جامعة الانبار
كلية العلوم التطبيقية – هيت
قسم الفيزياء الحياتية

الاجهزة الطبية

X-ray Machine

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In 1895, a German physicist, Wilhelm Röntgen discovered X-rays

The Nobel Prize in Physics 1901

"in recognition of the extraordinary services he has rendered by the discovery of the remarkable rays subsequently named after him"

Intensity (brightness)

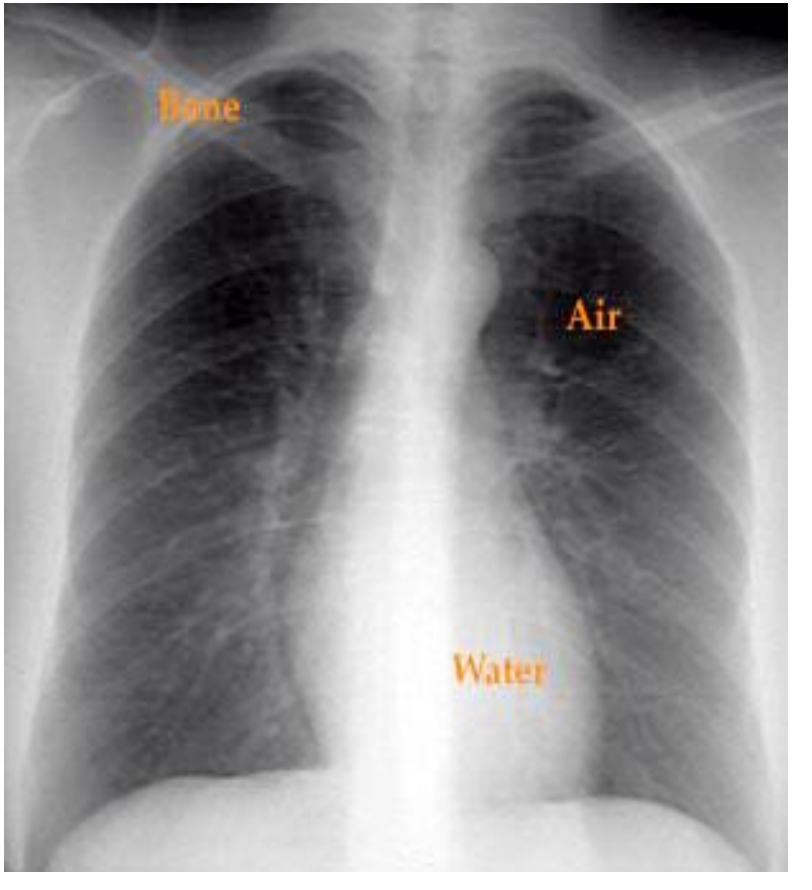
The intensity depends on:

- The **distance from the source**
- The **medium** the radiation is travelling through

X-rays penetration

❖ **Different tissues in our body absorb X-rays at different extents:**

- **Bone**- high absorption (white)
- **Tissue**- somewhere in the middle absorption (grey)
- **Air**- low absorption (black)



The X-ray Tube

- X-rays are produced in an x-ray tube.
- X-ray tube allows x-ray beam to be produced and controlled.
- Components of the x-ray tube:
    1. Cathode (negatively charged)
    2. Anode (positively charged)

X-ray Production Elements

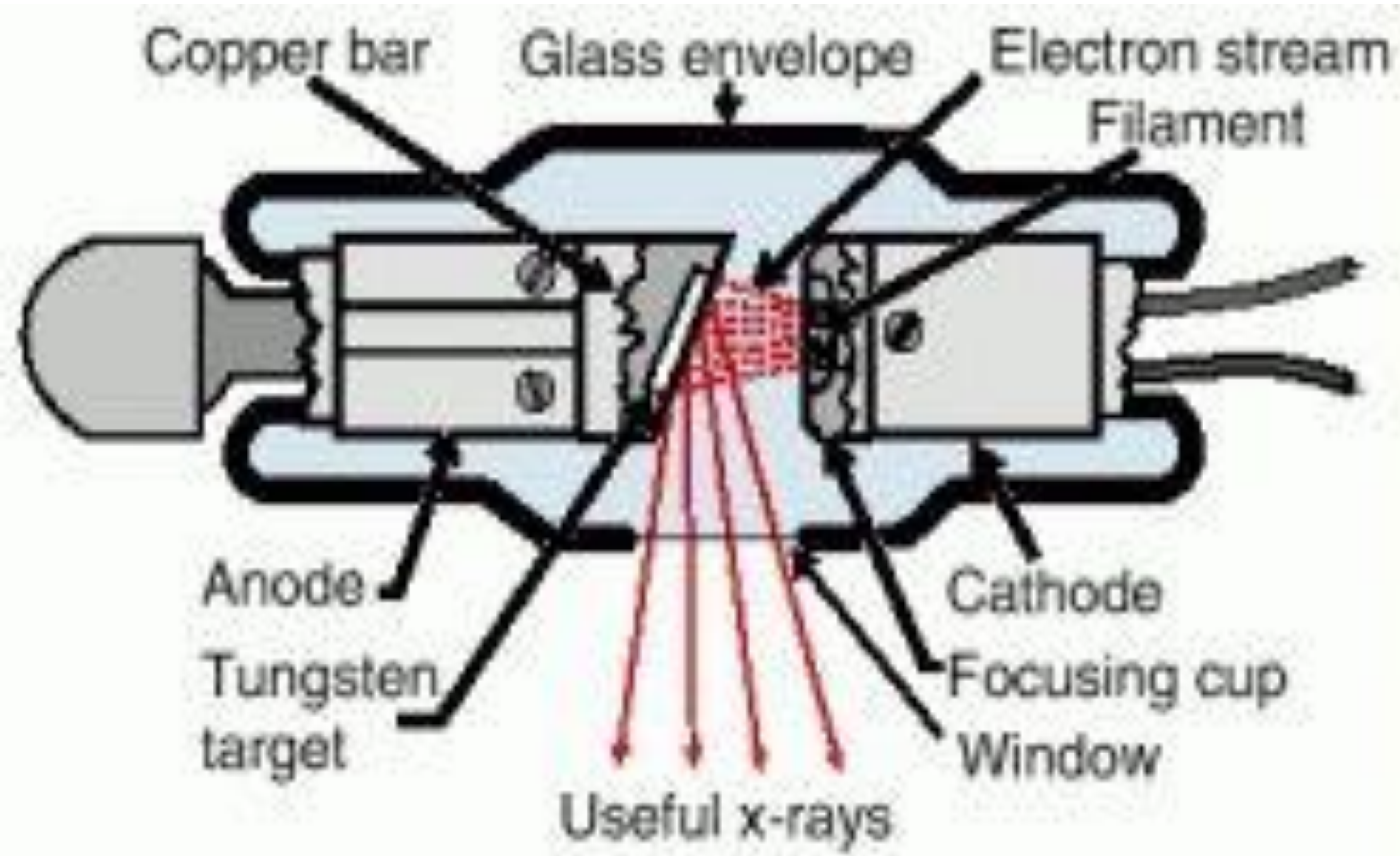
1. Source of electrons
2. Method of accelerating the electrons
3. An obstacle-free path for the passage of high speed electrons
4. A target in which the electrons can interact, releasing energy in the form of x-rays.
5. An envelope (tube) to provide a vacuum environment, eliminating the air molecule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

Electrons ►►Accelerate ►►Provide vacuum environment ►► Clear path ►► Target ►► Photons

X-ray tube components

1. 1. Cathode (-)
2. 2. Anode (+)
3. 3. Glass envelope encases these components and forms a vacuum.
4. Vacuum- an area from which all air has been removed.
5. Target for collision between electrons and positive charged on anode is located on the anode.
   - This collision produces heat (99%) and x-rays/radiation (1%).
6. Window acts as doorway for the exit of x-rays.
7. Entire x-ray tube is encased in a metal housing to prevent stray radiation and to protect glass envelope.

X-ray Generator components



X-ray Intensity and Energy

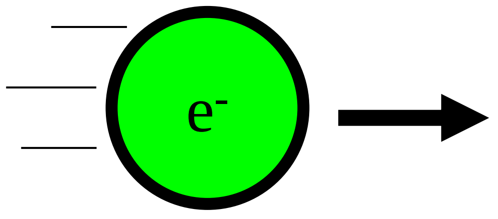
1. Kilovoltage peak (kVp) the peak energy of the x-rays which determines the quality (penetrating power) of the x-ray beam.
2. current (ampere, A) = number of particles per second (1/second, 1/s) x charge on each particle (coulomb, C)

$$I = N \times q$$

3. kinetic energy (joule, J) = charge on the electron (coulomb, C) x accelerating potential difference (volt, V)

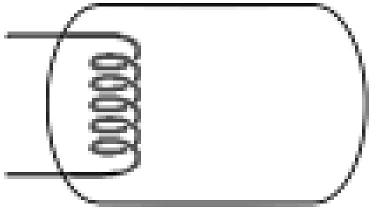
$$KE = \tfrac{1}{2} mv^2 = e \times V$$

Think of a moving electron in a CRT.



We know that kinetic energy is given by:
KE = ½ mv^2

Where has it got this energy from?

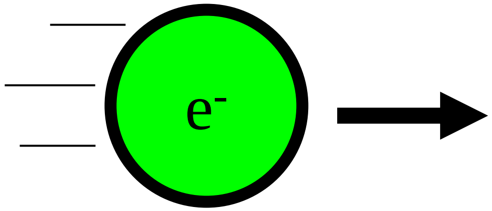


Answer: the accelerating voltage (V)

Kinetic Energy (1 electron) = charge of electron x **accelerating potential difference**

$$\mathbf{KE} = e \times V$$

Theoretical Background



$$KE = \tfrac{1}{2} mv^2 = e \times V$$

v = velocity of the electron (metres per second, m/s)
m = mass of an electron (kilograms, kg)
e = charge on the electron (coulomb, C)
V = accelerating potential difference (volt, V)
KE = kinetic energy (joules, J)

The charge on an electron is 1.6×10^{-19} C
The mass of an electron is 9.1×10^{-31} kg

Example

If the accelerating voltage in an electron gun is 3 kV, what is the kinetic energy of the electrons in the beam?

The charge on an electron is 1.6×10^{-19} C.

KE = eV

$KE = 1.6x10^{-19}$ x 3000

$KE = 4.8 x10^{-16}$ J

Example 2

What is the velocity of an electron that has been accelerated by the 2.5 kV anode voltage of a television picture tube?

$$\text{Energy} = eV = \tfrac{1}{2} mv^2$$

$KE = eV$

$KE = 1.6\times10^{-19} \times 2500$

$KE = 4.0 \times10^{-16}$ J

$KE = \tfrac{1}{2} mv^2$

$4.0 \times10^{-16} = 0.5 \times 9.1 \times 10^{-31} \times v^2$

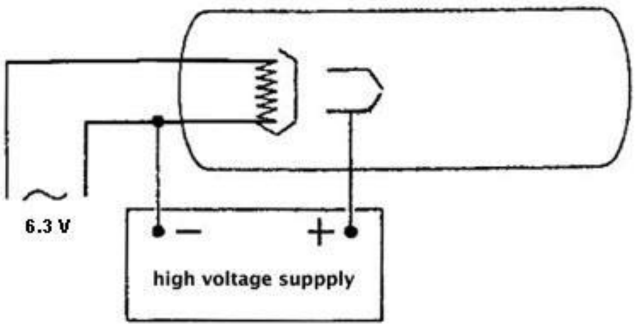
$4.0 \times10^{-16} = 4.55 \times 10^{-31} \times v^2$

$$\frac{4.0 \times 10^{-16}}{4.55 \times 10^{-31}} = v^2$$

$8.79 \times 10^{14} = v^2$

V = 29649973 m/s (2.96×10^7 m/s)

Example 3



(a) The acceleration voltage between the cathode and anode is 8 000 V. Calculate the kinetic energy of one electron when it has reached the anode.

KE = eV

$KE = 1.6 \times 10^{-19} \times 8000$

$KE = 1.28 \times 10^{-15}$ J

(b) 5.2×10^{16} electrons reach the anode per second. Calculate the current.

I = N q

$I = 5.2 \times 10^{16} \times 1.6 \times 10^{-19}$

I = 0.00832 A

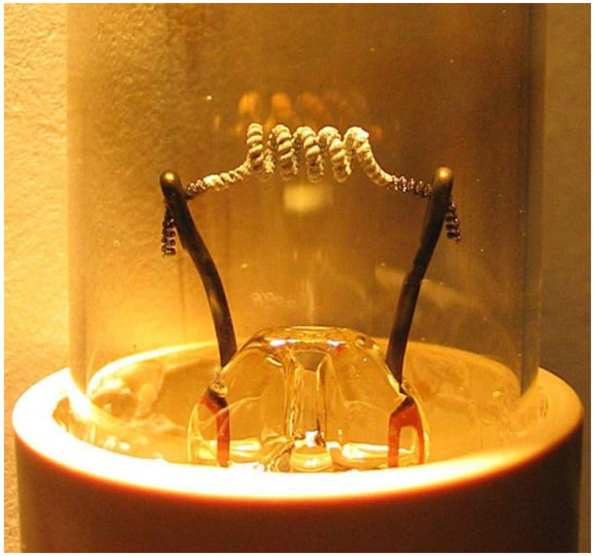
Cathode

- Cathode provides source of electrons and directs these electrons toward anode.
- Components of the cathode Filament فتيل- coiled wire similar to a light bulb- emits electrons when heated.

1. When heat is applied to atom, electrons become excited.
2. Excitation- when electrons are moved to a higher energy level within the atom.
3. 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.
  - Milliamperage (mA)-amount of electrical energy being applied to the filament. Describes number of x-rays produced during exposure.

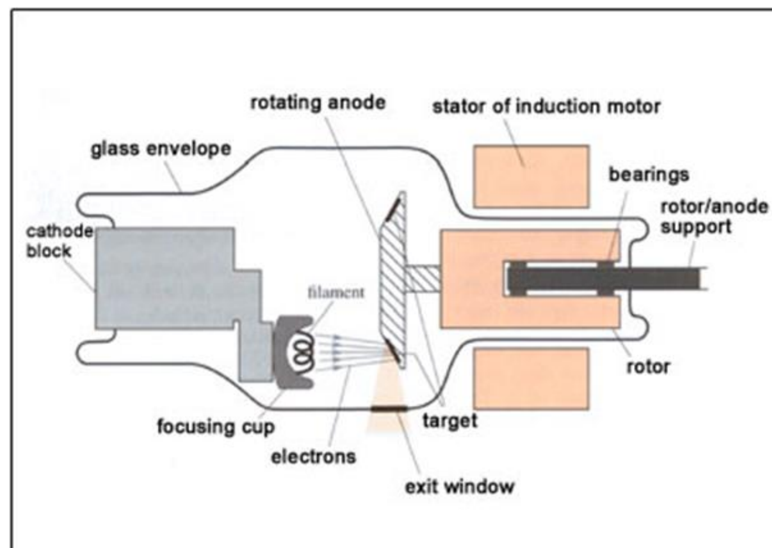
Filament

1. Quantity of electrons released depends on heat of the filament.
   - The hotter the more electrons, the greater the mA.
2. 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

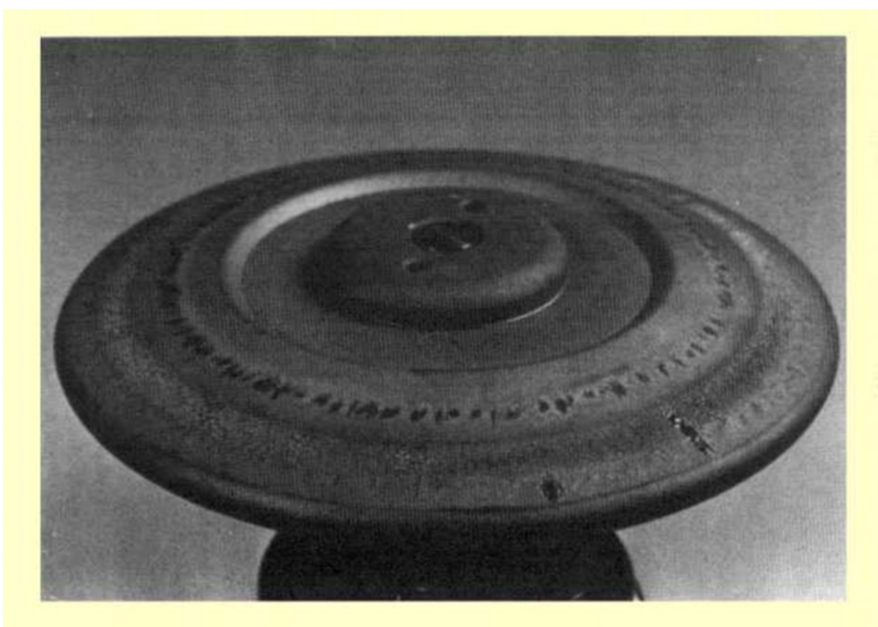
- Basic construction is a beveled target placed on a cylindric base.
- Heat is an issue- copper acts as a conductor of heat and draws the heat away from the tungsten target.
- Temperatures greater than 1000°C occur during x-ray production.

  - How to cool it?
    1. Copper is at base of target.
    2. Surrounding glass tube with oil
    3. Rotating the target anode
    4. Focal spot spreading



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:
  1. Inability to withstand large amounts of heat.
     - Repeated bombardment of target can cause damage to target.
     - This damage causes pitting of the target surface.
  2. Have to have a large focal spot to accommodate higher temperatures with low resolution imaging.

- If target is damaged,
  - may cause radiation to scatter in undesirable directions **Heel Effect**.
  - This will cause lighter x-rays than expected.

Rotating Anode

- Rotates through the center of the tube.
- Rotating anode can have small focal spot and still withstand a great amount of heat.
- Rotation provides a cooler surface for the electron stream. Why?
  - It 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.

Heel Effect

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

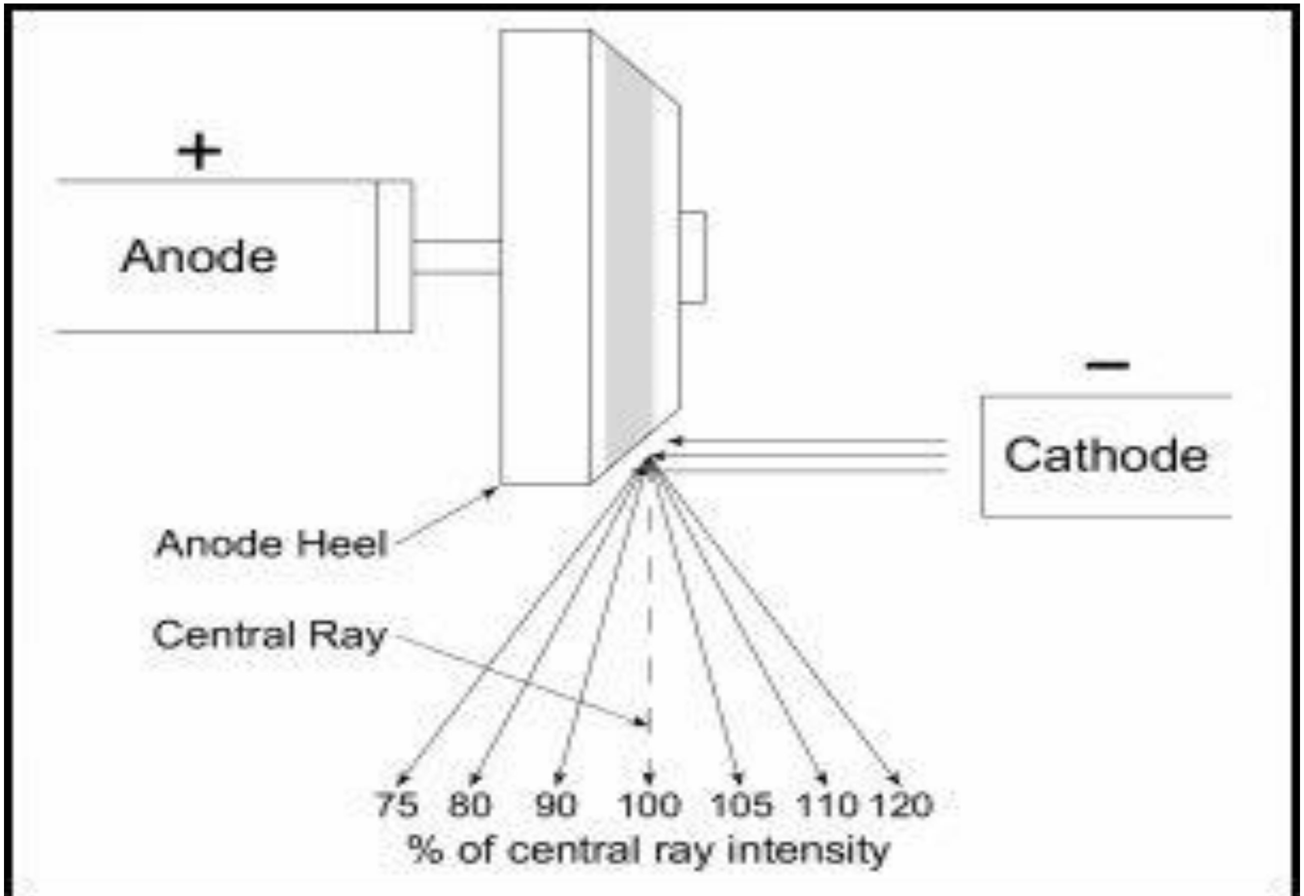


Figure 13: Schematic illustration of the heel effect (after Carlton and Adler, 1996)

Areas of Tube Failure

1. Cathode Failure
   - Filament failure- why? Cathode is not heated, no electrons produced.

   The pre-exposure button keeps this from occurring. Filament is not heated to level needed until pre-exposure button is depressed.

2. Anode Support Failure
   - Bearings get damaged from heat

3. Anode Target Failure
   - Damaged from heat. Causes changes in density or blackness to vary among uses.
   - To prevent this damage, high kVp's and low mA's should be used.

Areas of Tube Failures

1. Glass Envelope Damage
   A. metal (inner lining of glass) melts due to overheating.
      - This process is called arcing
   B. when air is present within glass housing

2. Tube Housing abnormalities
   A. Rarely occurs.
   B. Can be due to shift in glass envelope within metal housing. Causes partially exposed radiograph.
   C. Oil leak can cause overheating.

Technical Components

- Electrical
  - High Voltage Circuit
  - Low Voltage Circuit
  - Timer Switch

Rectification is the process of changing alternating current (AC) to direct current (DC).

X-ray Tube Rating

- Dictates maximum combinations of kVp and mA without overloading the tube.

- Based on 4 factors:
  - Focal Spot size
  - Target Angle (radiation angle)
  - Anode Speed
  - Electrical Current in Cathode)
  - Kilo Volts

Generator Types

- 3-Phase Generator
  1. Produces an almost constant electrical current by using 3 single phase currents.
  2. Most commonly used in modern x-ray tables.
  3. Produces low-energy x-rays so that radiation quality is increased.

- High Frequency Generators
  - Causes many thousands of waves per second to flow to x-ray tube and then convert to radiographic energy.

Other Components

- The Collimator: functions
  1. Restricting device used to control size of primary x-ray beam
  2. Prevent scattering
  3. Determine the geometric shape of x-ray

- The Tube Stand

  Supports x-ray tube during radiographic procedures.
  - Shaky stands can cause motion artifacts

The Control Panel

Includes:

1. On/off switch
2. Voltage compensator (converter)
3. Kilovoltage Calibrator (kV)
4. Milliamperage Calibrator (mA)
5. Timer
6. Exposure button
7. Warning light