INTERNATIONAL STANDARD

ISO 11970

First edition
2001-01-15

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

Descriptif et qualification d'un mode opératoire de soudage pour le soudage de production sur aciers moulés

Reference number
ISO 11970:2001(E)

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

Printed in Switzerland

Contents

Page

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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 11970 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 11, *Steel castings*.

Annex B forms a normative part of this International Standard. Annex A is for information only.

Introduction

All welding procedure approvals for production welding of steel castings shall be in accordance with this International Standard from the date of its issue.

Previous procedure approvals that conform to the range of approval of clause 8 are valid under this International Standard.

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

Specification and approval 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 approved,

It defines the conditions for the execution of welding procedure approval tests and the limits of validity of an approved welding procedure for all practical welding operations within the range of essential variables.

Tests shall 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 may be applied to other fusion welding processes subject to agreement between the contracting parties.

In the case of specific service, material or manufacturing conditions, more comprehensive tests may be specified by the purchaser, than are specified by this International Standard, 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, radiography, etc.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 148:1983, *Steel — Charpy impact test (V-notch)*.

ISO 857-1:1998, *Welding and allied processes — Vocabulary —Part 1: Metal welding processes.*

ISO 4969:1980, *Steel — Macroscopic examination by etching with strong mineral acids*.

ISO 4986:1992, *Steel castings — Magnetic particle inspection.*

ISO 4987:1992. *Steel castings — Penetrant inspection*.

ISO 4992:—[1)], *Steel castings — Ultrasonic inspection*.

ISO 4993:1987, *Steel castings — Radiographic inspection*.

1) To be published.

ISO 5817:—[2], *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections.*

ISO 6507-1:1997, *Metallic materials — Vickers hardness test — Part 1: Test method*.

ISO 6892:1998, *Metallic Materials — Tensile testing at ambient temperature*.

ISO 6947:1990, *Welds — Working positions — Definition of angles of slope and rotation*.

ISO 9606-1:1994, *Approval testing of welders — Fusion welding — Part 1: Steels.*

ISO 9692-1:—[3], *Welding and allied processes — Recommendations for joint preparation — Part 1: Manual metal-arc welding, gas-shielded metal-arc welding and gas welding of steels.*

ISO 9956-1:1995, *Specification and approval of welding procedures for metallic materials — Part 1: General rules for fusion welding.*

ISO 9956-2:1995, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure specification for arc welding.*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 857-1 and ISO 9956-1 as well as the following apply.

3.1
production welding
any welding carried out during manufacturing before final delivery to the purchaser including joint welding of castings and finishing welding

3.1.1
joint welding
welding used to weld cast components together or weld cast components to wrought steels in order to obtain an integral unit

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

3.2
repair welding
any 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 according to ISO 9956-2.

2) To be published. (Revision of ISO 5817:1992)

3) To be published. (Partial revision of ISO 9692:1992)

5 Welding procedure test

The making and testing of test pieces 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 approved for the appropriate range of approval 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 that shown in Figure 1.

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 test piece

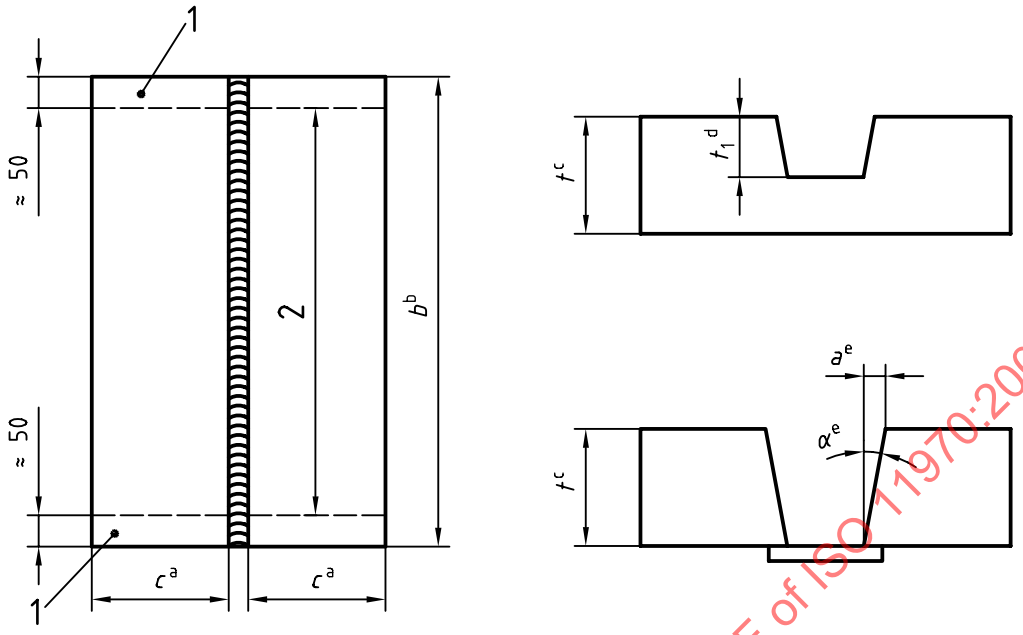
The preparation and welding of the test piece shall be carried out in accordance with the relevant pWPS. Angular tolerances may be agreed between the contracting parties or by the relevant application standard.

The dimensions and shape of the groove shall be in accordance with ISO 9692-1.

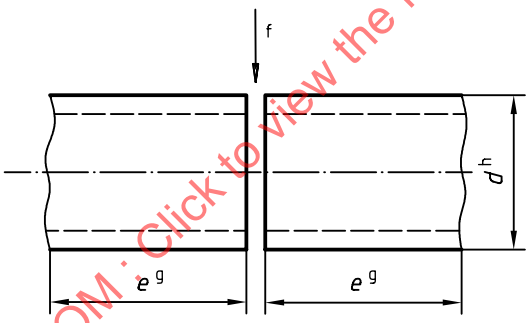
If tack welds are to be fused into the final joint they shall be included in the test piece.

Unless otherwise specified in the purchase order or contract review, welding and testing of the test piece(s) 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.

Dimensions in millimetres



a) Plate



b) Tube

Key

1 Discard

2 Inspection length

NOTE The dimensions shown are for information only and may be adjusted to meet production and testing requirements.

a $c = 3t \geqslant 150$ mm.

b $b = 6t \geqslant 350$ mm.

c $t \geqslant 15$ mm.

d $t_1 \geqslant 0{,}5t$.

e $a = 5$ mm to 15 mm or $\alpha = 5°$ to 20°.

f Edge preparation and fit-up as detailed in the preliminary Welding Procedure Specification (pWPS).

g $e \geqslant 150$ mm.

h d = outside diameter.

Figure 1 — Test piece

7 Examination and testing

7.1 Extent of testing

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

Table 1 — Examination and testing of the test pieces

Type of test	Extent
Visual	100 %
Radiographic[a] or ultrasonic [b]	100 %
Surface crack detection [c]	100 %
Transverse tensile test	1 specimen
Impact test [d]	2 sets
Hardness test	if required by the purchase order or by the relevant application standard
Macro-examination	if required by the purchase order or by the relevant application standard
Micro-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 Radiographic testing shall be carried out in accordance with ISO 4993.

b Ultrasonic testing shall be carried out in accordance with ISO 4992.

c Magnetic particle testing in accordance with ISO 4986 or, dye penetrant in accordance with ISO 4987.

d Impact V-notch tests are only required when the parent metal requires impact testing The same number of tests are 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 pieces

Location and cutting of test pieces shall be in accordance with Figure 2.

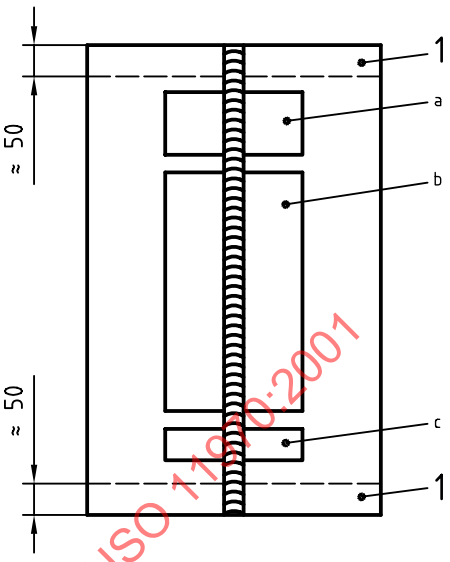
Test pieces shall be taken after non-destructive examination (NDE) has given satisfactory results.

7.3 Non-destructive examination

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 5817:1982 except for excess weld metal and excessive convexity for which level D shall apply. Standards for acceptance criteria relating to NDE methods shall be used for the evaluation of imperfections.

Dimensions in millimetres



Key

1 Discard

a Area 1 for:
1 tensile specimen

b Area 2 for:
Impact and additional test specimens if required

c Area 3 for:
1 macro/micro test specimen
1 hardness test specimen

a) Plate

Key

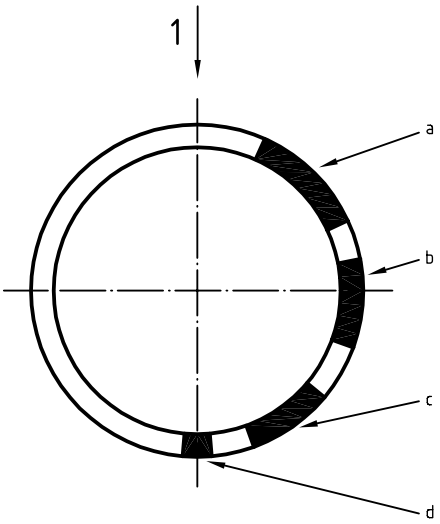
1 Top for fixed pipe

a Area 1 for:
1 tensile specimen
1 root and 1 face or 2 side bend specimens

b Area 2 for:
impact and additional test specimens if required

c Area 3 for:
1 tensile specimen
1 root and 1 face or
2 side bend specimens

d Area 4 for:
1 macro test specimen
1 hardness test specimen
2 side bend specimens



b) Tube

Figure 2 — Location of test specimens

7.4 Destructive test

7.4.1 Transverse (to weld groove) tensile test

Specimens and testing for transverse tensile testing shall be in accordance with ISO 6892.

The results of the tensile tests shall correspond to the specified values for the parent metal. 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 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 supplier and customer or application standard.

7.4.4 Impact testing

If impact testing is required the sets of test specimens shall be taken in accordance with Figure 2 for location of specimens, and in accordance with ISO 148 for dimensions and testing.

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 $\geqslant$ 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 testing

If hardness testing is required the location of the test shall be as shown in Figure 3. The method of hardness testing shall be agreed between the supplier and customer or by the application standard. When the Vickers method (HV10) is selected it shall be used in accordance with ISO 6507. 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 3).

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 1mm from the fusion line.

7.5 Qualification and retesting

If the test piece fails to comply with one or more of the requirements for visual examination or NDE 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.

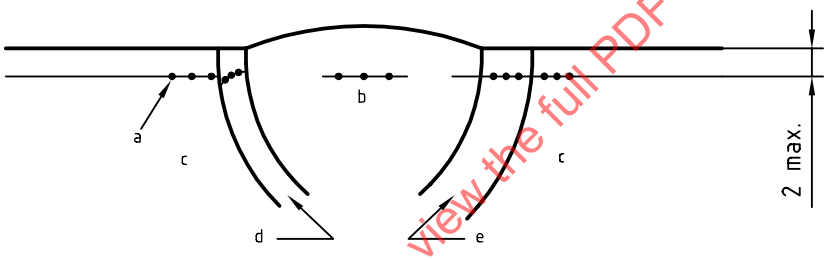
If any test specimen fails to comply with the relevant requirements of 7.4 (destructive testing) due only to weld imperfections, see 7.3, two further test specimens shall be obtained for each one that failed. These can be taken from the same test piece if there is sufficient material available or from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

Dimensions in millimetres



Key

a Indentations
b Weld metal
c Parent metal
d Narrow HAZ
e Wide HAZ

Figure 3 — Hardness testing positions

8 Range of approval

8.1 General

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

8.2 Related to the manufacturer

An approval 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. Approval 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 approves the sub group(s) of lower index, for example in group A:

— sub-group A4 approves sub-groups A1, A2 and A3

— sub-group A3 approves sub-groups A1 and A2

— sub-group A2 approves sub-group A1

A separate welding procedure approval 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 steel casting
A	**Carbon steels (Si 0,80 % max, Mn 1,70 % max)**
A1	C $\leqslant$ 0,25 %; yield stress $R_p \leqslant$ 275 MPa
A2	C $\leqslant$ 0,25 %; yield stress 275 MPa $< R_p \leqslant$ 360 MPa
A3	0,25 % $<$ C $\leqslant$ 0,35 %
A4	C $>$ 0,35 %
B	**Low alloy steels (annealed, normalized, or normalized and tempered)**
B1	Yield stress $R_p \leqslant$ 360 MPa
B2	Yield stress $R_p >$ 360 MPa
C	**Low alloy steels (quenched and tempered)**
C1	Yield stress $R_e \leqslant$ 500 MPa
C2	Yield stress 500 MPa $< R_e \leqslant$ 700 MPa
C3	Yield stress Re > 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 $\leqslant$ 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	PH stainless steels
J	**Nickel-base alloys**
J1	Nickel alloys
K	**Austenitic manganese steels**
K1	Austenitic Mn steels

8.3.2 Parent metal thickness (range of approval)

The approval of a welding procedure test on thickness "t" shall include thicknesses in the following ranges given in Table 3.

Table 3 — Range of approval for thickness

Thickness, t mm	**Range of approval**
$15 < t \leqslant 30$	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 approval according to the WPS is valid only for the welding process used in the welding procedure test (WPS). In a multi-process procedure test the approval is valid only for the sequence used during the approval test.

For multi-process procedures each welding process may be approved separately or in combination with other processes. Similarly one or more processes may be deleted from an approved WPS provided the joint thickness is within the approved 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 approves for welding in all positions.

When impact test and/or hardness requirements are specified for a weld, a test piece in position PC approves welding in PA as defined in ISO 6947.

8.4.3 Type of joint

An approval 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 approval 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 approval 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 approved is 15 % greater than that used in welding the test piece.

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

8.4.7 Preheat temperature

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

8.4.8 Interpass temperature

The upper limit of approval 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 approved. 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 approval 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 approval given is restricted to the wire system used in the welding procedure test (e.g. single-wire or multiple-wire system).

The approval 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) and 136 (Tubular cored metal arc welding with active gas shield; flux cored arc welding)

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

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