X RAY PRODUCTION IN DIAGNOSTIC RADIOLOGY

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**Abstract**

Electromagnetic waves with wavelengths of 0.01 to 10 nanometers are referred to as X-rays. X-rays have been used to image biological tissues and assist in the diagnosis of disease for a very long time in the field of diagnostic radiology. Simply put, X-rays are created when electrons are accelerated by a potential difference, which results in electromagnetic radiation. The fundamental parts of an X-ray production system consist of a generator and an X-ray tube, each of which parts is enclosed in a vacuum.

**I. INTRODUCTION**

A source of energy is necessary for medical imaging of the human body. The energy used to create the image in radiology's medical imaging procedures must be able to pass through tissues. Most medical imaging outside of the radiology department is done using visible light, which has a limited capacity to penetrate tissues at depth. Skin photography, endoscopy, and light microscopy are all applications of visible light pictures in pathology, gastrointestinal, and obstetrics. Direct visual observation, which also makes use of visible light, is a standard practice across all medical specialties. Mammography, computed tomography, magnetic resonance imaging, and nuclear medicine are examples of diagnostic radiology procedures that utilize electromagnetic spectrum wavelengths outside of the visible light region in addition to X-rays.

**II. PRODUCTION OF X RAY**

The glass envelope of a conventional X-ray tube is filled with high vacuum. A cathode (negative electrode) and a positive electrode, both hermetically sealed in the tube, are located at either end. Thermionic emission occurs when heat emits an electron from the tungsten plate that serves as the cathode. When extremely energetic electrons contact with materials, they turn their kinetic energy into electromagnetic radiation, producing X-rays.



Figure:1 X Ray Production

An evacuated route vacuum for electron acceleration and an electron source makes up the equipment that brings out the above task. Outside supply of energy to speed up that electron

**X-Ray Tube**

X-Ray Tube

1. Cathode

2. Anode

3. Rotor/Stator

4. Glass or Metal envelope

5. Tube Housing

**Cathode:**

1. A focusing cup surrounds a helical coil of tungsten wire that serves as the cathode.

2. The filament circuits supply a voltage of up to 10 V and up to 7 A of current to the filament.

3. The filaments are heated by electron resistance, which releases electrons.

4.When a positive voltage is given to the anode relative to the cathode, an electron released from the filament flows through the tube's vacuum to the anode.

**Focusing cup Figure:2 Cathode**

**** Shapes the electron beam's width and surrounds the filaments.

It is possible to bias an insulated focusing cup with a greater negative voltage (about 100V less) than the filament. intensify the electric field surrounding the filament.

1. Limits the beam's spread

2. Produces a narrow focal spot width

**Filament Current**

 The rate of thermionic electron emission is dependent on filament temperature, which is determined by filament current. A space charge cloud forms around the filament when no voltage is provided between the cathode and the anode.

the use of highly positive The electron is accelerated toward the anode by the cathode-to-anode voltage, which results in tube current. Relatively substantial changes in tube current can result from small changes in the filament current.

**Anode Figure: 3 Filament Current**

A metal target electrode known as the anode is kept at a positive potential differential with respect to the cathode.

Due to its high atomic number (Z=74) and high melting point (3,370°C), tungsten is the most commonly utilized anode material.

The surface of a tungsten anode can withstand significant heat deposition without cracking or pitting.

**Anode arrangements**

1. The simplest type of X-ray tube has a fixed or stationary anode.

2. is made up of a block of copper with a tungsten inlay inside.

3. Copper secures the tungsten target and efficiently removes heat from it.

4. A smaller target area slows down heat transfer, which lowers the maximum tube current and, as a result, the x-ray flux.

5. Used in dental X-ray machines, portable X-ray equipment, and portable fluoroscopy systems

**Rotating anode:**

1.The most common diagnostic x-ray applications employ rotating anodes.

2. Higher x-ray production capabilities due to increased heat loading

3. Electrons give a rotating target energy, distributing thermal energy across a vast surface and mass.

**Rotor:**

Copper bars are placed around a cylindrical iron core in the rotor. The stator is composed of electromagnets that encircle the rotor outside the x-ray tube. Rotor rotation is caused by alternating current flowing through the stator windings. The range of rotational rates is from low speed rotation at 3,000 to 3,600 rpm to high speed rotation at 9,000 to 10,000 rpm.

**Focal spot size**

Actual focal spot width and effective focal spot width are equivalent.

Actual focal length times sine of effective focal length

The line focus principle describes the foreshortening of the focal spot length when seen down the center ray.



Figure:4 Focal Spot Size

**Anode angle**

There is a suitable anode angle that depends on the clinical imaging application. A modest anode angle is preferred for small field-of-view image receptors, such as those found in cineangiographic and neuroangiographic equipment, whose field coverage is limited by the diameter of the image intensifier. High anode angles are necessary for standard radiography operations in order to achieve large field area coverage at close focal spot-to-image distances.

Effective focused spot length varies with picture plane position in the anode-cathode direction.Position in the picture plane has no discernible effect on the focus point size in the breadth dimension. Specified nominal size at the beam's center ray

**III. Transformers**

Perform task of “transforming” alternating input voltage into alternating output voltage using principles of electromagnetic induction Generic transformer has two distinct, electrically insulated wires wrapped about a common iron core



 Figure:5 Transformer

**Law of Transformers**

The ratio of the primary voltage to the secondary voltage is equal to the ratio of the number of coil turns in the primary winding to the number of coil turns in the secondary winding.

VP/VS equals NP/NS

1. A transformer may change the voltage or isolate it is dependent on the ratio of the turns in the two coils.

2.NS > NP: A "step-up" transformer that raises the secondary voltage

3.NS NP: a "step-down" transformer that lowers the secondary voltage

4.NS = NP: "isolation" transformer, primary voltage and secondary voltage are equal.

**Autotransformer**

consists of an iron core and a single coil of wire. The Transformers Law still holds true. operates on the self-induction, as opposed to mutual induction, premise. secondary voltage changes or climbs more gradually compared with conventional transformers electrically separates the primary circuit from the secondary circuit.

**Diodes**

Electrical devices that only permit current to flow in one direction and have two terminals The x-ray tube itself is an example of a diode. A semiconductor material crystal that is part of a solid-state diode is "doped" with traces of impurity elements. When voltage was applied in one direction, conductivity increased, but when voltage was applied in the opposite direction, it decreased to very low levels.

DIODES

ONE-WAY FLOW OF ELECTRON

 ANODE CATHODE

 Vacuum tube diode

 (e.g.-Ray Tube)

Solid-State Diode

 Figure:6 One Way Flow of E

**Triodes**

A vacuum tube diode with a grid-like third electrode near the cathode

The grid is required for electrons traveling from the cathode to the anode. By applying a tiny negative voltage to the grid, the cathode's electrons are subjected to a strong force that allows on/off switching or current regulation.



**Operator Console**

The operator sets the focused spot size, exposure duration, kVp, and mA (which represent the number of x-rays in the beam at a given kVp). Peak kilovoltage (kVp) regulates the x-ray beam's quality (penetrability), which affects subject contrast. The x-ray flux is determined by tube current (mA). The mA setting is typically used to determine the focus spot size. Some generators allow the use of preprogrammed processes.

**Timing the x-ray exposure**

Digital timers have mostly replaced electronic timers due to their excellent repeatability and microsecond precision. Only low-power, single-phase generators employ mechanical switches. High voltage switches used in three-phase and constant potential circuits The high-frequency inverter electrically switches the high-voltage transformer's primary side.

**Photo timers**

Check the radiation's actual impact on the image receptor. Stop the x-ray operation after an exact amount has been created. provides a continuous exposure to the image receptor while accounting for patient-specific differences in attenuation and thickness.

**Generator for Falling Load**

It delivers the greatest mA for the selected kVp while taking into consideration the features of the instantaneous heat load on the x-ray tube when used in conjunction with the photo timing (AEC) subsystem. The image receptor (IR) receives the required quantity of radiation in the shortest period of time feasible by continuously reducing the wattage as exposure time progresses.

**Factors affecting x-ray emission**

An x-ray tube's output is described by its quality, quantity, and exposure.

An x-ray beam's penetrability is characterized by quality

The quantity of the beam's photons is referred to as its size.

Since exposure is nearly proportional to the x-ray beam's energy fluence, it possesses features related to both quality and quantity.

Efficiency, exposure, quality, and amount of X-ray production are influenced by the following factors:

1. X-ray tube target material

2.Voltage

3. Current

4. Exposure

5. Beam Filter

6. Waveform of the generator

**Target (anode) material**

Have an impact on the creation of bremsstrahlung radiation. Atomic number and output exposure are roughly inversely related. The target material affects the energies of the characteristic x-rays. Target material impacts both the quantity and quality of characteristic radiation and bremsstrahlung radiation.

**Tube voltage (kVp)**

Determines the maximum energy of the bremsstrahlung spectrum and affects the quality of the output spectrum

The effectiveness of x-ray production is directly influenced by tube voltage. exposure typically equivalent to the cube of the kVp in the diagnostic range

$$Exposure∝kVp^{2}$$

To maintain the same exposure, increases in kVp must be balanced off by equal variations in mAs.

The patient's x-ray attenuation characteristics are another factor in procedure modification.

The mAs fluctuates with the fifth power of the kVp ratio in order to ensure equal transmitted exposure across a typical patient:



The rate at which electrons move from the cathode to the anode is known as tube current. The relationship between the beam's exposure and tube current for a given kVp and filtration is linear.

**Exposure**

The amount of time that x-rays are created is known as the exposure time. The connection between exposure duration (mAs) and the quantity of x-rays generated is simple.

**The beam optimizer**

By excluding only high-energy photons from the spectrum, beam filtering modifies the quantity and quality of the x-ray beam. The quality is enhanced as a result of an increase in average energy and a decrease in photon number (quantity).

**waveform of the power source**

The average potential difference between a single-phase generator and a three-phase or high-frequency generator is lower for the same kVp. The resulting x-ray spectrum's quality is impacted by this. Both the quantity of x-rays produced and the quality of the x-ray spectrum are impacted by the kVp ratio's fifth power.

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