Environment Protection Authority

Radiation Standard 6

Compliance requirements for ionising radiation apparatus used in diagnostic imaging: Part 2 – Radiography (medical) and bone mineral densitometry

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Introduction

Radiography is an essential part of medical procedures, both for diagnosis and in research. Diagnostic medical procedures inevitably deliver a radiation dose to the patient. In most cases, the benefits of diagnostic radiology far outweigh any potential risks to the patient from radiation. However, the level of risk is justified only when patients may receive a possible health benefit and everything reasonable has been done to reduce the dose.

Inadequate performance or quality assurance of radiation apparatus used for diagnostic purposes may cause an unnecessary increase in the radiation dose to patients. The complexities of modern apparatus make regular performance monitoring essential for maintaining best image quality.

The need to reduce the radiation dose to patients is widely acknowledged. This document aims to contribute to dose reduction by:

- making sure acceptable safety measures are provided to protect patients, occupationally exposed workers and the public from unnecessary radiation exposure
- improving the standard of radiation apparatus in use
- making sure apparatus performance is better monitored
- providing reference dose levels as a guide to patient exposure.

The *Radiography (Medical) and Bone Mineral Densitometry Radiation standard*, from here on referred to as the *Radiography standard* is for the information of owners (person responsible) and licensed users of radiographic apparatus, and persons accredited under section 8 of the *Protection from Harmful Radiation Act 1990* as consulting radiation experts. It is to be used by consulting radiation experts to assess apparatus for compliance with conditions of licence and should be read in conjunction with the Act and the Protection from Harmful Radiation Regulation 2013. In the event of an amendment to the Act or Regulation, references to the legislation in this document must be deemed to refer to the current legislation. If there's an inconsistency between the standard and the amended legislation, the requirements of the legislation prevail.

This document sets out the minimum requirements for compliance of diagnostic imaging apparatus, which are stated as '**must**' statements and promote industry best practice in radiation safety. These requirements are listed in Schedule 1 and 2 and apply to both fixed and mobile medical radiography and bone mineral densitometry apparatus respectively.

The *Radiography standard* was developed by the Radiation Unit of the NSW Environment Protection Authority (EPA) in consultation with the Radiation Advisory Council.

The EPA acknowledges the assistance of A/Prof Lee Collins, Mr Paul Cardew, Dr Jennifer Diffey, Mr Thomas Greig, Mr Peter Condon and Ms Lucy Cartwright, and the input received from stakeholders, in preparing this edition.

1. General requirements and recommendations

1.1. Advice to person responsible

1.1.1 The conditions of radiation management licences require licensees to make sure diagnostic imaging apparatus is tested for compliance with the EPA's mandatory requirements. An EPA-accredited consulting radiation expert **must** carry out testing for compliance with these requirements and certify that apparatus is compliant.

1.1.2 For radiography and bone mineral densitometry apparatus respectively to comply with the requirements they **must** meet the requirements listed in Schedule 1 and 2 of this standard.

1.1.3 The responsible person **must** have equipment quality control records available to the inspecting authority and to a consulting radiation expert on request (details of quality assurance and quality control program are discussed in section 3 and 4 of this standard).

1.1.4 Specifications for radiation shielding of protective barriers and the design details of rooms used for ionising radiation apparatus should be determined according to *Radiation Guideline 7: Radiation shielding design, assessment and verification requirements* (Radiation Guideline 7) and documented by an appropriately qualified person before building works start.

1.1.5 The provision of radiation shielding should make sure the radiation levels behind the shielding comply with the requirements of *Radiation Guideline 7.*

1.1.6 Where the X-ray apparatus is a fixed installation or a mobile that is used in a dedicated X-ray room, a protective shield **must** be provided for the operator's use. A protective shield **must** also be provided in case of any bone mineral density apparatus if beam geometry and patient workload dictate the need for operator protection.

1.1.7 Where a fixed protective shield is provided it should be not less than 2,100 millimetres (mm) in height.

1.1.8 The operator, when behind the protective shield, **must** have a clear view of the patient and **must** be able to communicate easily with the patient at all times.

1.1.9 In the case of new installations, the protective shield and all shielded walls and doors **must** be clearly and durably marked with the lead thickness or lead area density or, for non-lead material, the type and thickness of building material of which they are constructed.

1.2. Advice to consulting radiation expert

1.2.1 A consulting radiation expert **must** make sure any radiation monitoring device used for compliance testing is:

- suitable for the type of measurement for which it is to be used
- used only when it is fully operational and properly calibrated
- capable of measuring the type of radiation being assessed over the range of energies and dose rates required
- calibrated at least every two years to an Australian or international primary or secondary standard satisfactory to the manufacturers' requirements.

1.2.2 The following test equipment may be required to carry out compliance testing:

- a radiation dosimeter (including kVp and timer functions)
- aluminium filters (Grade 1100 or equivalent)

- tape
- a collimator alignment test grid or lead markers/paper clips
- a light meter
- lead sheets
- a tape measure
- radiographic cassettes or film/fluorescent screen
- a calculator with statistical functions / computer spreadsheet
- 1 mm copper sheet
- 5, 10, 15, 20-centimetre (cm) water or PMMA phantom.

1.2.3 The following information will be required to carry out compliance testing.

- An acquisition protocol to be used for testing of digital image receptors so as to acquire and access images that have minimal clinical image processing.
- Leakage technique factors for assessment of tube leakage radiation.

1.2.4 Before starting to test the manufacturer's warm-up procedure should be followed.

1.2.5 All measurements **must** be in SI units (e.g. Gy for air kerma).

2. Compliance requirements: medical radiography

Please note that in the case of radiographic apparatus that also has fluoroscopic capabilities the apparatus **must** comply with *Radiation Standard 6: Part 4 - Fluoroscopy* in addition to this radiography standard.

2.1. System performance

2.1.1 The consulting radiation expert **must** make sure all tests listed in **Table 1** that include any clause listed in Schedule 1 be carried out at the frequency specified and results **must** comply with the limits referenced in this standard.

Table 1: Tests required for medical radiography systems

Compliance Requirement	Test	Acceptance	5-Yearly	After tube replacement	After detector replacement
2.2	Radiation warning sign	✓	✓	×	×
2.3	Accuracy of kilovoltage controls	✓	✓	✓	×
2.4	Accuracy of timer controls	✓	✓	✓	×
2.5	Exposure consistency and linearity	✓	✓	✓	×
2.6	Filtration	✓	✓	✓	×
2.7	Indicators of operation	✓	✓	×	×
2.8	Exposure switch	✓	✓	×	×
2.9	Automatic exposure control	✓	✓	×	✓
2.11	Control of multiple X-ray tubes	✓	✓	✓	×
2.12	Leakage radiation	✓	×	✓	×
2.13	Markings on X-ray generators & tube assemblies	✓	✓	✓	×
2.14	Control of the primary beam during radiography	✓	✓	✓	×

2.15	Provision of an air kerma area product meter	✓	✓	✓	×
2.16	Stability of X-ray tube assembly	✓	✓	✓	×
2.17	Stability of mobile apparatus	✓	✓	✓	×
2.18	Capacitor discharge apparatus	✓	✓	×	×

2.2. Radiation warning sign

2.2.1 A radiation warning sign complying with Schedule 6 of the Regulation **must** be displayed on the outside of the entry doors to any:

a. room in which a fixed radiography apparatus is installed, or

b. dedicated room in which a mobile or portable apparatus is permanently used.

2.2.2 A radiation warning light **must** be positioned at the entry doors to all radiography rooms, except in the case of 2.2.1 (b) or where a consulting radiation expert has determined that it would not pose a risk to the safety of any person if there were no warning light.

2.2.3 Where a radiation warning light is provided, the light **must** remain illuminated for the duration of the exposure and **must** bear the words '**X-RAYS—DO NOT ENTER**' or similar. Illumination **must** be immediate.

2.3. Accuracy of kilovoltage controls

2.3.1 The accuracy of the kVp controls **must** be within ± 5% of the indicated value.

2.3.2 The coefficient of variation of at least three consecutive measurements at the same kVp setting **must not** exceed 0.02.

2.4. Accuracy of timer controls

2.4.1 The accuracy of the timer controls **must** be within ± 5% or ± one pulse of the indicated time, whichever is greater.

2.4.2 The coefficient of variation of at least three consecutive measurements at the same timer setting **must not** exceed 0.05.

2.5. Exposure consistency and linearity

2.5.1 The apparatus **must** produce a consistent radiation output, so that the coefficient of variation of at least three consecutive measurements, taken at the same control settings, does not exceed 0.05.

2.5.2 Where the current is selectable (mA can be manually controlled) the apparatus **must** produce a linear radiation output over a range of clinically used mA settings so that the coefficient of linearity does not exceed 0.1 for each focal spot size.

2.5.3 Where the current is not selectable (mA cannot be manually controlled) the apparatus **must** produce a linear radiation output over a range of clinically used mAs settings so that the coefficient of linearity does not exceed 0.1 for each focal spot size.

2.5.4 Capacitor discharge units are exempt from 2.5.2 and 2.5.3.

2.6. Filtration

2.6.1 The total filtration **must** make sure the first half value layer of the primary beam for a given X-ray tube and collimator is not less than the values shown in Table 2 or 3 (as applicable).

2.6.2 Where apparatus may operate with more than one thickness of filtration, an interlock system **must** be used to prevent exposure if the minimum filtration is not present in the beam, or alternatively the filter **must** be fixed permanently in position.

2.6.3 Where removable or operator-selectable extra filters are used, determination of the half-value layer **must** be carried out using minimum filtration.

Table 2: Minimum permissible half value layer for X-ray equipment installed pre-2015

X-ray tube voltage (kVp)	Minimum HVL (mm Al)
50	1.5
60	1.8
70	2.1
80	2.3
90	2.5
100	2.7
110	3.0
120	3.2
130	3.5
140	3.8
150	4.1

Table 3: Minimum permissible first half value layer for X-ray equipment installed since 2015

X-ray tube voltage (kVp)	Minimum half value layer (mm Al)
50	1.8
60	2.2
70	2.5
80	2.9
90	3.2
100	3.6
110	3.9
120	4.3
130	4.7
140	5.0
150	5.4

2.7. Indicators of operation

2.7.1 The tube voltage, current and, where appropriate, exposure time or combination of current and time **must** be displayed by an analogue or digital indicator, even if these factors are under automatic control. Should one factor be permanently fixed, its value **must** be indicated on the control panel.

2.7.2 There should be a visual indicator on the control panel to indicate to the operator when mains power is supplied to the apparatus.

2.7.3 There **must** be an obvious visual and/or audible indicator when radiation is being emitted.

2.8. Exposure switch

2.8.1 The exposure switch **must** be of the dead-man type. That is, it **must** have a circuit closing contact that:

a. can be maintained only by continuous pressure.
b. makes it impossible to make repeat exposures without releasing the switch, except in the case of programmed sequential exposures.
c. makes it possible to interrupt the exposure at any stage of a programmed exposure.

2.8.2 The exposure switch **must** be designed so that it cannot be accidentally operated.

2.8.3 The exposure switch **must** be arranged so that it cannot be operated from outside the shielded area. A consulting radiation expert may exempt an apparatus from this requirement where clinically necessary. The reasoning for doing so **must** be documented in the inspection report.

2.8.4 In the case of mobile or portable apparatus, a cable not less than 2 m in length **must** be provided for the exposure switch, except where the exposure is remotely controlled.

2.9. Automatic exposure control

2.9.1 There **must** be a visual indication when the automatic exposure control is selected.

2.9.2 When the automatic exposure control is used, the exposure **must** end after no more than six seconds or 600 mAs, whichever happens first.

2.9.3 The coefficient of variation in post exposure mAs, measured air kerma and displayed air kerma area product (if available), for a minimum of three exposures using the same exposure parameters and with the same absorber in the beam, **must not** exceed 0.05 for each automatic exposure control sensor.

2.9.4 In the case of 2.9.3, the percentage difference in post exposure mAs and measured air kerma between the lateral automatic exposure control sensors **must not** exceed 10%.

2.9.5 The automatic exposure control device should control exposures such that the displayed exposure index does not vary by more than 20% from the mean exposure index when kVp and patient thickness are varied over their typical clinical range (see Appendix 1 for systems with a non-linear relationship between exposure index and detector air kerma).

2.10. Digital detectors

2.10.1 An acquisition program should be available on a digital radiography system to get and view images that have minimal clinical image processing (flat-field images). This means removing any high frequency image processing, edge enhancement, noise reduction etc.

2.10.2 The signal transfer property of the system i.e. the relationship between the detector air Kerma and mean pixel value should be verified as simple (e.g. linear, logarithmic or power). Systems with an unknown or a complex relationship should not be accepted.

2.10.3 The maximum difference in mean pixel values between five regions of interest placed centrally and in the centre of the four quadrants of a uniform image should be within ±10% of the mean, of the mean pixel value. If the signal transfer property relationship is not linear, the pixel values should be linearised to detector air kerma $_{MPV}$ (see Appendix 1).

2.11. Control of multiple X-ray tubes

2.11.1 Where more than one X-ray tube can be operated from a control panel, there **must** be a clear indication on the control panel to signify which tube is energised.

2.12. Radiation leakage

2.12.1 The X-ray tube **must** be enclosed in housing so that the absorbed dose in air from leakage radiation, measured at a distance of 1 m from the focus of the tube averaged over an area not larger than 100 cm^2, does not exceed 1.0 mGy in 1 hour.

2.12.2 Diaphragms, cones or collimators used to limit the primary beam to the area of clinical interest **must** be constructed so that, in combination with the tube assembly and when fully closed, the leakage radiation does not exceed the limit stated in clause 2.12.1.

2.13. Markings on X-ray generators and tube assemblies

2.13.1 X-ray generators and tube assemblies **must** be permanently marked in English and the markings **must** be clearly visible.

2.13.2 X-ray generators **must** bear either:

a. the name or trademark of the manufacturer
b. the type or model number
c. the serial number, or
d. an EPA-generated number that links to (a), (b) and (c).

2.13.3 X-ray tube assemblies **must** bear either of the following in a visible position:

a. the name or trademark of the manufacturer of the X-ray tube housing and insert
b. the type or model number of the X-ray tube housing and insert
c. the serial number of the X-ray tube housing and insert, OR
d. EPA-generated number (s) that links to (a), (b) and (c).

2.13.4 As well as 2.13.3, X-ray tube assemblies should also have the following markings on the outer side of the tube housing in a visible position:

a. the position of the focal spot (s)*
b. the relative position of the anode and cathode.

*For dual focus X-ray tubes, a single indication of mean focal spot position is allowed.

2.14. Control of the primary beam during radiography

2.14.1 An adjustable multileaf collimator **must** be fitted to the X-ray tube assembly. The extent of the diagnostic radiation beam **must** be defined by a light beam unit.

2.14.2 The light beam collimator **must** be attached to the tube housing so that it cannot become detached without the use of tools. It should be capable of rotating around the centre of the X-ray beam, but this rotation **must** not cause the collimator to become loose or detached, or to damage the mounting plate.

2.14.3 The area illuminated by the light beam collimator **must** align with the irradiated area. The total misalignment of any edge of the light field with the respective edge of the irradiated field **must** not exceed 1% of the source to image distance. The centre of the illuminated area **must** be indicated.

2.14.4 Where tube locking devices are available, the alignment of the crosswire of the light field with the centre of the imaged area **must** be within 1% of the source image distance. Also,

where the centre of the detector housing is marked, the alignment of the crosswire of the light field with the detector housing markings **must** be within 1 cm at a source image distance of 100 cm.

2.14.5 When provision is made for the automatic adjustment of the collimator to the size of the detector in use:

a. it **must** be possible to manually override the collimator operation so that a smaller field can be selected.

b. the X-ray field **must not** exceed the size of the detector at the detector plane by > 1% of the source image distance.

2.14.6 The brightness of the light beam **must** be not less than 100 lux at a distance of one metre from the focal spot.

2.14.7 Means should be provided to limit the illuminating period to no greater than two minutes, with means of manually initiating further illumination.

2.14.8 Light sources should be easily replaced and should not be permanently connected.

2.15. Provision of an air kerma area product meter

2.15.1 An air kerma area product meter should be provided on all radiography systems.

2.15.2 Where provided, the air kerma area product meter **must** be functional. Accuracy of displayed kerma area product **must** be within ±20% of the measured value and should be within ± 10%.

2.16. Stability of X-ray tube assembly

2.16.1 The X-ray tube assembly **must** be supported and remain stationary when placed in position for radiography, except in tomography and other procedures in which it is a requirement that the X-ray tube assembly move in a predetermined manner.

2.17. Stability of mobile apparatus

2.17.1 Means **must** be provided on mobile apparatus to prevent movement away from its stationary position.

2.18. Capacitor discharge apparatus

2.18.1 For capacitor discharge apparatus, as well as the requirements of 2.12.1, the absorbed dose in air from leakage radiation through the dark shutter when the exposure switch or timer is not activated **must not** exceed 20 µGy in any one hour at 50 mm from any accessible surface of the X-ray tube assembly or associated diaphragm or collimator with the collimator fully open.

2.18.2 Capacitor discharge apparatus **must** be fitted with electrically interlocked shutters to limit emission of radiation before the exposure, after the termination of the exposure and during discharging of the capacitors when patient exposure is not needed.

2.18.3 Means **must** be provided to prevent the initiation of exposure during the charging of the capacitors.

2.18.4 Capacitor discharge apparatus **must** be provided with an automatic top-up facility that operates when the kilovoltage drops below the pre-set value by more than 3%.

2.18.5 A control switch **must** be provided to allow manual discharge of the capacitors when the apparatus is connected to the mains supply and when patient exposure is not needed.

2.18.6 Capacitor discharge apparatus **must** be limited to a maximum of 30 mAs. The lowest indicated terminating voltage **must not** be less than 45 kV.

2.18.7 Capacitor discharge apparatus should not be used for radiography of the skull, bones of the thorax, spine, pelvis or abdomen.

3. Quality assurance requirements: Medical radiography

3.1. Quality assurance program

3.1.1 A quality assurance program **must** be set up and maintained.

3.1.2 The program should make sure consistent, optimum-quality images are produced so that the exposure of patients, staff and the public to radiation satisfies the 'as low as reasonably achievable' principle.

3.1.3 Quality assurance procedures **must** be standardised and documented in a Quality assurance manual. RANZCR standards of practice and the RANZCR General X-ray QA and QC Guideline should be followed.

3.1.4 Equipment should be maintained and serviced according to manufacturer's recommendations. This should be at least annually.

3.2. Routine equipment testing

3.2.1 The quality assurance program should include checks and test measurements on all parts of the imaging system, as indicated in this standard, at appropriate time intervals not exceeding one year.

3.2.2 For film screen systems the program should include daily step wedge or equivalent electronic output quality control of X-ray film processors.

3.2.3 For X-ray systems with digital detectors, the ongoing site quality control program should include checks and test measurements listed in **Table 4** below, at appropriate time intervals not exceeding six months.

3.2.4 For X-ray systems with digital detectors when viewed using a narrow window width, an image of a uniform absorber (1 mm copper or test tool supplied by vendor) **must** appear visually uniform and **must** be free from any significant artefacts that have the potential to impact clinical diagnosis (such as variations in signal and/or noise, blurring, pixel line defects, stitching etc). This assessment must be completed at intervals not exceeding six monthly.

3.2.5 For X-ray systems with digital detectors exposure index **must** be repeatable, so that the coefficient of variation of at least three consecutive measurements, taken using the same exposure settings, does not exceed 0.1 This assessment **must** be completed at intervals not exceeding six months.

3.2.6 Also, other digital detector tests including detector calibration, dark noise evaluation, cleaning of computed radiography plates etc. should be routinely carried out as per manufacturer recommendations.

Table 4: Ongoing tests, recommended protocols and action limits

Test	Recommended protocol and action limits
Imaging system mechanical and safety evaluation (visual checks)	Section 5.1 RANZCR Guideline
X-ray to light field and detector alignment	Section 5.2 RANZCR Guideline
Automatic exposure control consistency (where applicable)	Section 5.5 RANZCR Guideline
Consistency of exposure index	Section 5.3 RANZCR Guideline
Image uniformity and artefact evaluation	Section 5.4 RANZCR Guideline

3.3. Image quality

3.3.1 The QA program should include periodic reviews of clinical images to make sure radiographers are using proper collimation, markers, correct positioning and exposure techniques to get clinical images. Based on the image quality reviews, corrective and/or preventive action should be taken.

3.3.2 Radiologists should be involved in the clinical image quality assessment. An example of image quality assessment criteria for chest X-ray is given in Section 6.1 of the RANZCR General X-ray QA and QC Guideline.

3.4. Diagnostic reference levels and exposure index

3.4.1 Dosimetric evaluation of diagnostic procedures should be conducted as part of the QA program.

3.4.2 Practice diagnostic reference levels for common X-ray examinations should be set up. **Table 5** shows the UK national diagnostic reference levels and can be used for comparison until Australian national diagnostic reference levels are made available. Dose levels that consistently exceed the national levels should be investigated and, where appropriate, the exposure factors adjusted to reduce the patient dose.

Table 5: Diagnostic reference levels per radiograph for a Standard-sized patient (70 kg) – UK 2010 review

Examination	Entrance surface dose * in mGy	Dose area product in $Gycm^2$
Chest (posterior to anterior)	0.15	0.1
Chest (anterior to posterior)	0.2	0.15
Chest (lateral)	0.54	-
Cervical spine (anterior to posterior)	-	0.15
Cervical spine (lateral)	-	0.15
Thoracic Spine (anterior to posterior)	3.5	1.0
Thoracic Spine (lateral)	7.0	1.5
Lumbar Spine (anterior to posterior)	5.7	1.5
Lumbar Spine (lateral)	10.0	2.5
Abdominal (anterior to posterior)	4.4	2.5
Pelvis (anterior to posterior)	3.9	2.2

*Entrance surface dose is absorbed dose in air including backscatter at the point of incidence of the beam axis with the patient entrance surface.

3.4.3 For imaging systems with digital detectors, the target range for the exposure index as recommended by the manufacturer for various diagnostic procedures should be displayed near the acquisition monitor. Any consistent change in the exposure index should be investigated.

3.4.4 New and upgraded digital radiography systems should display the deviation index as per International Electrotechnical Commission standard 62494-1 to provide radiographers the necessary feedback related to the level of exposure used to create the image. Radiographers should use this feedback to get diagnostic images at the lowest possible dose.

3.5. Wet film processing

3.5.1 Good processing procedures and quality control should be followed to make sure correct and consistent film processing and good-quality radiographs and to avoid the necessity for repeated X-ray examinations.

3.5.2 Chemicals used for developing and processing X-ray film should be according to manufacturer's recommendations.

3.5.3 Unexposed film **must** be stored as per manufacturer's recommendations for temperature and humidity. The film **must** be suitably protected from secondary radiation.

3.5.4 Chemistry supplies should be kept properly topped up according to the workload of the facility.

3.6. Digital image printing

3.6.1 Where digital images are printed for review or reporting by clinicians, a periodic check of printing quality should be done at appropriate intervals, not exceeding six months. The manufacturer-recommended protocol or section 4.2 of the RANZCR General X-ray QA and QC Guideline should be followed for printer quality control

3.7. Image viewing

3.7.1 Viewing conditions should meet the following requirements to make sure proper assessment of image quality and accurate reporting from films (including printed digital images):

a. the minimum brightness in the centre and in each quadrant of the illuminator should be >1000 candela/m^2. All brightness levels within an individual box should be within ± 10% of the mean value
b. the colour of the illuminator should be white or blue and should be consistent throughout a complete set of illuminators
c. it should be possible to restrict the illuminated area of the radiograph to avoid dazzling the viewer
d. a magnifier should be available to display areas of a radiograph by a factor of two to four times and be able to identify small image details of sizes down to 0.1 mm
e. a spotlight should be available for viewing exceptionally dark areas of the radiographic image
f. there should be a low level of ambient light in the viewing room.

3.7.2 For soft copy reporting, the primary monitors should comply with the current RANZCR Standards of Practice.

3.7.3 Monitor quality control should be performed at an appropriate interval not exceeding six months. Where an auto-quality control program is not installed on the primary monitor, the AAPM TG 18-QC test pattern of appropriate image resolution should be available for routine quality control. Details of this test pattern and the procedure for monitor quality control are discussed in Section 4.1 of the RANZCR General X-ray QA and QC Guideline.

4. Compliance requirements: bone mineral densitometry

4.1. Radiation warning sign

4.1.1 A radiation warning sign complying with Schedule 6 of the Regulation **must** be displayed on the outside of the entry doors to any room in which a bone mineral density apparatus is installed.

4.2. Markings on X-ray generators and tube assemblies

4.2.1 X-ray generators and tube assemblies **must** be permanently marked in English and the markings **must** be clearly visible.

4.2.2 X-ray generators **must** bear either:

a. the name or trademark of the manufacturer,
b. the type or model number,
c. the serial number, or
d. an EPA-generated number that links to (a), (b) and (c).

4.2.3 X-ray tube assemblies **must** bear either of the following markings in a visible position:

a. the name or trademark of the manufacturer of the X-ray tube housing,
b. the type or model number of the X-ray tube housing,
c. the serial number of the X-ray tube housing, or
d. an EPA-generated number that links to (a), (b) and (c).

4.3. Quality assurance program

4.3.1 A quality assurance program **must** be set up and maintained.

4.3.2 The program should make sure consistent, optimum-quality images are produced so that the exposure of patients, staff and the public to radiation satisfies the 'as low as reasonably achievable' principle.

4.3.3 QA procedures **must** be standardised and documented in a QA manual.

4.3.4 The manufacturer's recommended quality control program should be followed. This program should include daily calibration of bone mineral density before clinical use. A consulting radiation expert **must** examine the daily calibration results to determine whether the repeatability of bone mineral density results is within the manufacturer's limits.

4.3.5 The practice should have a control chart or data used for tracking bone mineral density variations and an action plan to address variations.

4.3.6 Equipment should be maintained and serviced according to manufacturer's recommendations. This should be at least annually.

5. Test protocols

5.1. Kilovoltage accuracy and reproducibility

Aim

- To determine how the measured kVp compares with the generator setting.
- To determine the variation in mean kVp over a number of exposures at the same generator setting.

Exposure factors

- kVp accuracy: Variable kVp, fixed mA and fixed time (e.g. 200 mA, 0.1s) or fixed mAs.
- kVp reproducibility: Fixed kVp, fixed mA and fixed time or fixed mAs.

Method

- Position the dosimeter at the distance recommended by the manufacturer.
- Collimate to the size of the dosimeter.
- Make a series of exposures across the clinically used kVp range and calculate the difference between the set and measured kVp.
- Make a minimum of three exposures at fixed kVp, mA and time (e.g. 70 kVp, 200 mA, 0.1s) and calculate the coefficient of variation from the quotient of the standard deviation (σ) and mean ($\bar{\mathbf{x}}$)

$$\textbf{Coefficient of variation} = \frac{\boldsymbol{\sigma}}{\bar{\mathbf{x}}}$$

Compliance requirement

See section 2.3.

Notes

- Do not use times below 0.1 seconds.
- Follow manufacturer recommendations regarding orientation of the dosimeter regarding the anode-cathode axis of the X-ray tube.

5.2. Exposure timer accuracy and reproducibility

Aim

- To determine how the measured exposure time compares with the set time.
- To determine the variation in exposure time over a number of exposures at the same generator setting.

Exposure factors

- Exposure timer accuracy: Fixed kVp, fixed mA, (e.g. 70 kVp, 200 mA) variable time.
- Exposure time reproducibility: Fixed kVp, fixed mA and fixed time.

Method

- Position the dosimeter at the distance recommended by the manufacturer.
- Collimate to the size of the dosimeter.
- Make a series of exposures starting at the clinically used shortest exposure time, then across the range of commonly used timer settings up to 0.5 seconds and calculate the difference in selected and measured time.
- Make a minimum of three exposures at fixed kVp, fixed mA and time (i.e. 70 kVp 200 mA, 0.1 s or similar) and the calculate the coefficient of variation.

Compliance requirement

See section 2.4.

Notes

This test is not needed for apparatus where mAs is selected as a single component.

5.3. Radiation output reproducibility

Aim

To determine the variation in radiation output over a number of exposures at the same generator setting.

Exposure factors

70 kVp, 20 mAs or similar.

Method

- Position the dosimeter at a fixed distance (75-100 cm) from the focal spot or at the distance specified by the manufacturer. Record the distance used.
- Place a lead sheet under the dosimeter to minimise backscatter (if applicable; note that some dosimeters are lead-backed).
- Collimate the beam to the size of the dosimeter.
- Make a minimum of three exposures and calculate the coefficient of variation.

Compliance requirement

See section 2.5.1.

Notes

If a unit fails to consistently reproduce output, other measurements may be meaningless.

5.4. Radiation output linearity with mA or mAs

Aim

To determine the linearity of the radiation output over a range of mA or mAs settings.

Exposure factors

70 kVp or similar, variable mA, 0.1 s or variable mAs.

Method

- Position the appropriate dosimeter at a fixed distance (75-100 cm) from the focal spot or at the distance specified by the manufacturer. Record the distance used.
- Place a lead sheet under the dosimeter to minimise backscatter (if applicable; note that some dosimeters are lead-backed).
- Collimate the beam to the size of the dosimeter. Make a series of exposures at as many mA or mAs settings as practicable, covering the clinically used range.
- Calculate μGy/mAs (X) by dividing output by the nominal mAs.
- Determine X_{max} and X_{min}
- Calculate the coefficient of linearity:

$$\textbf{Coefficient of linearity} = \frac{\mathbf{X_{max} - X_{min}}}{\mathbf{X_{min} + X_{max}}}$$

- The coefficient of linearity **must** not exceed 0.1.

Compliance requirement

See sections 2.5.2 and 2.5.3.

Notes

- kVp should be measured at each mA setting to assess kVp compensation.
- Linearity should be measured for both/all focal spot(s) sizes as μGy/mAs may vary.

5.5. Half-value layer

Aim

To assess the X-ray beam quality and determine the adequacy of filtration.

Exposure factors

Fixed kVp (i.e.70–100), fixed mAs (e.g 20 mAs).

Method

- Remove all optional or easily removable filtration.
- Position the dosimeter at a fixed distance (75-100 cm) from focal spot or at the distance specified by the manufacturer. Record the actual distance used.
- Place a lead sheet under the dosimeter to minimise backscatter (if applicable; note that some dosimeters are lead-backed).
- Collimate the X-ray beam to the size of the dosimeter.

If using direct meter reading

- Make an exposure and record the HVL from the dosimeter.

If using filters and air kerma measurements

- Make three exposures with no filters added (free in air), then calculate the mean air kerma.
- Position a 1 mm thick aluminium filter between the X-ray tube and dosimeter, make an exposure and record the air kerma.

- Repeat the exposures with extra aluminium filters until the measured air kerma falls to less than 50% of the unfiltered air kerma value.
- Plot air kerma against filter thickness using a semi-log scale.
- From the plot, determine the thickness of aluminium corresponding to half of the mean unfiltered air kerma.

Compliance requirement

See section 2.6.1.

Notes

- kVp should be checked before half-value layer assessment.
- Make sure the entire X-ray beam is intercepted by the filters.
- If the kVp selected for the half-value layer assessment is different from those listed in **Table 2**, use linear interpolation to estimate the minimum half-value layer needed for compliance.
- If the measured half-value layer complies with this requirement at a single set tube voltage, it is assumed that it complies at all available tube voltages.

5.6. Dead-man exposure switch

Aim

To make sure the exposure is ended by removing pressure from the exposure switch.

Exposure factors

Low kV, mA, long exposure time (e.g. 0.5 seconds).

Method

- Position the dosimeter in the primary beam at 50 cm or similar from focus.
- Initiate an exposure and release the switch before the exposure ends.
- Radiation emission **must** stop when the switch is released.
- The dosimeter will indicate the time taken for the exposure to end.

Compliance requirement

See section 2.8.

5.7. Backup/guard timer

Aim

To make sure the guard timer and/or backup timer are functioning, and the backup time or post exposure mAs do not exceed the specified tolerances.

Exposure factors

Low kVp (e.g. 40-50 kVp).

Method

- Cover the selected automatic exposure control sensor with the lead.

- Place the dosimeter in the beam.
- Make an exposure and record the displayed post exposure mAs and the measured exposure time.

Compliance requirement

See section 2.9.2.

Notes

- Use a low mA setting to test time cut off.
- Use a high mA setting to test for mAs cut-off.
- Some systems will activate the guard timer and an error message will be displayed indicating that the dose rate wasn't enough to produce a clinical image.

5.8. Automatic exposure control reproducibility

Aim

- To assess the variation in radiation output and exposure time for a number of exposures of the same object under automatic exposure control.
- To assess the percentage difference in sensitivity of lateral automatic exposure control sensors.

Exposure factors

80 kVp, 200 mA or similar.

Method

- Place 1 mm of copper or another appropriate absorber at the tube head.
- Place the dosimeter in the beam. If a lead backed dosimeter is used, make sure the dosimeter is not directly in front of the selected automatic exposure control sensor.
- Set the source to image distance and focal spot size to typical clinical conditions.
- Select the central automatic exposure control sensor and expose.
- Record the measured air kerma, post exposure mAs and displayed air kerma area product if available.
- Repeat twice.
- Repeat for all other automatic exposure control sensors.
- Calculate the coefficient of variation for all recorded parameters for each automatic exposure control sensor.
- Calculate the percentage difference in either the post exposure mAs and measured air kerma of the lateral automatic exposure control sensors (Y_{left} and Y_{right}).

$$\textbf{Percentage difference}\ (\%) = \frac{|Y_{left} - Y_{right}|}{Y_{mean}} \times 100$$

Compliance requirements

See section 2.9.3 and 2.9.4.

Notes

- For computed radiography, the dosimeter can be placed inside the Bucky next to the computed radiography cassette.
- For digital radiography the dosimeter should be placed on the detector housing at the periphery of the beam to make sure it does not cover any of the automatic exposure control sensors. Ideally the grid should be removed
- At acceptance, any combinations of automatic exposure control sensors used clinically should be assessed.
- An estimation of the automatic exposure control detector air kerma can be made by applying a distance correction and grid factor (if a grid is present) to the air Kerma measurement.
- Use identical technique factors when assessing difference in sensitivity of lateral sensors.
- If there are a total of five automatic exposure control chambers, the lateral sensors can be grouped into a left and right pair.

5.9. Automatic exposure control: kVp and thickness compensation

Aim

To make sure the automatic exposure control device controls exposure so that the exposure index is within 20% of the mean exposure index when both kVp and patient thickness are varied.

Exposure factors

Variable kVp, automatic exposure control exposure.

Method

- Place an appropriate absorber at the patient position (10 or 15 cm water or PMMA phantom is recommended).
- Make an exposure at a clinically utilised kVp using the central automatic exposure control sensor and record the exposure index. Repeat the measurements by varying the kVp across the clinical tube potential range (e.g. 60, 70, 80 etc.).
- Repeat the measurements at 70 kVp by varying the attenuator thickness to mimic the range of attenuations found clinically (e.g. 5 cm, 10 cm, 15 cm & 20 cm of PMMA).
- Determine the mean exposure index across the kVp range and the mean exposure index across the range of attenuator thicknesses.
- Determine if the variation in each exposure index measurement is within 20% of the respective mean EI.

Compliance requirements

See section 2.9.5.

Notes

- Collimation **must** be fixed during the test as the exposure index may change with variations in collimation.
- The grid should be present in the beam.
- The relationship between the exposure index and detector air kerma is not always linear. For non-linear systems, the relationship between the exposure index and detector air kerma can be gotten simultaneously with the system signal transfer property in section 2.10.2. The inverse of this relationship can then be used to linearise the exposure index measurements to detector air

$kerma_{EI}$ which will let them to be used quantitatively (see Appendix 1). In this case, each detector air $kerma_{EI}$ value should be within 20% of the mean detector air $kerma_{EI}$.

5.10. Digital image receptors: Signal transfer properties

Aim

To establish the relationship between detector air kerma and mean pixel value on digital detectors.

Exposure factors

70 kVp, various mAs.

Method

- Set the X-ray tube above the table top or floor and place the dosimeter in the centre of the X-ray beam at a minimum distance of 130 cm from the tube focus.
- Collimate the X-ray beam to the size of the dosimeter.
- Place an absorber (1 mm copper) at the collimator.
- Make a trial exposure and establish the mAs setting needed to result in an air kerma of approximately 10 µGy. Measure the air kerma at a range of mAs settings (typically 1, 4, 10 and 20 µGy).
- Remove the dosimeter and position the detector at the same distance from the focus. The detector should ideally be placed onto a lead apron to minimise backscatter.
- Remove the copper or absorber used and open the collimator to fully cover the detector. Put the absorber back on the collimator.
- Select the program that produces images with minimal clinical processing (flat-field images).
- Expose the entire detector using the mAs pre-set estimated above to give a detector air kerma of ~1 µGy. Draw a region of interest of approximate size 2 cm x 2 cm in the centre of the image and record the mean pixel value.
- Repeat the above procedure using the mAs presents required to give a range of detector air kermas of ~ 4, 10 & 20 µGy.
- Plot the relationship between detector air kerma and mean pixel value and get the detector's signal transfer property.

Compliance requirements

See section 2.10.2.

Notes

- Some detectors are integrated into a Bucky/housing that may incorporate a fixed grid. The air kerma measurements will overestimate the detector air kerma on these systems. However, this will not affect the methodology used to confirm the signal transfer property of the detectors.
- Region of interest analysis can often be completed within the software on the acquisition workstation. However, detectors from certain vendors will need the images to be viewed and analysed on a reporting workstation.
- The exposure index may also be recorded following each exposure. This will let the relationship between the detector air kerma and exposure index to be established.

5.11. Digital image receptors: uniformity and artefacts

Aim

- To quantify the uniformity of the recorded signal from a uniformly exposed digital detector.
- To visually inspect an image for uniformity and image for the presence of artefacts.

Method

- If test 5.10 has been performed, view the image taken with a detector air kerma of ~ 4 µGy on an appropriate workstation. Otherwise, get an image of a uniform absorber (1 mm copper or test tool supplied by vendor) at 70 kV and 10 mAs; follow protocol in 5.10 for guidance on focus to detector distance, collimation, image processing etc. If there is no acquisition protocol for minimal clinical processing (flat-field images), use an extremity protocol.
- Visually inspect the image using 1:1 magnification and a narrow window width to confirm that the image appears uniform and to identify any artefacts.
- Draw five regions of interest of an approximate size of 2 cm x 2 cm, one in the centre of the image and one in the centre of each quadrant. Record the mean pixel value in each region of interest.
- Calculate the mean of the mean pixel values across the five regions of interest.
- Calculate the percentage difference between each of the five regions of interest mean pixel values from the calculated mean of the mean pixel value.

Compliance requirements

See section 2.10.3 and 3.2.4

Notes

- If the detector's signal transfer property established in test protocol 5.10 is not linear, use the inverse of the signal transfer property equation to linearise pixel values to detector air $kerma_{MPV}$ (see Appendix 1).
- Region of interest analysis can often be completed within the software on the acquisition workstation. However, detectors from certain vendors will need the images to be viewed and analysed on a reporting workstation.

  To identify any areas of blurring, line defects or stitching artefacts, an image of a fine wire mesh can be created using a low kVp (50 kV, 2.5mAs, no copper in the beam) and viewed on a reporting monitor.

5.12. Digital image receptors: exposure index

Aim

To make sure the detector exposure index is repeatable.

Method

- Repeat the 4 µGy exposure in test protocol 5.10 three times and record the EI each time.
- Calculate the coefficient of variation in the EI measurements.

Compliance requirements

See section 2.10.5.

Notes

- For systems with a non-linear exposure index relationship with detector air kerma, the displayed EI's will need to be linearised to detector air kerma$_{EI}$ before being used quantitatively.
- To determine the accuracy of the displayed EI, it is recommended that the manufacturer methodology (where available) is adopted.

5.13. Leakage radiation

Aim

To measure any leakage radiation through the X-ray tube assembly and beam limiting device.

Exposure factors

Maximum clinical kVp, with appropriate mAs (time should not exceed one second). Make sure tube rating is not exceeded.

Method

- The collimator should be fully closed or covered with ~ 3 mm of lead.
- Position the dosimeter at 1 m from focal spot. Make a series of exposures to measure leakage at various positions, including the cathode, the anode and the front of tube assembly. Distances other than 1 m may be used as long as an inverse square law correction is applied.
- Calculate the time averaged leakage using the manufacturer recommended continuous mA rating at the kVp used for the measurement or alternatively, use tube cooling curve data.

Compliance requirements

See section 2.12.1 and 2.12.2.

Notes

- An incorrectly positioned X-ray tube insert or flaws in the lead shielding in a housing may give rise to narrow but intense beams of leakage radiation which fail to ionise the entire chamber and therefore appear not to exceed the specified limit; such beams are highly undesirable, and the cause should be remedied.
- Pinhole leaks or 'hotspots' can be detected by the use of a fluorescent screen or non-screen film wrapped around the X-ray tube assembly.

5.14. Control of the primary beam during radiography

Aim

- To make sure the radiation field and the light field are aligned.
- To make sure the centre of the light field and the centre of the imaged field are aligned.
- To make sure the centre of the light field and the image receptor housing markings are aligned (when the centre of the image receptor is marked on the receptor housing).
- The X-ray field **must** not exceed the size of the image receptor at the image receptor plane by > 1% of the source to image distance (when there is provision for automatic adjustment of the collimator).

Exposure factors

60 kVp, 5 mAs or similar.

Method

- Align the X-ray tube to the centre of the detector and set the source to image to 100 cm from the focus to the detector plane. The tube detents should be used for positioning when available.
- If the centre of the detector is marked on the housing, measure the distance between the crosswire of the light field and the detector housing markings.
- Place the beam alignment test tool on the detector housing with its central axis aligned with the crosswire of the light field and adjust the light field to alignment markers on test tool, or
- Collimate to about two-thirds of the detector size and use metal markers to delineate the four edges of the light field and the crosswire of the light field.
- Mark either the cathode or anode end of the tube for orientation purposes.
- Expose and process the image.
- Measure the distance between the radiation field and light field for all edges.
- Measure the distance from the marker indicating the crosswire of the light field to each of the four edges of the image. Calculate the difference between the crosswire of the light field and the centre of the imaged area.
- If the automatic adjustment of the collimator to the size of the detector is available, confirm that the light field does not exceed the detector at the detector plane by > 1% of the source image distance.

Compliance requirements

See section 2.14.3, 2.14.4 and 2.14.5.

Notes

- At acceptance and following the replacement of an X-ray tube, the above procedure should be completed using all available focal spot sizes.
- Apply an appropriate correction for magnification if a test tool or alignment markers are placed on the detector housing.
- X-ray assembly and collimator should be visually inspected to assess how perpendicular they are before starting alignment test.
- If the alignment of the radiation field and light field is within tolerance, the light field can be used for the purposes of assessing compliance with clause 2.14.5 b.

5.15. Accuracy of air kerma area product meter

Aim

To make sure the kerma area product meter is accurate for patient dosimetry audits.

Exposure factors

Variable kVp (e.g. 60, 80 or 100), 10 mAs or similar.

Method

- Position the X-ray tube over a table and collimate to ~ 10x10 cm at a distance of 100 cm from the focus of X-ray tube.
- Place the dosimeter at the centre of the X-ray beam.
- Expose using 60 kVp and 10 mAs and record the measured air kerma and displayed KAP.
- Remove the dosimeter and position a CR cassette or portable digital detector at the centre of the X-ray beam without changing distance or collimation.
- Expose using a low level of radiation (direct exposure of digital detectors should be avoided).
- Process the image and measure the irradiated area.
- Multiply the measured air kerma by the measured irradiated area to calculate kerma area product.
- At acceptance, the above procedure should be repeated at another clinically utilised kVp and using a different collimated area.

Compliance requirements

See section 2.15.2.

Notes

- Be aware of the different kerma area product units and apply any necessary corrections when comparing the measured and displayed kerma area product.
- If the X-ray and light field alignment is already established, the exposed area may be inferred using the light field.
- Some systems will not display a kerma area product unless a digital image receptor has been directly exposed. If this is the case, lead should be used to cover the image receptor when measuring the air kerma using a lead backed dosimeter.

Schedule 1: Compliance requirements for medical radiography apparatus

The clauses of the Standard listed in this Schedule are the requirements referred to in Radiation Management Licence Condition 3.1 that a 'person responsible' must make sure an apparatus meets for compliance with this Standard.

Requirements or condition	Clause(s)
Advice to person responsible	1.1.1, 1.1.3, 1.1.6, 1.1.8, 1.1.9
Advice to consulting radiation expert	1.2.1, 1.2.5
System performance	2.1.1
Radiation warning sign	2.2.1, 2.2.2, 2.2.3
Accuracy of kilovoltage controls	2.3.1, 2.3.2
Accuracy of timer controls	2.4.1, 2.4.2
Exposure consistency and linearity	2.5.1, 2.5.2, 2.5.3
Filtration	2.6.1, 2.6.2, 2.6.3
Indicators of operation	2.7.1, 2.7.3
Exposure switch	2.8.1, 2.8.2, 2.8.3, 2.8.4
Automatic exposure control	2.9.1, 2.9.2, 2.9.3, 2.9.4
Control of multiple X-ray tubes	2.11.1
Leakage radiation	2.12.1, 2.12.2
Markings on X-ray generators etc.	2.13.1, 2.13.2, 2.13.3
Control of primary beam during radiography	2.14.1, 2.14.2, 2.14.3, 2.14.4, 2.14.5, 2.14.6
Provision of an air kerma area product meter	2.15.2
Stability of X-ray tube assembly	2.16.1
Stability of mobile apparatus	2.17.1
Capacitor discharge apparatus	2.18.1, 2.18.2, 2.18.3, 2.18.4, 2.18.5, 2.18.6
Quality assurance program	3.1.1, 3.1.3
Digital detectors	3.2.4, 3.2.5
Wet film processing	3.5.3

Schedule 2: Compliance requirements for bone mineral densitometry apparatus

The clauses of the Standard listed in this Schedule are the requirements referred to in Radiation Management Licence Condition 3.1 that a 'person responsible' must make sure an apparatus meets for compliance with this Standard.

Requirements or Condition	Clause(s)
Advice to person responsible	1.1.1, 1.1.3, 1.1.6, 1.1.8, 1.1.9, 1.1.10
Advice to consulting radiation expert	1.2.1, 1.2.5,
Radiation warning sign	4.1.1
Markings	4.2.1, 4.2.2, 4.2.3
Quality assurance program	4.3.1, 4.3.3, 4.3.4

Appendix 1

(a) Digital detectors: signal transfer property

In order to get meaningful quantitative measurements, a digital detector system must have a relationship that can be made linear between detector air kerma and mean pixel value. This relationship defines the signal transfer property of the detector. Get a simple signal transfer property relationship (linear, logarithmic or power) as specified in compliance test 2.10.2. The equations for these signal transfer property relationships and their respective inverses are shown below, where a, b and c are constants, and detector air kerma$_{MPV}$ is the mean pixel value is made linear with the detector air kerma.

Linear: $MPV = a + bDAK \rightarrow DAK_{MPV} = \left(\frac{MPV-a}{b}\right)$ [A1.1]

Logarithmic: $MPV = a\mathbf{ln}(DAK) + b \rightarrow DAK_{MPV} = exp\left(\frac{MPV-b}{a}\right)$ [A1.2]

Power: $MPV = aDA\mathrm{K}^{\mathrm{b}} + c \rightarrow DAK_{MPV} = \left(\frac{(MPV-c)}{a}\right)^{\frac{1}{b}}$ [A1.3]

The inverse signal transfer property equations above can be used to get the detector air kerma$_{MPV}$ linear values needed for tests 2.10.2 and 2.10.3.

(b) Automatic exposure control - exposure index

Test 2.9.5 requires that the exposure index is recorded and used to check the consistency of the automatic exposure control function when varying both tube potential and water/PMMA thickness placed at the patient position. The exposure index values for all exposures should not vary by more than 20% from the mean exposure index. This quantitative analysis needs to result in a linear relationship between detector air kerma and exposure index.

If the detector has a non-linear relationship between detector air kerma and exposure index, the exposure index should be made linear with detector air kerma.

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Definitions

Absorbed dose means energy delivered from radiation per unit mass of absorbing material, measured in Gray (Gy) or mGy. One Gray equals one joule per kilogram.

Act means the *Protection from Harmful Radiation Act 1990*.

Air kerma means *kerma* measured in a mass of air.

Added filtration means quantity indicating the filtration affected by added filters in the useful beam but excluding inherent filtration.

Authority means NSW Environment Protection Authority.

Barrier means a protective wall of radiation attenuation material(s) used to reduce the dose equivalent on the side beyond the radiation source.

Coefficient of variation means the standard deviation divided by the mean of a set of numbers.

Coefficient of linearity = $(X_{max.} - X_{min})/(X_{min.} + X_{max})$

Council means the Radiation Advisory Council.

Detector air kerma is the kerma measured in a mass of air at the position of the radiographic detector.

Deviation Index is a parameter which quantifies the deviation of an actual exposure index from the appropriate exposure index (called target exposure index) as defined in IEC 62494-1. D = 10.log {EI/EI_T} where D is the deviation index, EI is the actual exposure index and EI_T is the target exposure index.

EPA means NSW Environment Protection Authority.

Exposure Index is a number which is a measure of the detector response to radiation in the relevant region of an image acquired with a digital X-ray imaging system.

Filtration means modification of the spectral distribution of an X-ray beam as it passes through matter by the differential absorption of poly-energetic photons.

Focal spot means the area of the *target* from which X-rays are emitted.

Half-value layer (HVL) means the thickness of a specified material that reduces the absorbed dose in air of a given X-ray beam to half its original value.

Inherent filtration means the *filtration* affected by the irremovable materials of an *X-ray tube assembly* (i.e. glass, oil and port seal), through which the radiation beam passes before emerging from the X-ray tube assembly. It is expressed in terms of thickness of a reference material that, at a specified potential difference and waveform, gives the same radiation quality in terms of *half-value layer*.

Kerma (K) means kinetic energy released in a material by ionising radiation and is determined as the quotient of dE_{tr} by dm, where dE_{tr} is the sum of the initial kinetic energies of all the charged ionising particles liberated by uncharged ionising particles in a material of mass dm (K = dE_{tr}/dm). The unit of kerma is the Gray (Gy), or joule per kilogram.

KAP means air kerma-area product i.e. air kerma multiplied by radiation area. The KAP value may be displayed on the operator's console, or on a separate kerma-area product meter. The units of KAP are typically Gy.cm^2, or similar e.g. mGy.cm^2, cGy.cm^2, µGy.m^2. It is important to make a note of the units when conducting a patient dosimetry audit.

Kerma rate means kerma per unit time and is determined as the quotient of dK by dt, where dK is the increment of kerma in the time interval dt. Variants include incident air kerma rate (does not include backscattered radiation) and entrance surface air kerma rate (includes backscattered radiation).

Lead equivalent means the thickness of lead causing the same attenuation of a beam of a specified radiation quality as the material under consideration.

New installation means a completely new build or modifications to barriers in an existing room.

Operator means a person licensed under section 7 of the Act to use ionising radiation apparatus.

Person responsible means as defined in section 6 of the Act.

Phantom means a test object that simulates the average composition of various structures.

Primary beam means all ionising radiation that emerges through the specified aperture of the protective shielding of the X-ray tube and the collimating device.

Radiographic apparatus means ionising radiation apparatus, which emits ionising radiation, used for the purpose of radiography.

Radiation leakage means ionising radiation transmitted through the protective shielding of a radiation source other than the primary beam.

Radiation quality refers to the penetrating ability of a beam of X-rays. It is determined by the energy distribution of the photons in the beam, which in turn depends on the kV waveform and peak voltage across the tube, and on the filtration through which the beam has already been transmitted. The quality of an X-ray beam is described by the HVL of the beam and is measured in terms of mm of aluminium in the diagnostic range.

Regulation means the Protection from Harmful Radiation Regulation 2013.

Scattered radiation means ionising radiation produced from the interaction of electromagnetic ionising radiation with matter. It has a lower energy than, or a different direction from, that of the original incident ionising radiation.

Target means the area of the anode that is struck by the electrons from the cathode.

Target Exposure Index means the expected value of exposure index when the detector is appropriately exposed.

Total filtration means the sum of inherent filtration and added filtration between the radiation source and the patient or other defined plane.

X-ray tube assembly means the *X-ray tube housing* with an *X-ray tube insert*, but not including a collimating device.

X-ray tube housing means a container in which an X-ray tube is mounted for normal use, providing protection against electric shock and against ionising radiation except for an aperture for the useful beam. It may contain other components.

X-ray tube insert means a highly evacuated vessel for the production of X-radiation by the bombardment of a *target*, usually contained in an anode, with a beam of electrons accelerated by a potential difference.

Unless otherwise defined, all words in this standard have the same meaning as in the Act and the Regulation.