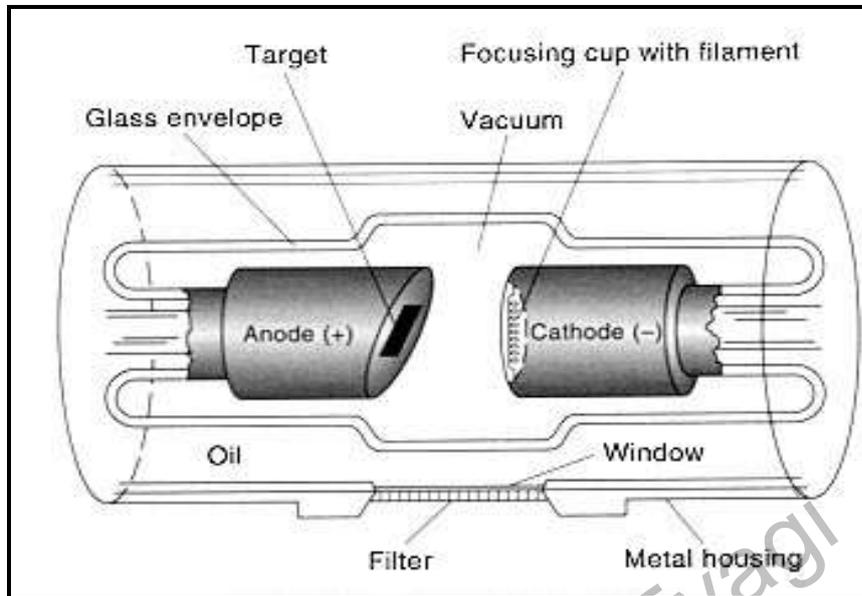


## DIAGNOSTIC X-RAY EQUIPMENTS

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### X-Ray tube

An X-ray tube is basically a thermo-ionic diode type electronic vacuum tube whose function is to convert the electrical energy into X-rays. It has following components-



Sketch of a stationary anode type X-ray machine

### Glass Envelope and Tube Housing

Anode and cathode of an X-ray tube are enclosed in a vacuum glass tube or envelope. Vacuum allows unobstructed path for the electron stream (tube current) and prevents oxidation and burning of the filament.

An X-ray tube is generally cylindrically in shape and measuring only 12-18 cm in length and 9 cm in breadth. The envelope is of Pyrex or borosilicate glass tube enables it to withstand extremely high temperature.

X-ray tube is housed in a metal housing which is lined with lead except at window. (The lead absorbs all X-rays). This metal housing contains sealed oil to serve as an electrical insulator and to help in heat dissipation. Some x-rays housing also have a fan to cool the tube. The metal also provides physical support to the x-ray tube.

### CATHODE

The negative side of the tube is called as cathode. It contains a tungsten or Tungsten-rhenium filament, focusing cups and supporting wires.

(i) **Filament:** Tungsten or Tungsten-rhenium alloy is preferred because of its-

- ★ High melting point (3370°C)

- ★ Little tendency to vaporize and
- ★ High atomic number (74).

The filament is supported by two stout wires, which connects it to the proper electrical source. A low voltage current is sent through one wire to heat the filament. Another wire is connected to high voltage source which provide high negative potential during exposure to drive away electrons towards anode.

Most modern X-ray machines are provided with two filaments mounted side by side. These filaments differ in size, producing two focal spots of different size in the target. Such X-ray tubes are called dual focus tube.

**(ii) Focusing cup:** The filament if embedded in a concave metal shroud made of nickel or molybdenum. It is called focusing cup. It is given negative electrical potential so that electrons emitted from cathode do not spread away. Because of focusing cup these electrons rush towards anode in a small stream only.

## **ANODE**

Anode is the positive side of x-ray tube. It is of two types-

1. Stationary cathode (Fixed anode)
2. Rotatory cathode

The stationary or fixed type anode are used in x-ray tubes which are low powered such as portable x-ray units, dental x-ray units etc. however the rotatory anode is required in larger capacity x-ray machines which produce high intensity x-ray beam.

Anode has two functions-

- ★ To provide mechanical support to the target.
- ★ To act as a good thermal conductor for heat dissipation.

**(i) STATIONARY CATHODE** (see figure at the start of this chapter)

It is consisted of block of copper in which a rectangular plate of tungsten-rhenium alloy 2-3 mm thick is embedded. This plate is called target. The tungsten is selected for the target area due to following reasons-

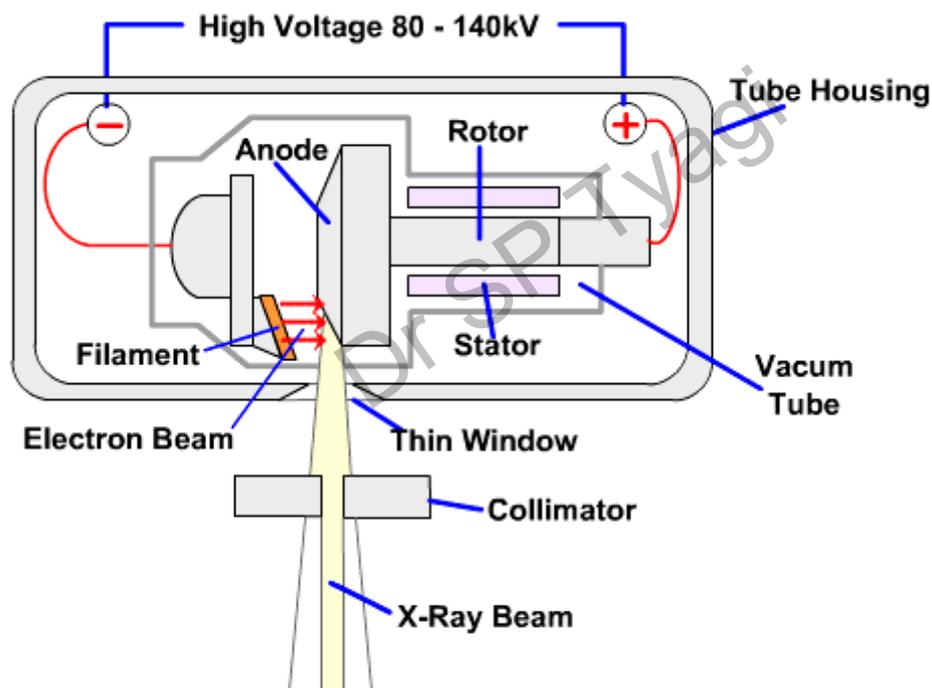
- ★ High melting point ( $3370^{\circ}\text{C}$ ) to withstand high temperatures produced during exposures.
- ★ High atomic number (74) allows high x-ray production.
- ★ Little tendency to vaporize.

The copper block increases the total thermal conductivity.

*(In medical applications, the target is usually tungsten or a more crack resistant alloy of rhenium (5%) and tungsten (95%), but sometimes molybdenum for more specialized applications, such as when soft X-rays are needed as in mammography, are also used. In crystallography, a copper target is most common and cobalt target is also often used when fluorescence from iron content in the sample might otherwise present a problem.)*

## **(II) ROTATIONARY ANODE**

Rotatory anode provides several hundred times larger target area for electron beam to interact and thus heat generated during an exposure is spread over a larger area of the anode.



Therefore, the use of rotating anode allows much higher exposure in much shorter exposure time. Rotating anode is made of molybdenum disc coated with a strip of tungsten-rhenium alloy and molybdenum stem. Rotating anode is driven by an electromagnetic induction motor, which consists of two main parts the rotor and stator. The stator is outside the glass envelope and is connected with molybdenum stem of anode. Current flowing in the stator produces a magnetic field which induces a current in the rotor making it to rotate. Rotating of anode at high speed requires excellent bearings with protection from heat generated during an exposure.

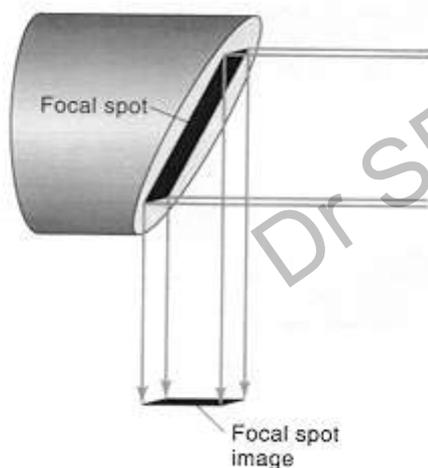
Self lubricating bearings coated with metallic barium or silver serve first purpose whereas disc and stem of molybdenum serves the second by virtue of its poor heat conductivity.

The tungsten-rhenium strip is beveled. The degree of beveling is called the target angle or anode angle.

### **FOCAL SPOT**

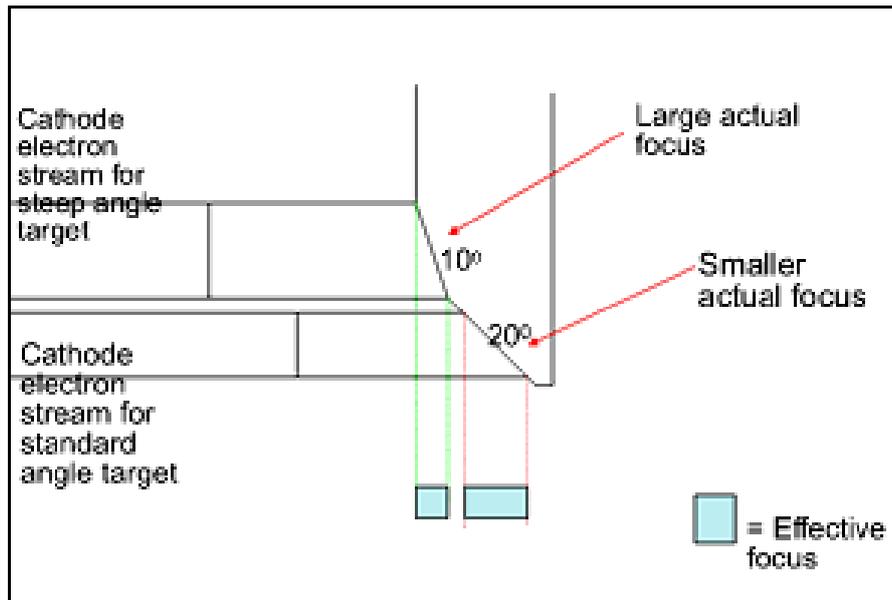
The focal spot on the target surface of the anode is that area which is bombarded by the electrons from the cathode during an exposure. The size and shape of focal spot is determined by

- ★ The size of the filament.
- ★ The size and shape of focusing cup.
- ★ The positioning of the filament in the focusing cup.
- ★ **Smaller the size of focal spot, sharper is the radiographic definition.**



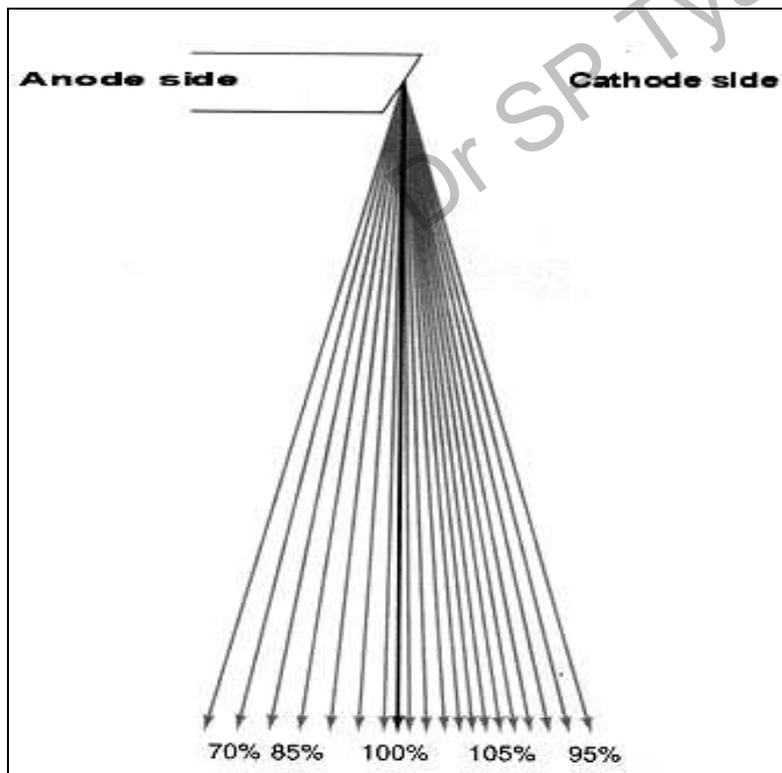
However, as the focal spot decreases in size, the heating of the target concentrate at a smaller area which may damage the target and thereby affecting x-ray production. These conflicting requirements are met to some extent by line focus principle. By employing this principle by beveling the anode (anode angle) the effective area of target can be made much smaller than the actual area of electron interaction. The lower is the anode angle; the smaller is effective focal spot size.

- For general radiography the target angle is usually not less than  $15^\circ$



### HEEL EFFECT

The radiographic intensity on the cathode side of the x-ray beam is higher than on the anode side. This difference in the intensity across the x-ray beam is called heel effect.



This is because of the fact that the x-rays are emitted from target in all the directions and those emerging parallel to the angled target is attenuated by target itself. Thus the intensity of x-ray on anode side is low. This difference in intensity may be as high as 40%.

- Therefore, while taking a radiograph of a part of unequal thickness, thicker or denser part/side should be positioned towards cathode and thinner side towards the anode.
- The smaller the anode angle more is the heel effect.
- The heel effect is more noticeable when FFD is less or film size is larger.

### **CAUSES OF X-RAY TUBE FAILURE & STEPS TO EXTEND TUBE LIFE:**

Cathode failure: Prolonged heating of the filament by normal current or due to repeated exposures causes evaporation of filament metal causing its progressive thinning which in turn renders it vulnerable to break.

Anode failure: Melting of anode results due to excessive heat production by the bombardment of electrons on it. This damage to anode causes uncontrolled x-ray production. It also causes vibrations in the rotor due to imbalanced disc which increases the possibility of anode stem fracture.

Glass envelope failure: it may crack due to secondary arcing from the filament to the metal deposits on the glass wall as a result of tungsten evaporation.

#### **Steps to extend tube life:**

- (i) Anode should be warmed up before actual exposure is made.
- (ii) Do not switch on ma or kvp setting while rotor is engaged (Because this causes torque force on the anode).
- (iii) Use high kvp and low ma settings to avoid overheating of anode.
- (iv) Consult correct tube rating chart to avoid overheating of anode.
- (v) Do not run rotary anode unnecessarily as this shortens the life of bearings.
- (vi) Adequate cooling of the tube housing must be ensured to avoid excessive heating of oil in the tube housing.
- (vii) Do not allow the overheating of the filament by repeated exposure in a short time.

#### **Types of x-ray machines:**

- (i) Portable X-ray machine
- (ii) Mobile X-ray machine
- (iii) Fixed X-ray machine

*(Read the advantages and disadvantages of these machines from text books).*