POLITEKNIK MALAYSIA

KEMENTERIAN PENGAJIAN TINGGI

KOLEJ KOMUNITI MALAYSIA

X-RAY MACHINE HANDBOOK Made Easy

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X-RAY MACHINE HANDBOOK: MADE EASY

1ST EDITION

ELECTRICAL ENGINEERING DEPARTMENT

JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI
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Editor:
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eISBN No: 978-967-2044-87-1

First Published in 2021 by:

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PREFACE

Medical imaging is a very broad field, encompassing mechanical and electrical engineering, physics, mathematics, computer science, and, of course, medicine. All of this knowledge has been consolidated for one purpose: to improve patient health through non -invasive imaging. This e-book was created with the goal of providing an overview of some of these fields and how they are used in medical imaging. The authors of this e-book come from biomedical and academic backgrounds and hope this contribution can make an impact in the field of biomedical-related education.

ABSTRACT

The x-ray is the most common and oldest form of radiology, and it is the key to many radiological procedures. An x-ray is a relatively simple procedure in which x-rays are emitted by the machine as particles that pass through the body, being absorbed in different frequencies by different internal structures until they are detected by the sensitive film, which produces the image. The x-ray creates images that look like the shadows of internal structures like bone and tissue. The operating principles of an x -ray machine are also highlighted for the reader's understanding of how an x -ray machine produces images. The biological risks due to radiation exposure and safety measures are clearly described in this e-book.

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SECTION 1

FUNDAMENTAL OF X-RAY PRODUCTION

YOUR VIBES IS THE

"X-RAY"

OF YOUR TOUGHT

BY TANU MANHAS

FUNDAMENTAL OF X-RAY PRODUCTION

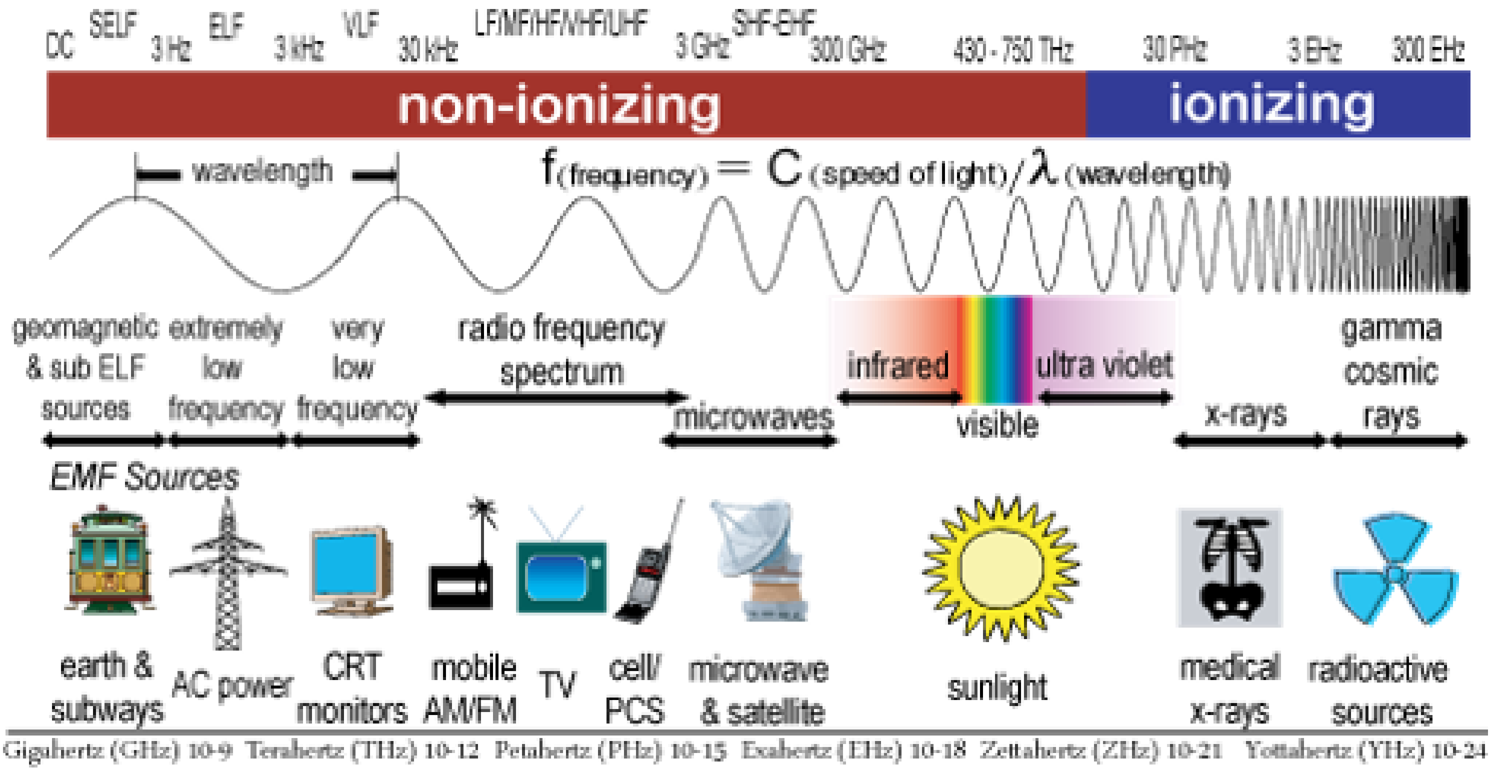
INTRODUCTION

X-rays are a type of electromagnetic wave radiation. Images of the inside of your body are created using X-ray imaging. The images depict various parts of your body in various shades of black and white. This is due to the fact that different tissues absorb different amounts of radiation.

When fast-moving electrons collide and interact with the target anode, they produce X-rays due to sudden deceleration. More than 99 per cent of the electron energy is converted into heat during this deceleration process, while less than 1 per cent of the energy is converted into x-rays.

DID YOU KNOW?

Calcium in bones absorbs x-rays the most, thus bones look white. Fat and alternative soft tissues absorb less and appearance gray. Air absorbs the least, so lungs look black.

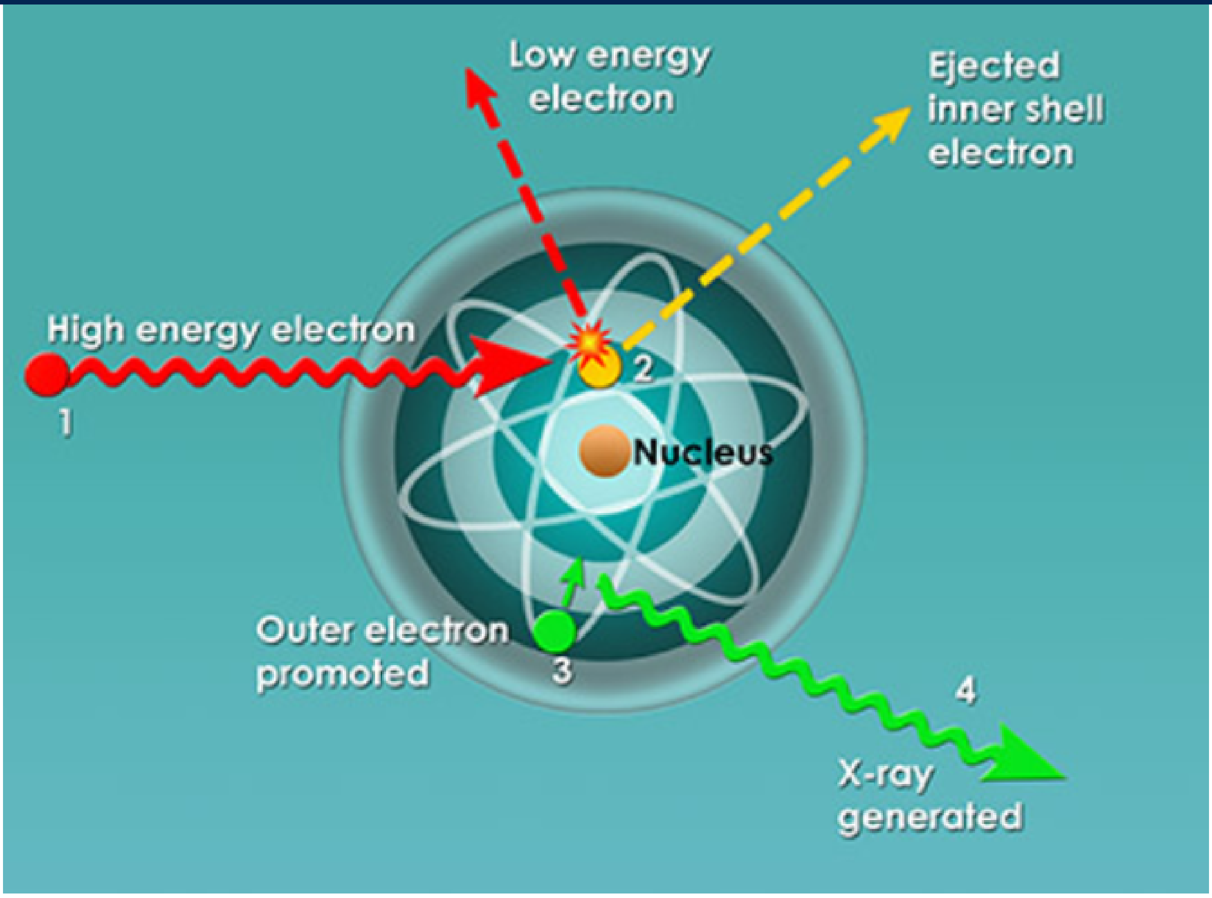


X-RAYS AND IONIZATION

Atoms are ionised by X-rays. The energy required for ionisation varies depending on the material (e.g., 34 eV in air, 25 eV in tissue), but it is typically in the several eV ranges. A 100 keV X-ray has the potential to produce thousands of ions. X-rays are produced by atomic electrons and free electrons that are decelerating in the vicinity of atoms.

X-rays are created by accelerating electrons through an electrical voltage potential and stopping them in a target. Many devices that use a high voltage and an electron source emit X-rays as an unintended byproduct of device operation. These are known as incidental X-rays.

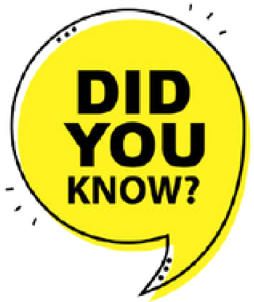
X-RAYS ARE CREATED WHILE ELEVATED ELECTRONS INTERACT WITH ELECTRONS OF METAL NUCLEI WITHIN THE TUBE ANODE. X-RAYS ARE PRODUCED IN FORMS: FEATURE RADIATION AND BREMSSTRAHLUNG RADIATION.



CHARACTERISTIC X-RAY GENERATION

Based on the figure above when a high energy electron (1) collides with an inner shell electron (2), both are ejected from the tungsten atom, leaving a 'hole' in the inner layer, as depicted in the diagram above. An outer shell electron (3) fills this, with an X-ray photon emitted as a loss of energy (4).

An electron in a higher orbital immediately falls to a lower energy level, releasing its excess energy in the form of a photon. The photon has a high energy level and is an x-ray photon because it is a large drop. As a result, they play an important role in analytical X-ray applications in research laboratories.



Bremsstrahlung

can be produced with any charged particles and any target. For example, at research laboratories, Bremsstrahlung has been produced by accelerating protons and allowing them to hit hydrogen.

COMPARISON BETWEEN CHARACTERISTIC X-RAY RADIATION AND BREMSSTRAHLUNG

Characteristic X-ray radiation

- Only accounts for small percentage of x-ray photons produced
- Bombarding electron interacts with inner shell electron
- Radiation released due to electron dropping down into lower energy state
- Radiation released is of a specific energy
- X-ray photon energy depends on element of target atoms, not tube voltage

Bremsstrahlung

- Accounts for 80% of photons in x-ray beam
- Bombarding electron interacts with whole atom
- Radiation released due to diversion of bombarding electron as a result of the atomic pull
- Radiation released is of a large range of energies
- X-ray photon energy depends on tube voltage

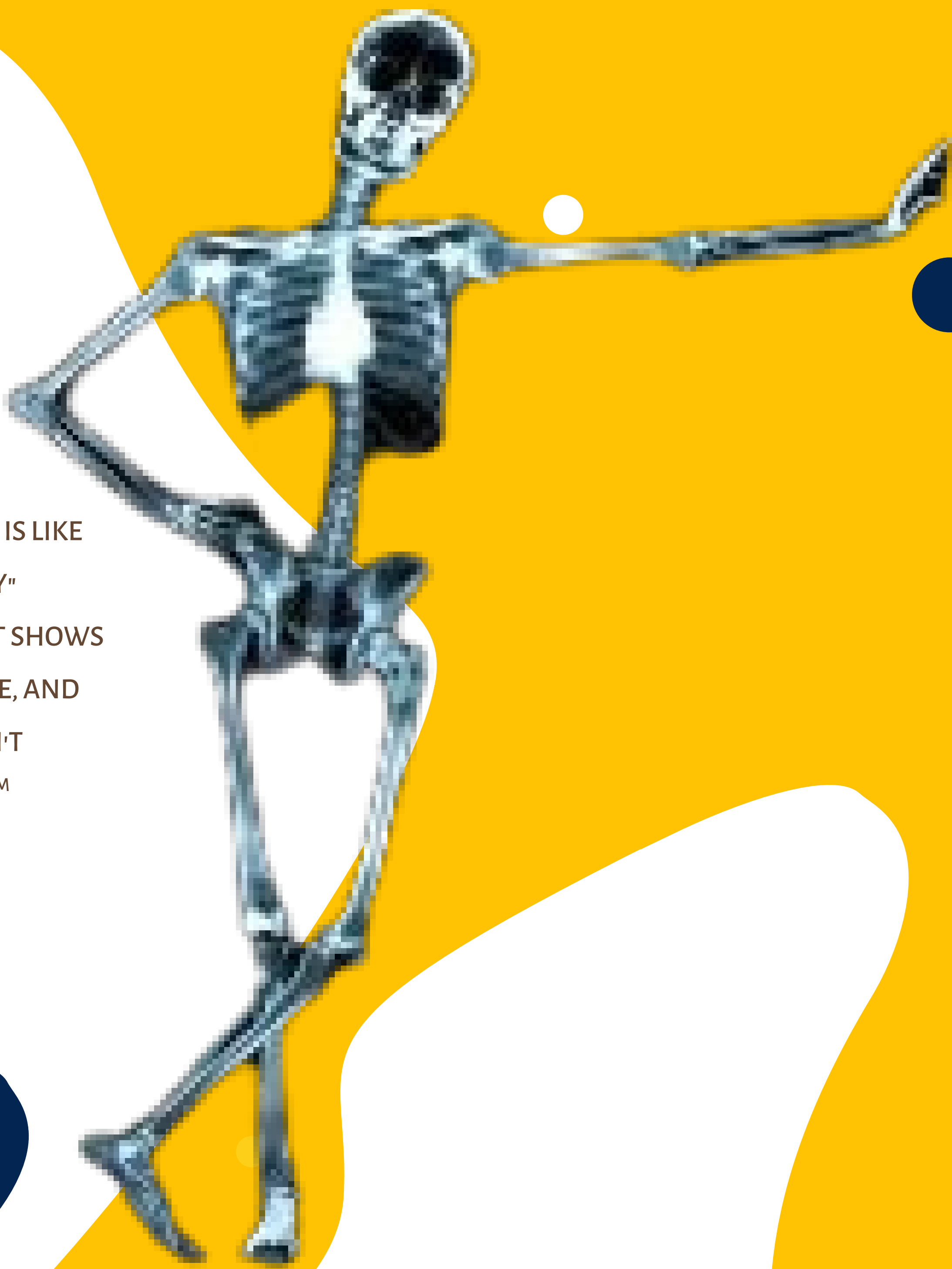
Outer shell interaction: low energy EM released and quickly converted into heat energy

Inner shell interaction: produces characteristic radiation

Nucleus field interaction: aka Bremsstrahlung

SECTION 2

X-RAY MACHINE



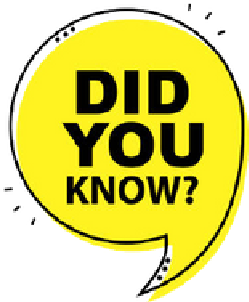
MOZART MUSIC IS LIKE
AN "X-RAY"
OF YOUR SOUL. IT SHOWS
WHAT IS THERE, AND
WHAT ISN'T

BY ISAAC STEM

X-RAY MACHINE

INTRODUCTION

An X-ray imaging device includes a generator manage console in which the operator selects preferred strategies to gain a great readable photo (kVp, mA, and publicity time), an x-ray generator that controls the x-ray tube current, x-ray tube kilovoltage, and x-ray emitting publicity time, an X-ray tube that converts the kVp and mA into real x-rays, and an image detection device.

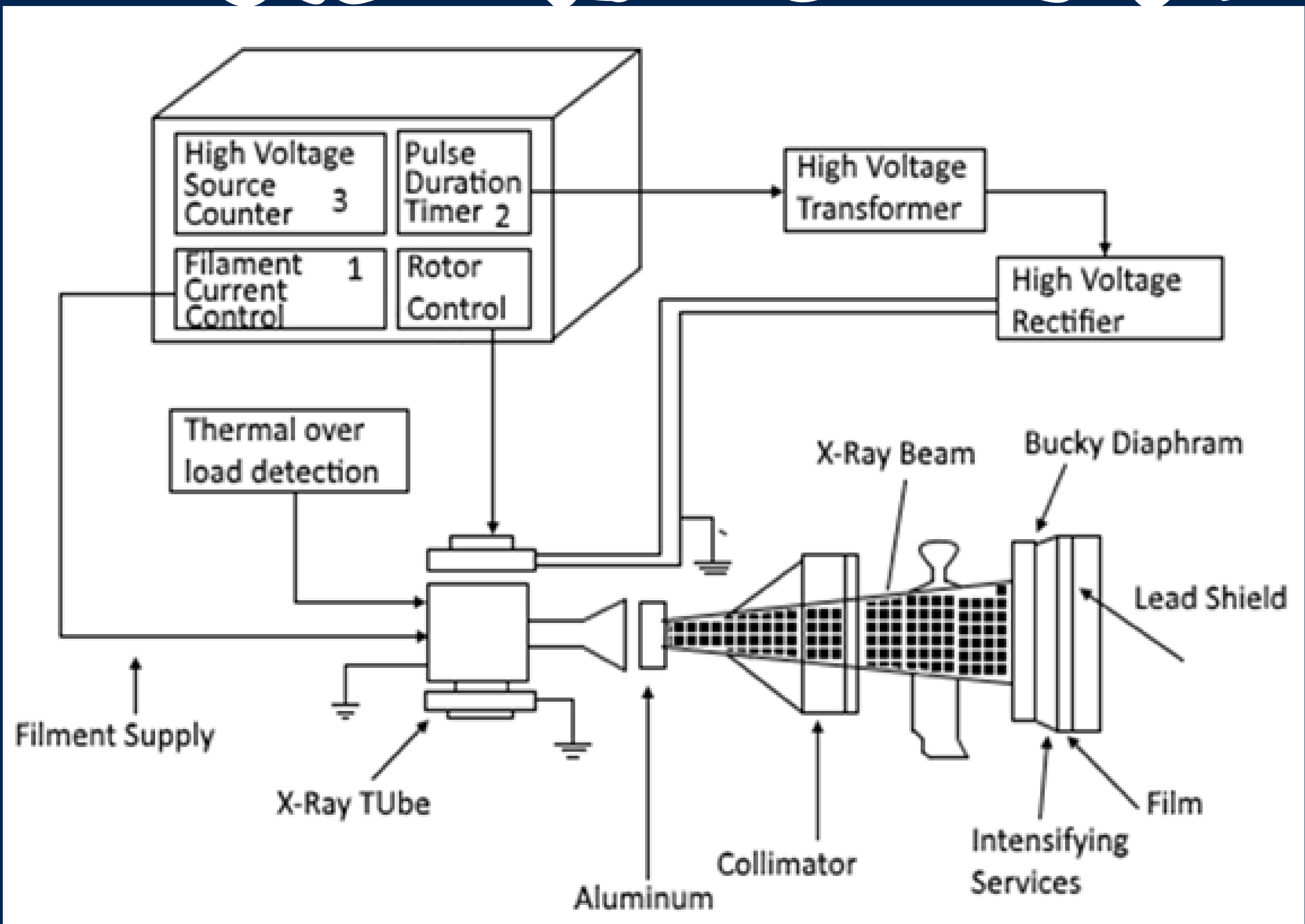


One of the first X-ray photographs was made of the hand of Röntgen's wife. The image displayed both her wedding ring and bones.

A cutting-edge is surpassed thru the tungsten filament, heating it up. As the filament heats up, the improved power lets in electrons to get away thru thermionic emission. Electrons are interested in the undoubtedly charged anode and strike the tungsten goal with the most power decided through the tube potential (voltage).

As electrons bombard the goal, they have interaction thru Bremsstrahlung and function interactions, ensuing withinside the conversion of power (99%) into warmth and x-ray photons (1 consistent with cent). The x-ray photons are launched from the tube's window in a beam of various energies (the x-ray spectrum) and function as the muse for the formation of x-ray images.

Block diagram of X-ray machine



High voltage source and high voltage transformer (H.V.T)

The high voltage source is responsible for supplying high voltage to the H.V transformer for a predetermined amount of time. The H.V transformer's output voltage ranges from 20 kV to 200 kV. Image contrast is determined by these voltages. Higher voltages result in greater contrast.

High voltage rectifier

This rectifier rectifies the high voltage produced by the H.V.T and supplies it to the anode of the X-ray tube.

Thermal overload detector

The heat from the X-ray tube (should not be increased by a specified range). If the temperature rises above a certain level, the thermal overload detector activates, causing the system to shut down.

Rotor control

An induction motor rotates the majority of X-ray tube anodes to limit beam power at any point and to help cool the anode.

Pulse duration timer

- The duration of the time must be very small so that:
- The patient does not receive an excessive dose.
- The film does not become overexposed.
- The X-ray tube does not overheat. The pulse duration timer determines this pulse duration.

FUN FACT

Aluminium Filter

The X-ray beam used in the medical field has a wide frequency range. Unwanted frequencies in x-ray based create side effects, such as extra dose for patient causing tumour, as well as a reduction in image contrast. These are known as soft x-rays. Aluminium filters are used to eliminate these effects.

Collimator

Another way to reduce the patient's dose is to confine the x-ray beam to the region of interest on the patient's body. This is accomplished by placing an external collimator between the patient and the filter.

Diaphragm

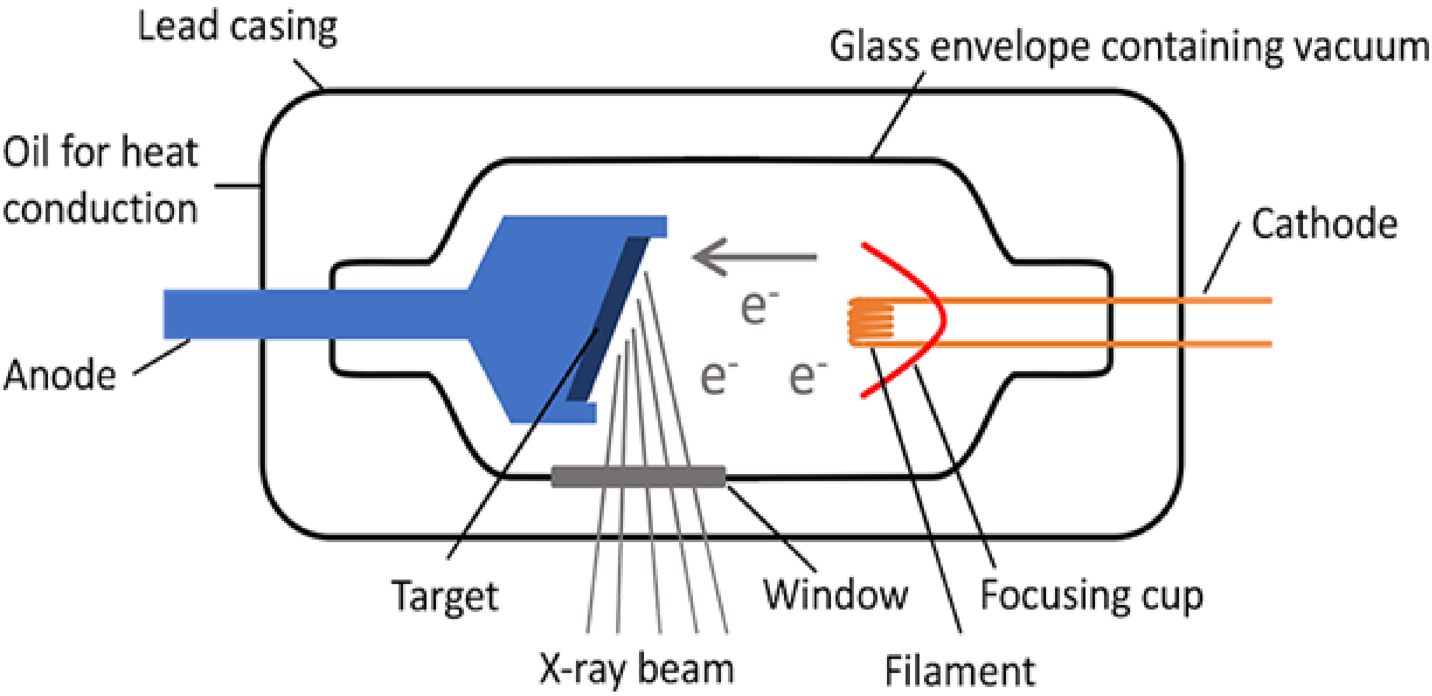
X-rays inside the patient cause x-ray scattering, which tends to burn the image. To absorb the scattered x-rays and eliminate image burning, a lead grid called the diaphragm is used.

Film and lead shield

[redacted] the desired region of the patient's body to the film, where they produce an image of the body's soft and hard parts. After striking the film with an x-ray, a lead shield is used to collect the x-rays.

The high voltage source generates a high voltage supply, which is rectified and applied to the anode of the x-ray tube by a rectifier. The filament is also available. As a result, x-ray tubes generate an x-ray beam that is passed through the body, creating an image of the body and the film, which is then examined in a laboratory.

X-ray Tube



An x-ray tube is a device that converts energy. It takes in electrical energy and converts it into two other forms: x-rays and heat. Heat is an unwelcome byproduct. X-ray tubes are designed and built to produce as many x-rays as possible while dissipating heat as quickly as possible.

The x-ray tube is a relatively simple electrical device with two main elements: a cathode and an anode. The electrons lose energy as the electrical current flows through the tube from cathode to anode, resulting in the generation of x-radiation.

DID YOU KNOW?

To produce x-radiation, relatively large amounts of electrical energy must be transferred to the x-ray tube. Only a small fraction (typically less than 1%) of the energy deposited in the x-ray tube is converted into x-rays; most appears in the form of heat.

CATHODE

The cathode's primary function is to expel electrons from the electrical circuit and focus them into a narrow beam aimed at the anode. A cathode is typically made up of a small coil of wire (a filament) that is recessed within a cup-shaped region. The cathode filament is heated in the same way that a light bulb filament is heated by passing a current through it. The cathode is heated to a glowing temperature during tube operation, and the heat energy expels some of the electrons from the cathode.

Filament

Made of thin (0.2 mm) tungsten wire because tungsten:

- has a high atomic number (A 184, Z 74)
- is a good thermionic emitter (good at emitting electrons)
- can be manufactured into a thin wire
- has a very high melting temperature (3422°c)

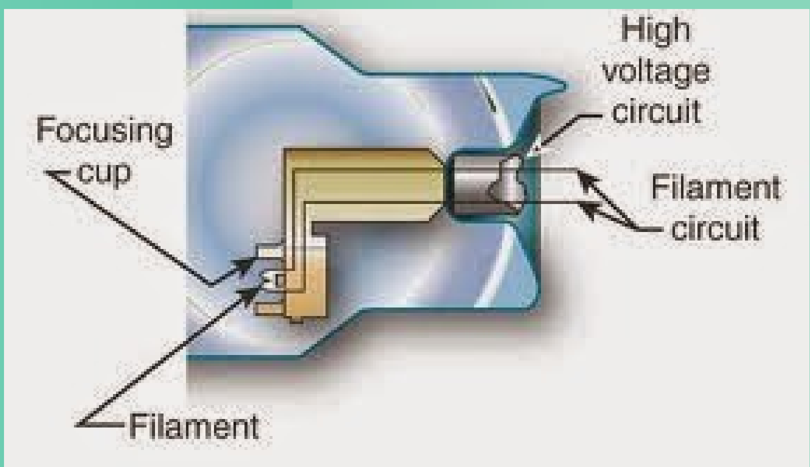
The size of the filament relates to the size of the focal spot. Some cathodes have two filaments for broad and fine focusing

Focusing cup

Made of molybdenum as:

- high melting point
- poor thermionic emitter so electrons aren't released to interfere with an electron beam from the filament

Negatively charged to focus the electrons towards the anode and stop spatial spreading



X-ray Cathode

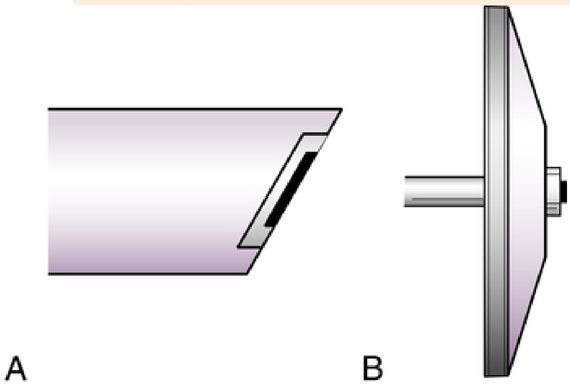
Anode

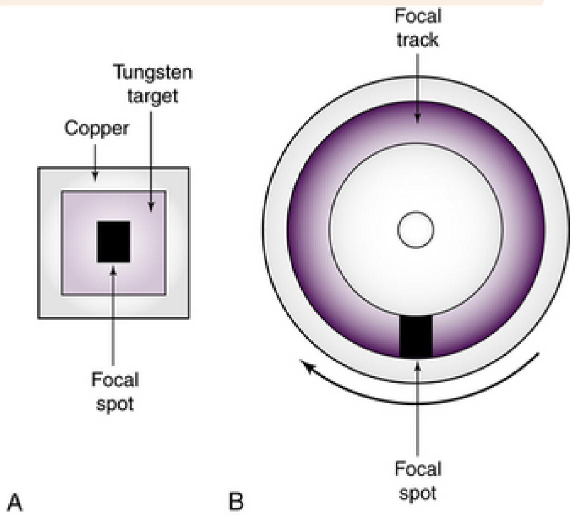
The anode is the component that generates the x-rays. It is a substantial piece of metal that connects to the positive side of the electrical circuit. The anode serves two primary purposes:
(1) to convert electronic energy into x-rays; (2) to dissipate the heat generated during the process The anode material is chosen to enhance these functions.

- For the same reasons as the filament, a tungsten target is used.
- Rhenium is added to tungsten to prevent anode cracking at high temperatures and usage.
- Set into a molybdenum anode disc with a positively charged stem to attract electrons
- Set at an angle to direct the x-ray photon beam downwards towards the patient. The typical angle is 50 - 150.

Stationary anode: Dental radiology and radiotherapy systems are the most common examples. An anode is fixed in place, and an electron beam is constantly streaming onto a small area.

Rotating anode: Most radiography, including mobile sets and fluoroscopy, employs this technique. A disc with a thin bevelled tungsten rim around the circumference that rotates at 50 Hz.





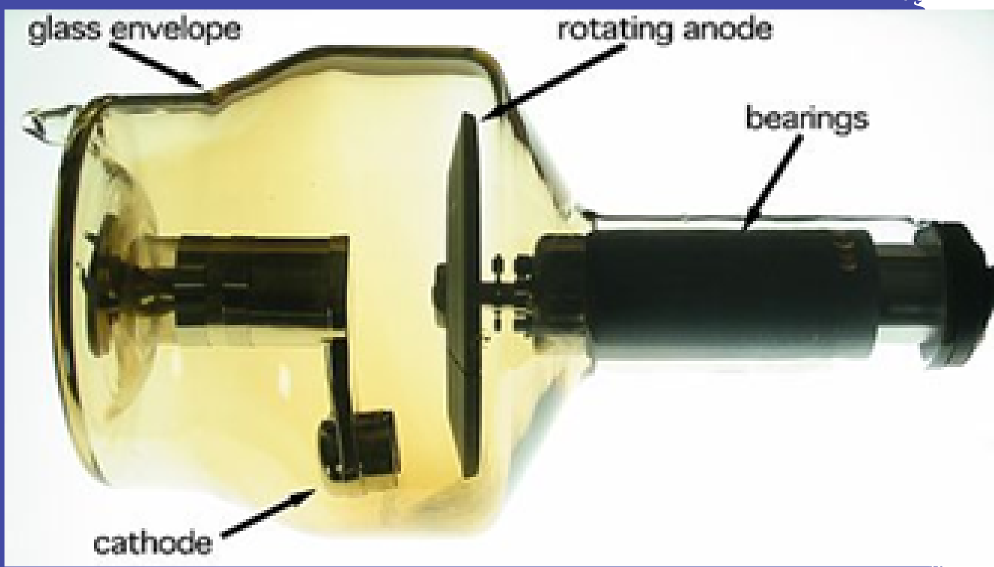
A - Stationary Anode

B - Rotating Anode

Glass Envelope

The anode and cathode are enclosed or enveloped in an airtight enclosure. The envelope and its contents are frequently referred to as the tube insert, which is the part of the tube with a limited lifespan that can be replaced within the housing. The majority of x-ray tubes have glass envelopes, but some tubes have metal or ceramic envelopes.

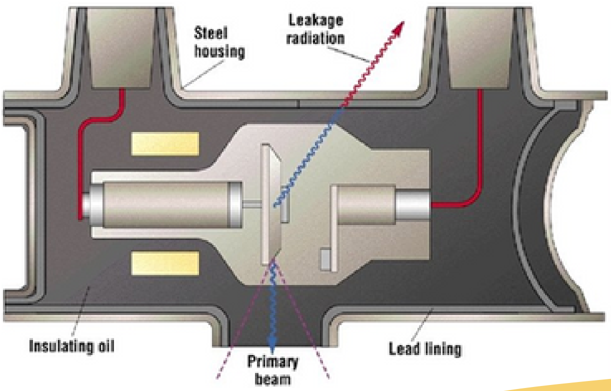
The envelope's primary functions are to support and electrically insulate the anode and cathode assemblies, as well as to maintain a vacuum in the tube. The presence of gases in the x-ray tube would allow electricity to flow freely through the tube instead of just in the electron beam. This would disrupt x-ray production and potentially damage the circuit.



X-ray tube with Glass Envelope

Housing

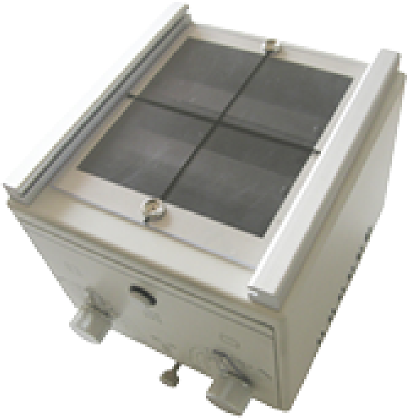
- In addition to enclosing and supporting the other components, the x-ray tube housing serves several functions.
- Except for the radiation that passes through the window as the useful x-ray beam, it acts as a shield and absorbs radiation.
- The majority of the heat generated within the tube is dissipated by its relatively large exterior surface.
- Oil fills the space between the housing and the insert, providing electrical insulation and transferring heat from the insert to the housing surface.

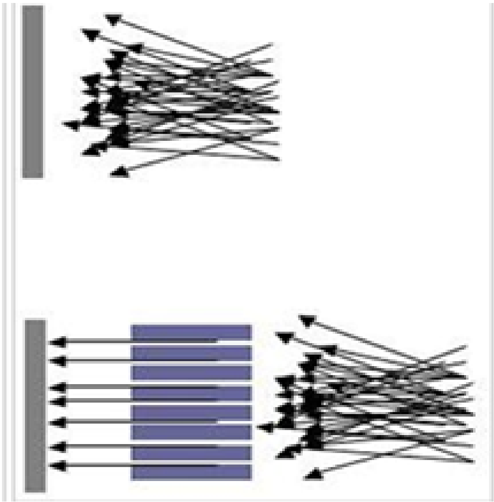


X-ray Tube, Lead Housing

The Collimator

- A collimator is a device that narrows a particle or wave beam in order to reduce the dose of an x-ray beam.
- A collimator is a device that filters rays so that only those travelling parallel to a specified direction pass through.
- Collimators, while improving resolution, also reduce intensity by blocking incoming radiation.



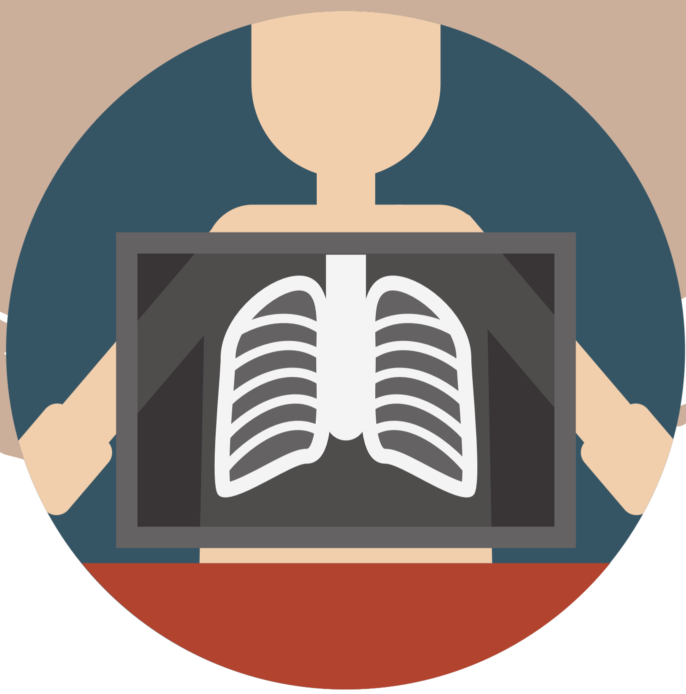


without a collimator

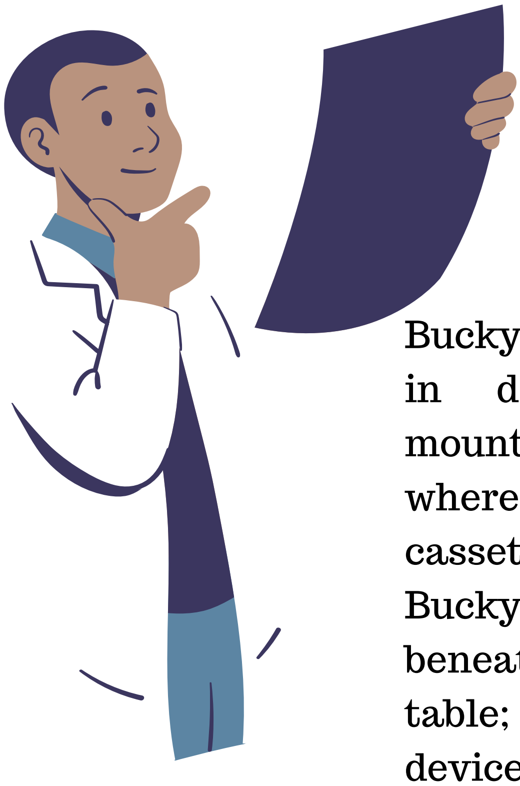
with a collimator

Collimation Effects

- For radiography and fluoroscopy projection imaging, X-ray beam collimation is vital for affected person dose and picture first-class.
- Active collimation to the quantity of hobby reduces the general vital dose to the affected person, thereby decreasing the radiation risk.
- Less irradiated quantity approach much less x-ray scatter incident at the detector. As a result, difficulty assessment and picture first-class are improved.
- X-ray discipline collimation differs from digital magnification in that the obtained discipline of view stays constant, and the ensuing spatial decision overall performance does now no longer improve.
- However, using collimation will commonly lessen picture brightness, necessitating an boom in radiation front pores and skin dose to the affected person, even though now no longer to the extent required while digital magnification is used, due to the fact the magnification benefit stays unchanged.



The Bucky Grid

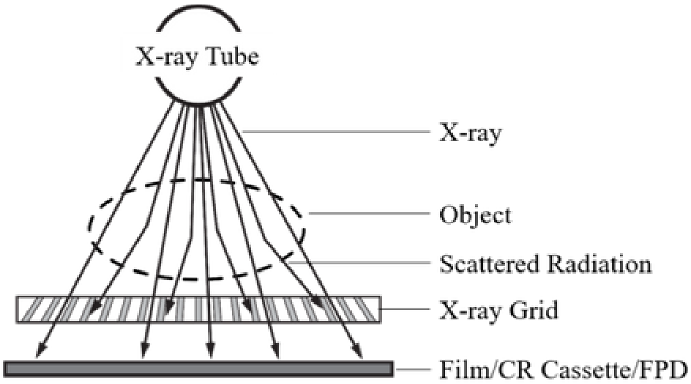


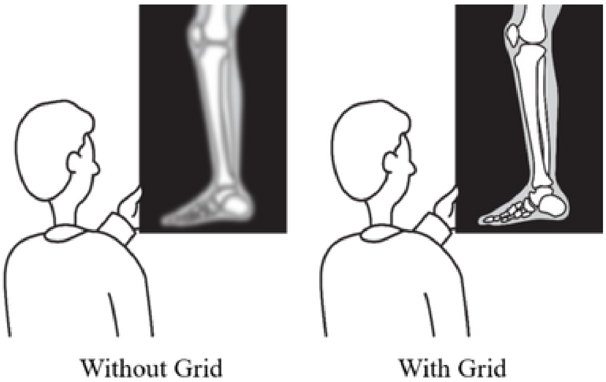
Bucky is typically found in desktop or wall-mounted X-ray systems, where he manages X-ray cassettes and grids. Bucky is a device found beneath the checking table; it is a drawer-like device that slides cassette tapes and grids into before taking X-rays.

- Some x-rays are deflected off their straight-line course after entering a patient by close encounters with atoms.
- This is known as scattering, and it causes smearing of the image at the edges as well as deterioration of image sharpness.
- A Bucky grid is used to recover the image's sharpness.

Bucky Wall

Bucky Stand





When Do I Need a Grid?

Grids are useful when used with body parts that are 10cm (4") or thicker. The grid becomes more important as the body thickens.

Grids remove scatter created as the X-ray moves through the body, and the more body the X-ray moves through, the more scatter is created.

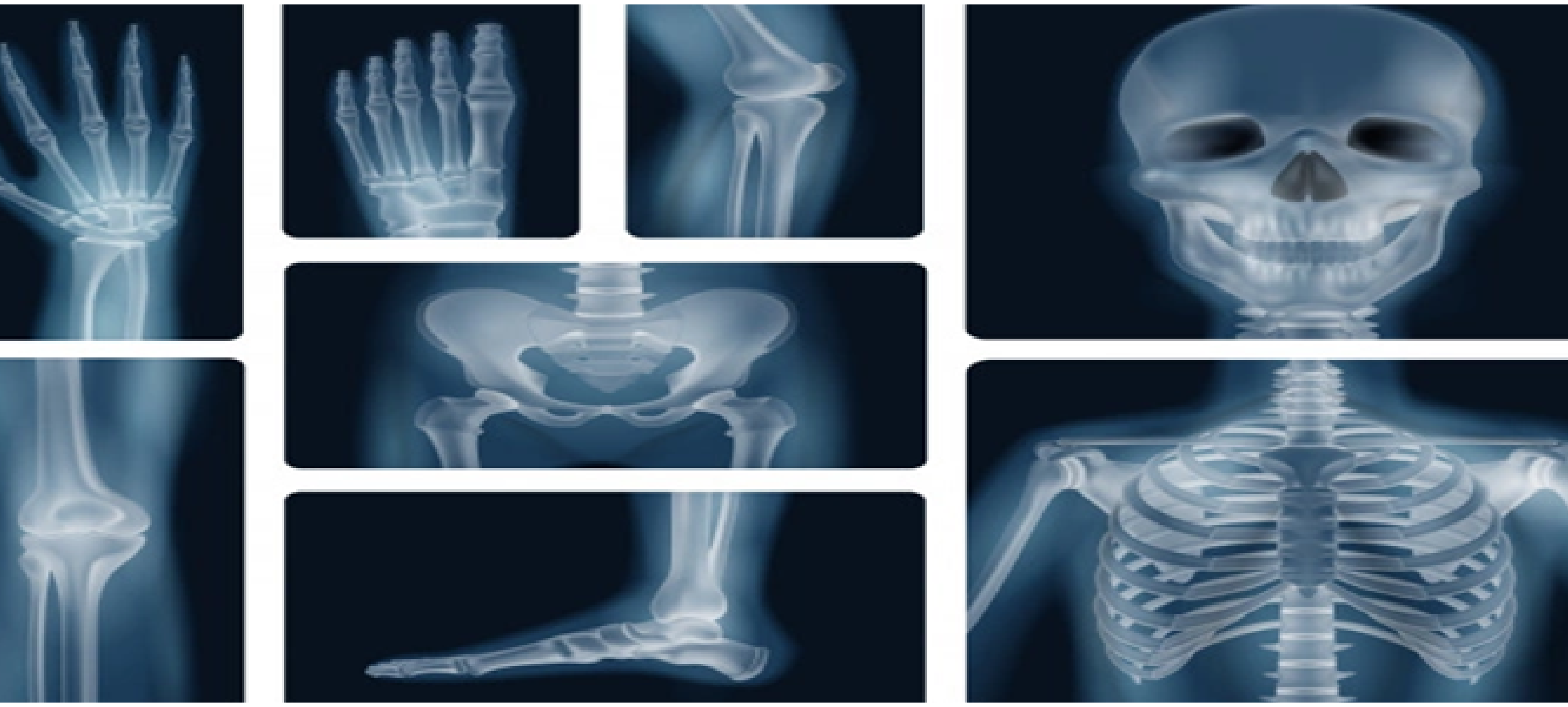
Removing the grid from a thin body part can reduce the amount of X-ray required for a good image. This is not true for a thick body part. This is due to the fact that, while more X-rays reach the film or detector without the grid, a much higher percentage of those X-rays scatter, destroying the image.

SECTION 3

X-RAY
IMAGE PRODUCTION

ALL BODIES ARE
TRANSPARRENT TO THIS
AGENT...FOR BREVITY'S SAKEI
USE THE EXPRESSION 'RAYS';
AND TO DISTINGUISG THEM
FROM OTHERS OF THIS NAME
I SHALL CALL THEM 'X-RAYS'

BY WILHELM RONTGEN



INTRODUCTION

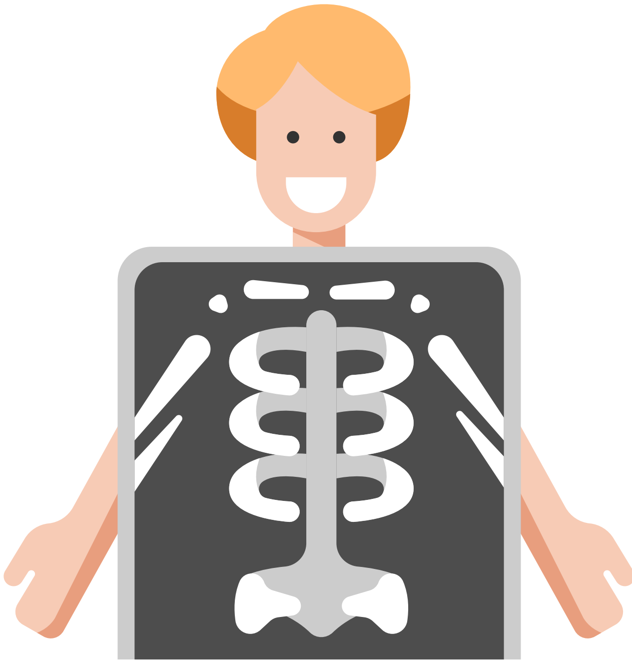
The X-ray tube generates the X-ray beam. A cathode, anode, rotor, envelope, tube port, cable sockets, and tube housing are the basic components of an X-ray tube. The generator enables the radiology technologist to control three-technique factors: tube voltage applied across the X-ray tube, tube current flowing through the X-ray tube, and total exposure time during which the current flows.

DID YOU KNOW?

The "X" in X-ray stands for "unknown". X-ray translates to "unknown beam or ray" in German. After initially inventing the x-ray, the name was fitting considering it was initially a mystery on how it would be used. X-ray can be spelt a varietyways including xray, X ray, X-ray, and x-ray.

The cathode is the electron source. It is the negative electrode in an X-ray tube, and it is typically made of a tungsten filament. The size of the filament used is determined by the technique. When energy is applied to the filament, it heats up; electrons accumulate at the cathode and are then released from the filament surface via a process known as thermionic emission. The current applied and the temperature of the filament determines the rate of electron release. Electrons speed up as they approach the positively charged anode.

The anode is where electrons decelerate, and the energy released from deceleration is released as heat and X-rays (photons). The output of the X-ray tube is emission-limited, and the filament current determines the X-ray tube current. At any tube voltage, the tube current is proportional to the x-ray flux. The emitted electrons are concentrated into a concentrated group and accelerated toward the anode, where they strike a small area known as the focal spot. The size of the focal spot is determined by the filament length and electron distribution.



Electrons released from the cathode are directed toward the positively charged anode. The majority of electrons that strike the anode deposit their kinetic energy, which is generated by the tube voltage and current, as heat. Only a small percentage of them go on to produce X-rays. As a result, a significant amount of heat is generated at the anode during the diagnostic image production process. In the past, stationary anodes were used. The small focal spot on a stationary anode, on the other hand, limits the number of X-rays that can be produced without damaging the anode. As a result, most X-ray machines today employ a rotating anode. This allows for the spread of heat over a larger area, which allows for greater tube currents and exposure durations.

The rotating anode is a disc mounted on a rotor assembly supported by bearings. The rotor is made up of an iron cylinder in the centre and copper bars around it. The stator is composed of electromagnets that surround the rotor. When an alternating current flows through the stator's electromagnets, it generates a rotating magnetic field. This field induces an electrical current in the copper bars of the rotor, which creates an opposing magnetic field to the one induced by the stator, resulting in the rotation of the rotor device. Speeds of up to 10,000 revolutions per minute can be achieved.

The X-ray tube insert consists of the cathode, anode, rotor apparatus, and other associated structures. They are all contained in a glass or metal enclosure and vacuum-sealed. The envelope is the name given to this enclosure. The focal spot's X-ray photons scatter in all directions. The use of a tube port aids in the formation of a useful beam.

The X-ray tube housing protects and cools the X-ray tube insert. Typically, a layer of oil is sandwiched between the insert and the housing to provide heat conduction and electrical insulation. In addition, a lead shield is applied to the inside of the housing to attenuate X-rays that are not directed at the tube port. However, not all X-rays are blocked, and the portion that passes through the housing is referred to as leakage radiation. Each tube housing has a maximum tube potential that should not be exceeded during operation to avoid excessive leakage radiation.

Collimators can adjust the size and shape of the X-ray field as the X-rays exit the tube port. The tube port is connected to the collimator housing. A light source is positioned at a virtual focal point and is reflected by a mirror that is angled at 45 degrees. When the collimator light is turned on, two pairs of parallel opposed lead shutters define the X-ray field and, when the collimator light is turned off, the X-ray and light fields.

As X-ray beams pass through materials, portions of the beam are attenuated, causing the shape of the produced spectrum to change. This is known as "filtration," and the change in spectra can be tailored by varying the type and amount of filter material used. Inherent filtration occurs when the anode material and the material placed over the X-ray tube's exit window achieve X-ray attenuation. This reduces the number of low-energy photons produced. Extra filtration is typically used to reduce patient radiation exposure and improve image contrast.

Filter materials that are commonly used are aluminium and copper. The average energy of the spectrum will rise as a result of these materials. It reduces radiation exposure by eliminating photons absorbed by the patient's soft tissue and by absorbing lower energy photons that do not contribute to image production. Another common filter material is molybdenum. Molybdenum absorbs a large percentage of high-energy photons, which improves image contrast. Collimators direct the beam to the focus area in the X-ray tube housing. They are made of lead, which absorbs photons and thus reduces the radiation dose to the patient. These are different from X-ray filters in that collimators completely block photons instead of just blocking a part of the produced spectrum.

The tube generator is the final piece of X-ray equipment used. The X-ray generator sends a high-voltage electrical current to the X-ray tube, which produces an X-ray beam. A basic principle of electromagnetic induction is that a constant current applied through a wire or coil produces a constant magnetic field. Changes in the magnetic field are caused by changes in the current. Transformers use electromagnetic induction to change the voltage of an electrical power source. They will increase (step-up), decrease (step-down), or leave the input voltage unchanged depending on the voltage required by the X-ray generator (isolate).

There are several types of X-ray generators. The high-frequency inverter generator is the most recent. It works by using an inverter circuit to convert the low-frequency, low-voltage input power to a high-voltage output waveform. This enables a nearly constant voltage to be applied to the X-ray tube for efficient X-ray production.

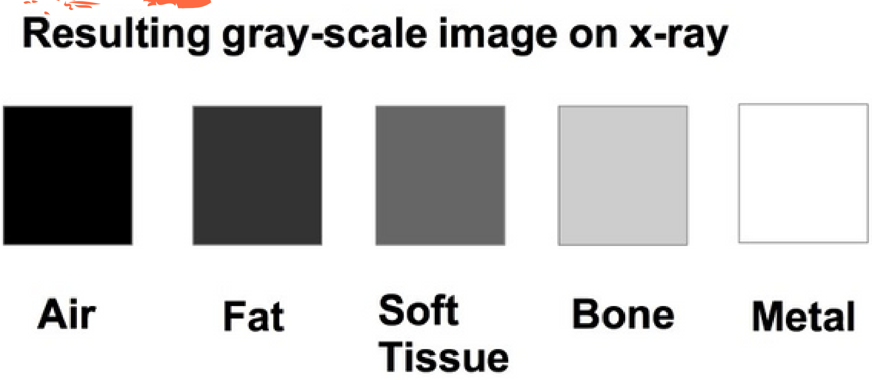
Anode material, X-ray tube voltage, X-ray tube current, beam filtration, and generator waveform are all factors that influence X-ray emission. The efficiency of X-ray radiation production is affected by the anode target material. The output is roughly proportional to the anode material's atomic number. Furthermore, the energies of the X-rays produced are affected by the target material. The maximum energy of the produced photons is determined by the tube voltage (kV). An increase in voltage leads to an increase in the efficiency, quantity, and quality of the resulting X-ray beam.

The intensity of the X-ray beam (or the number of photons in the beam) is proportional to the tube current and exposure time. [7] The voltage is the only parameter that can change the shape of the X-ray spectrum. By preferentially filtering low-energy photons, beam filtration alters the quantity and quality of the X-ray beam. The current required to achieve the desired X-ray intensity will be higher for more filtered beams. Finally, the generator waveform has an impact on the quality of the resulting X-ray spectrum. The output X-ray spectrum is of higher quality and quantity for the same voltage, current, and exposure time.

IMAGE APPEARANCE

In x-ray imaging, there are five 'basic' opacities with differential x-ray absorption capabilities: air, fat, soft tissue, bone, and metal. Because of air's simple molecular structure, a large portion of the incident x-ray beam passes through and reaches the image detector, resulting in a dark region on x-ray images. Metal, on the other hand, has a more dense structure and heavier atomic weights. Metal, on the other hand, absorbs a large portion of the incident x-ray beam. Metal is depicted in images as a bright white substance. Metal absorbs more incident x-rays than bone (cortical and medullary bone), producing a whiter image.

X-RAY GRAY-SCALE

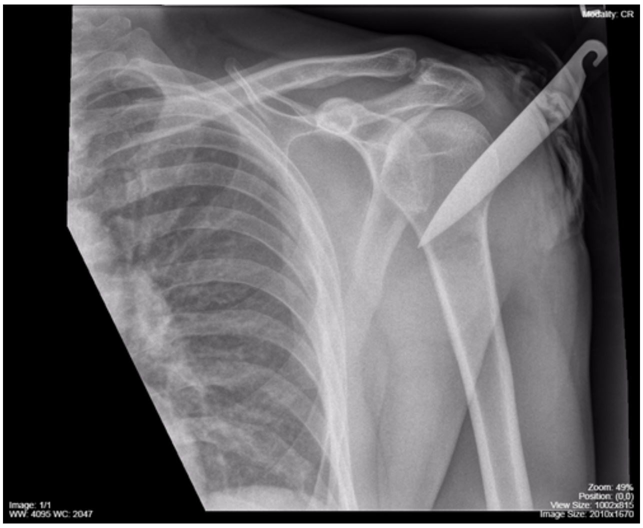


Appearance of different entities on x-rays

Opaque (opacity) – a patient region that absorbs or scatters a significant portion of the incident x-ray beam before it reaches the detector, i.e. the tissues in question prevent the x-rays from reaching the detector (whiter on the x-ray image). In x-ray imaging, metal, for example, would be described as opaque.

Lucent (lucency) – a region of the image through which a greater portion of the x-ray beam passed unobstructed to reach the detector (blacker on the x-ray image). Air, for example, would be described as lucent in x-ray imaging.

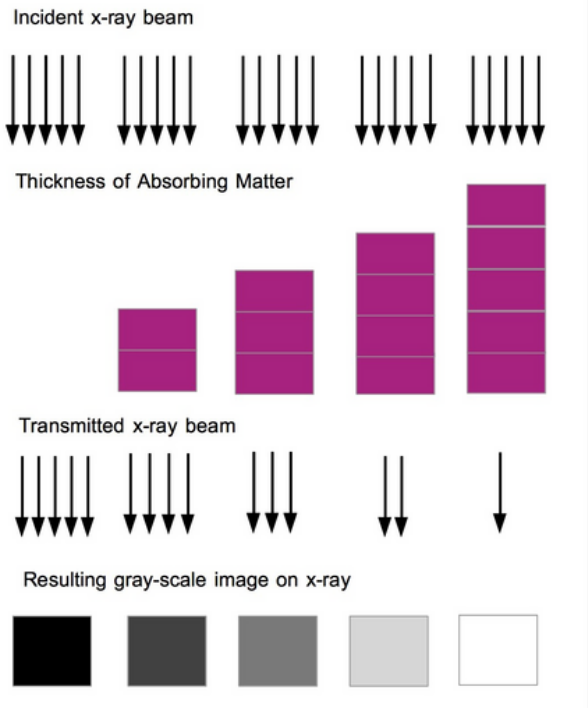
The figure below shows a clinical example of the various absorption spectra seen on x-rays. A patient with a knife embedded in his left shoulder is depicted in this image.



Left Shoulder x-ray

- The x-ray of the shoulder (shown above) reveals a very opaque (white) object that is consistent with the metallic blade of a knife. In comparison to the metal, the knife's handle is made of plastic and is very translucent.
- The blade of a metal knife is embedded in the proximal humerus bone. Take note of the opacity difference between the cortical and medullary bones.
- Because it contains more calcium than medullary bone, which contains fat-containing marrow, cortical bone is more compact and opaque (more lucent).
- Because a large portion of the original x-rays reached the detector, the air around the patient is extremely bright (black).
- The lung (shown on the left side of the image) has a low density but is denser than the surrounding air due to the sum of all the other anatomy in the chest from dorsal to ventral, but it is still quite lucent in comparison to other areas of the image.
- Because fat is more translucent than muscle, there are tissue planes visible between the arm muscles, particularly the bicep and deltoid muscles.
- Take note of the difference in fat density between the muscles and the gas trapped in the dressing used to cover the knife's entry point. The atmosphere has darkened (more lucent).

The thickness of the imaged anatomy also affects x-ray absorption. This is depicted in figure below.



Effect of tissue thickness on x-ray appearance

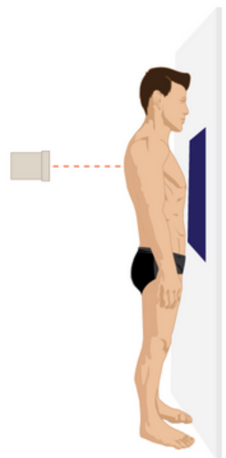
This is shown on a quality control image for x-ray tube calibration. The image below depicts an x-ray of a Lucite plastic plate with variable depth holes drilled into it, causing the circles to appear. As the thickness of the Lucite decreases, the circles become more translucent. The vertical stripes are made up of progressively thicker layers of aluminium applied to Lucite.

Common x-ray Test Object, Lucite Plastic Board

PATIENT POSITIONING FOR X-RAY IMAGES

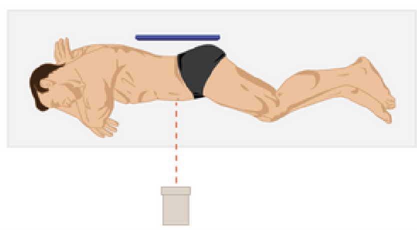
Most x-ray machines have the x-ray tube and detector in a relatively fixed position. The patient must be moved and positioned in order to obtain images in various anatomic projections. This may necessitate mounting the image detector on a wall or table, or it may be housed in a hand-held cassette. Some images may require the patient to be quite mobile, such as lying on their side or standing upright.

A fundamental tenet of plain x-rays is to obtain at least two views of the anatomy in question, usually 90 degrees apart (orthogonal). Typically, one image is obtained in anatomic position, and the second image is obtained at a 90-degree angle to the original anatomic position. As a result, the minimum two views are typically an anterior-posterior (AP) and a lateral. The image is called a posterior-anterior (PA) view if the x-rays enter the patient from the posterior anatomic side.



Posterior-anterior, upright, chest x-ray positioning.

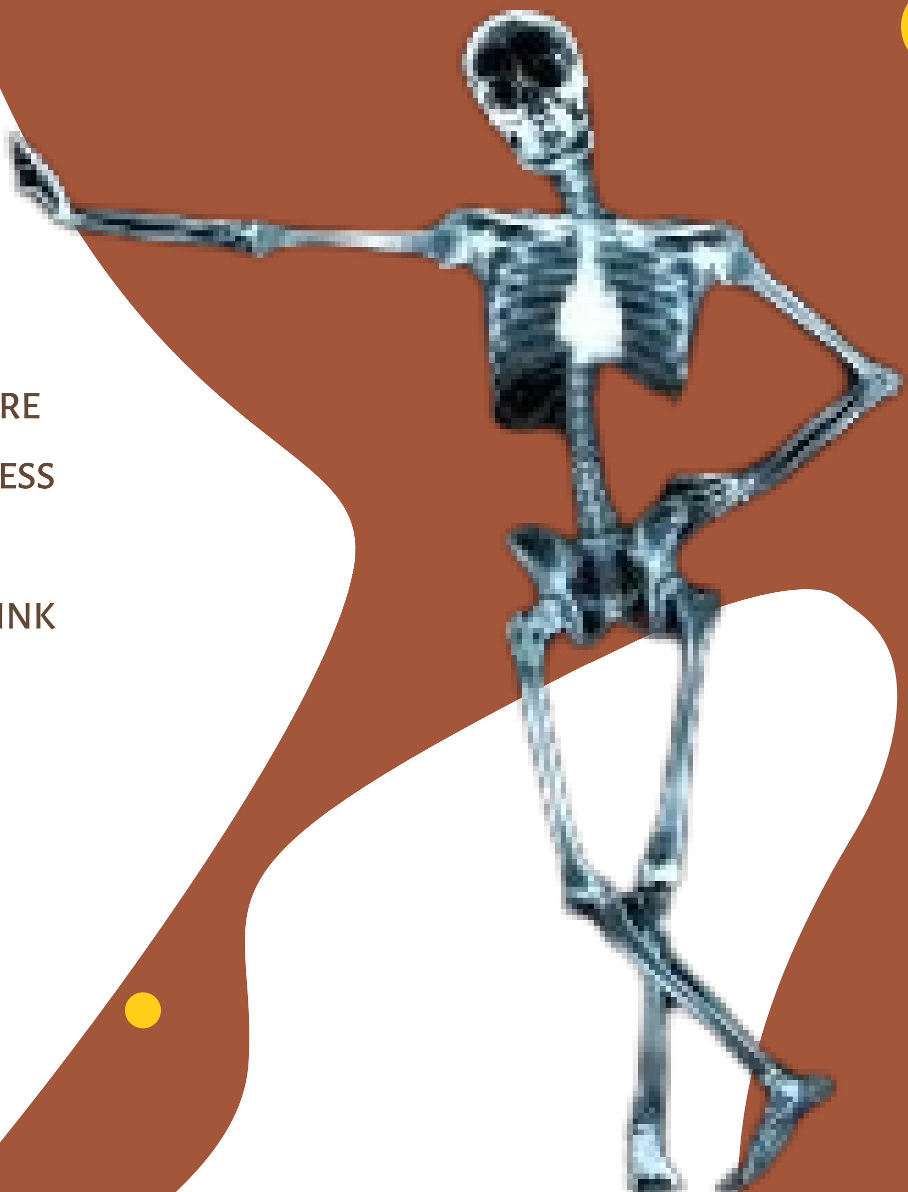
Lateral, upright, chest x-ray positioning.



Decubitus positioning for a chest or abdomen x-ray.

SECTION 4

FILM AND SCREEN FILM SYSTEM



GREAT DISCOVERIES ARE MADE ACCIDENTALLY LESS OFTEN THAN THE POPULACE LIKES TO THINK

BY WILHELM RONTGEN

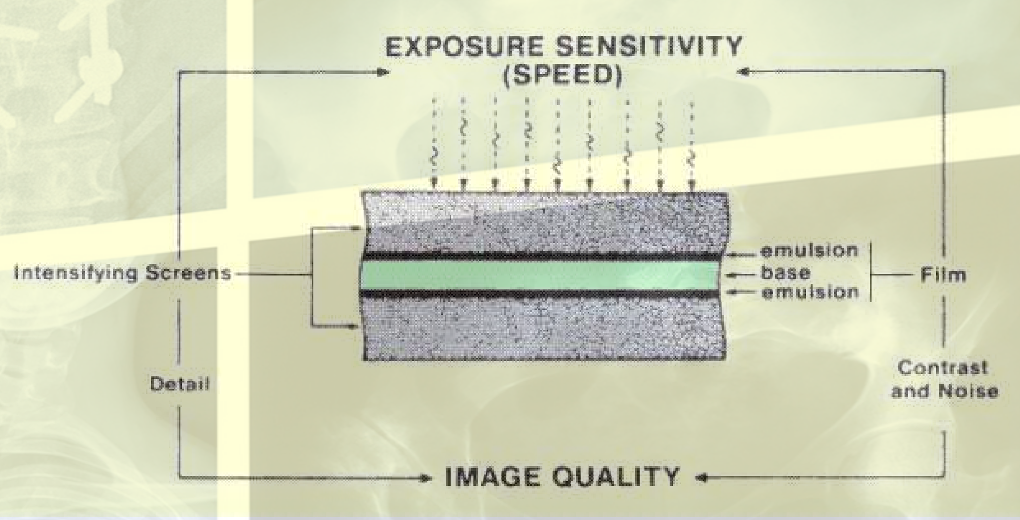
INTRODUCTION

The receptor in screen/film radiography is a film mounted in contact with one or two intensifying screens. Thin sheets or layers of fluorescent materials make up intensifying screens. The screen-film combination is stored on a cassette or in a film changer. The x-ray energy is absorbed by the intensifying screen material and some of it is converted to light. In turn, the light exposes the film. Because the film is much more sensitive to light than to x-radiation, intensifying screens are used; approximately 100 times as much x-radiation would be required to expose a film without intensifying screens.

DID YOU KNOW?

PEOPLE USED TO THINK THEY WERE HARMLESS.

In the early days, people thought x-rays passed through the body as harmlessly as normal light. It wasn't until Thomas Edison's assistant Clarence Dally, who had worked extensively with X-rays, died of skin cancer in 1904 that people started taking the health concerns about the new technology seriously.



A Conventional Screen/Film Radiographic Receptor

Unfortunately, intensifying screens introduce blurring into the imaging process and limit the visibility of detail, which must be taken into account when selecting screens for specific clinical applications.

There are several styles of intensifying screens available for clinical use. The selection of a screen for a selected procedure has typically supported a trade-off between image detail and patient exposure. Most radiographic procedures use a receptor with two intensifying screens mounted on either side of the double-emulsion film.

Using two screens during this manner maximises x-ray absorption and receptor sensitivity while producing the smallest amount of image blur. One intensifying screen is employed in conjunction with a single-emulsion film in some procedures that need high image detail, like mammography.

SCREEN FUNCTIONS

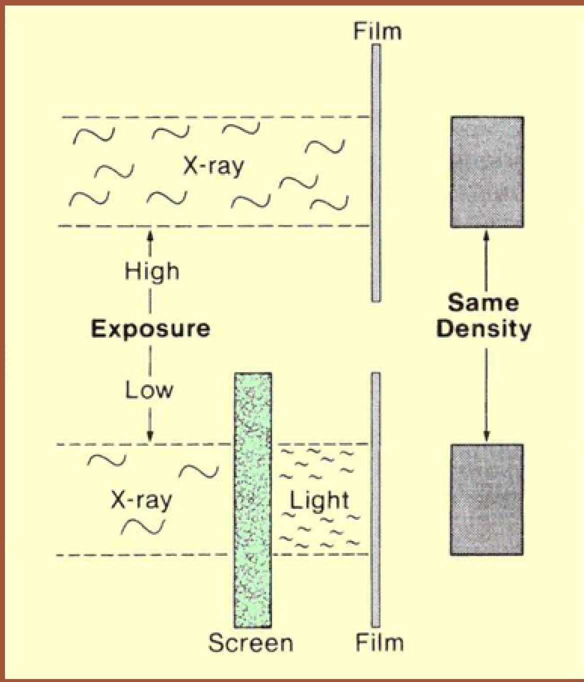
X-Ray Absorption

The first function of the intensifying screen is to absorb the x-ray beam (energy) emitted by the patient's body. The ideal intensifying screen would absorb all incoming x-ray energy; however, most intensifying screens are not thick enough to absorb all photons. As we will see later, increasing the thickness of an intensifying screen to increase its absorption capabilities degrades image quality.

In most cases, a significant portion of the x-ray energy is not absorbed by the screen material and instead passes through to the receptor. This is squandered radiation because it has no effect on image formation or film exposure. The percentage of incident radiation absorbed by the screen material is referred to as absorption efficiency. An ideal screen would have a 100 per cent absorption efficiency; however, most screens have absorption efficiencies that are less than 100 per cent. Three factors primarily influence absorption efficiency: (1) screen material, (2) screen thickness, and (3) photon energy spectrum.

Light Production

The intensifying screen's second function is to convert some of the absorbed x-ray energy into light. This is how the fluorescent process works. Fluorescence is a material property that allows it to absorb radiation energy in one portion of the photon-energy spectrum and emit some of it as lower energy photons. This property is found in materials that glow or emit visible light when exposed to high-photon energy ultraviolet light.



Conversion of X-Ray Energy in an Intensifying Screen

The diagram above depicts what happens to x-ray energy after it is absorbed by an intensifying screen. When such material is exposed to high-energy x-ray photons, the fluorescent process produces visible light in the intensifying screen. The intensifying screen is an energy converter, converting 5 to 20% of the absorbed x-ray energy into light. This percentage represents the screen's conversion efficiency and is determined by the material used in the screen.

Despite the fact that the total energy of light emitted by a screen is far less than the total energy of x-ray energy received by the screen, light energy is far more efficient in exposing film because it is "repackaged" in a far greater number of photons. One 50-keV x-ray photon can generate 1,000 2.5 eV blue-green light photons assuming a 5% energy conversion efficiency.

Exposure Reduction

Because the film is more sensitive to light than to x-ray exposure, an intensifying screen can be used to expose the film with much less radiation. If exposed directly to x-rays, conventional x-ray film has an x-ray exposure sensitivity in the range of 50 mR to 150 mR. The sensitivity of the film when combined with intensifying screens ranges from about 0.1 mR to 10 mR, depending on the type of screen and film used.

RECEPTOR SENSITIVITY

The sensitivity of a receptor, such as an intensifying screen-film combination, is measured in terms of the amount of exposure required to produce a film density one unit above the base plus fog level. Although some manufacturers do not provide sensitivity values for their receptor systems, the majority do provide speed values such as 100, 200, 400, and so on. The speed scale compares the different receptor systems' relative exposure requirements. The majority of speed numbers refer to a so-called par speed system, which is assigned a speed value of 100.

Speed is a less precise value used to compare film-screen combinations, whereas sensitivity is a precise receptor characteristic that expresses the amount of exposure the receptor requires. However, there is a general correlation between exposure requirements (sensitivity) and receptor speed values:

Sensitivity (mR) = 128/speed.

For example, a receptor with a true speed of 100 necessitates a 1.28 mR exposure to produce a 1-unit film density. The values of sensitivity and speed are inversely related. A faster receptor has a higher speed value than a slower receptor.

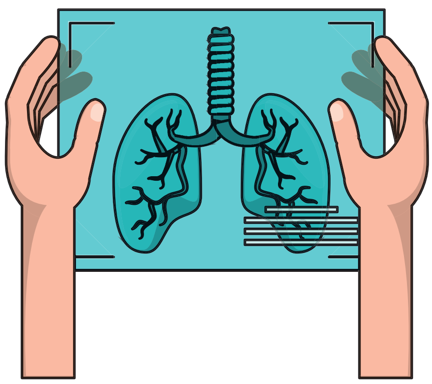
The manufacturer assigns a nominal speed rating to the majority of receptors. The actual speed varies depending on the x-ray spectrum (kV) and the film processing conditions. The sensitivity (speed) of an intensifying screen-film receptor is determined by the type of screen and film used, as well as the conditions under which the screen and film are used and the film is processed.

Materials

Intensifying screens are made from a variety of compounds. The material must have two major properties: (1) high x-ray absorption and (2) fluorescence. Intensifying screen materials are frequently referred to as phosphors due to their fluorescence.

Calcium tungstate was the primary material in intensifying screens soon after the discovery of x-rays and remained so until the 1970s. A number of new phosphor materials were developed at the time, many of which contained one of the rare earth chemical elements. The following phosphorus compounds are now used as intensifying screen materials:

- barium lead sulfate
- barium strontium sulfate
- barium fluorochloride
- yttrium oxysulfide
- lanthanum oxybromide
- lanthanum oxysulfide
- gadolinium oxysulfide.



Each compound contains one element that is the primary x-ray absorber.

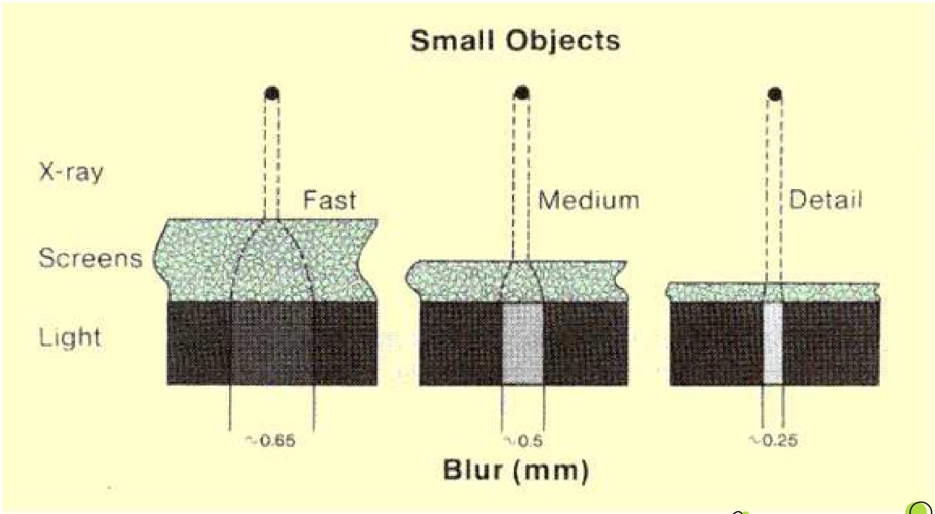
For many years, the most common screen material was calcium tungstate, which used tungsten as the absorbing element. The tungsten K edge is 69.4 keV. A large portion of the x-ray beam spectrum falls below this energy for the majority of x-ray examinations. As a result, tungsten-containing screens are limited in terms of x-ray absorption. The absorbing element in most intensifying screens today is either barium, lanthanum, gadolinium, or yttrium. These elements' K edges are located below a large portion of the typical x-ray beam spectrum. This raises the possibility of x-ray interaction and absorption.

Spectral Characteristics

The other elements in the compound contribute to the material's fluorescent properties. Each compound emits light of a specific colour (wavelength) due to its composition. Intensifying screens emit light in either the ultraviolet, blue, or green portions of the light spectrum and they are sometimes classified as blue or green emitters. The significance of this is that a screen must be used with a film that is sensitive to the colour of light emitted by the screen. Some radiographic films are only sensitive to blue light, while others (orthochromatic) are sensitive to both blue and green light. If the spectral characteristics of the screen and film are not properly matched, receptor sensitivity is severely reduced.

Thickness

The choice of a screen is typically a trade-off between exposure and image quality, as illustrated below. Thin screens absorb a small percentage of the x-ray photons; thicker screens absorb a larger percentage and thus require less x-radiation to produce the same film exposure. Unfortunately, as screen thickness increases, so does image blur.



Effects of Screen Thickness on Image Blur

Photon Energy (KVp)

Because sensitivity is directly related to absorption efficiency, the sensitivity of intensifying screens varies with x-ray photon energy. When the x-ray photon energy is just above the K edge of the absorbing material, absorption efficiency and screen sensitivity are at their peak. Because the K edge is at different energies, each intensifying screen material has a different sensitivity-photon energy relationship.

The spectrum of photon energies within an x-ray beam is most directly affected and controlled by the kV; thus, the sensitivity and speed of a specific intensifying screen are not constant but vary depending on the kV used for a particular procedure.

IMAGE BLUR

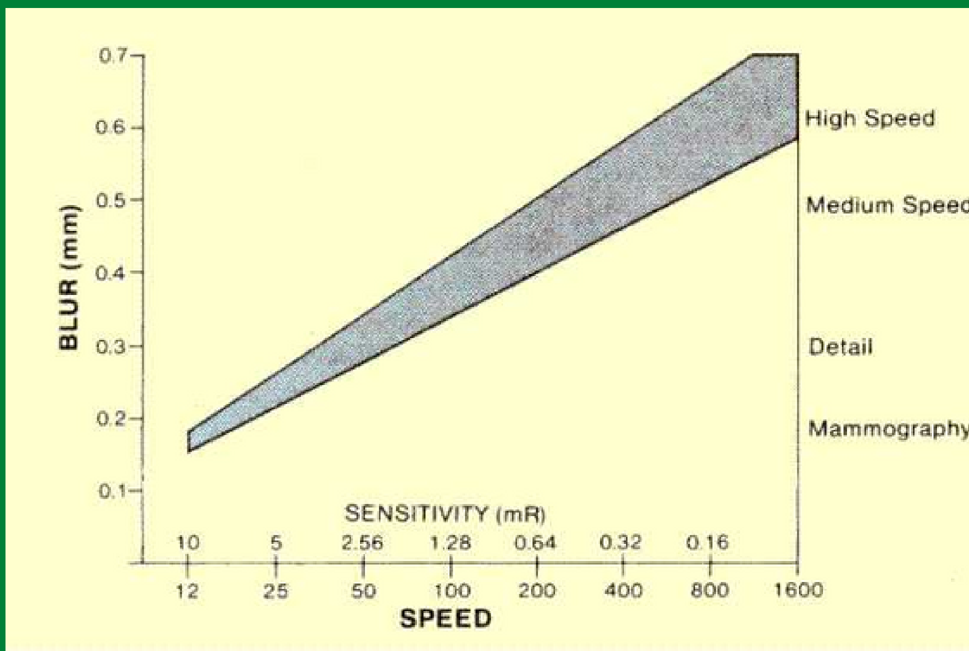
The most significant impact of intensifying screens on image quality is a blur. The reason for this was explained above. Consider the imaging of a tiny object, such as calcification. The x-ray photons absorbed by the object produce light along the vertical path extending through the intensifying screen. The light spreads out of the absorption path before exiting the screen, as shown. The light image of the object that appears on the surface of the intensifying screen is thus blurred; the degree of blurring caused by this process is proportional to the intensifying screen's thickness and light transparency.

The main challenge in selecting intensifying screens for a specific clinical application is striking the right balance between patient exposure and image quality, or, more specifically, between receptor sensitivity (speed) and image blurring (visibility of detail). Screens with the best detail visibility usually have a low absorption efficiency (sensitivity) and require a relatively high exposure. High-sensitivity (fast) screens, on the other hand, cannot produce images with high detail visibility due to increased blurring.

Brand names are commonly used to identify intensifying screens, but they do not always indicate specific characteristics. The majority of screens, on the other hand, fall into one of five categories:

1. mammographic
2. detail
3. par speed
4. medium speed
5. high speed.

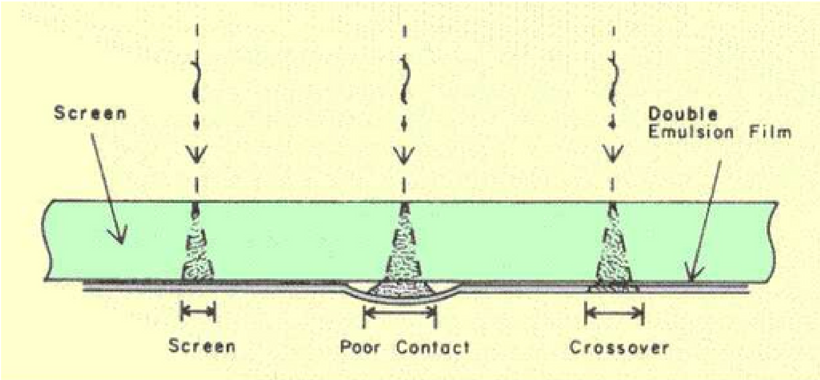
The figure below shows how these general screen types fit into the relationship between image blur and required exposure.



General Relationship between Image Blur and Sensitivity (Speed)

Screen-Film Contact

If the film and intensifying screen surfaces do not make good contact, the light will spread and cause image blurring, as shown below. This is an abnormal condition that occurs when a defective cassette or film changer does not apply sufficient pressure to the entire film area. In most cases, insufficient film-screen contact results in blurring in only a portion of the image area.



Sources of Blur in Screen-Film Receptors

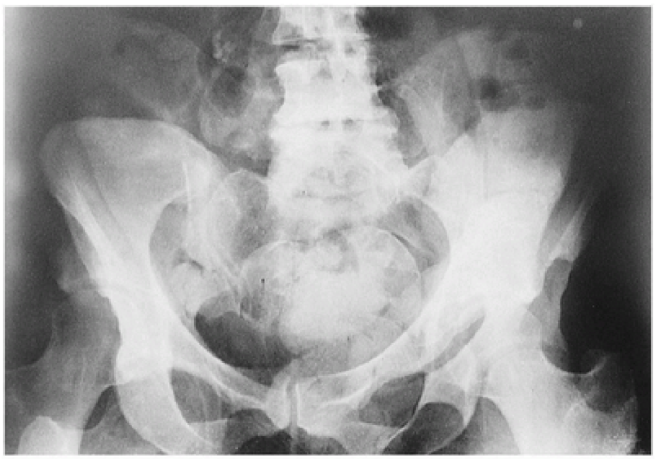
IMAGE NOISE

The characteristics of the intensifying screen influence the amount of noise in radiographic images to some extent; the crystal structure of the screen material produces a relatively small amount of image noise. In general, quantum noise is the most significant type of noise in radiographs. For reasons discussed in another chapter, intensifying screens with high conversion efficiencies produce more quantum noise than other screens. Additionally, the blurring created within screens reduces the visibility of noise to some extent.

ARTEFACTS

Image artefacts can be caused by intensifying screens. Scratches, stains, and foreign objects on the screen surface, such as hair, dust, and cigarette ashes, can cause artefacts. Intensifying screens should be cleaned on a regular basis, as directed by the manufacturer.

The image unsharpness was caused by patient movement.



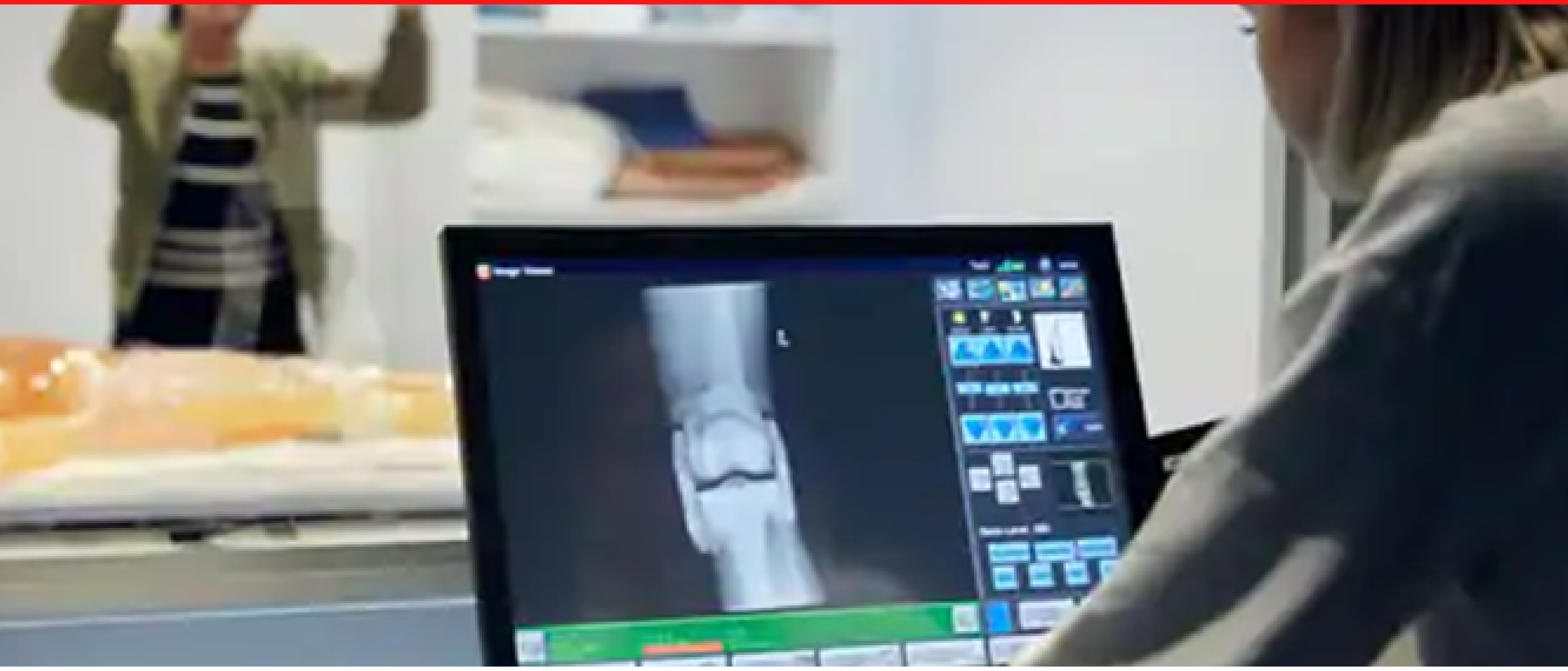
The peculiar appearance of the radiograph is the result of a double exposure.

SECTION 5

DIGITAL IMAGING SYSTEM

A NEW ERA IN THE PHYSIOLOGICAL INVESTIGATION OF LINGUISTIC SOUNDS WAS OPENED UP BY X-RAY PHOTOGRAPHY

BY ROMAN JAKOBSON



INTRODUCTION

Direct digital radiography is another name for digital radiography. The distinction between digital radiography and conventional radiography is analogous to that between old cameras that used films that had to be developed in a darkroom and modern digital cameras.

DID YOU KNOW?

Diamonds don't show up on X-rays.

X-rays can be divided into hard X-rays and soft X-rays. Hard X-rays have higher energy and, therefore, higher penetrative ability, making them useful in medical radiography and airport security.

Digital radiography is filmless, allowing for instant acquisition, deletion, editing, and transfer of films to a computer system, which generates the image almost instantly.

Digital radiography systems allow for imaging at any dose level and provide images that can be processed and displayed in a variety of ways. The systems are more expensive than traditional radiological systems, but they are becoming more popular as imaging and computer technology advance.

Digital radiography (DR) may be a more advanced kind of x-ray inspection that produces a digital radiographic image on a computer in real-time. This method uses x-ray sensitive plates to capture data during object examination, which is then immediately transferred to a computer without the utilization of an intermediate cassette. Incident x-ray radiation is converted into the same electrical phenomenon then into a digital image by a detector sensor.

Systems for digital radiology

The x-ray tube and image receptor are connected to and controlled by a computer, and the resulting digitally stored and processed image is displayed on a television screen. The digital image can be stored on magnetic media or optical disc, and a film writing device can be used to create a permanent analogue copy of the image.

Two classes of image receptors can be used in digital radiology:

- recording the whole image at once
- recording only part of the image at a time and obtaining a complete image by scanning both x-ray beam and receptor.

The receptors

- image intensifier,
- ionographic chamber
- stimulated luminescence plate

Rather than using film to detect and store image data, digital radiography employs digital detectors to generate a digital image, which is then stored separately on a digital medium. Image generation, processing, archiving, and presentation are the four steps in digital radiography.

Chest radiograph in a tablet computer

Image Acquisition and Processing

The conversion of absorbed X-ray energy into electrical charge is the basis for digital detection, which must then be represented digitally in grayscale images to show the quantified X-ray energy that was absorbed in each point in the digital image. Processing software is used to create the final image. The goal of image processing is to improve image quality by reducing noise, eliminating artefacts, and, if necessary, enhancing contrast.

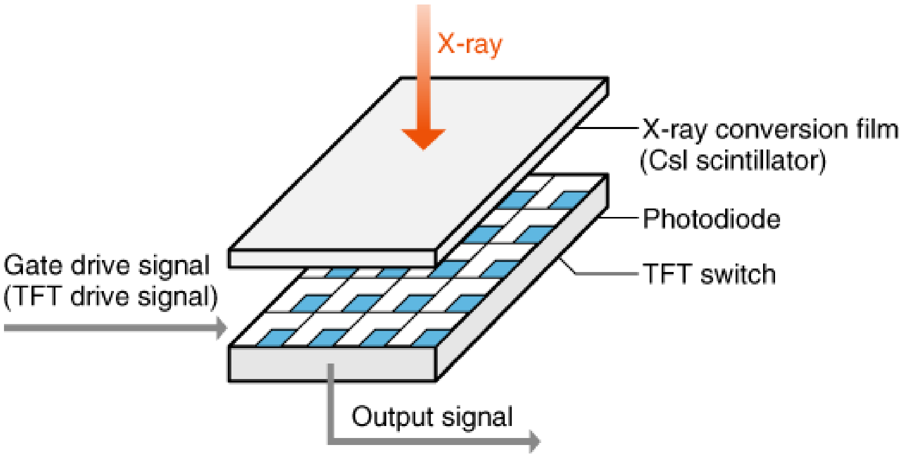
Image Archiving and Presentation

The final images are saved digitally on storage media and can be viewed on a computer. Images can be zoomed, measured for distance and angle, panned, or windowed while being viewed. Images can be sent to other computers for viewing remotely or linked to digital record systems for better retrieval and diagnosis.

The basic principle is thus to detect X-rays and then convert the X-rays to charge either directly or indirectly (via conversion to light as the first step by phosphors or scintillators). These images are digitally processed and viewed. The procedure takes no more than 10 seconds and does not require the use of a cassette.

Flat Panel Detectors

A flat panel detector is one type of detector plate used in digital radiography. There are two kinds of flat-panel detectors: direct conversion and indirect conversion. As needed, tiled arrays of detectors are used to cover the entire field of imaging.



Flat Panel Detectors

Advantages of Digital Radiography

Digital radiography's extremely high image quality is a significant advantage. Digital radiography is most commonly used in healthcare facilities with a high patient imaging workflow. The processing and diagnosis times are also greatly accelerated. Remote viewing is also possible, and images can be digitally saved for the patient to take elsewhere if desired.

The efficiency of X-ray detector systems is determined by how well photons are detected and how much noise is added to the detected signal. To quantify this, the detective quantum efficiency, or DQE, is used. A DQE of 100% indicates that every X-ray photon has been detected and that there is no noise. In comparison to computerised radiography, a digital radiography system can achieve DQEs of up to 65 per cent. It is advantageous to be able to use lower doses of radiation without increasing quantum noise.

Disadvantages of Digital Radiography

The disadvantage of digital radiography is the high cost of purchasing two separate detector plates, one for each Bucky position. These detectors are exorbitantly priced. Furthermore, they cannot be positioned for imaging at inconvenient angles. As a result, new designs for increasing the flexibility of this technique have been developed.

Other critical issues include the requirement for high luminance and high-resolution monitors to view final digital images, as well as the need to organise large volumes of digital storage on appropriate media. Digital radiography is also completely reliant on having picture archiving and communication systems (PACS) with high bandwidth in order to archive these high-resolution images.

Difference Between Digital and Computed Radiography

Active matrix flat panels or linear detector arrays are used in digital radiography systems, and they are made up of a detection layer deposited over an active matrix array of thin-film transistors and photodiodes.

Images from digital radiography are converted to digital data in real-time and are ready for analysis within seconds.

Instead of traditional x-ray film, computed radiography cassettes capture the X-ray image using photo-stimulated luminescence screens. The computed radiography cassette is then inserted into a reader, which converts the stored data into a digital image.

Imaging plates for computed radiography are flexible and do not require a rigid holder. There are flexible cassettes available that allow the detector to be fitted into curved areas.

While both computed and digital radiography has a wider dose range and can be post-processed to eliminate noise, DR has several advantages over computed radiography.

Digital radiography improves workflow by producing higher image quality instantly while using up to three times less dose than computed radiography.

Digital radiography is quickly becoming the preferred choice for non-destructive testing operators due to ongoing technological advancements and price reductions.

SECTION 6

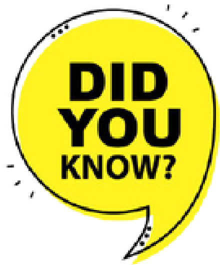
BIOLOGIC EFFECTS AND SAFETY

THERE IS NO SAFE AMOUNT OF RADIATION. EVEN SMALL AMOUNTS DO HARM.

BY LINUS PAULING

INTRODUCTION

Electromagnetic energy in the form of waves is what X-rays are. X-ray exposure has been linked to cancer and developmental issues, as well as the possibility of burns. Pregnant women should take extra precautions because the risks of x-ray exposure are greatest for foetuses. Hospital x-ray machines generate relatively high x-ray exposures, which pose a risk if adequate safeguards are not in place. Only trained personnel should operate these devices.



X-rays were once used for hair removal. In the 1920s, people attempted to use x-rays to remove unwanted hair. The FDA eventually banned this due to health concerns. Can you imagine that?

Biological Effects of X-ray Exposure

Some biological effects, such as skin damage, are dose-dependent, whereas others, such as cancer development, are unpredictable. Dose-dependent biological effects are detectable above 50mSv (millisieverts), and a whole-body dose of more than 10Sv (sieverts) is universally lethal.

The average radiation dose per person in the United Kingdom is 2.6mSv per year, of which 2.2mSv is background and 0.4mSv is medical exposure. Doses ranging from 0.02mSV (chest X-ray) to 10mSv are commonly used in diagnostic investigations (CT abdomen). This means that a chest X-ray exposes you to 3 days of background radiation, while a CT abdomen exposes you to 4.5 years!

Some body parts are more vulnerable to the unpredictable damaging effects of radiation. These are typically tissues with rapidly dividing cells; for example, a radiation dose to the stomach is more than 20 times more likely to result in fatal cancer than a similar dose to the bone.

Radiation exposure to reproductive organs poses a new risk to future generations. Children are more radiosensitive than adults, so exposing a foetus to radiation should be avoided whenever possible.

PROTECTION FROM X-RAY HAZARDS

Monitoring of exposure

X-ray facilities are built around the equipment, and the source of radiation is usually contained within a small area of the room. Personal DOSIMETERS are used to monitor worker radiation doses.

Personal Radiation Dosimeter

What does the dosimeter do?

A radiation dosimeter or badge does not provide protection, but rather detects and measures the amount of radiation to which you have been exposed. The badge is capable of detecting high-energy beta, gamma, or x-ray radiation. Low energy beta radiation from some isotopes, such as carbon-14, tritium, or sulfur-35, cannot be detected by dosimeters.

Who needs a dosimeter?

Workers who use x-ray machines, fluoroscopy units, certain unsealed and sealed radioisotopes, or are exposed to other sources of gamma or high energy beta radiation are generally required to wear one or more dosimeters.

Key Point

The maximum annual regulatory limit for radiation workers is 5,000 mrem Deep dose (DDE), 15,000 mrem Lens dose (LDE), and 50,000 mrem Shallow dose (SDE). National Average Annual Exposure from background (non-occupational) radiation is 625 mrem (NCRP 160, 2006).

Protection From X-rays

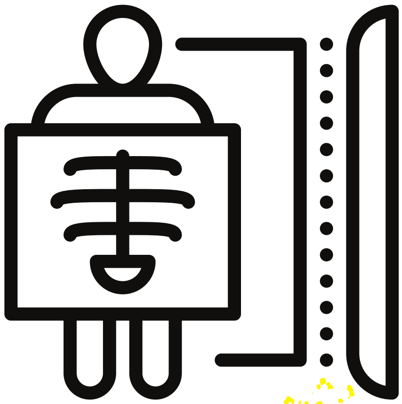
Radiation protection for technologists and physicians relies on

- the time spent near the machine while it is producing x-rays
- the distance between the worker and the x-ray source
- the shielding used by the worker and that of the tube housing

Increasing the distance and amount of shielding, as well as decreasing the time, will reduce a worker's radiation exposure.

Time

When using an x-ray system, work quickly and efficiently. Exams should be carefully planned and practised in advance to minimise exposure (beam-on) time and, as a result, total radiation exposure in the room.



Shielding

When installing a new x-ray system, make sure that each tube is shielded by a fixed shield. Permanent shielding is the most effective mechanism for protecting workers from unnecessary x-ray exposure. Never tamper with system interlocks and always operate these systems with all shielding and safety components in place.

Distance

Radiation is significantly reduced by distance:

- when the x-ray system is in use, move away from it.
- standing at least 2 metres away from an x-ray radiation source offers significant protection.

Because narrow x-ray beams do not "spread" as much as broad beams, even being 6 feet away from the system may result in much of the radiation beam being absorbed by your body if the beams are narrow.

Safety Precautions and Guidelines

- Before operating analytic x-ray machines, obtain proper training from the person in charge.
- Wear dosimeters on the side of your body that is facing the radiation source, between your shirt collar and waist.
- Monitor the radiation levels of newly installed machines, particularly before and after modifying the machine for special experiments.
- Before turning on the unit, double-check the shielding. Never assume that a unit was left in good working order by the previous user.

X-ray Safety for Health Workers

Radiation exposure for technologists, nurses, physicians, and others must be kept as low as is reasonably possible. During exposures, only personnel who are required for the x-ray procedures or training should be present in the x-ray room. Portable or fixed lead panels, as well as the following personal protective equipment (PPE), should be used by health workers:

- Lead aprons
- Lead safety glasses
- Thyroid shield
- Leaded gloves
- Gonad Shield

- Keep radiation exposure to a minimum, especially during fluoroscopy procedures.
- To reduce the number of repeat exposures, use proper techniques.
- Patients should not be routinely restrained by staff. When a patient or film requires additional support, use mechanical holding devices. If this is not possible, patients should be carried by a relative or friend wearing lead aprons and gloves.
- Notify the head of your department if you are pregnant.

X-ray Safety for Patients

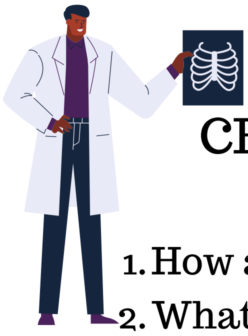
Patient Radiation Safety Principles

- Patient exposure should be reduced to a minimum.
- Radiation exposure to the patient should be kept low while not risking the exam's diagnostic quality.
- One goal of a viable quality assurance programme is to obtain a good quality radiograph while controlling the patient's radiation exposure.
- Use the proper technique for each examination; doing so reduces the need to repeat the procedure.
- Reduce the number of repeat examinations by obtaining a high-quality radiograph the first time.
- To reduce scatter radiation, collide the primary x-ray beam with the area of interest.
- When using portable x-ray machines, make sure that other patients are at least one metre from the scatter radiation, or use portable lead panels.
- Use gonadal shields for patients if they will not interfere with the medical assessment.
- Before undergoing any x-ray exams, identify pregnant patients and notify the referring physician.
- When necessary, wear protective eyewear and aprons.

LET'S DO SOME ASSESSMENT

ASSESSMENT IS TODAY 'S MEANS OF MODIFYING TOMORROWS INSTRUCTION.

BY CAROL ANN TOMLINSON



CHAPTER 1: Fundamental of X-ray Production

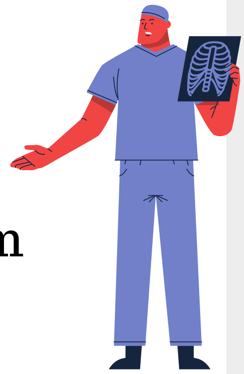
1. How are X-rays produced?
2. What are two types of X-rays generated?
3. Describe the process of characteristic radiation that produces x-rays.
4. Describe the process of bremsstrahlung that produces x-rays.
5. State what percentage of electron energy is converted to x-rays.
6. Compare between Characteristic X-ray radiation and Bremsstrahlung.

CHAPTER 2: X-ray Machine

1. Draw a block diagram for an x-ray machine.
2. State the function of each block diagram for an x-ray machine.
3. X-ray tube is also known as what?
4. What does an x-ray tube produce?
5. Explain the function of cathode and anode in an x-ray tube.
6. What is the function of a glass envelope for an x-ray tube?
7. What part of the x-ray machine serves as filters a stream of rays so that only those travelling parallel to a specified direction are allowed through?

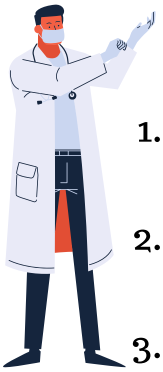
CHAPTER 3: X-ray Image Production

1. State the basic components of the X-ray tube.
2. Explain what happens when the cathode filament heats up.
3. Explain what happens to an electron when it hits the anode.
4. What happens when an alternating current passes through the electromagnets of the stator?
5. What is the function of oil in the x-ray tube housing?
6. What is the common material for filters?
7. Specify the part of the x-ray tube that provides an electrical current at a high voltage to the X-ray tube, resulting in X-ray beam production.
8. Identify five 'basic' opacities in x-ray imaging.



CHAPTER 4: Film and Screen Film System

1. What is a screen-film combination?
2. Why Intensifying screens are used in producing x-ray images?
3. Describe the selection factors of a screen for a specific procedure.
4. State 3 main functions of intensifying screen.
5. What percentage of x-ray energy is absorbed by the intensifying screen to be converted to light?
6. What is the exposure sensitivity value of conventional x-ray film if exposed directly by the x-ray radiation?
7. What are the 2 major characteristics of the material used to make intensifying screens?
8. State what happens if the intensifying screen thickness is increased.
9. Explain the situation if intensifying screen surfaces do not make good contact.



CHAPTER 5: Digital Imaging System

1. What are the differences between digital radiography and conventional radiography?
2. Describe the techniques used to produce a digital radiographic image instantly on a computer.
3. Where can digital images be stored?
4. State two classes of image receptors that can be used in digital radiology.
5. What are the components of a receptor?
6. Explain the image acquisition and processing steps.
7. Explain the image archiving and presentation steps.
8. Identify the advantages and disadvantages of digital radiography.

CHAPTER 6: Biologic Effects and Safety

1. List the biological effects of x-ray exposure.
2. What is the device that monitors the radiation doses of workers?
3. Explain the function of a personal radiation dosimeter.
4. Radiation protection for technologists and physicians relies on what?
5. Explain the distance factor in reducing the rate of radiation.
6. State the safety precautions while operating the x-ray machine.
7. List Personal Protective Equipment (PPE) that must be worn by health workers.

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e ISBN 978-967-2044-87-1