A Hand Book on Installation and Maintenance of Medical Diagnostic X-ray Machine

For Biomedical Equipment Technician and Medical Technologist (Radiology and Imaging)

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It will be updated continuously

Please write your problem and receive reply
With the rapid growth of medical technology, developed countries produce the digital X-ray to diagnostic the normal and abnormal condition physiological organs of human body. Without its proper installation, use and time being maintenance, Real diagnostic result could not obtain from the equipment. Considering the real situation of developing countries as Bangladesh, author writes some guideline for the safe installation, use and maintenance. Author badly believes that this coomon guideline will be helpful for the Biomedical Equipment
Installation & Maintenance of Medical X-ray Machine

1. X-ray room preparation or renovation: Normally for new hospitals a room is allocated for X-ray room and on the hand in oldest room is renovated for X-ray installation. Both of cases considered equipment dimension and capacity of equipment. During construction and room allocation hospital manager must be considered the incoming equipment or ask to local vendors or ask to in-house or concern engineer who is expert on the X-ray Equipment. Manufacture to manufacture the specification is varied and it will wise to construct the roof and floor for new construction.

Suggestion:

- For new construction room should be prepared only floor and roof and the radiation room should be in the ground floor and where visitors or other patient could not move easily and it means restricted area. Because scatter radiation or leakage radiation is hazards and harmful. Hospital planner keeps in mind and designs the hospital X-ray room according the advice of Clinical X-ray engineer.

- For any existing some modification and renovation work will be applicable

- Both of the cases the tender sub–missioner must be check the allocated room and separately price costing include in the tender and to ensure this terms must be included in the tender by the purchaser.
1. **X-ray room shielding, temperature humidity control**

Guidelines for shielding of x-ray installations. The utility can hence forth follow the standard layout plans as provided in web-site or customize it as per guidelines given below:

Options in shielding materials. X-ray equipment must be installed in adequately shielded rooms to ensure that public in the vicinity of the x-ray installations are not unduly exposed to x-ray radiation. The adequacy
of shielding depends on the material and thickness used for this purpose. Different materials can be used for shielding. However, brick or concrete are considered the best materials, as they are easily available, economical, and have good structural strength.

While lead is a suitable shielding option for energies encountered in diagnostic x-rays, it is a weak structural material with tendency to lose uniformity and needs periodic radiation survey to ensure its continued adequacy. Also, Lead poses a serious environmental hazard and the use of it is being discouraged the world over. Recently, many new materials are being used/ developed as potential shielding materials, as an alternate to Lead. AERB would like to promote use of these materials, on demonstration of shielding adequacy.

**Step-by-step guidelines for submission of layout plan in diagnostic radiology facility:**

i. Decide a suitable room for housing an X-ray unit to facilitate the easy movement of staff and patient positioning.

ii. Room should have preferably one entrance door and window if present, should be above 2m from the finished floor level outside the x-ray room.

iii. Door should have a hydraulic mechanism to ensure that door is closed during procedure and should be provided with overlapping at the joints to avoid streaming.

iv. Identify the walls as Wall A, Wall B, Wall C & Wall D (in any sequence)

v. Position the location of the equipment for each modality as follows:

   **a. Radiography and Fluoroscopy equipment:** Couch, Control console and chest stand

   - In such a way that chest stand is on the opposite wall of the entrance door and the control console.

   - Mobile protective barrier with lead equivalent glass viewing window should be positioned in such a manner that the operator is completely shielded during the exposure.
- Control console should be positioned as far away as possible from the x-ray tube.

b. **Computed Tomography and Interventional radiology equipment:** Gantry / C-Arm, Couch, Separate control console room, viewing window,
- Position the gantry and couch such that the patient is completely visible from the control console, during the scanning
- The entrance door to the gantry room from the control console shall have similar requirements as the patient entrance door.

c) **Mammography/ OPG/ CBCT:** Control console, Equipment and Protective barrier
Positioning of equipment should be as far as possible from the door and the control console.

   i. Decide on the material and thickness of walls and door by referring to equipment specific table.
   ii. Measure the distances of all the walls, doors, windows from the centre of the couch.
   iii. Tabulate the details of layout and shielding as given in Annexure-1
   iv. Note that the required shielding of any material shall be provided at least up to the height of 2m from external finished floor of x-ray room.

   ❖ **PLEASE NOTE:**
   The final assessment of the adequacy of the design and construction of structural shielding is based on the radiation survey of the completed installation to be carried out at the time of commissioning after installation by supplier of the equipment. If the assessment survey shows deficiencies, additional shielding or modification of equipment and procedures are required.

   ❖ **REFERENCE DATA ON SHIELDING OF X-RAY INSTALLATION ROOM**
<table>
<thead>
<tr>
<th>Radiography and Fluoroscopy Shielding Material</th>
<th>Distance from centre of patient Table</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5 m</td>
</tr>
<tr>
<td></td>
<td>2.0 m</td>
</tr>
<tr>
<td>Brick (cm)</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Concrete (cm)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td>Steel (cm)</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>Lead  (cm)</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>Any other material</td>
<td>2.0TVT</td>
</tr>
<tr>
<td></td>
<td>1.8 TVT</td>
</tr>
<tr>
<td></td>
<td>1.8 TVT</td>
</tr>
</tbody>
</table>

Floor (if installation is not on ground floor) and ceiling thickness of 6-8 inch concrete is adequate.

3. Basic Installation procedure of X-ray machine Preparation: Getting Started

Recently, I worked with an urgent care facility on their first x-ray machine installation. They asked what compliance steps they needed to take to begin scanning patients with their new system. This wasn’t the first time I’d received this question, nor do I suspect it will be the last.

Now, because it’s rude to tell only half of a story, and because you asked Google so nicely about your upcoming imaging equipment project, I’ll tell you what I told them.
Before you install your x-ray room...
- **Check with your state radiation authority**

Before you begin building your x-ray room, check with the section of your state’s health department responsible for x-ray radiation compliance. They’ll help you determine if you need to submit a preliminary drawing of your x-ray room prior to beginning construction.

Depending on the type of x-ray equipment you intend to install you may need to undergo a “shielding plan review”.

- **The review process varies from state to state, but the following items are commonly asked about:**

  - Purpose of application
  - Type of facility
  - Type of machine being used
  - Anticipated workload
  - Location of operator’s barriers in the room

The reviewers will also want a drawing of the rest of the building that shows adjacent areas/rooms. This is to ensure that the equipment won’t be installed right next to areas where care is administered to radiation-susceptible patients.

- **Build your facility in accordance with state and local regulations**

Some states do not require lead-lined walls for some mobile fluoroscopy equipment, like c-arms, but most have required standards for fixed x-ray equipment. Make sure that your building is built to code to include lead-lined walls as dictated. The thickness of the lead varies by state and machine type, so be careful to mind the particulars of your local standards. Your physicist can also put together a lead shielding plan for your contractor.
Installing radiation-emitting equipment is no time to rely on hearsay or assumptions. Check out the resources below to find the right people to help as you kick off your x-ray project.

- Choosing the Best Contractor for Your Medical Facility Construction
- Imaging Equipment Installation Dos and Don’ts

INSTALLATION CHECKLIST

- The Tube Support
  
  - Inspect wiring and electrical connections.
  - Inspect cable drapes.
  - Inspect tube support movement.
  - Check that all locks are adjusted properly.
  - Check all lamps and indicators.
  - Check SID indicator accuracy.
  - Check that all covers are in place and fastened. Inspect counterweight assembly. Check tube alignment to receptors.
  - Inspect the tube mounting hardware.

- The Table
  
  - Inspect tabletop movement.
  - Inspect vertical drive.
  - Inspect operation of locks.
  - Inspect Bucky and cassette tray.
- Check any safety interlocks.
- Check all lamps and indicators

**The Wall Receptor**

- Inspect vertical movement.
- Check locks adjustment.
- Inspect counterweight assembly.
- Inspect Bucky and cassette tray

**The Generator/Control**

- Check that all electrical connections are secure.
- Inspect all indicators and lamps.
- Check that all modes of operation are functional.
- Inspect all switches, buttons, and knobs.

**The High Voltage Transformer Unit**

- Inspect the high voltage cables and connections.
- Check all the generator interface connections.
- Check oil level in transformer.
- Check that all covers are in place and fastened securely.

**The X-ray Tube**
- Check that the high voltage cable ends are clean, sufficiently greased, and are securely tightened.
- Check rotor bearings (sound and speed).
- Check x-ray calibration (noninvasive)-record calibration results on a calibration form.
- Take a test film using a resolution phantom such as a pie mesh or line pair phantom to check tube resolution.
- Check the focal spot size of the tube.

- **The Collimator**
  - Test lamp operation.
  - Verify SID indicator accuracy.
  - Check light field accuracy.
  - Check actual x-ray field size with field size indicators.
  - Check the operation of the automatic system.

- **The A. E. C.**
  - Test A. E. C. operation with a flat field phantom.
  - Check for the proper density (i.e., 1.2 D).
  - Test for exposure repeatability.
  - Test all three chambers for correct balancing.
  - Test back-up timer function.
4. Trouble shooting and its prevention

Troubleshooting Sequence and its prevention state below:

- To recap, the troubleshooting sequence that the service engineer must follow to successfully resolve x-ray failures is as follows:
  - Gather as much information as possible about the failure.
  - Reproduce the failure.
  - Troubleshoot to component level.
  - Verify that the suspected component is actually bad.
  - Check that the new component is functioning properly.
  - Test all functions of the x-ray system.

- Failures with the X-ray Control
  - Common mA Failures
  - Time Control Failures
  - Failures with the High Voltage Transformer Unit

- Failures with the X-ray Tube
  - A filament could open,
  - High voltage arcing could occur in the tube housing or within the tube insert itself,
  - The rotating anode could fail,
  - The radiation output of the tube could drastically fall off, the resolution (i.e., focus) of tube could change,
  - The anode could become pitted causing erratic exposures, the housing seal or the glass insert could break causing an oil leak,
  - A receptacle could get damaged.
Filament Failures:

- Usually a filament wire wills either become open or it will become short.
- During emission of electrons a small amount of the tungsten material is also released (filament evaporator).
- Evaporated tungsten deposits could lead to arching within the tube insert.
- Due to evaporation filament wire become thinner and brittle as a result it may break.
- In that case no exposure.
- Remove the collimator and looking directly into the part of x-ray tube (no generator power).
- If part of the tube partially obstructed, measure the resistance of the wire at pins of the cathodes.
- May inspect the filament with the generator power on. In that case an optical device to protect his eyes from intense of high is needed.
- Filament can short to the focusing cup of the cathode that can be understood from generator overload.
- Short filament can be observed sagging. It can also be understood by resistance measurement.
- A new tube is to be installed to before that the actual cause of failure is to be sure. If it is due to over current that is to be solved before installing new tube.

Low Radiation Output:

- If the desired mA cannot be achieved regardless of the amount of filament current present.
- Low mA produced low radiation.
- This happen if tube is very old.
- This failure can be detected from the filament emission chart for that tube.
If the actual mA value cannot be achieved at the specified filament voltage or ever of a higher voltage is used, the tubes bad and replaced.

**X-Ray Tube Arcing:**

- A high voltage are can occur by two means.
- An alternate path of conduction within the glass insert.
- A breakdown or reduction of insulating oil within the tube housing.
- The arcing that occurs within the tube housing is potentially dangerous to persons who may be in the vicinity of the x-ray tube.
- Due to arcing highly sensitive get proms, solid-state device used in x-ray generator are most damaged.

**Gassy Tubes:**

- Vaporized gas deposits on the internal wall of the tube. This deposited material may again release gas molecules.
- The gas molecule within the path of the electron beam will create a conduction path causing an internal short-circuit and draws excessive current and shutdown the x-ray generator.
- Seasoning or conditioning the tube could remedy this problem.
- A gassy tube must be replaced.

**Failure with the High Voltage Cables:**

- Open (conductor may break)
- This open may cause arcing. This arcing could cause the x-ray generator to shutdown or it may cause an erratic kVp output.
Image quality problem

- Complains are
- Films are too dark or too light
- Grid lines on the image
- An un-sharp or blurry image
- Image with too low or too high control
- Blank film
- Artifacts
- 1st rule out film and film processing as the cause of the imaging problem.
- Developer that appears light yellow in color is good (brown is bad).
- Dip a film that has been exposed to light directly into the developer for a minute (if it turn black)
Artifacts seen on the film could also be caused by water marks or scratches caused by processing.

Grid lines problem may be turnout to be roller marks.

Film affects may be due to

Static electricity

Dirty screen in the film cassette

If RH drop below (30%-50% RH). The extremely dry environment is conduction to a buildup of static charge between different materials. Static electricity form wavy drives emanating in all direction from appoint film fogging (due to light in the dark room).

Image quality

Good image should have sufficient optical density so that interest structure can be clearly seen.

Optical density measured by densitometer

Human can distinguish up to about 2.5D. Normal film density t film range from 0.5 to 1.5

Image quality – image definition image resolution, image sharpness.

It is the differential absorption of the x-ray beam that essentially creates the image.

The film consults of a flexible bass (plastic), adhesive coating to which the emulsion adhere.

Emulsion is sensitive silver bromide suspended is a gelatinous material.

Silver bromide chemically charges to neutral silver with film (latent image).

Film is processed by a developer (contain silver mass) reacts with material silver for black metallic silver.

After that film is present with fixer. Which clear all an effected silver bromide, timer hardens the film and makes image permanent.

Beam quality is measured by HVL (Half valve larger) amount of aluminum required to receive the radiation output of the tube to one half to the original.

HVL express the thickness of equivalent amount of aluminum.

Al low kVp– beam constitute soft radiation.
- Hard beam (high energy x-ray photon) greater penetration ability, reduce dose by loss in image contrast.
- Increase kVp reduce image contrast increase scatter.
- A change of ± 5 KVP is out discernible.
- mA & seconds directly affects film density, image sharpness
- The sharpness of the image is affected by the type

5. Maintenance Methodology:
Medical equipment brings along with it associated benefits and problems. The problem that draws the most attention is maintenance. Lack of a maintenance policy can result in no advance planning for maintenance budgets and thus no availability of spares and accessories. Many laboratories and health care programmers suffer because the installation and maintenance requirements are not planned in advance. This renders much equipment unusable and many devices lie idle because of lack of spares or funds.

- Effective Maintenance Strategy
It is essential that we plan the resources required for maintenance. Planning will need to be made for both repair work and also for planned preventive maintenance. The following will also promote effective maintenance:

- User as well as service manuals
In procurement it should be made mandatory for the vendors to provide the following:
  - Training to technicians and operators
  - Providing user / operating manuals.
  - Providing service / maintenance manuals

- Receipt and incoming inspection
Incoming equipment should be carefully checked for possible shipment damages; compliance with specifications in the purchase order; and delivery of accessories, spare parts and operating and service manuals.

- **Inventory and documentation**

  A proper entry should be made in the inventory register. The inventory record should contain the serial number and date of receipt as well as date of completed inspection.

  Installation and final acceptance: Installation should be done by the vendor and training should be provided at this stage to the user as well as to the maintenance technicians.

- **Equipment history record**

  There should be an equipment history record sheet to track the performance of the equipment.

  This sheet should note down the date of installation and commissioning, preventive as well as corrective maintenance records.

- **Maintenance**

  Proper maintenance of medical equipment is essential to obtain sustained benefits and to preserve capital investment. Medical equipment must be maintained in working order and periodically calibrated for effectiveness and accuracy.

- **Condemnation of old and obsolete equipment**

  The life cycle of medical equipment will vary from 5-10 years. If the equipment is declared obsolete by the vendor it may not be possible to get spare parts. Even if the parts are available it can become too expensive to obtain them and the equipment is no longer economical to repair.

  Condemnation of equipment should be well planned and the necessary steps should be taken in advance to arrange replacement.
Types and approaches to Maintenance of Medical Equipment

There are two types of maintenance:

a. Corrective Maintenance (or Repair)

This is done to take corrective action in the event of a breakdown of the equipment. The equipment is returned repaired and calibrated.

b. Planned (or Scheduled) Preventive Maintenance

This work is done in a planned way before repair is required and the scheduled time for the work circulated well in advance. It involves cleaning, regular function / safety tests and makes sure that any problems are picked up while they are still small. The choice of approach for Preventive and Corrective Maintenance depends on the complexity of equipment.

c. Maintenance by in-house trained technicians

The majority of the problems is relatively simple and can be corrected by a trained technician.

Simple repairs and inspections are less costly when done this way. Workshop requirements for in-house medical equipment maintenance are described in references in chapter 11. Vendors should provide training to in-house technicians at the time of installation and commissioning.

d. Maintenance by manufacturer or third party

For specialized and advanced equipment, the vendor should provide maintenance services through a combination of on-call services and a maintenance contract negotiated at the time of the purchase. It will rarely be economical to provide this level of service in-house.
Levels of Maintenance

There are three levels of maintenance commonly identified:

Level 1: Maintenance by User (or first-line)
The user or technician will clean the filters, check fuses, and check power supplies etc. without opening the unit and without moving it away from the point of use.

Level 2: Maintenance by Biomedical Technician
It is recommended to call the local technician when first-line maintenance cannot rectify a fault or when a six monthly check is due.

Level 3: Maintenance by Specialized
Equipment such as CT Scanners, MRIs etc. will need specialized engineers and technicians trained in this specific equipment. They are normally employed by third party or vendor companies.

As stated in the introduction, this manual is focused on the User or First-Line Maintenance level. The reference section can be used to discover material for the other maintenance.

Basic Maintenance of X-Ray Machines

a. Function
X-Ray machines are used for imaging bones and hard tissues and diagnosing fractures, joint defects, choked lungs etc. Sometimes contrast agents are also used to highlight any defects in the abdomen under X-rays.

b. How it works
X-rays are high energy electromagnetic waves. The transformer produces a high voltage that directs electrons onto a target in the machine head. X-rays are produced by the target and are directed into beams by a collimator towards the human body. Soft body tissue absorbs less X-rays, i.e., passes more of the radiation, whereas bone and other solids prevent most of the X-rays from going through. A photographic film or electronic sensor displays how much X ray has passed through, forming an image of the interior of the body. Bone appears nearly white, because few X-rays strike the corresponding part of the film, leaving it largely unexposed; soft tissue allows much more radiation to pass through, darkening the film in those places.

Users must ensure proper radiation safety protocols and supervision are in place.

### Troubleshooting of X-ray Machine (End user)

<table>
<thead>
<tr>
<th>S/L</th>
<th>Fault</th>
<th>Possible Cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X-Ray unit does not switch on</td>
<td>Mains power not connected</td>
<td>Check the machine is plugged into the mains socket and that all switches are on.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Replace fuse with correct voltage and current if blown.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Check mains power is present at socket using</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>X-Ray machine not exposing, even when power is on.</td>
<td>Safety interlock is on</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>-------------------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety interlock is on</td>
<td>Check safety locks, all switches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exposure switch cable problem</td>
<td>Check for any loose connection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal error</td>
<td>Refer to biomedical technician</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Poor X-Ray image quality</td>
<td>X-Ray tube problem</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>The table does not move.</td>
<td>Table motor or cable problem</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety switch or fuse problem</td>
<td>Check relevant fuse or switch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control circuit problem</td>
<td>Refer to biomedical technician</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Electrical shocks</td>
<td>Wiring fault</td>
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<td></td>
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</tr>
</tbody>
</table>

c. **User Maintenance Checklist of X-Ray Machine**
<table>
<thead>
<tr>
<th><strong>Daily</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cleaning</strong></td>
<td>Clean dust from the unit with a dry cloth</td>
<td>Remove any tape, paper or foreign body from equipment</td>
</tr>
<tr>
<td><strong>Visual Checks</strong></td>
<td>Check all parts are present and connected</td>
<td>Check cables are not twisted and remove from service if any damage is visible</td>
</tr>
<tr>
<td><strong>Function checks</strong></td>
<td>Switch on power and check all indicators function</td>
<td></td>
</tr>
</tbody>
</table>

| **Weekly**                      |                                                                 |                                                                 |
| **Cleaning**                    | Clean all dust and dirt from the X-Ray machine and room         |                                                                 |
| **Visual checks**               | If any plug, cable or socket is damaged, refer to biomedical technician | Check all knobs, switches and wheels operate properly               |
|                                 |                                                                 | Check lead aprons for any defects                                   |
|                                 |                                                                 | Check table, cassette holder and grids for smooth movement         |
| **Function checks**             | If machine has not been in use, wear lead apron and check       | whether exposure indicator lights on switch operation              |
|                                 |                                                                 | Check collimator bulb, replace with correct type if needed         |

| **Every six months**            |                                                                 |                                                                 |
| **Check calibration**           | Biomedical Technician check required                             |                                                                 |

**Inspection & Preventive Maintenance (IPM) of Radiographic Units, General-Purpose:**

- **Generic Name:** Radiographic Units, General-Purpose
- **Also Called:** General Radiographic X-ray unit (300ma/500mA/800mA/1000mA)
- **Commonly Used In:** Radiology departments
- **Scope:** Applies to general-purpose radiographic systems and associated components with ceiling-suspended or integrated x-ray tube supports
- **Risk Level:** Recommended, as High
- **I PM interval:** Major 12 months, Minor 6 months & as per manufacturer’s instruction

**Overview**

General-purpose radiographic table systems are used to perform routine diagnostic x-ray procedures. Some systems can be enhanced with optional modular components for fluoroscopy and linear tomography. A general purpose radiographic system consists of a table, a Bucky film tray and grid, an x-ray tube with housing and suspension, and an x-ray generator.

The table consists of a rectangular steel or metal alloy pedestal base or an open frame that supports a tabletop constructed of carbon fiber or plastic or wood laminate. Tableside and footplate controls allow the table to be raised or lowered for transferring patients or accommodating different imaging procedures. Table movement is usually power assisted. Some tables can be tilted without moving the patient. Most tables can also be equipped with handgrips, headrests, compression bands, footrests, and other accessories necessary during certain radiographic procedures. The Bucky film tray and grid are located under the tabletop. The grid is used to reduce scatter radiation. Bucky systems are usually fully automatic and can accommodate film cassettes up to 35 × 43 cm (14” × 17”) in size. Most systems also include automatic exposure control (AEC) to automatically terminate the exposure when sufficient x-ray intensity has reached the film cassette.

The x-ray generator is usually three phases, high frequency, or constant potential, depending on the manufacturer. The x-ray tube has either a stationary or rotating anode and is housed in either an integrated tube stand or an overhead tube suspension. Beam restrictors (collimators) are used to regulate the shape and size of the x-ray beam to cover only the area of diagnostic interest.
**Figure:** Radiography X-ray system / analog / for multipurpose

- Test apparatus and supplies for IPM
Electrical multimeter

Noninvasive kVp meter (compatible with the x-ray generator being inspected)

Noninvasive timer (may be included with the kVp meter)

Ionization chamber with electrometer or a combination exposure meter

Five filters of 10 cm ×10 cm×1 mm Type 1100aluminum

Collimator alignment template marked in centimeters or inches Large (35 cm ×43 cm or 14”×17”), medium (25 cm×30 cm or 10”×12”), and small (20 cm×24 cm or 8”×10”) format x-ray cassette and film

Ten pieces of 30 cm ×30 cm×2.5 cm Plexiglas (or another patient-simulating material for testing the AEC)

Densitometer

Oscilloscope (calibration only)

High-voltage divider (calibration only)

Special precautions for IPM

Wear a lead apron and thyroid shield, and maintain the greatest possible reasonable distance from the x-ray source and all scattering material during all x-ray exposures. It should not be necessary to place hands or fingers in the x-ray beam; if this is unavoidable, wear lead gloves. Do not remove the high-voltage cables from the wells with the power on. Ensure that high-voltage cables are completely discharged by repeatedly touching the conductor to ground as soon as it is removed from the well.

Wear rubber gloves or other appropriate protection when exposed to blood or other body fluids.

Allow adequate time between repeated exposures to prevent overheating of the x-ray tube.

Procedure

Before beginning an inspection, carefully read this procedure and the manufacturer’s instruction and service manuals; ensure that you understand how to operate the equipment, the significance of each control and
indicator, and the alarm capabilities. Also determine whether any special inspection or preventive maintenance procedures or frequencies are recommended by the manufacturer.

This procedure is intended to ensure adequate system performance and maintenance. It should not be construed as providing full compliance with the requirements of all governmental regulations and accreditation standards of professional associations.

Such regulations and standards may include testing beyond that provided below and may also require documentation by a certified medical physicist.

For acceptance testing, we strongly recommend contracting with a medical physicist. Acceptance testing is crucial because it generates data on the baseline performance of the device.

▶ Qualitative tests

1.1 Chassis/Housing.

Examine the exterior of all equipment items (e.g., table, tube support, x-ray generator console and equipment cabinets, upright cassette holders) for cleanliness and general physical condition. Be sure that all hardware is present and tight and that there are no signs of spilled liquids, deep scratches, dents, or other serious abuse. Check the mechanical operation of all moving parts on all items, including the x-ray tube, x-ray tube support, collimator, tabletop, vertical table movement if applicable, and upright cassette holders. Ensure that all movements are smooth and easy, with no binding or undue resistance.

1.2 Brakes.

Check the brake or locking device for each movement of the x-ray tube, x-ray tube support, collimator, tabletop, upright cassette holders, etc. Ensure that all locks function properly and hold securely.

1.3 Strain Reliefs.
Examine the strain reliefs at both ends of all cables subjected to movement and stress. Be sure that they hold the cord securely.

1.4 Circuit Breaker/Fuse.
If the device has an external circuit breaker, check that it is accessible (not blocked by cabinets, covered with clipboards, or out of reach because of the presence of tables, counters, etc.) and operates freely.

1.5 Cables.
Inspect any cables (e.g., collimator cables, high-voltage cables, exposed interconnect cables) and their strain reliefs for general condition. Carefully examine cables to detect breaks in the insulation and to ensure that they are gripped securely in the connectors at each end to prevent rotation or other strain. For cables other than high-voltage cables, verify that there are no intermittent faults by flexing electrical cables near each end and looking for erratic operation. Use an ohmmeter if a problem is suspected. High-voltage cables should be removed from the wells (at the x-ray tube ends), cleaned, coated with high-voltage compound, reinserted, and tightened securely. The high-voltage transformer end should not require routine inspection if the wells are vertical and high-voltage oil is used.

1.6 Fittings/Connectors.
Examine all electrical cable connectors for general condition. Electrical contact pins or surfaces should be straight, clean, and bright. If keyed connectors are used, make sure that no pins are missing and that keying is correct.

1.7 Filters.
Check the condition of any air filters present in the systems. Clean or replace as needed.

1.8 Controls/Switches
Before changing any controls or alarm limits, check their positions. If any settings appear inordinate (e.g., high mA setting), consider the possibility of inappropriate clinical use or of incipient device failure. Record the setting of those controls that should be returned to their original positions following the inspection. Examine all controls and switches (x-ray initiation, collimation, technique selection, etc.) for physical condition, secure mounting, and correct motion. Check that control knobs, if present, have not slipped on their shafts. Where a control should operate against fixed-limit stops, check for proper alignment, as well as positive stopping. During the course of the inspection, be sure to check that each control and switch performs its proper function. Ensure that the fluoroscopic and radiographic exposure switches do not stick, that continuous pressure is required to continue exposure, and that release of pressure immediately terminates exposure. Ensure the proper operation of the two-position exposure switch (i.e., ensure that the x-ray exposure is not released with the first trigger only).

1.9 Indicators/Displays.
During the inspection, confirm the operation of all lamps, indicators, meters, gauges, and visual displays on the unit.

Examples of indicators and displays are technique settings, exposure time, x-ray on, and field size indicators on the collimator. Inspect the source-to-image distance (SID) indicator. If a tape measure is present, ensure that it operates smoothly and is accurate.

1.10 Alarms.
Induce conditions to activate audible and visual alarms (for example, x-ray on). Check that any associated interlocks (e.g., x-ray exposure is inhibited if the x-ray tube is not aligned with the image receptor) function. If the unit has an alarm silence feature, check the method of reset (e.g., manual or automatic) against the manufacturer’s specifications. It may not be possible to check out all alarms at this time since some may require abnormal operating conditions (e.g., long exposure times). Instruct users to document activation of these alarms to ensure that they are functional.

1.11 Audible Signals.
Operate the device to activate any audible signals (for example, radiographic exposure). Confirm appropriate volume. If audible alarms have been silenced or the volume set too low, adjust the alarm volume to the appropriate level.

1.12 Labeling.
Check that all necessary certification labels, warning labels, technique charts, and instruction cards are present and legible.

1.13 Accessories.
Confirm the presence and condition of accessories (e.g., clamp-on devices such as handgrips for the tabletop).

1.14 Positive Beam Limitation.
On units provided with positive beam limitation (automatic collimation), ensure proper operation by making visual checks of the light field with different-size cassettes in the Bucky and with the orientation of the cassettes changed. The light field should be limited to the size and orientation of the cassettes.

- Quantitative tests
2.1 Grounding Resistance.

Using an ohmmeter or multimeter with good resolution of fractional ohms, measure and record the resistance between common ground and exposed metal on the unit. Internationally recommend a maximum resistance of 0.5 Ω. Hand switches and footswitches that are powered from low voltages need not be grounded. Although confirmation of grounding integrity provides reasonable assurance of safety, NFPA 99 calls for voltage measurements for installed devices in the patient vicinity.

Using a voltmeter, measure and record the voltage between a reference grounding point (e.g., the grounding pin of an electrical receptacle or some other known ground) and exposed (i.e., unpainted and not anodized) metal on the chassis. A voltage reading below 500 mV is acceptable for general care areas in existing construction.

2.2 Leakage Current.

Chassis leakage current of permanently wired equipment cannot be readily measured after installation is completed. Permanently wired appliances in the patient vicinity should be tested before installation, while the equipment is temporarily insulated from ground. The leakage current from frame to ground of permanently wired appliances installed in general or critical patient care areas should not exceed 5 mA with all grounds lifted.

*Patient vicinity is defined as a space within six feet beyond the perimeter of the patient support in its normal location and extending seven-and-a-half feet above the floor.

2.3 Accuracy of kVp.

Perform this test on all x-ray tubes. Use a noninvasive kVp meter that has previously been calibrated against a high-voltage divider on the type of generator being tested.

Use the kVp meter in accordance with the manufacturer’s recommendations. These may include the kind of filters to use and the distance at which the kVp meter has to be placed. Some meters require that the user specify
the type of generator being tested and the amount of filtration present in the primary x-ray beam. Make measurements at low, medium, and high settings (e.g., 60, 80, 100 kVp). After the appropriate corrections have been applied to the measured kVp readings (e.g., for filtration), the difference between the measured kVp and the preset kVp should not exceed ±5% of the preset kVp.

2.4 Timer Accuracy

Use a noninvasive timer to measure the accuracy of the time settings. Most noninvasive kVp meters also display exposure times. Once the unit has been appropriately set up, dial up a midrange kVp setting (e.g., 80 kVp). The x-ray unit may display in mAs; if this is the case, calculate the time by factoring out the mA. Conduct measurements at typical low, medium, and high settings. The difference between the measured time and the preset time should not exceed ±1 msec or ±5%, whichever is greater.

2.5 Linearity of mAs

This test must be performed on all x-ray tubes. Use an ionization chamber with an electrometer (or a combination exposure meter) to measure the exposure in mR for this test. The ionization chamber should be placed centrally in the x-ray beam at a known standard distance from the focal spot (e.g., 100 cm). Dial up a midrange kVp setting (e.g., 80 kVp). Make radiographic exposures at this fixed kVp, and record the exposure values (in mR) from the electrometer or exposure meter at a minimum of three mA settings that span the range commonly used. Use an exposure time that is in the mid-range for each mA value. Calculate the mR/mAs at each setting and average the calculations. Each individual mR/mAs value should be within ±10% of the average.

2.6 Exposure Reproducibility

Use one of the above mR/mAs values as the one value to be used for evaluating short-term and long-term reproducibility of the x-ray tube and generator combination. For the short-term test, make a minimum of four exposures at the same mAs over a span of 15 minutes. The mR/mAs values should have a coefficient of
variation no larger than 10%. For long-term reproducibility, simply record the current average mR/mAs value from the four measurements above, and compare this with the value recorded during the preceding inspection. It is critical that identical test conditions be used for assessing reproducibility. For example, the same chamber-to-source distance should be used, and the technique (kVp, mAs) should be the same. Long-term reproducibility should be within ±10% of the average.

2.7 Half-Value Layer (HVL)

This test must be performed on all x-ray tubes. Use an ionization chamber, electrometer, and Type 1100 aluminum filters for this test. Place the ionization chamber in the center of the x-ray beam at about 100 cm from the focal spot. Collimate so that the x-ray field just encompasses the ionization chamber. Set the unit to operate at 80 kVp. Select a midrange mAs value. These kVp and mAs values should be held constant during the whole course of this test. Record the initial exposure value (in mR) with nothing in the primary beam (i.e., 0 mm of aluminum). Then record the exposure reading with aluminum thicknesses of 2 mm and 4 mm. The thickness of aluminum required to reduce the initial exposure reading by half is the half-value layer of the beam. The HVL is most accurately read by plotting the measurements on semi log graphing paper. Plot the exposure values on the logarithmic scale against the thickness of aluminum on the linear scale. At 80 kVp, the HVL should be a minimum of 2.3 mm of aluminum. The HVL measurement should be compared to measurements from previous inspections since a change in HVL may indicate tube deterioration.

2.8 Collimation

This test must be performed on all collimators and all receptor sizes. Place a medium-format x-ray film (25 cm×30 cm or 10 “×12”’) at an SID of 100 cm (40 “). Ensure that the x-ray film is perpendicular to the x-ray beam. Ensure that the x-ray tube is in the detent for alignment with the receptor or aligned using a centering light if there is no detent. Precisely center the collimator alignment tool on the cassette. Turn on the collimator light, and collimate to an area of 20 cm ×20 cm. Note the exact readout of the exposure area size indicators. Ensure that the light beam is exactly centered on the collimator alignment tool. Record the exact boundaries of
the illuminated area from the collimator alignment tool. Make an x-ray exposure (for a film/screen speed of 400, a unique of 55 kVp and 5 mAs should be sufficient), and process the x-ray film. Congruence of the light field to the x-ray field.

Measure the distances of L1, L2, W1, and W2 on the processed film. The sum of W1+W2+L1 +L2 is the total misalignment between the light field and the x-ray field. This sum must not exceed 2% of the SID; that is, at an SID of 100 cm, the misalignment should not exceed 2 cm (see Figure 1). Alignment of the x-ray source to the receptor. Mark the exact center of the exposed area on the film by drawing diagonals from corner to corner of the exposed area. Mark the exact center of the film by drawing diagonals from corner to corner of the film. Measure the distance between the two centers; this must not be more than 2% of the SID — that is, at an SID of 100 cm, the centers should be mis-aligned no more than 2 cm. Also, ensure that the exposed area is square to the film. Field size indicators versus actual exposed area. Measure the length and width of the exposed area on the exposed film. Compare the actual size of the exposed area with the readout of the exposure area size indicators noted earlier.

The dimensions of the exposed area must be within 2% of the SID - that is, 2 cm at an SID of 100 cm.

2.9 AEC Object Thickness Compensation.

This test is to be conducted on each available radiographic image receptor holder (e.g., spot film, table Bucky, wall Bucky). Place 20 cm of 30 cm x30 cm plexiglass on the table, or support it up against the wall Bucky. (It is acceptable to use another patient- simulating material for AEC tests, such as aluminum.) Ensure that the plexiglass covers the AEC detectors. Set the unit to operate at 80 kVp (or some other setting commonly used to image a medium-size patient). Load a cassette of a size commonly used with the standard film used at the facility, and place this into the receptor holder being tested. Then make an AEC-controlled exposure. Process the film on a processor that has previously been verified as operating optimally.
Use a densitometer to measure the optical density of the radiograph in the center of the image. If the optical density falls within the range chosen by the radiologists (typically 1.2 to 1.4 OD), repeat the test using identical setup conditions but with varying amounts of plexiglass in the beam. At a minimum, check the optical density at 15 cm and 25 cm of plexiglass. All films used in this test should come from the same batch, and only one cassette is to be used for all exposures. The optical density of all the processed films should agree to within ±0.3 OD of the optical density at 20 cm. 2.10 AEC kVp Compensation. This test should also be conducted on each available radiographic.

Collimation test setup image receptor holder (spot film, table Bucky, and wall Bucky). Place 20 cm of Plexiglas (or some other patient-simulating material) on the table, or support it up against the wall Bucky. Ensure that the AEC detectors are covered by the plexiglass. Use the most common size of films in the same cassette holder for all checks in this test. Make a series of AEC-controlled exposures of the 20 cm of plexiglass at different kVp values. At a minimum, use three kVp settings (e.g., 60, 80, 100 kVp). For each exposure, process the film on an optimally performing processor. Read the optical density of the radiograph using a densitometer. The optical density of the films at all kVp settings checked should agree to within ±0.3 OD.

- **Preventive maintenance**
  - Clean the exterior and interior. Take precautions when dealing with body fluids.
  - Lubricate as per the manufacturer’s instructions.
  - Calibrate the system to ensure performance within the manufacturer’s specifications, at intervals recommended by the manufacturer or as indicated by inspection results. Adjust all brakes, locks, and bearings to ensure proper performance.
  - Replace air filters, if needed.
❖ **Acceptance tests**

Acceptance testing is typically performed by a medical physicist.

❖ **Before returning to use**

Ensure that all controls are set properly. Set alarms loud enough to alert personnel in the area in which the device will be used. Other controls should be in their normal pre-use positions. Attach a Caution tag in a prominent position so that the user will be aware that control settings may have been changed.

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6. **Module of Inventory and Maintenance report writing**

A1. **Equipment Inventory Register**

<table>
<thead>
<tr>
<th>S/L</th>
<th>Reference ID</th>
<th>Equipment Name with Model, Brand &amp; origin</th>
<th>Contact of Vendors &amp; Supplier</th>
<th>Procuring Entity with Tender Contract No</th>
<th>Cost Per unit</th>
<th>Date of Equipment Issue</th>
<th>Date of Equipment Installation</th>
<th>Warranty Period with Expiry Date</th>
<th>AMC/CMC with period &amp; charge (if any)</th>
<th>Spare Parts/Consumables Inventory</th>
<th>Current Status of equipment</th>
<th>Remarks with signature</th>
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Note:

Inventory register should be updated half yearly for current status of functioning of the equipment, with name and signature of the concerned person by whom equipment has been checked. Necessary action should be taken if required so that equipment is nearly always available for the right
## A2. Equipment Maintenance Register

<table>
<thead>
<tr>
<th>S/L</th>
<th>Preventive Maintenance / Calibration</th>
<th>Expenditure with cost (if any)</th>
<th>Remarks of the service engineer with full name &amp; signature</th>
<th>Remarks of User with full name &amp; signature</th>
<th>Break down date and time</th>
<th>Break down details as find by user</th>
<th>Date and time of rectification</th>
<th>Total time taken</th>
<th>Rectification details with expenditure</th>
<th>Remarks of the service engineer with full name &amp; signature</th>
<th>Remarks of User with full name &amp; signature</th>
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- **Equipment Name with reference ID:**
- **Manufacturer/Brand/Origin:**
- **Equipment Serial No:**
- **Date of installation:**
- **Warranty Period with Expiry Date:**
- **Under AMC/CMC (with cost):**
- **Average Life (as per manufacture):**
- **Frequency of Planned Preventive Maintenance (as per manufacturer):**
- **Contact Details of Vendors:**
- **Location:**
- **Contact Details of Supplier (if any):**

**Remarks of the service engineer with full name & signature:**

**Remarks of User with full name & signature:**

**Date On Next on**
Note:

- Planned Preventive Maintenance Column should be filled with Green pen in Resister and with Green color in computer.
- Break down Maintenance Column should be filled with Red pen in Resister and with Red color in computer.

Acknowledgement

Author acknowledges to Ministry of Health & Family Welfare & Government of Bangladesh

References

3. X-ray equipment maintenance and repair workbook for radiographers & radiological technologists edit by Ian R McClelland, Chief technical support engineer (retired)