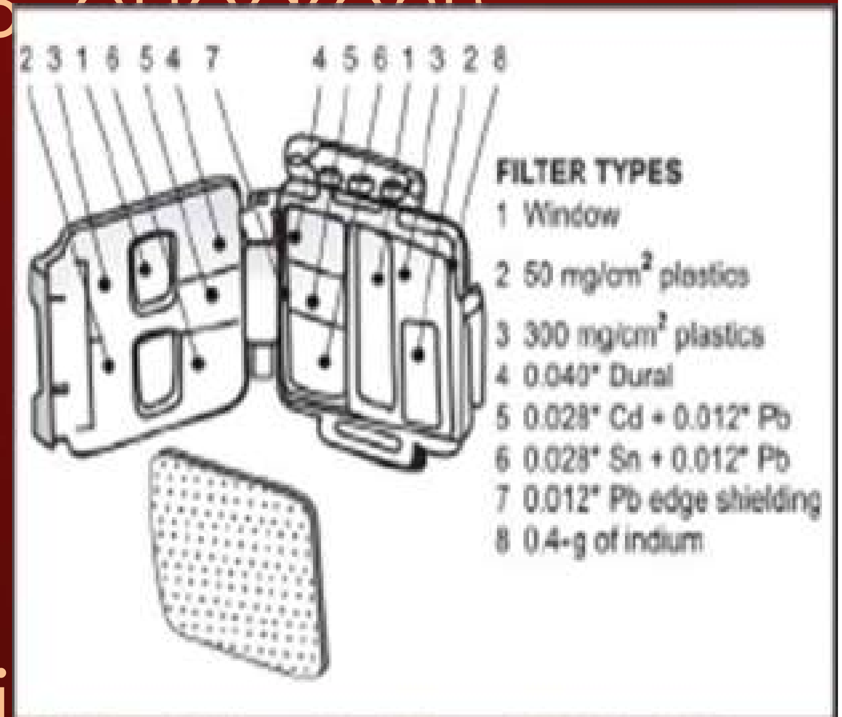
- The film badge uses a dental film enclosed in a light tight cover in a metal framework containing various filters.

The badge usually has 6 quadrants:

Open

Aluminum

Cadmium




- The ratio of blackening of the open part of the film to that produced in regions of filters gives an indication of the quality of the radiation to which the wearer has been exposed.

# Advantages

1. Good for measuring any type & energy of radiation. For eg , X-rays, $\gamma$-radiation.
2. Continuous assessment is possible.
3. Accumulated dose can be calculated.
4. Provides a permanent record of dose received.
5. Simply, robust & relatively inexpensive

# Disadvantages

1. Accuracy is only as 10 to 50 %, as many low energy photons may not penetrate the film.
2. Range of exposure is less.
3. The results are dependent on the processing, the strength & type of developer used & the speed of the film used, may lead to errors.
4. No immediate indication of exposure- all information is retrospective.

# Monitoring of the badge.

- The badge is usually monitored every 2 weeks, or sometimes in 4 weeks, in cases where it is certain that the radiation hazard is very small.

- If high accidental exposure be suspected, the film should be immediately processed.

- Badges are normally worn at the chest or waist level on the outside of the normal working clothes , to give an indication of the whole body exposure to which the work is subjected.

- If lead rubber gloves or a protective lead apron is worn, the badge should be underneath the apron, since it is exposure to the worker's body & not to the apron that is of interest.

- Modified versions of the badge are also available to be worn on the wrist, to indicate general hand exposure & on the forehead to provide an estimate exposure to the eyes.

- Badges are prone to filter loss.

- A recent development in the film badge dosimetry is the Twin Film Service.

- The subscriber receives a clip on film pack holder containing two separate film packs.

- One used for week dose determination.

- The customer keeps the same film holder for a 13 week period & is supplied with a new slide in film pack of a different color each week.
- At the end of the week, the used weekly packets are mailed to the service company laboratory.
- The films, sensitive to alpha, beta & gamma radiations are developed & compared in precision densitometers with films exposed accurately determined amounts of radiation.

# Thermoluminescence Dosimeter (TLD)

- This is used for measurements of the actual dose received by the operator/ patient as a result of radiography or radiotherapy exposures & are the most common type of personnel monitoring devices

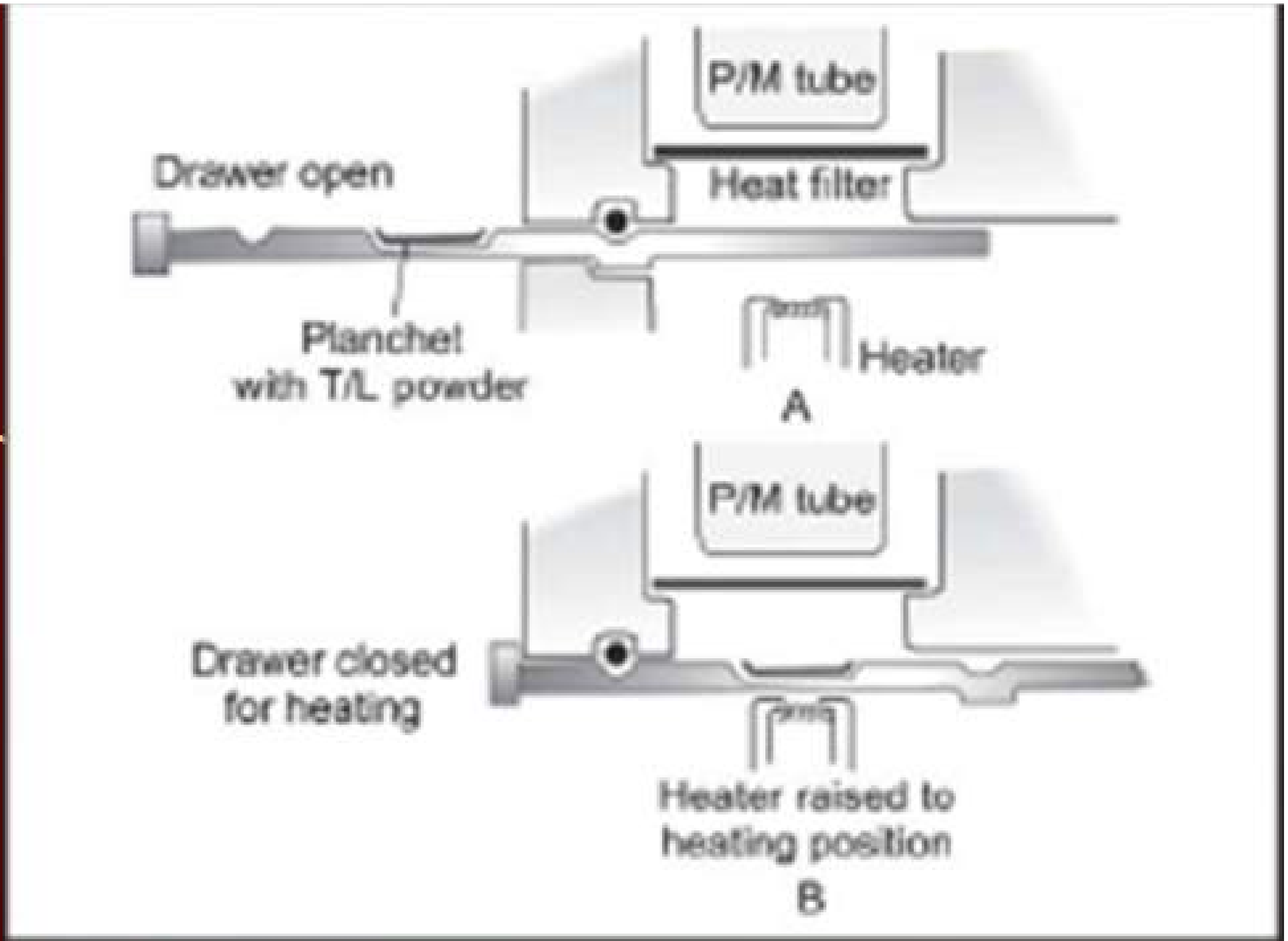
- Since the amount of the material & its size is small & it also causes nearly the same attenuation of the x-ray beam as does soft tissue, the TLD can be very easily be placed on the skin or in the body cavity during exposure.

- The TLD card consists of a Nickel plated aluminum plate having 3 symmetrical holes, each of diameter 12 mm, over which 3 identical CaSO4 embedded Teflon disks are dipped (13.2 mm diameter, 0.8 mm thickness, 280 mg

1.Open reg

2. Copper

3. Aluminur




- Thermoluminescence is the property of a substance (e.g. LIF) to emit light or energy which it has

# Principle of TLD badge:

- When the phosphor is irradiated , the X-ray energy is absorbed & secondary electrons are produced.

- The secondary

- These fall back into traps in meta stable states, where they are held.

- When the phosphor is heated , to 200-300∘C, the trapped electrons acquire energy to escape back to the conduction band.

- From the conduction band, they fall back to fill holes in the filled zone & when recombine, visible light is produced called "Thermo

- The TLD reader : The equipment used to heat the exposed material & measure the emitted light is called the TLD reader.

- The reading given by this equipment is used as a measure of the absorbed dose to which the material was subjected.

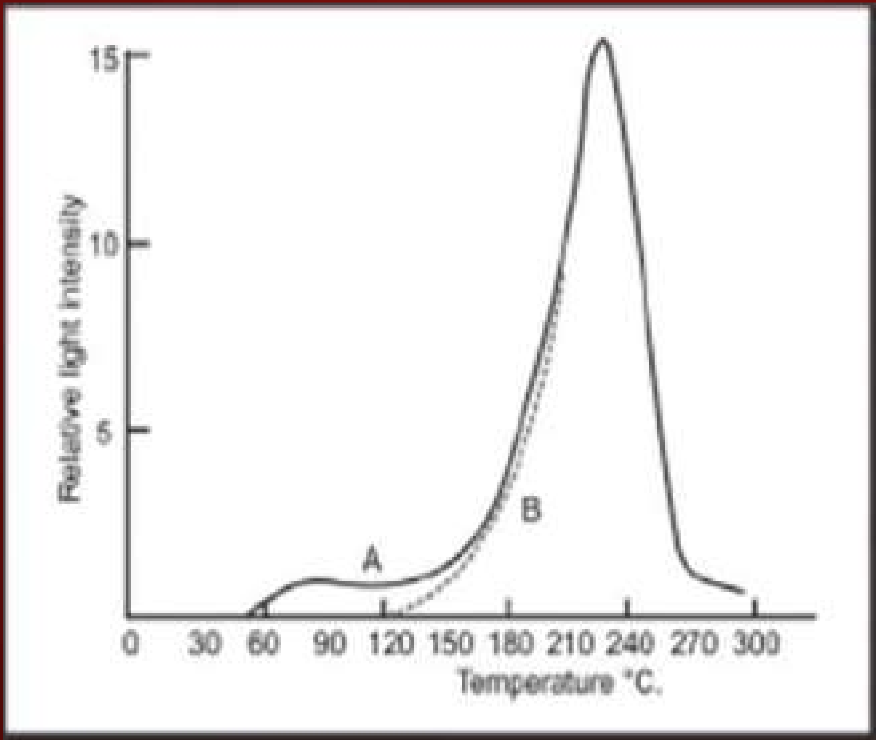
-

- The reader comprises of 3 main parts :

1. Heater
2. Photomultiplier tube
3. Electronic system

- Glow curve: - There is a variation of intensity of light emitted as the TLD material is heated up from room temperature to 300∘C.

- Quite a lot of light is emitted at temperatures below 150 -200∘C
-



- However , if the irradiated material is stored at room temperature before 'read-out' it is found that the glow curve changes.

- This is due to leakage electrons stored in more shallow traps during storage.

- Majority of this 'fading' occurs in the initial 24 hrs after which response is

Wearing of the badge:- The chest badge has a metallic clip & should be worn outside the working clothes & below the lead apron.

- Wrist badges have a snap for attachment.

- The badge has to be monitored every 2 months for radiation

# Applications

- Radiotherapy- for measuring doses received by patients while actually undergoing the treatment exposures.

- Radio diagnosis – with the increasing importance being placed on minimum dose received during radiography. TLD is assuming an important role.

- Personnel monitoring:- The ability of the TLD material to store dose over long period of times makes it very suitable for use an alternative to photographic film for personnel measurement.

# Advantages

1. Small in size & light in weight.
2. Chemically inert.
3. Almost tissue equivalent i.e. response similar to human tissue, as LiF has a lot atomic weight.
4. Usable over a wide range of radiation qualities.
5. Usable over a wide range of dose values.

8. Automation compatible.
9. No wet chemistry required.
10. Reusable. By employing proper annealing the TLD can be used a number of times.
11. Economical, Reusability, generally reduces the cost per reading.
12. Read out simple & quick.
13. Apart from initial fading, can store dose over long period of time.
14. Exposures can make 'in the field' away from the measuring

## Disadvantages

1. Read out is destructive, giving no permanent record , results cannot be rechecked or reassessed.
2. Only limited information provide on the type of energy of the radiation.
3. Dose gradients are not detectable.
4. Relatively expensive.