INTERNATIONAL STANDARD

ISO 17635

Second edition
2010-03-01

Non-destructive testing of welds — General rules for metallic materials

Contrôle non destructif des assemblages soudés — Règles générales pour les matériaux métalliques

Reference number
ISO 17635:2010(E)

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Published in Switzerland

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Foreword

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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 17635 was prepared by the European Committee for Standardization (CEN) Technical Committee TC 121, *Welding*, in collaboration with Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 17635:2003), which has been technically revised.

Requests for official interpretations of any aspect of this International Standard should be directed to the Secretariat of ISO/TC 44/SC 5 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

Non-destructive testing of welds — General rules for metallic materials

1 Scope

This International Standard gives guidelines for the choice of non-destructive testing (NDT) methods for welds and evaluation of the results for quality control purposes, based on quality requirements, material, weld thickness, welding process, and extent of testing.

This International Standard also specifies general rules and standards to be applied to the different types of testing, for either the methodology or the acceptance level for metallic materials.

Acceptance levels cannot be a direct interpretation of the quality levels defined in ISO 5817 or ISO 10042. They are linked to the overall quality of the produced batch of welds.

Requirements for acceptance levels for NDT comply with quality levels stated in ISO 5817 or ISO 10042 (moderate, intermediate, stringent) only on a general basis and not in detail for each indication.

Annex A gives correlations between quality, NDT and acceptance level standards.

Annex B gives an overview of the standards linked to quality levels, acceptance levels, and NDT methods.

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 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

ISO 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

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

ISO 10042, *Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections*

ISO 10675-1, *Non-destructive testing of welds — Acceptance levels for radiographic testing — Part 1: Steel, nickel, titanium and their alloys*

ISO 10675-2, *Non-destructive testing of welds — Acceptance levels for radiographic testing — Part 2: Aluminium and its alloys*

ISO 10863[1)], *Welding — Use of time-of-flight diffraction technique (TOFD) for testing of welds*

ISO 11666, *Non-destructive testing of welds — Ultrasonic testing of welded joints — Acceptance levels*

1) To be published.

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

ISO 17637, *Non-destructive testing of welds — Visual testing of fusion-welded joints*

ISO 17638, *Non-destructive testing of welds — Magnetic particle testing*

ISO 17640, *Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment*

ISO 17643, *Non-destructive testing of welds — Eddy current testing of welds by complex-plane analysis*

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

ISO 23277, *Non-destructive testing of welds — Penetrant testing of welds — Acceptance levels*

ISO 23278, *Non-destructive testing of welds — Magnetic particle testing of welds — Acceptance levels*

ISO 23279, *Non-destructive testing of welds — Ultrasonic testing — Characterization of indications in welds*

EN 473, *Non-destructive testing — Qualification and certification of NDT personnel — General principles*

EN 13068-3, *Non-destructive testing — Radioscopic testing — Part 3: General principles of radioscopic testing of metallic materials by X- and gamma rays*

EN 14784-2, *Non-destructive testing — Industrial computed radiography with storage phosphor imaging plates — Part 2: General principles for testing of metallic materials using X-rays and gamma rays*

EN 15617, *Non-destructive testing of welds —Time-of-flight diffraction technique (TOFD) — Acceptance levels*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
testing level
degree of thoroughness and selection of parameter settings with which a testing method is applied

[ISO/TR 25901:2007 [2], 2.376]

NOTE Different levels correspond to different sensitivities and/or probabilities of detection. The selection of testing levels is normally related to the quality requirements.

3.2
testing organization
internal or external organization carrying out non-destructive testing

NOTE Adapted from ISO/TR 25901:2007 [2], 2.377.

3.3
indication
⟨non-destructive testing⟩ representation or signal from a discontinuity in the format allowed by the non-destructive testing method used

NOTE Adapted from ISO/TR 25901:2007 [2], 2.193.

3.4
internal discontinuity
⟨non-destructive testing of welds⟩ discontinuity that is not open to a surface or not directly accessible

3.5
quality level
description of the qualities of a weld on the basis of type, size, and amount of selected imperfections

[ISO/TR 25901:2007 [2], 2.294]

3.6
inspection lot
〈non-destructive testing of welds〉 group of welds which is expected to show a uniform quality

NOTE 1 Group members can be a part of a weld, a full weld or several welds.

NOTE 2 The uniform quality can be due to welding procedure applied, material, type of joint, welder, environmental conditions during execution, time period or other items affecting the quality.

4 Abbreviated terms

For the purposes of this International Standard, the abbreviations given in Table 1 apply.

Table 1 — Abbreviations

Testing method	Abbreviation
Eddy current testing	ET
Magnetic particle testing	MT
Penetrant testing	PT
Radiographic testing	RT
Ultrasonic testing	UT
Visual testing	VT

5 Limitations

5.1 Stage of manufacture

This International Standard has been prepared for the testing of completed welds (see 10.3). Testing of parent materials prior to welding or between welding sequences is not covered by this International Standard. It is, however, recommended that such testing be performed in accordance with the reference standards for methods and acceptance levels.

5.2 Extent of testing

The extent of testing shall be given in an application standard or defined in a specification.

5.3 Materials

This International Standard includes requirements for testing of fusion welds in the following materials, their alloys and their combinations:

a) steel;

b) aluminium;

c) copper;

d) nickel;

e) titanium.

The use of this International Standard for other metallic materials shall be specified.

6 Personnel qualification

Personnel performing NDT and the evaluation of the results for final acceptance of welds shall be qualified in accordance with EN 473 or ISO 9712 or equivalent at an appropriate level in the relevant industrial sector.

7 Testing organization

The testing organization should be organized independently of the production and its activities should be controlled by a quality assurance system.

8 Documentation

8.1 Documentation prior to testing

Prior to testing, all necessary preliminary information required by the testing method standards shall be provided.

8.1.1 Written procedures

All testing shall be performed in accordance with written procedures as required by the standard for the individual testing method or as specified.

8.1.2 Testing plan

It can be necessary to carry out additional testing including more than one NDT method (other than visual testing) or multiple applications of one method. In such cases, all methods used shall be defined in a testing plan, which shall determine the sequence and extent of testing and other relevant aspects for control of testing and other related activities.

8.2 Documentation after testing

8.2.1 Records of individual testing

All testing shall be recorded as required by the referred standard for the relevant testing method.

8.2.2 Final report

For each component or group of components, a final report shall contain the information required by the testing plan and shall as a minimum include:

a) reports required by the standards for the individual testing method;

b) identification of the component;

c) reference to the individual testing records, including status (not inspected, accepted, rejected);

d) identification of welds examined and/or reference to documents identifying these welds;

e) system for marking of the individual welds and/or reference to documents indicating the description of system used for the coordination of the testing;

f) identification of personnel and organizations that have performed the testing;

g) record of deviations from the applied standard regarding testing technique and acceptance levels.

9 Selection of testing method

9.1 General

This International Standard determines requirements for selection of testing methods for various types of materials and types of fusion welds. These methods may be used alone or in combination in order to give the required result.

Before selecting testing methods and levels, the following items should be considered:

a) welding processes;

b) parent metal, welding consumable and treatment;

c) joint type and geometry;

d) component configuration (accessibility, surface condition, etc.);

e) quality levels;

f) discontinuity type and orientation expected.

If necessary, testing methods and levels other than those listed in Annex A may be selected. If an application standard only requires another selection of methods, testing levels listed in Annex A can be used as appropriate. Such alterations shall be specified.

9.2 Butt- and T-joints with full penetration

The generally accepted methods for testing of welds are given in Table 2 for surface discontinuities and in Table 3 for internal discontinuities.

Table 2 — Generally accepted methods for detection of accessible surface discontinuities for all types of welds, including fillet welds

Materials	Testing method
Ferritic steel	VT VT and MT VT and PT VT and (ET)
Austenitic steel, aluminium, nickel, copper and titanium	VT VT and PT VT and (ET)
NOTE Methods in parentheses are only applicable with limitations.	

Table 3 — Generally accepted methods for detection of internal discontinuities for butt- and T-joints with full penetration

Materials and type of joint	Nominal thickness of the parent material to be welded t mm		
	$t \leqslant 8$	$8 < t \leqslant 40$	$t > 40$
Ferritic butt-joints	RT or (UT)	RT or UT	UT or (RT)
Ferritic T-joints	(UT) or (RT)	UT or (RT)	UT or (RT)
Austenitic butt-joints	RT	RT or (UT)	RT or (UT)
Austenitic T-joints	(UT) or (RT)	(UT) and/or (RT)	(UT) or (RT)
Aluminium butt-joints	RT	RT or UT	RT or UT
Aluminium T-joints	(UT) or (RT)	UT or (RT)	UT or (RT)
Nickel and copper alloy butt-joints	RT	RT or (UT)	RT or (UT)
Nickel and copper alloy T-joints	(UT) or (RT)	(UT) or (RT)	(UT) or (RT)
Titanium butt-joints	RT	RT or (UT)	
Titanium T-joints	(UT) or (RT)	UT or (RT)	
NOTE Methods in parentheses are only applicable with limitations.			

9.3 Butt- and T-joints without full penetration and fillet welds

For partial penetration welds and fillet welds, the unfused root can prevent satisfactory volumetric testing when using the methods given in Table 3. If special testing methods have not been agreed, the quality of the weld shall be assured by control of the welding process.

Techniques other than those given in Tables 2 and 3 can be agreed for determining the actual degree of penetration and the dimensions of other discontinuity types.

It is recommended that welds in steel with a minimum yield strength above 280 MPa in austenitic steel, in aluminium, in nickel and copper alloys, and in titanium be examined using one or more methods in addition to visual testing, in accordance with Table 2.

10 Performance of testing

10.1 Determination of standard to be applied

See Annex A.

10.2 Conditions for testing

Prior to the testing, the testing personnel shall have access to all information relevant to the object, including:

a) necessary preliminary information required by the standard for the individual testing methods;

b) testing plan, if required;

c) actions to be taken if non-conforming welds are detected;

d) responsibility for coordination of the inspection of parts of subassemblies manufactured by subcontractors;

e) time and place of testing.

10.3 Time of testing

The testing should be carried out after completion of all required heat treatments. Welds in materials sensitive to hydrogen cracking (e.g. high-strength steels) or other time-delayed cracking shall not be examined until the minimum time required after welding is achieved or as defined in a specification.

If defined in a specification, special conditions may call for testing prior to final heat treatment or lapse of a certain time.

If a surface testing method is to be carried out, it shall be performed prior to any testing for internal discontinuities.

If accessible, welded joints should typically be tested and evaluated by visual testing in accordance with ISO 17637 or with another appropriate surface testing method, before testing for internal discontinuities.

10.4 Non-acceptable indications

If non-acceptable indications are detected, the criteria shall be given in the application standard or defined in a specification.

If non-acceptable discontinuities are repaired, the weld shall normally be examined at least as required for the original weld.

Further guidance is given in Annex C.

Annex A
(normative)

Rules and standards to be applied

A.1 General

This annex gives the correlation between the quality levels of ISO 5817 or ISO 10042 and the testing techniques, testing levels and acceptance levels of NDT standards.

It shall be noted that the correlations are not quantitative links.

A.2 Visual testing

See Table A.1.

Table A.1 — Visual testing (VT)

Quality levels in accordance with ISO 5817 or ISO 10042	Testing techniques and levels in accordance with ISO 17637	Acceptance levels [a]
B	Level not specified	B
C	Level not specified	C
D	Level not specified	D
[a] The acceptance levels for visual testing are equal to the quality levels of ISO 5817 or ISO 10042.		

A.3 Penetrant testing

See Table A.2.

Table A.2 — Penetrant testing (PT)

Quality levels in accordance with ISO 5817 or ISO 10042	Testing techniques and levels in accordance with ISO 3452-1	Acceptance levels in accordance with ISO 23277
B	Level not specified	2 X
C		2 X
D		3 X

A.4 Magnetic particle testing

See Table A.3.

Table A.3 — Magnetic particle testing (MT)

Quality levels in accordance with ISO 5817	Testing techniques and levels in accordance with ISO 17638	Acceptance levels in accordance with ISO 23278
B	Level not specified	2 X
C		2 X
D		3 X

A.5 Eddy current testing

See Table A.4.

Table A.4 — Eddy current testing (ET)

Quality levels in accordance with ISO 5817 or ISO 10042	Testing techniques and levels in accordance with ISO 17643	Acceptance levels
B	Level not specified	Agreed by specification
C		
D		

A.6 Radiographic testing (RT)

A.6.1 Radiographic testing using film(s)

See Table A.5.

Table A.5 — Radiographic testing using films (RT-F)

Quality levels in accordance with ISO 5817 or ISO 10042	Testing techniques and levels in accordance with ISO 17636	Acceptance levels in accordance with ISO 10675-1 or ISO 10675-2
B	B	1
C	B [a]	2
D	At least A	3

[a] However, the minimum number of exposures for circumferential weld testing may correspond to the requirements of ISO 17636, class A.

A.6.2 Radioscopic testing with digital image acquisition (dynamic ⩾ 12 bit)

See Table A.6.

Table A.6 — Radioscopy (RT-S)

Quality levels in accordance with ISO 5817 or ISO 10042	Testing techniques and levels in accordance with EN 13068-3	Acceptance levels in accordance with ISO 10675-1 or ISO 10675-2
B	Sb [a b]	1
C	Sb [a b c]	2
D	Sb [a b c]	3

[a] Weld-specific requirements, e.g. minimum number of exposures, shall conform to ISO 17636, class A for quality level D and class B for quality levels B and C.

[b] In addition to EN 13068-3, the visibility of image quality indicators (IQIs) shall be proven to be in agreement with ISO 17636, class A for quality level D and class B for quality levels B and C in the digital images and the details documented.

[c] The minimum number of exposures for circumferential weld testing may correspond to the requirements of ISO 17636, class A.

A.6.3 Testing with computed radiography using storage phosphor imaging plates

See Table A.7.

Table A.7 — Computed radiography (RT-CR)

Quality levels in accordance with ISO 5817 or ISO 10042	Testing techniques and levels in accordance with EN 14784-2	Acceptance levels in accordance with ISO 10675-1 or ISO 10675-2
B	B [a]	1
C	B [a b]	2
D	At least A [a]	3

[a] Weld-specific requirements, e.g. minimum number of exposures, exposure geometries and IQI requirements shall conform to ISO 17636, class A for quality level D and class B for quality levels B and C. The IQI visibility has to be proven in the digital images and shall be documented. X-ray voltages shall conform to EN 13068-3. The unsharpness shall be proven in accordance with ISO 19232-5 and EN 14784-2.

[b] The minimum number of exposures for circumferential weld testing may correspond to the requirements of ISO 17636, class A.

A.7 Ultrasonic testing of ferritic steels (UT)

A.7.1 Ultrasonic pulse echo technique

See Table A.8.

Table A.8 — Ultrasonic pulse echo technique (UT-PE)

Quality levels in accordance with ISO 5817	Testing techniques and levels in accordance with ISO 17640 [a]	Acceptance levels in accordance with ISO 11666
B	At least B	2
C	At least A	3
D	Not defined	Not required [b]

[a] When characterization of indications is required, ISO 23279 shall apply.

[b] UT is not recommended but can be defined in a specification (with the same requirements as quality level C).

A.7.2 Time-of-flight-diffraction technique (TOFD)

See Table A.9.

Table A.9 — Time-of-flight-diffraction examination (UT-TOFD)

Quality levels in accordance with ISO 5817	Testing techniques and levels in accordance with ISO 10863	Acceptance levels in accordance with EN 15617
B	C	1
C	At least B	2
D	At least A	3

Annex B
(informative)

Graph of standard context

See Figures B.1, B.2, and B.3.

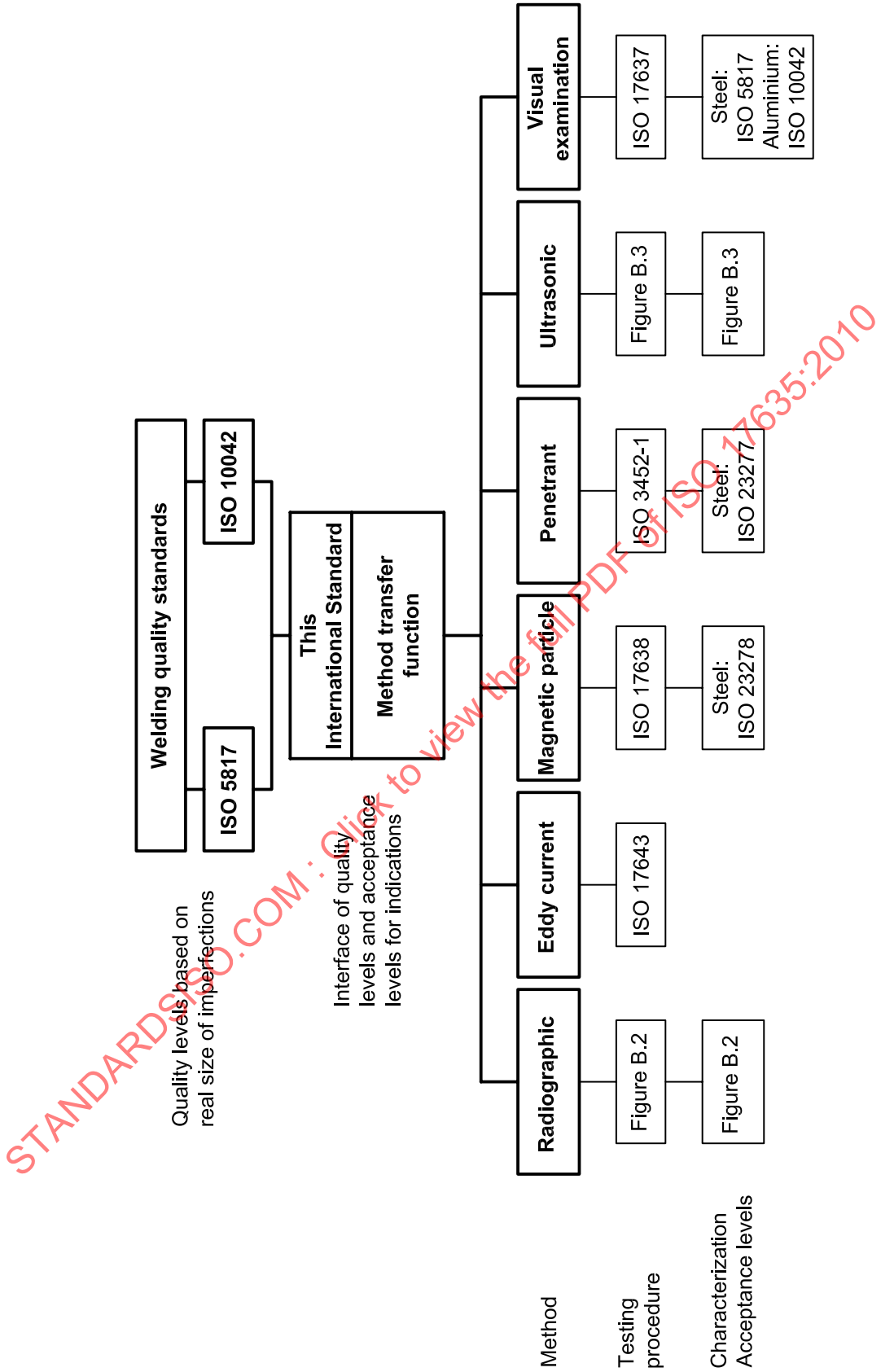

Figure B.1 — Graph of standard context