# GBZ

NATIONAL OCCUPATIONAL HEALTH STANDARD

OF THE PEOPLE'S REPUBLIC OF CHINA

ICS 13.100

C 57

# GBZ/T 250-2014

# Radiation shielding specification for room of industrial X-ray radiography

工业 X 射线探伤室辐射屏蔽规范



**Issued on: May 14, 2014** **Implemented on: October 01, 2014**

**Issued by: National Health and Family Planning Commission of the People's Republic of China**

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# Foreword

This standard was drafted in accordance with the rules given in GB/T 1.1-2009.

This standard was formulated in accordance with Law of PRC on Prevention and Control of Occupational Diseases.

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# Radiation shielding specification for room of industrial X-ray radiography

## 1 Scope

This standard specifies the radiation shielding requirements for industrial X-ray radiography room.

This standard applies to the industrial X-ray radiographic device room below 500 kV.

## 2 Terms and definitions

The following terms and definitions apply to this document.

**2.1**

**Room of X-ray detection**

It refers to the dedicated X-ray detection device room which is used for X-ray detection work with a shield structure to protect the outdoor radiation safety.

**2.2**

**Reference point**

It refers to the location outside the detection room which has decisive effect onto the detection room shielding structure AND needs to be determined during the detection room shielding design and dose estimation. It is generally the location 30 cm away from the external surface of the detection room where personnel may be exposed to the maximum dose. At a certain distance to the detection room, the locations where the public member residence factor is high AND the exposure dosage is high shall also be focused.

**2.3**

**Shielding transmission factor**

penetrating through the detection room wall, it shall be controlled based on the dose rate reference control level $\dot{H}_c$ (μSv/h) of 3.1.1 c).

2) As for the inaccessible detection room roof, the dose rate reference control level at the location 30 cm away from the detection room roof external surface is generally taken as 100 μSv/h.

### 3.2 Radiation needed Shielding

**3.2.1** The entire wall surface of the corresponding primary radiation shall adopt the primary radiation shielding, AND it is not needed to consider the scattered radiation entering into the primary radiation region.

**3.2.2** As for the scattered radiation, CONSIDER the 90° scattered radiation which is incident into the detected work piece at 0°.

**3.2.3** When there is a possibility of a combined effect of leakage radiation and scattered radiation, generally respectively ESTIMATE the leakage radiation and each scattered radiation; when the difference between their shielding thicknesses is equal to or more than one tenth value layer (TVL) thickness, SELECT the thicker shielding; when the difference is less than one tenth value layer (TVL), then at the thicker shielding, ADD a half value layer (HVL).

### 3.3 Other requirements

**3.3.1** The detection room shall generally be provided with personnel doors and separate work-piece doors. As for the small work piece detection room wherein detection can be through manual handling, it can only provide the personnel door. AND the personnel door for the detection room shall adopt the labyrinth type.

**3.3.2** The control room of the detection device shall be placed outside the detection room, AND the control room and personnel door shall avoid the direction of irradiation from primary radiation.

**3.3.3** In the shielding design, it shall consider the shielding for the gap, pipe hole and other weak links.

**3.3.4** When the detection room uses multiple X-ray radiography devices, DESIGN the shielding based on the maximum tube voltage and the normally used maximum tube current under such tube voltage.

**3.3.5** It shall consider the detection room structure, building cost, and space covered; AND the commonly used material is concrete, lead, and steel plate, etc.

$R_o$ - The distance from the radiation source point (target) to the work piece under detection, in meters (m);

I - The commonly used maximum tube current of X-ray radiography device at the maximum tube voltage, in milliamps (mA);

$H_o$ - The output at the location 1 m away from the radiation source point (target), μSv • $m^2$/(mA • h), USE the value in the unit of mSv • $m^2$/(mA • min) to multiple by 6 x $10^4$; SEE Table B.1 of Appendix B.

F - The radiation field area at $R_o$, in square meters ($m^2$);

α - Scattering factor, which is the ratio of the scattered radiation dose rate of the incident radiation onto the location 1 m away from it by the scatterer of 1$m^2$ unit area to the incident radiation dose rate on this unit area. α is related to the scattering material; if the α value of the corresponding material does not obtained, USE the α value of water scatterer for conservative estimation; SEE B.4 of Appendix B;

c) When the shielding material thickness X is given, as for the corresponding shielding transmission factor B, in accordance with Table 2 and the corresponding values in Table B.1 of Appendix B, DETERMINE the TVL of 90° scattered radiation, then USE the equation (5) for calculation. The scattering dose rate $\dot{H}(\mu Sv/h)$ for the reference point is calculated in accordance with the equation (10):

$$\dot{H}=\frac{I\cdot H_0\cdot B}{R_s^2}\cdot\frac{F\cdot\alpha}{R_0^2} \qquad \text{.....(10)}$$

Where:

I - The commonly used maximum tube current of X-ray radiography device at the maximum tube voltage, in milliamps (mA);

$H_o$ - The output at the location 1 m away from the radiation source point (target), μSv • $m^2$/(mA • h), USE the value in the unit of mSv • $m^2$/(mA • min) to multiple by 6 x $10^4$; SEE Table B.1 of Appendix B.

B - Shielding transmission factor;

F - The radiation field area at $R_o$, in square meters ($m^2$);

α - Scattering factor, which is the ratio of the scattered radiation dose rate of the incident radiation onto the location 1 m away from it by the scatterer of 1$m^2$ unit area to the incident radiation dose rate on this unit

that is, the required shielding wall thickness of the detection room is more than that of the sidewalk; in accordance with the dose rate requirements f the office building, ESTIMATE the final shielding thickness.

**C.1.2.2** Examples of north wall (primary radiation) shielding estimation

a) CONDUCT estimation in accordance with the methods of 4.1: from Table B.1, the primary radiation output of the 300 kV tube voltage under 3 mm copper filtering conditions is 11.3 mGy•m$^2$/(mA•min).

CALCULATE in accordance with the equation (3):

$$B=\frac{2.5\times 2.3^2}{6\times 10^4\times 5\times 11.3}=3.9\times 10^{-6}$$

From the lead transmission curve of Figure B.1, the required lead thickness is 22.4 mm. It can also calculate the required concrete thickness is 560 mm.

b) ESTIMATE using the typical data sheet method: from Table 4, it is found that lead required at 2m and 3m is 23 mm and 21 mm respectively. Through the interpolation, the lead shielding thickness at 2.3 m is 22.4 mm. It can also calculate the required concrete thickness which is 560 mm.

**C.1.2.3** Example of west wall (leakage radiation and scattered radiation combination) shielding estimation:

a) ESTIMATE in accordance with the methods in 4.2:

1) Leakage radiation:

From Table 1, the leakage dose rate of 300 kV X-ray at 1 m from the target is 5 × 10$^3$ μSv/h. From Table C.1, $\dot{H}_e$ is 1.2 μSv/h. CALCULATE In accordance with the equation (7):

$$B=\frac{1.2\times 2.3^2}{5\times 10^3}=1.3\times 10^{-3}$$

From the Table B.2 of Appendix B, the tenth value layer of 300 kV X-ray in lead is 5.7 mm, and then USE the equation (6) to calculate the required lead thickness:

$$X=-5.7\cdot \lg(1.3\times 10^{-3})=16.4\ \text{mm}$$

2) Scattered radiation:

# References

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[5] HMSO. Handbook of radiological protection, part 1: data. London: HMSO, 1971.

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