X-ray Machine

Part-1

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X-ray machines

Standard machine

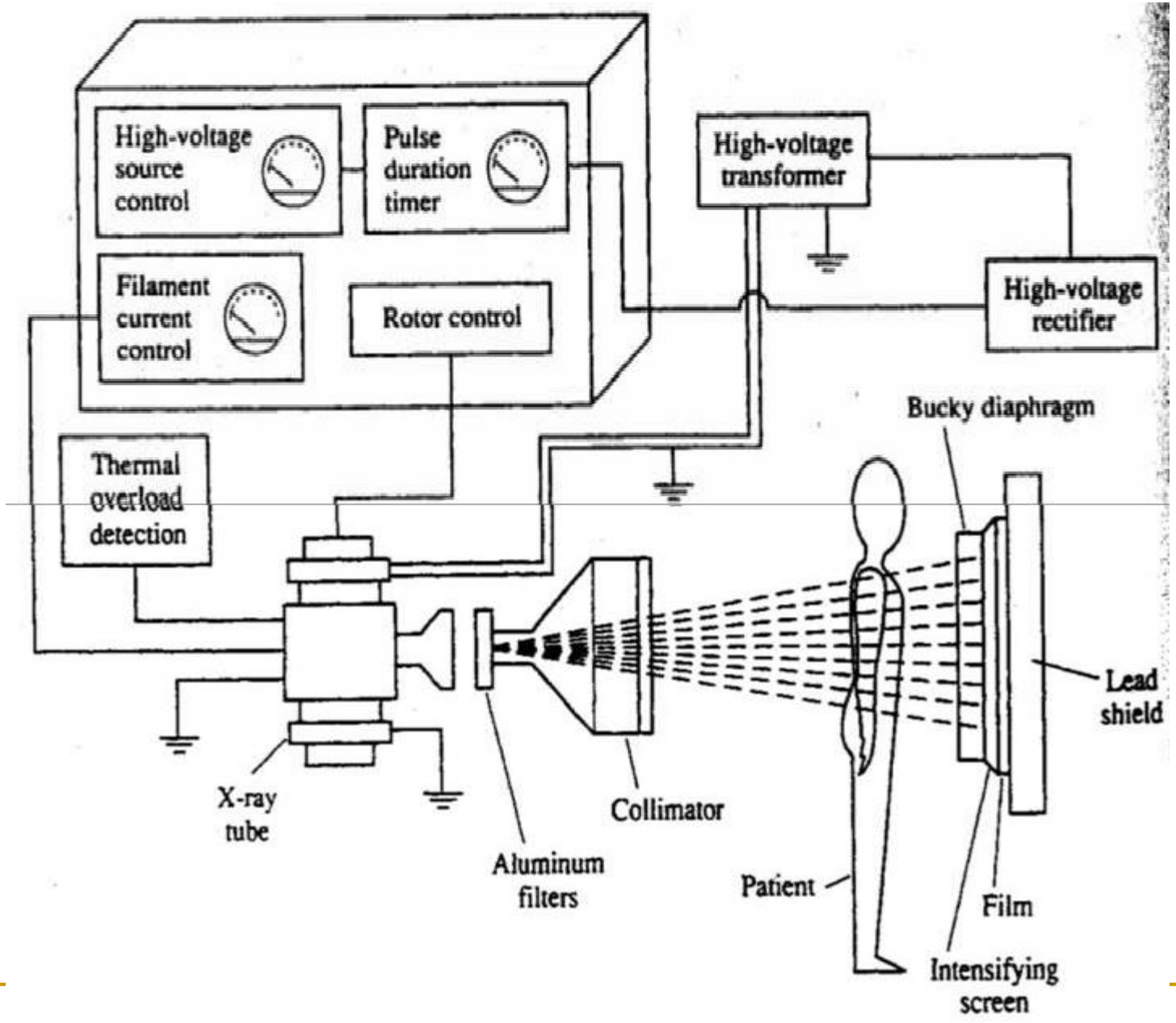
C-arm

Introduction

- An X.ray machine is a complex device used in variety of circumstances around the world.
- With the ability to penetrate hard objects, they are used for various purposes such as air port security check points, in the medical field to look for broken bones or problems within the body.
- Wilhelm Conrad Roentgen, professor of physics who first discovered the X-ray in 1895, referred to as the father of diagnostic radiography

Working principle

- An X-ray machine in actual fact is like a camera. It uses X-rays instead of visible light. X-rays are like light in that they are electromagnetic waves, but they are more energetic so they can penetrate many materials to varying degrees. Since bone, fat, muscle, tumors and other masses all absorb X-rays at different levels. When the X-rays hit the film, the image of a particular structure is formed on X.ray film in different and distinct structures inside the body because of the different levels of exposure on the film.


High-voltage source control
Pulse duration timer
High-voltage transformer
Filament current control
Rotor control
High-voltage rectifier
Thermal overload detection
Bucky diaphragm
Lead shield
X-ray tube
Aluminum filters
Collimator
Patient
Film
Intensifying screen

Elements necessary for x-ray production

1. Source of electrons
2. Method of accelerating the electrons
3. An obstacle-free path for the passage of high speed electrons
4. A target in which the electrons can interact, releasing energy in the form of x-rays.
5. An envelope (tube) to provide a vacuum environment, eliminating the air molecule obstacles from the electron stream and preventing rapid oxidation of the elements.

Parts of X.ray Machine

- X-Ray tube
- Operating Console
- High Frequency Generator
- Tube Head or Protective Housing
- Collimator
- Patient Table
- Grid
- Bucky
- Radiographic film

Operating console

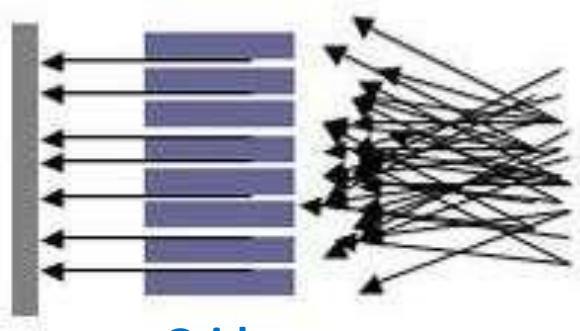
- The operating console allows the radio technologist to control the x-ray tube current and voltage so that the useful X-ray beam of proper quantity and quality can be produced.
- Operating console includes:
  - On/off switch
  - Voltage compensator
  - Kilo voltage selector (kV)
  - Milli amperage selector (mA)
  - Timer
  - Exposure button
  - Warning light

High Frequency Generators

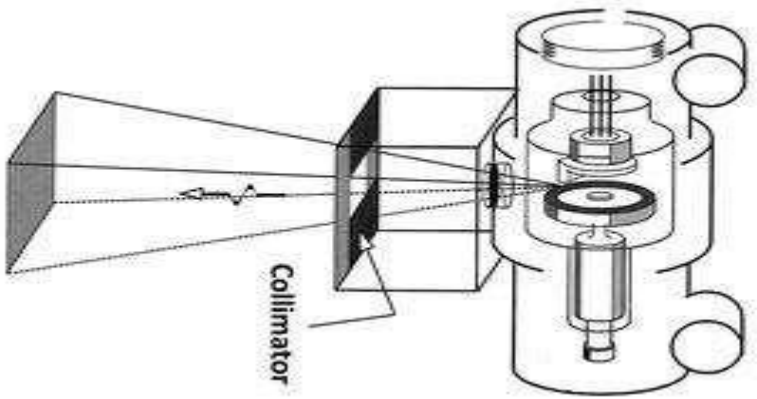
- A high frequency generator powers the X-ray tube.
- Earlier, high voltage generators were used.
- High frequency generators are used for X-ray because they operate on single phase and give less voltage ripples.
- Another reason for using is its small size, which makes it portable.

Collimator and Grid

- **Collimator** is a device used to minimize the field of view, avoid unnecessary exposure using lead plates. Lead shutter are used to restrict the beam. The collimator is attached to the X-ray tube below the glass window where the useful beams is emitted.
- **Grid** is similar to a collimator except they have different positions. Grid is placed between the patient and the X-ray film . It is made up of lead strips, which is used to eliminated scattered light. These strips only allow rays at 90^{o} to pass through.



Grid

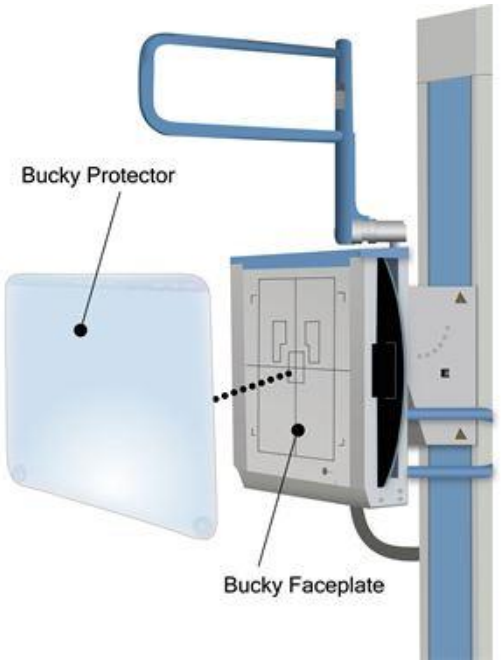


X-rays film

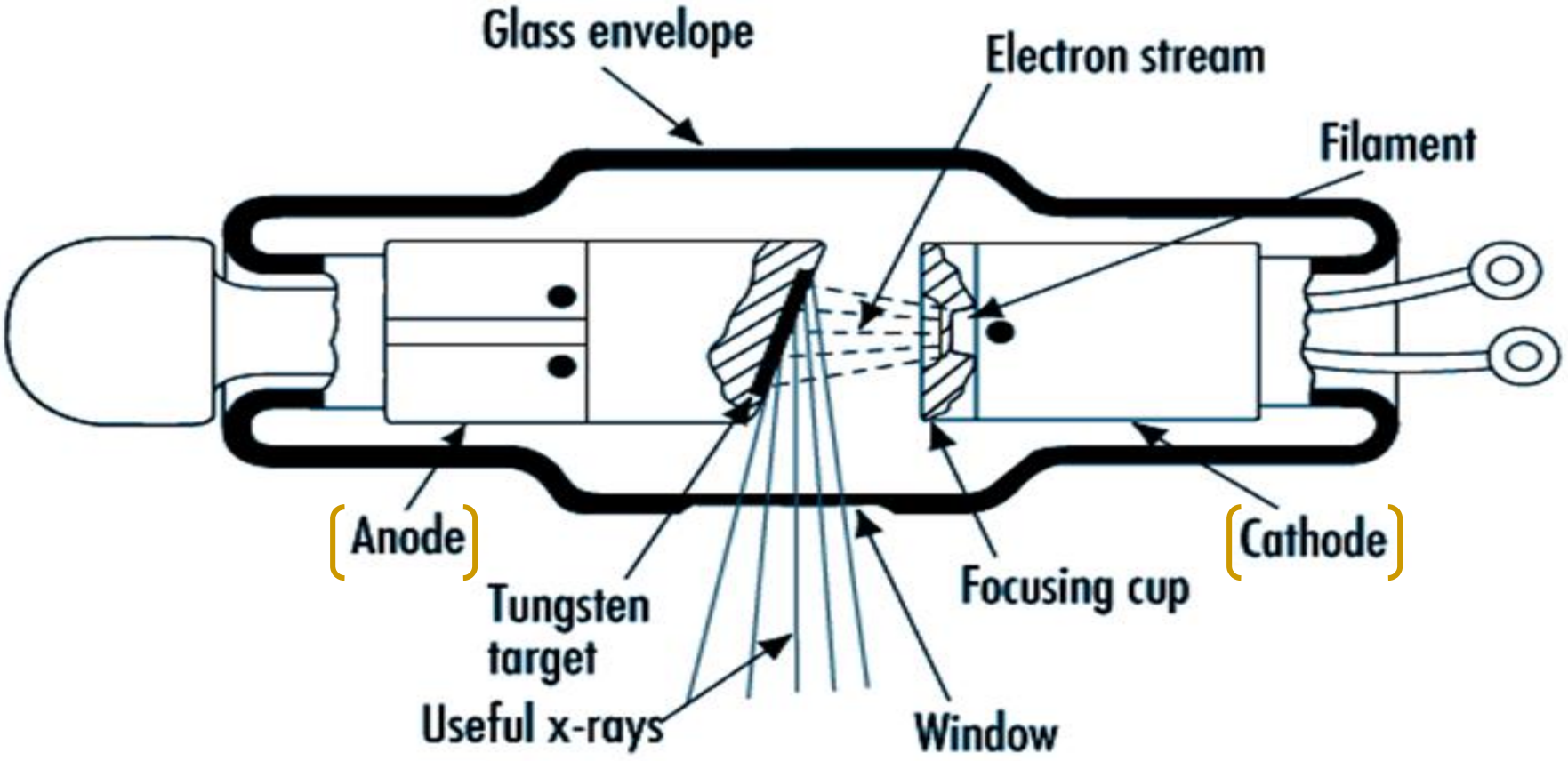
- X-ray film is a sensitive material(sheet) for the x-ray. A film that is exposed to x-rays shows an image of the x-ray intensity.
- X-ray films for general radiography consist of an emulsion-gelatin containing radiation sensitive silver halide crystals, such as silver bromide or silver chloride, and a flexible, transparent, blue-tinted base.
- It turns black when X-rays interact with it and stays white where the X-rays are absorbed. This causes an image to be formed that is black, grays and white.

bucky

- ✓A **bucky** is typically used for table or wall mounted x-ray systems and holds the **x-ray** cassette and grid.
- ✓ **bucky**, is found underneath the exam table, a drawer like device that the cassette and grid is slide into before shooting **x-ray**



The X-ray Tube



X-ray tube components

- 1. Cathode (-)
- 2. Anode (+)
- 3. Glass envelope: encases these components and forms a vacuum.
- 4. Vacuum: an area from which all air has been removed.
- 5. Expansion bellows (provide space for oil to expand)
- 6. Protective housing serves as both an insulator against electric shock and as a thermal cushion to dissipate the heat.
- 8. Rotor (for CT scan, MRI to rotate the cathode, in X.ray machine cathode is stationary)

X-ray tube cont….

- 9. Window: acts as doorway for the exit of x-rays.

  Entire x-ray tube is encased in a metal housing to prevent stray radiation and to protect glass envelope.

X-ray Machine

Part-2

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Cathode

- Cathode provides source of electrons and directs these electrons toward anode.
- Components of the cathode:
  - **Filament**- coiled wire similar to a light bulb- emits electrons when heated.
    - When heat is applied to atom, electrons become excited.
    - This excitation forms an electron cloud that is then attracted towards the anode.

Filament

- The filament is constructed of tungsten because of high melting point and high atomic number.
- The higher the atomic number, the more electrons that are available for excitation.
- Filament is housed in focusing cup and is heated by a low energy circuit.
  - Milli amperage (mA)-amount of electrical energy being applied to the filament. Describes number of x-rays produced during exposure.

Filament (contd…)

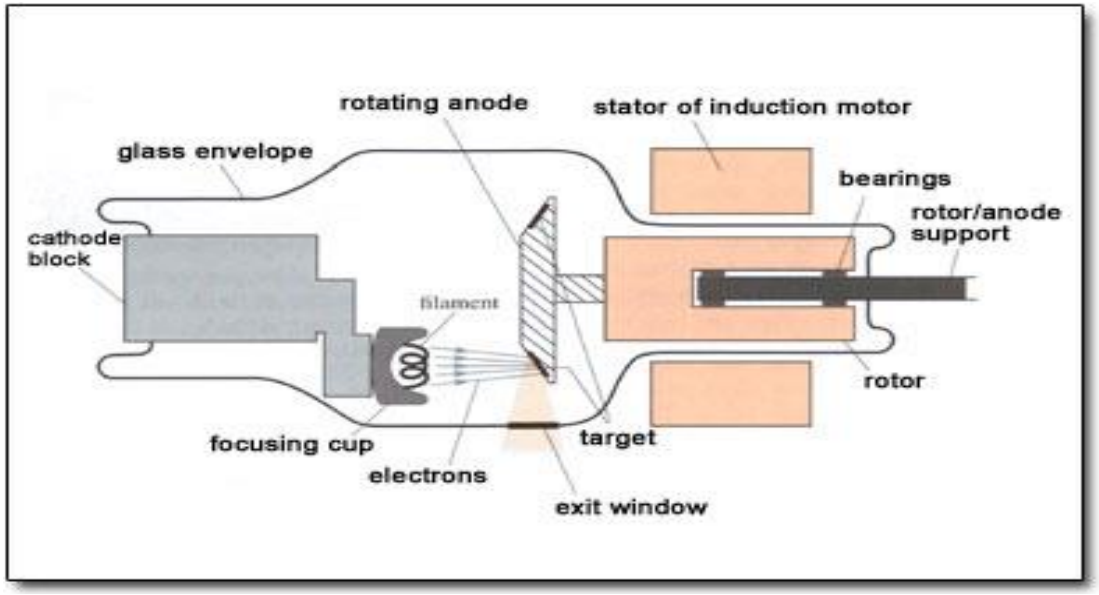
- Quantity of electrons released depends on heat of the filament.
  - hotter the filament, release more electrons, the greater the mA.
- Electrons are released but must then be accelerated for collision with target on anode.
  - Acceleration is controlled by kilovoltage (kV) which is the amount of electrical energy being applied to the anode and cathode to accelerate the electrons from the cathode to the anode.

Anode

- Basic construction is a beveled target placed on a cylindric base.
- Heat is an issue- copper acts as a conductor of heat and draws the heat away from the tungsten target.
- Temperatures greater than 1000°C occur during x-ray production.
  - How do we cool?
    - Copper is at base of target.
    - Surrounding glass tube with oil

Types of Anodes

- Differences in anode type is associated with maximum level of heat dissipation possible.
- 2 main types of Anodes
  - 1. Stationary Anode
  - 2. Rotation Anode

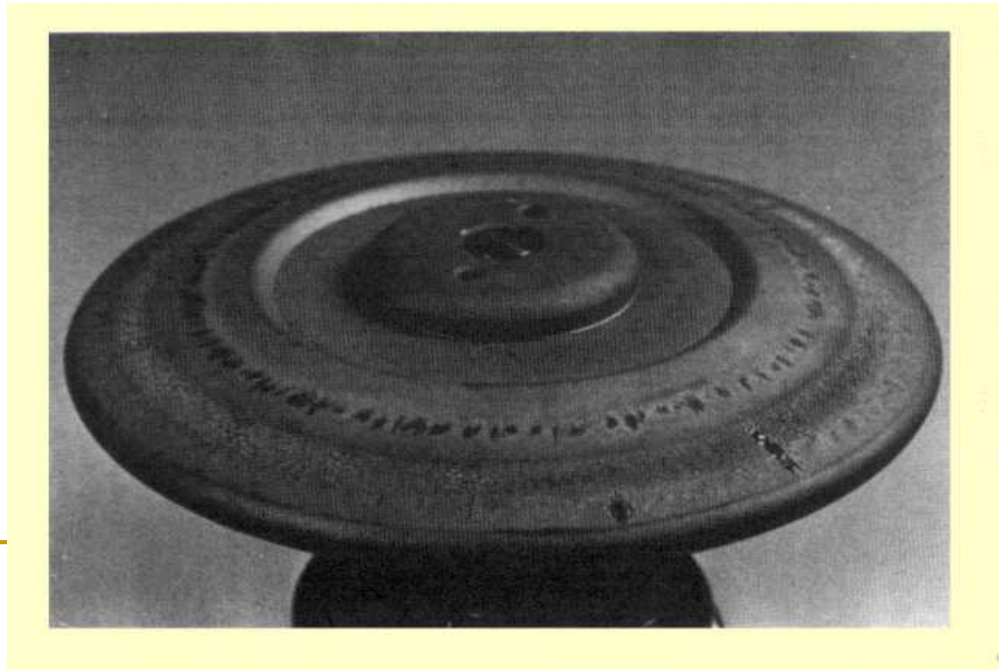


Stationary Anode

- Is “fixed” in place. Found in dental and small portable radiography units. Have small capacity for x-ray production.
- Limitations:
  - Inability to withstand large amounts of heat.
    - Repeated bombardment of target can cause damage to target.
    - This damage causes pitting of the target surface.
- If target is damaged, may cause radiation to scatter in undesirable directions.

Rotating Anode

- Rotates through the center of the tube.
- Rotation provides a cooler surface for the electron stream.
  - Helps to distribute heat over a larger area.



Focal Spot

- The small area of the target with which electrons collide.
- The size of the focal spot has an important effect on the formation of the x-ray image.
  - Larger the focal spot, the less clarity.

Rotating anode can have small focal spot and still withstand a great amount of heat.

➢ Sharpness of radiograph ↑as size of radiation source ↓
Heat ↑ as focal spot ↓in size

Heel Effect

- More x-rays leave tube on cathode side of the tube

The heel effect: The heel effect is due to a portion of the x-ray beam being absorbed by the anode. This results in an x-ray beam that is less intense on the anode side and more intense on the cathode side. The heel effect is more marked with steeper anode angles.

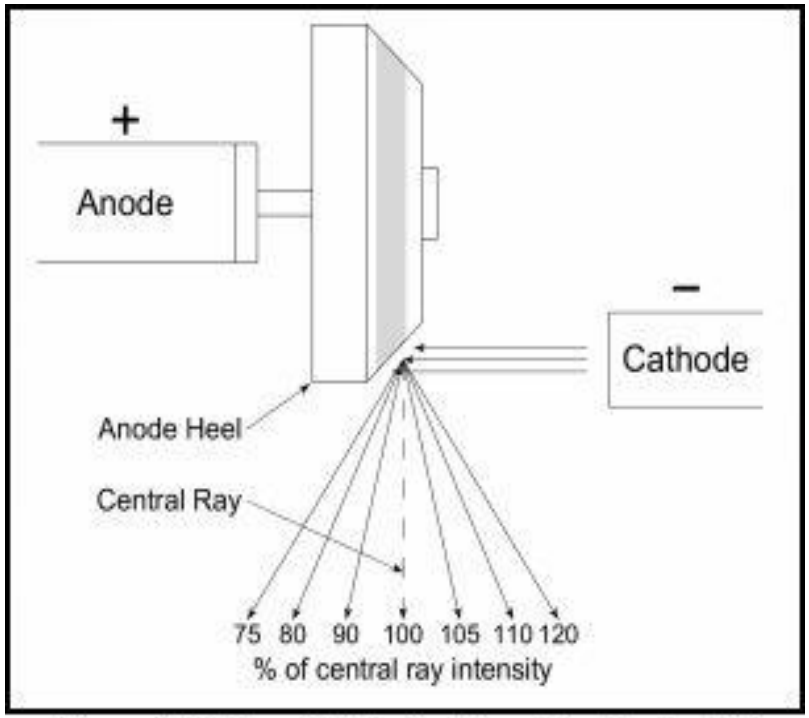
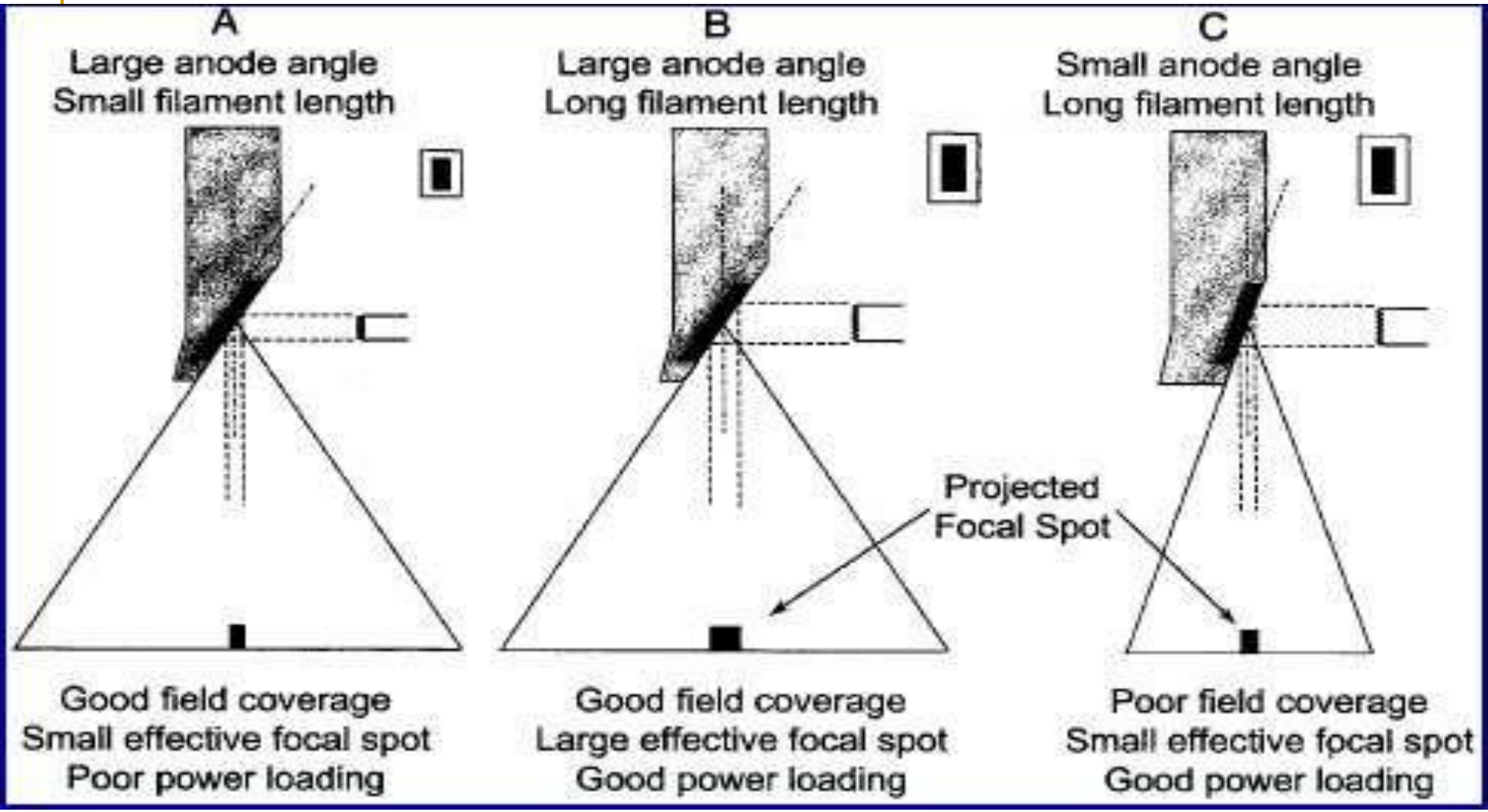
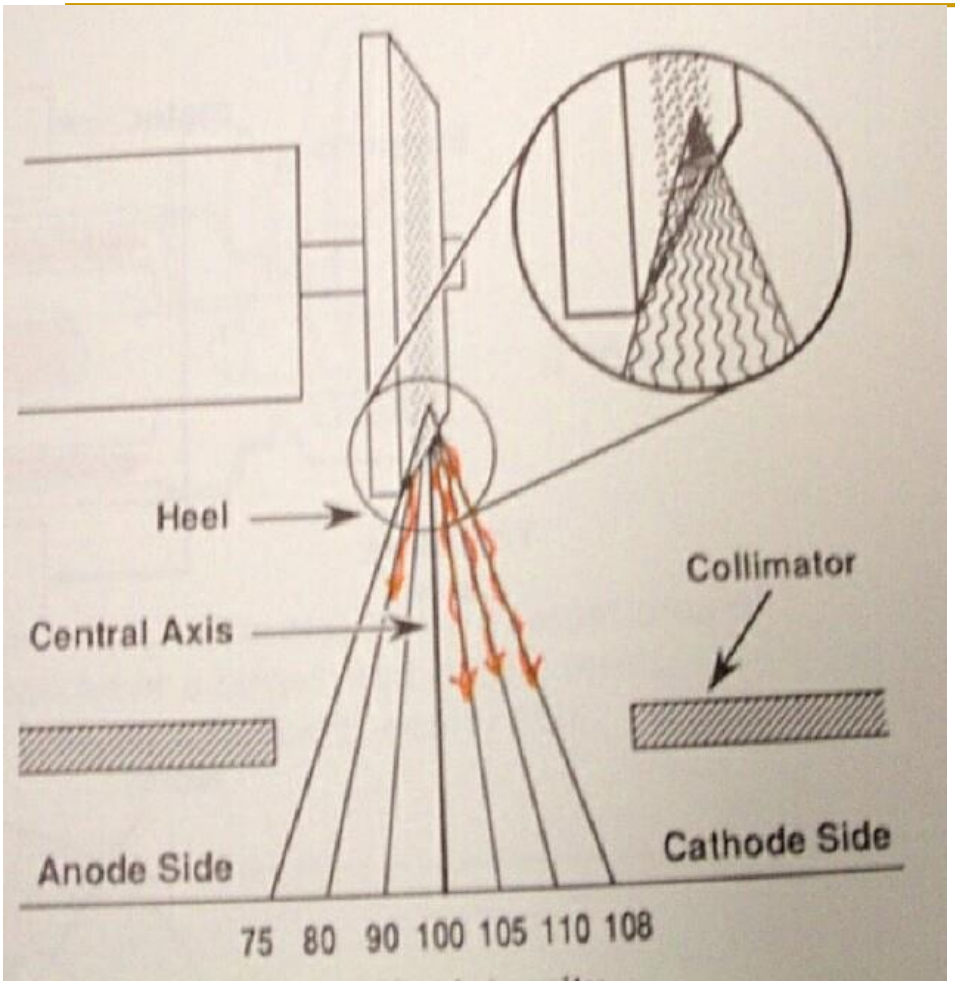


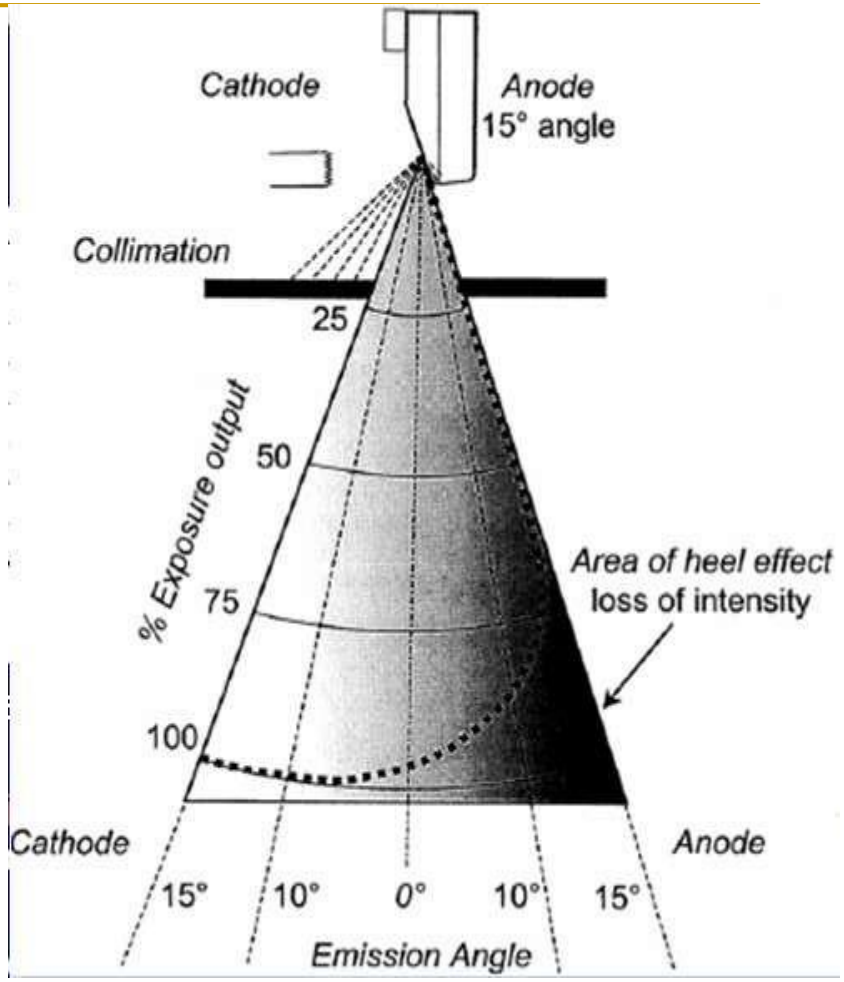
Figure 13: Schematic illustration of the heel effect (after Carlton and Adler, 1996)

Anode angle



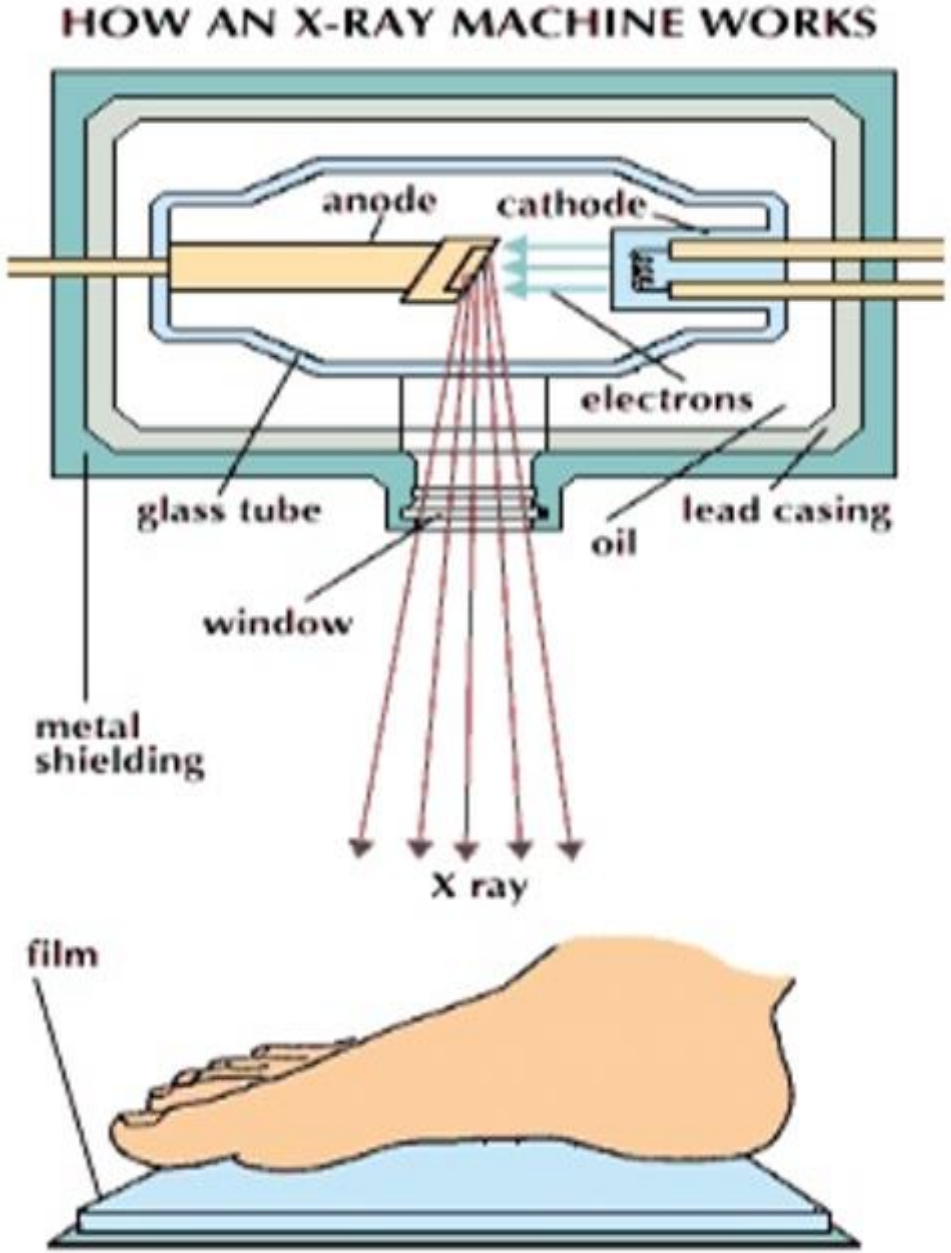
Large focal spot = greater heat loading.
Small focal spot = good radiographic detail.





The heel effect should be considered when positioning areas of the body with different thickness or density.

The cathode side should be over the area of greatest density.


HOW AN X-RAY MACHINE WORKS
anode
cathode
electrons
glass tube
oil
lead casing
window
metal shielding
X ray
film

•The intensity of the x-rays emitted through the heel of the target is reduced because they have a longer path to travel in the target. The diff in intensity is as much as 45%

Factors affecting the heel effect:

1.Anode angle: the steeper the target → ↑↑ heel effect.

2.FFD: ↑↑ FFD → ↓↓ heel effect "with fixed film size".

3.Film size: ↓↓ film size → ↓↓ heel effect "with fixed FFD".

4.Roughening of the target surface → ↓↓ X-rays output & ↑↑ the heel effect.

•In radiographs of body parts of different thicknesses → the thicker parts should be placed toward the cathode (filament) side of the x-ray tube.

•e.g. AP film of the thoracic spine → anode end over the upper thoracic spine where the body is less thick & the cathode end of the tube is over the lower thoracic spine where thicker body structures will receive the increased exposure.

What is kVp?

- Kilo voltage peak (kVp)- the peak energy of the x-rays which determines the quality (penetrating power) of the x-ray beam.

Medical Applications of X.rays

The uses of x rays in the fields of medicine and dentistry have been extremely important.

Examples might include the observation of the broken bones and torn ligaments of football players, the detection of breast cancer in women, or the discovery of cavities and impacted wisdom teeth.