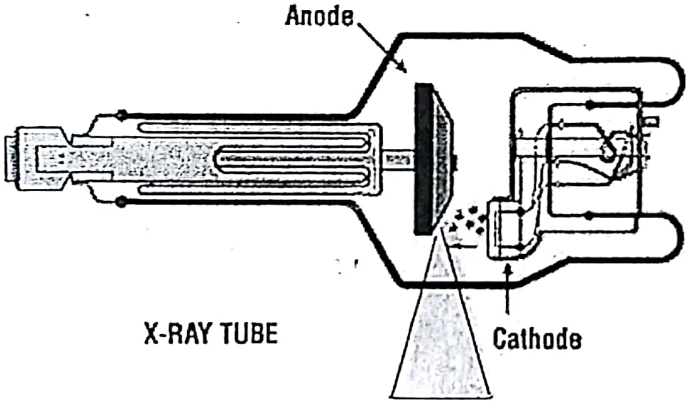
MEDICAL RADIATIONS PHYSICS

X-RAY TUBE CHARACTERISTICS

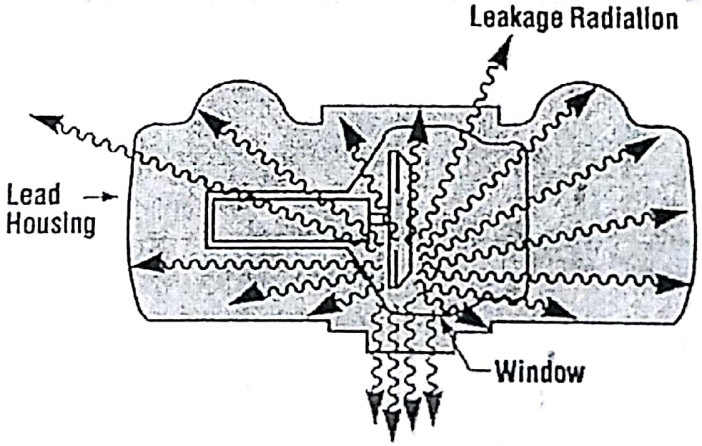
■ Introduction

- An x-ray tube consists essentially of an *evacuated enclosure* surrounded by the *protective housing.*
- Inside the tube is a *cathode* (held at a –ve voltage) and an *anode* (held at a +ve voltage).



■ Protective Housing

- The protective housing is lined with lead to minimize *leakage radiation.*



- It also protects against accidental electric shock.
- It may contain oil to help cool the tube.

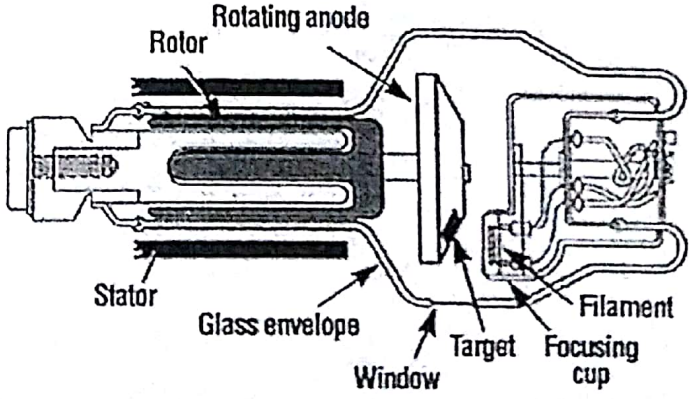
MEDICAL RADIATIONS PHYSICS

Tube Enclosure

- Maintains a vacuum inside the tube.
- If air were present it would interfere with movement of electrons and x-ray production could not be accurately controlled.
- Generally made of *glass* but high power x-ray tubes are made of *metal.*
- The x-ray *window* is a thin area of the tube enclosure through which the useful x-ray beam exits.

Cathode

- The –ve electrode of the tube and the source of electrons which are accelerated to the anode to produce x-rays.
- It consists of:
  - Tube *filaments* (usually two)
  - *Focussing cups* (one for each filament)
  - Control circuitry (external to tube for filament heating, focussing and switching)



MEDICAL RADIATIONS PHYSICS

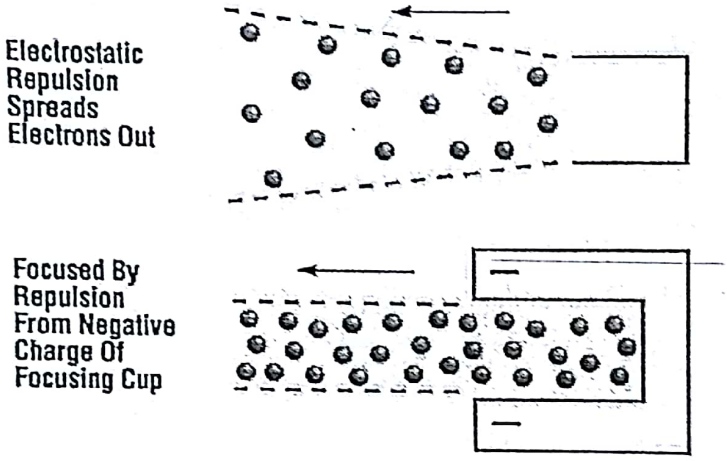
Filament.

- Produces electrons by the process of *thermionic emission* (electrons are "boiled off" at high temperature).
- Material must have the following characteristics:
  - Minimal energy (ie, temperature) required to liberate electrons
  - High melting point to resist vapourisation
  - Mechanically strong to resist heating/cooling
  - Able to be manufactured into filaments.
- Commonly made of *tungsten* (W).
- Is heated to 2000 °C or more for efficient emission.
  - Melts at 3370 ° C.
- Evaporation of W from filament can coat tube enclosure and shorten tube life.
  - 1 – 2 % thorium (Th) added to reduce this.
- Produced as a wire 0.2 mm thick and coiled to form a cylinder 2 mm diameter by 10 to 15 mm long.
- A 10 V and 3 - 5 A current is applied to the filament to heat it in order for it to eject electrons by thermionic emission.
- The ejected electrons form a cloud around the filament called a *space charge*.
- A high voltage is applied between the cathode and anode which accelerates electrons toward the anode.
- *Electrostatic repulsion* between the electrons causes the electron beam to spread out.
  - Need to focus the beam to keep its dimensions small.

MEDICAL RADIATIONS PHYSICS

Focussing Cup

- Provides a –ve electrostatic field to prevent electron beam diverging



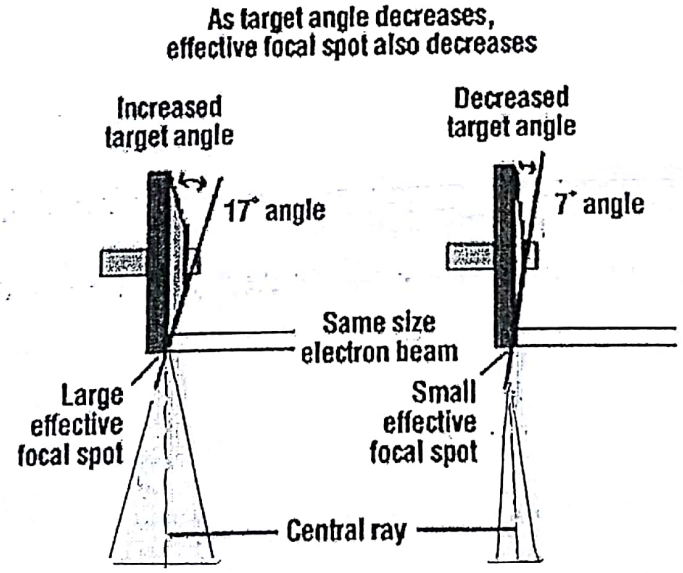
- Usually made of nickel, steel or molybdenum.

Anode

- Is the +ve terminal of the x-ray tube to which the electron beam is accelerated by the applied tube voltage.
- It supports the *target* for the electron beam to interact with.
- Can be *stationary* or *rotating* depending on tube loading requirements.
- For general x-ray usage the target is made of *tungsten* (W).
  - It has a high atomic number (74) resulting in high efficiency x-ray production.
  - It has good thermal heat conductivity for heat dissipation.
  - It has a high melting point and is not readily vapourised.

MEDICAL RADIATIONS PHYSICS

- The area where the electron beam strikes is called the *focal area.*
  - ↗ Large focal spots can absorb more heat without damage.
  - ↗ Small focal spots produce sharper images.
- The solution is to have a large physical focal spot that "appears" small at angle of useful x-ray beam out of the tube.
- Achieved by setting the focal spot at an angle to the electron beam.
- Known as the *Line Focus principle.*



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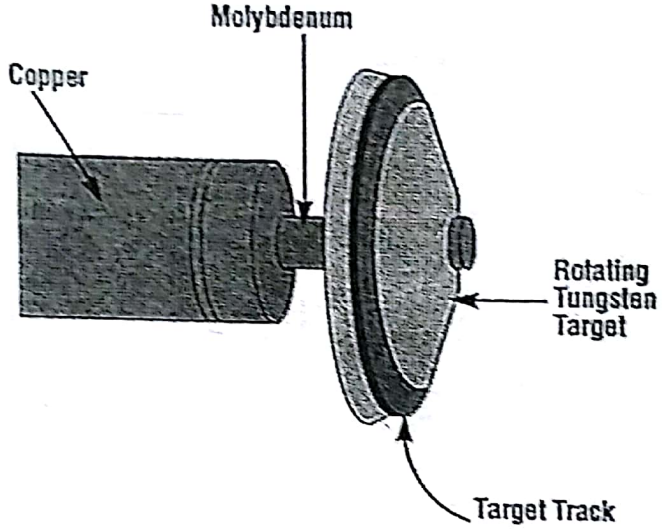
The Rotating Anode

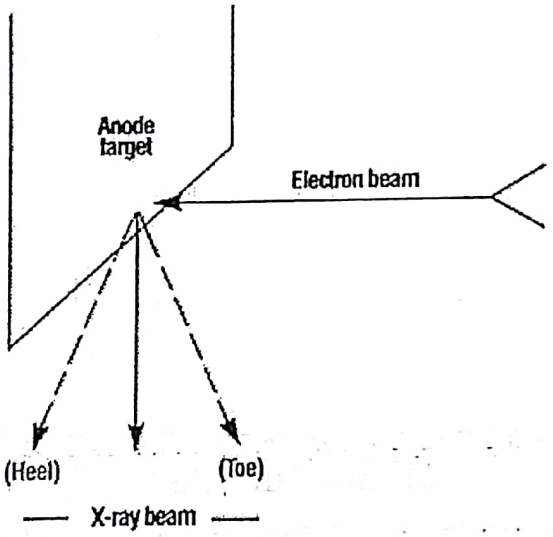


- Increases the area on which the electron beam impacts without increasing the effective focal spot because the electron beam energy is spread around the circumference of the circular anode.
- The anode cools during each rotation before more energy is deposited.
- Cooling occurs via "radiative" heat transfer.

MEDICAL RADIATIONS PHYSICS

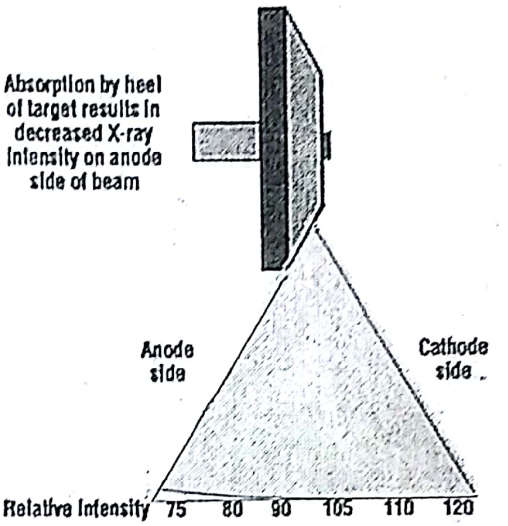
The Heel Effect

- X-rays are produced below the surface of the target and must pass through some tungsten before escaping.
- X-rays must traverse a greater thickness of tungsten on the anode side of the x-ray beam compared to x-rays on the cathode side.



- This greater thickness of tungsten causes more of the x-ray beam to be absorbed toward the anode side of the tube – this is known as the **heel effect**.
- The difference in radiation intensity across the useful x-ray beam can vary as much as 45 %.
- If the radiation intensity along the central ray is designated as 100 %, then the intensity on the cathode side may be as high as 120 % and that on the anode side may be as low as 75 %.

MEDICAL RADIATIONS PHYSICS



X-Ray Tube Failure

- Excessive heat results in reduced x-ray tube life.
- The anode may glow red hot during an exposure.
- Localised surface melting and pitting of the anode can occur.
- This in turn results in variable and reduced radiation output.
- If the temperature increases to rapidly the anode may crack.
- Hence the need to warm up the tube.
- The most common cause of abrupt tube failure is electron arcing from the filament to the enclosure due to vapourised tungsten.