

PART III

**Fault diagnosis
and repair modules**

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MODULE 5.0

Common procedures for fault diagnosis and repairs

Aim

The aim is to provide information for common procedures involved in diagnosing or repairing a problem. Most of these procedures are applicable to all of the fault diagnosis and repair modules.

Objectives

On completion of this module the student will be able to:

- Adopt a systematic approach to fault diagnosis, as an introduction to the modules for individual equipment.
- Be aware of methods for locating broken wires, and faults in plugs and sockets.
- Test and replace a fuse with a suitable replacement.

Task 8, 'Fuse identification', should be attempted on completion of this module.

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a. Problem diagnosis, or trouble-shooting

Method

Trouble-shooting is a procedure of observation, then making suitable tests to either eliminate, or confirm, a suspect section of equipment. As the area under examination is reduced by further tests, it becomes easier to locate the actual problem.

Note. With any trouble-shooting technique, it is not necessary to approach a problem from any specific direction or set of rules. Rather, you should first observe, consider a possibility and then devise a test to check that assumption.

Consider which items are quick or easy to check. This can save time if first carried out. When a problem occurs, record how the equipment was used just before the problem occurred. This allows a similar procedure to be used as a test, in case the symptoms of the recorded problem are not easily reproduced.

During the process of locating the cause of a problem, record the tests or checks made, and the results. This will provide a valuable record if it becomes necessary to ask advice from the service department.

Typical problems

- Operator error.
- Equipment incorrectly calibrated.
- Faulty connecting plugs, sockets, or cables.
- A safety interlock is preventing equipment operation.
- Electrical or electronic failure.
- High-tension cable or X-ray tube failure.
- Mechanical problems.
- Alignment adjustments.

Observation of a problem

This is important, especially at the time a problem occurs. Possibilities that may be observed are:

- Is there an operator error?
 - A burning smell? Where does it come from?
 - Is there an increase in temperature? For example:
 - The X-ray tube housing has become very hot to touch.
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- A lock coil, in the area where a burning smell is observed, is very hot to touch.
- Unusual sound. What sort of sound? Where from?
- Absence of sound. For example:
 - No anode rotation noise from the X-ray tube.
 - Ventilation fans are quiet
- Wrong mechanical operation. Look for obstructions, or loose sections. For example:
 - An indicator knob on a control panel has slipped into a wrong position.
 - A film is jammed in the processor.
- Visual observation. For example:
 - Appearance of the film immediately as it leaves the processor.
 - Smoke rising from equipment, or a HT cable end.

Equipment manuals

Should be referred to whenever there is a problem. The operation manuals often include a section on fault or problem symptoms, as do the installation or service manuals. The spare parts illustrations can help find the physical positions of parts, such as locating a fuse in equipment.

If during maintenance or other events manuals appear to be missing, replacements should be obtained as soon as possible. Quite often, service engineers attending your equipment will also require these manuals. If not available, this could lead to delays in correcting a problem.

Request for assistance

When requesting advice from the service department, the following information may be required.

- Hospital name, address, fax, and phone number.
- Who to contact at the hospital when discussing the problem. Include the department and phone number.
- Department and room number for equipment location.
- Make and model number of equipment.
- A description of the problem. Include any symptoms.
- What tests have been made, and the results.
- Are you asking for advice, or is this a direct request for a service call?
- If a request for a service call, is an order number available?
- Any conclusions that were made regarding the cause of the problem, or what will be needed to correct the problem.

If the request is made via e-mail or by fax, then this information should always be included. If the request

is made via a phone call, having the information available will save time.

A record should be kept of service department address details. This should include the address, e-mail, phone, and fax numbers. Where a service engineer is assisting with advice, include the engineer's name and contact details.

A sample service request form is provided in appendix 'C' page 177.

b. Safety first

Before investigating a possible fuse or wiring problem, always ensure power is turned off and unplugged from the power point. If the equipment is part of a fixed installation, besides switching the generator power off, ensure the isolation power switch for the room is also switched off.

With battery operated mobiles, ensure the battery isolation switch is in the off position. If this cannot be located, contact the service department for advice before proceeding.

c. Locating bad connections

Typical areas

- The generator handswitch cable.
- The connecting cable to the collimator.
- The fluoroscopy footswitch for a fluoroscopy table.
- Plugs or sockets used with mobile or portable X-ray equipment.
- Power plugs.
- Plugs or sockets for tomographic attachments.
- Cables, which are pulled or twisted.

Locating a broken wire or bad connection

- Remove the cover from the plug or socket, and check if wires have broken away from the contact pins.
- Wires can break inside a cable. This will occur where there is a lot of twisting or stretching. For example, a handswitch cable.
- **Note.** Some wires may seem intact, but can be broken a short distance from a connection point. This is difficult to see, as the wire is covered by the plastic insulation.
- A simple test is to give a gentle to firm tug to a suspect wire. If a particular wire appears to stretch, compared to other wires, it is probably broken

inside the insulation. However, this test is not reliable, as a break can occur in another position.

- A multimeter should be used to give an accurate test of a suspect connection or broken wire.
 - i. Select the low ohms position of the multimeter.
 - ii. Connect the two probes together. The scale should read less than 1.0ohm. If using an analogue meter, adjust the zero-ohms knob on the meter, so the meter needle is on the zero position.
 - iii. Record the minimum value that was indicated when the probes were touched together.
 - iv. Connect the meter probes at the two ends of the wire being tested. The meter should indicate less than 2.0ohms above the value previously recorded with the probes connected together.
 - v. A broken wire in a cable may have a partial connection, and cause an intermittent fault. Give the cable under test a tug or twist while watching the meter. If the meter flickers or indicates a changing value while the cable is moved, the wire is faulty.

Check for a faulty handswitch, or handswitch cable.

Caution.

Ensure the generator is switched off, and the room power isolation switch also turned off. If this is a mobile or portable generator, ensure it is switched off, and the power cable unplugged from the power point.

- This test should be performed with the assistance of an electrician or electronics technician.
- Make a diagram, so that when the handswitch is disconnected or unplugged, it can be correctly reconnected.
- A multimeter is required, set to the low ohms position. Check that the meter indicates zero ohms with the meter probes touching together.
- Open the hand switch assembly, and identify the terminals of the suspect switch. With the meter probes touching the switch terminals, operate the switch. The meter should indicate zero ohms. Repeat this test for other switches in the handswitch.
- Identify the connecting wires between the switch terminals and the other end of the handswitch cable. With the meter connected to each end of the cable wires, the meter should indicate less than 2.0ohms. When making this last test, if at first you have a good result, test again by tugging on the

connecting lead, and also move the cable in different positions.

- If there is a broken wire in the handswitch cable, this often occurs close to the handswitch, and sometimes where the cable enters or is attached to the control desk.
- To look for a broken wire, cut open the cable outer insulation to expose the internal wires. Commence where the cable enters the handswitch, and continue about 15cm down the cable. Test individual conductors by giving a firm pull. If a broken wire is found, shorten the cable past the bad section, and reconnect to the handswitch. *The entire cable should be replaced as soon as possible, in case of other partially broken wires.*
- The above procedures should be repeated for all the switches in a handswitch assembly.

A plug or socket may have a fault

This can occur due to:

- A pin or contact has moved out of position.
 - i. This is due to bad assembly during manufacture. However, the plug or socket may have considerable use before this fault occurs.
 - ii. Remove the back of the plug or socket assembly.
 - iii. Locate the wire attached to the pin or contact.
 - iv. Try pushing it firmly back into position. If it sets in place and will not move with a gentle to firm tug on the wire, all is well.
 - v. If the pin or contact is not firmly attached, then remove it and look for bent 'hooks' on it. Straighten these out, so that when reinserted they will keep the pin or contact in position.
- The contacts of a socket may have become enlarged, and not provide a reliable or good contact.
 - i. The contact can be adjusted by pushing the sides of the contact closer together. A useful tool is a large sewing needle.
 - ii. Care must be taken not to damage the contact.
 - iii. This problem may occur where plugs and sockets have had a lot of use. For example, with a portable X-ray generator.

Power plug connections

The wires connected to the power plug terminals can become loose. This can cause arcing, and may cause a fuse to become open circuit.

The wires must be held securely inside the plug. If the cable is pulled, this should not pull the wires from the plug terminals. If the plug does not have a suitable method to prevent this from happening, then replace the plug with an improved type.

If wires have pulled loose from a power plug, this may be due to a previous incorrect assembly. Have the connections checked by an electrician or electronics technician. This is to ensure the active and neutral wires are connected to the correct positions on the power plug, and, most important, correct connection of the earth or ground wire.

While wire colours now conform to international standards, older equipment may use non-standard colours. If this is found, have the power cord replaced by an electrician.

d. Is a fuse open-circuit?

Indications and tests

- Some glass fuses can visually show if they are open circuit by metal deposited on the glass. If the failure is a small break in the wire, this is not easy to see.
- Fuses may have fine wire, again not easy to see, so it may appear open circuit, but still be in good condition.
- A continuity test with a multimeter is the only reliable way of verifying if a fuse is good or open circuit. The meter is set to the low ohms range. If the meter shows no indication when the probes are attached to the fuse, the fuse is open circuit.
- Do not try to test a fuse with a meter while it is still connected in the equipment, this can give a false result.

Fuse locations

The physical location of fuses will vary greatly depending on the manufacturer and model of equipment. Electrical regulations in many countries require a fuse to be protected from access without using a tool. Where fingers may be able to unscrew the cap of a fuse holder, a protective cover must first be removed.

Possible fuse locations are:

- X-ray generator, fixed installation. There will not be any external access fuses. Most fuses will be located in the control cabinet, and a panel will need to be removed to gain access. In some cases, there may be additional fuses under a cover at the HT transformer.
- **Note.** In some installations miniature circuit breakers may be fitted instead of fuses. These have a reset switch, or button, mounted on top of the device.
- Mobile or portable X-ray generators can have external access fuses mounted on a rear panel. Otherwise internal access to the equipment is required.

- The Bucky table may have an external access fuse panel on one side, or else on the side of a small control box. Otherwise, a panel may have to be removed to gain access.
- The vertical Bucky and stand may have a small power supply box for magnetic locks. This may have external access to a fuse, or require removal of the box cover.
- The fluoroscopy table may have external access power fuses located at the table foot. There will be additional fuses inside the control cabinet, or inside electronic control boxes placed on the table body.
- A floor-ceiling tube stand can have a small power supply box mounted at the top of the column. This usually has external access to the fuses.
- A ceiling suspension tube support may have external access to the fuses. In most cases a panel cover will need to be removed.
- The operation or installation manuals often show the location of fuses. The parts manual will also indicate fuse positions, however the diagrams can be very complex. Otherwise, contact the service department for advice.

Why has a fuse failed?

- There is a fault. The fuse has blown to protect the equipment. There will often be a heavy metal deposit on the glass. On replacing the fuse, the new fuse will also fail.
- There was a temporary fault caused by a power surge.
- There is no fault. The fuse has become 'fatigued' or 'tired'. This sometimes happens. If a glass fuse, the wire may show a small broken section.
- An incorrect fuse was previously fitted. For example, a 5A fuse fitted where a label indicates a 7.5A fuse. This may have been a temporary replacement, however first contact the service department for advice.
- When a blown fuse is found, contact the service department for advice. Give full details of the fault symptoms, fuse number or identification, and position in the equipment.

Removing and replacing a fuse

Never attempt to remove or replace a fuse unless all power is switched off, and where applicable, unplugged from the power point. In an X-ray room, also turn off the main power isolation switch.

There are a large variety of fuse holders. Some types are listed below.

- The fuse is held between two spring clips.
 - i. Remove by pushing or lifting first at one end. If trying to prise out by lifting in the middle, some glass fuses may break.
 - ii. When re-inserting a fuse, the spring clips should have a positive grip. If not, remove the fuse, bend the clips inwards a little, and then reinsert the fuse.
- The fuse is in a container, totally enclosing the fuse.
 - i. The front appears as a small square. There is no screwdriver slot. In this case there should be a small gap under the square front. Pushing a small screwdriver into this gap will release the catch, allowing an internal spring to push the fuse out.
 - ii. There is a round cap, similar to a large version of a toothpaste tube cap. Grip with the fingers, and turn anticlockwise to undo.
 - iii. Two versions may have a screwdriver slot. One version has a bayonet catch. To remove, first push inwards with a screwdriver, then rotate anticlockwise a quarter turn. This should unlatch the top. In the second version, this is a simple threaded type. Undo with a screwdriver, turning anticlockwise.

Common fuse types

Fuses come in a great variety of styles, shapes and sizes. Most common are the larger 3AG sizes, 6 × 32 mm, and the smaller M205 size, 5 × 20 mm. The fuse may have a glass or ceramic body.

Of the above fuses, there are two main types.

- General-purpose fuse.
 - i. The element is normally a straight piece of wire, or a thin metal strip.
 - ii. European fuses may have 'MT' marked on one end.
- Slow blow or delay fuse.
 - i. These fuses are designed to allow a short high surge current. This allows for the momentary peak current demand from motors, transformers, or power supplies, when first switched on.
 - ii. The element appears as a piece of wire, attached to a spring.
 - iii. Another version has a wire, similar to a general-purpose fuse. However, the wire has two small metal beads spaced along the fuse wire.
 - iv. European fuses may have 'T' marked on one end.

Circuit breakers

Circuit breakers may be fitted instead of fuses. In most cases they are designed to handle large currents, such as the main power supply to an X-ray generator. In some cases, small circuit breakers are also fitted instead of standard 5A or 10A fuses.

If a circuit breaker has tripped, the switch at the front of the circuit breaker may be half way between the 'off' and 'on' positions. To reset, push the switch to the off position, then back to the on position.

Caution: Circuit breakers, like fuses, should only be reset after the supply power is switched off.

Selecting a replacement fuse

Providing the fuse has the same rating and characteristic, a ceramic fuse may be replaced with a glass fuse.

If a fuse of the correct current rating is not available, then a smaller rated fuse might sometimes be substituted as a temporary replacement, providing it is close to the original value. Eg, a 2.5A fuse might substitute for a 3A fuse. In case a delay fuse is not available, a standard fuse of the same rating may be tried as a temporary replacement. **Do not** substitute a delay fuse for a standard fuse.

Special fuses for high-frequency generators

These are very large fuses, sometimes rated up to 200amps, for use in the inverter. The fuse may be a long, large diameter cartridge fuse, seated in heavy-duty brass clips; or else a large ceramic type, retained by a nut and bolt. While inverter fuses can fail due to fatigue, or a temporary problem due to X-ray tube instability, there could be a semiconductor failure in the inverter.

- **Only an electrician or electronics technician should attempt to test or replace an inverter fuse.**
- Before replacing the fuse, a test for a possible short circuit in the inverter should be made.
- **Caution:** High residual voltages can be present in the power supply capacitors.
- **Always consult the service department for advice before attempting to test or replace an inverter fuse.** The service department may require specific tests to be made before replacement, otherwise further damage could occur.

TASK 8

Fuse identification

You have been supplied with a mixed selection of fuses.

- What is the current and voltage rating of each fuse?
- Are any of these fuses a 'delay' or 'slow blow' version?

Fuse No	Voltage	Current	Delay fuse?
1			
2			
3			
4			
5			
6			

One or two of these fuses may be faulty. Test the fuses, using a multimeter. Use the instructions provided in module 8.0

Were any of these fuses faulty? Indicate which fuse No. _____

Was there any difficulty in using the multimeter? _____

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____

Date _____

Tutor

MODULE 6.0

X-ray generator: Fixed installation

Aim

The aim is to provide information and procedures for diagnosing, or repairing, a problem with an X-ray generator. The generator is installed as a fixed installation in an X-ray department. Flow charts are provided to indicate logical steps, when diagnosing a problem.

Objectives

On completion of this module, the student will be able to carry out a set of procedures to locate a problem area in the generator. This will allow minor repairs to be carried out. An electrician or electronics technician may also provide assistance. Otherwise an accurate description of the problem can be provided to the service department, if requiring advice or direct assistance.

This module is divided into two sections. The first section looks at problems that occur during preparation for an exposure. The second section looks at problems affecting an exposure, after preparation for an exposure has been completed.

Task 9. 'No Preparation, Part 1' and task 10. 'No Preparation, Part 2', should be attempted after section one of this module.

Task 11. 'No Exposure', and task 12. 'X-ray output linearity', should be attempted after section two of this module.

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Section 1: No preparation

Part 1. Nothing happens.

Part 2. Is there a bad connection or fuse?

Part 3. Warning signals due to a fault condition.

Part 4. X-ray tube tests.

Part 5. Other tests.

Section 2: No radiographic exposure

Part 6. Operation tests.

Part 7. No mA or kV.

Part 8. High-tension problems.

(Note: Reference module page numbers refer to the title page.)

Section 1: No preparation

This section examines a number of situations where the generator prepares for an exposure. Before the control system will permit preparation to begin, the generator makes a number of safety tests. Once the generator enters into the preparation mode, more tests are made. When all tests are satisfied, the control system signals ready for an exposure. There are a total of five parts, each with an associated flow chart.

Study each flow chart first, and then read the text for additional information.

Part 1. Nothing happens

Refer first to the flow chart, Fig 6-1 page 75, 'Unable to obtain preparation, part one'.

On attempting to have the control prepare for an exposure, nothing happens. There is no sound of X-ray tube anode rotation. At the end of the normal preparation time, there is no sign the generator is ready for an exposure.

Are there any warning lights on the control panel?

The warning light could indicate a fault in the generator, or else an operator error. In some systems there may be two warning lights, one for incorrect setting of the X-ray control, and the other for a fault in the generator.

In the case of a warning light indicating wrong exposure factors, this could be due to:

- The kV set for the exposure is above the maximum X-ray tube rating. Reduce the kV setting.
- The kV is below the minimum kV specified by radiation regulations. Increase the kV setting.
- The mA selection is too high for the required mAs. Select a lower mA position, and a longer exposure time.
- The combination of a high value of mA, and a low value of kV. This could overheat the X-ray tube filament. Either increase kV, or else select a lower value of mA and increase the exposure time.
- With some generators, selecting a very short exposure time combined with a low mA will prevent operation. For example, if the limit is 0.5 mAs, then 500 mA at 0.001 second is accepted. However, if 250 mA is selected, then the minimum exposure time becomes 0.002 second.
- The X-ray control microprocessor has calculated the amount of heat in the X-ray tube anode from previous exposures. A further exposure would cause the anode heat capacity to be exceeded. Wait a few minutes for the anode to cool down.
- **Note.** Most X-ray controls, which calculate total anode heat, display the result on the control panel. This may take the form of a number, or a bar graph. In other cases a small symbol indicates excessive anode heat.

Does the control panel display a message, instead of a warning light?

Modern microprocessor-controlled generators can have special display modes to indicate problems or operator error. Compared to a single indicator light, these systems give increased information. For example:

- A direct message 'Reduce mAs' appears on the control panel. This direct type of message might be displayed with microprocessor-controlled generators, together with a plasma or liquid crystal display panel.
- The kV display does not show the required kV. Instead a code E2 appears in the kV display. This is another way a microprocessor-controlled generator may indicate an error.
- The operation manual has a list of the codes and what they mean. In this case E2 could mean 'Set kV is too high'. **Codes are used to also indicate fault conditions.** A code F3 could mean the generated mA exceeded the calibration limit during the previous exposure. **If a fault code appears, consult the service department for advice.**
- *The actual code numbers, where they appear on the control panel, and their meanings, depend on the*

make and model of equipment. Only some X-ray controls have these features.

Does resetting the exposure factors turn off the warning light?

- If the warning light does not turn off, **go to part three.**
- If the warning light is off, then test again for preparation. If preparation can now be obtained, all is well. Otherwise continue with 'Other basic checks'.

Other basic checks

- Is a suitable technique selected? For example, if the fluoroscopy table is selected instead of the table Bucky, handswitch operation may not be permitted.
- Is a suitable focal spot selected? If the exposure factors were suitable for the large focal spot, selecting the small focal spot with the same exposure factors could prevent operation.
- Check all other settings. If unsure of their correct use or position, please refer to the operation manual, or contact the service department for information.
- Was an Automatic Exposure Control (AEC) in use for the last exposure? The AEC may have generated an inhibit signal. Disable the AEC and try again.
- Does the X-ray room have a door-open safety switch or 'interlock'? The operation of this switch may be faulty.
 - When the door is closed, can you hear the switch operate? In this case, it is probably ok.
 - If no indication is heard, check the switch operation with a multimeter.
 - Ensure all power is turned off, including the room power isolation switch.**
 - Set the multimeter to the low ohms position. Connect the probes together. The meter should indicate close to zero ohms.
 - With the probes connected to the switch contacts, test the switch operation by opening and closing the door.

Can preparation now be obtained?

If the answer is yes, the problem is solved. **Otherwise continue with part two.**

Part 2. Is there a bad connection or fuse?

Refer first to the flow chart, Fig 6-2 page 76, 'Unable to obtain preparation, part two'. **In this situation, the tests indicated in part one have been completed.** No warning lights or error codes are displayed on the control panel.

Is there a fault with the handswitch?

- Listen at the X-ray tube while an assistant presses the preparation button. Is there any sound of anode rotation, or other noise, from the X-ray tube when the button is pressed? If there is, then the handswitch is ok. Proceed to part four.
- On pressing the preparation button, can you instead hear a relay operate in the generator control cabinet? If so, the hand switch is not at fault. Proceed to part four.

Check for a faulty preparation switch, or handswitch cable

- **First ensure the generator is switched off, and the room power isolation switch also switched off.**
- This test should be performed with the assistance of an electrician or electronics technician.
- To test the handswitch or cable, refer to **module 5.0 page 65**.
- If there was no problem found with the handswitch, or handswitch cable, proceed to part 5.

Part 3. Warning signals due to a fault condition

Refer first to the flow chart, Fig 6–3 page 77, 'Unable to obtain preparation, part three'.

In this situation, a warning light or code may appear immediately the generator is switched on, or else during the last exposure. The checks indicated in part one have been performed. Operator error or incorrect exposure settings are not the cause of the problem.

A warning light or code appears when switched on

This indicates a serious fault condition. If a code or message is displayed, refer to the operation manual for its meaning. If the code indicates an operator or setting error, then recheck the tests carried out in part one. Otherwise contact the service department. Provide details of the fault code, and any other symptoms that were observed.

- A fuse may have failed, or a circuit breaker tripped.
 - i. **Before opening any panels to check a fuse, always ensure the equipment is switched off, and the room power isolation switch also turned off.**
 - ii. Procedures for testing or replacing a fuse, are described in **module 5.0, page 65**.
 - iii. If a fuse is open circuit, or a circuit breaker has tripped, consult the service department for advice regarding the possible cause.

- Is the mains power supply voltage too low? Or is one phase missing? This could happen after a storm or power failure.
 - i. If the generator has a manual adjustment for the mains voltage, check and make sure it is set correctly.
 - ii. Other generator designs have automatic compensation for changes in supply voltages. Depending on the design, the mains voltage may have changed outside the adjustment range of the automatic compensation. Ask an electrician to check or measure the supply voltage.
 - iii. A three-phase generator may still switch on with only two phases of the mains supply available. Some designs have a fault detector in case this happens. Ask an electrician if there is a problem with the hospital power.

A warning light or code appears during preparation

If a code or message is displayed, refer to the operation manual for its meaning, or contact the service department. Provide details of the fault code, and any other symptoms that were observed.

- Does the warning light appear **immediately** on pressing the preparation switch? This may indicate a serious problem with the X-ray tube filament control section of the generator. Contact the service department before proceeding.
- In case the warning light occurs during or just at the end of preparation, this may indicate a filament connection problem, or failure to pass the anode rotation safety test. **Proceed to part four.** Otherwise contact the service department for advice.
- Did the warning light operate **during** the last exposure? This can indicate an over current (mA) situation. Over-current may be caused by instability in the X-ray tube, or else a fault in the HT cable or cable end.
 - i. Try resetting the fault detection by switching the X-ray control OFF then ON again. Then try to obtain preparation.
 - ii. If preparation can now be obtained, go to part 8.
 - iii. If preparation still cannot be obtained, **proceed to part four**, or contact the service department for advice.

Part 4. X-ray tube tests

Refer first to the flow chart, Fig 6–4 page 78, ‘Unable to obtain preparation, part four’. There are no warning lights or message codes. On attempting preparation, some sound was observed at the X-ray tube. This indicates the preparation handswitch is ok. During preparation the X-ray control applies a test for anode rotation, and minimum filament current in the selected focal spot. There may be a problem with anode rotation, or else a poor connection to the X-ray tube filament.

Does anode rotation appear normal?

This should be the normal sound of the anode accelerating to the required preparation speed. Instead it may be just a buzzing or humming noise. The possibilities are:

- One of the three conductors for the X-ray tube stator is broken or has a bad connection.
 - i. Check the stator cable where it enters the X-ray tube housing.
 - ii. Does the cable show signs of being pulled or stretched? A wire may have been pulled away from a terminal.
 - iii. **Before checking any connections, always ensure the equipment is switched off, and the room power isolation switch also turned off.**
 - iv. Some x-ray tube housings have a plug and socket for the stator cable connection. Has this become loose, or is there a bad connection to the plug or socket terminals?
- The X-ray tube itself is faulty, either with seized bearings, or else with broken glass. If the glass is broken, the anode may appear to rotate slowly, and very quickly come to a stop when the preparation switch is released.
- Is there oil leaking from the X-ray tube housing? An arc may have occurred during the last exposure, causing internal damage.
- Is there an open circuit fuse, or tripped circuit breaker, supplying power to the X-ray tube starter? This can be a common problem with some high-speed starters.
 - i. **Before opening any panels to check a fuse, always ensure the equipment is switched off, and the room power isolation switch also turned off.**
 - ii. If unsure where such a fuse or circuit breaker may be located, contact the service department for advice.

- iii. If the fuse is faulty, take care to replace with the correct size and type. **See module 5.0 page 65.**
- iv. Examine the stator cable where it enters the X-ray tube housing. If there is a possibility the cable has been pulled, remove the cover plate and check the connections for a possible short circuit.
- v. If on restoring power, or attempting preparation again, the fuse blows, then **stop**, and contact the service dept.

Is the focal spot filament connected?

During preparation the X-ray control tests for a minimum filament current. This test is only to ensure the filament is intact, and is at a minimum temperature.

Note. This test does not ensure the correct mA will be generated. A poor HT cathode-cable connection can cause a drop in the required filament current, but still be above the minimum value for the filament current test. **See part seven, ‘No radiographic exposure’.**

- The selected focal spot may be open circuit, or have a bad connection. Try obtaining preparation with the other focal spot.
- There may be a bad connection to that focal spot due to a bad HT cathode-cable cable-end pin connection. There are three pins on the cable end. If there is a bad connection at the centre pin, this will affect both focal spots.
 - i. Before proceeding, ensure all power is switched off.
 - ii. To check, undo the cathode cable-end retaining ring nut. Partly withdraw the cable end about 2~4mm, then reinsert the cable end. Replace and firmly tighten the cable-end ring nut.
 - iii. Test for preparation. If moving the cable end has cleared the preparation problem, the cable end will require further attention. This involves removal of the cable end, cleaning the cable-end pins, and re-sealing. For this procedure, **see module 7.3 page 117.**
 - iv. **Caution.** The cable end may have silicon grease as insulation instead of anti-corona silicon pads. Removal of the cable end by more than 2~4mm can reduce the effectiveness of the insulating grease. As a precaution, do not exceed 100kV until the cable end is re-sealed with fresh silicon grease, **see module 7.3 page 117.**

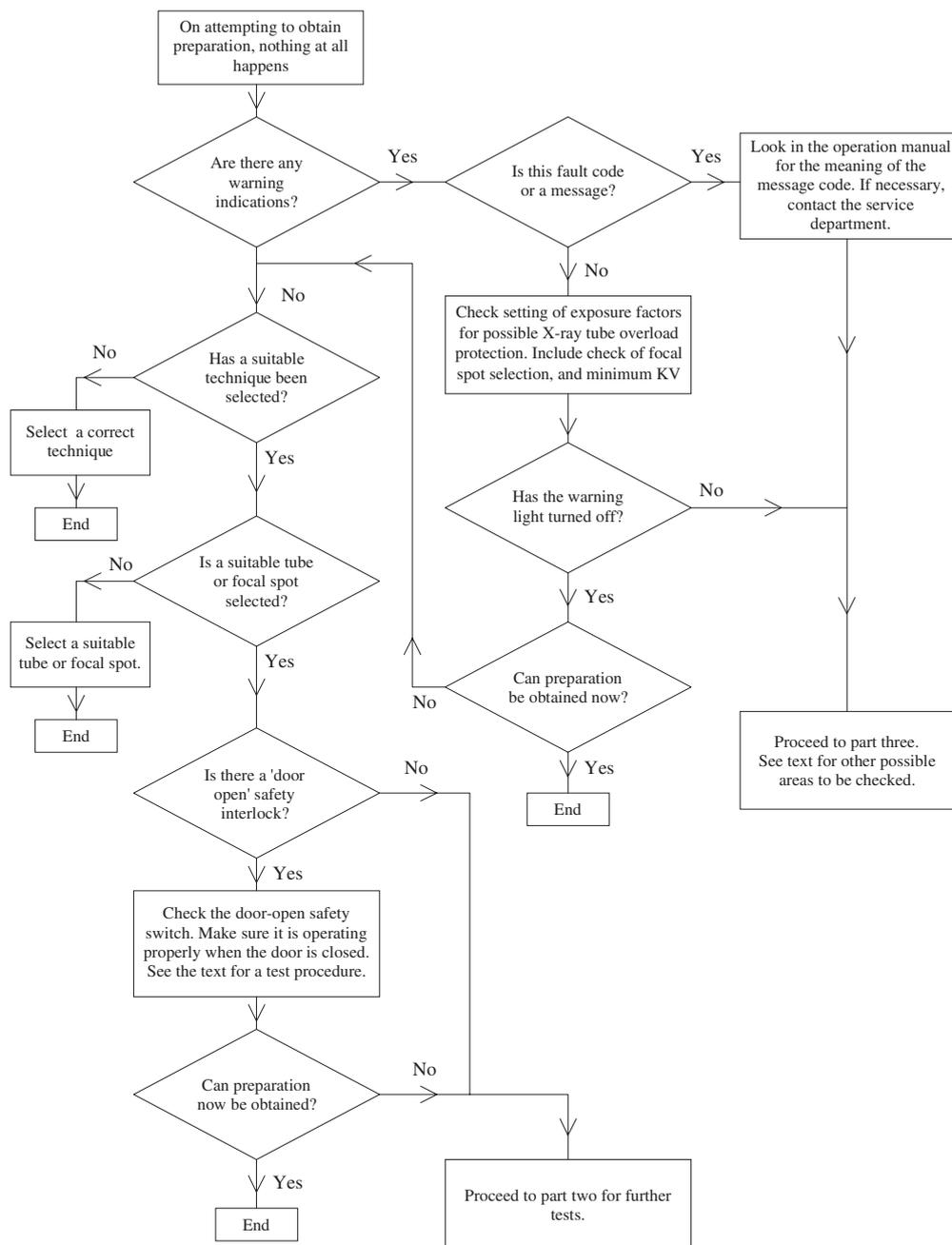


Fig 6-1. Unable to obtain preparation, part one

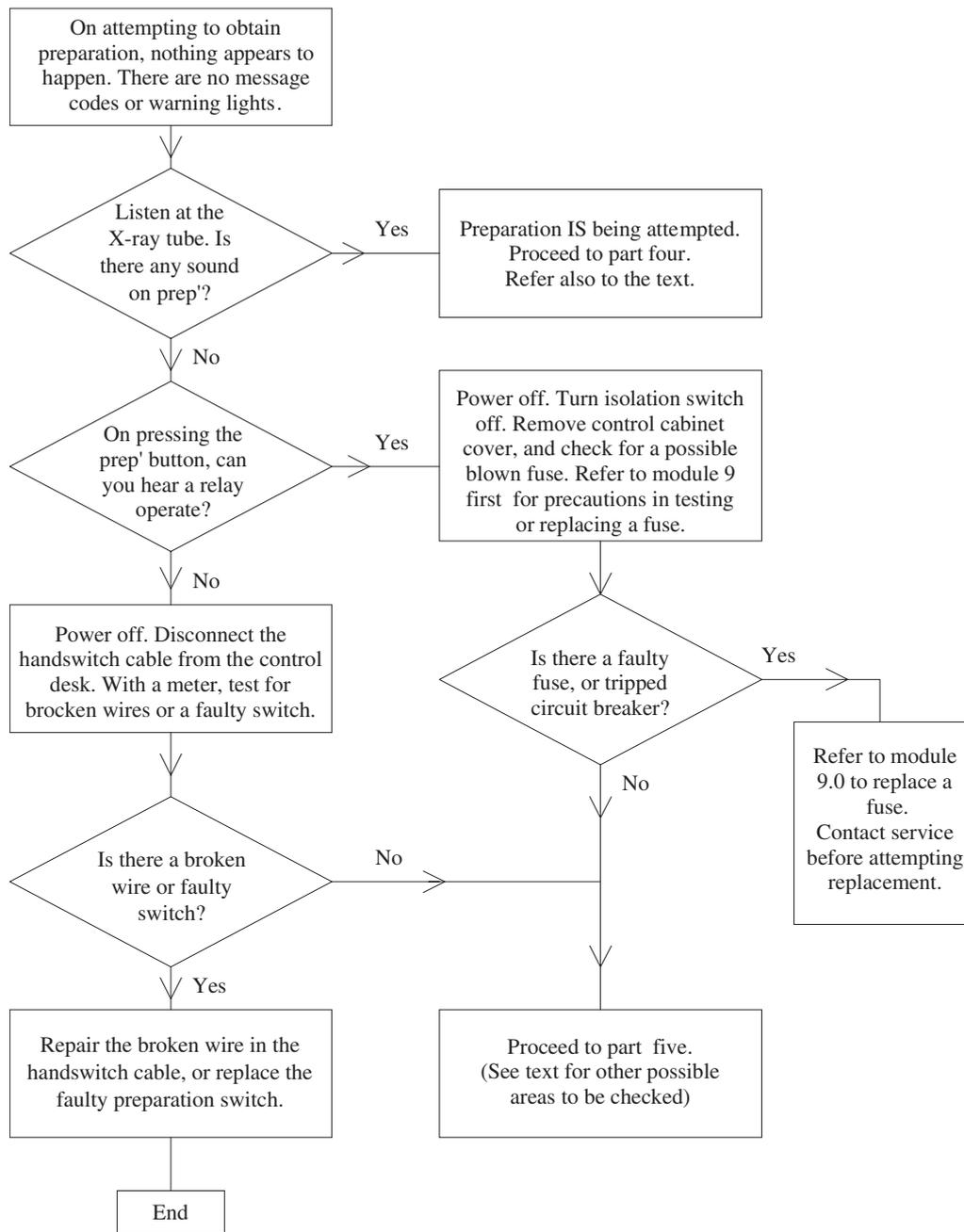


Fig 6-2. Unable to obtain preparation, part two

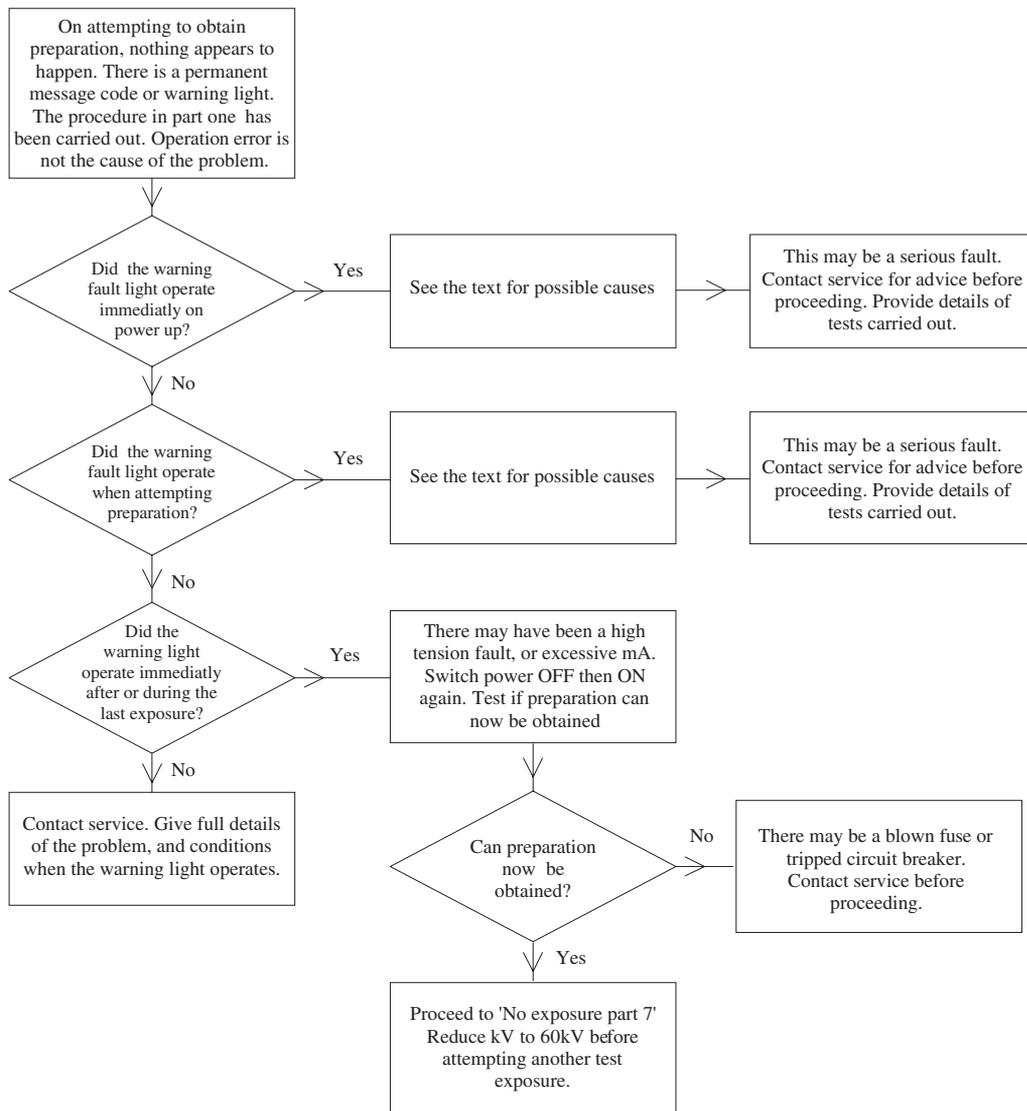


Fig 6-3. Unable to obtain preparation, part three

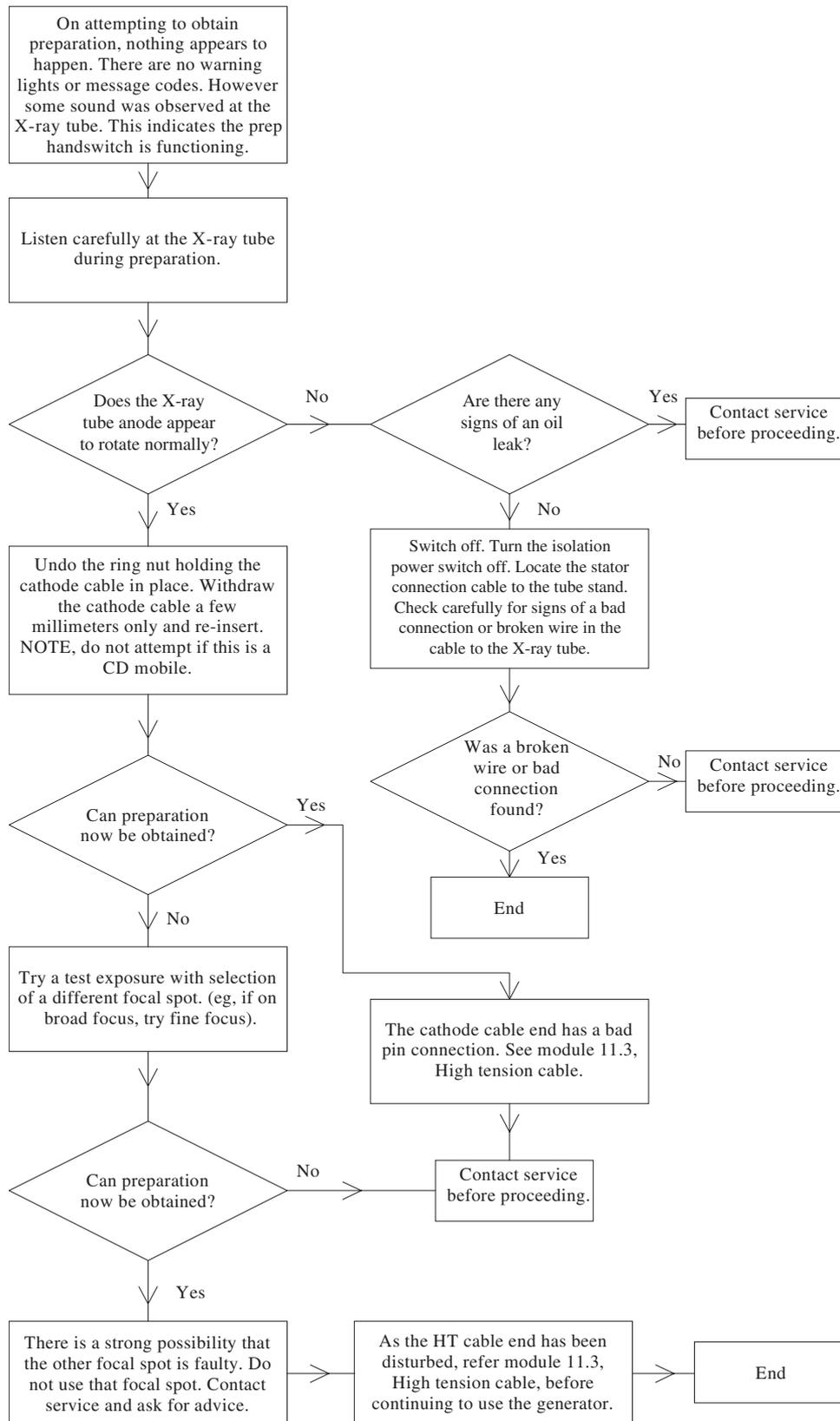


Fig 6-4. Unable to obtain preparation, part four

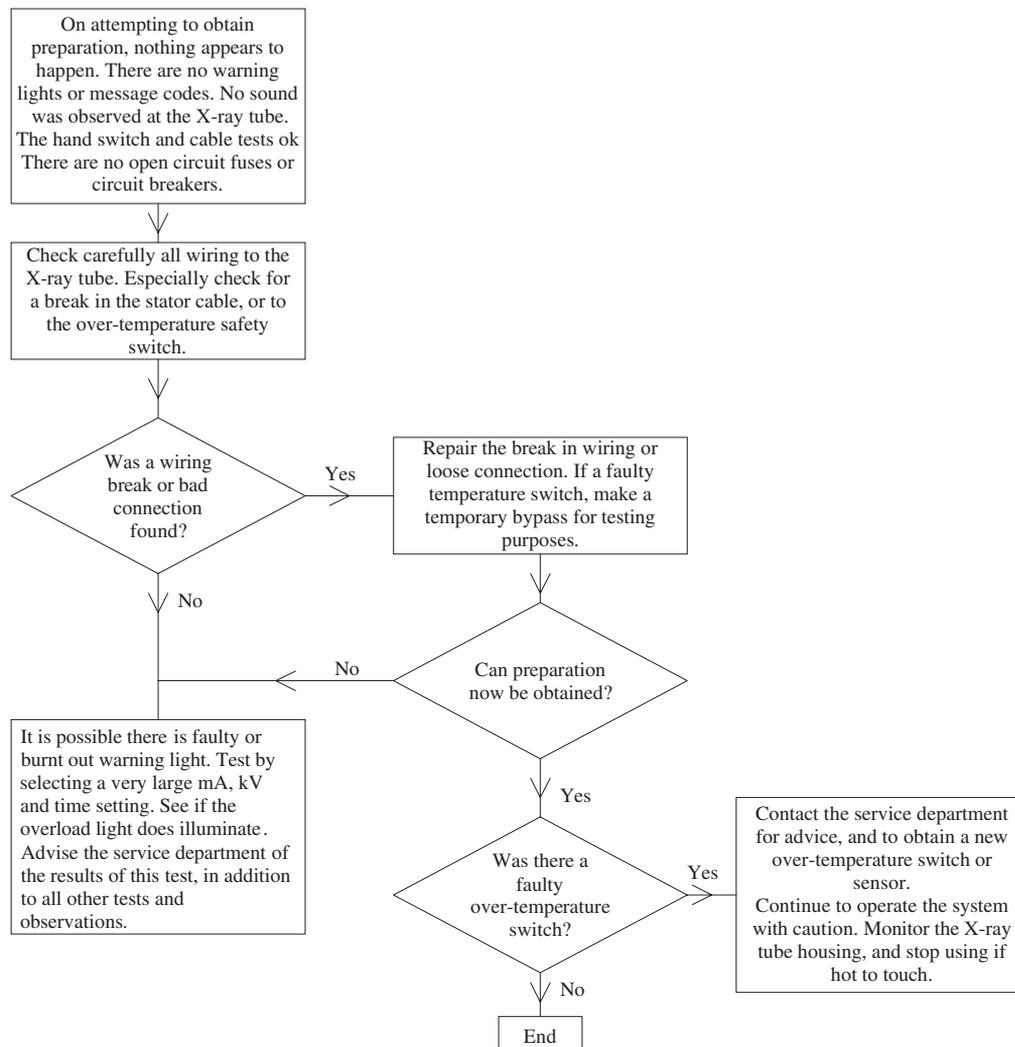


Fig 6–5. Unable to obtain preparation, part five

Part 5. Other tests

Refer first to the flow chart, Fig 6–5 page 79, ‘Unable to obtain preparation, part five’.

There remain two possibilities to be checked.

- The wiring to the X-ray tube stator or the housing over-temperature switch is broken or has a bad connection. This could occur where it enters the X-ray tube, or where the cable has received a lot of flexing or twisting. See **module 7.1 page 104**.
- There may be an internal fault or problem in the generator, but the warning light is also faulty or burnt out. Test the light by setting very high exposure factors, which would normally cause a tube overload condition. If no warning light illuminates, then the globe or control circuit is faulty.
- Include the results of all tests, when requesting help from the service department.

Section 2: No radiograph exposure

This section assumes you are able to obtain preparation, the control has indicated preparation is completed, and is ready for an exposure. On attempting to obtain an exposure, nothing happens. Or else, the control appears to expose, but the film is blank or very light. Each part has an associated flow chart. Refer to these flow charts before reading the text.

Part 6. Operation tests

Refer first to the flow chart, Fig 6–6 page 83, ‘No exposure, part six’.

The control has indicated it is ready for an exposure. On attempting to obtain an exposure, nothing appears to happen. There is no sound from the Bucky. The exposure light does not operate.

Operation tests

- Check the technique selection to ensure a valid operation. Look for selection buttons or switches that are sticking, and may not have properly operated or released.
- Is an Automatic Exposure Control (AEC) in operation?
 - i. The warning light or signal with the AEC reset button may have failed. Press reset and try exposing again.
 - ii. Have you selected the correct AEC mode for the particular Bucky or technique?
 - iii. Disable AEC operation, select suitable manual exposure factors, and attempt another exposure.
 - iv. If you can now expose, continue using the system with AEC switched off. For AEC tests, see **module 10.0 page 140**.
- Select the direct, or non-Bucky, handswitch technique. Try again to expose. If successful, consider the following.
 - i. **First ensure all power is turned off, including the room power isolation switch.**
 - ii. There is a possible open fuse or circuit breaker supplying power to the Bucky. If found faulty, check the wiring to both Bucky's before replacing the fuse. There may be loose connections, causing a short circuit. A film marker may have fallen onto electrical connections in the vertical Bucky.
 - iii. Similar to the above, there may be a loose or broken connection to a particular Bucky. This is most likely to occur at either a plug or socket, or else at the Bucky terminals on the side of the Bucky.
 - iv. The grid may have become dislodged, stopping operation of the grid drive motor. A common cause is poor attachment of lead numerals to the cassette. When the cassette and tray is inserted, these catch on the grid, dislodging it.
 - v. Some older Bucky's have small motor drive gears. These gears may be damaged. As a result, although the motor operates, the grid does not oscillate or move to the expose position.
 - vi. In the case of a vertical Bucky, a lead numeral may become dislodged, and fall into the drive motor area. This could prevent operation, or cause a short circuit.
 - vii. For other problems with the Bucky, refer to **module 8.0 page 121**.
- Does the X-ray room have a safety 'Door closed' interlock? This may, depending on installation methods, interrupt preparation if the door is opened, or simply prevent an exposure. When the door is closed, can you hear the switch operate? If so, it is probably ok.
 - i. If no indication is heard, check the switch operation with a multimeter.
 - ii. **Ensure all power is turned off, including the room power isolation switch.**
 - iii. Set the multimeter to the low ohms position, and check the meter shows minimum ohms with the probes connected together.
 - iv. With the probes connected to the switch contacts, test the switch operation by opening and closing the door.
- Can you hear a relay operating on pressing the expose switch? If so, the switch and connecting cable are properly working.
- If the handswitch is suspect, then the switch and connecting cable should be checked with a multimeter set to the low ohms scale.
 - i. **Ensure all power is turned off, including the room power isolation switch.**
 - ii. If available, request an electrician or electronics technician to assist.
 - iii. Use the method described in part two of this module. 'Check for a faulty preparation switch, or handswitch cable'. See **module 5.0, page 65**.

Part 7. No mA or kV

Refer first to the flow chart, Fig 6–7 page 84 'No exposure, part seven'.

On attempting to obtain an exposure, the film was blank, or very under exposed. The control indicates preparation is completed and ready for an exposure. The exposure indication operates on pressing the expose position of the handswitch.

There is no warning light or fault indication during the attempted exposure.

Check the cathode cable connection

A bad cable-end connection in the X-ray tube cathode-receptacle is a common cause of light or blank films. This occurs where the cable-end pins fit into the receptacle. For example: Sufficient current flows through the filament to satisfy the generator tests during preparation. However the filament temperature is too low for the required mA. A test exposure should be tried first on the other focal spot. However, if the cable-end centre pin has a bad connection, this can affect **both** focal spots.

Note. During an exposure, if there is low, or no mA, then the actual kV can rise above the set value of kV.

As a result, a microprocessor-controlled generator may display 'kV too high' as a fault message, instead of 'low mA'. Always select low mA and kV for test exposures.

- To check for a poor cable end connection.
 - i. **Ensure all power is switched off, before any adjustment is made to the HT cables.**
 - ii. To check, undo the cathode cable-end retaining ring nut. Partly withdraw the cable end about 2~4mm, then reinsert the cable end. Replace and firmly tighten the cable-end ring nut.
 - iii. **Caution.** The cable end may have silicon grease as insulation instead of anti-corona silicon pads. Removal of the cable end by more than 2~4mm can reduce the effectiveness of the insulating grease. As a precaution, do not exceed 100kV until the cable end is re-sealed with fresh silicon grease. **See module 7.3 page 117.**
- Try a test exposure after adjusting the cathode cable end. If the test exposure is OK, there was a poor pin connection at the cable end. The cable-end pins need to be cleaned and adjusted. **See module 7.3 page 117.**
- If the test exposure still fails after adjusting the cathode cable-end, try exposing again on the other focal spot. If the exposure is now OK, the first focal spot may have a fault. This is caused by;
 - i. The filament has a short circuit to the focus cup. Only part of the filament is heated.
 - ii. The filament is able to pass the 'open circuit' safety test in preparation, but the actual mA on exposure is less than half the expected value. In this case, the X-ray tube requires replacement.
 - iii. To inspect the filament, see **module 7.1 page 104.**
 - iv. Unfortunately, this type of fault is not uncommon. The problem occurs when the filament bends, and touches the focus cup during preparation. This causes the filament to become welded to the focus cup, shorting out a section of the filament.
 - v. Contact the service department for advice.

Has an inverter fuse failed?

If a trial exposure on the other focal spot also fails, this may be due to no high voltage. With high frequency generator systems, a common cause is an open circuit inverter fuse. This often fails due to fatigue, or a temporary fault with the inverter. Depending on the make or model of generator, there may be no warning signal, or message, to indicate high-voltage failure.

- **First ensure all power is turned off, including the room power isolation switch.**
- **Before attempting to test or replace the fuse, contact the service department for advice. As well as the fuse location, special test precautions can apply before and after replacement.**
- **Checking or replacing the fuse, should only be performed by an electrician, or electronics technician.**
- **See module 5.0 page 65.**

- i. Before attempting to test the fuse, measure the primary power filter capacitors, and ensure the residual voltage is at a safe level.
- ii. If the fuse is open circuit, check the inverter SCR or power transistors for a possible short circuit, before replacing the fuse.
- iii. After the fuse is replaced, examine the power circuit for charging the capacitors on initial power up. There is normally a resistor in series with each phase to limit the charging current. These resistors are shorted out by a contactor after a few seconds time delay. This circuit needs to be disabled so the resistors remain in operation.
- iv. On power up, monitor the voltage on the capacitors to ensure they are in fact charging normally. This ensures there is no undetected direct short circuit in the inverter.
- v. A short test exposure at low kV and mA should be attempted. If OK, then switch off, and restore the operation of the charge current-limit resistors to normal operation.

Other possible causes for no exposure

- A faulty fuse or connector in the generator control cabinet.
 - i. *Ensure all power is turned off, including the room power isolation switch.*
 - ii. With the aid of an electrician or electronics technician, look for an open circuit fuse, or tripped circuit breaker.
 - iii. Look for loose plugs and sockets, or other connectors.
- Look for damage caused by rats eating the wiring. This can especially apply inside cable ducts, or cables to the HT transformer. Some species of rats can bite through cables, or a wiring harness, as if their teeth were cutting pliers.

Part 8. High-tension problems

Refer first to the flow chart, Fig 6–8 page 85, ‘No exposure, part eight’.

On attempting to obtain an exposure, the film was blank, or very under exposed. The control indicated preparation was completed, and ready for an exposure. The exposure indication operates on pressing the expose position of the handswitch, but only a very short exposure results.

A warning light or error message is generated during, or at the end of exposure.

Record the exposure factors, focal spot, and technique in use. Include any fault codes or error messages.

Check for a high-tension fault

The cause of the problem may be due to:

- No kV was generated. The inverter fuse is open circuit in a high frequency generator. **See part seven.**
- A kV fault. Caused by a short circuit in the HT cable or cable end.
- A high voltage arc in the high-tension generator, cables, or X-ray tube housing.
- An unstable X-ray tube, due to gas. This can generate a kV or mA fault indication. Instability can occur if a high kV exposure is made, after using the tube for a long time at a medium or low kV output.
- A kV fault can be caused if mA is too low. For example, due to a bad connection in the cathode cable end, or a partial short circuit in the X-ray tube filament.
- The mA output has exceeded the correct value. For example, although 200mA was selected for an exposure, the mA increased to over 300mA. This could be due to a fault in the mA regulation circuit, a high-tension fault, or an unstable X-ray tube.

Check for a HT cable fault

HT cable faults normally occur at the X-ray tube end, due to the HT cable twisting as the tube is positioned. Arcing can also occur where the cable ends plug into the X-ray tube, due to a fault in the insulation grease.

- Was a ‘bang’ heard during the exposure?
- Check for a burning or acrid odour at the HT cable ends. If not sure, undo the retaining ring nut, ‘sniff’, and then replace the ring nut.
- If at all uncertain of the condition of the HT cable ends, refer to **module 7.3 page 117**.

- **Caution.** Do not make this test on a CD mobile, unless the capacitor is fully discharged. See **module 6.2 page 94**.
- If the HT cable or cable ends appear OK, then attempt a test exposure at low output.
 - i. **Caution.** *If the fault occurred below 80kV, do not test further without advice from the service department.*
 - ii. Select a low kV and mA output. A suggested exposure is 60kV, 100mA, for 0.1 seconds. Close the collimator and make a test exposure.
 - iii. If the control is fitted with an mA or mAs meter, observe the meter carefully during the test exposure.
 - iv. If the mA meter needle moves very quickly, or the mAs meter indicates 20% more than the expected value, this can indicate a high tension fault.
 - v. Should the generator fail a test at 60kV, stop. There is a possible fault at the HT cable ends, these should now be removed and carefully examined. See **module 7.3 page 117**.
 - vi. **Caution.** *Before removing the cable ends, contact the service department for advice. Include the exposure factors, focal spot, and any error codes or messages.*

Test the X-ray tube high-tension stability

If the test exposure at 60kV is ok, then test the X-ray tube at higher kV.

- Do this by applying the seasoning procedure, described in **module 2.1 page 48**. When applying this procedure, take care to observe the HT cable at the X-ray tube, in case an arc occurs.
- Observe the mA meter (if available). An unstable tube can indicate an increase of mA when test exposures are first made, then return to the correct value after a few exposures at the same kV. Then when kV is increased, the first exposure may again show an increase of mA, returning to the correct value after the second or third exposure.
- In case any unusual occurrence takes place, immediately stop. HT cable or cable-end faults will become apparent at higher kV values. If not fully checked before, do so now. See **module 7.3 page 117**.
- **Caution.** *Before removing the cable ends, contact the service department for advice. Include the exposure factors, focal spot, and any error codes or messages.*

- If the HT cable ends have been fully checked, then start the seasoning test again, starting at 10kV below the level where a problem occurred. Should the problem still occur, then stop. Consult the service department for advice.
- Providing the X-ray tube passes the seasoning test, all is well.
- Make an entry in the logbook. Include a description of the problem, together with the tests and results.

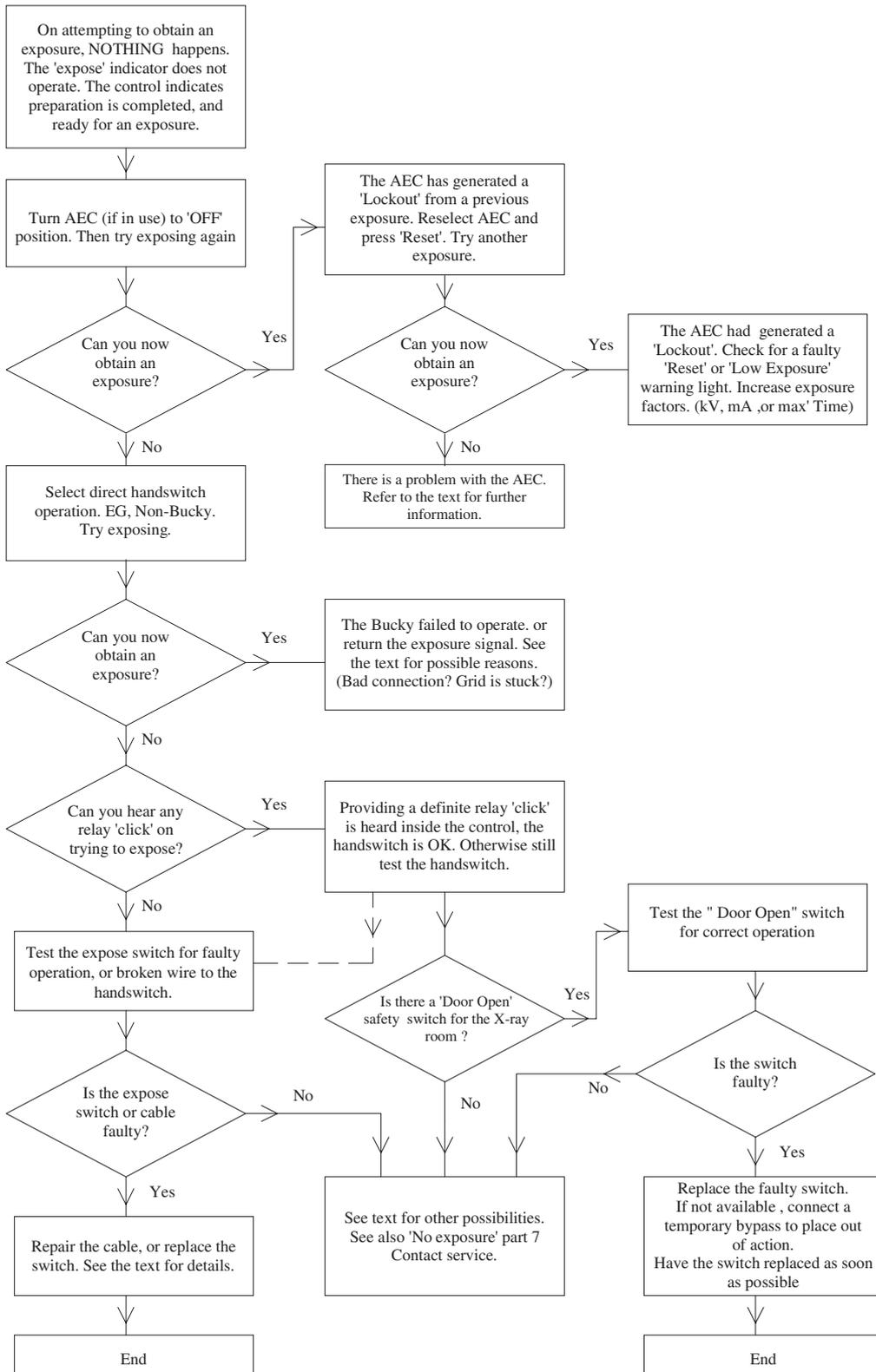


Fig 6-6. No exposure, part six

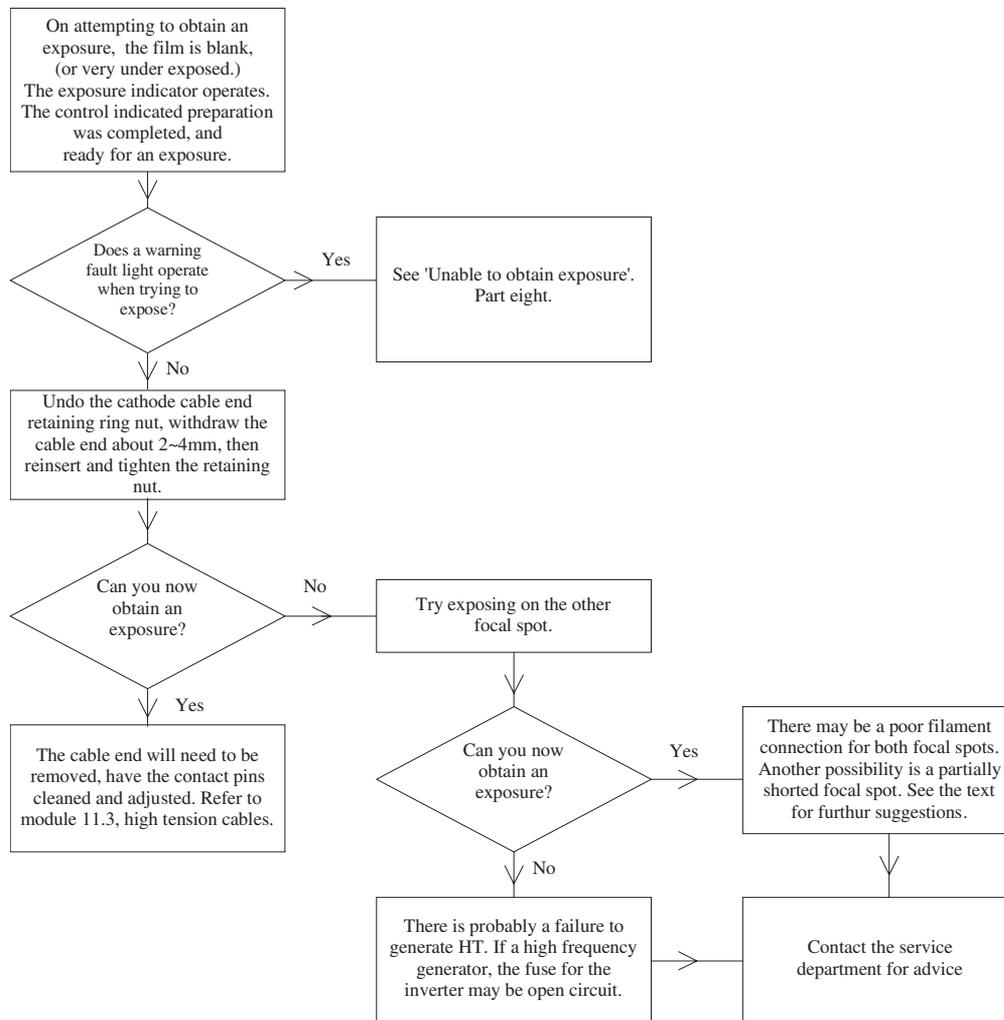


Fig 6-7. No exposure, part seven

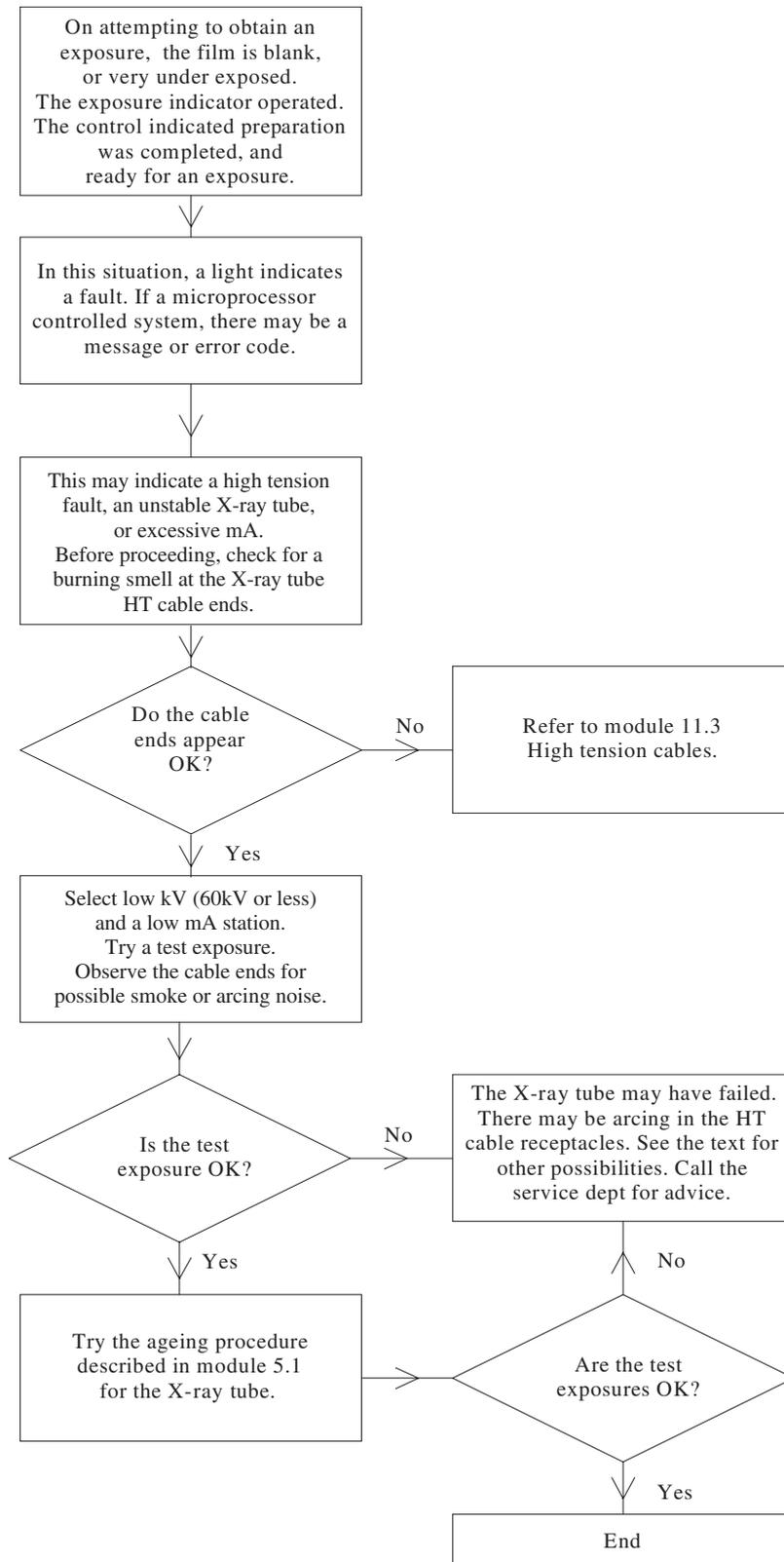


Fig 6-8. No exposure, part eight

TASK 9

No preparation Part I

You have a patient on the table. After instructing him to 'take a deep breath and hold it', you press the preparation button. However, the 'ready to expose' signal does not occur.

What action should be taken first?

Make a list of your tests and observations.

What do you think is the cause of the problem?

What action may be taken to correct the problem?

Tutor's comments

Satisfactory/Unsatisfactory

Signed

Date

Tutor

TASK 10

No preparation Part 2

The X-ray control does not provide the 'ready for exposure' signal after pressing the preparation switch. You have just completed a previous check for a similar report, and taken action that should have corrected the problem. However, while there are now 'signs of response' when the preparation button is pressed, the ready for exposure indication still cannot be obtained.

What was the previous observed problem, and action taken?

Make a list of your further tests and observations.

What do you think is the cause of this problem?

What possible actions may be taken to correct the problem?

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____

Tutor

Date _____

TASK 11

No exposure

You have positioned a patient on the upright Bucky to take a chest exposure. You place the generator into preparation, and press the exposure switch when the control indicates 'ready to expose'. However, no exposure occurs. After removing the patient, you investigate for a possible cause of the problem.

Make a list of possible reasons for this problem.

Describe suitable tests to either confirm, or eliminate, possibilities from this list.

Carry out these tests. What were the results?

What action is needed to correct the problem?

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____

Tutor

Date _____

TASK 12

X-ray output linearity

You have a report of 'light' films occurring in room 2. This appears to happen only on selection of fine focus. Devise a test, using the stepwedge, to check the exposure linearity between the fine and broad focus selections of mA. _____

Which exposure factors will be used for your generator? _____

After carrying out the above test, you find the 100mA station has reduced output. A comparison test of 50mA and 200mA indicates correct results. What is the most likely cause? _____

What are two other possible reasons for light films on this 100mA station? _____

Give reasons why these possibilities are low, considering that 50mA and 200mA indicated normal results.

Make another series of stepwedge tests. This time remain on the mA station that produced a low output. Make a series of four test strips, and increase kV by 2.0kV for each exposure. What increase of kV was required to increase density by one step? _____

Your test was first carried out at 80kV. You find that if kV is increased by 4.0kV, the density steps on the 100mA test strip are darker than the test strips for 50 or 200mA stations. In terms of a 5% permitted kV error, would the test result be:

OK? _____ Marginal? _____ Outside acceptance? _____

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____

Date _____

Tutor

MODULE 6.1

Mobile or portable X-ray generators

Aim

The aim is to provide information related to servicing or repairing a mobile or portable X-ray generator. This information is additional to that provided for a fixed installation described in module 6.0 page 71.

Note. Capacitor discharge mobiles are discussed in module 6.2 page 94. Reference module page numbers refer to the title page.

Objectives

On completion of this module, the student will be aware of common problems with mobile or portable X-ray generators. When used together with the module 6.0 procedures, the student will be able locate a problem area, and carry out minor repairs. An electrician or electronics technician may provide added assistance where indicated in this module.

Contents

- a. General precautions
- b. Transport problems
- c. The generator will not switch on
- d. No preparation or no exposure
- e. The generator appears to expose, but film is blank
- f. Collimator light-beam alignment keeps changing
- g. The magnetic locks sometimes do not work, or are weak in action
- h. Problems with the motor drive

a. General precautions

- Before removing any covers, or testing any wires or connections:
 - i. **Ensure the system is switched off, and unplugged from the power point.**
 - ii. Mobile high-frequency generators may be battery operated. The batteries in these are connected in series, and may have a total voltage of up to 240V DC. *Refer to the operating or installation manuals for the position of the battery isolation switch, and ensure this is switched off before removing the covers or testing wires and connectors.*
 - iii. **Do not** attempt to replace the batteries if a mobile has more than two 12V batteries. Ask for assistance from an electrician or electronics technician.
- If removing a collimator or X-ray tube on a mobile generator.
 - i. **Do not** rely on the vertical lock system.
 - ii. Ensure the suspension system is at the limit of its maximum vertical travel.
 - iii. Or, attach a rope so that the system cannot move upwards, once the weight of the collimator or X-ray tube is removed.
- **When replacing a motor drive battery.**
 - i. Remove your wristwatch if it has a metallic band. The same precaution extends to any rings. While 12 volts, or even 24 volts, is too low to cause a serious shock, the battery can cause serious burns if a short circuit occurs across a watchband or ring.
 - ii. **Disconnect first** the battery terminal that connects to the mobile body or framework. This prevents the danger of accidentally shorting the other battery terminal to the mobile body.
 - iii. In the case of multiple battery systems, refer always to the operation or installation manuals. In some cases, the batteries will have the centre connections between two batteries connected to the mobile body. These connections should be removed first, and replaced last. It is advisable to

request the aid of an electrician. If in any doubt, contact the service department for advice.

b. Transport problems

Mobile and portable equipment are subject to additional problems due to transport. Portable equipment may be dropped, while mobile generators may pass over severe bumps while travelling. There are also problems due to dust, or corrosion due to high humidity. This last can occur if the system is used in an air-conditioned area, then parked in a general area which is not air conditioned.

c. The generator will not switch on

- Check the power cable.
 - i. Is the power point faulty? Check by plugging a lamp or other suitable item into the power point.
 - ii. Is there a broken connection at the power-cable plug? Important, check also the earth connection.
 - iii. The power cable may plug into a socket on a portable generator. In this case check the generator socket connections as well as the cable.
 - iv. The power cable-reel for a mobile can have broken wires or faulty contacts in the mechanism. If faulty, have an electrician connect a temporary power cable directly into the mobile, while waiting for a replacement.
 - v. If there is a bad connection to a power plug or socket, this should be checked and repaired by an electrician.
 - vi. For information on locating bad connections, **see module 5.0 page 65.**
 - vii. Moving the mobile while still plugged into a power point is not recommended.
- Check for a blown or faulty fuse. **See module 5.0 page 65.**
- The power on/off switch is faulty. Check for loose connections. Test the switch operation with a multimeter set to the low ohms range. Ask an electrician or electronics technician for assistance.

d. No preparation or no exposure

Note. The following checks are to be made with all power disconnected. If a battery operated high frequency system, ensure the battery circuit breaker or switch is opened.

- Look for possible blown fuses. **See module 5.0 page 65.**

- Check the hand switch, and handswitch cable. **See module 5.0 page 65.**
- Check all external plugs and sockets. **See module 5.0 page 65.**
- Look for dislodged components internally, or poor connections.
- Plugs and sockets can develop poor connections due to build up of oxides, or else slight corrosion of the plating. Check by unplugging and reconnecting the plugs and sockets.
 - i. ***This procedure should only be carried out by an electrician or electronics technician.***
 - ii. Printed circuit board edge connectors are subject to corrosion and poor connections, especially older types that are not gold plated. Later model generators use plugs and sockets for the printed circuit boards.
 - iii. **Ensure the generator is unplugged from the power point.**
 - iv. *Before removing a printed board, touch the main metal framework of the generator. This is to discharge any static electricity from the body. This is very important if working in a carpeted area, or there is low humidity.*
 - v. Only remove and replace one board at a time. Take careful note of its position, so the board is not replaced the wrong way.
 - vi. On removal of the printed board, clean the edge connectors with a cloth dampened with a little alcohol, or methylated spirits. After cleaning, do not touch the contacts with your fingers.
 - vii. Printed circuit boards may become cracked, breaking some of the tracks. For example, if equipment was dropped. Examine with a magnifying glass for this possibility. If there are signs of corrosion, it is possible some of the tracks on the board have become open circuit. This can be a problem near the sea.
- Have any relays become dislodged? Move them slightly in their sockets in case of a bad socket connection.
- Bad contacts on control switches etc.
 - i. A build up of dirt on switch contacts can cause excessive wear, and poor contact operation. In most cases, spraying with a suitable contact cleaner will restore normal operation.
 - ii. An optimum spray is one designed to clean and lubricate. CRC 2.26 is recommended. WD-40 is less optimum, but may also be used. Your electrician may have a suitable contact cleaner.
 - iii. Before spraying, cover adjacent areas with cloth or tissues to protect from unwanted spray.

- iv. **Note. Never use any spray on electrical equipment while it is energized.**
- The X-ray tube head, or housing. (An X-ray 'tube head' combines the X-ray tube, and the high-tension transformer, in one housing.)
 - i. Check all connections to the X-ray tube head.
 - ii. For mobiles with a conventional X-ray tube housing, check the stator cable.
 - iii. The HT cable may have a poor connection to the X-ray tube cathode. For test procedures, **see module 7.3 page 117.**

e. The generator appears to expose, but film is blank

- Ensure the collimator opened correctly. Look inside the collimator for loose or disconnected parts, due to vibration in transport.
- Was an unusual noise or arcing heard during the attempted exposure?
 - i. With conventional X-ray tube housings, check the HT cable ends for arcing. **See module 7.3 page 117.**
 - ii. If a rotating anode tube, does it slow down quickly when preparation is released? The tube may be broken, and the anode is now immersed in oil.
 - iii. By rotating the X-ray tube head or housing, can you hear oil moving inside the housing? This can indicate a broken tube.
 - iv. See also **module 7.1 page 104.**

f. Collimator light-beam alignment keeps changing

- Parts of the collimator may have become loose due to transport vibration. Remove the collimator cover, and check for loose sections.
- For adjustments to the collimator, **see module 7.2 page 110.**

g. The magnetic locks sometimes do not work, or are weak in action

There are two types of electromagnetic locks. Older types require power to operate. Later types have a permanent magnet, and require power to remove, or cancel, the magnetism.

- The lock sometimes operates, depending on the tube stand movement.
 - i. There may be a poor connection to the lock coil or the lock switch.

- ii. The mechanical position of the lock coil has too large an air gap. Adjust the position for a smaller air gap, with the lock in the off position.
- iii. There is a build up of dirt, or oil, on the lock-coil pole-piece. A thin piece of cardboard soaked in methylated spirits is a good cleaning aid. Place the cardboard between the pole-piece and the brake plate. Energise the lock, while slowly pulling the cardboard out from between the lock and the brake plate. Repeat this a number of times, until fresh sections of cardboard show no smudges of dirt from this wiping action.
- The lock does not energise. (Old type.) Or does not release. (Permanent magnet type.) Check for the following.
 - i. The lock switch may be faulty.
 - ii. Look for an open circuit fuse.
 - iii. A broken wire to the lock coil.
 - iv. The lock coil itself may be open circuit. Test by disconnecting one wire, then with a multimeter set to a medium or high ohms scale, check for continuity of the lock coil. If necessary, request assistance from an electrician.

h. Problems with the motor drive

Many mobiles are fitted with battery-powered motor drives. A 12 volt car battery is most commonly fitted, and in some cases two batteries to provide 24 volts.

Caution

Battery powered high-frequency generators operate the motors from the same high voltage supply used to power the high-frequency inverter. **Due to the high voltages that may be present, do not remove the covers, or attempt any internal adjustment. This should only be attempted by an electrician or electronics technician, under instructions from the service department.**

- There is no motor drive in either direction.
 - i. Units fitted with a drive control key switch. The switch may be faulty, or have a loose connection.
 - ii. The fuse for battery power is open circuit.
 - iii. The battery is discharged.
 - iv. There is a bad connection to the battery terminal. Remove the battery terminals, and scrape corrosion from the posts or terminal clamps.
 - v. **Caution.** See part a, general precautions, before disconnecting a battery.
 - vi. The brake release bar on the handle operates a microswitch. The microswitch may need adjustment to operate correctly.

- vii. Check the electrical cables for loose plugs or sockets.
- There is no forward motor drive.
 - i. The anti-crash bumper may be stuck in the operated position, or one of the switches operated by the bumper is damaged.
- There is only a low level of motor drive assistance.
 - i. The motor may be in bedside mode. A control switch selects the change between bedside speed, and travel speed. The control switch could be faulty, or the knob has slipped, and indicates the wrong position.
 - ii. Other mobiles require the tube stand to be placed in the travel position before permitting full power. In which case a microswitch to sense the tube stand position may need adjustment. Ask an electrician or electronics technician to check the switch, or microswitch operation.
 - iii. New mobiles have microcomputer control of the motor power. Some systems allow the operator to change the amount of power assistance. Refer to the operation manual to adjust the level of motor power.
 - iv. There may be a poor battery connection due to corrosion. Remove the battery terminal clamps, scrape of any corrosion, and reassemble.
 - v. **Caution.** See part a, general precautions, before disconnecting a battery.
- The battery is not charged up.
 - i. The battery was not charged overnight. Or the power point used was faulty. Check the power point with a lamp or similar item.
 - ii. The power cord used for battery charging has a bad connection. Have an electrician repair the connection. (Do not move the mobile while plugged into a power point.)
 - iii. There is an open circuit fuse, in the battery charge section of the mobile. To check a fuse, **see module 5.0 page 65.**
 - iv. **Caution.** *If this is a battery operated high-frequency generator, this check should only be performed by an electrician, or electronics technician.*
- After charging, the battery soon loses power.
 - i. Has the electrolyte level of the battery been checked? (This may not be possible with sealed or low maintenance batteries.)
 - ii. The battery may have a shorted cell, or the cells are sulphated, in this case a new battery is required. Before replacing the battery, have the battery tested at a garage, or by an auto electrician.
 - iii. **Caution.** See part a, general precautions, before disconnecting a battery.

MODULE 6.2

Capacitor discharge mobile

Aim

The aim is to provide information related to servicing or repairing a capacitor discharge (CD) mobile. This information is additional to that provided for a fixed installation described in module 6.0 page 71, and mobile generators described in module 6.1 page 90. **(Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with capacitor discharge mobile generators. When used together with modules 6.0 and 6.1 procedures, the student will be able locate a problem area, and carry out minor repairs. The student will also be aware of special precautions when dealing with the capacitor high-voltage system, where repairs must only be attempted by an electrician or electronics technician.

Contents

- a. CD mobile operation modes
- b. General precautions
- c. High-tension cable precautions
- d. The mobile does not switch on
- e. Unable to charge the capacitor
- f. On charging the capacitor, there is a loud 'bang'
- g. Unable to obtain preparation
- h. On going into preparation, the capacitor discharges
- i. No exposure
- j. The kV does not adjust to a lower value
- k. Apparently there is an exposure, but the film is blank
- l. On exposing, the exposure continues till the capacitor is fully discharged
- m. Problems with the motor drive

a. CD operation modes

Unlike the fixed installation, or standard mobile generator, the CD mobile has special modes of operation. This list is provided as a reminder.

- High voltage is applied to the X-ray tube continuously while the capacitor is charged. This includes the kV remaining after the exposure.
- When not in preparation, the X-ray tube filament has no pre-heating. There is also a high negative voltage applied between the cathode cup or grid, and the filament. Despite these precautions, a very small electron emission does occur. This is called 'dark current'.
- To prevent X-ray emission due to dark current, the collimator has an additional lead shutter. This shutter blocks all X-ray emission. The shutter moves out only when the mobile begins preparation, or else just before the X-ray exposure.
- When in preparation, the exposure is prevented by the negative voltage applied to the X-ray tube grid. During an exposure, this voltage is removed, allowing full emission from the cathode. At the end of the exposure, the negative voltage is again connected to the grid. This shuts off the electron beam to the anode, ending the exposure.
- Earlier CD mobiles set the exposure as a percentage of kV drop during an exposure. Later systems have an mAs timer.
- The capacitor discharges during an exposure, at the rate of 1 kV per mAs. As a result, the X-ray output of a CD mobile is not linear. A 20 mAs exposure will not give twice the output of a 10 mAs exposure.

b. General precautions

- **Before removing any covers, ensure the mobile is switched off, and unplugged from the power point.**
- If removing a collimator or X-ray tube.
 - i. Do **not** rely on the vertical lock system.
 - ii. Ensure the suspension system is at the limit of its maximum vertical travel.

- iii. Or, attach a rope so that the system cannot move upwards, once the weight of the collimator or X-ray tube is removed.
- When replacing a motor drive battery.
 - i. Do **not** attempt to replace the batteries if a mobile has more than two 12V batteries. Ask for assistance from an electrician or electronics technician.
 - ii. Remove your wristwatch if it has a metallic band. The same precaution extends to any rings. While 12 volts, or even 24 volts, is too low to cause a serious shock, the battery can cause serious burns if a short circuit occurs across a watchband or ring.
 - iii. Disconnect **first** the battery terminal that connects to the mobile body or framework. This prevents the danger of accidentally shorting the other battery terminal to the mobile body.
 - iv. If two batteries are fitted, refer always to the operation or installation manuals. In some cases, the batteries will have the centre connection between the two batteries connected to the mobile body. These connections should be removed first, and replaced last. It is advisable to request the aid of an electrician. If in any doubt, contact the service department for advice.

c. High-tension cable precautions

Special care is required due to dangerous high voltage stored in the capacitors. Several of the tests described involve removing or exchanging the high-tension cables. This requires taking care to ensure the capacitor is fully discharged, before any attempt is made to remove or adjust the cable ends. *Only an electrician, or electronics technician, should attempt this procedure.*

- If possible, make an exposure to fully discharge the capacitor, or reset the kV to the minimum level possible.
- Wait until the kV has dropped to below 5 kV, as indicated on the panel meter. If no indication of capacitor high-voltage by a panel meter, wait overnight before proceeding.
- **Switch off, and unplug the power cord.**
- Open the control panel, and locate the two manual capacitor-discharge control knobs. These may be operated by lifting and rotating, and must stay in the discharge position. ***If uncertain of their operation, refer to the installation or service manual for the mobile. Otherwise contact the service department for advice.***

- Before operating the discharge knobs, you may observe two neon lamps glowing. On operation of the discharge knobs, both of these lamps should turn off. ***If one lamp continues to glow, contact the service department for advice before proceeding.***
 - i. Undo the ring nut holding the cable end in position at the X-ray tube receptacle.
 - ii. **Do not** remove the cable end, but first inspect the safety-shield metal braid for damage. Twisting of the cable may have caused it to break, and become disconnected from the cable end.
 - iii. If the shield does not appear damaged, then re-tighten the ring nut so the cable shield is properly grounded.
 - iv. Undo the ring nut holding the high-tension cable in the high-tension tank receptacle. On withdrawing the cable end, **do not touch** the pins, but first short them to the side of the receptacle. This is to ensure any possible charge in the high-tension cable is completely shorted out.
 - v. In case the high-tension cable shield appears damaged at the X-ray tube end, then remove the cable end from the X-ray tube **first**. Again, touch the end pins to side of the receptacle to discharge any residual high voltage. This will include any charge in the capacitor as well as the high-tension cable. Now undo the ring nut, and remove the cable end from the high-tension tank.
 - vi. The above precautions are in case the knobs for discharging the capacitors have not operated correctly. In part (iv) only a small spark will occur if the capacitor was not discharged, but in part (v) take care, as there may be a very big spark. Normally, there should be no spark at all. In case there is, then contact the service department before proceeding further.
- When the high-tension cable is removed or replaced, the cable ends must be cleaned and re-sealed. **See module 7.3 page 117.**
- After replacing or adjusting the high-tension cable, return the discharge knobs to their normal position.

d. The mobile does not switch on

- Is the power cable faulty?
 - i. Is the power point faulty? Check by plugging a lamp or other suitable item into the power point.
 - ii. Is there a broken connection at the power-cable plug? Important, check also the earth connection.

- iii. The power cable-reel may have broken wires or faulty contacts in the mechanism. If faulty, have an electrician connect a temporary power cable directly into the mobile, while waiting for a replacement.
- iv. If there is a bad connection to a power plug or socket, this should be checked and repaired by an electrician.
- v. For information on locating bad connections, **see module 5.0 page 65.**
- vi. Moving the mobile while still plugged into a power point is not recommended.
- Check for a blown or faulty fuse. **See module 5.0 page 65.**
- The power on/off switch is faulty. Check for loose connections. Test the switch operation with a multimeter set to the low ohms range. Ask an electrician or electronics technician for assistance.

e. Unable to charge the capacitor

On pressing the charge button, nothing happens. Otherwise all appears normal.

- With power switched off, and the mobile unplugged from the power point, check the following;
 - i. Some CD mobiles have the capacitor charge switch mounted on the hand switch. There may be a broken wire or a faulty switch.
 - ii. To check the hand switch or cable, **see module 5.0 page 65.**
 - iii. Open the control panel, and check for an open circuit fuse. At this time also check internally for loose plugs or sockets, and or loose connections.
 - iv. Check the wiring to the collimator for broken or loose connections.
 - v. Remove the collimator cover. Locate the dark-current shutter mechanism. Check that the shutter is in the correct position, and the shutter microswitch operates correctly.
 - vi. Have the manual capacitor-discharge knobs been left in the discharge position, after a high-tension cable was adjusted? Or, is a micro-switch, operated by these knobs, sticking? This will indicate the manual discharger is still operated, and prevent the capacitor charging.

f. On charging the capacitor, there is a loud 'bang'

This indicates a high-tension fault. This could be the capacitor, but may instead be in a cable end, or perhaps the X-ray tube.

These tests should only be performed by an electrician or electronics technician. Refer to (b), 'High-tension precautions', before proceeding.

- Undo the ring-nuts retaining the high-tension cable-ends in the X-ray tube receptacles. Is there a strong odour from one of the cable ends?
 - i. If there is, either the cable end is faulty, or there has been an arc-over in the receptacle.
 - ii. **With the capacitor fully discharged and safe,** withdraw the suspect cable end. (See part b. High-tension cable precautions.)
 - iii. After taking the precaution of shorting the pins to ground, examine the cable end and receptacle for traces of carbon. An easy way to find contamination of grease etc is to wipe with a paper tissue.
 - iv. If there is no indication of arcing inside the receptacle, but there is a strong odour from the high-tension cable as it enters the cable end, the cable is faulty and requires replacement.
 - v. In case there are signs of arcing in the receptacle, then the receptacle and cable end must be carefully cleaned, and re-sealed. **See module 7.3 page 117.**
 - vi. After a cable end has been withdrawn, it will need to be re-sealed with fresh grease, or have new anti-corona pads fitted. **See module 7.3 page 117.**
- Do the high-tension cables or X-ray tube receptacles appear OK? The capacitors or X-ray tube could have a short circuit. Contact the service department for assistance. Provide full details of the fault, tests made, and the results.

g. Unable to obtain preparation

- Is the capacitor fully charged? Check by pressing the charge button. Or else by increasing the preset kV, in which case the charge mode should operate.
- There may be a faulty preparation switch, or a faulty cable from the handswitch. To check the switch or cable, **see module 5.0 page 65.**
- Check the wiring to the X-ray tube and collimator, especially if it has been subject to pulling. This includes;
 - i. Stator cable and connections.
 - ii. Connections to the thermal overload switch, in the tube housing.

- Check for a loose plug or socket. **See module 5.0 page 65.**
- Look for a loose or open circuit fuse. **See module 5.0 page 65.**
- Contact the service department for assistance. Provide full details of the fault, tests made, and the results.

h. On going into preparation, the capacitor discharges

The negative control voltage applied to the X-ray tube grid is missing. As the filament heats up, this results in an uncontrolled exposure, and may fully discharge the capacitor. A common cause is a faulty high-tension cathode cable, with an internal short circuit between the grid wire, and one of the filament wires. To check for a possible fault in the high-tension cable, the cables can be exchanged between anode and cathode. (Of course, there is a possibility the cables were previously exchanged, but no record kept of this event.)

This procedure should only be performed by an electrician, or electronics technician.
Refer to (b), 'High-tension precautions', before proceeding.

- Mark each cable end before removal, to ensure they are correctly exchanged after being re-inserted.
- Ensure the capacitor is fully discharged, power is disconnected, and the manual discharge knobs are in position.
- Undo the ring nuts' holding the cable ends in position, and withdraw the cable ends from the high-tension transformer. Take note, which receptacle is positive, and which is negative. The X-ray tube cathode must connect to the negative receptacle.
- Remove the high-tension cable ends from the X-ray tube housing.
- For cleaning and resealing the cable ends on reinsertion, see **module 7.3 page 117.**
- Both high-tension cables have now been disconnected. Now reconnect the cables to the X-ray tube and generator. The previous cathode cable is connected to the anode, and the previous anode cable is connected to the cathode.
- Take care to connect the anode cable to the positive receptacle, and the cathode cable to the negative receptacle of the high-tension transformer.
- Power up. Recharge the capacitor and make a test exposure.

- If all is well, attach a label to the previous cathode cable. This should indicate it has an internal short circuit, and is suitable as an anode cable only.
- If the problem still occurs, contact the service department for assistance. Provide full details of the fault, tests made, and the results.

i. No exposure

- Does the mobile have a Bucky connection option? Try exposing with the Bucky option switched off or bypassed.
- Is the capacitor fully charged? In some designs, if the capacitor is not fully charged to the required value, this will prevent preparation. In other systems it may instead prevent a radiographic exposure.
- Check the operation of the handswitch, or a possible broken wire in the handswitch cable. To check the switch or cable, **see module 5.0 page 65.**
- Check the wiring and connections to the collimator.
 - Remove the collimator cover and check for correct operation of the dark-current shutter. This should move out of the way, either during preparation, or just before an exposure.
 - Check the microswitch operated by this shutter. If sticking, or not fully operated, this may be the cause.

j. The kV does not adjust to a lower value

For example, after charging the capacitor, you decide to use less kV for the exposure. However, on trying to reset to a lower kV, nothing immediately happens, although the capacitor voltage may very slowly drop in value.

To reset the kV down to the new setting, the generator makes a low mA exposure. Radiation is prevented from leaving the collimator by the dark-current shutter. The shutter also operates a safety microswitch. This prevents the low mA exposure if the shutter is not closed.

- Switch the power off, and unplug the power cord from the power point.
- Remove the collimator cover.
- Check the collimator dark-current shutter for correct operation.
- Check if the shutter microswitch has operated correctly, and there are no bad connections or broken wires to the collimator.
- If the shutter and microswitch appear correct, contact the service department for advice. Provide full details of the fault, tests made, and the results.

k. Apparently there is an exposure, but the film is blank

On exposing, the capacitor voltage drops the expected amount of kV. For example, the kV dropped by 10kV after a 10 mAs exposure.

- In this situation, the dark-current shutter has failed to open properly. Remove the collimator covers and check the operation of the shutter, and its associated microswitch.

l. On exposing, the exposure continued till the capacitor was fully discharged

- The X-ray tube may have become unstable. Try a test exposure at a much lower kV setting. If successful, then try the X-ray tube seasoning procedure. **See module 2.1 page 48.**
- If a low kV test exposure shows the same fault, contact the service department for assistance. Provide full details of the fault, tests made, and the results.

m. Problems with the motor drive

Some mobiles are fitted with battery-powered motor drives. A 12 volt car battery is most commonly fitted. In some cases two batteries are used, to provide 24 volts.

Whenever possible, refer first to the operation or installation manual. If in doubt contact the service department, or request the assistance of an electrician.

- There is no motor drive in either direction.
 - i. Units fitted with a drive control key switch. The switch may be faulty, or have a loose connection.
 - ii. The fuse for battery power is open circuit. **See module 5.0 page 65.**
 - iii. The battery is discharged.
 - iv. There is a bad connection to the battery terminal. Remove the battery terminals, and scrape corrosion from the posts or terminal clamps.
 - v. **Caution.** See part b, general precautions, before disconnecting a battery.

- vi. The brake release bar on the handle operates a microswitch. The microswitch may need adjustment to operate correctly.
 - vii. Check the electrical cables for loose plugs or sockets.
- There is no forward motor drive.
 - i. The anti-crash bumper may be stuck in the operated position, or one of the switches operated by the bumper is damaged.
 - There is only a low level of motor drive assistance.
 - i. The motor may be in bedside mode. A control switch selects the change between bedside speed, and travel speed. The control switch could be faulty, or the knob has slipped, and indicates the wrong position.
 - ii. Other mobiles require the tube stand to be placed in the travel position before permitting full power. In which case a microswitch to sense the tube stand position may need adjustment. Ask an electrician or electronics technician to check the switch, or microswitch operation.
 - iii. There may be a poor battery connection due to corrosion. Remove the battery terminal clamps, scrape of any corrosion, and reassemble.
 - iv. **Caution.** See part b, general precautions, before disconnecting a battery.
 - The battery is not charged up.
 - i. The battery was not charged overnight. Or the power point used was faulty. Check the power point with a lamp or similar item.
 - ii. There is an open circuit fuse in the battery charge section of the mobile. **See module 5.0 page 65.**
 - After charging, the battery soon loses power.
 - i. Has the electrolyte level of the battery been checked? (This may not be possible with sealed or low maintenance batteries.)
 - ii. The battery may have a shorted cell, or the cells are sulphated, in this case a new battery is required. Before replacing the battery, have the battery tested at a garage, or by an auto electrician.
 - iii. **Caution.** See part b, 'general precautions', before disconnecting a battery.

MODULE 7.0

X-ray tube stand**Aim**

The aim is to provide information for repairing or adjusting the tube stand. This is additional information to the maintenance procedures, provided in **module 2.0 page 44**. Procedures for electrical tests are provided in **module 5.0 page 65**.

(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with the X-ray tube stand. When used together with the module 5.0 procedures, the student will be able identify a problem area, and carry out minor repairs. An electrician or electronics technician may provide added assistance where indicated in this module.

Task 13. 'Bucky tabletop and tube-stand centre', should be attempted on completion of this module.

Contents

- a. General precautions
- b. The vertical movement is not balanced
- c. When power is turned off, the tube stand starts moving
- d. The tube stand is not centred to the vertical Bucky
- e. Check the tube stand centre stop position
- f. Mechanical centre-stop adjustments
- g. Electrically operated centre-stop adjustments
- h. An electromagnetic lock fails to operate
- i. A group of locks fail to operate

a. General precautions

- Electrical safety.
 - i. In most installations the tube-stand power will come from the generator, but in some installations, switching off the generator does not remove power from the tube stand.
 - ii. **Before removing any covers, ensure the generator is switched off, and the room power isolation switch is also turned off.**
 - iii. This also applies if testing wiring connections, or electrical components.
- If removing an X-ray tube, or collimator.
 - i. **See module 7.1 page 104, and module 7.2 page 110.**
 - ii. Ask an electrician or electronics technician for assistance.
 - iii. Do **not** rely on the vertical lock system.
 - iv. Attach a rope so that the system cannot move upwards, once the weight of the collimator or X-ray tube is removed.
 - v. The X-ray tube is heavy. Removal or replacement requires two people.
 - vi. Make a diagram of electrical connections. Attach labels to wires or high-tension cables. This is to ensure correct connection when an X-ray tube or collimator is replaced.
 - vii. Place all screws or other small parts in a box, so they are not lost.
- Do not place a ladder against a tube stand. The tube stand may suddenly move.
- An adjustment to any tube-stand bearing requires skill, and good mechanical knowledge. When a problem is identified, request the service department to make the required adjustments.

b. The vertical movement is not balanced

For example, with the vertical locks off, or if power is turned off, the tube carriage tends to move down, or up. This problem may have occurred after fitting a replacement X-ray tube.

- Most tube stands have a system of ‘trim weights’. Adding or removing these weights balances the vertical suspension.
 - i. With ceiling suspensions, these weights may be positioned inside the cross arm.
 - ii. Floor ceiling tube stands allow for trim weights to be attached to the main counterbalance weight. To gain access, a panel is removed from either behind the tube stand, or from one side of the tube stand.
 - iii. If added trim weights are required, these may be formed from lead sheet, available from a builder’s hardware shop.
- Some ceiling mounted tube stands require a spring to be added or removed to achieve balance. The service department should make this adjustment.
- Floor ceiling tube stands may have a large spring instead of a counterweight. The variable ratio pulley at the top of the tube stand can identify this method. Final counterbalance may still be achieved using trim weights attached to the cross-arm. Otherwise contact the service department.

c. When power is turned off, the tube stand starts moving

- A common reason is the support method of the HT cables. Providing the tube stand movement is not restricted, arrange for added or more suitable HT cable support.
- With a floor ceiling stand, this may be due to a floor that is not level. It may be possible to improve by adding shims under the floor rail. Check the floor rails with a spirit level.
- With a ceiling mounted system, the ceiling rails may not be level. This may be due to incorrect initial installation. There is a possibility the ceiling attachment points have shifted, or a problem with the building. Check the rails with a spirit level. Depending on the age or style of construction, have the installation checked by a building inspector.

d. The tube stand is not centred to the vertical Bucky

In this situation, the x-ray tube may appear to be correctly centred to the table centre. However, when the X-ray tube is rotated, it is not centred to the vertical Bucky.

- The tube stand may not be vertical.
 - i. A floor-ceiling tube stand may be checked with an accurate spirit level. A more accurate check is to use a plumb bob.

- ii. A ceiling mounted tube stand can only be checked with a plumb bob. With the tube stand first at lower, then at maximum height, the plumb bob should deviate by only a few millimetres.
 - iii. A ceiling mounted tube stand may need adjustment of the gantry-rail bearings.
 - iv. The floor-ceiling tube stand has a ceiling or wall mounted guide rail. Check the guide-rail bearing assembly. This may be loose or incorrectly adjusted.
- The cross arm may not be horizontal.
 - i. This can be a common fault with some floor ceiling tube stands. Check the cross arm with a spirit level.
 - ii. Look for broken or loose bearings, especially with the cross-arm bearings inside the vertical movement.
 - iii. *Adjustments to any tube-stand bearings require specialized knowledge. When a problem is identified, request the service department to make the required adjustments.*
 - Is the light-field vertical alignment correct?
 - i. Bring the collimator down onto the tabletop. If necessary adjust the X-ray tube rotation in the trunnion rings, so it sits ‘flat’ on the tabletop.
 - ii. Raise the tube a small amount. With the collimator light switched on, place a marker in the centre of the light field.
 - iii. Raise the collimator to the normal operating height. The centre of the light field should stay on the marker. If not, rotate the tube a small amount in the trunnion rings, and repeat this test.
 - iv. Alignment is correct when the light field does not shift, as the X-ray tube is raised or lowered.

After checking the first three items, now centre the light field to the centre of the tabletop. **Caution**, do not use the cross arm centre stop as a guide, as this may also need adjustment.

- If the Bucky table has lateral movement of the tabletop, the centre stop position of the tabletop should first be checked.
 - i. Move the tabletop to the centre position.
 - ii. Place a cassette in the Bucky, with a marker positioned on the centre of the cassette.
 - iii. Place another marker on the centre of the tabletop.
 - iv. Make a low kV and mAs exposure. Process the film. The markers should have the same position on the film.

- v. If required, adjust the position of the tabletop centring device. **See module 8.0 page 121.**

Rotate the X-ray tube to face the vertical Bucky. Move the tube stand close to the Bucky. The light field should be centred to the Bucky. Next, move the tube stand away from the Bucky. Check the position of the light field.

- Although the light field is not centred to the vertical Bucky, it does not shift as the tube stand moves away from the Bucky.
 - i. Was the vertical Bucky positioned correctly during installation? Attach a string to the far end of the tabletop, positioned at the centre. Take the other end of the string to the centre of the vertical Bucky.
 - ii. When the string is tightened, it should remain centred along the full length of the tabletop.
 - iii. Is the tube stand movement parallel to the tabletop? The light field should remain centred while the tube stand is moved from the table foot end to the table head end. If the light moves off centre, this could indicate either the tube stand or the Bucky table was incorrectly installed
- The light beam shifts off centre, as the tube stand is moved away from the vertical Bucky.
 - i. The tube stand cross-arm may not be horizontal. Check with a spirit level.
 - ii. Many tube stands allow rotation of the cross arm. (In some cases, the entire tube stand rotates.) The rotation index-plate may be loose, or not correctly centred.
 - iii. Common rotation angles are -90 degrees, centre, and $+90$ degrees. A lock pin is inserted into a slotted index-plate to hold the rotation position. The index-plate and locking pin may be worn, or incorrectly adjusted.

e. Check the tube stand centre-stop position

- If the Bucky table has lateral movement of the tabletop, the centre stop position of the tabletop should be checked.
 - i. Move the tabletop to the centre position.
 - ii. Place a cassette in the Bucky, with a marker positioned on the centre of the cassette.
 - iii. Place another marker on the centre of the tabletop.
 - iv. Make a low kV and mAs exposure. Process the film. The markers should have the same position on the film.

- v. If required, adjust the position of the tabletop centring device. **See module 8.0 page 121.**

- Is the tube stand centred to the Bucky table?
 - i. Make this test, after checking the light-field vertical alignment described in part 'd'.
 - ii. Move the Bucky tabletop to the centre position.
 - iii. Switch on the collimator lamp.
 - iv. Test the lateral centre-stop position of the tube stand. With the cross-arm retracted, move the X-ray tube out towards the centre stop position. The light field should be centred to the tabletop.
 - v. Repeat the test, start with the cross-arm extended, then move inwards to the table centre. The light field should again be centred to the tabletop.
 - vi. The actual centre stop position can depend on how quickly the X-ray tube is moved across the table, and the method used to indicate the stop position. Depending on the design, accurate centring may require moving the X-ray tube from one direction only.

f. Mechanical centre-stop adjustments

- A steel ball, pushed by a spring, clicks into a slot when the cross arm is centred. This holds the cross arm in position.
- If the spring is weak, it is difficult to feel when the centre position is reached.
- There is usually a screw provided, to adjust the spring tension. Adjust this screw to provide the best 'feel' when centring the X-ray tube.
- The centre-stop position is adjusted by changing the position of the mechanical system on the cross arm.
- To adjust the position, see the directions provided in the installation manual. Otherwise contact the service department for advice.

g. Electrically operated centre-stop adjustments

Caution: Before making any electrical tests, ensure the generator is switched off, and the room power isolation switch is also turned off. An electrician or electronics technician should carry out electrical tests or adjustments. **See module 5.0 page 65.**

A number of different electrical centre-stop sensors have been developed. These operate the lateral lock when in position.

- A microswitch, operated by a cam. In normal operation, you may hear a small 'click' as the switch passes over the cam. The position of the cam con-

trols the centre stop position. A problem may be caused by:

- i. The cam height is too small. As a result, there is insufficient pressure on the microswitch for reliable operation.
 - ii. The cam or microswitch has become loose, and the microswitch does not operate.
 - iii. A broken wire or connection to the microswitch.
 - iv. A ceiling tube stand may have incorrect adjustment of the lateral movement bearings. This may cause the cam to move away from the switch, so it does not operate. In some cases, it may instead move too close, damaging the switch. A close visual inspection can indicate if this is a problem.
- A vane operated sensor. A vane passes through a small slot in the sensor. The position of the vane controls the centre stop position. A problem may be caused by;
 - i. The vane is positioned too high, and does not fully enter the sensor. This can cause unreliable operation.
 - ii. The vane is missing.
 - iii. The vane or sensor is damaged. Check by visual observation.
 - iv. A broken wire or connection to the sensor.
 - An optical sensor, operated by reflected light. This system requires a white or silvered reflector, mounted opposite the sensor at the stop position. A problem may be caused by;
 - i. The reflector is a small piece of foil, with a self-adhesive backing. Due to poor adhesive, this may have become dislodged.
 - ii. The sensor is not close enough to the reflector for reliable operation.
 - iii. The reflector is dirty, or there is dirt on the sensor.
 - iv. A broken wire or connection to the sensor.

h. An electromagnetic lock fails to operate

This may be due to a faulty lock coil. Other reasons may be a faulty switch, or a broken connection due to a cable being pulled. **See module 5.0 page 65.**

First ensure the generator is switched off, and the room power isolation switch is also turned off.

- The lock may have too large an air gap. This can also cause erratic or slow operation. Most locks have slotted mounting plates. Adjust by undoing the screws a small amount, adjust the lock position, and retighten the screws.
- The lock may only partially release. In this case it may be too close to the surface. Again, adjust its position. In some cases, the lock has residual magnetism. This can be a design problem with some tube stands. Contact the service department for advice.
- Permanent magnet locks have become popular. These ensure the locks remain on when power is removed.
- Some ceiling suspended tube-stands use a solenoid operated 'piston', attached via a lever to a brake pad. A spring maintains brake operation, until the solenoid operation pulls the pad away from the surface. If the stroke is too long, the piston fails to pull inside the solenoid, and the lock does not release. Adjustment is by a screw thread fitted with a locknut.
- In some cases, there is a fuse specific to the failed lock. Before checking fuses, ensure all power is turned off.
- **See Module 5.0 page 65.**

i. A group of locks fail to operate

First ensure the generator is switched off, and the room power isolation switch is also turned off.

- Look for an open circuit fuse at the tube stand.
- In most installations, the tube stand obtains power from the generator. This may involve several different voltage supplies. Check at the generator and at the high-tension transformer for an open circuit fuse.
- **See Module 5.0 page 65.**
- Check where cables enter the tube stand or control panel. If the cables are pulled during the tube stand movements, a wire may have broken from a terminal strip.

TASK 13

Bucky tabletop and tube-stand centre

A number of films have appeared which show incorrect lateral centring. You decide to verify the accuracy of the X-ray tube and table centre-stop.

1. Design a method to verify the tabletop is accurately centred over the Bucky. Note: this should include possible errors due to the film position in the cassette.

Carry out this test; include moving the tabletop to centre position from either direction.

Is the tabletop correctly centred to the cassette? _____

If not, is the cassette tray correctly centred in the Bucky? _____

Is the crosshair on the collimator faceplate correctly centred to the 'closed' position of the collimator leaves?

With the X-ray tube positioned close to the tabletop, is the crosshair aligned to the tabletop centre? Include moving the X-ray tube to centre position from either direction. _____

As the X-ray tube is raised from the tabletop, does the crosshair move away from the centre mark?

What adjustment might be made so that the crosshair position does not move as the X-ray tube is raised from the tabletop? _____

If this adjustment is performed, will it affect the centre-stop position of the X-ray tube cross-arm?

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____

Tutor

Date _____

MODULE 7.1

X-ray tube

Aim

The aim is to provide information for testing or replacing the X-ray tube. Different failure modes are examined. This module is an extension of module 2.1 page 48. Reference should also be made to module 7.3 page 117.

(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with the X-ray tube, together with the test procedures. This includes removal or replacement of the X-ray tube, together with assistance from an electrician or electronics technician.

Contents

- a. General precautions
 - b. X-ray tube failure modes
 - c. Inspection of the anode or filament
 - d. Focal spot performance
 - e. Oil leaks
 - f. Removal of the X-ray tube
 - g. X-ray tube transport
 - h. Re-installation of the X-ray tube
-

a. General precautions

- **Before disconnecting any wires, or removing the high-tension cables, always ensure power is turned off and unplugged from the power point. If the equipment is part of a fixed installation, besides switching the generator power off, ensure the isolation power switch for the room is also switched off.**
- Mobile high-frequency generators may be battery operated. The batteries in these are connected in series, and can have a total voltage of up to 240V DC. *Refer to the operating or installation manuals for the position of the battery isolation switch, and ensure this is switched off before removing the covers, or testing wires and connectors.*
- If removing a collimator or X-ray tube from a tube stand.
 - i. Do not rely on the vertical lock system.
 - ii. An X-ray tube is heavy. Two people are required for removal or installation.
 - iii. Use a rope to prevent the system moving upwards, when a collimator or X-ray tube is removed.
 - iv. Provide a container to hold all small parts, or screws. Protect against loss.
- If removing an X-ray tube from a capacitor discharge mobile, observe the high-tension precautions described in **module 7.3 page 117**.

b. X-ray tube failure modes

- The X-ray tube is unstable. A common cause is gas, which causes very high current to flow during an exposure. Unstable operation is usually corrected by 'seasoning'. This is described in **module 2.1 page 48**.
- Attempts to improve the performance by seasoning are not successful. This can be due to;
 - i. The glass has developed micro-fine cracks. With the collimator removed, this will be observed as a fine 'crazing' effect on the output window, or port. These cracks indicate the glass is punctured. As a result, the tube is gassy.

- ii. The bearings have seized, so X-ray exposures are hitting a stationary anode.
- iii. In both cases, the tube requires replacement.
- Arcing at the HT cable ends or in the receptacles.
 - i. You may have observed smoke at one receptacle. Or an actual spark.
 - ii. The X-ray control might generate 'mA overload' or 'kV fault' signals. This depends on the design of the X-ray control and the severity of the arcing.
 - iii. You have noticed there is a strong odour at the suspect cable end or receptacle.
 - iv. High-tension cable problems are discussed in **module 7.3 page 117**.
- The bearings have become very noisy. In many cases a tube with noisy bearings can still have a useful life. However, budget for a replacement if the anode slows down quickly once preparation is released. This can indicate a failure in the near future, and is especially the case if the anode slows down while still in preparation.
- Poor X-ray resolution.
 - i. The anode is badly worn.
 - ii. The anode is cracked or distorted, so that the focal spot wobbles as the anode rotates.
 - iii. Heavy metal deposits on the output window. This causes excessive hardening or filtration of the X-ray output. In this case, it will not be possible to observe the anode or cathode after removing the collimator. Metal deposits can also lead to a micro arc through the glass, causing the tube to become unstable or gassy.
 - iv. See 'inspection of the anode or filament' in part 'c'.
- A filament is open circuit. To test, use a multimeter set to the low ohms scale. There should be a very low resistance between any two pins in the cathode receptacle. An exception is the X-ray tube for some mobiles, which may have only one focal spot.
- A filament has a partial short circuit. This is due to a section of the filament touching the cathode focus cup, and then welding itself to the cup. Unfortunately, this is not a rare occurrence.
 - i. The generator will indicate sudden low mA output, while films will not only appear underexposed, but may also have poor contrast due to an increase of kV. With high frequency, or microprocessor-controlled generators, a kV fault signal may be generated.
 - ii. Checking the other focal spot will indicate normal operation.
 - iii. Attempting to re-calibrate mA output will indicate a rapidly increasing filament drive current,

especially at higher mA output. In addition, correction of mA at medium to low kV calibration points becomes very difficult. (Space charge compensation).

- iv. In some cases it is possible to see a faulty filament, after the collimator is removed. See 'inspection of the anode or filament'.

c. Inspection of the anode or filament

Note. This technique must not be attempted with a capacitor discharge mobile, due to high voltage that may be stored in the capacitor.

- **Removing the collimator.**
 - i. Where possible, refer first to the installation manual of the collimator. If in doubt, contact the service department for instruction. Two people are recommended, to hold the assembly in position as it is removed or replaced.
 - ii. Rotate the X-ray tube so it is aimed at the ceiling. Adjust the height close to the tabletop.
 - iii. Secure the vertical movement of the tube stand so it cannot move upwards once the collimator is removed. **Do not rely on the magnetic lock system, this can slip, or not operate when power is switched off.**
 - iv. Examine the connecting cables to the collimator, and the tube-stand operation panel. Is there sufficient length? Undo any cable ties if required, to allow cables to hang freely.
 - v. **Ensure all power is off. Turn off power at the room isolation switch. Do not rely on the generator power switch, as some installations allow direct power to the tube stand.**
 - vi. To avoid pulling on cables once the collimator is removed, place a box of a suitable height on the tabletop. The collimator can rest on this box when removed from the tube head. This may include the tube-stand control panel.
 - vii. If the cables are short, disconnection is required. Make a careful diagram of connection terminals before disconnecting, and ensure the wires have a suitable label or mark. Ensure any attached labels will not fall off. Any exposed terminals attached to wires must be covered with insulation tape. (Power may need to be re-applied to see inside the X-ray tube.)
 - viii. Undo the retaining screws holding the collimator to the tube housing, and place the collimator

mator on the tabletop, or box. Take care on removal, as part of the collimator can extend into the tube-housing port. In some cases, the tube-stand control panel will be detached at the same time. Assistance may be required to hold or place components as they are removed.

- ix. *Have a container ready to receive screws etc. These are easily lost.*
- x. The tube-housing port may have an aluminium filter, and a lead 'proximal' diaphragm fitted. The latter is often in the form of cone extending into the port, and the filter is then placed under this lead diaphragm. The proximal diaphragm is held in place by a spring clip, or else by two or four very small screws. Before removing the lead diaphragm, make a mark so it can be replaced in the same position.
- xi. **Caution:** do not remove the larger screws holding the port assembly in place. Air will enter the housing, or oil will leak out. If this happens, the tube housing needs to be reprocessed.

- **Inspecting the anode.**

- ii. With the collimator, proximal diaphragm, and any added filter removed, it should now be possible to see the anode and filament.
- iii. Often observation of the anode may be made using a torch. However, any metal evaporation on the glass acts as a mirror, and prevents observation.
- iv. Most generators have a filament pre-heat circuit, which will light up the filament, and allow observation of the anode. Ensure any disconnected wires have their ends taped up, and then switch on the generator.
- v. **Note.** If the glass has heavy metal deposits, this technique may only yield limited results. In this case, the future reliability of the tube is not good.
- vi. To observe the anode for defects, the anode needs to slowly rotate.
- vii. To rotate the anode, press the preparation button on the handswitch. This should be very brief, so that the anode only just starts spinning. **Do not expose.** As a safety precaution, preset minimum kV and time, and a low mA station.
- viii. As the anode slows down, carefully observe the track area. Look for the following.

—Anode wobble, this indicates possible cracking, and poor focal spot performance.

—Stationary hits. These appear as small melted areas of the anode, as if hit by a small arc welder.

—Worn anode. This appears as a fine crazed pattern, like coarse sandpaper.

—Overloaded anode. This has a fine orange peel pattern.

—Smudged areas. This often occurs during manufacture. However, if the tube is unstable, this can be an indication of gas.

- **Inspecting the filament.**

- ix. When the generator is switched on, the pre-heat circuit will light up the selected focal spot.
- x. Select fine focus, and then broad focus. The broad focus will appear a little longer and larger in diameter.
- xi. (An exception to the above will occur with a fluoroscopy table. In this case, the fine focus remains selected at all times, unless in preparation for radiography).
- xii. If there is a partial short in the broad focus, then the broad focus will appear shorter in length than the fine focus. Careful observation can sometimes see a short length of filament that is not heated.

- **Are there fine cracks in the glass?**

- i. These can appear over the anode or cathode area. A minor case may appear as a single fine line, like a single strand of spider web. More severe cases can appear as a fine crazed pattern.
- ii. These marks are due to high voltage discharge through the glass. This condition occurs more often with metal deposits on the glass, which increases the possibility of arcing in this area.
- iii. The presence of these marks, together with a suspect unstable or arcing tube, means the tube is gassy and will need replacement. In this case, seasoning is not effective.

- **Replacing the collimator.**

- i. Re-assembly is in the reverse order as the dismantle process.
- ii. Take care that any added aluminium filters are returned to their previous position, and the proximal diaphragm is correctly aligned.
- iii. After reassembly the collimator will need realignment. Please refer to **module 7.2 page 110.**

d. Focal spot performance

Focal spot performance can be tested using a 'Star pattern' gauge.

In use, the gauge is positioned in the centre of the X-ray beam, close to the focal spot. This gives a magnified view of the star pattern. Part of this pattern is

blurred. The diameter of the blurred area is used to calculate the size of the focal spot.

There are several versions of star patterns. Use the directions enclosed with the pattern, which includes a formula specific to the supplied star pattern.

A star test pattern may be obtained as a loan item from the service department, or from the physics department of a major hospital.

When measuring the focal spot, take the following precautions.

- Use a low value of kV. (60–70 kV)
- Use a medium value of mA suitable for the focal spot under examination. **Note.** As mA is increased, the focal spot will also increase in size.
- Use non-screened film. Or else a cassette with detail screens.
- Exposure time should be more than 0.04 seconds. This allows at least two rotations of the anode, in case anode wobble is degrading the focal spot.
- If the test result is too light, increase the time or mA station.
- If the result is too dark, consider increasing the FFD or reducing kV.
- If the outer blurred area is too large in diameter to measure easily, then reduce the magnification, and adjust mA and kV to suit.

e. Oil leaks

Oil leaks should always be reported. Even a very slow oil leak has the possibility of letting air into the housing. An air bubble in the wrong position can lead to arcing, and possible destruction of the X-ray tube.

- Oil leaks may be seen at either end of the tube housing, or at the collimator, if a crack or faulty seal occurs in the housing port.
- An X-ray tube with oil leaks will need to be repaired by the service department. In some situations, the service department may supply a loan unit, while the faulty housing is repaired.
- To locate where the oil leak occurs, first thoroughly wipe clean with a paper tissue. Leave overnight, and then test by wiping with a fresh tissue next morning. This will indicate the origin, and assist in repairs when the tube is returned to the service department.
- Occasionally, when a tube is returned after a repair, an apparent oil leak might appear. This can be caused by a small amount of spilt oil around such areas as the external terminal strip etc. A few drips may initially occur, and then no further symptoms appear. If drips continue after a few days, then this

needs to be reported, and have the tube returned for further attention.

f. Removal of the X-ray tube

Due to the presence of an oil leak, or to have a new insert installed, the X-ray tube and housing is required at the service department.

- Preparation for removal.
 - i. Where possible, refer first to the installation manual of the tube stand. If in doubt, contact the service department for instruction.
 - ii. **Two people are recommended to assist in removing or installing the X-ray tube assembly. This is a heavy object.**
 - iii. Rotate the X-ray tube so it is aimed at the ceiling. Adjust the height close to the tabletop.
 - iv. Secure the vertical movement of the tube stand so it cannot move upwards once the collimator is removed. **Do NOT rely on the magnetic lock system, this can slip, or not operate when power is switched off.**
 - v. Examine the connecting cables to the collimator, and the tube-stand operation panel. Undo any cable ties or clamps, to allow cables to hang freely.
 - vi. Carefully mark the anode and cathode cables.
 - vii. **Hint.** The stator cable normally enters at the anode end of the housing. (In some cases, it enters at the centre. Be careful in this situation)
 - viii. **Ensure all power is off. Turn off power at the room isolation switch. Do not rely on the generator power switch, as some installations allow direct power to the tube stand.**
 - ix. If removing an X-ray tube from a capacitor discharge mobile, observe the high-tension precautions described in **module 7.3 page 117.**
 - x. Undo the ring nuts holding the HT cable ends, and withdraw the cable ends from the housing. As they are withdrawn touch the end pins to the tube stand. This is to discharge any residual high-tension that may be present. When they are withdrawn, wrap the cable ends in cloth or paper towel to protect from damage.
 - xi. To avoid pulling on cables once the collimator is removed, place a box of a suitable height on the tabletop. The collimator can rest on this box when removed from the tube head. This could also include the tube-stand control panel.
 - xii. Disconnection of all wires to the tube housing is required. Make a careful diagram of con-

nection positions before removing, and ensure the wires have a suitable label or mark. Ensure any attached labels will not fall off. **Any exposed terminals attached to wires must be covered with insulation tape.** (This is in case power is turned back on)

- xiii. Undo the retaining screws holding the collimator to the tube housing, and place the collimator on the tabletop, or box. Take care when removing, as part of the collimator may extend into the tube housing port. In some installations, the tube-stand control panel will be detached at the same time. Assistance will be required to hold or place components as they are removed.
 - xiv. Have a container ready to receive screws etc. These are easily lost.
- Removal of the X-ray tube housing from the tube stand.
 - i. Check again, that vertical movement of the tube stand is properly secured.
 - ii. After the collimator, high-tension cables, and stator cables have been removed, examine carefully the shape of the trunnion mounting rings. With the X-ray tube aimed at the ceiling, the bottom section of the rings should be able to hold the housing in place, after the top section is removed. Sometimes the assembly is installed in the reverse direction, so then the tube needs to face the tabletop.
 - iii. With the housing in the required position, undo the top half's of the trunnion rings, taking special note if any washers have been inserted between where the trunnion rings are fastened together. (These are sometimes fitted to adjust the trunnion rings, in case they are too tight a fit for the tube housing.)
 - iv. The tube housing may now be lifted up out of the rings. This is a heavy object. Two people should assist in this process.

g. X-ray tube transport

The X-ray tube housing offers no protection to the X-ray tube if it is bumped or dropped. Incorrect packaging for transport can easily result in a broken tube, due to the weight of the anode.

- Before sending the tube to the service department, take careful note of all housing and X-ray tube details. Include serial numbers.
- Attach full documentation to the housing. This should give a full description of the problem to be rectified. There should also be full contact details,

such as hospital address, phone number, person to contact, etc. Include an order number or other authorisation if required.

- Include a request for suitable silicon grease, and or anti-corona silicon pads to be supplied when the tube is returned.
- Before looking for suitable boxes etc, contact the service department. They may be able to send a suitable size box and packing material.
- Select a box size about twice that of the housing. Pack the housing in the centre, using material to cushion any bumps. For example, shredded polystyrene foam. Make a mark on the box to indicate the anode end.
- Place this box in another box about twice the size of the first box. Fill the space between the two boxes with suitable cushion packing.
- Position the second box so that the X-ray tube is vertical, and the anode end is towards the bottom of the box.
- Attach very large labels with an arrow to indicate 'This side up' on the sides of the box. Attach another label on the top to indicate 'Top side'. Attach 'Fragile, do not drop' labels on all sides.
- Take care both the service department address and the hospital return address is protected, eg, inside a transparent plastic cover. If sending to another country, be sure to provide suitable information for customs etc.
- Ensure you have a full copy of the shipping details. Also phone the service department and notify them of the method of transport etc. If the X-ray tube is sent to another country, enclose copies of the required customs forms.

h. Reinstallation of the X-ray tube

Caution: If a new tube insert or assembly is supplied, a complete mA re-calibration is required. This should be performed by the service department.

The X-ray tube is re-installed in the reverse order of the instructions for removal. Eg, first it is mounted in the trunnion a ring, then the collimator is attached, and finally the wiring and HT cables. These precautions should be observed.

- Check the HT receptacles. If there is any grease residue, this must all be removed, and the receptacles left in a polished condition. Even if apparently clean, still wipe them carefully with fresh paper tissues. This is to remove any possible moisture. Do not touch the inside with the fingers, or scrape the sides with a metal object. (This may leave very slight traces of metal behind).

- If the housing has been repaired, or a new insert fitted, check carefully for any areas of oil residue, and wipe away with paper tissues.
- Before installing the collimator, ensure the proximal diaphragm and aluminium filters are in place.
- Reconnect the wires, using the diagram previously made when the tube was removed. If a new tube and housing is supplied, and the connection points appear different, contact the service department before connecting any wires.
- When inserting the high-tension cable ends, use the instructions provided in **module 7.3 page 117**.
- Important. After the cable ends have been inserted, and the ring nut fully tightened, retighten a few hours later, and again next day.
- The collimator will need re-alignment. Please refer to **module 7.2 page 110**.
- Before making a test exposure, just enter preparation only. Listen carefully to the tube anode as it rotates. Is this the normal anode rotation sound?
- *Providing the original tube insert and housing has been returned*, then the mA calibration should be the same. Select a low mA position, set 60kV, and 0.1 second exposure time. Make a test exposure. If any problem occurs, **STOP**. Contact the service department for advice.
- The X-ray tube should now be seasoned. Use the technique described in **module 2.1 page 48**.
- Keep the boxes and packing the X-ray tube assembly arrived in for future use.

MODULE 7.2

X-ray collimator**Aim**

The aim is to provide information and procedures related to adjusting the X-ray collimator. This is in addition to the collimator maintenance, provided in module 2.2 page 50.

(Note: Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with the collimator and their solutions. Adjustments and repairs may be carried out. Some tests for the collimator lamp can be made with the help of an electrician, or electronics technician.

Task 14. 'Help! No spare globe for the collimator', should be attempted on completion of this module.

Contents

- a. General precautions
- b. The light field has insufficient brightness
- c. Changing the collimator globe
- d. A wrong collimator globe
- e. This collimator was not designed to rotate
- f. Centring of the collimator lamp
- g. Centring of the X-ray beam
- h. The light field is larger than the X-ray field
- i. The Bucky centre light
- j. The X-ray field fades out on one side of the film
- k. The collimator blades close, after adjusting the field size
- l. The collimator lamp fails to operate
- m. The globe has failed, and there is no spare globe

Equipment required

- Basic tool kit.
- X-ray alignment template.*
- 24/30 cm cassette.
- Spare collimator globe.
- Cloth, for cleaning.
- Detergent.

* The template is described in appendix 'B' page 169.

a. General precautions

- **Before disconnecting any wires, or removing a cover, always ensure power is turned off and unplugged from the power point. If the equipment is part of a fixed installation, besides switching the generator power off, ensure the isolation power switch for the room is also switched off.**
- Whenever changing a collimator lamp, ensure all power is turned off.
- If removing a cover, position the collimator close to the tabletop. Secure the tube stand so it cannot move upwards once the cover is removed.
- The timer switch may be fastened to the cover. Place a small box or pillow within reach to support

the cover when removed, so the connecting wires are not pulled.

b. The light field has insufficient brightness

This may be due to several causes, some of which can combine to give an overall drop in light level.

- Dirt or dust builds up on the inside of the transparent exit cover of the collimator.
 - i. To clean, it will be necessary to include removal of the collimator outer cover. Before removal, ensure all power is turned off.
 - ii. Clean with a soft rag and mild detergent. Wipe off any residual detergent.

iii. The above also applies if cleaning the mirror. Take care not to scratch the surface, or change the position of the mirror.

- The globe has metal evaporation on the inside of the globe. Fit a new globe.
- The voltage supply to the lamp is too low. This is due to a supply voltage that has not allowed for voltage drop, due to wiring resistance. As an example, when the lamp is switched on, the voltage can drop by 2~5 volts. This is a common problem when installed with long connecting cables.
 - i. **Ask an electrician, or electronics technician, to measure and adjust the lamp voltage.**
 - ii. Check if the lamp has the correct voltage. To do this, set the multimeter to a convenient AC voltage range. For example, 25V or 100V AC. Remove the lamp covers, and place the meter probes on the lamp terminals. Look away from the lamp while switching the light on, and then measure the operating voltage. This might be only 7~8V for a 12V lamp, or perhaps 17~20 V for a 24V lamp.
 - iii. A number of systems have a transformer, with a selection of output voltages. The required voltage is selected by changing a connection on a terminal strip.
 - iv. During installation this may be set at the lamp voltage. For example, set at 12V output for a 12V lamp. This is incorrect, as it does not allow for voltage loss in the connecting cable.
 - v. A correct installation may even set the voltage as high as 16V for a 12V lamp. This compensates for voltage drop due to cable resistance, when the lamp is switched on.
 - vi. If the test voltage is low, eg, below 10V for a 12V lamp, then contact the service department for instructions to adjust the voltage supply. Include the make and model of the collimator and the generator.
 - vii. In some other situations, there may be spare conductors in the cable. These may be placed in parallel with the existing wires for the lamp, to reduce the voltage drop. This is best left to a technician from the service department to carry out.
 - viii. **Note.** While an 8V operating voltage for a 12V lamp is too low, increasing to the full 12V will give a shorter lamp life. A compromise between brightness and life for a 12V lamp is 10~11V.

c. Changing the collimator globe

Before attempting to replace a collimator globe, ensure all power is turned off.

When replacing the globe, take care not to touch the glass with the fingers. This especially applies to quartz iodide globes, as slight oil or perspiration from the fingers will cause premature failure. Use a paper tissue to hold the globe.

d. A wrong collimator globe

Two versions of a quartz iodide globe appear very similar. If the wrong version is installed, there is a large error between the light field, and the X-ray field.

- The correct globe has longer connecting pins. OR, the filament is placed further towards the tip of the lamp. Both are correct, in that the filament is the same distance from the rear end of the pins.
- The incorrect version has shorter pins, so that the distance between the filament and the rear end of the pins is smaller.
- In an emergency, the short pin version may be used. Insert the lamp sufficiently to make good contact in the socket, however do not push it all the way in. There will still be an error in the light beam to X-ray alignment, so obtain the correct version as soon as possible.

e. This collimator was not designed to rotate

Older installations may have a collimator of European origin. With this collimator, four adjustable metal 'fingers' attach the collimator to a circular flange, or plate. There is no other adjustment. Correct adjustment is with the fingers tightened, so the collimator does not rotate.

However, in some installations these fingers are not tightened, allowing the collimator to be rotated.

- The collimator can only be aligned correctly to the focal spot in one position. When it is rotated, correct alignment to the light beam may be lost, especially if the light beam has also been adjusted. See 'Centring of the X-ray beam', part 'g'.
- Rotating the collimator can cause wear to the metal fingers. As the wear increases, the collimator may 'wobble' when pointed at a wall Bucky. In a severe wear case, the top of the metal finger breaks off. Replacement metal fingers are difficult to obtain.
- As the adjusting screws were not tightened, these can vibrate to a more open position. This will cause

erratic collimation. In a severe situation, the collimator may even detach from the flange, and fall off.

- Assuming the collimator **must** rotate, please take the following precautions.
 - i. Apply a very thin layer of oil to the upper surface of the mounting ring, to reduce wear.
 - ii. After the metal fingers have been adjusted, apply a dab of nail polish to the outer threads of the adjusting screws. This will help prevent them from unwinding.

f. Centring of the collimator lamp

There are two methods of aligning the light beam to the X-ray field. One is to move the position of the lamp, and the other is to adjust the position of the collimator relative to the X-ray beam.

With a collimator that can rotate, it is essential to adjust in the correct sequence, otherwise alignment is correct only in one position.

- Bring the collimator down until it touches the tabletop, and adjust the tube rotation so the collimator face is flat against the tabletop. Now raise the collimator to its normal working height.
- Rotate the collimator clockwise 90 degrees.
- Place a used X-ray film on the table top as a template. A suggested size is 24 × 30 cm. Switch the collimator lamp on, and adjust the collimator so the light field just covers the film.
- Next, rotate the collimator anti-clockwise 180 degrees. With the lamp switched on, look for any error in alignment. This should be less than 2.0 mm in any direction.
- Before making any adjustment, check to see the correct lamp is fitted. If in doubt, contact the service department to obtain positive identification.
- If adjusting the lamp position, adjust so the error is reduced by 50%. Then adjust the film position to the light, and test again with the collimator rotated 180 degrees to the previous position.
- Can the mirror be adjusted?
 - i. With most collimators, the mirror is fixed in position. Attempting to move the mirror against the clamping screws can distort or break it, requiring a replacement. (If the mirror is distorted, the sides of the light field are at an angle, and not parallel).
 - ii. The exception is where there is a spring-tensioned adjustment screw. This may be found on some mobiles or portable units. In this case, the lamp may be adjusted sideways, and the mirror rotation replaces the vertical adjustment of the lamp.

g. Centring of the X-ray beam

Attempting to adjust the collimator to the X-ray beam should only be attempted after checking that the light beam is correctly centred. This especially applies when the collimator can rotate.

- An X-ray alignment template is required. A suitable design is shown in **appendix B page 169**.
- Place the X-ray alignment template on a 24/30 cm cassette.
- Collimate the light beam to the outer 20 by 26 cm rectangle.
- Make a low kV and mAs exposure.
- Develop the film.
- **Does the alignment meet the required compliance?**

Two versions are provided as an example only. The actual compliance requirement will depend on individual country regulations.

 - i. *The X-ray field edges should not deviate by more than 2% of the distance between the plane of the light field and the focal spot.*

$$[a1] + [a2] \leq 0.02 \times S.$$

$$[b1] + [b2] \leq 0.02 \times S.$$

Where S is the distance from the focal spot, a1 and a2 are the two sides on one axis, and b1 and b2 are the two sides of the other axis. For example; at a FFD of 100 cm, if the two vertical edges of the light field were displaced by 10 mm, this would be at the limit of acceptance. *If only one edge was displaced, then 2.0 cm is at the limit of acceptance.*
 - ii. Another version has a different requirement. *The total misalignment of any edge of the light field with the respective edge of the irradiated field must not exceed 1% of the distance between the plane of the light field and the focal spot.*

For example; at a FFD of 100 cm, the maximum displacement of **any** edge should be less than 10 cm.
- In case the X-ray field is off-centre by more than the permitted amount, re-centring is required.
- **To adjust a non-rotating collimator.**
 - i. Refer where possible to the installation or operation manuals for the collimator. If necessary, contact the service department for information specific to your version of collimator.
 - ii. Locate the adjusting screws for the metal fingers. These usually require an Allen key for adjustment.
 - iii. By slackening off one finger, then tightening the opposite finger, the collimator will move relative to the X-ray field. Only a small adjustment,

- of about one turn of the screw, is sufficient to move the X-ray field several millimetres.
- iv. Adjust the collimator to move in the same direction you require the X-ray field to move.
 - v. After adjusting, make another test film and compare the results.
 - vi. If necessary, make further adjustments until compliance is achieved.
 - vii. Tighten carefully all four fingers, ensuring the collimator position does not change.
 - viii. Make a final test film for verification.
- **To adjust a rotating collimator.**
 - i. Refer where possible to the installation or operation manuals for the collimator. If necessary, contact the service department for information specific to your version of collimator.
 - ii. With a true rotating collimator, the ring or bearing on which it rotates is repositioned relative to the X-ray beam. (Unfortunately some simplified systems may not have this facility, and so can only be correct in one position).
 - iii. It is necessary to locate the screws that clamp this ring in position. These may require a small spanner. Undo these screws a small amount, so the ring can just be moved.
 - iv. With some rotating collimators, once the rotation ring is free to move, adjusting screws similar to the fixed-collimator, are used for alignment. Otherwise gently tap the collimator into position, moving it only a part of a millimetre at a time.
 - v. Adjust the position and test in the same fashion as the fixed-collimator.
 - vi. Repeat the above test, with the collimator rotated 90 degrees clockwise, and 90 degrees counter clockwise.
 - vii. Ensure the ring clamping screws are correctly tightened when alignment is satisfied. Make a final test film for verification.

h. The light field is larger than the X-ray field

Most collimators depend on a standard distance between the X-ray tube housing and focal spot. If a manufacturer supplies non-standard tube housing, this distance may be incorrect.

- The collimator is required to be positioned at a specific distance from the focal spot. Some collimators are supplied with shims. These can be added or subtracted to make the required adjustment. Check with the service department for this possibility.
- A common reason is the method of installation.

- i. The bracket for the tube-stand command panel is placed between the collimator and the X-ray tube port. This increases the collimator to focal spot distance. As a result the X-ray field becomes smaller.
- ii. In some cases it may be possible to have a mounting block machined to reduce this added distance, or have shims removed. Otherwise the mounting method of the control panel will need to be changed to correct the situation.

i. The Bucky centre light

Collimators have been fitted with a number of methods to indicate Bucky centre. Two versions are discussed here.

- One method is a fixed slot, immediately below the collimator lamp. If the lamp is not correctly adjusted, then the light shines at an angle through this slot, creating an error. This is usually corrected by re-alignment of the collimator. See 'Centring of the collimator lamp', part 'f'.
- Other versions may have a small focussing lens, attached to a slit in the collimator cover. Adjusting the lens can shift the position of the light beam.

j. The X-ray field fades out on one side of the film

If the fade out occurs towards the anode side of the film, when selecting a large format, this is probably due to the 'heel affect' of the X-ray tube anode.

Otherwise, it may be due to the following.

- The collimator is not centred to the focal spot, and the lamp has been adjusted to align the light beam to the X-ray field. Test by making sure the light field remains centred as the collimator is rotated. See 'Centring of the collimator lamp'.
- The collimator primary-beam shutter, or blade, is touching the side of the X-ray tube port, or 'throat'. The cause is due to incorrect centring of the collimator.
(This problem depends on the collimator design, and how the collimator is attached to the X-ray tube.)
- The lead proximal-diaphragm has been incorrectly fitted inside the tube port. For example, after replacement of the X-ray tube.
- The collimator lead-shutters, or blades, are out of adjustment. This may be either the middle blade, or the bottom blade.
 - i. The shutters are coupled to the field size knob by a thin stainless-steel cable.

- ii. The cable may be loose, or has slipped where it attaches to the shutters. To check, remove the collimator cover, and make a careful comparison of both sets of collimator blades. The lead strip, on the bottom blades, can be adjusted in most collimators.
- In some cases there may be a slow fade off towards the cathode side of the film. This is more noticeable at lower kV levels. If this is an older, or hard worked X-ray tube, then it might be due to metal deposits on the glass. To check, you will need to remove the collimator. **See module 7.1 page 104.**

k. The collimator blades close, after adjusting the field size

A collimator has an internal 'brake' or 'clutch'. If this becomes loose, the springs, fitted between the collimator blades, cause the blades to close.

Two common methods are described here.

To adjust, it is necessary to remove the collimator cover. Ensure power is turned off, and the tube stand is prevented from moving vertically.

- Japanese origin.
 - i. The shutter control knob is attached to a round shaft. This shaft, which controls the opening of the blades, passes through a cylinder attached to the inside front of the collimator.
 - ii. A small nylon pad forms the brake action. This is pressed firmly against the shaft that passes through the cylinder.
 - iii. A screw, attached to the cylinder, controls the amount of pressure. As the screw is turned clockwise, the pressure of the nylon pad against the shaft increases.
 - iv. To adjust, first undo the locknut on the screw. Then turn the adjusting screw about a quarter turn clockwise. Retighten the locknut, and test the feel of the control knob.
 - v. Repeat the above action so the knob is firm to turn, without being over tight.
 - vi. Check and adjust the other shutter control knob.
 - vii. Replace the cover.
- European origin.
 - i. The shutter control knob is attached to a round shaft. This shaft, which controls the opening of the blades, passes through to the rear of the collimator.
 - ii. At the rear of the collimator, a circular disc is attached to the end of the shaft.
 - iii. There are two screws on the outer side of this disc. These adjust the pressure of a wide spring washer on the disc.

- iv. The screws are adjusted so the control knob is firm to adjust, but not over tight.
- v. These screws tend to become loose. After they are adjusted, clean around the screw heads with alcohol. Then paint the immediate area with nail polish. This will help retain the screws in position.
- For other collimators, contact the service department for advice regarding adjustment of the brake and its location.

l. The collimator lamp fails to operate

The most common cause of failure is, of course, a burnt out globe. In case this is not the reason, then check the following. **Ask an electrician, or electronics technician, for assistance.**

- The lamp timer switch. Mechanical types are prone to failure, and to a lesser degree, electronic versions.
 - i. Ensure all power is switched off, while removing the cover to gain access to the timer.
 - Note.** Some tests for the timer will require power after the cover is removed.
 - ii. Check the internal wiring, looking for loose connections.
 - iii. Mechanical timers have only two terminals. Operate the timer, and with a multimeter set to low ohms range, check the timer-switch contacts for continuity. **See module 5.0 page 65.**
 - iv. An alternate test is to set the multimeter to AC volts, and look for voltage across the terminals. This should be 12~15V for a 12V lamp. When the timer is operated, there should be no voltage across the terminals.
 - v. Electronic timers have several connections. It is necessary to trace out the wiring and locate the two terminals that switch the power to the lamp. Look for voltage across these terminals. This should be 12~15V for a 12V lamp. When the timer is operated, there should be no voltage across the terminals.
 - vi. In case the timer is faulty, a temporary repair is to remove the timer and replace it with a standard on-off switch. Order a new timer and replace the temporary switch at the first opportunity.
- No power to the collimator. Check the connecting cable for broken connections, especially if the collimator is a rotating version.
- There may be a faulty fuse in the collimator power circuit. Contact the service department for the location of this fuse.

m. The globe has failed, and there is no spare globe

- The collimator should have a scale on the front. This indicates the field aperture as the blades are opened. The accuracy of this scale has, hopefully, been checked at the last routine service. However, let us assume this has not happened.
 - i. Lower the collimator so it is touching the tabletop. Adjust any angulation or rotation, so it sits flat on the tabletop.
 - ii. Adjust the tube stand so the collimator is at the table centre.
 - iii. Place a ruler on the tabletop, end-on against the centre of the collimator. Use this as a guide to assist in centring the Bucky to the collimator.
 - iv. Raise the tube to the normal working height. Adjust the X-ray control for a low kV and mAs exposure.
 - v. Place a 24 × 30 cm cassette in the Bucky. Adjust the collimator to the film size using the scale on the collimator. Make a test exposure.
 - vi. If the test exposure shows all the film was exposed, then repeat the above test, this time reducing the collimator aperture a small amount. If all is well, the film should now have a border around all four sides.
 - vii. Continue the above test with the most commonly used sizes of films and orientation. Adjust the position of the control knob on the collimator shaft to obtain a correct indication. Or, place a mark on the collimator front to indicate the required opening for the different films.
 - viii. A similar test to the above is required for the wall Bucky.
- To estimate the position of the anatomy under examination. AP view.
 - i. With the patient on the tabletop, bring the collimator close to the area under examination. View the position both from the head, or foot, end of the table, as well as the side of the table.
 - ii. To estimate the area to be covered, place a sheet of film on the patient, centred directly under the collimator. This is to simulate the previous appearance with the light beam. The actual area will be about 10% less.
 - iii. Where possible, protect other immediate areas of the patient by masking with lead rubber strips.
 - iv. Raise the X-ray tube to its normal height, and set the aperture size using the scale on the front of the collimator.
- To assist in Bucky centring during an examination.
 - i. Attach a length of string to the front of the collimator side, positioned at the centre. Attach a small weight at the end to act as a plumb bob.
 - ii. Move the X-ray tube across the table, so the plumb bob is over the Bucky tray. Centre the Bucky to the X-ray tube, and then return the X-ray tube back to the table centre position.
 - iii. Coil up the string etc on the X-ray tube when not in use.
- To estimate the position of the anatomy under examination. Oblique view.
 - i. A simple method is to use a long ruler, or similar object, resting against the upper or lower side of the collimator. This is extended towards the patient. By alternating the ruler on the upper and lower side of the collimator, a reasonably accurate positioning of the X-ray field may be made.
 - ii. A torch may be used. The torch should be the type that has a focussed spotlight, and a flat bottom end.
 - iii. Hold the torch bottom end against the centre of the collimator faceplate. Switch the torch on, and place a marker in the centre of the light beam on the tabletop.
 - iv. Rotate the torch, and check that the light beam stays in position. This test indicates the torch is suitable for use.
 - v. Now place the patient on the table. Adjust the X-ray tube to the required angle. Place the torch on the collimator front as before, and use the torch light to indicate the X-ray beam centre.
 - vi. As before, a sheet of film may be used to estimate the area to be covered.
 - vii. Set the collimator aperture, using the scale on the front of the collimator.
 - viii. Use lead rubber strips to protect the patient.

TASK 14

Help! No spare globe for the collimator

The collimator globe has failed. On checking supplies, there is no spare globe. You are required to continue processing patients, while waiting for a new globe.

Please refer to module 11.2 for an outline of suggested techniques.

Note; for this exercise, the collimator lamp must not be used.

Using a 24/30 cm film, test the accuracy of the collimator scales. Is the accuracy adequate? Does the scale need to be reset?

Make a suggestion for other methods to achieve patient positioning, with an AP view.

Can this method be adapted for a wall Bucky?

With a water phantom to simulate the patient, try the methods suggested for an oblique view. Will this give the required accuracy?

Discuss other problems that may arise if the lamp fails. Suggest a technique that may be used.

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____

Tutor

Date _____

MODULE 7.3

HT cable

Aim

The aim is to provide information related to the high-tension (HT) cable. This includes repairing common faults, and procedures for replacing the HT cable. Information in this module also applies to module 7.1 page 104.

(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with the high-tension cable, and their symptoms. With the assistance of an electrician or electronics technician, a number of corrective actions can be carried out.

This includes:

- Repairs to eliminate high-tension arcing.
- Correcting bad cathode cable connections to the X-ray tube filament.
- Removal and reinsertion of the cable ends, when the X-ray tube is replaced.
- Replacement of the HT cable.

Contents

- a. Safety precautions
 - b. High-tension failure of the HT cable
 - c. Damage to the cable electrical safety shield
 - d. Arcing in the X-ray tube receptacle
 - e. Burnt pins on the cathode cable end
 - f. Caution on removing HT cable ends
 - g. HT cable replacement
 - h. HT cable fault with CD mobiles
 - i. Preparation prior to inserting the HT cable end
 - j. Inserting the HT cable end
 - k. Need for re-calibration
-

a. Safety precautions

- **Do not attempt repairs or replacement of the HT cables by yourself. Ask an electrician, or an electronics technician, for assistance.**
- **Before disconnecting any wires, or removing the HT cables, always ensure power is turned off and unplugged from the power point. If the equipment is part of a fixed installation, besides switching the generator power off, ensure the isolation power switch for the room is also switched off.**
- Mobile high-frequency generators may be battery operated. The batteries in these are connected in series, and can have a total voltage of up to 240V DC. **Refer to the operating or installation manuals for the position of the battery isolation switch, and ensure this is switched off, before removing the covers, or testing wires and connectors.**
- **If removing a HT cable from a capacitor discharge mobile, observe the high-tension precautions described in module 6.2 page 94.**
- **Whenever a HT cable is removed from a receptacle, immediately short the cable-end pins to ground. This is to remove any residual high voltage in the cable. The same precaution applies before applying grease or any other handling of the cable end. Failure to take this precaution could cause a severe electrical shock.**

b. High-tension failure of the HT cable

The HT cable tends to fail at the cable ends. This is due to the added flexing, or twisting, as the X-ray tube is rotated and repositioned. This is often due to poor support of the HT cable. Failure is usually accompanied with a pungent, or acrid, smell.

- A metal 'cuff' often hides the actual failure point. This cuff helps support the cable end where it enters the tube housing. If suspicious of the HT cable, then undo the retaining ring nut, and slide the cuff out of the way. Then inspect again for an unusual smell. Make a comparison with the other cable end.

- If a HT cable is suspect, test by replacing the cable.
 - i. This may be a spare cable from an old installation, or else a loan cable sent from the service department.
 - ii. Observe carefully the procedures and precautions in this module, before replacing a cable.
- See 'Arcing in the X-ray tube receptacle', part 'd'.

c. Damage to the cable electrical safety shield

The HT cable is fitted with a wire mesh safety shield. This is just below the outer insulation. If there is a failure of the cable insulation, the shield conducts the high-voltage spark to ground. The safety shield is soldered to the metal flange of the cable end. Twisting of the HT cable can cause the wire strands to break.

In some cases, the shield is found completely disconnected. This can be very dangerous. See 'Caution on removing high-tension cable ends', part 'f'.

- To inspect, undo the cable-end retaining ring-nut. Slide back the cable support cuff. Check for broken strands.
- In some cases, the shield connection is wrapped in insulation tape. This form of construction is weak, and is prone to have damage to the shield. Unwrap the tape to inspect for broken strands. If ok, then re-wrap using fresh tape.
- If there are broken strands, and especially if this is extensive, a repair should be attempted. An electrician or electronics technician should perform this repair, after obtaining advice from the service department.
 - i. A soldering iron is required. 75–100 watt is optimum. This is to allow quick soldering to the cable end without spreading excessive heat.
 - ii. You will need some fine multi-strand 'hook up' wire. (The type needed for general electronics wiring). Or if possible, the braided shield from a length of co-axial cable. If using hook-up wire, remove the insulation from the wire.
 - iii. Gather the broken strands of the shield wire. If necessary, remove a little of the cable outer insulating sheath. Twist together to make four bunches, spaced around the cable end.
 - iv. Solder to one end of the hook-up wire. Take the hook-up wire a full turn clockwise around the cable end, then solder to the cable end.
 - v. Repeat this with the other three bunches, alternating the direction around the cable end. Eg, anticlockwise, then clockwise, and finally anticlockwise.
 - vi. Use insulation tape to cover the repaired shield connection.

- **Please note.** In some cases it may be claimed that the system is safe, providing the shield is connected to ground at the transformer end. This is not correct. Besides possible danger, this can upset the performance of high-frequency X-ray generators, and create interference in other equipment.

d. Arcing in the X-ray tube receptacle

This is a common cause of failure. Arcing can be caused by a number of reasons. There may be poor quality or dried-out insulating grease. The grease may have been incorrectly applied. If the cable end is loose, this will create air gaps, and eventual arcing. Later systems use silicon rubber anti-corona insulating pads. Unless care is taken installing these pads, arcing will occur. Finally, a fault can occur inside the cable end itself. In effect, a fault in the HT cable, but not externally apparent until the cable end is removed.

- **See 'Caution on removing HT cable ends', and 'Preparation prior to inserting the cable end'.**
- With the cable end withdrawn, look for possible carbon tracks on the cable end, or in the receptacle.
- Where there is grease in the receptacle, wipe the grease with a fresh paper tissue. If arcing occurs in the grease, this will show up as carbon deposits on the paper. Old grease may have a yellow colour, but this does not indicate arcing.
- Examine the cable end carefully for signs of swelling or cracking. This would indicate arcing. In this case a replacement HT cable is required.
- Wipe out all grease from the receptacle and the cable end. With a torch examine the receptacle carefully for signs of arcing.
- If silicon rubber anti-corona pads are fitted, these may remain attached to the cable end. More often they will remain in the receptacle.
 - i. Pads are often used without grease. However, wipe the inside of the receptacle and the cable-end with a fresh paper tissue. If it appears dirty, this is a sign of arcing.
 - ii. Examine the pads for possible hairline black marks, which indicate arcing.
 - iii. The pads should be replaced after being disturbed.
 - iv. In case a replacement pad is not immediately available, then they may be returned to service. Take care not to touch them directly with the fingers. (Use a paper tissue.) Have the pads replaced at the first opportunity.

e. *Burnt pins on the cathode cable end*

The cathode filament current may be between 4.0–5.5 amps. If the pins on the cable end do not make good contact inside the receptacle, they will become burnt. This produces added resistance to the filament circuit, and reduced filament heating.

In the case where light or no exposures occur, this may be due to poor contact of the cathode cable-end pins.

Do not make the following test with a capacitor discharge mobile. Please refer to ‘High tension precautions’ in module 6.2 page 94.

Undo the ring nut sufficiently to withdraw the cable end about 2–4 mm. Then reinsert the cable end and tighten the ring nut. If this action restores or improves the X-ray output, then the cable-end pins are suspect.

The cable end should now be fully withdrawn and examined.

- See ‘**Caution on removing HT cable ends**’, and ‘**Preparation prior to inserting the cable end**’.
- Examine the cable-end pins. Look for a pin that shows burn marks, or pitting.
- Clean the pin with fine emery cloth or sand paper.
- If the cable-end pins are burnt, then the pin sockets of the housing receptacle will also need cleaning. One method is to use a wire coat hanger, with one end filed flat. This can be used to scrape the sides of the socket into which the cable-end pins fit.
- Most HT cable-end pins are solid brass, split in two halves. These tend to close together, and make a less secure fit in the receptacle. The pins may be carefully spread apart, so the air gap in the middle is parallel.
- **Caution;** these pins are brittle. Do not try to spread them apart using a screwdriver. The best tool is a utility knife with a retractable blade. This blade is just slightly thicker than the required gap. Push the blade into the gap very carefully, so the gap becomes almost, or just, parallel.
- **Help.** A pin is broken. All is not lost. However, you will need to exchange the anode and cathode cables. (At the HT transformer as well as the X-ray tube)
- Before attempting to reinsert the cable end, ensure it is thoroughly cleaned. This is especially important after handling the end, as small traces of perspiration or fingerprints etc may be left behind. See ‘Inserting the HT cable end’.

f. *Caution on removing HT cable ends*

- **If in a capacitor discharge mobile, please refer to ‘High tension precautions’ in module 6.2 page 94.**

- When replacing a cable, remove the cable-end first at the X-ray tube, and then at the high-tension transformer. This especially applies if the safety earth shield is damaged at the X-ray tube end.
- **As the cable end is withdrawn, touch the endpins to the screw-thread side of the housing receptacle.** This is to short out any residual high voltage in the HT cable. This especially applies if high voltage was generated, but with no mA.
- The cable end may be a very tight fit. Do not try tugging on the HT cable to remove it. Instead, use two screwdrivers, one on each side of the cable-end flange, to lift, or ease, the cable end from the receptacle.

g. *HT cable replacement*

- If the anode HT cable is replaced with a different type or length, in most cases this makes little difference to the performance, especially if the difference in length is less than 10–15%.
- An exception may be with some medium frequency inverter systems, which have an adjustment for different lengths of HT cables. Check with the service department for this possibility.
- In the case of the cathode cable, a different length or type can change the mA calibration. Providing the anode cable is the same type and length as the failed cathode cable, then exchange cables, so the replacement is used for the anode side. This will avoid the requirement for immediate mA recalibration.

h. *HT cable fault with capacitor discharge mobiles*

The CD mobile cathode-cable can develop a short circuit between the internal control-grid wire, and the filament wires. In most cases, the anode cable will be in good condition, and can be exchanged for the cathode cable. mA calibration is not critical, and will not need to be adjusted. If exchanging cables, attach an internal notice to indicate a change has been made. This will avoid future frustration in case another change is attempted.

Before attempting to remove or replace a CD mobile cable, please refer to ‘High tension precautions’ in module 6.2 page 94. Otherwise replacement is the same as for a standard system.

i. Preparation prior to inserting the HT cable end

- Old grease on the cable end, and in the receptacle, should be removed.
- Thoroughly clean the receptacle and cable end. When cleaning the receptacle, use paper tissues wrapped around a wood or plastic rod.
- If necessary, a hydrocarbon cleaning solvent may be used. Be sure to remove all residues. When cleaning a cable-end, avoid touching with your hand, this can leave unwanted perspiration or skin oil. After cleaning, the cable end or receptacle should have a high polished appearance.
- Examine the cable-end pins of the cathode cable. If of the split pin version, check the pins are not bent together, and the gap is parallel. See '**Burnt pins on the cathode cable end**', for tips on adjusting.
- Most HT cable ends have a rubber sealing-ring. This is placed over the cable end, up against the flange. Ensure this is fitted correctly before applying grease.
- Fresh insulating grease is now required, or a silicon anti-corona disk.
 - i. Grease is applied using a wooden or plastic spatula. For example, a tongue depressor. Do not apply or smooth the grease with a finger. First wrap a paper tissue around the finger, to avoid directly touching the grease.
 - ii. Apply the grease to about 70% of the length of the cable-end, starting at the pin end. The depth of grease at the pin end should be about 2~3 mm, tapering off at the 70% point. The application of grease is not critical, as any irregular area will flow around the sides of the cable end, as it is inserted.
 - iii. A layer of about 1~2 mm may also be applied to the front of the pin end, between the pins.
- If a silicon rubber anti-corona disk is used.
 - i. The disk should be supplied in a sealed package. Handle the disk with a pair of clean tweezers, or else by a paper tissue.
 - ii. Place the disk in position on the cable end, with the pins passing through the disk.

- iii. A small layer of silicon grease may be placed around the sides of the cable end. This is an option. If in doubt, check with the service department for advice.

j. Inserting the HT cable end

- The cable end has a 'key' at the flange end. This fits into a 'notch' in the receptacle. Before inserting the cable end, check the rotational position, so these two areas will be aligned on insertion.
- On inserting the cable end, try to keep it aligned in the centre of the receptacle. This ensures an even distribution of the grease.
- As it becomes fully inserted, rotate the end a little to align the cable-end pins into the receptacle sockets.
- A very firm continuous pressure is often required. This is due to pockets of air in front of the grease, as well as the viscosity of the grease itself.
- Once the cable-end pins are properly inserted into the receptacle sockets, it should now be possible to attach the cable-end retaining ring-nut and cable support cuff.
- Tighten the ring nut fully. Then check again every few minutes until it can no longer be even partially rotated. This should be checked again over the next few days.
- Attach cable ties to support the HT cable in position.

k. Need for recalibration

Note. Replacement of the **cathode** cable can alter the mA calibration. While replacement with an identical type and length may have very little effect on the calibration, this should still be checked.

In case the **cathode** cable is a different length or type, this may have a large effect on the mA calibration, depending on the design of the generator. **Before attempting any calibration, check first with the service department for the recommended procedure.**

MODULE 8.0

Bucky and Bucky table**Aim**

The aim is to provide information and procedures related to problems with the Bucky and Bucky table. This is an addition to the maintenance procedures, provided in module 3.0 page 53.

(Note: Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with the Bucky and Bucky table, together with their solutions. Adjustments and repairs may be carried out. Some tests or repairs will require the assistance of an electrician or electronics technician.

Task 15. 'A film exhibits grid lines', should be attempted on completion of this module.

Contents

- a. General precautions
- b. Grid lines sometimes appear on the film
- c. Grid lines appear on all films
- d. The film is dark in the centre, but fades out to either side
- e. No exposure on a selected Bucky
- f. The cassette tray does not hold the cassette properly in the vertical Bucky
- g. The Bucky lock does not operate
- h. The table magnetic locks slip, or are unreliable
- i. The table auto-centre does not operate, or is not accurate
- j. Noisy tabletop movement
- k. Elevating Bucky-table problems

a. General precautions

Please take the following precautions.

- **Before testing any fuses, or removing a cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- Test procedures for fuses or wiring, are described in **module 5.0 page 65.**
- When removing the cover from a vertical Bucky, make sure the Bucky cannot move upwards when the cover is removed. For example, attach a rope to hold it in position, or remove the cover with the Bucky set to maximum height.
- In most cases removal of the Bucky cover is a simple operation. However, where possible refer to an installation manual. This will indicate if there is any special procedure for removing or installing the cover.
- In the case of a Bucky table, removal of the tabletop may be required. The method used depends on the table design.
 - i. Most tabletops may be removed once the screws holding the 'profile rails' in position are removed. Before attempting to remove these screws, make sure the screw slots are not blocked with dirt, and use a screwdriver that has a good fit and is not blunt.
 - ii. In other cases, removal of the tabletop end-stops will allow the tabletop to extend to over one end. As the tabletop is moved past the end-stop position, the tabletop will disengage from the far-end bearings. Have a chair or other suitable object ready to support the tabletop.
 - iii. In some cases, power will need to be switched on to release the table locks.
 - iv. To avoid unexpected problems, make sure at least one person is available to assist.
 - v. On replacement of the tabletop, check and manually reseal the locks to allow the tabletop to pass over them.
 - vi. Ensure the end stops are securely replaced.
- Keep all screws, or other small parts in a container, to avoid loss.

b. Grid lines sometimes appear on the film

There are several possibilities.

- The grid starts oscillating as soon as the X-ray control is placed in preparation.
 - i. This form of operation does not synchronise the exposure to the grid position. As a result, an exposure can commence when the grid has reached the end of travel, and is reversing direction.
 - ii. Test by looking for grid movement when in preparation, before an exposure. If this is the cause of the problem, re-installation of the Bucky wiring is required. Consult the service department for advice.
- The Bucky has a slow moving grid. In this case, there is insufficient grid movement when performing short exposure times. A replacement Bucky of a later design is required.
- Some Bucky's have a rotating cam to operate the grid.
 - i. The grid moves quickly at first, then slower until the full 'in and out' cycle is completed. This is repeated till the exposure is completed.
 - ii. The Bucky has an adjustment to ensure the exposure commences at the point of maximum speed. If incorrectly adjusted, then the exposure could commence before that point, when the grid is at minimum speed.
 - iii. This is indicated if grid lines occur on short exposure times. If adjustment is required, request the service department to adjust the Bucky.
- In the case of mammography, many Bucky's have a speed adjustment.
 - i. Optimum adjustment is for the grid to reach 75% of its stroke during an average exposure. If grid lines occur on short exposures, then increase the speed. Or, if grid lines occur during long exposures, then reduce the speed.
 - ii. This may be a screwdriver adjustment at the back of the Bucky, or it may be an internal adjustment. In that case, the service department must make the adjustment.
- The grid movement may be hitting an obstruction, and while moving far enough to permit an exposure, then stops moving. Or, in some cases, the grid drive may be sticking. This can be indicated if short exposure times are ok, but long exposure times have grid lines.
 - i. Close the collimator, and direct the X-ray tube away from the Bucky.

- ii. Select minimum kV, the lowest mA station, and a long exposure time.
- iii. Remove the cassette tray, so the grid may be clearly observed.
- iv. Have an assistant make an exposure, using the Bucky under test. Observe the grid movement, looking for signs of hesitation. Does it tend to stop before reversing?
- v. If a problem is indicated, then remove the Bucky cover, or tabletop, and examine the mechanism while it is moving. Look for film markers causing an obstruction.
- vi. Some motors can have damaged gears, with missing teeth. In this case, repair kits may be available.
- vii. Apply a small amount of oil to moving surfaces.

c. Grid lines appear on all films

- The wrong Bucky was selected. Is the selection switch correctly labelled?
- Listen for a Bucky sound during a test exposure. Does the selected Bucky operate? Does it sound normal?
- A common cause is a dislodged grid. For example, the grid has fallen from the grid frame, or holder. In this situation, although the frame moves, permitting an exposure, the grid itself does not move. To remount the grid in the frame, removal of the Bucky cover, or tabletop, may be required.

d. The film is dark in the centre, but fades out to either side

- The grid was removed, and then reinserted upside down.
- Is the grid focal distance within the range you are using?
 - i. Can the grid be removed? Look for a label that provides the focal length of the grid.
 - ii. If it is difficult to remove the grid, try a test exposure after changing the FFD. Make a direct low kV and mAs exposure, without a patient.
- Is the vertical Bucky correctly aligned to the X-ray tube?
 - i. For example, is the Bucky at an angle to the x-ray beam?
 - ii. This can occur if the vertical Bucky is not correctly installed. The Bucky may be mounted against a wall, which is not at an angle of ninety degrees to the tube-stand.
- Image fade off to one side may be a problem due to the X-ray tube or collimator. To check, make a direct exposure to a cassette on the tabletop.

- i. A direct exposure at low kV will exhibit some fade off towards the cathode side of the tube. On large films, a larger fade-off can occur towards the anode side of the film, due to the anode heel-affect.
- ii. To test at the kV values normally used, a suitable filter is necessary. For example, 1.0mm of copper in front of the collimator. Or else 10cm of water in a plastic container.
- iii. Set a similar kV to that used when observing the problem. Adjust the mAs to achieve a suitable density.
- iv. If the fade off is still present, the collimator may be out of alignment. For example, the collimator is incorrectly centred to the X-ray tube, and the light beam was adjusted to compensate. **See module 7.2 page 110.**
- v. There may be excessive metal deposits on the X-ray tube glass. You will need to remove the collimator to check. Contact the service department for advice before attempting removal. **See module 7.1 page 104.**

e. No exposure on a selected Bucky

In this situation, a test exposure using direct non-Bucky radiography is successful.

- Close the collimator, and move the tube away from the Bucky.
- Select minimum kV, a low mA station, and a medium time setting.
- When trying to make a Bucky exposure;
 - i. Listen carefully at the Bucky for any sound. With the cassette tray removed, see if the grid moves.
 - ii. If no sign of any grid movement, check the Bucky cable for a possible loose connection or broken wire. **See module 5.0 page 65.**
 - iii. Check for a possible blown fuse. To locate the fuse, **see module 5.0 page 65**, or consult the service department.
- When trying to make a Bucky exposure, the Bucky starts to operate, but there is no exposure.
 - i. Check the Bucky cable for a possible loose or broken connection. **See module 5.0 page 65.**
 - ii. Remove the Bucky cover, or the tabletop.
 - iii. Look for any object that could be blocking the grid movement, such as a lost film marker. This can happen with a wall Bucky, or a Bucky with a fluoroscopy table.
 - iv. On attempting an exposure, does the grid drive motor operate? Look for damaged fibre gears, or a broken drive cord.

- v. Does the grid manage a full 'stroke'? As the grid moves from the 'rest' to the 'expose' position, a microswitch is operated. This microswitch allows the exposure to commence. Check the microswitch for correct operation. **See module 5.0 page 65.**

f. The cassette tray does not hold the cassette properly in the vertical Bucky

- In some cassette tray designs, the amount of 'grip' is insufficient. To prevent the cassette slipping down, the manufacturer supplies small wood blocks with an attached magnet. In other designs, a metal support is provided, which fits into a series of holes.
- The rubber grips attached to the tray jaws become smooth, allowing the cassette to slip. The rubber grips can be improved by cleaning with lighter fluid, or a similar hydrocarbon.
- The jaws may not be closing fully. Check and adjust the position of the clamping knob on the shaft.

g. The Bucky lock does not operate

- Look for a faulty switch, or broken connection, either to the switch or the magnetic lock coil. The lock coil may be open circuit. Test with a multimeter set to medium 'ohms' scale. **See module 5.0 page 65.**
- The lock coil may have too large an air gap. Adjust it closer to the operating surface.

h. The table magnetic-locks slip, or are unreliable

- **Before testing any fuses, or removing a cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- Test procedures for fuses or wiring, are described in **module 5.0 page 65.**
- No locks operate.
 - i. A fuse could be open circuit. Before replacing, check the wiring to the lock coils or switches, and look for possible damaged insulation.
 - ii. A foot switch is faulty, or has a bad cable connection.
- A specific lock fails to operate.
 - i. If other locks are operating, it is unlikely to be an open circuit fuse. However, still check, as the lock may not be the same type, and has a separate fuse.

- ii. There may be an open circuit lock coil, or winding.
- iii. To check the lock coil, first ensure all power is switched off. Disconnect the lock from the table. Use a multimeter set on a medium ohms scale to check the resistance of the lock coil. This may measure around 500 to 2000 ohms depending on design. If unsure, check against a similar lock coil in the table, or contact the service department.
- iv. Check the wiring for possible loose or broken connections.
- v. Check the control switch.
- The table lateral-movement lock is weak.
 - i. Check the number of locks installed for lateral operation. Some tables were supplied with only one lock. In this case, apart from cleaning the front of the lock, little improvement can be made.
 - ii. Where there are two locks, one of the lock coils may have failed. Watch the locks when they are switched on and off. If only one lock moves, the other lock might have an open circuit winding. In some cases, you may find the suspect lock coil to touch.
 - iii. **Note.** Locks may be positioned either at one end, or at both ends of the table.
 - iv. To check the lock coil, first ensure all power is switched off. Disconnect the lock from the table. Use a multimeter set on a medium ohms scale to check the resistance of the lock coil. This may measure around 500 to 2000 ohms depending on design. If unsure, check against a similar lock coil in the table, or contact the service department.
 - v. Check the wiring for possible loose or broken connections to the suspect lock coil.
- The locks make a rattling or buzzing noise. Check the mounting of the locks. Is the lock parallel to the operating surface? Is there a large air gap when not switched on? Another possibility is dirt on the top, or face, of the lock.

i. The table auto-centre does not operate, or is not accurate

- To test the table lateral centre-position.
 - i. Place a cassette in the Bucky, with a marker positioned on the centre of the cassette.
 - ii. Place another marker on the centre of the tabletop.
 - iii. Move the tabletop to the lateral centre-position.
 - iv. Make a low kV and mAs exposure. Process the film and check if both markers are in the same position.

- Some tables have a mechanical centre stop. A spring tensioned steel ball clicks into a slot when the table is centred.
 - i. The spring can have a tension adjustment screw. Tighten the screw to obtain a firm stopping action.
 - ii. Are the screws holding the mechanical centre stop loose?
 - iii. To adjust the stop position, undo the screws a small amount, and push the centre stop to the required position. Tighten the screws to prevent movement. Make a test film to confirm the table is centred.
- Other tables may switch on the electromagnetic locks when in the centre position. This is usually by a cam passing over a microswitch. (Later designs may use electronic sensors, such as optoelectronics.)
 - i. If the microswitch is positioned away from the cam, unreliable operation can result. If positioned too close, then poor centring action results. For example, the stopping position becomes wide.
 - ii. Centre position is adjusted by moving the cam, or else the microswitch.
- The centre microswitch, or the auto-centre selection switch can have faulty contacts. Ensure power is turned off. Check with a multimeter set to low ohms scale to test the switch.
- For other possibilities, contact the service department for advice.

j. Noisy tabletop movement

A 'clunking' noise is heard as the tabletop is moved.

- This may be due to a faulty bearing, or it may be caused by dirt in the bearing tracks, or on the rim of the bearings. Spray the bearings and bearing track with light aerosol oil, and wipe down with a rag.
- Watch the bearings as the tabletop is moved. A faulty bearing may have a cracked or missing rim. In some cases, the bearing does not rotate, and the table is stiff to move.
- Contact the service department for a replacement bearing, plus advice for replacing the bearing.

k. Elevating Bucky-table problems

- The tabletop will rise up, but not move down.
 - i. Many tables have been damaged after being brought down onto a chair or patient stool. Two common safety devices are now used.

- ii. A pressure-pad is installed on the floor, positioned at both ends of the table. Pressure on these pads activates a relay, which stops the downward movement of the table. Is there an object pushing on the pad, or has the pad become damaged?
- iii. A sensitive microswitch is installed in the middle of the longitudinal bearing tracks. This may require adjustment. Contact the service department for advice.
- The table does not stop at the operating height.
 - i. A cam-operated microswitch is used to switch off the motor once the operating height is reached.
 - ii. The position of the cam or microswitch may require adjustment.
- The motor does not operate.
 - i. On some tables, occasional failure of the motor power fuse occurs. *Before attempting to replace the fuse, ensure all power is turned off.*
 - ii. When replacing the fuse, use a delay or slow-blow type. **See module 5.0 page 65.**
 - iii. For location of the fuse, refer to the parts or installation manuals.
 - iv. If the fuse continues to fail, contact the service department for advice.

TASK 15

A film exhibits grid lines

After taking a chest X-ray, you notice prominent grid lines on the film.

Make a list of possible reasons for this problem.

Describe suitable tests to either confirm, or eliminate, possibilities from this list.

Carry out these tests. What were the results?

What action is needed to correct the problem?

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____

Tutor

Date _____

MODULE 8.1

Tomography attachment

Aim

The aim is to provide information and procedures related to problems with a tomography system. This may be a tomography attachment, fitted to a standard tube-stand, or integrated with a Bucky table. This is an addition to the maintenance procedures, provided in module 3.1 page 55.

(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with the tomography attachment, including operator error, or problems with a safety interlock. Adjustments and repairs may be carried out. Some tests or repairs will require the assistance of an electrician or electronics technician.

Contents

- a. General precautions
 - b. Failure to operate
 - c. The tomography image has poor definition
 - d. The required exposure time is difficult to estimate
-

a. General precautions

Please take the following precautions.

- **Before testing any fuses, or removing a cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- When investigating a possible bad connection, open circuit fuse, or faulty switch, refer to the procedures in **module 5.0 page 65**.
- Older tomography attachments have either limited, or no safety interlocks. Do not operate the motor without the fulcrum pole.

b. Failure to operate

This may be due to incorrect set-up, operation of a safety interlock, or an open circuit fuse to the motor. Where sections of the attachment are connected via plugs and sockets, these need to be checked.

- Incorrect set-up may cause operation of a safety interlock. This helps guard against operator error. When all else fails, then read the operation manual.
 - Current tomography attachments can have a number of safety interlocks, depending on the design, and integration with the tube stand.
 - Older systems depend more on correct set-up, such as ensuring the rotation and longitudinal tube-stand locks, and Bucky lock, is off. This requires care by the operator before using the system.
 - Typical interlocks for a tomography attachment can include:
 - i. The fulcrum pole interlock. If the fulcrum pole is not attached, the tomography system does not 'know' the stop or start positions. If energized, the motor would drive the tube-stand to the end of the tube-stand track. The interlock usually consists of a microswitch. This is operated when the fulcrum pole is attached to the tube-stand cross-arm. The actuating lever for this microswitch may be damaged, or out of adjustment. Listen for a small 'click' as the fulcrum pole is placed in position.
-

- ii. An exception to the above is where the motor has an arm that engages with a floor, or ceiling, slotted guide plate. This system can only operate over the distance controlled by rotation of the arm. However, later systems do have an interlock to check if the fulcrum pole is fitted. This prevents a wrong exposure.
 - iii. X-ray tube height. If not correct, then tomography calibration is incorrect. This is measured by a cam-operated microswitch, or in some cases by an optoelectronic sensor and reflective strip. Operation of the height sensor occurs only over a narrow distance. Try moving the tube-stand up or down a small amount.
 - iv. Tube-stand and Bucky locks are often automatically turned off or on by selection of tomography operation. However, in some systems this is not the case, and failure to switch off the longitudinal lock can prevent the motor from moving the tube stand.
 - The tomography motor has a high 'inrush' current on start up. An open circuit fuse is not uncommon.
 - i. **Before testing or replacing a fuse, ensure all power is turned off. See module 5.0 page 65.**
 - ii. Look for any cables that might be damaged, causing a short circuit.
 - iii. The fuse could be positioned close to the motor system, or else in the tomography control cabinet. Use a delay, or slow-blow, fuse as a replacement.
 - iv. If the fuse fails shortly after replacement, contact the service department for advice.
 - The fulcrum tower has a number of contacts controlled by rotation of the fulcrum. These may be cam operated switches, or else a metal-strip with a sliding contact, or 'commutator'. Selection of the appropriate section controls the start-stop position of the motor, and the tomographic angle.
 - i. There may be broken connections in the cable plug and socket. Another possibility is a broken microswitch, or commutator brush, inside the fulcrum tower. **Before investigating, ensure all power is turned off.**
 - ii. An exception is where the tomographic angle and start-stop position is controlled by a series of cams coupled directly to the drive motor. In this case, the tower will only have a motor and light for setting the fulcrum height.
- spot. This requires a smooth movement when travelling through the actual exposure area.
- To evaluate the actual performance, the tomographic resolution test piece described in appendix B page 169, section is recommended. When operated at the correct height, a clear image of the central paper clips should be obtained.
 - i. To avoid over exposing the film, use a low mA station, and low kV. If the film is still too dark, then insert a sheet of paper between one intensifying screen and the film.
 - ii. Repeat this test for different combinations of speeds and angles.
 - If a good image is not obtained with the test piece, then check the following.
 - i. Uncouple the fulcrum pole. Otherwise remain in tomographic set-up mode.
 - ii. Check that the tube rotation lock is off. The tube should be able to rotate smoothly, and remain balanced as it is rotated.
 - iii. Check the Bucky movement. The Bucky lock should be fully off, and the Bucky should move smoothly in the table.
 - iv. Is the longitudinal lock released? With some systems, it will be necessary to exit tomographic mode, and then check the lock releases correctly.
 - v. Is the fulcrum tower securely mounted?
 - vi. Is the fulcrum pole in good condition? The fulcrum pole should not bend or twist.
 - vii. With the fulcrum pole in position, but not in tomographic mode, push the tube-stand across the floor. Look for any sudden stiffness, or jerking. Look for dirt in the guide rails.
 - viii. A wire cable is used to pull some systems. Is the cable firm, and not slipping on the motor drive pulley?
 - ix. The same applies to units with a belt drive. A loose belt can stretch, and give an uneven start to the movement.
 - x. Some motors have a drive wheel pressed against the floor. Depending on the floor surface, the wheel slips and drives unevenly. To stop the wheel slipping, glue a strip of material that has a rough surface, to the floor. For example, the type that is fitted to the steps of a staircase.

c. The tomography image has poor definition

During a tomographic scan, the film in Bucky must retain the correct alignment with the X-ray tube focal

d. The required exposure time is difficult to estimate

- A microprocessor controlled tomography unit, integrated with the X-ray control, may directly set the

exposure time. Otherwise the operator must select a minimum exposure time, called the 'backup' time.

- The backup time must be longer than the actual exposure time, which is controlled by the combination of tomography speed and angle. The tomograph operation manual should indicate the actual exposure times. A minimum backup time of 5~10% longer is recommended.
- If the operation manual indicates times for 60hz operation only, a correction factor is needed for 50hz operation. Multiply the 60hz tomographic times by the conversion factor of 1.20.
- If no information is available, contact the service department. They may need to measure the actual exposure times, and then make a suitable reference chart.

MODULE 9.0

Fluoroscopy table

Aim

A fluoroscopy table can range from the most basic version to a highly sophisticated remote control micro-processor system. Many problems are caused when 'standard' operating procedures are changed. For example, switches and selections may be set to a different position.

The fluoroscopy table has a large number of safety interlocks. These can be activated by operator error. Other possibilities are problems with the X-ray tube, the X-ray control, and the TV imaging system.

The information and procedures provided in this module are for basic tables fitted with an under-table tube. Some suggestions will however be common to all versions.

(Note: Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with the fluoroscopy table,

including operator error, or problems with a safety interlock. Adjustments and repairs may be carried out. If assistance is required from the service department, an accurate description of the problem can be provided.

Note: Some tests or repairs will require the assistance of an electrician or electronics technician.

Contents

- a. General precautions
- b. No fluoroscopy exposure, X-ray control checks
- c. No fluoroscopy exposure, table interlock checks
- d. No fluoroscopy exposure, table electrical checks
- e. The X-ray control indicates fluoroscopy is operating, but no image
- f. No radiography exposure
- g. Artefacts on the film
- h. Manual collimation has unwanted beam limitation
- i. X-ray beam alignment is incorrect
- j. Table movements do not operate
- k. Table locks do not operate

a. General precautions

Please take the following precautions.

- **Before testing any fuses, or removing a cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- Test procedures for fuses, switches, or wiring; are described in **module 5.0 page 65.**
- Any dismantling of the table to test connections, switches, or broken wires; should be performed by an electrician, or electronics technician.
- If removing a cover, or dismantling any section, place the screws in a container to avoid loss.

b. No fluoroscopy exposure, X-ray control checks

- Has a correct technique been selected?
- Check the fluoroscopy timer. Has it timed out?

- Does the X-ray control have automatic regulation of fluoroscopy output? If so, turn this off, and try a manual setting of mA and kV.
- Is there a fault indication at the control on trying an exposure?
 - i. In some cases, if actual fluoroscopy mA is too high, the exposure immediately stops. A fault condition may only illuminate while attempting an exposure, but disappear once the exposure attempt is released. In other cases, it may be necessary to switch 'off' then 'on' again to reset the safety interlock.
 - ii. Reduce the fluoroscopic mA and kV setting, close the table collimator, and try another fluoroscopy exposure.
 - iii. If at a lower mA setting, fluoroscopy is now ok, then try slowly advancing the mA knob during a test exposure. Watch the mA meter. Look for

instability, as this could indicate a gassy tube, or perhaps a high-tension fault. An 'over mA' fault may occur when mA reaches 6.0mA, but in some cases be as low as 4.0mA, depending on equipment design.

- iv. Some controls have no manual selection of mA; instead the value of mA is controlled by fluoroscopy kV. In this case, advance the kV control, as in part (v). Observe the mA meter for excessive mA or instability.
- v. If excessive mA is not the cause of the problem, then slowly advance the kV control. Again, watch the mA meter, looking for instability. Should a problem occur as kV is increased, this could indicate gas in the X-ray tube, or an arc where the high-tension cable-end enters the X-ray-tube receptacle. **See module 7.1 page 104, and module 7.3 page 117.**

c. No fluoroscopy exposure table, interlock checks

The fluoroscopy table can have a number of interlocks for radiation safety. Some of the possibilities discussed depend on individual table design, and may not be present in your table.

- Is the correct technique selected at the table?
 - i. For example, a remote controlled table may be in tomographic mode, or a collimator key switch may have been turned to manual operation.
 - ii. The table may have a separate fluoroscopic timer. Has this timed out?
 - iii. Some designs have a fluoroscopy-preparation switch. This must be pressed to place the table in operation, *after* selecting fluoroscopy operation at the X-ray control. (The switch has a fluoroscopy symbol.) With this system, the table is automatically deselected if the technique is changed at the control, and must be reselected each time prior to use.
- Are there any warning lights or fault codes displayed on the table? Refer to the operating manual, or contact the service department for further information.
- Is the image intensifier, or fluorescent screen correctly mounted, and not loose?
 - i. This especially applies if the image system is removed from the table, to park the serial-changer out of the way.
 - ii. The safety interlock is a small microswitch. The microswitch actuator may have become bent, or out of adjustment, when the image system was repositioned, or not operated if the image system clamps are loose.

- Is the serial-changer fully positioned in the operating position?
 - i. When the serial-changer is brought forward from the parked position to the operating position, a microswitch is operated, permitting fluoroscopy operation.
 - ii. Locate the position of this microswitch, and check if it has operated correctly. It may be possible to hear a small 'click' as the serial-changer is moved into position.
 - iii. Some designs uncouple the undertable tube carriage to allow parking of the serial-changer. As the serial-changer is brought forward, the tube carriage should lock back in position. Check to make sure this has happened. Again, a safety interlock microswitch needs to be operated. This microswitch may need adjustment.
- Is there a cassette incorrectly positioned?
 - i. For example, in the 'load/unload' position.
 - ii. Manually operated serial-changers have a microswitch, which prevents fluoroscopy unless the cassette carriage is fully retracted. For example, when the cassette carriage is brought to the radiography position, fluoroscopy is immediately switched off. Further movement operates another microswitch, which sends the preparation request to the X-ray control. Check the operation of these microswitches.
- Is the Bucky parked at the foot-end of the table?
 - i. This can apply to tables where a radiation shield covers the Bucky-slot when the Bucky is parked. Check the safety microswitch operated by this shield. It may be possible to hear a small 'click' as the shield is opened and closed.
- Some older tables were designed to enable the undertable tube to be used with a wall Bucky. These have a microswitch to ensure the tube is correctly positioned for fluoroscopy. This rarely has a problem, but should be checked.

d. No fluoroscopy exposure, table electrical checks

Note. Test procedures for fuses, switches, or wiring; are described in **module 5.0 page 65.**

- The footswitch is a common cause of failure. The connecting cable can have broken connections, either at the footswitch, or where it connects to the table. In addition, the cable itself may have a broken internal wire.
 - i. **Before removing any covers, or make any measurements, ensure all power is disconnected.**

- ii. With a multimeter set to the low ohms position, test the continuity of the cable and footswitch contacts. This test should be made where the cable enters the table.
- iii. With the footswitch operated, a low resistance reading of less than five ohms should be obtained.
- The connecting cables from the serial-changer to the table foot, or to the table serial-changer 'tower', may have broken or loose connections. This especially applies if the cables are pulled or stretched during operation. Broken internal wires in the cables can also occur. If suspect, the individual wires can be checked by measuring across both ends, in a similar fashion to the footswitch. **This procedure must only be attempted by an electrician or electronics technician.**
- Have there been any indications of rats? Some rats enjoy biting wires. This especially applies to the internal wiring of a table. Damage can appear similar to cutting wires with a pair of scissors.

e. *The X-ray control indicates fluoroscopy is operating, but no image*

On attempting fluoroscopy, the X-ray control indicates a fluoroscopic exposure is operating, and the mA meter indicates a normal value of mA.

- Has the TV been properly switched on and adjusted? **See module 9.1 page 135.**
- Is the collimator closed?
 - i. Try operating the collimator controls to the half open position.
 - ii. To ensure the collimator is in fact open, place a cassette face down on the tabletop. Make a one or two second fluoroscopy exposure, and process the film.
 - iii. If the film is blank, there can be a problem with the collimation control. Contact the service department for advice.
 - iv. If the film is exposed, there is a problem with the TV image system. **See module 9.1 page 135.**
- If operating under automatic regulation, change to manual operation. Check that a suitable value of mA and kV can be obtained. If mA is too low, there may be a poor filament connection at the cathode cable end into the X-ray receptacle. **See module 7.3 page 117.**

f. *No radiography exposure*

The safety interlocks and conditions that prevent fluoroscopy will also prevent radiography. So pro-

viding fluoroscopy operates correctly, we can consider the requirements of most interlocks satisfied. However, there are some additional requirements for radiography.

- Has the cassette has already been exposed? Try another cassette.
- Has a cassette of the correct size for the required format been inserted?
 - i. Try a different size cassette or format selection.
 - ii. If a different size cassette allows operation, there is either a problem with the internal recognition of the cassette size, or else the cassette is not compatible with the table. For example, trying to use an imperial dimension cassette, in a table designed for metric sized cassettes.
 - iii. Contact the service department for advice.
- Does the cassette move forward into the expose position? (This assumes a motor drive cassette carriage.)
 - i. Try ejecting and reinserting the cassette. If the cassette does not eject, it may have been incorrectly inserted, and fallen out of position. This can cause the carriage to become jammed.
 - ii. In case of a cassette jam, try lifting the cassette using a long **wooden or plastic** ruler. This may then allow the cassette to be driven out. Otherwise it will be necessary to gain access by either removing the serial-changer cover, or removing the image intensifier. **Make sure all power is switched off before removing the cover.**
- As the cassette moves forward into the expose position, does the X-ray control go into preparation mode, and then indicate 'ready for exposure'?
 - i. Check for normal operation of the X-ray control by a test exposure on the over-table tube.
 - ii. A hand operated cassette carriage operates a microswitch when it moves towards the expose position. This microswitch produces the preparation request for the X-ray control. There may be two microswitches close together. As the carriage moves forward, listen carefully for a 'click' from each microswitch. A small adjustment may be required to obtain correct actuation.
 - ii. Listen to the X-ray tube. Can you hear anode rotation on the preparation request? If not, check the stator cable for possible damage. For example, it may have been caught up in the undertable mechanism, or have a broken internal wire where it enters the serial-changer longitudinal carriage. Ask an electrician or electronics technician for assistance.

- iv. There may be a problem with the large focus. Try radiography on the fine focus. If preparation is now OK, there could be a poor filament connection with the cathode cable-end, in the X-ray tube receptacle. In this case affecting the large focus only. **See module 7.3 page 117.**
- The cassette has moved into the 'expose' position. The X-ray control indicates 'ready for exposure' however, an exposure cannot be made.
 - i. Check for normal operation of the X-ray control by a test exposure on the over-table tube.
 - ii. Some table designs prevent an exposure if the motorized cassette carriage has stopped outside the correct expose position. Try either a 'full format' exposure, or else a 'split' format exposure. If the change of format allows an exposure, the carriage drive requires adjustment. Contact the service department for advice.
 - iii. The serial-changer has additional 'close to film' shutters that are operated when selecting split formats. If these shutters are not in their correct position, this can cause prevent an exposure. This problem can occur with motor driven shutters after a cassette jam occurs, or due to lack of maintenance. Track lubrication is required.
 - iv. With a manually operated cassette carriage, a microswitch is operated when the carriage reaches the 'stop' position. On some tables this assembly can become loose and require adjustment. Before attempting any disassembly, contact the service department for advice.
 - v. See also 'No fluoroscopy exposure, table electrical checks' regarding the possibility of broken wires and rat damage etc.

g. Artefacts on the film

Film artefacts are due to several possibilities.

- The cassettes were incorrectly stored in the room, and have been subject to scattered radiation. Remember, one minute of fluoroscopy at 2.0mA and 110kV is equal to four 30mAs exposures at 110kV.
- Poor calibration of the automatic collimation can mean the X-ray field is much wider than the size required for fluoroscopy. This can allow radiation to penetrate the lead shield, designed to protect the film while the cassette is waiting in its 'garage' or parked position. This can cause intermittent bar patterns on the film, depending on the type of

examination, fluoroscopy kV levels, and exposure duration.

- i. To test, attach a 35 × 35 cm directly beneath the serial-changer. Apply a few seconds of fluoroscopy, then process the film
- ii. The fluoroscopy pattern on the film should be about 5–10% less than the stated diameter of the image intensifier.
- iii. A problem was experienced similar to the above with some earlier designs of remote controlled tables. In this case, it was possible to obtain fluoroscopy with the collimator key switch in the manual position. The problems disappeared after a design change, so that fluoroscopy was only permitted under automatic beam limitation.
- iv. Some models of fluoroscopy tables, although collimation **was** correct, still required additional lead shielding. For example, the problem was due to scatter. Discuss this possibility with the service department.
- Radio-opaque contrast solutions find their way into unusual places. Barium deposits are easy to see. Media used for an IVP is less easy to see. If in doubt clean all surfaces, including under the serial changer. Look also under the tabletop, and on top of the undertable tube collimator.
- Another cause can be wiring cables moved out of position under the tabletop. A frequent cause is due to the Bucky not parked fully at the table end.

h. Manual collimation has unwanted beam limitation

In many examinations, such as a barium swallow, the radiologist will desire to cone in horizontally to optimize the image. When the film is developed, it is found the top and bottom areas of the film are not exposed. This affect is due to the collimator field size required for fluoroscopy. For example, the X-ray field must not exceed the diameter of the image intensifier field of view.

Many later designs of tables have an added facility, called 'semi automatic collimation'. In this mode the lateral collimation remains in the position set during fluoroscopy, while the vertical collimation opens to the film size during radiography.

It is sometimes possible to convert an older table, depending on make and model, to also have semiautomatic collimation. Discuss this with your service department.

i. X-ray beam alignment is incorrect

- Remove the bottom table cover.
- Check if the collimator is loose on the X-ray tube.
- The X-ray beam is shifted to one side of the image. Lateral shift of the image.
 - i. In most cases, the tube may have shifted in the trunnion mounting rings.
 - ii. Release the trunnion ring clamp, rotate the tube position only a small amount and test again.
 - iii. The most critical position is with the spot film at maximum height from the tabletop.
 - iv. Check with the table horizontal and vertical. If necessary, a small adjustment between the two positions may be needed.
- The X-ray beam has shifted vertically.
 - i. In many cases the tube and trunnion assembly is mounted to the table via a 'spigot'. A bump or vibration of the table can cause this to rotate slightly.
 - ii. Locate the clamping screws for the spigot, undo them just a small amount. Then rotate the assembly so the beam is realigned. Tighten the screws, and re-check the alignment.
 - iii. Small changes in alignment are easily seen with the spot film at maximum height from the tabletop.
 - iv. Check with the table horizontal and vertical. If necessary, a compromise adjustment for the two positions may be required.
- If not able to adjust the X-ray tube position, or if not sure of the procedure to suit your table, contact the service department for advice.

j. Table movements do not operate

- Has an emergency stop switch been activated? The warning lamp may have failed. Some switch designs, once pushed in, require the knob to be rotated to release. Remote controlled tables can have two switches, one at the control desk, and the other at the table body. Check both switches.
- Is the vertical compression lock activated? As a safety precaution this can disable tabletop movements. In some alternate designs, the compression lock is automatically released when moving the tabletop.
- Has a patient protection device been operated? In some tables this is a light beam. Collisions with a patient trolley can cause this to be misaligned, or else there is dirt on the optical system. Look also for table drapes in the wrong position, which can block the light beam.

- The tabletop will only move in one direction. This usually means a limit switch has been operated. A common cause is a faulty microswitch. See also 'No fluoroscopy exposure, table electrical checks' in case of broken wires, or rat damage.
- Is there an open circuit fuse? Depending on table design, this may only affect one motor, or else a group of motors. *Always ensure power is turned off before checking or attempting a replacement. See module 5.0 page 65. If unsure, contact the service department for the fuse location, and to verify the correct rating and type.*
- The table will not tilt vertically.
 - i. If the table will not tilt in either direction, there may be an open circuit fuse. **Always ensure power is turned off, before checking or attempting to replace a fuse. See module 5.0 page 65.**
 - ii. The table may have reached its maximum angle in one direction, and be unable to return. (Perhaps it is in Trendelenburg position) This could be caused by operation of the anti-crash safety interlock. This may be a bar, or metal flap at the table end. This can be damaged and stick in the operated position. Some systems use a pressure mat on the floor. Look for an object trapped between the table base and the mat.

k. Table locks do not operate

- Has the compression lock been activated? Depending on the table design, this will release the serial-changer longitudinal and lateral locks.
- Is there a problem with the wiring? See 'No fluoroscopy exposure, table electrical checks' for possible broken wires and rat damage.
- The lock may have too large an air gap. With the power switched off, adjust the lock so this gap is at a minimum.
- A lock coil, or winding, may be open circuit.
 - i. **An electrician, or electronics technician, should test the lock coil.**
 - ii. Before testing, first ensure the lock activation switch is off. Then ensure all power is turned off.
 - iii. Disconnect one of the lock coil connections.
 - iv. With a multimeter set to medium ohms position, test the lock coil for continuity.
 - v. Depending on design, the lock coil should measure well below 20,000 ohms. If unsure of the typical value to expect, contact the service department.

MODULE 9.1

Fluoroscopy TV

Aim

The aim is to provide information and adjustment procedures, related to problems with a TV imaging system.

The basic TV imaging system consists of the image intensifier (II), the TV camera and monitor, with possibly a videocassette recorder (VCR). Systems with greater complexity, such as DSA and electronic radiography, are not included.

Older TV cameras use camera tubes such as 'Vidicon', 'Chalnicon', or similar device. Some adjustments for these cameras are included in this module. (**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be aware of common problems with the TV imaging system. This includes adjustments to the monitor, and tests to locate the cause of poor image quality. The VCR is included in these objectives.

Contents

- a. General precautions
 - b. No image on the TV monitor
 - c. The image is not sharp
 - d. The picture has no detail in bright areas
 - e. Is it possible to connect a VCR
 - f. The VCR recording is the wrong shape on another monitor
 - g. Is the image intensifier faulty
 - h. The image rotates as the fluoroscopy table is tilted
-

a. General precautions

Please take the following precautions.

- **Before testing any fuses, or removing a cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- *Do not attempt any internal adjustment of a TV monitor. Ask an electronics technician to assist if internal adjustment of a TV monitor is required. Dangerous voltages can exist for some time after the monitor is switched off.*
- The TV monitor may not use a standard power voltage. Damage to the monitor will occur, if connected to the wrong voltage.
- Test procedures for fuses, switches, or wiring; are described in **module 5.0 page 65**.
- If removing a cover, or dismantling any section, place the screws in a container to avoid loss.
- Current TV cameras now use a 'charge coupled device' (CCD) instead of a camera tube. CCD cameras have very good stability and reliability. Adjustments to a CCD camera are complex, and should only be attempted by a qualified technician.
- If in doubt of any adjustment described in this module, contact the service department before proceeding.

b. No image on the TV monitor

This most common help request to the service department can have a large variety of causes. Many are due to operator error. Whenever a request is made to the service department, accurate reporting of the problem will save time.

- Has the TV been properly turned on and adjusted?
 - i. Check the position of the brightness and contrast controls. Adjust the brightness control and check if the picture tube lights up.
 - ii. Some monitors have two video inputs. Check that the selection switch is in the right position.

- iii. Is a VCR fitted? This may not be switched on. Or, the video connecting cables have been wrongly connected. This occurs if the VCR was used at another location, and then returned.
- iv. If a VCR is fitted, this may be incorrectly set up. Check the input settings. To make a positive check, disconnect the VCR, and connect the video cable from the TV camera directly into the monitor.
- Is the image intensifier receiving a correct fluoroscopic exposure? For tests of the collimator, table interlocks, foot switch and generator, please see **module 9.0 page 130**.
- Check the video cable from the TV camera to the monitor. This cable is sometimes pulled partway out of its connector, disconnecting the centre wire, or else causing the connecting pin to pull out.
 - i. A quick test is to disconnect the video cable. In most cases, this will cause a change in the monitor brightness level.
 - ii. The above test can also indicate if a video signal is coming from the TV camera. For example, has the camera been switched on?
- For further tests, see 'Is the image intensifier faulty?'

c. *The image is not sharp*

Besides the possibility of poor 'system focus', this can also be caused by problems with the video cable, or a faulty picture tube.

System focus includes electronic focus of the image intensifier and TV camera, and optical focus of the TV camera. (A CCD camera does not have an electronic focus adjustment.)

Focus adjustments are sometimes attempted without checking for other reasons first. They are also attempted without a focus test tool, which makes it difficult to find the optimum position. Unfortunately, the focus adjustment is often the first adjustment that is 'fiddled' with.

Many image intensifiers have multiple adjustments; these must be carried out in the right sequence. For these reasons, always consult the service department first, before attempting any focus adjustments.

- Is the picture tube, or monitor, faulty?
 - i. The simplest test, if available, is to try another monitor in the same position.

- ii. Adjust the brightness control for a medium setting. Examine the picture tube closely. The scanning lines, or raster, should be clearly visible. In some monitor designs, a focus control may be available either from the front panel, or the rear of the monitor.
- iii. Does the monitor focus become blurred at medium brightness levels, but appears ok at a minimal brightness setting? This indicates a worn picture tube. Replacement is required.
- iv. Does the monitor take a long time to 'warm up'? For example, at first the available brightness is low, and brighter areas of an image merge together. This is an indication of low electron emission, from the picture tube cathode. Picture tube replacement is required.
- Is the 75ohm video-cable termination switch set correctly?
 - i. This is a common error. It is often found that if this switch is turned 'off', or unterminated; the picture appears brighter and has more contrast. However, in many cases this will cause a loss of fine detail. The correct position is 'on', or terminated; except when there are two or more monitors. In this case, monitors in the middle should have the termination switch turned off, while the last, or end, monitor has the termination switch turned on. (The final monitor will have only one video cable connection.)
 - ii. Has a 'T' connector been used to connect another monitor or VCR? This is incorrect, as proper termination of the video cable cannot be obtained, together with possible loss of fine detail.
- The video, or coaxial, cable has a woven metal shield under the first layer of insulation. This is connected to ground by the video connector. Is the shield pulled out from the connector? This can also give rise to interference patterns on the monitor, as well as a loss of picture sharpness.
- Is the TV camera electronic focus correct?
 - i. This does not apply to CCD cameras, and only to some cameras that have an accessible focus control. This adjustment is normally very stable.
 - ii. Contact the service department to locate the position of the focus adjustment.
 - iii. Tape a line-pair gauge directly under the serial changer, as close as possible to the image intensifier. If the gauge is not available, then use the 'focus aid' described in appendix B page 169.
 - iv. Set a minimum fluoroscopic kV and mA level, just sufficient to obtain a good image.
 - v. With fluoroscopy 'on', adjust the focus control for best results. This should be better than 12

LP/mm for a 9" image intensifier. (A typical result might be 14LP/mm with a CCD camera, and 16LP/mm with a vidicon camera.)

- Is the TV camera optical focus correct?
 - i. Optical focus is normally very stable, however sometimes the image intensifier moves a slight amount in the housing, or the camera tube and deflection assembly moves a small amount in the TV camera head.
 - ii. Older cameras may have a screwdriver operated focus control at the rear of the camera head. (This is sometimes 'fiddled' with.) In other cases it is necessary to remove a cover plate to obtain access to the lens.
 - iii. If directly adjusting the lens, first make a mark on the adjustment ring so the lens can be returned, if needed, to its previous position. In most cases, it is necessary to undo a 'locking' screw before an adjustment is possible. Some lenses also have an adjustable 'iris' Take care not to accidentally adjust this instead of the focus.
 - iv. Tape a line-pair gauge directly under the serial changer, as close as possible to the image intensifier. If the gauge is not available, then use the focus aid described in appendix B, page 169.
 - v. Set a minimum fluoroscopic kV and mA level, just sufficient to obtain a good image.
 - vi. With fluoroscopy 'on', adjust the lens focus for best results. Or adjust the focus control at the rear of the camera head with a screwdriver.
 - vii. This should be better than 12LP/mm for a 9" image intensifier. (A typical result might be 14 LP/mm with a CCD camera, and 16LP/mm with a vidicon camera.)
- Is the image intensifier focus correct?
 - i. Current image intensifiers have very stable focus adjustments. Older systems may occasionally require adjustment.
 - ii. If you have a multi-field, or dual-field image intensifier, check the resolution first on all fields. If all fields indicate poor resolution, this will indicate the problem is elsewhere, or else a component failure in the intensifier power supply.
 - iii. Older designs have a single external focus adjustment. This is a screwdriver adjustment, positioned towards the top of the image intensifier. *Do not attempt adjustment of the image intensifier focus, if there is more than one adjustment. In this case, contact the service department for advice.*
 - iv. Tape a line-pair gauge directly under the serial changer, as close as possible to the image inten-

sifier. If the gauge is not available, then use the focus aid described in appendix B page 169.

- v. Set a minimum fluoroscopic kV and mA level, just sufficient to obtain a good image.
- vi. With fluoroscopy 'on', adjust the image intensifier for best focus.
- vii. The combined TV and II focus should be better than 12LP/mm for a 9" image intensifier. (A typical result might be 14LP/mm with a CCD camera, and 16LP/mm with a 'vidicon' camera.)

d. The picture has no detail in bright areas

- Is the automatic fluoroscopy system set at too high a level?
 - i. Change over to manual operation, select a lower kV or mA and observe if this corrects the problem.
 - ii. If there is now a good image, remain on manual operation, and contact the service department to have the automatic fluoroscopy system adjusted.
- Is the TV monitor correctly adjusted? If the monitor contrast is set too high, in some monitors this will cause bright parts of the image to merge together, or to appear 'flat'. In other cases, an overbright image will appear smeared, or wiped, horizontally across the picture tube.
- Does the monitor take a long time to 'warm up'? For example, at first the available brightness is low, and brighter areas of an image merge together. This is an indication of low electron emission. Picture tube replacement is required.
- TV cameras that use a camera tube instead of a CCD have a 'beam current adjustment'.
 - i. If beam current is low, bright areas of the image lack contrast and merge together. If beam current is too low, the image will just appear white, with no detail. In this case, the image may become clear for a very short time, immediately after fluoroscopy is switched off.
 - ii. If beam current is too high, this will result in poor image quality and reduced focus.
 - iii. Beam current is a common adjustment for older TV cameras. Contact the service department to locate the position of this adjustment, and any required precautions before adjusting. Ask an electronics technician to make this adjustment.

e. Is it possible to connect a VCR?

- The videocassette recorder (VCR) must operate to the same scanning format as your imaging system.

In most cases, the X-ray TV system will use the same standard as domestic TV, allowing a domestic VCR to be used.

- i. A 525 line, 60hz system requires a NTSC compatible VCR
 - ii. A 625 line, 50hz system requires a PAL compatible VCR.
- In case your imaging system operates at a higher line rate, such as 1049 or 1249 lines, then connecting a VCR is not possible, unless there is an alternate output from the TV camera, at the standard line rate.
 - Playback of a recording will be the same aspect ratio used by the X-ray TV camera and monitor. The standard aspect ratio is 4:3, however, some systems, including CCD cameras, use a 1:1 aspect ratio. If a recording is played back on a monitor adjusted for a 4:3 aspect ratio, the image will be stretched horizontally, and appear 'egg shaped'
 - The VCR must have direct video input and output connections. A simple installation connects the video lead from the TV camera to the video input of the VCR, and the VCR video output to the monitor. In most cases, this will require the VCR to be always switched on during fluoroscopy.

f. The VCR recording is the wrong shape on another monitor

This is a common complaint when the recording is made from an X-ray TV using a 1:1 aspect ratio, instead of the domestic 4:3 aspect ratio.

- To see if the system is adjusted for a 1:1 aspect ratio, adjust the monitor brightness so the scanning lines, or raster, is clearly visible. A 4:3 aspect ratio will show scanning lines extended fully across the screen, while a 1:1 aspect ratio will show a small blank area at both sides of the picture tube.
- Apart from systems deliberately set to a 1:1 aspect ratio for a CCD TV camera, it is possible the TV camera and monitor is incorrectly adjusted.
 - i. For example, if the original size and shape of the image from the camera was incorrectly adjusted, and then the monitor was adjusted to give the required size and shape.
 - ii. This is an incorrect set-up, as the monitor should first be adjusted to the required aspect ratio and size, then finally the TV camera adjusted to suit the monitor.
 - iii. Fortunately, in most cases the TV camera and monitor can be realigned for use with other monitors. This possibility should be discussed with your service department.

- iv. **Note.** This adjustment is not available if a CCD camera is used.

g. Is the image intensifier faulty?

There is no X-ray image on the monitor. The monitor adjustments appear correct, and the X-ray control indicates a normal fluoroscopic exposure.

- Is radiation entering the image intensifier?
 - i. Is the collimator closed? The collimator may have a fault.
 - ii. Place a cassette on the table, underneath the image intensifier.
 - iii. Make a 2~3 second fluoroscopy exposure, and develop the film.
 - iv. The film should be very dark.
 - v. If the film is unexposed, the collimator could have a fault. Contact the service department for advice.
- Is the TV camera faulty?
 - i. Check the camera is switched on, and the video cable is not disconnected or damaged.
 - ii. **The following test should only be performed on advice from the service department.**
 - iii. Remove the TV camera from the image intensifier. Switch on the camera power. Point the camera around the room, but do **not** aim the camera at any bright light. An 'off focus' image should be obtained of objects in the room.
 - iv. Some systems, especially those with 'last image hold', will require fluoroscopy to be 'on' during the above test. First ensure the collimator is closed, and the fluoroscopy kV is adjusted to its lowest setting.
- There is a flickering background illumination, even without fluoroscopy.
 - i. This is a possible electrical discharge or instability in the image intensifier.
 - ii. With a dual or multi-field intensifier, selecting another field size can alter the appearance of this illumination. This indicates a fault in the image intensifier, or image intensifier power supply. If the image intensifier loses focus on selecting a different field size, the power supply is faulty.
 - iii. **The following test should only be performed on advice, and instructions, from the service department.**
 - iv. Remove the TV camera. Cover the camera lens.
 - v. Switch the power back on.
 - vi. Close the fluoroscopy collimator. **Do not** make a fluoroscopy exposure.

- vii. Turn off the room lights. Now look directly into the image intensifier lens.
- viii. If any 'glow' pattern is observed, the image intensifier is faulty.
- ix. Repeat this test for each image intensifier field size.
- The image has a bright central area during fluoroscopy.
 - i. This is an indication of 'gas' inside the image intensifier. This may occur if the image intensifier has not been used for some time. In this case, leave the system switched on overnight, and test again next day.
 - ii. To test, place a piece of lead, of about one third of the image intensifier diameter, up against the serial changer. Position the lead test piece in the middle of the image. This prevents radiation entering the centre of the image intensifier.
 - iii. With fluoroscopy 'on', the area covered by the lead should show very little illumination. If there is gas, this will be seen as a bright area in the centre, where radiation is blocked by the lead test piece. The Image intensifier will need replacement.
- Is the image intensifier 'worn out'? This is a common question with older systems, especially if there is poor penetration with a 'noisy' or 'snowy' image.
 - i. The conversion gain of an image intensifier drops with age as well as use. However in most cases, adjusting the lens aperture on the TV camera can compensate for reduced brightness.
 - ii. A measurement is made of the radiation value, required to produce a standard video level, from the TV camera.
 - iii. The radiation is set to the required value, and the lens iris is adjusted to obtain the required video level. If the required video level is not obtained, then the image intensifier may need replacement.
 - iv. Before replacing the image intensifier, the TV camera should also be checked.
 - v. This applies if the TV camera uses a 'Vidicon' camera tube. The 'target' voltage may need adjustment.
 - vi. The above test and adjustment should be requested from your service department before considering a replacement system.

h. The image rotates as the fluoroscopy table is tilted

This affect is caused by an interaction with the earth's magnetic field. It depends not only on the local field strength inside the hospital, but also the orientation as the table is tilted.

Standard image intensifiers have a magnetic shield in the housing to reduce this effect. However they are not shielded at the entrance plane. (This is where the X-ray radiation enters the II.)

Image intensifiers intended for high performance digital image systems might be fitted with a 'Mu-Metal' magnetic shield, to cover the entrance plane into the II. While this virtually eliminates the rotation problem, the added filtration reduces the conversion efficiency of the image intensifier.

MODULE 10.0

Automatic exposure control (AEC)

Aim

The aim is to provide a series of tests for an automatic exposure control (AEC). These tests are aimed at determining whether there is a problem due to the AEC, or caused by other reasons.

Objectives

A correctly installed and adjusted AEC can produce excellent results. However, correct use of the system is still required to obtain the desired performance. On completion of this module, the student will be aware of AEC operation requirements, and will be able to perform basic tests for the AEC performance. These tests will provide important information when requesting advice, or else attendance by the service department.

Contents

- a. AEC operation precautions
 - b. AEC film density test
 - c. AEC incorrect operation
 - d. When a request is made for service
-

a. AEC operation precautions

- Incorrect selection of a technique not covered by AEC operation.
For example:
The wall Bucky may be fitted with a selection of three separate measuring fields or chambers, while the table Bucky has a central field only. Good design of an AEC should prevent selection of an incorrect field. Unfortunately, some AEC systems, in particular those fitted outside the X-ray control as an accessory, may allow selection of an invalid field position.
- Some AEC systems have a 'film sensitivity' control in addition to the film density control. While this gives greater flexibility, the film sensitivity control is often never used. Instead it is left at a standard setting.
 - i. The use of the film sensitivity selection control can be forgotten. This includes the original setting. If the setting position is accidentally changed, then a sudden large change in film density occurs. This results in an unnecessary service call.
 - ii. In some cases, due to bad calibration, the film sensitivity control may need to be reset when changing from the table Bucky to the vertical Bucky. This can easily result in operator error, and should be corrected wherever possible.
- X-ray output for the exposure is too low. For example, too low a kV, or insufficient mAs. In this situation, the generator timer terminates the exposure, and not the AEC. A light film results.
 - i. The AEC system, depending on design, may prevent further exposures until a 'reset' button is pressed. There may be only a small indicator lamp to indicate this condition, which is sometimes overlooked.
 - ii. Other AEC systems may provide a short audible signal. In some cases this is for only a few seconds, and is easily ignored. As a result another radiograph is made without adjusting

the exposure setting. A complaint is made about 'occasional light films'

- X-ray output is too high. As a result the AEC cannot terminate the exposure quickly enough.
 - i. The 'minimum switch-off time' is more of a problem on older single or three-phase generators; especially those fitted with mechanical exposure contactors. This can cause unreliable results if AEC exposure times below 0.02–0.03 seconds are attempted.
 - ii. Modern high-frequency systems are able to respond quickly to the AEC exposure-stop signal, so this is not a problem. However it is still good practise to keep exposure times above 0.005 seconds. This is due to the energy stored in the HT cable, which will slightly extend the actual exposure time.
 - iii. If AEC exposure times are close to the minimum switch-off time, reduce kV or mA for the next exposure.
- Selection of a less optimum chamber. For example, use of a chamber centred behind the spine, instead of the left or right chambers for a chest or lung exposure.
- Combining two or more chambers. This depends on the method of AEC operation. While the systems appear similar, they can deliver different results.
 - i. In one system, the chambers are combined together, and the **average** output of the chambers controls the exposure.
 - ii. In the other system, each chamber has separate control of the exposure. When chambers are combined, only the chamber receiving the **higher level of radiation** controls the exposure. (This is called the 'OR' technique by one manufacturer)
- Incorrect collimation. If collimating to a smaller area, part of the measuring chamber is also coned off. A dark exposure results.
- Bad patient positioning. In this case, radiation passes through a relatively thin portion of the anatomy, compared to the main item of interest. In some cases, the measuring chamber may receive a portion of direct radiation. In either case a light exposure will result.
- The AEC chambers are sensitive to soft, or scattered, radiation.

Although the grid removes most of this radiation, the remainder still has an effect on the exposure. In addition, with the chamber in front of the cassette, this soft radiation is filtered from entering the cassette.

- i. The AEC is calibrated for a patient to be positioned against the Bucky. If there is an air gap, this reduces the amount of soft radiation entering the chamber, and the film becomes darker.
 - ii. The above problem is much greater if there is no grid in front of the AEC chamber.
 - iii. An extreme example is found on older fluoroscopic tables that have the chamber mounted in front, instead of behind the grid. In this case, an air gap of only about 6 cm may double the exposure time. The doctor should keep the spot film close to the patient at all times, while using the AEC.
- In case the cassettes, film, or intensifying screens are changed, the AEC will need recalibration.

b. AEC film density test

The AEC calibration may require calibration, or there may be a fault.

This test allows the performance to be verified, and indicate if an individual chamber has a problem.

- A test phantom is required. This can be a plastic bucket with water, or else a large flat-sided plastic bottle. An empty plastic container used for bulk detergent is ideal.
- Place a plastic bucket filled with water to a height of 18 cm on the tabletop, positioned over the middle of the Bucky.
- Place a 24/30 cm cassette in the Bucky. Set X-ray tube height to 100 cm.
- Select exposure factors of 90 kV, 100–250 mA, and backup time of 0.5 sec. (Some X-ray controls allow kV adjustment only, mA and backup time is automatically set by the AEC)
- Select the AEC central chamber only. Set the density control to the middle, or '0' position.
- Make a radiographic exposure. Note the actual exposure time, or alternately the mAs value. This depends on the meter indications provided.
- In case a warning signal indicates an incorrect exposure, reduce the level of water to about 10 cm. If the next exposure still indicates a problem, stop testing that chamber. Contact the service department for advice.
- Process the film. Film density should be in the region of 1.4 to 1.6. If a densitometer is not available, compare the film density to a previously exposed reference film. (The actual value of film density often depends on individual doctor preferences.)

- For under-table Bucky's fitted with three fields, repeat the above test for each chamber. Adjust the phantom so it is positioned above the selected chamber.
- A similar exposure time and film density should be obtained with each chamber. In case there is a difference, expose another film, after adjusting the density control by one step. If more than one step is required to obtain a similar density, then calibration of individual chambers is out of tolerance.
- If any chambers fail this test, do not use that chamber until the problem is corrected. Contact the service department; advise them of the problem, and the tests carried out

A similar test can be applied to the vertical Bucky. A flat-sided plastic container with water is required. If an empty bulk detergent container is not available, then two empty fixer or processor bottles can be used, placing them side by side. Rinse the bottles before filling with water.

c. AEC incorrect operation

These tests are only provided as a general guide. This is due to the great variety of AEC systems in use, most of which require specialized instructions and test equipment for calibration or service.

- The AEC exposures produce light films, and are not consistent.
 - i. The AEC can be affected by humidity, or by light leaking into a photomultiplier system. This is a test for stability during a long exposure time.
 - ii. Set exposure factors for minimum mA and kV. Set the backup exposure time to 5.0 seconds. For those systems that provide adjustment of kV only, set kV to minimum, and select fine focus.
 - iii. Set the density control to minimum density. Select the centre chamber.
 - iv. Close the collimator, and aim the X-ray tube away from the Bucky under test.
 - v. Leave all room lights fully ON.
 - vi. Perform a radiographic exposure. The AEC should indicate the maximum exposure time was reached, and the exposure was not terminated by the AEC.
 - vii. Repeat this test for each chamber in the Bucky or spot filmer under test. Caution; as these are large test exposures, allow cooling time between exposures.
 - viii. Does a chamber fail this test?
 - ix. Test again, this time with the room lights turned off. If the AEC now gives a longer test

exposure, this is a system using photomultipliers, and external light is leaking into the AEC chamber or photomultiplier assembly.

- x. Examine the front edge of the chamber assembly carefully. Cassettes may have hit it, when they were placed in the Bucky. This can damage the chamber, allowing external light to enter. Cover the damaged area with metal foil, and test the chamber again.
 - xi. Many AEC systems use ionization chambers to measure radiation. Older versions were sensitive to humidity. Design changes overcame this problem. Contact the manufacturers service department, in case there is a design modification to upgrade your unit.
 - xii. If any chambers fail this test, do not use that chamber until the problem is corrected. Contact the service department; advise them of the problem, and the tests carried out.
- One or more chambers have stopped working.
 - i. Check the condition of the connecting cable. This especially applies in fixed installations where the cable passes through ducts etc. Some varieties of rats appear to like chewing on small wires.
 - ii. On a mobile system, check inside the connecting plug for possible broken connections.
 - The film density has changed. It is necessary to adjust the density control several steps to compensate.
 - i. Is a similar change of density setting required for both the wall Bucky and the table Bucky? This may be due to the processor instead of the AEC. Check the processor for possible problems with chemicals or temperature.
 - ii. Has the problem occurred after a new batch of film? The new film may have a different sensitivity. The AEC will require recalibration.
 - iii. Were the intensifying screens changed? The AEC will require recalibration.
 - For further assistance, contact the service department. If an electronics technician is available, the technician can carry out further tests after obtaining advice from the service department. This would be specific to the make and model of the AEC requiring attention.

d. When a request is made for service

- After carrying out the maintenance tests for the AEC, problem areas may be located.
 - i. Retain all test films, and document the conditions of test. This includes mA station, kV, FFD,

- depth of water phantom, and indicated exposure time.
- ii. Test films made with anatomical test objects may be very interesting. However, testing with a water phantom produces the most consistent results, and allows direct comparison with previous tests.
- When an AEC system has been in use for a while, it may be found that the density control has to be adjusted for different examinations. While it is a simple matter to have service recalibrate the system to “0” density setting, the following information can indicate if attention is also required to kV tracking, or short time compensation.
 - i. The type of patient examination.
 - ii. The chamber in use, and the density setting in use for that chamber.
 - iii. Does density setting have to be changed on chamber selection?
 - iv. Does density have to be changed depending on kV used?
 - v. The kV and mA values used. Or kV and focal spot if mA is not selected manually.
 - vi. The indicated exposure time obtained after an exposure.
 - **Be aware that some apparent AEC problems are due instead to film processor drift. Before requesting service for the AEC, ensure the processor performance has been checked.**

