Guideline for Design and Validation of Shielding of Radiotherapy Facility

May 2022

Department of Health

Tasmanian Government

Contents

Design and Validation of Shielding of Radiotherapy Facilities

Radiation shielding specifications and certification[1] is carried out by accredited persons. Once certification has been granted an application to register the room(s) may be made by the person seeking to register the place.

The requirements in this document are those that must be used by accredited persons when calculating the structural shielding specifications for rooms where therapeutic X-ray units are used. The document also contains the requirements for validating and certifying rooms where these X-ray units are used.

This document draws on internationally recognised methodologies based on the work of the National Council for Radiation Protection and Measurements, Structural Shielding Design and Evaluation for Megavoltage X-and Gamma Ray Radiotherapy Facilities (NCRP 151), and the work of the 'Radiation Protection in the Design of Radiotherapy Facilities' (SRS 47)

Requirement 1 - Method

The radiation shielding design report must state whether it has been designed following the methods and assumptions of NCRP 151 or SRS 47. ***Using a mixture of these methods is not permitted***.

Requirement 2 - Attenuation of Some Common Shielding Materials

Annexe A refers to NCRP 151 and SRS 47 for useful information

Requirement 3 - Densities of Certain Shielding Materials

For therapy installations above 500 kV Compton absorption dominates, and the shielding material will absorb the radiation according to the density of the material.

For therapy installations operating above 10 MV, shielding against neutrons must be considered. Concrete contains a relatively high hydrogen content and is therefore efficient at shielding against fast neutrons. Capture reactions of slow neutrons with many materials and penetrating capture gamma rays must be considered in the shielding design

Annexe A refers to NCRP 151 and SRS 47 for densities of materials that can be assumed in calculations.

[1] The place has been issued a certificate of compliance issued by a person accredited under the Radiation Protection Act 2005

Requirement 4 - Dosimetric Quantities

It is not practical to base shielding design directly on the effective dose, E. Determination of E is complex, and depends on the attenuation of photons and neutrons in the body in penetrating to the radiosensitive organs and hence on the energy spectra of the photons and neutrons, and also on the posture of the recipient with respect to the source. (NCRP 151, 1.4)

Shielding design calculations involving neutrons and photons must be expressed in dose equivalent (H)[2] (NCRP 151, 1.2).

Requirement 5 - Workload

The workload (W) is best specified as the absorbed dose delivered to the isocenter in a week, and is selected for each accelerator based on its projected use. This includes the maximum number of patients (or fields) treated in a week and an estimate of the absorbed dose delivered per patient (or field). It should also include an estimate of the maximum weekly absorbed dose delivered during quality control checks, calibrations or other physics measurements. Further guidance on workloads can be found in NCRP 151, Chapter 3 including calculating the workload for IMRT.

The design of radiation shielding barriers can be based on a workload distributed evenly throughout the year by using a weekly design goal equal to one-fiftieth of the annual design goal, However, the NCRP cautions against scaling design goals to shorter intervals. NCRP 151, 3.3 states *'the issue of using measured instantaneous dose-equivalent rates (IDR), with the accelerator operating at maximum output, does not properly represent the true operating conditions and radiation environment of the facility. It is more useful if the workload and use factor are considered together with the IDR when evaluating the adequacy of a barrier. For this purpose, the concept of time averaged dose equivalent rate (TADR) is used along with the measured or calculated IDR'.*

The IDR at barriers, and scaled to appropriate time averages, may be useful for comparing direct measurement after the facility has been built and the treatment unit installed.

Both SRS 47, 2.4, NCRP 151, 3.3 provide equations for calculating IDR and time averaged values.

Requirement 6 - Occupancy

Occupancy adjusted air Kerma is used to calculate the required attenuation to meet the shielding design goal. The occupancy assigned is based on the fraction of time spent in a location by the person who is there the longest (BIR 1.5). When determining the air Kerma for a shielded barrier the distance to the occupied area of interest is taken to be from the source to the nearest likely approach of the sensitive organs of a person to the barrier. For a wall this is not less than 0.3 m. For a source located above potentially occupied spaces the sensitive organs of the person below is taken to be not more than 1.7 m above the lower floor, while for ceiling transmission the distance of

[2] Dose equivalent is defined as the product of the quality factor for a particular type of ionizing radiation and the absorbed dose (D) [in gray (Gy)] from that type of radiation at a point in tissue (ICRU, 1993). The units of dose equivalent are J kg–1 with the special name sievert (Sv).

at least 0.5 m above the floor of the room above is used. In the absence of actual occupancy data for a particular situation, the following occupancy weighting factors may be used:

NCRP 151 Table B.1 provides the occupancies that can be used in calculations.

Table 1 - Occupancy Factors (NCRP 151)

Area Type	Occupancy Factor
Full occupancy areas (areas occupied full-time by an individual), e.g., administrative or clerical offices; treatment planning areas, treatment control rooms, nurse stations, receptionist areas, attended waiting rooms, occupied space in nearby building	1
Adjacent treatment room, patient examination room adjacent to shielded vault	1/2
Corridors, employee lounges, staff rest rooms	1/5
Treatment vault doors	1/8
Public toilets, unattended vending rooms, storage areas, outdoor areas with seating, unattended waiting rooms, patient holding areas, attics, janitors' closets	1/20
Outdoor areas with only transient pedestrian or vehicular traffic, unattended parking lots, vehicular drop off areas (unattended), stairways, unattended elevators	1/40

Requirement 7 - Use Factor

The use factor describes the different beam orientations used for treatment when calculating the required barrier thickness for each beam orientation. Simply put it is the fraction of time during which the radiation under consideration is directed at a particular barrier (SRS 47, 2.3 and NCRP 151, 1.6).

Conventional use factors are discussed in NCRP 151, 3.1.2 and Table 3.1. Other use factors for individual installations must be documented in the shielding design.

Requirement 8 - Shielding Design Goal

Shielding design goals (P) are levels of dose equivalent (H) used in the design calculations and evaluation of barriers constructed for the protection of occupationally exposed people or members of the public. (NCRP 151, 1.4).

- 0.1 mSv (H) per week or 5 mSv/year for occupationally exposed persons; and
- 0.005 mSv (H) per week or 0.25 mSv/year for members of the public.

Utilisation of above shielding design goals will result in effective dose values below the limits for occupationally exposed person and members of the public. (NCRP 151, 1.43 for discussion about conservative assumptions).

Requirement 9 - Calculation of Shielding Requirements

The methods given in SRS 47 Chapter 5 or NCRP 151, Chapter 2, must be used to specify the shielding requirements for:

- Primary Barriers (SRS 47, 5.1, NCRP 151, 2.2 and equations 2.1 – 2.6)
- Secondary Barriers (SRS 47, 5.2, NCRP 151, 2.3 and equations 2.7 and 2.8)
- Roofs (SRS 47, 5.3)
- Doors and Mazes (SRS 47, 5.5, SRS 47, 5.4, NCRP 151, 2.4 and equations 2.9 – 2.20)
- Neutrons in High energy Linear Accelerator Rooms (SRS 47, 5.6)
- Capture Gamma and Neutron Doses at the Maze Entrance (SRS 47, 5.7, NCRP 151, 2.4 and Table 2.1)

Requirement 10 - Special Considerations

When ground shine, skyshine and side scatter situations may exist for a particular facility, the treatment of those situations must be carried out according to Chapter 5, NCRP 151.

Requirement 11 - Structural Details

Structural details for individual installation will vary, however they must conform to the objectives given in NCRP 151, Chapter 4. The requirements for joints, concrete slab junctions and ducts, conduits and penetrations all require particular consideration in line with the details in NCRP 151, 4.4 and 4.6

Requirement 12 - Practical Assessment of Shielding

A physical inspection of the facility must be carried out during construction. More than one inspection may be required. The inspection must include an evaluation of at least the following items (NCRP 151, 6.1):

- the location and width of the primary barriers relative to the proposed isocenter;
- the thickness and density of concrete as well as thickness and type of any other material used in the barriers;
- the thickness of metal shielding and polyethylene used for neutron shielding.
- the adequacy of direct-shielded doors, which require special inspection since they leave little room for error. That is:
    - make sure the concrete wall at the door is plumb over vertical within 3.2 mm (1/8 inch)
    - check that special shielding materials (e.g., lead, polyethylene) are in place before the door is put up
    - measure the door overlap at top and sides of door
    - measure the door gap at top, sides, and bottom before door finishing materials are installed.
- measure the thickness of metal behind recesses in the concrete (e.g., +laser boxes);
- measure the thickness and composition of the HVAC shielding baffle if one is used;

- check the location and size of conduit or pipe used for physics cables; and
- Interlocks, restrictive devices and radiation warning signs and lights must be tested.
- verification that the shielding design has been followed.

A summary document outlining the results of the construction inspection must be prepared by the qualified expert and forwarded to the regulator, and other parties such as the owner of the facility, the architectural firm involved in the construction.

Any items of noncompliance must be clearly indicated and recommendations for corrections should be made.

Radiation survey measurements made to assess the adequacy of barriers are normally made over periods of time that are much less than the length of time (i.e., weekly or annually) specified in the recommended shielding design goals. Therefore, instantaneous or near-instantaneous measurements of the dose-equivalent rate are only appropriate in the determination of compliance with the shielding design goals if appropriate allowances are made for all of the factors that influence the projected weekly dose equivalent at the appropriate location behind the barrier.

Immediately after the accelerator has been made operational surveys must be carried out as per NCRP 151, 6.3. A shielding evaluation report must also be prepared for the licence holder and the regulator (NCRP 151, 6.4)

Annexe A

NCRP 151, Annexe B

SRS 47, Table 1 and 5.8 Data

Annexe B - Form of the Shielding Report and Certificate of Compliance

The accredited person must produce a shielding report containing:

- A scaled floor plan of the place to which the shielding report applies.
  - The floor plan must include all occupied locations around the X-ray unit(s).
  - The floor plan must assign the numerical occupancies from NCRP or BIR to the locations around the X-ray units (including areas outside the place) and dimensions from the source of exposure to these locations.
- X-ray workload and technique for each X-ray unit in the place
- Unambiguous markings or legend on the plan that identify the thickness and type of any additional structural shielding required, or of existing structural materials that will provide sufficient shielding (e.g. existing block work or plaster)
- Any manufacturer's radiation scatter diagrams that were used to estimate exposure

When the accredited person is satisfied the place complies with the specification in the shielding report a 'Certificate of Compliance' for the place may be issued.

A certificate of compliance for a radiation place must contain at least the following information:

- Address and room number(s) sufficient to uniquely identify the place.
- The date that compliance was finally determined.
- The name and signature of the holder of the certificate of accreditation under which the certificate of compliance is being issued.
- The title of the Code of Practice the radiation place was assessed against.
- A statement to the effect that the certificate of compliance is being issued in accordance with the requirements of the Tasmanian Radiation Protection Act 2005.
- A certificate of compliance identification number, which must be of the form:

The final date, as year (YYYY), month (MM) and day (DD), on which the assessment of the radiation place demonstrated that the place was in compliance with the relevant Code of Practice and any other prescribed specifications followed by a four digit Radiation Place Identification Number (RPIN provided by the regulator).

For example: **2010 07 31 0251** means that the place with identification number 0251 was shown to comply with the relevant Code of Practice and any other prescribed specifications on 31 July 2010.