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GENERAL GUIDELINES WITH REGARD TO THE DESIGN OF X-RAY ROOMS

The guideline if intend to educate the license holders about the design requirements and recommendation of X-Ray rooms.

Document History

Final Version	Reason for Amendment	Effective Date
0	First issue and published for implementation	October 2009
1	- Content structured on the new SAHPRA Guideline Template - A unique document number SAHPGL-RDN-XR-11 allocated to this Guideline	August 2022

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Contents

Glossary

Abbreviation/ Term	Meaning
ALARA	As low as reasonably achievable
CT	Computed Tomography
CEPH	Cephalometric
PAN	Panoramic
ICRP	International Commission of Radiation Protection
NCRP	National Commission of radiation Protection and Measurements
C-Arm	X-Ray Imaging medical device in C-shaped arm
CATH LAB	X-Ray diagnostic imaging equipment used in the Catheterization laboratory procedures
Fluoroscopy	a medical procedure that makes a real-time video of the movements inside a part of the body by passing X-Rays through the body over a period
Lead equivalent	the thickness of lead affording the same attenuation, under specified conditions, as the material in question.

1. INTRODUCTION

Several factors need to be considered to ensure an effective X-Ray room design. X-ray rooms should be of a size that allows unhindered access and ease of movement around the equipment, the patient table and the operator's console. Another consideration regarding the location of the room and the position of the equipment in the room must be planned to limit radiation exposure to patients, workers, and the public. As such dose limits should be kept as low as reasonably achievable (ALARA Principle).

1.1 Purpose

The purpose of this guideline is to set the requirements for the design of general X-Ray rooms and special procedure rooms to ensure safety of the radiation workers and the public in limiting the dose limits.

1.2 Scope

The schematic diagram of the facility/room is required before licensing a radiation emitting devices and must meet the requirements stipulated.

2. LEGAL PROVISION

The Regulation R1332 of the hazardous substances act 15 of 1973; requires that a joint product and premises licence be obtained for X-Ray equipment before it may be installed and commissioned.

a) Licences are not transferable and are issued to a specific person or institution.

b) For specific equipment and its application, and

c) For specific premises.

It is the responsibility of the prospective user of an X-Ray unit to be in possession of a licence from the regulator prior to installation of the unit. Practitioners may be assisted by the supplier of the equipment in this process.

3. DESIGN OF X-RAY ROOMS REQUIREMENTS

NOTE: Shielding thickness could be decreased by an increase in distance and/or a decrease in workload.

3.1 General/ Fluoroscopy Rooms

3.1.1 Room size

i. General radiographic rooms should be approximately 16 m^2. There should be sufficient space for a permanently built protective cubicle.

ii. Fluoroscopic rooms should be approximately 25 m^2.

iii. Special procedure rooms should be considered individually.

3.1.2 Doors and Walls

i. Access doors should be of the sliding type giving better radiation protection.

ii. A clearing of 1.5 m is recommended. The overlap should be 100 mm each side.

iii. The doors should be lined with lead sheet of 2 mm thickness.

iv. The walls should be 230 mm kiln baked solid clay brick or 2 mm lead sheet sandwiched between partitioning or 115 mm brick with 6 mm barium plaster.

v. Lead equivalence see table 1.

vi. Barium Plaster mix:

- 1-part coarse barium sulphate
- 1-part fine barium sulphate
- 1 part cement

vii. Walls should be protected up to a height of 2.2 meter.

Table 1: Shielding material with the required lead equivalent

Material	Thickness of material (in mm)	Lead equivalence (in mm) at tube voltage	
		100 kV	**150 kV**
brick	115	1.0	0.9
brick	230	2.4	2.0
barium plaster	6	1.0	0.55
barium plaster	11		1.0

3.1.3 Ceiling and floors

i. X-Ray rooms should preferably be sited on the ground floor of a building.

ii. If the X-Ray room is above ground level the solid concrete slab of density 2.35 g/cm3 must be of 150 mm thickness.

iii. Thickness of ceiling slabs, if space above is occupied, should not be less than 100 mm.

iv. Single storey buildings do not require a ceiling slab.

3.1.4 Windows and air conditioning units

i. Windows and air conditioning units should be sited at least 2 m above the floor. Alternatively access near the window must be prevented effectively.

ii. Windows of upper floor X-Ray rooms can be of normal height.

3.1.5 Protective cubicle

i. A protective cubicle allowing space for the control as well as the operator should be constructed in the X-Ray room.

ii. The cubicle should be located such that unattenuated direct scatter radiation originating on the examination table or the erect bucky do not reach the operator in the cubicle.

iii. The X-Ray control for the system should be fixed within the cubicle and should be at least 1.02 m from any open edge of the cubicle wall which is nearest to the examination table.

iv. The cubicle should have at least one viewing window which will be so placed that the operator can view the patient during any exposure.

v. The size of the window should be at least 30 cm x 30 cm.

vi. The minimum height of the cubicle is 2.2 meter.

vii. The lead equivalence of the wall or panel as well as the protective glass should be at 2 mm, i.e., 230 mm brick or 115 mm brick barium plastered (6 mm) or 2 mm leadsheet.

viii. The lead glass and protective material must overlap each other by at least 25 mm.

3.1.6 Change cubicles

i. Should the change cubicles lead into the X-Ray room the doors must be lined with at least 1.5 mm leadsheet.

ii. Access doors into the X-Ray room must be lockable from the X-Ray room side to prevent entrance during radiation exposures.

3.1.7 Radiation warning notices / lights

i. Warning lights are required at the entrances to fluoroscopy rooms. The light must be connected to the generator in such a way that it will illuminate only during activation of the tube.

ii. A radiation warning notice must be displayed at all entrances to X-Ray rooms.

4. SPECIAL PROCEDURE ROOMS

General guidelines for special procedure rooms:

4.1 Computed tomography

- Doors - lined with 1.6mm lead sheet
- Walls - The walls should be 230 mm kiln baked solid clay brick or 1.6 mm lead sheet sandwiched between partitioning or 115 mm brick with 4 mm barium plaster.
- Protective glass –1.5 mm lead glass (90 mm plate glass).
- Warning lights are required outside all entrances to CT rooms. The light must be connected to the generator in such a way that it will illuminate only during activation of the tube.

4.2 Cath Lab

- Doors - lined with 2 mm lead sheet
- Walls - The walls should be 230 mm kiln baked solid clay brick or 2 mm lead sheet sandwiched between partitioning or 115 mm brick with 6 mm barium plaster.
- Protective glass - The lead equivalence of the viewing window must be at least 1 mm of lead.
- Warning lights are required outside all direct entrances to Cath Labs. The light must be connected to the generator in such a way that it will illuminate only during activation of the tube.

4.3 PAN/CEPH Dental Unit

- Doors - lined with 1 mm lead sheet
- Walls 115 mm brick or 1 mm lead sheet

4.4 Dental X-Ray Unit

No special requirements. In case where partition walls are used, lead plate with dimensions 1m x 1m and 1mm thick, should be attached to the wall. The height of the plate should be 0.5m above the floor in order to fully intercept radiation from the primary beam. This is required only in cases where for example the waiting room is adjacent to the X-Ray room with patients sitting at distances less than ±3m from the tube head of the X-Ray unit.

4.5 Fixed C-Arm (or mobile used as a fixed unit)

- Doors - lined with 1 mm lead sheet
- Walls - 115 mm brick or 1 mm lead sheet

4.6 Mammographic Unit

- No requirements
- NOTE: Specific shielding requirements for radiographic installations can be determined as set out in the attached table 5 of NCRP 49.

4.7 Mini C-Arm Fluoroscopy Systems

4.7.1 Shielding

No additional shielding is required if all non-radiation workers are at a distance of more than 2 m away from the tube-head during operation (provided that the exposure rate due to scattered radiation at a distance of 30 cm at any point from the source is less than 20 mR/h).

4.7.2 Operator & Application

Fluoroscopic X-Ray examinations with mini-C-Arm units may only be carried out by qualified radiographers, radiologists and orthopedic surgeons specifically trained in fluoroscopy procedures with a Mini C-Arm. The C-Arm units may be used only for X-Ray examinations in a theatre.

The policy is based on International Guidelines as stated in the following documents:

- NCRP Report No. 102 {1989; paragraph 3.3.4 (e) & (o)};
- NCRP Report No. 107 {1990; p. 54}; and

- ICRP Publication 57 {1989; paragraph 193}.

5. REFERENCES

The following related documents are referenced:

5.1 NCRP 49: Structural Shielding Design and Evaluation for Medical Use of X-Rays and Gamma-Rays up to 10 MeV

5.2 NCRP Report No. 102, Medical X-Ray, Electron Beam and Gamma-Ray Protection for Energies Up to 50 MeV (Equipment Design, Performance and Use

5.3 NCRP Report No. 107, Implementation of the Principle of As Low As Reasonably Achievable (ALARA) for Medical and Dental Personnel

5.4 ICRP, 1990. Radiological Protection of the Worker in Medicine and Dentistry. ICRP Publication 57. Ann. ICRP 20 (3).

5.5 The Design of Diagnostic Medical Facilities where Ionizing Radiation is used; RPII. June 2009

5.6 South Africa, 1973. Hazardous Substances Act, 1973 (Act of 15 of 1973). https://www.sahpra.org.za/radiation-control-acts-and-regulations/

5.7 South Africa, 1973. Regulations Concerning the Control of Electronic Products. Regulation Gazette No 3991. https://www.sahpra.org.za/radiation-control-acts-and-regulations/

6. VALIDITY

This guideline is valid for a period of 5 years from the effective date of revision and replaces the old guideline for Design of X-Ray Rooms, revised October 2009. It will be reviewed on this timeframe or as and when required.

7. ANNEXURES

7.1 Annexure A - TEST PROCEDURE FOR DIAGNOSTIC X-RAY UNITS –

A. SHIELDING EVALUATION

Name of licence Holder (user)									
Make		**Model**			**Serial no.**				
Inspector no		**Name of person that perform Test**			**User License No**				
ROOM NO[1]		**TYPE OF INSTALLATION[2]**				**Date**			
Position		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RADIATION[3]									
P[4]									
T[5]									
	P/T								
W[6]	**Patient /week (W_p)**								
W_A[7] mA-min/patient (excluding CT									
W_s[7] – slices per patient CT - Axial									
W_s[7]– scan length per patient CT - Helical									
SETTINGS	**kV[8]**								
	mA-min (M_A[9])								
Scl[10]	Scan length CT								
W_{AS} for CT = Ws divided by Scl									
SHIELDED MEASUREMENT in mSv (D_s[11])									
CALCULATED VALUE[12] mSv/w									
SHIELDING	**X[13]**								

B. SHIELDING WORKLOAD

ROOM TYPE		WORKLOAD PER PATIENT (mA min/pat)	NUMBER OF PATIENTS PER WEEK		NOTES
			Average	**Busy**	
Gen Radiography	Chess wall	0.6	120	160	
	Table ⇒ floor	1.69	120	160	
	Cross table	0.17	120	160	
	Other wall (2)	0.038	120	160	
	Tot floor and walls (1 + 2)	1.9	120	160	Workload for scatter measurements on table
	Rad total	2.5	120	160	
Chest Room		0.22	200	400	
Fluoru Tube (R&F room)		13	20	30	
Rad Tube (R&F room)		1.5	25	40	
Mammo room		6.7	80	160	
Cardiac Angiography		160	20	30	
Peripheral Angiography		64	20	30	
CT - Axial – single slice		40 slices per patient	60	150	Use 10 mm single and one rotation for measurement
CT - Helical – Multi-slice		400 to 600 mm per patient	100	200	Single rotation and use total width (sum of all slices e.g. 16 slices of 2 mm each = 32 mm

RECOMMENDED OCCUPANCY FACTORS, T, Table 2

Controlled areas	1
Uncontrolled areas	
Secretarial office, shops, living quarters, kids' play area, laundry, dark room, attended waiting room	1
Nurses' station, patient examination & treatment rooms, kitchens, cafeterias	½
Corridors, patient rooms, employee lounge	1/8
Toilets, vending areas, storage rooms, outdoor area with seating	1/20
Outdoor areas with only transient pedestrian or vehicular traffic: Minimal occupancy areas; transient traffic, attics, stairways, patient holding areas	140
Unattended: Waiting & dressing rooms, parking lots, elevators, etc	

1. Attached a drawing
2. Diagnostic room; Dedicated chest unit; CT room; etc. – column 1 of Table 1
3. Primary (P) or Secondary (S)
4. P = Design dose; Controlled area = 0.1 mSv per week, Uncontrolled area = 0.02 mSv per week, Darkroom = 0.025 mSv per week and loaded cassettes must be protected to receive not more than 0.5 µSv (e.g. hatch) – see page 81 - 82
5. T = Occupancy - see table 2 (page 31 table 4.1).
6. **WP** = Workload (number of patients per week) – see Table 1. May use higher patient numbers
7. For **WA** and **WS** see Table 1 (mA min/pat)
8. See table 4.2, page 35 – 36 of NCRP 147)

   For Gen rad and for table work use 90 kV and 120 kV for vertical bucky (chest) and for Chest room use 120 kV.

   For all Fluoroscopy procedures use 100 kV

   OR if the highest setting is lower use it.

   Use 30 kV for Mammo.

   For CT use average kV (120-140) used

9. For **MA** please remember that mAs/60 = mA-min.
10. **Scl** see Table 1
11. Please remember that:
    a. Primary measurement must be performed without a patient/scatter material in the beam.
    b. For general radiography, an area that must be protected from primary will also receive secondary (scatter), therefore perform measurement also for secondary. Workload for secondary (**WA**) = Total workload (2.5 mA min/patient) **minus** Primary mA min/patient
12. Short cut: **Ds x Wp x WA / MA** = mSv per week and if this is ≤ P/T, acceptable. If 11b is applicable, add secondary to primary first. For CT: **Ds x Wp x WAS** = mSv per week and if this is ≤ P/T, acceptable.
13. √ = Shielding sufficient or **X** = Shielding insufficient.

    If shielding is insufficient (just not enough, be careful) it could be that more sophisticated procedures are required!

7.2 Annexure B - DISPLAY AND FORMAT OF RADIATION WARNING SIGNS AT ENTRANCES TO ROOMS CONTAINING X-RAY UNITS

1. DISPLAY OF RADIATION WARNING SIGNS

1.1 Radiation warning signs must be displayed at the entrances to all areas where the operator of an X-ray unit in that room or area is subjected to individual monitoring.

2. FORMAT OF RADIATION WARNING SIGNS

The sign (fig 2) shall be triangular in shape, has a golden yellow background (suitable SABS 1091 colour) and a black border.

2.2 The minimum length for the legs of the triangle shall be 150mm.

2.3 The basic symbol shall be black with the design and proportions as in fig 1.

2.4 At least 50% of the area of the sign shall be yellow; consequently, the relative sizes of the triangle and the symbol have to satisfy the following conditions:

$$l \geq 27R$$

2.5 The sign must be fixed in a prominent position and easily visible.

Fig 1 Basic symbol

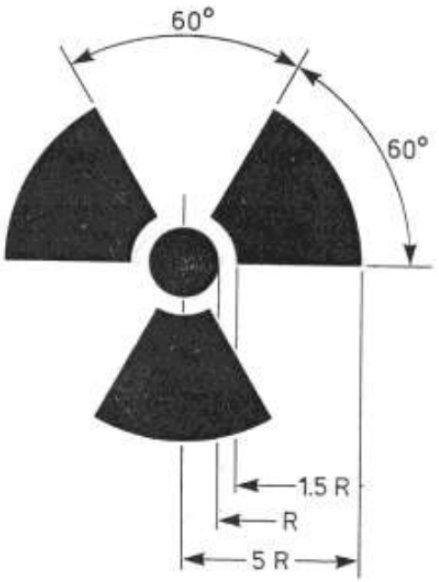
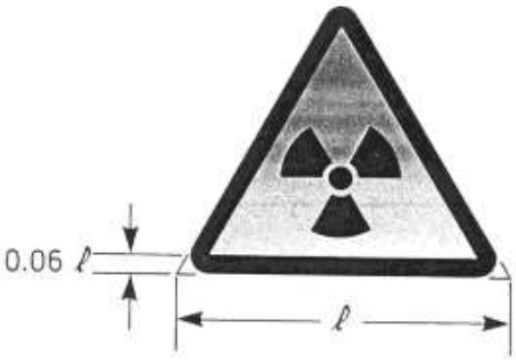


Fig 2 Warning sign



2.6 Explanatory wording, however not compulsory, may be used to give information about access or to identify an area. Wording must be kept to a minimum. The wording must be put on a supplementary sign that shall be oblong or square with the text in black on a background which is white or golden yellow.

2.7 A warning sign and its supplementary sign may, if desired, be mounted on a common white background. Examples of warning and supplementary signs are given in figures 3, 4 & 5.

2.8 The material of the warning and supplementary signs must be water and oil resistant.

Fig 3 Entry of controlled area

Fig 4 Storage cabinet

Fig 5 Sign on the door of an x-ray room

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Documents of the NRPB, Occupational, Public and Medical Exposure, vol. 4 no. 2 1993

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