Principles of Imaging Science I (RAD 119)

X-ray Tube & Equipment

X-ray Imaging Systems

- Medical X-ray Equipment
  - Classified by purpose or energy/current levels
    - kVp, mA
  - Radiographic
    - Non-dynamic procedures only
    - ED Department
    - Skeletal, Abdominal, Thorax
    - Others??

X-ray Imaging Systems

- Radiographic /Fluoroscopic
  (General Purpose)
  - Non-dynamic (static) procedures
  - Dynamic (moving) procedures
X-Ray Imaging Systems

Diagnostic X-ray Unit

X-ray Imaging Systems

- Chest X-ray
- Mobile
The generic components of diagnostic radiographic equipment include the x-ray tube (A), collimator (B), radiographic table (C), top and tilt controls (D), Bucky tray for cassette (E), and moving tabletop (F). The tube is suspended from an overhead tube stand, and the control console is behind a leaded wall.

**Radiographic Tables**

- **X-ray Tables Characteristics**
  - Flat or curved surfaces
  - Radiolucent material
  - Easily cleaned
  - Scratch resistant
  - Bucky tray
  - Bucky slot cover
  - Grid

**X-ray Table Types**

- Fixed
- Floating
- Elevating
- Mobile
Radiographic Table Fluoroscopy

Ancillary X-ray Equipment
- Foot board
- Shoulder supports
- Hand grips
- Compression band
- Upright Bucky stand

X-ray Tube Supports
X-Ray Imaging System Components

- Control Console
  - Located behind lead barrier
  - Operated by technologist
- High Voltage Generator
  - Convert low energy to high energy necessary for x-ray production
  - Often located in radiographic room
- X-Ray Tube

Types of X-Ray Equipment

- Two types:
  - Diagnostic and therapeutic
    - Diagnostic ranges
      - 10-1200 milliamperes (mA)
      - 0.001 to 10 seconds
      - 25-150 kilovoltage peak (kVp)

X-ray Control Console

- Settings:
  - kVp
  - mA, time, mAs
  - APR
  - AEC/AED
  - Rotor Switch
  - Exposure Switch
    - Single vs Dual
    - Others??
X-Ray Tube Housing

- Protective housing of x-ray tube
- Lead lined to absorb isotropic x-ray photons
  - Off-focus radiation
- Primary beam exits through segment that is not lead lined
  - Useful beam
  - Effective focal spot

X-ray Tube Housing

- Decreases leakage radiation to maximum level of 100 mR/hour at a distance of 1 meter
  - Minimizes exposure dose to patient and radiographer
- Provides mechanical support for x-ray tube
- Oil circulates around x-ray tube
  - Insulator protecting from electric shock
  - Dissipates heat
    * Cooling fan
**X-ray Tube Design**

- **Pyrex Glass or Metal Envelope**
  - Maintains a vacuum
  - Increases x-ray production efficiency
  - Average dimensions
    - 30–50 cm long, 20 cm diameter
  - Encases the electrodes
    - Cathode (-)
    - Anode (+)
  - X-ray beam exits window
    - Thinner segment
      - @ 5 cm²

**Glass vs. Metal**

- **Pyrex glass**
  - Heat absorber
  - Subject to gas development
    - Increased heat, Decreased x-ray production
    - Leads to tube failure
  - Subject to aging
    - Tungsten filament vaporizes and collects on glass envelope
    - Leads to tube failure

- **Metal enclosure (partial or full)**
  - Less likely to develop gas and filament vaporization
  - More constant electrical potential
  - Longer life due to decreased electron interaction with enclosure
  - Used in most modern x-ray tubes with high kVp, mA settings
THE X-RAY TUBE

X-ray Tube Components

- Cathode (- electrode)
  - Comprised of:
    - Tungsten filament
      - High melting point (3410°C)
      - 1-2% Thorium added to increase tube life
    - Rhenium, Molybdenum options
      - 1-2 cm long, 2 mm diameter
      - Source of electrons: Thermionic emission
      - Dual FSS
        - Small: 0.1–1 mm (<300 mA)
        - Large: 0.3–2 mm (All mA stations)

- Focusing Cup
  - Directs the electron stream toward the anode with filaments in a metal cup
  - Limits spread of electrons from filament
    - Actual focal spot

- Supporting Wires
  - Connected within x-ray circuitry

Cathode (- electrode)
Filament Current

- Low current is flowing to filament when x-ray unit is turned on insufficient for thermionic emission
- Small increase in filament current yields a large increase in tube current dependent upon voltage
  - Space charge
  - Space charge effect
  - Saturation current (emission limited)

The x-ray tube current is actually controlled by changing the filament current. Because of thermionic emission, a small change in filament current results in a large change in tube current.

Saturation Current

At a given filament current, tube current reaches a maximum level called saturation current.
X-ray Tube Components

- Anode (+ electrode)
  - Stationary vs Rotating

Anode Elements

- Tungsten
- Rhenium
- Graphite
- Molybdenum

Anode Elements

- Tungsten
  - High Atomic Number (74)
  - High Thermal Conductivity
  - High Melting Point
Anode Elements

- Rhenium
  - Adds strength to handle stress from rotation speed
- Molybdenum, Graphite
  - Thermal insulation to increase heat load capacity
- Focal Track and Focal Spot
- Stator, Rotor
  - Prep & Exposure Switches

THE ANODE

Anode Images
**Review X-Ray Tube**

- Stator electromagnets
- Armature
- Rotating portion
- Molybdenum neck and base
- Bearing
- Tungsten anode
- Envelope
- Filament circuit
- Filament
- X-ray beam

**Line Focus Principle**

- Reduces the primary beam size
  - FSS, Anode Angle
- Effective vs Actual focal spot
- Anode Angle:
  - 7 - 17 degree angle (12 degree average)
Anode (Target)

Some targets have two angles to produce two focal spots.

Line Focus Principle

- Large FFS vs Small FSS

Line Focus Principle
Line Focus Principle

Anode Heel Effect

– Intensity of radiation is greater on cathode side of tube, absorption by angled heel
– To ensure even image density, place cathode over thicker part of body

Anode Heel Effect

CATHODE OVER HIP  CATHODE OVER KNEE
Anode Heel Effect

X-ray Tube Failure

- Caused by excessive heat production
- How heat is produced:
  - **Radiation** production (99.8% heat, 0.2% x-ray photons)
  - **Conduction** results when energy from one area transfers to another area
  - **Convection** results when heat from one substance transfers to another location by movement
- Controlled by the radiographer
X-ray Tube Failure

- Anode surface melting and/or anode pitting due to a single high heat exposure
  - Vaporization on glass envelope
    - Filter x-ray beam from passing through window
    - Impede electron flow cathode to anode
  - Anode heat increases rapidly causing cracking and/or instability
    - Warm x-ray tube in AM
    - Avoid using maximum exposure values on a cold anode

X-ray Tube Failure

- Anode is kept at high heat for an excessive period
  - Conducted to rotor affecting bearings
- Filament vaporization due to high x-ray tube current (mA)
  - Filter x-ray beam from passing through window
  - Impede electron flow cathode to anode
  - Cause abrupt periodic changes in tube current

X-ray Tube Rating Charts

- Designed for specific manufacturer and tube design based upon:
  - FSS
  - Anode rotational speed
  - Anode angle
  - Voltage rectification
- Used to ensure heat limits are not exceeded
  - Should be followed for safe operation of the x-ray tube
- Demonstrates how 3 factors interact to produce heat
  - kVp, mA, exposure time
- Interpretation & use
X-ray Tube Rating Charts

X-Ray Tube Rating Chart Application

X-Ray Tube Rating Chart
Single Phase 12 pulse Unit

60 Hertz stator operation
Effective focal spot size - 0.6 mm
Anode Cooling Chart

- Used to prevent damage to the anode by allowing it to cool sufficiently between exposures
  - Heat storage capacity
- Shows how long it takes the tube to cool from its maximum level of heat
- Can be used to calculate cooling time even when heat level has not reached maximum level

Anode Cooling Applications:
- 350,000 HU = 15 min cool
- 200,000 HU = 13 min cool
- 50,000 HU = ???

Anode Cooling Chart Application

- Calculate heat units, then apply to chart
  - kVp x mA x time (single phase)
  - kVp x mA x time x 1.4 (3phase or high frequency)
Proper Use of X-ray Tube

• Follow manufacturer specifications for x-ray tube warming & specified charts
  – Overload micro-switch, Heat dissipation visual
• Avoid excess rotor prep
  – Single control vs Dual control
• Use low mA stations as possible
  – Effect on exposure duration
• Avoid rotating x-ray tube housing swiftly
• Report any x-ray tube malfunction