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Radiography of welds and viewing conditions for films — Utilization of recommended patterns of image quality indicators (I.Q.I.)

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2504 was drawn up by Technical Committee ISO/TC 44, *Welding*.

It was approved in February 1972 by the Member Bodies of the following countries :

Australia	India	South Africa, Rep. of
Austria	Ireland	Spain
Belgium	Israel	Sweden
Canada	Italy	Thailand
Czechoslovakia	Netherlands	Turkey
Egypt, Arab Rep. of	New Zealand	United Kingdom
Finland	Norway	U.S.A.
France	Portugal	U.S.S.R.
Germany	Romania	

The Member Body of the following country expressed disapproval of the document on technical grounds :

Switzerland

Radiography of welds and viewing conditions for films — Utilization of recommended patterns of image quality indicators (I.Q.I.)

1 SCOPE AND FIELD OF APPLICATION

This International Standard relates to the conditions for use of recommended patterns of image quality indicators (I.Q.I.) for radiography of welds and viewing conditions for films.

2 REFERENCES

ISO/R 947, *Recommended practice for radiographic inspection of circumferential fusion welded butt joints in steel pipes up to 50 mm (2 in) wall thickness.*

ISO/R 1027, *Radiographic image quality indicators — Principles and identification.*

ISO/R 1106, *Recommended practice for radiographic inspection of fusion welded butt joints for steel plates up to 50 mm (2 in) thick.*

ISO 2405, *Recommended practice for radiographic inspection of fusion welded butt joints for steel plates 50 to 200 mm thick.*

3 POSITION OF INDICATORS

An image quality indicator of one or other of the two types specified in ISO/R 1027 shall be placed on the surface of the weld facing the source of radiation, so that the image of the I.Q.I. appears on the radiograph near the end of each film.

If the wire type I.Q.I. is used, the wires shall be placed across the weld or, alternatively, a shim shall be placed under the I.Q.I. so that the metal thickness penetrated by the radiation is equal to the maximum thickness penetrated through the weld. In this latter case the wire I.Q.I. may be placed beside the weld.

If the step and hole type of I.Q.I. is used, it shall be placed close to the weld with the thinnest steps towards the end of the radiograph and on a shim so that the thickness of metal under the I.Q.I. penetrated by the radiation is equal to the maximum thickness penetrated through the weld.

Whichever I.Q.I. is used, the diameters of the elements (wires or holes) shall be chosen so that one element along the I.Q.I. represents a just discernible image.

NOTES

1 In cases where a continuous length of film is used to cover a circumferential weld (or similar applications) at least three I.Q.I.s

shall be used. They shall be placed equidistantly at distances apart not greater than 1 m.

2 In the case of the "double-wall/double-image" technique, used for circumferential welds on pipes, the I.Q.I. shall be placed near the ends of the portion of weld under examination, on the surface of the piece nearest the source.

3 If the surface of the weld facing the source is not accessible for the placement of the I.Q.I., it is not possible to utilize an I.Q.I. directly. The sensitivity of the radiographic technique to be used shall be determined separately, by radiography of a piece which is similar to the work piece under examination, but in which the surfaces are accessible.

In this test, an I.Q.I. shall be placed on each face. By comparison of the readings of the I.Q.I. sensitivity from both I.Q.I., an indication of the actual sensitivity can be obtained. Great care shall be taken that the same radiographic technique and conditions are used.

4 If all the elements (holes or wires) in the I.Q.I. are visible on the radiograph, a correct measure of sensitivity will not be obtained.

4 DETERMINATION OF I.Q.I. SENSITIVITY (IMAGE QUALITY VALUES)

The radiograph shall be examined on a film-viewing screen, constructed for this purpose. The conditions for viewing radiographs, including some tests of the operator, are detailed in separate recommendations (see section 6).

Generally the image of the I.Q.I. shall be examined in its entirety without the use of a mask to conceal any part of the image. Masks to prevent glare from other areas of the radiograph may be necessary and can be employed.

For the wire type I.Q.I., when this is laid across the weld, the discernibility shall be determined for that part of the image of the I.Q.I. which is across the weld region.

From the examination of the image of the I.Q.I. on the radiograph, the diameter of the smallest wire or hole which can be discerned is determined. In the case of the step and hole type I.Q.I., if there are two holes of the same diameter, both shall be discernible, in order that the step be considered as visible.

The image quality obtained shall be indicated on the report of the radiographic examination. This can be done in various ways, but in each case the type of indicator used shall be clearly stated, as shown on the I.Q.I.

For example :

I.Q.I. ISO/R 1027, 11 wires/1.25 mm;

I.Q.I. ISO/R 1027, 5 holes/3.2 mm.¹⁾

The designation of the I.Q.I. shall be followed by the image quality value obtained, given in one of the following ways :

- number of wires or steps visible;
- diameter of the smallest discernible wire or thickness of step;
- sensitivity obtained, in %;
- index of visibility in the case of the step and hole type of I.Q.I. (see Annex).

The image quality value obtained is valid only for the particular type of I.Q.I. used; it will not be the same for a step and hole I.Q.I. as for a wire I.Q.I.

The image quality value may be compared with acceptable values which are detailed below for the different radiographic techniques and metal thicknesses.

5.2.2 A series of radiographs or a series of readings for the same radiograph shall be accepted for examination if the image quality attained is at least 70 % of the readings for a wire diameter or step thickness equal to the values in Tables 1 to 3, provided that no reading found exceeds by more than one step the value shown in the Tables.

TABLE 1 – X-ray examination – Class B
(ISO/R 1106 and ISO/R 947)

Values in millimetres

Steel thicknesses		Visibility required	
above	under or equal to	of the hole with diameter	of wire with diameter
10	16	0.5	0.2
16	25	0.63	0.25
25	32	0.8	0.32
32	40	1.0	0.4
40	50	1.25	0.5
50	80	1.25	0.63

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TABLE 2 – Examination by gamma rays from Iridium 192

Values in millimetres

Steel thicknesses		Visibility required	
above	under or equal to	of the hole with diameter	of wire with diameter
10	16	0.8	0.32
16	25	0.8	0.4
25	32	1.0	0.5
32	40	1.0	0.5
40	60	1.25	0.63
60	80	1.25	0.8
80	100	1.6	1.0

5 ACCEPTABLE IMAGE QUALITY VALUES ON STEEL

5.1 Required values

The image quality values given in Tables 1 to 3 represent values which should be attained or improved upon if the techniques detailed in ISO documents are properly applied. They are to be regarded only as a guide to the correct use of these radiographic techniques.

The upper thickness limit of 85 mm for steel represents, with X-rays, the use of 400 kV X-rays.²⁾

For thicknesses above 60 mm the image quality values can be improved by the use of front screen materials of low atomic number and high specific densities (for instance Ni, Cu, Zn and their alloys) instead of lead front screens and with lead back screens.

5.2 Tolerances

5.2.1 All the radiographs for which the diameter of the wire or step thickness is under or equal to the values shown in Tables 1 to 3 shall be accepted for examination.

TABLE 3 – Examination by gamma rays from Cobalt 60

Values in millimetres

Steel thicknesses		Visibility required	
above	under or equal to	of the hole with diameter	of wire with diameter
25	32	1.25	0.8
32	40	1.25	1.0
40	50	1.6	1.0
50	80	1.6	1.25
80	100	2.0	1.25

1) These are not necessarily equivalent values.

2) The use of higher X-ray energies is detailed in ISO 2405.

6 VIEWING CONDITIONS FOR RADIOGRAPHS

6.1 Introduction

In deciding on an optimum film density and suitable film viewing conditions for maximum sensitivity, it is important to emphasize at the outset that film density and viewing screen brightness are inter-related parameters.

Minimum observable contrast, i.e. the minimum discernible density-difference on a film placed on an illuminated screen, depends both on the brightness of the light reaching the eye of the observer through the film and on the degree of dark-adaptation of the observer. It is reasonable to assume that the discernibility of fine detail such as low contrast lines (crack images, etc.) also depends in the same manner on the brightness of the image, as presented to the eye of the observer.

It follows therefore that it is possible to have information on a radiograph which, when it is placed on an illuminated screen of unsuitable brightness, is not visible. By changing the screen brightness (usually increasing), more detail may be made visible. Therefore "correct film density" is only meaningful on the assumption that illuminators of suitable brightness are used, and conversely suitable film-viewing conditions have to relate to the film density being used.

Most codes of good practice for radiographic inspection specify an acceptable film density which is based on the density-contrast characteristics of good commercial X-ray films. This acceptable film density is usually approximately 2.0 for film for use with metal intensifying screens, but densities as high as 3.0 are sometimes recommended. For films used with salt intensifying screens, low film densities may be specified.

Recommendations for illuminator brightness are therefore detailed for three film densities, 1.0, 2.0 and 3.0. Values of screen brightness for intermediate densities can be interpolated. Densities greater than 4 are not generally used.

In addition to screen brightness, it is necessary to consider the importance of glare. Fine-grain film increases in contrast up to a very high density (of at least 6) and it may be argued that to get maximum sensitivity such high densities should be used. If suitable high-intensity illuminators for these very high densities are built, however, there are such

serious problems with glare when films are changed or badly masked, that the inherent advantage of the high density tends to be lost.

6.2 Illuminator brightness

The luminance (or brightness) of the illuminated radiograph shall be not less than 30 cd/m^2 *, and wherever possible approximately 100 cd/m^2 or greater.

This minimum value requires the following illuminator brightnesses :

- for film density 1.0 : 300 cd/m^2 ;
- for film density 2.0 : $3\,000 \text{ cd/m}^2$;
- for film density 3.0 : $30\,000 \text{ cd/m}^2$.

The brightness of a viewing screen can be checked with most ordinary photographic exposure meters, if a suitable light meter is not available. The exposure meter shall be held with its sensitive element close to the screen and shall be set for a film speed of 100 ASA. Then a reading on the meter of an exposure of 0.01 s at $f : 10$ corresponds to a screen brightness of $1\,000 \text{ cd/m}^2$.

6.3 Colour of light

The colour of the illuminator light shall normally be white, but colours between orange and pale green are acceptable.

6.4 Diffusion of light

The light shall be diffused, but it need not be fully diffused; for example, one sheet of thin opal glass will usually be found to be adequate. (Greater thicknesses absorb more light and so reduce the screen brightness.)

6.5 Uniformity of brightness

The illuminated area shall be masked to the minimum required for viewing the radiographic image. The edges of the radiograph shall always be masked, and if the radiograph contains regions of density which are considerably less dense than the area under examination, these also shall be masked off.

6.6 Ambient light for viewing

The radiograph shall be examined in a darkened room or enclosure, with care being taken that as little light as possible is reflected off the film surface directly towards the observer.

* candela per square metre : the name nit has been used for this unit. Equivalence with other units (of the C.G.S. system) is as follows :

$$1 \text{ cd/m}^2 = \pi \text{ apostilb}$$

$$= 0.1 \pi \text{ millilambert.}$$

In practice there is usually sufficient light transmitted through a radiograph on an illuminated screen to provide ambient light for writing, etc., but, if desired, the ambient lighting can be increased, provided that the source of this light does not produce any specular reflections off the surface of the radiograph.

The luminance of a white opaque card put in place of the radiograph, due to the ambient light, shall not exceed 10 % of the luminance of the illuminated film in the area under inspection. (This can be checked with a photographic exposure meter.)

6.7 Adaptation

As adaptation depends markedly on the lighting conditions to which the observer is subject before viewing, firm rules are not possible.

As guidance, an observer coming from full sunlight should allow at least 10 min in subdued lighting before commencing viewing; from ordinary artificial room lighting, about 30 s adaptation is necessary. The adaptation time shall be one continuous period of time.

If the eyes are subject to the full brightness of the illuminator during the changing of radiographs, at least 30 s re-adaptation is necessary.

6.8 Viewing distance

The film viewing distance shall be that at which the observer passes the eyesight test detailed in 6.9, but the maximum distance shall be of the order of 40 cm.

The use of a low power magnifying lens (X 3 to X 4) of reasonable area is strongly recommended and such a lens should always be available.

6.9 Eyesight of observer

All film readers shall be checked annually for their ability to see small details at their normal film viewing distance. Wearing of reading spectacles or use of a magnifying lens may be necessary.

All film readers shall be able to read the letters and numbers of the second line on the attached chart at their normal viewing distance.

Explanatory note on reading chart

The attached photostat of a reading chart is for size-guidance only. The letters are not so clearly reproduced as on the original chart.

For the construction of a chart for this purpose, the characters shall be 0.5 mm high, in a clear letter-style such as "Univers", and the line spacing shall be 0.5 mm.

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ANNEX

THE INDEX OF VISIBILITY IN THE CASE OF STEP AND HOLE I.Q.I.

The number *b* of steps that would be visible if the visibility limit were a hole the diameter of which would conventionally and precisely be *k* % of the examined thickness, is determined.

In the latter estimate, the first hole in the counting is the hole the diameter of which is equal to or immediately next upwards to the calculated value.

$$k = 5 \text{ for the ISO step and hole indicator}^1).$$

The number *a* of steps visible on the radiograph is determined. The index of visibility is the number *N*, positive, negative or zero :

$$N = a - b$$

The greater the value of *N*, the better the image quality.

For the calculation involving *a* and *b*, it is, where required, supposed that the progression of the step indicator has been extended as necessary. Thus in the case of the I.Q.I. – ISO, 11 steps 3.2 mm indicator, if two steps/holes are visible in a radiographed thickness of 85 mm, the index of visibility is *N* = + 3.

The following relationship exists between the index *N* and the sensitivity % :

<i>N</i>	- 1	0	+ 1	+ 2	+ 3	+ 4
Sensitivity for ISO step and hole I.Q.I.	6.3 to 8 %	5 to 6.3 %	4 to 5 %	3.2 to 4 %	2.5 to 3.2 %	2 to 2.5 %

This table takes into account the values normally encountered using various techniques and with various thicknesses of steel. High values of *N* are most often obtained when large thicknesses of steel are examined, using appropriate techniques. When the thickness diminishes, it becomes increasingly difficult, if not impossible, to attain these values, so that the lowest values may correspond to the examination of small thicknesses, using ordinary techniques.

This table expresses the following mathematical relation between sensitivity *S* % and index *N* :

$$S = k \frac{1}{r^N}$$

where

r is the ratio of the preferred numbers adopted for the step thicknesses of I.Q.I. considered;

k has the value given above.

In the table above, for each value of *N*, the minimum sensitivity corresponds to the stated value *N*. The possible variation of sensitivity for a given value of *N* is due to the discontinuous nature of step grading and to the rule fixed for the calculation of *b*.

1) This figure is valid in the case of X-rays.

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