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RADIATION SAFETY IN X-RAY FACILITIES

STUK
Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

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This Guide is valid as of 1 January 2002 until further notice. It replaces Guide ST 3.6 "Radiation shielding of X-ray examination rooms", issued on 20 December 1991.

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Authorisation

Under section 70, paragraph 2, of the Radiation Act (592/1991), STUK – Radiation and Nuclear Safety Authority (Finland) issues general instructions, known as Radiation Safety Guides (ST Guides), concerning the use of radiation and operations involving radiation.

The Radiation Act stipulates that the party running a radiation practice is responsible for the safety of the operations. The responsible party is obliged to ensure that the level of safety specified in the ST Guides is attained and maintained.

Translation. Original text in Finnish.

1 General

The Radiation Act (592/1991) and the Radiation Decree (1512/1991) set out the general radiation safety requirements applicable to the use of radiation. Section 24 of the Radiation Act stipulates that a radiation device, its place of use and associated equipment and materials shall be such as to enable the radiation device to be used safely. The Radiation and Nuclear Safety Authority (STUK) shall confirm the safety requirements to be considered in the design of buildings, prefabricated units and structures affecting the safe use of radiation devices.

This guide specifies the radiation safety requirements for structural shielding and other safety arrangements used in X-ray facilities in medical and veterinary X-ray activities and in industry, research and education. The guide is also applicable to premises in which X-ray equipment intended for radiation therapy and operating at a voltage of less than 25 kV is used. The guide applies to new X-ray facilities and to any old X-ray facilities in which new X-ray equipment is installed or to which X-ray equipment that has been used elsewhere is transferred.

The radiation safety requirements for radiation therapy X-ray devices operating at a voltage exceeding 25 kV, and for the premises in which such devices are used, are set out in Guide ST 2.2. The requirements for premises in which dental X-ray and mammography equipment are used are set out in Guides ST 3.1 and ST 3.2. The radiation safety requirements for industrial radiography are set out in Guide ST 5.6.

2 Structural Shielding

2.1 General Principles

The shielding of an X-ray room must be designed and constructed so that the dose limits prescribed in the Radiation Decree are not exceeded in the premises surrounding the room under any circumstances. The dose constraints referred to in section 7 of the Radiation Decree (Amendment 1143/1998) must be applied in designing the shielding so as to implement the principle of optimisation and to allow for exposure arising from various radiation sources. The dose constraint when using X-ray devices shall be 0.3 mSv per year.

If there are several X-ray devices in an X-ray room or if there are other premises in which radiation is used that are adjacent to the room, then the combined effect of all of these must be considered when designing the shielding. The X-ray devices and other radiation sources in an X-ray room and its adjacent premises are to be regarded as a single source of exposure.

2.2 Specification of Structural Shielding

The literature references to this guide include calculation formulae and other information necessary for specifying the shielding of an X-ray room numerically.

The specification of the shielding must be based on the highest voltage that will be used in the X-ray device, the largest field size of the radiation beam and the largest estimated work load of the device. Orientation factors and occupancy factors may also be used. In directions not affected by the radiation beam the shielding is to be determined on the basis of the leakage radiation penetrating the X-ray tube housing and the radiation scattered from the patient or the object under examination. The scattered radiation is then assumed to be attenuated in the same way as the primary radiation.

If the fixed structures of the X-ray device cover the entire radiation beam, then the attenuation of the radiation within these structures may be considered. Attenuation in the patient or the object under examination is not generally considered.

Although lead is the most common material used for the shielding of an X-ray room, other materials (such as concrete or brick) may also be

used. When using other materials, consideration is to be given not only to their elemental composition and density, but also to whether there are pores or cavities in the material. For example, the shielding capacity of the hollow slabs used in the intermediate floors of buildings is much less than might be inferred from the slab thickness.

If orientation factors and occupancy factors are used, then these must satisfy the following conditions:

Orientation factor (U)

- If the radiation beam is oriented in some particular direction for more than 50 per cent of the time when the device is in use, then a value of U = 1 is used for specifying the shielding in this direction.
- If the radiation beam is oriented in some particular direction for less than 50 per cent of the time when the device is in use, then a value of $0.25 \leq U \leq 1$ may be used for specifying the shielding. However, the orientation factor must always be no smaller than the proportion of time in use for which the beam is oriented in this direction.
- A value of U = 1 is used in directions affected only by leakage and scattered radiations.

Occupancy factor (T)

- A value of T = 1 is used in working premises and, in the case of medical use of radiation, also in waiting rooms and patient rooms.
- A value of $0.1 \leq T \leq 1$ may be used in indoor or outdoor premises where human beings do not remain on a continual basis (e.g. WCs, corridors, storerooms or streets). However, the occupancy factor shall always be no smaller than the proportion of time during which human beings occupy the area concerned.

2.3 X-Ray Rooms Used for Medical Activities

In the medical use of radiation, X-ray devices are often used at voltages that are lower than the maximum possible voltage. Further, the workloads of the devices are not very high. For these reasons it is not necessary, in the case of most X-ray rooms intended for normal*) use, to calculate the shielding using the calculation formulae set out in the literature references of this guide. Experience has shown that 3 mm of lead (300 mm of concrete or 350 mm of brick)**) suffices for most shields in the direction of the radiation beam. The size of the shield is generally 1.5 x 1.5 m^2. In directions affected only by leakage and scattered radiations 2 mm of lead (200 mm of concrete or 250 mm of brick) is enough. The shield on walls affected only by leakage and scattered radiations generally extends to a height of no less than 2 m.

If it can be shown that the dose constraint set out in item 2.1 is not exceeded in the premises surrounding the X-ray room by the normal use of the X-ray device to be installed in the room, then lead values, even smaller than those given above, will suffice for the thickness of the shields.

The shielding for X-ray rooms used in medical activities involving operations other than normal X-ray examinations and in which the workloads of the devices are high are to be specified according to item 2.2. Activities such as angiography, CT examinations and interventional radiology are carried out in these rooms. The adequacy of shields is to be verified from dose measurements.

*) The normal use of an X-ray room here means activities involving the most common X-rays of musculosceletal and respiratory organs, and fluoroscopic examinations of gastrointestinal organs. The annual number of examinations and X-rays should not exceed 10,000.

**) Densities: Lead 11.3 $g \cdot cm^{-3}$, concrete 2.3 $g \cdot cm^{-3}$ and brick 1.8 $g \cdot cm^{-3}$.

In rooms where low power X-ray devices of well shielded construction are used there is no absolute need for separate structural shielding if staff and other persons are not in the immediate vicinity of the device during its use. Devices of this kind include equipment for measuring bone density and X-ray devices operating at voltages of less than 25 kV. If the walls of the room in which the device is used are of light construction (e.g. wood or chipboard), however, then the need for extra shielding should be separately investigated.

2.4 X-Ray Rooms in Industry and in Research and Education

The use of radiation in industry and in research and education is application-specific and so the need for shielding of X-ray rooms is to be determined separately in each case. Experience indicates that if the voltage of the X-ray tube does not exceed 150 kV and the tube itself is well shielded, then the material thicknesses set out in the first paragraph of item 2.3 will suffice for the shielding of the room. Material thicknesses at voltages exceeding 150 kV are to be specified according to item 2.2.

No separate shielding is needed in rooms where only fully-shielded diffraction and fluorescence devices are used.

3 Size of X-ray Rooms

3.1 X-ray Rooms Used for Medical Activities

It is important from the viewpoint of radiation protection that X-ray rooms are of a size and arrangement that is suited to their purpose. Where necessary, there must be enough space around an X-ray device, for example, to enable bedridden patients to be examined and to accommodate the peripheral devices and instruments needed for operations. It is not always possible to vacate the room during examinations or fluoroscopy. In such cases, however, the persons performing the operation and any others present must be able to move away to a sufficient protective distance or to shelter behind a separate shield. For this reason, the design of such rooms must give particular consideration to the size and number of X-ray stands, to the need for movement of these stands and of the patient's bed, to the positioning of mobile shields or, for example, ceiling-mounted shields, to the type of operations, to patient material and to the number of staff in the room during operations.

3.2 X-ray Rooms in Industry and in Research and Education

The size of X-ray rooms shall be dimensioned according to the type of activity, having regard to the radiation and industrial safety of the persons taking X-rays and other staff and students, the distance from places where work is performed and the purpose for which premises adjacent to the X-ray room are used.

4 Warning Signs and Lights and Locking of Rooms

The doors leading to X-ray facilities must carry a sign calling attention to a radiation hazard. If access to the premises by outsiders is barred, or if access control is otherwise arranged, then it is sufficient to indicate the hazard by means of a sign stating the purpose for which the facilities are used. If there are warning lights next to or above the door leading to the premises, then these lights must be of the following kind:

- A yellow or white light indicating when the X-ray device is engaged and ready for operation. It is recommended that this light bears the text "DEVICE OPERATIONAL".
- A red light indicating when the X-ray device is producing radiation. It is recommended that this light bears the text "NO ENTRY".

A sign shall be placed on the doors of premises surrounding any X-ray facility for which the shielding has been calculated using an occupancy factor of $T < 1$ (e.g. stores and closets for cleaning materials and equipment) forbidding

permanent occupancy of the said premises. It must be possible to lock the doors of an X-ray facility. At least one door must be capable of being opened from within the facility at all times.

5 Bibliography

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