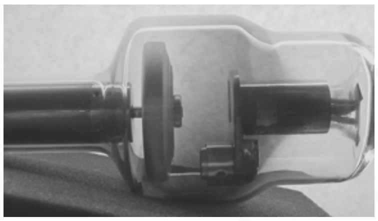
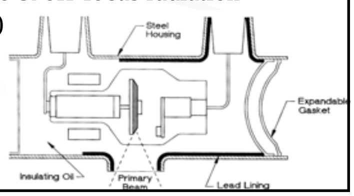
The X-ray Tube



Tube Housing

- Made of cast steel & is usually lead-lined
  - Provides for absorption of most off-focus radiation
- Purposes:
  - Controls leakage & off-focus radiation (discussed later)
  - Isolates high voltages
  - Helps to cool the tube



Glass Envelope

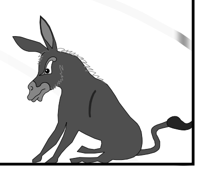
- Surrounds entire cathode & anode assemblies except for the stator
  - Made of several layers of Pyrex w/ varying densities
  - Glass is fitted to the metal of the anode & cathode ends
  - Must be airtight to maintain a good vacuum

Glass Envelope

- A target window is constructed in the glass envelope to allow less scatter & attenuation of the photons
  - In most tubes - simply a thinner “cut” of glass
  - In mammography - a special metallic beryllium window prevents attenuation of lower energy photons

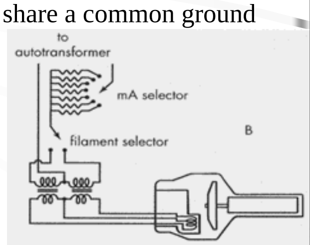
Cathode

- The cathode is the negative end of the x-ray tube.
  - Made up of the filament(s) and a focusing cup.



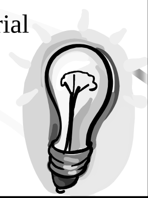
Filament

- Most x-ray tubes have a dual filament cathode assembly - also known as dual focus
  - The two filaments sit parallel to each other in the focusing cup & share a common ground wire.
  - Most filament coils are 7-15mm long , 1-2mm wide, 0.1-0.2mm thick



Filament

- Filaments must be able to:
  - Boil off electrons (thermionic emission)
  - Withstand great amounts of heat
- Filament materials
  - Tungsten - most widely used material
    - High boiling point (3,370° C)
    - It is difficult to vaporize
  - Rhenium (3,170° C)
  - Molybdenum (2,620° C)

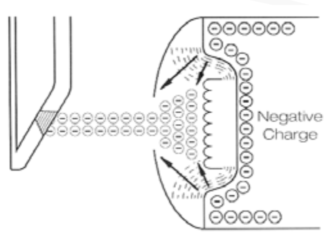


Filament

- Vaporization occurs over time
  - When the particles vaporize (turn into a gaseous form), they solidify on the glass of the x-ray tube, called sun-burning or sun-tanning of tube.
    - Reduce the x-ray output of the tube
    - destroy the vacuum integrity of the tube, leads to arcing and ultimately tube failure
- Thorium (a radioactive metallic element) is added to the filament material to make the tube last longer.

Focusing Cup

- The focusing cup helps control electron cloud
  - The electrons repel each other & want to spread out. The focusing cup forces the electrons to form a small stream as they move toward the target material
  - Made of nickel
  - Has a low negative charge



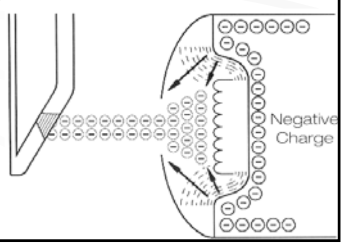
Grid-Controlled Focusing Cups

Some x-ray procedures require exposures be taken at quick intervals.

- Grid-controlled focusing cups have a variable charge applied to the focusing cup that acts as an exposure switch
  - When the tube is activated, the charge increases & decreases rapidly
  - Short bursts of electrons flowing to the target.

Grid-Controlled Focusing Cups

- May be found in:
  - portable capacitor discharge units
  - digital subtraction angiography
  - digital radiography
  - Cineradiography

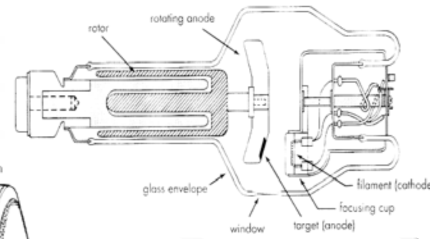


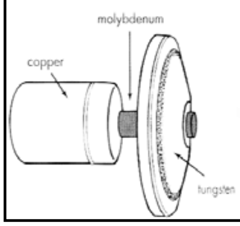
Anode

The Anode is the part of the x-ray tube where accelerated electrons move to after kV is applied to the tube.

- Two types:
  - Stationary anode (old type) - just a tungsten button imbedded in copper bar.
  - Rotating anode consists of a molybdenum disk(target) rotated by an induction motor.

Rotating Anode Assembly





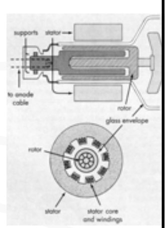
This is a diagram of a rotating anode without & with the tube.

Rotating Anode Stator and Rotor

Consists of two main parts:

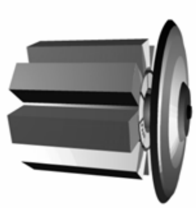
- Stator
  - Rests just outside of the glass tube
  - Made up of a series of electromagnets equally spaced around the neck of the tube
    - Designed to energize opposing pairs, in sequence, so that they induce the rotation of the rotor.
- Rotor
  - Located within the glass tube
  - Made up of copper bars & soft iron around a molybdenum shaft

Mutual Induction



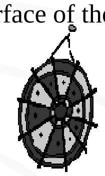
Rotating Anode Stator and Rotor

- When the rotor is rotating at the desired level, the x-ray exposure may be completed.
- Most revolve at 3400 revolutions per minute (rpm) minimum.
- By rotating the anode we spread the generated heat over a larger surface area allowing greater technique loads.



Anode Target Characteristics

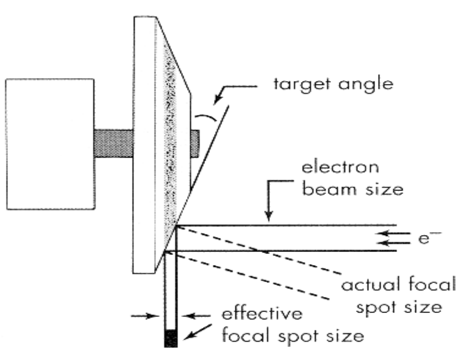
- Anode target - the point on the anode where the electrons strike
- Tungsten – rhenium alloy is the most common material and is plated onto the surface of the molybdenum disk
- Tungsten has:
  - High atomic number (74)
  - High thermal conductivity level
  - High melting point
- Rhenium added to increase thermal capacity and tensile strength



The Line-Focus Principle

- 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.
- Best described by the angle of the anode
  - the smaller the angle of the anode, the smaller the effective focal spot size (any angle $<45^0$ results in the effective FS being smaller than the actual FS)
  - 12^0 target angle most common because it is the minimum that will cover a 14x17 at 40”

The Line-Focus Principle cont.

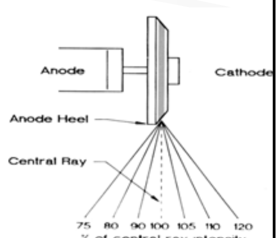


The Anode Heel Effect

- Caused by the angle of the anode vs. the intensity of the electrons striking it.
- X-rays exiting the target on the anode side have to traverse the "heel" of the anode
  - Photons directed toward the cathode end do not have to travel through as much of the anode because of the angle of the target so more make it out
  - Those directed toward the anode end must travel through more material so more are absorbed
  - Results in the beam being of lower intensity on the anode side.

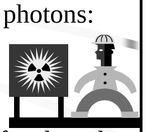
The Anode Heel Effect

- As much as 20% more photons at the cathode end of the tube & as little as 25% fewer photons at the anode end of the tube.
- Most noticeable with:
  - Small focal spot
  - Short S.I.D.
  - Large field



Production of Off-Focus Radiation

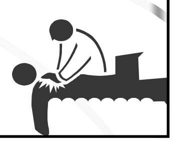
- Radiation produced from x-ray photons or electrons that have reflected off of the anode
- These x-rays or electrons can strike a number of things in the tube and produce scatter photons:
  - Side of the focusing cup
  - Tungsten particles from sun-burn



- Because they are not produced in the focal track they are "off-focus" and while most are absorbed by the housing, some make it out of the tube and degrade the radiographic image.

Extending Tube Life

- Practical methods
- Tube rating charts
  - Determines if a technique is safe
  - Used to test overload protection circuits
- Calculating heat units and using cooling charts.



Practical Methods

The life of the tube is under your control!

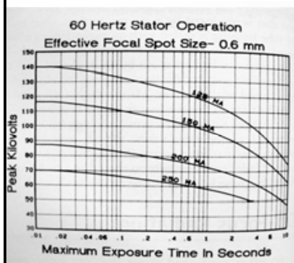
- Proper warming extends tube life
- Avoid repeated exposures close to tube load limit
- Do not hold the rotor switch unnecessarily

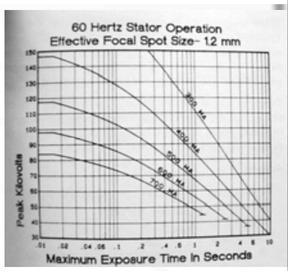
<u>Listen to your equipment!</u>

Tube rating charts

- Rules for use
  - Select the correct chart
  - Plot the point using technical factors
  - ANYTHING ON OR ABOVE THE GIVEN mA LINE IS UNSAFE

Tube Rating Charts





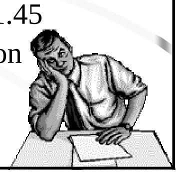
Calculating Heat Units (hu)

kV x mA x time (s) x C_r x # of exposures

The heat unit rectification constants (C_r) are:

- 1 ϕ 2 pulse (full wave) = 1.00
- 3 ϕ 6 pulse = 1.35
- 3 ϕ 12 pulse = 1.41
- High frequency = 1.45

An anode cooling curve based on the tube’s rating chart must be used when calculating multiple exposures.



Calculating Heat Units (hu)

If 10 exposures of 80 kVp, 200 mA & 0.43 s. is made on a high frequency unit, how many heat units (hu) are produced?

kV x mA x time (s) x C_r x # of exposures

80kVp x 200mA x 0.43 sec x 1.45 x 10 = 99,760 hu

If the anode is at its maximum how long must we wait before making the exposures?

Anode Cooling Chart