SAWA UNIVERSITY

CONVENTIONAL RADIOLOGICAL EQUIPMENT TECHNIQUES

Construction of Film, Intensifying Screens, Cassette

جامعة ساوة

كلية التقنيات الصحية والطبية

قسم تقنيات الأشعة والسونار

المرحلة الثانية

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X-ray tube failure

is a common issue in radiology equipment, and understanding its causes and preventive measures is essential for ensuring equipment longevity and patient safety. X-ray tubes are highly stressed components that generate significant heat during operation, which can lead to various types of failures over time.

Common Causes of X-ray Tube Failure

1- Excessive Heat

X-ray tubes generate large amounts of heat during use. If this heat is not properly dissipated, it can cause severe damage to tube components.

- **Anode pitting:** Frequent overheating can cause the anode (often made of tungsten) to develop pits or cracks. These deformations reduce the efficiency of X-ray production and can lead to inconsistent image quality.
- **Anode cracking:** If the anode overheats too quickly (e.g., when using high power without allowing the anode to warm up), it can crack due to thermal stress, leading to catastrophic failure.
- **Bearing failure:** The rotating anode is supported by bearings, which can wear out over time, especially under extreme heat conditions. Bearing failure causes uneven rotation or complete seizing of the anode, resulting in uneven X-ray production or total tube failure.
- **Glass envelope cracking:** High heat can lead to expansion and contraction of the glass envelope (which houses the X-ray tube components). If subjected to rapid temperature changes, the glass may crack, causing a vacuum loss and rendering the tube unusable.

2- Overuse or High-Load Conditions

Operating the X-ray tube under high-load conditions (e.g., high voltage, current, or long exposure times) without proper cooling times can accelerate wear and tear.

- **Filament burnout:** The filament in the cathode, which emits electrons when heated, can fail after prolonged use at high temperatures. A burned-out filament will prevent electron production, stopping X-ray generation altogether.

- **Cathode damage:** Prolonged overuse can lead to damage in the cathode structure, making electron production less efficient, leading to tube failure.

3- Arcing

Electrical arcing is a sudden discharge of electrical energy between the cathode and anode or between the electrodes and the tube housing. This can result in:

- **Damage to the glass envelope:** Arcing can cause the glass to crack or develop electrical tracks, compromising the vacuum integrity of the tube.
- **Arcing between anode and cathode:** This can lead to tube instability, resulting in poor image quality and increased risk of failure. Arcing is often caused by excessive wear of the electrodes or contamination (e.g., vaporized tungsten deposits inside the tube).

4- Tube Aging

Like any mechanical or electronic component, X-ray tubes have a finite lifespan. Over time, parts like the anode, cathode, and bearings naturally degrade, even with normal usage.

- **Reduced output:** Over time, the X-ray tube produces lower-quality X-rays, resulting in images with poor contrast or resolution.
- **Increased exposure times:** As the tube’s efficiency decreases, longer exposure times may be required to obtain adequate images, which can lead to increased patient radiation exposure and further stress on the tube.

5- Vacuum Loss

X-ray tubes operate in a vacuum, which prevents the interaction of electrons with air molecules, ensuring efficient X-ray production. A loss of vacuum inside the tube (due to cracks, seals, or other issues) will cause tube failure, as it prevents proper electron movement from the cathode to the anode.

6- Mechanical Shock

Physical impacts or vibrations, whether during use, transportation, or maintenance, can cause damage to internal tube components or misalign critical parts like the anode, leading to failure.

Results of X-ray Tube Failure

1- Unusual Noises: A grinding or rattling noise from the rotating anode indicates bearing wear or failure. This can lead to uneven rotation, which affects the uniformity of the X-ray beam.

2- Reduced Image Quality: Poor-quality images, such as those with low contrast, artifacts, or inconsistent exposure, can result from a malfunctioning X-ray tube. These issues may indicate damage to the anode, arcing, or filament degradation.

3- Fluctuating Output: If the X-ray output fluctuates or is inconsistent, this could be a sign of electrical arcing or worn-out components within the tube, such as the filament or anode.

4- Overheating Warnings: Modern X-ray machines have built-in temperature monitoring systems. Frequent overheating alerts may suggest that the tube is not dissipating heat properly, which could indicate an impending failure.

5- Extended Exposure Times: If the machine requires longer exposure times to achieve proper image quality, this could be a sign that the tube's efficiency has decreased, often due to aging or filament issues.

Preventing X-ray Tube Failure

1- Proper Warm-Up Procedures

Before using the X-ray tube at full power, it's important to perform a proper warm-up. Gradually increasing the exposure settings allows the anode to reach operational temperature more evenly, reducing thermal stress.

Note: Follow the manufacturer's guidelines for warm-up times and techniques to prevent rapid heating and cracking of the anode.

2- Heat Management

Avoid overheating the X-ray tube by adhering to recommended cooling times between exposures. Continuous high-power exposures should be followed by adequate cooling periods.

Some X-ray systems have cooling fans, oil baths, or water-cooling systems to dissipate heat more effectively. Regular maintenance of these systems is crucial.

3- Regular Maintenance

Periodic inspection of the tube and its components, including bearings, glass envelope, and electrical connections, can help identify early signs of wear.

Monitor for buildup of tungsten vapor inside the tube, which can lead to arcing.

4- Monitoring Usage

Avoid exceeding the manufacturer’s recommended exposure limits for the tube. Keeping track of the tube's exposure history (number of exposures, power settings, etc.) helps in determining when the tube may be nearing the end of its lifespan.

Use the X-ray tube within its rated specifications, particularly for voltage, current, and exposure time.

5- Prevent Contamination

Ensure the X-ray tube is not exposed to dust, dirt, or other contaminants that could affect the vacuum seal or internal components.

6- Mechanical Handling

Minimize physical impacts or vibrations when handling the X-ray equipment. During transport or installation, ensure the tube is properly secured to avoid damage from mechanical shock.

Summary of Common X-ray Tube Failures

- **Excessive heat:** Causes anode pitting, cracking, bearing failure, and envelope damage.
- Arcing: Leads to damage of internal components and poor image quality.
- **Filament burnout:** Causes total loss of X-ray production.
- **Tube aging:** Results in reduced output and longer exposure times.
- **Vacuum loss:** Prevents proper electron flow and X-ray generation.

1. X-Ray Film

X-ray film is used to record the image produced by the X-rays passing through the patient's body. It consists of multiple layers:

- **Base:** The film’s foundation, made from a transparent polyester material, providing structural support and flexibility.
- **Emulsion:** Contains silver halide crystals (usually silver bromide) suspended in gelatin. When exposed to X-rays and developed, the silver halide crystals form a latent image that becomes visible after processing.
- **Supercoat:** A protective outer layer that shields the emulsion from scratches and handling damage.

Film Construction:

- **Double-sided film:** Most X-ray films are coated with an emulsion layer on both sides to enhance image quality and reduce patient exposure by using intensifying screens.
- **Single-sided film:** Occasionally used for specialized purposes where high detail is required (e.g., mammography).

2. Intensifying Screens

Intensifying screens are essential in reducing the patient's exposure to X-rays by amplifying the radiation's effect. They are placed on both sides of the film inside the cassette. The construction includes:

- **Base layer:** Provides support and is made from polyester or cardboard.
- **Phosphor layer**: This is the active layer, consisting of phosphor crystals (e.g., calcium tungstate, gadolinium oxysulfide). When struck by X-rays, these phosphor crystals emit light, which in turn exposes the film.
- **Reflective layer:** Positioned between the phosphor layer and base to enhance light reflection toward the film, improving efficiency.
- **Protective coat:** A transparent top layer that shields the phosphor layer from damage and wear.

Function:

- X-rays passing through the patient strike the phosphor layer of the intensifying screens, producing visible light.
- The visible light then exposes the X-ray film, reducing the amount of radiation needed compared to using the film alone.

3. Cassette

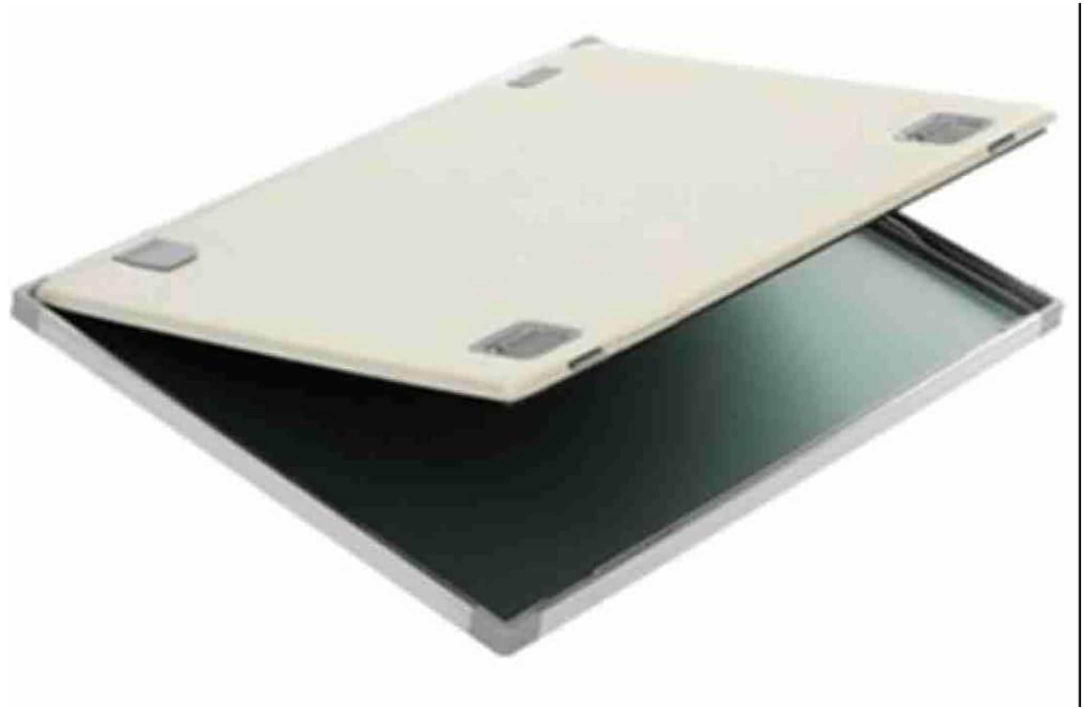
The cassette is a rigid container that holds both the X-ray film and the intensifying screens. Its main function is to protect the film and screens from light and physical damage. Cassettes are typically made from materials like aluminum, plastic, or carbon fiber to ensure strength and durability, while remaining lightweight.

Cassette Construction:

- **Front plate:** Designed to be radiolucent (transparent to X-rays), allowing the X-rays to pass through easily. It is often made from carbon fiber or plastic.
- **Padding layer:** Cushions and ensures close contact between the film and the intensifying screens, providing a uniform image.
- **Back plate:** Made from metal (e.g., lead) to absorb scattered X-rays and reduce fogging of the film.
- Locking mechanism: Keeps the cassette tightly sealed to prevent light exposure.

Types of Cassettes:

- **Standard cassette:** Contains two intensifying screens (one on each side of the film) and is used in general radiography.
- **Grid cassette:** Incorporates a grid to reduce scatter radiation, improving image contrast.



Workflow Process Summary:

- **Film Placement:** The X-ray film is placed inside the cassette, which also houses two intensifying screens (one in front and one behind the film).
- **Patient Positioning**: The patient is positioned between the X-ray source and the cassette, and the desired body part is aligned with the X-ray beam.
- **Exposure:** X-rays pass through the patient's body, with different tissues absorbing or attenuating the X-rays to different extents, depending on their density (e.g., bones absorb more X-rays than soft tissue).
- **Light Emission:** The X-rays that pass through the patient strike the phosphor crystals in the intensifying screens. These crystals emit visible light that exposes the film, creating a latent image.
- **Film Development:** After exposure, the cassette is opened in a darkroom, and the film is removed for chemical processing. The development process turns the latent image into a visible one by reducing the exposed silver halide crystals into metallic silver.

Manual Processing of the Latent Image

1. Developing

In the latent image, only those silver halide crystals exposed to X-rays or light are chemically altered. The developer solution reduces these exposed silver halide crystals to black metallic silver, forming the visible image.

Chemicals in Developer:

1- Developing agents: These reduce exposed silver halide crystals to metallic silver.

- Hydroquinone: Provides contrast by developing areas of high exposure.

- Phenidone: Develops lighter or less exposed areas for tonal range.

2- Activator (e.g., sodium carbonate): Maintains an alkaline environment, aiding the action of the developing agents.

3- Preservative (e.g., sodium sulfite): Prevents oxidation of the developer and maintains solution stability.

4- Restrainer (e.g., potassium bromide): Limits the action of the developer to only exposed crystals, preventing overdevelopment of unexposed silver halide.

Development Process:

The film is immersed in the developer for a precise amount of time (typically around 90 seconds to 5 minutes, depending on the system).The temperature is crucial (usually around 20°C to 24°C). Warmer temperatures accelerate development, but too high a temperature can result in fogging or overly dark images. The developer converts the exposed silver halide crystals into visible metallic silver.

The more X-rays that struck an area, the more silver will be deposited, creating darker areas on the film (e.g., bones appear light because fewer X-rays pass through them, while soft tissue areas appear darker because more X-rays expose the film).

2. Rinsing/Stop Bath

After development, the film undergoes a rinsing or stop bath process. This is important to halt the developing process and remove any remaining developer chemicals.

Chemicals in Stop Bath:

Acidic solution (e.g., acetic acid): Neutralizes the alkaline developer solution and stops further reduction of silver halides.

Process:

The film is immersed briefly (about 10-30 seconds) in the stop bath or rinsed in water. This stops further chemical reaction and removes developer residue.

3. Fixing

Once the film has been developed, the next step is fixing, which removes the unexposed and undeveloped silver halide crystals from the emulsion, leaving only the developed metallic silver image intact. The fixer makes the image permanent and light-resistant.

Chemicals in Fixer:

- Fixing agent (e.g., sodium thiosulfate or ammonium thiosulfate): Dissolves and removes unexposed silver halide crystals.

- Acid (e.g., acetic acid): Maintains an acidic environment, aiding the fixing process.

- **Hardener (e.g., potassium alum):** Hardens the gelatin emulsion, preventing it from becoming too soft or damaged during washing or handling.
- **Preservative (e.g., sodium sulfite):** Prevents oxidation and degradation of the fixing solution.

Fixing Process

- The film is submerged in the fixer for around 2-4 minutes.
- This step renders the film no longer sensitive to light, making it possible to handle the film in regular light after fixing.

4. Washing

After fixing, the film must be thoroughly washed to remove any remaining chemicals, particularly the fixer, which can degrade the film over time if not completely removed.

Washing Process

- The film is placed in running water for about 10-20 minutes.
- Water temperature must be controlled (usually between 18°C and 24°C) to avoid damage to the film.
- Adequate washing ensures the longevity of the radiograph, preventing yellowing or staining of the film over time.

5. Drying

The final step is to dry the film. After the washing step, the film is carefully dried to ensure it is ready for storage or review.

Drying Process

- The film is either air-dried or passed through a warm-air drying machine in an automatic processer.
- Drying must be even and thorough to prevent damage to the film emulsion or water spots.

Automatic Processing of the Latent Image

Automatic processing of X-ray films significantly speeds up the development of the latent image, ensuring more consistent results compared to manual processing.

Components of an Automatic X-Ray Film Processor

1- Transport system: Consists of rollers and transport racks that move the film through the processor's various sections.

2- Chemical tanks: Separate tanks hold the developer, fixer, and water for washing.

3- Heater: Maintains optimal temperature in the developer and fixer tanks.

4- Drying chamber: Equipped with warm air blowers that dry the film before it exits the processor.

5- Replenishment system: Automatically adds fresh chemicals to the developer and fixer to maintain proper chemical strength during extended use.

6- Circulation system: Ensures consistent mixing and distribution of chemicals in the tanks for uniform processing.

1. Film Entry and Transport

- The film is inserted into the processor in a light-tight compartment, allowing safe handling without exposure to light.
- Once inserted, the film is automatically transported by a series of rollers that move it sequentially through each processing stage.
- Transport racks and guide plates ensure the film is submerged in each chemical solution without getting stuck or misaligned.

2. Developing

- The film first passes through the developer tank.
- The developer chemically reduces the exposed silver halide crystals in the film emulsion to black metallic silver, making the latent image visible.
- Temperature control: Automatic processors heat the developer solution to around 30-35°C (higher than manual processing, which is typically done at 20°C). This higher temperature accelerates the development process.

- Developer replenishment: Fresh developer is automatically added as needed to maintain solution strength and prevent exhaustion.

3. Fixing

- After developing, the film moves into the fixer tank.
- The fixer removes the unexposed silver halide crystals, leaving only the black metallic silver image behind.
- Like the developer, the fixer tank is replenished automatically to keep the solution fresh, ensuring consistent fixing throughout the day.

4. Washing

- After the fixer stage, the film is transported through a water bath to wash away any residual chemicals, particularly the fixer, which can degrade the film over time if not properly removed.
- Automatic processors use a constant supply of clean, running water to ensure thorough washing.
- Adequate washing is critical to prevent yellowing or staining of the film during storage.

5. Drying

- Finally, the film is moved into the drying chamber, where it is subjected to warm air blowers.
- The film is dried evenly and quickly to prevent water spots or damage to the emulsion.
- Once dried, the film exits the machine, ready for viewing or storage.

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