Equipment Operation and Quality Control

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ARRT Specifications

- Principles of Radiation Physics 9
- Imaging Equipment 9
- Quality Control 4
- Total questions: (11% of exam) 22

Principles of Radiation Physics

- X-ray Production
- Target Interactions
- X-ray Beam

X-ray Production

- X-rays are produced whenever high speed electrons are suddenly decelerated.

X-ray Production

- Source of electrons
- Acceleration of electrons
- Deceleration of electrons

X-ray Production

- Focusing of electrons
- Vacuum
- Heat removal mechanism
Processes in X-ray Production

- Bremsstrahlung
- Characteristic

Bremsstrahlung (Brems)

- Electron-nuclear field interaction
- Electron loses kinetic energy and changes direction
- Lost KE appears as an x-ray photon

Bushong, 2004

Bremsstrahlung (Brems)

- Produces heterogeneous beam
- Comprises 70-90% of beam (kVp > 80)
- Maximum energy photon = kVp level

Bushong, 2004

Characteristic

- Electron-orbital electron interaction
- X-rays are produced by electron transition
- Photon energy = difference in shell binding energies

Carlton & Adler, 2006

Characteristic

- Produces a discrete spectrum
- Only k-characteristic photons are useful
- Comprises 10-30% of beam (kVp > 80)

Bushong, 2004

Emission Spectrum

- Composite of Brems and Characteristic radiation
- Polyenergetic
- Heterogeneous

Bushong, 2004
Emission Spectrum

- **Quantity**
  - mAs
  - kVp
  - Filtration
  - "Z" of target
  - Distance
    - Inverse Square Law
    - Voltage Waveform

- **Quality**
  - kVp
  - "Z" of target
  - Filtration
    - Amount
    - Atomic Number
  - Voltage Waveform

Emission Spectrum (mAs: mA and Time)

- Carlton & Adler, 2006

Emission Spectrum (kVp)

- Carlton & Adler, 2006

Emission Spectrum (Atomic # of Target)

- Bushong, 2004

Emission Spectrum (Filtration)

- Bushong, 2004

Emission Spectrum (Voltage Waveform)

- Carlton & Adler, 2006
**Fundamental Properties of X-rays**

- Electromagnetic radiation
  - High Energy
  - High Frequency
  - Short Wavelength
    - (0.1 - 0.5 A)
  - Constant velocity
    - $3 \times 10^8$ m/s

Carlton & Adler, 2006

**Fundamental Properties of X-rays**

- Travel in straight lines
- Cause biological damage
  - Ionization
  - Photoelectric Effect
  - Compton Scatter
  - Excitation
- Cause phosphorescence
- Undetectable by human senses

Carlton & Adler, 2006

**Imaging Equipment**

- Types of Radiographic Units
- Components of Radiographic Units
- X-Ray Generator, Transformers, and Rectification System
- Components of Fluoroscopic Units
- Components of Digital Imaging Units
- Accessories

**Types of Units**

- Stationary
  - Radiographic
  - R & F
- Mobile
  - Radiographic
  - Fluoroscopic (C-arm)
- Specialized/Dedicated
  - Chest units
  - Tomography units
  - Mammography
  - Bone Densitometry

**Basic Radiographic Units**

- X-ray Tube
- Control Console

**X-ray Tube Design**

- Basic Components
  - Envelope
  - Cathode Assembly
  - Anode Assembly
  - Induction Motor
- Held within the Tube Housing
**Tube Housing**
- Provides mechanical support for x-ray tube
- Absorbs leakage radiation
- Protects against electric shock
- Aids in heat dissipation

**Envelope**
- Pyrex Glass / Metal
- Vacuum Tube
- Port Window

**Cathode Assembly**
- Negative electrode
- Components:
  - Filaments
  - Electrical connections
  - Focusing cup

**Anode Assembly**
- Positive electrode
- Decelerates projectile electrons
- Types:
  - Stationary
  - Rotating

**Anode Assembly**
- Designed according to the Line Focus Principle
  - Large actual area for heat dissipation
  - Small projected area for improved detail

**Induction Motor**
- Two parts:
  - Stator (external)
  - Rotor (internal)
- Rotation speed:
  - Normal 3000-3600 rpm
  - High Speed 10,000 rpm
Control Console

- kVp selector
- mA selector
- Time selector
- Rotor Switch
- Exposure Switch

kVp Selector:
- Sets voltage difference between cathode and anode
- Controls kinetic energy of projectile electrons
- Controls beam quality

mA Selector:
- Sets filament current
- Controls heating of the filament and thermionic emission
  - (# of electrons available for x-ray production)
- Controls beam quantity

Time Selector:
- Sets length of exposure
- Controls how long electrons are allowed to flow from the cathode to the anode
- Controls beam quantity

Rotor Switch
- Brings rotor up to speed
- Triggers filament heating
- Triggers grid in Bucky (if activated)

Exposure Switch
- Completes circuit
- Initiates kVp production

Circuit Components Associated with Control Panel

- kVp Selector – Autotransformer
- mA Selector – Rheostat
- Time Selector – Timer circuit
- Rotor Switch – Stator of induction motor
- Exposure Switch – Remote switch
Timer Circuit

- Manual
  - Mechanical
  - Synchronous
  - Electronic
  - mAs timers
- AEC / AED
  - "phototimer"
  - Automatically terminates exposure after a preset amount of radiation has reached the image receptor

AEC / AED

- Utilizes a flat, parallel plate ionization chamber
- Minimum response time
  - 1 mSec

AEC / AED Detectors

- Must select correct photocells
- Must set optimum kVp level
- Must set backup timer
  - 150% of expected time
  - 600 mAs

AEC / AED Density Control

- -3, -2, -1, 0, 1, 2, 3
- Changes mAs
  - 25-30% (Papp)
  - 12-15% (Carlton & Adler)
- Changes OD
  - 0.1 (Bushong)
  - 0.15 (Carlton & Adler)
  - 0.2–0.25 (Papp)

X-ray Tube Operation

- Warm-up Procedures
- Tube Rating Charts
- Anode Cooling Curves
- Heat Unit Calculations

Tube Warm-up Procedures

- Prevents thermal shock
  - cracking of a cold anode
- Refer to manufacturer’s guidelines
  - 2-3 moderate exposures
  - Automated series of exposures
**Tube Rating Charts**
- Determines if a set of exposure factors is "safe" for tube operation.

**Anode Cooling Curve**
- Used to determine the amount of time the anode must cool in order to make additional exposures.

**Heat Unit Calculations**
- HU = kVp * mA * Time * Generator Factor
- Generator Factors:
  - Single Phase: 1.0
  - Three Phase, 6-pulse: 1.4
  - Three Phase, 12-pulse: 1.4
  - High Frequency: 1.4

**Tips for Extending Tube Life**
- Warm up the anode.
- Don’t hold the rotor switch unnecessarily.
- Use lower mA stations when possible.
- Use lower rotor speed when possible.
- Don’t make repeated exposures near the tube loading limit.
- Don’t use the tube when you hear loud rotor bearings.
- Use the appropriate operational charts.
X-ray Generation and Rectification

• Basic Electronics
• Transformers
• Rectification
• X-ray Circuit

Simple Electric Circuit

• Components
  – Conductor
  – Voltage Source
  – Resistor

Circuit Factors

• Current (I)
  – Unit: Ampere
• Voltage (V)
  – Unit: Volt
• Resistance (R)
  – Unit: Ohm

Ohm’s Law

• \( I = \frac{V}{R} \)
• The current flow in a circuit is directly proportional to the voltage and inversely proportional to the resistance.

Types of Circuits

• Series Circuit
• Parallel Circuit

Series Circuit

• All components are connected in a row on the main conductor.
Effect of Series Circuit on Circuit Factors

- \( I_t = I_1 = I_2 = I_3 \)
- \( V_t = V_1 + V_2 + V_3 \)
- \( R_t = R_1 + R_2 + R_3 \)

Parallel Circuit

- Components are connected on separate branches of the circuit.

Effect of Parallel Circuit on Circuit Factors

- \( I_t = I_1 + I_2 + I_3 \)
- \( V_t = V_1 = V_2 = V_3 \)
- \( \frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} \)

Transformers

- Principle of operation: Electromagnetic Induction
- Effect on circuit factors:
  - Voltage
  - Current
- Types:
  - Fixed Ratio
  - Variable Ratio

Transformer Laws

- Transformer Ratio = \# of secondary turns \# of primary turns
  - \( TR > 1 \): step-up transformer
  - \( TR < 1 \): step-down transformer
Transformer Laws

- $\frac{V_{\text{secondary}}}{V_{\text{primary}}} = \frac{N_{\text{secondary}}}{N_{\text{primary}}}$
- $\frac{I_{\text{secondary}}}{I_{\text{primary}}} = \frac{N_{\text{primary}}}{N_{\text{secondary}}}$

Transformer Placement in Circuit

Rectification

- Definition
- Devices
- Cycle Modifications
- Voltage Ripple

Rectification

- The process of converting AC to pulsating DC for more efficient X-ray tube operation.

Types of Rectifiers

- X-ray tube
- Valve Tube
- Solid State Devices

Cycle Modifications

- 1Ø, Full Wave
  - Inverts the negative alteration to produce 2 electrical pulses/cycle
  - 100% voltage ripple
Cycle Modifications

• 3 Ø, 6-pulse
• Synonymous with 3 Ø, half-wave rectification
• 13-25% voltage ripple

Carlton & Adler, 2006

Cycle Modifications

• 3 Ø, 12 pulse
• Synonymous with 3 Ø, full-wave rectification
• 4-10% voltage ripple

Carlton & Adler, 2006

Cycle Modifications

• High Frequency Generators
  – 500-5000 Hz
  – < 1% voltage ripple

Bushong, 2004

Cycle Modifications

Carlton & Adler, 2006

Completed X-ray Circuit

Quality Control

• Beam Restriction
• Recognition and Reporting of Malfunctions
• Shielding Accessories
Beam Restriction

- Beam Restriction
  - Light Field/ Radiation Field Alignment:
    - +/- 2% of SID
  - PBL: +/- 2% of SID
- Central Ray Alignment

Radiographic Unit Maintenance

- Equipment Calibration
  - kVp
  - mA
  - Timer
  - SID

Equipment Calibration

- kVp: +/- 5%
- mAs
  - Linearity: +/- 10%
  - Reproducibility: +/- 5%
  - Reciprocity: +/- 10%
- Timer accuracy:
  - +/- 5% > .01s
  - +/- 20% < .01s
- SID: +/- 2%

Shielding Accessories

- Lead Apparel Check
  - Bi-annually
  - Fluoroscope/ Radiograph

Be A Professional Radiographer

- Know how your equipment operates
- Understand your technical factors
- Your knowledge and skills result in better patient outcomes!