IMAGE PRODUCTION & FILM PROCESSING

By: Alvin P. Cacayan, RRT

DARK ROOM

- Radiography begins and ends in the dark room
- A scientific laboratory with a controlled environment

IMPORTANT REQUIREMENTS FOR AN EFFICIENT DARK ROOM (PROCESSING ROOM)

- Location
    - Adjacent, approximate and near the exposure room
    - Must be accessible
- Size
    - 15x9.5ft (4.5x2.9m) for DRs that processes 200 radiographs/day
    - There should be 4 feet distance between the wet and dry sections to avoid area contamination

Dry Section
- Film Bin

Wet Section
- Negatoscope; View box; Wet Film Illuminator

- Protection Against Radiation
    - Hollow Blocks: should have cement fillings within hollows
    - Concrete: minimum 6 inches thick
    - Wood: should be coated with Lead; 1.5mm Pb (one-line coat) and 0.75 (sandwich coat)
- Ventilation
    - Humidity (Moisture) Range: 30 – 60% humidity
    - Temperature: 65 – 83°F (18 – 24°C)

    DARK ROOM:
    Psychrometer – measure humidity in the dark room
    Humidity: 30 – 60%
    Temperature: 65 – 83°F (18 – 24°C)

    STORAGE ROOM:
    Hygrometer – measure humidity in storage room
    Humidity: 30 – 60%
    Temperature: 50 – 70°F (10 – 21°C)

- Air Movement
    - Ceiling Fan: 15 – 25ft/min
    - Exhaust Fan: 8 – 10 room changes of air/hour
        - ✓ Exhaust fan should be light-proof
- Cleanliness
- Light-Tight Entrance – prevent light entrance to the dark room
    - Single Door
        - Simplest type

        - Rubber Sealer – all corners of the door are covered with rubber
        - Pass box (cassette/film transfer cabinet) – allow transfer of film without using the main door
    - Double/Light-Lock Door
        - Interlocking Mechanism – door on the other side cannot be opened unless the other is fully closed
    - Labyrinth/Maze
        - Easy Access
        - Involves NO doors; space consuming
    - Revolving/Rotating Door
        - Fast Access
        - Has a heavily-tinted rotating glass capsule
- Illumination
    - White Light Illumination – for quality control and assurance
        - 2 – 4 units; 48 inches each
        - Fluorescent light
        - Possess a short duration of phosphorescence
    - Safelight Illumination – for illumination not detrimental to image quality
        - Most common source of fog
        - 40 secs: duration still safe of safelight fog
        - >40 secs: duration when safelight fog begins

        SAFELIGHT

        - Bulbs:
            - Tungsten
            - Amber
            - Sodium Vapor – for very busy dark rooms (labyrinth/maze); 6ft away
            - LED
        - Distance (from Processing Tank):
            - 3ft away: 7.5Watts; for single coat emulsion
            - 4 – 5ft away: 15Watts; for double/duplitized coat emulsion
            - 6ft away: exclusive for Sodium Vapors
        - Filters:
            - Wratten 6B (<550nm)
                - AKA Amber fil.; Kodak Morlite (produces more bright colors)
                - Only filters wavelength and intensity
                - Emits red-orange-yellow light (amber color)
            - GBX2 (<620nm)
                - AKA Red fil.; all-purpose; multipurpose; Kodak 2filter
                - Eliminates the orange and yellow colors and remain red
                - Emits only red light
        - Types:

General:
Luminescence – all types of light emission
Specific:
Fluorescence – light emitted while struck by radiation
Phosphorescence – afterglow; light still emitted after struck by radiation

Incandescent Lamp – possess the longest phosphorescence

What do Safelight Filter?
- Wavelength (550-620nm)
- Intensity
- Color
- Energy

Green – most sensitive color

- Direct (Fixture type) – downward illumination
  - Indirect (Ceiling type) – upward illumination
- Replacement:
  - Every year – for 24/7 use; for tungsten, amber and Na Vapor bulbs
  - Every 2 years – for 12/7 use; for tungsten, amber and Na Vapor bulb
  - Every 15 years – for LED

Filter INSIDE Dark Room: Safelight
Filter OUTSIDE Dark Room:
Total: 2.5 – 3.0 mm Al
Inherent: 1.0 mm Al
Added: 1.5 mm Al

Purpose of Filters:
- To reduce patient dose
- To homogenize the heterogeneous x-ray beam

- Color of Walls
  - Pastel – increase safelight illumination
  - Light -
  - Enamel/Epoxy – enamel for wood, epoxy for cement; easy to clean and durable; quick dry
  - Matte Finish – decreases white light reflectance; texture of wall should be flat, not glossy; flat color
- Electric Wiring
  - Should not be octopus wiring
  - To prevent static electric artifacts

TYPES OF PROCESSING ROOMS

- Dry Section
  - Loading Bench
  - Film Bin
  - Storage Cabinet
  - Cassette Transfer Cabinet (Pass box)
- Wet Section
  - Processing Tank (1 Master Tank, 2 Insert Tanks inside)
  - Wash Tank (single or cascade)
  - Temperature Control Unit
  - Wet-Film Illuminator (Negatoscope)
  - Film Dryer

EFFECTS OF HUMIDITY AND TEMPERATURE

- Humidity is INVERSELY proportional to temperature
- **LOW HUMIDITY** produces characteristic artifacts or **STATIC ARTIFACTS**
- Types of Static Artifacts: Tree, Crown, Smudge
- To Prevent Static Artifacts:
  - Humidity: should be 30 – 60%

- Handling: proper handling should be maintained
  - Put the film into the cassette softly and gently
  - DO NOT slide the film, sliding produces friction
- Anti-Static Compound/Solution: solutions applied to prevent static artifacts
  - Water, cotton, mild soap (or body soap)
  - Alternative: 70% Isopropyl alcohol
  - DO NOT use denatured alcohol or detergent
- Natural Fiber – cloth of attire worn by storage technologist
  - Commonly COTTON
  - DO NOT use synthetic fiber (e.g. polyester)
- Electrical Wiring
  - Prevent octopus wiring – when it short circuit, it might cause static electricity artifacts

- High temperature in the dark room produces heat fog or thermal fog, thus increasing density
- 60 – 90% of density comes from fog
- Mechanisms That Maintain Proper Moisture Thus Helping to Provide Quality Radiographs:
  - Ion Generator
  - Humidifier
  - Exhaust Fan – keeps harmful fumes out of the dark room; must be light-proof
- High Temperature in the exposure room decreases IS speed and activity, thus decreasing density
  - The low IS speed alters the bright light it emits into a darker color, which leads to poor spectral matching

Effects of Low Humidity:
In Dark R.: static artifacts

Effects of High Temperature:
In Dark R.: increase heat fog & density
In Exposure R: decrease speed & density

Spectral Matching
- Film Sensitivity – responsiveness of film to light emitted by IS
- Spectral Emission – speed and color of light emission of IS

ARTIFACTS

- Plus-Density Artifact – appears darker than its surroundings; e.g. static artifacts
- Minus-Density Artifact – appears lighter than its surrounding; e.g. those that are exposed with high atomic number

Artifact – any aberrations in the image providing no valuable information

HAZARDS AND STORAGE OF PROCESSING CHEMICALS

- Fumes of processing chemicals are toxic and carcinogenic
- Dark Room Disease – hypersensitivity to processing chemicals
- Permissible Chemical Exposure Limits:
  - Hydroquinone: 0.44 PPM
  - Phenidone: 0.2 PPM
  - Acetic Acid: 10 PPM
  - Ammonium Thiosulfate: 50 PPM
- Processing chemicals should NOT be stored near films
  - P. Chemicals release radioactive elements in the form of Potassium 40

- Emission: 7 micro Roentgens/hour (12uR/hr)
- 8uR/hr: detrimental for image quality
- Creates secondary radiation fog
- Geiger-Muller Counter – measures radiation emission (measure must not exceed the above values)

SPECTRAL SENSITIVITY OF FILM

Spectral Sensitivity – color of which the film is most sensitive to
Screen Speed – duration of which the IS is able to emit light

- Monochromatic
  - Blue light sensitive; globular grains
  - Sensitive to photon wavelengths emitted from Calcium Tungstate
  - Calcium Tungstate ($CaWO_4$)
    - emits blue violet light (indigo to violet)
    - lower speed: because of broadband emission (many colors)
- Orthochromatic
  - Green light sensitive; tabular grains
  - Sensitive to green light emitted by rare earths, particularly Gadolinium oxysulfide and Lanthanum oxysulfide
  - Oxysulfide – the agent to emit green lights
  - Rare Earths used: Yttrium, Gadolinium, Lanthanum
  - Rare Earth
    - Can produce blue and green lights, but MOST sensitive to green
    - Higher speed: because of line emission (one color)
  - Yttrium Tantalate – also emits green light, but not only green (green-blue-violet)
- Panchromatic
  - Sensitive to all visible light spectrum
  - Disadvantage: needs total darkness in the processing room (no safelight)

Types of Mottle:
Quantum Mottle – photons are randomly distributed
Spatial Mottle – phosphors are randomly distributed
Film Mottle – silver halide crystals are randomly distributed

GENERAL TYPES OF FILM

- Direct Exposure Film
  - No screen involved; purely x-ray forms the image
  - High exposure factor; high patient dose
  - Thick emulsion; single coated
- Indirect Exposure Film
  - Screen is involved; xray is converted into light by IS and absorbed by the film
  - Low exposure factor; low patient dose
  - Thin emulsion; double/duplitized coat

EMISSION OF LIGHT

- Luminescence – emission of light from the screen when stimulated by radiation
- Fluorescence
  - While/within x-ray emission
  - Phosphors emit light while struck by radiation or within a rotation or cycle
  - emits light the same time with stimulus
- Phosphorescence
  - AKA Afterglow; Screen Lag
  - Cease/after x-ray emission
  - Phosphor continue to light after exposure has stopped
  - Still emits light when stimulus ceases

QUALITY ASSURANCE & CONTROL FOR PROCESSING ROOM

- Dark Room Environment
  - Schedule: daily
  - Use psychrometer (for room humidity) and thermometer (for room temperature)
- Safelight Test
  - Schedule: semi-annually (every 6 months)
  - Safelight Testing – involves a film with lead covers exposed to the safelight, then removing a lead cover within a given duration
    - 4 Quarter (4 minutes, remove lead cover every 1 minute)
    - 2 Quarter (2 minutes, film is equally bisected into right and left)
  - Acceptable Safelight Fog: 0.04 OD + Fog (0.05 OD + Fog gives low image quality)
  - Latensification – increase of sensitivity (2 – 8x) of film to light after an exposure

Optical Density – indicates the use of a densitometer

Densitometer – a device that measures light transmittance

Penetrometer (Al Step Wedge)
- 5mAs, 70kVp, 40in(100cm) SID

- Automatic Processor Temperature
  - Schedule: weekly
  - Standard: should not vary greater than +/- 0.5°F (0.3°C) to avoid change in density
  - High Temperature = High Activity = High Density = High Oxidation = Low Contrast
  - High developer temperature produce chemical fog
  - High density = low contrast (density is inversely proportional to contrast)
  - Fog is gray, Contrast is black
  - Fog – where 60 – 90% of density comes from; additional density

Contrast
- Variation of densities
- Change in densities
- Difference in density

Contrast VS. Density
- High Density = Low Contrast
- Density can exist without contrast

- Replenishment Rate
  - Schedule: weekly
  - Standard: +/- 5% replenishment
  - Replenishment only occurs when a 14x17 or 14x14 film enters the processor
  - Replenish 60-70cc of developer and 100-110cc of fixer

OXIDIZED DEVELOPER

- Old or exhausted developer whose reducing/developing property has been reduced brought about by aerial or chemical oxidation
- Decrease of all agent concentration in the solution (except restrainer)
- Increase of restrainer (acidic) concentration in the solution
- Increase of monosulfate (a by-product of hydroquinone)
- Ammonium odor – by-product of oxidation
- Alkalinity of solution becomes acidic
- The clear brown solution becomes dark and muddy

Hydroquinone – most sensitive chemical to light

Light – causes external oxidation

Distilled Water – neutral ph (7.0); water is boiled and vapors are gathered

TYPES OF OXIDATION

- Aerial (External) Oxidation
  - Reduction of chemical strength as a result of exposure to air, but sometimes also by other external factors (e.g. light)
- Chemical (Internal) Oxidation
  - Reduction of chemical strength as a result of chemical fight in the solution
  - The opposite of synergism (AKA Super-Addivity; two chemicals when combined works better compared when separated)
  - Inherent components of solution with conflicting effects
- Use Oxidation
  - AKA Redox (reduction oxidation) or Devox (development oxidation)
  - Reduction of chemical strength as a result of exposure to high temperature over an extended period
  - Oxidation – a very important process in developing; requires replenishment

Importance of Oxidation

- No oxidation, no development
- Oxidation produce electrons, which shall be used in reduction (EUROPE)

Compensation for an Oxidized Developer

- Increase mAs
- Replenishment of developer

OXIDATION VS. CONTAMINATION

- Oxidation
  - Cause: evaporation of developer
  - Effect: decreased developing/reducing activity
  - Solution: replenishment of developer
- Contamination
  - Cause: accidental amount (0.1%) of fixer solution splashed to developer
  - Effect: production of chemical fog
  - Solution: total replacement (some references also include replenishment)

REPLENISHMENT

- Physical and chemical means of maintaining the level of processing solution

REPLENISHER

- A solution containing more reducing agents, activator and preservative (w/o restrainer since it is already plenty in the solution)
- Maintain chemical activity of the solution to the original
- Maintain proper dilution with water
- Maintain the physical level of processing solution
- Types:
    - MQ Replenisher – without restrainer
    - PQ Replenisher – with restrainer (Benzothiazole), since Benzothiazole will be exhausted

CLASSIFICATION F DEVELOPER AS TO ADDIVITY

- MQ Developer
    - Elon/metol-hydroquinone developer
    - Used for manual processing
- PQ Developer
    - Phenidone-hydroquinone developer
    - Used for automatic processing
    - 15x more super-Addivity than MQ developer

REPLENISHMENT SYSTEMS

- Volume
    - Most commonly used
    - Recommended Use: for processing 25 – 50 14x14 films/8 hours
    - Film Size: mainly for 14x14 or 14x17
    - Has a microswitch
        - Located at the entrance of the automatic processor (@ entrance roller)
        - A sensor not an actual switch
        - Controls the replenishment rate of processing chemicals, or how much chemistry is required per 14in of film travel
        - Works only on 14x14 film sizes
    - Replenishes only when the microswitch is activated
    - Replenishment Time: 2 minutes
    - Replenishment Rates:
        - Developer: 60cc (4in) – 70cc (5in)
        - Fixer: 100cc (6in) – 110cc (8in)
- Flood
    - AKA Timed type or Standby type

- Recommended Use: for processing 24 or lower 14x14 films/8 hours
- Film Size: any film size
- Used mainly where 14x14 films are rarely used (e.g. children hospitals)
- Replenishes every 5 minutes
- Replenishment Time: 20 seconds
- Replenishment Rate:
  - 65cc for both developer and fixer
  - Can replenish 780cc/hour

PROCESSOR QUALITY CONTROL TESTS

- Developer Solution pH – quarterly; between 10 – 11.5 pH
- Fixer Solution pH – quarterly; between 4 – 4.5 pH
- Developer Specific Gravity – quarterly; not exceeding 0.004
  - The concentration of chemicals in the developer solution
  - Hydrometer – measures specific gravity
  - Formula: **SG = CX/CW**
    wherein: **SG** is specific gravity, **CX** is concentration of the chemical agent, **CW** is concentration of water (H_2O)
  - Values: Developer 1.07 – 1.1 and fixer 1.077 – 1.11
- Processor Control Chart Monitoring – daily; not exceeding +/- 0.15 OD from baseline
  - Scheduled daily, on 5 consecutive days/week
  - Indicators:
    - Hydroquinone: contrast indicator; D-max; black; high density
    - Phenidone: speed indicator; D-min (toe); 1.2 OD (gray); midpoint density
      (Metol for manual processing)

pH (Power of Hydrogen)

- **Base/Alkaline (7.1–14)**
  Developer
  Has HO- that accept H+
- **Neutral (7.0)**
  Distilled Water
- **Acidic (0-6.9)**
  Fixer
  Can donate H+

INTRODUCTION TO FILM SENSITOMETRY

- Film Sensitometry – the quantitative measurement of the response of the film to exposure (or air kerma) and development (or processing)
- Testing Film Sensitometry
  - Uses: a control box (controlled film)
  - Done: early in the morning, when tube is warmed up, or when machine is already operated 20mins
- Instruments:
  - Penetrometer (Aluminum Step Wedge)
    - Uses x-rays to pass through a step wedge (Al) with consecutive thicknesses
    - Requires an x-ray machine
    - Prone to errors when there is machine fluctuation or uncalibrated
  - Sensitometer (Optical Step Wedge)
    - Uses a Sensitometric Strip (Step Tablet)
    - A device that produces a constant simulated x-ray exposure

        - Doesn't require an x-ray machine
    - Densitometer
        - Measures percentage of light transmittance (optical density)
        - Measures the processed image made with a penetrometer or a sensitometer
- Spectral Sensitivity – responsiveness of film to light emitted by IS; color of which the film is most sensitive
- Spectral Matching – light emitted by IS must be matched with the spectral sensitivity of film
- Types of Contrast
    - Film Contrast – inherent to the film; capability of film to produce contrast
    - Subject Contrast – controlled (by manipulation of kVp); differential absorption of different tissues
- Film Speed – sensitivity of film to x-ray (penetrometer) and light (sensitometer)
- Graphing Paper – after measuring film sensitometry, a graphing paper is used to represent the outcome of the measure
    - Control Chart – better than graphing paper; has a predetermined high/low threshold

FILM SENSITOMETRY

- Film Sensitometry – quantitative measurement of film response to exposure and development
- Sensitometer
    - Device that produce a constant simulated x-ray exposure
    - Produces a latent image
    - No involved reading or evaluation
- Sensitometric Strip (Step Tablet)
    - Made by exposing successive areas on a film
    - Starting with "no exposure" area then making progressively increasing exposures until the maximum density (D-max) is reached
    - Strips: 11 Steps and 21 Steps
- Densitometer
    - Device that measures the percentage of light transmittance
    - Used to evaluate optical density
    - After processing the latent image produced by the sensitometer, optical density is measured using the densitometer
    - Types of Light Emitted by Densitometer:
        - Incident Light – always 100% light transmittance; full amount of light emitted by densitometer to the film
        - Transmitted Light – light emitted to the film with varying transmittance
    - Light Transmittance (Density Unit)
        - 100% (0), 10% (1), 1% (3), 0.1 (4)
- Sensitometric Curve
    - AKA Film Characteristic Curve, Hurter & Driffield Curve (H&D Curve), Density Logarithm Exposure Curve (DLogE Curve)

- Product of sensitometry
- Hurter and Driffield introduced the Sensitometric Curve
- D-Max and D-Min
  - D-Min – toe; Phenidone/Metol; 0.25 – 1.2
  - D-Max – shoulder; hydroquinone; 1.3 – 2.4 (maximum of 3.0)
- Film Gamma – straight line region of Sensitometric Curve

3.0 OD – maximum density capability of film

Elements of Sensitometric Curve

- Base + Fog (0.18 OD)
- Shoulder
- Toe
- Film Gamma

- Base Density
  - AKA Dye Density, Manufacture Density
  - Inherent to film base; density resulting from manufacture of film
  - Average of 0.14
- Base Plus Fog (B+F)
  - Inherent fog caused by processing conditions (commonly safelight fog)
  - Acceptable fog of 0.04
  - Base Density of 0.14 + Fog of 0.04 = 0.18 (B+F = 0.18)
- D-Min
  - AKA Minimum Density, Toe of Characteristic Curve
  - Range: 0.25 – 1.2 OD
  - OD starts slightly higher than B+F
- D-Max
  - AKA Maximum density, High Density, Shoulder of Characteristic Curve
  - Range: 1.3 – 2.4 OD (3.0 as the maximum)
- Average Gradient
  - Reflects the film contrast
  - Measured 0.25 – 2.0 density units above B+F
  - The more vertical this line, the greater the film contrast
- Speed Point
  - AKA film sensitivity
  - Point which a certain amount of exposure is required to produce a net density

Dense Fog Viewer

- Used for images with poor quality
- For 2.0 density units or lower

THE GURNEY-MOTT THEORY OF LATENT IMAGE FORMATION

Photographic Effect – formation of the latent image; explained by the Gurney-Mott Theory

- The Invisible Image
  - Image-forming x-rays exit patient then strikes the IS which then glows and deposit visible light energy to the film emulsion
  - The energy is deposited in a pattern that represents the anatomical part being examined
  - Immediately after exposure, the film contains no observable image
  - However, there is actually an invisible image called a latent image
  - The invisible image can become a visible image with proper chemical processing

- Silver Halide Crystal
  - Silver (Ag), Bromine (Br), Iodine (I) atoms are fixed in a crystal lattice in ion form
  - Silver is positive ion and the halides are negative ions
    - Ag releases outer-shell electron and attaches to a halide atom, making the Ag^+ and halides Bromide (Br^-) and Iodide (I^-)
  - Electrons are free to migrate within the Ag(H) crystals
  - Halide ions are found in great concentration along the surface of crystal (negative surface charge) matched by the (positive interstitial charge) of Ag inside the crystal
  - Frankel Defect: inherent defect of Ag(H) crystal consisting of interstitial Ag ions and Ag ion vacancies

Ion – any atom with an excess or lack of electron
- Cation (+ion) – less e^-
- Anion (-ion) – more e^-

Crystal Lattice – formed by the ions of Ag(H) crystal; when the ions become stable, the lattice is destroyed

- Photon Interaction with Silver Halide Crystal
  - Light photons from the IS interact with the film, actually to the Ag and halide atoms
  - The interaction releases electrons from the crystal surface (where Br^- and I^- are located)
  - The released electrons have sufficient energy to travel within the crystal
  - While traveling, the electron dislodges additional electrons from the lattice
  - These additional electrons migrate to the *sensitivity center* and are trapped
  - The released electrons are mostly from Br^- and I^- converting them into neutral atoms
  - As the halides become neutral, they break from the lattice because of loss of ionic charge and migrates into the gelatin of emulsion
  - The evacuation of the halides then destroys the lattice freeing up the interstitial Ag ions
- Sensitivity Speck into Latent Image Center
  - As a sensitivity center captures an electron, it becomes more negatively charged
  - The sensitivity center then attracts mobile interstitial Ag ions (electrostatic effect)
  - The trapped electron and Ag ion combines in the sensitivity center and form metallic Ag atoms
  - An optimally exposed film, most developable Ag(H) crystals have collected **4 – 10 Ag atoms** at a sensitivity center
  - The group of Ag atoms are then called a *latent image center*
- Latent Image into Manifest Image
  - Latent Image – the unobservable information contained in a radiation-in/activated Ag(H) crystals
  - Crystals with 4-10 Ag atoms deposited in the sensitivity center are converted into black grains (black metallic Ag) by the developer
  - Crystals not irradiated remain crystalline and inactive, which will be removed by fixer

Sensitivity Speck/Center into Latent Image Center
- Sensitivity Center – captures e^- and attract Ag^+
- $e^- + Ag^+$ = Ag atom
- 4 – 10 Ag atom forms Latent Image Center
- Latent Image Center – where visible quantities of Ag form during processing and create the radiographic image

IMAGE PRODUCTION: THE PROCESSING OR RADIOGRAPHS

PROCESSING OF RADIOGRAPHS

1. Wetting – reduce surface tension; swell the emulsion; provide uniform development

2. Developing – convert the latent image into visible (manifest) image
3. Stop Bath – stop the development process
4. Fixing – permanent what was developed and remove what was not
5. Washing – remove remaining processing chemicals
6. Drying – remove excessive moisture and prepare radiograph for assessment

Processing Tank Construction:

- 1 Master Tank
- 2 Insert Tanks (inside master)

Locations:

- Stop Bath – master tank
- Dev/Fix – insert tank (each)
- Washing – separate tank

Stop Bath vs. Rinse Bath

- Stop Bath – w/ 1% BAS Acid
- Water Rinse Bath – w/o BAS Acid
- ✓ BAS = Boric, Acetic, Sulfuric

I. WETTING PROCESS

Purpose:

- Reduce surface tension
- Swell up the emulsion for the easy entry of processing chemicals
- Provide uniform development

Processing Chemicals:

- Wetting Agent
    - Water (H_2O)
        - Universal solvent

Kodak – the company which has the largest consumption of Silver (Ag).

II. DEVELOPING PROCESS

Process:

- The exposed film is immersed in the alkaline (basic) developer solution
- The developer softens and swells the gelatin and ionizes the exposed Ag(H) crystals
- The reducing agents transform the silver ions into clumps of metallic silver
- Unexposed Ag(H) are not affected by this treatment

Purpose:

- **<u>Convert</u>** chemically the invisible (latent) image to the visible (manifest) silver image

Secondary Purpose:

- Amplify the amount of metallic silver in the film by increasing the silver atoms by a factor of millions in each latency center
- Reduce the amount of Ag(H) crystals on the film

Processing Chemicals:

- Reducing Agents
    - AKA Developing Agent
    - Chemical: Elon and Metol, Phenidone, Hydroquinone
    - Purpose: Reduce exposed Ag(H) crystals to black metallic silver
        - Metol/Phenidone – builds up detail quickly; during first half of dev process

Fog – AKA supplementary density; hyperactivity of developer causes development fog

Preservative – prevents development fog

        - Hydroquinone – build up contrast slowly; during whole dev period
    - Combinations:
        - Elon, Metol, Hydro – for manual processing
        - Pheni, Hydro – for automatic processing; x15 super-addivity than MQ
- Activator
    - AKA Buffer, Activator, Accelerator, Alkalinizer, Wetting
    - Chemical: Sodium Hydroxide, Sodium Bi/Carbonate
    - Purpose: provide necessary alkaline medium; swell the gelatin emulsion so reducing agents can attack Ag(H) crystals
    - pH: 9.6 – 10.6
- Restrainer
    - AKA Starter, Anti-foggant, Regulator, Restrainer
    - Chemical: Sodium/Potassium Bromide, Benzothiazole, Iodide
        - Benzothiazole – organic restrainer; added to PQ developer since bromide cannot retrain Phenidone; for automatic processing
    - Purpose: control activity (prevent hyperactivity) of reducing agents; prevent fog
- Preservative
    - AKA Preservative, Antioxidant, Stabilizer
    - Chemical: Sodium/Potassium Sulfite, Cycon
        - Sodium Sulfite – for manual processing
        - Potassium Sulfite – automatic processing
        - Cycon – for both processing types
    - Purpose: prevent rapid oxidation of reducing agents
    - Reacts with:
        - Quinone – a dye by-product of hydroquinone; capable of staining the film; forms hydroquinone, a colorless compound
        - Monosulfate – colorless compound found in an oxidized developer
- Solvent
    - Chemical: Distilled/Drinking Water
        - If tap water was used, must be with sequestering agent

Other Components:

- Hardening Agent
    - AKA weak/temporary hardener
    - Chemical: Dialdehyde, Glutaraldehyde
    - Usage: ONLY for automatic processing; 1st used on Eastman Kodak (1956) automatic processor that uses roller transport system
    - Purpose: prevent over-swelling of emulsion; prevent emulsion pick-off, gelatin build-up in rollers and film transportation problems; maintain uniform film thickness and assist in film transport
- Sequestering Agent
    - Chemical:
        - Sodium Salts of Ethylene Diamine Tetra-Acetic Acid (Editate)
        - Sodium Hexametaphosphate (CALGON)

        - Chelates
    - Usage: If Distilled water was not used, tap water can be an alternative if it was supplied with a sequestering agent to eliminate calcium and iron impurities
    - Purpose: to prevent calcium sludge (showing as chalky deposits) on the film, calcium or iron artifacts, and scaling of tank
- Wetting Agent
    - Chemical: water
    - Purpose: prevent surface tension; promote uniform development
- Anti-Frothing/Anti-Foaming
    - Purpose: prevent bubble formation on the solution that would cause aerial oxidation (added to the preservative as antioxidant)
- Fungicide
    - Chemical: Bleach
    - Purpose: prevent generation and growth of fungi inside the tank
- Buffer
    - Chemical: Boric Acid, Sodium Hydroxide
    - Purpose: maintain the proper pH value of the solution (9.6 – 10.6)

✓ **DO NOT** shake chemicals, especially liquid chemical mix, to prevent bubble formation that would cause aerial oxidation

WHEN TO CONSIDER THE DEVELOPER IS OLD/EXHAUSTED

When the concentration of:

- Reducing agents (PHEM) go down
- Preservatives (Sulfite) go down
- Alkalinizer (Carbonate) go down
- Buffer (Hydroxide) go down
- Restrainer (Bromide) go up
- By-product of Development (Monosulfate) go up

✓ Although some developers are acidic, it is an indication that Phenidone was used, ***Phenidone is Acidic.***

Synergism/Synergistic Effect – activity of each component of reducing agent is less than the activity when both are combined; working together of the two agents

FACTORS AFFECTING THE DEVELOPMENT TIME

- Temperature of Solution – higher temperature denotes a faster developing time
- Exhaustion of Developer – exhaustion decreases activity of reducing capability of the developer, resulting a slower development time
- Size of Film – a bigger film denotes a bigger area to develop, resulting to a slower development
- Size of Grains in the Film – although a bigger grain gives a better quality, it takes longer to develop a bigger surface area
- Agitation of the Film – giggling the film in the developer makes it easier to travel within the film thus easier to attack the Ag(H) crystals, resulting a faster development time
- Power of Hydrogen (pH) – a higher basic/alkaline concentration results faster development
- Specific Gravity – higher concentration of developer solution gives faster development

III. RINSING PROCESS

Water Rinse Bath VS. Stop Bath

- Water Rinse Bath
    - Purely water
- Acid Rinse Bath (AKA Stop Bath, Short Stop)
    - Water with 1% of Boric, Acetic, Sulfuric Acid

Process:

- From the developer, the film is transported to the rinsing bath
- The water in the rinsing tank slows down or stops the developing action of the reducing agents by reducing its concentration

Purpose:

- Water Bath – slow down the developing process by reducing the concentration of reducing agents in the film
- Stop Bath – stop the development process, because of the BAS acids that act upon and neutralize the reducing agents

IV. FIXING PROCESS

Process:

- From the rinse bath, the film is transported to the fixing tank
    - Most commonly in automatic processing, the rinsing process is eliminated and is transported directly from the developer to the fixer solution)
- The fixer solution clears the film of undeveloped Ag crystals, forming a silver complex of thiosulfate (Monoagrento-dithiosulfuric acid)
- It then hardens the gelatin to make it able to withstand physical damage and avoid transportation/processing problems

Purpose:

- **<u>Remove</u>** the unexposed Ag(H) crystals and **<u>Permanent</u>** the image

Secondary Purpose:

- Stop the development process (if rinse bath is not available)
- Harden the emulsion

Processing Chemicals:

- Fixing Agent
    - Chemical: Sodium/Ammonium Thiosulfate
        - Ammonium Th. – liquid form; in automatic processing
        - Sodium Th. – powder form; in manual processing
    - Purpose: Dissolve (or remove, clear) unexposed Ag(H) crystals, thereby producing a permanent visible image

✓ Silver atoms sticks with thiosulfate, and a ***thiosulfate can only contain 1 Ag atom***. When it already contains a Ag atom, it will no longer be used and settles in the bottom of the tank.

✓ **Thiosilver Sulfate** – the combination of silver and thiosulfate

✓ The ***fixer solution is considered oxidized*** when it already contains too many Ag atoms

- Comparison of the Chemicals:
    - Ammonium Th. Fixes film more rapidly than sodium Th. (in equivalent concentration)
    - Ammonium complexes are less stable than sodium complexes
    - Staining and deterioration occurs faster in sodium complexes
    - Ammonium Th. is used mainly in liquid concentrates

Hyporetention
- AKA Thiosulfate Retention; Silver Sulfide Stain
- Remaining thiosulfate on the film after processing
- Appears as yellowish to brownish stains
- After a week from processing, Hyporetention will tarnish and become brown stains

HypoKit
- A test tool for measuring the degree of hyporetention

- Neutralizer
  - AKA Acidifier
  - Chemical: Acetic Acid
  - Purpose: Serves as an acid medium and neutralizes the developer carried over by the film
- Preservative
  - AKA Stabilizer
  - Chemical: Sodium Sulfite
  - Purpose:
    - Maintain equilibrium of chemicals in the fixer solution
    - Prevent aerial oxidation of fixing agent
    - Prevent decomposition and precipitation of sulfur from the thiosulfate fixing agent (sulfurization)
- Hardener
  - AKA Tanning Agent, Strong/Permanent Hardener
  - Chemical: Potassium/Chrome Aluminum, Aluminum Chloride
  - Purpose:
    - Raise the temperature to soften the gelatin (then hardens the emulsion)
    - Prevent too much absorption of water by the gelatin
    - Make the film less susceptible to physical damage
  - Process:
    - As the film travels in the fixer solution, aluminum atoms travel within the emulsion and is stuck in the interspaces within the gelatin
    - Hardened Emulsion = Silver + Gelatin + Aluminum
  - Comparison of the Chemicals:
    - Potassium Aluminum
      - Widely used
      - Keeps hardening property almost indefinitely
      - When pH is above 5.5 (oxidized), white blooms form on the surface of film brought by precipitation of aluminum hydroxide
    - Chrome Aluminum
      - Do not keep its hardening property for more than a few days
    - Aluminum Chloride
      - Used in concentrated hardener solutions
      - Rapid hardening action
      - Associated with ammonium thiosulfate fixers
- Solvent

- Chemical: Distilled/Drinking Water
    - If tap water was used, must be with sequestering agent

Other Components:

- Sequestering Agent
  - AKA Anti-Sludging Agent, Buffer Agent
  - Chemical: Boric Acid/Salts (Anti-Sludging Agent)
  - Purpose: delay the precipitation of aluminum hydroxide
  - Alternative: Boric/Acetic/Sulfuric Acid
- Hyponeutralizer
  - Usage: ONLY in manual processing (between fixing and final washing stage)
  - Purpose: eliminate hyporetention, stop thiosulfate action, reduce wash time

✓ Another indication of an oxidized fixer is the ***increased concentration of Aluminum Hydroxide*** in the solution

Clearing – the process by which the fixing agent acts on the unexposed Ag(H) crystals to form soluble complexes which eventually diffuses out of the film into the fixer

FACTORS THAT AFFECT THE USE OF FIXER

- Type of fixing agent used
- Concentration of the fixing solution
- Temperature of the fixing solution
- Presence of hardener
- Film material used
- Agitation of film
- Exhaustion of fixing solution

CAUSES OF EXHAUSTION OF THE FIXING SOLUTION

- Dilution of water being carried into the fixer tank
- Increasing alkalinity brought by the film from the alkaline developer (decreasing Acidity)
- Accumulation of silver complexes which eliminate the clearing action of thiosulfates
- Loss of hardener power
- Oxidation of sodium sulfite (preservative)

RELATIONSHIP OF DEVELOPMENT TIME TO FIXING TIME

- The main purpose of developing is to convert latent into manifest image
- Fixing involves two main purposes which are to permanent what was developed and remove what was not
- Meaning, fixing time needs to have twice the time that of developing for it has two jobs
- Example: if a minute is designated for developing, 2 minutes should be for fixing time

Fixing Time = Hardening (Permanenting) Time + Clearing Time

V. WASHING PROCESS

Process:

- From the fixing stage, the film undergoes washing stage
- Residual processing chemicals and silver salts are washed out (removed) from the radiograph using water
- In an automatic processor, wash water is maintained 5^{O}Farenheit ($2.8^{O}C$) below developer temperature
- Wash bath also stabilizes developer solution

Purpose:

- The ***most important*** step for archival quality
- Remove excess processing chemicals
- Remove silver complexes, thiosulfate and salts from the film

Archival Quality – the permanence of image after processing

FACTORS AFFECTING WASHING TIME

- Temperature of the wash bath
- Concentration of fixer in the emulsion and wash bath
- Agitation

VI. DRYING PROCESS

Process:

- From the washing step the film undergoes the final step of processing, drying
- 85 – 90% of moisture is removed from the film
- Some (10 – 15%) of the moisture is retained for easy handling and storage, while maintaining the quality of the diagnostic image
- Consumes most of the electric power (60 – 80%) and uses a filament
    - Current: 10 amperes
    - Wattage: 1500 – 2500 watts
    - Air Blower (Ventilation Air Dock) Movement: 100 – 300 ft^3/min

Purpose:

- To remove excess moisture in the film
- To prepare the film for viewing and assessment

FACTORS AFFECTING THE DRYING TIME

- Temperature
- Humidity
- Air flow from the air blower

SEQUENCE OF EVENTS IN PROCESSING RADIOGRAPHS

	APPROXIMATE TIME

STEP	MANUAL	AUTOMATIC
Wetting	15s	---
Developing	5min	22s
Rinsing	30s	---
Fixing	15min	22s
Washing	20min	20s
Drying	30min	26s
TOTAL TIME	>1hr	90s

DEVELOPMENT OF FILM PROCESSING

- 1942 (Pako) – First Prototype Automatic Film Processor
    - Total Processing Time: 40 minutes (per film)
    - Could process 120 films/hour
    - Uses specialized film hangers
- 1956 (Kodak) – First Roller-Transport System Processor
    - Total Processing Time: 6 minutes
- 1965 (Kodak) – 90s-Rapid Processor
    - Total Processing Time: 90 seconds (dry-drop time)
    - Could process 215 films/hour
- 1987 (Konica) – Automatic Film Processor
    - Total Processing Time: approx. 45 seconds

SYSTEMS OF AN AUTOMATIC PROCESSOR

PARTS OF THE AUTOMATIC PROCESSOR

1. Transport Sys. – transport the film and controls time of immersion
2. Temperature-Control Sys. – thermostatically control the temperature of the processing solutions
3. Circulation/Filtration Sys. – agitate the film and filter gelatin impurities
4. Replenishment Sys. – maintain proper concentration of processing chemicals
5. Dryer Sys. – remove excess moisture in the film
6. Electrical Sys. – provide electricity to the different systems

I. TRANSPORT SYSTEM

Purpose:

- Transport the film
- Control processing (by controlling the time the film is immersed in the wet chemistries)

Subassemblies:

- Roller Subassembly
  - Turn-Around Roller
    - AKA Master, Solar roller
    - Location: bottom of tank, surrounded by transport rollers and metal or plastic guide shoes (deflector plates)
    - Purpose: turning the film form downward to upward
    - Size: 3in diameter (Biggest roller)
  - Cross-Over Roller
    - AKA Squeegee roller (made of squeegee rubber)
    - Location: top of tank
    - Purpose: transports the film from one tank to another
  - Transport Roller
    - AKA Planetary roller
    - Location: surrounds the turn-around roller

Entrance Rack

- Feed tray
- Entrance roller
- Guide shoes
- Microswitch (if volume temp-control)

Cross-Over Rack

- Transport rack
- Cross-over rollers
- Guide shoes

Materials Used as Roller

- Stainless Steel
- Polyester
- Plexy (Acrylic Plaster) glass
- Rubber (for entrance)
- Phenolic Resin (for drying stage; most sensitive material; absorbs water)

- Purpose: convey the film along its path (from chemistries to dryer)
    - Guide Shoes/Plates
        - Slightly curved plates that guide the film along the direction of its curve
        - Consists of 7, 14, 21 guide plates
- Transport Rack Subassembly
    - Purpose: provide attachment for transport rollers are positioned in each wet chemistry
- Drive Subassembly
    - Electric Motor – provide power for the roller assembly
    - Motor Drive:
        - Motor: 1725 - 1750 rpm
        - Gear Reduction Mechanism: 10 – 20 rpm
        - Power: 0.14 – 0.5 horsepower
    - Purpose:
        - Connect the mechanical energy of the drive motor to the mechanism of rack assembly
    - Subassemblies
        - Belt and pulley
        - Chain and sprocket
        - Gears (No. 25)

Stratification

- an event where activity (concentration) of chemistry is higher on a part of the solution from the other
- uneven concentration or activity
- caused by improper mixing of the chemicals in the tank
- increase hyporetention

✓ To avoid stratification, ***feed a fresh*** film to the processor to enable the movement of chemistries in the tank (DO NOT use processed film to avoid contamination)

✓ Only ***0.1%*** of fixer to the developer solution is considered contaminated

II. TEMPERATURE-CONTROL SYSTEM

Purpose:

- Temperature control in each tank is provided by a thermostatically controlled heating element
- Developer temperature is maintained at 95^{o}F (35^{o}C)
- Wash water is maintained 5^{o}F (2.8^{o}C) lower than that of the developer

Types:

- Gross Control Temperature
    - AKA Warm-Water Processor
    - Water-Mixing Valve – device that interconnects incoming hot and cold water
- Fine Control Temperature
    - AKA Cold-Water Processor
    - Thermostat – maintains a certain level of temperature
    - Uses a thermostatically controlled heating element (heat exchanger)
    - Occurs within the developer tank, gathering the heat from the air blower in the drying system

III. CIRCULATION/FILTRATION SYSTEM

Purpose:

- Circulation System (Agitating System)
    - Agitating Pumps – provide the following:
        - Movement of chemistry through the filters
        - Uniform chemical activity through the tank
        - Uniform chemical components, temperature and agitation
- Filtration System
    - Trap particles in the developer-circulation system
    - Trap flocks of gelatin dislodged from the emulsion

IV. REPLENISHMENT SYSTEM

Purpose:

- Meter each tank the proper amount of chemistry to maintain volume and chemical activity

Microswitch

- Device located at the entrance of the automatic processor
- Control replenishment rate of processing chemicals
- Replenishment rates are established based on amount of chemistry required per 14-inch film travel
- Replenishment Rates:
    - 60 – 70cc of developer
    - 100 – 110cc of fixer

Replenishing Pumps Used

- Diaphragm-type
- Bellows-type
- Piston-type
- Magnetic Drive Centrifugal pump
- Percentage-Time pump

V. DRYER SYSTEM

Purpose:

- Consist of a blower, ventilation ducts, drying tubes and an exhaust fan
- Completely extracts all residual (85 – 90%) moisture from processed radiographs

Process:

- The dryer blows hot (110 - 120^{o}F) air across the surface of film to remove surface moisture
- Air is maintained dry by a dehumidifier
- The vent in the dryer release build-up air as new air is pulled into the system

- The dried radiograph then drops in the receiving bin for pickup

VI. ELECTRICAL SYSTEM

Purpose:

- Provide electrical power to the thermal and mechanical components of each of the system

ALTERNATIVE PROCESSING METHODS

- Rapid Processing
  - Processes films as fast as 30 seconds
  - Useful in procedures where time is critical (e.g. angiography, surgery, special procedures and in emergency rooms)
  - Used in more concentrated chemicals at higher temperature
- Extended Processing
  - Processing may be as long as 3 minutes
  - Applicable with single emulsion films (e.g. mammography)
  - Advantage:
    - Greater image contrast
    - Lower patient dose
- Daylight Processing
  - Films can be processed while there is light in the room (no need for darkrooms)
  - Takes only 15 seconds for technologist to insert exposed cassette into the daylight loader and retrieve a fresh cassette
  - Total Load-Unload-Process Time: 2 minutes
  - Multiple film sizes automatically accommodated

SILVER RECOVERY (SILVER RECLAMATION)

Reasons for Silver Recovery

- An economically wise and environmentally friendly way of acquiring Silver (Ag)
- In-demand supply of Silver
- Monetary return
- Silver is an environmental hazard

Methods of Silver Recovery

- Chemical Recovery
  - AKA “Precipitation of Silver”
  - Definition: Oldest
  - Method: Sodium Sulfite (Preservative) is added to the fixer solution and silver is precipitated in the form of Silver Sulfite

- Electrolytic Recovery Unit
    - AKA Electrolysis, Platine
    - Definition: Most Commonly Used, Most Efficient (92 – 98%)
    - Method:
        - Electrical current is passed through an ionized solution
        - Two electrodes are used: Carbon (as anode) and Stainless Steel (as cathode)

Cathode - where most Silver is recovered

- Metallic Replacement
    - AKA Displacement Method, "Replacement of Silver with another Metal"
    - Definition: Cheapest, Easiest Method
    - Method: Silver is placed within the fixer solution, Silver then sticks with the steel wool
    - Disadvantage:
        - Iron displacement (in the form of Iron Oxide or rust)
        - Drain Stoppage
        - Channeling

Factors Affecting Silver Recovery

- Agitation
- Surface area of Metal
- Temperature

Blue Film – color of film after processing with Ag(H) crystals removed
Violet Film – color of film before processing with Ag(H) crystals still intact

✓ When a film undergoes development, only **50%** of its Silver can be recovered

Films Where Silver Can Be Recovered

- Green Film – 100% Ag recovery; expired films
- Exposed Film – 100% Ag recovery; films that were exposed to light but wasn't developed
- Scrap Film – 50% Ag recovery; spoilage films
- Archival Film – 50% Ag recovery; outlived films
    - 5 years for common medical cases
    - 40 years for medicolegal cases

RADIOGRAPHIC ARTIFACTS

Artifact – any unwanted, undesirable information that limits the interpretation of the image

General Classification of Artifacts

- Plus-Density Artifact
    - Appears as increased density artifacts (black)
    - Caused by overstimulation of the Ag(H) crystals in the emulsion, either by pressure or uneven chemistry in the solution
    - Involves events before processing
- Minus-Density Artifact
    - Appears as reduced density artifacts (white)
    - Caused by removal of the Ag(H) crystals in the emulsion, either by pressure, scratches, dirty rollers or exposure of material with high atomic number (patient artifacts)

    - Involves (but not always) events during/after processing

Causes of Exposure Artifacts

- Poor Screen-Film Contact
    - Caused by a defective cassette
    - Film is not in full contact with the intensifying screen
    - Can be measured using a wire mesh
- Double Exposure
    - Caused by an already exposed cassette with its film inside to be exposed again
- Patient Motion
    - Caused by either voluntary or involuntary movement of patient's body part being examined
- Poor Patient Preparation (e.g. clothing, jewelry, glasses, belt, etc.)

Wire Mesh Test

- Method of measuring film-screen contact
- A wire mesh is put on a cassette with a fresh film inside and exposed with radiation. Portions with blurredness indicates a poor screen-film contact.

Patient Artifacts

- Pacemaker
- Nasogastric Tube
- Intravenous Tubes (e.g. dextrose tubes)
- Metal Implants
- Safety Pins

Causes of Processing Artifacts

- Dirty Rollers
    - Leave deposits on film
    - Shows increased or reduced densities
    - Occasionally, some sludge may not be washed off and dried onto the film
- Improper/Inadequate Chemistry of Processing Solutions
    - Causes chemical fog
    - Leaves a uniform dull gray haze on the film
    - May also be seen in two different colors
- Guide Shoes Are Sprung or Improperly Positioned
    - Ridges in guideshoes press against the film creating artifacts (e.g. scratches)
- Poor Washing
    - Fast processing or improper washing process

Processing Artifacts

- Pi-Lines
    - Appears 3.14 inches apart
    - Caused by dirt or stain on a roller
- Pressure Marks
    - Caused by irregular or dirty rollers
    - Accumulated dirt presses against the film creating pressure marks
- Water Marks

- Caused by inadequate washing
- Hesitation Marks
  - Caused by pulling the film from the automatic processor while the film is being processed
- Hyporetention
  - Hypo = thiosulfate, Retention = remained
  - Appear as yellowish to brownish stain on finished radiographs
  - Mostly noticeable on the drying stage
  - Measured by using “Hypo-Kit” (a test tool to measure degree of hyporetention)

Handling and Storage Artifacts

- Light/Radiation Fog
  - Appears as streaks of increased density (commonly caused by white light)
  - Causes:
    - Improper closing of the cassette that would allow entry of white light inside
    - Safelight is too close on the working area
    - Safelight with the wrong wattage was used
    - Film was left in the exposure room during exposure
- Kink/Crescent Marks
  - Appears as crescent moon-shaped artifact
  - Caused by too much pressure of fingernails to the film
  - Also called crescent marks because of the imprint from fingernails appearing like a crescent moon
- Static
  - Appearances:
    - Crown – resembles a crown; static with branches coming from a center
    - Tree – resembling a tree; static with many branches coming from a center
    - Smudge – accumulated static resembling like a smudge of dirt
  - Caused by build-up of electrons in the emulsion
- Dirt/Smudge Marks – AKA dirt speck; accumulation of actual dirt
- Marker and Paper – neglected markers that gone through processing with the film
- Film Folds – folding of film

Indications of Inadequate Processing

- Decrease in Density
  - Causes:
    - Developer is exhausted/under-replenished
    - Fast developing process
    - Low developer temperature
    - Improper mixture of developer
- Increase in Density
  - Causes:
    - Developer in over-replenished
    - High developer temperature

        - Light leak in the processor
        - Improper mixture of developer
- Pinkish Stain (AKA Dichroic/Dichoic Stain)
    - May also appear pink or green
    - Cause: Contamination of developer by fixer
- Brown Stain (AKA Thiosulfate Stain, Hyporetention)
    - Cause: inadequate washing
- Emulsion Removed by Developer (AKA Emulsion Pick-off)
    - Cause: Insufficient hardener in developer
    - Gelatin then sticks onto the rollers, later causing pressure or dirt artifacts)
- Milky Appearance
    - Cause: Exhausted fixer, inadequate washing
- Streaks
    - Cause: Dirty processor rollers, inadequate washing/drying
- Water Spots
    - Cause: Inadequate drying
- Scratches

THE RADIOGRAPHIC FILM

Remnant Radiation

- The x-ray that interacts with the x-ray film
- Remnant Radiation – the image-forming radiation that passes completely through the patient
    - Only few of the original x-rays actually makes the image

Sequence of Forming Remnant Radiation

- The beam started as a relatively uniform intensity as it exits the tube
    - Only less than 1% of the energy is x-radiation and the rest is converted into heat
- Upon striking the patient, the beam is attenuated, some were absorbed, and some became scatter radiation
- Radiation that hits the film are referred to as remnant (or useful) radiation

Types of X-Ray

- Type A (Scattered)
    - X-Rays that was scattered by Compton interaction
    - Hits the patient but scattered to random directions
- Type B (Absorbed)
    - X-rays that was absorbed by means of photoelectric absorption
    - Hits and absorbed by the patient
- Type C (Attenuated, Transmitted)
    - X-Rays that exit the patient without interaction
    - Hits and passes through the patient making the image

Radiographic Film

- A media making a permanent record of the image
- Creates a recorded image caused by exposure to x-ray photons
- The most common image receptor
- Parts: Base, Emulsion, Adhesive layer, Protective coating

History of the Radiographic Film

- 1895 – Photographic Glass Plate
    - First used in World War 1
- 1904 – Double-Emulsion Glass Plate
    - Demonstration of double-emulsion radiography of Charles Leonard
- 1918 – Cellulose Nitrate Film base (Double-Emulsion Films)
    - Cellulose Nitrate
        - Highly flammable and easily torn
        - Responsible for many fire incidents in hospital basements
    - Commercial availability of Duplitized (Double-Emulsion) films
- 1920 – Cellulose Triacetate Film base
    - Considered "Safety Film Base"
    - Also highly flammable, not as bad as cellulose nitrate
    - Emulsion cracks and peels away from base when processing chemicals are too hot
- 1924 – Cellulose Acetate Film Base
- 1933 – Tinted Film Base
- 1936 – Direct Exposure Films
- 1940 – Films Suitable for Both Direct/Indirect Exposures
- 1958 – Fast Light-Sensitive Film
- 1960 – Polyester Film Base and Films for Rapid Processing

Tinted Film Base

- Eliminates print-through
- Reduce eye fatigue

Cross Section of the Radiographic Film Base

- Film Base – provides flexible but not elastic support for the emulsion
- Adhesive Layer (Substratum) – promotes contact of the emulsion to the base
- Emulsion – consists of the Silver Halide crystal as recording medium and gelatin as structural support
- Protective Coating (Supercoat) – protects the emulsion from outside elements

Film Construction

- Film Base
    - Requirements:
        - Made of polyester plastic
        - Must have strong, clear and consistent thickness
        - Tinted with pale blue or blue-gray dye
    - Characteristics:
        - Dimensional stability
        - Uniform lucency

        - Slightly tinted with blue dye
    - Polyester as Film Base Material:
        - Composition: Ethylene Glycol + Dimethyl Terephthalate
        - Superior dimensional stability
        - Stable optical clarity
        - Waterproof
        - High tensile strength and flexibility
        - Chemical memory
        - Inert to processing chemicals
- Adhesive Layer (Substratum)
    - Purpose: allow the emulsion and base to maintain proper contact and integrity during use and processing
- Emulsion
    - Definition:
        - Can be on one side (single) or both sides (duplitized) of the base
        - Consists of a gelatin containing the film crystals
        - Considered the active layer of the film
    - Characteristics:
        - Mixture of gelatin and Silver Halide (Fluorine, Chlorine, Bromine, Iodine) crystals
        - Most are made of $AgBr$ (98%) and AgI (2%)
        - Photographically active, activated by light and radiation to create an image
    - Manufacturing Process:
        - Mixing of gelatin
        - Emulsification
        - Physical ripening (coalescence and Ostwald)
        - Cooling
        - Shredding and Sieving
        - Washing
        - Chemical Ripening
        - Doctoring for additive (sensitizer, hardener, fungicide, wetting, plasticizer)
    - Types:
        - Standard Contrast emulsion
            - Serves as the basis of the other types
            - B+F density = 0.18
            - Average Gradient = 2.16
            - D-Max = 3.5 – 4.0
            - Speed = logarithm of 1.53
        - Half Speed emulsion
        - Latitude (L) emulsion
        - Contrast (C) emulsion
        - High Speed emulsion
            - 800 speed (made of tabular grains)
        - Holographic emulsion
            - Extreme high resolution
- Protective Coating (Overcoat/Supercoat/Top coat)

    - Purpose: a cellulose layer that serve as protection in moving the film across the screen (intensifying screen)

Film Emulsion

- Gelatin
    - Characteristics:
        - Clear – to transit light to the Ag(H) crystals
        - Porous – for processing chemicals to reach the Ag(H) crystals
        - Provide Support Medium – to hold the Ag(H) crystals in place
    - Collagen and Colloid as Gelatin Material:
        - Even suspension of crystals
        - Able to swell, shrink and harden
        - Increase sensitivity of Ag(H) crystals
- Silver Halide Crystals
    - Purpose: recording medium
    - Characteristics:
        - Consist of 98% AgBr and 2% AgI
        - Commonly tabular in shape and used mostly in general radiography
        - About 1 micrometer thick for screen-film exposure
        - Crystals in cubic structure
        - Crystal Lattice containing Ions
        - Manufactured to have specific characteristics (e.g. speed, contrast, resolution)
        - Manufactured to be sensitive to specific colors of light (spectral matching)

Film Characteristics

- Film Speed
    - Definition:
        - The degree of sensitivity of film to x-ray and light
        - Determined by the number and size of Ag(H) crystals
    - Emulsion and Film Speed:
        - Single Coat: max of 150 speed
        - Double Coat: 200 speed
    - High Film Speed = High Sensitivity
    - Speed value must match with the intensification factor of the IS
        - Speed Value – exact value of speed of film
        - Intensification Factor – measure of screen speed
            - Screen Speed – measure of amount of light the IS produces; light emission
    - Relative Name: slow or fast
- Film Contrast
    - Types:
        - Low Contrast Emulsion
        - High Contrast Emulsion
- Exposure Latitude

Types of Contrast

Film Contrast
- Inherent to the film
- Caused by manufacturing

Subject Contrast
- Controlled by kVp
- Depends on patient thickness

- Definition:
  - AKA Margin of Error (chance for errors)
  - Capability of the film to produce optical density
- Exposure Latitude and Contrast:
  - Low Contrast Emulsion = wider exposure latitude (grants more range of factors to create an image)
  - High Contrast Emulsion = narrower exposure latitude (requires an exact or nearly exact factor to achieve its high contrast)

- Reciprocity Law
  - Applicable only to screen-films
  - Means of which an exposure factor, when changed will produce the same density compared to the first one

Image Formation

- X-rays are emitted and hits the intensifying screen
- The screen then converts the high energy x-rays into low energy visible light
- An (latent) image is then recorded in the film, however it cannot be seen
- The said image will then be made visible by means of processing
- After processing, the visible image is called manifest image

Types of Film

- Singe Emulsion Film
  - Advantage: better detail
  - Disadvantage:
    - Halation – emulsion is double exposed by IS (controlled by anti-halation layer)
    - Increased patient dose
- Double (Duplitized) Emulsion – less detail
  - Advantage: Less patient dose
  - Disadvantage:
    - Parallax (Print-Through)
      - An image is created on both emulsions, then superimposes each other resulting to a slight blurring of edges of the image
      - Blue Dye – decreases parallax effect
      - Crossover Control Layer – located in the base, reduces crossover to zero

Umbra – the true size image
Penumbra – the blurred edges of an image caused by 2 same images superimposing each other

Film Sizes

- 14x17in – used mainly on abdomen, chest (male), lower extremity
- 14x14in – used mainly on chest (female or adolescents)
- 11x14in – used mainly on chest (pedia), lower extremities (2 projections)
- 10x12in – used mainly on skull, foot, chest (infant)
- 8x10in – used mainly on hand, chest (infant)