PART II

Routine maintenance modules

MODULE 1.0

Routine maintenance overview

Aim

The aim is to provide an overview of routine maintenance requirements. This includes requirements to commence, or carry out, a routine maintenance programme.

Objectives

On completion of the routine maintenance modules, the student will have developed knowledge and skills to apply a practical maintenance programme for X-ray equipment. This includes keeping proper records of tests, and ensuring all documents and required manuals are available.

Task-1 'Maintenance survey for an X-ray room' should be performed on completion of this module.

Contents

a. What is 'routine maintenance'?

Routine maintenance is a procedure to ensure equipment is kept in good condition, and provide a long operating life. Routine maintenance may also discover potential problems, which could cause equipment failure. Potential problems can then be corrected, with a minimum of down time. 'Quality control' procedures, to ensure correct operation and calibration, are also a part of routine maintenance.

Carrying out routine maintenance produces good knowledge of the equipment, and in case of a problem, this knowledge will help to locate the cause. Where there is a more serious problem, accurate reporting for assistance will allow faster and more economic response. **For example, the service engineer can then arrive with suitable parts and test equipment.**

A major part of routine maintenance is just inspection of equipment. This should be done as if seeing the equipment for the first time. At the same time, make note of less understood operation areas, and refer to the operation manual for explanation.

This is also an opportunity to correct any 'legacy' problems. As an example of a legacy problem, a generator might have a notice, 'Do not use fine focus'. This notice may have been there for some time. And, due to staff movements, the reason is not known. As part of maintenance, this long accepted problem should be investigated. It could be an X-ray tube that has a failed fine focus. (Then the tube should be replaced) But more often, this might have been due to some other problem, or even operator error. So, although a note was attached, no action was taken to correct the problem, or to investigate further. Sometimes a part is required, but the service provider has forgotten to come back with this part. In which case routine maintenance inspection ensures that:

- The nature of the problem is properly investigated and documented.
- If needed, a 'follow up' reminder is sent to the service provider.

b. Who should carry out routine maintenance?

This depends on the size of the department, and available staff. In a district hospital, which has just one radiographer, then perhaps that radiographer is 'it'. However, external assistance should be made available if required, for example, assistance provided by an electrician.

When the department has a number of staff, one member should be selected as maintenance co-ordinator. Other staff members may be allocated specific areas or items of equipment to be checked. Where possible, these duties should be rotated. This allows all staff to become familiar with the equipment.

In some hospitals, an electronics technician may be available. But, as the technician does not use the equipment, problems may go undiscovered. For this reason a staff member needs to assist the electronics technician, during maintenance or repairs.

c. Objections to routine maintenance

Existing staff may regard routine maintenance as an unwanted extra duty. This list provides answers for possible objections.

- This is boring.
  Yes, it can be. But even more boring, or frustrating, is using equipment that does not function correctly.
- This is not my responsibility.
  Even when a specific member of staff **does** carry out a comprehensive maintenance programme, your own input will be appreciated. This can be as simple as reporting a problem area, to taking direct action. For example, tighten that loose screw on a Bucky tray handle, before the handle falls off.
- The department is kept very busy. There is no spare time.
  And to make matters worse, you have to use equipment that does not operate correctly. A maintenance programme does not have to take the room out of action. Instead, just one section at a time can be checked. This may take only ten minutes for each section. After the reported problem areas have been fixed, the room will become more efficient.
- The hospital has a paid routine maintenance contract with an X-ray service company. This is carried out every six months.
  You are lucky. However you still need to carry out an inspection to ensure the service is completed as required. A service technician may find a problem, which requires immediate attention. This reduces the time available for the remainder of the maintenance. As a result, some areas are not checked. Your own inspection, together with suitable record keeping, will help ensure contract service is carried out correctly.

d. How often should maintenance be carried out?

- Equipment in heavy use, for example a mobile travelling to different parts of the hospital, should be checked every four months.
- Other equipment, such as a Bucky or Fluoroscopy room, every six months.
- However, in many respects, maintenance in the form of **observation** is a continuous process. If a minor problem occurs, always enter this in the logbook, so it **will** receive attention during the next opportunity.

e. Typical objectives of routine maintenance

- A complete operation and function inspection, list any incorrect operation or area requiring further attention.
- By means of prepared checklists, ensure all required areas are covered. The results are to be retained in a suitable folder. Any problems or areas requiring further attention are entered in the logbook.
- When a problem is located, if this is minor, correct the problem immediately. In case of a larger problem, still attempt to complete the rest of the routine maintenance, while waiting to have the specific problem corrected.
- In case of a specific problem outside local resource to immediately correct, and then request an electrician, or the service department, for assistance. If such a problem is found, be sure to file a report and enter specific details in the logbook.
- Inspection of all electrical plugs, cables, and other electrical connections.
- A full mechanical inspection, adjustment and lubrication as required.
- Tests for calibration of equipment. This may also be part of a quality control programme.
- Cleaning of equipment. Remove pieces of sticky tape, old sticking plaster marks etc.

f. Familiarization of equipment

With much equipment there is often a legacy of misunderstanding. As a result many functions may be ignored or incorrectly interpreted.

Common reasons are:

- The operation manual has been lost. Or is only referred to as a last resort.

- Replacement staff may be incorrectly instructed in the use of the equipment. This legacy tends to be passed on.
- A pre-existing fault is accepted as part of the normal operation of the equipment, and possible correction is ignored.
- The equipment was modified to interface with a non standard system. As a result, some controls are different to those described in the operation manual.
- Where there are any specific limitations or precautions, these should be listed in the logbook. This will assist any replacement staff. This information should also be shown to the service technician

During routine maintenance, you should attempt to be familiar with ***all*** operation modes of your equipment. This includes.

- Indicator lights. When do they light up? What do they mean?
- Audible signals. When do they occur? What is the reason?
- During preparation, or an exposure, do you hear a contactor or relay operating?
- What is the normal sound produced by the X-ray tube anode, during preparation?
- What sound does the Bucky make during an exposure?
- Meters or indicators can display different readings depending on the generator operation. For example, a meter might first display a percentage of X-ray tube load, then display the mAs obtained after an exposure.

g. Routine maintenance programme

To commence a routine maintenance programme, the following is suggested.

- Where a quality control programme is to be established, ensure that all required procedures for routine maintenance are properly documented.
- Make a list of replacement parts or materials that may be required.
- Suitable tools. A list of suggested tools is provided in appendix 'B' page 169.
- Test tools. Simple test tools that may be constructed are also described in appendix 'B' page 169.
- Be familiar with all operation modes of the equipment to be maintained. (Study the operation manual).
- Allocation of a specified time period to carry out maintenance. This will depend on the patient workload, and will need to be flexible.
- Record keeping.
  i. A separate logbook should be kept for each room of equipment. In the case of mobile or portable equipment, an individual logbook should be kept for each unit. This may be in the form of a loose-leaf binder, and allow insertion of checklists as maintenance is carried out.
  ii. A sample logbook page is provided in appendix 'C' page 177.
  iii. Proper identification of all equipment is required. This includes make, model and serial number, date of installation, and any special features, such as a high-speed starter option or AEC. This information should be entered into the logbook.
  iv. An individual checklist for each item of equipment helps ensure all-important areas are covered. External contractors may also use these lists to assist correct service. Completed checklists, together with service job sheets, should be kept in a master file, or logbook, for each X-ray room. This provides quick reference for future service, or else a previous problem.
  v. Sample checklists are provided in appendix 'D' page 186.
  vi. If an additional repair or service is required, mark this for attention in the logbook. Otherwise, if there is a long delay, the repair or service might be forgotten.
- Equipment manuals.
  Manuals need to be kept in a safe designated area. If manuals are lost or stolen, then every effort should be made to obtain a replacement. **Manual title and publication numbers should be recorded in the logbook.** Depending on the manufacturer, manuals may be presented in many different formats. Some may be in separate folders, while other manufacturers may combine all in the one folder. Typical manuals, which should be available, are listed below.
  i. Operation.
  ii. Specification.
  iii. Parts list.
  iv. Installation, including calibration procedures.
  v. Data sheets for the X-ray tube.
  vi. Service. (*)
  vii. Circuits or connection diagrams.
  viii. Technical explanation of operation. (*)
  ix. (*) Indicates these manuals might be restricted to a service department, or available only on request.
- In some countries, the equipment supplier is required to supply two complete sets of all manuals

originally supplied with the equipment. One set is kept in the X-ray department, and the other retained by the government purchase authority. This provides a backup copy in case of lost or damaged manuals.
- As some information in the manuals can be confidential, manuals need to be kept in a safe place, and restricted to authorized use only.

h. Keeping a logbook

- The logbook may be of any convenient construction.
- The logbook should not confine entries to a single line. Leave space to provide full details.
- If additional columns are required, the logbook may also cover the opposite page.
- The logbook need not be hard bound, but instead be a collection of report sheets kept in an 'insert' folder. This can include the checklists, produced after routine maintenance. Coloured dividers can separate each section.
- A single logbook can contain all the required information for an X-ray room. A separate logbook should be kept for a mobile generator, or a portable system.
- The front page of the logbook should include all details of the equipment, (Make, model, serial No. etc.)
- The logbook should also contain a list of all equipment manuals. This should include any reference numbers, to facilitate re-ordering of lost or damaged manuals.

i. Routine maintenance modules

The modules are for routine maintenance of equipment. Due to the diversity of equipment that may be in use, from very old to the latest technology, not all of the suggestions will apply to your system.

The maintenance modules are designed as individual units, however some cross-reference is required. The reference module name, and title-page number, is indicated in the text as required.

A sample routine maintenance checklist for each module is provided in appendix 'D' page 186.

The equipment covered in the maintenance modules includes the following.

- X-ray generator, fixed installation.
- X-ray generator, mobile unit.
- X-ray generator, capacitor discharge.
- X-ray generator, portable system.
- X-ray tube stand.
- X-ray tube.
- Collimator.
- The Bucky table and vertical Bucky.
- Tomography attachment.
- Fluoroscopy table.
- Fluoroscopy TV systems.
- Automatic film processor.

Data	Requirement	Response	Performedly	Reference No
24-12-02	Routine maintenance of tube stand	Carried out by staff	John Bell	Report no 75
2-2-03	Tube stand has failed bearing	Request attention by X-ray service ltd	X-ray service	Job No X2203
4/2/03	Collimator lamps required	Ordered 3 from Osram supplies	Jean Wells	Order No 45963
10-4-03	No exposure	See service request form. Unit out of action waiting handswitch	John bell	Order No 45964
14/4/03	New handswitch	Fitted new handswitch	John Bell	Report No 76

Fig 1–1. A typical logbook page

TASK 1

Maintenance survey for an X-ray room

You are required to make a basic maintenance survey of a general purpose Bucky room. This may be a room in a different hospital, OR, it may be a room with which you are fully familiar.

The hospital administration has offered to have all defects rectified, but first requires a quick report; a more detailed report can be supplied later.

When making this survey, look for minor defects as well as those affecting performance.

X-ray control:

Tube stand:

X-ray tube and collimator:

Bucky table and Bucky:

Wall Bucky:

Condition of the room and accessories: Suggestions to make this an efficient environment, and aid patient management.

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____ Date _____

Tutor

MODULE 1.1

X-ray generator, fixed installation

Aim

The aim is to provide information and procedures for routine maintenance of an X-ray generator, installed as a fixed installation in an X-ray department. Maintenance for the X-ray tube is provided in module 2.1 page 48. Instructions for generator repairs are provided in module 6.0 page 71.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance procedures for the X-ray generator. These procedures can also be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Tasks 2, 3, 4, and 5 should be attempted on completion of this module.

Contents

Equipment required

- Basic tool kit.
- Stepwedge.*
- 24/30 cm Cassette.
- Two pieces of lead rubber.
- Aerosol spray lubricant.
- Cleaning solvent.
- Cloth.

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

a. Safety precautions

Before removing any covers, ensure the generator is switched off, and the room power-isolation switch is also turned off.

b. Visual inspection of the control desk, power off

- Check all knobs and switches. Where knobs have a pointer attached, check that the pointer aligns correctly at all positions of the indicated scale. **Tip.** Check the pointer at full clockwise and counter clockwise positions of the knob. Look for possible loose knobs, or for push button switches that might tend to stick.
- If controls have had extra labels attached, are these labels still required? If so, are they in good condition?
- Older X-ray controls often have analogue meters instead of digital displays.
  i. With power switched off, the meter needle should be pointing at the 'zero' calibration mark.
  ii. Most meters have a small adjustment screw for zero calibration. If adjusting, first tap gently in case the meter tends to 'stick'.
  iii. **Caution. Contact the service department before adjusting.** In some cases, the meter may be deliberately adjusted 'off zero', as an incorrect method of calibration.

c. Operational inspection of the control desk, power on

- Check all indicator lamps. If necessary, operate different selection techniques to ensure all indicators operate correctly. In particular, pay attention to the following. (Depending on make or model, some of these indicators may not be available).
  i. Small focus / broad focus selection indication. On some controls, the mA selection switches

control selection of the focal spot. Other controls can have a separate focal spot selection switch.

ii. X-ray tube number, or position. This should be linked to technique selection. Some controls may also indicate the actual fine and broad focus size.

iii. X-ray tube overload protection. Select high pre-exposure factors, and check operation of the overload light. (On some controls with a microprocessor, the system might not allow selection of excessive output.)

iv. Automatic Exposure Control (AEC), or Phototimer. When this option is fitted, check that all chamber and station selection indicators operate correctly.

v. **Note.** On older systems, it may be possible to select an AEC chamber or station combination that is not available. In that case ensure a notice is fitted, to warn against incorrect operation.

vi. Illumination of kV, mA, and time selection. Where a digital readout of selected values is provided, select a number of different values to ensure there are no display errors, or missing segments of the display.

- Older controls may have manual adjustment of power line voltage, with a meter to indicate correct compensation. Check the range of adjustment. It should be possible to reset the voltage by 10%, above, or below, the required voltage.

d. X-ray tube overload protection

Note. Reference to X-ray tube rating charts is required for this section.

Tip. You may select specific values from the chart, and record them separately on a check sheet. This will save time in the future.

- Maximum radiographic kV.
  i. Select a short exposure time, and a low mA station. Increase kV setting till the exposure-prevention, or inhibit, light operates.
  ii. The maximum available kV should not exceed the specified kV for the particular X-ray tube.
  iii. In some cases, the available kV limit may be 10% less than the possible maximum. For example, a 150 kVp tube may be limited to 140 kVp. This is a safety precaution, as 150 kV is the maximum limit only when the tube is in excellent condition.
- Minimum radiographic kV. This will often be set at 40 kV, depending on individual country regulations. Variations will exist where an interlock at the collimator is provided for different filters.
  i. Select a low mA station and a short exposure time. Adjust kV towards the minimum available value. An exposure inhibit should occur if kV is too low.
  ii. Repeat this test for systems that have a removable filter in the collimator. In this case, with the filter removed, an exposure inhibit should occur as kV is increased. (Depending on the system, this may be above 60 kV.)
  iii. **Note.** Although the collimator will have the required minimum filtration for full operation, an additional filter, typically 0.5 mm, may be inserted. This is an option, and does not require an interlock.
  iv. On older generators, especially those with 'stud', or switch selection, and pre-reading kV meters, it may be possible to set kV below the safety requirement. Where this can occur, provide a warning notice, and contact the service provider in case an upgrade is available.
- Minimum kV for filament over-heat protection. Refer to the rating charts, to see if a particular combination of high mA and low kV should be avoided. This is to avoid overheating the filament during preparation.
  i. Select the maximum available mA station and a short exposure time. Reduce kV towards the minimum kV available. Either the kV will not be permitted to extend below the minimum specified value, or else should cause an exposure inhibit to operate.
  ii. As an example, the minimum kV with 500 mA selected may be 55 kV, while if 400 mA is selected, the minimum kV might extend down to 45 kV.
  iii. Repeat for both focal spots.
  iv. **Note.** This protection may not be available on older X-ray controls. If a combination of high mA and low kV is possible, provide a warning notice. In some cases, an upgrade may be available from your service provider. In other cases, a re-allocation of available mA stations may be available.
- Anode maximum heat load. This is the maximum instantaneous heat input to the anode.
  Note. The X-ray tube rating charts assume a cold anode. For this reason, some X-ray controls de-rate the maximum output. This allows for anode heat produced by previous exposures.

For example, on over-table operation, output may be limited to 95% of maximum, while with a fluoroscopy table, this limit be reduced to around 70~80% of maximum output.

i. Select the appropriate anode-rating chart for the X-ray tube in use.
   The anode speed is normally controlled by the power frequency.
   Take care to select between 50 or 60 hz for low-speed operation, or between 150 or 180 hz for high-speed operation.
ii. In addition to anode speed, select either single or three phase operation, depending on the type of generator.
iii. If you have a high frequency generator, select the three-phase chart. This will still apply if the generator is supplied by single-phase mains power.
iv. **Note.** The rating charts provide a family of curves. It is not required to use the same mA or kV for testing. For example, 0.1 sec', 125 kV & 360 mA is the same as 90 kV & 500 mA.
v. On the rating charts, select suitable time periods. (For example. 0.02, 0.1, 0.3, 1.0, 5.0 seconds). At these time selections, determine a suitable mA station, and the maximum kV that can be used with that mA selection. Adjust the kV towards this maximum value. The exposure inhibit should occur before this value is reached. Repeat this test for each of the preselected time settings.
vi. Repeat this test for each mA station; together with both fine and broad focus spot selection.
vii. Some X-ray controls may have provision for both high **and** low speed operation. In these cases, the maximum load available for low speed operation, should not exceed 85~90% of the value indicated in the low speed chart.

- **Note.** Many microprocessor-controlled systems have the rating charts pre-installed in computer memory. On selection of the manufacturers X-ray tube, a code for that tube is entered into the computer. If the manufacturer of the X-ray control does not supply the X-ray tube, a good match of a rating chart may not be possible. In this situation, contact the service department for advice.

e. *mA calibration*

(For this test, the X-ray control is required to display the actual mA, or mAs, resulting from an exposure. The control may have either an mAs meter, or a quick acting mA meter).

Microprocessor controlled systems have an internal switch, which is set to 'calibration mode'. This should only be adjusted on direct advice from the service department.

When the X-ray control has an mAs meter:

i. mAs meters may be of two types. Type one is 'ballistic'. With this version, watch for the maximum reading on exposure, before the needle returns to zero.
ii. The other version is a true integrating mAs meter. This type will hold the reading for a period of time, often while the preparation button is kept pressed at the end of exposure. With this type of meter, ignore the peak needle deflection, and only record the steady reading.
iii. mAs meters may be dual function. In some controls, the meter will first indicate the % of anode load, and on preparation change over to the mAs function. Another type first indicates the preselected mAs, and on exposure indicates the actual mAs. Actual mAs remains displayed until preparation is released.
iv. When choosing an exposure time, avoid uneven times like 0.01, 0.03, etc. This avoids timer problems that can exist on older units. Select an exposure time of 0.1 second for easy calculation.
v. Test mAs output using two kV positions. Values suggested are 60 kV and 90 kV. Repeat this test for all mA stations and focal spots.
vi. The test mAs output should be within 10% for older systems, and in modern equipment within 5%. Variations of mAs between adjacent mA stations should be less than 5%, including older designs.
vii. When preparation is complete, allow another half to one second before exposing. This is to eliminate possible errors due to incorrect pre-heating of the filament.
viii. To check for a possible filament pre-heating problem, select 60 kV, and the largest mA station. Make an exposure immediately preparation is completed, and record the mAs output. Now make another exposure, but this time wait for about one second after preparation is completed, then make an exposure.
ix. If the difference between the two tests is more than 5%, contact the service department for advice. The generator should have the filament pre-heating adjusted, or else a small increase in preparation time.

When the X-ray control has a mA meter only:

i. Select a low kV, between 60 and 70 kV.
ii. Make an assessment of tube loading with the selected mA station by selecting an exposure time of two seconds.
iii. Assuming a two second time would permit an exposure; now select a time of 0.8–1.0 second. This time allows the mA meter to reach a steady reading, during the exposure.
iv. When preparation is complete, allow another half to one second before exposing. This is to eliminate possible errors due to incorrect pre-heating of the filament.
v. On exposing, watch the mA meter needle arrive at the expected value. Record the steady reading. (Ignore any bounce or overshoot.)
vi. MA should be within 10% of the required value.
vii. Repeat this test on both focal spots. Test only the mA stations that are well within the anode load safety limit, at the exposure times of 0.8–1.0 second.
viii. Between test exposures, allow at least three to five minutes for anode cooling.
ix. To check for a possible pre-heating problem, select 60 kV, and the largest mA station that was previously tested. Make an exposure immediately preparation is completed, and record the mA output. If the change in mA is more than 5%, contact the service department for advice. The generator should have the pre-heating adjusted, or else a small increase in preparation time.

f. Radiation reproducibility tests, using a step-wedge

- This test should be carried out after the film processor has received its general maintenance.
- Adjust the FFD to 100 cm.
- Place the stepwedge on a 24/30 cm cassette.
- Several exposures can be made on the one piece of film. Place two pieces of lead rubber on top of the cassette, positioned against either side of the stepwedge. As the stepwedge is repositioned, the lead rubber prevents unwanted radiation entering the cassette.
- Select a suitable mAs and kV combination, and make a total of four exposures.
  i. Allow about 0.5–1.0 second delay after preparation is completed, before making each exposure. This is to ensure the filament has reached a stable temperature.
  ii. After each exposure, reposition the stepwedge and lead rubber on the cassette.
  iii. Develop the film. As the exposure settings are the same for all exposures, the film should show very little variation.
  iv. If necessary, change kV or mAs so the film displays a good range of densities, then repeat this test.
- Make another series of four exposures, using the same settings as before.
  i. This time, do not delay the exposure, but expose immediately preparation is completed.
  ii. This is a test for filament pre-heating, or temperature stability.
- Compare all eight exposures. If available, use a densitometer. As the same output settings were used, the exposures should show very little variation.
  i. If the second group is lighter, or darker, than the first group, the filament pre-heating or preparation time should be adjusted. Contact the service department for advice.
  ii. In case there is a general variation of densities in either group, this may be due to power mains voltage fluctuations. If suspect, repeat this test at a later time when power is more stable.
  iii. Variable output can be caused by a poor connection to the X-ray tube filament. This is due to a problem with the cathode high-tension cable, where the cable-end plugs into the X-ray tube housing. See **module 7.3 page 117**.
- Repeat the test for each focal spot.
- Record the settings used in the maintenance logbook for future use. Include which cassette used. Retain the test films for comparison with future tests.

g. X-ray output linearity test, using a step-wedge

This is an important check on overall performance. By using a stepwedge, a comparison test may be made, not only between the mA stations of the unit under maintenance, but also with other units in the department.

- This test should be carried out after the film processor has received its general maintenance.
- **Note.** This test will indicate variations in kV output as well as mAs.
- For this test, select an mAs value that can be repeated over a number of mA stations by changing time factor only. (To avoid possible errors due to kV rise and fall time, avoid exposure times below 0.02 seconds.)

- Set 80 kV, and a FFD of 100 cm.
- Position the stepwedge on a 24/30 cm cassette.
- Several exposures can be made on the one piece of film. Place two pieces of lead rubber on top of the cassette, positioned against either side of the stepwedge. As the stepwedge is repositioned, the lead rubber prevents unwanted radiation entering the cassette.
- Using the selected value of kV and mAs make a series of exposures. Change the mA station after each exposure, and adjust the time to obtain the same mAs.
  i. Allow about 0.5–1.0 second delay after preparation is completed, before exposing. This is to ensure the filament has reached a stable temperature.
  ii. If the film is too light, increase the kV, and repeat the test.
  iii. If the film is too dark, add extra aluminium under the step wedge. Or, place a sheet of paper between one side of the film, and the intensifying screen in the cassette.
- It may not be possible to obtain the same mAs value for all mA stations. In this case, select a different mAs value, but include one of the mA stations previously tested. Repeat the test with the new selection of mA values.
  This is illustrated in table 1–a, where 100 ma is used for both 20 mAs and 30 mAs comparisons.

Table 1–a. Selection of mAs values for test

mA	Time	mAs	mA	Time	MAs
500	0.04	20	100	0.3	30
400	0.05	20	150	0.2	30
200	0.1	20	300	0.1	30
100	0.2	20			

- If one of the mA stations shows a significant change in density, make another test with that mA station, this time change kV to obtain the required film density.
  i. Providing the required kV change is not more than 2~3%, the station is within tolerance.
  ii. If no more than 3~5% it is still within tolerance. However, make a note in the maintenance record, and have the calibration checked next time the service department pays a visit.
  iii. If greater than 5%, then that station is out of tolerance. This may be due to mA or kV calibration. If significant, then place that mA station 'out of operation' and contact the service department for advice.
  iv. An estimation of mA calibration error can be made by a comparison exposure, changing time only. This needs an initial time setting of 0.1 second or greater. For example, if the suspect mA station of 200 mA showed a low output, and on changing the exposure time to 0.11 second still showed a slightly low output, then the mA station is more than 10% out of calibration.
  v. Besides a possible change of mA or kV calibration, the timer may not be accurate. A single-phase generator can have an error of plus or minus 0.01 seconds. This is a large error at short time settings. A 'Spinning top' test can indicate single-phase generator exposure times. See appendix 'B' page 169.
- Record all calibration settings used with the stepwedge in the logbook. Include the kV, mAs, FFD, and the cassette used. This will allow a quick set-up when this test is repeated. Save the films for comparison with future tests.

TASK 2

X-ray control familiarization Part I

You have just been transferred to an X-ray department in another hospital, and have been requested to commence a routine maintenance programme. You are not familiar with this particular X-ray control. The control is situated in a standard Bucky table room, with an over-table X-ray tube only.

1. Locate the manufacturer model and serial number, for recording in the logbook. (In some cases, it may be necessary to look behind the control desk or X-ray control cabinet.) _____

2. Check carefully the range and type of controls. Some are unfamiliar. Suggest a way that the function of these controls may be verified. _____

3. Check and list the full range of mA stations available. Which mA stations are available for the broad focus, and for the fine focus? _____

4. Is individual selection of fine and broad focus available? If so, which mA stations may be used on *either* fine or broad focus? _____

5. It is possible that initial inspection indicates the control operates on selection of mAs and kV only. ('Two knob' technique.) Is there a control switch to enable operation by individual selection of mA, time, and kV? ('Three knob' technique.) _____

6. Older basic X-ray controls often have a meter and knob to adjust line voltage. If your unit has such a system, does the meter have a calibration mark? Is it possible to adjust line voltage so the meter indicates excessive voltage, as well as low line voltage? _____

7. kV selection and method of generation depends greatly on the type, model and age of X-ray control being investigated. From your general inspection, which method of kV generation is applicable to this control?

   Single phase, self rectified. _____

   Single phase, full wave rectified. _____

   Three phase, six or twelve pulse. _____

   High frequency inverter system. _____

   Capacitor discharge. _____

8. Discuss possible methods to identify the other versions of kV generation.

   _____

   _____

   _____

   _____

   _____

   _____

   _____

   _____

9. What is the maximum and minimum possible kV to select with this X-ray control? (Make this test after selecting low mA and a short exposure time.) _____

   _____

   _____

10. Is it possible to obtain a simultaneous selection of *maximum* kV, mA, and time? In this case an overload or exposure inhibit signal should be indicated. What form does this take? _____

    _____

    _____

11. On some controls, selection of a high mA station and low kV may generate an overload or inhibit signal, even for very short exposure times. This inhibit signal disappears on *increasing* kV, or reducing mA. Does this apply to this X-ray control? _____

    _____

    Discuss the reason for such a protection, and to which part of the X-ray tube this is applicable. _____

    _____

    _____

    _____

    _____

_____

Tutor's comments

Satisfactory/Unsatisfactory

_____

Signed _____ Date _____

Tutor

TASK 3

X-ray control familiarization Part 2

You have identified the functions of the various controls on the X-ray generator control desk. In addition, you have made a test to ensure the overload protection system is working, and correct line voltage can be obtained. It is now time to make test exposures, and carefully observe the system in operation.

1. Ensure the X-ray tube collimator is closed, and the tube is angled away from the control desk.
2. Select 100 mA, 60 kV and 0.1 s time. (Or 10 mAs if individual selection is not available). Ensure there are no warning lights or signals displayed. Select non-Bucky operation.
3. Press the preparation switch. Note; if a single button controls both preparation and exposure, at this point, only press it half way.
4. Carefully observe the control panel. Did any meters change their reading, or indicator lamps immediately signal a different operation mode? _____
5. Shortly after pressing the preparation switch, the control should indicate 'Ready for exposure' How is this indicated? Approximately how long is the delay time before 'ready' is indicated? _____
6. Release the preparation switch, and again press to go into preparation. This time listen carefully for sounds of a relay or contactor. It is possible several may operate. Hint. If the X-ray control has a door that may be opened, this will allow better observation. *Take care not to touch or open any of the internal sections.* _____
7. Once again carry out preparation. This time listen carefully at the X-ray tube. It should be possible to hear the anode speed up, and when preparation is released, to slowly slow down.

   You may need an assistant to carry out preparation for you, as you will need to be close to the X-ray tube.

   Is the acceleration of the anode during preparation clearly audible? _____

   Does the anode gradually slow down when preparation is released? _____

8. If the X-ray tube is operated at high-speed, you should hear a fast drop in anode speed when preparation is released. This is the brake cycle. There are two types of brake cycle. The DC brake cycle quickly slows the anode to a complete stop. A dynamic brake cycle will quickly reduce the anode speed to about 3000 RPM, after which the anode gradually slows down to a full stop.

   Assuming high-speed operation.
   On release of preparation, does the anode come quickly to a full stop? _____

   _____

   _____

   Or, does the anode quickly brake to a slow speed, then very slowly coast to a full stop? _____

   _____

   _____

   _____

9. Once again, go into preparation mode. This time, when 'ready' appears, press the exposure button. Keep pressing this button after the exposure ends. At the same time carefully observe the control panel.

   Does a radiation 'On' indicator light up on the control panel? _____

   _____

   _____

   Does an audible signal occur during the exposure? _____

   _____

   _____

   Is there an indication of the mA or mAs generated during the exposure? _____

   _____

   _____

   If the control has an mAs meter, does the reading of the mAs meter remain until the exposure, or preparation, switch is released? _____

   _____

_____

Tutor's comments

Satisfactory/Unsatisfactory

_____

Signed _____ Date _____

Tutor

TASK 4

Test for X-ray tube overload calibration Part I

During the routine maintenance check, you decide to ensure the X-ray tube operating parameters are within safe limits. You also want to check if this X-ray tube allows optimum use of the generator output power.

Please note; this test assumes the generator has independent selections of mA and time. Some controls may allow an mAs mode as well as individual selection of mA and time. In that case switch off the mAs mode.

If the control only provides mAs selection, this test is still valid, providing the control indicates which mA position is actually in use.

1. Locate the make, model and serial number, also the focal spot sizes, of the X-ray tube.
   a. Note, in some cases the label with this information may be on the side of the X-ray tube throat. You may need a mirror and torch to read the label.
   b. Enter this information into the routine maintenance logbook, and check sheet.

   _____

   _____

2. Depending on the mains power-supply frequency, what is the theoretical maximum anode speed for low speed operation?

   a. Input power-supply frequency. _____

   b. Anode speed, low speed operation. _____

3. Does this generator have a high-speed starter? If so;
   a. What is the frequency generated by the high-speed starter? (Two common frequencies are 150 hz and 180 hz)
   Hint. Refer to the specifications for the starter, in either the operation or installation manual for the starter, or the generator. The frequency generated by the starter need not be related to the power frequency.

   _____

   b. Depending on the starter frequency, what is the possible maximum anode speed?

   _____

   c. Is high speed anode rotation:
      i. Always high-speed?

      _____

      ii. Automatic selection between high or low speed depending on the X-ray tube load?

      _____

      iii. High or low-speed is individually selected by the operator?

      _____

4. Is the generator single or three-phase operation? (A high frequency generator is considered three-phase.)

   _____

5. From the information obtained in the preceding parts, select the appropriate anode load charts from the X-ray tube specification or operation manual. **Note.** To avoid mistakes, tick the appropriate charts, and place a cross against the unwanted charts.

6. Select a suitable series of exposure times. Times of 0.01, 0.03, 0.1, 0.3, 1.0, and 3.0 seconds are suggested. Using these times, determine from the charts the maximum kV/mA product that is allowed.
   - kV **max** is the maximum kV indicated on the charts for an individual mA/time selection.
   - kV **test** refers to the maximum kV the control would allow for an exposure, at the same selections of mA/time. This should be less than kV max.

   a. Broad focus
      i. Time _____ mA _____ kV-max _____ kV-test _____
      ii. Time _____ mA _____ kV-max _____ kV-test _____
      iii. Time _____ mA _____ kV-max _____ kV-test _____
      iv. Time _____ mA _____ kV-max _____ kV-test _____
      v. Time _____ mA _____ kV-max _____ kV-test _____
      vi. Time _____ mA _____ kV-max _____ kV-test _____

   b. Fine focus.
      i. Time _____ mA _____ kV-max _____ kV-test _____
      ii. Time _____ mA _____ kV-max _____ kV-test _____
      iii. Time _____ mA _____ kV-max _____ kV-test _____
      iv. Time _____ mA _____ kV-max _____ kV-test _____
      v. Time _____ mA _____ kV-max _____ kV-test _____
      vi. Time _____ mA _____ kV-max _____ kV-test _____

7. Using the values for time, mA, and kV max, set the control to the predetermined mA and time. Advance the kV setting until the control indicates an inhibit signal. Enter that value for kV-test.
   a. If the control has optional high and low speed operation, the above test should first be made with high-speed selected. After which make a second test for low speed, using data from the appropriate load charts.
   b. Some later model controls may have a selection for 'Load full' or 'Maximum load'. Ensure this selection is made for the above test.

8. Compare kV-max and kV-test. kV-test should be less than kV-max. Are there any points where kV-test is just under or slightly over kV-max?

   _____

   _____

   Express an opinion if this could be a reason for concern. For example, are normal exposures close to these limits?

   _____

   _____

   _____

   _____

9. Compare the generators rated maximum output, at 0.1 second, with that of the X-ray tube. (Also at 0.1 second). Does the present tube make optimum use of the generator power?

_____

_____

_____

10. Based on (9), if the X-ray tube was replaced, would you prefer any change in the X-ray tube specifications? Discuss the reasons why.

_____

_____

_____

_____

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____ Date _____

Tutor

TASK 5

Test for X-ray tube overload calibration Part 2

You have verified the anode load parameters are operating within the X-ray tube specifications. There remain two areas to test.

1. Maximum kV protection.
   a. Select the large focal spot, combined with the lowest mA station and a short time.
   b. From the X-ray tube specifications, what is the maximum kV that may be used? _____
   c. Increase the kV selection at the generator. Is an exposure inhibit generated before the maximum kV is reached? _____

2. Minimum kV protection.
   a. From the X-ray tube rating charts, examine the fine and broad focus characteristics, and look for a possible mA limitation related to kV. As an example, a 60 kV curve may be shown part dotted, or have a cut off line. This indicates the maximum mA available for that kV value.
   b. Take care to use the charts related to either single or three-phase operation, depending on the generator mode of operation.
      i. From the chart data, are any generator mA stations affected by this restriction? _____
      _____
      ii. What is the minimum kV for these mA stations? _____
      _____
   c. Select the affected mA station and set a short time. Try reducing kV below the indicated minimum level for that station. Is an exposure inhibit generated before that level is reached? _____
      _____
   d. If it is possible to adjust kV below the minimum kV requirement, describe how accidental operation could be reduced, or what action should be taken. _____
      _____
      _____
      _____

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____ Date _____

Tutor

MODULE 1.2

X-ray generator, mobile unit

Aim

The aim is to provide routine maintenance procedures for a mobile X-ray generator. Within the mobile generator capabilities, a similar check is made as used for a fixed installation. Maintenance includes mechanical operation of the mobile, together with the X-ray tube and collimator. Instructions for repairs to the mobile are provided in module 6.1 page 90.

Capacitor discharge mobile procedures are provided in module 1.3 page 37.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance procedures for a mobile X-ray generator. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Contents

Equipment required

- Basic tool kit.
- X-ray alignment template. *
- Stepwedge. *
- 24/30 cm Cassette.
- Two pieces of lead rubber.
- Aerosol spray lubricant.
- Cleaning solvent.
- Cloth.

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

a. General precautions

- ***Before removing any covers, or testing any wires or connections, ensure the system is switched off, and unplugged from the power point.***
- **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 240 V DC. Refer to the operating or installation manuals for the position of the battery isolation switch, and ensure this is switched off before removing any covers.**
- **If the power plug has loose connections, have an electrician check the plug. The plug may be assembled incorrectly.**

b. Visual inspection of the control panel, power off

- Check all knobs and switches. Where knobs have a pointer attached, check that the pointer aligns correctly at all positions of the indicated scale.
  Tip. Check the pointer at full clockwise and counter clockwise positions of the knob. Look for possible loose knobs, or for push button switches that may tend to stick.
- Where controls have had extra labels attached, are these labels still relevant? If so, are they in good condition?
- Older X-ray mobiles often have analogue meters instead of digital displays.

i. With power switched off, the meter needle should be on the 'zero' calibration mark.
ii. If not, first tap gently in case the meter tends to 'stick'. If the needle is not sitting on the zero mark, most meters have a small adjustment screw in the middle for zero calibration.
iii. Caution. Contact the service department before adjusting. In some cases, the meter may be deliberately adjusted 'off zero', as an incorrect method of calibration.

- With the aid of a suitable solvent, clean off the residue left behind from sticking plaster, and pieces of sticky tape.

c. Mechanical and electrical inspection, power off

- Look for any loose panels or sections. Pay particular attention to the mounting of the collimator. With a screwdriver, check for possible loose screws, particularly with the tube support arm and the vertical bearing tracks.
- With the X-ray tube set to minimum height, check the vertical suspension wire rope for possible broken strands. CAUTION, do not test with bare fingers, and instead test by rubbing the cables up and down using a piece of cloth.
- Check the action of the tube-stand bearings. Are there any visible gaps between the bearings and the track surface? Also are there any 'clunking' noises or 'jerking' when moved, which can indicate damaged bearings.
- Spray the tube stand tracks and bearings with a light aerosol lubricant. Wipe down afterward, so only a very small film is left on the tube stand tracks.
- Check for possible loose lock handles, and ensure manually operated locks have an adequate range of adjustment.
- Ensure the mobile brakes operate in a positive fashion when the hand is released from the handle, and that they are fully released while the mobile is travelling.
- Pay particular attention to the cabling from the X-ray tube and tube stand. All movements of the system should not cause any stress or pulling of the cables.
- Inspect the HT cables for any sign of damage to the safety earth shield at the X-ray tube cable ends. Ensure the cable ends are firmly inserted into the X-ray tube, and the securing ring nut is not loose.
- Where there is evidence of twisting or pulling on the HT cables, particularly at the X-ray tube end, investigate means of providing additional support. If necessary, discuss with the service department.
- Examine carefully all plugs and sockets attached to cable ends. The outer insulation of cables should not be pulled out from the cable clamp.
- Check the condition of the power cable. If necessary, remove the plug cover, and ensure terminations are tight, and no connections are stretched or have broken strands. Should the cable exhibit excessive twisting, or have cracks in the outer sheath, ask an electrician for to replace the cable or plug.
- Older mobiles with battery operated power assistance should have the battery electrolyte level checked.
  i. Ensure first that the power cable is unplugged from the power point.
  ii. To gain access to the battery, refer to the operation or service manual.
  iii. Top up with either distilled water or else fresh rainwater.
  iv. Later systems use sealed or 'low maintenance' batteries. This includes high-frequency mobile generators.

d. Operation inspection of the control panel, power on

- Check all indicator lamps etc. If necessary, operate different selection techniques to ensure all required status indicators operate correctly.
- Where a digital readout of radiograph settings is provided, select a number of different values to ensure there are no display errors or missing segments.
- Older controls may have manual adjustment of power line voltage, with a meter indicating correct compensation. Check the range of adjustment. It should be possible to reset the voltage by 10%, above or below, the required voltage.
- With battery-operated equipment, check the status of the battery charge indicator. If low, place the unit on charge, and check that after a reasonable time the system indicates fully charged. This time should not be greater than an overnight period.

e. Mechanical and electrical inspection, power on

- Test operation of the electromagnetic locks. There should be no hesitation in operation, nor should the lock 'stick on'. In some cases the surface of the lock may require cleaning, to obtain a better 'grip'

- With power assisted mobiles, check for correct operation in all forward and reverse modes. Where there is an anti-crash bumper, manually operate the bumper. This should stop motor drive. (Do NOT test by standing in front while the unit is moving forward)

f. X-ray tube and collimator

- Inspect the X-ray tube housing for possible oil leaks.
- When in preparation, listen for excessive X-ray tube bearing noise.
- Check the operation of the collimator lamp timer. With mechanical timers, listen for possible sticking of the clockwork.
- Check the alignment of the collimator lamp and X-ray beam. This should be checked through 180 degrees rotation of the collimator.
- The collimator has a scale associated with the adjustment knob to indicate the field size. The knob can slip on the shaft, or not be correctly positioned after replacing a collimator globe.
  i. Place a 24/30 cm cassette on the tabletop. Adjust the FFD to 100 cm
  ii. With the collimator light switched on, check the knob pointer indicates the correct position on the scale.
  iii. If necessary, reposition the knob on the shaft.
  iv. Repeat this test for other cassettes in use.
  v. If the scale is worn or not legible, use a marker pen to indicate positions for common cassettes in use. Order a new scale from the service department.
  vi. While waiting for a new scale, ensure you have a spare collimator globe in stock.
- To test the rotation accuracy of the light beam;
  i. Rotate the collimator 90 degrees in either direction.
  ii. With the light on, open the collimator so an average size field is projected on the tabletop. For example, a 24/30 cm cassette size.
  iii. Place markers to indicate the light beam position.
  iv. Now rotate the collimator 180 degrees in the opposite direction. The light field should be within 1% or better, compared to the previous position. If not, see module 7.2 page 110.
- To test the alignment of the X-ray to the light beam;
  i. Place the X-ray alignment template on a 24/30 cm cassette.
  ii. Adjust the FFD to 100 cm.
  iii. Adjust the light beam to the template markers.
  iv. Make a low kV and mAs exposure.
  v. Develop the film.
  vi. Measure the distance where the X-ray does not coincide with the markers. Any error should be inside the compliance requirements for the country. See module 7.2 page 110.
  vii. Repeat this test, with the collimator rotated 90 degrees clockwise, and 90 degrees counter clockwise.
  viii. If there is an alignment problem, see module 7.2 page 110.

g. mA calibration

- Some microprocessor-controlled mobiles allow mA to be checked and also calibrated via the front panel. These systems require either an internal switch to be operated, or else a code entry at the panel. To test or adjust calibration, the procedure in the manufacturer's service manual **must** be referred to.
- This test only applies to older mobiles that allow individual selection of mA and time. A panel mounted mA meter is also required.
  i. Use 70~80 kV and an exposure time of around 1.0 second. (The actual exposure time used should allow the mA meter to just reach a steady reading)
  ii. Select the mA station to be tested, and obtain preparation. Wait about 1.0 second after 'ready' is obtained, then expose. Record the reading obtained from the mA meter.
  iii. Milliampere should be within 10% of the required value.
- Repeat the above for all mA stations, and both focal spots. Caution, as the X-ray tube for the mobile will have a small heat capacity, allow cooling time between exposures.
- Filament pre-heat test.
  i. Select the highest mA station, and 60 kV. Go into preparation, and immediately 'ready' is obtained, make an exposure.
  ii. Make another exposure. This time wait about one second after 'ready' is obtained, before exposing.
  iii. If the difference between the two tests is more than 5%, contact the service department for advice. The generator should have the filament pre-heating adjusted, or else a small increase in preparation time.

h. Radiation reproducibility

- This test should be carried out after the film processor has received its routine maintenance.

- Position the stepwedge on a 24/30 cm cassette.
- Several exposures can be made on the one piece of film. Place two pieces of lead rubber on top of the cassette, positioned against either side of the stepwedge. As the stepwedge is repositioned, the lead rubber prevents unwanted radiation entering the cassette.
- Adjust the FFD to 100 cm
- Select a suitable mAs and kV combination, and make a total of four exposures.
  i. Allow about 0.5~1.0 second delay after preparation is completed, before making each exposure. This is to ensure the filament has reached a stable temperature.
  ii. After each exposure, reposition the stepwedge and lead rubber on the cassette
  iii. Develop the film. As the exposure settings are the same for all exposures, the film should show very little variation.
  iv. If necessary, change kV or mAs so the film displays a good range of densities, then repeat this test.
- To test filament-heating stability, make another series of four exposures, using the same settings as before. This time expose immediately 'ready' is obtained.
- Develop the film and compare to the first series of exposures. If any significant difference is obtained, either filament pre-heating or preparation time may need adjustment. Contact the service department for advice.

i. X-ray output linearity test, using a step-wedge

Note. *This test is only applicable to mobiles with independent selection of mA and time settings.*

This is an important check on overall performance. By using a stepwedge, a comparison test may be made, not only between the mA stations of the unit under maintenance, but also with other units in the department.

Note. This test will indicate variations in kV output, as well as mAs.

- This test should be carried out after the film processor has received its routine maintenance.
- Position the stepwedge on a 24/30 cm cassette.
- Several exposures can be made on the one piece of film. Place two pieces of lead rubber on top of the cassette, positioned against either side of the stepwedge. As the stepwedge is repositioned, the lead rubber prevents unwanted radiation entering the cassette.
- For this test, select an mAs value that can be repeated over a number of mA stations by changing time factor only.
- Set 80 kV, and a FFD of 100 cm.
- Using the selected value of kV and FFD make a series of exposures, changing the mA station, and adjusting time setting to obtain the same mAs.
  i. Allow about 0.5~1.0 second delay after preparation is completed, before exposing. This is to ensure the filament has reached a stable temperature.
  ii. If the film is too light, select a different mAs value, or kV, and repeat the test.
  iii. If the film is too dark, add extra aluminium under the step wedge. Or, place a sheet of paper between one side of the film, and the intensifying screen in the cassette.
- It may not be possible to obtain the same mAs value for all mA stations. In this case, select a different mAs value, but include one of the mA stations previously tested. Repeat the test with the new selection of mA values.
- This is illustrated in table 1–b, where 10 ma is used for both the 20 mAs and 30 mAs comparisons.

Table 1–b. Selection of mAs values for test

mA	Time	mAs	mA	Time	MAs
50	0.4	20	10	3.0	30
40	0.5	20	15	2.0	30
20	1.0	20	30	1.0	30
10	2.0	20			

- If one of the mA stations shows a significant change in density, make another test with that mA station only, but this time change kV.
  i. Providing the required kV change is not more than 2~3%, the station is within tolerance.
  ii. If no more than 3~5% it is still within tolerance. However, make a note in the maintenance record, and have the calibration checked next time the service department pays a visit.
  iii. If greater than 5%, then that station is out of tolerance. This may be due to mA or kV calibration. If significant, then place that mA station 'out of operation'. Contact the service department for advice.

iv. Besides a possible change of mA or kV calibration, the timer may not be accurate. A single-phase generator can have an error of plus or minus 0.01 seconds. This is a large error at short time settings. A 'Spinning Top' can check single-phase generator exposure times. See appendix 'B' page 169.

Record all calibration settings used with the step-wedge in the logbook. Include the kV, mAs, FFD, and the cassette used. This will allow a quick set-up when this test is repeated. Save the films for future comparison tests.

MODULE 1.3

X-ray generator, capacitor discharge mobile

Aim

The aim is to provide routine maintenance procedures for a capacitor discharge (CD) mobile generator. Within the CD mobile capabilities, a similar check is made as for a conventional mobile. There are however, some important differences. These relate to the non-linear output due to the kV/mAs relationship, plus other modes of operation. Maintenance includes mechanical operation of the CD mobile, together with the X-ray tube and collimator. Instructions for repairs to the CD mobile are provided in module 6.2 page 94.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance procedures for a portable X-ray generator. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Contents

Equipment required

- Basic tool kit.
- X-ray alignment template.*
- Stepwedge.*
- 24/30 cm Cassette.
- Two pieces of lead rubber.
- Aerosol spray lubricant.
- Cleaning solvent.
- Cloth.

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

a. General precautions

- ***Before removing any covers, or testing any wires or connections, ensure the system is switched off, and unplugged from the power point.***
- **If the power plug has loose connections, have an electrician check the plug. The plug may be assembled incorrectly.**
- ***Do* NOT *make any adjustments to the HT cables without first discharging the capacitor.* See module 6.2 page 94.**

b. Visual inspection of the control panel, power off

- Check all knobs and switches. Where knobs have a pointer attached, check that the pointer aligns correctly at all positions of the indicated scale.
  Tip. Check the pointer at full clockwise and counter clockwise positions of the knob. Look for possible loose knobs, or for push button switches that may tend to stick.
- Where some mobiles have had extra labels attached, are these labels still relevant? If so, are they in good condition?

- Older CD mobiles have an analogue kV meter instead of a digital display. With power off, the meter needle should be on the 'zero' calibration mark, **providing the capacitor is fully discharged**. If not, first tap gently in case the meter tends to 'stick'. **Do not attempt to adjust the meter zero position without reference to the service manual, and operation of the internal capacitor discharge device.**
- Other CD mobiles may have a line voltage meter. This meter should read zero on power off. If necessary, the meter zero position may be adjusted by the centre screw. Tap the meter gently first, to ensure the meter is not sticking.
- With the aid of a suitable solvent, clean off the residue left behind from sticking plaster, and pieces of sticky tape.

c. Mechanical and electrical inspection, power off

- Inspect for any loose panels or sections. Pay particular attention to the mounting of the collimator. With a screwdriver, check for possible loose screws, particularly with the tube support arm and the vertical bearing tracks.
- With the X-ray tube set to minimum height, check the vertical suspension wire rope for possible broken strands. **CAUTION**, do not test with bare fingers. Test instead by rubbing the cables up and down with a piece of cloth.
- Check the action of the tube-stand bearings. Are there any visible gaps between the bearings and the track surface?
- Are there any 'clunking' noises or 'jerking' movements, when the X-ray tube is positioned? This can indicate damaged bearings.
- Spray the tube stand tracks and bearings with a light aerosol lubricant. Wipe down afterward, so only a thin oil film is left on the tube stand tracks.
- Check for possible loose lock handles, and ensure manually operated locks have an adequate range of adjustment.
- Ensure the mobile brakes operate in a positive fashion when the hand is released from the handle, and that they are fully released while the mobile is travelling.
- Pay particular attention to the cabling from the X-ray tube and tube stand. All movements of the system should not cause any stress or stretching of the cables.
- Inspect the HT cables for any sign of damage to the safety earth shield at the X-ray tube cable ends. Ensure the cable ends are firmly inserted into the X-ray tube, and the securing ring nut is not loose.
- ***Note. Never remove the HT cable ends unless the capacitor is fully discharged, and the capacitor safety switches are operated. See module 6.2 page 94.***
- Where there is evidence of twisting or pulling of the HT cables, particularly at the X-ray tube end, investigate means of providing additional support. If necessary, contact the service department for advice.
- Examine carefully all plugs and sockets attached to cable ends. The cable outer insulation should not be pulled out from the cable clamp.
- Check the condition of the power cable. If necessary, remove the plug cover, and ensure terminations are tight, and no connections are stretched or have broken strands. Should the cable exhibit excessive twisting, or have cracks in the insulation, replacement is required. **An electrician should carry out any repairs to the power cable or plug.**
- With motorized mobiles check the battery electrolyte level.
  i. *Ensure the power cable is unplugged from the power point*.
  ii. To gain access to the battery, refer to the operation or service manual.
  iii. Top up with distilled water or else fresh rainwater.
  iv. If the mobile is fitted with a 'low maintenance' battery, contact the service department for advice.

d. Operational inspection of the control panel, power on

- Check all indicator lamps operate.
- For CD mobiles equipped with an analogue or digital kV meter, test the kV adjustment for correct operation.
  i. Set the required kV to 60 kV and press the charge button.
  ii. The charge light should illuminate. Once the required kV is reached, then the 'ready' lamp should light up.
  iii. Check that the kV displayed on the meter closely agrees with that indicated at the kV control knob.
  iv. Observe the kV meter for a few minutes. The kV should slowly drop back by about 2~3 kV, then return briefly to the charge mode. (This is called 'topping up')

v. Increase the set kV to 90 kV. The charge light should illuminate, until the kV meter reaches 90 kV.
vi. Now reset the required kV back to 60 kV. The X-ray ON light should illuminate. At the same time the indicated kV should quickly drop down to the required value.
vii. **Note.** A low mA X-ray exposure is produced when the kV is reset. Radiation is blocked in this mode by a lead shutter in the collimator.
viii. In case the kV resets very slowly, similar to discharge prior to topping-up, this can indicate a problem. See **module 6.2 page 94**.

- Some CD mobiles have an adjustment for power line voltage. A meter indicates when the voltage is correct. Check the range of adjustment, to ensure compensation may be set approximately 10% above or below the required voltage.
- **Note.** The power line voltage adjustment can directly affect the kV charge on the capacitor.
- With motorized mobiles, check the status of the battery charge indicator. If low, place the unit on charge. Charging time should not be greater than an overnight period.

e. *Mechanical and electrical inspection, power on*

- Test operation of the electromagnetic locks. There should be no hesitation in operation, nor should the lock 'stick on'. In some cases the surface of the lock may require cleaning to obtain a better 'grip'
- With motorized mobiles, check for correct operation in all forward and reverse modes. Where there is an anti crash bumper, manually operate the bumper. This should stop motor drive. (Do NOT test by standing in front while the unit is moving forward)

f. X-ray tube and collimator

- Inspect the X-ray tube housing for possible oil leaks.
- During preparation, listen for excessive X-ray tube bearing noise.
- Check the operation of the collimator lamp timer. With mechanical systems, listen for possible sticking of the clockwork.
- The collimator normally has a scale associated with the adjustment knob to indicate the field size. The knob can slip on the shaft, or not be correctly positioned after replacing a collimator globe.
  i. Place a 24/30 cm cassette on the tabletop. Adjust the FFD to 100 cm
  ii. With the collimator light switched on, check the knob pointer indicates the correct position on the scale.
  iii. If necessary, reposition the knob on the shaft.
  iv. Repeat this test for other cassettes in use.
  v. If the scale is worn or not legible, use a marker pen to indicate positions for common cassettes in use. Order a new scale from the service department.
  vi. While waiting for a new scale, ensure you have a spare collimator globe in stock
- Check the alignment of the collimator lamp and X-ray beam. This should be checked through 180 degrees rotation of the collimator.
- To test the rotation accuracy of the light beam;
  i. Rotate the collimator 90 degrees in either direction.
  ii. With the light on, open the collimator so an average size field is projected on the tabletop. For example, a 24/30 cm cassette size.
  iii. Place markers to indicate the light beam position.
  iv. Now rotate the collimator 180 degrees in the opposite direction. The light field should be within 1% or better, compared to the previous position. If not, refer to the collimator service notes.
- To test the alignment of the X-ray to the light beam;
  i. Place the X-ray alignment template on a 24/30 cm cassette.
  ii. Adjust the FFD to 100 cm.
  iii. Collimate the light beam to the outer 20 by 26 cm rectangle.
  iv. Make a low kV and mAs exposure.
  v. Develop the film.
  vi. Measure the distance where the X-ray does not coincide with the markers. Any error should be inside the compliance requirements for the country. See **module 7.2 page 110**.
  vii. Repeat this test, with the collimator rotated 90 degrees clockwise, and 90 Degrees counter clockwise.
  viii. If there is an alignment problem, see **module 7.2 page 110**.
- Check operation of the 'dark current' shutter. This is an additional lead shutter fitted close to the focal spot. Its purpose is to block all radiation except when making a radiographic exposure. (In some mobiles, the shutter is retracted immediately prior to the exposure, in other mobiles the shutter is retracted during preparation.)
  i. Place the X-ray alignment template on a 24/30 cm cassette.

ii. Adjust the FFD to 100 cm
iii. Adjust the light beam to the central markers.
iv. Set 90 kV on the control panel, and press the charge button.
v. When the mobile indicates 'ready', or 'charging completed', do not expose or enter preparation. Instead, reset the kV down to 60 kV.
vi. A low mA X-ray exposure is produced when the kV is reset. Radiation is blocked in this mode by the dark-current shutter in the collimator.
vii. Wait till the control again indicates 'ready', and then process the film. The film should be clear, and not indicate any patterns from the alignment test phantom.

g. mAs calibration

- **Note.** This only applies to mobiles fitted with an mAs control, and a kV meter.
- A CD mobile has a direct relationship of mAs and kV. During an exposure, the kV will drop by one kV per mAs. (This is for a one microfarad mobile)
- Ensure the collimator is fully closed.
- Select 90 kV and 20 mAs
- Once charging is completed, make an exposure, observing the kV meter. There should be a drop from 90 kV to 70 kV.
- (In some cases a smaller drop of kV may occur. For example, from 90 to 72 kV. This is due to capacitor manufacturing tolerance.)
- Select several other combinations of kV and mAs and repeat the above test.

h. Radiation reproducibility

- This test should be carried out after the film processor has received its general maintenance. The test films can be used for comparison with future tests.
- Adjust the FFD to 100 cm.
- Place the stepwedge on a 24/30 cm cassette.
- Several exposures can be made on the one piece of film. Place two pieces of lead rubber on top of the cassette, positioned against either side of the stepwedge. As the stepwedge is repositioned, the lead rubber prevents unwanted radiation entering the cassette.
- Select a suitable mAs and kV combination, and make a total of four exposures.
  i. After each exposure, reposition the stepwedge and lead rubber on the cassette.
  ii. Develop the film. As the exposure settings are the same for all exposures, the film should show very little variation.
  iii. If necessary, change kV or mAs so the film displays a good range of densities, then repeat this test.
- **Note.** If a step wedge is not available, a water phantom may be used. In which case a series of four films are required.
- Record all calibration settings used with the stepwedge in the logbook. Include the kV, mAs, FFD, and the cassette used. This will allow a quick set-up when this test is repeated. Save the films for future comparison tests.

MODULE 1.4

X-ray generator, portable unit

Aim

The aim is to provide routine maintenance procedures for a portable X-ray generator. Within the portable generator capabilities, a similar check is made as for a mobile generator. The portable generator may be either self-rectified, or else full wave rectified. The stationary anode X-ray tube and HT transformer are contained in a single housing. Maintenance includes mechanical operation of the portable, together with the X-ray tube and collimator. Instructions for repairs to the portable generator are provided 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 familiar with maintenance procedures for a portable X-ray generator. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Contents

Equipment required

- Basic tool kit.
- X-ray alignment template.*
- Stepwedge.*
- 24/30 cm Cassette.
- Two pieces of lead rubber.
- Aerosol spray lubricant.
- Cleaning solvent.
- Cloth.

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

a. General precautions

- ***Before removing any covers, or testing any wires or connections, ensure the system is switched off, and unplugged from the power point.***
- **If the power plug has loose connections, have an electrician check the plug. The plug may be assembled incorrectly.**

b. Visual inspection of the control panel, power off

- Check all knobs and switches. Where knobs have a pointer attached, check that the pointer aligns correctly at all positions of the indicated scale.
  Tip. Check the pointer at full clockwise and counter clockwise positions of the knob. Look for possible loose knobs, or for push button switches that may tend to stick.
- Where extra labels have been attached, are these labels still relevant? If so, are they in good condition?
- The generator will often have an analogue line-voltage and mA meter. These meters should read zero on power off. If necessary, the meter zero position may be adjusted by the centre screw. Tap the meter gently first, to ensure the meter is not sticking.
- **Caution;** check the meter zero position when the control is mounted, or placed, in its usual position.
- With the aid of a suitable solvent, clean off the residue left behind from sticking plaster, and pieces of sticky tape.

c. Mechanical and electrical inspection, power off

- Look for any loose panels or sections. Pay particular attention to the mounting of the collimator. With a screwdriver, check for possible loose screws, particularly with the tube support arm and the vertical bearing tracks.
- Check the operation of the height adjustment system. Does it operate smoothly without binding or sticking?
- Check the action of the height adjustment bearings. Are there any visible gaps between the bearings and the track surface?
- Are there any 'clunking' noises or 'jerking' movements, when the X-ray tube is positioned? This can indicate damaged bearings.
- Check for possible loose lock handles, and ensure the locks have an adequate range of adjustment.
- Spray the height adjustment tracks and bearings with a light aerosol lubricant. Wipe down afterward, so only a thin oil film is left on the height adjustment tracks.
- Examine carefully all plugs and sockets attached to cable ends. The outer insulation of cables should not be pulled out from the cable clamp.
- Check the condition of the power cable. If necessary, remove the plug cover, and ensure terminations are tight, and no connections are stretched or have broken strands. *Should the cable exhibit excessive twisting, or have cracks in the insulation, ask an electrician to replace the cable or plug.*

d. Operation inspection of the control panel, power on

- Check all indicator lamps operate in each mode of operation.
- Check the range of adjustment of line voltage, to ensure this may be set approximately 10% above or below the optimum position.
  Note. Adjustment of the line voltage can directly affect the radiographic kV.

e. X-ray tube head and collimator

- Look for possible oil leaks.
- Check operation of the collimator lamp timer. (If fitted)
- With clockwork lamp timers, check for possible sticking of the clockwork.
- To test the alignment of the X-ray to the light beam;
  i. Place the X-ray alignment template on a 24/30 cm cassette.
  ii. Adjust the FFD to 100 cm.
  iii. Collimate the light beam to the outer 20 by 26 cm rectangle.
  iv. Make a low kV and mAs exposure.
  v. Develop the film.
  vi. Measure the distance where the X-ray does not coincide with the markers. Any error should be inside the compliance requirements for the country. See **module 7.2 page 110**.
  vii. Some units may be fitted with a rotating collimator. Repeat this test, with the collimator rotated 90 degrees clockwise, and 90 degrees counter clockwise.
  viii. If there is an alignment problem, see **module 7.2 page 110**.

f. mA calibration

- **Note.** Depending on system design, mA selection may be linked to the kV knob. Other units may have an independent selection of mA.
- Ensure the collimator is fully closed.
- Select 60 kV and the maximum associated mA station. Select an exposure time of 1.0 second.
- Commence preparation, and expose when preparation is complete. Observe the mA meter, and record the indicated value.
- Repeat this test for all other mA and kV combinations. Record the results.
- If mA on any position has an error of more than 10%, recalibration is required. On some systems, this may be accessed with a screwdriver through an access hole. Please refer to the operation or service manual before adjusting.
- If in doubt, contact the service department for advice.

g. Radiation reproducibility

- This test should be carried out after the film processor has received its general maintenance.
- Place a stepwedge on a 24/30 cm cassette.
- Several exposures can be made on the one piece of film. Place two pieces of lead rubber on top of the cassette, positioned against either side of the stepwedge. As the stepwedge is repositioned, the lead rubber prevents unwanted radiation entering the cassette.
- Adjust the FFD to 100 cm.
- Select a suitable mAs and kV combination, and make a total of four exposures.
  i. After each exposure, reposition the stepwedge and lead rubber on the cassette.

ii. Develop the film. As the exposure settings are the same for all exposures, the film should show very little variation.
iii. If necessary, change kV or mAs so the film displays a good range of densities, then repeat this test.

- **Note.** If a step wedge is not available, a water phantom may be used. In which case a series of four films are required.

Record all calibration settings used with the step-wedge in the logbook. Include the kV, mAs, FFD, and the cassette used. This will allow a quick set-up when this test is repeated. Save the films for future comparison tests.

MODULE 2.0

X-ray tube-stand

Aim

The aim is to provide routine maintenance procedures for the X-ray tube-stand, or suspension. The instructions provided are for the floor ceiling tube stand. Most of these procedures can also be applied to a ceiling mounted tube suspension. Repair procedures are provided in module 7.0 page 99.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance procedures for the X-ray tube-stand. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Task 6, 'X-ray tube-stand maintenance', should be attempted on completion of this module.

Contents

Equipment required

- Basic tool kit.
- X-ray alignment template. *
- 24/30 cm cassette.
- Aerosol spray lubricant.
- Cleaning solvent.
- Cloth, for cleaning.

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

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 a mechanic, or the service department, to make the required adjustments.

b. Mechanical and electrical inspection

- Inspect for any loose panels or sections. Pay particular attention to the collimator and the control panel.
- Check the tube-stand suspension, tracks and bearings.

i. With the X-ray tube set to minimum height, check the vertical suspension wire rope for broken strands. CAUTION, do not test with bare fingers. Test by rubbing the cables up and down with a piece of rag.
ii. With the vertical lock released, the X-ray tube should balance in the vertical direction. It should need the same effort to move either up or down.
iii. Check the action of the tube-stand bearings. Are there any visible gaps between the bearings and the track surface?
iv. Are there any 'clunking' noises or 'jerking' movements, when the X-ray tube is positioned? This can indicate damaged bearings.
v. Check the vertical guide rails. Look for loose mounting screws.
vi. Spray the tube stand vertical guides and bearings with a light aerosol lubricant. Wipe down afterward, so only a thin oil film is left on the vertical guide rails.
vii. Clean any accumulated dirt on and inside the floor track. Spray the track and tube-stand floor-bearings with a light aerosol lubricant. Wipe off any excess.
viii. Look for loose mounting screws along the floor rail.
ix. Observe the position of the bearings on the ceiling rail. These should be fully engaged along the full length of the rail. Check the rail is properly fastened in place, and does not move.

- Check for loose mechanical lock handles, and ensure manually operated locks have an adequate range of adjustment.
- Test operation of the electromagnetic locks. There should be no hesitation in operation, nor should the lock 'stick on'. In some cases the surface of the lock will require cleaning, to obtain a better 'grip' when operated.
- HT cables should be supported at the X-ray tube, to minimize twisting or pulling at the cable end.
- Pay attention to the cabling from the X-ray tube and tube stand. Any movements of the system should not cause any stress or stretching of the cables. Nylon or plastic cable-ties should be used to secure loose cables, not sticking plaster.
- Examine carefully all places where cables pass into different sections of the tube-stand.
  i. Where the cables pass though holes in a metal cover, there should be protective inserts to avoid damaging the cable insulation.
  ii. Look for possible damage to the outer insulation of electrical cables.
  iii. Check electrical cables where they enter plugs and sockets, the outer insulation may be pulled back, exposing individual conductors.

c. Tube-stand lateral centre

Lateral centring over the Bucky table should be checked in both directions. In some cases this may be accurate only when approached from one direction.

i. Tape a thin piece of wire, or a paper clip, to the centre of a 24/30 cm cassette. Place the cassette in the Bucky.
ii. Position the X-ray tube to the lateral centre position.
iii. Adjust the table top also to the lateral centre position.
iv. Bring the collimator face to rest on the tabletop, and ensure it is flat against the tabletop. Then rise to 100 cm S.I.D.
v. As the collimator moves away from the tabletop, check that the light beam remains central to the tabletop. If not, adjust the tube angle a small amount so the light beam remains in position.
vi. If the tube-stand centre position appears incorrect, this may need adjustment. Before adjusting, continue with the rest of these checks.
vii. Place the X-ray alignment template on the centre of the tabletop.
viii. Adjust the light beam to the template markers.
ix. Select a low kV and mAs, expose and develop the film.
x. The radiation field should be centred to the template markers. If not, the collimator requires adjustment. This should be corrected before any adjustment to the tube-stand centre. See **module 7.2 page 110**.
xi. The position of the template marker is compared to the wire marker on the cassette. This checks the tabletop centre accuracy. If not correct, see **module 8.0 page 121**.
xii. If the tube stand centre is not correct, see **module 7.0 page 99**.

- After checking lateral centring to the table Bucky, check the centring to the wall Bucky.
  i. Keep the X-ray tube rotation in the trunnion rings at the same setting for the Table Bucky.
  ii. Bring the collimator close to, or up against the wall Bucky. The light field should be centred to the Bucky-centre mark.
  iii. Move the tube stand away from the Bucky to the distance normally used. The light beam should remain centred.

iv. In case of a small error, a compromise adjustment of the tube rotation in the trunnion rings may be made. Otherwise, see **module 7.0 page 99**, and **module 8.0 page 121**.

d. Tube stand command arm, or panel

- The X-ray tube trunnion-ring rotation-lock should operate firmly, and prevent unwanted rotation.
- Hand grips should not be loose.
- The indicator for tube angle should rotate smoothly, and not hesitate before changing its position.
- Check all indicator lamps and switches for correct operation.
- Check alignment of the Bucky centre light. (When fitted.)
- Ensure all labels are legible.
- With a tape measure, check for correct indication of the focal spot to Bucky distance. (FFD.)
- Rotate the tube head and check the angulation indicator operates smoothly and does not stick.
- Clean and remove remains of sticking plaster, adhesive tape, etc.

TASK 6

X-ray tube-stand maintenance

The X-ray tube stand in room 1 is due for its maintenance check.
Carry out this check, using the maintenance checklist provided in appendix 'D' of this workbook as a guide.

What is the tube stand model No? _____ Serial No? _____

Was it necessary to make any adjustments? (Provide details) _____

_____

_____

_____

Are there any areas still requiring attention? _____

_____

_____

_____

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____ Date _____

Tutor

MODULE 2.1

X-ray tube

Aim

The aim is to provide routine maintenance procedures for the X-ray tube. This includes techniques to improve the high-voltage performance or reliability of the X-ray tube. Fault diagnostic procedures are provided in 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 familiar with maintenance procedures for the X-ray tube. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Contents

Equipment required

- Basic tool kit.
- Cable ties.

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.**
- During the seasoning technique, make sure the collimator is closed. Aim the X-ray tube away from the X-ray control.
- If a problem occurs during seasoning, **stop**. Depending on the symptoms, see **module 7.1 page 104**, or **module 7.3 page 117**.

b. X-ray tube inspection

- Check rotation of the X-ray tube in the trunnion rings. The locking device should hold the housing firmly in place, but allow free rotation on release.
- Ensure no attachments, such as a command arm control panel, or collimator, have become loose.
- Examine electrical cables to the X-ray tube. Ensure they are securely clamped into position, and not subject to being pulled. Where cables pass into the housing, they should be protected from sharp edges.
- Inspect the HT cables for any sign of damage to the safety earth shield, at the X-ray tube cable ends.
- Ensure the HT cable ends are firmly inserted into the X-ray tube, and the securing ring nut is not loose.
  Note. In some systems there is a locking screw on the side of the ring nut. Undo this screw first, and then check the ring nut is fully tightened, then re-fasten the locking screw. This check is most important if the X-ray tube or cables have recently been replaced.
- Where there is evidence of twisting or pulling on the HT cables, particularly at the X-ray tube receptacle, investigate means of providing additional support. If necessary, contact the service department.
- Examine the X-ray tube housing for any oil leaks.
- At the generator, go into preparation, then release preparation without exposing. Listen to the anode rotation for excessive noise.

- If a high-speed tube, check that the anode brake cycle operates normally.
  i. Some systems use direct current (DC brake) to bring the anode to rest.
  ii. Other use alternating current, to bring the speed down to 3000 rpm, after which the anode coasts to rest.

c. *X-ray tube seasoning*

- This is also called 'ageing', and is a process to reduce residual gas in the X-ray tube. Seasoning improves the stability of the tube, when operated at high kV.
- Seasoning should always be performed if a new X-ray tube is installed, or has not been used for more than one month. The same applies where the tube has not been used over 80~90 kV for some time, and then it is desired to use 110 kV or higher.
- If using an X-ray tube of 125 kV capacity at 110 kV or higher, seasoning should be performed each day prior to use. If the tube is rated at 150 kV, the same applies if operating above 125 kV.
- During seasoning, an X-ray tube may at first appear unstable. After two to three exposures, the tube should now be stable. If not, see **module 7.1 page 104**.
- Many manufacturers specify a seasoning procedure. This can be found in the X-ray tube operation or installation manual. Operation or installation manuals for mobile generators may include a seasoning procedure.
- Table 2–a is suggested for a 150 kVp X-ray tube with a fixed installation.
- Table 2–b is typical for a mobile generator, with a 125 kVp tube.

Table 2–a. Seasoning technique for a 150 kVp X-ray tube

Step	kV	mAs	Times	Pause time (Seconds)
1 #	60	20	2	40
2 #	70	20	2	40
3 #	80	20	2	40
4	90	20	2	40
5	100	20	2	40
6	110	20	2	40
7	115	20	2	40
8	120	20	2	60
9	125	20	2	60
10	130	10	4	60
11	135*	10	4	60
12	140**	10	2	60

Note

i. Recommended output is 200 mA and 0.1 sec for 20 mAs. For 10 mAs use 100 mA and 0.1 sec.
ii. # Steps 1,2, and 3 are only required if the tube is just installed, or has not been in use for more than one month.
iii. * If, for example, you never use above 125 kV, then ignore steps 11 and 12.
iv. ** Although an X-ray tube is rated at 150 kV, this is the absolute maximum rating. This can reduce as the tube becomes worn, and especially as metal evaporation collects on the glass. Operation above 140 kV may result in premature failure.

Table 2–b. Seasoning technique for a 125 kVp tube

Step	kV	mAs	Times	Pause time (Seconds)
1 #	60	10	2	40
2 #	70	10	2	40
3 #	80	10	2	40
4	90	10	2	40
5	100	10	2	40
6	110	10	2	50
7	115	10	2	50
8	120*	10	2	60
9	125*	10	2	60

Note

i. The majority of mobiles provide selection of mAs only. If mA and time selection is available, then aim for exposure times less than 0.3 sec.
ii. # Steps 1,2, and 3 are only required if the tube is just installed, or has not been in use for more than one month.
iii. * If, for example, you never use above 110 kV, then ignore steps 8 and 9.

MODULE 2.2

X-ray collimator

Aim

The aim is to provide routine maintenance procedures for the X-ray collimator. These maintenance suggestions are for a standard collimator used on a standard tube-stand. Adjustment procedures are provided in module 7.2 page 110.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance and performance checks for the X-ray collimator. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Task 7, 'X-ray tube and collimator maintenance', should be attempted on completion of this module.

Contents

Equipment required

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

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

a. General precautions

Whenever changing a collimator lamp, always ensure power is turned off and equipment 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.

b. General maintenance

- Check electrical cable to the collimator. Ensure the cable entry is protected against sharp edges of the collimator housing. Rotation of the collimator should not stretch or pull the cable.
- Check the operation of the collimator blades. These should stay in position when adjusted, and not slip if the X-ray tube is repositioned. If adjustment of the clutch or brake is required, see **module 7.2 page 110**. (Do **not** rely on adhesive tape to hold the knob in position.)
- Check the operation of the collimator lamp timer. With clockwork systems, look for possible sticking of the mechanism.
- Evaluate the intensity of the light beam from the collimator. If too dim, see **module 7.2 page 110**.
- Check the type of globe fitted, and make sure you have a spare globe in stock. **Note.** Some globes may appear similar but have the filament in a different position. See **module 7.2 page 110**.
- The following precautions should be observed if changing the globe.
  i. ***Ensure power to the generator and/or tube stand is turned off.***
  ii. If a globe has just failed, wait for it to cool down.
  iii. When unpacking and inserting a new globe, do not handle it directly. Instead use a tissue or a piece of cloth so your fingers do not touch the globe. This is very important when handling Quartz-Halogen globes.

c. Alignment tests

- Check the crosshair alignment of the front transparent cover.
  i. With the collimator blades almost closed, the crosshair should be in the centre of the light field. Check at both horizontal and vertical settings.
  ii. If adjustment is required, on most collimators, the cover may be moved after loosening the four retaining screws. (In some cases, the cover may at first stick in place.)
- Check the Bucky centre light, if fitted. If out of alignment, see **module 7.2 page 110**.
- The collimator has a scale combined with the adjustment knob to indicate the field size. The knob can slip on the shaft, or not be correctly positioned after replacing a collimator globe.
  i. Place a 24/30 cm film on the tabletop, and position the X-ray tube 100 cm above the tabletop.
  ii. With the collimator light switched on, adjust the light field to the film size.
  iii. Check that the knob pointer indicates the correct position on the scale.
  iv. If necessary, reposition the knob on the shaft.
  v. Repeat this test for other films in use.
  vi. If the scale is worn or not legible, contact the service department and obtain a new scale. In the meantime, use a marker pen to indicate positions for common cassettes in use.
  vii. Attention to the scale is important. The lamp might fail, and the spare globe has already been used.
- To test the alignment of the X-ray to the light beam;
  i. Place the X-ray alignment template on a 24/30 cm cassette.
  ii. Collimate the light beam to the outer 20 by 26 cm rectangle.
  iii. Make a low KV and mAs exposure.
  iv. Develop the film.
  v. In many cases the collimator is enabled to rotate. Repeat the above test, with the collimator rotated 90 degrees clockwise, and then 90 degrees counter clockwise.
  vi. If there is an alignment problem, see **module 7.2 page 110**.
- 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 1.0 cm, 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 1.0 cm.

TASK 7

X-ray tube and collimator maintenance

The X-ray tube and collimator in room 1 is due for its maintenance check.
Carry out this check, using the maintenance checklists provided in appendix 'D' of this workbook as a guide.

What is the X-ray tube model No? _____ Serial No? _____

Focal spot sizes are; Broad focus. _____ Fine focus. _____

Collimator model No? _____ Serial No? _____

Examine carefully the HT cables as they enter the X-ray tube. Note, you will need to undo the retaining ring nut, and slide back the cable support clamp.

Is the safety earth shield in good condition? _____

_____

Examine the collimator globe. How would you describe this globe if requesting a replacement? (**Hint**, look in the parts manual) _____

_____

Carry out tests for X-ray beam and light beam alignment. Is this correct for all rotation positions of the collimator? _____

_____

If alignment is outside acceptable limits, explain how to readjust the collimator. _____

_____

_____

_____

Were any adjustments required? Provide details. _____

_____

_____

Do any areas still require attention? _____

_____

Tutor's comments

Satisfactory/Unsatisfactory

Signed _____ Date _____

Tutor

MODULE 3.0

Bucky table and vertical Bucky

Aim

Aim is to provide routine maintenance procedures for the Bucky table and vertical Bucky. Adjustment and repair procedures are provided in module 8.0 page 121.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance and performance checks for the Bucky table and vertical Bucky. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Contents

Equipment required

- Basic tool kit.
- Torch.
- Aerosol spray lubricant.
- Cloth, for cleaning.
- Detergent.

a. General precautions

Please take the following precautions.

- **Before removing a cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- 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.
- Keep all screws, or other small parts in a container, to avoid loss.

b. Bucky table

- Examine the physical condition of the table. Clean the remains of adhesive tape etc from the table body.
- **Hint.** Car polish, designed to 'rejuvenate' faded and oxidised paint, can often improve the appearance of an older table. Silicon furniture polish can assist in removing scuffmarks and fingerprints etc.
- Check for loose screws on the tabletop profile rails. The rails can become loose due to using a compression device.
- Examine the condition of the compression device. Check for correct operation. Remove the band from the mechanism, and have it laundered.
- Check the operation of switches and indicator lamps.
- With an elevating Bucky table, use a tape measure to check the table height at the centre stop position.
- Check the operation of the magnetic locks.
  Note. Some movements may have two or more magnetic locks. Carefully observe these locks and ensure all locks are actually in operation. If adjustment is required, see **module 8.0 page 121**.
- Check the operation of the tabletop lateral centre-stop. Where this is mechanical, the spring tension may need adjustment. In case of operation by the magnetic locks, the stop position is normally

controlled by a microswitch. Adjustment of this microswitch can control the width and position of the centre-stop operating position. See **module 8.0 page 121**.

- Move the tabletop in all positions. If there is scraping or binding in some positions, check the position of the locks. Look also for a faulty bearing.
- Spray the bearing tracks and bearings with a light aerosol lubricant, then clean the residue away from the tracks, so only a thin film is left.

c. Potter Bucky

- Move the Bucky to both ends of the table. Check that the Bucky carriage operates smoothly, and that the Bucky lock operates correctly in all positions across the table.
- Electrical cables to the Bucky should be firmly attached at the Bucky, and no twisting or puling occurs on the cable, at any position of the Bucky.
- Where there is a folding support arm for the connecting cable, look for possible binding or excessive 'droop'. This can indicate loose mounting screws.
- Spray the Bucky track with a light aerosol lubricant, and then wipe the residue from the track.
- Remove the Bucky tray. With a torch, examine the Bucky interior for lost film markers.
- Look for loose screws holding the tray handle. Take care not to over-tighten, as this might damage the thread.
- Test the action of the Bucky tray cassette clamps. If they do not hold the cassette firmly, see **module 8.0 page 121**.
- Spray the moving sections on the underside of the Bucky tray with a light aerosol lubricant, move the cassette clamps in and out, and then clean off all residue. Take care that no residue appears on top of the tray.
- Test the grid oscillation.
  i. At the generator, select the lowest mA station, 50 kV, and exposure time of 1~2 seconds.
  ii. Ensure the collimator is closed, and the tube is positioned away from the Bucky. Then make an exposure with the Bucky selected.
  iii. During the exposure, check for smooth operation of the grid.
  iv. Watch for any shaking, or vibration of the Bucky, as the grid reverses its movement. Or else, just as the grid first starts to move.
  v. Should shaking or vibration occur, this can cause reduced sharpness of the radiograph. If this occurs, contact the service department for advice.

d. Vertical Potter Bucky

- The vertical Bucky should be checked in the same manner as the table Bucky, but with the following provision for retrieving lost film markers. These markers can fall into the motor section at the bottom of the Bucky, and may cause a problem. To inspect, it is necessary to remove the front cover.
  i. With power off, ensure the vertical lock firmly holds the Bucky in place. If not, keep the Bucky in position by tying with a rope, or by adding extra weights.
  ii. Carefully examine the method of attaching the front cover. In most cases this is a series of screws around the front cover. Other systems may attach by screws on the top and bottom sides.
  iii. If separating profile rails from the front cover, make a small mark so they can be returned to the same position, including left and right, on re-assembly.
  iv. After removal of the front cover, look carefully for any film markers. A torch will help to locate them.
  v. Re-assemble the front cover, taking care not to over-tighten any screws.
- Check operation of the vertical lock.
- Vertical movement. Check and lubricate the vertical track. Wipe off any excess.
- Check the rotation or tilt lock. (Only on Bucky with this option)

MODULE 3.1

Tomography attachment

Aim

Aim is to provide routine maintenance procedures for a tomographic attachment. This may be fitted to a standard tube stand, or integrated with a Bucky table. Adjustment and repair procedures are provided in module 8.1 page 127.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance and performance checks for the tomographic attachment. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Contents

Equipment required

- Basic tool kit.
- Tomography resolution tool.*
- Or, tomography test tool.*

* The tomography resolution tool is described in appendix 'B' page 169.
* A tomography test tool is described in the WHO '*Quality assurance workbook*.'

a. General precautions

Please take the following precautions.

- **Before removing a cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- Keep all screws, or other small parts in a container, to avoid loss.

b. Mechanical and electrical inspection

- Inspect all sections of the attachment for loose or missing screws. This can be a common problem with some coupling arms.
- Inspect connecting cables. The outer insulation of electrical cables should not be pulled out from the plug or socket cable clamps. Plugs or sockets should be in good condition and fit firmly into position.
- Check the rotation lock on the tube stand. With the rotation lock 'off', the X-ray tube should rotate easily.
- The Bucky lock should disengage, and the Bucky move freely along the guide rails.
- When assembling the unit, pay attention to bearings or pivot points, which the coupling arm passes through. The arm should move up and down freely.
- When attaching the coupling arm to the tube stand, ensure the clamp holds the arm firmly.
- With the coupling arm attached, switch off the tube stand longitudinal-lock. Disengage the tomographic motor, and push the tube stand by hand to each end of the normal tomographic travel. Check that the tube stand and Bucky moves smoothly, and there is no sudden jerking to the movement. (This test depends on individual system design, and may not be possible with some units)
- Check the fulcrum height adjustment. This should operate smoothly, and have a clear indication of setting height. This may be a scale and pointer, or a digital readout in later systems.

c. Operation test

- This test may be performed by using the 'Reset' switch to drive the unit to either direction. If this facility is not available, or is only available at a slow speed, then it is necessary to produce a radiographic exposure. In this case, select minium kV and mA, an exposure time sufficient to allow full operation, and ensure the collimator is closed.
- Operate the tube stand travel in all speeds and modes of operation. Check for the following possibilities.
  i. Lack of positive drive during the start of travel. For example, the drive system is slipping.
  ii. Poor stopping position or overshoot at the end of travel, especially when operated at maximum speed and angle.
  iii. Shaking or uneven travel through the active area of movement. Some initial shaking may occur at the start of travel, but should stop before reaching the exposure position.

d. Performance test

- This is a test for layer height, and providing the tomography resolution test is used, an evaluation of image sharpness.
  i. Select a low kV and mA position.
  ii. Select a medium angle. Set exposure time to suit the speed and angle.
  iii. Adjust the fulcrum height to the centre height position of the test piece.
  iv. Perform a tomographic exposure.
  v. Examine the film. There should be even blurring of the test objects above and below the test piece centre, which should be sharply defined.
  vi. If the top and bottom paper clips are not equally blurred, then adjust the fulcrum height a small amount, and repeat this test.
  vii. If the central paper clips are blurred in any direction, this can indicate shaking or uneven movement of the Bucky, or tube stand. See **module 8.1 page 127**.
  viii. Repeat this test using the maximum angle and speed, then again using minimum speed.
  ix. Retain the films as a record. Include on the films the exposure setting and mode of operation.
- In case the fulcrum height is incorrect, or the image sharpness is poor, record the test procedures used. Include the tomograph speed and angle. Contact the service department for advice.

MODULE 4.0

Fluoroscopy table

Aim

Aim is to provide routine maintenance procedures for the fluoroscopy table. These procedures are intended for an under-table tube fluoroscopy table. The under-table Bucky maintenance procedures are described in **module 3.0 page 53**.

Fluoroscopy TV maintenance is provided in **module 4.1 page 60**. Adjustment and repair procedures are provided in **module 9.0 page 130**.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance and performance checks for the fluoroscopy table. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Contents

Equipment required

- Basic tool kit.
- Torch.
- Spirit level.
- Cloth, for cleaning.
- Detergent.

a. General precautions

- **Before removing any cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- If removing a cover, or dismantling any section, place the screws in a container to avoid loss.

b. Mechanical and electrical inspection

- Make a general inspection of the table body and serial-changer. Tighten any loose screws, or panels and fittings.
- Check the rails holding the tabletop in place. Tighten any loose screws.
- Examine all suspension system cables and chains for any sign of wear, or uneven tension in the case of dual systems.
- Check electrical cables, particularly at the rear of the table. Pay special attention to cables that may be twisted or tangled. It may be necessary to remove existing cable ties, reposition the cables, and then install fresh cable ties. (Use plastic or nylon cable ties only)
- Where electrical cables enter the table, check that the cable clamps properly secure them. The protective outer insulation of the cable should not be pulled back, exposing inner conductors.
- The serial-changer should be able to move smoothly from the 'park' position, and lock firmly into place.
- Check the operation of all switches and operation lights on the serial-changer.
- Additional control switches are sometimes placed on the side of the table body. Patient trolleys can damage these switches.
- Older systems with a demountable image intensifier (II).
  i. The II should balance vertically when removed from the serial-changer.
  ii. The II should be held firmly in position when clamped to the serial-changer. Look for loose clamps.
- Is the serial-changer lead-rubber radiation shield in good condition? Can it be easily positioned?

- With the aid of a torch, make a careful examination for lost film markers inside the serial-changer.
- **The footrest requires careful attention. If there is any tendency for the locking mechanism to slip, this will require urgent correction.**

c. Operation test, table body

- Check operation of all locks. The serial-changer vertical lock should operate quickly when operated, and not 'stick on' when released.
- Check all switches and indicator lamps for correct operation. This especially includes those on the table body, which may be damaged by patient trolleys.
- Operate the tabletop in all positions. Listen for any unusual squeaks or bearing rattles.
- On tabletops fitted with a lateral centre stop, the stop position should be checked. Use the procedures described in **module 2.0 page 44**.
- Rotate the table to the vertical and Trendelenburg positions. Listen for unusual bearing or motor noise while the table is rotating. Does the table stop quickly after the rotation control is released, or does it tend to continue or 'coast' for a short while? This could indicate a failure of the motor brake system. Contact the service department for advice.
- The table should stop in the horizontal position, on returning from the vertical position. Use a spirit level to check the horizontal position.
- With the table tilted at maximum position in either direction, check the electrical cables are not pulled tight, or restrict the movement of the serial-changer up and down the table.
- Some tables have power assistance for movements, such as longitudinal movement of the serial-changer; this should be smooth and free from sudden jerks. See **module 9.0 page 130**.
- Some tables have safety anti-crash bars or flaps. Pushing against these safety devices should prevent the table from rotating.
- With the vertical or compression lock 'on', operate the tabletop longitudinal movement. On some tables, movement should not operate, and on others, the vertical lock should release on movement of the tabletop. If not, contact the service department. There may be a safety upgrade available.
- Place a standard 24/30 cm cassette in the serial-changer. With the vertical lock 'off', check for vertical balance when moved up and down.
- Rotate the table into the vertical position. With the serial-changer longitudinal lock 'off', check the serial-changer and tower assembly for balance, while moving it along the table body.

d. Operation test, serial-changer (Spot filmer)

- Compression cone movement should operate smoothly, and lock into position.
  i. If the movement is stiff or hesitant, try cleaning the slide tracks, then spray with an aerosol lubricant.
  ii. Operate several times, and wipe off any excess spray.
- Some serial-changers have manually operated 'close to film' shutters. These are coupled to the film format selection. If stiff or hesitant, clean and lubricate the tracks in the same manner as for the compression cone.
- Manually operated cassette movement.
  i. Load a 24/30 cm cassette in the tray.
  ii. Select a low kV and mAs setting at the X-ray control.
  iii. At the serial-changer, select the four-spot mode.
  iv. Set the collimator control to 'Automatic'.
  v. Advance the cassette, and expose all four divisions. Watch the cassette as it moves into the 3rd spot division. If the cassette 'slams' into position, a pneumatic 'damper' may need replacement. Contact the service department for advice.
  vi. Process the film, and check that the four spots are evenly distributed around the film, are the same size, and without overlap.
  vii. If incorrect, see **module 9.0 page 130**.
  viii. Provide a similar test for other split formats.
- Motorized cassette movement.
  i. Place a 24/30 cm cassette in the cassette carriage.
  ii. Press the 'load' button. The cassette should be withdrawn and stop smoothly. A 'bang' at the end of travel can indicate an adjustment problem, caused by the cassette carriage overshooting, and hitting the end stop. Contact the service department for advice.
  iii. Press the 'eject' button. The cassette should move to the 'eject/load' position, and stop smoothly. There should be no 'bang' at the end of travel to indicate travel 'overshoot'. Enough of the cassette should extend to allow easy removal.
  iv. Reload the 24/30 cm cassette.
  v. Select a low kV and mAs setting at the X-ray control.

vi. At the serial-changer, select the four-spot mode.
vii. Set the collimator control to 'Automatic'.
viii. Advance the cassette, and expose all four divisions. Watch the cassette as it moves into the 3rd spot division, for possible failure of the movement damper. (Only on some older systems)
ix. Process the film, and check that the four spots are evenly distributed around the film, are the same size, and without overlap. If incorrect, see **module 9.0 page 130**.
x. Repeat the above test for other split formats and film sizes.

e. *X-ray beam alignment*

- Install a 24/30 cm cassette, and select the four-spot mode.
- At the X-ray control, select a low level of fluoroscopy kV and mA. This should be just sufficient to see the position of the X-ray beam shown on the TV monitor. (Or the fluorescent screen)
- With fluoroscopy 'on', manually collimate the beam to the maximum four spot size.
  i. The edge of the beam should be sharply defined by the four-spot cone or by the 'close to film' shutters.
  ii. In case one side is less sharp, and shows movement with only a small adjustment of the collimator, then beam alignment is incorrect.
- Observe the beam alignment with the serial-changer at both minimum and maximum height positions above the tabletop.
- Repeat the above test with the table tilted to vertical position.
- **Note.** In most cases, beam alignment will shift a little when the table is moved from horizontal to vertical. The amount of misalignment is usually due to flexing of the table framework. In some cases this may be due to incorrectly adjusted bearings. Contact the service department for advice.
- If beam alignment is incorrect, see **module 9.0 page 130**.

f. Cleaning

- Due to the types of examinations, barium spills can leave deposits under the tabletop, or on the protective cover under the tabletop. Inspect with the tabletop moved to its maximum position in each direction.
- **Hint.** Shine a torch beam between the tabletop and the protective cover.
- Another cause of artefacts is contrast media from an IVP examination. This is sometimes found underneath the serial-changer, as well as the tabletop. The contrast media is not easy to see when it has dried out.
- The contrast residues may be cleaned with a mixture of household detergent and warm water. Use sufficient to just dampen the cleaning cloth.
- Fluoroscopy tables are subject to marks from patient trolleys etc.
  i. These marks and scratches can be reduced with the aid of car polish.
  ii. The type to use is one with a mild abrasive, advertized to 'Restore faded or chalky paint'.
  iii. Silicone furniture polish can help remove scuff-marks, fingerprints etc.

MODULE 4.1

Fluoroscopy TV

Aim

Aim is to provide routine maintenance procedures for the fluoroscopy TV system. These include checks for image sharpness, and the automatic brightness control. The basic TV imaging system consists of an image intensifier (II), TV camera, and monitor. Systems with greater complexity, such as DSA and electronic radiography, are not included. Adjustment and repair procedures are provided in module 9.1 page 135.
(**Note:** Reference module page numbers refer to the title page.)

Objectives

On completion of this module, the student will be familiar with maintenance and performance checks for the fluoroscopy TV system. These procedures can be used as a version of quality control, together with the routine maintenance check-sheets provided in the appendix.

Contents

Equipment required

- Basic tool kit.
- Resolution test piece.*
- Plastic container for water phantom.

* A 'V' pattern test piece is described in appendix 'B' page 169.

a. General precautions

- **Before removing any cover, always switch the generator power off, and ensure the isolation power switch for the room is also switched off.**
- Do not remove the cover of the TV monitor. Dangerous voltages can exist for a considerable time after the monitor is switched off.
- Do not attempt any adjustments to the TV camera, unless under instruction by the service department.
- If removing a cover, or dismantling any section, place the screws in a container to avoid loss.

b. Mechanical and electrical inspection, image intensifier (II)

- On older systems with a ceiling suspension.
  i. If the unit is dismounted from the serial-changer, the vertical balance should be neutral.
  ii. When attached to the serial-changer, the clamp or latch system should hold the II securely, with minimum movement.
  iii. Up and down movement should be free, without binding or unusual noises.
  iv. The ceiling suspension unit should travel freely. (Some systems may hesitate before moving, this is normal.)
- Electrical cables to the II and TV camera should be securely attached. The cables should not be pulled, or stretched, during table movements.
- Push buttons and selection switches should have their function clearly marked. **Note.** Some knobs or control settings may be for an option only, and not be installed. This should be noted in the logbook.

c. Mechanical and electrical inspection, TV system

- Electrical cables should be securely attached to the monitor trolley. There should be no possibility of pulling against cable connections. This also applies in case of wall mounted plugs and sockets.
- Examine the video cable connection, both at the monitor and TV camera. The cable should be firmly

attached to the plug, including the outer earth shield. Moving the cable at the plug should not cause any 'flicker' or change in the TV image.

- Check the video-input 75 ohm termination-switch. In the case of a single video connection only, this should be 'ON'. If two or more monitors, then the switch on the end monitor should be 'ON', while the middle monitor, with two video connections, should be switched to the 'OFF' position. (In some cases, a termination plug is fitted to the unused video 'out' connection.)
- Ensure the monitor is securely fastened to the monitor trolley. This especially applies to monitor trolleys with a tilting platform.

d. Image sharpness

- An evaluation of image sharpness or focus is best carried out with a 'Line pair' gauge. The industry standard is one made from 0.1 mm lead.
- An alternate test piece for testing focus may be constructed from long sewing needles arranged in a 'V' pattern. See appendix 'B' page 169.
- There are several methods used to evaluate performance of an imaging system. The basic method described here is to indicate if resolution has drifted below an acceptable level.
  i. Tape the gauge onto the centre of the input face of the image intensifier. If access is difficult, then tape the gauge to the under surface of the serial-changer.
  ii. To avoid interaction with grid lines, attach the gauge so it is rotated approximately 25~45 degrees. (On some CCD TV cameras, this also avoids interaction between pixels.)
  iii. Lift the serial-changer to maximum height above the tabletop.
  iv. If the system has automatic kV control, this should be turned off. Set manual fluoroscopy kV to 50~55 kV.
  v. With fluoroscopy 'on', adjust kV or mA to obtain a normal brightness and contrast image on the monitor.
  vi. Carefully observe the line-pair patterns. The limiting definition is the line pair group that is reasonably visible, while the next group is completely blurred out. (This can sometimes be a good test of individual eyesight.)
  vii. If using the 'V' pattern test piece, measure the distance to the apex before blurring occurs.
  viii. Record the line pair resolution, or 'V' pattern distance obtained, and compare with any earlier tests.
  ix. Repeat this test for other field sizes if a multi-field II is installed.
  x. As a guide, with a 9" image intensifier, resolution should not be less than 1.0 line pairs/mm. (Typical resolutions for current systems are 1.4 line pairs/mm minimum for a standard CCD camera, while some higher performance systems may achieve resolutions of more than 2.0 line pairs/mm.
  xi. If image sharpness, or image quality, is not good, see module 9.1 page 135.

e. Automatic brightness/kV control

- Automatic brightness adjusts the TV image as different sections of anatomy are examined.
- Automatic brightness normally controls the fluoroscopic output, either by kV or mA, or else a combination of both kV and mA. Older methods operate by direct compensation in the TV camera only. Current systems often use a combination of both methods.
- Systems with automatic control of fluoroscopy kV or mA.
  i. Place a plastic bucket or container with about 3.0 cm (1.25") of water on the tabletop.
  ii. Bring the serial-changer down close to the water phantom.
  iii. With fluoroscopy 'on', the image on the monitor should be a normal brightness level.
  iv. If automatic control is by kV only, or mA only, this may not provide complete compensation. If the image has excess brightness, it may be necessary to reset the manual adjustment.
  For example.
  —If automatic control is by kV only, and kV has reached its minimum value of 50 kV, but the mA indicates 3.0 mA, then reduce the fluoroscopic mA setting.
  —If automatic control is by mA only, and the manual kV was set to 120 kV, then of course, reduce kV.
  v. Increase the height of water in the container to about 18.0 cm (7") of water.
  vi. With fluoroscopy 'on' kV or mA should automatically adjust to maintain the correct brightness.
  vii. Close the collimator. Then with fluoroscopy 'on', kV or mA should now reach its maximum value.
  viii. **Note.** For the above tests, the brightness should stabilize without oscillating up and down in brightness level. (This means the 'settling time' is not stable.)

- Systems with automatic control of brightness by the camera only.
  i. Place a plastic bucket or container with about 5.0 cm (2.0") of water on the tabletop.
  ii. Set Fluoroscopy kV to about 60 kV, and the mA control to about 1.0 mA.
  iii. Bring the serial-changer down close to the water phantom.
  iv. With fluoroscopy 'on', the image on the monitor should be a normal brightness level.
  v. If overbright, and it is necessary to reduce kV still further, the camera brightness control is not effective.
  vi. If brightness appears normal, increase kV in 10 kV steps, till the image becomes over bright, or 'flaring' occurs. A good system should be able to compensate up to about 100 kV. (This is based on a target-controlled vidicon TV camera. CCD types may have reduced control.