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Maintenance

Mobile X-Ray Units

REVISION HISTORY

REVISION	DATE	REASON FOR CHANGE
0	OCT 11, 2019	First Edition
1	MAR 20, 2020	General update and corrections.
2	DEC 20, 2021	Corrections in Checking the Leakage Current Section.
3	SEP 13, 2022	Sections updated: “Procedures related with the Batteries and Battery Chargers”, “Test for kV Loop”, “Test for Digital mA Loops” and “Checking the Radiation Leakage”.

This Document is the English original version, edited and supplied by the manufacturer.

The Revision state of this Document is indicated in the code number shown at the bottom of this page.

ADVISORY SYMBOLS

The following advisory symbols will be used throughout this manual. Their application and meaning are described below.

DANGER !

DANGERS ADVISE OF CONDITIONS OR SITUATIONS THAT IF NOT HEEDED OR AVOIDED WILL CAUSE SERIOUS PERSONAL INJURY OR DEATH.

WARNING

ADVISE OF CONDITIONS OR SITUATIONS THAT IF NOT HEEDED OR AVOIDED COULD CAUSE SERIOUS PERSONAL INJURY, OR CATASTROPHIC DAMAGE OF EQUIPMENT OR DATA.

CAUTION

Advise of conditions or situations that if not heeded or avoided could cause personal injury or damage to equipment or data.

Note ☞

Alert readers to pertinent facts and conditions. Notes represent information that is important to know but which do not necessarily relate to possible injury or damage to equipment.

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SECTION 1 INTRODUCTION

The purpose of this Periodic Maintenance is to assure a continuous safe performance of the X-ray Unit, to increase serviceability, to reduce the costs (down time, repairs, etc.) and to assure personal safety.

The following checks and maintenance procedures together with the suggested intervals, are the manufacturer's recommendation for the most effective Periodic Maintenance schedule for this unit.

Service tasks herein described must be performed exclusively by service personnel specifically trained on medical X-ray Generators.

The first Periodic Maintenance Service should be performed six (6) months after installation, and the subsequent services every twelve (12) months. Periodic Maintenance Service depends on the working load of the Generator and X-ray Tube.

NEVER ATTEMPT TO PERFORM MAINTENANCE TASKS WHILE THE MEDICAL EQUIPMENT IS IN USE WITH A PATIENT.

1.1 TOOLS AND TEST EQUIPMENT REQUIRED

The following test equipment may be required for carrying the procedures detailed herein:

Note ☞ *Access to the Service Mode when necessary, through the Main Screen and/or the Head-Assembly Screen (if it is present), as described in the Configuration and Calibration Chapter of the Service Manual.*

- Standard service engineers tool kit including Allen and Torx key sets.
- Alcohol cleaning agent.
- Digital Multimeter.
- Non-invasive kVp Meter.
- Digital mAs Meter.
- Calculator.

1.2 GENERAL CAUTIONS

DANGER !

THE GENERAL CAUTIONS INDICATES IN THIS SECTION MUST BE COMPLETELY UNDERSTOOD AND HEEDED.

DANGER !

CAREFULLY HANDLE ALL INTERNAL PARTS OF THE EQUIPMENT, ESPECIALLY PARTS LOCATED UNDER COVERS. DANGEROUS DC VOLTAGE IS PRESENT IN THE UNIT EVEN WHEN UNPLUGGED FROM THE AC LINE.

BEFORE HANDLING ANY ELECTRIC PART OF THE UNIT, REFER TO THE GENERAL SCHEMATICS IN ORDER TO ISOLATE THE AFFECTED AREA.

DANGER !

THESE UNITS CAN BE POWERED ON IN ALL SITUATIONS (WHEN CONNECTED TO THE POWER LINE THROUGH THE LINE PLUG OR WORKING IN STAND-ALONE MODE).

KEEP THE PROTECTIVE COVERS IN PLACE AT ALL THE TIMES, REMOVING THEM ONLY TO PERFORM SERVICE OPERATIONS. INTERNAL PARTS, SUCH AS BATTERY CHARGERS, DC CIRCUIT BREAKER, GPIO TROLLEY BOARD, INVERTER, DMC, UNR, PFC (ORANGE NEONS ARE ON) ARE PERMANENTLY POWERED ON AND HAVE THE FULL VOLTAGE POTENTIAL OF THE BATTERIES (APPROX.400 VDC) EVEN WHEN DISCONNECTED FROM THE POWER LINE OR WITH THE CONTROL CONSOLE OFF. USE CAUTION WHEN WORKING IN THESE AREAS.

WARNING

ENSURE THAT THE MAIN CAPACITORS OF THE HIGH VOLTAGE INVERTER DO NOT HAVE RESIDUAL CHARGE. WAIT UNTIL THE LIGHT EMITTING DIODES ON THE CHARGER BOARDS AND GPIO TROLLEY BOARD ARE OFF, APPROXIMATELY 1 MIN AFTER TURNING OFF THE UNIT.

Note ☞

Before performing the periodic maintenance, verify that the Unit has been connected to the mains for at least 9 – 10 hours. This will ensure a complete and full Battery charging.

1.3 MAINTENANCE CHECKLIST

Note ☞ *For further information about following steps refer to its respective Section.*

CHECKLIST FOR PERIODIC MAINTENANCE		DONE	
1	General cleaning:		❑
	External Covers and Control Console cleaning, touching up of painted surfaces as required.	❑	
	Internal inspection of major components, vacuum cleaning when necessary.	❑	
2	Cable checks: Electrical connectors, wires and ground lead interconnections checking, Arrestor, Power Line and Detector Cables Rewind Mechanism cleaning and lubrication.	❑	
3	HV Transformer condition: Oil leakages.	❑	
4	Test of Batteries and Chargers conditions.	❑	
5	Control Console and Handswitch connections and cables checking, Console operation test, indicators and parameters verification.	❑	
6	Radiographic parameters:		❑
	Test for kV loop, verification of kV values.	❑	
	Test for digital mA loops open and closed, verification of mAs values.	❑	
7	Mechanical checks:		❑
	Telescopic Column - Telescopic Arm: 3 sections / 4 sections - Head-Assembly Support, checking the movements, verifying controls, brakes, balance of vertical movement and conditions of the Steel Cable, Spring, Pulleys, Anti-fall Safety System.	❑	
	Motion Assemblies checking, lubrication, motor motion, operation of gauges, handle, handgrips, brakes, microswitches, bumper and wheels.	❑	

SECTION 2 PERIODIC MAINTENANCE PROCEDURES

2.1 GENERAL CLEANING

NEVER ATTEMPT TO CLEAN OR HANDLE ANY PART OF THE UNIT WHEN IT IS TURNED ON. SWITCH OFF THE UNIT MAIN DISCONNECT BEFORE CLEANING OR INSPECTING.

2.1.1 EXTERNAL SURFACES

Clean the equipment frequently, particularly if corroding chemicals are present.

Clean external covers and surfaces, especially parts which might be in contact with patients, with a cloth moistened in warm water with mild soap. Wipe with a cloth moistened in clean water.

When it is needed to disinfect the Control Console, clean it with a cloth impregnated with isopropyl alcohol.

Do not apply directly any liquid on the screen or other surfaces, nor use cleaners containing bleach, ammonia or any other abrasive or solvent liquid, it could cause damage to the equipment.

Also check painted surfaces for scratching and touch up as required.

2.1.2 INTERNAL CLEANING

Remove the external covers from the unit. Visually inspect all major components for dust or foreign items. Search carefully to detect objects which might cause short circuits and for loose connections.

If excess dust is present, clean the interior of the unit using a dry brush or vacuum cleaner.

Note ☞ *Do not re-install the external covers of the Unit until the Periodic Maintenance process has been completed.*

2.2 CABLE CHECKS

CAREFULLY HANDLE ALL INTERNAL PARTS OF THE UNIT.

1. Check that all electrical connections are firm and secure and that all cable clamps and strain reliefs are in place. Also check that connectors do not have exposed wire-veins and check cable sheaths for wear and fraying.
2. Check that all cables are correctly routed.
3. The central reference ground is located at the Battery Module 4. Check the ground lead interconnections continuity using a multimeter at its lowest ohms range.
4. Visually check the status of the arrestor wear and ensure that the ball makes contact with the floor; replace the Arrestor kit or the Discharger part as necessary.
5. Verify the Rewind Mechanism of the Power Line Cable and Detector Cable. Clean the cables and lubricate the rewind mechanism if necessary.

2.3 RADIOGENIC UNIT CONDITION

The Radiogenic unit contains oil.

Ensure that:

- Oil leakage is not present.
- All parts are mechanically secure without leakage.
- All parts are electrically secure.

2.4 PROCEDURES RELATED WITH THE BATTERIES AND BATTERY CHARGERS

Note ☞ *This Section must be performed at least once a year.*

KEEP IN MIND THE GENERAL CAUTIONS INDICATED IN SECTION 1.2.

Within the recommended operating temperature, under optimum float conditions and depending upon the working load of the Unit, batteries service life expectancy could last for 2 - 5 years.

If the unit has not been used or it has been stored for two months, it should be energized to prevent deep discharge of the batteries. A deep discharge will cause permanent damage to the batteries.

If the unit is stored within its crate, recharge the batteries according to the date indicated in the label on the crate.

For battery maintenance, the Service Engineer must be familiar with the technical specifications for the batteries and related circuitry and must also understand how the indicators and charge cycles function.

Note ☞ *The batteries must be fully charged before maintenance.*

Follow the instructions in the Section entitled "*Preliminary Test of Battery and Charger Conditions*" in the Troubleshooting Chapter.

2.5 CONTROL CONSOLE CONDITION

Note ☞ *Check the proper connection and condition of the cables connected to the Main Control Console.*

Check correct operation of the Console by performing the following test:

1. Turn the Unit / Console ON.

2. Touch different points on the touch screen (in the operator applications) to check for proper calibrated.

3. Check the Handswitch condition. Verify that the Handswitch cable and its connection to the Unit are in good condition.

4. Verify that the Console works properly:

   - Select a radiographic technique and verify that the different indicators and parameters on the Console appear when prompted, e.g. errors, limits, indications.
   - Change technique parameters and observe that changes are correctly displayed.
   - Select the parameters for a normal exposure. Press "*Prep*" and "*Exposure*" and observe that the respective indicators are activated during exposure.

Note ☞ *For systems provided with the Head-Assembly Screen, repeat the maintenance procedures in this Console.*

2.6 RADIOGRAPHIC PARAMETERS

Before performing the following checks, bear in mind that:

- To measure the kVp, a Non-Invasive kVp Meter is necessary. This Meter is placed in the X-ray beam.
- To measure mA or mAs, an mAs Meter should be plugged into the banana connections on the Advanced Control Board (connect the mAs Meter for Digital mA Loops calibration).

Note ☞ *Before starting periodic maintenance perform the X-ray tube warm-up procedure if the tube has not been in use for approximately four hours (refer to Operator Manual).*

2.6.1 TEST FOR KV LOOP

1. Place and center a Non-Invasive kVp Meter on the X-ray Tube output at SID:100 cm (*refer to the Non-Invasive kVp Meter documentation*).
2. Turn the Unit ON and select the "*Free*" workstation.

Note ☞ *"Free" Workstation must have been previously created in the Service Tool / Service Mode. Refer to Configuration and Calibration Chapter.*

3. Select 80 kV, 200 mA, 100 ms. Make an exposure and note the kV at the end of the exposure.
4. Ensure that the kV value read on the kV Meter is 80 ±(3% + 1 kV).

   If the kV value does not coincide with the above value, perform the kVp Gain Calibration procedure.
5. Turn the Unit OFF and remove the Non-Invasive kVp Meter.

2.6.2 TEST FOR DIGITAL mA LOOPS

1. With the Generator power OFF:
   - Remove the link between the banana plug connections on the Advanced Control Board.
   - Connect the mAs Meter to the banana plug connections to measure mA or mAs.

2. Turn the Unit ON and select the “*Free*” workstation.

TEST FOR DIGITAL mA LOOP OPEN

3. Select 80 kV and the following mA stations. Make an exposure and note the mAs values reading on the mAs Meter.

	Minimum mA for Small Focal Spot	Maximum mA for Small Focal Spot	Minimum mA for Large Focal Spot	Maximum mA for Large Focal Spot
mAs value				

4. Verify that the mAs values readings on the mAs Meter are the same mAs displayed on the Console with a tolerance of ±(5% + 0.1 mAs).

   If the mAs values do not comply with the above values, perform the respective Auto-Calibration procedures.

TEST FOR DIGITAL mA LOOP CLOSED

Note ☞ *If both Small Focus and Large Focus are available in the following exposure conditions, make an exposure by using either Small Focus or Large Focus.*

5. Select the following parameters, make an exposure and note the mAs values on the mAs Meter for:

	80 kV, 100 ms, 50 mA.	80 kV, 100 ms, 200 mA.
mAs value		

6. Verify that the mAs values readings on the mAs Meter are the same mAs displayed on the Console with a tolerance of ±(5% + 0.1 mAs).

   If the mAs values do not comply with the above values, perform the respective Auto-Calibration procedures.

7. After testing the Digital mA Loops:
   - Switch the Generator power OFF.
   - Disconnect the mAs Meter to the banana plug connections.
   - Re-install the link between the banana plug connections on the Advanced Control Board

2.7 MECHANICAL CHECKS

2.7.1 TELESCOPIC COLUMN - TELESCOPIC ARM - TUBE-COLLIMATOR SUPPORT ASSEMBLIES

1. Check correct operation of the controls, detents, limits and move to all possible positions. Movements must be balanced, noiseless and smooth.

2. Operate Brakes / Locks: Telescopic Arm, Column Rotation and Vertical Movement of the Head-Assembly, replacing if necessary.

3. Lubricate the Column tracks with a cloth with lubricant oil. In case of noise during movement, clean and lubricate again (vertical movement).

4. Remove the Upper and Rear Column Cover and verify that the Steel Cable and Pulleys are in good condition. Replace the Steel Cable if it is damaged / frayed (*refer to Section 2.7.2*).

   Nylon-coated Steel Cable do not require lubrication; for Steel Cable without Nylon-coated apply grease along the surface.

5. Verify the anchoring of the Steel Cable.

6. Verify the balance of the vertical movement, adjusting if necessary by tightening or loosing the Spring Tensioner Screw.

Note ☞

Perform the mechanical check of the Column Rotation, the Vertical Movement of the Head-Assembly and Telescopic movement of the Column (Telescopic Column Sliding Section).

Remove the corresponding Covers of the Sliding Section and the Base Section and verify that the Steel Cable and Pulleys are in good condition. Replace the Steel Cable if it is damaged / frayed (refer to Section 2.7.2).

2.7.2 STEEL CABLE PREVENTIVE MAINTENANCE

The Steel Cable revision should be done during the yearly preventive maintenance service.

Note ☞

Perform a visual inspection of the coated Steel Cable (wire rope with cover) in order to identify any damage.

The visual inspection can not precisely determine the state of degradation of the coated Steel Cable, but obtained evidences may indicate the need for replacement.

1. Check for the condition of the outer surface (cover), such as abrasion, cuts, etc.
2. Check for the condition of the inner components, such as broken wires, strands gap, corrosion, abrasion, core deterioration, non uniform diameter, etc.
3. Clean the coated Steel Cable surface with a soft cloth or cotton bud.

CAUTION

A faulty strand or a broken wire may indicate an issue, as additional faulty strands or broken wires may be hidden within the cable and this could lead to an accelerated degradation of the Steel Cable.

The degradation of the coated Steel Cable will depend on its usage and therefore the process may accelerate for heavily used equipments.

It is recommended to replace the coated Steel Cable as soon as damage is detected.

CAUTION

Do not use any type of cleaner or detergent as that can cause chemical reaction, degradation and rust on the steel cable surface.

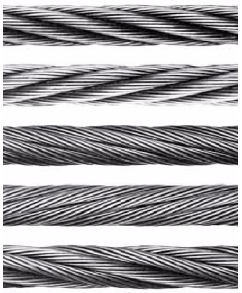
Note ☞

Nylon-coated steel cables do not require lubrication.

Standard recommendations which are in line with ISO 4309, call for the following signs to promote a replacement:

- Replace the steel cable if there are:
  - 6 or more broken wires in one lay of the steel cable.
  - 3 or more broken wires in one strand (in one lay) of the steel cable.
  - 3 or more broken wires in one lay in standing steel cables.

Steel Cable Lay



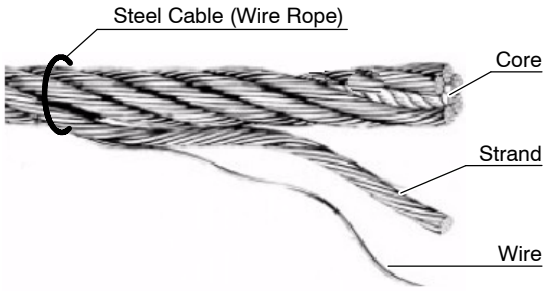
Right Regular Lay (RRL)

Left Regular Lay (LRL)

Right Lang Lay (RLL)

Left Lang Lay (LLL)

Right Alternate Lay (RAL)



- Worn / Abraded wires. Reduced diameter.
  Replace if there are flat areas along cable outer surface, which would indicate friction. Look for brighter areas along the cable.

- Stretch.

- Corrosion.
  Look for any signs of rust and discoloration along the cable, should there be any replace cables.

- Core protrusion.
  Replace the steel cable when inner core starts poking through strands.

- Kinks.
  Kinks seriously reduce steel cable strength. If there are sections with kinks, the steel cable should be discarded.

- Damages on the Nylon-coated Steel Cable.
  Replace if there are any signs of damage on cable cover (abrasion, cuts, etc.) or if the cable is damaged.

CAUTION

Close inspection should be made of cable terminations. Broken wires at cable terminals will require immediate cable replacement.

Note ☞

Life test shows that cables may last for over 5 years without problems, but as precaution and given the fact that the damage of a broken wire in the Mobile Column can be far more expensive than a single steel cable replacement.

WARNING

THE STEEL CABLE OF THE COLUMN MUST BE REPLACED EVERY 5 YEARS.

The cable revision can be scheduled during the regular yearly preventive maintenance revision.

2.7.3 MOTION ASSEMBLIES

1. Check lubrication and motor motion and check both motion gauges by performing the Functional Check.

2. Check operation of front Handle, Brakes and Microswitches.

3. Check operation of the Front Bumper.

4. Clean the front wheels and check that both run freely.

SECTION 3 OTHER MAINTENANCE PROCEDURES

Note ☞ *Local Standards may require checking procedures that are not considered Periodic Maintenance by the manufacturer.*
Below are described some of these procedures and the manufacturer recommendations to perform them.

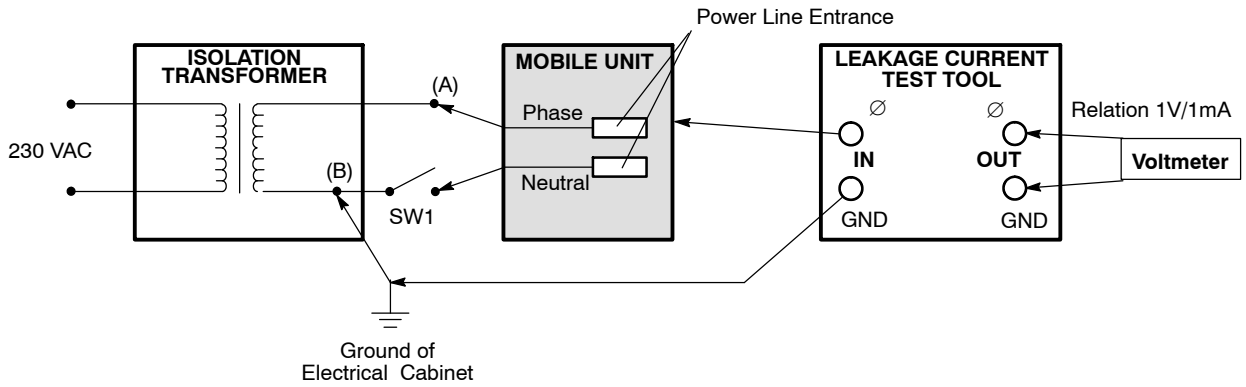
3.1 CHECKING THE LEAKAGE CURRENT

Besides the standard tools and test equipment, this procedure requires the following:

- Leakage Current Test Tool (RC).
- Isolation Transformer.
- Voltmeter.

1. Unplug the Unit from the mains. Remove the Ground wire of the AC plug. Remove any external Ground connection to the Mobile.
2. Place the Mobile on a surface that is isolated from ground such as wood or non-conductive plastic.
3. Connect the AC Power Supply Cable to the secondary of the Isolation Transformer and the primary of the Isolation Transformer to 230 VAC.
4. Turn ON the Mobile. Connect the Leakage Current Test Tool as follows:

Illustration 3-1
Leakage Current Test Connection



5. As shown in Illustration 3-1, the Voltmeter is set to VAC and connected to the Test Tool at the **OUT** points. Connect **Ø (IN)** to a metallic part of the Mobile Unit. Connect **GND (IN)** to the Ground of the Electrical Cabinet and to an output of the secondary of the Isolation Transformer (B).

6. The reading from the Voltmeter (1V = 1mA) gives the leakage current under **normal conditions**. Turn OFF the Mobile and disconnect the connection between the secondary of the Isolation Transformer (B) (or with a switch as identified in the illustration). The measurement in the voltmeter gives the leakage current under **fault conditions**.

7. Swap the wires connected from the Isolation Transformer to the Mobile (marked as "*A*" and "*B*" in the illustration) and repeat the measurement specified before (*step 6.*).

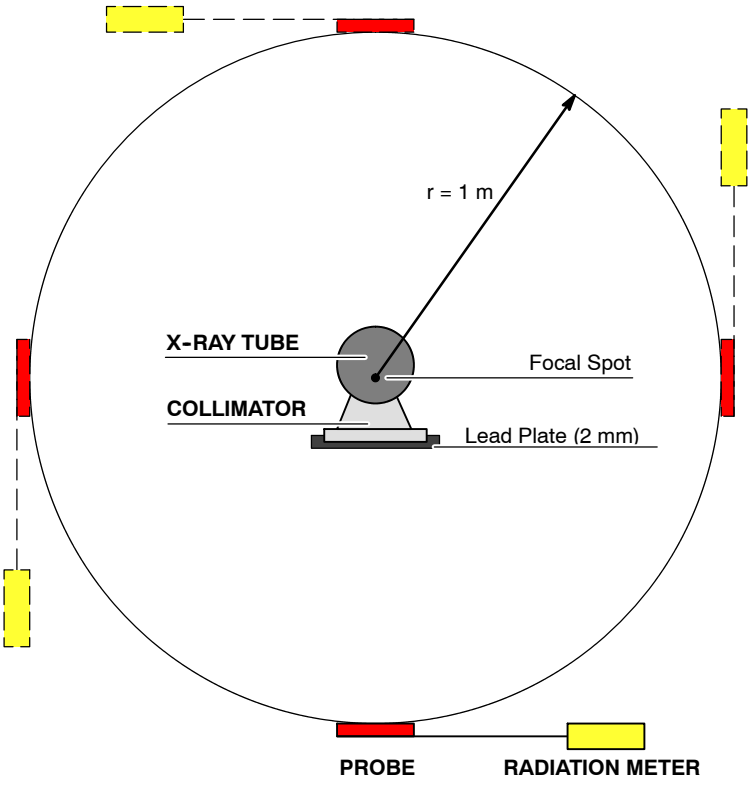
8. The Leakage Current Value should not exceed 2.5 mA under Normal Conditions or 5 mA under Fault Conditions. If the measurements exceed this range, check the Power Supply Cable and Plug (VAC) for leakage current and replace the "EMC Filter" (line entrance) if required.

9. Disconnect all connections made in the previous steps and return the Mobile to operational wiring. Place the ground wire back to the plug and ensure a firm connection.

3.2 CHECKING THE RADIATION LEAKAGE

Besides the standard service tools, a Radiation Meter is necessary for checking Radiation Leakage. Radiation measurement will be setup as indicated in Illustration 3-2

Illustration 3-2
Radiation Leakage Setup



1. Cover the Collimator window with a Lead Plate (≅ 2 mm of thickness) with at least 1 cm overlap on all sides and open the Collimator blades.

Illustration 3-3
Installation of Lead Shielding Plate

2. On the Control Console, select the following parameters: maximum kVp (150 kVp), 50 mAs (20 mA , 2.5 s).

3. Select *Dose* mode (0.00 μR) on the Radiation Meter.

4. Make an exposure and note the radiation readout, indicating the position where the probe is placed respect to the Tube-Collimator. Repeat this step with the probe at various positions around the Head-Assembly (maintaining a radius of 1 meter). *Refer to Illustration 3-2.*

5. The Radiation Leakage Technique Factor of each X-ray Tube is provided by the X-ray Tube manufacturer in the specifications document. As example of the Leakage Factor:

X-RAY TUBE MODEL	LEAKAGE FACTOR
E7886	3.4 mA @ 150 kVp
XRR3331	3.4 mA @ 150 kVp

6. Calculate the maximum value of the Radiation Leakage in one hour at any measured point, for an exposure of 20 mA (2.5 s) @ maximum Generator kVp (150 kVp), according to the following formula:

$$RL/h = D \times \frac{3600\ (s)}{1\ (h)} \times \frac{1}{\text{Exposure time (s)}} \times \frac{\text{Radiation Leakage Factor (mA)}}{\text{exposure current (mA)}}$$

where:
RL/h = rate of Radiation Leakage per hour [*μR/h or μGy/h*]
D = radiation readout [dose in *μR or μGy*]
RLF = Radiation Leakage Factor [*mA*]

The following is an example of the formula stated in Step 6.

X-ray Tube : Canon E7886
Radiation Leakage Factor : 3.4 mA (at 150 kVp exposure)
Exposure values : 150 kVp, 20 mA, 2.5 s, 50 mAs
Radiation readout : 110 μR

$$\text{Rate of Radiation Leakage per hour} = \frac{110 \times 3600 \times 1 \times 3.4}{1 \times 2.5 \times 20} = \mathbf{26928\ \mu R/h} \text{ or } \mathbf{234.16\ \mu Gy/h}\ (\mu R/h\ /\ 115)$$

$$= \mathbf{26.9\ mR/h} \text{ or } \mathbf{0.234\ mGy/h}\ (mR/h\ /\ 115)$$

The Radiation Leakage limit is 100 mR / h (0.88 mGy / h); Based on the obtained result, the radiation leakage for this example is:
26.9 mR/h or **0.234 mGy/h** (26.9 mR/h / 115)

7. Based on the radiation reading at any position, ensure that the Radiation Leakage is lower than the limit of 100 mR/h (0.88 mGy/h). Note the position and value of the maximum radiation reading.

   If the Radiation Leakage is over the limit at any position, first replace the Collimator and then repeat this procedure. If leakage is still present, replace the X-ray Tube and repeat this section.

   When finished, remove the Lead Plate from the Collimator window.

3.3 RECOMMENDATIONS FOR INSULATION RESISTANCE TEST

VDRs (Voltage Dependent Resistor) connected between mains and earth avoid damage on the equipment due to overvoltage.

The Standard IEC 60601-1 states:

> " **20 Dielectric strength**:
> Only insulation with a safety function need be subject to testing".
>
> "20.4 Tests:
> *j) Power-consuming voltage-limiting devices, in parallel with an insulation to be tested, are disconnected from the earthed side of the circuit. Lamps, electronic tubes, semiconductors or other automatic regulating devices may be removed or rendered inoperative if necessary to carry out the test".

In order to conduct the Insulation Resistance Test, 500 VDC have to be applied to the unit. The VDRs will work decreasing their resistance, avoiding that the overvoltage goes to the rest of the circuits. Therefore, the VDRs have to be removed before applying 500 VDC in order to measure the correct insulation resistance.

For further information on disconnecting the VDRs, refer to General Schematic and PBA Input Module.

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