ATOMIC ENERGY COUNCIL

GUIDANCE ON THE DESIGNS AND LAYOUT OF MEDICAL RADIOLOGY FACILITIES

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Date: 17th day of July the year 2023

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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.

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, 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.

1.3 Purpose

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

1.4 Scope

This guideline presents recommendations and technical information related to the design and structural shielding for facilities that use radiation for medical use. It also highlights factors to be considered when designing and installing radiation machines as per the international standards.

1.5 Background

The location, structural design and equipment layout of radiation rooms must be carefully considered from a radiation protection perspective. This is easier when the imaging 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).

Imaging 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 imaging room and when installing the machines.

Schedule 3 (1) 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.

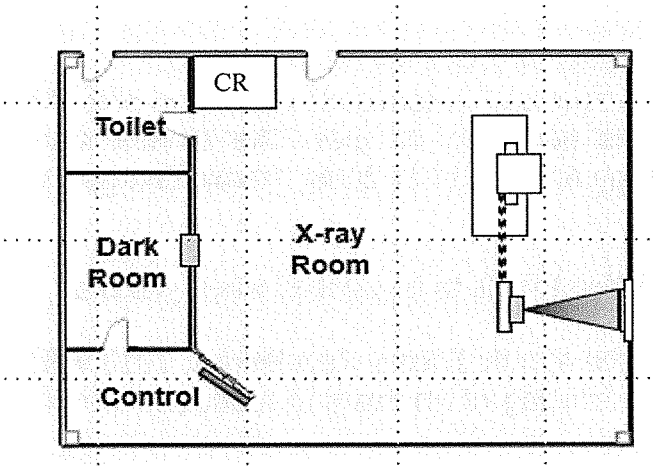
Radiation shielding shall be designed by a qualified expert to ensure that the required degree of protection is achieved. Also, the Atomic Energy Council ***may*** be consulted during the early planning stages.

2.0 FACILITY DESIGN CONSIDERATIONS

A. General/fluoroscopy room

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.

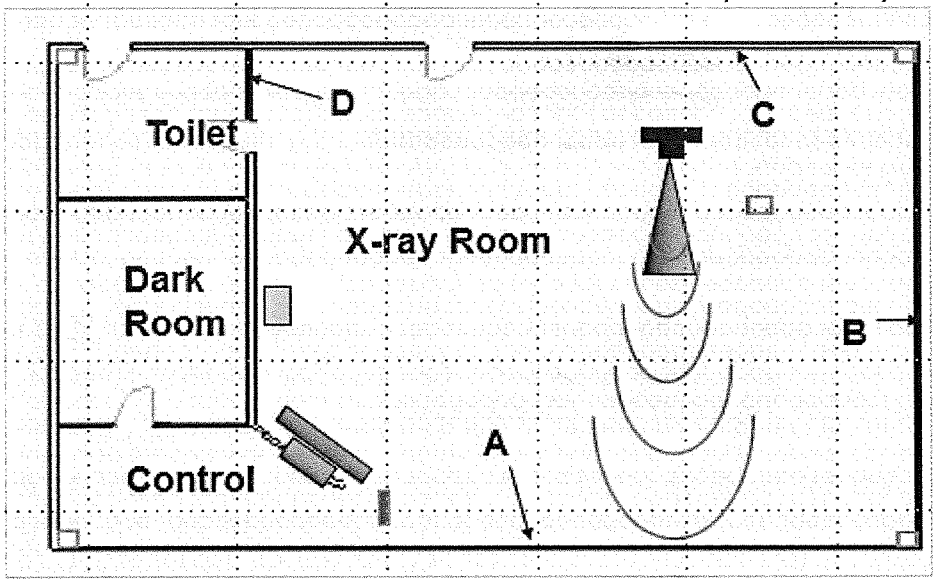
2.2 Space and Layout

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

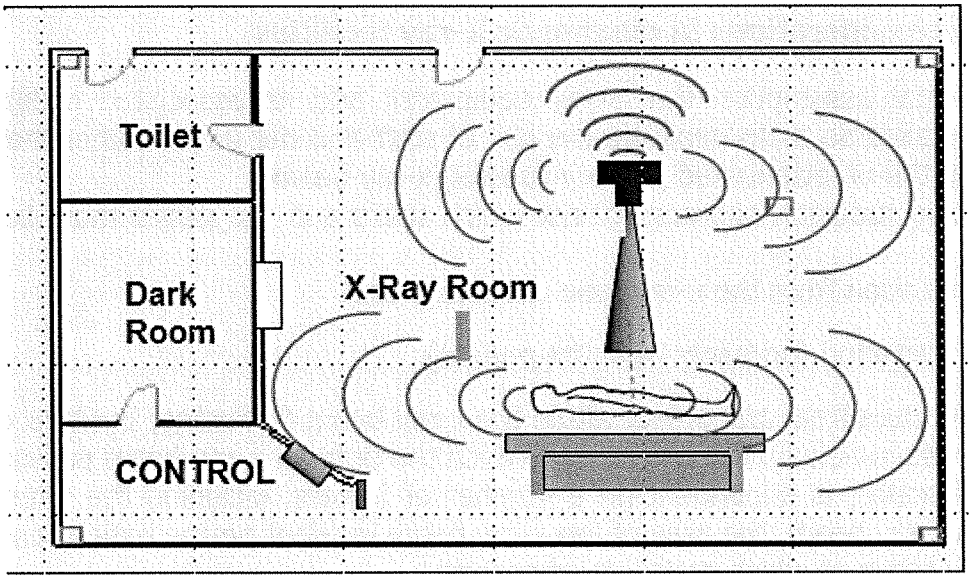


Figure 3: Location of Secondary barrier

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. 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 2.3 g/cm3.

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 $2.35 gcm^{-3}$, 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 5m 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 ***shall*** 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 ***shall*** 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 ***shall*** 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

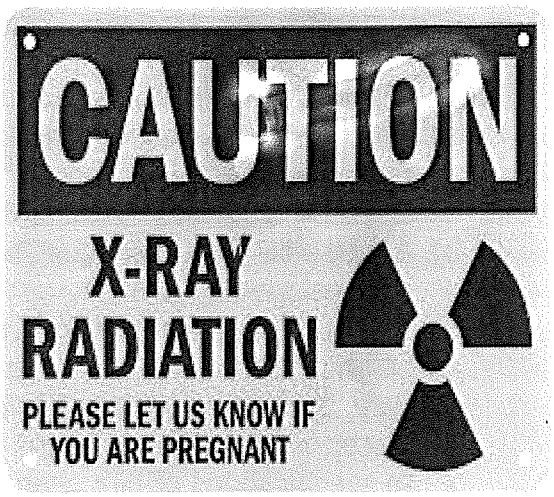


Figure 5: Example 2 of a radiation warning sign

b) All classified areas and entrance to the x-ray room should be posted with a sign or signs bearing the radiation caution symbol and words" Caution Radiation Area"
c) 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.
d) The red light must be synchronised with the exposure switch.
e) 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 ***shall*** 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 ***should*** be 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 is 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) Position the gantry and couch 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 shall 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 250mm solid bricks or 1.6mm lead sheet sandwiched between partitioning. The protective glass located in the control room ***should*** have a lead equivalent of at least 0.8mm.
- 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)

7.0 Nuclear Medicine

7.1 Imaging rooms

Imaging rooms should be at least as large as given in the manufacturer's recommendations, but preferably larger, to accommodate patients on stretchers. A larger area provides a more pleasant working environment and reduces the risk of radiation to staff.

Rooms should have double glazed and insulated windows to avoid the build-up of dust. Tight fitting oversize doors and efficient heating, air conditioning and humidity control units are also required. All rooms should have their own separate power supply and stabilizers and be equipped with hand washbasins with hot and cold running water. An intercom and/or telephone are important for facilitating communication.

7.2 Cardiac stress laboratory for nuclear cardiology

The cardiac stress laboratory should be planned in consultation with the cardiologists and equipped for treadmills and bicycles or pharmacological stress studies. Drug and life support facilities should be available in cases of emergency.

7.3 Conference room

The conference room can be used primarily for interdepartmental conferences, consultations with physicians and support activities for nuclear medicine staff. While functions could be accommodated in one large room with or without a partition, two separate rooms might be preferable. Space for scan interpretation, computers and ancillary equipment such as Local Area Networks should be provided. A library, Internet access and other teaching aids should be available to the conference room(s).

7.4 Offices

There should be sufficient office space for physicians, radio pharmacists, physicists, chief technologists, managers and secretarial staff in addition to a staff lounge. The number of offices depends on the size of the service.

7.5 Other space requirements

Additional spaces may be required for the following purposes:

a) Storage of clean supplies
b) Radioactive waste disposal
c) Toilet facilities for patients
d) Staff restroom and toilet facilities
e) Showers for decontamination purposes.

7.6 In Vitro and Radioimmunoassay Laboratories

The first point to consider in the establishment of a Radioimmunoassay (RIA) laboratory is the purpose for which it is intended. RIA facilities may be created to support a specific research activity, whereas more often than not, they are initially designed to provide a clinical

diagnostic service (e.g. hormone assays). Such centres would only take on other functions, such as research and teaching, at a later stage. Within this context, the general issues that need to be considered are the location of the laboratory, building specifications, staff, training and equipment.

7.6.1 Location

The most successful RIA laboratories are attached to nuclear medicine centres that offer in vivo and in vitro diagnostic tests. An advantage to this is that the two types of tests are often complementary in the diagnostic follow-up of patients with commonly encountered disorders such as those related to the thyroid.
Provisions should be made at the initial planning stage for future in vivo activities (with a gamma camera, etc.) at the same site as the in vitro testing facilities.
On the other hand, in places where the two branches of nuclear medicine activity occupy separate premises there is little, if any, decrease in their effectiveness. The essential consideration should always be that where an RIA centre serves a cost effective clinical diagnostic function, it should be easily accessible to the end user although, in the case of in vitro tests, a high proportion of samples may be sent to the laboratory by post or other means.

7.6.2 Building

The design and structure of the building can affect the quality of a RIA centre. Premises should generally provide working conditions that are hygienic and spacious, and may include special features depending on the extent to which radionuclides are used.
A patient reception area with a waiting room and an area for taking blood samples should be available. It is essential to reserve an area for record keeping and the sorting and labelling of samples that, depending on the tests required, may be taken in the laboratory or obtained from outside.

The core of the RIA unit is the area in which the assays themselves are performed. It should be spacious enough to accommodate the number of technicians employed, be well ventilated and have a constant and reliable supply of electricity and clean water. Floors and bench-tops should be smooth and of non-absorbent material to facilitate cleaning and decontamination in the event of chemical or radioactive spillage.

Most RIA protocols require a decantation step following the separation procedure, and therefore sinks should be conveniently located at each workbench. A separate washbasin, labelled to this effect, should be reserved for the washing of hands of laboratory personnel, with its use prohibited for any other purpose. The washing-up area for glassware, used RIA tubes and reusable pipette tips should have one or two large sinks and a drying oven. Sensitive electronic equipment, such as counters, computers and analytical balances, needs to be stored in air conditioned surroundings, particularly where the outside environmental conditions are hot, humid, dusty or otherwise unfavourable.

7.7 Positron Emission Tomography (PET)

The overall size of a PET facility and the number of rooms required depends on whether it is integrated with an established nuclear medicine service or not. An average facility will include:

a) Rooms for reception:

Scanner, control, waiting, injection, blood testing, reporting and administration rooms.

b) Cyclotron specific rooms:

Cyclotron, control, hot laboratory, quality control, preparation, gas store and administration rooms.

c) Other rooms:

Electricity, air–water cooling, ventilator–conditioner and waste control rooms.

8.0 RADIOTHERAPY

The design considerations depend on whether it is a new facility or remodelling an existing facility. The facility should ensure that the local hospital staff who will perform the radiotherapy treatments, the hospital administrators and the equipment manufacturers are involved in the planning of these facilities.

The layout of the facility should be planned taking into consideration equipment requirements, water and electrical utilities needed, room shielding required (including dosimetry ports) and climate control. Careful attention must be focused on the flow of patients in the treatment facility. The layout should be planned in accordance with the national and internationally accepted radiation safety standards and in consultation with the radiation oncologist, medical physicist and equipment manufacturer.

8.1 Reception and waiting areas

The reception and main waiting areas should be located at the main entrance to the department and act as distribution point for all the different sections in the department. The facility should have separate waiting areas for patients attending clinics, follow-ups and those awaiting treatment. The clinic waiting area should have space for approximately eight patients for each physician.

8.2 Clinic consulting area

Sub-waiting areas at the various clinics for consultations need to be provided with their own reception or nurses' station.

The size of the clinical consultation rooms should be adequate to house a desk and two to three visitor chairs and include a screened or separate examination area with a wash hand

basin (WHB). The total number of consultation rooms would be related to the number of radiation oncologists, medical officers and trainees in the department.

8.3 External beam therapy

It is advisable to place bunkers above ground, together with the rest of the facility. When infrastructure, power and financial resources are constrained, use of natural lighting and ventilation can be maximized. In addition, in tropical or high rainfall regions, waterproofing and drainage of an excavated site could be an additional challenge.

The construction of fully shielded underground bunkers (as opposed to retaining structures only) may also be required if future plans for adjacent underground facilities are not known. Facilities are ideally designed with adjacent bunkers to reduce costs by sharing the primary shielding structures and, in so doing, minimize the footprint and the total volume of shielding material needed.

The thicknesses of the primary and secondary walls must be scientifically calculated taking into considerations the distances from the isocentre, weekly workload, type of shielding materials among others considerations.

The minimum recommended inside room dimensions are 7 m × 7 m with the isocentre positioned approximately in the centre of the room. These room dimensions provide space for the structure of the teletherapy unit and for the maximum longitudinal extension of a typical patient treatment table. Similarly, the width will enable comfortable access around the gantry and the patient for all angles of rotation.

The minimum structural room height should be 4 m, including along the maze. This height is necessary for ease of access when equipment is delivered, to provide for the air conditioning, heating, exhaust and ventilation system design, and for installing additional electrical supply cabling. A false ceiling can be added later. A maze width of 2.0–2.2 m will also ensure an adequate turning circle for equipment delivery. A lintel restricting the height to 2.4 m should be installed along the maze at some point, as reducing the cross-section provides additional shielding against neutrons if the use of higher energies in the future is considered.

When establishing services for the first time, provision for the base-frame is highly recommended; measuring from the centre of the back of the unit, a 6 m × 2 m × 0.3 m deep excavation in the floor will suffice. Finishing of the floors, ceiling and walls should be completed by the supplier so that the final levelling and ergonomic design is customized to the treatment unit.

A bunker does not need a shielded roof if the primary beam can never be directed towards adjacent structures; this can be confirmed using geometrical projections of the radiation field

external to the facility based on the infrastructure, ownership and zoning of the surrounding properties.

Access to the roof itself should be restricted and cordoned off, with a security entrance, interlocked to the treatment machine. It is possible to place the water chiller and the air-conditioning plants on the roof, for instance, as both require controlled access.

However, if at one time and during the treatment process, the beam might be directed on the roof, the adequate shielding of the roof is a MUST. In general, it is better to assume that the primary beam will be directed to the roof so that the entire shielding of the facility is considered at once.

It is highly recommended that the plane of gantry rotation is parallel to the treatment control panel area. The overall orientation of the bunkers should take into account all high occupancy areas.

Additional secondary shielding should be added to the layout in order to provide for higher workloads, which may be important when a transition is made to intensity modulated radiotherapy or dose escalation techniques, for instance.

It is important to design the facility to accommodate the various types of treatment equipment. For example, if the facility plans to install a LINAC of 6MV but envisages that they might in future install a LINAC of more than this energy say greater than 10MV, then shielding requirements for LINACS with energies greater than 10MV should be considered. The advantage is that even a Co-60 treatment machine can be accommodated by this bunker and neutron shielding especially for the entrance door would have been catered for.

All final layouts require that detailed shielding calculations should be performed, and signed-off by a local, clinically qualified medical physicist and have approval of the Atomic Energy Council.

The bunker may include plumbing for a WHB and should have adequate storage space for all positioning and immobilization devices and accessories. Provisions for joints, ducting and sleeves should not follow the divergence of the primary beam, and this is easily achieved by placing these in the secondary shielding and using a curved path.

Some thought should be given to mechanical, electrical and safety considerations, for example, the ability to dim the room lights, emergency switches and the provision of standby lighting, which could be achieved by placing rechargeable torches in the treatment room, for instance. Ducting is required for connection between the gantry structure and the treatment control panel. In addition, isolated ducts should be provided for dosimetry cables (minimum 150 mm diameter) and connectivity to the chiller system.

Each bunker should be provided with a control area. All radiotherapy treatment control areas should be provided with a patient intercommunication device and at least two closed circuit television monitors. Privacy and confidentiality in the use of these devices is mandatory.
The worktop should be of adequate length for all patient information sheets and images to be immediately available to the staff member, who should also have a direct view of the control panel and the closed circuit television monitors. Power skirting therefore needs to be provided along the length of the worktop and allow for multiple devices to be powered, including additional emergency switches.

A provision for an X-ray viewing box or equivalent should be catered for and the ambient lighting should provide adequate viewing conditions.

Cultural aspects need to be considered, such as gender separation and the fact that many family members sometimes accompany each patient. Chairs can be immovable so that access pathways and wheelchair and stretcher bays are not obstructed. At least one stretcher bay needs to be provided per treatment unit and be large enough to allow clinical assessment of the patient.

Clear signposting using international signage and/or all local languages is recommended for all waiting areas. A clear access route starting at the main entrance for patients who are only receiving daily treatment needs to be available. Local practice sometimes prefers changing rooms outside of the treatment rooms to improve patient flow, but this decreases the time that the radiation therapists have to communicate with patients on an individual basis. Changing rooms can however only be included if patient privacy is maintained and enough security can be provided for their belongings. In many departments, the radiation therapists prefer to assist patients to undress in the treatment room.

In order to optimize workflow in the vicinity of any external beam treatment machine, double (separate) circulation passages for patients and staff are highly recommended. This can be achieved using partitioning. In addition, an access route with adequate floor loading should be available for all future equipment deliveries.

Provision should be made near the treatment area for a networked imager or printer, or a small plumbed darkroom for processing X-ray films. This can be shared with brachytherapy or imaging but the amount of time the radiation therapists need to spend away from the treatment control area should be minimized. A small store room of at least 3 m × 3 m for the major dosimetry equipment near the treatment units is needed for the medical physics services.

8.4 Brachytherapy

A brachytherapy suite should include the shielded treatment room, a control area, a procedure/preparation room, a recovery area, a sluice room and an imager or film processing area. This suite should be positioned behind a red line. Some centres prepare the patient in the treatment room whereas others prefer to do this in a separate procedure room. If patients are prepared in a separate room, then movable, interchangeable patient tables are generally supplied so that the patient is not moved unnecessarily between applicator insertion and treatment delivery.

A C-arm is generally required for applicator placement and therefore will need to be installed in the appropriate room, either the procedure room or the treatment room depending on the local practice. When there is a high workload of gynaecological applications using 3-D techniques, then a computerized tomography (CT) or magnetic resonance imaging (MRI) scanner and control console could be installed in the procedure room. The CT will have the same shielding requirements as the X-ray bunkers. The other option is to share the resources and locate the brachytherapy service in the vicinity of the CT scanner required for the imaging and treatment planning area.

The shielding should assume operation at maximum source activity for 1 hour per shift. It should have a maze design with wall and ceiling thicknesses of at least 100 cm (primary and secondary shielding concepts are irrelevant for isotropic radiation applications).
The maze should be at least 1.8 m wide to allow for easy access in the event of an emergency. Access control can be achieved using light beams to trigger an interlock. This also improves the sterility of the environment. Since there is generally no public access to this functional area, staff vigilance at the control area is less likely to be disturbed and physical barriers can therefore be avoided during operation.

The inside dimensions of the room should be a minimum of 4 m × 4 m × 3.6 m in order for there to be enough space around the unit to manoeuvre a C-arm and a procedure trolley, if the patient is prepared in the treatment room. An easily accessible applicator storage cupboard should be provided with enough clearly marked hanging space for all catheters and transfer tubes to minimize contamination.

The treatment control area has the same requirements for the operators as the megavoltage units but should include space for an on-line treatment planning system. Alternatively, a separate space can be allocated for a treatment planning workstation. If 3-D techniques are used, the radiation oncology and medical physics teams need to spend more time in this area to perform the actual treatment planning. This workstation should be networked to the CT or MRI scanner.

A sub-waiting area may be necessary for brachytherapy, but this depends on the location of the suite from other waiting areas, e.g. those used for EBRT.