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Radiation Guideline 7

Radiation shielding design assessment and verification requirements

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

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Introduction

Radiation Guideline 7: Radiation shielding design assessment and verification requirements (the guideline) assists owners of radiation apparatus or sealed source devices, occupiers of premises and consulting radiation experts (CREs) to assess shielding requirements for licensing purposes under the *Radiation Control Act 1990* (the Act).

The guideline should be read in conjunction with the Act and the Radiation Control Regulation 2013 (the Regulation). If the Act or the Regulation is amended, references to the legislation in this document must be deemed to refer to the current legislation. If an inconsistency between the guideline and the legislation occurs, the requirements of the legislation would prevail.

This document sets out the minimum shielding assessment requirements for premises where:

- radiation apparatus (i.e. diagnostic imaging apparatus, radiotherapy apparatus) are to be installed
- sealed source devices are to be used or installed
- radioactive substances are to be used or stored.

The guideline does not apply to existing installations or premises where shielding is already in place unless there are changes to the existing building, equipment or the use of surrounding areas.

The requirements which are stated as '**must**' statements are mandatory and promote industry best practice in radiation safety.

Note: The accreditation of CREs for the purposes of assessing shielding requirements as set out in this guideline is currently being considered by the Environment Protection Authority (EPA).

1. General requirements

1.1 Scope of guideline

- 1.1.1 The aim of this guideline is to help CREs when they are assessing shielding requirements for premises, where:
 - a. radiation apparatus and sealed source devices (SSDs) are kept or used
 - b. radioactive substances are kept or used.
- 1.1.2 This guideline will also help owners and occupiers of premises when conducting a self-assessment of specified low-risk premises, and to identify which premises will require a shielding plan.
- 1.1.3 The guideline may also be used as a reference source by facility designers, architects and builders.

1.2 Shielding assessment requirements

- 1.2.1 The guideline sets out the requirements for shielding assessment and verification for premises where radiation apparatus, SSDs and radioactive substances will be stored or used.
- 1.2.2 Premises are divided into three main categories of risk: low, medium and high. The level of expertise required to assess and verify shielding requirements will vary depending on the complexity and nature of the business operations.
- 1.2.3 For most low-risk premises, a shielding assessment can be carried out by owners of radiation apparatus or SSDs or occupiers of premises, and no shielding plan will be required, although a self-assessment report will need to be completed.
- 1.2.4 Section 2 provides information on low risk premises and whether an activity can be self-assessed. Section 5 provides guidance on how to prepare a self-assessment report. A self-assessment does not need to be carried out by a CRE.
- 1.2.5 Where premises do not meet the requirements for self-assessment, a shielding plan is required. Section 6 provides guidance on how to prepare a shielding plan.

1.3 Owner's responsibilities

- 1.3.1 For low-risk premises, an owner **must** ensure a written shielding self-assessment report, as detailed in Section 5 of this guideline, has been prepared to determine whether a shielding plan is required.
- 1.3.2 Where a shielding self-assessment determines that no additional radiation shielding is required for a low-risk premises, the owner **must** ensure that the statement, 'No additional shielding is required', is stated on the shielding self-assessment report.
- 1.3.3 For premises that do not meet the requirements for self-assessment, the owner **must** ensure a shielding plan as detailed in Section 6 of this guideline is prepared. There is no requirement for the shielding plan to be prepared by a CRE, but the plan **must** be assessed by an appropriately accredited CRE to ensure compliance with this guideline. A shielding plan is required for:

- a. low-risk premises that fall outside the criteria for self-assessment
 - b. all medium-risk premises
 - c. all high-risk premises.
- 1.3.4 Where a shielding plan determines that no additional radiation shielding is required, the owner **must** ensure that the statement, 'No additional shielding is required', is written on the shielding plan and certified by a CRE.
- 1.3.5 The owner **must** ensure that a CRE approves the shielding plan and that any changes to an approved shielding plan are re-assessed by a CRE and documented on the shielding plan.
- 1.3.6 In the case of a high-risk premises, and for radiotherapy in the medium-risk category, the owner **must** ensure that a second CRE, who is appropriately accredited, carries out an independent assessment of the shielding plan to verify that it is correct. The independent assessment by the second CRE **must** be documented on the shielding plan. The shielding plan **must** be certified by the second CRE to the effect that the independent assessment has been undertaken and is satisfactory and compliant with this guideline.
- 1.3.7 Where additional shielding is required, the owner **must** ensure that a CRE verifies that the approved shielding plan has been followed in the construction, and documents this on the shielding plan.
- 1.3.8 The owner **must** ensure a copy of the shielding self-assessment report or shielding plan/s are kept at the premises for:
- evaluation by the EPA - for auditing purposes, or
 - for assessment by a CRE for compliance with registration requirements.
- 1.3.9 The owner of equipment or occupier of the premises, if engaging the services of a CRE, **must** ensure that the CRE is accredited appropriately to undertake the work required.

1.4 CRE's responsibilities

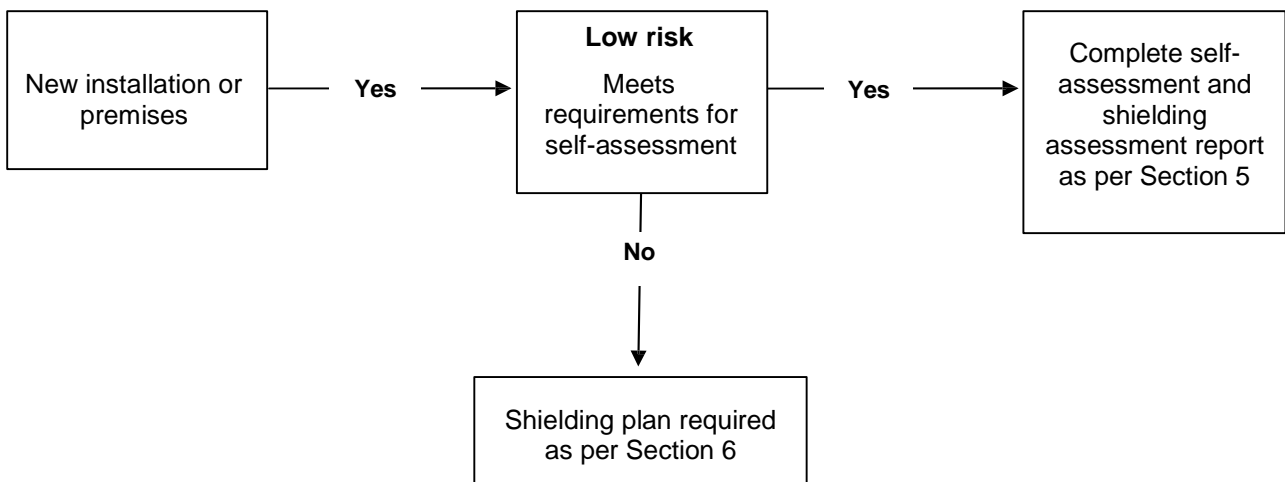
- 1.4.1 A CRE can only undertake activities specified in their conditions of accreditation. Accreditation is granted if an individual has met the appropriate criteria for each category and level of risk.
- 1.4.2 The CRE who carries out the assessment or verification of shielding **must** hold an accreditation for both the level of risk (that is, high, medium or low) and the type of radiation source in use, for example, diagnostic radiography, radiotherapy or industrial uses of radiation.
- 1.4.3 A CRE **must** ensure that shielding plans are prepared as detailed in Section 6 of this guideline.
- 1.4.4 A CRE **must** re-assess any changes made to an approved shielding plan.
- 1.4.5 In cases where the assessment determines that no additional radiation shielding is required, the CRE or the person carrying out the assessment **must** state this on the shielding plan or the self-assessment report.
- 1.4.6 In the case of a high-risk premises, and for radiotherapy in the medium-risk category, an independent assessment of the shielding plan **must** be carried out by a second CRE who is appropriately accredited to verify that the shielding plan is correct. The independent assessment by the second CRE **must** also be documented on the shielding plan.
- 1.4.7 A CRE **must** verify that the shielding material installed meets the requirements of the shielding plan and certifies the shielding plan to this effect. CREs verifying shielding **must** attach a copy of the verification methodology and verification results to the shielding plan.

- 1.4.8 The verification process that the shielding material installed meets the requirements of the shielding plan can involve, but is not restricted to, one or more of the following activities:
- inspecting the shielding material as it is installed
 - testing shields with X-ray or radioactive sources
 - taking core samples of walls, floors and ceilings
 - conducting radiation surveys of the premises during use
 - ensuring that all shielded barriers are clearly and durably marked with the lead equivalent and the kVp of the x-ray beam at which the lead equivalent was measured.

1.5 Design constraints

- 1.5.1 The design assessment and verification of shielding is to ensure that the ALARA principle is achieved. (See 'Definitions' for a description of the ALARA principle.)
- 1.5.2 Schedule 5 of the Regulation sets out dose limits for the members of the public and occupationally exposed persons, which **must** not be exceeded.
- 1.5.3 To achieve this requirement, the protective measures:
- should ensure that radiation levels in affected areas do not give rise to an equivalent dose greater than 100 μSv per week for occupationally exposed persons from all sources of exposure
 - must** ensure that radiation levels in affected areas do not give rise to an equivalent dose greater than 20 μSv per week for members of the general public.

1.6 Shielding requirement assessment flow chart



2. Low-risk premises

2.1 General description

- 2.1.1 Premises where radiation apparatus or radioactive substances are kept or used are classified as low risk where the potential for radiation exposure is minimal and where little shielding is required to operate within occupational and public dose limits.
- 2.1.2 For most low-risk premises no additional shielding will be required and a shielding self-assessment report must be completed. The self-assessment report can be carried out by the owner of radiation apparatus or device, or the occupier of a premises. The self-assessment report does not need to be carried out by a CRE. Section 5 provides guidance on how to prepare a self-assessment report.
- 2.1.3 Recommendations for best practices to be applied when installing shielding material in low-risk premises are provided in Appendix C.
- 2.1.4 Where premises do not meet the requirements for self-assessment, a shielding plan is required. Section 6 provides guidance on how to prepare a shielding plan.
- 2.1.5 A list of apparatus, devices and premises that are considered suitable for self-assessment is as follows:

- **Diagnostic radiology:**

- standard dental radiography (Section 2.2)
- orthopantomogram (OPG) dental radiography (Section 2.2.)
- OPG dental with cephalometric attachment less than 10 exposures per day (Section 2.2)
- small animal veterinary radiography (Section 2.3)
- chiropractic radiography (Section 2.4)
- diagnostic mammography, less than 50 mammographic exposures in any one day (Section 2.5)

Note: A screening mammography X-ray unit, greater than 50 exposures per day, is considered medium risk (Section 3.2.1)

- bone densitometry, other than bone densitometers with a wide fan beam operating at above 80 kV (Section 2.6).
- **Self-shielded/sealed source devices** (Section 2.7)
 - X-ray baggage inspection apparatus
 - cabinet X-ray inspection apparatus
 - enclosed X-ray diffraction, absorption and fluorescence analysers
 - sealed source devices (e.g. blood irradiators, radiation gauges).
- **Premises** (Section 2.8):
 - where unsealed radioactive sources for industrial, scientific or research applications are kept or used and graded as 'low level' when assessed, using Appendix F of *AS 2243.4–1998: Safety in laboratories – Part 4: Ionizing radiations* (Standards Australia 1998)

- where sealed radioactive sources for industrial, scientific or research applications are kept or used, classified as ‘category 5 or below’ as shown in Appendix A.

Note: Where there are two or more different sources that are kept or used at the same location, they **must** be aggregated in accordance with Appendix B.

- 2.1.6 Anything not covered in the classifications above **must** be assessed by a CRE.
- 2.1.7 If the self-assessment by the owner of the equipment or occupier of a premises indicates that normal plasterboard or a brick wall will provide sufficient shielding, a detailed shielding plan is not required.
- 2.1.8 Mobile diagnostic x-ray equipment (<20 mA minutes a week at the location being assessed) does not require shielding assessment (see Section 2.4).

2.2 Standard dental radiography

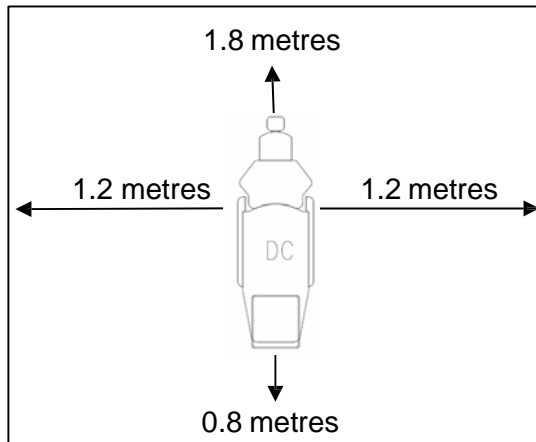
- 2.2.1 A standard dental exam room does not need additional shielding beyond that provided by normal plasterboard walls and can be self-assessed if:
 - a. workloads in the room are not above the rates described in Table 1
 - b. only extra-oral x-ray tubes with intra-oral image receptors are used in the room.
- 2.2.2 Partition walls with 10 mm of plasterboard on both sides will provide sufficient protection in most circumstances. Plasterboard 20 mm thick has approximately 25% transmission of scattered radiation at 70 kVp. Table 1 indicates those situations in which this amount of shielding will be adequate.

Table 1: Minimum distance from the patient to the barrier permitted for a dose constraint of 20 µSv per week as a function of workload

Films per week	Images per week – low dose computed radiograph/digital radiograph	Minimum distance between the patient and a 20 mm plasterboard barrier
50	100	1 metre
100	200	1.5 metres
200	400	2 metres
500	1000	3 metres

Note: Data based on average scatter plus primary dose equal to 1 µGy per film at a distance of 1 metre from the patient.

Figure 1: Layout of a standard dental room showing the minimum distance from the radiation source to walls and other occupied spaces

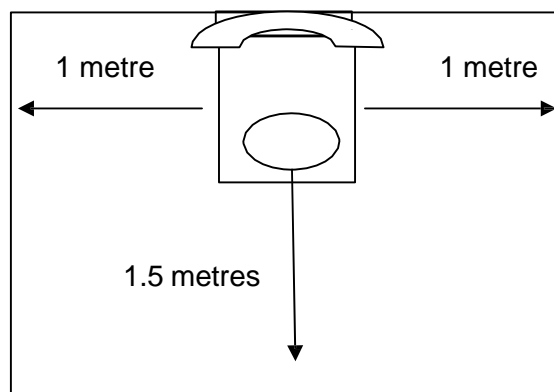


Note: Most standard dental exam rooms are likely to exceed these dimensions. The requirement for shielding may be alleviated by repositioning the chair.

Example: Rooms where only an extra-oral x-ray tube is used with intra-oral image receptors, with an output of approximately 70 kVp (4 mAs), that perform 50 images per week and conform to or exceed the dimensions of Figure 1, require no further shielding and can be self-assessed.

2.2.3 Special considerations may be required for x-ray rooms using Panoramic and cephalometric x-ray systems. However, rooms where there is a low level of use (a total of less than 10 exposures per day of either OPG or cephalograms) will not require additional shielding above that which is provided by the apparatus and by normal plasterboard walls (2 sheets, each 10 mm thick). These can be self-assessed.

Figure 2: Layout of a low-use panoramic X-ray room design showing the minimum distance from the radiation source to walls and other occupied spaces



Note: Most standard dental exam rooms are likely to exceed these dimensions. The requirement for shielding may be alleviated by repositioning the chair.

2.2.4 A shielding plan **must** be prepared when workloads exceed the levels indicated in Table 1 and 2.2.3 or when dimensions are smaller than those described in this section.

2.3 Small animal veterinary radiography

- 2.3.1 If a small animal veterinary practice meets all of the following criteria it requires no additional shielding, can be self-assessed and no shielding plan is required:
- the workload is less than 20 mA minutes in one week (see Table 2 as a guide to workload equivalents)
 - the distance from the X-ray tube to any area occupied by other staff or the public is greater than or equal to 2 metres and the minimum wall construction is equivalent to a double sheet of plasterboard (2 sheets each 10 mm thick), or the distance from the X-ray tube to any area occupied by other staff or the public is greater than or equal to 1 metre and the minimum wall construction is a single layer of solid brick with full thickness mortar joints
 - if there is at least 3 metres between any occupied area and where shielding is provided by the door to the room, a shielded door is not required
 - where any areas above or below the room are occupied, there **must** be a standard structural concrete floor (this will provide sufficient shielding protection).
- 2.3.2 Where a timber floor separates the room from any occupied area below the x-ray room, a shielding plan **must** be prepared.

Table 2: Example of calculation of total workload per week which would not exceed 20 mA minutes in one week

Examination	Typical exposure per film (E)	Films per examination (F)	Examinations per week (N)	Weekly workload $E \times F \times N = 60$
Limbs	5 mAs	2	60	10 mA-min
Abdomen	15 mAs	1	8	2 mA-min
Chest	6 mAs	2	30	6 mA-min
Total weekly workload	–	–	–	18 mA-min

2.4 Chiropractic and mobile radiography

- 2.4.1 A room used for chiropractic or mobile radiology requires no additional shielding, can be self-assessed and no shielding plan is required if it meets all of the following criteria:
- the workload is less than 20 mA minutes in one week (see Table 3a as a guide to workload equivalents)
 - the distance from the X-ray tube to any area occupied by other staff or the public is greater than or equal to 2 metres and the minimum wall construction is equivalent to a double sheet of plasterboard (2 sheets, each 10 mm thick), or the distance from the X-ray tube to any area occupied by other staff or the public is greater than or equal to 1 metre and the minimum wall construction is a single layer of solid brick with full thickness mortar joints
 - for an erect bucky, a 2.1-metre high and a 1-metre wide shield using 15 kg/m² lead **must** be used in the primary beam area

- d. if there is at least 3 metres between an occupied area and where shielding is provided by the door to the room, a shielded door is not required
- e. where areas above or below the room are occupied, there **must** be a standard structural concrete floor (this will provide sufficient shielding protection).

2.4.2 Where a timber floor separates the room from any occupied area below the x-ray room, a shielding plan **must** be prepared.

Table 3a: Example of calculation of total workload per week equivalent in films and examinations which would *not* exceed 20 mA minutes in one week

Examination	Typical exposure per film (E)	Films per examination (F)	Examinations per week (N)	Weekly workload $E \times F \times N = 60$
AP spine	50 mAs	2	6	10 mA-min
Lat spine	120 mAs	2	1	4 mA-min
Lat cervical spine	20 mAs	2	6	4 mA-min
Total weekly workload	–	–	–	18 mA-min

2.4.3. Where workloads for mobile radiography or fluoroscopy exceed 20 mA minutes in one week in any one area (see Table 3b as a guide to workload equivalents and Section 3.2) a shielding plan will be required.

Table 3b: Example of calculation of total workload per week equivalent in films and examinations which *would* exceed 20 mA minutes in one week

Examination	Typical exposure per film (E)	Films per examination (F)	Examinations per week (N)	Weekly workload $E \times F \times N = 60$
AP spine	50 mAs	2	9	15 mA-min
Lat spine	120 mAs	2	3	12 mA-min
Lat cervical spine	20 mAs	2	6	4 mA-min
Total weekly workload	–	–	–	31 mA-min

2.5 Mammography

2.5.1 A room used solely for mammography requires no additional shielding, can be self-assessed and no shielding plan is required if it meets all of the following criteria:

- a. the workload is not greater than 50 mammographic exposures in one day
- b. the unit is at least 1 metre from the entrance door
- c. the walls are at least 2 layers of 10 mm plasterboard thick (i.e. 20 mm thick).

2.6 Bone densitometers

2.6.1 A room used for bone densitometry requires no additional shielding, can be self-assessed and no shielding plan is required if it meets the following criterion:

- the bone densitometer operates at a voltage that is equal to or less than 80 kV and a maximum current of 3 mA.

Note: The scatter radiation at 1 metre from the scanner is typically 0.3 $\mu\text{Sv/h}$ and scan times are between 10–30 seconds.

2.6.2 Pencil beam scanners are highly collimated and operate at relatively low levels of kV and mA and can also be self-assessed.

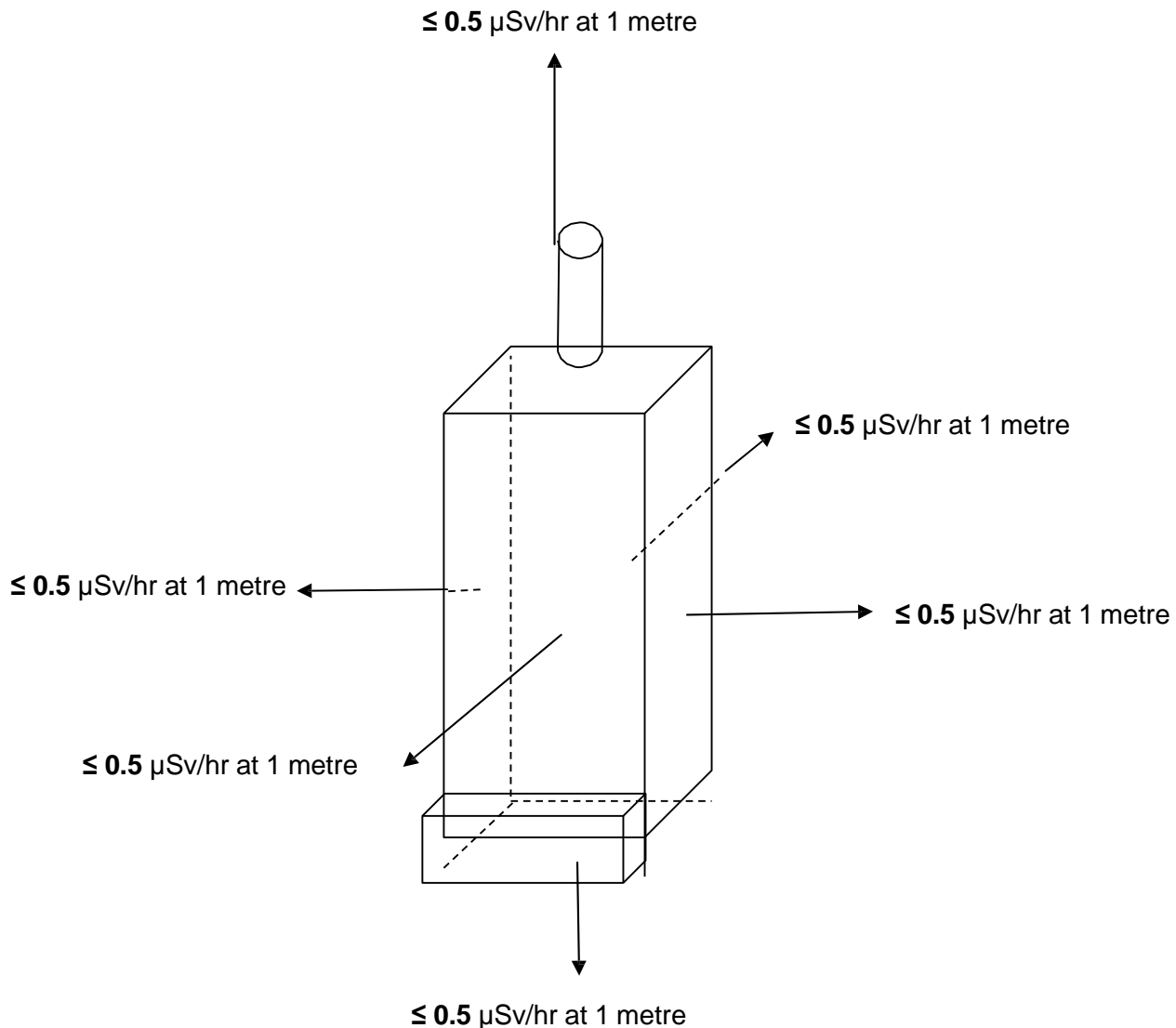
2.6.3 See medium-risk requirements if a wide fan-beam scanner operating above 80 kV is to be used (Section 3).

2.7 Self-shielded and sealed source devices

2.7.1 Self-shielded and sealed source devices can be self-assessed and no shielding plan is required if:

- the product of the occupancy factor and the dose rate at 1 metre is less than or equal to 0.5 $\mu\text{Sv/hr}$. See Section 3 if the product of the occupancy factor and the dose rate at 1 metre is greater than 0.5 $\mu\text{Sv/hr}$.

Figure 3: Example of a self shielded device that can be self-assessed



Note: The minimum distance to all fully occupied areas (occupancy factor equals 1) **must** be greater than or equal to 1 metre.

2.8 Premises where radioactive substances are kept or used

2.8.1 Premises can be self-assessed and no shielding plan is required, where unsealed radioactive substances that are used for industrial, scientific or research purposes are kept or used, if the following criteria are met:

- a. premises are graded as 'low level' when assessed using Appendix F of AS 2243.4 *Safety in laboratories – Part 4: Ionizing radiations* (Standards Australia 1998)
- b. the design, location or shielding **must** ensure that any member of the general public occupying the adjoining areas, including above and below, is not exposed to more than the general public design constraint of $20 \mu\text{Sv}$ a week.

2.8.2 Premises where sealed radioactive sources for industrial, scientific or research applications are kept or used, can be self-assessed and no shielding plan is required if the following criteria are met:

- a. premises where the sealed source threshold activities are classified as 'category 5 or below' as listed in Appendix A.

Note: Where there are two or more different sources that are kept or used at the same location they **must** be aggregated in accordance with Appendix B.

- b. the design, location or shielding **must** ensure that any member of the general public occupying the adjoining areas, including above and below, is not exposed to more than the general public design constraint of 20 μ Sv a week.

3. Medium-risk premises

3.1 General description

- 3.1.1 Premises where radiation apparatus, sealed source devices or radioactive substances are kept or used are classed as medium-risk premises where the potential for radiation exposure is increased and where additional shielding is required to operate within the dose limits.
- 3.1.2 A shielding plan **must** be prepared for all medium risk premises as detailed in Section 6 of this guideline.
- 3.1.3 There is no requirement that the shielding plan be prepared by a CRE, however, the plan **must** be assessed by an appropriately accredited CRE to ensure compliance with this guideline. In addition, for medium-risk radiotherapy premises, a second CRE who is also appropriately accredited **must** carry out an independent assessment of the shielding plan and verify that the plan is satisfactory for the purposes of the proposed use and that it complies with the requirements of this guideline.
- 3.1.4 Recommendations are provided in Appendix C of the specifications for best practices to be applied when installing shielding in medium-risk premises.
- 3.1.5 Medium-risk premises include those that are listed and detailed below (and any others that do not meet the criteria for either low-risk or high-risk premises):
- diagnostic radiology (Section 3.2)
 - radiotherapy (Section 3.3)
 - nuclear medicine (Section 3.4)
 - non-medical premises where radioactive substances are kept or used (Section 3.5)

3.2 Diagnostic radiology

- 3.2.1 The following diagnostic radiology applications are covered under medium risk:
- a. general radiography
 - b. mobile diagnostic X-ray equipment used at the same location where the weekly workload is >20 mA minutes a week
 - c. computed tomography (CT)
 - d. fluoroscopy rooms
 - e. screening mammography (screening mammography means the use of mammography X-ray apparatus in a screening program for asymptomatic patients where it might reasonably be expected to perform more than 50 mammographic exposures in any one day.
Note: Diagnostic mammography is considered low risk – see Section 2.1.1)
 - f. operating theatres (workload is >20 mA minutes a week)
 - g. dental computed tomography
 - h. OPG with cephalometric attachment (workload is > 20mA minutes a week)
 - i. chiropractic radiography (workload is > 20mA minutes a week)
 - j. large animal veterinary radiography
 - k. bone densitometers with a wide fan beam operating above 80 kV.

3.2.2 The following factors **must** be taken into account in the design of radiation shielding for diagnostic imaging:

- a. the maximum X-ray tube voltage and rated continuous tube current
- b. the maximum weekly workload
- c. the type of radiation (i.e. primary or secondary)
- d. the distance from the radiation source or scatter to occupied areas
- e. the surface area of the irradiated medium
- f. occupancy of the adjoining areas
- g. use factors
- h. allowance for variations in the quality of the shielding materials to be used
- i. allowance for reasonable growth in the business
- j. dose constraints for occupied areas
- k. additional shielding requirements for film storage (if required).

3.3 Radiotherapy

3.3.1 The following radiotherapy applications are covered under medium risk:

- a. superficial therapy up to 150 kVp
- b. radiotherapy simulators.

3.3.2 These activities require the same consideration as diagnostic radiology (see Section 3.2.2). The same factors **must** be taken into account when designing radiation shielding for a premises.

3.4 Nuclear medicine

3.4.1 The following nuclear medicine applications are medium risk:

- a. medical diagnostic
- b. veterinary diagnostic.

3.4.2 The shielding plan **must** take into account the:

- a. range and number of clinical studies to be performed
- b. radionuclides used and their activities
- c. external dose rate from the patients
- d. occupancy factors and dose constraint for adjacent areas
- e. radiation levels in the imaging room that would degrade image quality.

3.4.3 For diagnostic examinations, the operator requires most protection. Consequently, it may not be necessary to provide shielding for nuclear medicine imaging rooms, other than those used for positron emission tomography (PET) imaging.

3.4.4 Operator protection can be enhanced by installing fixed shielding around the gamma camera workstation. Where fixed shielding is impractical, mobile shielded barriers with lead glass viewing panels can be used.

- 3.4.5 Lead body shields with lead glass viewing panels **must** be available wherever radiopharmaceuticals are dispensed. The thickness of the shield will depend on whether radionuclides with gamma energies higher than 140 keV from ^{99m}Tc (such as 364 keV from I¹³¹) will be used.
- 3.4.6 Fixed shielding **must** be provided for hybrid SPECT/CT systems when installed. The shielding will usually be determined by the necessity to limit exposure from the scattered radiation during the CT phase of the examination.
- 3.4.7 The radioactive source may be a patient, a vial or a syringe containing a radiopharmaceutical. The dose constraints for a member of the public will apply to a receptionist or to a secretary and may necessitate some structural shielding (e.g. in the reception desk).
- 3.4.8 Local shielding (i.e. shielding around a specified source) should be applied wherever possible, thus limiting the need for room shielding.
- 3.4.9 Shielding should also be considered for the radioactive waste generated by the nuclear medicine facility. Such shielding will usually include shielded 'sharps' containers for used syringes and may require separate storage bins for radionuclides with short (less than 1 day) and longer half-lives.
- 3.4.10 The use of lead-lined doors is usually not necessary.

3.5. Non-medical premises where radioactive substances are kept or used

3.5.1 The following non-medical premises are considered medium risk:

- premises where unsealed radioactive sources are kept or used are graded as 'medium level' when assessed using Appendix F of *AS 2243.4 Safety in laboratories – Part 4: Ionizing radiations* (Standards Australia 1998)
- premises where sealed radioactive sources are kept or used and where the sealed radioactive sources (or aggregation of) threshold activities are classified as 'category 4' as listed in Appendix A.

Note: Where there are two or more different sources that are kept or used at the same location they **must** be aggregated in accordance with Appendix B.

See Section 1 if the threshold activities of sealed radioactive sources fall into category 5 or below, these can be self-assessed. See Section 4 if the threshold activities of sealed radioactive sources fall into categories 1, 2 and 3.

3.5.2 The shielding plan **must** ensure that any member of the general public occupying the adjoining areas (including above and below) is not exposed to more than the general public design constraint of 20 µSv per week.

4. High-risk premises

4.1 General description

- 4.1.1 Premises are classified as high-risk where the potential for radiation exposure is high and substantial shielding is required to operate within dose limits.
- 4.1.2 A shielding plan **must** be prepared for all high-risk premises as detailed in Section 6 of this guideline. Complex shielding plans for high risk premises may require significantly more detail than the minimum requirements listed in Section 6.
- 4.1.3 There is no requirement that the shielding plan be prepared by a CRE, however, the plan **must** be assessed by an appropriately accredited CRE to ensure compliance with this guideline. In addition, for all premises classified as high risk, a second CRE who is appropriately accredited **must** carry out an independent assessment of the shielding plan to verify that the plan is satisfactory for the proposed use and that it is compliant with the requirements of this guideline. The shielding plan **must** be certified by the second CRE.

4.2 High-risk applications

- 4.2.1 Premises not classified as low or medium are considered to be high risk. These include:
 - a. radiotherapy using a sealed source or irradiating apparatus greater than 150 kVp, including remote after-loading devices
 - b. positron emission tomography (PET)
 - c. in patient isolation facility for nuclear medicine therapy using unsealed gamma emitting radionuclides
 - d. industrial radiography in fully-or partially-enclosed sites and other industrial, research and non-medical activities using radiation apparatus or using and storing sealed sources (where the activity thresholds for sealed radioactive sources, or aggregation of, are categorised as category 1, 2 or 3 as listed in Appendix A,).

Note: Where there are two or more different sources that are kept or used at the same location they **must** be aggregated in accordance with Appendix B.

 - e. other industrial research and non-medical activities using or storing unsealed sources, that are, non-medical premises graded as 'high level' when assessed using Appendix F *AS 2243.4 Safety in laboratories – Part 4: Ionizing radiations* (Standards Australia 1998)
 - f. particle accelerators, including cyclotrons and synchrotrons.
- 4.2.2 Due to the complex nature of high-risk premises each shielding plan is to be assessed by an appropriately accredited CRE on a case by case basis.

5. Self-assessment report

5.1 Self-assessment documentation

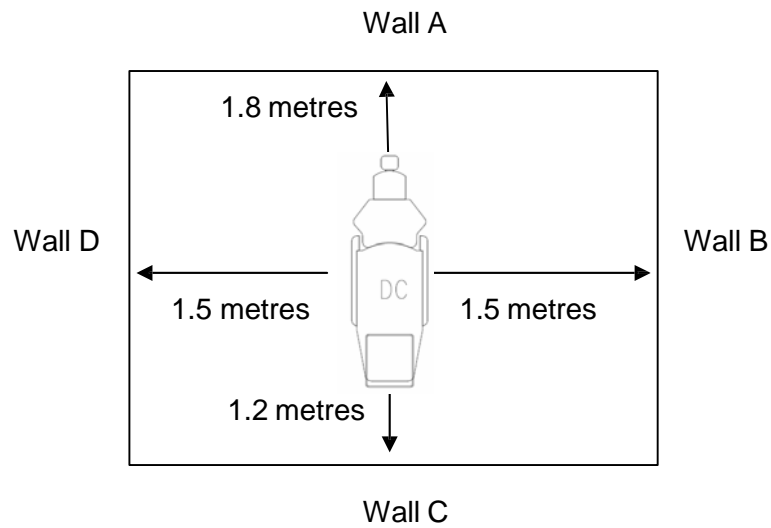
- 5.1.1 The following information **must** be provided in the shielding assessment report:
- a. the name of the owner or occupier of the premises
 - b. the address of the premises
 - c. the proposed use of the premises
 - d. the category of risk
 - e. the radiation apparatus, self-shielded device or radioactive substances to be used at the premises
 - f. the maximum workload for radiation apparatus including the rationale for this estimate
 - g. documentation, which identifies each sealed radioactive source and its activity, that supports the self-assessment
 - h. the section of the guideline which was used to determine that a shielding plan was not required to be prepared, and a statement that the premises meets the requirements of this section
 - i. the name and position of the person undertaking this self-assessment
 - j. the date that the self-assessment was completed
 - k. a plan of the premises showing the dimensions of the room/s and the location of the radiation apparatus or self-shielded device, or where the radioactive substances are to be used.
- 5.1.2 The completed shielding self-assessment report **must** be kept at the premises and be available for inspection by the EPA.

5.2 Shielding assessment report example

- a. **Owner:** General Hospital
- b. **Radiation premises address:** Dental Room 1, General Hospital, Surbitown, NSW
- c. **Proposed use of premises:** Dental radiology
- d. **Category of risk:** Low risk
- e. **Radiation apparatus details:** Trophy Elitys 2000
- f. **Workload:** Maximum of 100 films per week
- g. **Assessment findings and section of the guideline used:** This self-assessment demonstrates that the workload, dimensions and construction of the premises are such that, in accordance with the EPA Radiation Guideline 7, a radiation shielding plan is not required. (Section 2.2 – Standard Dental Radiology).
- h. **This self-assessment was undertaken by:** Dr Spock, Consultant Dentist, General Hospital, Surbitown.
Signature:
- i. **Date:**
- j. **Room layout:** (see Figure 5)

Figure 5: Example of a plan showing the layout of a room where a intra oral dental x-ray unit is used.

The existing inner and outer walls of A, B and D are constructed of 10 mm plaster board, and wall C is constructed with double brick. These walls provide adequate shielding for the proposed use. No additional shielding is required.



6. Shielding plan

A shielding plan is a document providing shielding requirements (design report; shielding plan drawings; and details of persons preparing, assessing and verifying shielding plans) for a radiation premises.

Complex shielding plans for high-risk premises may require significantly more detail than the minimum requirements set out below.

6.1 Shielding plan requirements

6.1.1 The shielding plan **must** include the following minimum requirements:

- a. the name of the owner/occupier
- b. the address of the premises
- c. the proposed use of the premises
- d. the classification of the premises as low, medium or high risk
- e. the maximum X-ray tube voltage and rated continuous tube current for diagnostic imaging
- f. the radionuclides and associated activities to be used, where applicable
- g. the maximum weekly workload
- h. the type of radiation (i.e. primary or secondary)
- i. the distance from the radiation source or scatter source to occupied areas
- j. the surface area of the irradiated medium
- k. the occupancy of the adjoining areas
- l. use factors
- m. a minimum 1:100 scale plan showing the position of the radiation source(s) and identifying all areas, including those adjoining the premises
- n. the location and description of minimum shielding requirements
- o. the methodologies used in the design of radiation shielding
- p. the allowance for reasonable growth in the business
- q. the allowance for variations in the quality of the shielding materials to be used
- r. any restrictions or other conditions relating to the use of the premises
- s. the name and signature of the person who prepared the shielding plan
- t. CRE approval of the shielding plan
- u. a second assessment by an appropriately accredited CRE for all high-risk premises and all radiotherapy in the medium-risk category. The independent assessment by the second CRE **must** be documented on the shielding plan, that is, CRE approval of the shielding plan.

6.1.2 The shielding plan **must** include the following shielding verification documentation:

- a. verification that the shielding installed complies with the specifications of the design
- b. a copy of the verification methodology and verification results undertaken by the CRE. The CRE is to attach these to the shielding plan.

6.1.3 Areas where particular attention should be given when designing a shielding plan are:

- a. door jambs
- b. the overlap of lead sheets and other materials
- c. behind switches, locks and other conduits
- d. the control panel
- e. behind the erect bucky
- f. the overlap of double doors.

6.2 Shielding design report example

Note that plan details can vary depending on the situation, however, the minimum requirements outlined in 6.1.1 **must** be provided. The following example will not be relevant for all situations and is an example of a possible shielding plan.

a. **Owner:** General Hospital

b. **Address of premises:** X-ray Room 1, General Hospital, Surbitown, NSW 2000

c. **Proposed use of premises:** General radiography

d. **Classification of premises:** Medium-risk – radiography

e. **Details of radiation apparatus:**

- general diagnostic X-ray unit 125 kVp (max)
- ceiling mounted X-ray tube
- X-ray table
- wall mounted erect bucky

f. **Design parameters:**

- Workload:
 - table tube: 300 mA-min/week
 - chest tube: 12 mA-min/week
- Workload derivation:
 - table tube: 720 exposures at average of 20mAs
 - chest tube: 60 chest x-rays at 10 mAs/exposure
 - plus 20% increase for growth of business
- Max kVp: 125
- Max continuous current: 2mA
- Max tube leakage: 1 mGy/hr @ 1m
- Input field size:
 - table tube: 720 cm²
 - chest tube: 1500 cm²
- Focus skin distance:
 - table tube: 0.6 m (table bucky)
 - chest tube: 1.8 m (erect bucky)

g. Conditions of the design

- The position and orientation of the X-ray equipment **must** be as shown in the working plans
- The primary beam when used with the table **must** only be directed at the walls designated A, B and F and towards the floor (refer to Figure 6).
- The primary beam from the chest tube position **must** only be directed at the erect bucky.
- The 1-metre wide shield behind the erect bucky **must** be centred on the bucky and extend to a minimum height of 2.1 metres.
- The defined use of associated areas **must** not change.
- Use factors other than towards the floor **must** not exceed the values stated in the report.
- The workload **must** not increase beyond 300 mA-min/week.
- Shielding will extend from the floor to a height of 2.1 m except where specified.
- All barriers **must** be continuous and free from voids.
- Where materials used do not meet the standard shielding properties for materials specified in this report, the thicknesses must be increased to compensate for this.
- Where shielding thicknesses are other than stated in this plan, this **must** be documented and details attached to the plan.

h. Details of recommended shielding

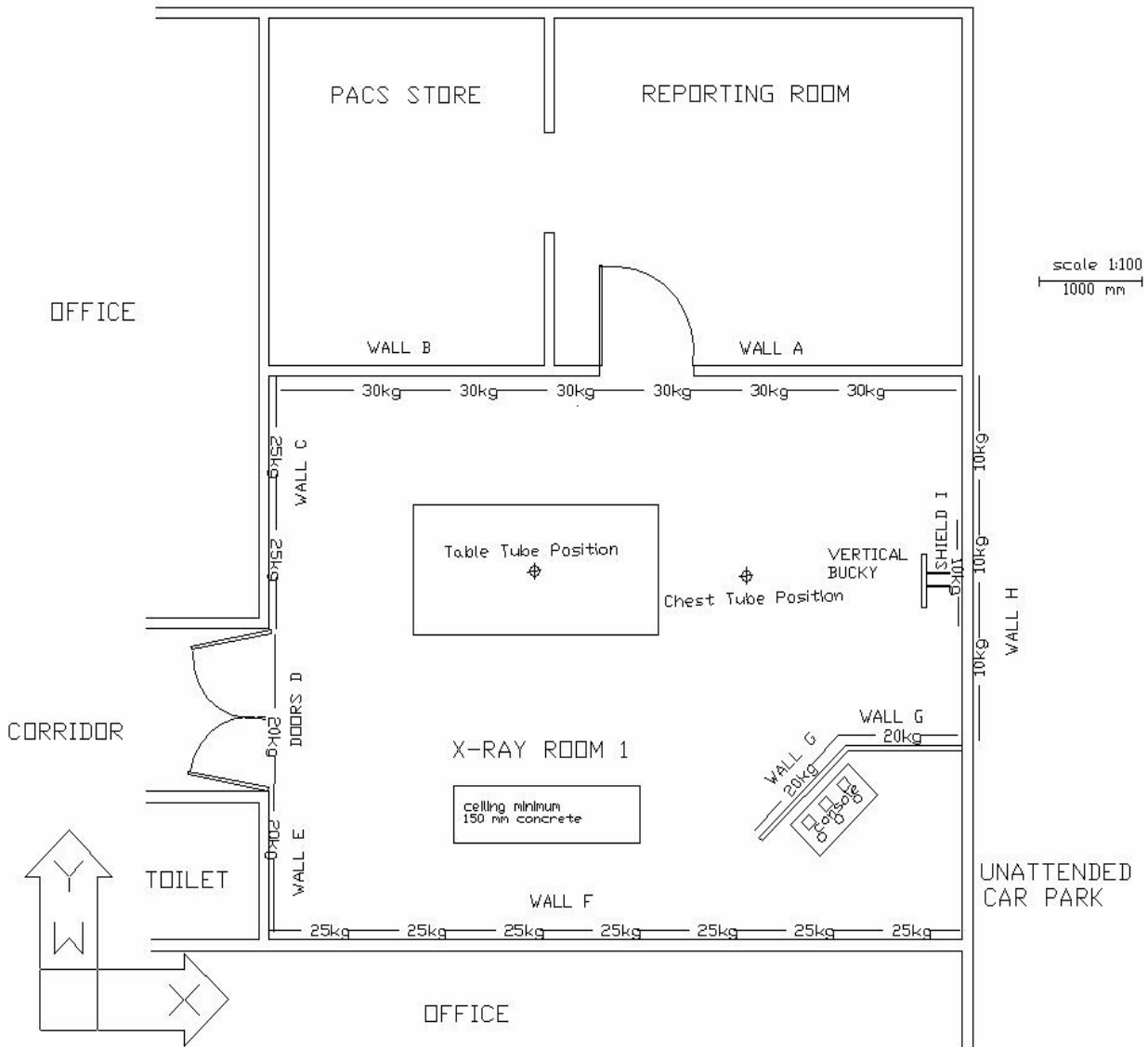
Concrete thickness is specified for density of 2350 kg m³

Wall	Use factor – table tube	Use factor – chest tube	Occupancy factor	Weekly design limit μSv	Recommended shielding Pb (kg/m ²)	Minimum shielding (mm Pb unless otherwise stated)
A Reporting room	0.09	0	1	20	30	2.64
B PACS store	0.09	0	0.05	20	30	2.64
C Office	0.02	0	1	20	25	1.76
D Corridor doors	0	0	0.2	20	20	1.76
E Toilet	0	0	0.05	20	25	2.2
F Office	0.02	0	1	20	20	2.2
G Operators console	0	0	1	100	20	1.8
H Outside car park	0	0	0.025	20	10	0.6
I 1-mwide bucky shield	0	1	0.025	20	10	1.1
					Additional to wall	
J Ceiling	0	0	1	20	100	150 mm concrete
K Floor	0.89	0	0	20	00	

- i **Methodologies used in the design of radiation shielding:** Structural shielding design for medical X-ray imaging facilities, National Council on Radiation Protection Report No. 147, 2004.

6.3 Shielding plan drawing example

Figure 6: Sample shielding plan drawing



6.4 Details of persons preparing, assessing and verifying shielding plans

a. Name and signature of person preparing shielding plan:

Name:

Position:

Company:

Address:

Phone:

Fax:

Email:

Signature:

Date:

b. CRE approval of shielding plan:

Declaration:

I hereby declare that I have assessed the shielding plan and certify that the shielding plan is satisfactory for the purposes of the proposed use and that it is compliant with the requirements of *Radiation Guideline 7: Radiation shielding design assessment and verification requirements* for the purposes of registration (shielding) under the *Radiation Control Act 1990*.

Name:

EPA CRE accreditation no.: Company:

Address:

Phone:

Fax:

Email:

Signature:

Date:

c. Approval of shielding plan by second CRE:

Note: In the case of a high-risk premises and radiotherapy in a medium-risk premises, an independent assessment of the shielding plan **must** be carried out by a second CRE who is appropriately accredited.

Declaration:

I hereby declare that I have undertaken an independent assessment of the shielding plan and verify that the plan is satisfactory for the purposes of the proposed use and that it is compliant with the requirements of *Radiation Guideline 7: Radiation shielding design assessment and verification requirements* for the purposes of registration (shielding) under the *Radiation Control Act 1990*.

Name:

EPA CRE accreditation no.: Company:

Address:

Phone:

Fax:

Email:

Signature:

Date:

d. CRE verification of shielding

I hereby certify that the shielding installed is in accordance with the shielding plan.

Name:

EPA CRE accreditation no.: Company:

Address:

Phone:

Fax:

Email:

Signature:

Date:

Note: CREs verifying shielding **must** attach a copy of the verification methodology and verification results to the shielding plan.

Appendix A – Threshold activities for sealed radioactive sources

Categories calculated using ARPANSA (2007) *Code of Practice for the Security of Radioactive Sources*, Radiation Protection Series No. 11, Schedule B.

Radionuclide	Category 1 (TBq)	Category 2 (GBq)	Category 3 (GBq)	Category 4 (GBq)	Category 5 (MBq)
Am-241	60	600	60	0.6	0.01
Am-241/Be	60	600	60	0.6	0.01
Cd-109	20 x 10 ³	200 x 10 ³	20 x 10 ³	200	1
Cs-137	100	1000	100	1	0.01
Cf-252	20	200	20	0.2	0.01
Co-57	700	7000	700	7	1
Co-60	30	300	30	0.3	0.1
Cm-244	50	500	50	0.5	0.01
Gd-153	1000	10 x 10 ³	1000	10	10
Ge-68	700	7000	700	7	0.1
Au-198	200	2000	200	2	1
I-125	200	2000	200	2	1
I-131	200	2000	200	2	1
Ir-192	80	800	80	0.8	0.01
Fe-55	800 x 10 ³	8 x 10 ⁶	800 x 10 ³	8000	1
Kr-85	30 x 10 ³	300 x 10 ³	30 x 10 ³	300	0.01
Mo-99	300	3000	300	3	1
Ni-63	60 x 10 ³	600 x 10 ³	60 x 10 ³	600	100
Pd-103	90 x 10 ³	900 x 10 ³	90 x 10 ³	900	100
P-32	10 x 10 ³	100 x 10 ³	10 x 10 ³	100	0.1
Pu-238	60	600	60	0.6	0.01
Pu-239/Be	60	600	60	0.6	0.01
Po-210	60	600	60	0.6	0.01
Pm-147	40 x 10 ³	400 x 10 ³	40 x 10 ³	400	10
Ra-226	40	400	40	0.4	0.01
Ru-106/Rh-106	300	3000	300	3	0.1
Se-75	200	2000	200	2	1
Sr-90/Y-90	1000	10 x 10 ³	1000	10	0.01
Tc-99m	700	7000	700	7	10
Tm-170	20 x 10 ³	200 x 10 ³	20 x 10 ³	200	1
Tl-204	20 x 10 ³	200 x 10 ³	20 x 10 ³	200	0.01
H-3 (Tritium)	2 x 10 ⁶	20 x 10 ⁶	2 x 10 ⁶	20000	1000
Yb-169	300	3000	300	3	10

Appendix B – Categorisation or aggregation of sealed radioactive sources

The following information was extracted from ARPANSA (2007) Code of Practice for the Security of Radioactive Sources, Radiation Protection Series No. 11, Schedule B.

In determining the appropriate category for a radioactive source, or aggregation of radioactive sources:

- (a) The categorisation for a single radioactive source is to be assigned the value in column 1 of Table B.1, based on the calculated value of activity ratio in column 2 of Table B.1, where the relevant D value for the radioactive source is determined from Table B.2.
- (b) Where there is an aggregation of radioactive sources of the same radionuclide, the aggregated ratio A/D **must** be calculated by dividing the summed activities of the radionuclide by the appropriate D value determined from Table B.2 using the equation:

$$\text{Aggregate } A/D = \sum_i A_i / D$$

The calculated ratio A/D is then compared with the ratios A/D given in Table B.1, thus allowing the set of sources to be categorised on the basis of activity.

- (c) Where there is an aggregation of radioactive sources with various radionuclides, the aggregated ratio A/D **must** be calculated separately for each radionuclide as detailed in B1.2(b) above. Then the sum of the ratios A/D **must** be determined using the equation:

$$\text{Aggregate } (A/D) = \sum_i A_{i,1} / D_1 + \sum_i A_{i,2} / D_2 + \dots + \sum_i A_{i,n} / D_n$$

Where $A_{i,n}$ = activity of each individual source i of radionuclide n ;

D_n = D value for radionuclide n .

The aggregated ratio A/D is then compared with the ratios A/D given in Table B.1, thus allowing the set of sources to be categorised on the basis of the sum of the aggregated ratios A/D for each radionuclide.

Table B.1 Categorisation of sources by activity ratio

Category	Activity ratio (A/D) ^a
1	$A/D \geq 1000$
2	$1000 > A/D \geq 10$
3	$10 > A/D \geq 1$
4	$1 > A/D \geq 0.01$
5	$0.01 > A/D > \text{Exempt}^b / D$

a. Where:

- **A** is the total activity of a specific radioactive source, or aggregation of radioactive sources, containing a particular radioactive isotope, in units of gigabecquerel (GBq); and
- **D** is the value specified in Column 2 of Table B.2, in units of GBq.

The D-value for the specific radionuclide corresponds to the activity level at which the radioactive source is considered to be a Dangerous Source. The ratio of the activity in the radioactive source to the corresponding D-value for the radionuclide in the source (A/D), determines the category of the source.

b. Exempt quantities are given in Schedule 4 of the *National Directory for Radiation Protection*.

Table B.2 Activity for Source (D-value)^a

Column 1	Column 2
Radionuclide	D-value Activity Level GBq
americium-241	60
americium-241/beryllium	60
cadmium-109	2×10^4
caesium-137	100
californium-252	20
cobalt-57	700
cobalt-60	30
curium-244	50
gadolinium-153	1×10^3
germanium-68	700
gold-198	200
iodine-125	200
iodine-131	200
iridium-192	80
iron-55	8×10^5
krypton-85	3×10^4
molybdenum-99	300
nickel-63	6×10^4
palladium-103	9×10^4
phosphorus-32	1×10^4
plutonium-238	60
plutonium-239/beryllium	60
polonium-210	60
promethium-147	4×10^4
radium-226	40
ruthenium-106 (rhodium-106)	300
selenium-75	200
strontium-90 (yttrium-90)	1×10^3
technetium-99m	700
thallium-204	2×10^4
thulium-170	2×10^4
tritium (H-3)	2×10^6
ytterbium-169	300

^a If an isotope is not mentioned in this table, contact the regulatory authority for the relevant D value.

Appendix C – Guide to shielding specifications for low- and medium-risk premises

1 Introduction

- 1.1 The purpose of this guide is to provide information on the best practices to be applied when installation of shielding is required in low- and medium-risk premises.

2 Shielding integrity

- 2.1 Shielding should be continuous. The geometry should be such that a sufficient number of scatters occur between the radiation source and the area outside the barrier so the radiation leakage through any gap is acceptably low.
- 2.2 At diagnostic energies and workloads, this means that there should be at least two scatters. In practical terms, the shielding should overlap so that there are no direct lines of sight through a gap from the patient or tube.
- 2.3 Care with design is required at the boundaries between different materials such as wall to window, or double entry doors. Shielding should typically extend from the room finished floor level (FFL) to a height of at least 2.1 metres above the FFL.

3 Floors

- 3.1 It is assumed that flooring is at least 150 mm thick, made of concrete and has a density of 2350 kgm^{-3} . Some buildings have floors constructed with ribs supporting thinner areas of concrete (often called waffle slabs). In these, care should be taken that the minimum thickness is accurately determined.

4 Wall penetrations

- 4.1 Care should be taken to ensure that there is no loss in shielding integrity to openings in shielded walls. For example, any general power point outlet (GPO) inserted into a shielded barrier should incorporate shielding behind the GPO.

5 Floor penetrations

- 5.1 Any floor and ceiling penetrations which can reasonably be in the direct radiation beam (e.g. around 1 metre outside the maximum X-ray tube reach) should be covered with at least 2 mm of lead sheet or equivalent for diagnostic installations.

6 Lead sheet

- 6.1 If used, lead sheet should be securely laminated to a suitable substrate. Penetrations of the sheet for fixing purposes should be avoided as far as possible between 750 mm and 1500 mm above the FFL.
- 6.2 Penetrations caused by normal fixing screws are generally not a problem. Joins should be shielded to the extent of an overlap of 10–15 mm.

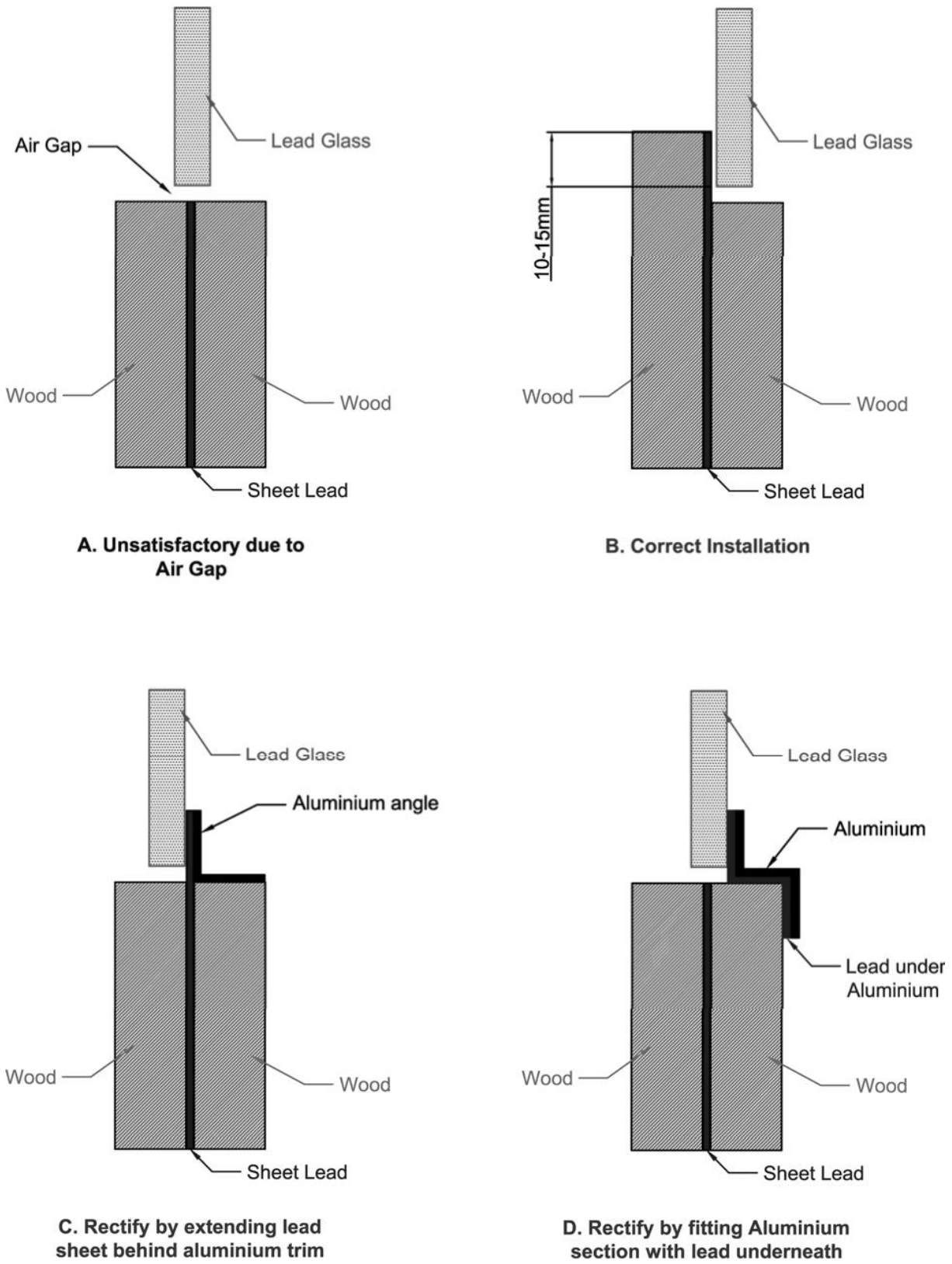
7. Viewing windows (see Figure C1)

- 7.1 Where viewing windows are to be incorporated into walls or doors, the windows should be made of lead acrylic or lead glass.
- 7.2 The lead equivalence of the window material should be at least the minimum required to provide suitable shielding at the kilovoltage and workload assumed by the calculations.
- 7.3 Care should be taken to ensure that there is no gap in shielding at the join between the window and wall which provide a line of sight for primary or first scatter radiation through the barrier. It is suggested that an overlap of 10–15 mm be used where the shielding materials are in direct contact.

8. Labelling

- 8.1 Ensure that all shielded barriers are clearly and durably marked with the lead equivalent and the kVp of the x-ray beam at which the lead equivalent was measured.

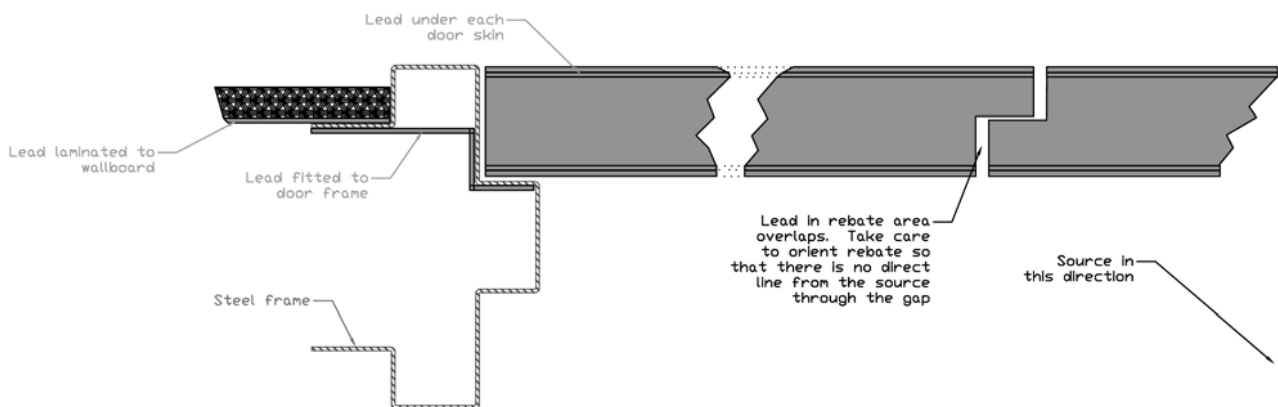
Figure C1: Example of incorrect installation of lead glass and a lead wall (A). Correct method of installation (B) and methods of rectifying the incorrect installation (C&D)



9. Doors

- 9.1 Doors and frames should be constructed so appropriate shielding geometry is achieved. This is done by ensuring that lead is installed into the frame rebate and that, if the door is edge stripped, that the rebate is sufficiently deep to achieve suitable overlap.
- 9.2 Double doors require rebates or other shielding method (e.g. shielded t-bar) to ensure that there are no direct ray-lines from the tube or patient through the space between the doors. This may require that a particular door is the active leaf (see Figure C2).

Figure C2: Example of a lead door where rebates have been used to ensure no gaps in the lead shielding



9 Erect bucky stands

- 9.1 Where an erect bucky stand is to be installed in x-ray rooms and additional shielding for the primary beam is required, it may take the form of a shield placed behind the stand extending a minimum of 500 mm on either side of the bucky centreline, and being no higher than 500 mm above FFL to no lower than 2100 mm above FFL.
- 9.2 Except where the assessment requires a heavier shield, a 20 kg/m² bucky shield is recommended to allow for future growth and change in use, except for chiropractic uses where workloads are reduced.

Please note: where a radiation barrier is shared between two x-ray rooms the shielding recommended applies **once** only to the wall. That is, the shielding does not have to be duplicated in each room.

Further reading

- ARPANSA 2007, *Code of Practice for the Security of Radioactive Sources*, Radiation Protection Series No. 11. Australian Radiation Protection and Nuclear Safety Agency, Canberra, www.arpansa.gov.au/publications/codes/rps11.cfm.
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Definitions

In this guideline:

Accreditation means a person to whom a certificate of accreditation as a consulting radiation expert is issued under s. 9 of the *Radiation Control Act 1990*.

ALARA means that a radiation dose to any person is as low as reasonably achievable with social and economic factors taken into account.

Brick wall means in terms of low-risk premises and self-assessment, a brick wall is to mean any standard brick and mortar construction built of solid material a minimum of 20 mm thick.

Bucky (erect) means an assembly which holds the X-ray film cassette in a vertical position. It contains a grid to prevent scattered radiation from reaching the X-ray film during exposure.

CRE means a consulting radiation expert who is appropriately accredited by the EPA to undertake specific activities with respect to design and assessment of shielding and verification of shielding.

Design and assessment of shielding means the process of calculating or verifying required shielding required for a premises using practices approved by the EPA.

Diagnostic mammography means a diagnostic mammography X-ray unit that is used for follow-up studies on patients presenting with symptoms of breast disease and would not be expected to perform more than 50 mammographic exposures in any one day.

High-risk activities mean the radiation usage has the potential to result in radiation exposures exceeding the maximum permissible limits. Preparation of a shielding plan **must** be undertaken by a CRE who has been accredited for high-level risk assessments.

Low-risk activities mean the radiation usage is inherently safe and is unlikely to result in unacceptable radiation exposures under normal work practices. Validation of shielding requirements can be achieved by verifying that minimal design requirements are met.

Medium-risk activities mean the radiation usage has the potential to result in unacceptable radiation exposures under normal work practices. Assessment of the shielding plan **must** be undertaken by a CRE who has been accredited for medium- or high-level risk assessments.

Occupancy factor means the factor by which the workload should be multiplied to correct for the degree of occupancy (by any one person) of the area in question while the source is in the 'on' condition and emitting radiation (*National Council on Radiation Protection 2004b*).

Occupationally exposed person means a person who is exposed to ionising or non-ionising radiation directly arising out of, or in the course of, their employment (*Radiation Control Act 1990*).

Occupied area means an area that is accessible during the time exposure to radiation is possible and that is assigned an occupancy factor to represent the proportion of time it is assessed as being occupied.

Premises means a building and land or a place and any part of a premises.

Protective measures means those steps taken to ensure dose constraints and dose limits are not exceeded and all measures are taken to reduce personal radiation exposures including fixed radiation shielding.

Screening mammography means the use of mammography x-ray apparatus in a screening program for asymptomatic patients where it might reasonably be expected to perform more than 50 mammographic exposures in any one day.

Sealed source device (SSD) means equipment or a gauge, instrument or device that contains a sealed radioactive source and permits the controlled emission of radiation, but does not include a container used solely for the storage or transport of a sealed radioactive source.

Self-shielded device means gamma irradiators in which the radioactive substance is completely enclosed in a dry container constructed of solid material that shields the radioactive substance.

Shielding plan means a document providing shielding requirements (design report; shielding plan drawings; and details of persons preparing, assessing and verifying shielding plans) for a radiation premises. The document **must** provide information on the factors on which the plan is based and refer to the methodology used in the assessment. The plan should include dimensions, layouts, usage of equipment (workload), and occupancy of adjoining rooms.

Solid brick wall means, in terms of high-risk premises where substantially more shielding is required, a wall constructed from solid dry pressed brick with full mortar thickness.

Superficial therapy means a maximum of 150 kVp.

Use factors mean the fraction of the workload for which the radiation is directed at a particular barrier.

Verification means the process of testing the compliance of shielding with the requirements of a shielding plan using practices approved by the EPA. This includes verifying the correct shielding material as specified in the shielding plan and ensuring appropriate construction techniques have been used.

Workload for X-rays means the result of multiplying tube current and time e.g. mA min. For radioactive sources, this means the result of multiplying the activity and time e.g. GBq hr.