Shielding Manual:

Plan approval guidelines for X-ray installation

April 2022

saskatchewan.ca

Saskatchewan

Acknowledgement

The content of this X-ray shielding installation manual and its associated checklists were modeled after the guidelines developed by the British Columbia Centre for Disease Control (BCCDC). With permission, much of the content in this document was taken directly from the *BCCDC X-ray Shielding Guidelines*. Special thanks to Francine Anselmo and her team for developing the BCCDC Guideline and for permitting us to use their excellent work.

Table of Contents

Introduction

The Shielding Manual should be used by owners, installers and contractors of ionizing radiation (X-ray) equipment when developing an X-ray shielding plan. Plans must comply with the requirements set out in Section 5-3 of *The Saskatchewan Employment Act* (Act) and be approved by the Radiation Safety Unit with the Occupational Health and Safety Branch of the Ministry of Labour Relations and Workplace Safety.

Section 5-3 of the Act states:

Establishment and alteration of ionizing radiation installation, installation of ionizing radiation equipment

5-3(1) In this section and sections 5-4 and 5-7, "substantial alteration" includes:

a) respecting any ionizing radiation equipment that emits a primary beam outside the housing of the equipment, any alteration or change of position that causes the equipment to be capable of emitting a primary beam in any direction other than the direction for which approval was granted when the plans for the installation were approved;

b) any alteration in the shielding properties of the room or other place in which the ionizing radiation equipment is placed or installed;

c) any increase in the maximum generating voltage or maximum beam current of ionizing radiation equipment in an installation; and

d) the placement or installation of any units of ionizing radiation equipment in an ionizing radiation installation in excess of the number of units approved when the plans for the installation were approved.

(2) Unless a plan of the proposed installation or proposed alteration has been approved in writing by a radiation health officer, no person shall:

a) establish or cause to be established an ionizing radiation installation for any purpose; or

b) make or cause to be made any substantial alteration in any ionizing radiation installation.

(3) Subsection (2) does not apply to any prescribed ionizing radiation installation or prescribed substantial alteration.

(4) A radiation health officer may withhold approval of a plan submitted for approval pursuant to subsection (2) until the radiation health officer is satisfied that the ionizing radiation installation will be constructed or altered in a manner such that all reasonable precautions are taken to minimize the exposure of any person to radiation.

(5) No person shall use any mobile ionizing radiation equipment in any location other than one approved by a radiation health officer.

Section 5-3(2) mandates that any proposed installation or alteration requires a shielding plan approved in writing by a radiation health officer to ensure the shielding is sufficient to protect all persons from radiation exposures exceeding regulatory limits. A shielding plan must be submitted and approved by an officer prior to the beginning of construction/ installation in order to be compliant with section 5-3.

Following the latest recommendations of the International Commission on Radiological Protection (ICRP) on dose limits, this shielding manual and associated checklists are designed to protect workers and the public outside the X-ray room to an effective dose of less than 1 millisievert (mSv) per year.

The following section will go step-by-step through the submission process and outline the documentation necessary to submit a complete shielding plan. Definitions of the terminology used in this document and associated checklists are provided in the Definitions section. Review these definitions for the proper interpretation of the shielding guidelines. Refer to the Shielding Material Standards and Shielding Material Substitutions sections to choose appropriate materials that are consistent with those indicated in the shielding checklists. Finally, the Radiation Hazard Signage section gives an overview of the signage required for diagnostic X-ray installations.

Submitting a Shielding Plan for Approval

The Radiations Safety Unit has developed several pre-packaged plans designed for a broad variety of scenarios. These pre-packaged plans may be used for submission purposes provided that all conditions in the plan can be met in the installation and operational design. A pre-packaged shielding plan is comprised of four elements:

1. Plan Approval Submission Form

This is the main submission form which provides general information about the installation including who owns the equipment, who is performing the installation and the proposed location of the installation.

2. Installation Layout Diagram

A room layout diagram showing the location of the proposed installation is required. This diagram must include the orientation of the installation (i.e., direction of north), location of the X-ray equipment (i.e., position and orientation in the room), location of the operator during operation, occupancy and use of all adjacent areas. The diagram must provide a means to assess physical distances (i.e., drawn to scale with a scale conversion provided and/or actual dimensions marked up on the diagram itself). The material composition, thickness and height of all shielding surfaces should be indicated.

3. Installation Checklist(s)

A variety of checklists have been created to represent typical installation parameters for a range of X-ray modalities. For a submission to be valid, all conditions on the checklist(s) must be satisfied. Each checklist provides an assessment table to select the amount of shielding for each barrier (e.g., walls, doors, floors, ceilings and control

booths as required) taking into account occupancy factors. A sample diagram of a typical room layout is given to assist in identifying each of the labeled barriers ('A', 'B', 'C', etc.). To determine the shielding for a facility with more than one X-ray room, apply the appropriate checklist to each room individually. This applies to X-ray rooms that share common walls. The position and orientation of the X-ray equipment relative to the labelled walls is important. If the submitted plan does not closely match the layout of the checklist, the checklist may not be applicable to the situation.

4. Installation of Lead Shielding in a Diagnostic X-ray Facility Checklist

If the installation requires lead shielding to be installed, this checklist must also be included to ensure that appropriate installation methods and materials are used.

If none of the pre-packaged plans fit the situation, or any item with the applicable checklist cannot be satisfied, it will be necessary to submit comprehensive shielding calculations performed by individuals with current knowledge of structural shielding design and the acceptable methods of performing these calculations.

Links to the forms and checklists required for plan submission can be found at on page 8 or on saskatchewan.ca.

Before beginning construction, submit the plan for approval (electronic submission preferred) by e-mail, fax or mail to:

Email: radiationsafety@gov.sk.ca

Mail:

Regina Office:

Ministry of Labour Relations and Workplace Safety
Radiation Safety
300-1870 Albert Street
Regina, Saskatchewan S4P 4W1

Saskatoon Office:

Ministry of Labour Relations and Workplace Safety
Radiation Safety
851-122 3rd Avenue North
Saskatoon, Saskatchewan SK S7K 2H6

Fax: 306-787-2208

Please allow at least two weeks for the plan approval submission to be processed. Allow time in the schedule to avoid construction delays. Establishment or alteration of the X-ray installation can only proceed after a radiation health officer has provided written approval. Provide a copy of the completed guideline and approval to the person(s) responsible for designing the facility and for carrying out construction. Keep copies of the plan approval in on file for future reference and inspection needs.

Definitions

Absorbed dose: the ionizing radiation energy absorbed per unit mass, expressed in grays.

Effective dose: the sum of the products, in sieverts, obtained by multiplying the equivalent dose of radiation received by and committed to each organ by an appropriate organ weighting factor (see Table 2 of *The Radiation Health and Safety Regulations, 2005*).

Equivalent dose: the product, in sieverts, obtained by multiplying the absorbed dose of radiation and the appropriate radiation weighting factor (see Table 1 of *The Radiation Health and Safety Regulations, 2005*).

Full occupancy: applies to areas occupied by any individual for a total of more than 1.5 operating hours per day on a continuing basis and applies to adjacent rooms and tenanted facilities. Examples of full occupancy areas are: X-ray control stations, administrative or clerical offices, adjacent independent businesses, laboratories, pharmacies, receptionist areas, attended waiting rooms, children's indoor play areas, adjacent X-ray rooms, film reading areas, nurse's stations, X-ray control rooms, and rooms used for regular patient examinations or treatments.

Gray (Gy): the special name for unit of absorbed dose: 1 gray = 1 joule per kilogram.

Ionizing radiation: any atomic or subatomic particle or electromagnetic wave emitted or produced directly or indirectly by a machine or radioactive isotope and having sufficient kinetic or quantum energy to produce ionization. For the purposes of these guidelines, Ionizing Radiation specifically refers to X-rays.

Ionizing radiation equipment: a device capable of emitting ionizing radiation, but does not include:

(i) equipment operated at less than 15 kilovolts and not designed principally to produce useful radiation;

(ii) equipment that:

(A) is in storage, in transit or not being used; or

(B) is operated in a manner such that it cannot produce radiation;

(iii) any radioactive substance; or

(iv) any other prescribed equipment or category of equipment.

Ionizing radiation installation: the whole or any part of a building or other place where ionizing radiation equipment is manufactured, used, placed or installed for use.

Operator: a person who uses or controls the use of any radiation equipment.

Owner: a person having management and control of a radiation installation or radiation equipment.

Partial occupancy: applies to areas that will not be occupied by any individual for a total of more than 1.5 operating hours per day and applies to areas such as: corridors, patient rooms, employee lounges, staff rest, corridor doors, public toilets, unattended vending areas, storage rooms, unattended waiting rooms, patient holding areas, outdoor areas with only transient pedestrian or vehicular traffic, unattended parking lots, vehicular drop off areas (unattended), attics, stairways, unattended elevators, and janitor's closets. Areas that can be converted from partial occupancy to full occupancy (e.g., from storage to office) should be considered as full occupancy for shielding requirements.

Radiation: in this context refers to ionizing radiation and specifically X-rays.

Radiation worker: a person who, in the course of their duties, business, professional activities, studies or training:

(i) is exposed to radiation; and

(ii) if exposure limits, exposure levels or dose limits are specified for members of the public, might receive radiation exposure in excess of those limits or levels.

Sievert (Sv): the special name for the unit of both equivalent and effective dose: 1 sievert = 1 joule per kilogram.

Use: includes construct, demonstrate, test, operate, handle, repair, service and maintain.

Shielding Material Standards

The required minimum thicknesses of various shielding materials are provided in the shielding checklists. Material composition and density also play a role in shielding efficacy. The following section outlines minimum standards in the composition and density of the shielding materials referenced in the checklists. These composition and density standards must be satisfied in the installation construction in order to satisfy the shielding checklist criteria. A rough conversion table is also provided to aid the user in substituting materials with equivalent shielding capacity (e.g., substitution of plate glass for gypsum drywall).

Lead

All lead shielding must be rolled and at least 99.9% pure by composition and conform to the following specifications:

- For a thickness of 1/32" ($\sim$0.8 mm) the weight per area must be at least 2 lb/ft^2
- For a thickness of 1/16" ($\sim$1.6 mm) the weight per area must be at least 4 lb/ft^2

Gypsum Drywall

As gypsum is a powdery substance in its natural state, it must be compressed and glued to form drywall sheeting. The weight per area of gypsum drywall sheets used for shielding must meeting the following minimum standard:

- For a thickness of 1/2" the weight per area must be at least 1.6 lb/ft^2
- For a thickness of 5/8" the weight per area must be at least 2.2 lb/ft^2

Glass

Ordinary plate glass may be used only where protection requirements are very low (e.g, installations where lead or concrete shielding is not required). In cases where protection requirements are higher, leaded glass should be used. Leaded glass is specified in equivalent thicknesses of lead (e.g., 1.6 mmPb equivalent). For shielding purposes, leaded glass equivalent thicknesses should match that of the lead required in the wall where the glass is to be installed.

Concrete

All calculations in the shielding checklists assume 'standard-weight' (or normal weight) concrete. This type of concrete is typically used for most foundations and main structural elements. Standard-weight concrete must have the following minimum density:

- 2.4 g/cm^3 (147 lb/ft^3).

Some constructions use 'light-weight' concrete as a weight saving and fire protection measure. Typically, light-weight concrete will have a density of 1.8 g/cm^3 (115 lb/ft^3) depending on the type of aggregate used. The lighter weight is accomplished by creating voids in the concrete. This has an impact on the shielding efficacy of the material. As such, 'light-weight' concrete may not be used to satisfy the requirements of the shielding checklists.

Some slab constructions have structural designs where the slab thickness varies across its surface. Always assume the minimum thickness for shielding calculations in assessing your shielding design.

Steel

Steel comes in a range of densities (7.75 – 8.05 g/cm^3) depending on the alloy composition. For the shielding checklists, there is no specific restriction on what type of steel is used. However, it is recommended to use materials that are designed specifically for shielding installations. This type of steel is sometimes referred to as 'high-Z' steel and contains traces of tungsten or other high atomic number elements that boost the shielding efficacy of the alloy.

Shielding Material Substitutions

The following list of conversions may be useful for substitution of materials with equivalent shielding properties:

- ½" (12.7 mm) gypsum drywall may be substituted with:
  - ≥ 0.05 mm lead
  - ≥ 6 mm plate glass
  - ≥ 6 mm solid concrete
  - ≥ 0.3 mm steel

- 1/32” (0.8 mm) of lead may be substituted with
  - ≥ 80 mm solid concrete
  - ≥ 10 mm steel

Radiation Hazard Signage

If ionizing radiation (X-ray) equipment capable of producing dose rates greater than 25 microsieverts per hour is operated, the owner of the equipment must ensure that:

a) in the case of a room used solely for medical diagnosis of patients, a sign bearing the word “X-Ray” is prominently displayed on each door that gives access to the room;

b) in the case of a room that houses analytical, therapy or industrial X-ray equipment, a sign bearing the word “X-ray” or the word “Radiation” and one of the three radiation hazard symbols shown below or any other symbol approved by an officer is prominently displayed on each door that gives access to the room; or

c) in the case of an open area:

(i) a mobile barrier is erected to enclose the area in which a dose rate greater than 25 microsieverts per hour may be produced; and

(ii) signs bearing the radiation hazard symbols mentioned in clause (b) are placed on the barrier so that at least one sign is always clearly visible as the area is approached.

Signage must be readable and as prominent as practicable. The size of the signage must:

- be consistent with the size of the object to which it is affixed;
- permit the symbol to be recognized at a safe distance; and
- maintain proper proportions.

Forms and checklists

Plan Approval Submission Form for X-Ray Installation/Room Layout Diagram Template

Installation of Lead Shielding in a Diagnostic X-Ray Facility Checklist

Checklists for Medical/Chiropractic Installations

General Radiography Checklist

Dedicated Chest Radiography Checklist

Fluoroscopic (Radioscopic) Radiography Checklist

Radiographic and Fluoroscopic Radiography Checklist

Mammographic Radiography Checklist

Computed Tomography (CT) Checklist

Mobile Radiography (Medical) Checklist

Checklists for Dental Installations

Intraoral Radiography Checklist

Panoramic and/or Cephalometric Dental Radiography Checklist

Cone Beam Computed Tomography (CBCT) Checklist

Checklists for Veterinary Installations

Small Animal Veterinary Radiography Checklist

Small Animal Veterinary Multi-Purpose Room Radiography Checklist

Mobile Radiography (Veterinary) Checklist

Checklists for Industrial/Analytical Installations

Non-Destructive/Industrial Radiography Checklist

Analytical Cabinet X-ray Systems (Self-Shielded) Checklist

Handheld X-ray Fluorescence (XRF) Checklist

Shielding Manual:

Plan approval guidelines for X-ray installation

2022

For more information, please contact the Ministry of Labour Relations and Workplace Safety Occupational Health and Safety Branch at:

Regina

300-1870 Albert Street
Regina, SK S4P 4W1

Saskatoon

8th Floor, 122 3rd Avenue North
Saskatoon, SK S7K 2H6

Toll Free

1-800-567-7233