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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

Essais non destructifs des tubes en acier —
Partie 7: Contrôle par radiographie 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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 10893-7:2011), which has been technically revised. The main changes compared with the previous edition are as follows:

a) some terms and definitions from ISO 17636-2 have been included;

b) a safety warning for X and gamma rays has been added at the end of Clause 4;

c) Figure 2 has been aligned with ISO 17636-1 up to 1 000 kV;

d) the symbols for mathematical formula have been changed in accordance with the ISO/IEC Directives;

e) it has been clarified in 4.7 when the detector size is smaller than the applicable weld length;

f) "contact technique" has been deleted from the test method in Clause 6;

g) a reference to ISO 17636-2 has been added in 6.8 for additional details related to spatial resolution;

h) the requirements for duplex wire IQI position have been added in Clause 7;

i) a reference to ISO 17636-2 for the calibration of DDAs has been added in Clause 8;

j) Figure 4 and the figures in Annex A have been revised.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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 document is to qualify the use of those alternative systems currently available. This document describes the steps required to deliver these benefits.

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

It can also be applicable to the testing of circular hollow sections.

NOTE As an alternative, see ISO 10893-6 for film-based radiographic X-ray testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 NDT personnel*

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

ISO 17636-2:2013, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors*

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

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

ISO 19232-5, *Non-destructive testing — Image quality of radiographs — Part 5: Determination of the image unsharpness and basic spatial resolution value using duplex wire-type image quality indicators*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
tube
hollow long product open at both ends, of any cross-sectional shape

3.2
welded tube
tube (3.1) 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 conformity of the delivered products with all applicable provisions of the relevant standard(s)

3.4
agreement
contractual arrangement between the *manufacturer* (3.3) and the purchaser at the time of enquiry and order

3.5
signal-to-noise ratio
SNR
S/N
ratio of mean value of the linearized grey values to the standard deviation of the linearized grey values (noise) in a given region of interest in a digital image

[SOURCE: ISO 17636-2:2013, 3.10, modified — The symbol *S/N* has been added.]

3.6
basic spatial resolution of a digital detector
$R_{bs}^{detector}$

resolution that corresponds to half of measured detector unsharpness in a digital image and to the effective pixel size, and indicates the smallest geometrical detail, which can be resolved with a digital detector at a magnification equal to one

Note 1 to entry: For this measurement, the duplex wire image quality indicator (IQI) is placed directly on the digital detector array or imaging plate.

Note 2 to entry: The measurement of unsharpness is described in ISO 19232-5, see also ASTM E2736 and ASTM E1000.

[SOURCE: ISO 17636-2:2013, 3.8, modified — The symbol has been changed from $SR_b^{detector}$.]

3.7
representative quality indicator
RQI
real part, or a fabrication of similar geometry in radiologically similar material to a real part, that has features of known characteristics that represent those features of interest for which the parts to be purchased are being examined

[SOURCE: ASTM E1817:2008]

3.8
digital detector array system
DDA system
electronic device converting ionizing or penetrating radiation into a discrete array of analogue signals, which are subsequently digitized and transferred to a computer for display as a digital image corresponding to the radiologic energy pattern imparted upon the input region of the device

[SOURCE: ISO 17636-2:2013, 3.3]

4 General requirements

4.1 Unless otherwise specified by the product standard or agreed on by the manufacturer and the purchaser, 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 who are certified (e.g. ISO 9712) or qualified (e.g. ISO 11484 or ASNT SNT-TC-1A), and supervised by competent personnel nominated by the manufacturer. In the case of third-party inspection, this shall be agreed on between the manufacturer and the purchaser.

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 definitions of levels 1, 2 and 3 can be found in the 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.

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 the detector size is smaller than the applicable weld length, the pipe or the detector shall move into start-stop mode and digital radiographs shall be taken when the pipe is not moving.

WARNING — Exposure of any part of the human body to X-rays or gamma-rays can be highly injurious to health. Wherever X-ray equipment or radioactive sources are in use, appropriate safety measures shall be applied.

Local, national or international safety precautions when using ionizing radiation shall be strictly applied.

5 Test equipment

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

a) CR with storage phosphor imaging plates (e.g. EN 14784-1 and EN 14784-2);

b) radiology with DDAs (e.g. ASTM E2597-07 and ASTM E2698);

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 Clause 5 a) to c).

6.2 Two image quality classes, A and B, conforming to ISO 17636-2, shall be specified:

— 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 image 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 If the geometric magnification technique (see 6.8) is not used, the detector shall be placed as close to the object as possible.

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 Formulae (1) and (2):

for image quality class A:

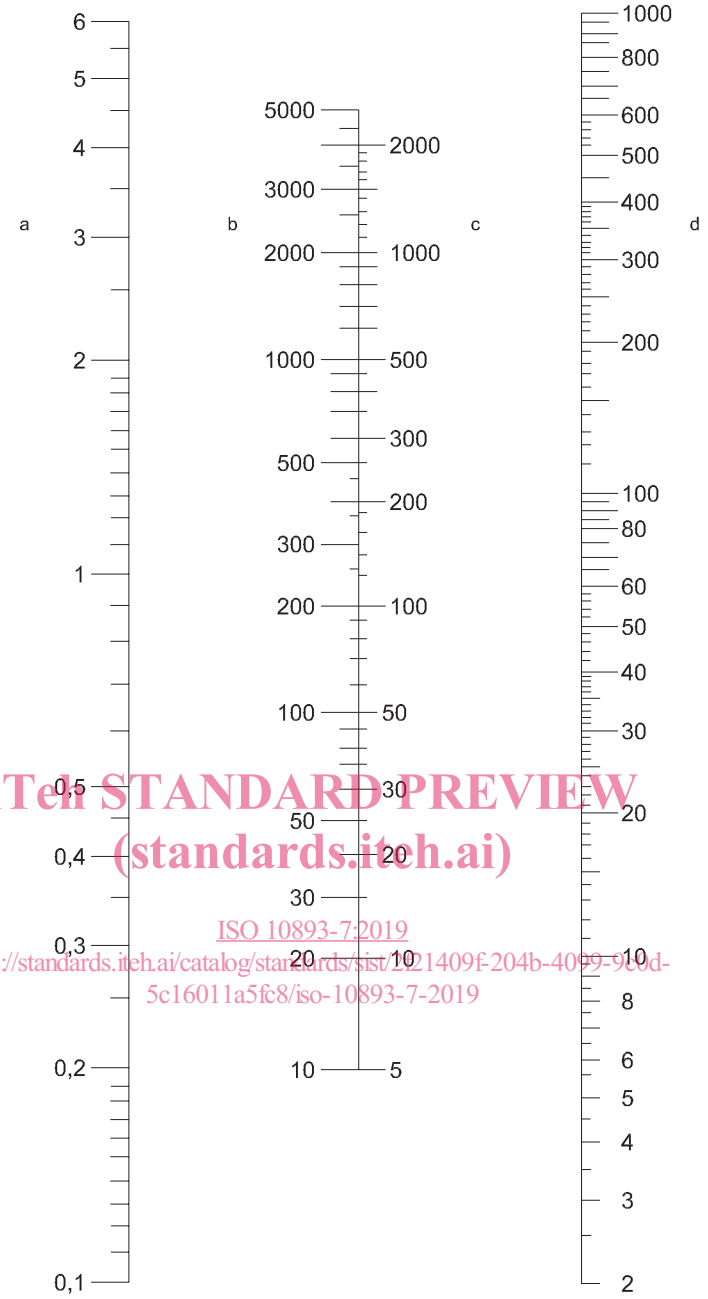
$$\frac{f}{d} \geq 7{,}5 \times b^{2/3} \tag{1}$$

for image quality class B:

$$\frac{f}{d} \geq 15 \times b^{2/3} \tag{2}$$

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 µm) 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