X-ray Circuits, Generators and Equipment

This unit will be an introduction into the x-ray circuitry and various types of x-ray equipment.

Diagnostic Radiographic Equipment

• All diagnostic x-ray equipment have three basic components:
  – the x-ray tube (discussed later)
  – the operation console
  – the high-voltage generator

Diagnostic Radiographic Equipment

• Comes in a variety of configurations to meet the specific needs of the technologist. Some different types of diagnostic x-ray machines are:
  – Tomography
  – Urology
  – Mammography
  – Portable
X-ray Tables

- Fixed (pedestal)
- Floating (movable in all directions)
- Tilting
- Some have attachments to help with exams:
  - Footboards
  - Handles
  - Shoulder supports
  - Side rails

X-ray Tube Supports

- A variety of configurations:
  - Wall-mounted
  - Floor-mounted
  - Floor-to-ceiling
  - Overhead suspension
  - Mobile x-ray tubes
  - C-arm x-ray tubes

The Control Panel

- Three primary controls:
  - kVp - quality
  - mA
  - Time (s)
    quantity
- Auxiliary controls
  (anatomical programs and AEC controls)
Main X-ray Circuit

• Two divisions to the main x-ray circuit:
  – Primary or control console section
    • Incoming current
    • Exposure switch
    • Autotransformer
    • Primary winding of the step-up transformer
  – Secondary or high voltage section
    • Secondary step-up transformer
    • Full-wave rectification circuits
    • Wiring leading to & from the x-ray tube

Filament X-ray Circuit

• mA Selector
  – is a Rheostat (variable resistor)
  – Adjusts resistance and is represented by the mA stations on the control panel
• Filament step-down transformer
  – Responsible for changing amps into milliamps.
**Rectification**

- Process of converting alternating current (AC) to direct current (DC)
- Required to ensure electron flow in one direction – from cathode to anode
  - Half-wave
  - Two rectifiers increase heat load capacity and protect the x-ray tube

**Rectification**

- Full-wave
- Four rectifiers create a routing system sending electrons through the x-ray tube the same way every time, in effect creating DC

**Characteristics of Incoming Line Power**

- Incoming line power may be 110 or 220 volts and 60 Hz in the U.S. and Canada.
- The usual voltage taken by the equipment is 210-220v.
- May need an additional transformer to stabilize incoming voltage
Characteristics of Incoming Line Current

- Phasing
  - Single-phase
  - Three-phase, six pulse
  - Three-phase, twelve pulse
- High Frequency

Single-Phase Power

- Allows the potential of the main current to drop down to zero with every change of the current flow.
- It has a single wave form.

Three-Phase Power

- Has three waves of power flowing at evenly spaced intervals from each other:
  - One wave is starting before the previous wave is depleted
  - The overall waveform never reaches zero
How Phases Affect Generator Output

• Single phase mode
  – the voltage always drops down to zero
  – 100% ripple

How Phases Affect Generator Output

• Three phase
  – Individual voltages drop to zero but there is always an overlap of wave pulses
  – When wave pulses are rectified, the average value never drops to zero
  • Makes x-ray production more efficient
  • Easier on the equipment

How Phases Affect Generator Output

• Three-phase, 6-pulse
  – produces a 13% voltage ripple
  – voltage supply to x-ray tube never falls below 87% of maximum value.

• Three-phase, 12-pulse
  – 4% voltage ripple is produced
  – value of the voltage never falls below 96% of maximum value.
How Phases Affect Generator Output

• There is also a high frequency generator that produces less than 1% voltage ripple. Value never falls below 99% of maximum value.
• Uses inverter circuits to convert DC to a series of square pulses and capacitor banks to smooth voltage.

This is what we have in our labs!

Capacitor Discharge Mobile Units

• A capacitor builds up a charge when the circuit is closed (when exposure button is pushed)
• When pre-selected charge is reached, the capacitor completes the circuit & sends the charge to the x-ray tube.
• Disadvantage - x-ray production falls off throughout exposure (end kV is approx. 1 kV per mAs lower than starting kVp)

Battery-Operated Mobile Units

• A nickel-cadmium battery supplies the necessary charge to produce quality x-rays
• Production is of higher quality
  – They obtain higher rms* voltage
  – No possibility of leakage
  – Combined with High Freq. Technology
  – Mobile was first to benefit from High Freq.

*rms (root mean square) – calculation that takes into account the constant fluctuation of the AC sine wave. See pg. 69 of Carlton.
Falling-Load Generators

- Used to provide the highest mA settings at the shortest time possible.
  - The operator selects mAs setting
  - The computer automatically calibrates the time of exposure (allowing consistently shorter exposures)
  - The mA is therefore controlled by the falling-load generator.
  - The mA starts at the highest possible setting and "falls" throughout the exposure.
    - This causes the kV to fluctuate slightly throughout exposure.
    - Can shorten tube life due to constant use of high mA

Automatic Exposure Control (AEC) Timers:

- Photomultiplier (old type)
  - Uses a fluorescent screen & converts the light produced by the screen to an electrical charge
  - When a pre-selected charge is reached, the photomultiplier terminates the exposure
  - Must be located behind the film!

- Ionization chamber
  - Uses radiolucent material located in front of the film
  - As x-rays pass through cell, they ionize the cell, when pre-set ionization level is reached signal is generated to terminate exposure.
  - Cells must be calibrated to a particular film/screen combination when installed
  - The body part in front of the cell determines how long it takes for the pre-set ionization level to be reached.
Problems with Minimum Reaction Time

- The time needed for the AEC & generator to terminate an exposure, also called response time
  - Short exposure times must be long enough to get a reading from the AEC & to the generator.
    - It is easy for the machine to overexpose the radiograph
    - Fast film & screen speeds also contribute to this problem.
    - This was a problem with older units and is less of a factor today

Backup Timers with AECs

- A safety device used to terminate the exposure if the AEC fails to do so
- As a rule, the backup timer cannot exceed the tube limit & it should be set at 150% of the expected manual exposure mAs

Manual Timers

- Synchronous timer – uses a synchronous motor that turns a shaft at 60 rps (times are a subdivision of this 1/60, 1/20, 1/30).
- Electronic timer – most sophisticated and most accurate, based on time required to charge a capacitor through a variable resistor. Accurate down to 1ms.
- mAs timer – used with falling load generators, monitors product of mA and time (tube current) and is the only timer located in the secondary circuit.
Tomography

• Purpose – to enhance the visualization of structures in a plane of interest by blurring adjacent structures.
• Principle – by moving the x-ray tube and film in opposite directions, a plane is visualized at the fulcrum (pivot point)
  – Structures beyond the fulcrum “travel” a greater distance across the film and are blurred.
  – Structures at the fulcrum “travel” a lesser distance across the film and remain relatively focused

Tomography

• Considerations
  – The wider the tomographic arc the thinner the cut. (30 – 40 degrees typical)
  – Must have an exposure time long enough to allow exposure throughout tube travel (low mA long exposure time. Example 20 mA @ 2 sec = 40 mAs)
  – Tomography has a high patient dose
  *Note: For nephrotomography measure patient in cm, divide answer by 3 and add 1 for first cut.
Tomography

• Motions:
  – Linear is still in use today, primarily for IVPs
  – Other motions were designed and used prior to CT and MRI to improve blurring and get better images. (see text for examples and descriptions of motions)