RADIATION HEALTH SERIES

No.7

Guidance Notes on the Design of Protective Shielding for Medical, Dental and Veterinary Diagnostic X-ray Facilities

Radiation Health Unit
Department of Health

Foreword

The Radiation Health Series serves to provide some basic information on the safe use of ionizing radiation in medicine, industry and education in the Hong Kong SAR.

We have prepared these information brochures on the basis of the recommendations made by notable international authorities, such as the International Commission on Radiological Protection (ICRP), World Health Organisation (WHO), International Labour organization (ILO) and International Atomic Energy Agency (IAEA). We hope you find the information useful in safeguarding your own health, as well as the health of your neighbours, when you work with ionizing radiation.

If you have questions on the contents of these documents or have suggestions on improvements, please contact us at the

Radiation Health Unit
Department of Health
3/F, Sai Wan Ho Health Centre,
28 Tai Hong Street,
Sai Wan Ho,
Hong Kong

Tel: 2886 1551
Fax: 2834 1224
e-mail: rhu@dh.gov.hk
Domain: http://www.info.gov.hk/dh-rhu

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INTERPRETATION AND REGULATIONS

Ionising Radiation means electromagnetic radiation (e.g. x-ray, gamma ray) or corpuscular radiation (e.g. alpha particles, beta particles, electrons, positrons, protons, neutrons or heavy particles) being electromagnetic radiation or corpuscular radiation capable of producing ions and emitted from a radioactive substance or from a machine that is intended to produce ionising radiations, or from a machine in which electrons are accelerated by a voltage of not less than 5 kilovolt.

Irradiating Apparatus means any apparatus which –

(a) is intended to produce or emit ionising radiation; or

(b) is capable of producing or emitting ionising radiation at a dose rate exceeding of 5μSv per hour at a distance of 5cm from any accessible point of the surface of the apparatus.

All activities involving ionising radiation in Hong Kong are controlled by the following legislations:

Radiation Ordinance (Cap 303)

Radiation (Control of Radioactive Substances) Regulations

Radiation (Control of Irradiating Apparatus) Regulations

Under this Ordinance and Regulations,

(1) No persons shall, except in accordance with a licence issued under this Ordinance and Regulations:-

(a) manufacture or otherwise produce; or

(b) sell or otherwise deal in or with; or

(c) have in his possession or use,

any radioactive substance or irradiating apparatus.

(2) Any person who contravenes any of the provisions shall be guilty of an offence and shall be liable to a fine of $50,000 and to imprisonment for 2 years.

The requirements for material protection for static irradiating apparatus are stipulated in section 17 (1), (2) and (3) of the Radiation (Control of Irradiating Apparatus) Regulations.

Basic Protection Requirements

The requirement for protective shielding of a radiological device depends on the type and workload of the device, the energy of the radiation it produces, the size of the room and the occupancy of nearby areas. The requirement is higher for shielding of the direct radiation beam than for shielding of the scattered radiation field. Therefore whereas a dental x-ray room may require a nominal shielding of about 1.5mm lead for the direct beam and about 0.7mm lead for the scattered field, a diagnostic x-ray room may require a nominal shielding of about 3mm and 1.5mm for the direct beam and scattered field respectively. For clay brick and concrete, the equivalent material thicknesses at different x-ray output voltages are given in Table 1. The nominal thicknesses of commercially available lead sheets are given in Table 2.

Protective shielding close to the x-ray head is the most economical arrangement; the thickness is the same, but the area to be covered is smaller. Most x-ray housings have sufficient built-in shielding to limit the radiation mainly to the useful beam passing through the aperture, but it is still necessary to shield against the useful beam itself, the small amount of leakage radiation from the housing, and the scattered radiation from the patient and other irradiated objects such as the floor and walls of the room.

The amount of shielding required depends on a number of factors, including:

a) the x-ray tube voltage

b) the workload: mA-min/week

c) the type of radiation: e.g. useful beam, leakage, or scattered

d) the distance from the radiation source or the scattering source to the occupied area

e) the type of area: controlled or uncontrolled (the latter being open to the general public)

In view of the fact that limited facilities are inevitably called on to take larger workloads, it is highly desirable to plan the protection of an x-ray room for the maximum foreseeable load, allowing for the time taken to arrange patients and carry out the x-ray examination.

In radiography, the useful beam is usually directed towards the floor or the wall. To ensure a high factor of safety, protective shielding against primary radiation is provided on any wall area towards which the useful beam is likely to be directed and on the entire floor. Other areas not routinely exposed to the useful beam require protective shielding against secondary radiation.

However, when building a new x-ray room it is always better to plan for effective shielding against **primary** radiation in **all** directions so that there are no further problems when the equipment is moved or changed. Under no circumstances must an area be left unprotected since scattered radiation penetrates in every direction. In private practice where x-ray machines are located in commercial buildings with adjacent rooms being public areas, it is particularly important to ensure that the radiation levels do not exceed the regulatory limits.

Special attention should be given to the protection of the operator. Only licensed users are allowed to operate x-ray machines on human body. Effective shielding will be achieved by locating the control of the x-ray equipment in an adjacent room provided with a lead-lined door. A shielded control booth without a door can be used if access is provided by means of a maze that effectively reduces the scattering of radiation into the control area.

Design of protective shielding

The thickness of protective shielding necessary to reduce the exposure rate from any x-ray machine to the maximum permissible level depends on the tube potential, the extent to which the machine is used (work-load), the distance from the tube to the occupied area, the degree and nature of the occupancy, the type of area, and the material of which the barrier is constructed.

Care must be taken to ensure that the required protective barrier is not reduced by openings or voids in the barrier.

Guidance for installation of lead lining as protective shielding is given in the following paragraphs.

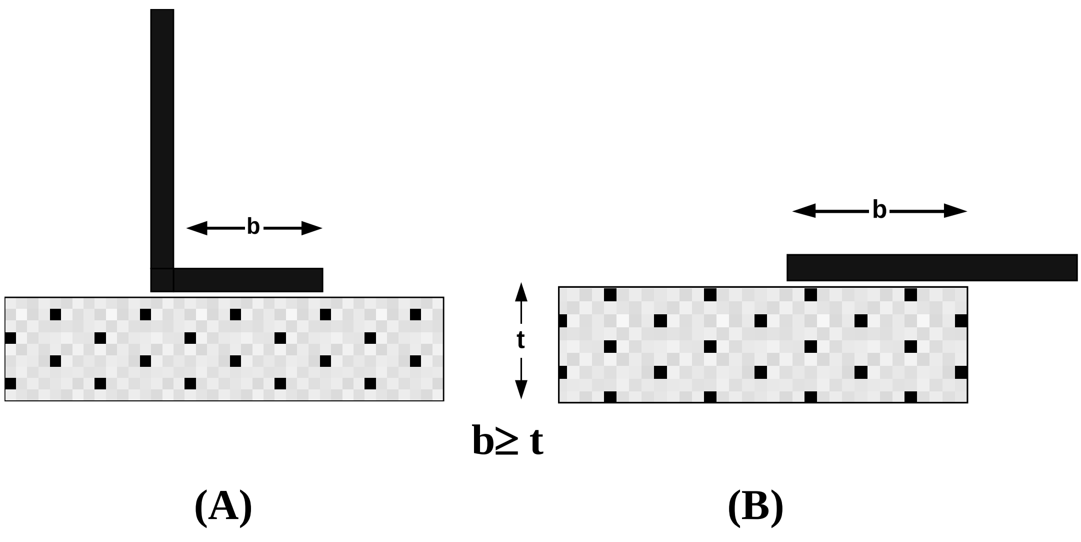
Joints

The possibility of leakage at joints is eliminated by overlapping the protective materials. The amount of overlap required depends on the distance between the layers, the thickness of the shielding, and the relative thickness of the two layers. Fig. 1 shows how the overlapping between lead and concrete can be carried out. The width of overlapping (b) must be at least as great as the thickness of concrete (t).

Lead sheets should be jointed to each other with an overlap of at least 1cm or twice the thickness of the sheet, whichever is the greater.

Joints between different kinds of protective materials are constructed so that the overall protection of the barrier is not impaired

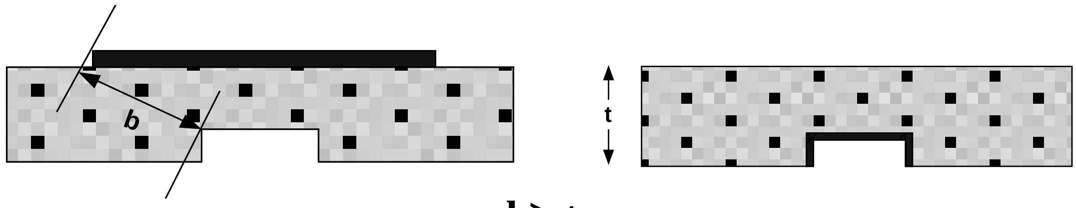
FIG. 1 OVERLAPPING BETWEEN LEAD AND CONCRETE



Recesses

Recesses in the barrier (e.g. for electrical outlets and locks) must be covered to give protection equivalent to that of the required protection barrier (Fig. 2).

FIG. 2 PROTECTION OF RECESSES IN SHIELDING

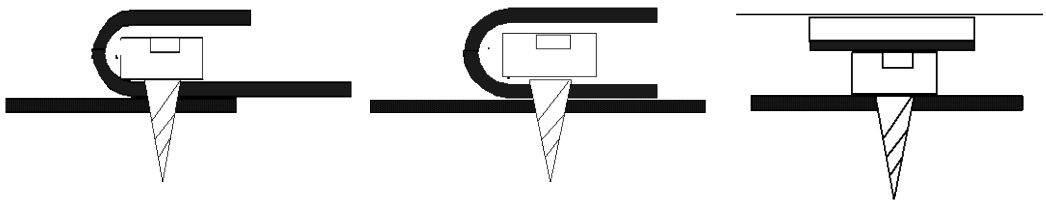


b≥ t

Perforations

Nails and screws that perforate lead barriers must be covered to give protective equivalent to that of the unperforated barrier (Fig.3).

FIG. 3 COVERING OF PERFORATIONS



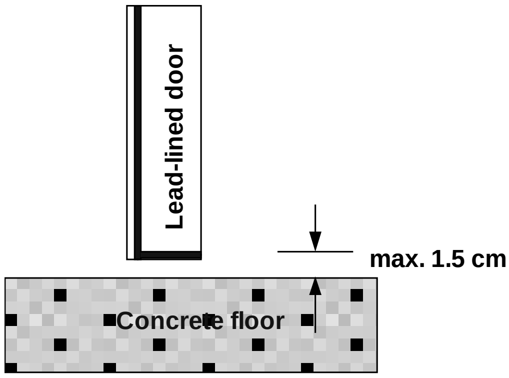
Joints at floor and ceiling

The overlap between the lead in the wall and the concrete in the floor or ceiling must have at least the same width as the thickness of concrete (Fig 1A).

Doors

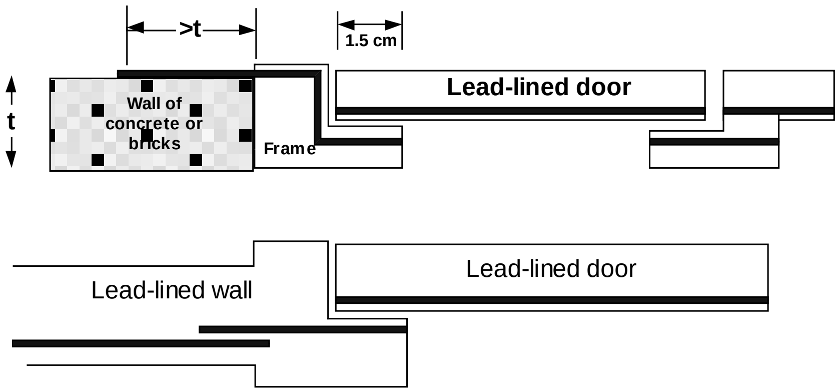
The radiation facility should be so designed that primary radiation does not strike the door. Since the door is then exposed only to secondary radiation, the threshold may be arranged as a baffle, formed by the lead lining of the door and the concrete in the floor (Fig 4).

FIG. 4 SHIELDING BENEATH DOORS NOT EXPOSED TO PRIMARY RADIATION



The door and door frame must have the same lead equivalence as the adjacent wall. The protective lead covering the door must overlap that of the door frame by at least 1.5cm. The protective lead covering the door frame must overlap the concrete or brick in the wall by at least the same amount as the thickness of the concrete or brick (Fig 5).

FIG.5 SHIELDING OF DOORS AND DOOR FRAMES



Observation window

The window and window frame must have the same lead equivalence as that of the adjacent wall. Lead sheets in contact with lead glass must have an overlap of a least 1cm or equal to the thickness of the lead glass, whichever is the greater (Fig. 6).

FIG. 6 SHIELDING ROUND THE EDGE OF AN OBSERVATION WINDOW

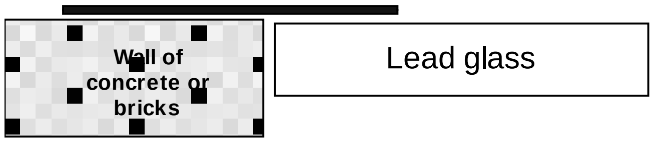


Table 1: Lead equivalence of various materials for low energy x-rays

			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

Table 2: Commercial lead sheets

Thickness in inches	Thickness in millimetre (mm)	Thickness in inches	Thickness in millimetre (mm)
1/64	0.40	1/8	3.17
3/128	0.60	5/32	3.97
1/32	0.79	3/16	4.76
5/128	1.00	7/32	5.55
3/64	1.19	1/4	6.35
7/128	1.39	1/3	8.47
1/16	1.58	2/5	10.76
5/64	1.98	1/2	12.70
3/32	2.38	2/3	16.93

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