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**Non-destructive testing of steel tubes —  
Part 7:  
Digital radiographic testing of the weld  
seam of welded steel tubes for  
the detection of imperfections**

**iTeh STANDARD PREVIEW** —  
*Essais non destructifs des tubes en acier —*

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*Partie 7: Contrôle radiographique numérique du cordon de soudure  
des tubes en acier soudés pour la détection des imperfections*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10893-7 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 19, *Technical delivery conditions for steel tubes for pressure purposes*.

ISO 10893 consists of the following parts, under the general title *Non-destructive testing of steel tubes*:

- *Part 1: Automated electromagnetic testing of seamless and welded (except submerged arc-welded) steel tubes for the verification of hydraulic leaktightness*
- *Part 2: Automated eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections*
- *Part 3: Automated full peripheral flux leakage testing of seamless and welded (except submerged arc-welded) ferromagnetic steel tubes for the detection of longitudinal and/or transverse imperfections*
- *Part 4: Liquid penetrant inspection of seamless and welded steel tubes for the detection of surface imperfections*
- *Part 5: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections*
- *Part 6: Radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*
- *Part 7: Digital radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*
- *Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections*
- *Part 9: Automated ultrasonic testing for the detection of laminar imperfections in strip/plate used for the manufacture of welded steel tubes*
- *Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections*
- *Part 11: Automated ultrasonic testing of the weld seam of welded steel tubes for the detection of longitudinal and/or transverse imperfections*
- *Part 12: Automated full peripheral ultrasonic thickness testing of seamless and welded (except submerged arc-welded) steel tubes*

## Introduction

Digital radiography has been used for the testing of longitudinal weld seams in submerged arc-welded steel tubes for some years. Digital radiography can be automated, and is considered to be more environmentally friendly than film-based radiographic techniques.

Digital radiography maintains the levels of security and availability afforded by X-ray film testing, which have been in place for many years. Images can be made available in a fraction of the time previously taken by film-based techniques, and usually at a lower exposure level and increased detector unsharpness when compared to film.

The storage and handling of digital images maintain the same levels of integrity available from film-based techniques, yet gain all the benefits associated with comprehensive data storage and retrieval systems.

Imaging systems are constantly under development, and an important aspect of this part of ISO 10893 is to qualify the use of those alternative systems currently available. This part of ISO 10893 describes the steps required to deliver these benefits.

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# Non-destructive testing of steel tubes —

## Part 7:

# Digital radiographic testing of the weld seam of welded steel tubes for the detection of imperfections

## 1 Scope

This part of ISO 10893 specifies the requirements for digital radiographic X-ray testing by either computed radiography (CR) or radiography with digital detector arrays (DDA) of the longitudinal or helical weld seams of automatic fusion arc-welded steel tubes for the detection of imperfections. This part of ISO 10893 specifies acceptance levels and calibration procedures.

This part of ISO 10893 can also be applicable to the testing of circular hollow sections.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5576, *Non-destructive testing — Industrial X-ray and gamma-ray radiology — Vocabulary*

ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

ISO 11484, *Steel products — Employer's qualification system for non-destructive testing (NDT) personnel*

ISO 17636, *Non-destructive testing of welds — Radiographic testing of fusion-welded joints*

ISO 19232-1, *Non-destructive testing — Image quality of radiographs — Part 1: Image quality indicators (wire type) — Determination of image quality value*

ISO 19232-2, *Non-destructive testing — Image quality of radiographs — Part 2: Image quality indicators (step/hole type) — Determination of image quality value*

ISO 19232-5, *Non-destructive testing — Image quality of radiographs — Part 5: Image quality indicators (duplex wire type) — Determination of image unsharpness value*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5576 and ISO 11484 and the following apply.

### 3.1

#### **tube**

hollow long product open at both ends, of any cross-sectional shape

### 3.2

#### **welded tube**

tube made by forming a hollow profile from a flat product and welding adjacent edges together, and which after welding can be further processed, either hot or cold, into its final dimensions

**3.3 manufacturer**  
organization that manufactures products in accordance with the relevant standard(s) and declares the compliance of the delivered products with all applicable provisions of the relevant standard(s)

**3.4 agreement**  
contractual arrangement between the manufacturer and purchaser at the time of enquiry and order

## 4 General requirements

**4.1** Unless otherwise specified by the product standard or agreed on by the purchaser and manufacturer, a radiographic inspection shall be carried out on welded tubes after completion of all the primary manufacturing process operations (rolling, heat treating, cold and hot working, sizing and primary straightening, etc.).

**4.2** This inspection shall be carried out by trained operators qualified in accordance with ISO 9712, ISO 11484 or equivalent. Competent personnel, nominated by the manufacturer, shall supervise all inspection. In the case of third-party inspection, this shall be agreed on between the purchaser and manufacturer.

The operating authorization issued by the employer shall be according to a written procedure. Non-destructive testing (NDT) operations shall be authorized by a level 3 NDT individual approved by the employer.

NOTE The definition of levels 1, 2 and 3 can be found in appropriate standards, e.g. ISO 9712 and ISO 11484.

**4.3** The tubes under test shall be sufficiently straight and free of foreign matter as to ensure the validity of the test. The surfaces of the weld seam and adjacent parent metal shall be sufficiently free of such foreign matter and surface irregularities which would interfere with the interpretation of the radiographs.

Surface grinding is permitted in order to achieve an acceptable surface finish.  
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**4.4** In cases where the weld reinforcement is removed, markers, usually in the form of lead arrows, shall be placed on each side of the weld such that its position can be identified on the radiographic image. Alternatively, an integrated automatic positioning system may be used to identify the position of the weld.

**4.5** Identification symbols, usually in the form of lead letters, shall be placed on each section of the weld seam radiograph such that the projection of these symbols appears in each radiographic image to ensure unequivocal identification of the section. Alternatively, an integrated automatic positioning system may be used to identify the position of each radiographic image along the pipe weld.

**4.6** Markings shall be displayed on the recorded radiographic images to provide reference points for the accurate relocation of the position of each radiograph. Alternatively, the automated measured image position may be displayed on the digital image viewing screen by software for accurate position relocation.

**4.7** When carrying out radiography on a continuous length of a weld, the pipe or pipe wall shall pass between the X-ray tube and detector at a speed which is sufficient to allow accurate defect detection, or the pipe shall move in start-stop mode and digital radiographs shall be taken when the pipe is not moving.

## 5 Equipment

The following digital imaging methods can be used in replacement of radiographic film:

- a) computed radiography (CR) with storage phosphor imaging plates (e.g. EN 14784-1 and EN 14784-2);
- b) radiology with digital detector arrays (e.g. ASTM E2597);
- c) digital radioscopy with image integration (e.g. EN 13068-1, EN 13068-2 and EN 13068-3).



## 6 Test method

6.1 The weld seam shall be tested by a digital radiographic technique, corresponding to 5 a) to 5 c).

6.2 Two image quality classes, A and B, conforming to ISO 17636, shall be specified as:

- class A: radiographic examination technique with standard sensitivity;
- class B: radiographic technique with enhanced sensitivity.

NOTE Image quality class A is used for most applications. Image quality class B is intended for applications where increased sensitivity is required to reveal all the imperfections being detected.

The required image quality class should be stated in the relevant product standard.

6.3 The digital image displayed shall meet the required quality class A or B.

6.4 The beam of radiation shall be directed at the centre of the section of the weld seam under examination and shall be normal to the tube surface at that point.

6.5 The diagnostic length shall be such that the increase in penetrated thickness at the ends of the useful length of the sensitive detector input screen shall not exceed the penetrated thickness at the centre of the detector by more than 10 % for image quality class B or by more than 20 % for image quality class A, provided the specific requirements of 6.9 and Clause 7 are satisfied.

6.6 The single wall penetration technique shall be used. When the single wall technique is impracticable for dimensional reasons, the use of the double wall penetration technique may be used, by agreement, if the required sensitivities can be shown to be achievable.

6.7 The separation between the detector and the weld surface shall be as small as possible for contact technique (no magnification).

The minimum value of the source-to-weld distance,  $f$ , shall be selected such that the ratio of this distance to the effective focal spot size,  $d$ , i.e.  $f/d$ , conforms to the values given by the following formulae (contact technique):

for image quality class A:

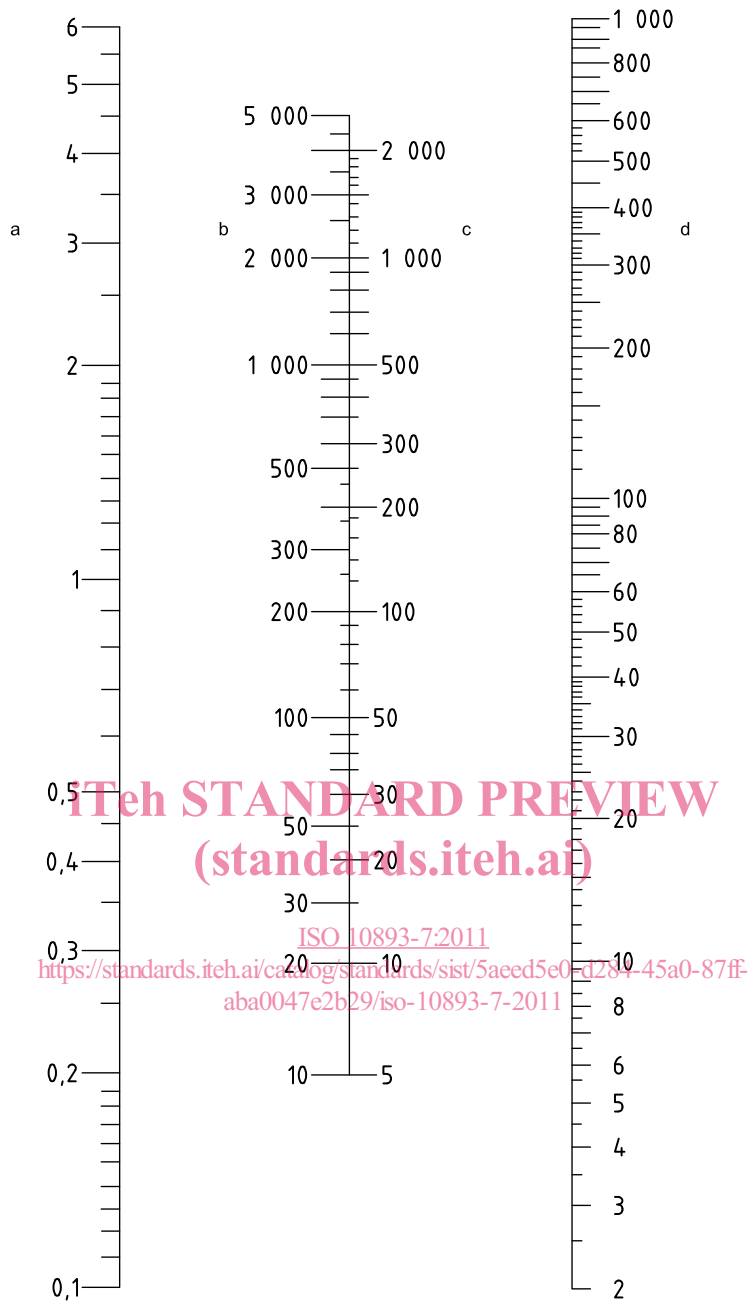
$$\frac{f}{d} \geq 7,5 \times b^{2/3} \quad (1)$$

for image quality class B:

$$\frac{f}{d} \geq 15 \times b^{2/3} \quad (2)$$

where  $b$  is the distance between the source side of the weld and the sensitive surface of the detector, in millimetres.

NOTE These relationships are presented graphically in Figure 1.



- a Effective focal spot size,  $d$ , in millimetres.
- b Minimum source to weld distance,  $f$ , for class B, in millimetres.
- c Minimum source to weld distance,  $f$ , for class A, in millimetres.
- d Weld-to-detector distance,  $b$ , in millimetres.

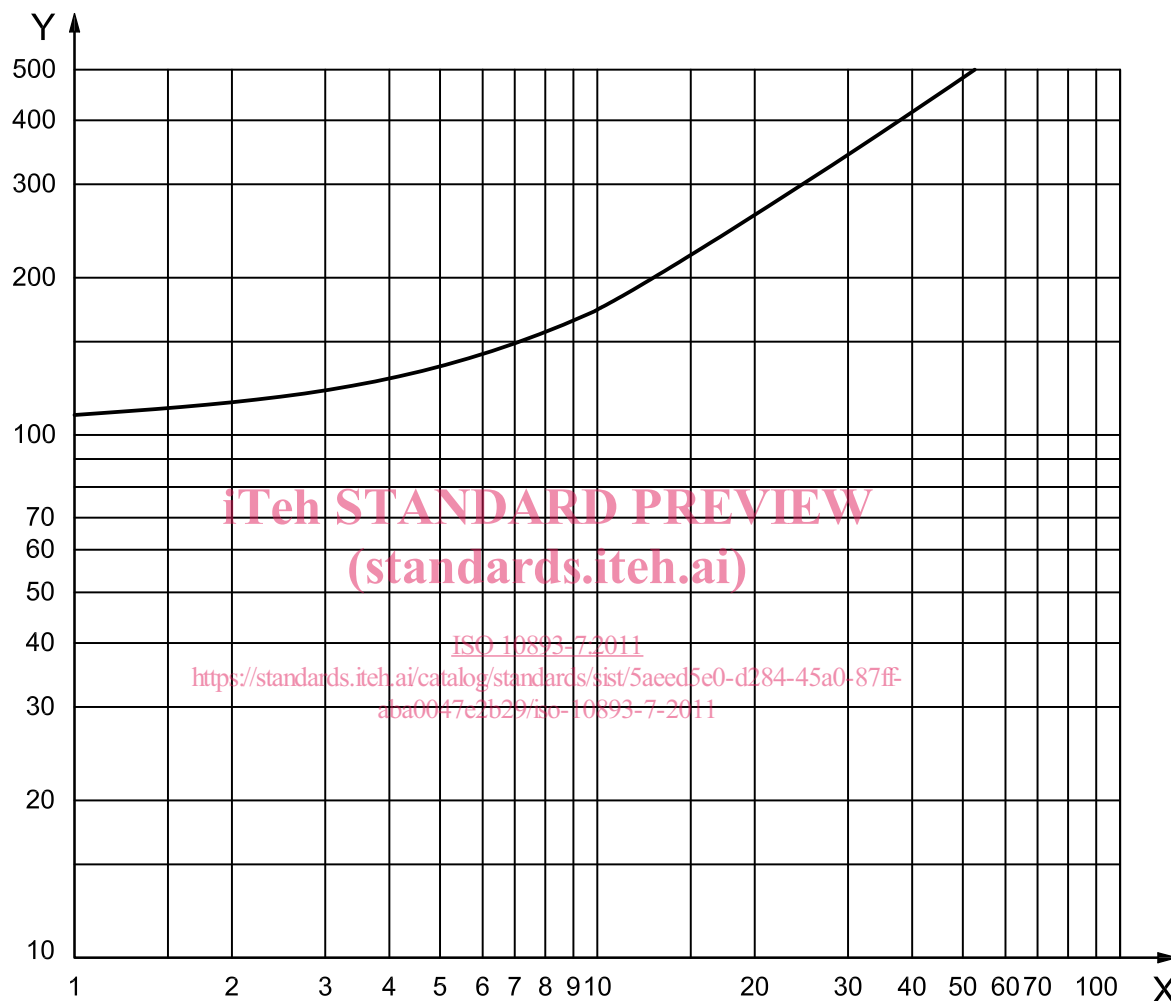
**Figure 1 — Nomogram for determination of minimum source-to-weld distance,  $f$ , in relation to weld-to-detector distance,  $b$ , and the effective focal spot size,  $d$**

**6.8** An obstacle to the implementation of DDA systems is the large ( $> 50 \mu\text{m}$ ) pixel size of the array compared to the small grain size in film (which leads to film having very high spatial resolution).

It can, therefore, not be possible to achieve the required geometric resolution with a setup typically used for film radiography. This difficulty may be circumvented by using geometric magnification to achieve the required geometric resolution or by making use of the compensation principle [increasing the signal-to-noise ratio (SNR) in the image] described in 7.1. Any combination of these measures is allowed.

**6.9** Exposure conditions, including X-ray tube voltage, shall achieve the image quality indicator (IQI) requirements in Clause 7. Image contrast and brightness may be adjusted as required for digital image viewing.

**6.10** To maintain sufficient contrast sensitivity, the X-ray tube voltage should not exceed the maximum values given in Figure 2. A voltage above the values shown is allowed, as long as the minimum sensitivity is obtained.



#### Key

X penetrated thickness, mm

Y X-ray voltage, kV

**Figure 2 — Maximum X-ray voltage for X-ray devices up to 500 kV as a function of penetrated thickness**

## 7 Image quality

**7.1** The image quality shall be determined by the use of IQIs of the type specified in ISO 19232-1, ISO 19232-2 and ISO 19232-5, and agreed on between the purchaser and manufacturer. The appropriate IQI shall be placed on the source side of the weld on the base material adjacent to the weld. In the case of a wire type IQI, at least 10 mm of the wires shall be visible on the parent material (see Figures 3 and 4).