International Journal of Engineering Research and Science & Technology

ISSN : 2319-5991
Vol. 4, No. 1
February 2015

www.ijerst.com

Email: editorijerst@gmail.com or editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 4, No. 1, February 2015

Research Paper

DESIGN CONSIDERATIONS TO MINIMIZE STAFF DOSES IN NUCLEAR MEDICINE UNITS

Nadia M Sirag[1]* and Abd Elrazek Z Hussein[2]

Corresponding Author: Nadia M Sirag*** ✉ *dr_nsirag@yahoo.com*

Purpose: The aim of this study was to required to achieve the principle ALARA, to reduce the radiation exposure to workers in the field of the radioactivity medical as much as possible to minimize staff doses, and become familiar with the types of sources used in diagnostics and radiation therapy. And become aware of how the basic principles of defense in depth, safety of sources and optimization are applied to the design of diagnostics and radiation therapy facility. Methods: pursuant to paragraph the Radiation Protection the Regulations, GD-52: Design Guide for Nuclear Substance Laboratories and Nuclear Medicine Rooms. It includes guidance on finishing and, plumbing, storage, security, ventilation, shielding, and dose estimation for basic, intermediate, high, and containment level nuclear substance laboratories and nuclear medicine rooms. Results: This paper document provides information for a recommended approach for meeting the requirements related to site description and room design the Nuclear Substances and Radiation Devices Regulations and performing shielding design analysis as a component of keeping doses As Low As Reasonably Achievable (ALARA). Conclusion: Therefore Medical facilities require extensive internal shielding to adequately protect occupationally exposed workers. Adequate structural shielding is needed for the PET scanner whereas the requirements are less for the CT scanner. Building materials should be used in the design of facilities that are easily decontaminated on a daily basis in all areas, where liquid radio pharmaceuticals are handled.

Keywords: Visual Analysis, Visualization Tool, Price Distribution, Agriculture Economy

INTRODUCTION

Nuclear radiation plays a big role in medicine, used in diagnosis and in treatment as well, in hospitals, a special unit of nuclear medicine is found to diagnose and treat cancer diseases. It is often that doctor asks patient a PET imaging for the diagnosis, this unit entirely depends on the radioactive material, which is called medicine nuclear and nuclear medicine in which radioactive material is used to depict the internal organs of the human body. Using nuclear medicine techniques, four have different characteristics of

[1] Egyptian Nuclear and Radiological Regulatory Authority, Nasr City, Cairo, Egypt.
[2] Sites and Environmental Department, Cairo, Egypt.

the radioactive elements for images and science, it is considered the best way to get alleged pictures of the tumors of cancer tumors. Based on the condition, the doctor may direct the patient for examination and sometimes diagnosis requires the use of more technology. Unexpected but feasible exposures are termed 'potential exposures'. Potential exposures can become actual exposures if the unexpected situation does occur; for example as a consequence of equipment failure, design or operating errors, or unforeseen changes in environmental conditions, If the occurrence of such events can be foreseen, the probability of their occurrence and the resulting radiation exposure can be estimated.

Single Photon Emission Computed Tomography (SPECT)

Positron Emission Tomography (PET)

Cardiovascular Imaging

Bone Scanning

Treatment in Nuclear Medicine

In tests that use radioactive elements in nuclear medicine is not considered harmful to the human body because the age of survival in the short body up for a few minutes and sometimes hours are limited and are considered dangerous photography this means foregoing less dangerous than the devices, which use X-rays, such as computed tomography CT and get rid of body rights of these materials through the urine. Dose Estimates for Nuclear Medicine Room Design Applications Dose estimates will only give a reasonable representation of potential exposures if the parameters are examined carefully to ensure they properly characterize the design and operation of the facility. The applicant or licensee should consider the following parameters when calculating the dose estimates resulting from its intended operations:

1. Layout and construction;
2. Locations at which these nuclear substances and activities will be used;
3. Distances between the nuclear substance or patient and the occupied locations of other persons;
4. Occupancy of the other rooms in the nuclear medicine department and surrounding areas by persons other than the patient (if the facility has more than one floor, consider occupancy above and below);
5. Nuclear substances and activities (Bq) to be used for the nuclear medicine procedures performed; and
6. Maximum number of patients per procedure to be treated, annually.

Methods

Classification of Areas and Signs

- Controlled area
- Supervised area

Facilities that contain radioactive material and facilities that contain radiation generators, including nuclear installations, medical radiation facilities for the management of radioactive waste, installations for the processing of radioactive material, irradiation facilities, that involve or could involve exposure to radiation or exposure due to radioactive material;

- Should be defined by the RPO and RPC Controlled areas: Room for preparation of radiopharmaceuticals.
- Room for dispensing radiopharmaceuticals.

- Room for storage of radionuclide.
- Room for storage of radioactive waste.
- Room for administration of radio pharmaceuticals.
- Imaging rooms, if or when administration is done, 1

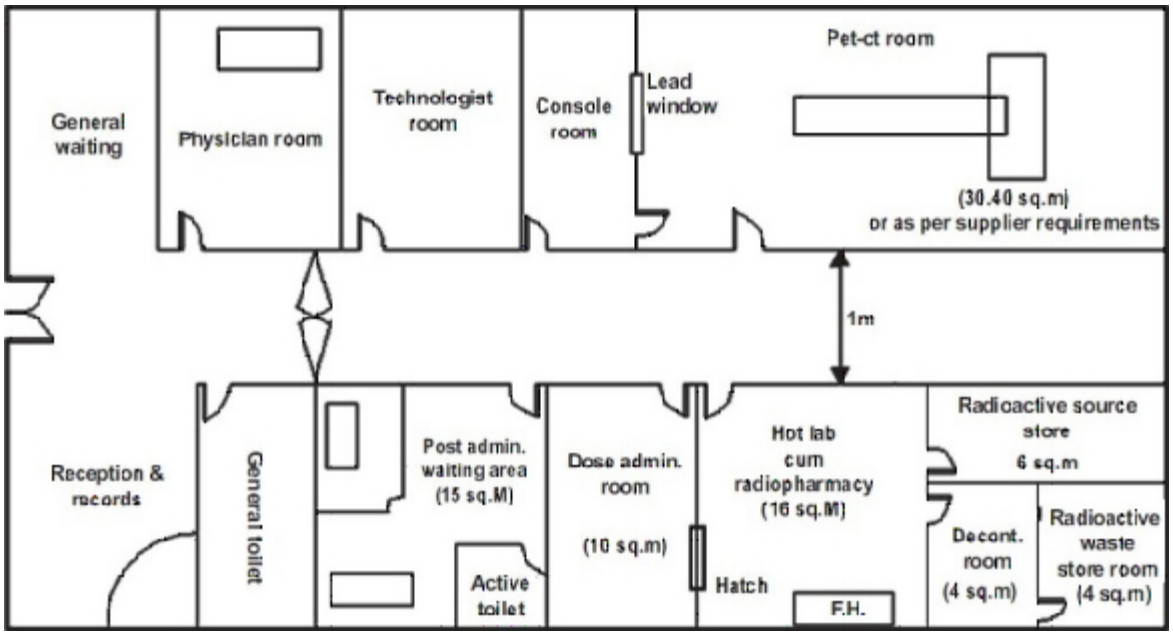
In determining the boundaries of any controlled area, registrants and licensees shall take account of the magnitudes of the exposures expected in normal operation, the likelihood and magnitude of exposures in anticipated operational occurrences and in accident conditions, and the type and extent of the procedures required for protection and safety. Figure 1 shows signs of Classification Areas.

Figure 1: Shows Signs of Classification Areas

SITE AND LAYOUT PLAN APPROVAL

The user has to submit to AERB two copies each of the proposed layout plan, site plan, and elevation drawing of the facility indicating the floor, nature of occupancy around, above and below, if any, has to be submitted in "B3" size paper (353 × 500 mm^2) along with the application form AERB/RSD/NMF/SLA (downloadable from www.aerb.gov.in). The user has to clearly indicate the

Figure 2: Shows Lay-out Design of a Positron and PET-CT Facility Explain All the Walls, Rooms, and Place Their Own Equipment

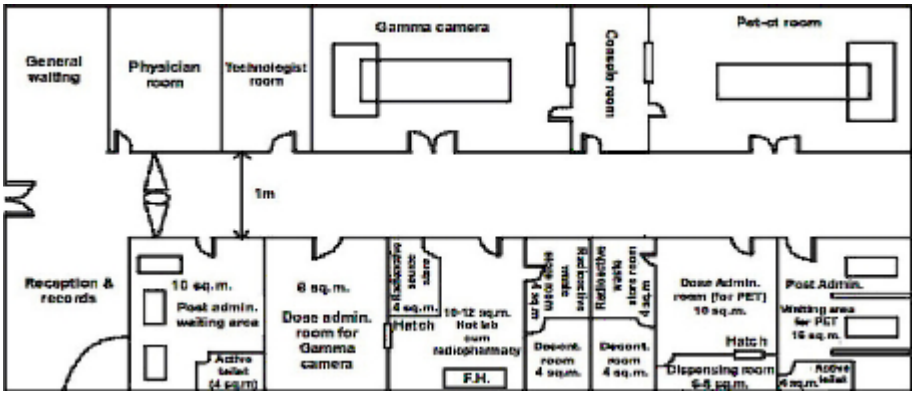


dimension of each of the rooms associated with the facility in the proposed layout plan of the NM department. When the user has to plan the laboratory, it is required that the arrangement of the various rooms associated with the facility has to follow the principle of low active area to high active area, that is, entrance of the facility should have reception/general waiting area, and at the end hot laboratory cum radiopharmacy/ radioactive waste storage area is to be planned.

Figure 2 shows a typical layout of a positron emission tomography computed tomography (PET-CT) facility. Note: All the walls of the PET-CT facility should be made of thick brick or thick concrete but the walls of PET-CT room should be concrete only, the thickness of which depends on the area and workload. (FH = fume hood; fume hood should be installed, if required).

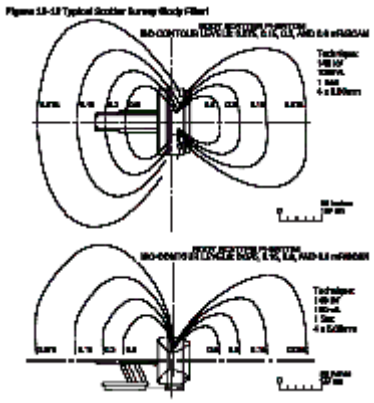
Figure 3 shows a typically out for nuclear medicine facility having both gamma camera and positron emission tomography-computed tomography (PET-CT) installations. Note: All the walls of the PET-CT facility should be made of thick brick or thick concrete but the walls of PET-CT room should be concrete only, the thickness of which depends on the area and workload. (FH, fume hood; fume hood should be installed, if required).

Figure 3: Shows Lay-out Design of a Positron and PET-CT Facility Explain All the Walls, Rooms, and Place Their Own Equipment



CT Scatter Plot

Figure 4: Shows Scatter Plot Horizontal Perspective Field



Patient Areas

- Separation of radioactive patients and other patients waiting is an example of good practice, especially in a busy department.
- Separate toilet room for the exclusive use of injected patients should always be considered. This patient washroom should not be used by general public or hospital staff as it is likely that the floor, toilet sea and sink faucet handles will be contaminated frequently.

Room Shielding

- CT unit needs separate control area
- Operator cannot sit in the room with the patient
- Use CCTV to watch, and an intercom to communicate with patient

Cyclotrons – Radiation

- Prompt radiation
  - Radiation exposure – primarily gamma
  - On shield surface near targets and seams between shield blocks the neutron dose

    = 10-50% of total measured dose
- Room door closed during bombardment to prevent casual entry
- Residual radiation
  - Low levels after cool down (could be 2 days)
  - Cyclotron servicing: Survey before work

PET Cyclotron - Technical Consideration for Radiation Safety

- Cyclotron: Self-shields vs. Vault
- Room shielding
- Safety interlocks
- Cyclotron ON lights
- Room radiation monitors
- Preventive maintenance (PMS)
- Surveys
- Pocket dosimeters
- Action levels
- Waste disposal: long-lived

Features of a typical cyclotron,15 cm steel cylindrical magnet acts as primary shield Cyclotron enclosed in cylindrical shielding system consisting of 68 cm thickness of boron-doped water Wall of vault is 60 cm thick concrete.

Examples of cyclotron shielding

Inner shield is approximately 30 cm thick high-densitye core cast out of a mixture of lead, epoxy, and boron carbide	Inner shield is approximately 30 cm thick high-densitye core cast out of a mixture of lead, epoxy, and boron carbide
Outer shield is approximately 70 cm thick made of polyethylene and boron carbide loaded concrete	Outer shield is approximately 76 cm thick made of polyethylene and boron carbide loaded concrete

Shielding

Much cheaper and more convenient to shield the source, where possible, rather than the room or the person, Structural shielding is generally not necessary in a nuclear medicine department, but becomes necessary with PET-CT. However, more extensive and heavier shielding usually is required in facilities that use ^{18}F versus those that do not.

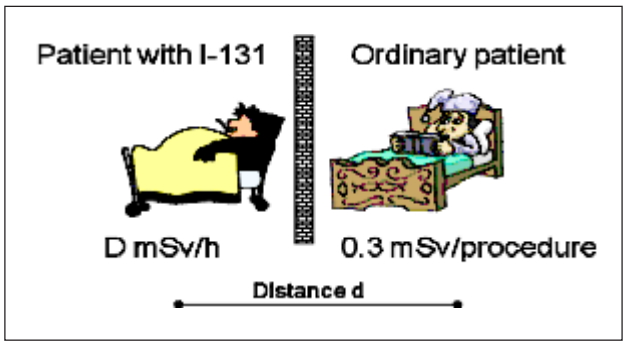
- Higher energy gamma rays are more penetrating - standard lead/concrete protection is not adequate

- Dose rates are higher than those for ^{99m}Tc
- Staff should be outside the scanning room (in a control room as with CT scanning), not inside the PET scanning room during acquisitions.

Structural Shielding

The absorbed dose is determined by factors such as:

- source strength;
- length of exposure;
- distance from the source;
- Transmission through the protective barrier.



Example

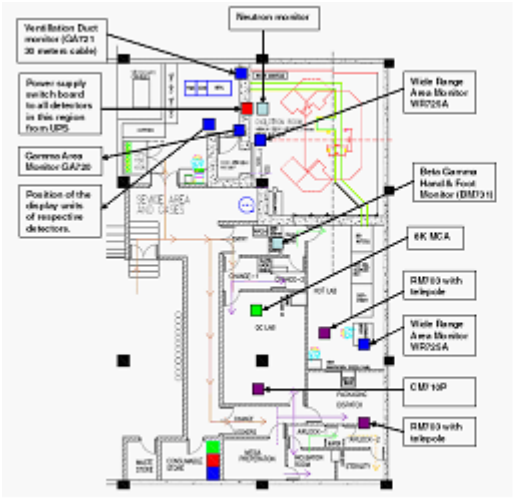
Source Strength: 1 mSv/h at 1 m from the radioactive patient Length of exposure: 1 week=168 h. We assume that the ordinary patient will be in bed all the time. Distance from the source: 3 m.

The unshielded exposure of the ordinary patient 1/9 mSv/h = 18.7 mSv in a week.

The dose to the ordinary patient should be constrained to 0.3 mSv ,in a week, which means that we need a protective barrier that reduces the exposure by a factor of 18.7/0.3=62.

Figure 5 In addition to an 18 port bnc patch panel connecting the data room and beam line area, there are also a series of differing types of cables permanently installed. These included: five ribbon cables, two DB9 serial cables, three DB25 serial cables, and two GPIB cables. Figure 6 shows our data room is located directly above the radiation effects Facility beam line. The room is independently cooled and well insulated from building noise. Located on the floor of the data room are two four inch diameter cable passages

Figure 5: Data Room and Beam Line Area



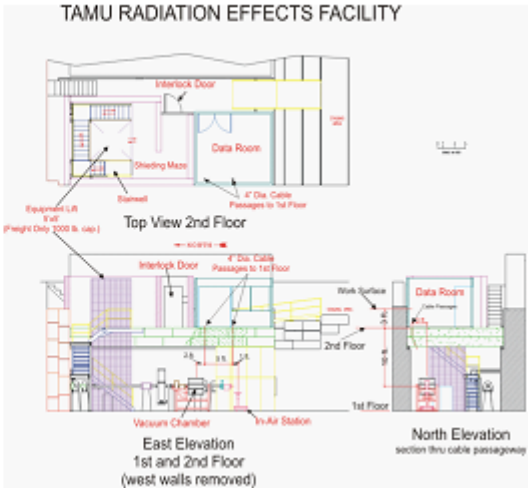
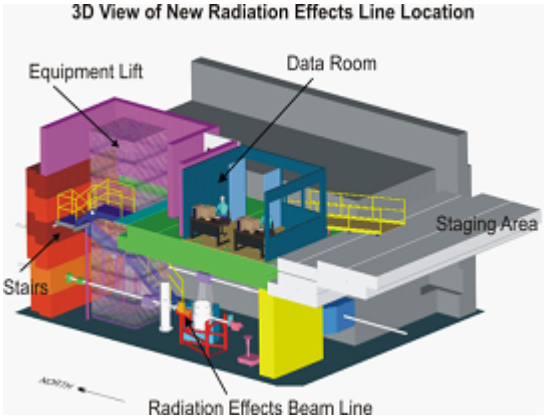
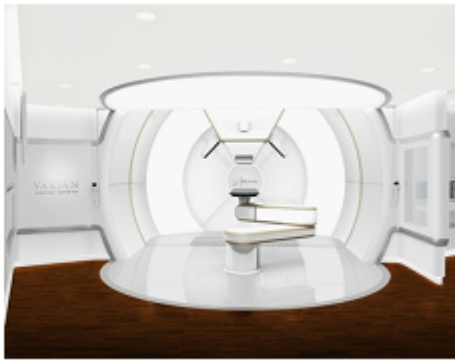


Figure 6: Data Room is Located Directly Above the Radiation Effects Facility





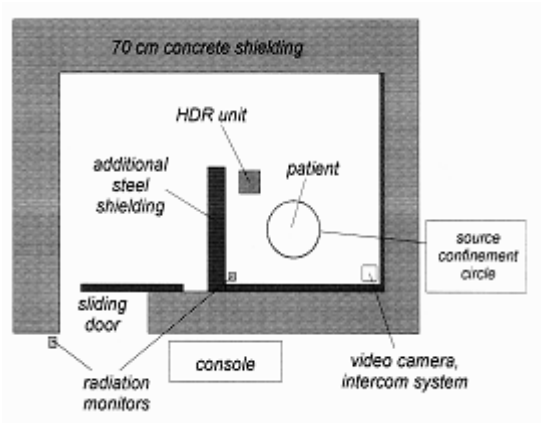
to provide the shortest distance possible between your equipment and your test board. From a table top in the data room to the top of the in-air station platter is approximately 15 feet**.**

Design HDR Treatment Rooms

The design of these rooms follows similar guidelines to those of accelerator rooms. Maze and door must typically be included similar interlocks to those used in accelerator rooms are required.

Figure 7 shows some centers use accelerator rooms for HDR brachytherapy treatment. This practice has some disadvantages: Usually not enough space for diagnostic equipment for source localization. Time pressure - the next external beam radiotherapy patient is scheduled. Difficulties in predicting what assumptions shall be used for shielding calculations.

Figure 7: HDR Room Design (Example)



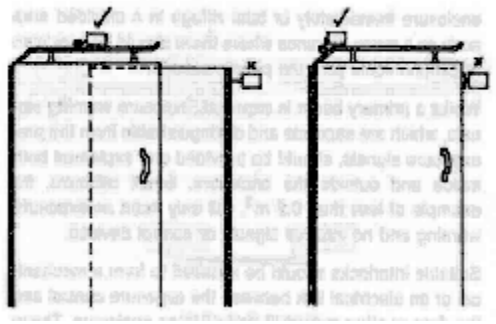
Design Considerations

- Treatment rooms
  - Shielding/door/maze - discussed in next lecture
  - Interlocks
  - Emergency off buttons
  - Warning signs
  - Beam on/off indicator

Interlocks

- The possibility of accidental exposure can be minimized by measures such as room interlocks involving (possibly as a combination).
- Door Figure 8 shows Way sliding door for sealing.
- Gate
- Light beams.
- Audible alarm.

Figure 8: Sliding Door for Sealing



Emergency Off Buttons: Where Should They Go?

Suggested Solution

Warning Signals

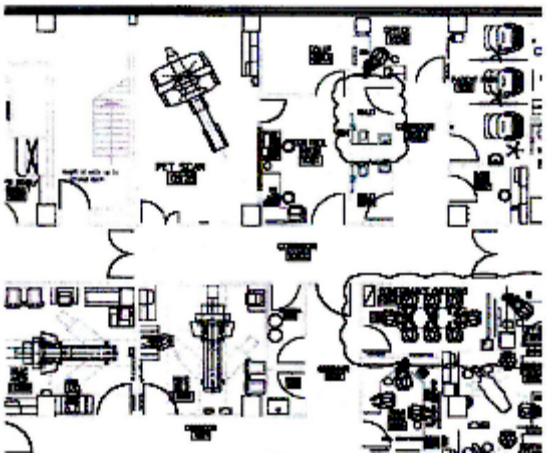
- There should be a visible signal when radiation is being produced at the entrance of the maze, control area and in the treatment room.
- There should be an audible signal in the treatment room just prior to radiation being produced.

Some information required

- Drawings to scale - including:
  - Direction of north.
  - Exact position of the equipment.
  - Location of doors and windows.
  - Ducts or other penetrations through a wall relevant.
  - Identification of rooms (number).
  - Cross sections (above and below?).
  - Exact distances where relevant.
- Indications of adjacent areas/buildings.

In a case study: Figure 9 shows what has been applied from previous studies on the design. Taking into account what has already been studied in the design.

Figure 9: Shows Applied from Previous Studies on the Design



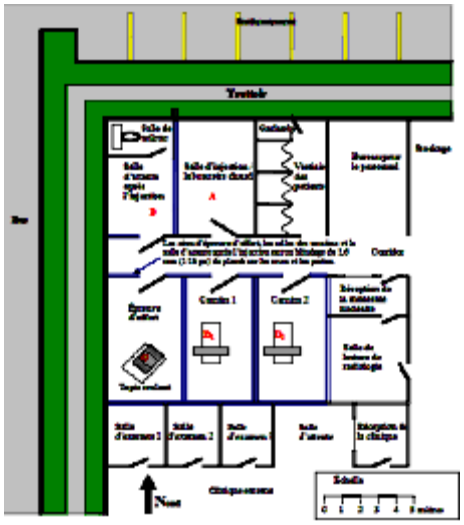
Sample Calculation for Dose Estimates for Nuclear Medicine Rooms

Using the method outlined in the following approach can be used to estimate the doses to persons (other than the patient) in and around a nuclear medicine room.

Step 1: Facility Layout

Figure 10 shows a hypothetical nuclear medicine department layout. Dimensions and basic

Figure 10: Hypothetical Nuclear Medicine Department Layout, 9



shielding details are shown. Key locations where nuclear substances and nuclear medicine patients will be present for significant periods of time over the course of the workday are identified using letters A to D2, 9.

Step 2: Estimating Workload

For any given nuclear medicine facility, several different gamma emitting nuclear substances can be identified that are used regularly (e.g., 51Cr, 67Ga, 99mTc, 111In, 123I, 131I and 201Tl). It is unlikely that all of the nuclear substances will be used or will contribute significantly to the annual dose at a particular location. Rather, it is likely that only one or two nuclear substances and procedures will be of importance.

For this example, we assume that persons (other than the patient) will occupy the following locations: the corridor, the office, the camera room(s), the exam rooms in the neighboring clinic, and the reception area. These key locations cover areas of occupancy of technicians, including the physician in the adjoining clinic. Other locations may also need to be considered—the locations used in this example are for illustrative purposes. The complete example in this guide is worked out only for the reception area/receptionist. The same approach would be used for the other locations or other representative individuals.

The key parameters needed to estimate the total annual doses are listed in Table 1.

Dose Rate Calculations

The following approach assumes the source/patient can be approximated as a point source. For most distances, the point source is a sufficiently accurate representation. In addition, at distances greater than 1 m, assuming point source geometry is conservative compared to other viable geometrics such as a volumetric source. The choice of source geometry is left to the discretion of the applicant, but the method for estimation must be clearly indicated.

A general formula for performing dose rate calculations for a point source is:

$$R_{ij} = \frac{\Gamma_i A_i 10^{-(t_m / TVL_{ml})}}{d_{ij}^2} \quad ...(2)$$

Tenth Value Layer (TVL) thicknesses for common gamma-emitting nuclear substances and various shielding materials are available from a number of different sources. Diagnostic nuclear medicine rooms are typically shielded using commercially available lead sheeting, with normal thicknesses varying from 0.8 mm (1/32 inch) to 3.2 mm (1/8 inch). For poly-energetic sources, the “first” broad beam TVL thickness may be much smaller than subsequent TVLs due to the selective absorption of low energy photons via photoelectric interactions. This effect is commonly referred to as “radiation hardening” or “beam hardening”. For this reason, care must be taken when evaluating transmission through barriers greater than 1 TVL thick for nuclear substances such as 67Ga, 111In, 123I, 131I, or 201Tl.

Example

Table 2 summarizes the parameters required to perform the dose rate estimates for the receptionist. The distances *dij* were measured directly from Figure 10. Lead thicknesses are based on the assumption that all interior walls of Stress Testing, Camera Room 1, Camera Room 2 and the “hot” post-injection waiting room are lined with 1.6 mm (1/16 inch) lead. All other interior walls are assumed to be constructed of ordinary drywall (gypsum board) and to provide minimal attenuation.

Table 1: Occupancy Summary

NEW	NEW	Important Location(s) Occupied	Source Location(s) Making Significant Contribution to Dose	Occupancy Factor (T) At Each Location Occupied	Rationale/Comment
Yes	Yes	Corridor	A, B, C, D_1, D_2	16-Jan	
No	Yes	Office	A, B, C, D_1, D_2	4-Jan	
No	Yes	Camera Room 1 or Camera Room 2	D_1 or D_2	1	Although procedures will be split between Camera Rooms 1 and 2, when evaluating the dose to a technologist, it can be assumed that all of the procedures are performed in one room, since this will not alter the total dose received by the technologist.
Yes	No	Nuclear Medicine Reception	A, B, D_1, D_2	1	C need not be considered since radiation emitted from injected patients in these rooms must pass through multiple shielded walls to reach the reception area.
Yes	No	Exam Room 2	C, D_1, D_2	2-Jan	An occupancy factor of 1/2 is used because it was stated that each physician spends approximately 1/2 their time in the Exam Rooms.
					A physician may be present in any of Exam Rooms 1, 2 or 3. The central room, Exam 2, is reasonably representative of their average location.
					Source locations A and B are distant from the Exam Rooms and are doubly shielded by the lead lining of the intervening Stress Test and Camera Rooms and thus will make a negligibly small contribution to the dose in comparison with source locations C, D_1, and D_2.

Table 2: The Distances d_{ij} were Measured Directly

Where:		
R_{ij}	is the dose rate produced by nuclear substance *i* at location *j*	($\mu Sv\ h^{-1}$)
Γ_i	is the specific gamma ray constant for nuclear substance *i*	($\mu Sv\ h^{-1}\ MBq^{-1}\ m^2$)
A_i	is the activity of nuclear substance *i*	(MBq)
d_{ij}	is the distance between nuclear substance *i* and location *j*	(m)
t_m	is the thickness of shielding material *m* in any shielded barrier between nuclear substance *i* and location *j*	(mm)
TVL_{mi}	is the "Tenth Value Layer" thickness of material *m* for nuclear substance *i* (i.e., the thickness of material *m* that would be required to reduce the photon radiation dose rate produced by nuclear substance *i* to $1/10^{th}$ of its initial value)	(mm)

Structural Shielding

The absorbed dose is determined by factors such as:

- Source strength
- Length of exposure
- Distance from the source
- Transmission through the protective barrier

Sample Design Criteria

- Assume typical 400 MBq injected activity
- Resting phase 1 h
- Scanning phase 30 min
- Workload supplied by hospital.
- Dose constraint for all areas outside resting/ scanning rooms 300 mSv.
- Occupancy factors included in some areas (fraction of time a given room is occupied).

Dose Rate from Patients - 18F

- 65 mSv/h predicted from point source calculation.
- 33 mSv/h at 5 cm from unshielded syringe with 555 MBq of 18F.
- max 70 mSv/h at 1 m after injection.

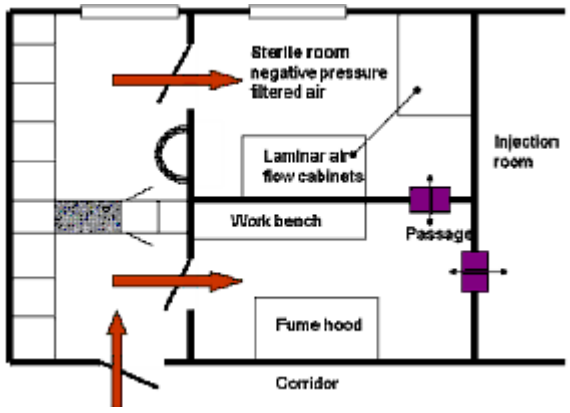
AAPM Task Group 108: PET and PET/CT Shielding Requirements *Med. Phys*. Vol. 33, Issue 1, January 2006; DOI: 10.1118/1.2135911

- Standard building material may not afford sufficient protection for PET studies.
- Each facility individually needs to be analyzed carefully; Generally, 300 mm concrete appears to be conservative and is considered “safe”.
- There is a need to consider shielding for patient’s administration room and if regulations require for patient waiting area and has been taking in the design considerations

Ventilation

Figure 11 shows rooms where work with unsealed sources are taken place should be under negative pressure to minimize the risk of airborne radionuclides to be spread. The sterile environment that might be necessary in preparation of radio pharmaceuticals is achieved in a laminar air flow bench.

Figure 11: The Ventilation System



- Laboratories in which unsealed sources, especially radioactive aerosols or gases, may be produced or handled should have an appropriate ventilation system that includes a fume hood, laminar air flow cabinet or glove box.
- The ventilation system should be designed such.
- That the laboratory is at negative pressure relative to surrounding areas. The airflow should be from areas.
- Of minimal likelihood of airborne contamination to areas where such contamination is likely.
- All air from the laboratory should be vented through a fume hood and must not be

recirculated either directly in combination with incoming fresh air in a mixing system, or indirectly, as a result of proximity of the exhaust to a fresh air intake.

Fume Hood

The fume hood must be constructed of smooth, impervious, washable and chemical-resistant material. The working surface should have a slightly raised lip to contain any spills and must be strong enough to bear the weight of any lead shielding that may be required.

The air-handling capacity of the fume hood should be such that the linear face velocity is between 0.5 and 1.0 m/s with the sash in the normal working position. This should be checked regularly.

Sinks

- If the Regulatory Authority allows the release of aqueous waste to the sewer, a special sink shall be used.
- Local rules for the discharge shall be available.
- The sink shall be easy to decontaminate.
- Special flushing units are available for diluting the waste and minimizing contamination of the sink.

If the Regulatory Authority allows the release of aqueous waste to the sewer a special sink shall be used. Local rules for the discharge shall be available. The sink shall be easy to decontaminate. Special flushing units are available for diluting the waste and minimizing contamination of the sink.

Pipes

Drain-pipes from the radioisotope laboratory sink should go as directly as possible to the main building sewer, and should not connect with other drains within the building, unless those other drains also carry radioactive material. This is to minimize the possibility of a "back up" contaminating other, non-controlled areas and the final plans of the drainage system which are supplied to maintenance personnel must show which drains are from radioisotope laboratories.

Note: Some countries require that drain-pipes from the nuclear medicine department and especially from isolation wards for patients undergoing radionuclide therapy shall end up in a delay tank.

The use of the room should be taken into account, e.g., a waiting room as opposed to a control room.

Washing Facilities

The wash-up sink should be located in a low-traffic area adjacent to the work area.

Taps should be operable without direct hand contact and disposable towels or hot air dryer should be available.

An emergency eye-wash should be installed near the hand-washing sink and there should be access to an emergency shower in or near the laboratory.

- The wash-up sink should be located in the dose preparation area adjacent to the work area.
- Taps should be operable without direct hand contact and disposable towels or hot air dryer should be available.

Patient Toilet

- The patient washing facilities SHOULD NOT be used by hospital staff, as it is likely that the floor, toilet seat and sink faucet handles will be contaminated frequently.
- Sited so that staff do not have to accompany patient.



The facilities should

- Include a sign requesting patients to flush the toilet well and wash their hands.
- Include a wash-up sink as a normal hygiene measure.
- Consider wall mounted sanitary ware so that floor is completely clear.
- A separate toilet room for the exclusive use of injected patients is recommended.
- Washrooms designated for use by nuclear medicine patients should be finished in materials that are easily decontaminated.

Floors

- Impervious material
- Washable
- Chemical-resistant
- Curved to the walls
- All joints sealed
- Glued to the floor
- No carpet!


Walls and Ceiling

Should be finished in a smooth, and washable surface with joints being sealed, wherever practicable. Walls should be painted with washable, non-porous paint (e.g., glossy paint).

The use of the room should be taken into account, e.g., a waiting room as opposed to a control room.

Worktop Surfaces

- Worktop surfaces must be finished in a smooth, washable and chemical-resistant surface with all joints sealed,
- Open shelving should be kept to a minimum to prevent dust accumulation,
- Services (e.g. gas, electricity, vacuum) should not be mounted on top of the bench, but on walls or on panels for this purpose,
- Light fixtures should be easy to clean and of an enclosed type in order to minimize dust accumulation,
- Structural reinforcement may be necessary,

since a considerable weight of lead shielding may be placed on work tops.

- Some laminates do not resist certain chemicals, and the supplier should be consulted with regard to the specific chemicals to be used in the laboratory.
- Cover the surface with absorbing paper.


Rest Room

- CCTV to monitor patient.
- Be finished in materials that are easily decontaminated.
- Lights that can be dimmed.
- Quiet area.
- Separate area for each patient.

Dispensing area be finished in materials that are easily decontaminated, be tidy.

Emergency Facilities

- An emergency eye-wash should be installed near the hand-washing sink.
- There should be access to an emergency shower in or near the dose preparation area.

RECOMMENDATIONS

A safety culture should be inculcated that governs the attitudes and behavior in relation to protection and safety of all individuals and organizations dealing with sources of radiation; in-depth defensive measures should be incorporated into the design and operating procedures for radiation sources to compensate for potential failures in protection or safety measures; and protection and safety should be ensured by sound management and good engineering, comprehensive safety assessments .

SUMMARY OF FACILITY DESIGN

- Because cyclotrons accelerate particle beams at high energy for the production of positron emitters, it is important for them to have adequate shielding to protect occupationally exposed workers.
- Adequate structural shielding is needed to maintain exposure rates below established acceptable limits due to the radiotracers used for PET imaging as well as the X ray flux involved with CT imaging.
- It is necessary that the facility be designed so as to minimize dose both to occupationally exposed personnel and to the public at large, and this includes the use of building materials that are easily decontaminated on a daily basis in all areas where liquid radiopharmaceuticals are handled.

In Nuclear Medicine (NM), the diagnostic and therapeutic procedures using unsealed radioisotopes shall be carried out only in a facility approved by the Atomic Energy Regulatory Board (AERB). The approved nuclear medicine facility

Category of hazard	Fume hood	Ventilation	Plumbing	First aid
Low	no	normal	standard	washing
Medium	yes	good	standard	washing & decontamination facilities
High	yes	may need special forced ventilation facilities	may need special plumbing facilities	washing & decontamination facilities

Category of hazard	Structural shielding	Floors	Worktop surfaces walls, ceiling
Low	no	cleanable	cleanable
Medium	no	continuous sheet	cleanable
High	possibly	continuous one sheet folded to walls	cleanable

should not be located in the residential building and shall comply with all the regulatory requirements as specified in the AERB safety code on nuclear medicine facilities AERB/RF-MED/SC-2 (Rev. 2), 2011. All the application forms pertaining to nuclear medicine facility which are required to be submitted during various stages for its approval are available at www.aerb.gov.in.

The various stages of approval of nuclear medicine facility by AERB are given as follows:

1. Site and Layout Plan Approval: Two copies each of the proposed layout plan, site plan and elevation drawing of the facility indicating the floor, nature of occupancy around, above and below, if any, has to be submitted in "B3" size paper (353 x 500 mm^2) along with the application form no. AERB/RSD/NMF/SLA. The dimension of all the rooms in the proposed layout plan of the nuclear medicine department should be indicated clearly along with the thickness and material of all the walls pertaining to the facility. The typical layout plans may be referred to design the nuclear medicine facility with respect to the arrangement / allocation of rooms and area requirement. The above documents have to be submitted to Head, Radiological Safety Division (RSD), AERB. On scrutinizing the above submitted plans, necessary approval for the construction of facility may be granted.
2. Application for Authorization for Commissioning of the Facility

3. Pre-commissioning Inspection.
4. Approval for Commissioning / Routine Operation.
5. Decommissioning.

DISCUSSION

Considerations: Resting phase requires patients to be within facility for many hours, All restrooms may be occupied all day for a high-volume facility, Post-scan patients are hungry ,and may require refreshment before being sent home. Separate areas for patients not yet injected, and those accompanying patients, are likely to be required.

Areas of Concern: Staff whole body dose can be significantly higher than with conventional nuclear medicine, Staff extremity doses can approach dose limits without good technique and shielding Public dose limits can be exceeded in surrounding areas if structural shielding is not adequate, Multiline CT scanners may need protection to full ceiling height.

Shielding Design Issues: Construction, breeze blocks/plasterboard partitions/single course of brick cladding. Building shared with non-radiation workers. Buildings/areas very close to scanner suite Areas above and below scanner.

Preconstruction Design Issues: Dose constraints for staff and public must be adopted in designing the facility, Layout of department should be considered. Direct lines of sight between resting areas and staff areas should be eliminated, Shielding should be calculated taking into account all radiation sources. Allowance should be made for the short half life of the radionuclide's to avoid over- protection.

Post-construction Design Issues: Following construction, if actual measured exposure levels are too high, shielding must be increased or other corrective measures taken. Diligent monitoring of staff and public exposure levels must be performed. Any changes with time, such as significant increase in the number of patients handled per day, may necessitate increased shielding or other corrective measures to remain in compliance.

General design considerations for the design, construction, renovation, expansion, equipment, asbestos use in building materials.

- Stairways flooring shall have slip-resistant surfaces.

  Slip-resistant flooring products shall be considered for flooring surfaces in wet

  Areas (e.g., ramps, shower and bath areas) and areas that include water for patient.

- Carpet cannot be used in examination and treatment rooms, if used in patient.

  Waiting areas and corridors carpet shall be glued or stretched tight and free of loose edges or wrinkles.

  Selected flooring surfaces shall be easy to maintain, readily cleanable, and appropriately wear-resistant for the location.

- The minimum ceiling height shall be 2.39 m (7 feet 10 inches), Wall finishes shall be washable, moisture-resistant and smooth, wall finish treatments shall not create ledges or crevices that can harbor dust and dirt, wired glass; or plastic, break-resistant material that creates no dangerous cutting

- Edges when broken shall be used in certain areas such as glass doors and sidelights.

- Highly polished flooring, walls or finishes that create glare shall be avoided.
- Color contrast between walls, floors and doors shall be considered as it may reduce falling risk of blurred vision patients.
- All doors between corridors, rooms, or spaces subject to occupancy shall be of the swing type or shall be sliding doors.
- Patient's room door swings should be oriented to provide patient privacy.
- Curtains used throughout the hospital shall be washable/cleanable, fireproof and maintained clean at all times.
- Each patient shall have access to a toilet room without having to enter a corridor.

Bedpan-washing fixtures shall be installed in dedicated rooms, separate from patient care areas unless located in a toilet room, The OT entrance door must be wide (about 2.13 m width) preferably consisting of two parts, which can be opened in either sides or automatic one.

- Independent dirty exit is recommended in Operation Theatres (OT). The floors, ceilings, and walls must be created by a continuous connection Interior surfaces should be constructed of materials that are monolithic and impervious to moisture.
- The floors and walls should be anti-static, heat resistant, anti-bacterial, anti-fungal and resistant to disinfectants.
- Adequate ventilation and air exchange (with at least 25 air changes per hour as per American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) requirement) shall be maintained in the operation room which should be at positive pressure relative to the adjacent preparation areas. Minimum of two air supply inlets with proper contamination control filters i.e.,
- High Efficiency Particulate Air (HEPA) filters delivered at or near the ceiling, which should not be directed over the operation table, in addition to a minimum of, two exhaust outlets located near floor level, bottom exhaust outlets should be at least 75 mm above the floor. Differential pressure indicating device, humidity indicator, and thermometers should be installed and should be located for easy observation.
- Room temperature shall be maintained between 18-22 °C with room humidity between 35-70% and the temperature and relative humidity set points should be adjustable.
- The scrub facility shall be located adjacent to the operation room.

Staff changing area shall be separate for males and females. It must contain special entrance for the staff and suitable place for changing of clothes with a minimum of one toilet for the staff in this area. Toilets air pressure should be kept negative pressure with respect to any adjoining areas and should have minimum 10 air changes per hour.

Sterilizing area air pressure should be kept negative pressure with respect to any adjoining areas and should have minimum 10 air changes per hour. Relative humidity should be maintained at 30% to 60%. High efficiency filters should be installed in the air handling system, with adequate facilities provided for maintenance, without introducing contamination to the delivery system or the area served.

Planning and Layout

- When planning a new facility assumptions must be clearly stated.

- Plan for the future - consider expansions and increase in workload.
- Megavoltage treatment rooms are typically in the basement.
- It is usually best to place bunkers together to use common walls.
- Size matters - bunkers should be generous.

Advantage of Large Bunker

- Distance is effective shielding.
- Need storage space for accessories and patient immobilization.
- Allows for future upgrades of equipment (FAD 80 —> 100 cm) and increases in shielding.
- Costs can be reduced if the design is good for extension is usually much larger than for allowing for expansion already during the building phase Typical megavoltage room layout.

CONCLUSION

Design Criteria

External Beam Treatment Area

- Clear signs are required in areas leading to treatment units.
- Patient and visitor waiting areas should be positioned so that patients are unlikely to enter treatment areas accidentally.
- Patient change areas should be located so that the patient is unlikely to enter a treatment area accidentally.
- Shielding/maze/doors.
- Door interlocks Protocol for closing the door and activating radiation door interlocks.
- Clear view of surrounding area.
- Control of access to bunker.

Good engineering practice

As applicable, the sitting, location, design, construction, assembly, commissioning, operation, maintenance. Shall be based on engineering which shall, as appropriate:

a. Take account of approved codes and standards and other appropriately

Documented instruments;

b. Be supported by reliable managerial and organizational features, with the aim

Of ensuring protection and safety throughout the life of the sources;

c. Include sufficient safety margins for the design and construction of the sources, taking into account quality, redundancy, with emphasis on preventing accidents, mitigating their consequences and restricting any future exposures.

REFERENCES

1. (CBAHI), Kingdom of Saudi Arabia.
2. AAPM Task Group 108: PET and PET/CT Shielding Requirements, *Med. Phys.,* Vol. 33, Issue 1, January 2006; DOI: 10.1118/1.2135911
3. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). *ASHRAE Handbook,* ASHRAE, 2003.
4. Cabinet Decision number (33) of 2009 promulgating the bylaw of the medical liability law.
5. Canadian Standards Association. CSA Z316.5-04—Fume Hoods and Associated Exhaust Systems. CSA, 2004.

6. Design Guide for Nuclear Substance Laboratories and Nuclear Medicine Rooms GD-52
7. Determining Appropriate Staffing Levels (Improving Healthcare Quality and Safety – 2005)
8. Equip 4 guide of the Australian Council on Healthcare Standard – ACHS
9. Guidelines for Design and Construction of Health Care Facilities Issued by the Facility.
10. Guidelines Institute (FGI)
11. http://cyclotron.tamu.edu/ref/data_room.php
12. http://cyclotron.tamu.edu/ref/data_room.php
13. http://www.aerb.gov.in, March, 2011.
14. http://www.bigdug.co.uk/safety-signs-labels-c425/radiation-laboratory-signs-c679/radiation-control-area-x-rays-fixed-no-entry-red-light-safety-sign-pp3795
15. http://www.cnsc-ccsn.gc.ca/eng/acts-and-regulations/regulatory-documents/published/html/gd52/#P99_4312
16. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3003281/
17. http://www.who.int/patientsafety/events/07/02_05_2007/en/index.html and accesses on 30th
18. Hubbell, J.H. and Seltzer, S.M. Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients (version 1.4). National Institute of Standards and Technology, Gaithersburg, MD 2004.
19. IAEA Training Material on Radiation Protection in Nuclear, Medicine, Part 12, Protection of the General Public.
20. IAEA Training Material on Radiation Protection in Radiotherapy, Radiation Protection in, Radiotherapy, Part 4, 7, Design of Facilities and Shielding.
21. IAEA, International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources Safety Series No.115, Interim Edition (2011).
22. IAEA/WHO Manual on Radiation Protection in Hospital and General Practice, Volume 4, Nuclear Medicine.
23. International Atoic Energy FACILITY DESIGN, L 5
24. International Commission on Radiological Protection. ICRP 68: Dose Coefficients for Intakes of Radionuclides by Workers.
25. International Council of Nurses: Nurse Patient Ratio
26. Issued by the Joint Commission. DHA Private Healthcare Standards.
27. Madsen Mark *et al*. (January 2006), "AAPM Task Group 108: PET/CT Shielding Requirements", *Medical Physics,* Vol. 33, pp. 1 4-15.
28. Maria d, Renato P (2013), "ESI-EFOMP European School of Medical Physics", Installation Shielding in Nuclear Medicine, University Hospital S Udine, Italy.
29. National Council on Radiation Protection and Measurements (NCRP). NCRP Report No. 151: Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities.
30. National Radiological Protection Board (2002), NRPB-W22, Industrial Uranium Compounds: Exposure Limits, Assessment of Intake and Toxicity after Inhalation. 2002.

31. NCRP (1996), NCRP Report No. 124: Sources and Magnitude of Occupational and Public Exposures from Nuclear Medicine Procedures. NCRP.
32. Saha G B (2003), *Fundamentals of Nuclear Pharmacy*, 5th Edition, Springer Verlag, ISBN 0-387-40360-4
33. Stanford University. Stanford Laboratory Standard and Design Guide: Section 1 General Requirements for Stanford University Laboratories.
34. The 4th Edition of Joint Commission International Accreditation Standards for Hospitals.
35. The National Hospital Standards of the Central Board of Accreditation for Health Institutions
36. The nine Patient Safety Solutions published by the World Health Organization website
37. US Department of Labor. Occupational Safety and Health Administration (OSHA) Technical Manual, Section III, Chapter 3.
38. UAE federal Law number (2)/1996 concerning Private Health Facilities.
39. UAE Federal Law number 10/2008 concerning Medical Liability.

International Journal of Engineering Research and Science & Technology
Hyderabad, INDIA. Ph: +91-09441351700, 09059645577
E-mail: editorijlerst@gmail.com or editor@ijerst.com
Website: www.ijerst.com