Presented by Brian Wilson, CBET, CRES.
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**Grids**

- Grids are filters that prevent deflected radiation from causing poor image quality.
- Invented by Dr. Gustav Bucky, the original design left line artifacts on the image.
- Dr. Bucky found moving the grid during exposure reduced grid artifact and improved image quality.
Portable Grid
Grids Reduce Scatter
Grid Ratio

- Grid Ratio is determined by taking the height of the strips divided by the distance between them.

- Example, if a lead strip is ten units high and one unit apart. The grid ratio would be 10 to 1 (10:1)

- Some popular grid ratios include 5:1, 6:1, 8:1, 10:1, 12:1

- The higher the grid ratio, the better the image quality. The mA must be increased with the ratio.
Grid Identification

Ratio: 8:1
Focus: 40-72SD
LPI: 178
Serial#: 123415
Date: 7/8/10
Model#: P1417

PROTECT-A-GRID

Manufactured by REINA IMAGING, Crystal Lake, IL 800-755-4116
Grid Frequency

- Grid Frequency is the number of grid lines per inch or cm.
- Low frequency grids have about 100 to 120 lines per inch.
- Medium frequency grids have about 120 to 150 lines per inch.
- High frequency grids have about 150 to 180 lines per inch.
Grid Types

● Focused grid- is where the lead strips are angled inward as they move away from the center of the grid. The grid is designed to work at a set focus in relation to the beam.

● Crossed grid- is two grids merged together to form both horizontal and vertical grid lines.

● Linear (Parallel) grid- is several lead strips laid out in a parallel pattern. Also known as an unfocused grid. Not recommended for FFD’s under 56 inches.
Focused Grid
Grid Cutoff

- **Distance De-Centering** - is caused by using the wrong FFD (Focal Film Distance) in relation to the focused grid. This will cause cutoff of the image along the borders and reduce optical density.

- **Lateral De-Centering** - is caused when the primary beam is not correctly aligned with the grid center. This will reduce optical density and cutoff portions of the image.
Off Focus Cutoff
Off Center Cutoff
Grid Cutoff

- Inverted focused grid-results in a severe cutoff of the edges of the image. Also results in a dark exposure in the center of the image.
- Parallel grid cutoff-will cause decreased density towards the edges of the film. And the grid strips will make shadows on the image. This is a result of the grid being misaligned to the beam.
Inverted Focused Grid
Energy Conversion

- X-Ray conversion from electrons results in 99% heat and 1% photon energy.

- This conversion can be divided into two types of energy.
  - Broad spectrum General (Brems)
  - Narrow spectrum (Characteristic)
Electromagnetic Energy

- General Radiation or Bremsstrahlung (Brems) is an energy conversion to photons from electrons that have been slowed down.

- Characteristic Radiation is energy conversion from electrons striking a target material (anode) to photons.

- Anode material determines the efficiency of x-ray production and the type of characteristic radiation emitted.
Brems
Ionizing Radiation

- Variation of x-ray production with kV and mA.
  - As kV increases, photon energy increases.
  - kV also effects the amplitude of Characteristic Radiation.

- mA controls the rate of photon production.
Radiation Units

- Roentgen (R) is the unit used to express the intensity of the x-ray beam at a given point.
- Inverse Square Law - the intensity of an x-ray beam is inversely proportional to the square of the distance from the x-ray source.
  
  \[
  \text{Dose at Distance 2} = \frac{(\text{Distance 1})^2}{(\text{Distance 2})^2} \times (\text{Dose at distance 1})
  \]

- 1 Gray (Exposure) = 115 Roentgen.
Radiation Units

- **RAD** (Radiation Absorbed Dose) Quantity of energy absorbed per kilogram. Used to express the radiation dose received by an object.

- **REM** (Radiation Equivalent Man) Absorbed dose, used to express the biological effects of radiation on body tissues. It's based on the dose received by the patient.
  
  - 1 REM = 1 RAD
Radiation Units

- 1 Gray (Gy) = 1J/Kg = 100 RAD
- 1 cGy (Centigray) = 1RAD
- 1 Sievert (Sv) = 100 REM
- 1 mSv (millisievert) = 100 mREM
X-Ray Tube

- Tube housing - made of aluminum and lined with lead.
- Controls scatter and leakage radiation.
- Isolates high voltage.
- Cools the tube.
X-Ray Tube Cutaway
X-Ray Tube

● Frame - made of glass, steel or copper.

● Provides a mount for the cathode and anode.

● Provides high voltage insulation.

● Maintains the tube's vacuum.
X-Ray Tube Diagram

- glass envelope
- rotating anode
- stator of induction motor
- bearings
- rotor/iodine support
- cathode block
- focusing cup
- electrons
- target
- exit window
- rotor
X-Ray Tube

- Cathode - supplies the electrons for x-ray production.

- Filaments - are coiled wires made of tungsten. They produce the stream of electrons.

- Focusing Cup - is used to focus the stream of electrons towards the anode.
Dual Focus X-Ray Tube

- Dual focus x-ray tubes have two filaments.
- Both filaments housed in the same focus cup.
- The small filament is for lower dosage levels.
- The large filament is for higher dosage levels.
X-Ray Tube

- The anode has a positive charge.
- Produces photons and heat, when electrons from the cathode strike it.
- Two types of anodes, with stationary or rotating targets.
- Stationary targets have a lower rating & tube life.
- Rotating targets are the most commonly used.
X-Ray Tube

- Rotating targets are able to take more heat, typically add to a longer tube life.

- The rotor is an induction motor that spins the target during x-ray production.

- The bearing assembly supports the rotor and target assemblies.
X-Ray Tube

- Anode heel effect - photons leave the anode target at an uneven intensity. The x-ray beam is more intense towards the cathode side of the tube.
- Penumbra - is the out of focus blur around the edges of the image. This is caused by the x-ray beams hitting the receptor at different angles.
X-Ray Tube

- Actual Focal Spot - Is the area of the anode where the beam of electrons from the cathode are focused on.
- Effective Focal Spot - is the area on the anode that the focused beam of photons is emitted from.

This is the point where the x-ray beam can be measured from.

The effective focal spot will increase in size as the x-ray tube ages.
X-Ray Tube

● Heat Units (HU) are used to measure the maximum heat the anode target can take before damage occurs.

● The (HU) formula for a single phase generator is $kV \times mA \times \text{time. (in seconds)}$

● The (HU) formula for a three phase generator is $Kv \times mA \times \text{time (in seconds)} \times 1.35$

● Heat ratings can also be calculated in joules. $\text{Joule} = \text{HU} / 1.4$
Tube Heating Protection

- Modern x-ray systems have software to track the heat units (HU) produced by the x-ray tube.
  - This protects the anode and other tube components from heat damage.
- Older x-ray systems have heat transducers that are located inside the x-ray tube.
  - When the temperature limit is exceeded, the power to the tube is disabled until the tube cools down within its operating range.
Tube Loading Charts

- Older x-ray systems have a tube loading chart that is used by the technologist to calculate maximum kV and mA output at any given setting.

- This is to prevent damage to the tube from overloading its physical limits.

- Modern systems have software built in to protect the tube from exceeding the maximum kV & mA settings.
Tube Loading Charts

[Diagram showing loading charts for different currents and exposure times]

Maximum Exposure Time in Seconds
Space Charge

- Space charge is where electrons cluster around the filament and do not leave until they acquire enough thermal energy to break free.

- This normally happens at lower kV settings.

- The higher the kV, the lower the filament heat current.
Generators

- Generators provide the power to the X-ray tube.
- Available in several different sizes and types, depending on the application.
- Output waveforms and amount of ripple to the tube, vary from the different types.
HF Generator
Self Rectified Generator

• The X-Ray Tube acts as the rectifier.

• Current only flows from the cathode to the anode.

• Power is from the secondary of the high voltage transformer.

• Used in dental and mobile units.
Half Wave Rectified Generator

- Connected to the secondary of the high voltage transformer, through a diode rectifier.
- Only the positive side of the AC waveform is rectified.
- 60 pulses per second and 100% ripple to the tube.
- Considered to be inefficient, with its use of only 50% of the available power.
Single Phase Generator Output
Full Wave Rectified Generator

- Both the positive and negative sides of the AC waveform are utilized.
- Power is supplied from the secondary of the high voltage generator and is fed through a bridge of four rectifiers.

- It has a short exposure time available.
- Much more output than self or half rectified designs.
Falling Load Generator

- Provides highest mA settings in the shortest time possible.

- The mA starts at the highest setting and falls through the exposure.

- This model causes excessive wear on the tube due to the use of high mA settings.
Capacitor Discharge Generator

- The generator is supplied by a capacitor.
- Smaller and less expensive than battery powered generators.
- Lower power output.
- Needs time to recharge between exposures.
Three Phase, 6 Pulse Generator

● The generator is supplied by three phased AC inputs.
  ● Each AC input is fed into a "wye" step up transformer. Then is supplied to the rectifier.
● The AC power is then rectified and combined as a single DC waveform.
● The waveform is in six smaller peaks, with a 13% ripple effect to the tube.
● Offers greater efficiency and less ripple over single phase designs.
Three Phase, 6 Pulse Output
Three Phase, 12 Pulse Generator

- The generator is supplied by three phase AC power.
- A combination wye-delta transformer is used to create a twelve pulse waveform.
- The twelve pulse generator has half the ripple of the 6 pulse generator. And is much more efficient than single phase designs.
Three Phase, 12 Pulse Output
High Frequency Generator

- The generator is supplied by three phase AC power.
- Most commonly used type in modern systems.
- Creates a virtual ripple free waveform.
- Converts AC power to a flat DC voltage, using a inverter / chopper circuit.
- Smaller and lighter than other generator models.
High Frequency Generator Output
High Frequency Generator Block Diagram
Battery Powered Generator

- The generator is supplied by several rechargeable DC batteries.
- Used in mobile x-ray equipment.
- Allow for the same performance as High Frequency generators, but at a lower output.
- Only require standard AC power to recharge the batteries.
Exposure Control Timers

- Used on older model units.
- Can be either mechanical or electronic.
  - Mechanical versions turn at 60 rps.
  - Electronic versions more reliable and accurate than mechanical versions.
- Timers terminate exposure after a preset time.
- Not as accurate as AEC controlled models.
Automatic Exposure Control

- Older units use a photomultiplier tube.
- Located behind the image receptor.
- The photomultiplier tube produces a charge when exposed to the X-Rays.
- When the preset charge is reached, the generator is shut off and the exposure is terminated.
Exposure Control Console
Automatic Exposure Control

- Current models use an Ion Chamber.
- Located ahead of the image receptor and behind the object being imaged.
- The Ion cell ionizes when exposed to the X-Rays.
- When the preset level is reached, the generator is shut off and the exposure is terminated.
Imaging Modalities

- Diagnostic radiographic x-ray.
- Diagnostic fluoroscopic x-ray.
  - Linear tomography.
- Computed tomography (CT).
Radiographic System
Fluoroscopic System
Linear Tomography
Computed Tomography (CT).
Imaging Modalities

- Diagnostic ultrasound.
- Magnetic Resonance Imaging (MRI).
- Nuclear Medicine.
- Mammography.
Ultrasound Unit
MRI Unit
Nuclear Medicine
Mammography System
Interaction with Matter

- **Attenuation** - The decrease in intensity of an x-ray beam caused by absorption and scatter as it passes through an object.
- **Coherent Scattering** - is a scattered photon created by a source photon passing through an object. It has the same energy as the source photon but travels in a different direction.
- **Photodisintegration** - is when a high energy photon interacts with the mass of a atomic nucleus. This causes the nucleus to decay and emit a single photon.
Radiation Safety

- **Time** - Keep your time to a minimum amount when working around an active x-ray source.

- **Distance** - Maximize the distance between you and a active x-ray source.

- **Shielding** - Always wear a lead apron when working around a active x-ray source. If possible utilize both stationary and portable shielding to reduce exposure.
21 CFR - Performance Standards

● Half Value Layer - The thickness of pure aluminum needed to drop the intensity of a x-ray beam by 50%. Used to check the penetrating quality of the beam.

● mA Linearity - is similar generator output for the same kVp and mAs regardless of the mA station used. Output values must be +/- 10% between mA stations.

● Repeatability - The ability of the generator to repeat the same exposure for the same technique. Must be +/- 5% between exposures.
21 CFR - Performance Standards

- Half Value Layer - The thickness of pure aluminum in relation to kVp.

50 kVp = 1.9 mm of pure aluminum.
75 kVp = 2.8 mm of pure aluminum.
100 kVp = 3.7 mm of pure aluminum.
125 kVp = 4.6 mm of pure aluminum.
150 kVp = 5.4 mm of pure aluminum.

Approximate thickness of aluminum to reduce beam intensity by 50%.
21 CFR - Performance Standards

- Collimation - Cannot vary more than 2% of SID from the collimator to the image receptor.

- SID - Indicated SID cannot vary more than 5% from measured SID.

- Positive Beam Limitation - the length or width dimensions of the x-ray field must not exceed 3% of SID.
21 CFR - Performance Standards

- Fluoro Dose - Entrance skin exposure (ESE) is limited to 10R / minute. With a timer, newer systems are allowed up to 20R for short exposures.

- MQSA - Mammography Quality Standards Act. Passed by Congress to have uniform regulations for Mammography testing centers. Regulated by the American College of Radiologists.
Film and Processing

- **Developer** - Converts the latent image exposed on the film into a visible image.
  
  - **Fixing** - Removes the excess silver halide crystals. Also keeps the image from fading over time.

- **Washing** - Removes all chemicals and prevents the discoloration of the film.

- **Drying** - Allows the film to be handled, helps prevent the film from being scratched.
Film Characteristics

- **Speed** - (Sensitivity) determines how well the film responds to radiation and light.
  - **Density** - Is used to measure the blackening of the film.
- **Contrast** - Is the different film densities from white to black.
- **Latitude** - Is the range of exposures that produce usable film densities for radiographic studies.
H-D Curve

*Typical Characteristic Curve (H&D Plot)*

- $\gamma = \Delta R / \Delta \log(B)$
- Recording Range
- $R_{\text{max}}$

*Figure 1*
Film Measurement

- Densitometer - is used to measure the density of exposed and processed film.

- Sensitometer - used to create a series of exposures on a strip of film. Used for quality assurance of exposed film.

- Fog - Reduces film contrast. Can be caused by film age, improper storage and temperature. Background radiation.

- Base Density - Is the density of unexposed film. Determined by the dye used in the film base.
Film Densitometer

![Image of Film Densitometer](image-url)
Film Densitometer
Film Sensitometer
Film Screens

- Film Screens - used to convert x-rays to light. Film is more sensitive to light than x-rays. Screens allow lower dosage levels to the patient.
- Placed inside a film cassette, in front of the film.
  Made of phosphor, cesium iodide or selenium.
- Film screens must match the film's sensitivity and speed.
Fluoroscopy

- Fluoroscopy - Allows for real time, moving images of inside the patient.

- Normally viewed on a video monitor.

- Useful for both diagnostic and interventional procedures.
Fluoro Tower
Image Intensifiers

- Image Intensifiers (II's) - are used to convert x-ray photons into visible light.

- It has three major parts. The Cathode, electrostatic grids and a anode.

- Allows for a lower dose of x-rays to the patient.
Image Intensifier
Image Intensifiers

- Cathode - is the larger end of the II.

- The x-rays leaving the patient strike the input phosphor of the cathode. The photons are then converted to light.

- The light is then converted to electrons by the photo cathode.
Cathode
Image Intensifiers

- The electrons are then focused and sent across the II by the electrostatic grids.

- At the anode, the electrons are converted back into light (visible images) through the output phosphor.

- The image is then sent to the image gate, so it can be viewed and recorded.
TV Cameras

- Pick Up Tubes (PUT) - convert the output image of the II into a video signal.

- They use the older analog tube technology. They have an input cathode and a output anode.

- Some popular models include, Plumbicon, Saticon, Nuvicon and Vidicon.
Charged Couple Device (CCD)

- Charged Couple Devices (CCD) are solid state equivalents to Pick Up Tubes.
- Have lower power consumption and no warm up time compared to Pick Up Tubes.
- Resolution and contrast not as good as Pick Up Tubes.
Cut Film Camera

- Cut Film Cameras - Are movie cameras that record the output of the II.

- They are available in 100mm and 105mm film sizes.

- They can be set up in a frame by frame mode. Or can be made to run in continuous frames, up to 12 frames per second.
Cine Camera

● Cine Cameras - are 35mm movie cameras. They use motion picture film.

● They require special film processors and review viewing stations.

● The system uses a signal from the pulsed x-ray tube to open and close the shutter.

● Receives its input from the output of the II.
Computed Radiology (CR)

- Replacement for traditional film and processors.

- It utilizes a image plate (IP) that can be exposed, scanned and then reused.

- After exposure, the IP is scanned and digitized by the CR reader.
CR Reader
Computed Radiology (CR)

- Images can then be viewed and stored on a digital PACS system.
- Eliminates the cost and extra time needed for film systems.
- Utilizes existing x-ray equipment that used film previously.
Indirect Digital Imaging

- CR Readers.

- Digitizers.

- CCD Cameras connected to a digital archive.

- They allow images to be viewed and stored on a digital PACS system. Can also be modified with post exposure software.
Film Digitizer
Direct Digital Imaging

- Digital Detectors, convert photons into electrons. The electrons are digitized into a electronic signal and sent directly to a image storage system.

  - Used on both Rad and Fluoro Systems.
  
  - Images are ready instantly. No waiting for processing after the exposure is made.

- Digital detectors are very expensive. Becoming more common with newer systems..
Digital Cath Lab
Digital Detector Function

• Cesium Iodide scintillator absorbs x-ray photons and converts them to light.

  • A photodiode array absorbs the light and converts it into an electronic signal.

  • Each photodiode represents a pixel of information.

  • The pixel information is sent to a image processor and is converted into a digital image.
PACS

- Picture Archiving and Communication Systems.
- PACS is made up of four major parts.
  - Image Modality, Secure Network, Review Work Stations and a Archive for storage and retrieval.
  - PACS represents the network and equipment connected to it..
DICOM

- DICOM - Stands for Digital Imaging and Communications in Medicine.
- DICOM is the protocol that integrates the different parts of the PACS system together.
- It allows equipment from different manufacturers to work with each other on the same network.
DICOM

- DICOM has seven different layers it operates on.

- The upper levels include, Application, Presentation and Session.

- The lower levels include, Transport, Network, Data Link and Physical.