Final Draft
Radiation Guideline 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 receive a commensurate health benefit and everything reasonable has been done to reduce the dose.

The complexities of modern radiography apparatus make regular performance monitoring essential for maintaining optimum image quality. It is important that the performance level of each apparatus is established during acceptance testing, and that performance standards are maintained over time by an appropriate quality assurance program. Inadequate performance and quality assurance procedures may cause an unnecessary increase in radiation exposure to the patient and staff and a decrease in the diagnostic value of the examination.

The objectives of this guideline are to:

- ensuring that adequate 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
- ensuring better monitoring of apparatus performance
- providing reference dose levels as a guide to patient exposure.

The guideline for medical radiography and bone mineral densitometry is for the information of the person responsible and licensed users of radiographic apparatus, and persons accredited under section 8 of the *Radiation Control Act* 1990 as Consulting Radiation Experts (CREs). It is to be used by CREs to assess apparatus for compliance with conditions of radiation management licence, and should be read in conjunction with the Act and the Radiation Control 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. In the event of an inconsistency between the guideline and the amended legislation, the requirements of the legislation prevail to the extent of the inconsistency.

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 guideline was developed by the Hazardous Materials, Chemicals and Radiation Section of the Environment Protection Authority in consultation with the Radiation Advisory Council.

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1. General requirements and recommendations

1.1 Advice to person responsible

1.1.1 Compliance testing of diagnostic imaging apparatus for the purpose of certification for compliance **must** be conducted by an EPA-accredited Consulting Radiation Expert (CRE).

1.1.2 Requirements listed in Schedule 1 and 2 of this guideline are to be met for compliance of medical radiography and bone mineral densitometry apparatus respectively.

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

1.1.1 Specifications for radiation shielding of protective barriers and the design details of rooms used for ionising radiation apparatus should be determined in accordance with Radiation Guideline 7: Radiation shielding design, assessment and verification requirements and documented by an appropriately qualified person before building works start.

1.1.2 The provision of radiation shielding should ensure that the radiation levels behind the shielding comply with the requirements of *Radiation Guideline 7.*

1.1.3 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 BMD apparatus if beam geometry and patient workload dictate the need for operator protection.

1.1.4 Where a fixed protective shield is provided it should be not less than 2100 mm in height.

1.1.5 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.

1.1.6 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.

1.1.7 All protective clothing used **must** comply with the requirements of the EPA *Policy on x-ray protective clothing.*

2.1 Advice to Consulting Radiation Expert

1.2.1 A CRE **must** ensure that 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 meter/detector (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 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 Prior to commencing testing 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 CRE must comply with radiation guideline 6 part 4 Fluoroscopy in addition to this radiography guideline.

2.1 System performance

2.1.1 All tests listed in Table 1 that include any clause listed in Schedule 1 **must** be carried out at the frequency specified and results **must** comply with the limits referenced in this guideline.

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	✓	✓	×	×
2.10	Mounted grids	✓	✓	×	×
2.11	Digital image receptors	✓	✓	×	✓
2.12	Control of multiple x-ray tubes	✓	✓	✓	×
2.13	Leakage radiation	✓	×	✓	×
2.14	Markings on x-ray generators & tube assemblies	✓	✓	✓	×
2.15	Control of the primary beam during radiography	✓	✓	✓	×
2.16	Provision of a kerma area product meter	✓	✓	✓	×
2.17	Stability of x-ray tube assembly	✓	✓	✓	×
2.18	Stability of mobile apparatus	✓	✓	✓	×
2.19	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 CRE has determined that not to do so would not pose a risk to the safety of any person.

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. Immediate illumination **must** be ensured.

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** ensure that the first HVL 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 additional filters are used, determination of the HVL **must** be carried out using minimum filtration.

Table 2: Minimum permissible HVL 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 HVL for x-ray equipment installed since 2015

X-ray tube voltage (kVp)	Minimum HVL (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 CRE 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 (AEC)

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

2.9.2 Where AEC sensor positions are marked on the detector housing, it **must** be verified that they correlate with the AEC sensor selection on the console.

2.9.3 Where AEC is provided, the exposure **must** terminate after no more than 6 seconds or after an exposure of no more than 600 mAs, whichever occurs first.

2.9.4 The variation in measured radiation output or displayed kerma area product, for a minimum of three exposures using the same exposure parameters and with the same absorber in the beam, **must** not exceed ± 5% for each AEC sensor.

2.9.5 In case of 2.9.4, variation in sensitivity of lateral sensors **must** not exceed 10%.

2.9.6 The AEC device should control exposures such that the displayed exposure index (EI) does not vary by more than 20% from the average when kVp and patient thickness are varied over their typical clinical range.

2.9.7 The AEC should not activate unless the x-ray tube is centred to the Bucky or AEC device.

2.10 Mounted grids

2.10.1 Where a grid is used, image **must** be free from any grid artefacts.

2.10.2 In case of a moving grid, there **must** be no lamellae visible on the image at the shortest exposure time used clinically.

2.11 Digital image receptors

2.11.1 An acquisition protocol **must** be available on a digital radiography system to acquire and access images that have minimal clinical image processing. This means removing any high frequency image processing, edge enhancement, noise reduction etc. and having a fixed relationship between detector air kerma and pixel value.

2.11.2 The Signal Transfer Property (STP) of the system i.e. the relationship between detector air kerma and pixel value **must** be verified as simple (e.g. linear, log or power). Systems with unknown or complex relationship **must** not be accepted.

2.11.3 The maximum difference in pixel values across five ROI's on a uniform image **must** be within ±10% of the mean pixel value. If the STP relationship is not linear, the pixel values need to firstly be linearised (see Appendix 1).

2.11.4 When viewed at a narrow display window width, the image acquired in 2.11.3 **must** be free from any significant artefacts (such as stitching, blurring, dead pixels etc.) that have the potential to impact clinical diagnosis.

2.11.5 The 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. If the relationship between detector air kerma and exposure index is non-linear, the repeatability should be checked after EI values are linearised with detector air kerma.

2.12 Control of multiple x-ray tubes

2.12.1 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.

2.13 Radiation leakage

2.13.1 The x-ray tube **must** be enclosed in housing in such a manner 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.

2.13.2 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 2.13.1.

2.14 Markings on x-ray generators and tube assemblies

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

2.14.2 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).

2.14.3 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).

2.14.4 In addition to 2.14.3, x-ray tube assemblies should also bear 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 permissible.

2.15 Control of the primary beam during radiography

2.15.1 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.

2.15.2 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.

2.15.3 The area illuminated by the light beam collimator **must** be effectively coincident 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 SID. The centre of the illuminated area **must** be indicated.

2.15.4 Where tube locking devices are available, the alignment of the crosswire with the centre of Bucky and the centre of the irradiated area **must** be within 1% of the SID.

2.15.5 When provision is made for the automatic adjustment of the collimator to the size of the image receptor 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 image receptor at the image receptor plane by > 1% of the SID.

2.15.6 The illuminance of the light beam **must** be not less than 100 lux at a distance of 1 metre from the focal spot.

2.15.7 Means should be provided to limit the illuminating period to no greater than 2 minutes, with means of manually initiating further illumination.

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

2.16 Provision of an air kerma area product (KAP) meter

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

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

2.17 Stability of x-ray tube assembly

2.17.1 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.

2.18 Stability of mobile apparatus

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

2.19 Capacitor discharge apparatus

2.19.1 For capacitor discharge apparatus, in addition to the requirements of 2.13.1, 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 1 hour at 50 mm from any accessible surface of the x-ray tube assembly or associated diaphragm or collimator with the collimator fully open.

2.19.2 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 required.

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

2.19.4 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%.

2.19.5 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 required.

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

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

Note: In the case of radiography apparatus that also has fluoroscopy capabilities; the CRE must comply with Radiation Guideline 6: Part 4 (the Fluoroscopy Guideline).

3. Quality assurance requirements: medical radiography

3.1 Quality assurance program

3.1.1 A quality assurance (QA) program **must** be instituted and maintained.

3.1.2 The program should ensure that 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 QA procedures **must** be standardised and documented in a QA manual. Where applicable, 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. The service frequency should be at least annually.

3.2 Routine equipment testing

3.2.1 The QA program should include checks and test measurements on all parts of the imaging system, as indicated in this guideline, 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 image receptors, the ongoing site quality control program **must** include checks and test measurements listed in table 4 below, at appropriate time intervals not exceeding six months.

3.2.4 In addition, other digital receptor tests including detector calibration, dark noise evaluation, cleaning of CR 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
AEC 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 **must** include periodic reviews of clinical images to ensure that radiographers are using proper collimation, markers, correct positioning and exposure techniques to obtain clinical images. Based on the image quality reviews, corrective and/or preventive action **must** 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 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 (DRLs) for common x-ray examinations should be established. Table 5 shows the UK national DRLs and can be used for comparison until Australian national DRLs are made available. Dose levels that consistently exceed the national DRLs should be investigated and, where appropriate, the exposure factors adjusted to reduce the patient dose.

Table 5: Diagnostic reference levels per radiograph for standard size patient (70 kg) – UK 2010 review

Examination	Entrance Surface Dose (ESD*) in mGy	Dose Area Product (DAP) in Gy-cm^2
Chest PA	0.15	0.1
Chest AP	0.2	0.15
Chest Lat	0.54	–
Cervical spine AP	–	0.15
Cervical spine Lat	–	0.15
Thoracic Spine AP	3.5	1.0
Thoracic Spine Lat	7.0	1.5
Lumbar Spine AP	5.7	1.5
Lumbar Spine Lat	10.0	2.5
Abdominal AP	4.4	2.5
Pelvis AP	3.9	2.2

* ESD 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 receptors, the target range for the EI as recommended by the manufacturer for various diagnostic procedures should be displayed near the acquisition monitor. Any consistent change in the EI should be investigated.

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

3.5 Wet film processing

3.5.1 Good processing procedures and quality control should be adhered to in order to ensure 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 in accordance with 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 Adequate chemistry replenishment should be provided in accordance with 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 **must** be done at appropriate intervals, not exceeding six months. The manufacturer-recommended protocol or section 4.2 of RANZCR General X-ray QA and QC Guideline should be followed for printer QC.

3.7 Image viewing

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

a. the minimum luminance 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. means should be available to restrict the illuminated area of the radiograph to avoid dazzling the viewer

d. means for magnifying details in the displayed radiograph should be available. These means should magnify by a factor of two to four times and contain provisions to identify small image details of sizes down to 0.1 mm

e. an additional 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 QC **must** be performed at an appropriate interval not exceeding six months. Where an auto-QC program is not installed on the primary monitor, the AAPM TG 18-

QC (2k) test pattern **must** be available for routine QC. Details of this test pattern and the procedure for monitor QC are discussed in section 4.1 of the RANZCR General X-ray QA and QC Guideline.

3.8 Inspection and testing of x-ray protective clothing

3.8.1 The QA program **must** include regular testing of x-ray protective clothing as required in the EPA *Policy on X-ray Protective Clothing.*

3.9 Records

3.9.1 A record of maintenance and QA test results **must** be kept for each item of radiation apparatus, monitors and printers. Information on any defects found and their repair should be included.

3.9.2 Records for each radiation apparatus should include any information necessary to allow retrospective dose assessment.

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 (QA) program **must** be instituted and maintained.

4.3.2 The program should ensure that 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 QC program **must** be followed. This program **must** include daily calibration of BMD. CRE **must** examine the daily calibration results to determine whether the repeatability of BMD results is within the manufacturer’s limits.

4.3.5 The practice **must** have a control chart or data used for tracking BMD variations and an action plan to address variations.

4.3.6 Equipment should be maintained and serviced according to manufacturer’s recommendations. The service frequency 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 average 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 kV meter at the distance recommended by the manufacturer.
- Collimate to size of detector.
- Make a series of exposures across the clinically used kVp range and calculate the difference in selected 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 average and standard deviation to estimate coefficient of variation.

Compliance requirement

See section 2.3.

Notes

- Do not use times below 0.1 seconds.
- Follow manufacturer recommendations regarding orientation of the kVp meter/detector with respect to the anode-cathode axis of the x-ray tube.

5.2 Exposure timer accuracy and reproducibility

Aim

- To determine how the exposure time compares with the selected 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 digital timer or detector at the distance recommended by the manufacturer.
- Collimate to size of detector.
- Make a series of exposures commencing at the clinically used shortest exposure time, then across the range of the timer at commonly used 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 100 ms or similar) and calculate average and standard deviation to estimate coefficient of variation.

Compliance requirement

See section 2.4.

Notes

This test is not required 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 appropriate ion chamber or detector at a fixed distance (75-100 cm) from focal spot or at the distance specified by the manufacturer. Record actual distance.
- Place lead sheet under chamber to absorb backscatter.
- Collimate beam to size of chamber/detector.
- Make a minimum of three exposures and calculate the coefficient of variation

Compliance requirement

See section 2.5.1.

Notes

- If a unit fails output reproducibility 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 ion chamber or detector at a fixed distance (75-100 cm) from focal spot or at the distance specified by the manufacturer. Record actual distance.
- Place lead sheet under chamber to absorb backscatter.
- Collimate beam to size of chamber/detector.
- 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 linearity coefficient:

$$\text{linearity coefficient} = \frac{X_{max} - X_{min}}{X_{min} + X_{max}}$$

- Linearity coefficient **must** not exceed 0.1.

Compliance requirement

See sections 2.5.2 and 2.5.3 (medical radiography).

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.
- This test does not directly check if mA settings have been correctly calibrated.

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 appropriate ion chamber or detector at a fixed distance (75-100 cm) from focal spot or at the distance specified by the manufacturer. Record actual distance.
- Place the lead sheet under the chamber to absorb backscatter.
- Collimate the beam to the size of the chamber.

If using direct meter reading

- Make an exposure and record the HVL from the dose meter.

If using filters and exposure measurements

- Make three exposures with no filters added (free in air), then take the average.
- Tape 1 mm of the aluminium filter on the face of the collimating device and make an exposure.
- Repeat exposures with additional aluminium filters until dose falls to less than 50% of unfiltered dose.
- Plot exposure against thickness of filter using a semi-log scale.
- Halve the average free in air exposure and determine corresponding thickness of aluminium from graph.

Compliance requirement

See section 2.6.1.

Notes

- kVp should be checked before HVL assessment.
- Ensure entire beam is intercepted by filters.
- If kVp selected for HVL assessment is different from those listed in Table 2, use linear interpolation to estimate minimum HVL required for compliance.
- If the measured HVL is compliant with this requirement at a single set tube voltage, it is assumed that it is compliant at all available tube voltages.

5.6 Dead-man exposure switch

Aim

- To ensure that the exposure is terminated by removing pressure from the exposure switch.

Exposure factors

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

Method

- Position timer in the primary beam at 50 cm or similar from focus.
- Initiate exposure and release switch before exposure is terminated.
- Radiation emission **must** cease when switch is released.
- Measuring instrument will indicate time when exposure is terminated.

Compliance requirement

See section 2.8.

5.7 Correct selection of automatic exposure control sensors

Aim

- To ensure that the AEC sensor selection on the console matches the AEC sensor in the system.

Exposure factors

- 70 kVp or similar.

Method

- Set SID and focal spot to clinical conditions.
- Open the collimators to ensure that all of the AEC sensors are covered by the x-ray beam.
- Place 1 mm copper or another absorber at the tube head.
- Select the centre AEC sensor at the control.
- Cover the remaining (non-selected) AEC sensors active areas marked on the bucky with 2 mm of lead.
- Repeat exposure and note the mAs to confirm that recorded mAs is as expected and back-up time is not activated.
- Repeat the above procedure for remaining AEC sensors, covering non selected sensors with 2 mm lead.

Compliance requirement

See section 2.9.2.

Notes

- This test is applicable only if AEC sensors positions are marked and clearly visible.
- Some digital systems have five AEC sensors; confirm correct selection of all AEC sensors.

5.8 Backup timer

Aim

- To ensure that the backup timer is functioning and backup time does not exceed the specified time.

Exposure factors

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

Method

- Cover the selected AEC sensor active area with lead sheet.
- Place an electronic timer/detector in the beam to record exposure time.
- Set automatic exposure control density to 0.
- Expose and note the backup time from the electronic timer.

Compliance requirement

See section 2.9.3.

Notes

- Use low mA setting to test time cut off.
- Use high mA setting to test for mAs cut-off.

5.9 Automatic Exposure Control reproducibility

Aim

- To assess the variation in radiation output and exposure time for a number of exposures of the same object in Automatic Exposure Control (AEC) mode and to assess the difference in sensitivity of lateral AEC sensors.

Exposure factors

- 80 kVp, 200 mA or similar.

Method

- Place 1mm of copper or another absorber at tube head.
- Place an electronic timer/detector in the beam to record exposure time.
- Set SID and focal spot to clinical conditions.
- Select the central AEC sensor and expose.
- Record the exposure time, post exposure mAs and/or displayed dose area product (DAP) reading, if available.
- Repeat twice.
- Repeat selecting other AEC sensors.
- Calculate average and standard deviation of recorded parameters for each AEC sensor to estimate coefficient of variation.
- Calculate the difference in response of lateral AEC sensors.

Compliance requirements

See section 2.9.4 and 2.9.5.

Notes

- For CR, the dosimeter can be placed inside the Bucky next to the CR cassette.
- For DR, the dosimeter should be placed on the detector housing at the periphery of the beam to ensure it does not cover any of the chambers. Ideally the grid should be removed
- Use identical technique factors (including density setting) when assessing difference in sensitivity of lateral sensors.

5.10 Automatic Exposure Control: kVp and thickness compensation

Aim

- To ensure that the AEC device controls exposure such that the exposure index is constant when kVp and patient thickness are varied.

Exposure factors

- Variable kVp.

Method

- Place an appropriate absorber at the patient position (10 or15 cm water or PMMA phantom is recommended).
- Undertake an exposure at a clinically utilised kVp using the central AEC chamber and record the exposure Index. Repeat the measurements by varying kVp across the clinical tube potential range (e.g. 60, 70, 80 etc.).
- Repeat the measurements at a reference 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).

Compliance requirements

See section 2.9.6.

Notes

- Collimation **must** be fixed during the test as exposure indicator may change with 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 dose kerma can be obtained simultaneously with the system STP in section 2.11.2. The inverse of this relationship can then be used to linearise the exposure indicator measurements which will enable them to be used quantitatively.

5.11 Mounted grids

Aim

- To ensure that image is free from any grid artefacts when grid is used.
- To ensure that there are no lamellae visible on the image at the shortest clinical exposure time where a moving grid is used.

Exposure factors

- 70 kVp, AEC exposure

Method

- Set the source to image distance same as grid focus distance and ensure grid is in place and bucky is centred.
- Open the light field to the size of the detector or CR plate.
- Place an absorber in the beam (1 mm copper or similar can be used and easily placed at the collimator).
- Take an AEC exposure at 70 kVp and process.
- View the image on a reporting monitor using 1:1 magnification and visually inspect for any grid related artefacts.
- In case of an oscillating grid repeat the above procedure using highest selectable mA and shortest exposure time (or use AEC with falling load) and view the image for any lamellae present.

Compliance requirements

See section 2.10.

5.12 Digital image receptors: Signal transfer properties

Aim

- To establish the relationship between detector air kerma and image pixel value.

Exposure factors

- 70 kVp, various mAs

Method

- Set the x-ray tube above the table top or floor and place a dosimeter in the centre of the x-ray beam at a minimum distance of130 cm from the focus of the tube.
- Open the collimator to cover the dosimeter.
- Place an absorber (1 mm copper) at the collimator.
- Make a trial exposure and establish the mAs settings required to give a range of detector air kermas of ~ 1, 4, 10, 20 µGy. Record the set mAs and the measured detector air kerma.
- Remove the dosimeter and position the CR plate or digital receptor at the same distance at which dosimetry was done (in case it is not possible to set the same distance, apply inverse square law to estimate the dose to the detector).
- Remove the copper or absorber used and open the collimator to fully expose the image receptor. Put the absorber back on the collimator.
- For CR, select the acquisition protocol that has minimal clinical image processing
- For DR, select the acquisition protocol that provides flat-field corrected DICOM images that are free of any additional processing.
- Expose the detector using the mAs preset estimated above to give a detector air kerma of ~1 µGy. Draw a ROI in the centre of the image and record the pixel value.
- Repeat the above procedure using the mAs presets required to give a detector air kerma of ~ 4, 10 & 20 µGy.
- Plot the relationship between detector air kerma and pixel value and obtain the STP equation

Compliance requirements

See section 2.11.2.

Notes

- The exposure index may also be recorded following each exposure. This will enable the relationship between the detector air kerma and EI to be established. For CR, it may be necessary to repeat the exposures using a different acquisition protocol.

5.13 Digital image receptors: Uniformity and artefacts

Aim

- To quantify the uniformity of a recorded signal from a uniformly exposed digital image receptor.

Method

- For CR use the same methodology and beam conditions as in 5.12 and expose the plate to a detector air kerma of ~ 2 µGy. Mark the position of the CR plate. Rotate the plate through 180 degree and expose again giving a total detector air kerma of ~ 4 µGy. This is to cancel out any non-uniformity due to heel effect. Select the acquisition protocol with minimum image processing.
- For DR use the image obtained in 5.12 by exposing the detector to an air kerma of ~ 4 µGy. (Note: Rotation is not required as the flat field correction is applied; it is however important to check that the detector has been calibrated as per manufacturer requirements).
- Visually inspect the CR and DR DICOM image on a reporting monitor using 1:1 magnification and narrow window width to identify any obvious artefacts.
- Draw five region of interest ~2 cm x 2 cm, one in the centre and one in the centre of each quadrant. Record the mean pixel value in each ROI.
- If the STP equation in 5.12 is not linear, use the inverse STP equation to linearise pixel values to detector air kerma (see Appendix 1).
- Calculate an average of the five ROI's.
- Calculate the percentage difference of each of the 5 ROI pixel values from the calculated average pixel value.
- To identify any areas of blurring, line defects or stitching artefacts, an image of a fine wire mesh can be obtained using low kVp (50 kV, 2.5mAs, no Copper in the beam) and viewed on a reporting monitor.

Compliance requirements

See section 2.11.3 and 2.11.4.

5.14 Digital image receptors: Exposure index

Aim

- To ensure that the detector exposure index is repeatable.

Method

- Repeat the 4 µGy exposure in 5.12 three times and record the exposure index each time.
- Calculate the standard deviation and average of the three measurements to estimate coefficient of variation.

Compliance requirements

- See section 2.11.5.

Notes

- For systems with a non-linear exposure indicator relationship with detector air kerma, the displayed exposure indicators will need to be appropriately linearised prior to being used quantitatively. For CR, it may be necessary to repeat the exposures using a different acquisition protocol.
- To determine the accuracy of the displayed exposure index, it is recommended that the manufacturer methodology (where available) is adopted.

5.15 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 1 second). Ensure tube rating is not exceeded.

Method

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

Compliance requirements

See section 2.13.1 and 2.13.2.

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.

5.16 Collimation

Aim

- To ensure coincidence of the radiation field with the light field.

Exposure factors

- 60 kVp, 5 mAs or similar.

Method

- Position the x-ray tube to the centre of image receptor. Set SID to 100 cm.
- Place the beam alignment & congruency test tool at the centre of the image receptor.
- Adjust the light field to alignment markers on test grid or collimate to approximately two-thirds of cassette/detector size and use metal markers to delineate edges of the light field.
- Mark cathode or anode end of the tube for orientation.
- Expose and process the image to verify collimation.

Compliance requirements

See section 2.15.3.

Notes

- Repeat for each focus.
- Apply appropriate correction for magnification if the test grid or alignment markers are placed on the detector housing.
- X-ray assembly and collimator should be visually inspected to assess perpendicularity before starting alignment test.

5.17 Accuracy of air kerma area product (KAP) meter

Aim

- To ensure accuracy of the KAP meter 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 centre of the x-ray beam.
- Expose using 60 kVp 10 mAs and record the measured dose and displayed KAP.
- Remove the dosimeter and position the CR plate or digital detector at the centre of the x-ray beam without changing distance or collimation.
- Expose using low level of radiation (direct exposure of digital receptors should be avoided).
- Process the image and measure the exposed area.
- Multiply the measured dose and exposed area to calculate KAP.
- Repeat the above procedure at another clinically utilised kVp and collimation.

Compliance requirements

- See section 2.16.2.

Notes

- Be aware of the different KAP units and apply necessary corrections when comparing the measured and displayed KAP.

If x-ray and light field alignment is already established, the exposed area may be measured using the light field.

Schedule 1: Compliance requirements for medical radiography apparatus

The clauses contained in this Schedule are the requirements referred to in condition 4.1 of radiation management licence which the apparatus **must** meet for compliance.

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 CRE	1.2.1, 1.2.6, 1.2.7, 1.2.8
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	2.71, 2.73
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, 2.9.5,
Mounted Grids	2.10.1, 2.10.2
Digital image receptors	2.11.1, 2.11.2 2.11.3, 2.11.4, 2.11.5,
Control of multiple x-ray tubes	2.12.1
Leakage radiation	2.13.1, 2.13.2

Requirements or Condition	Clause(s)
Markings on x-ray generators etc.	2.14.1, 2.14.2, 2.14.3, 2.14.4
Control of primary beam during radiography	2.15.1, 2.15.2, 2.15.3, 2.15.4, 2.15.5, 2.15.6,
Provision of an air kerma area product meter	2.16.2
Stability of x-ray tube assembly	2.17.1
Stability of mobile apparatus	2.18.1
Capacitor discharge apparatus	2.19.1, 2.19.2, 2.19.3, 2.19.4, 2.19.5, 2.19.6
Quality assurance program	3.1.1, 3.1.3, 3.1.4
Routine equipment testing	3.2.3
Image quality	3.3.1
Wet film processing	3.5.3
Digital imaging printing	3.6.1
Image viewing	3.7.3
Inspection and testing of protective clothing	3.8.1
Records	3.9.1

Schedule 2: Compliance requirements for bone mineral densitometry apparatus

The clauses contained in this Schedule are the requirements referred to in condition 4.1 of radiation management licence which the apparatus **must** meet for compliance.

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 CRE	1.2.1, 1.2.5,
Radiation warning sign	4.1.1

Requirements or Condition	Clause(s)
Markings	4.2.1, 4.2.2, 4.2.3
Quality assurance program	4.3.1, 4.3.3, 4.3.4, 4.3.5

References and further reading

American Association of Physicists in Medicine (AAPM) Task Group 18: *Assessment of Display Performance for Medical Imaging systems* (deckard.mc.duke.edu/~samei/tg18).

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The British Institute of Radiology: *Radiation Shielding For Diagnostic Radiology,* Report of a BIR Working Party, 2012, U.K. Publication.

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Definitions

In this guideline:

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 *Radiation Control Act 1990*.

AEC means automatic exposure device.

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.

CRE means Consulting Radiation Expert.

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. $mGy.cm^2$, $cGy.cm^2$, $\mu Gy.m^2$. It is important to make a note of the unit 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.

Optical density (OD) means the degree of film blackening produced during development, where optical density is the log of the reciprocal of the fraction of light transmitted through the blackened film.

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 Radiation Control 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.

SID means source-to-image receptor distance.

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.

X-ray tube potential difference means the peak value of the potential difference applied to the x-ray tube, expressed as kilovolts peak (kVp).

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

Appendix 1

(a) Digital Image Receptors: Signal transfer property and uniformity of detector

In order to obtain meaningful quantitative measurements, a digital detector system must have a linearisable relationship between detector air kerma (K in μGy) and mean pixel value (PV), also called the signal transfer property (STP). The detector response is established by plotting PV against K as specified in *compliance test 2.11.2 and test protocol 5.12*. This STP relationship is then used for quantitative analysis of detector uniformity when it is exposed to known detector air kerma (K).

If the detector response is linear with K, the PV from a region-of-interest on a flat-field image with minimal image processing can be used to quantify the uniformity of the detector (*compliance test 2.11.3*). However, not all radiographic systems have a linear response. If the test results of *compliance test 2.11.2* indicate a non-linear detector response, PV's cannot be used to directly quantify detector uniformity. In this case, a linearised K (K_{PV}) value can be calculated from the corresponding PV. The K_{PV} values can then be used to quantify the detector uniformity of these non linear systems. These K_{PV} values are calculated by using the inverse STP equation. Examples are given below for a linear, logarithmic and power STP.

Linear STP

If the relationship between K and PV is linear and the graphical plot shows a straight line, the STP equation can be written as;

$$PV = a + bK \rightarrow K_{PV} = \left(\frac{PV-a}{b}\right) \qquad \text{[A1.1]}$$

where a and b are constants

As discussed above, in this case PV or K_{PV} can be used for quantification of uniformity as the STP is linear.

Logarithmic STP

If the relationship between K and PV shown to be logarithmic when plotted in a graphical form, the STP equation can be written as;

$$PV_{log} = a\mathbf{ln}(K) + b \rightarrow K_{PV} = exp\left(\frac{PV-b}{a}\right) \qquad \text{[A1.2]}$$

where a and b are constants

K_{PV} must be used for quantification of the detector uniformity

Power STP

If the relationship between K and PV is shown to follow a power law when plotted in a graphical form, the STP equation can be written as;

$$PV_{pow} = a\mathrm{K}^{\mathrm{b}} + c \rightarrow K_{PV} = \left(\frac{(PV-c)}{a}\right)^{\frac{1}{b}} \qquad \text{[A1.3]}$$

where a, b and c are constants

K_{PV} must be used for quantification of the detector uniformity

(b) Digital Image Receptors – Exposure Index

The repeatability of the EI (*compliance test 2.11.5*) is assessed by calculating the coefficient of variation in the EI from a series of exposures if the relationship between EI and K is linear. The system EI however is often non-linear with K. The EI needs to be linearised using the same process as described above in section (a), prior to it being used to calculate the exposure index repeatability.

For a non-linear relationship between EI and K, the EI can be interchanged for the pixel value (PV) in the appropriate equation (A1.1, A1.2 or A1.3) to obtain a linearised K (K_{EI}). These EI measurements can often be completed as part of *compliance test 2.11.2*; however, some CR systems may require a different acquisition protocol to be used for measuring the EI.

(c) Automatic Exposure Control – Exposure Index

Compliance test 2.9.6 uses the EI to check the consistency of the system automatic exposure control with varying tube potential and water/PMMA thickness placed at the patient position. The EI values for all exposures should not vary by more than 20 % from the average EI. This quantitative analysis requires a linear relationship between EI and K.

For non-linear systems, the measured EI values when operating under AEC with water/PMMA placed at the patient position can then be used to infer K_{EI} from the K vs EI relationship recorded in *compliance test 2.11.2* when using 1 mm Copper at the tube exit.