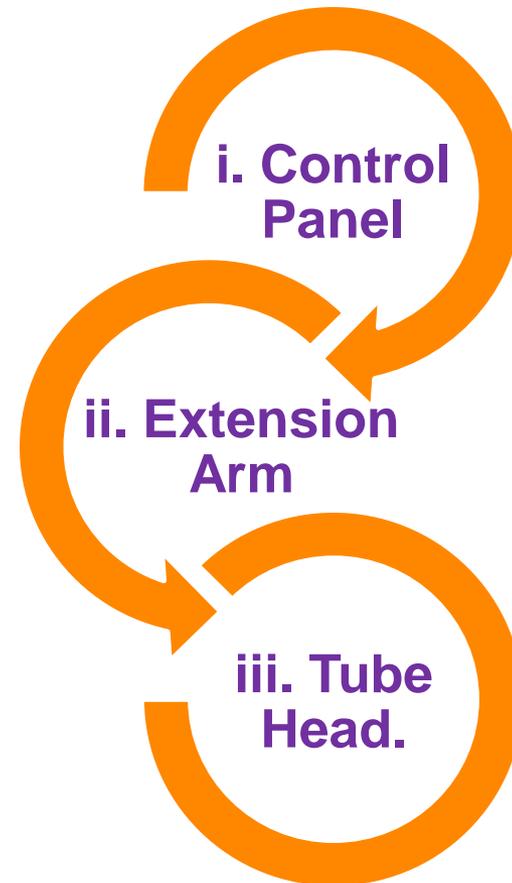
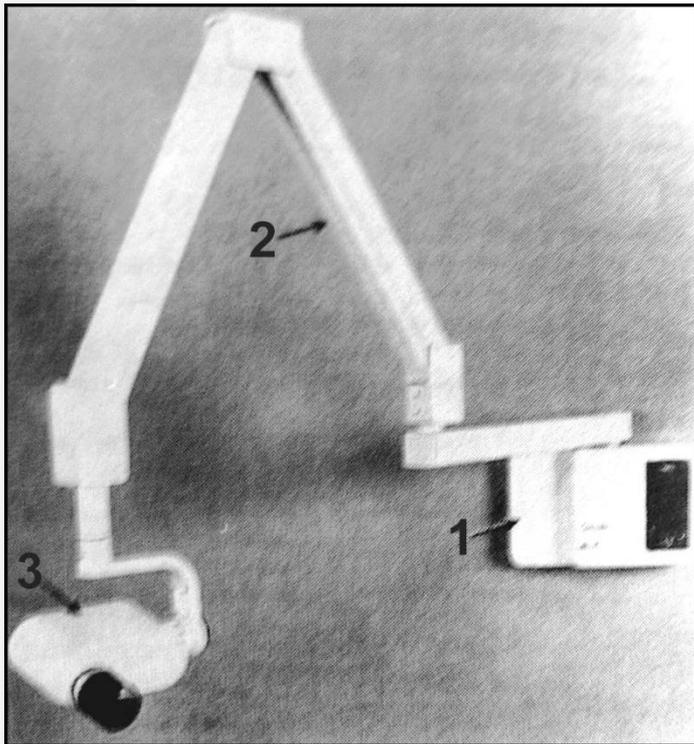


Production of X-rays

INTRODUCTION

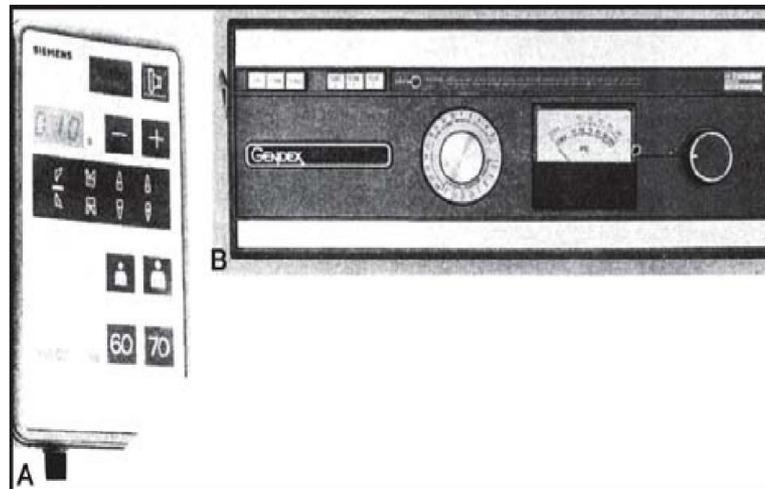
- ▶ X-rays are produced by the sudden deceleration or stoppage of a rapidly moving stream of electrons at a metal target in a high vacuum tube.
- ▶ *The X-ray tube is an important part of any X-ray machine.*
- ▶ Dental X-ray machines can be used to expose intraoral as well as extra oral films.

- ▶ The dental X-ray machine is made up of three parts or components:

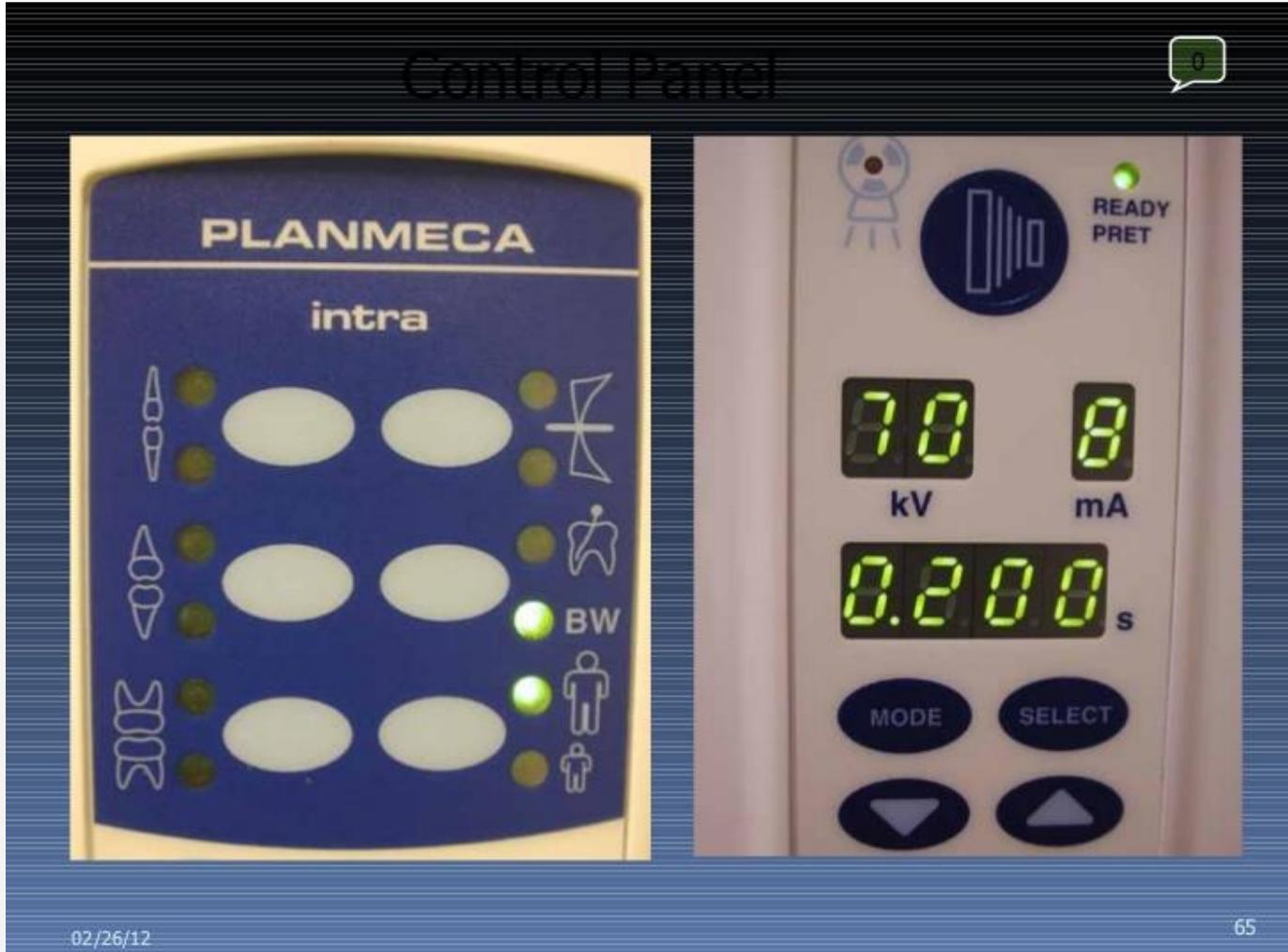


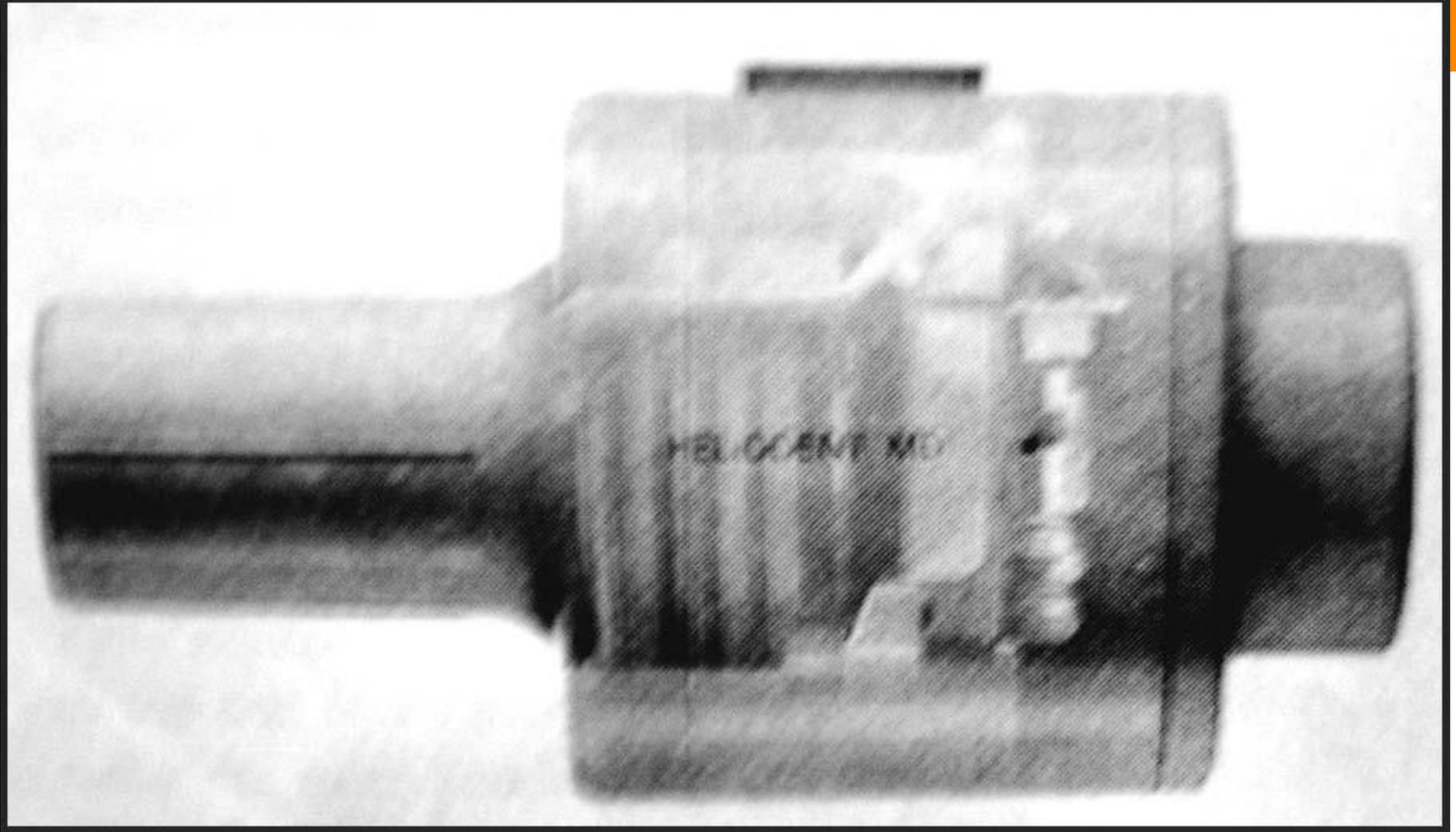
CONTROL PANEL

- ▶ of the dental X-ray machine contains
 - a. An on and off switch and an indicator light
 - b. An exposure button and indicator light
 - c. Control devices (time, kilo voltage, milli amperage selectors) to regulate the X-ray beam.



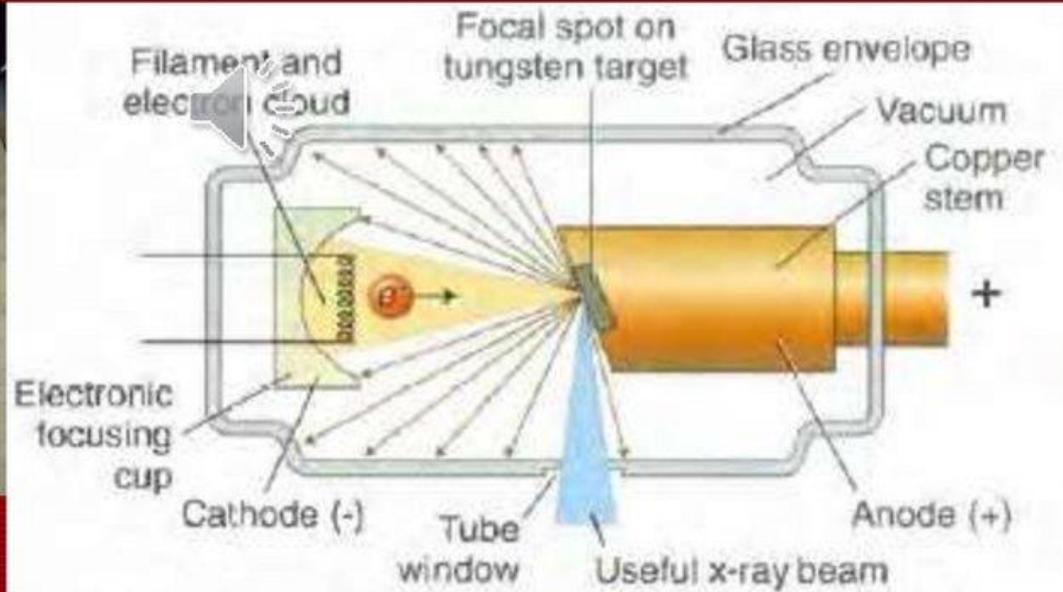
CONTROL PANEL

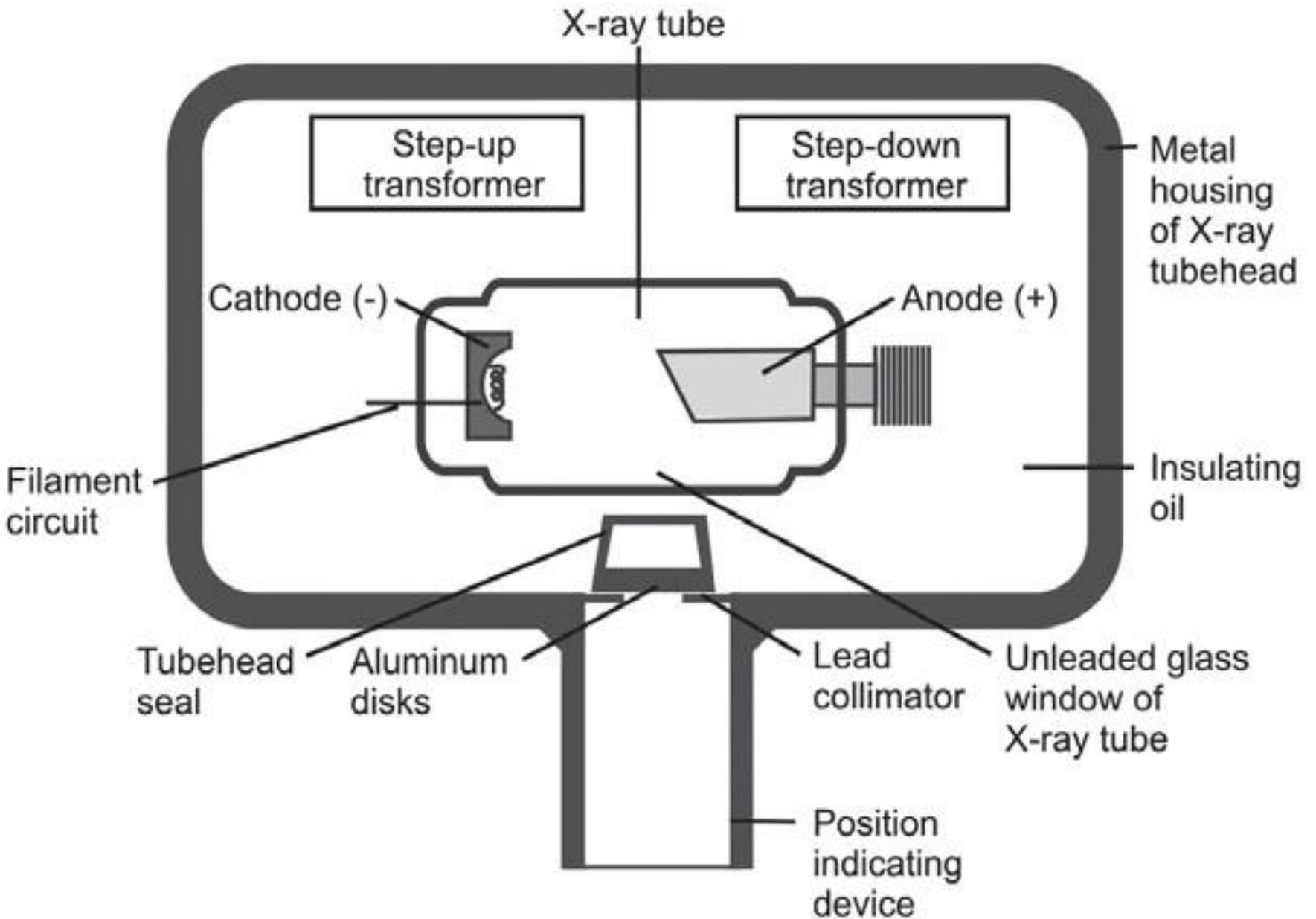




X-Ray Tube

- Glass envelope





THE COMPONENT PARTS OF THE X-RAY TUBE INCLUDE THE FOLLOWING:

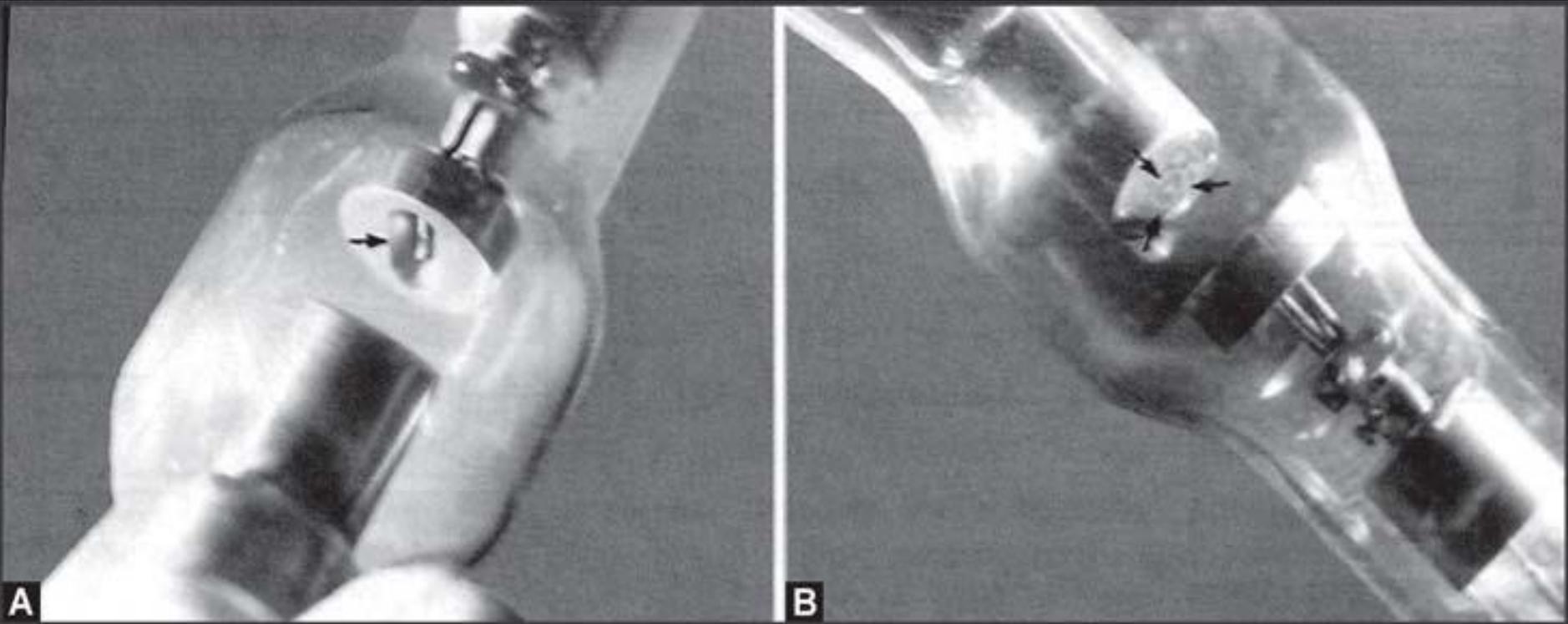
- i. Metal Housing.* This is the metal body of the tube head that surrounds the X-ray tube and transformer and is filled with oil, it protects the X-ray tube and grounds the high voltage component.

- ii. Insulating Oil.* It is that which surrounds the X-ray tube and transformer inside the tube head, it prevents over heating by absorbing the heat created by the production of X-rays.

iii. *Tube Head Seal:* Aluminium or leaded glass of the tube head that permits the exit of X-rays from the tube head, it seals the oil in the tube head and acts as a filter to the X-ray beam.

iv. *X-ray Tube:* It is the main X-ray generating system.

FOCUSING CUP

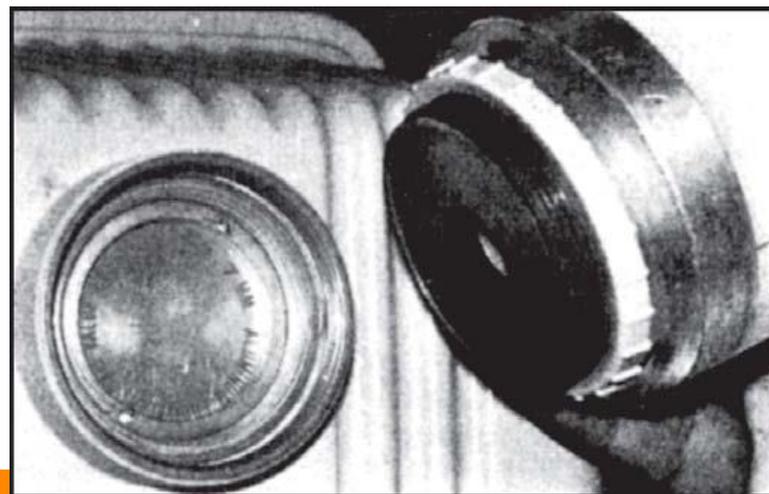


- A. Focusing cup containing a filament in the cathode of the tube from an X-ray machine.
- B. The focal spot area on the target of the tube. The size and the shape of the focal area approximate those of the focussing cup

v. Aluminium Disks: The sheets of 0.5 mm thick aluminum is placed in the path of the X-ray beam. They filter out the non penetrating, longer wave length X-rays, resulting in a higher energy and more penetrating useful beam, which is less harmful to the patient (decreased skin dose).

- ▶ In the dental X-ray tube head there are two types of filtration:

- a. Inherent filtration.
- b. Added filtration.



a. **Inherent filtration** takes place when the primary beam passes through the glass window of the X-ray tube, the insulating oil and the tube head seal.

- ▶ In the dental X-ray machines the inherent filtration is approximately equivalent to 0.5 to 1 mm of aluminum.

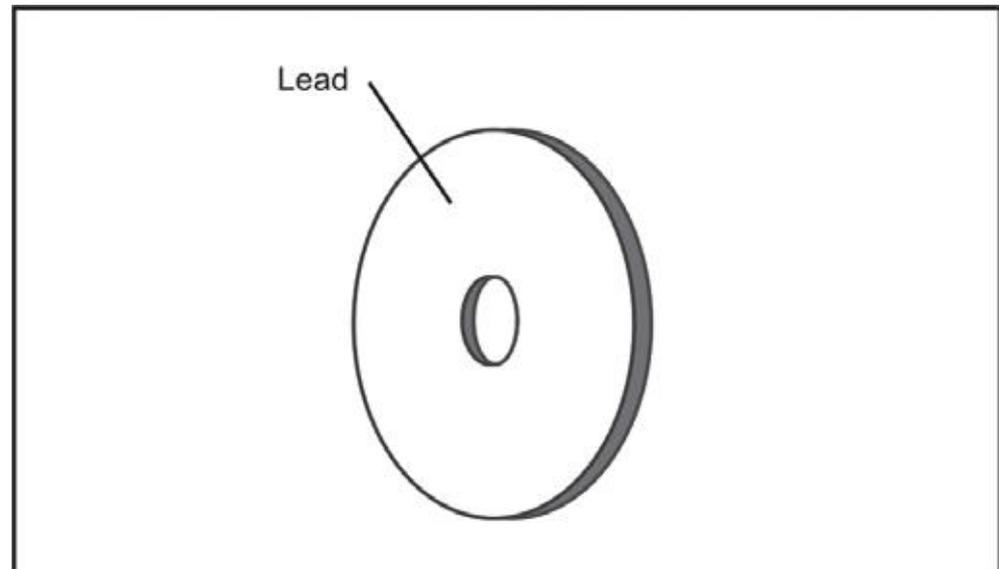
b. **Added filtration** refers to the placement of aluminium disks in the path of the X-ray beam between the collimator and the tube head seal in the dental X-ray tube head.

- ▶ Aluminium disks may be added in 0.5 mm increments.
- ▶ **Total filtration** (inherent + added filtration) is regulated by the state and federal law (in USA). Dental machines operating:
 1. At or below 70 kVp. require a minimum total filtration of 1.5 mm of aluminium thickness.
 2. Above 70 kVp. require a minimum total filtration of 2.5 mm of aluminium thickness.

vi. Lead collimator. It is a lead plate with a central hole that fits directly over the opening of the metal housing where the X-rays exit.

- ▶ Collimation is used to restrict the size and shape of the X-ray beam and thus reduce exposure to the patient.

- Collimators are of two types:
a. Fixed. b. Adjustable.
- In the dental X-ray machine usually the **fixed collimators** are used, they may either have a round or rectangular opening.



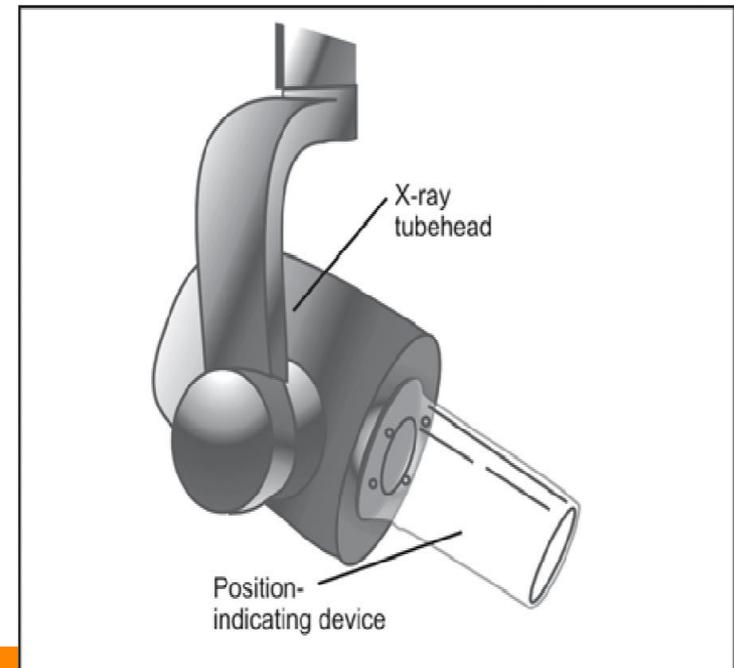
vii. *Position Indicating Device (PID)* : or open ended lead cylinder, that extends from the opening of the metal housing of the tube head also called the “cone”.

- ▶ The PID appears as an extension of the tube head and it aims and shapes the X-ray beam.
- ▶ There are three types of PID's:

i. conical

ii. rectangular

iii. round.

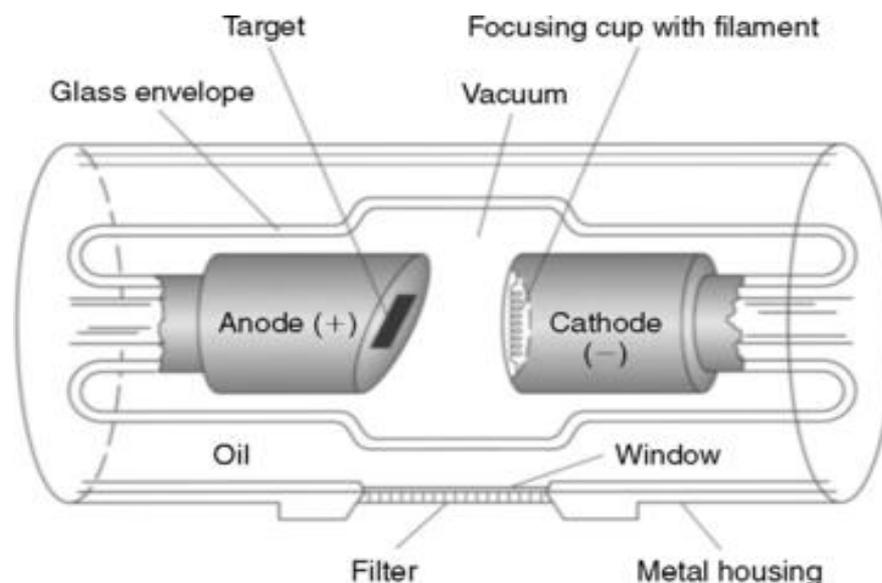


- ▶ Both rectangular and round PID's are available in two lengths:
 - ▶ i. short (8 inches)
 - ▶ ii. long (16 inches).

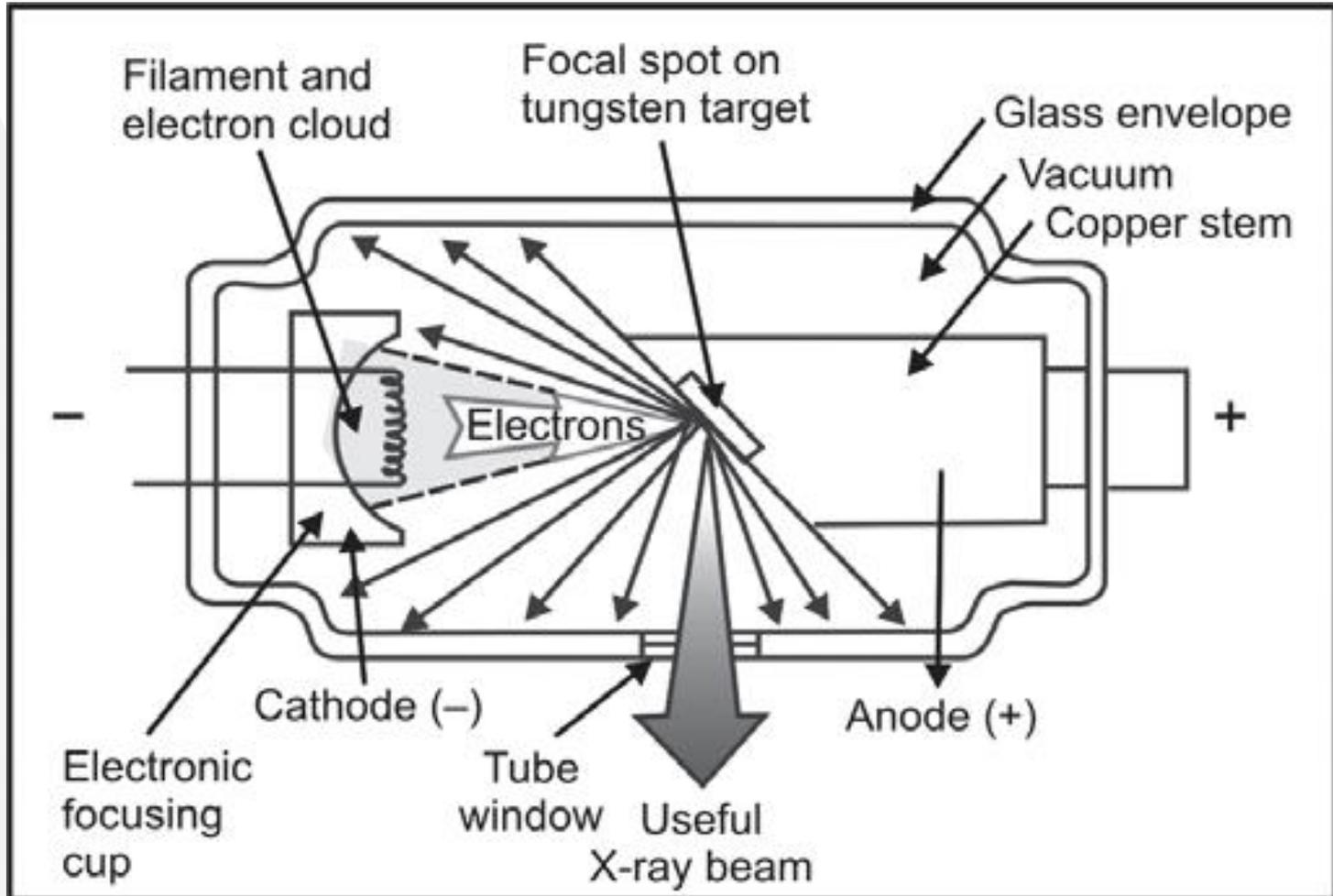


X-RAY TUBE

- ▶ It is the **heart** of the X-ray generating system. This consists of a glass vacuum tube from which all of the air has been removed.
- ▶ The X-ray tube used in dentistry measures approximately several inches long by one inch in diameter.
- ▶ The component parts of the X-ray tube consist of:
 - a. A leaded glass housing
 - b. A negative cathode
 - c. A positive anode.



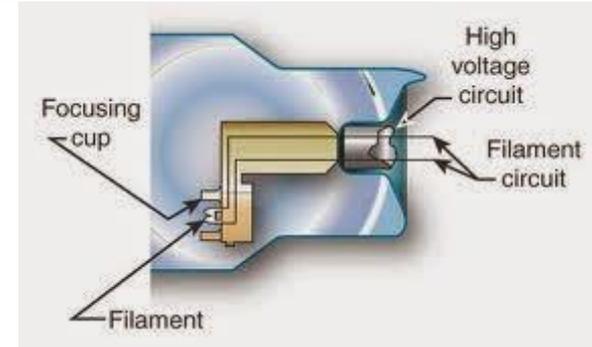
X-RAY TUBE WITH THE MAJOR COMPONENTS



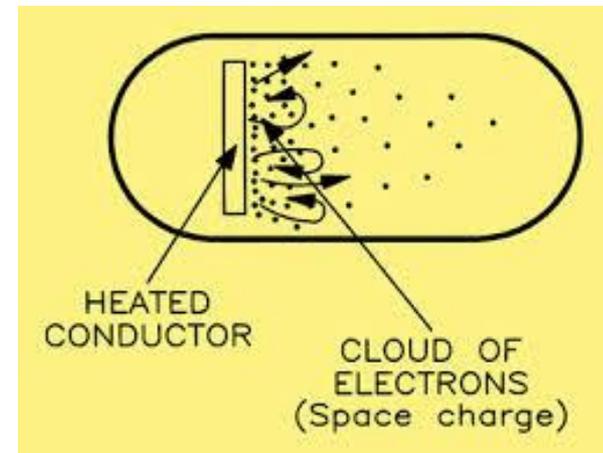
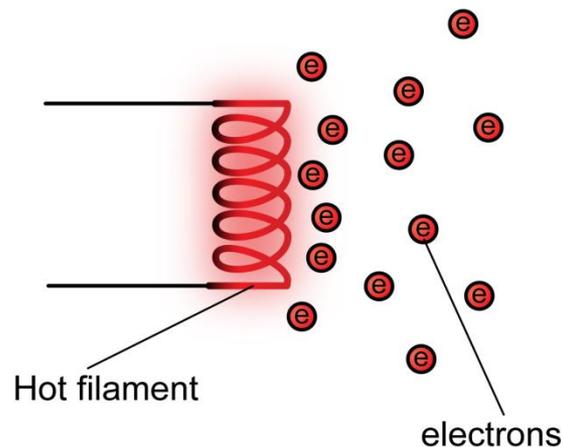
a. A leaded glass housing. It is a leaded glass vacuum tube that prevents X-rays from escaping in all directions (radiation leakage).

b. A negative cathode: It is principally composed of two parts:

- ▶ i. filament.
- ▶ ii. focussing cup.
- ▶ The filament is the source of electrons in the tube, it is made up of a coil of tungsten wire (atomic number 74), approximately 0.2 cm in diameter and 1cm or less in length.
- ▶ It is mounted on two strong stiff wires, that support it and carry the electric current. These two mounted wires lead through the glass envelope to serve as a connection to the low and high voltage electrical source.
- ▶ The filament is heated to incandescence through a range of temperatures by varying voltage (10V), across the filament from a step down transformer in a low voltage circuit.

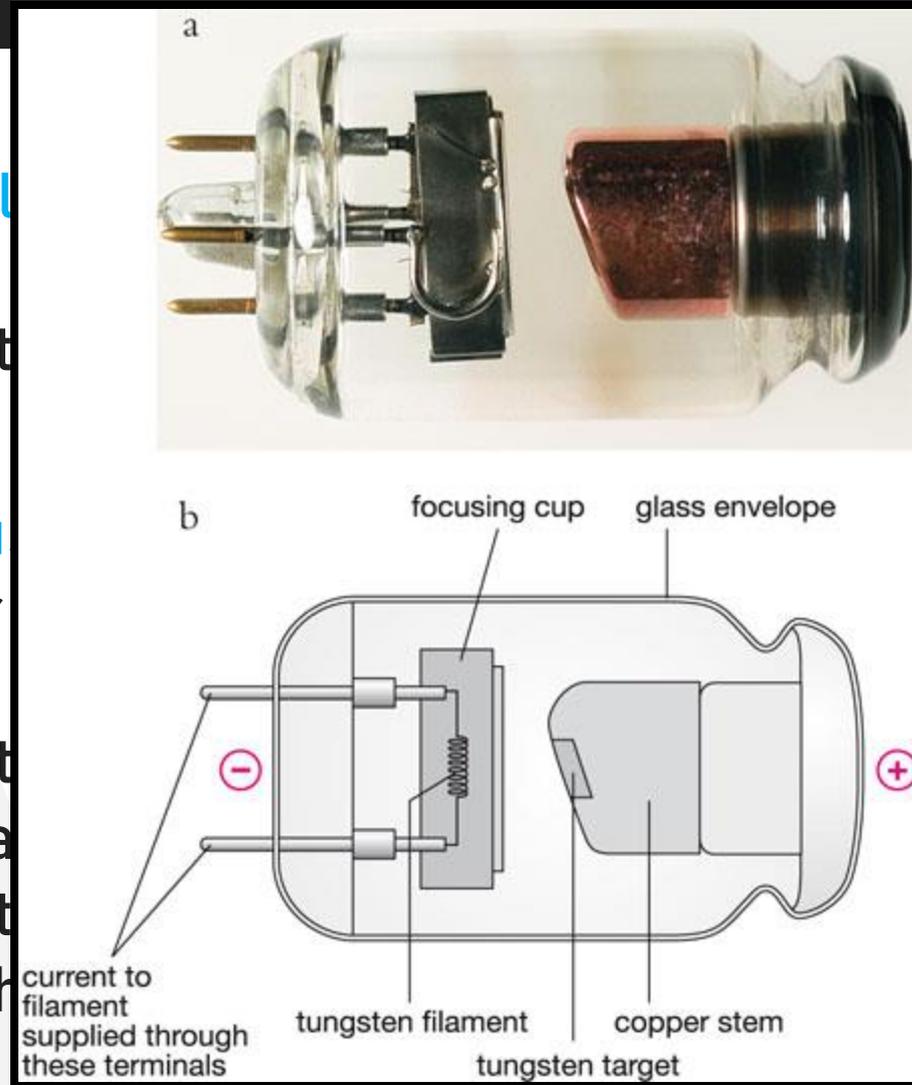


- ▶ The hot filament emits electrons that are separated from the outer orbits of tungsten atoms at a rate proportional to its temperature by a process called *“Thermionic emission”*.
- ▶ The electrons lost by the filament form a **cloud** or space charge around the filament.



- ▶ The **milliampere** quantity turn control

- ▶ The **focus** reflector filament. the electron into a narrow beam the electron area in the



controls the
ts, which in

ged concave
houses the
ally focuses
ent filament
g the size of
rectangular

c. A positive anode or the positive electrode: It consists of a wafer thin tungsten plate (target) embedded in a solid copper stem.

- ▶ The purpose of the target is to convert the kinetic energy of the electrons generated from the filament into X-ray photons.

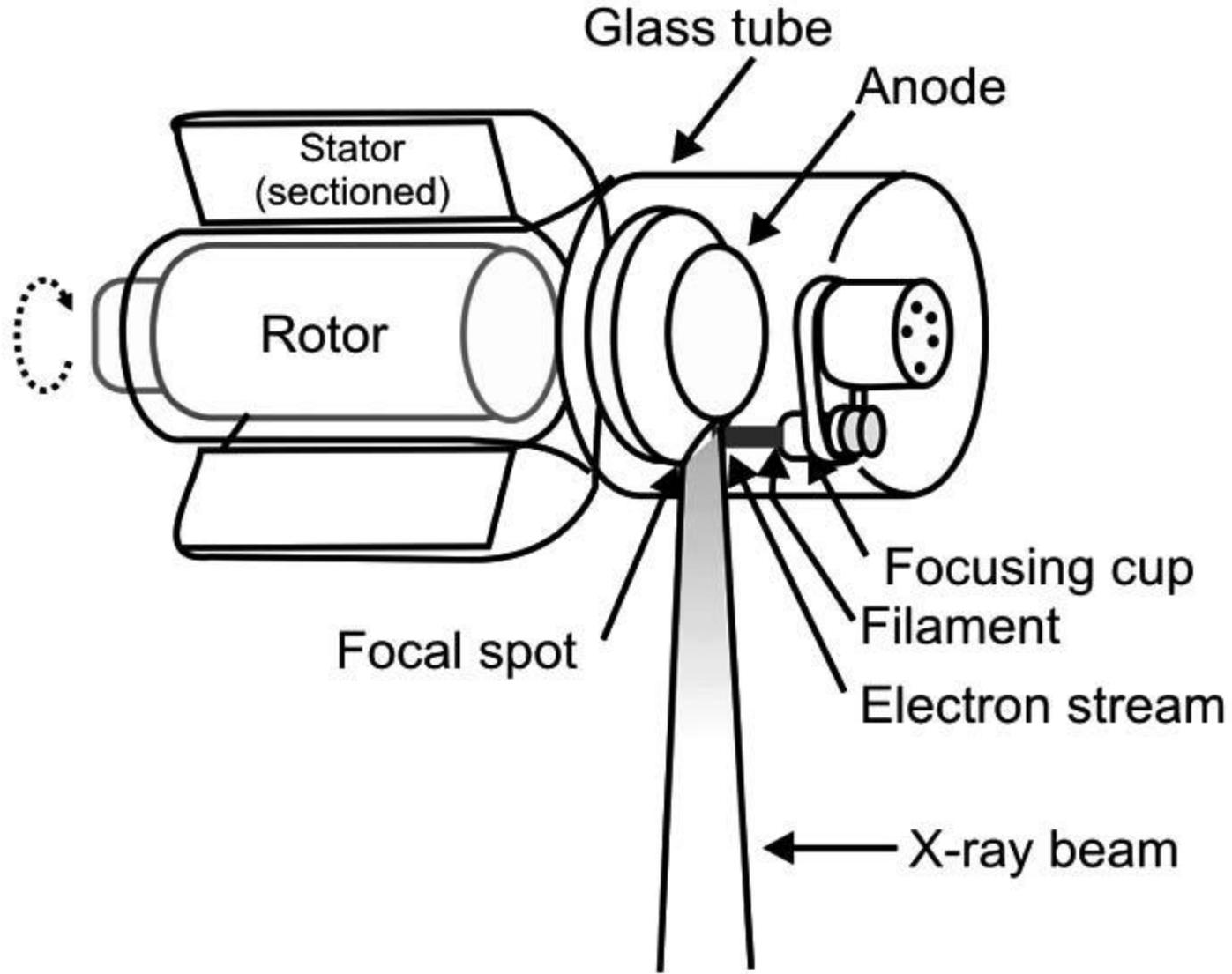
- ▶ Tungsten is usually selected as the target material because it represents an effective compromise between the features of an ideal target material, namely:

- i. High atomic number.*

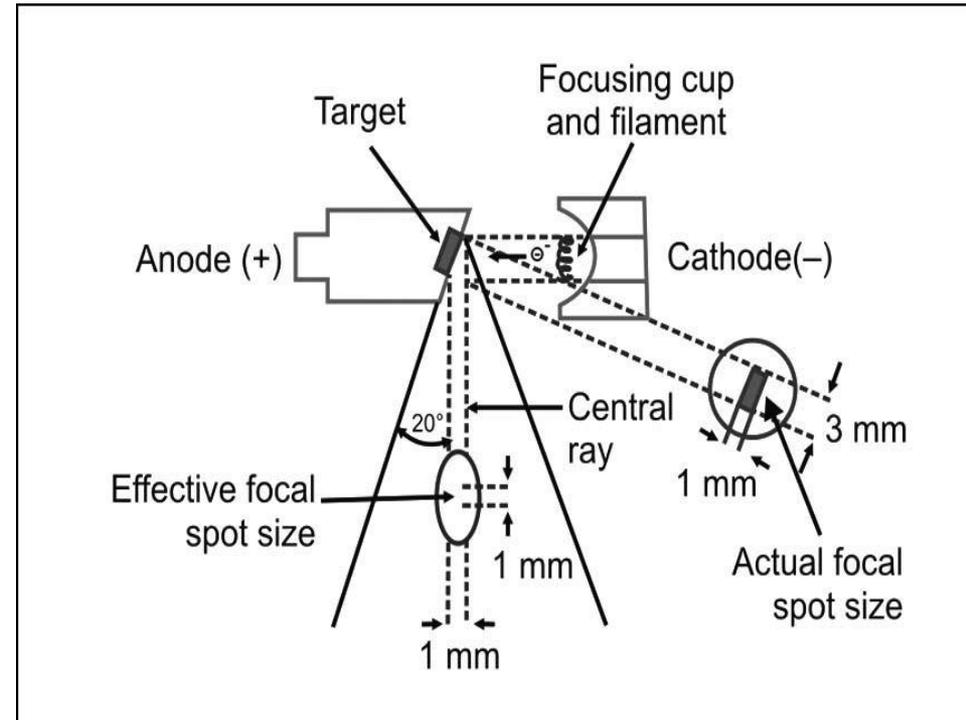
- ii. High melting point.*

- iii. Low vapor pressure.*

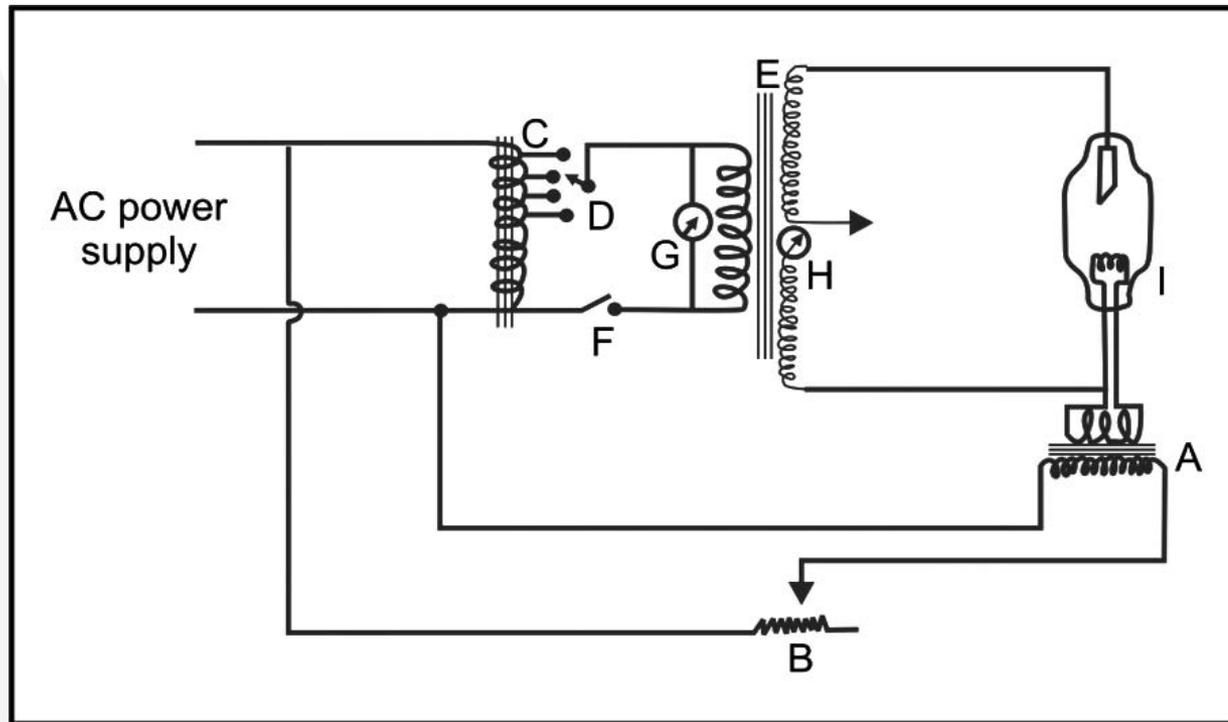
- iv. High specific heat*



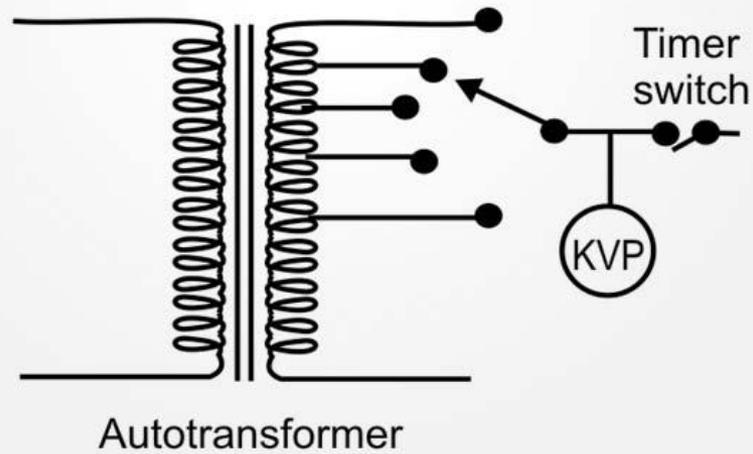
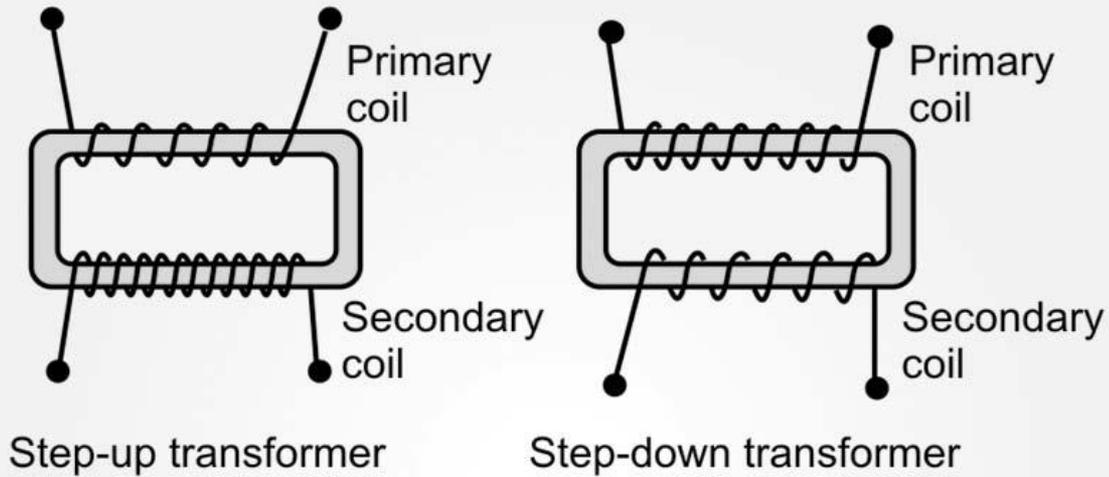
- In practice the target is inclined at an angle of 20° to the central ray of electrons.
- This causes the effective focal spot to be $1\text{ mm} \times 1\text{ mm}$, in contrast to $1\text{ mm} \times 3\text{ mm}$ of the actual focal spot size.
- This results in a smaller source of X-rays and sharper image with a larger actual focal spot for effective heat dissipation.
- This is known as **“Line focus principle”** and the twenty degree angle is called as **“the angle of truncation”**



Dental X-ray machine circuit, with the major components Labeled - A. Filament Step-Down Transformer; B. Filament Current Control (mA switch); C. Autotransformer; D. kVp Selector Dial (switch); E. High Voltage Transformer; F. X-ray Timer (switch); G. Tube Voltage Indicator (Volt Meter); H. Tube Current Indicator (Ammeter); I. X-ray Tube



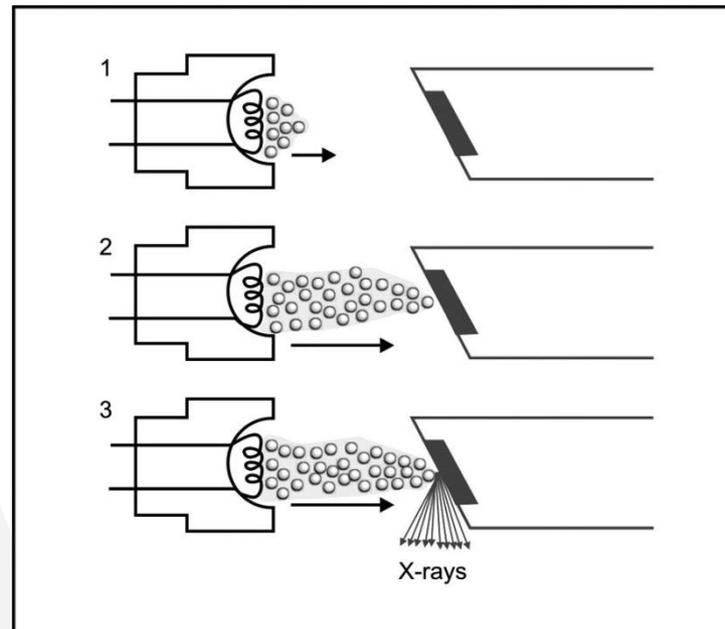
- ▶ **Transformer** - It is a device that is used to either increase or decrease the voltage in an electrical circuit. It alters the voltage of the incoming electrical current and then routes the electrical energy to the X-ray tube.
- ▶ In the production of X-rays three transformers are used:
 - i. **Step Down Transformer.** It is used to decrease the voltage from the incoming 110-220 line voltage to 3-4V as required for the filament circuit. (This transformer has more coils in the primary coil than in the secondary coil).
 - ii. **Step Up Transformer.** It is used to increase the voltage from the incoming 110-220 line voltage to 65,000- 1,00,000 volts as required by the high voltage circuit.
 - iii. **Auto Transformer.** This serves as a voltage compensator that corrects the minor fluctuations in the current.



PRODUCTION OF X-RAYS

- ▶ 1. Electricity from the wall outlet supplies the power to generate X-rays. When the X-ray machine is turned on, the electric current enters the control panel, via the plugged in cord and from there to the tube head via electrical wires in the extension arm.
- ▶ 2. The current is directed to the filament circuit through the step down transformer, which reduces the 110-220 voltage to 3-5 volts.

- ▶ 3. The filament circuit uses the 3-5 volts to heat the tungsten filament. Thermionic emission occurs, which results in the release of electrons from the tungsten filament, which form an *'electron cloud'*. This cloud remains around the filament till the high voltage circuit is activated.



- ▶ 4. When the exposure button is pushed the high voltage circuit is activated. The electron cloud produced at the cathode is accelerated across the X-ray tube to the anode. The molybdenum cup of the cathode directs the electrons to the tungsten target in the anode.
- ▶ 5. The electrons travel from the cathode to the anode. When the electrons strike the tungsten target, their energy motion (kinetic energy) is converted to X-ray energy and heat. **Less than 1 percent of the energy is converted to X-rays, the remaining 99 percent is lost as heat.**

- ▶ 6. The heat produced is carried away by the copper stem and absorbed by the insulating oil in the tube head. The X-rays produced are emitted from the Target in all directions. However, the leaded glass housing prevents the X-rays from escaping from the X-ray tube in any direction. Only a small number of X-rays are able to exit from the X-ray tube via the unleaded glass window portion of the tube.
- ▶ 7. The X-rays travel through the unleaded glass window, the tube head seal, the aluminium disks, which filter the long wave X-rays from the beam.
- ▶ 8. The size and shape of the X-ray beam is controlled by the lead collimator. The X-ray beam then travels down the lead lined PID and exits the tube head at the opening of the PID.

TYPES OF X-RAYS PRODUCED

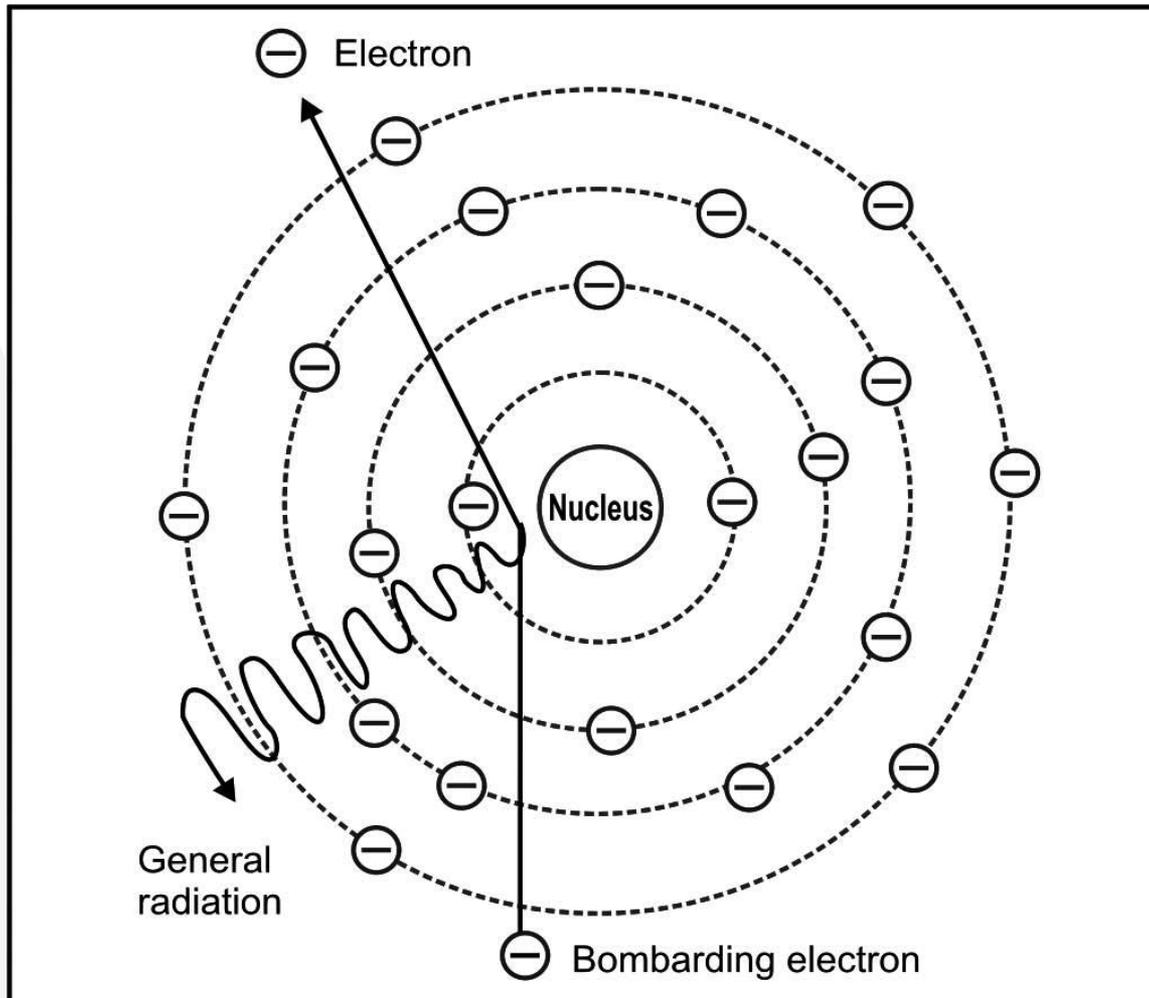
- ▶ 2 types of radiation:
 1. Bremsstrahlung/General radiation.
 2. Characteristic radiation.

Bremsstrahlung radiation :

- ▶ Produced by sudden stopping/braking of high speed electrons at target.
- ▶ 70 percent of the X-rays are produced in this manner.

- ▶ This occurs in stages:
 - a. Acceleration of electrons to high velocity by high voltage applied b/w filament & target of x-ray tube.
 - b. electron interaction with the electrostatic field of target nucleus. The closer the electrons are to the nuclei ,the greater will be the electrostatic interaction b/w electrons. This will increase the braking effect b/w the target & bombarding electrons & hence the energy of resultant photons will increase.

When an electron that passes close to the nucleus of a tungsten atom is slowed down, an X-ray photon of lower energy known as general radiation results



Characteristic radiation :

Radiation produced when a bombarding electron from filament displaces an electron from a shell of target atom.

- Void in deficient inner shell attracts an electron from higher energy outer shell.
- Emission of energy equivalent to the difference in two orbital binding energies in form of photon called as '**characteristic radiation**'

An electron that dislodges an inner shell electron from the tungsten atom results in the arrangement of the remaining orbiting electrons and the production of an X-ray photon known as characteristic radiation

