

## *X – Ray tube/basic design*

X – Ray tube consists of four major components:

- Cathode
- Anode
- Glass Envelope
- Protective housing

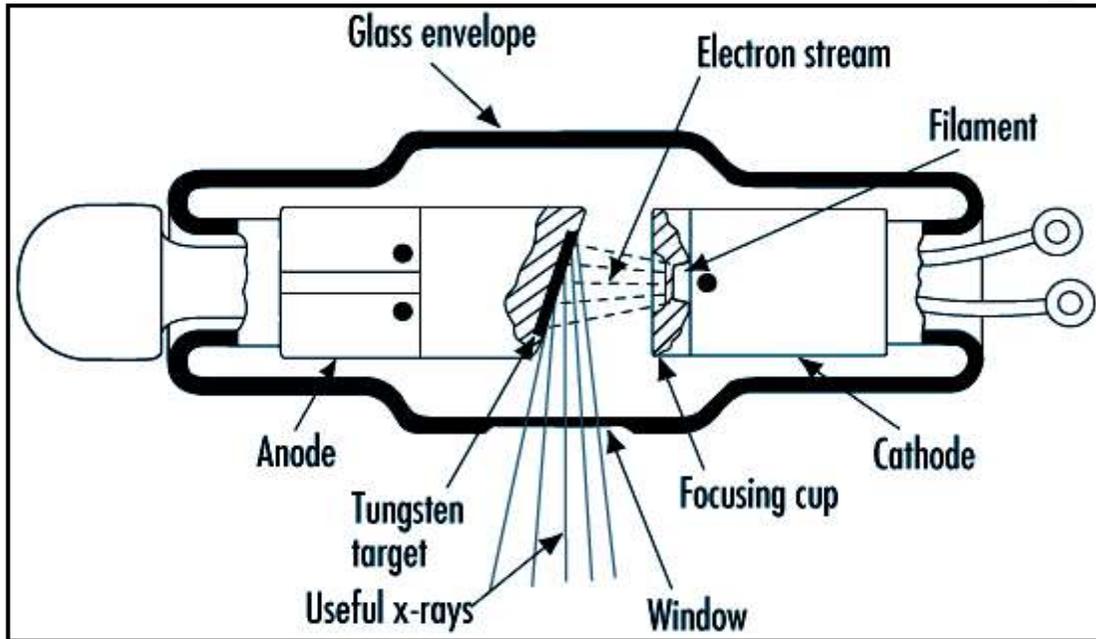


Fig. (1): illustration of X – ray tube components.

### **Cathode:**

The cathode is the negative side of the x-ray tube because it is a source of electrons and has two primary parts: filament & focusing cup .

### **☞ The filament:**

Is a coil of wire usually about 2 mm in diameter and 1 to 2 cm long . An x – ray filament emit electrons when it heated. When the current through the filament sufficiently intense, approximately 4 A and above , the outer – shell electrons of the filament atoms are literally boiled off and ejected from the filament. this phenomenon is known as thermionic emission.

Filaments are usually made of thoriated tungsten, because its melting point is  $3410\text{ C}^\circ$ , and therefore it is not likely to burn-out. Also tungsten doesn't vaporize easily, if it did, the tube would quickly become gassy and its internal parts coated with tungsten. This is the most common cause of tube failure, the addition of 1% to 2% thorium to the tungsten filament increases efficiency of thermionic emission and prolongs tube life.

Fig. (2) shows a magnified view of the cathode face and it shows dual filaments. Only one filament at a time will work. The small filament is designed to be used with relatively small parts while the large filament is used when larger body parts are being x-rayed.

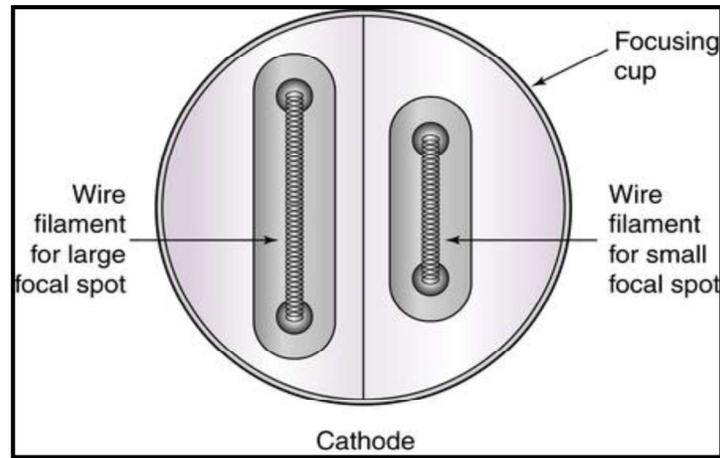


Fig. (2): Dual filaments.

The number of electrons that are released will directly influence the number of x-rays that are generated and therefore the dose of radiation also. Figure (3) shows how a low mA will result in fewer x-rays being produced and a high mA will result in a greater number of x-rays. The term mA is a unit of measure of electrical current that is used when the technologist selects the exposure factors.

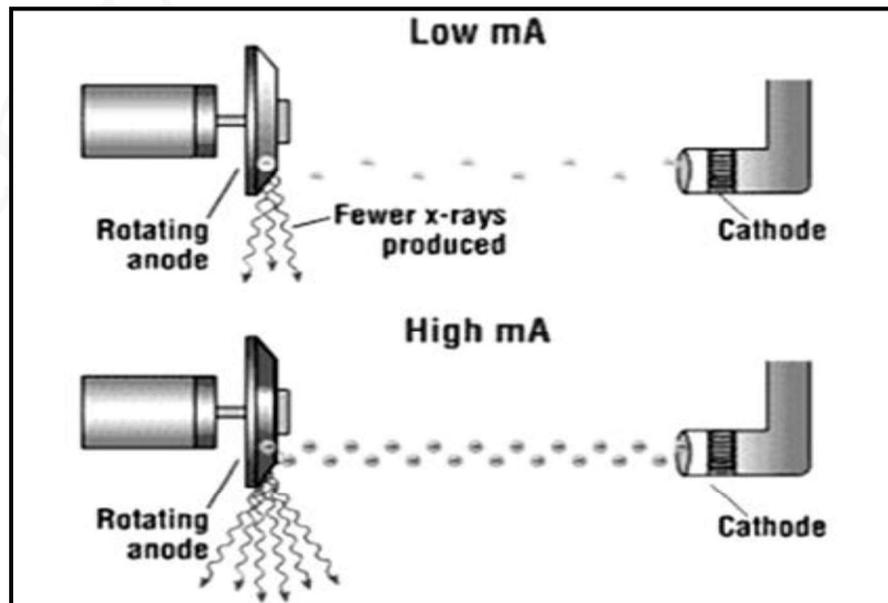


Fig. (3): Effect of low & high mA on the number of x-rays.

By referring to the types of the filaments, the small filament directs its electron stream to the small focus while using the large filament, directs the stream over the larger focal spot. The small focal spot is superimposed over the large one.

## ☞ The Focusing cup:

When the x-ray machine is powered up, electrons will literally “boil” off the filament. It glows white hot and the electrons hover around the filament in a “space charge” until the moment of exposure and then they accelerate very rapidly towards the anode which is not very far away. This process is known as “thermionic emission”. Thermionic emission occurs when the technologist begins to make an exposure by pressing the “ready” button on the machine. The filament is embedded in a metal shroud called the focusing cup to eliminate the space charge and concentrate the electron stream in a pre-determined area on the anode target area known as a “focal spot”. Since all the electrons accelerated from cathode to anode are electrically negative, the beam tend to spread out owing to electrostatic repulsion and some electrons can even miss the anode completely, the focusing cup is negatively charged so that it condenses the electron beam to a small area of the anode, Figure (4). The filament has its own circuit powered by a relatively low voltage and 4 – 6 amperes.

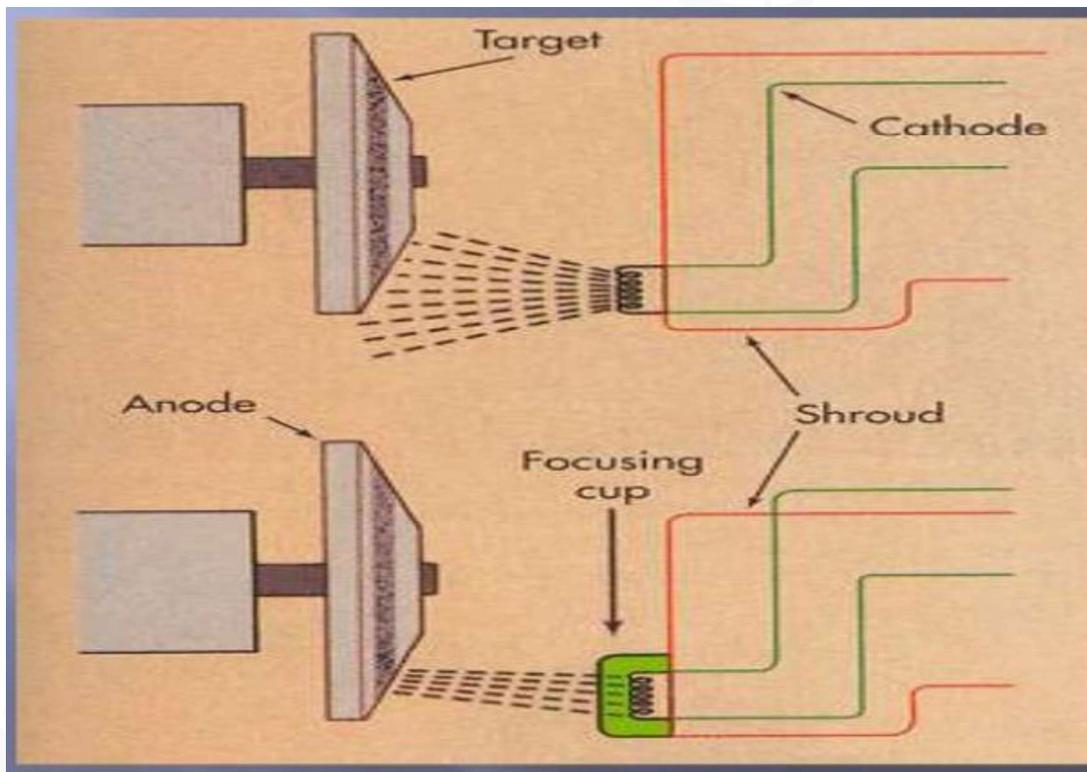


Fig. (4): filament without and with a focusing cup.

### **Anode:**

The anode is the positive side of the x-ray tube, which divided into two types:

- Stationary – anodes that are used in dental x-ray machine, some portable machines and other special purpose units in which high tube current and power are not required.

➤ Rotating – anode which are used in general purpose x – ray tubes because they must be capable of producing high – intensity x – ray beams in a short time .

The rotor is actually part of a motor that is made to rotate at very high speed. In most x-ray tubes, the revolutions per minute is usually at 3,200 for standard technique settings, however if the technologist selects exposure factors that are considerably larger and therefore very hot, then the rotor can rotate at a much greater speed exceeding 5,000 rpm. The rotation of the anode ensures that not any one spot will receive successive pulses of electrons. If there was no rotation, then it is very likely that the anode face would be damage due to high heat. Rotating the anode allows a large surface area over which heat spread, providing an ability to tolerate greater heat deposition and to produce more x-ray photons per unit time compared with a fixed anode.

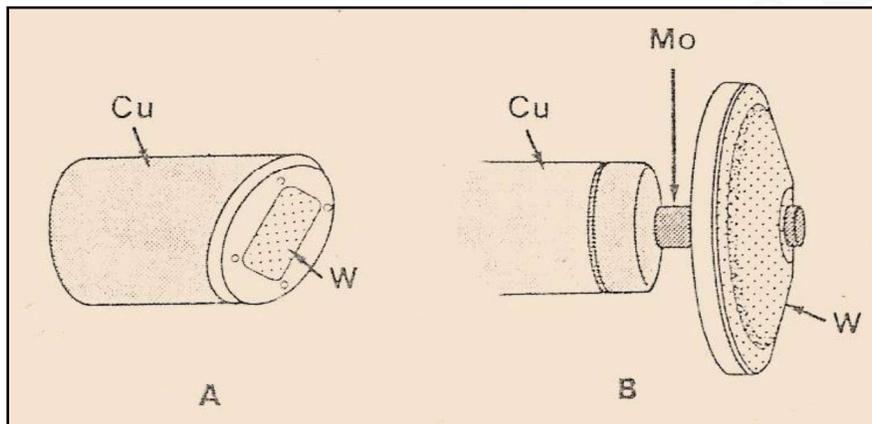


Fig (6) : A, the target is embedded in in a stationary –anode. B, the target is the rotating disc.

### Target:

The target is the area of the anode struck by the electrons from the cathode. In stationary – anode tubes the target consists of a tungsten – alloy metal embedded in the copper anode. In rotating – anode tubes the entire rotating disc is the target. Alloying the tungsten (usually with rhenium) gives it added mechanical strength to withstand the stress of the high rotation.

### The Benefits Of Using Tungsten As A Target Material

1 – Atomic number :

Tungsten's high atomic number ,74, results in higher – efficiency x – ray production and in higher – energy x – rays .

2 – Thermal conductivity :

Tungsten has a thermal conductivity nearly equal to that of copper. It is therefore an efficient metal for dissipating the heat produced.

3 – High melting point:

Any material, if heated sufficiently, will melt and become liquid. Tungsten has a high melting point (3410 C°) and therefore can stand up under high tube current without pitting or bubbling.

The anode target must be a good thermal conductor, when the electrons comprising the tube current slam into the anode, more than 99% of their kinetic energy is converted into heat. This heat must be conducted away quickly before it can melt the anode. copper is the most common anode material.

4-Resists vaporization at high temperatures.

5- Its availability makes it cost-effective.

The distance between the cathode and the rotating anode disc is very close. This is designed this way to ensure that the projectile electron stream has a reasonably good chance of arriving at the anode in a relatively tight pattern. If the electrons were permitted to spread out, then the x-ray production process would become very inefficient

### *Line focus principle*

It is the angling of the anode target that makes the effective focal spot much smaller than the actual area of interaction.

#### **The focal spot:**

The focal spot is the area of electron interaction and emanation of x-rays from the target surface. Typical dimensions are nominal sizes of 1.0- to 1.2-mm (large) and 0.3- to 0.6-mm (small) focal spots, where nominal encompasses a range of focal spot sizes that are as acceptable according to manufacturer standards. Ideally, the use of small focal spots is preferred to minimize geometric blurring of patient anatomy with magnification. However, the small focal area constrains x-ray tube output and heat loading factors, mainly due to heat concentrated in a small area. Larger focal spots have higher instantaneous x-ray production capacity and are preferred, as long as blurring does not adversely affect resolution.

The focal spots which are imbedded in the rotating anode disc are angled in such a way that when the electrons strike the anode focal track, the angle makes it easier for the x-rays to be emitted in a downward direction.

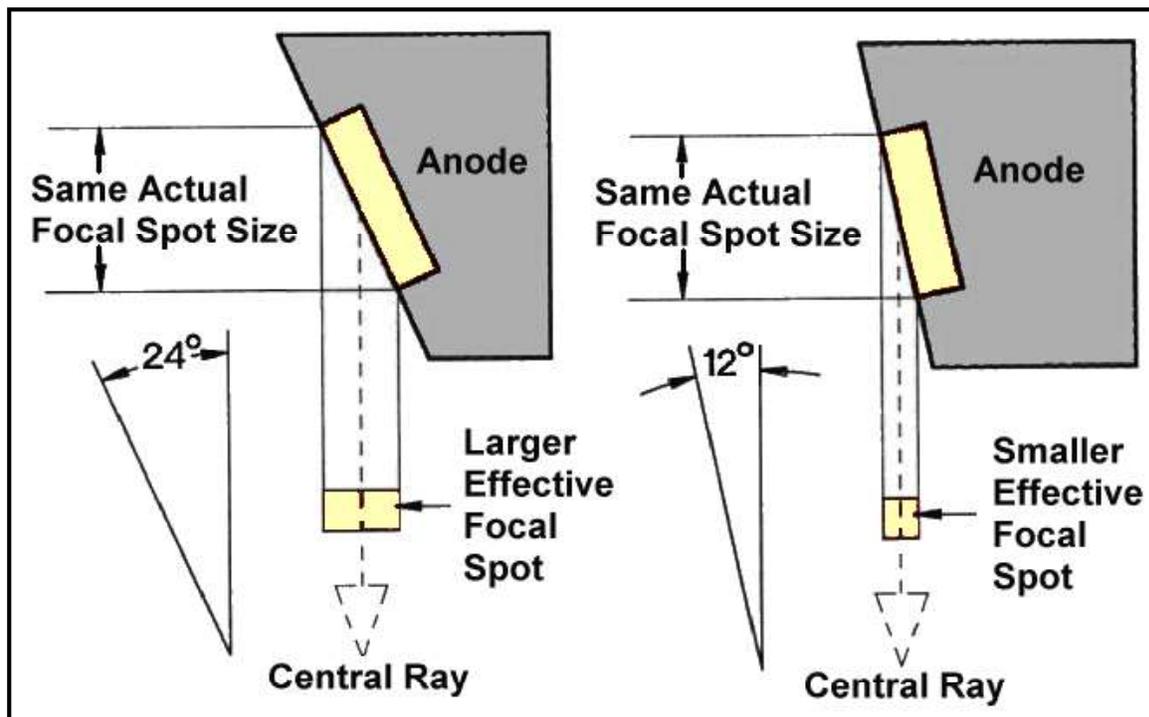


Fig. (7): Anode Angle versus Focal Spot Size

However depending on the angle of the anode face, this will change the appearance of the focal spot as seen from below or where the x-ray image receptor is positioned. The anode angle and the resulting appearance of the focal spot as it would appear from the image receptor is known as the “Line Focus Principle”.

*In the Fig. (7)*, note that as the angle of the anode decreases from 24 degrees to 12 degrees, the focal spot will appear smaller because you are looking up at it at an angle or obliquely. As the angle decreases, you actually see less of the focal spot dimensions and this will actually enhance the details recorded on the image. In general, the smaller the focal spot, the better the detail will be on the finished image.

**Two types of focal spot:**

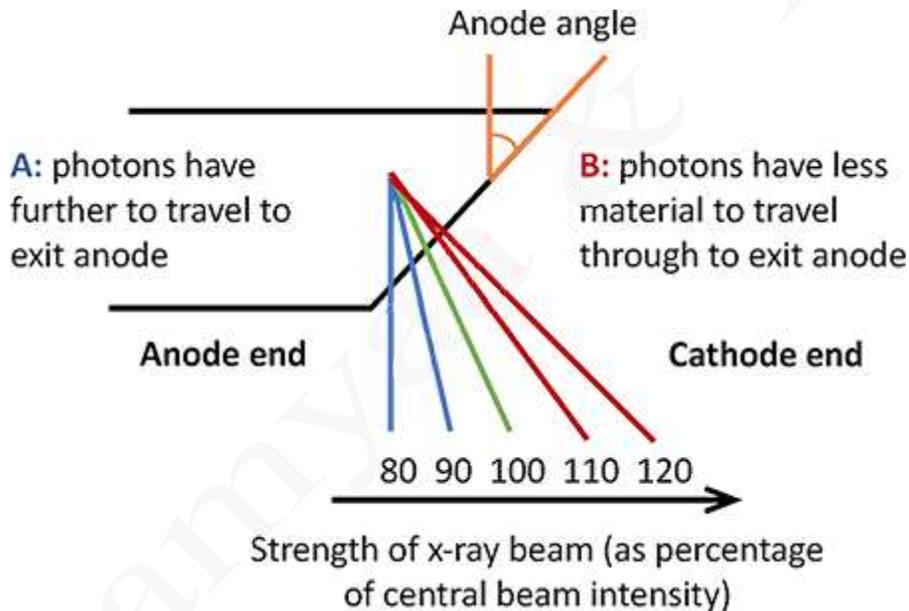
- \* Actual focal spot - the area of the target material being bombarded by electrons from the filament.
- \* Effective focal spot - the imaginary geometric line that can be drawn based on the actual focal spot size vs. the angle of the anode.

Any angle <45 degrees results in the effective FS being smaller than the actual FS, but 12 degrees target angle is the most common.

## *Anode Heel effect*

An x-ray beam gets attenuated on the way out by the target material itself causing a decrease in intensity gradually from the cathode to anode direction as there is more of the target material to travel through. Therefore, the cathode side should be placed over the area of greatest density as this is the side with the most penetrating beam. Decreasing the anode angle gives a smaller effective focal spot size, which is useful in imaging, but a larger anode heel effect. This results in a less uniform and more attenuated beam.

**\*\* smaller angle = smaller focal spot size but larger anode heel effect \*\***



### **Glass envelope:**

Is the container of the x-ray tube components, which supports the anode and cathode structures. which is usually made of Pyrex glass to enable it to withstand the tremendous heat generated, maintains a vacuum inside the tube, this vacuum allows for more efficient x-ray production and longer tube life. If the tube were filled with gas, the electron flow from cathode to anode would be reduced, fewer x-rays would be produced, and more heat would be created.

A recent improvement in tube design incorporates the metal rather than glass as part or all of the envelope. As glass envelope tubes age. Some tungsten vaporizes and coats the inside of the glass envelope. This alters the electric potential of the tube, allowing tube current to stray and interact with the glass envelope, the result is arcing and tube failure.

Metal envelope tubes maintain a constant electric potential between the electrons of the tube current and the envelope. Therefore, they have longer life and are less likely to fail. Virtually all high – output x-ray tubes now use metal envelopes.

The tube window is a segment of the glass envelope, approximately  $5 \text{ cm}^2$ , that contains a thin section of glass through which the useful beam of x-rays is emitted. The thin window serves to allow maximum emission of x-rays with minimum absorption in the glass envelope.

**Protective housing :**

The x – ray tube is always mounted inside a lead – lined protective housing designed to control two serious hazards that plagued early radiology :

- Excessive radiation exposure
- Electric shock

The protective housing also provides mechanical support for the x – ray tube and protects the tube from damage caused rough handling. The protective housing around some x – rays tubes contains oil that serves as both an electrical insulator and a thermal cushion. Some protective housings have a cooling fan to air – cool the tube or the oil in which the x – ray tube is immersed.