Draft Radiation Guideline 6
Compliance requirements for ionising radiation apparatus used in diagnostic imaging

Part 3
Dentistry (including maxillofacial)
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Introduction

Radiological procedures are an essential part of dentistry. Although the effective dose from such procedures is low, the frequency of examinations is high enough to warrant monitoring of the doses delivered. Poor performance of radiation apparatus and inadequate quality assurance procedures may cause an unnecessary increase in patient dose.

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

- 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.

This guideline is for the information of owners (person responsible) and licensed users of dental radiography apparatus, and persons accredited under Section 9 of the Radiation Control Act 1990 as Consulting Radiation Experts (CREs). It is to be used by CREs to assess apparatus for compliance with the 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 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 legislation, the requirements of the legislation prevail to the extent of the inconsistency.

This document sets out the minimum requirements for diagnostic imaging apparatus, which are stated as ‘must’ statements and are listed in Schedule 1, and promotes industry best practice in radiation safety. It applies to all dental apparatus, both fixed and mobile.

Radiation Guideline 6 – Dental was developed by the Hazardous Materials Chemicals and Radiation Section of the Environment Protection Authority in consultation with the Radiation Advisory Council.

The EPA acknowledges the assistance of Associate Professor Lee Collins, Dr Richard Smart, Dr Philip Pasfield, Mr Paul Cardew, Dr Jennifer Diffey, Dr Ravinder Grewal, Mr Glen Burt and Mr Adam Jones, and the input received from stakeholders, in preparing this edition.
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 of this guideline must be met for compliance of dental radiography apparatus.

1.1.3 Responsible person requirements of Code of Practice and Safety Guide for Radiation Protection in Dentistry (RPS 10) must be met.

1.2 Advice to Consulting Radiation Expert

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

- a radiation meter/detector
- aluminium filters (Grade 1100 or equivalent)
- masking tape
- a light meter
- lead sheets
- a tape measure
- radiographic cassettes and film/fluorescent screen
- a calculator with statistical functions or preconfigured spreadsheet.

1.2.2 Prior to commencing testing the manufacturer’s warm-up procedure should be followed.

1.2.3 All measurements should be in SI units (i.e. Gy for absorbed dose). All radiation output measurements should be recorded as air kerma.

1.2.4 A Certificate of Compliance must be completed and provided to the owner of the apparatus within a time not exceeding 21 days from the date of compliance testing, regardless of whether the apparatus has passed or failed.

1.2.5 The CRE conducting the compliance test must issue the owner a signed report (including readings and calculations) detailing non-compliance with any mandatory requirements and recommendations.

1.2.6 The report must include details of the test protocols (if significantly different from those outlined in this guideline) and test equipment used (including the date equipment was last calibrated).

1.2.7 The report should note any mandatory requirements that are not applicable to the apparatus.

1.2.8 The report may include recommendations relating to matters outside mandatory requirements listed in Schedule 1 of this guideline (for example, recommended best practice).

1.2.9 Where an apparatus fails to comply with a mandatory requirement but may be safely used while the fault is corrected, a CRE may, at their discretion, certify the equipment as compliant. In exercising this discretion a CRE should specify a deadline (not exceeding three months) for the apparatus to be brought to full compliance and may impose restrictions on the use of the apparatus until it is repaired.
1.3 Advice to operator

1.3.1 The operator should ensure that no person, other than the patient, remains within 2 m of the primary beam during an exposure unless that person is behind a protective screen or is wearing a protective apron.

1.3.2 The only persons who should be present in the room during the x-ray examination are those:
   a. whose presence during the procedure is necessary, or
   b. who are responsible for the care of the patient, or
   c. who are receiving instruction from the person conducting the procedure.

1.3.3 When using portable or mobile apparatus, the operator should ensure that no person other than the patient is within 2 m of the primary beam unless shielded.

1.4 Radiation shielding for dental apparatus

1.4.1 Appropriate radiation shielding should be provided for the doors, walls, floor and ceiling of the room in which the apparatus is installed and for any protective barrier intended for use as a shield for the operators, to ensure that the radiation dose to any person is as low as reasonably achievable.

1.4.2 To achieve the requirements of 1.4.1, the provision of radiation shielding should ensure that the radiation levels behind the shielding will not give rise to a dose equivalent greater than:
   a. 100 μSv per week for occupationally exposed persons
   b. 20 μSv per week for members of the general public.

1.4.3 Where the room dimensions, workloads, and wall constructions meet the requirement for self-assessment under Section 2.2 of Radiation Guideline 7, no additional shielding will be required.

1.4.4 Where a fixed protective shield is provided for the operator’s use, it must, in the case of new installations, be clearly and durably marked with the lead equivalent and the kilovoltage (kVp) of the x-ray beam at which the lead equivalent was measured.

1.4.5 The operator, when behind the protective shield, must have a clear view of the patient for medical diagnostic radiology procedures, and must be able to communicate easily with the patient at all times.

1.4.6 Where a viewing window is used as part of the protective shield, the lead equivalent and the kVp of the x-ray beam at which the lead equivalent was measured must, in the case of new installations, be clearly and durably marked on the viewing window.

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

1.5 Radiation warning sign

1.5.1 A radiation warning sign complying with Schedule 6 of the Regulation must be displayed on the outside of the entry to any room that is designated exclusively for the use of dental or maxillofacial apparatus. Where there is no requirement for a radiation warning sign on the outside of the room, there must be a radiation warning sign conspicuously displayed in the immediate vicinity of the apparatus.
1.6 Location of exposure control switch
1.6.1 The exposure control switch must be arranged so that while the x-ray tube is energised, the operator can remain:
   a. outside the useful x-ray beam and at least 2 m from the x-ray tube and from the patient, or
   b. behind a protective barrier.

2. Dental apparatus specifications and performance

2.1 Exposure indication
2.1.1 The apparatus must incorporate a device that provides a warning to the operator whenever the tube is energised; that warning must consist of:
   a. a light, clearly marked as to its function.
   b. an audible signal, other than sounds produced fortuitously by switching devices or contactors, to indicate either the duration of the exposure or its termination.
2.1.2 Both audible and visible signals must be at the control panel or, for remotely controlled apparatus, where these devices could not otherwise be seen or heard, at the position of the operator.

2.2 Control of operation
2.2.1 An electronic timer must be provided that will terminate the exposure after a pre-set time setting or at a pre-set product of current and time or programmed exposure.
2.2.2 Termination of the exposure must cause automatic resetting of the timer to its initial setting or zero.
2.2.3 It must not be possible to energise the x-ray tube if the timer is set to zero.
2.2.4 It must be possible to alter the timer setting to a higher or lower value without initiating an exposure.
2.2.5 The exposure control switch, including that for remote-control handpieces, must be of the dead-man type, such that continuous pressure is necessary to maintain the x-ray exposure, and it must not be possible to make repeat exposures without releasing the switch.

2.3 Remote control
2.3.1 Where the exposure is initiated by a remote-control handpiece, this handpiece must:
   a. be encoded to the x-ray control unit so that no other remote-control handpiece can initiate exposure
   b. be permanently labelled with a warning identifying the purpose of the control.

2.4 Indicators of exposure
2.4.1 Analogue meters, digital displays or scales or permanent markings must indicate either:
   a. The selected voltage (kVp) and current (mA) and the exposure time, or
   b. the selected kVp and the product of tube current and exposure time (mAs).
2.4.2 Apparatus that provides for object-programmed control (exposure selection by an icon) must indicate the selected exposure time in seconds on the control panel or on the exposure control switch. This may be achieved, for example, by having a table of calibrated times corresponding to each icon permanently fixed on or adjacent to the control panel.

2.4.3 When object-programmed control exposure times can be modified by a further control that can be adjusted to account for variations in the speed of the film or digital receptor used, that control must:
   a. be clearly labelled to indicate its purpose
   b. clearly indicate on or adjacent to it the setting to be used for normal diagnostic intra-oral techniques.

2.5 Beam-limiting devices

2.5.1 For dental radiography using intra-oral image receptors, a beam-limiting device or cone must:
   a. limit the focus-to-skin distance to not less than 200 mm
   b. be of the open-ended type
   c. limit the maximum dimension of the useful beam at the open end of the cone to not more than 60 mm.

2.5.2 For beam-limiting devices for panoramic tomography:
   a. for film and CR systems the dimensions of the primary beam must not exceed the slot in the secondary collimator immediately adjacent to the image receptor and the vertical dimension of the primary beam should not exceed the height of the image receptor.
   b. for a DR system where there is no slot in the secondary collimator adjacent to the image receptor, the primary beam must meet the manufacturer’s tolerances for alignment with the detector.

2.5.3 For beam-limiting devices for cephalometric radiography:
   a. a beam-limiting device must be provided to restrict the radiation field to the image receptor area. The dimensions of this field, where practicable, should be smaller than the maximum, e.g. 180 mm × 240 mm and must not exceed 240 mm × 300 mm
   b. for a DR system where there is no slot in the secondary collimator adjacent to the image receptor, the primary beam must meet the manufacturer’s tolerances for alignment with the detector
   c. there must be means to ensure correct alignment of the image receptor and the primary beam
   d. where the beam-limiting device is a light beam type, the area illuminated by the light field must be coincident with the irradiated area. The total misalignment of any margin must not exceed 1% of the selected distance from the focus-to-image receptor.
   e. the illuminance of any light beam must be not less than 100 lux at a distance of 1 metre from the light source.

2.5.4 For beam-limiting devices for cone beam CT:
   a. a beam-limiting device must be provided to restrict the radiation field to the image receptor area.
b. the primary beam shall meet the manufacturer’s tolerances for alignment with the detector.

c. there must be means to ensure correct alignment of the image receptor and the primary beam

d. where the beam-limiting device is a light beam type, the area illuminated by the light field must be coincident with the irradiated area. The total misalignment of any margin must not exceed 1% of the selected distance from the focus-to-image receptor.

e. the illuminance of any light beam must be not less than 100 lux at a distance of 1 metre from the light source.

2.6 Filtration

2.6.1 The total filtration must ensure that the half-value layer (HVL) of the primary beam for a given x-ray tube and collimator is not less than the values shown in Table 1.

<table>
<thead>
<tr>
<th>Type of apparatus</th>
<th>X-ray tube voltage (kVp)</th>
<th>Minimum HVL (mm Al)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparatus using intra-oral image receptors</td>
<td>60</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>2.5</td>
</tr>
<tr>
<td>Other dental apparatus</td>
<td>50</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>1.8</td>
</tr>
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<td></td>
<td>70</td>
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<td>120</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>125</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Note: HVL for intermediate voltages should be obtained by linear interpolation.
2.7 Operating kilovoltage

2.7.1 The nominal kVp of dento-maxillofacial apparatus must satisfy the requirements of Table 2.

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<thead>
<tr>
<th>Apparatus</th>
<th>Nominal tube voltage (kVp)</th>
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</thead>
<tbody>
<tr>
<td>Apparatus designed for use with intra-oral image receptors</td>
<td>60–90</td>
</tr>
<tr>
<td>Panoramic tomography</td>
<td>55–125</td>
</tr>
<tr>
<td>Cephalometric</td>
<td>60–125</td>
</tr>
</tbody>
</table>

2.8 Accuracy of kilovoltage

2.8.1 Selected kVp must be accurate to within ± 5 kVp of the indicated value.

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

2.9 Accuracy of intra oral and cephalometric apparatus timer controls

2.9.1 The exposure controls must ensure that the measured exposure time across the clinical range is within ± 10% or ± one pulse of the indicated time, whichever is greater.

2.9.2 The exposure time must be determined from the time the kV waveform first rises to 75% of the kVp or 50% of the radiation output until it falls below this value.

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

2.10 Exposure consistency and linearity

2.10.1 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.

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

2.10.3 Where the current is not variable (mA cannot be manually controlled) the apparatus must produce a linear radiation output with respect to the product of the exposure time and the current. The coefficient of linearity must not exceed 0.1 for each focal spot size.

2.11 Absorbed dose in air at the patient’s skin surface

2.11.1 The absorbed dose in air at 10 mm from the end of the collimator for a typical bitewing should not exceed 3 mGy when x-ray film or CR is used.

2.11.2 For the DR image receptors the exposure factors should be adjusted to meet the optimal doses for the receptor used, and must result in doses lower than those required for x-ray film.
2.11.3 The absorbed dose in air at 10 mm from the end of the collimator for any single bitewing radiograph must not exceed 4 mGy on any setting.

2.11.4 For Cone Beam Computed Tomography (CBCT) apparatus the Kerma Area Product for a standard image for the placement of a first upper molar implant for a standard adult patient should not exceed 250 mGy.cm². Field sizes larger than this should be normalised to a 4 cm x 4 cm field.

2.11.5 For a panoramic examination the Kerma Area Product for any examination should not exceed 100 mGy.cm².

2.11.6 For a cephalometric examination the incident air kerma should not exceed 3 mGy for an AP/PA skull and 1.5 mGy for a lateral skull.

2.12 Radiation leakage

2.12.1 The x-ray tube must be enclosed in a housing in such a manner that the air kerma from radiation leakage measured at a distance of 1 m from the focus of that tube in one hour, averaged over an area not larger than 100 cm², does not exceed:

a. 0.25 mGy for apparatus used with intra-oral image receptors
b. 1 mGy for other apparatus.

2.12.2 Beam-limiting devices referred to in clause 2.6 used to limit the primary beam to the area of clinical interest must be constructed so that, in combination with the tube assembly, they comply with the leakage limits set out in clause 2.13.1.

2.13 Stability of x-ray tube assembly

2.13.1 The x-ray tube assembly must remain stationary when placed in position for radiography, except for panoramic tomography and cone beam CT.

2.13.2 For hand held units, the design must be such that motion artefacts are not apparent on any image.

2.14 Control of multiple x-ray tubes

2.14.1 Where it is possible to control more than one x-ray tube with a single control unit, it must not be possible to energise more than one x-ray tube at any one time. Safety procedures must be provided to ensure against accidental activation of the wrong x-ray tube.

2.14.2 Where more than one x-ray tube can be operated from a control panel, there should be a clear indication on the control panel to signify which tube is energised.

2.15 Markings on x-ray generators and/or tube assemblies

2.15.1 X-ray generators and tube assemblies must be permanently marked in English and the markings must be readily available on labels on the apparatus.

2.15.2 X-ray generator markings must include one of the following:

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

2.15.3 X-ray tube assembly markings must include one of the following:

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

d. an EPA-generated number that links to (a), (b) and (c).

2.16 Cephalometry

2.16.1 Any dental apparatus designed for use with intra-oral film **must** not be used for cephalometry.

2.17 Cone Beam CT

2.17.1 Any equipment used for generating computed tomographic images of the head **must** be specifically designed for that purpose.
3. **Quality assurance**

3.1 **Quality assurance program**

3.1.1 A quality assurance program should be instituted and maintained.

3.1.2 The 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.

3.1.3 QA procedures should be standardised and documented in a QA manual.

3.1.4 The owner should ensure that a logbook is maintained in which all details of test results apparatus faults and repairs are recorded. This logbook should be made available to the Authority on request.

3.2 **Maintenance**

3.2.1 Regular maintenance of dento-maxillofacial apparatus should be carried out in accordance with the manufacturer’s instructions.

3.3 **Film Processing quality control**

3.3.1 The owner should ensure that a test film is exposed and processed at regular intervals, not exceeding one week, before the processing of clinical x-ray film.

3.3.2 The test film procedure should follow the protocol described in ARPANSA RPS 10, *Code of Practice & Safety Guide for Radiation Protection in Dentistry*.

3.4 **CR and Digital Receptor Quality Control**

3.4.1 Equipment using digital detectors such as CCD sensors require periodic calibration. The manufacturer’s recommendation for such calibrations and routine testing should be followed.

3.4.2 PSPs (Photostimulable Phosphor Plates) are subject to artefacts caused by scratches, bending of contamination of the surface. These require regular care and testing to ensure such damage does not lead to artefacts on the images rendering them unacceptable for diagnostic purpose.

3.4.3 All tests results must be recorded.

3.5 **Additional requirements for CBCT**

3.5.1 Reject analysis of radiological examinations should be carried out as images are acquired. Images should be scored as either Excellent (no faults in image), Acceptable (faults in image, but not affecting interpretation, or Unacceptable (faults leading to image being uninterpretable). The reason for rejection should be recorded. Whilst the lowest number of unacceptable images is the desired outcome, where the rejection rate exceeds 5% a more detailed review of the cause should be undertaken and additional measures taken to reduce rejects. An acceptable QA program would be expected to reduce the proportion of unacceptable examinations by 50% in each successive audit cycle of at most 6 months.

3.5.2 Image quality checks should be undertaken at least monthly with a phantom (preferably a manufacturer’s phantom for the specific apparatus). The images should be compared against baseline data, and changes in exposure parameters, KAP reading, artefacts and image detail recorded. Where changes are significant in terms of patient dose or diagnostic quality, corrective action should be taken.
4. Test protocols

4.1 Radiation shielding

Aim
- To determine that sufficient shielding is provided to all occupied areas (see section 2.1.2).

Method
- For self-assessed dental x-ray room, check room dimensions, equipment positioning and workloads to verify they meet the requirements of the Shielding Guideline 7.
- Identify control and other areas around the x-ray room likely to be occupied when x-ray beam is on.
- Note the type of apparatus (i.e. intra oral, panoramic, cephalometric or cone beam CT).
- Visually inspect the room barriers (i.e. walls, doors, viewing window, if present, etc.) to confirm that
  - the operator can clearly see and communicate with the patient at all times.
  - the operator can be a minimum of 2 m from the patient if no shield is present.
  - where an operator’s shield is installed, the viewing window and other x-ray room barriers are marked with lead equivalence in case of new installations.

If unsure of adequate protection in the case of panoramic, cephalometric or CBCT apparatus, the following procedure may be used to verify shielding:
- Place a suitable scatter phantom in the primary beam. Collimate the x-ray field to the phantom. Take a series of exposures using the maximum safe kVp and suitable mAs. Measure dose inside the control area and outside the room at various positions likely to be occupied by staff or members of the public when x-ray beam is on. Repeat by rotating the x-ray tube to simulate other geometries used clinically. Determine weekly scatter dose based on workload.

Compliance requirement
See section 2.1.

Notes
- In the case of hand held dental equipment, verify that any protective shield is attached and provides an appropriate level of shielding to meet the requirement for occupational exposure limit in 2.1.2

4.2 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. 8 mA, 0.1s ) or fixed mAs
• kVp reproducibility: Fixed kVp, fixed mA and fixed time or fixed mAs

Method
• Position detector in centre of beam at a distance to ensure proper coverage.
• Make a series of exposures across the clinically used kVp range and calculate the difference in selected and measured kVp.
• Make a minimum of five exposures at fixed kVp, mA and time (e.g. 70 kVp, 8 mA, 0.1s ) and calculate average and standard deviation to estimate coefficient of variation.

Compliance requirement
See section 2.9.

Notes
• If an apparatus fails kVp reproducibility other measurements may be meaningless.
• Where exposure times are less than 0.1s, use the largest exposure time available.
• Follow manufacturer recommendations regarding orientation of the kVp meter/detector with respect to the anode-cathode axis of the x-ray tube.
• For panoramic and CBCT apparatus, where possible use stationary mode for testing.
• Where practical protect digital detectors using appropriate shielding material

4.3 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, 8 mA) variable time
• Exposure time reproducibility: Fixed kVp, Fixed mA and fixed time

Method
• Position detector in centre of beam at a distance to ensure proper coverage.
• 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 the maximum used 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 kVp8 mA 0.1s or similar) and calculate average and standard deviation to estimate coefficient of variation.

Compliance requirement
See section 2.10.

Notes
• This test is not required for apparatus where mAs is selected as a single component.
• This test is not required for panoramic and CBCT apparatus.
• Where practical protect digital detectors using appropriate shielding material.

4.4 Radiation output reproducibility

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

Exposure factors
• Intra-oral apparatus 70 kVp, 8mA 0.1s or similar
• Cephalometric, panoramic and CBCT apparatus, use typical clinical setting.

Method
• Position detector in centre of beam at a distance to ensure proper coverage.
• Place lead sheet under chamber to absorb backscatter.
• Make a minimum of three exposures and calculate the coefficient of variation

Compliance requirement
See section 2.11.

Notes
• If an apparatus fails output reproducibility other measurements may be meaningless.
• For older apparatus with mechanical switching, turn controls away from set positions between exposures and return to original settings.
• For panoramic and CBCT apparatus an alternate measurement of dose rate can be used in conjunction with an abbreviated exposure (2 – 4 s) to limit loading of the x-ray tube and protection of any digital detector.

4.5 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
• Cephalometric, panoramic and CBCT apparatus, use typical clinical setting.

Method
• Position detector in centre of beam at a distance to ensure proper coverage.
• Place lead sheet under chamber to absorb backscatter.
• 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 $X_{\text{max}}$ and $X_{\text{min}}$
• Calculate linearity coefficient:
linearity coefficient = \( \frac{X_{\text{max}} - X_{\text{min}}}{X_{\text{min}} + X_{\text{max}}} \)

- Linearity coefficient must not exceed 0.1.

**Compliance requirement**

See sections 2.11.

**Notes**

- For panoramic and CBCT apparatus an alternate measurement of dose rate can be used in conjunction with an abbreviated exposure (2–4 s) to limit loading of the x-ray tube and protection of any digital detector.

**4.6 Half-value layer**

**Aim**

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

**Exposure factors**

- Fixed kVp (i.e. 70), 8mA 0.1s
- Cephalometric, panoramic and CBCT apparatus, use typical clinical setting.

**Method**

- Position detector in centre of beam at a distance to ensure proper coverage.
- 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 increasing steps of between 0.2 and 0.5 mm aluminium.
- 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 2.7.

**Notes**

- kVp should be checked before HVL assessment.
- Ensure entire beam is intercepted by filters.
- 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 panoramic and CBCT apparatus an alternate measurement of dose rate can be used in conjunction with an abbreviated exposure (2–4 s) to limit loading of the x-ray tube and protection of any digital detector.

4.7 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

Method
• Position detector in centre of beam at a distance to ensure proper coverage.
• 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.

Note: Given the extremely short exposure times on intra-oral dental apparatus calibrated for use with DR receptors, this may not be a practical test to undertake.

4.8 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 0.5 second). Ensure tube rating is not exceeded.

Method
• Collimator should be 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 positions, including cathode, anode and front of tube assembly. Distances other than 1m may be used and 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 using 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.

4.9 Collimation

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

Exposure factors
- Intra-oral apparatus longest conventional exposure
- Cephalometric apparatus use typical AP/PA skull exposure
- Panoramic and CBCT apparatus use typical clinical setting.

Method
Intra-oral apparatus:
- Use alignment object such as 7cm wire cross and position on a detector such as one or more films/CR plates, gafchromic film, or Fluorescent screen with collimator centred on cross.
- Mark cathode, anode or other identifiable part on the tube for orientation.
- Expose and process the image to verify collimation.

Compliance requirements
See section 2.6.

4.10 Collimation (intra-oral apparatus only)

Aim
- To ensure skin doses are within acceptable limits

Exposure factors
- Determine factors for standard patient bitewing exposure.
- Determine factors for maximum patient bitewing exposure

Method
- Setup detector 1 cm below end of intra-oral cone.
- Expose and record dose for both settings.

Compliance requirements
See section 2.12.
## Schedule 1: Mandatory compliance requirements for dental radiation apparatus

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

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References and further reading

NSW EPA, *Radiation Guideline 7: Radiation Shielding design assessment and verification requirements*


European Commission, *Radiation Protection Number 162: Criteria for Acceptability of Medical Radiological Equipment Used in Diagnostic Radiology, Nuclear Medicine and Radiotherapy, 2012*

European Commission, *Radiation Protection Number 172: Cone Beam CT for Dental and Maxillofacial Radiology – Evidence Based Guidelines, 2012*

Health Protection Agency (UK), *HPA-CRCE-010 Guidance of the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment – Report prepared by HPA working party on Cone Beam CT equipment, 2010*
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*.

**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 the NSW Environment Protection Authority.

**CRE** means consulting radiation expert.

**Coefficient of variation** means the quotient of the standard deviation and the mean.

**Coefficient of linearity** = \((X_{\text{max}} - X_{\text{min}})/(X_{\text{min}} + X_{\text{max}})\).

**CBCT (Cone Beam Computed Tomography)** means the process of acquiring a 3D image of a patient’s anatomy, dental, maxillofacial or ENT, by use of a divergent beam x-ray source and an image receptor which acquires a series of images from exposures taken around the patient’s head.

**Dento-maxillofacial apparatus** means radiation apparatus, which emits ionising radiation, used for the purpose of radiographic imaging of the teeth and maxillofacial region. This includes apparatus with extra-oral x-ray sources designed for use with intra-oral image receptors, dental panoramic tomography and cephalometric radiography.

**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.

**Image receptor** is the device or medium used to record the image from an x-ray procedure. This may be, but is not limited to, an x-ray film, a digital receptor incorporating a wired or wireless sensor (DR), or a photostimulable plate (PSP).

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

**Kerma (K):** means kinetic energy released in a material by ionising radiation, and is determined as the quotient of \(dE_u\) by \(dm\), where \(dE_u\) is the sum of the initial kinetic energies of all the charged ionising particles liberated by uncharged ionising particles in a material of mass \(dm\) (i.e. \(K = dE_u/dm\)). The unit of kerma is the gray (Gy), or joule per kilogram.

**Kerma-area-product** is the integral of the air kerma over the area of the X-ray beam in a plane perpendicular to the beam axis. Common units for dental radiography are mGy cm².

**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 \(dt\).

**Operator** means a person licensed under Section 7 of the Act to use ionising radiation.

**Owner** means the owner of radiation apparatus to which Section 6 of the Act applies.

**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.

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.

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

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

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 ionising radiation except for an aperture for the useful beam. It can 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.