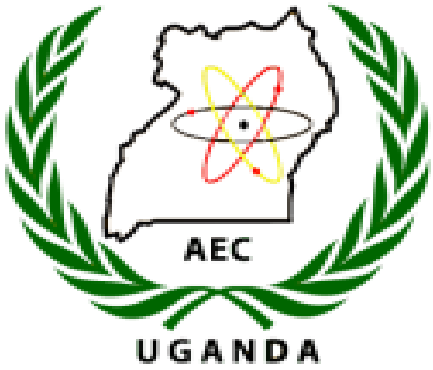

ATOMIC ENERGY COUNCIL

GUIDANCE ON THE DESIGNS AND LAYOUT OF MEDICAL RADIOLOGY FACILITIES

Vol.1, 2017

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FOREWARD

The Atomic Energy Council (AEC) was created by the Atomic Energy Act, No. 24 of 2008 with a mandate to regulate the peaceful applications of ionizing radiation, to provide for the protection and safety of individuals, society and the environment from the dangers resulting from ionizing radiation, to provide for the regulation of the development of nuclear energy for use in compliance with international safety requirements and advise government and other agencies on matters within its competence.

This guidance is intended to assist operators in understanding the intent of the regulation. It complements the regulation by describing its intent from a technical perspective using practical terms and examples. The Design Guide is not to be used as a standard design, and the use of this Design Guide does not limit the medical physicist's, project Architect's and Engineer's responsibilities to develop a complete and accurate project design that best meets the user's needs and the applicable code.

APPROVAL

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1.0 INTRODUCTION

Several aspects need to be considered in order to ensure an effective X-ray design. These may include the analysis of flow patterns, equipment, use, workload and occupancy factor. The location of the radiation rooms and placement of equipment in those rooms must be planned to minimise radiation exposure to patients and employees. By careful computation, the physicists can prescribe safe protective barriers using cost saving materials and techniques.

1.1 Authority

Under section 74 of the Atomic Energy Act No.24 of 2008, Council may issue guidelines for operations involving ionizing radiation known as Radiation Safety Guides/Guidelines. This guide has been prepared to supplement the Atomic Energy Regulations on the implementation of the requirements for authorization to possess and use a radiation generator.

1.2 Citation

This guide may be cited as Atomic Energy Council guidance on the designs and layout of medical facilities Vol. 1, 2017

1.3 Purpose

The purpose of this guide is to provide basic requirements/ recommendations for designing and constructing medical radiology facilities.

1.4 Scope

This guideline presents recommendations and technical information related to the design and structural shielding for facilities that use X-rays for medical use. It also highlights factors to be considered when installing an X-ray diagnosis machine as per the international standards.

1.5 Background

The location, structural design and equipment layout of X-ray rooms must be carefully considered from a radiation protection perspective. This is easier when X-ray facilities are not designed as stand-alone rooms but are planned as part of an integrated radiology/imaging department with its supporting areas and services. Planning the room layouts should start as early as possible in the design process and be based on inputs from a team including architects, engineers, hospital management, radiologists, radiographers, the radiation safety officer, other consultant medical staff such as cardiologists or vascular surgeons where relevant, and once identified, the equipment supplier(s).

X-ray rooms should be of a size that allows unimpeded access and ease of movement around the equipment, the patient table and the operator's console. The size of the room will vary greatly depending on the modality.

In this guideline, the recommendations are expressed in terms of: ***Shall*** and ***should***, where;
Shall*:* indicates a recommendation that is necessary to meet the current standards of radiation protection as per the Atomic Energy Act No. 24 of 2008, Atomic Energy Regulations and/or international Standards

Should*:* indicates an advisory recommendation that is to be applied when practical

In this guideline the dose limitation as per the Atomic Energy Regulations, 2012 will be taken into consideration when designing and constructing of an X-ray room and when installing the X-ray machines.

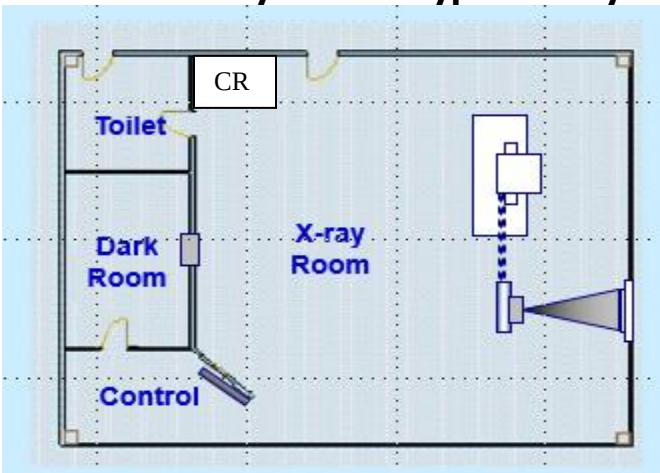
Schedule 3 (1) a of the Atomic Energy Regulations, 2012 indicates that the occupational worker ***should*** receive an effective dose not exceeding 20mSv per year averaged over five consecutive years and the public should not receive an effective dose not exceeding 1mSv per year. To achieve these dose limits, good shielding, proper installation and many other radiation protection tools must be done and/or practiced based on sound engineering as per Regulation 21(8) of Atomic Energy Regulations (AER), 2012. Additionally, shielding and other protective measures should be optimized in accordance with the requirements of these Regulations in order to protect the public from dangers of ionizing radiation as per regulation 57(1), AER, 2017.

Radiation shielding shall be designed by a qualified expert to ensure that the required degree of protection is achieved. Also the Atomic Energy Council ***may*** be consulted during the early planning stages.

2.0 FACILITY DESIGN CONSIDERATIONS

When designing a general/fluoroscopy X-ray room, several factors must be taken into consideration. Some of the factors include; location, walls, floors etc.

2.1 Default layout for a typical X-ray room



CR: Changing room

Figure 1: Default layout for a typical X-ray room

An X-ray room should:-

- have adequate safety provisions to minimize the probability of accidental exposures;
- be designed so that safety systems or devices are inherent to the equipment or the room;
- take into account the working area required; be appropriate to the types of examinations to be performed and the type of X-ray equipment to be used.

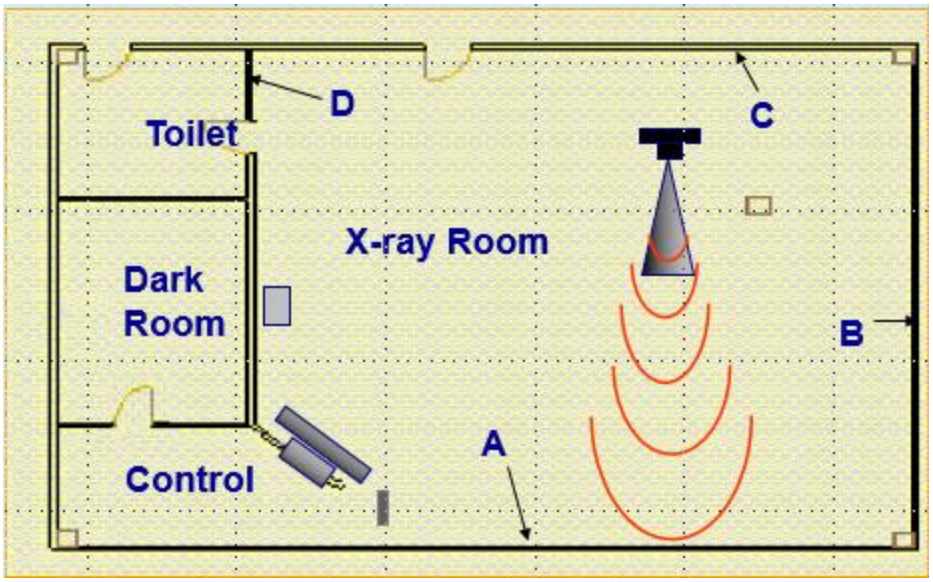
2.2 Space and Layout

In addition to considerations of structural radiation protection, the person designing an X-ray facility must consider:-

- patient and staff movement patterns
- the types of procedures to be undertaken. e.g. for radiography of trauma patients, etc., the facility will require unobstructed access for the movement of wheelchairs, trolleys and hospital beds. Examinations may be performed on patients while on trolleys or in bed.
- the weight of the X-ray and ancillary equipment for floor loadings and also for equipment that may be suspended from the ceiling or from walls.
- the floor area allocated to each room. Adequate space can create a safer and more efficient work place but the increased distance between the operator and the X-ray tube and patient is also an important radiation safety consideration.
- the location of X-ray control panels and their protective barriers which can additionally shield access points between the X-ray room, film sorting areas and darkrooms, etc.

2.2.1 Primary Protective Barrier

This is a structural surface at which the useful X-ray beam may be directed.



- Wall A is the primary barrier
- Walls B, C and D are secondary

Figure 2: Location of primary barrier

2.2.2 Secondary Protective Barrier

This where scatter radiation and leakage radiation is attenuated

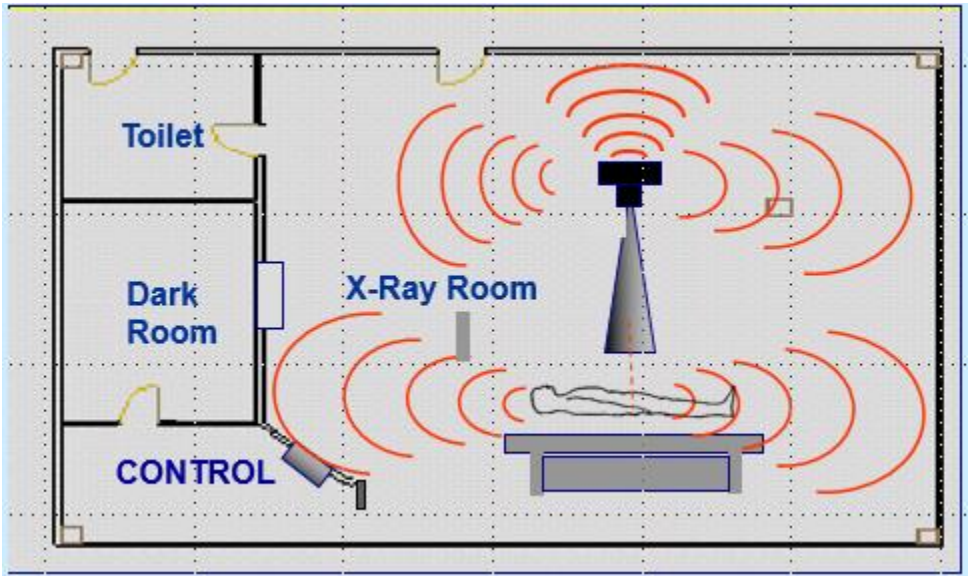


Figure 3: Location of Secondary barrier

2.3 Location of the X-ray room

The practical requirements for radiation protection depend on the clinical functions the room is designed for as well as the workload and adjacent occupancy. For simplicity, at this point, rooms will be divided into four broad categories:
1) General radiography (e.g. dental, mammography, plain X-ray machines etc.).
2) Fluoroscopy (e.g. general or interventional applications).
3) Computed Tomography (CT).
4) Shared function rooms (e.g. operating theatres or emergency departments where mobile or fixed X-ray equipment may be used.

An X-ray room ***should*** be sited on the ground floor of a double or more storied building. If floor mounted equipment is used, the single stored building may not need the ceiling slab. In addition, the following should be taken into consideration;

i. Any X-ray equipment must be installed in adequately shielded rooms to ensure that workers and the public in the vicinity of the X-ray installations are not unduly exposed to X-ray radiation as per the dose limits in the Atomic Energy Regulations, 2012.
ii. The imaging room should not be located in the middle of other rooms unless there is perfect shielding.
iii. The adequacy of shielding depends on the material and thickness used for this purpose. Different materials can be used for shielding. However, brick or concrete are considered the best materials, as they are easily available, economical, and have good structural strength.

2.4 Shielding considerations in diagnostic X-ray facilities

It is a fundamental assumption that X-ray equipment and its associated facilities will be designed and installed so as to minimize the risk of staff and the public (other than patients) being exposed to the un attenuated primary (useful) X-ray beam.
The remaining two radiation sources against which users and the public must be protected are:-

- leakage radiation from the X-ray tube assembly; and
- Scattered radiation (primarily from the patient).

Scatter radiation arises from any object within the X-ray beam (including, but to a very limited extent in diagnostic radiology, the air through which the primary X-ray beam passes).
The intensity of scatter is dependent on a number of factors, including the intensity of the primary (useful) X-ray beam, the area of the X-ray beam incident on the patient and the angle from the primary beam at which scatter is assessed.

The potential radiation dose that might be received by users and the public depends on:-

- the effectiveness of the shielding between them and the radiation source;
- Their distance from the source; and

- the nature and volume of the X-ray workload

2.4.1 Important points to note about shielding

- Should be calculated according to principles of optimization of protection
- Dose constraints shall be developed and used while bearing in mind that different X-ray equipment may be installed in the same room at a later date and the work load may increase
- Suitable structural shielding should be provided for persons performing X-ray procedures (occupational exposure) and for persons in adjacent areas (may be the public).
- A shielded barrier should be placed at the X-ray control to protect staff and so avoid any need for the routine use of protective clothing.
- X-ray rooms should be designed so that the useful X-ray beam cannot be directed at any area which is not appropriately shielded for that purpose.
- Directing the useful X-ray beam at room entrances (and cassette pass hatches) should be avoided.
- Doors, generally, may require protection against scattered radiation and should be kept closed during X-ray exposures.
- The operator should be able to clearly observe the patient during exposures from their protected position at the control panel (e.g. lead equivalent window, mirror, CCTV).

2.4.2 Shielding materials

Factors that should be considered:-

- the required thickness and density of the material
- possibility of multiple use
- uniformity of the shielding
- permanence of shielding
- optical transparency
- quality control requirements
- cost of material
- Appearance

2.4.3 Materials generally used for shielding

- Lead sheet brick

- Concrete block
- Gypsum or high density plaster board
- Lead glass or acrylic

2.5 Walls

For medical X-ray imaging, there is primary and secondary radiation. Primary radiation is the radiation emitted directly from the X-ray tube.

a) Primary wall is that wall which intercepts the radiation emitted directly from the X-ray tube (figure 2). This ***should*** be thick enough to shield most of the radiation. The ideal thickness for the primary wall of an X-ray room ***should*** be at least 250mm solid baked clay bricks or 150mm in case of mortar/concrete walls for plain radiography. Hollow bricks should be plastered with a thickness of 6mm barium plaster and should be protected up to 2.2m from the floor level.
b) Secondary radiation consists of scatter radiation from the patient or hardware and leaking radiation from the X-ray tube housing (figure 3). This radiation needs to be taken into consideration when building the walls of the X-ray room
   The secondary wall should have a minimum thickness of 230mm and density of 2.35 g/cm^3.

Although there are some factors that might reduce public exposures, like distance and time, there is need to make the walls for the X-ray room as thick as possible to keep public exposure very minimum (ALARA principle).

c) The wall ***should*** be of uniform thickness of the required thickness 230mm and 250 mm for primary and secondary walls respectively up to a height of 2.2 meters from the ground.

However, the correct thickness must be calculated by a medical physicist taking into consideration / account of occupancy, shielding material used and the work load.

The facility may consider making all the walls to have a uniform thickness if it is envisaged that the location of the primary barrier might change. In this case, the thickness of the primary barrier should be considered.

2.6 Floor and Ceilings

Concrete is a basic construction material used in floors and ceilings. The radiation attenuation effectiveness of a concrete barrier depends on its thickness, density and composition. Using an average density concrete of $2.35gcm^{-3}$, a thickness of at least 150mm and 100mm is ideal for ceiling and for floor respectively. The minimum ceiling height should be 2.5m.

2.7 Size

2.7.1 Plain radiography X-ray room

a) The minimum general X-ray room floor area should not be less than 21m^2 including the control room and 16m^2 excluding the control room. No single dimension of the X-ray room shall be less than 4.0m. **Excluding the darkroom size and changing room**
b) When building the X-ray room there should be enough space for a permanent protective booth.
c) Tube shall be oriented such that the primary beam (chest stand) is not directed towards the main door, darkroom windows or any opening.

2.7.2 Dental radiography X-ray rooms

The minimum dental X-ray room floor area shall be 12m^2 including the mobile shield or cubicle. No single dimension of the dental room shall be less than 3m.

2.7.3 Rooms for Computed Tomography and Fluoroscopy

The room housing the gantry of the computed tomography (CT) scan and fluoroscopy unit shall not be less than 25m^2 excluding the control room and no single dimension of the room shall be less than 4m.

2.7.4 Mammography rooms

The room housing a mammography X-ray unit shall not be less than 9m^2 and no single dimension of X-ray room shall be less than 3m.

NOTE: Not more than one unit of any type shall be installed in the same room.

Below is a summary of the room size for the different practices.
Table 1: summary of the room size

S/N	Practice	Room area (m^2)
1.	Conventional	≥21 (At least 4m of each length)
2.	Mammography	≥9 (At least 3m of each length)
3.	Fluoroscopy	≥25 (At least 4m of each length)
4.	Computed Tomography	≥25 (At least 4m of each length)
5.	Dental	≥12 (At least 3m of each length)

2.8 Control Cubicle

a) The cubicle booth ***should*** be constructed with a minimum ground area of 5m^2 if located inside the X-ray room. This area is excluded from the area of the X-ray room
b) The cubicle must not be in line with the tube and the vertical/chest bucky.
c) It ***should*** have enough space for the control console and the operator and ***should*** be located such that un-attenuated direct scatter radiation originating from the

examination table is less than 10μSv/h or the erect bucky does not reach the operator in the cubicle.

d) The minimum height of the cubicle/ mobile shield ***should*** be 2.0m.
e) The cubicle booth ***must*** have a lead glass viewing window that allows the operator to view the patient during all X-ray exposures. The operator must be able to view the chest bucky and X-ray table at ease.
f) The lead glass viewing window ***should*** provide the necessary attenuation required. A minimum lead equivalent of 2mm is ideal and should be visible on the viewing window.
g) The viewing window ***should*** be at least 0.3m x 0.3m for plain X-ray facilities and 0.6m x 0.6m for Computed Tomography and fluoroscopy.
h) The lead glass and the protective material must overlap each other by at least 2.5cm.

2.9 Doors

a) All the doors leading to an X-ray room ***should*** be reinforced with a shielding material of appropriate thickness so that the leakage radiation though it is less than 10μSv/h at any machine settings. For lead, 2mm of lead sheet may be adequate.
b) Doors ***should*** overlap by a minimum of 100mm each side when closed. The door ***should*** be at least 1.5m long and 2m high. The overlap requirement also applies to flap doors that make a single entrance door but closing from different sides of the door.
c) All doors should have handles and locks on the inside and the outside so that they may always be closed during exposures thus controlling access.

2.10 Labelling and Warning signs

a) The public and workers should be aware of the presence of radiation in any room. Therefore, standard radiation warning signs and notices at all entrances with a standard radiation trefoil must be displayed. In supervised area, the warning sign in figure 4 must be displayed while at the entrance door to the imaging room, the symbol in figure 5 must be displayed. The symbol must contain the type of radiation. Similar signs must be displayed in the imaging room. The labelling or notices shall be in English and any other language.

Figure 4: Example 1 of radiation warning sign

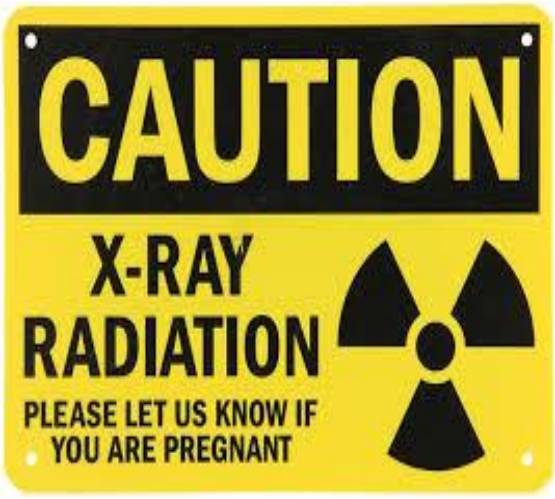


Figure 5: Example 2 of a radiation warning sign

b) The red light showing that the X-ray machine is in use must be installed at the top of each door leading to the X-ray room.
c) The red light must be synchronised with the exposure switch.
d) The red light should also be visible for the people walking towards the X-ray room.

2.11 Windows and Air conditioning units

a) Windows are not preferred in the X-ray room, but if there are installed, they ***must*** be at least 2m above the floor from the outside and access must be prevented.
b) Wall mounted air conditioning units ***should*** be placed at least 1.5m above the ground from inside.
c) For mobile air conditioned devices, they should be located in a place where they will serve the intended purpose

2.12 Patients changing room

There should be a changing room.

a) If the changing room is inside the X-ray room, the walls and doors must be sufficiently shielded.
b) The door must be lockable from the X-ray room side.

3.0 PROCESSING ROOM

3.1 Manual Processing room: Dark room

a) For those facilities which do not use or plan to use digital system and computed radiography, a dark room shall be build adjacent to the X-ray room but adequately shielded to ensure that exposure to dark room personnel or films doesn't occur.
b) A cassette pass box must be available with proper shielding to prevent exposure of undeveloped film

c) It should have a minimum ground area of at least $10m^2$ with a minimum recommended height of 3m.
d) Safe light fitted with bulbs of correct intensity ***should*** be available and placed about 1.2m from the worktop. These safelights should have filters appropriate to specifications of film used.
e) Both film storage and good ventilation ***should*** be in place.
f) It should have Formaica worktop with a cupboard and a film hopper beneath.
g) The dark room should have appropriate lockable door or blackened maze entrance to ensure light tightness to prevent fogging.
h) The dark room floor should be welded vinyl sheet and walls finished in a non-faking chemical resistant paint.
i) Proper drainage
j) The developer, fixer and wash tanks should always be kept covered.
k) There dark room should have wooden hangers for the films
l) There should be a timer in the processing room.
m) The desk top in the dark room was easy to clean.

3.2 Automatic Processing

a) The room should be maintained dry.
b) The receiving area should have a sink with draining board and bowl suitable for cleaning processor racks

4.0 INSTALLATION OF A GENERAL/FLUOROSCOPY X-RAY MACHINE

Although the design of an X-ray room might be perfect, orientation of the equipment might change the whole post. The orientation of the X-ray machine relative to the control booth must therefore be taken into consideration during installation.

4.1 Position of the equipment for each modality

4.1.1 Radiography and Fluoroscopy equipment: Couch, Control console and chest stand

The following considerations may be taken care of while positioning the couch, console and the chest stand;

a) Chest stand should be on the opposite wall of the entrance door and the control console.
b) Mobile protective barrier with lead equivalent glass viewing window should be positioned in such a manner that the operator is completely shielded during the exposure.
c) Control console should be positioned as far away as possible from the X-ray tube.

4.1.2 Computed Tomography and Interventional radiology equipment: Gantry/C-Arm, Couch, Separate control console room, viewing window,

a) The gantry and couch should be positioned such that the patient is completely visible from the control console, during the scanning.

b) The entrance door to the gantry room from the control console should have similar requirements as the patient entrance door.

4.1.3 Mammography/Cone beam computerised tomography/OPG Orthopantomography

Control console, Equipment and Protective barrier positioning of equipment should be as far as possible from the door and the control console.

5.0 OTHER SPECIAL PROCEDURE ROOMS

5.1 Computed Tomography room

Although some of the above may apply when designing the computed tomography rooms, the doors ***should*** be lined with 1.6mm lead sheet. The walls ***should*** be constructed of 300mm solid bricks for primary walls and 250mm for secondary walls or 1.6mm lead sheet sandwiched between partitioning. The protective glass located in the control room ***should*** have a lead equivalent of at least 2mm.

- Position the gantry and couch such that the patient is completely visible from the control console, during the scanning
- The entrance door to the gantry room from the control console shall have similar requirements as the patient entrance door i.e. have a hydraulic mechanism to ensure that door is closed during procedure and should be provided with an overlapping mechanism at the joints to avoid streaming.

5.2 Dental X-ray Unit room

The room ***should*** be constructed from 115mm solid bricks. 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 the waiting room is adjacent to the X-ray room with patients sitting at a distance less than 3m from the tube head of the X-ray unit. The switch ***should*** be placed outside the room. The viewing window of 30 x 30cm with lead equivalent of 1mm ***should*** be installed on the door. The door ***should*** be lined with 1mm lead sheet.

5.3 Mammography room

The room ***should*** be constructed from 115mm solid bricks. The sliding door ***should*** be lined with 1mm lead sheet. The protective glass should have a lead equivalent of at least 0.8mm. Positioning of equipment should be as far as possible from the door and the control console.

6.0 OTHER RECOMMENDATIONS

6.1 Planning process

The planning of the radiology facility ***shall*** be based on the opinion of the expertise of the director of radiology (radiologist in charge), radiographer in charge, biomedical engineer, medical physicist, architect, hospital administrator.

6.2 Designing team

The designing team should have a minimum of six (6) personnel outlined above who require the responsibility and skills to minimise construction errors.

6.3 Appropriate spacing

Consideration must be made to adequate space for patient waiting and dressing areas, film-file room and space for clerical support, holding areas for stretcher patients, offices, lounge and special procedure rooms, dark room.

6.4 Penetration in Protective barrier (Walls)

Air condition ducts, electrical sockets and other infrastructure may penetrate walls, floors and ceiling hence impairing the protective wall. In this case supplementary lead shielding is necessary. Joints between the lead sheets ***should*** be constructed so that their surfaces are in contact and overlap. Where possible this service ***should*** be provided in the secondary walls instead of the primary wall.

6.5 Personal Protective Equipment

Depending on the practice, each radiology department should have a minimum of the following protective equipment.

6.5.1 Lead aprons of lead equivalent not less than 0.25mmPb

a) Large size with a hanger
b) Medium size with a hanger
c) Small size with a hanger
d) Thyroid shield

6.5.2 Lead gloves of lead equivalent not less than 0.25mmPb

a) Large size
b) Medium size

6.5.3 Lead gonad shields of lead equivalent not less than 0.25mmPb

a) Large size (Adult)
b) Medium size(Child)
c) Small size(Infant)

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