IS 2595 : 2008

(Reaffirmed 2013)

(Reaffirmed 2018)

(Reaffirmed 2020)

भारतीय मानक

औद्योगिक रेडियोग्राफी परीक्षण — रीति संहिता

(दूसरा पुनरीक्षण)

Indian Standard

INDUSTRIAL RADIOGRAPHIC TESTING — CODE OF PRACTICE

(Second Revision)

ICS 77.040.20

BUREAU OF INDIAN STANDARDS
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October 2008

Price Group 6

Non-destructive Testing Sectional Committee, MTD 21

FOREWORD

This Indian Standard (Second Revision) was adopted by Bureau of Indian Standards, after the draft finalized by the Non-destructive Testing Sectional Committee had been approved by the Metallurgical Engineering Division Council

This standard was first published in 1963 as a guide to industry for carrying out radiographic testing satisfactorily and subsequently revised in 1978. The recommendations made in this Code are based on accepted current practice for enabling the best results to be achieved. It is hoped that the use of this Code shall ensure a more unified practice and help in attaining satisfactory sensitivity in radiographic testing.

In this revision following modifications have been carried out:

a) Reference clause has been added,

b) Clause on classification has been modified,

c) Clause on test arrangement has been modified,

d) Clause on Identification and marking has been modified,

e) Table 2 has been modified, and

f) Clause 13 on protection of personnel from radiation exposure has been modified.

As the practice of radiographic testing involves hazardous materials, it is mandatory that the following Atomic Energy Regulatory Board (AERB) Guides are referred and complied with, to avoid statutory violations:

a) SG/IN-1 Radiological Safety in Enclosed Radiography Installation, and

b) SG/IN-2 Radiological Safety in Open Field Radiography.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

INDUSTRIAL RADIOGRAPHIC TESTING — CODE OF PRACTICE

(Second Revision)

1 SCOPE

This standard covers the basic rules of industrial radiography using X-rays and gamma rays for flaw detection purposes, using film techniques applicable to metallic product and materials.

2 REFERENCES

The following standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
2478 : 1991	Glossary of terms relating to industrial radiography
3657 : 1978	Radiographic image quality indicators (*first revision*)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 2478 shall apply.

4 CLASSIFICATION OF RADIOGRAPHIC TECHNIQUES

4.1 The radiographic techniques are divided into the following techniques, which can be employed only for components having both sides access:

a) *Technique A* — It is a general technique, adequate for most applications; and

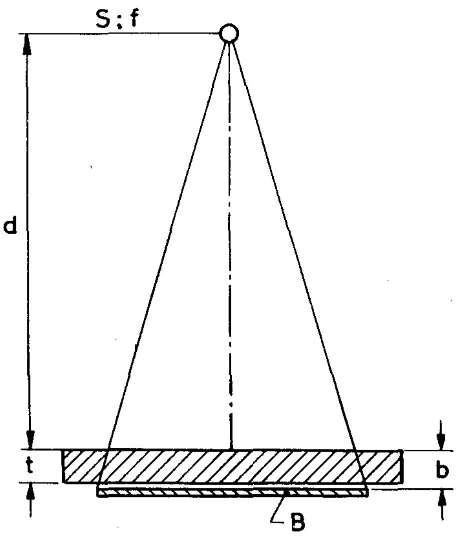
b) *Technique B* — A more sensitive technique intended for use where the Technique A may give unsatisfactory results or is unlikely to reveal the anomalies sought. It generally requires longer exposure times.

c) *Technique C* — This specific technique is applicable as agreed upon between the buyer and the supplier having adequate flaw sensitivity. Some applications of radiography require the radiographs to cover a range of specimen thicknesses of specific nature.

In addition to having an adequate flaw sensitivity, some applications of radiography require the radiographs to cover a range of specimen thicknesses. Several modifications of either Technique A or B shall produce an increase in thickness latitude (*see* **8.5**).

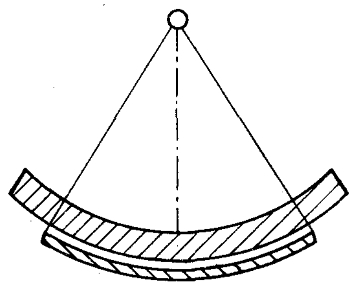
5 TEST ARRANGEMENT

5.1 The test arrangements consist of the radiation source, test object and the film or film-screen combination in a cassette. It depends on the size and shape of the object and the accessibility from both sides of the object for the area to be tested. Generally one of the arrangements illustrated in Fig. 1 to Fig. 7 should be used, Fig.1 being the most usual case.



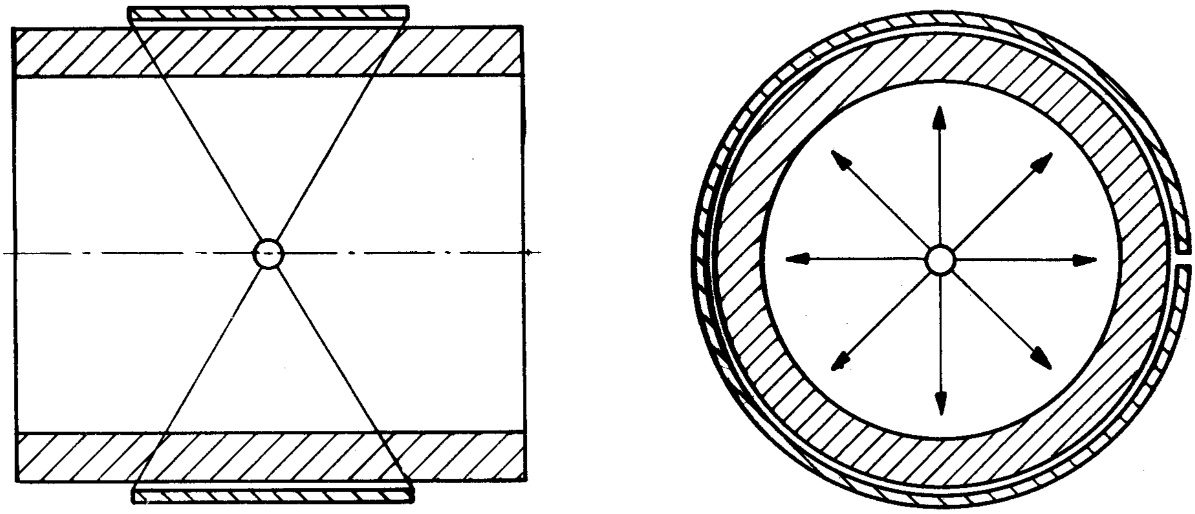
S = radiation source with an effective optical focus size f
B = film
d = source-to-object distance
t = material thickness
b = distance between film and the surface of the object nearest the source

FIG. 1 ARRANGEMENT I, SINGLE WALL PENETRATION OBJECTS WITH PLANE WALLS



NOTE — Source off-centre on concave side, film on convex side. This arrangement is preferred to arrangement IV (Fig. 4).

FIG. 2 ARRANGEMENT II, SINGLE WALL PENETRATION OBJECT WITH CURVED WALLS



NOTE — One advantage of this technique is, that the whole circumference may be radiographed in one exposure. This arrangement is preferred to arrangements II (Fig. 2), IV (Fig. 4) and V (Fig. 5).

FIG. 3 ARRANGEMENT III, SINGLE WALL PENETRATION OBJECT WITH CURVED WALLS, SOURCE LOCATED CENTRALLY

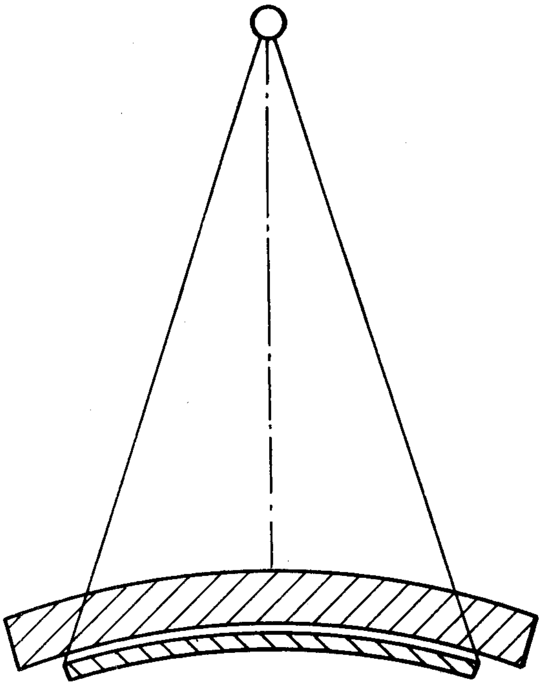


FIG. 4 ARRANGEMENT IV, SINGLE WALL PENETRATION, OBJECT WITH CURVED WALLS, SOURCE ON CONVEX SIDE, FILM ON CONCAVE SIDE

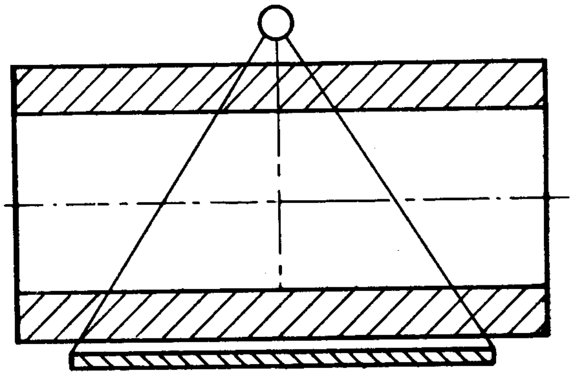


FIG. 5 ARRANGEMENT V, DOUBLE WALL PENETRATION, SINGLE WALL EVALUATION, SOURCE AND FILM OUTSIDE, BECAUSE THE SOURCE IS CLOSE TO THE UPPER WALL, FLAWS IN THIS WALL SHALL NOT BE EVALUATED

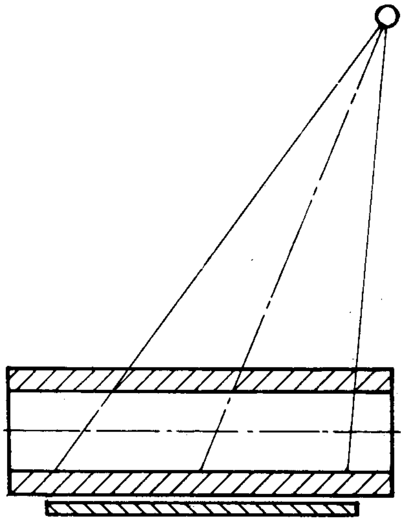


FIG. 6 ARRANGEMENT VI, DOUBLE WALL PENETRATION, DOUBLE WALL EVALUATION SOURCE AND FILM OUTSIDE

NOTE — For some applications the radiation beam might be used at a different angle (not perpendicular to the centre of film).

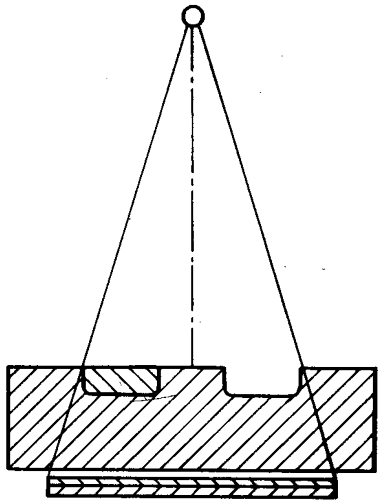


FIG. 7 ARRANGEMENT VII, SINGLE WALL PENETRATION, OBJECTS WITH PLANE OR CURVED WALLS OF DIFFERENT THICKNESSES OR MATERIALS, TWO FILMS WITH THE SAME OR DIFFERENT SPEEDS

5.2 The beam of radiation should be directed to the middle of the section under examination and should be normal to the surface at that point, except when especially seeking certain flaws which it is known are best revealed by a different alignment of the beam. When radiographs are taken in a direction other than normal to the surface, it should be specified in the test report.

5.3 Double wall techniques may be used only, if outside diameter (OD) of tube is less than 90 mm.

When the OD of the pipe/tube is less than or equal to 89 mm, the weld shall be radiographed by double wall double image technique (DWDI). In this technique (as shown in Fig. 6), the source shall be suitably offset, such that both the top and bottom weld appear on the radiographic image (as ellipse) with suitable separation and are evaluated.

6 SURFACE CONDITION

Visible surface irregularities which might adversely affect evaluation of the radiograph should be removed before radiography is carried out. In special cases it may be advantageous to remove excessive surface roughness before the test.

7 IDENTIFICATION AND MARKING

7.1 Markers in the form of letters or symbols should always be affixed to each section of a test object being radiographed. The image of these markers should appear in the radiograph to ensure unequivocal identification of the section, as well as the position of the area being examined. The use of a film imprinter or other means prior to development is also permitted. Identification or location markers should not mask the area of interest in radiograph.

7.2 In general permanent markers on the test object shall provide reference points for the accurate relocation of the position of each radiograph. Where the nature of the material and its service conditions render stamping impossible, other suitable means for relocating the radiographs should be sought. This may be done by paint marks or by accurate sketches.

7.3 Location markers for identification like that of lead must be placed on the part exactly on the marked surfaces of specimens and NOT on cassettes. This would help in identifying an area of interest in case of occurrence of defect. If a repaired part is re-radiographed, it is advisable to use letter '*R*' to designate the repaired area and with suffixes 1, 2, 3 etc, to '*R*' to indicate number of repairs.

8 TECHNIQUES FOR MARKING RADIOGRAPHS

8.1 The ability to detect flaws on a radiograph depends on the viewing conditions and on the photographic density differences (contrast) and the sensitivity. Overall radiographic sensitivity depends on the following factors:

a) Radiation source and energy,

b) Scattered radiation,

c) Type of film and screens,

d) Type of filter,

e) Materials and specimen thickness, and

f) Processing conditions.

8.2 Choice of Film and Intensifying Screens

8.2.1 *Film Types*

The types of X-rays films suitable for industrial radiography are given in Table 1.

Table 1 Classification of Radiographic Films
(*Clause* 8.2.1)

Sl No.	Film Classes	Graininess	Speed
(1)	(2)	(3)	(4)
i)	G I	Very fine grained	Very slow
ii)	G II	Fine grained film	Slow
iii)	G III	Speed and size of medium grain size	Medium speed
iv)	G IV	Speed and size of larger grain size	High speed

8.2.1.1 For Technique A, G I, G II and G III films, and for Technique B G I and G II films should be used. G IV films are only recommended to be used with fluorescent or fluoro-metallic screens.

8.2.2 *Intensifying Screens*

Screens of metal foil of thickness given in Table 2 should be used. These screens shall be clean, smooth and free from mechanical defects which might affect the interpretation. They shall be held in close contact with the film emulsion. Screens showing sign or evidence of physical damage shall be discarded.

The most commonly used screen material is lead and the thickness of screen depends on the energy of radiation used. In special cases where lead can not be used, copper, gold or tantalum and lead oxide screen are used as screen material.

Table 2 Lead of Intensifying Screens

Sl No.	Energy	Thickness of Front Screens mm	Thickness of Back Screens mm
(1)	(2)	(3)	(4)
i)	X-ray, less than 120 kV	0.025-0.050	0.125
ii)	120 to 250 kV	0.025-0.125	0.125
iii)	250 to 400 kV	0.100-0.150	0.125
iv)	1 to 6 MeV	0.150-0.250	0.250
v)	6 to 15 MeV (Iridium) (Cobalt)	0.1-0.15 0.15-0.25	0.125 0.25
vi)	Gamma rays	0.100-0.250	0.125

8.2.2.1 *Fluorescent/fluoro-metallic screens*

In general for a given source of radiation, fluorescent/fluoro-metallic materials should be used only when the exposure necessary without them would be prohibitively long. In any event, if such fluorescent/fluoro-metallic screens should be used, they have proven capable of achieving the required quality level. Good screen-film contact is essential for the successful use of fluorescent/fluoro-metallic screen.

8.2.2.2 In the double film technique (*see* **8.5.2** and **8.5.3**), intermediate screens should be used.

8.2.3 *Cassettes and Film Holders*

Films and screens should be contained in cassettes. The cassettes for holding film may be either rigid or flexible depending on the specimen and the circumstances under which the radiograph is taken. When screens are used in combination with the film a good uniform contact between screens and film is important. In such cases, use of rigid, spring back cassettes is recommended. Cassettes may be pressed or clamped against the material to be radiographed. The weight of the material or the flexing of the cassettes, when bent to fit inside some structure, may be used to ensure contact.

8.2.4 *Storage of Films*

Unexposed films should be stored vertically in light tight containers and should be protected from the effects of excessive humidity, heat, temperature and chemical vapours/fumes. The storage boxes should be lead lined and the place of storage should be a safe distance from the radiation exposure zone.

8.3 Geometric Conditions

In order to reduce geometric unsharpness to minimum the requirements given in **8.3.1** and **8.3.2** should be fulfilled. In case of curved specimens, the source should be positioned to avoid any geometrical distortion.

8.3.1 *Source-to-Object Distance*

8.3.1.1 The minimum distance (d) between radiation sources and the nearest surface of the specimen is given in Fig. 8 in terms of specimen thickness (t) and the effective optical focus size (f) for the two test classes. The specimen thickness required for calculating geometric unsharpness Ug, the distance between film and source side surface of object to be taken (*see* nomogram in Fig. 9). The corresponding geometric unsharpness Ug may be calculated by the following formula:

$$Ug = (f.t)/d \quad \text{.......(1)}$$

In case of DWDI technique, for the calculation of geometric unsharpness, 't' refers to the OD of pipe/tube. Hence for DWDI equation 1 can be rewritten as:

$$Ug = f(\text{OD of pipe/tube})/d \quad \text{.......(2)}$$

8.3.1.2 In calculation of the minimum source-to-object distance, the effective optical focus size (f) shall be as given below for the different shapes of focus (*see* Fig. 10):

$f = a$ for a square focus where 'a' is the length of each side of the square.

$f = \dfrac{a+b}{2}$ for a rectangular focus where 'a' and 'b' are the length of the sides of the rectangles.

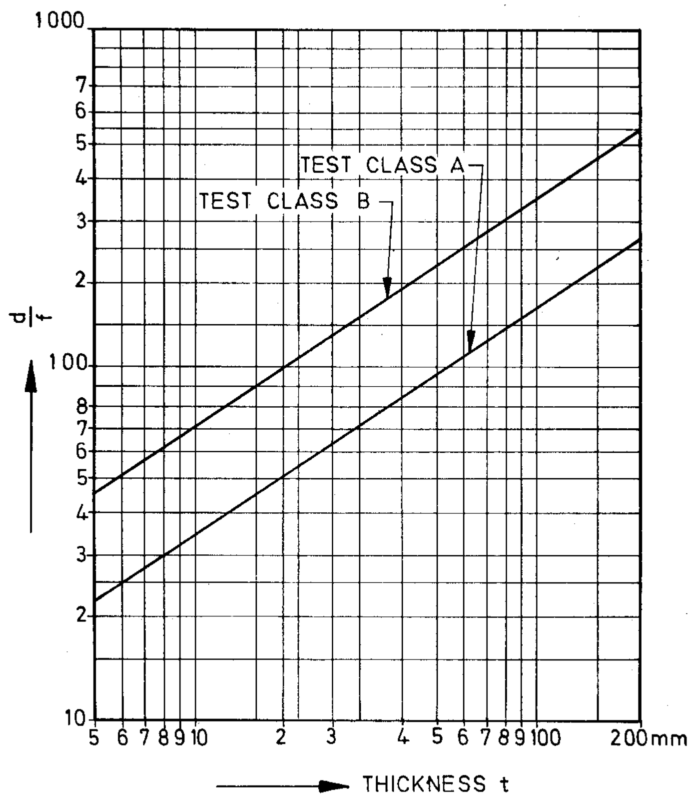


FIG. 8 REQUIRED MINIMUM VALUES OF RATIO $\frac{d}{f}$ IN TERMS OF THICKNESS '*t*'

where

d = source to object distance in mm,

f = effective optical focus size in mm, and

t = material thickness in mm.

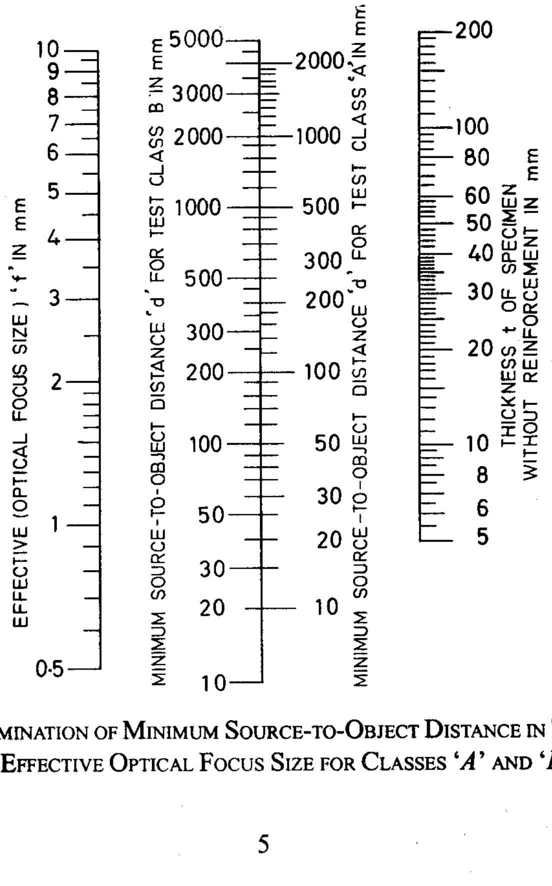


FIG. 9 NOMOGRAM FOR THE DETERMINATION OF MINIMUM SOURCE-TO-OBJECT DISTANCE IN TERMS OF MATERIAL THICKNESS AND EFFECTIVE OPTICAL FOCUS SIZE FOR CLASSES '*A*' AND '*B*'

f = 'd' for circular focus where 'd' is the diameter of the surface.

$f = \frac{a+b}{2}$ for elliptical focus where 'a' and 'b' are the major and minor axes of the ellipse.

The focal spot shall be determined by the pinhole method. The size of the pinhole shall be one order less than the size of the focal spot as quoted by the manufacturer. The pinhole shall be made in a high Z material such as lead with a thickness which is at least three HVLs for the given radiation energy.

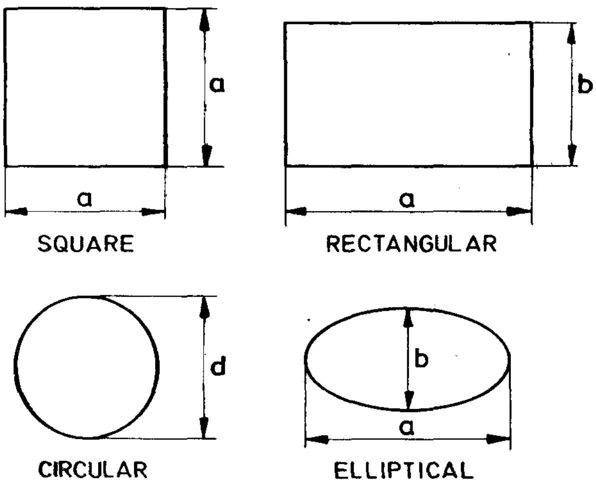


FIG. 10 IDEALIZED FORM OF EFFECTIVE OPTICAL FOCUS

8.3.1.3 The source-to-object distance is usually a compromise between the technically desirable distance and acceptable short exposure time. An increase in d shall generally produce an improvement in flaw sensitivity.

8.3.2 *Object-to-Film Distance*

The cassette should be in close contact with the surface of the test object whenever possible. If this is not possible and when the distance between the film and the surface of the object nearest to the source (b) is very large compared to the thickness t, t should be replaced by b on the abscissa of Fig. 8.

8.3.3 *Special Rules for Objects with Curved Test Areas*

When objects with curved test areas are to be tested, the distance d according to Fig. 8 and Fig. 9 may be reduced to half the value but not less than the relevant radius of the object if placing the radiation source inside the test object (for example, a pipe or pressure vessel). Arrangement II or III leads to a more suitable direction of radiation than at arrangements IV, V or VI.

8.4 *Choice of Radiation Energy*

8.4.1 The choice of radiation energy is dependent on the specimen thickness and its material and sometimes on the assessibility for suitable radiographic equipment. As a general rule, radiation contrast improves as the radiation energy decreases. Hence a optimum radiation energy compatible with an acceptable exposure time, should be used (for X-rays up to 450 kV, *see* Fig. 11; for X-rays above 1 MeV and for gamma-rays, *see* Table 3). Other voltages may also be used, if the required quality is achieved.

Table 3 Range of Material Thickness (in mm) for Which Different Radiation Sources are Suitable
(*Clauses* 8.4.1 *and* 8.4.3)

Sl No. (1)	Class (2)	Radiation Source (3)	Steel, Iron, Nickel and Its Alloys (4)	Copper and Its Alloys (5)	Lead and Its Alloys (6)
i)	Technique A	Ir 192	20 to 100 (10 to 100)[1)]	15 to 90	5 to 40
		Co 60	40 to 200[2)]	20 to 170	15 to 125
		X-rays 1 to 2 MeV	50 to 200		
		X-rays More than 2 MeV	50 and over		
ii)	Technique B	Ir 192	40 to 90 (10 to 90)[1)]	35 to 80	15 to 35
		Co 60	60 to 150 (40 to 200)[1)]	50 to 135	40 to 100
		X-rays 1 to 2 MeV	60 to 150		
		X-rays More than 2 MeV	60 and over		

[1)] *See* **8.4.3**.
[2)] For 40 to 60 mm, 0.4 to 0.7 mm front and back screens of steel (alloyed or unalloyed) or copper have to be used.

8.4.2 There are only a few gamma-ray radio-isotopes with characteristics suitable for industrial radiography and only two of these — Iridium 192 and Cobalt 60 — are widely used. Tantalum 182, Ytterbium 169 and Thulium 170 are used in special cases.

8.4.3 If the use of X-ray equipment with respect to accessibility is technically impossible or if there exists larger probability of flaw detection due to more advantageous direction of radiation-beam, it is recommended to use radioactive source instead of X-ray tubes in the thickness ranges given in Table 3 within brackets, although image quality of radiographs taken with radioactive sources is not as high as that of radiographs taken with X-ray equipment in these thickness ranges.

8.4.4 *Radiographic Equivalence Factors*

It is that factor by which the thickness of the material should be multiplied in order to determine what thickness of a standard material shall have the same attenuation. Radiographic equivalence factors of several common metals are given in Table 4 with aluminium taken as the standard material and arbitrarily given factor of 1.0 at 50 and 100 kV and steel for higher voltages. This may be used :

a) To determine the practical thickness limits for radiation sources for metals other than the standard materials, and

b) To determine exposure factors for one metal from exposure charts compiled for other metals.

8.5 Thickness Latitude

For some applications, where the thickness or the absorption of the specimen changes rapidly over a small area, so that the thickest and thinnest sections may not be rendered with adequate contrast on a single film, it is desirable to use a modified or a special radiographic technique to ensure that the range of thickness required to be examined falls within the useful film density region. Any of the five techniques listed below may be used.

8.5.1 Use a higher X-ray kilovoltage than shown in Fig. 11 together with filter on the X-ray tube, close to source. Filters are also used for improving contrast:

a) By decreasing under cutting when the object size is smaller than the radiation field, and

b) By reducing the scattered radiation.

Generally filters will be placed at closer locations to radiation source thus minimizing the size of the filter and at times they are used between the object and film (cassette) to absorb scattered radiation from the object.

Suitable filter thicknesses are:

For 200 kV X-rays 0.5 mm lead
For 400 kV X-rays 1.0 mm lead

8.5.2 Expose two films of the same speed in one cassette, each to have density at the minimum value specified in **10.1** under the thinnest part of the specimen. Superimpose the two films to examine the thicker region. This position shall be recorded on both films, either of which may be viewed alone.

Table 4 Approximate Radiographic Equivalence Factors for Various Metals
(*Clause* 8.4.4)

Sl No.	Metal	50-kV X-Ray	100-kV X-Ray	150-kV X-Ray	220-kV X-Ray	400-kV X-Ray	1MeV X-Ray	2MeV X-Ray	4 to 25 meV X-Ray	Gamma Ray Ir-192	Gamma Ray Cs-137	Gamma Ray Co-60
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	Magnesium	0.6	0.6	0.05	0.08	—	—	—	—	—	—	—
ii)	Aluminium	1.0	1.0	0.12	0.18	—	—	—	—	0.35	0.35	0.35
iii)	Titanium	—	—	0.45	0.35	—	—	—	—	—	—	—
iv)	Steel	—	12.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
v)	18.8 stainless steel	—	12.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
vi)	Copper	—	18.0	1.6	1.4	1.4	—	—	1.3	1.1	1.1	1.1
vii)	Zinc	—	—	1.4	1.3	1.3	—	—	1.2	1.1	1.0	1.0
viii)	Brass[1)]	—	—	1.4	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.1
ix)	Inconel alloys	—	16.0	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
x)	Lead	—	—	14.0	12.0	—	5.0	2.5	3.0	4.0	3.2	2.3

NOTE — In this table, aluminium has been taken as the standard material for 50 and 100 kV X-rays, and steel in all other cases.

[1)]Tin or lead in the brass will increase these factors.

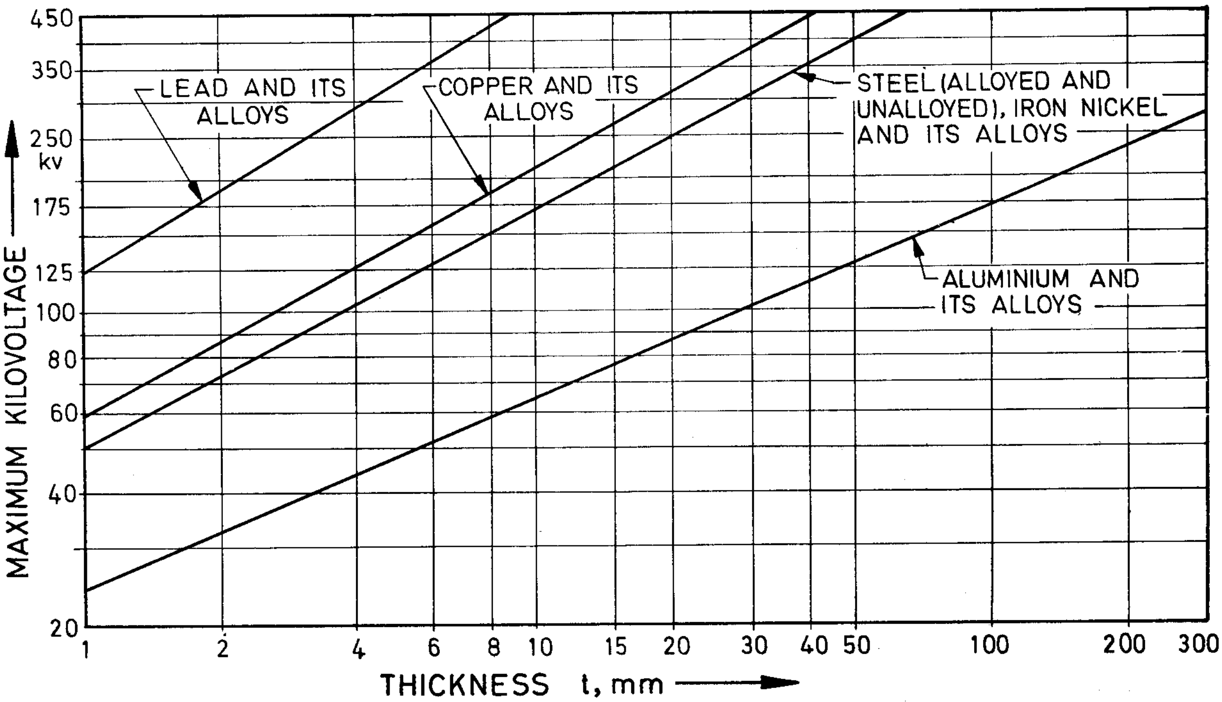


FIG. 11 MAXIMUM KILOVOLTAGES FOR X-RAYS UP TO 450 kV FOR DIFFERENT MATERIALS FOR CLASSES '*A*' AND '*B*' FOR MATERIAL THICKNESS '*t*'

8.5.3 To produce acceptable film densities on the image of the thickest part of the specimen on the faster film and on the thinnest part of the specimen on the slower film.

8.5.4 Use a special film with extremely fine grain and single side coating.

8.5.5 Reduce the minimum permissible density to 1.0 for Technique A and to 1.5 for Technique B.

NOTE — The techniques mentioned in **8.5.4** and **8.5.5** lead to a poorer flaw sensitivity than would be obtained with a normal technique.

8.6 Exposure Charts

Exposure charts relating to the material thickness, kilovoltage and exposure are usually furnished by the manufacturers of radiographic equipment for use with their units. The exposure charts apply to a set of specific conditions such as:

a) The radiation sources used,

b) A certain focus to film distance,

c) A particular type of film and screen,

d) Processing conditions used, and

e) The film density on which the chart is based.

Only if all the conditions used in making a radiograph are kept the same as in the preparation of the exposure chart, values of exposure may be read directly from the chart. Any change will require application of correction factors.

8.7 Precautions Against Scattered Radiation

8.7.1 Scattered radiation reaching the film is an important cause of reducing image quality, particularly with X-rays between 150 to 400 kV. Scattered radiation may originate both from inside the specimen and outside. In order to minimize the effect of scattered radiation, the radiation beam should be restricted to the area of interest. This is normally done by restricting the primary cone of the radiation beam, either with a physical cone or with a diaphragm on the tube head. The film should also be shielded from radiation scattered from other parts of the specimen or from objects behind or to the side of the specimen. This may be done by using a back intensifying screen of extra thickness or by using a sheet may be inside the cassette or be placed immediately behind the cassette. Depending on the set-up, typical lead thicknesses are in the range of 1 to 4 mm.

8.7.2 If the edge of the specimen is within the radiation field, a method of reducing undercutting scatter is generally necessary, Fig. 12 shows two typical methods.

8.7.3 When X-rays of 6 MeV energy or more used without back intensifying screens, shielding against radiation is not necessary, unless there is scattering material close behind the film.

8.7.4 In general, with X-rays between 150 and 400 kV and with gamma rays, if a beam restrictor may not be used, such as when panoramic exposures are being

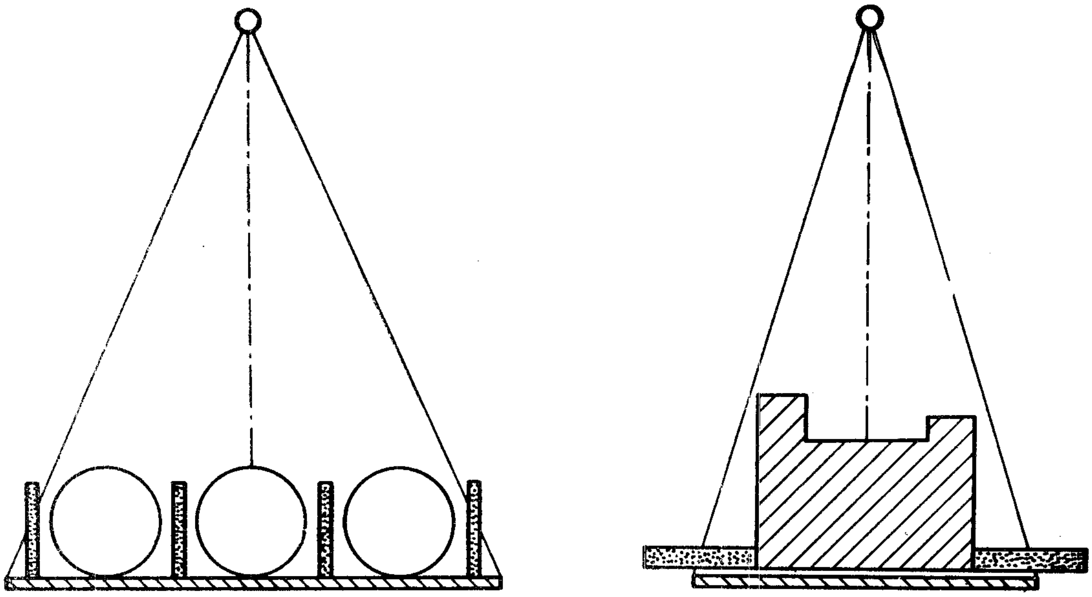


FIG. 12 METHODS OF REDUCING THE EFFECT OF SCATTERED RADIATION

made, the exposures should be made in as large a room as possible, so that extraneous scatter is attenuated by distance, the specimens, whenever possible, should be well above floor level and the floor near the specimen should be covered with lead.

8.7.5 To check the presence of back scattered radiation, a lead letter (0.32 cm thick) may be attached to the back of the cassette and the radiation made conventionally. If the image of the lead letter '*B*' appears on the processed radiograph as a lighter density image than the background, it indicates that the protection against back scattered radiation is insufficient and additional shielding is to be given. Length of lead letter should be minimum 10 mm.

9 IMAGE QUALITY INDICATORS

9.1 The quality of the radiograph shall be determined by an image quality indicator conforming to IS 3657.

9.1.1 The general quality level required using image quality indicators (IQI's) shall be equal to 2 percent of material thickness unless a higher or lower quality level is agreed upon by supplier and purchaser.

9.2 The image quality indicator sensitivity which may be expected to be obtained with Class A and Class B techniques is given in Table 5.

Table 5 Image Quality Indicator Sensitivities
(Percentage Sensitivity)

Sl No.	Specimen Thickness mm	Technique A		Technique B	
		Wire Type	Step/Hole Type	Wire Type	Steel/Hole Type
(1)	(2)	(3)	(4)	(5)	(6)
i)	3	—	—	2.4	5.1
ii)	6	—	—	1.6	3.6
iii)	12	2.4	4.6	1.4	3.0
iv)	25	1.7	3.0	1.2	2.5
v)	40	1.5	2.5	1.1	2.1
vi)	50	1.3	2.2	1.0	1.8
vii)	75	1.1	2.0	0.9	1.6
viii)	100	1.0	1.8	0.8	1.4
ix)	150	0.9	1.8	0.7	1.3

9.3 The image quality indicator (IQI) selected shall be of the same radiographically similar material as the object being radiographed. In case, IQI's of the same or radiographically similar material are not available. IQI's of the required dimensions but of lower absorption material with equivalent thickness (calculated using radiographic equivalence factor) may be used.

9.4 The IQI shall be placed during radiography on the source side and in the least favorable location. In case, due to object configuration or other constraints, it is not possible to place the penetrameter on the source side, the IQI may be kept on the film side. In such cases, a letter *F* shall also be placed to indicate that the IQI is on the film side. The selection of IQI shall be made as per IS 3657.

10 FILM DENSITY

10.1 The exposure conditions shall be selected such that the background density including fog density of the radiograph in the area of the specimen being examined is 1.8 - 3.0 for Technique A, and 2.00 to 3.00 for Technique B. Higher density may be permitted if adequate film viewing conditions are provided.

10.2 Radiographic film should be checked periodically for fog density which should not be exceed 0.3 for GI, GII and GIII types of film, and 0.4 for GIV type film.

10.3 In the case of multi film technique with composite viewing, the minimum density in the area of interest in each film shall be 1.3 and the maximum density when both the films are superimposed on each other during viewing shall be 3.0. Higher densities may be permitted provided suitable illuminators and adequate film viewing conditions are provided.

11 FILM PROCESSING

11.1 Layout of Processing Room

Unless the processing room is completely equipped in every detail, it is impossible to get highest possible photographic quality in the exposed radiographs. The layout of the processing room should be compact, floor space occupied being as small as practical and the arrangement of different equipment should be suitably planned. In assigning the space for the processing room, proper consideration should be given to the total quantity of work to be processed, and the processing tanks, namely, developing tank bath, fixing and washing tanks, should be designated accordingly. A loading bench for handling of films and other things should be provided on the other side of the room away from the processing tanks and within its convenient reach racks should be provided for hangers, cassettes, exposure holders, clamps, etc. A small lead-lined foam storage bin should be provided for storing films for daily use. The room should either have a double door room adjacent to the radiographic room with lead-protected film transferring cabinet in the wall which serves for maximum turn out of exposed films. Though the interior of the processing room should be coloured suitably to avoid any reflection of light, it should in no case be coloured black. It should be clean and fresh air is an important factor. Air conditioning the processing room is recommended which could profitably be utilized for the storage of X-rays films properly.

11.2 Illumination

As far as possible, the general illumination should be indirect. For light in specific sections of the processing room, such as the loading bench, processing tank, etc, the choice and arrangements vary depending on the amount and angle of illumination desired. For general illumination, a white light is provided at a place away from the loading bench.

11.3 Safety of Illumination

Screen-type films are more sensitive and hence liable to fogging from safe lights. The checking of the safe light therefore plays an important role in eliminating fogging of films.

A simple method of checking the safety of illumination is to cover part of a film with black cover and expose the remainder for different lengths of time at the loading bench and then to subject the test film to standard development. If no density shows on the portions that received a reasonably long exposure, as compared with covered part, the illumination may be assumed to be safe.

11.4 Processing

Only the general technique of processing is given below irrespective of the type of processing chemicals used. In regard to the specific conditions, such as time temperature development schedules, replenishment or renewal of solutions, specific practices for certain films, etc, the recommendations of the manufacturers of radiographics supplied should be followed.

11.4.1 *General Considerations*

The most common method of processing industrial radiographs is the tank processing system. The processing solutions are contained in tanks that are deep enough for the largest film to be hung in them vertically. The temperature of the processing solutions is kept at 20°C and is controlled by regulating the water-bath in which the processing tanks are immersed.

11.4.2 *Developing*

With only the safe light on, the exposed films should be taken out of the cassettes and mounted on the developing hangers. The number of films to be developed at a time should be such that a minimum separation of 25 mm exists between hangers. The hangers should then be lowered as one unit smoothly and carefully into the developer without any splashing of the developing solutions. The films shall not touch each other when in the developer. The development time should be strictly according to the recommendations of the manufacturers. During the developing process sufficient agitation should be provided by lifting the films with the hangers and shaking up and down slightly within developer bath. The procedure should be repeated every minute during the course of development.

11.4.2.1 *Testing of developer*

It is necessary to monitor the level and activity of the developer on a regular basis. The activity of the developer can be monitored by periodic development of film strips that have been exposed under standard conditions to a graded series of radiation intensities (for example using a step wedge). The same shall be compared with a standard strip for densities achieved. Replenisher shall be added at periodic intervals to maintain the level and activity of developer. The developer shall be discarded once the quantity or replenisher added is about 3 times the original quantity of developer or the developer gets oxidized, whichever is earlier.

11.4.3 *Rinsing*

When the development is complete, the hangers should be lifted and transferred to a stop bath for rinsing. If the level of the developer solution is maintained simply by additions of replensisher, sufficient time should be allowed to let the excess developer on the film drain back into the tanks before transferring into the stop bath which could be running water or water with 2 percent glacial acetic acid. The hangers should be lifted, drained and reimmersed several times before they are transferred to the fixing bath.

11.4.4 *Fixing*

When the films are placed in the fixer solution during fixation, the hangers should be agitated once or twice to ensure uniform action of the chemicals. The total fixing time should be at least twice the developing.

11.4.5 *Washing*

The films should then be next transferred to a washing tank. The hourly flow of water should be not less than 4 times nor more than 8 times the volume of the tank and the time of washing should be at least 20 min. The film should be placed in the washing tank near the outlet end. As more films are put in the washing tank, those already partially washed are moved towards the inlet so that the final part of the washing of each film is done in fresh uncontaminated water.

After the film is thoroughly washed, to make the water drain off evenly from the film and also by facilitating uniform drying, the film is dipped in a tray with wetting agent for about 30-60 s.

11.4.6 *Drying*

Films should be left on the hangers and mounted so as to hang more or less rigidly for drying. For dark rooms where a considerable number of films is to be processed, suitable driers with built-in fans, filters and heaters may be used.

12 VIEWING RADIOGRAPHS

12.1 Illuminator

The illuminator used for viewing radiographs should provide light of an intensity that would illuminate the average density areas of the radiographs and it should diffuse the light evenly over the viewing area. Commercial illuminators are satisfactory for radiographs of moderate density; however high intensity illuminators with fluorescent lamps used for densities up to 3.5 or 4.0. Masks should be available to exclude any extraneous light from the eyes of the viewer when radiographs smaller than the viewing port or to cover low density areas.

12.2 Viewing Room

The viewing room should have subdued lighting rather than total darkness. The brightness of the surroundings should be about the same as the area of interest in the radiographs. The room illumination should be so arranged that there are no reflections from the surface of the film under examination.

12.3 Viewing Distance

The maximum film viewing distance shall be of the order of 40 cm. The use of low power magnifying lens (X 3 or X 4) of reasonable area should be used for viewing radiographs.

13 PROTECTION OF PERSONNEL FROM RADIATION EXPOSURE

13.1 The exposure of any part of the human body to X-rays or gamma rays may be highly injurious to health. It is therefore, essential that whenever radiation sources are used, adequate precautions should be taken to protect the radiographer and any other person in the vicinity.

13.2 To ensure precaution against the exposure of personnel engaged in the use of industrial radiation sources, the safety requirements given in AERB SG/IN-1 and AERB SG/IN-2 shall be followed.

14 RECOMMENDATIONS CONCERNING AGREEMENTS

There should be mutual agreement between the purchaser and the supplier on the following points:

a) Marking of the object to be radiographed,

b) Class of radiographic technique,

c) Radiation source,

d) Type of film and screen,

e) Film plan and size,

f) Image quality indicator,

g) Test arrangement, and

h) Maximum difference in material thickness for each exposure.

15 RECORDS, REPORTS AND IDENTIFICATION OF ACCEPTED MATERIAL

15.1 Records

A log book should be maintained in the radiographic section wherein complete record of each job examined should be entered. The record should include such details as: (a) Job numbers; (b) Identification of the parts, materials or area radiographed; (c) Date of exposure; (d) Complete X-ray equipment or gamma ray source, type of film and screen, focus (source) to film distance, kilovoltage, tube current, exposure time, marking system; and (e) Any other special circumstances which would allow a better understanding of results. If any rectification or repair and re-examination is done on the job, this should also be entered in the log along with the interpretation and observations on the radiographs with interpreter's initials for each job.

The radiographs should be properly wrapped in folders and kept serially in a filling cabinet. The job number, the identification of the job, date of exposure, etc, should be written on the folders so as to correspond with the record kept in the log book. The custody of radiographs and the length of time they are required to be preserved should be agreed to between the contracting parties.

15.2 Reports

When written reports on radiographic examination are required, these should include the following, in addition to such other items as may be agreed to between the contracting parties:

a) Job number,

b) Heat number,

c) Identification number,

d) Material — Specification/type,

e) Material thickness,

f) IQI and sensitivity achieved,

g) Number of films with size,

h) Source of radiation used X-ray/gamma-ray,

j) Source/Focal spot size,

k) Source to film distance,

m) Radiography technique, and

n) Acceptance standard suggested.

15.3 Identification of Accepted Material

If radiography is used for acceptance or rejection of material, all parts and material which have been accepted should be marked permanently to indicate the face of radiographic acceptance to the final inspectors.

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Review of Indian Standards

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This Indian Standard has been developed from Doc : No. MTD 21 (4650).

Amendments Issued Since Publication

Amendment No.	Date of Issue	Text Affected

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Printed at Government of India Press, Faridabad