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ISO 11970

Second edition
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Specification and qualification of welding procedures for production welding of steel castings

Descriptif et qualification de modes opératoires de soudage pour le soudage de production des aciers moulés

Reference number
ISO 11970:2016(E)

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Contents

Page

Foreword

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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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 17, *Steel*, Subcommittee SC 11, *Steel castings*.

This second edition cancels and replaces the first edition (ISO 11970:2001), which has been technically revised. In particular, Figures 1, 2 and 3 have been redrawn to clarify labels.

Introduction

All welding procedure qualifications for production welding of steel castings are intended to be in accordance with this International Standard.

Previous procedure qualifications that conform to the range of qualification of Clause 8 are valid under this International Standard.

Where additional tests have to be carried out to complete the qualification, it is only necessary to perform the additional tests to the requirements of Clauses 6 and 7.

Specification and qualification of welding procedures for production welding of steel castings

1 Scope

This International Standard specifies how a welding procedure specification (WPS) for production welding of steel castings is qualified.

It defines the conditions for the execution of welding procedure qualification tests and the limits of validity of a qualified welding procedure for all practical welding operations within the range of essential variables.

Tests are intended to be carried out in accordance with this International Standard unless additional tests are specified by the purchaser or by agreement between the contracting parties.

This International Standard applies to the arc welding of steel castings. The principles of this International Standard can be applied to other fusion welding processes subject to agreement between the contracting parties.

In the case of specific service, material or manufacturing conditions, tests more comprehensive than those specified by this International Standard can be specified by the purchaser, in order to gain more information, e.g. longitudinal weld tensile tests, bend tests, chemical analyses, ferrite determination in austenitic stainless steels, elongation, Charpy "V" impact tests, and radiography.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable to its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 857-1, *Welding and allied processes — Vocabulary — Part 1: Metal welding processes*

ISO 4136, *Destructive tests on welds in metallic materials — Transverse tensile test*

ISO 4969, *Steel — Macroscopic examination by etching with strong mineral acids*

ISO 4986, *Steel castings — Magnetic particle inspection*

ISO 4987, *Steel castings — Liquid penetrant inspection*

ISO 4992-1, *Steel castings — Ultrasonic examination — Part 1: Steel castings for general purposes*

ISO 4992-2, *Steel castings — Ultrasonic examination — Part 2: Steel castings for highly stressed components*

ISO 4993, *Steel and iron castings – Radiographic inspection*

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

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6892-1, *Metallic materials – Tensile testing – Part 1: Method of test at room temperature*

ISO 9016, *Destructive tests on welds in metallic materials — Impact tests — Test specimen location, notch orientation and examination*

ISO 9606-1, *Qualification testing of welders — Fusion welding — Part 1: Steels*

ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules*

ISO 15612, *Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 857-1 and ISO 15607 and the following apply.

3.1
production welding
any welding carried out during manufacturing before final delivery to the purchaser

3.1.1
joint welding
production welding used to weld cast components together or weld cast components to wrought steels

3.1.2
finishing welding
production welding carried out in order to ensure the agreed quality of the casting

3.2
repair welding
welding carried out after delivery to the end user, i.e. after the casting has been in service

4 Preliminary welding procedure specification (pWPS)

A preliminary welding procedure specification shall be prepared. It shall specify the range of all the relevant parameters in accordance with ISO 15612.

5 Welding procedure qualification

The making and testing of test specimens representing the type and the position of welding used in production shall be in accordance with Clauses 6 and 7.

The welder who undertakes the welding procedure test satisfactorily in accordance with this International Standard is qualified for the appropriate range of qualification according to ISO 9606-1. Additional welders shall be qualified in accordance with 7.6.

6 Test piece

6.1 General

The test piece shall be in accordance with those shown in Figures 1, 2, 3, and 4.

Dimensions in the figures are for information only and may be adjusted to meet production and testing requirements.

6.2 Shape and dimensions of test piece

Additional test pieces, or longer test pieces than the minimum size may be prepared in order to allow for extra and/or retesting specimens (in accordance with 7.5).

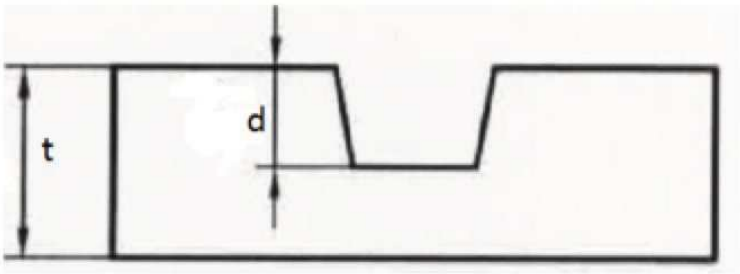
6.3 Welding of sample

The preparation and welding of the sample shall be carried out in accordance with the relevant pWPS. Angular tolerances may be agreed between the contracting parties or by the relevant application standard.

The dimensions and shape of the groove shall be in accordance with Figures 1, 2, 3, and 4.

If tack welds are to be fused into the final joint, they shall be included in the sample.

Unless otherwise specified in the purchase order or contract review, welding and testing of the samples shall be witnessed by an examiner (or test body). When the examiner (or test body) is not specified in the purchase order, the manufacturer may appoint a suitable examiner.

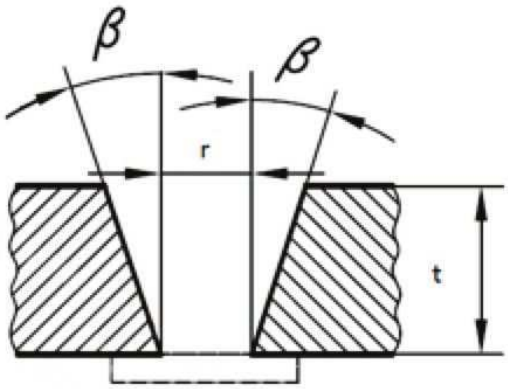


Key

t base metal thickness > 15 mm

d depth of cavity > 0,5 t. For TIG welding, "d" may be ≤ 0,5 t

Figure 1 — Weld cross section for weld cavity



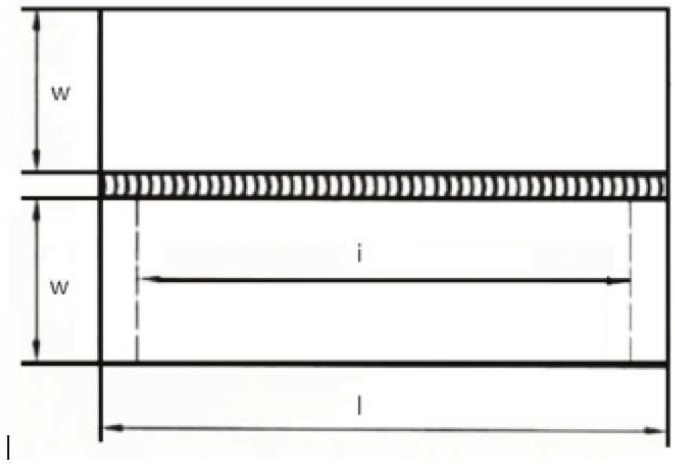
Key

t base metal thickness > 15 mm

r root width 15 mm > r > 5 mm

β groove angle 20° > β > 5°

Figure 2 — Weld joint



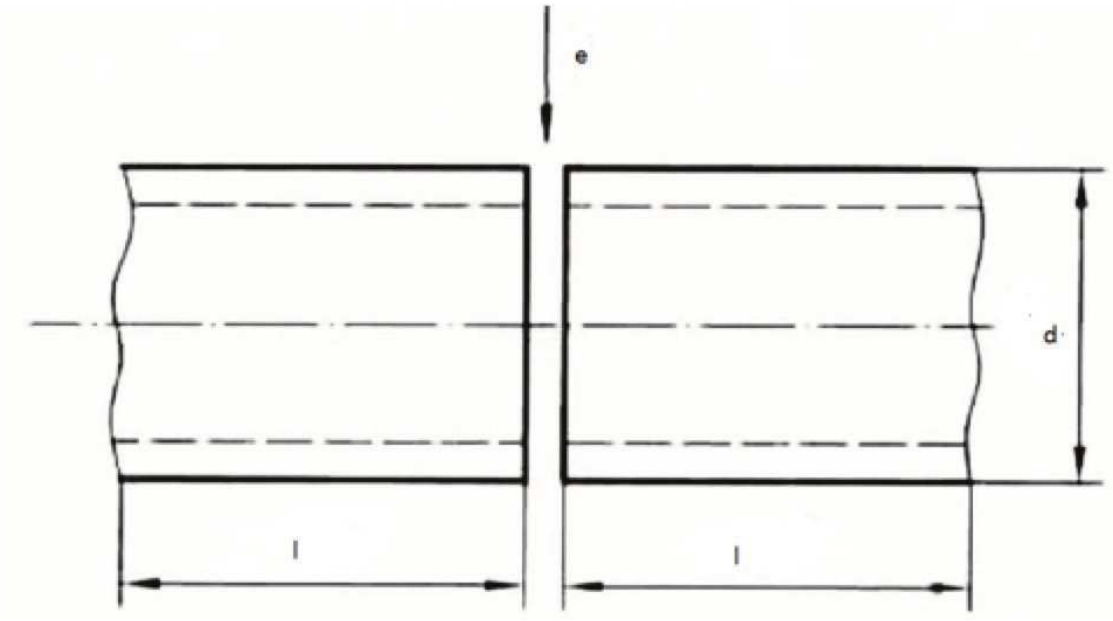
Key

w width of weld base material (w = 3 t or ≥ 50 mm whichever is greater)

l length of weld (l = 6 t or ≥ 350 mm whichever is greater)

i inspection length (i = l less 50 mm from each end)

Figure 3 — Weld sample (Plate)



Key

l length of tube section (l ≥ 150 mm)

d outside diameter of the tube

e edge preparation and fit up as detailed in the preliminary Weld Procedure Specification (pWPS)

Figure 4 — Weld sample (Tube)

7 Examination and testing

7.1 Extent of testing

The examination and testing includes both non-destructive testing (NDT) and destructive testing (DT) which shall be in accordance with the requirements given in Table 1.

Table 1 — Examination and testing of the test pieces

Type of test	Extent
Visual	100 %
Radiographic or ultrasonic	100 %
Surface crack detection	100 %
Transverse tensile test	1 specimen
Impact test[a]	2 sets
Hardness test	if required by the purchase order or by the relevant application standard
Macrostructure-examination	if required by the purchase order or by the relevant application standard
Microstructure-examination	if required by the purchase order or by the relevant application standard
Bend tests	if required by the purchase order or by the relevant application standard
Corrosion tests	if required by the purchase order or by the relevant application standard
Additional tests	if required by the purchase order or by the relevant application standard

[a] Impact V-notch tests are only required when the parent metal requires impact testing. The same number of tests is required in the weld metal and HAZ.

All tests shall be carried out after any required post-weld heat treatment.

7.2 Location and cutting of test specimens

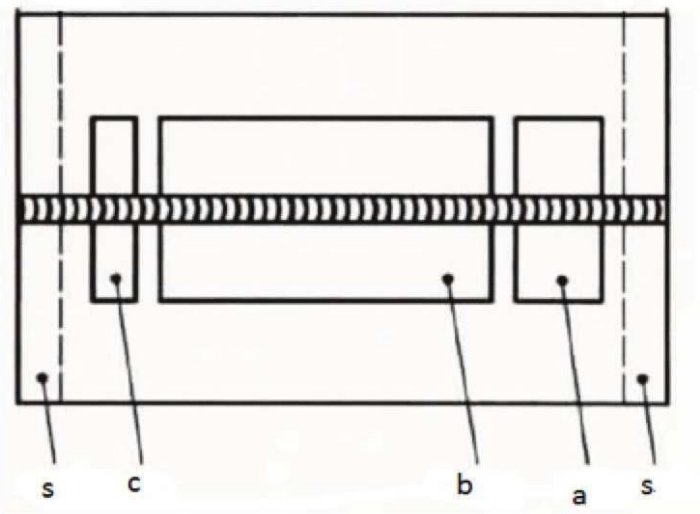
Location of test specimens shall be in accordance with Figures 5 and 6.

Test specimens shall be taken after non-destructive testing (NDT) has given satisfactory results.

7.3 Non-destructive testing

The quality requirements of the HAZ shall be in accordance with the requirements for the parent metal.

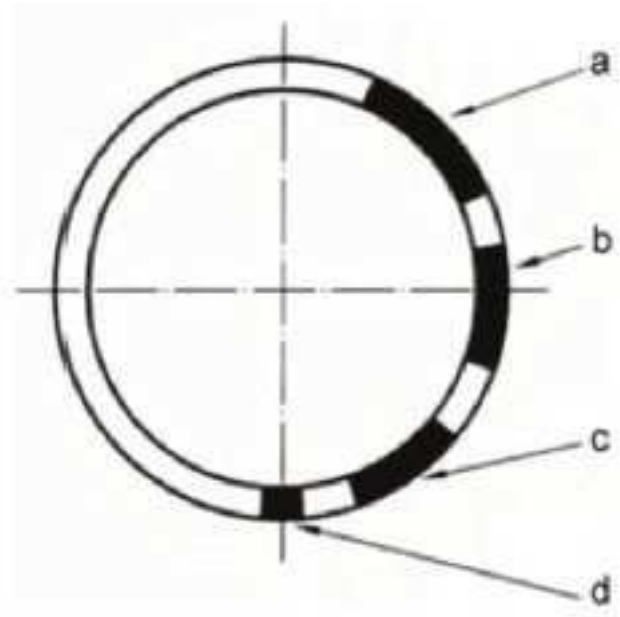
The acceptance requirements of the weld deposit shall comply with level C of ISO 5817 except for excess weld metal and excessive convexity for which level D shall apply. Standards for acceptance criteria relating to NDT methods shall be used for the evaluation of imperfections.



Key

a tensile specimen
b impact or additional specimens
c microstructure, macrostructure and hardness specimens
s scrap greater than 50 mm

Figure 5 — Test specimen location from plate



Key

a tensile specimen and 1 root and 1 face or 2 side bend specimens
b impact or additional specimens
c tensile specimen and 1 root and 1 face or 2 side bend specimens
d macrostructure and hardness specimens or 2 side bend specimens

Figure 6 — Test specimen location from tube

7.4 Destructive test

7.4.1 Transverse (to weld groove) tensile test

Specimens and testing for transverse tensile test shall be in accordance with ISO 6892-1 and ISO 4136.

In the tensile test only the value of Rm is required. If the specimen breaks outside of the weld or fusion line, the result is acceptable if the strength is not more than 5 % below the minimum tensile strength, Rm, of the parent metal piece.

7.4.2 Macro-examination

If macro-examination is required the test specimen shall be prepared and etched on one side to clearly reveal the fusion line, the HAZ and the build-up of runs, in accordance with ISO 4969.

Unaffected parent metal shall be included in the macro-examination.

The acceptance levels stated in 7.3 shall apply.

7.4.3 Micro-examination

If micro-examination is required the test specimen shall be prepared and etched on one side to clearly reveal the fusion line, the structure of the weld and the HAZ. The acceptance level is to be agreed between the manufacturer and customer or application standard.

7.4.4 Impact test

If an impact test is required, the sets of test specimens shall be taken in accordance with Figures 5 and 6 for location of specimens, and in accordance with ISO 148-1 for dimensions and test. The location of the notch and test reporting requirements shall be in accordance with ISO 9016.

Charpy V notch specimens shall be used. Each set shall be comprised of three specimens. The notch shall be perpendicular to the surface of the weld. Test pieces with Charpy V notch shall be sampled at least 2 mm below the surface of the parent metal and transverse to the weld.

Two sets of specimens shall be used, one from the weld metal and one from the HAZ. The set from weld metal, test specimen is type VWT (V: Charpy V notch; W: notch in weld metal; T: notch through the thickness). The set for the HAZ specimen is type VHT (V: Charpy V notch; H: notch in HAZ; T: notch through the thickness).

For thicknesses ≥ 50 mm, two additional sets of specimens shall be taken, one from the weld metal and one from the HAZ. The two sets may be taken either from just below the mid thickness or in the root area of the weld.

The test temperature and absorbed energy shall be in accordance with the requirements for the parent metal.

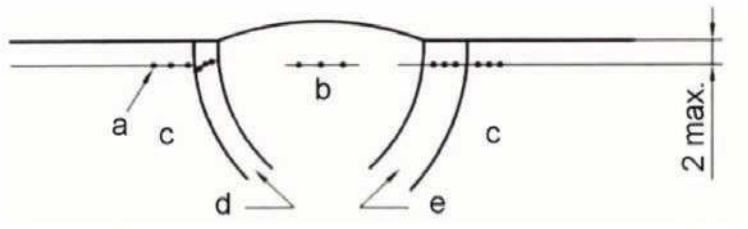
7.4.5 Hardness test

If a hardness test is required the location of the test shall be as shown in Figure 7. The method of hardness test shall be agreed between the manufacturer and customer or by the application standard. When the Vickers method (HV10) is selected it shall be used in accordance with ISO 6507-1. The indentation shall be made in the weld, the HAZs and the parent metal with the object of measuring and recording the range of values in the weld joint. This will include rows of indentations one of which shall be 2 mm maximum below the surface (see Figure 7).

For each row of indentations there shall be a minimum of 3 individual indentations in the weld, HAZ (both sides) and the parent metal (both sides).

For the HAZ the first indentation shall be placed at a distance no greater than 1 mm from the fusion line.

Dimensions in millimetres



Key

a indentations
b weld metal
c parent metal
d narrow HAZ
e wide HAZ

Figure 7 — Hardness test positions

7.5 Qualification and retesting

If the test piece fails to comply with one or more of the requirements for visual examination or NDT specified in 7.3, one additional test piece shall be welded and subjected to the same examination. If this additional test piece does not comply with the relevant requirements, the pWPS shall be regarded as not capable of complying with the requirements of this International Standard without modification.

If any test specimen fails to comply with the relevant requirements of 7.4 (destructive testing) due only to weld imperfections (see 7.3) two further test specimens shall be obtained for each one that failed. These can be taken from the same test piece if there is sufficient material available or from a new test piece, and shall be subjected to the same test.

If either of these additional test specimens do not comply with the relevant requirements, the WPS shall be regarded as not capable of complying with the requirements of this International Standard without modification.

7.6 Welder qualification

Welders shall be qualified in accordance with the procedures described in ISO 9606-1.

8 Range of qualification

8.1 General

Changes outside the ranges specified shall require a new welding procedure test.

8.2 Related to the manufacturer

A qualification of a WPS obtained by a manufacturer is valid for welding in workshops or sites under the same technical and quality control of that manufacturer.

8.3 Related to the material

8.3.1 Parent metal — Grouping system for cast steel grades

In order to minimize the number of welding procedure tests, steels shall be grouped as shown in Table 2. Qualification of one material in a sub-group qualifies the procedure for all materials in that sub-group.

Within each group A, B, C or F, each sub-group qualifies the sub group(s) of lower index, for example in group A:

— sub-group A3 qualifies sub-groups A1 and A2;

— sub-group A2 qualifies sub-group A1;

A separate welding procedure qualification shall be obtained for each cast steel not covered by the grouping system.

Table 2 — Grouping system for cast steel grades and filler metals

Group	Type of cast steel
A	**Carbon steels (Si 0,80 % max, Mn 1,70 % max)**
A1	C ≤ 0,25 %; yield stress $R_{p0,2}$ ≤ 275 MPa
A2	C ≤ 0,25 %; yield stress 275 MPa < $R_{p0,2}$ ≤ 360 MPa
A3	Yield stress $R_{p0,2}$ > 360 MPa
B	**Low alloy steels (annealed, normalized, or normalized and tempered)**
B1	Yield stress $R_{p0,2}$ ≤ 360 MPa
B2	Yield stress $R_{p0,2}$ > 360 MPa
C	**Low alloy steels (quenched and tempered)**
C1	Yield stress $R_{p0,2}$ ≤ 500 MPa
C2	Yield stress 500 MPa < $R_{p0,2}$ ≤ 700 MPa
C3	Yield stress $R_{p0,2}$ > 700 MPa
D	**Ferritic stainless steels**
D1	Ferritic stainless steels
E	**Martensitic stainless steels**
E1	Martensitic stainless steels
F	**Austenitic stainless steels**
F1	Austenitic with ferrite ≤ 35 %
F2	Fully austenitic
G	**Duplex stainless steels**
G1	Duplex stainless steels with ferrite > 35 %
H	**Austenitic heat resisting steels**
H1	Austenitic heat resisting steels
I	**Precipitation hardened stainless steels**
I1	Precipitation hardened stainless steels
J	**Nickel-base alloys**
J1	Nickel-base alloys
K	**Austenitic manganese steels**
K1	Austenitic manganese steels

8.3.2 Parent metal thickness (range of qualification)

The qualification of a welding procedure test on thickness "*t*" shall include thicknesses in the ranges given in Table 3. The range of qualification is valid, whatever the thickness of the welded casting.

Table 3 — Range of qualification for thickness

Thickness, *t* mm	**Range of qualification**
$15 < t \leq 30$	3 mm to 2 *t*
$t > 30$	0,5 *t* to 2 *t* or 200 mm, whichever is the greater

8.4 Common to all welding procedures

8.4.1 Welding process

The qualification according to the WPS is valid only for the welding process used in the WPS. In a multi-process procedure test, the qualification is valid only for the sequence used during the qualification test.

For multi-process procedures, each welding process may be qualified separately or in combination with other processes. Similarly one or more processes may be deleted from a qualified WPS, provided the joint thickness is within the qualified thickness range of the relevant welding process(es) to be applied.

8.4.2 Welding positions

When neither impact nor hardness requirements are specified, welding in any one position qualifies for welding in all positions.

8.4.3 Type of joint

An qualification established using the arrangements shown in Figure 1 is valid for all types of butt weld (joint and/or finishing welding).

8.4.4 Filler metal

The qualification range of filler metals shall meet the requirements of the materials listed in Table 2. Other filler metals may be used as long as they are

— either in the same group of tensile properties (unless impact testing is required), or

— matched to the nominal composition of the parent metal, or

— overmatched to maintain the ferrite balance of the parent metal of group F, or

— overmatched to meet service considerations for parent metal groups D, E, F, G, H, I, J, and K.

8.4.5 Type of current

The qualification given is only for the type of current (AC, DC, pulsed current) and polarity used in the welding procedure test.

8.4.6 Heat input

The requirements of this clause apply only when the control of heat input is specified.

When impact testing requirements apply, the upper limit of the heat input qualified is 15 % greater than that used in welding the sample.

When hardness requirements apply, the lower limit of heat input qualified is 15 % lower than that used in welding the sample.

8.4.7 Preheat temperature

The lower limit of qualification is the nominal preheat temperature applied at the start of the welding procedure test.

8.4.8 Interpass temperature

The upper limit of qualification is the nominal interpass temperature reached in the welding procedure test.

8.4.9 Post-weld heat treatment

Addition or deletion of post weld heat treatment is not permitted.

The temperature range specified for the welding procedure test is the range qualified. Heating rates, cooling rates and holding time shall be related to the production component.

8.5 Specific to process

8.5.1 Processes 111 [manual metal arc welding (metal arc welding with covered electrode); shielded metal arc welding] and 114 (self-shielded tubular-cored arc welding).

The qualification given is for the diameter of electrode used in the welding procedure test plus or minus one electrode diameter for each run, with the exception of the root run on single side welding without backing butt welds for which no size change is permissible.

8.5.2 Process 121 (submerged arc welding with one wire electrode)

The qualification given is restricted to the wire system used in the welding procedure test (e.g. single-wire or multiple-wire system).

The qualification given for the flux or wire type and combination is restricted to the conditions of the weld procedure test.

8.5.3 Processes 131 (metal-arc inert gas welding; MIG welding; gas metal arc welding), 135 (metal active gas welding; MAG welding; gas metal arc welding), 136 (tubular cored metal arc welding with active gas shield; flux cored arc welding) and 138 (MAG welding with metal cored electrode)

The qualification given is restricted to the face and/or back shielding gas and the type of gas used in the welding procedure test.

The qualification given is restricted to the wire system used in the welding procedure test (e.g. single-wire or multiple-wire system).

8.5.4 Process 141 (Tungsten inert gas welding; TIG welding; gas tungsten arc welding)

The qualification given is restricted to the face and/or back shielding gas and the type of gas used in the welding procedure test.

9 Welding procedure qualification record (WPQR)

The welding procedure qualification record (WPQR) shall be a statement of the results of assessing each test piece including re-tests (see Annex A). The relevant items listed for the WPS in Annex B (details of

weld test) shall be included, together with details of any features that would be subject to rejection by the requirements of Clause 7. If no such features or unacceptable test results are found, a WPQR detailing the welding procedure test results is qualified and shall be signed and dated by the examiner or test body.

Annex A
(informative)

Record form (WPQR) welding procedure qualification — Test certificate

Manufacturer's welding procedure	Examiner or test body
Reference No.:	Reference No.:
Manufacturer:	
Address:	
Code/testing standard:	
Date of welding:	
Range of qualification:	
Welding process:	
Joint type:	
Parent metal(s):	Conditions if tempered:
Metal thickness (mm):	
Outside diameter (mm):	
Filler metal type:	
Shielding gas/flux:	
Type of welding current:	
Welding position:	
Preheat:	
Post-weld heat treatment and/or ageing:	
Other information:	

Certified that test welds prepared, welded and tested satisfactorily in accordance with the requirements of the code/testing standard indicated above.

Location	Manufacturer	Examiner or test body
Date of issue	Name, date and signature	Name, date and signature

Annex B
(normative)

Details of weld test

Location:
Manufacturer's welding procedure:
Reference No.:
WPQR No.:

Manufacturer:
Welder's name:
Welding process:
Joint type:

Weld preparation details (sketch):[1)]

Examiner or test body:

Method of preparation and cleaning:
Parent metal specification:

Material thickness (mm):
Outside diameter (mm):

Welding position:

Joint design	Welding sequences

Welding details

Run	Process	Size of filler metal	Current A	Voltage V	Type of current/ polarity	Wire feed speed	Travel speed	Heat input[1)]

Filler metal classification and trade name:

Any special baking or drying:
Gas/flux-shielding:
backing:
Gas flow rate-shielding:
backing:
Tungsten electrode type/size:
Details of back gouging/backing
Preheat temperature:
Interpass temperature:
Post-weld heat treatment and/or ageing:
Time, temperature, method:

Other information[1)]:
e.g. weaving (maximum width of run):

Oscillation: amplitude, frequency, dwell time:

Pulse welding details:
Stand-off distance:
Torch angle:

1) If required.

Heating and cooling rates:[2)]

Manufacturer

Name, date and signature

Examiner or test body

Name, date and signature

Test results

Manufacturer's welding procedure
Reference No.:
Visual examination:
Penetrant/magnetic particle test[2)]:

Examiner or test body:
Reference No.:
Radiography[2)]:
Ultrasonic examination [2)]:

Tensile tests

Temperature

Type/No.	R_p MPa[a]	R_m MPa[a]	A %	Z %	Fracture location	Remarks
Requirement						

[a] 1 MPa = 1 N/mm2.

Bend tests

Former diameter

Type/No.	Bend angle degrees	Elongation[2)] %	Result

Macro examination:
Micro examination[2)]:

Impact test[2)]: Type: Size: Requirements:

Notch location: direction	Temperature °C	Values J	Average J	Remarks

Hardness tests[2)]

Location of measurements (sketch)[2)]

Type/load:
Parent metal:
H.A.Z.:
Weld metal:

Other tests:
Remarks:
Tests carried out in accordance with the requirements of:
Laboratory report references No.:
Test results were acceptable/not acceptable
(delete as appropriate)

Examiner or test body

Name date and signature

2) If required.

Bibliography

[1] ISO 6947, *Welding and allied processes — Welding positions*

ICS 25.160.10; 77.140.80

Price based on 16 pages