SAWA UNIVERSITY

اساسيات الفيزياء الشعاعية/ الكورس الاول

GENERATING THE TUBE VOLTAGE

Sawa University — جامعـــــــة ســــــــاوة الاهلية

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Second Stage — المرحلـــــــــــــــة الثانية

محاضرة رقم (1) — الجانب النظري

Lecture No. (1) — Theoretical

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(X-RAY PRODUCTION)

- X-ray production requires three essentials:

1. Source of electrons (filament heating).
2. Acceleration of electrons (tube voltage, kVp).
3. Rapid deceleration at the target (anode).

- Efficiency: only <1% of electron energy → x-rays, >99% → heat.
- Thus, careful control of voltage, current, and time is critical for quality imaging and equipment safety.

(GENERATING TUBE VOLTAGE (KVP))

- Definition: The potential difference applied between the cathode and anode of the x-ray tube.
- Determines:

- Electron speed (kinetic energy).Maximum photon energy (keV).
- Formula: $E_{max}(keV) = e \times v_{tube}$

- Example: 120 kVp → photons with max energy of 120 keV.
- Higher voltage = shorter wavelength, higher penetration power.

(HIGH-VOLTAGE SUPPLY)

- Uses step-up transformer (converts ~220 V → 30–150 kVp).
- Rectification circuits ensure unidirectional current:

- Single-phase (obsolete, 100% ripple).
- Three-phase 6-pulse & 12-pulse (reduced ripple, improved efficiency).
- High-frequency generators (modern standard, <1% ripple).

- Ripple affects photon output: less ripple = more consistent x-ray beam.

(EFFECT OF KVP ON IMAGE & DOSE)

- Higher kVp:
- More penetrating X-rays.
- Lower image contrast (longer grayscale).
- Reduced patient dose for the same image receptor exposure.
- Lower kVp:
- Higher contrast (shorter grayscale).
- Increased patient dose due to absorption.
- Clinical example:
- Chest x-ray → 110–125 kVp (needs penetration).
- Extremities → 50–65 kVp (requires contrast).

(EXPOSURE TIME)

- **Definition:** Duration for which electrons cross tube = time x-rays are produced.
- Controlled by electronic timers (modern).
- Expressed in milliseconds (ms).
- Directly influences total radiation output:

$$mAs = mA \times s$$

- Key role: minimizing motion blur (heart, lungs, pediatrics).

(EXPOSURE TIMER TYPES)

1. **Mechanical Timers** – old, inaccurate, only seconds.
2. **Synchronous Timers** – linked to AC supply cycles (60 Hz → 1/60s resolution).
3. **Electronic Timers** – most common, accurate to <1 ms.
4. **AEC (Automatic Exposure Control):** stops exposure once the image receptor receives enough radiation → dose optimization.

(FALLING LOAD PRINCIPLE)

- A generator method where exposure begins with maximum tube current (mA), which gradually decreases as the tube heats up.
- Benefits:

- Shortest possible exposure time.
- Maintains constant kVp.
- Prevents anode overheating.

- Applications: angiography, CT, fluoroscopy, cardiac imaging.

(FALLING LOAD CURVE VS. FIXED LOAD)

- Fixed load: constant mA throughout exposure → longer exposure time.
- Falling load: mA decreases → faster exposure.
- Visual analogy: draining water from a tank by opening the valve wide at first, then narrowing as the tank empties.
- Advantage: allows imaging of moving structures (e.g., blood vessels) without blur.

(FILAMENT VOLTAGE)

- Filament = tungsten coil heated by low voltage (~6–12 V, 3–5 A).
- Heating → thermionic emission: electrons "boiled off" the cathode.
- Forms electron cloud (space charge).
- Tube current (mA) directly depends on filament temperature.

(RELATIONSHIP BETWEEN PARAMETERS)

- kVp → controls photon energy (quality).
- mA → controls photon quantity (intensity).
- Time (s) → determines total exposure.
- mAs = mA × s → controls image receptor exposure.
- Example:

- 100 mA × 0.5 s = 50 mAs.
- 200 mA × 0.25 s = 50 mAs (same dose, less motion).

(HEAT AND TUBE LOADING)

- 99% energy → heat, only 1% → x-rays.
- Filament overheating = burnout risk.
- The tube housing features oil and cooling fans.
- Falling load prevents instant overload by distributing heat across exposure.
- Heat Units (HU):

$$HU = kVp \times mA \times s \times phase\ factor$$

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(SUMMARY)

- **Tube voltage**: controls penetration & contrast.
- **Exposure timing**: balances dose & motion blur.
- **Falling load:** optimizes exposure time & tube protection.
- **Filament voltage**: regulates electron supply → x-ray output.
- Integration of all ensures quality diagnostic images with minimum patient risk.

QUIZ

Q 1: WHICH COMPONENT IN THE X-RAY CIRCUIT PRIMARILY DETERMINES THE TUBE VOLTAGE (KVP)?

A. AUTOTRANSFORMER B. RECTIFIER C. FILAMENT TRANSFORMER D. EXPOSURE TIMER.

Q2: THE PRIMARY PURPOSE OF THE EXPOSURE TIMER IN RADIOGRAPHIC EQUIPMENT IS TO:

A. CONTROL THE INTENSITY OF X-RAYS B. LIMIT THE EXPOSURE DURATION TO AVOID PATIENT OVEREXPOSURE

C. REDUCE THE FILAMENT HEATING D. INCREASE THE ANODE ROTATION SPEED

Q 3: FALLING LOAD TECHNIQUE IS MAINLY USED IN RADIOGRAPHIC SYSTEMS TO:

A. REDUCE THE TUBE VOLTAGE DURING EXPOSURE B. ACHIEVE THE SHORTEST POSSIBLE EXPOSURE TIME

C. MAINTAIN CONSTANT TUBE CURRENT D. MINIMIZE PATIENT DOSE

Q 4: THE FILAMENT VOLTAGE WILL RESULT IN:

A. INCREASED NUMBER OF ELECTRONS IN THE TUBE CURRENT B. HIGHER PHOTON ENERGY OF X-RAYS

C. LONGER EXPOSURE DURATION D. REDUCED SPACE CHARGE AROUND THE FILAMENT

Q 5: WHICH OF THE FOLLOWING CORRECTLY MATCHES THE PARAMETER WITH ITS DIRECT EFFECT?

A. TUBE VOLTAGE (KVP) → DETERMINES ELECTRON NUMBER B. FILAMENT VOLTAGE → DETERMINES X-RAY ENERGY

C. EXPOSURE TIME → DETERMINES PHOTON QUANTITYD. FALLING LOA D → REDUCES ANODE HEATINGCORRECT

Any questions?

Thank You