भारतीय मानक
Indian Standard

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Realtime Radioscopic Examination of Weldments

ICS 19.100

भारतीय मानक ब्यूरो
B U R E A U O F I N D I A N S T A N D A R D S
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Non-Destructive Testing Sectional Committee, MTD 21

FOREWORD

This Indian Standard was adopted by the 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 covers the practices and the measuring systems for the display under recording of radioscopic images on a television monitor.

In the formulation of this standard assistance has been derived from BS EN 13068-3 : 2001 'Non-destructive testing—Radioscopic testing — Part 3 General principles of radioscopic testing of metallic materials by X-and gamma rays' and also from AERB Guide No SG/IN-1 'Radiological safety in enclosed radiography installations'.

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

REALTIME RADIOSCOPIC EXAMINATION OF WELDMENTS

1 SCOPE

1.1 This standard covers a uniform procedure for real time radioscopic examination of weldments. This procedure describes practices and image quality measuring system for real-time, non-film detection, display and recording of radioscopic images. These images used in weld inspection are generated by ionizing radiation passing through the subject weld and producing an image on the imaging device, the image intensifier. This method applies only to the use of equipment for radioscopic examination in which the image is finally presented on a television monitor for, operator evaluation.

1.2 The techniques described in this test method provide adequate assurance for defect detectability, however for special applications, specific techniques using more stringent requirements may be needed to provide additional detection capability. This procedure does not (suggest or) specify the radioscopic extent, the quality level and the acceptance criteria, which can be decided by the contracting parties by mutual agreement.

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 are indicated below:

IS No.	*Title*
2953 : 1985	Glossary of terms used for interpretation of welds and casting radiographs (*first revision*)
13805 : 2004	General standard for qualification and certification of non-destructive testing personal (*first revision*)

3 EQUIPMENT

3.1 System Configuration

Many different radioscopic configurations are possible and it is important to understand the advantages and limitations of each. The minimum examination system configuration shall include an appropriate source of penetrating radiation, a means for positioning the test object within the radiation beam and a detection system. An electronic imaging system to display a bright, two-dimensional gray scale image of the test part at the operators control console. A digital image processing system to perform image enhancement and image evaluation functions. An archival quality image recording system. A radiation protective enclosure with appropriate safety interlocks and radiation warning system.

3.2 Radiation Source

Selection of the radiation source for a specific real-time inspection system depends upon the variables regarding the weld being examined, such as material composition and thickness and also the required rate of inspection. The suitability of the source shall be demonstrated by attainment of the required image quality. The radiation flux is a major consideration in the selection of the radiation source. For stationary or slow moving objects radiation sources with high outputs at continuous duty cycle are desired. Radiation sources can be X-rays or gamma rays. In general due to consideration for image quality with good contrast X-ray sources are widely used. X-ray sources are of following three different types. Conventional X-ray sources of focal spots size of above 1.0 mm, mini- focal sources of size 0.1-1 mm and micro-focus sources of size less than 0.1 mm:

a) Detector unsharpness;
b) Overall sensitivity required; and
c) Geometric magnifications desired (*see* **4.2**).

3.2.1 Therefore the effect of raster orientation upon the radioscopic examination system's ability to detect fine detail, regardless of orientation, must be taken in to account.

3.2.2 *Source Geometry*

The physical size of the source of radiation is a parameter that may vary considerably. One reason is the dominating unsharpness in the radiation detector. Conventional X-ray source with focal spots of 1.0 mm and larger are useful at low geometric magnification values close to 1X. Minifocal source focal spots from 0.1–1.0 mm are useful for a geometrical magnification of 1.5 - 2X. Micro-focus X-ray sources of focal spot size less than 0.1 mm are useful for geometric magnification of above X2 with high sensitivity. Using micro-focus sources, the reduced focus to object distance (FOD), the geometrical unsharpness will increase. This effect shall be compensated with increased object to detector (ODD) distance so as to achieve higher geometric magnification and radiographic sensitivity.

3.2.3 *Diaphragms and Masks*

These are used to avoid brightness in areas outside the object, which improves contrast and avoids blooming of the camera.

3.3 Imaging System

An imaging system can be described as a device or sub-system that transforms an X-ray field into a prompt response optical or electronic signal. When X-ray photons pass through the weld, they are attenuated and as a result the character of the flux field in a cross-section of the X-ray beam is changed. Variations in photon flux density and energy are most commonly encountered. The analysis of this flux is used for detection of discontinuities in the weld and castings. The field of view of the imaging system, its resolution and the dynamic inspection speed are inter-related. The resolution of the detector is fixed by its physical characteristics, so if the X-ray image is projected upon its full size (the weld and its image planes in contact), the resultant resolution shall be approximately equal to that of the detector. When the detector resolution becomes the limiting factor, the weld may be moved away from the detector and towards the source to enlarge the projected image and thus allow details to be resolved by the same detector. As the image is magnified, however, the detail contrast is reduced and its outlines are less distinct. As a general rule, X-ray magnification should not exceed 2 X except when using micro-focus X-ray source.

3.3.1 The inherent sensitivity of the imaging system may be defined as its ability to respond to small, local variations in the radiant flux to display the features of interest in the weld being examined. It would seem that a detector that can display density changes of the order of 1 to 2 percent at resolutions approaching that of radiography would satisfy all of the requirements for successful real-time radioscopic imaging.

3.3.2 The selection of the appropriate imaging system is dependent upon variables such as the size of the weld being examined and the energy and intensity of the radiation used for the examination. The suitability of the imaging system shall be demonstrated by attainment of the required image quality.

3.3.3 *Image Intensifier*

This is the most commonly used imaging device for real-time radioscopy of weld and castings. An image intensifier is a vacuum tube device, suitably packed in a metal housing. The intensifier comprises a photo-cathode input, which is a coating of multi-alkali or semiconductor layers on the inside of the input window, and a phosphor screen, which is a fluorescing phosphor coating on the inside of the output window. A portion of the incident photons striking the photo-cathode causes the release of electrons *via* the photoelectric effect. In a small electric field between the photo cathode and the small output screen the emitted electrons are accelerated and focused through concentrically arranged electron lenses. These electrons strike the coating and cause it to release light. This released light consists of many photons for every incident electron striking the photo-cathode surface. As a result of this acceleration and electro optical linear image reduction, the electrons produce diminished image with enhanced brightness on the fluorescent output screen, typically 10 000 or more times brighter than that found on the input phosphor. The basic lens converts the divergent light of the output screen into parallel light. The output end of the tube is normally designed to be optically coupled to a CCTV for readout.

3.3.4 Apart from image intensifiers, X-ray sensitive vidicons shall be used for real time radioscopy applications. These vidicons have higher spatial resolution. In addition to this, flat panel digital array detectors can also be used when better defect sensitivity and resolution is required.

4 IMAGE DISPLAY AND PROCESSING

4.1 The X-ray image converted to light image by the image intensifier is picked up by a CCTV camera, is amplified and displayed on a TV monitor. This is a raw image in analog form and is of poor quality since it contains noise. In order to eliminate the noise and to enhance the contrast and definition, it is essential to convert the image to digital format so that the data can be displayed, processed, quantified, stored, retrieved and converted back to the original analog format for video presentation. The digital image examination data shall be recorded and stored in videotape, magnetic disc or optical disc.

4.2 When employing a television image presentation, vertical and horizontal resolution are often not the same. Therefore the effect of raster orientation upon the radioscopic examination system's ability to detect fine detail, regardless of orientation, must be taken into account.

4.3 The system shall, as a minimum include the following:

a) Digitizing system,

b) Display system,

c) Image processing system, and

d) Image storage system.

5 PROCEDURE OF TESTING

5.1 Time of Examination

Unless otherwise specified by the applicable contract, the real time radioscopic examination of the weld should be performed after heat treatment.

5.2 Surface Preparation

Unless otherwise agreed upon, remove the weld bead ripple or weld surface irregularities on both the inside and outside by any suitable process so that the image of the irregularities cannot mask the image of any discontinuity.

5.3 Radioscopic Techniques

5.3.1 *Single Wall Technique*

As far as possible perform radioscopy of the weld using a technique in which the radiation passes through only one wall.

5.3.2 *Double Wall Technique*

For circumferential welds 90 mm outside diameter or less, use a technique in which the radiation passes through both walls and both walls are viewed for acceptance on the same image. Unless otherwise specified, either elliptical or superimposed projections may be used. A sufficient number of views should be taken to examine the entire weld where design or access restricts a practical technique from examining the entire weld, the agreement between contracting parties must specify necessary weld coverage.

5.3.3 For circumferential welds greater than 90 mm outside diameter use a technique in which only single wall viewing is performed. A sufficient number of views should be taken to examine the entire weld where design or access restricts a practical technique from examining the entire weld, agreement between contracting parties must specify necessary weld coverage.

5.4 Geometric Unsharpness

When performing real time radioscopic systems (RTR), the geometric unsharpness (*see* Fig. 1) of the inspection setup needs to be taken into consideration, especially when using geometric magnification. The size of the X-ray tube focal-spot and the magnification factors, namely the source-to-specimen and specimen-to-detector distances, are used to calculate the geometric unsharpness of the inspection setup. In general, the allowable geometric unsharpness limit is 1/100 of the material thickness up to a maximum of 1 mm (0.040 inch) (*see* Annex A)**.**

5.5 Radioscopic Coverage

Unless otherwise specified by the purchaser and supplier agreement, the extent of radioscopic coverage shall include 100 percent of the volume of the weld and adjacent base metal.

5.6 Examination Speed

For dynamic examination, the speed of the object motion relative to the radiation source and detector shall be controlled to ensure that the required radioscopic quality level is achieved.

5.7 Image Identification

A system shall be provided for positive identification of the image. As a minimum, the following shall appear on the image:

The name or symbol of the company performing radioscopy, the date and the weld identification number traceable to part and contract. Identify subsequent images made of a repaired area with the letter 'R'.

5.8 Location Markers

The location marker should be placed on the source side until and unless specified. Place location markers outside the weld area. The radioscopic image of the location markers for identification of part location with the images shall appear on the image without interfering with the interpretation and with such an arrangement that the complete coverage is obtained. For welds that require a series of images, to cover the full length or circumference of the weld, apply the complete set of location markers at one time, wherever possible. A reference or zero position for each series must be identified on the component. When using a double wall technique only one location marker is required in the image.

6 RADIOSCOPIC IMAGE QUALITY

The same principles apply for real time systems as for film radiography. Image quality is governed by two factors, image contrast and resolution. Since most real time systems are resolution limited a great emphasis is placed on devices that measure resolution. Therefore, many systems require several devices such as (Image Quality Indicator), IQIs and wire mesh to assure the proper image quality.

6.1 Image Quality level

Radioscopic quality level shall be determined upon agreement between the purchaser and the supplier and shall be specified in the contract. Radioscopic quality shall be specified in terms of equivalent penetrameter (IQI) sensitivity and shall be measured using IQI. The images of conventional IQI are largely dependent on contrast and are not much affected by change in unsharpness, so that it is still possible with an RTR system to obtain a very good IQI sensitivity value. However, the ability to show small planar flaws such as cracks depends on having a small unsharpness as well as a good contrast. Hence for applications such as weld inspection, it is recommended to assess the effective unsharpness with duplex wire indicator in addition to IQI sensitivity. IQI selection table may be incorporated as annexure.

6.2 Image Quality Indicator (IQI) Selection

Performance measurement using IQI shall be in accordance with the accepted industry standards describing the use of IQIs. For selection of the image quality indicator, the thickness on which the image quality indicator is based on the single wall thickness plus the lesser of the actual or allowable reinforcement. For any thickness an image quality indicator acceptable for thinner materials may be used, provided all other requirements for radioscopy are met.

6.3 Placement of IQI

Place the IQI on the source side adjacent to the weld being examined; where the weld metal is not radioscopically similar to the base material or where geometry precludes placement adjacent to the weld, place the IQI over the weld. In those cases where the physical placement of the image quality indicators on the source side is not possible, place the IQI on detector side. In case of small radioscopic field of view or other situations where it is not practical to place the IQI in the field of view with the test object and maintain it normal to the X-ray beam, the IQI may be imaged immediately before and after the test object examination.

6.4 Number of IQIs

Place at least one IQI in the area of interest representing an area in which the brightness is relatively uniform. If the image brightness in an area of interest differs by more than the agreed amount between the purchaser and the supplier, use two IQIs. One of the IQI, to demonstrate acceptable image quality in the darkest portion of the image and the other one to demonstrate acceptable image quality in the lightest portion of the image. When a series of images are made under identical conditions, it is permissible for the image quality indicators to be used only on the first and last images in the series, provided this is agreed upon between the purchaser and the supplier.

6.5 Duplex Wire Image Quality Indicator

For measuring image unsharpness, it is a particularly useful tool for establishing and monitoring the performance of real time radioscopic systems. This IQI consists of 13 wire pairs embedded in rigid plastic. The wires are of platinum and tungsten, and are exactly spaced to correspond to the diameter of each pair. The degree of unsharpness is indicated by the number of wire pairs that can be seen. As unsharpness increases, the wires merge to form a single image. Each IQI is engraved with a unique serial number and is supplied with a declaration of conformity together with instructions in a storage box. Annex B shows the picture of duplex wire type image quality indicator containing unsharpness values corresponding to various wire diameters in the duplex wire.

7 SYSTEM PERFORMANCE MEASUREMENT

7.1 Real time radioscopic system performance parameters shall be determined initially and monitored regularly with the system in operation to assure consistent results. The system performance shall be monitored at sufficiently scheduled intervals to minimize the probability of time-dependent performance variations. System performance tests require the use of the calibration block, line pair test pattern and step wedge.

Also, for real time radioscopy of weldments with digital array type detectors, image unsharpness or also called as projected unsharpness (U_{im}) (that is similar to total unsharpness (U_t) in X-ray film radiography) shall be calculated from the following equation:

$$U_{im} = \left(\frac{1}{m}\right)\sqrt[3]{(ug)^3 + \left(1.6\,SR_b\right)^3}$$

where

m = magnification,

ug = geometric unsharpness, and

SR_b = basic spatial resolution.

In the above equation, to determine the basic spatial resolution (SR_b) of the X-ray detector, duplex wire without any absorbing material shall be used. SR_b shall be calculated in a real time digital detector where the wire pair that can be seen in the image with minimum contrast modulation of 20 percent.

7.2 Measurement With a Calibration Block

The calibration block may be an actual test object with known features that are representative of the range of features to be detected, or may be fabricated to simulate the test object with a suitable range of test features. The calibration blocks containing known natural defects are useful in a single task basis. The calibration block should be made of the same material with the similar dimensions. It is permissible to produce calibration block in sections. Real time radioscopic technique utilised for the calibration block shall be identical to those used for the actual examination of the test object.

7.3 Calibrated Line Pair Test Pattern and Step Wedge

A calibrated line pair test pattern and step wedge shall be used to determine and track radioscopic system performance in terms of spatial resolution and contrast sensitivity. The line pair test pattern shall be used without an additional absorber to evaluate the system resolution. The step wedge shall be used to evaluate system contrast sensitivity. The step wedge must be made of the same material as the test object with steps representing 100 percent, 99 percent, 98 percent, and 97 percent of both the thickest and thinnest material section to be inspected. Additional step thicknesses are permissible.

7.4 The line pair test pattern and the step wedge tests shall be conducted in a manner similar to performance measurements for the IQI or the calibration block. It is permissible to adjust the X-ray energy and intensity to obtain a usable line pair test pattern image brightness. Contrast sensitivity shall be evaluated at the same energy and the intensity levels as are used for the radioscopic technique.

7.5 A system that exhibits a spatial resolution of three line pairs/mm (lp/mm) a thin section contrast sensitivity of 3 percent, and a thick section contrast sensitivity of 2 percent may be said to have an equivalent performance level of 3 percent -2 percent - 3 lp/mm.

7.6 A written procedure is required and shall contain, as a minimum, the following system performance parameters:

a) Image digitising parameters-modular transfer function (MTF), line pair resolution, contrast sensitivity and dynamic range;
b) Image display parameters-format, contrast and magnification;
c) Image processing parameters that are used;
d) Storage-Identification, Data compression and media (including precautions to be taken to avoid data loss); and
e) Analog output formats.

8 EVALUATION

The digital image shall be evaluated using appropriate monitor luminosity display techniques, room lighting to ensure proper visualisation of details. The quality of system performance is determined by the component specified in **6**. The digital images shall be free of system induced artefacts in the area of interest that could mask or be confused with the image of any discontinuity. To assist in proper interpretation of the digital examination data, details of the technique used shall accompany the data. All mandatory radioscopic examination accept/reject decisions shall be based upon the assessment of static images. Dynamic or in-motion imaging may be used to gain useful information about the test object. However, the final assessment of image information shall be made in the static mode.

9 STORAGE OF RADIOSCOPIC IMAGES

The radioscopic images can be recorded and stored on videotape, magnetic disc, optical disc, Electronic Digital Memory such as ROM (Read Only Memory) or EPROM (Erasable Programmable Read Only Memory). The digital recording on magnetic disc to store the image of the test object are characterised by limited storage capacity at video frame rates, therefore limiting the ability to capture the test part motion in dynamic radioscopic systems. Digital recording on optical disc used to store the image of the test object digitally; offers larger storage capacity than magnetic disc or tape.

When storage is required by the contract, the images should be stored in a format stipulated by the applicable contract or the agreement between the purchaser and the supplier. The image storage duration and location shall be agreed between the purchaser and the supplier.

10 PERSONNEL QUALIFICATION

NDT personnel performing the test shall be qualified to Level I / Level II in accordance with IS 13805.

11 RADIATION SAFETY

Radiation safety of the personnel working with the radioscopy system as well for other non-occupational workers shall be ensured as per the guidelines given in the AERB guide SG/IN-1.

12 RECORDS

The following radiographic records shall be maintained as agreed to between the purchaser and the supplier:

a) Radioscopic standard shooting sketch, including examination geometry, source to-object distance, object-to-detector distance and orientation;
b) Material and thickness range examined;
c) Equipment used, including specification of source parameters (such as voltage, current, focal spot size) and imaging equipment parameters (such as detector size, field of view, electronic magnification, camera black level, gain, etc) and display parameters;
d) Image quality indicator placement;
e) Image processing parameters;
f) Image storage data;
g) Weld repair documentation; and
h) Performa for reporting 'Welding radiographic examination instruction sheet' (*see* Annex C).

ANNEX A

(*Clause* 5.4)

GEOMETRIC UNSHARPNESS

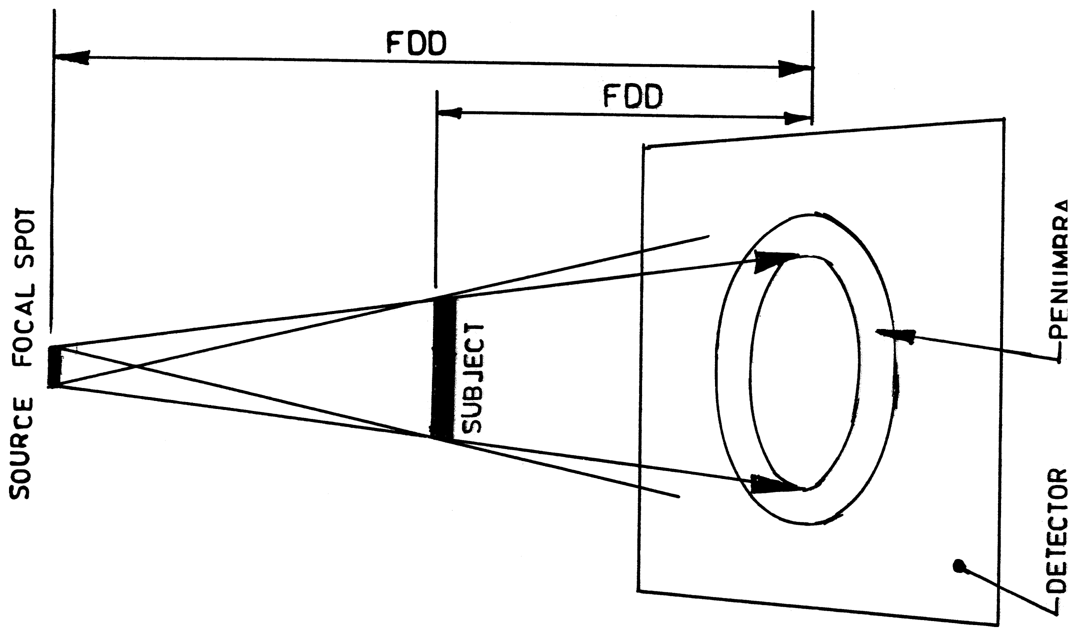
$$\text{Geometric Sharpness } (\mu_g) = d.\frac{(FDD - FOD)}{FOD}$$

or

$$\mu_g = d.\left(\frac{FDD}{FOD} - 1\right)$$

$$\mu_g = d.\,(M - 1)$$

with *d* being focal spot.



where

μg = geometrical unsharpness,

FDD = focal spot to detector distance,

FOD = focal spot to object distance, and

M = them magnification factor = *FDD* / *FOD*.

(For *FDD* = *FOD*, M becomes 1)

FIG. 1 CONCEPT OF GEOMETRIC UNSHARPNESS

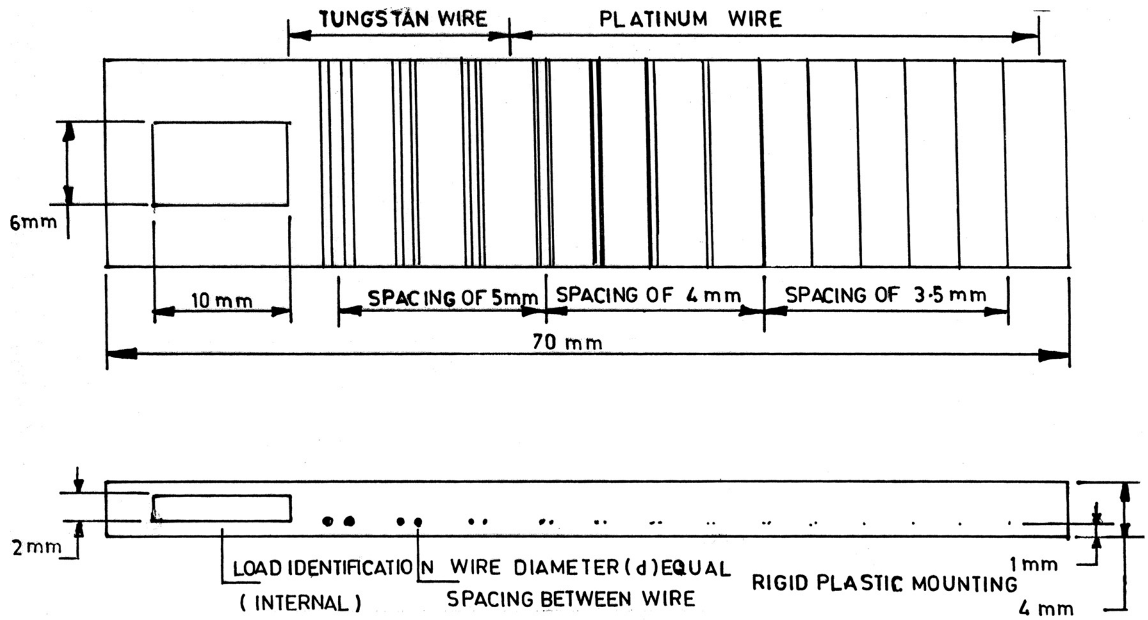
ANNEX B

(*Clause* 6.5)

DUPLEX WIRE UNSHARPNESS INDICATOR

B-1 Figure 2 shows the duplex wire type along with element No. wire diameter and spacing unsharpness.

All dimensions in millimetres.



(*D* = Duplex)	Unsharpness	Wire Diameter and Spacing
13d	0.10	0.050
12d	0.13	0.063
11d	0.16	0.080
10d	0.20	0.100
9d	0.26	0.130
8d	0.32	0.160
7d	0.40	0.200
6d	0.50	0.250
5d	0.64	0.320
4d	0.80	0.400
3d	1.00	0.500
2d	1.26	0.630
1d	1.60	0.800

FIG. 2 DUPLEX WIRE TYPE IMAGE QUALITY INDICATOR

ANNEX C

[*Clause* 12(h)]

WELDING RADIOGRAPHIC EXAMINATION INSTRUCTION SHEET

Date .... Revision level ....

Purchaser of radioscopic services ....

Supplier of radioscopic services..

Radioscopic shooting sketch provided by ....

Date of shooting sketch preparation ....

Entity performing radioscopy ....

Welding information..

Drawing number ....

Identification number ....

Descriptive name ....

Material type and specification ....

Heat number ....

Pattern number ....

Welding condition when radioscopy is performed ....

Method for determining image quality ....

Radioscopic location	1	2	3	4
Single-Wall thickness	....	....	....	....
finished thickness	....	....	....	....
Double-Wall thickness	....	....	....	....
finished thickness	....	....	....	....
IQI	....	....	....	....
Required sensitivity	....	....	....	....
Calibration block	....	....	....	....
Required feature	....	....	....	....
Actual test part	....	....	....	....
Required feature	....	....	....	....
Required feature	....	....	....	....
X-ray kV range or radioisotope Energy	....	....	....	....
X-Ray mA range or radioisotope energy	....	....	....	....
Focal spot size	....	....	....	....
Magnification mode	....	....	....	....
Source- detector dist.	....	....	....	....
Object-detector dist	....	....	....	....
Accept/Reject std.	....	....	....	....
Severity level	....	....	....	....

Approval for use ....

Date ....

Bureau of Indian Standards

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

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Amendments Issued Since Publication

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