Al-Mustaqbal University
College of Health and Medical Techniques
Radiological Techniques Department

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Radiation Protection Course

Lecturer

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Design of Protective Barriers in X-Ray Installations

Designing protective barriers in X-ray installations is critical to ensure the safety of both patients and staff from ionizing radiation. These barriers should comply with relevant regulatory standards and guidelines, such as those provided by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) in the United States. The thickness of protective shielding necessary to reduce the exposure rate from any x-ray machine to the maximum permissible level depends on the tube potential, the extent to which the machine is used (workload), the distance from the tube to the occupied area, the degree and nature of the occupancy, the type of area, and the material of which the barrier is constructed. Here is a detailed guide on designing protective barriers in X-ray installations:

- **Regulatory Compliance(الامتثال التنظيمي)**:
  Ensure that your X-ray installation complies with all relevant local, national, and international regulations and standards. This includes guidelines from organizations such as the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA).
- **Occupancy Category(فئة الاشغال)**:
  Classify areas based on their occupancy category, which depends on how often individuals are present. For example, areas with continuous occupancy (e.g., radiology control rooms) have stricter design requirements than those with occasional occupancy (e.g., waiting rooms).

Structural of x-ray room shielding design

Factors to be considered in

Use Factors:

The concept of "use factors" is essential to determine the required shielding thickness for different areas of the room. Use factors take into account the radiation exposure levels in different areas based on how frequently and under what conditions they are occupied. These factors are used to calculate the effective shielding requirements for each area. The location has use factor floor 1 walls 14 and ceiling 12-1/4 depending on equipment and techniques

Workload (W): refers to the amount of time and the conditions under which the X-ray machine is in use and emitting radiation. This factor is based on the number and energy of X-ray procedures performed in a given area. A higher workload increases the required barrier thickness. It is one of the factors considered in designing the structural shielding of an X-ray room to ensure that the protection provided is sufficient for the level of radiation exposure.

Occupancy factor (T) : Is a critical parameter in the structural design of X-ray room shielding. It represents the fraction of time during which the space within the X-ray room is occupied by staff, patients or public. The occupancy factor helps determine the level of shielding required to protect these occupants from radiation exposure. Typical occupancy factors; Full occupancy (T=1), work area, offices, nurses, stations.

Partial occupancy (T= ¼), corridors, rest room.

Occasional occupancy (T =1/8 -1/16), waiting room, outside area

Primary Radiation:

A barrier is required to attenuate the primary beam to a level that complies with the dose constraint. Primary barriers arc typically required in general radiographic rooms, dedicated chest rooms and rooms where there is a combination of radiograph) and Fluoroscopy. For mammography, fluoroscopy, CT the entire primary beam is normally incident on the face of the image detector which acts as a primary beam stop.

Secondary radiation scatter and leakage:

Secondary radiation is, in practice, the most ubiquitous radiation type for which shielding is provided. It is a combination of scattered radiation (generally from the patient) and leakage (from the tube housing). The former is frequently the dominant component. For shielding calculations, the patient may be regarded as the source of scattered radiation. It is also dependent on the spectrum of the primary beam and the scattering angle. The scattered radiation is generally present throughout the room and decreases with the distance from its source.

Design of Primary Protective Barrier

The design of a primary protective barrier for X-ray installations is a critical aspect of ensuring the safety of both patients and healthcare workers. When designing a primary protective barrier, several factors need to be considered, including the type and energy of X-rays, the location of the barrier, and regulatory requirements. Here are the key steps in designing a primary protective barrier for X-ray facilities.

Barrier Material:

Lead is the most commonly used material for primary protective barriers due to its high density and effectiveness in blocking X-rays. Lead sheet of nominal total thickness 2 mm. The lead sheet may be used as such, sandwiched between two layers of plywood. Solid concrete block or concrete block filled with grout or sand, and having a total thickness of not less than 150 mm. A 3-cm thickness of concrete is approximately equivalent to 0.4 mm of lead

Design the Barrier:

The primary barrier is typically constructed in the walls, ceilings, and floors of the radiology room. Ensure that the barrier design covers all areas where radiation may penetrate.

d = Distance in meters from the radiation source to the area to be protected

P =Maximum permissible weekly exposure

B = transmission factor or (attenuation factor).

$$P = \frac{WUT}{d^2} \times B$$

$$B = \frac{Pd^2}{WUT}$$

Design of Secondary Protective Barrier

Secondary radiation consists of radiation scattered from or produced by interactions with the patient and other objects as well as the leakage radiation from the protective housing of the source

Designing a secondary protective barrier to address leakage radiation in an X-ray room is a crucial step in ensuring radiation safety for both patients and healthcare professionals. This barrier is meant to capture any scattered or leakage radiation that may escape from the primary protective barriers and X-ray equipment.

$$B_{sco} = \frac{60 \times I \times Pd^2}{WYT}$$

I = Current intensity

Y = The permissible leakage rate depends on the type of tube

Calculating the number of half-value layers required for shielding N from the relationship

$$B = e^{-N} \qquad N = \frac{lnB}{ln2} = \frac{lnB}{0.693}$$

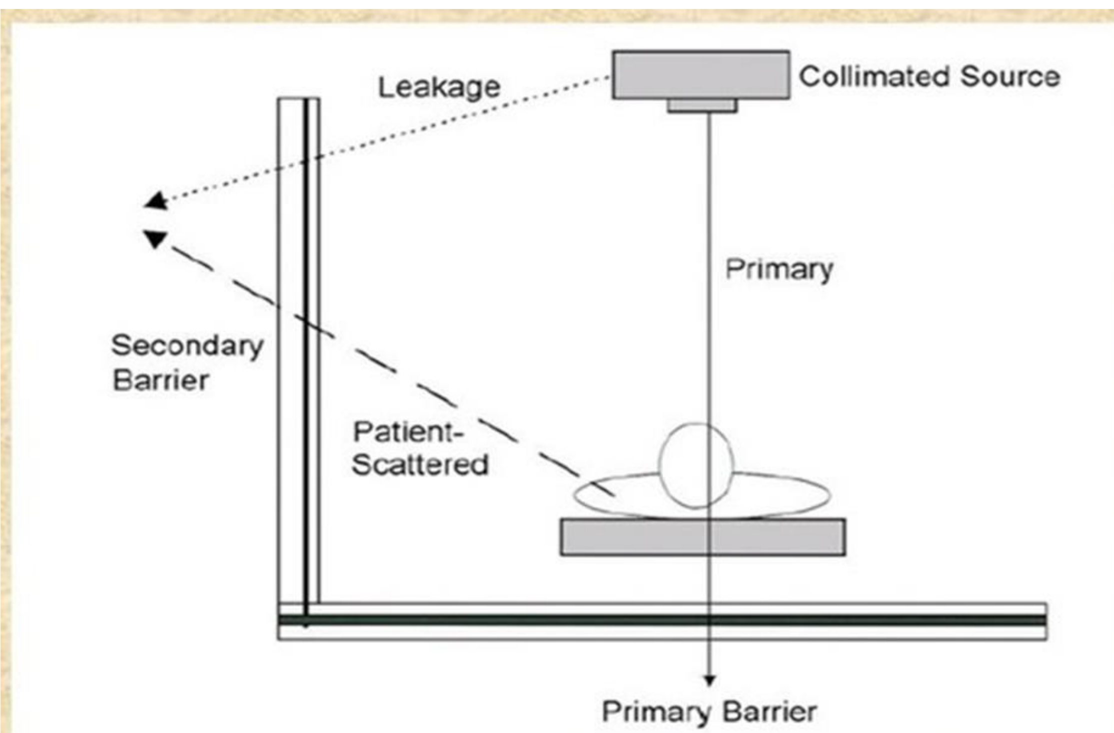

Fig. 1.2. Schematic of radiation sources (primary, leakage and patient-scattered) and the primary and secondary barriers.

Factors That Affect Barrier Thickness

The thickness of a material that can block or attenuate X-rays is determined by several factors, including:

X-ray Energy: The energy or wavelength of the X-rays plays a significant role in determining their penetration through materials. Higher-energy X-rays (shorter wavelengths) can penetrate more deeply into matter, so they require thicker barriers to block effectively.

Material Density: The density of the material through which the X-rays pass affects their attenuation. Materials with higher densities, such as lead or tungsten, are more effective at blocking X-rays. Thicker barriers of less dense materials may be needed to achieve the same level of attenuation.

Atomic Number (Z) of the Material: The atomic number of a material is related to the number of protons in its atomic nucleus. Materials with higher atomic numbers tend to be more effective at blocking X-rays. For example, lead (Pb) has a high atomic number and is commonly used in X-ray shielding.

Thickness of the Barrier: Naturally, the thickness of the material itself is a critical factor. The thicker the barrier, the more X-rays it can block. The required thickness will depend on the X-ray energy and the material being used.

X-ray Exposure Time: The duration of X-ray exposure also affects the amount of radiation that passes through a material. Longer exposure times result in more X-rays interacting with the barrier, potentially requiring a thicker barrier for the same level of protection.

Scattering Effects: X-rays can scatter when they interact with matter, and this scattering can reduce their effectiveness in penetrating a material. Some materials scatter X-rays more than others, and this scattering effect can influence the required barrier thickness.

Angle of Incidence: The angle at which X-rays approach the barrier can impact their ability to pass through. For example, X-rays incident at a shallow angle may penetrate more effectively than those incident at a steep angle.

Specific X-ray Equipment: Different X-ray machines and sources can produce X-rays with varying energy levels, which may require different barrier thicknesses for effective shielding.