ISSN 0021 – 1907

INIS ISRRAC EG

بحـــوث النظــائر والإشــعاع

ISOTOPE AND RADIATION RESEARCH

VOLUME 46 No. 3 2014

مجلة علمية متخصصة يصدرها

مركز الشرق الأوسط الإقليمى للنظائر المشعة للدول العربية

Specialized Scientific Bulletin Issued By

MIDDLE EASTERN REGIONAL RADIOISOTOPE

CENTRE FOR THE ARAB COUNTRIES

www.merrcac.org

ISOTOPE & RAD. RES., 46(3), 387-395 (2014). *ISSN 0021-1907*
INIS ISRRAC EG

STUDY OF REQUIREMENTS FOR DESIGNS OF THE MEDICAL X-RAY FACILITIES FOR RADIATION PROTECTION PURPOSES AND LICENSING

SIRAG, N.M. and HAMED, A.A.

Nuclear and Radiological Regulatory Authority, Cairo, Egypt.

Key words: Radiation protection, Design of X-ray unit, Radiological buildings.

دراسة المتطلبات التنظيمية فى تصميم المنشآت الطبية المستخدمة للأشعة السينية لاستيفاء أغراض الترخيص والوقاية من الإشعاع

نادية محمود سراج وعبد الفتاح عبد العال حامد

خلاصــة

من الأهداف الرئيسية للسلطات التنظيمية فى الأنشطة النووية الإشعاعية وإنشاء الأنظمة لمنع مخاطر الإشعاع المؤين إلى البيئة والجمهور (العاملين والعامة والمرضى) هو الوقاية الإشعاعية من الأشعة السينية التى يمكن أن تكون مصدر غير مبرر لجرعات زائدة للإشعاع بسبب تصاميم هندسية غير مدروسة لبناء وحدات التشخيص بالإشعاع. ووضع قواعد تصميم المبنى هو واحد من أهم المتطلبات التنظيمية وهذا البحث يتناول الأساليب العملية الهندسية لتطبيق القواعد الأساسية التى تحقق متطلبات الوقاية الإشعاعية فى بيئة العمل الخاصة بالأشعة السينية.

ABSTRACT

One of the main aims of the regulatory authorities in the nuclear and radiological activities is establishing applicable regulations for preventing ionizing radiation hazards to human (public, workers or patients) and environment. The primary and scattering radiation beam from radiological machine could be source of unjustified radiation exposure doses due to the uncorrected designs of the radiological buildings. Developing rules for radiological units licensing are represented in this study by considering the building design as one of the regulatory recuirements. This article discusses

Accepted December 2014.

engineering practical approaches to apply the fundamental rules that afford X-ray technologists a lifetime of safe occupation employment.

INTRODUCTION

Radiation protection can be divided into occupational radiation protection which is the protection of workers, medical radiation protection which is the protection of patients and the radiographer which is protection of individual members of the public and the population as a whole. The designing and planning of the X-ray department is a critical step to ensuring optimum performance of the radiology department. A proper X-ray room design can ensure better work flow during the X-ray taking process as well as offer the proper space required to install and maintain the X-ray equipment. A poorly planned X-ray room design can involve higher costs and fees in the long run as well as increase the amount of X-ray lead shielding required to protect the staff, patients and facility from gamma and X-rays.

Specific shielding designs are related to the shielding formula used to protect personnel, patients and visitors from ionizing radiation. Shielding is a required practical method of radiation protection and the commonly used materials for shielding are lead, concrete or bricks to prevent or reduce the transmission of radiation. The main primary radiation types encountered in diagnostic imaging for which shielding should be designed are gamma and X-rays and alpha and beta particles. The most important considerations in the prevention of radiation is known as cardinal rule of maximize distance. The three cardinal rules of radiation protection are focused on: 1) time, 2) distance and 3) shielding. Concerning the time, the operator must trained to reduce the time of exposures that he takes for handling a source. On the other hand, the increasing of distance reduces the dose due to the inverse square law. Additionally, the shield refers to a mass of absorbing material placed around a source or other radioactive source to reduce the radiation to a level safe for humans.

The present study explains that the architectural design is one of the most important safety and radiation protection factors. These factors include the distribution of orientation, ventilation, doors and finishing materials which proved to have the greatest impact in reducing the exposure of workers and the public and patients to a dose of radiation. The present study was carried out to determine the licensing requirements for facilities used for radioactivity.

DESIGN FEATURES

Architectural and constructional drawings are referred to a complete description of facility design issues. The layout of the facility should be planned considering equipment requirements, water and electrical utilities needed, room shielding required and climate control. Careful attention must be focused on the flow of patients in the treatment facility and the layout should be planned in accordance with internationally accepted radiation safety standards and in consultation with the radiation oncologist, physicist and the equipment manufacturer (IAEA, TECDOC-1040). The important steps are the design layout, planning, directions, areas of classification and distribution.

Direction:

In order to reduce the radiation dose near the entrance, a restricted access passageway leading to the room may be incorporated in the design. This passageway is termed the maze which should be long with small cross-section as possible. The minimum width may be determined by the dimensions of the treatment unit to be delivered by this route or by access for a hospital bed. The maze ensures that photon radiation can exited to the room after scattering has attenuated and also it reduces the need for a heavy shielding door. If the length of the maze is sufficient or if there are enough bends, there may be no need for a radiation protection door at the maze entrance. However, it is recommended that a physical barrier such as a normal door(s) or gate should install to discourage entry to the maze during patient treatment if a shielded door is not required. Linear accelerators require a gate to prohibit entry during treatment times and/or motion detectors to detect unauthorized entry if a shielded door is not required to reduce dose rates. Another advantage of a maze is a route for ventilation ducts and electrical conduits without compromising the shielding.

Treatment control area:

The treatment control area is the place at which the operators control the machine. This area should be close to the entrance to the treatment bunker so that, the operators can view the entrance area. The control area should be sufficiently large to accommodate the treatment unit control console and associated equipments. There may be computer terminals for record and verification, electronic portal imaging, hospital information system and dosimetry equipment as well as closed circuit TV monitors for patient observation. There should be clear access to any dosimeter ducts.

Classification of areas:

There are areas classified as controlled or supervised areas. The controlled areas are the treatment rooms for all external beam and treatments as well as the source storage and preparation rooms. In addition, these areas require special access restrictions by means of door interlocks and signs when sources are exposed. The supervised areas are the operating consoles of the external beam treatment unit as well as any area where calculated exposure rates through shielding barriers are likely to result in exposures of 1 mSv in a year. The examination rooms should be in close proximity to the treatment room.

Treatment planning room:

The treatment planning room should be located in proximity to the simulator room although the two areas do not have to be adjacent. The room should be large enough to house the treatment planning computer with its video monitor, printer and plotter, digitizer tablet and other requirements.

Waiting areas:

It is desirable to have separated waiting areas for patients attending clinical visits and those waiting treatment. The clinical waiting area should have space for approximately eight patients for each physician.

The treatment waiting area should be adjacent to the treatment room with space for seating of about twelve people for each machine and another area should provided for stretcher patients. This area should be adjacent to the treatment area but preferably separated from the ambulatory patients. The area should be large enough to accommodate three stretchers.

Layout and shielding:

Concerning the relationship between design and shielding, the amount of shielding required in each of the barriers of the treatment bunker will depend to some extent on the use of the surrounding areas. Areas with high occupancy levels will require greater shielding and wherever possible, the treatment bunker should be surrounded with rooms that have low or controlled occupancy. For example locks or signs prohibiting unauthorized entry could control access to the roof space above a bunker (IAEA Safety Reports, Series No. 47).

The shielding of the simulator room should be designed according to the recommendations of NCRP Report 491 and the Regulatory Authority. The room should be large enough to accommodate the simulator allowing the full range of motion of the treatment table. A means of securely mounting patient positioning lasers to the wall at points appropriate to project lines through the isocenter should be included in the plans. Means for dimming the room lights should be considered in the design of the room and adequate space should be planned for cabinetry to store treatment devices and daily quality assurance equipments. If the immobilization devices are to be fabricated in the simulator room, cabinet space to store supplies for their fabrication will be required and a sink should be provided in this room. A viewing window should be provided for the control room and light boxes in the control and simulator rooms are useful.

The doors of the storage rooms should be locked and have a sign indicating that there are radioactive materials stored within. The responsible person should indicate to contact in the event that entry is needed such as for fire safety purposes.

Concerning the distance, the X-ray department staffs are working adjacent or near the X-ray facility. In radiology, the radiation travels away from the tube (gamma or X-ray source) then spread, therefore, the intensity of the radiation follows the inverse square law. This law refers to the fact that the intensity of radiation becomes weaker as it spreads out from the source since the same radiation becomes spread over a larger area (NCRP Report 491). Stands to the reason that the longer a person is exposed to a field of radiation the greater that

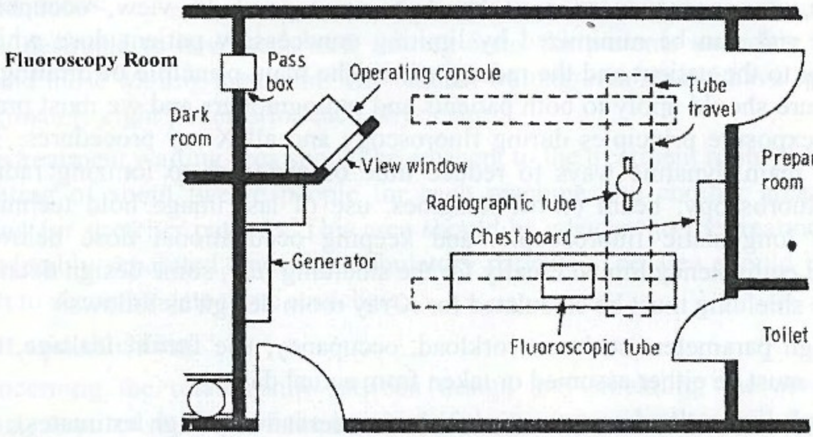


Fig. (1): Typical design for X-ray room.

Figure (1) also explains the minimum room dimensions (length, width and height) and should be large enough to allow full extension of the couch in any direction, with room for an operator to walk around it. The desirable size depends upon the type of treatment, e.g. a total body irradiation procedure will require a larger treatment distance to one wall. For intra-operative procedures that require extensive support staff and equipment, the room may need to be larger. The accessory equipments such as electron applicators, breast positioning boards, etc. are usually stored within the room and should be located to minimize the walking distance for each patient set-up (IAEA Safety Reports, Series No. 47).

The space must be able to accommodate large beds and trolleys and for the used aesthetic equipment, cables must locate in holes in floors to be away from radiation beams. Additional preparation room, toilet, operating console and pass box to dark room should have radiation warning signs and all shielded doors should have radiation warning lights outside.

Fluoroscopy room:

Lead glass clear view and good lighting must be able to accommodate large beds and trolleys and for any used aesthetic equipment, cables must locate in holes in floors to be away from radiation beams. For fluoroscopy angiography and CT, all shielded doors should have radiation warning signs and radiation warning lights outside. Of protective equipment, lead vinyl materials (especially gowns lead vinyl is 0.3-0.5 mm + equivalent front) is more important than rear (only high Pb). If the staff member is not standing with back towards patient, he must be examined at the beginning and ~ every 12 months (using fluoroscopy).

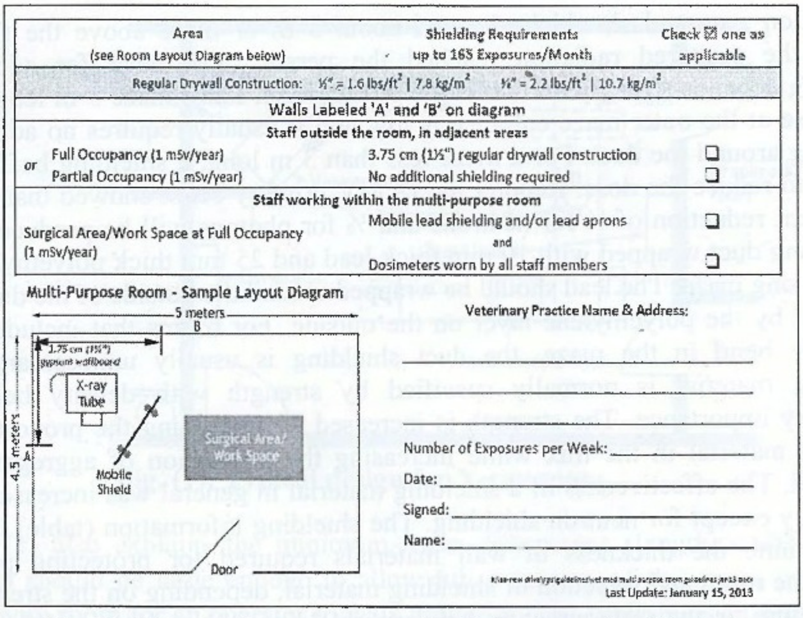
Concerning the shield around ducts, the maze entrance is used for high energy machines. The photon and neutron dose equivalent rates at the maze door, where the ducts penetrate the barrier, may be estimated using the method described in the penetration area and should be located about 3 m or more above the floor to reduce the scattered radiation reached the person. The need for additional shielding depends strongly on the length of the maze. For a maze 5 m length, the total dose at the outer maze entrance is low and it usually requires no additional shielding around the duct. For a maze less than 3 m long, a shielding baffle may needed to reduce the dose. Reports for 18 MV primary beam showed that a dose equivalent reduction of ¼ for neutrons and ½ for photons will be produced by a 1.2 m long duct wrapped with 10 mm thick lead and 25 mm thick polyethylene in a 3.6 m long maze. The lead should be wrapped around the outside of the duct first followed by the polyethylene layer on the outside. For rooms that include more than one bend in the maze, the duct shielding is usually unnecessary. The shielding material is normally specified by strength with density being of secondary importance. The strength is increased by increasing the proportion of different material in the mix while increasing the proportion of aggregate was increased. The effectiveness of a shielding material in general was increased with its density except for neutron shielding. The shielding information (table) is used to determine the thickness of wall materials required for protecting persons outside the room and selection of shielding material, depending on the strength of the machine, is the differentiation between shielding materials according to the location, dimensions of the room, finishing materials as well as material cost.

Table: Lead equivalence of various materials for low energy X-rays.

			mm lead equivalent at applied kilovoltage of			
Material	**Density ($kg\ m^{-3}$)**	**Material thickness (cm)**	**50**	**75**	**100**	**150**
Clay brick	1600	10	0.6	0.8	0.9	0.8
		20	1.4	1.7	1.9	1.7
		30	2.2	2.7	3.1	2.6
		40	-----	3.8	4.5	3.7
		50	-----	-----	-----	4.8
Barytes plaster or concrete	3200	1	0.9	1.5	1.8	0.9
		2	1.8	2.7	3.3	1.8
		2.5	2.3	3.3	4.0	2.2
		5	-----	-----	-----	4.3
		7.5	-----	-----	-----	5.9

Licensing:

The X-Ray units need to be licensed by the National Regulatory Authority and the radiotherapy installation needs major construction. The regulatory authorities shall provide authorization before construction begins, therefore, the application for a license must be prepared at early stage and should contains all the relevant elements to assure the regulatory authority that the planned facility will be safe. An example of a detailed outline of the elements for a license is given.



Area (see Room Layout Diagram below)	Shielding Requirements up to 165 Exposures/Month	Check ☒ one as applicable
Regular Drywall Construction: ½" = 1.6 lbs/ft² | 7.8 kg/m² ⅝" = 2.2 lbs/ft² | 10.7 kg/m²		
Walls Labeled 'A' and 'B' on diagram		
Staff outside the room, in adjacent areas		
Full Occupancy (1 mSv/year)	3.75 cm (1½") regular drywall construction	☐
or Partial Occupancy (1 mSv/year)	No additional shielding required	☐
Staff working within the multi-purpose room		
Surgical Area/Work Space at Full Occupancy (1 mSv/year)	Mobile lead shielding and/or lead aprons	☐
	and	
	Dosimeters worn by all staff members	☐

Multi-Purpose Room - Sample Layout Diagram

Veterinary Practice Name & Address:

Number of Exposures per Week:

Date:

Signed:

Name:

Last Update: January 15, 2013

Fig. (2): Building plans are required to be submitted to the Radiation Protection of Environmental Health Services.

Figure (2) checklist facility design which meet the guideline requirements. The shielding information are used to determine the thickness of wall materials required for protecting persons outside the room. The assessment should be completed then provide a copy to the responsible person on site and if this guideline does not apply, you may solicit the services of a Radiation Shielding Design and Assessment Consultant.

CONCLUSION

The design of shielding for X-ray room is a relatively complex task but can be simplified by the use of some standard assumptions which are essential to ensure traceability. Each X-ray installation must be assessed for shielding requirements based on the dimensions of the room position of the X-ray control, vertical and operator proposed construction materials (protective screens, walls, floors, doors), areas adjacent to X-ray room (occupancy, future use) and X-ray workload. Structural protection plans must be supplied for construction or for existing buildings prior to the use of X-ray equipment in the room. Radiation shielding requirements for diagnostic X-ray facilities is concerning the standardized regulations for licensing the diagnosis and therapeutic units.

The study noted a number of observations in diagnostic radiology:

- Many hospitals under investigation do not obligate by workers capabilities in the radiological and nuclear medicine units due to inefficiency of radiation protection requirements for issuing personal license for workers in the radiological field.

- Lack of sufficient knowledge and appropriate experience of some radiation protection officers.
- The method used for shielding design and basic shielding calculation procedures must be considered.

REFERENCES

Bushong, S.C., Radiologic Science for Technologist: Physics, Biology and Protection, 7th ed., St. Louis, Missouri, Mosby (2001).

Early, P.J., Principles and Practice of Nuclear Medicine, 2nd ed., St. Louis, Missouri, Mosby (1995).

http://answer.net.in/notfound.php?url=radprotection.wikispaces.com/three+cardinal+rules.

http://newton.ex.ac.uk/handbook/rad

http://www.ceessentials.net/index.php

http://www.hc.sc.gc.ca/ewh-semt/pubs/radiation/index-eng.php

IAEA Safety Reports, Series No. 47, Radiation Protection in the Design of Radiotherapeutic Facilities.

IAEA Safety Reports, Series No. 47, Radiation Protection in Diagnostic and Interventional Radiology.

IAEA, TECDOC-1040, Clinical, medical physics, radiation protection and safety aspects.

Laboratory Safety Guidance, Occupational Safety and Health Administration.

NCRP, Report 491, Requirements of the BSS.

Online Radiography Continuing Education for Radiologic X-ray Technologist 1-800-370-0614.

Radiation Health Series:

No. 1: Guidance Notes on Radiation Protection for Diagnostic Radiology.

No. 2: Safe Handling of Radioactive Consignments.

No. 3: Techniques to Reduce the Radiation Hazards from Using Phosphorus-32.

No. 4: Guidance Notes on Radiation Protection for Dental Radiography.

No. 5: Code of Practice for the Handling, Storage, Packaging, Transportation and Disposal of Radioactive Wastes.

No. 6: Ionizing Radiation.

No. 7: Guidance Notes on the Design of Protective Shielding for Medical, Dental and Veterinary Diagnostic X-ray Facilities.

Seeram, E., Computed-Tomography, Philadelphia, Pennsylvania, W.B. Saunders Co. (1994).

Selman, J., The Fundamentals of X-ray and Radium Physics, 6th ed., Springfield, Illinois, Thomas Books (1980).

Sprawls, P., Physical Principles of Medical Imaging, Rockville, Maryland, Aspen Publishers Inc. (1987).