Environment Protection Authority

Radiation Standard 6

Compliance requirements for ionising radiation apparatus used in diagnostic imaging: Part 6 – Veterinary Science

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Introduction

Veterinary radiological procedures are an essential part of veterinary science, both for diagnosis and in research. Diagnostic veterinary 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 objects of this standard are to:

- provide adequate safety measures to protect patients, occupationally exposed persons and the public from unnecessary radiation exposure
- improve and maintain the standard of radiation apparatus
- ensure better monitoring of apparatus performance.

This standard for veterinary radiography is for the information of the person responsible and licensed users of ionising radiation 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 in the assessment of apparatus for compliance with conditions of the radiation management licence and should be read in conjunction with the Act and the Radiation Control Regulation 2013. In the event of 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 standard 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, 2 & 3 and apply to all radiographic and fluoroscopic and computed tomography apparatus, both fixed and mobile.

The standard was developed by the Hazardous Materials, Chemicals and Radiation Section of the NSW Environment Protection Authority (EPA) 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 1,2 and 3 of this standard are to be met for compliance of veterinary radiography fluoroscopy and computed tomography apparatus.

1.1.3 The responsible person should 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 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 in accordance with *Radiation Guideline 7: Radiation shielding design, assessment and verification requirements* and documented by an appropriately qualified person before building works start.

1.1.5 The provision of radiation shielding should ensure that 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.

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 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 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 & film/fluorescent screen

- a calculator with statistical functions / computer spreadsheet
- 2 mm copper sheet
- 20-centimetre (cm) water or equivalent phantom
- Westmead Test Object (or equivalent image quality phantom)
- high contrast resolution test object.

1.2.3 The following information may be required for fluoroscopy equipment

- nominal field sizes (including how defined)
- image receptor to grid face distance
- grid factor
- source to image receptor distance
- leakage technique factor (this is required for both - radiography and fluoroscopy apparatus).

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: veterinary radiography, fluoroscopy and computed tomography

2.1. System performance

2.1.1 All tests in **Table 1, 2 and 3** that include any clause listed in Schedule 1, 2 and 3 must be carried out at the frequency specified and results must comply with the limits referenced in this standard.

Table 1: Tests required for veterinary radiography systems

Compliance requirement	Test	Acceptance	5-yearly
2.2	Radiation warning sign	✓	✓
2.5	Exposure consistency	✓	✓
2.7	Indicators of operation	✓	✓
2.8	Exposure switch	✓	✓
2.10	Control of multiple X-ray tubes	✓	✓
2.11	Leakage radiation	✓	✗
2.12	Markings on X-ray generators & tube assemblies	✓	✓
2.13	Control of the primary beam during radiography	✓	✓
2.14	Capacitor discharge apparatus	✓	✓
2.26	Stability of X-ray tube assembly	✓	✓
2.27	Stability of mobile apparatus	✓	✓

Table 2: Tests required for veterinary fluoroscopy systems

Compliance requirement	Test	Acceptance	5-yearly
2.2	Radiation warning sign	✓	✓
2.7	Indicators of operation	✓	✓
2.8	Exposure switch	✓	✓
2.10	Control of multiple X-ray tubes	✓	✓
2.11	Leakage radiation	✓	✗
2.12	Markings on X-ray generators & tube assemblies	✓	✓

2.17	Control of the primary beam during fluoroscopy	✓	✓
2.18	Fluoroscopic timing device	✓	✓
2.19	Restriction of entrance air kerma rate during fluoroscopy	✓	✓
2.23	Protection of the fluoroscopist	✓	✓
2.24	Fluoroscopy units with an over-table X-ray tube	✓	✓
2.26	Stability of X-ray tube assembly	✓	✓
2.27	Stability of mobile apparatus	✓	✓

Table 3: Tests required for Veterinary computed tomography systems

Compliance requirement	Test	Acceptance	5-yearly
2.2	Radiation warning sign	✓	✓
2.7	Indicators of operation	✓	✓
2.12	Markings on X-ray generators & tube assemblies	✓	✓

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 X-ray 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 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 or when fluoroscopy is in progress 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 Where kilovoltage (kVp) is manually selectable, the accuracy of the selected kVp should be within ± 5% of the measured value.

2.3.2 In case of 2.3.1, the coefficient of variation of at least three consecutive measurements at the same kVp setting should not exceed 0.02.

2.4. Accuracy of timer controls

2.4.1 Where exposure time is manually selectable, the accuracy of the timer controls should be within ± 5% or ± one pulse of the indicated time, whichever is greater.

2.4.2 In case of 2.4.1, the coefficient of variation of at least three consecutive measurements at the same timer setting should not exceed 0.05.

2.5. Exposure consistency and linearity

2.5.1 For radiographic exposures, 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 should 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 should 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 should 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 4 or 5** (as applicable).

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

2.6.3 Where removable or operator-selectable additional filters are used, determination of the HVL should be carried out using minimum filtration.

Table 4: 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

Table 5: 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 should be displayed by an analogue or digital indicator, even if these factors are under automatic control. Should one factor be permanently fixed, its value should 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 radiographic 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 Where AEC is provided, the exposure should terminate after no more than 6 seconds or after an exposure of no more than 600 mAs, whichever occurs first.

2.9.2 The variation in radiation output measured through a tissue-equivalent absorber for a minimum of five exposures at the same settings and with the same absorber in the beam should not exceed ± 5%.

2.9.3 Where fixed fluoroscopic apparatus is capable of radiography, an AEC device should be provided for the radiographic mode.

2.9.4 The AEC should not operate in the radiographic mode unless the Bucky or portable AEC device is selected.

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

2.10. Control of multiple X-ray tubes

2.10.1 Except for apparatus specifically designed for two-tube techniques, means **must** be taken to ensure that it is not possible to energise more than one X-ray tube at any one time. Safety measures **must** be provided to ensure against accidental activation of the wrong X-ray tube. In the case of two-tube techniques, there **must** be a clear indication on the control panel that two tubes are energised.

2.10.2 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. In the case of an under-table tube and associated over-table tubes used in fluoroscopic apparatus, there should be a visual indicator at or near the fluoroscopy controls to signify which tube is selected.

2.11. Leakage radiation

2.11.1 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.

2.11.2 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 2.10.1.

2.12. Markings on X-ray generators and tube assemblies

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

2.12.2 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).

2.12.3 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 link to (a), (b) and (c).

2.12.4 In addition to 2.12.3, 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 should be clearly indicated.

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

2.13. Control of the primary beam during radiography

2.13.1 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, except in the case of examinations using a serial changer in association with a fluoroscopic apparatus or where the X-ray source and field size are fixed in relation to the image receptor.

2.13.2 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.

2.13.3 The area illuminated by the light beam collimator should 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 should not exceed 1% of the SID. The centre of the illuminated area should be indicated.

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

2.13.5 When provision is made for the automatic adjustment of the collimator to the size of the image receptor in use:

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

b. the X-ray field should not exceed the size of the image receptor at the image receptor plane by > 1% of the SID.

2.13.6 The illuminance of the light beam should be not less than 100 lux at a distance of 1 metre (m) from the focal spot.

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

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

2.14. Capacitor discharge apparatus

2.14.1 For capacitor discharge apparatus, in addition to the requirements of 2.11.1, 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.

2.14.2 Capacitor discharge apparatus should 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.

2.14.3 Means should be provided to prevent the initiation of exposure during the charging of the capacitors.

2.14.4 Capacitor discharge apparatus should be provided with an automatic top-up facility that operates when the kilovoltage drops below the pre-set value by more than 3%. The lowest indicated terminating voltage **must** not be less than 45 kV.

2.14.5 A control switch should be provided to allow manual discharge of the capacitors when the apparatus is connected to the mains supply and when animal exposure is not required.

2.15. Fluoroscopic imaging apparatus

2.15.1 The apparatus should be capable of automatic exposure rate control.

2.15.2 The apparatus should be capable of replaying a continuous cine loop on the viewing monitor.

2.15.3 The new apparatus should be capable of retaining the last image on the viewing monitor (‘last-image-hold’).

2.16. Focus-to-skin distance

2.16.1 Fluoroscopic apparatus should be designed and constructed such that;

a. the minimum distance between the X-ray tube focus and the animal entrance surface is not less than 300 mm, or

b. in the case of special surgical applications requiring shorter distances, the minimum focus-to-skin distance is not to be less than 200 mm.

2.16.2 Where the focus-to-skin distance can be varied, the animal should be positioned as close as possible to the image intensifier or image receptor, except where an isocentre is to be maintained.

2.16.3 In the case of fluoroscopic apparatus specifically designed and labelled for extremity use only, means should be provided to restrict the focus-to-skin distance so that the dose limits in section 2.19 are not exceeded.

2.17. Control of the primary beam during fluoroscopy

2.17.1 It **must not** be possible to operate the X-ray tube without the image receptor being properly aligned relative to the primary beam.

2.17.2 The primary beam **must** be centred to the input phosphor of the image intensifier or image receptor and **must** appear as the centre of the image on the monitor.

2.17.3 The primary beam **must not** fall outside the image receptor (including its housing) under any circumstances.

2.17.4 The beam-limiting device **must** be of a type designed specifically for fluoroscopic use with the controls situated so that the operator is shielded from stray radiation.

2.17.5 The beam-limiting device must automatically limit the primary beam to the X-ray image receptor area so that the maximum ratio of the radiation field area to the imaged field area is less than 1.15. This limitation of area is to apply at all focal-image receptor distances selected within the normal operating range of movement.

Note: This requirement is not applicable when the beam-limiting devices attached to X-ray tubes are not used for fluoroscopic purposes, even when used as second tubes in association with fluoroscopic table.

2.17.6 Beam-limiting devices should allow the collimation of the primary beam to the clinical area of interest.

2.17.7 It **must not** be possible to manually override the beam-limiting operation so that a larger field can be provided.

2.18. Fluoroscopic timing device

2.18.1 The fluoroscopic control circuit must activate a cumulative timing device when it is energised and should give an indication of the total screening time until reset.

2.18.2 The timer device must give a continuous audible signal at the end of a predetermined time interval not exceeding five minutes.

2.19. Restriction of entrance air kerma rate during fluoroscopy

2.19.1 The entrance air kerma rate during fluoroscopy should not exceed the values given in **Table 6**, when measured under the conditions listed in **Table 7**.

Table 6: Entrance air kerma rate during fluoroscopy

Mode	Maximum entrance air kerma rate (mGy/min)
Manual*	50
Automatic	100
High level (boost)	150

* For fluoroscopy systems where automatic exposure control is not provided.

Table 7: Conditions for measurement of entrance air kerma rate

Condition	Detector position
1. UNDER-TABLE X-RAY TUBE X-ray tube permanently **under** table	**on** the table
2. OVER-TABLE X-RAY TUBE Image receptor permanently **under** table	300 mm **above** the table
3. C- OR U-ARM SYSTEMS X-ray tube and image receptor mechanically linked, with or without permanent animal support	300 mm from the image receptor plane but not less than 400 mm from the focal spot
4. OTHER FLUOROSCOPIC SYSTEMS *No permanent animal support*	400 mm from the focal spot

2.19.2 Any mode in which the maximum air kerma at skin entrance can exceed the normal values applicable to manual or automatic systems is classified as high-level boost. Where a high-level boost is activated, the control **must**:

a. require continuous activation by the operator for its operation
b. maintain a continuous audible signal that is readily distinguishable from normal fluoroscopy, to indicate that the high-level control is in use
c. automatically return to the lower dose rate setting if not used within five minutes or if power to the apparatus is disconnected
d. be restricted to a maximum of 20 seconds, after which the system returns to normal fluoroscopic mode
e. only be accessed through the automatic mode of operation.

2.20. Entrance air kerma rate at surface of image receptor

2.20.1 Under Automatic Exposure Rate Control (AERC), the entrance air kerma rate at the input surface of the image receptor (i.e. with grid removed or corrected) should comply with the manufacturer's specifications and should be below the values in **Table 8**.

Table 8: Entrance air kerma rate at the input surface of the image receptor

Field size (cm)	Entrance surface air kerma rate (µGy/min)
11–14	120
>14–23	80
> 23	60

2.21. High contrast resolution

2.21.1 The high-contrast resolution of the live image, when measured by using an absorber, with AERC settings used clinically, should not be less than the values indicated in **Table 9**.

Table 9: High-contrast resolution

Apparatus	Field size (cm)	Resolution (line pairs/cm)
New	11 to < 18	18
	18 to < 26	16
	26 to 30	14
	>30	12
Existing	≤ 25	12
	> 25	10

2.22. Low-contrast resolution

2.22.1 Using the Westmead Test Object (or equivalent image quality test object) and 20 cm water equivalent phantom or 2 mm cu, the low-contrast resolution of the live image should not be less than the values indicated in **Table 10**.

Table 10: Low-contrast resolution

Apparatus type	Minimum resolution
General	6 circles (1.5 mm)
High dose rate	7 circles (1.0 mm)

2.22.2 Under the same measurement conditions, the low-contrast threshold of the live image should not be less than 4% (minimum 10 large circles should be visible using Westmead phantom).

2.23. Protection of the fluoroscopist

2.23.1 For fluoroscopic apparatus with a fixed under-table X-ray tube and adjacent operator controls, an adjustable drape **must** be provided, and **must**:

a. have a minimum width of 450 mm
b. be designed to attach to the lower edge of the image receptor carriage
c. consist of overlapping sheets, or equivalent
d. attach to the image receptor carriage in such a way that there is no gap between the drape and the image receptor carriage
e. reach the table top when the image receptor carriage is in its maximum vertical position
f. be adjustable so as to protect the operator when the table is in the tilted position.

2.23.2 The adjustable drape should have a lead equivalent of not less than 0.5 mm at 150 kVp.

2.23.3 Apparatus used in a sterile environment need not necessarily comply with clause 2.23.1. However, alternative means of operator protection, such as a ceiling-suspended shield, **must** be provided.

2.23.4 For a fluoroscopic table also designed for radiography, a protective cover **must** be provided for this Bucky slot radiation.

2.24. Fluoroscopy units with an over-table X-ray tube

2.24.1 In the case of fluoroscopic apparatus with a fixed over-table X-ray tube:

a. the collimator **must** contain a light beam device
b. an exposure switch for radiographic exposures **must** be located at the control panel
c. additional radiographic exposure switches **must not** be provided at the table unless shielding is provided for use by the operator.

2.25. Provision for radiography on mobile fluoroscopic apparatus

2.25.1 All images should be derived from the imaging system and the radiographic mode on mobile fluoroscopic apparatus should be disabled.

2.26. Stability of X-ray tube assembly

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

2.27. Stability of mobile apparatus

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

2.27.2 Mobile fluoroscopic apparatus **must** be effectively balanced or positively locked so as to remain stable when the C-arm is in any position.

3. Quality assurance

3.1. Quality assurance program

3.1.1 The quality assurance program should ensure that consistent, optimum-quality images are produced so that the exposure of operator, staff and the general public to radiation satisfies the ‘as low as reasonably achievable’ principle.

3.1.2 X-ray equipment should be maintained and serviced according to manufacturer’s recommendations. The service frequency should be at least annually.

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

4. Test protocols

4.1. Kilovoltage accuracy and reproducibility

kVp accuracy and reproducibility is only required if the kVp is manually selectable.

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.

4.2. Exposure timer accuracy and reproducibility

Timer accuracy and reproducibility is only required if the exposure time is manually selectable.

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.

4.3. 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.

4.4. 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.

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.

4.5. 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) OR automatic exposure rate control (AERC) for fluoroscopy systems.

Method

- Remove all optional or easily removable filtration (for fluoroscopy systems access to service mode may be required).
- 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.

If using filters and exposure measurements with AERC:

- place 5 mm of aluminium filters between the ion chamber (or detector) and the image receptor i.e. filters are behind the chamber
- make three exposures with no filters between the X-ray tube and the chamber then take the average dose rate
- take 1 mm of the aluminium filter from behind the chamber, tape it to the X-ray tube exit port and make an exposure
- repeat exposures with additional aluminium filters moved from behind the chamber to the X-ray tube exit port, 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 4**, 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.
- For under-table fluoroscopic X-ray tubes, position the chamber midway between table top and image receptor and place aluminium filters on the table top under the chamber, instead of at the face of the X-ray tube.
- If using AERC, make an exposure of sufficient time to ensure dose rate stabilises (e.g. 4–5 s).

4.6. 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 2.8.1.

4.7. 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 2.9.1.

Notes

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

4.8. Automatic Exposure Control reproducibility

Aim

To assess the variation in radiation output and exposure time for a number of exposures of the same object in Automatic Exposure Control (AEC).

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 and post exposure mAs.
- Repeat twice.
- Calculate average and standard deviation of recorded parameters for the central AEC sensor to estimate coefficient of variation.

Compliance requirements

See section 2.9.2.

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 the selected chamber.

4.9. Leakage radiation

Aim

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

Exposure factors

Maximum clinical kVp, minimum mAs. Ensure tube rating is not exceeded.

Method

- Collimator should be fully closed or covered with ~ 3 mm of lead.
- Position the leakage chamber at 1m 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.
- In addition to the above, for capacitor discharge apparatus position the leakage chamber at 5 cm below face of the collimator with shutters fully open. Take one reading immediately on charging the unit and one immediately after discharge.

Compliance requirements

See section 2.11 and 2.14.1.

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.

4.10. Collimation

Aim

- To ensure coincidence of the radiation field with the light field and imaged field.
- To ensure that primary beam is confined to the image receptor (including its associated housing).

Exposure factors

60 kVp, 5 mAs or similar for radiography; Automatic Exposure Rate Control (AERC) or low kVp/mA for fluoroscopy.

Method

Radiography

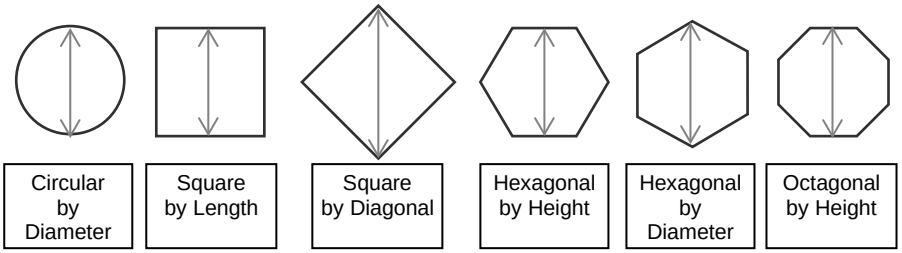
- Position the X-ray tube to the centre of image receptor. Set SID to 100 cm.
- Place the beam alignment and congruency test tool at the centre of the image receptor.
- Adjust the light field to alignment markers on test grid or collimate to approximately two-thirds of cassette/detector size and use 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.

Fluoroscopy

- Note: this example uses a CR cassette. Other means to measure the radiation field area may be substituted.
- Set maximum SID.
- Ensure collimators are fully open.
- Place CR cassette as close as possible to image receptor surface.
- Expose cassette under AERC for 1–2 seconds.
- Record the radiation field shape and measure the dimensions (see below). Note: A magnification correction is required for the distance between the image receptor and the CR cassette.
- Calculate the radiation field area (see below).
- Remove the CR cassette and place a test object of known physical dimensions (ideally with markings at known spacings) as close as possible to the image receptor surface.
- Expose under AERC for 1–2 seconds.
- Record the shape of the imaged field.
- Record the dimensions of both the image and the test object on TV monitor. Use the ratio of the nominal test object length and measured test object length from the display image and calculate the imaged field dimensions. Note: A magnification correction is required for the distance between the image receptor and the test object.
- Calculate the imaged field area (see below).
- Repeat measurements for a selection of nominal field sizes, including the maximum and minimum.
- Repeat all the above at minimum SID.
- Compare the radiation field area to the imaged field area for all selected field sizes.
- Compare the imaged field dimensions to the nominal field dimensions.
- Confirm that the radiation field lies within the image receptor (including its associated housing).

Calculating area

- the dimension of the radiation field and imaged field should be measured as per the following diagrams:



- the radiation and imaged field areas should be calculated for the specific field shape using the formula below:
- dimension^2 x shape-specific constant (see **Table 11**)

Table 11: Specific field shapes and their constants

Field shape	Constant
Circular (by diameter):	0.785
Square (by length):	1.000
Square (by diagonal):	0.500
Hexagonal (by height):	0.866
Hexagonal (by diameter):	0.650
Octagonal (by height):	0.828

Compliance requirements

See section 2.13.3, 2.17.3 and 2.17.5.

Notes for radiography

- 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.

4.11. Maximum incident air kerma rate

Aim

To measure the maximum incident air kerma rate during fluoroscopy.

Exposure factors

Maximum kVp and maximum mA.

Method

Measurement should be made in scatter-free conditions.

- Set minimum SID.
- Place ion chamber or detector at the position appropriate for that apparatus (see **Table 7**).
- Ensure chamber is central to the X-ray field.

- Cover image receptor with at least 2 mm of lead to protect it; this also ensures that maximum factors are selected under Automatic Exposure Rate Control.
- Irradiate chamber at maximum kVp and mA until dosimeter reading of dose rate stabilises.

Compliance requirement

See section 2.19.

Notes

- Ensure that the image receptor is completely covered with lead to avoid damage. If the lead is smaller than the image receptor, collimate to the size of the lead.
- If the chamber is not placed at the location in **Table 7**, apply an inverse square law correction to the measured dose rate.
- If the measurement is made with an ion chamber, ensure that it does not include backscatter (if any) from an absorber placed in the beam.
- Tolerance levels in **Final Draft**
- **Table 6** are taken from AS/NZS 3200.2.7:1999.

4.12. Entrance air kerma rate at surface of image receptor

Aim

To measure the entrance air kerma rate at the input surface of the image receptor during fluoroscopy.

Exposure factors

Automatic Exposure Rate Control (AERC).

Method

- Set SID based on manufacturer's specifications.
- Remove the grid, if possible. If this is not possible, apply an appropriate grid correction factor to the measurements.
- Place ion chamber or detector without lead backing on the input surface of the image receptor (or as close as possible; see previous bullet point). A detector with lead backing may be placed outside the region controlling the AERC.
- Tape 2 mm Cu to X-ray tube exit port.
- Irradiate chamber until reading of dose rate stabilises.
- Repeat for a range of clinically used settings and field sizes, including those for which the manufacturer has specified a value.

Compliance requirement

See section 2.20.

Notes

If a grid correction factor is not available, use 1.4.

4.13. High contrast resolution

Aim

To assess the ability of the fluoroscopic imaging system to display high contrast information.

Exposure factors

Automatic Exposure Rate Control (AERC).

Method

- Set SID at normal operating distance or 100 cm.
- Place high contrast resolution test object (e.g. line pair gauge) directly onto centre of the image receptor surface at 45° to the grid and to the raster lines.
- Place an absorber material (20 cm water equivalent phantom or 2 mm Cu) in the beam.
- Collimate to test object.
- Make an exposure and score the number of line pairs visible on the live image on the monitor.
- Repeat for all field sizes.

Compliance requirement

See section 2.21.

Notes

- This is a subjective test that can be affected by room lighting, monitor contrast and brightness settings, orientation of test gauge and absorption and scatter characteristics of the absorber.
- The compliance requirements are written for fluoroscopy systems with image intensifiers using 20 cm water phantom as an absorber. For systems with flat panel image receptors, resolution is limited by pixel size; in this case baseline value should be recorded at acceptance and overtime results be compared against the baseline.
- This test **must** be performed without any time integration or image enhancement.

4.14. Low contrast performance and image distortion

Aim

- To assess the ability of the fluoroscopic imaging system to display low contrast information.
- To assess any image distortion.

Exposure factors

Automatic Exposure Rate Control (AERC).

Method

- Set SID at normal operating distance or 100 cm.
- Place test object directly onto centre of image receptor.
- Place an absorber material (20 cm water equivalent phantom or 2 mm Cu) in the beam.
- Collimate to test object.
- Make an exposure and score the phantom on the live image on the monitor.

- Monitors should be viewed from a distance of four times the screen diameter in ambient light.
- Adjust monitor brightness and contrast settings to optimum. This is achieved when both low contrast circles in square backgrounds are seen.
- Record:
  a. distortion – note any ‘S’ or pincushion distortion
  b. contrast threshold – the number of large circles detectable on the live image
  c. contrast detail – the number of hole sizes visible from the contrast detail portion of the test object on the live image (i.e. circles of decreasing size).
- Repeat for all field sizes.

Compliance requirement

See section 2.22.

Notes

- These are subjective tests which can be affected by room lighting, monitor contrast and brightness settings and orientation of test gauge and absorption and scatter characteristics of the absorber.
- Many units have an “auto brightness” setting on the monitor. This should be activated, where present.
- This test **must** be performed without any time integration or image enhancement.

Schedule 1: Compliance requirements for veterinary 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	1.1.1,1.1.6, 1.1.8
Advice to CRE	1.2.1, 1.2.5,
System Performance	2.1.1
Radiation warning sign	2.2.1, 2.2.2, 2.2.3
Exposure consistency and linearity	2.5.1
Indicators of operation	2.7.3
Exposure switch	2.8.1, 2.8.2, 2.8.3, 2.8.4
Control of multiple X-ray tubes	2.10.1, 2.10.2
Leakage radiation	2.11.1, 2.11.2
Markings	2.12.1, 2.12.2, 2.12.3
Control of primary beam during radiography	2.13.1, 2.13.2,
Capacitor discharge apparatus	2.14.1, 2.14.4
Stability of X-ray tube assembly	2.26.1
Stability of mobile apparatus	2.27.1

Schedule 2: Compliance requirements for veterinary fluoroscopy 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, 1.1.6, 1.1.8,
Advice to CRE	1.2.1, 1.2.5
System Performance	2.1.1
Radiation warning sign	2.2.1 2.2.2, 2.2.3
Indicators of operation	2.7.3
Exposure switch	2.8.1, 2.8.2, 2.8.3, 2.8.4
Control of multiple X-ray tubes	2.10.1, 2.10.2
Leakage radiation	2.11.1, 2.11.2
Markings	2.12.1, 2.12.2, 2.12.3
Control of the primary beam (fluoroscopy)	2.17.1, 2.17.2, 2.17.3, 2.17.4 2.17.5, 2.17.7
Fluoroscopic timing device	2.18.1, 2.18.2
Restriction of entrance air kerma rate	2.19.2
Protection of fluoroscopist	2.23.1,2.23.3, 2.23.4
Fluoroscopy (over-table tubes)	2.24.1
Stability of X-ray tube assembly	2.26.1
Stability of mobile apparatus	2.27.1, 2.27.2

Schedule 3: Compliance requirements for veterinary computed tomography 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	1.1.1,1.1.6, 1.1.8
Advice to CRE	1.2.1, 1.2.5
Radiation warning sign	2.2.1, 2.2.2, 2.2.3
Markings	2.12.1, 2.12.2, 2.12.3
Indicators of operation	2.7.3

References and further reading

Australian Radiation Protection and Nuclear Safety Agency: *Fundamentals for Protection against Ionising Radiation (2014)*, Radiation Protection Series Publication F- 1, ARPANSA February 2014.

Australian Radiation Protection and Nuclear Safety Agency: *Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation*, ARPANSA RPS 14 (2008).

Australian Radiation Protection and Nuclear Safety Agency: *Safety Guide for Radiation Protection in Diagnostic and Interventional Radiology*, ARPANSA RPS 14.1 (2008).

Australian Radiation Protection and Nuclear Safety Agency: *Code of Practice and safety guide: Radiation Protection in Veterinary medicine*, ARPANSA RPS 17 (2009).

International Atomic Energy Agency, *Radiation Protection and Safety of Radiation sources: International Basic Safety Standards*, IAEA Safety Standards No. GSR Part 3, 2014, IAEA, Vienna.

International Commission on Radiological Protection: The 2007 *Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103, Ann. ICRP 37 (2-4), 2007.

National Council on Radiation Protection and Measurements: *Structural Shielding Design and for Medical X-Ray Imaging Facilities*, NCRP Report No. 147, NCRP, Washington DC, USA.

Standards Australia/Standards New Zealand, 1996, *Approval and Test Specification—Medical Electrical Equipment Part 1.3: General Requirements for Safety—Collateral Standard: Requirements for Radiation Protection in Diagnostic X-ray Equipment*. AS/NZS 3200.1.3:1996.

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

The Royal Australian and New Zealand College of Radiologists: *RANZCR General QA and QC Guideline*, November 2013, Sydney, Australia.

Definitions

In this standard:

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.

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 standard have the same meaning as in the Act and the Regulation.