Radiography Instrumentation

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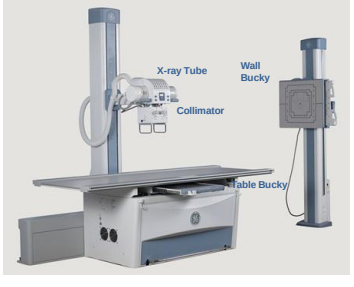
Overview

- X-ray Tube Design
- X-ray beam-shaping
- Anti-scatter grid
- Automatic exposure control (AEC)
- Radiographic detection systems

Radiography System



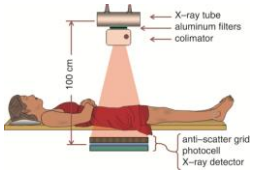
Stationary Radiography System

Mobile Radiography System

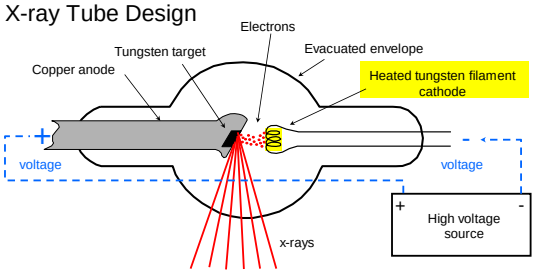
Radiography System

Key components of a radiography system:

- Generator - power supply
- X-ray tube - source of photons
- Filter - removes low energy photons
- Collimator - modifies the size of the X-ray beam
- Anti-scatter grid - removes scattered photons reaching image detector and improves image quality
- Image detector
  - ✓ Photostimulable image plate (CR)
  - ✓ Flat Panel Detector (DR)



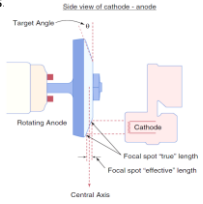
X-ray Tube Design



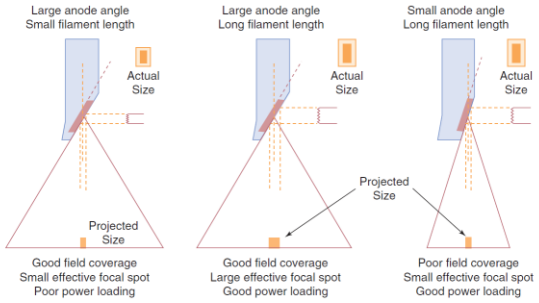
- X-rays: produced from conversion of electron kinetic energy into high energy electromagnetic radiation
- Electrons are emitted from a heated filament at the cathode
- Voltage between cathode (-) and anode (+) accelerates electrons in vacuum up to an energy equal to the potential difference

Anode Angle & Focal Spot

- **Anode angle** is the angle of the target surface w/ respect to the central ray in the x-ray field
  - Angle is usually between 8 - 20 degrees.
  - More area for X-ray production, better heat capacity
- The area generating x-rays is called **focal spot.**
  - Actual fs: actual area struck by electrons
  - Effective fs: the projected fs area at the central ray.
  - Effective fs < actual fs
  - Typical fs size: 0.6mm and 1.2mm

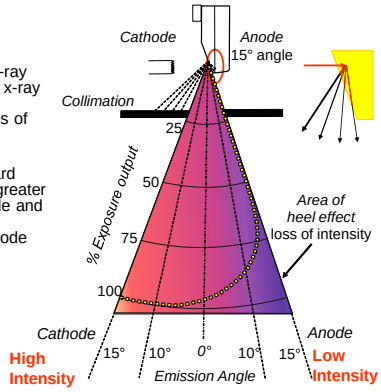


Anode angle, focal spot, and field coverage tradeoffs



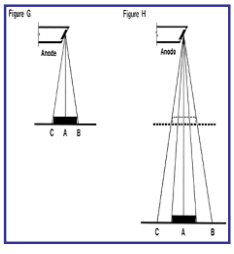
Heel effect

- The intensity of the x-ray beam that leaves the x-ray tube is not uniform throughout all portions of the beam.
- Photon directed toward anode side transit a greater thickness of the anode and experience more attenuation than cathode side

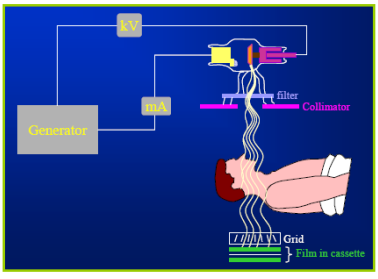


Clinical Implications

- The heel effect is less noticeable
  - when larger source-to-image distance is used
  - when smaller size film is used
  - when anode angle is increased
- The heel effect can be taken advantage of by placing denser parts of the body under the cathode side of the tube and thinner parts under the anode side.



X-Ray Beam-shaping

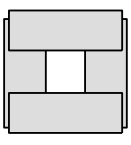


Filtration

- To remove non-diagnostic, low-energy photons from the primary beam.
  - do not contribute to image formation
  - increase patient dose
- Inherent filtration
  - X-ray tube port (glass or metal insert)
  - Housing oil
  - Field light mirror
  - ~ 0.5 mm Al equivalent
- Added filtration
  - sheets of metal intentionally placed to remove low energy photons
  - Al and Cu material most used
  - typically 0~3.0mm of Al in Radiography
  - Additional filtration increases the mean energy of the beam.

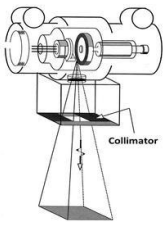
Beam Collimation

- Collimators adjust the size and shape of x-ray field emerging from the tube port.
- Collimator using adjustable parallel-opposed lead blades (shutters) defines the x-ray beam size used
- Rectangular arrangements common in radiographic units
- Major functions of collimators:
  - Prevent unnecessary patient exposure
  - Reduce scatter radiation and improve image contrast



Positive Beam Limitation (PBL)

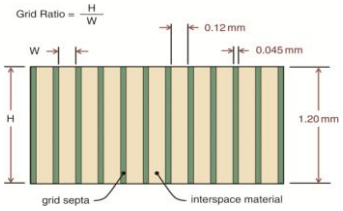
- PBL collimators automatically limit the x-ray field size to the useful area of the detector.
- Mechanical sensors in the cassette holder detect the cassette size and location and automatically adjust the collimator blades so that the x-ray field matches the cassette dimensions.



Anti-scatter Grid

- Grids remove x-rays that are scattered in patient's body
- Grid is placed between patient and image detector.
- Grid construction: series of lead strips spaced apart other materials such as aluminum
- Grid slits are aligned with the primary radiation.
- Primary radiation preferentially passed through grid matrix
- Scatter preferentially absorbed in lead strips

Grid Ratio



- Grid ratios range from 4:1 to 17:1. Typical value is 10:1 for general radiography.
- Higher grid ratios remove more scattered x-rays but results in greater radiation doses to patient.

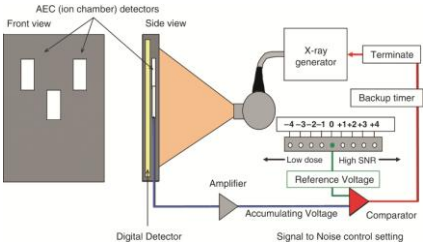
Bucky Factor

$$\text{Bucky Factor} = \frac{\text{exposure with grid}}{\text{exposure without grid}}$$

- Estimates increased exposure to receptor (and radiation dose to patient) resulting from use of grid
- Value > 1, typical values ranges from 2 ~ 5
- Grid ratio ↑→ Bucky factor↑ → patient dose↑

Automatic Exposure Control (AEC)

- Purpose: to provide consistent exposure to image receptor regardless of patient thickness.
- Phototimers measure the actual amount of radiation incident on the image receptor and terminate x-ray production when the proper radiation exposure is obtained.

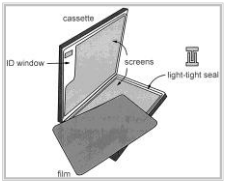


Radiographic Detectors

- Screen/film systems
- Computed radiography (CR)
- Flat panel detectors (FPD)

Screen-Film System

- Majority of radiographic imaging procedures are S/F based in last century.
- S/F system: a sheet of film with light-sensitive emulsion on both sides is sandwiched b/w two intensifying screens.



- Disadvantages:
  - Narrower exposure range
    → under or over exposure → high retake rate
  - Dark room and Film processing
  - Image storage and transfer

Digital Detection Systems

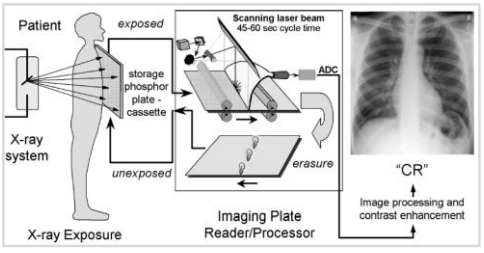
- Photostimulable Phosphor (PSP)
  - Computed radiography (CR)
- Flat Panel X-ray Imaging (DR)
  - Indirect detection systems
  - Direct detection systems

Computed Radiography (CR)

- Uses conventional x-ray machine together with an imaging plate made of a photostimulable phosphor.
- Image plate is placed in a cassette similar to old film/screen systems.
- CR image plates (IP) are re-usable and resulting images are digital.
- After exposure an image plate needs to be "read" by a special CR reader system using lasers.
- Electronic signals are produced by a reader system which are proportional to the absorbed x-ray energy.

http://www.medicalimagingsystems.com/equipment/computed/

CR Imaging System



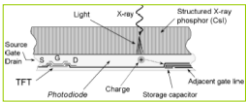
Digital Radiography (DR)

- Uses flat panel image detector that converts X-ray energy into electronic signals.
- No "reader" system is necessary.

Two FPD Technologies

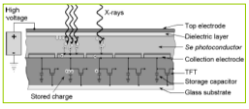
Indirect Detection FPD:

Conversion of x-rays into light which in turn gets converted to electronic signal

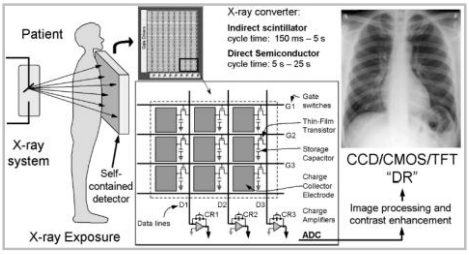


Direct Detection FPD:

Conversion of x-rays into electronic signal (no screen).



DR Imaging System



Compared to CR:

- No Image plate and reader needed
- Rapid display of acquired image
- Better image quality
- Higher image acquisition speed
- Increased patient throughput
- Higher initial cost

Exposure Index (EI)

- Exposure index (EI) in digital radiography has been used to indicate the relative speed and sensitivity of the digital receptor.
- It provides feedback in regard to achieving optimal images at the lowest dose.
- EI doesn't directly indicate patient dose.
- It is importance to track and evaluate EI values in an effort to ensure correct use of the equipment and to optimize radiation dose on an exam-by-exam basis for appropriate patient care.

References

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  - Page 182-185; Chapter 7.3; 7.5
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  - Projection X-ray Image: (3) Radiographic Image Receptors
  - Projection X-ray Image: (6) Radiographic and Mammography Systems (Radiography system only)
- Korner et al. Advances in digital radiography: physical principles and system overview. Radiographics. 2007 May-Jun;27(3):675-86.