

Second Stage/ Radiation Physics Lab



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X-Ray Production and Entrance Surface Dose

Lecture 2

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The aim of the experiment:

- 1-How are x-rays produced.
- 2- Find the Entrance Surface Dose.

The devices used in the experiment:

- 1-X-ray tube .
- 2- filament cathode.
- 3- Copper anode with tungsten inset.

Introduction:

X-rays are produced when energetic electrons interact with target and convert their kinetic energy into electromagnetic radiation (x-rays). This task can be accomplished in a device called **x-ray tube** where an electron source (cathode) a target (anode), and an evacuated path for electron acceleration is available. In addition, a source of energy is required to accelerate the electrons (generator).

Theory:

X-ray tube is composed of a cathode and an anode situated within an evacuated glass envelope or tube. The glass of the tube is leaded to prevent (the generated X – ray) from escaping in all directions. While the window is of unleaded glass so that X – ray exist out through this window.

1-Anode:

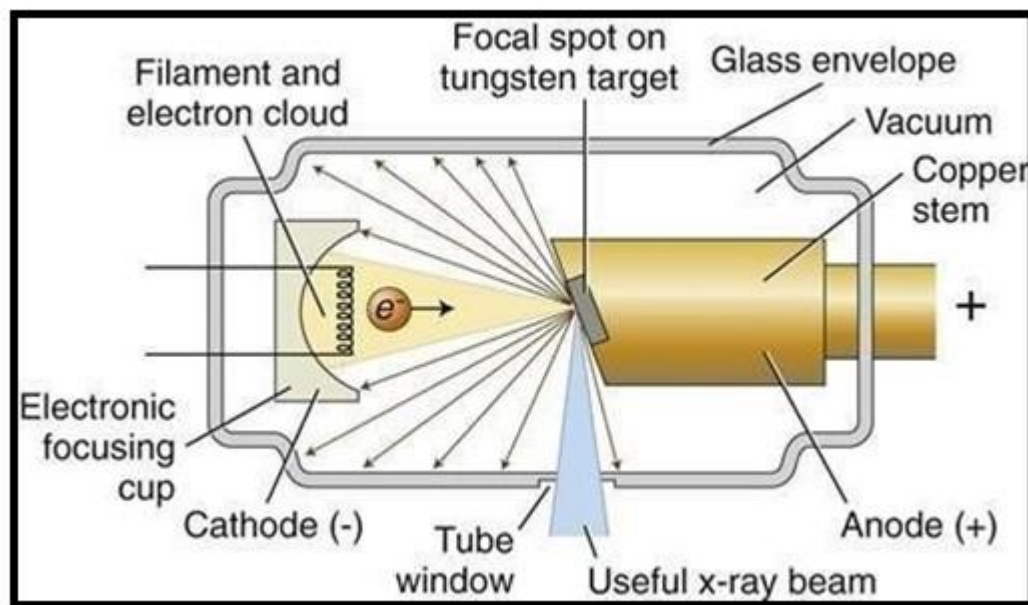
The anode is the component in which the x-radiation is produced. It is a relatively large piece of metal that connects to the positive side of the electrical circuit.

The anode has two primary functions:

1-convert electronic energy into x-radiation

2-dissipate the heat created in the process.

The fraction of the total electronic energy that is converted into x- radiation (efficiency) depends on two factors: the atomic number (Z) of the anode material and the energy of the electrons. Most x-ray tubes use tungsten, which has an atomic number of 74, as the anode material. In addition to a high atomic number, tungsten has several other characteristics that make it suited for this purpose. Tungsten is almost unique in its ability to maintain its strength at high temperatures, and it has a high melting point and a relatively low rate of evaporation.



Figure(1): Schematics of a conventional X-ray tube

2-Cathode:

The basic function of the cathode is to expel the electrons from the electrical circuit and focus them into a well-defined beam aimed at the anode. The typical cathode consists of a small coil of wire (a filament) recessed within a cup-shaped region.

The filament of the cathode is heated in the same way as a light bulb filament by passing a current through it. This heating current is not the same as the current flowing through the x-ray tube (the MA) that produces the x-radiation. During tube operation, the cathode is heated to a glowing temperature, and the heat energy expels some of the electrons from the cathode.

The high-voltage source is typically of the order of 10^3 to 10^6 volts. The filament (cathode) is heated to incandescence and emits electrons by the process of thermionic emission. At such high temperatures (2200°C) the atomic and electronic motion in a metal is sufficiently violent to enable a fraction of the free electrons to leave the surface. These electrons are then repelled by the negative cathode and attracted by the positive anode. The electrons are accelerated by the high voltage source toward the target (anode). **Because of the vacuum**, they are not hindered in any way, and bombard the target with a velocity around half the speed of light.

Entrance Surface Dose:

Entrance Surface Dose (ESD) is the measure of the radiation dose absorbed measured in milligrays (mGy) by the skin as it reaches the patient. ESD is a directly measurable quantity, often, measured using thermoluminescent dosimeters (TLD).

ESD is usually a benchmark measurement used to assist in quality control and optimization in radiography departments. However, it is a poor indication of radiation risk as it does not account for tissue sensitivity, penetration, and area of the X-Ray beam.

ESD is used in plain radiography to set diagnostic reference levels (DRLs), a reference level that establishes a benchmark for optimizing medical radiation, ensuring departments adhere to the principles of radiation protection.

Method of Working:

This work includes four commonly performed diagnostic X-ray examinations at hospitals. These examinations on which the measurements were conducted are Chest, Skull, Pelvis, and Cervical in some patients.

The inherent filtration of X-ray machines in the hospitals was 1 mm and 1.5 mm. Before initiating the measurement, the X-ray generator and equipment were tested for time accuracy, voltage accuracy, output linearity, and filtration (HVL).

The ESD for patients was determined by measuring air kerma in an indirect method during the examination by using a calibrated kVp meter.

ESD may be calculated in practice by knowing the tube output, the relationship between the X-rays unit current-time product (mAs), and the air kerma in the air which is established at a reference point in the X-rays field at 80 KVp tube potential. Subsequent the estimate of the ESD can be done by recording the relevant parameters (tube potential, filtration, mAs, and FSD) and correcting for

distances and backscattered radiation as shown in the equation below:

$$\text{ESD} = \text{OP} \times \left(\frac{\text{kV}}{80}\right)^2 \times \text{mAs} \times \left(\frac{100}{\text{FSD}}\right)^2 \times \text{BSF}$$

Where:

OP is the tube output per mAs measured at a distance of 100cm from the tube focus along the beam axis at 80 kVp. ((**OP = 0.071 mAs**)).

kV is the peak of the tube voltage, recorded for any given examination. Where in many cases the output is measured at 80 kVp, and therefore this appears in the equation as a quotient to convert the output into an estimate of that which would be expected at the operational kVp. The value of 80 kVp should be substituted with whatever kVp the actual output is recorded at in any given instance.

MAs: is the tube current-time product that is used in any given instant.

SID: is source-to-image distance.

FSD : is the focus-to-patient entrance surface distance.

$$\text{FSD} = \text{SID} - \text{Thickness}$$

BSF: is the Backscatter factor.

Data Table:

Examination	kVp	mAs	SID	Thickness	FSD	BSF
Chest	70	35	130	23		1.2
Chest	69	36	140	23		1.2
Chest	75	35	140	23		1.2
Skull	65	25	80	20		1.3
Skull	55	24	120	20		1.3
Skull	58	22	80	20		1.3
Pelvis	70	40	100	23		1.2
Pelvis	80	34	110	23		1.2
Pelvis	75	30	100	23		1.2
Cervical	66	24	140	13		1.2
Cervical	64	10	120	13		1.2
Cervical	70	20	120	13		1.2