INTERNATIONAL STANDARD

ISO 17607-5

First edition
2023-12

Steel structures — Execution of structural steelwork —

Part 5: **Welding**

Structures en acier – Exécution des charpentes et ossatures en acier —

Partie 5: Soudage

Reference number
ISO 17607-5:2023(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published 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.

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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 167, *Steel and aluminium structures*.

This first edition cancels and replaces ISO 10721-2:1999, which has been technically revised.

A list of all parts in the ISO 17607 series can be found on the ISO website.

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

Specific requirements for the achievement of structures that are optimal with respect to safety, the state of the economy, development and general values of a nation are given in the appropriate regional or national standards, if they exist.

Many nations do not have their own standards for structural steelwork. Some reference other national or regional standards. Some permit the project's standard to be selected by the owner, designer or constructor of the structure. Some do not require any standards to be followed.

The ISO 17607 series of standards on the execution of structural steelwork was developed to serve as a means to provide a set of requirements and guidance for projects that are constructed without a governing regional or national standard. The ISO 17607 series can also serve to reduce trade barriers.

Additional requirements to be addressed in the execution of structural steelwork, as structures or as fabricated components, can be found in the other parts of the series:

— ISO 17607-1 (General requirements and terms and definitions);

— ISO 17607-2 (Steels);

— ISO 17607-3 (Fabrication);

— ISO 17607-4 (Erection);

— ISO 17607-6 (Bolting).

Steel structures — Execution of structural steelwork —

Part 5: Welding

1 Scope

This document defines the general requirements for welding in the execution of structural steelwork as structures or as manufactured components in conjunction with ISO 17607-1.

Additional requirements to be addressed in the execution of structural steelwork, as structures or as fabricated components, can be found in other parts of the ISO 17607 series.

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 636, *Welding consumables — Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine-grain steels — Classification*

ISO 2560, *Welding consumables — Covered electrodes for manual metal arc welding of non-alloy and fine grain steels — Classification*

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

ISO 3834 (all parts), *Quality requirements for fusion welding of metallic materials*

ISO 4063, *Welding, brazing, soldering and cutting — Nomenclature of processes and reference numbers*

ISO 5817:2023, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

ISO 6520-1, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding*

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

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

ISO 10474, *Steel and steel products — Inspection documents*

ISO 13588, *Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology*

ISO 13916, *Welding — Measurement of preheating temperature, interpass temperature and preheat maintenance temperature*

ISO 13918, *Welding — Studs and ceramic ferrules for arc stud welding*

ISO 14171, *Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels — Classification*

ISO 14174, *Welding consumables — Fluxes for submerged arc welding and electroslag welding — Classification*

ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes*

ISO 14341, *Welding consumables — Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels — Classification*

ISO 14555, *Welding — Arc stud welding of metallic materials*

ISO 14731, *Welding coordination — Tasks and responsibilities*

ISO 14732, *Welding personnel — Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials*

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

ISO 15610, *Specification and qualification of welding procedures for metallic materials — Qualification based on tested welding consumables*

ISO 15611, *Specification and qualification of welding procedures for metallic materials — Qualification based on previous welding experience*

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

ISO 15613, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test*

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 16371-1, *Non-destructive testing — Industrial computed radiography with storage phosphor imaging plates — Part 1: Classification of systems*

ISO 16371-2, *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*

ISO 16834, *Welding consumables — Wire electrodes, wires, rods and deposits for gas shielded arc welding of high strength steels — Classification*

ISO 17607-1, *Steel structures — Execution of structural steelwork— Part 1: General requirements and vocabulary*

ISO 17660-1, *Welding — Welding of reinforcing steel — Part 1: Load-bearing welded joints*

ISO 17660-2, *Welding — Welding of reinforcing steel — Part 2: Non load-bearing welded joints*

ISO 17632, *Welding consumables — Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels — Classification*

ISO 17635:2016, *Non-destructive testing of welds — General rules for metallic materials*

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 17652-1, *Welding — Test for shop primers in relation to welding and allied processes — Part 1: General requirements*

ISO 17652-2, *Welding — Test for shop primers in relation to welding and allied processes — Part 2: Welding properties of shop primers*

ISO 18275, *Welding consumables — Covered electrodes for manual metal arc welding of high-strength steels — Classification*

ISO 18276, *Welding consumables — Tubular cored electrodes for gas-shielded and non-gas-shielded metal arc welding of high strength steels — Classification*

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

ISO 26304, *Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels — Classification*

IIW-2259-15, *Recommendations for Fatigue Design of Welded Joints and Components*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17607-1 apply.

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

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

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

4 Execution specification and quality requirements

National standards and documents that provide technically equivalent conditions may be used, in whole or in part, in place of referenced ISO standards or requirements of this document. In these cases, the technically equivalent national standards and documents, and deviations from the requirements of this document, shall be referenced in the execution specification.

The necessary information and technical requirements for execution of each part of the structural steelwork shall be agreed upon and complete before commencement of execution of that part of the structural steelwork. There shall be procedures for making alterations to a previously agreed execution specification.

The execution specification shall consider the following items in Annex A as relevant:

a) additional information, see A.1;

b) options, see A.2;

c) requirements related to execution levels (EXL), see A.3;

5 Constituent products

5.1 General

See ISO 17607-1.

The inspection documents for welding consumables, except for shielding gases, shall be Type 2.2 in accordance with ISO 10474.

For shielding gases, the inspection document shall be a document issued by the manufacturer declaring that the products supplied conform with the specified requirements of the order, without test results.

5.2 Welding consumables

Welding consumables shall be in accordance with Table 1, or, if applicable, the requirements of the national standard or documents.

The type of welding consumables shall be appropriate to the welding process, the material to be welded and the welding procedure.

When welding improved atmospheric corrosion resistant steel, welding consumables shall be selected that will produce welds with atmospheric corrosion resistance at least equivalent to the parent metal. The execution specification shall specify if colour matching is required.

NOTE Selection of welding consumables can be based on welding consumable manufacturer recommendations, steel manufacturer recommendations or the appropriate product standard.

Table 1 — Standards for welding consumables

Welding consumables	Product standard
Shielding gases for arc welding and cutting	ISO 14175
Wire electrodes and deposits for gas-shielded metal arc welding of non-alloy and fine grain steels	ISO 14341
Solid wires, solid wire-flux and tubular cored electrode-flux combinations for submerged arc welding of non-alloy and fine grain steels.	ISO 14171
Covered electrodes for manual arc welding of high strength steels	ISO 18275
Tubular cored electrodes for metal arc welding with and without gas shield of non-alloy and fine grain steels	ISO 17632
Fluxes for submerged arc welding	ISO 14174
Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine grain steels	ISO 636
Covered electrodes for manual arc welding of non-alloy and fine grain steels	ISO 2560
Wire electrodes, wires, rods and deposits for gas-shielded arc welding of high strength steels	ISO 16834
Wire and tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels	ISO 26304
Tubular cored electrodes for gas shielded metal arc welding of high strength steels	ISO 18276

5.3 Stud welding

Studs and ceramic ferrules shall be in accordance with ISO 13918.

The inspection documents for studs shall be Type 3.1 in accordance with ISO 10474.

6 Welding

6.1 General

Welding shall be undertaken in accordance with the relevant part of the ISO 3834 series or, if applicable, the requirements of the national standard or documents.

NOTE Guidelines for implementation of the ISO 3834 series on quality requirements for fusion welding of metallic materials are given in ISO/TR 3834-6.

The welding of reinforcing steel to structural steel shall be performed in accordance with the recommendations given in ISO 17660-1 and ISO 17660-2.

In accordance with the execution level (EXL), the following parts of the ISO 3834 series apply:

— EXL1: ISO 3834-4, Elementary quality requirements;

— EXL2: ISO 3834-3, Standard quality requirements;

— EXL3 and EXL4: ISO 3834-2, Comprehensive quality requirements.

NOTE See ISO 17607-1 for information on execution levels.

6.2 Welding plan

6.2.1 Requirements for a welding plan

A welding plan shall be provided as part of the production planning required by the relevant part of the ISO 3834 series.

6.2.2 Content of a welding plan

For EXL1, the welding plan shall be in accordance with ISO 3834-4.

For EXL2, EXL3 and EXL4, the welding plan shall include as relevant:

a) the welding procedure specifications;

b) measures to be taken to minimize distortion during and after welding, including details of restraints to be applied;

c) the sequence of welding with any restrictions or acceptable locations for start and stop positions, including intermediate stop and start positions where joint geometry is such that welding cannot be executed continuously;

d) requirements for intermediate checking of the welding activities;

e) turning of components in the welding process, in connection with the sequence of welding;

f) measures to control heat input and prevent local hardness issues;

g) measures to be taken to avoid lamellar tearing;

h) treatment and handling of welding consumables (storage, low hydrogen, conditioning);

i) requirements for acceptance criteria of welds in accordance with 6.6;

j) requirements for inspection and test plan in accordance with 7.2;

k) requirements for weld identification;

l) requirements for welding through coatings.

If welding or assembly overlaps or masks previous welds, special consideration shall be given concerning which welds are to be executed first and the possible need to inspect or test a weld before the second weld is executed or before masking components are assembled.

If there are welding requirements related to fatigue or seismic detail categories, these shall be included in the execution specification.

If there are specific requirements related to the inspection, maintenance, and repair of welding equipment, these shall be included in the execution specification.

6.3 Welding processes

Welding shall be performed using the welding processes as defined in ISO 4063, or as permitted by the execution specification.

6.4 Qualification of welding procedures and welding personnel

6.4.1 Qualification of welding procedures

6.4.1.1 General

Welding shall be carried out using qualified welding procedure specifications (WPS) in accordance with Table 2. The method of qualification of the WPS depends on the execution level, the parent metal and the degree of mechanization.

The specification and qualification of welding procedures shall be in accordance with ISO 15607. Although there are no specific requirements for welding procedure specifications to ISO 15607 in ISO 3834-4, the execution specification may specify that, for EXL1, appropriate work instructions that specify the welding process, consumables and welding parameters to be used shall be provided.

Specific conditions for tack welds shall be included in the WPS.

For joints in hollow section lattice structures, the WPS shall define the start and stop zones and the method to be used to address locations where the welds change from a fillet weld to butt around a joint.

6.4.1.2 Qualification to ISO 15613 or ISO 15614-1

The following conditions apply when qualifying WPSs are in accordance with ISO 15613 or ISO 15614-1 (see also Table 2):

a) If impact tests are specified, they shall be carried out at the lowest temperature required for impact testing of the material qualities being joined.

b) For quenched and tempered steels, one specimen for micro-examination is necessary. Photographs of weld metal, fusion line zone and HAZ shall be recorded. Microcracks are not permitted.

NOTE Information on microcracks can be found in ISO 5817.

c) If welding on prefabrication primers, tests shall be carried out on the maximum (nominal + tolerance) accepted layer thickness.

Table 2 — Methods of qualification of welding procedures

Method of qualification	ISO standard	EXL2	EXL3	EXL4
Welding procedure test	ISO 15614-1 ISO 14555 ISO 17660-1 ISO 17660-2	X	X	X
Pre-production welding test	ISO 15613 ISO 14555 ISO 17660-1 ISO 17660-2	X	X	X
Standard welding procedure	ISO 15612	X	X [a]	X [a]
Previous welding experience	ISO 15611 ISO 14555	X	–	–
Tested welding consumables	ISO 15610			

Table 2 *(continued)*

Method of qualification	ISO standard	EXL2	EXL3	EXL4
Key				
X = Permitted				
A dash (–) = Not permitted				
[a] If permitted by the execution specification.				

6.4.1.3 Validity of a welding procedure qualification

The validity of a welding procedure depends on the requirements of the standard used for the qualification.

6.4.2 Welders and welding operators

Welders (including personnel undertaking tack welding) shall be qualified in accordance with ISO 9606-1 and welding operators in accordance with ISO 14732 or other standards that provide equivalent technical conditions.

Welders of reinforcing steel shall be qualified in accordance with ISO 17660-1 or ISO 17660-2.

Welders of a hollow section branch connection with angles less than 60° shall be qualified in accordance with ISO 9606-1, or other standards that provide equivalent technical conditions, and as follows, unless otherwise specified:

a) test piece dimensions, weld details and welding positions shall be typical of those used in production;

b) for welding of circular onto circular hollow sections, test pieces for examination shall be taken from each of the four positions A, B, C and D shown in Figures B.2 and B.3 in Annex B;

Records of all welder and welding operator qualification tests shall be retained.

6.4.3 Welding coordination

For EXL2, EXL3 and EXL4, welding coordination shall be maintained during the execution of welding by welding coordination personnel suitably qualified for and experienced in the welding operations they supervise as specified in ISO 14731.

The technical knowledge of welding coordination personnel for welding reinforcement steel shall be in accordance with ISO 17660-1.

6.4.4 Prefabrication primers

Prefabrication primers shall demonstrate their weldability according to ISO 17652-1 and ISO 17652-2. The welding procedure is qualified if the imperfections in the test piece are within the specified limits of quality level B according to ISO 5817 except for porosity which shall be as follows:

a) no linear porosity (cluster of porosity with distance between pores ≤ diameter of pores);

b) 8 % maximum as required in ISO 5817:2023, Annex A for components generally, or 4 % maximum for components specified as being subject to fatigue.

6.5 Preparation and execution of welding

6.5.1 Joint preparation

6.5.1.1 General

The joint preparation shall be appropriate for the welding process. Tolerances for joint preparations and fit-up shall be given in the WPSs.

If cope holes are provided to ensure accessibility, they shall have a minimum radius of 40 mm unless otherwise specified.

NOTE 1 ISO 9692-1 and ISO 9692-2 provide some recommended weld preparation details.

The joint preparation shall be free from visible cracks. For steel grades with yield strengths higher than 460 MPa, cut areas shall be descaled by grinding, and verified to be free from cracks by VT, PT or MT. Visible cracks shall be removed by grinding and the joint geometry, corrected, as necessary.

If large notches or other errors in joint geometry are corrected by welding, a qualified procedure shall be used, and the area shall be subsequently ground smooth and feathered into the adjacent surface without abrupt changes in contour.

All surfaces to be welded shall be free from material (e.g. rust, organic material, galvanizing) that would adversely affect the quality of the welds or impede the process of welding.

Prefabrication primers may be left on the fusion faces only if they do not adversely affect the welding process. For EXL2, EXL3 and EXL4, prefabrication primers shall not be left on the fusion faces, unless welding procedure tests in accordance with ISO 15614-1 or ISO 15613 have been completed using such prefabrication primers.

NOTE 2 ISO 17652-2 describes tests for assessing the influence of prefabrication and shop primers on weldability.

6.5.1.2 Hollow sections

For hollow sections being used as branch components in welded joints, the fit-up of the joint geometry shall suit the requirements of the WPS. Branch joints between circular hollow sections may be cut in straight segments to prepare them for interconnection at saddle joints.

Annex B illustrates branch joints between circular hollow sections.

For branch connections in hollow section lattice structures, any adjustment for lack of fit by a welded surface deposit shall be covered by a suitable welding procedure.

6.5.2 Storage and handling of welding consumables

6.5.2.1 General

Welding consumables shall be stored, handled and used in accordance with the manufacturer's recommendations. See also 6.5.2.2.

After consumables have been removed from their original packages, they shall be protected or stored in accordance with the manufacturer's recommendations so that their specified properties and welding characteristics are not adversely affected.

Consumables that have not been stored in dry conditions, kept free from rust, oil, grease or other foreign materials or that have been wet shall be discarded.

Welding consumables showing signs of damage or deterioration shall be discarded.

If electrodes and fluxes need to be dried and stored, appropriate temperature levels and times shall be fulfilled in accordance with the manufacturer's recommendations.

NOTE Examples of damage or deterioration include cracked or flaked coatings on covered electrodes, rusty or dirty electrode wires and electrode wires with flaked or damaged copper coatings.

6.5.2.2 Coated electrodes for manual metal arc welding and fluxes with specific controlled hydrogen properties

Coated electrodes for manual metal arc welding (ISO 4063 process 111) and fluxes with specific controlled hydrogen properties shall be stored in accordance with the welding consumable manufacturer's recommendations.

If no recommendations are available for welding electrodes, baking and storage shall be in accordance with Table 3.

Table 3 — Temperature and time for baking and storage of coated electrodes (ISO 4063 process 111)

Condition	Temperature level *T* °C	Time *t*
Baking [a]	$260 < T \leq 370$	2 h min.
	$370 < T \leq 430$	1 h min.
Storage [a]	≥ 150	prior to welding
Storage [b]	≥ 100	during welding
[a] Fixed oven.		
[b] Portable quiver.		

Immediately after being removed from their original packages, coated electrodes shall be stored in ovens in accordance with the electrode manufacturer's recommendations.

If the original packaging shows evidence of damage, electrodes shall be baked in accordance with the electrode manufacturer's recommendations.

Consumables remaining unused at the end of the welding shift shall be baked in accordance with the electrode manufacturer's recommendations.

For coated electrodes, baking shall be carried out no more than twice. Unused coated consumables that have been baked twice shall be discarded if unused at the end of the welding shift.

6.5.3 Weather protection

The welder, the consumables and the working area shall be adequately protected against the effects of wind, rain and snow.

Gas shielded welding processes are particularly sensitive to wind effects. Typically, wind velocity in the vicinity of the weld should be a maximum of 2 m/s (8 km/h).

Surfaces to be welded shall be maintained dry and free from condensation.

When the base metal temperature is below 0 °C, the base metal shall be preheated to at least 10 °C and this minimum temperature maintained during welding.

Welding shall not be done when the ambient temperature is lower than –20 °C, except with the express consent of the constructor's welding coordinator.

NOTE Alternative minimum ambient temperatures for field welding are described in Annex D.

6.5.4 Assembly for welding

Components to be welded shall be brought into alignment and held in position by tack welds or external devices and maintained during initial welding. Assembly shall be carried out such that the fit-up of joints and the final dimensions of the components are all within the specified tolerances. Suitable allowances shall be made for distortion and shrinkage.

The components to be welded shall be assembled and held in position such that the joints to be welded are readily accessible and easily visible to the welder and inspection personnel.

Assembly of hollow section components to be welded should be in accordance with the guidance given in Annex B, as either appropriate or unless specified in the execution specification, or both.

Changes to the welding details or the addition of welds not shown on the fabrication drawing shall be approved prior to welding. Methods of locally strengthening a welded joint in a hollow section lattice structure should facilitate the testing of the integrity of the as-welded joint. The alternative of thickening the component should also be considered.

6.5.5 Preheating

Preheating shall be carried out in accordance with ISO 13916 and ISO/TR 17671-2.

Preheat shall be undertaken in accordance with applicable WPS and applied during welding, including tack welding and the welding of temporary attachments.

6.5.6 Temporary attachments

If the assembly or erection procedure requires the use of components temporarily attached by welds, they shall be positioned such that they can easily be removed without damage to the permanent steelwork. All welds for temporary attachments shall be made in accordance with an established WPS. Any areas where welding of temporary attachments is not permitted shall be specified.

Any restrictions on the use of temporary attachments for EXL3 and EXL4 shall be specified in the execution specification.

The removal of temporary welded attachments by cutting, gouging or chipping shall be carried out in such a way that the parent metal is not damaged and shall subsequently be carefully ground smooth without abrupt changes in contour.

The removal locations shall be visually inspected and, for steel grades with yield strengths greater than or equal to 355 MPa, the locations shall be subjected to visually enhanced NDT, i.e. MT or PT.

Chipping and gouging are not permitted on steel grades with yield strengths greater than or equal to 460 MPa or on components subject to fatigue, unless otherwise specified.

6.5.7 Tack welds

For EXL2, EXL3 and EXL4, tack welds shall be made using a qualified welding procedure. The minimum length of the tack shall be the lesser of four times the thickness of the thicker part or 50 mm, unless a shorter length can be demonstrated as satisfactory by test.

Tack welds that are incorporated into the final weld shall have a suitable shape and be free from defects and be cleaned thoroughly before final welding.

Tack welds that are not incorporated into final welds shall be removed unless otherwise specified in the execution specification.

Tack welds containing defects, including cracks, shall be removed.

6.5.8 Fillet welds

Fillet welds, as deposited, shall not be less than the specified dimensions for either throat thickness or leg length, or both, as appropriate, taking into account that:

a) the specified throat thickness is achievable using WPSs for deep or partial penetration welding processes;

The control of heat input is critical and should be considered in developing the WPS.

b) if the gap, h, exceeds the imperfection limit, it may be compensated for by an increase in the throat thickness $a = a_{nom} + 0{,}7h$, where a_{nom} is the specified nominal throat thickness. For incorrect fit up ISO 6520-1 (item 617) quality levels apply provided that the throat thickness is maintained in accordance with ISO 6520-1 (item 5213);

c) for bridge orthotropic decks, particular manufacturing requirements apply (e.g. for throat thickness of fillet welds), see 6.5.17.

6.5.9 Butt welds

6.5.9.1 General

The execution specification (shop drawing) shall specify the location of butt welds used as splices to accommodate available lengths of constituent products.

The ends of butt welds shall be terminated in a manner that ensures sound welds with full penetration. For all welds where a run-on/run-off plate is not used, all craters shall be filled to the full cross-sectional area of the weld bead.

For EXL3 and EXL4, and for EXL2 if specified, run-on/run-off plates shall be used to ensure full penetration at the edge. The weldability of such run-on/run-off plates shall not be less than that of the parent metal.

After completion of the welds, any run-on/run-off plates or supplementary material shall be removed and their removal shall conform with 6.5.6.

If a flush surface is required, the excess weld metal shall be removed to satisfy the quality requirements.

6.5.9.2 Single sided welds

Full penetration welds welded from one side may be produced with or without metallic or non-metallic backing material.

Unless otherwise specified in the execution specification, permanent steel backing material may be used.

If steel backing is used, the carbon equivalent value (CEV) of the backing material shall not exceed 0,43 %. The carbon equivalent value shall be based on the CE_{IIW} in Formula (1):

$$CE_{IIW} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (1)$$

NOTE ISO/TR 17844 provides additional information on the CE_{IIW} formula.

When determining the carbon equivalent value, consideration should be given to other intentionally added elements (e.g. boron) on the carbon equivalent and resulting weldability of the steel.

Backing materials shall be fitted tightly to the parent metal and should generally be continuous for the full length of the joint. For EXL3 and EXL4, permanent backing metal shall be made continuous by means of full penetration butt welds. Tack welds shall be incorporated into the butt welds.

Flush grinding of single-sided butt welds in joints between hollow sections executed without backing is not permitted, unless specified in the execution specification; if those welds are fully backed, they may be ground off flush with the general surface profile of the parent metal.

6.5.9.3 Back gouging

Back gouging shall be carried out to a sufficient depth to ensure full penetration into the previously deposited weld metal.

Back gouging shall produce a contour of a single U-shaped groove with its fusion faces readily accessible for welding.

6.5.10 Welding of improved atmospheric corrosion resistant steels

Welding of improved atmospheric resistant steels shall be carried out using appropriate welding consumables.

Welding consumables shall either have improved atmospheric resistance or be C-Mn consumables used under the following conditions:

a) For the body of a multi-run fillet or butt weld provided at least two layers on all exposed surfaces are made using welding consumables with improved atmospheric resistance. When this option is used, consideration shall be given to the atmospheric resistance of the exposed ends of multi-pass welds after removal of run-on/run-off plates.

b) Single pass welds meeting the following conditions:

   1) single pass groove welds made from one side onto backing;

   2) single pass groove welds made from both sides, with a single pass on each side;

   3) single pass fillet welds that conform with the maximum size criteria as given in Table 4.

Table 4 — Single pass fillet welds maximum size criteria for C-Mn consumables

Process [a, b]	Maximum single pass fillet size
11	6 mm
12	12 mm
13, 114	8 mm

[a] In accordance with ISO 4063.

[b] Other processes if specified in the execution specification.

6.5.11 Joints in hollow sections including branch connections

Recommendations for joints in hollow sections including branch connections are given in Annex B.

6.5.12 Stud welding

Stud welding shall be carried out in accordance with ISO 14555.

Procedure testing undertaken in accordance with ISO 14555 shall be consistent with the application.

6.5.13 Slot and plug welds

Holes for slot and plug welds shall be sized to permit adequate access for welding.

Dimensions for plug welds shall meet the following conditions:

— the minimum diameter of the hole shall be T + 8 mm;

— the maximum diameter of the hole shall be the greater of T + 12 mm or 2,25 T.

where T is the thickness of the part in which the hole is made.

Dimensions for slot welds shall meet the following conditions:

— the minimum width of the slot shall be T + 8 mm;

— the maximum width of the slot shall be the greater of T + 12 mm or 2,25 T;

— the maximum length of the slot shall be 10 T.

where T is the thickness of the part in which the slot is made.

— the ends of the slot shall be semi-circular.

Any fillet welds made in plug or slot welds shall be visually inspected prior to filling of the plug or slot weld.

6.5.14 Other weld types

The requirements for other weld types not within the scope of this document shall be in accordance with appropriate ISO standards or other national standards or documents.

6.5.15 Post-weld heat treatment

If required by the execution specification, post-weld heat treatment shall be carried out in accordance with a WPS/WPQR.

NOTE Guidance on quality requirements for heat treatment is given in ISO 17663.

6.5.16 Execution of welding

Considerations shall be given to prevent stray arcs. If stray arcs occur, the surface of the steel shall be visually inspected for cracks or other surface defects.

For static applications using steels with yield strength of 350 MPa or less, arc strikes do not need to be ground. For static applications using steels greater than 350 MPa, arc strikes shall be lightly ground to ensure a smooth and flush surface condition.

For fatigue, seismic and special corrosion applications, arc strikes shall be lightly ground to ensure a smooth and flush surface condition followed by PT or MT.

Precautions should be taken to avoid weld spatter where the same treatment for stray arcs is to be applied.

Visible imperfections such as cracks, cavities and rejectable imperfections shall be removed from each pass/run before deposition of further passes/runs.

Requirements for grinding and dressing of the surface of completed welds, if any, shall be stated in the execution specifications.

Slag should be removed from the surface of each weld pass, with particular attention to the junctions between the weld and the parent metal.

6.5.17 Welding of bridge orthotropic decks

Production tests shall be carried in accordance with 7.2.5 c). Production tests are not required for stiffener-deck plate connection outside the roadway (curbs) which is without loading by vehicles.

For stiffener-deck plate connections and local welds (e.g. at stiffener-stiffener connections with splice plates), the starts and stops shall be removed.

For stiffener-crossbeam connections with stiffeners passing through the crossbeam with or without cope holes, the stiffeners should be welded first to the deck plate and the crossbeams subsequently assembled and welded.

6.6 Acceptance criteria

6.6.1 Routine requirements

Unless specified in the execution specification, for EXL1, EXL2 and EXL3 the acceptance criteria for weld imperfections shall be as follows, with reference to ISO 5817, except "Incorrect weld toe" (505) and "Micro lack of fusion" (401) which are not to be taken into account. Any additional requirements specified for weld geometry and profile shall be considered.

— EXL1, quality level D except quality level C for "Insufficient throat" (5213);

— EXL2, generally quality level C except quality level D for "Overlap" (506), "Stray arc" (601) and "End crater pipe" (2025) and quality level B for "Insufficient throat thickness" (5213);

— EXL3, quality level B.

For EXL4, the weld quality required shall be specified in the execution specification with respect to identified welds and shall meet the requirements for EXL3 as a minimum.

6.6.2 Seismic requirements

Unless specified in the execution specification, the requirements given in 6.6.1 shall apply to welds subject to seismic actions.

6.6.3 Fatigue requirements

For welds subject to fatigue, the execution specification shall specify the relevant acceptance criteria in terms of the FAT fatigue classification in accordance with IIW-2259-15.

The option to use the FAT classification allows less onerous requirements to be specified for a weld subjected to relatively low fatigue loading in a joint with a higher classified resistance in accordance with IIW-2259-15. The conservative assumption for specification is that the acceptance criteria for a weld should be specified to meet the full resistance level associated with that classified structural detail.

For EXL2, EXL3 and EXL4, in addition to the criteria specified in 6.6.1, the acceptance criteria for welds shall be in accordance with ISO 5817:2023, Annex C:

— FAT not exceeding 63: Quality level C63 (EXL2, EXL3 or EXL4);

— FAT above 63 and not exceeding 90: Quality level B90 (EXL3 or EXL4 only);

— FAT above 90 and not exceeding 125: Quality level B125 (EXL3 or EXL4 only).

The execution specification shall specify any additional execution requirements that are necessary to conform with the assumptions of design for fatigue resistance.

6.6.4 Nonconformity assessment

In the case of a nonconformity with the requirements of this document, each weld defect may be assessed on the function of the component in which the defect occurs and on the characteristics of the imperfection (type, size, location) in deciding if the weld is to be accepted or repaired.

Where it can be demonstrated, by the use of fracture mechanics or other suitable method of assessment, that a specific defect will not be injurious to the performance of the structure, that specific defect does

not need to be repaired or re-welded, provided that the specific defect is acceptable in accordance with the provisions of the execution specification (see ISO 17607-1).

Repaired welds shall be re-inspected to the same quality level as that specified for the original weld (see 7.2.2.3).

6.6.5 Bridge decks

If additional limits of imperfections are required for bridge decks, they shall be specified in the execution specification.

6.7 Welding dissimilar steels

When welding dissimilar steels, the welding coordinator shall consider the appropriate welding techniques, welding processes and welding consumables. Issues associated with contamination and galvanic corrosion should be considered carefully.

7 Inspection, testing and correction

7.1 General

See ISO 17607-1.

7.2 Welding

7.2.1 General

Inspection and testing before and during welding shall be included in the inspection plan in accordance with the requirements given in the relevant part of the ISO 3834 series.

The inspection and test plan shall include type testing (see 7.2.2.2), routine inspection and testing (see 7.2.2.3) and project specific inspection and testing (see 7.2.2.4). The inspection and test plan shall identify joints for specific inspection of the fit-up that are likely to present difficulties in achieving the specified fit-up.

Non-destructive testing (NDT) methods used for inspection shall be selected in accordance with ISO 17635 as the basis for the inspection and test plan required by the welding plan.

NDT, with the exception of visual inspection, shall be performed by personnel qualified according to ISO 9712 minimum Level 2.

7.2.2 Inspection after welding

7.2.2.1 Timing

The visual inspection and supplementary NDT of a weld shall not be completed until after the minimum hold time after welding shown in Table 5 Option 1, unless permitted in the execution specification.

Where preheat is applied as specified in ISO/TR 17671-2:2002, Annex A, the visual inspection and supplementary NDT of a weld shall not be completed until after the minimum hold time after welding shown in Table 5 Option 2 or 3 as applicable, unless permitted in the execution specification.

The hold times in Table 5 should also be observed if it is specified that the parent metal adjacent to a weld zone shall be inspected for laminations after welding.

For welds requiring preheat, these periods may be reduced if the weldment is post-heated for a period after welding is complete.

If a weld will become inaccessible through subsequent work, it shall be inspected prior to subsequent work being carried out.

Any weld located in a zone where unacceptable distortion has been corrected shall be inspected again.

Table 5 — Minimum hold times

		Hold time hours [b]	
Option 1: Preheat not applied in accordance with ISO/TR 17671-2:2002, Annex A			
Weld size mm [a]		**Yield strength 355 MPa to 450 MPa**	**Yield strength > 450 MPa to 700 MPa**
(a or s) ≤ 12		Cooling period only	12
12 < (a or s) ≤ 37		Cooling period only	24
37 < (a or s)		48	48
Option 2: Where preheat is applied in accordance with Method A of ISO/TR 17671-2:2002, Annex A			
Weld size mm [a]	**Heat input Q kJ/mm**	**Yield strength 355 MPa to 450 MPa**	**Yield strength > 450 MPa to 700 MPa**
(a or s) ≤ 6	All	Cooling period only	24
6 < (a or s) ≤ 12	≤ 3	8	24
	>3	16	40
(a or s) > 12	≤ 3	16	40
	> 3	24	48
Option 3: Where preheat is applied in accordance with Method B of ISO/TR 17671-2, Annex A			
Weld size mm [a]		**Yield strength 355 MPa to 450 MPa**	**Yield strength > 450 MPa to 700 MPa**
(a or s) ≤ 20		Cooling period only	24
(a or s) > 20		24	48

[a] Size applies to the nominal throat thickness a of a fillet weld or the nominal material thickness s of a full penetration weld. For individual partial penetration butt welds the governing criterion is the nominal weld depth a, but for pairs of partial penetration butt welds welded simultaneously it is the sum of the weld throats a.

[b] The time between weld completion and commencement of NDT shall be stated in the NDT report. In the case of cooling period only, this is until the weld is cool enough for NDT to commence.

7.2.2.2 Type testing

For the first five joints made to the same new WPS, the following requirements shall be fulfilled:

a) the quality level B of ISO 5817 is required for demonstration of the WPS in production conditions;

b) the minimum length to be inspected is 900 mm.

If testing gives non-conforming results, an investigation shall be carried out in order to find the reason and a new set of five joints shall be tested. The guidance in ISO 17635:2016, Annex C should be followed.

7.2.2.3 Routine inspection and testing

All welds shall be 100 % visually inspected along their entire length. If surface breaking defects are detected, surface testing by penetrant testing or magnetic particle inspection shall be carried out on the inspected weld.

Unless otherwise specified in the execution specification, no supplementary NDT is required for EXL1 welds. For EXL2 and EXL3 welds, the extent of supplementary NDT is as specified in Table 6.

For EXL4 welds, the scope of supplementary NDT shall be specified in the execution specification with respect to each identified weld.

The extent of NDT covers both testing of surface or internal imperfections if applicable.

The methods to be used for supplementary NDT shall be selected by the appropriate welding coordination personnel from those given in 7.2.2.6.

NOTE 1 Supplementary NDT is any NDT other than visual inspection.

Once it has been established that production welding according to a WPS meets the quality requirements according to 7.2.2.2, the required extent of supplementary NDT shall be in accordance with Table 6 with further joints welded according to the same WPS treated as a single continuing inspection lot. The percentages apply to the extent of supplementary NDT treated as the cumulative amount within each inspection lot.

The percentage extent of testing (p %) according to Table 6 is defined as a part of an inspection lot according to the following rules, unless otherwise specified:

a) each weld in the inspection lot shall be tested over a length of minimum p % of the individual length. The area to be tested shall be selected at random;

b) if the total length of all the welds in an inspection lot is less than 900 mm, at least one weld shall be tested in its entire length regardless of the p %;

c) if an inspection lot consists of several identical welds with individual length less than 900 mm, randomly selected welds with a minimum total length of p % of the total length of all welds in the inspection lot shall be tested in their entire length.

The joints for routine inspection according to Table 6 shall be selected to ensure that sampling covers the following variables as widely as possible: the joint type, the constituent product grade, the welding equipment, and the work of the welders. The extent of inspection in Table 6 is related to production welds over a rolling annual basis.

If routine testing of production welds in a given workshop on an annual basis or using electronic methods of monitoring welding parameters demonstrates consistently acceptable quality for welds of a specific type (i.e. joint type, constituent product grade and welding equipment) the extent of routine supplementary NDT in that workshop may be reduced below the percentages given in Table 6 at the discretion of the appropriate welding coordination personnel, provided that a three monthly programme of production audit testing is implemented and documented.

The execution specification may identify specific joints for inspection together with the extent and method of testing (see 7.2.2.4). This testing may be counted within the extent of routine testing as appropriate.

If inspection gives non-conforming results, investigation shall be carried out in order to find the reason.

Table 6 — Extent of supplementary NDT

Type of weld	Shop and site welds		
	EXL1	EXL2	EXL3[d]
Transverse butt welds and partial penetration welds in butt joints	0 %	10 %	20 %
Transverse butt welds and partial penetration welds:			
in cruciform joints	0 % [a]	10 %	20 %
in T joints	0 %	5 %	10 %
Transverse fillet welds in tension or shear [b]:			
With a > 12 mm or t > 30 mm	0 %	5 %	10 %
With a ≤ 12 mm and t ≤ 30 mm	0 %	0 %	5 %
Full penetration longitudinal welds [c] between web and top flange of crane girders	0 %	10 %	20 %

Table 6 *(continued)*

Type of weld	Shop and site welds		
	EXL1	EXL2	EXL3[d]
Other longitudinal welds and welds to stiffeners and welds specified in the execution specification as being in compression	0 %	0 %	5 %
[a] 10 % for such welds executed in steel ≥ S420.			
[b] *a* and *t* refer respectively to the throat thickness and the thickest material being joined.			
[c] Longitudinal welds are those made parallel to the component axis. All the others are considered as transverse welds.			
[d] For EXL4, the percentage extent shall be at least that given for EXL3.			

7.2.2.4 Project specific inspection and testing

For EXL1, EXL2 and EXL3, the execution specification may identify requirements for production testing and specific joints for inspection together with the extent of testing.

For EXL4 execution specification shall identify specific joints for inspection together with the extent of testing, which shall be that specified for EXL3 as a minimum.

If specified, weld inspection classes (WICs) may be used to classify specific welds for inspection, and in this respect to define the scope and percentage extent of supplementary testing and the test methods to be used according to the criticality of the weld (see Annex C for guidance). If WICs are used, the execution specification shall be used to identify the WIC for each relevant weld.

7.2.2.5 Visual inspection of welds

Visual inspection shall be performed in accordance with ISO 17637 after completion of welding in an area and before any other NDT is carried out.

Visual inspection shall include:

a) the presence and location of all welds;

b) inspection of the welds in accordance with ISO 17637;

c) stray arcs and areas of weld spatter.

Visual inspection of the shape and surface of welds of welded branch joints using hollow sections shall pay careful attention to the following locations:

d) for circular sections: the mid-toe, mid-heel and two mid-flank positions;

e) for square or rectangular sections: the four corner positions.

If planar imperfections are detected by visual inspection, the affected segments of the weld shall be tested using other appropriate NDT methods to determine the extent.

7.2.2.6 Supplementary NDT methods

All NDT shall be performed in accordance with written procedures for the individual test methods as follows:

a) penetrant testing (PT) in accordance with ISO 3452-1;

b) magnetic particle (MT) in accordance with ISO 17638;

c) ultrasonic testing (UT) in accordance with ISO 17640, ISO 23279;

d) radiographic testing (RT) in accordance with ISO 16371-1 and ISO 16371-2.

If an NDT method, that is not referenced in ISO 17635, is specified for use by the execution specification, it shall be carried out in accordance with a written procedure with specified acceptance levels, e.g. phased array UT in accordance with ISO 13588.

The field of application of NDT methods is specified in their relevant standards or written procedures. The acceptance levels of NDT shall be performed in accordance with written procedures for the individual test methods e.g. ISO 13588.

7.2.2.7 Correction of welds

For EXL2, EXL3 and EXL4, repairs by welding shall be carried out in accordance with qualified welding procedures.

Corrected welds shall be checked and shall meet the requirements of the original welds.

7.2.3 Inspection and testing of welded shear studs for composite steel and concrete structures

Inspection and testing of welded shear studs for composite steel and concrete structures shall be carried out in accordance with ISO 14555.

NOTE This inspection includes checking the length of the studs after welding.

Non-conforming studs shall be repaired or replaced. It is recommended that replacement studs be welded in an adjacent new position.

The proper operation of welding equipment used on site should be rechecked after it has been moved and at the commencement of each shift or other period of work by using tests on studs welded with the equipment in accordance with ISO 14555.

7.2.4 Inspection and testing of welding of reinforcing steel

Inspection and testing of welding of reinforcing steel for composite steel and concrete structures shall be carried out according to ISO 17660-1 or ISO 17660-2.

7.2.5 Production tests on welding

If specified, for EXL3 and EXL4, production tests shall be carried out as follows:

a) each welding procedure qualification used for welding steel grades of higher than 460 MPa yield strength shall be checked with a production weld. Testing includes VT, PT or MT, UT or RT (for butt welds), hardness testing and macroscopic examination. The tests and results shall be in accordance with the relevant standard for the welding procedure test;

b) if the deep penetration of a welding process is used for fillet welds, the penetration of the welds shall be checked. The results of the actual penetration shall be documented;

c) for bridge deck orthotropic steel plates:

   1) stiffener to deckplate connections welded by fully mechanized welding process shall be checked with a production test for each 120 m length of bridge, with a minimum of one production test for a bridge and inspected by macro-examination. Macro section tests shall be prepared at start or stop and at the middle of the weld;

   2) stiffener to stiffener connections with splice plates shall be checked with a production test.

8 Documents required to claim conformity to this document

8.1 General

Constructors may claim conformity with the requirements of this document either by:

— adoption of the ISO standards referenced as applicable; or

— adoption of other standards or documents that provide technically equivalent conditions to the ISO standards listed in this document;

— adoption of other documents that provide technically equivalent conditions to the ISO standards listed in this document.

Unless otherwise listed in the execution specification, it is the responsibility of the constructor to demonstrate that the standards or documents selected provide technically equivalent conditions to those in the corresponding ISO standards.

Prior to execution, adoption of other standards or documents shall be verified and approved by the specifier and shall be incorporated into the execution specifications.

8.2 Declaration of conformity

A constructor claiming conformity with these requirements shall list the applicable supporting standards or documents.

Annex A
(normative)

Additional information, list of options and requirements related to the execution levels

A.1 List of required additional information

Table A.1 provides the additional information that is required in the text of this document as appropriate to fully define the requirements for execution of the work to be in accordance with this document (i.e. where the wording "shall be specified" is used).

Table A.1 — Additional information

Clause	Additional information required
6.4.1.2	Start and stop zones and methods for hollow section joints
6.5.6	Areas where welding of temporary attachments is not permitted
6.5.6	Use of temporary attachments for EXL3 and EXL4
6.5.9.1	The location of butt welds used as splices to accommodate available lengths of constituent products
6.5.13	Dimensions of holes for slot and plug welds
6.5.14	Requirements for other weld types
6.5.16	If VT of stray arcs on steel grades < 460 MPa is to be supplemented by PT or MT
	Requirements for grinding and dressing of the surface of completed welds
6.6	Any additional requirements for weld geometry and profile
6.6.1	Weld quality for identified welds for EXL4
6.6.2	Acceptance criteria in terms of detail category (DC) for welded joint locations subject to fatigue
7.2.2.3	The scope of supplementary NDT for each identified EXL4 weld
7.2.2.4	Specific EXL4 joints for inspection together with the extent of testing

A.2 List of options

Table A.2 lists the items which may be specified in the execution specification to define requirements for the execution of the work where options are given in this document.

Table A.2 — List of options

Clause	Option(s) to be specified
4.	If a quality plan for execution of the welding is required
5.2	If traceability for each individual constituent product is specified
5.2	If other options than those in Table 6 shall be used
5.2	If colour matching is required for when welding improved atmospheric corrosion resistant steel
6.2	If there are welding requirements related to fatigue or seismic detail categories
6.2	If there are specific requirements related to the inspection, maintenance, and repair of welding equipment
6.3	If use of other welding processes is explicitly allowed

Table A.2 *(continued)*

Clause	Option(s) to be specified
6.4.1.1	If special deposition conditions for tack welds are required
	If work instructions are to be used for EXL1
6.4.1.2 a)	If impact tests are required
6.4.1.2	If standard welding procedures may be used for EXL3 or EXL4
	Alternative conditions to testing in accordance with ISO 9018
6.5.1.1	If cope holes may have a radius less than 40 mm
6.5.4	Other specification than in Annex B for assembly of hollow section components to be welded
6.5.6	If chipping and gouging are permitted on grades ≥ 460 MPa or on components subject to fatigue
	If cutting and chipping are permitted for EXL3 and EXL4
6.5.7	If tack welds that are not incorporated into final welds need to be removed
6.5.9.1	For EXL2, if run-on/run-off pieces are required for full penetration transverse butt welds
	For EXL2, EXL3 and EXL4, if run-on/run-off pieces are required for full penetration longitudinal butt welds or partial penetration butt welds
	If a flush surface is required
6.5.9.2	If permanent steel backing material shall not be used for single side welds
6.5.9.2	If flush grinding of single-sided butt welds in joints between hollow sections executed without backing is permitted
6.5.13	If plug welds performed without previous slot welding are permitted
6.5.16	If, for steel grades ≥ 460 MPa, removing of weld spatter is not required
6.6.1	If, for EXL1, EXL2 and EXL3, other acceptance criteria for weld imperfections are required
6.6.2	If alternative acceptable criteria for welds subject to seismic actions applies
6.6.3	Alternative criteria if acceptance criteria for welds subject to fatigue are not to be specified in terms of detail category (DC)
	If acceptance criteria to ISO 5817:2023, Annex C are to be used
6.6.5	Requirements for welds in orthotropic bridge decks
7.2.1	If specific joints are identified for inspection together with the extent and method of testing for EXL1, EXL2 and EXL3
	If WICs are to be used for defining the scope and percentage extent of supplementary, and, if so, the WIC for each relevant weld
7.2.2.1	If visual inspection and supplementary NDT of a weld can be completed before the designated hold time
7.2.5	If production tests are required for EXL3 and EXL4
Annex B – Welded joints in hollow sections	
B.4(d)	If the hidden toe area is not to be welded

A.3 Requirements related to the execution levels

This clause lists requirements specific to each of the execution levels referenced in this document.

Items identified in bold letters in Table A.3 relate to the general system of control of execution and are amenable to a common choice of execution level across the whole of the structural steelwork (or a phase of the structural steelwork). The other items generally demand the selection of the appropriate execution level on a component–by-component or a connection detail-by-detail basis.

Table A.3 — Requirements to each execution level

Clauses	EXL1 [a]	EXL2 [a]	EXL3	EXL4
4 – **Execution specification and quality requirements**				
Quality documentation	—	Yes	Yes	Yes
5 – **Constituent products**				
Inspection documents	See Table 1	See Table 1	See Table 1	See Table 1
Traceability	—	Yes (partial)	Yes (full)	Yes (full)
	—	Yes (by marking)	Yes (from receipt to handover)	Yes (from receipt to handover)
Marking	—	Yes	Yes	Yes
6 – **Welding**				
6.1 General	ISO 3834-4	ISO 3834-3	ISO 3834-2	ISO 3834-2
6.4 Qualification of welding procedures and welding personnel				
6.4.1 Qualification of welding procedures	—	See Table 2	See Table 2	See Table 2
6.4.2 Welders and welding operators	Welders: ISO 9606-1 Operators: ISO 14732	Welders: ISO 9606-1 Operators: ISO 14732	Welders: ISO 9606-1 Operators: ISO 14732	Welders: ISO 9606-1 Operators: ISO 14732
6.4.3 Welding coordination	—	Technical knowledge and competence ISO 14371	Technical knowledge and competence ISO 14371	Technical knowledge and competence ISO 14371
6.5.1 Joint preparation	—	—	Prefabrication primers not allowed	Prefabrication primers not allowed
6.5.6 Temporary attachments	—	—	Use to be specified Cutting and chipping not permitted	Use to be specified Cutting and chipping not permitted
6.5.7 Tack welds	—	Qualified welding procedure	Qualified welding procedure	Qualified welding procedure
6.5.9 Butt welds **6.5.9.1 General** **6.5.9.2 Single side welds**	—	Run on/run off pieces if specified	Run on/run off pieces Permanent backing continuous	Run on/run off pieces Permanent backing continuous
6.5.16 Execution of welding	—	—	Removal of spatter	Removal of spatter
6.6 Acceptance criteria	ISO 5817 Quality level D	ISO 5817 Quality level C generally	ISO 5817 Quality level B	ISO 5817 Quality level B with specific criteria for identified welds
7 – **Inspection, testing and correction**				
7.2.1 General	VT	NDT: See Table 6	NDT: See Table 6	NDT: See Table 6
7.2.2.7 Correction of welds	No WPQR required	In accordance with WPQR	In accordance with WPQR	In accordance with WPQR
7.2.5 Production tests	—	—	If specified	If specified

Table A.3 *(continued)*

Clauses	EXL1 [a]	EXL2 [a]	EXL3	EXL4
Key				
A dash "—" means no specific requirement in the text.				

Annex B
(informative)

Welded joints in hollow sections

B.1 General

This annex gives guidance for execution of welded joints in hollow sections.

B.2 Guidance for start and stop positions

The following guidance may be used for in-line joints:

a) stop and start positions of welds for in-line splice joints in chords should be chosen to avoid these positions coming directly under the location of a subsequent weld between a brace and the chord;

b) stop and start positions for welds between two in-line square or rectangular hollow sections should not be located at or close to the corner positions.

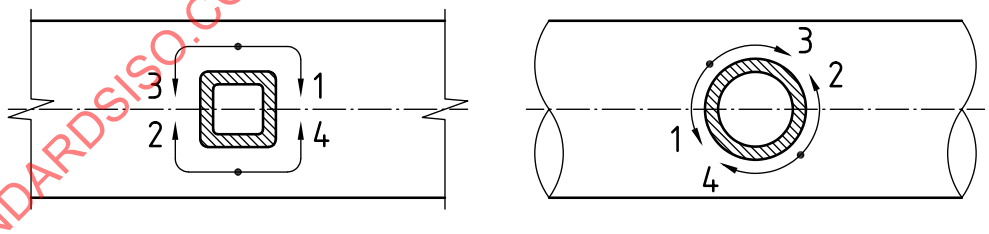
The following guidance may be used for other joints:

c) stop and start positions should not be located at or close to the toe position or lateral flank positions of a joint between two circular hollow sections in accordance with Figure B.1;

d) stop and start positions should not be located at or close to the corner positions of a joint between a square or rectangular hollow section bracing and a hollow chord component;

e) recommended welding sequence for welding brace to chord joints are given in Figure B.1;

f) welding between hollow sections should be completed all round, even if this total length of weld is not necessary for strength reasons.



a) Square/rectangular section **b) Circular section**

Key

• weld start point

1, 2, 3, 4 order of welding

Figure B.1 — Start and stop positions and welding sequence

B.3 Preparation of joint faces

With reference to 6.5.1.2, examples of application of ISO 9692-1 to brace to chord joints between hollow sections are given in Figures B.2 to B.5.

Recommendations for the weld preparation and fit-up for mitre butt joints are locally the same as for butt welds between two components in-line, which requires the bevel angle to be increased on the inside of the mitre and reduced on the outside as shown in Figure B.6.

B.4 Assembly for welding

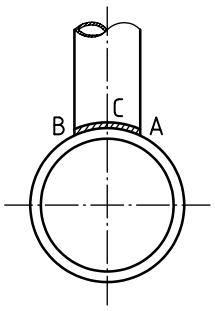
In accordance with 6.5.4, assembly of hollow section components to be welded should be in accordance with the following requirements:

a) assembly using non-overlapping welding of the separate components is preferred (Case A in Figure B.7);

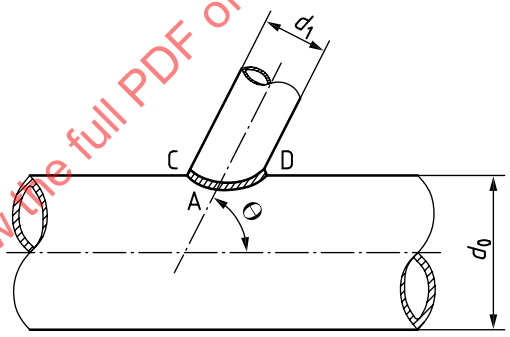
b) assembly of overlapping components should be avoided; if necessary Case B in Figure B.7 is acceptable;

c) if components overlap (as Case B), the welding details shall specify which components are to be cut to fit around other components;

d) the hidden toe area (as Case B) does not have to be welded unless specified in the execution specification.



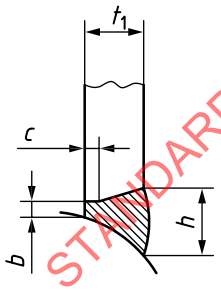
a) End view



$d_1 < d_0$

θ = 60° to 90°

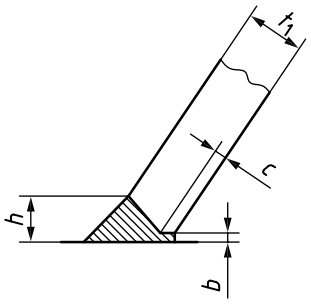
b) Side view



b = 2 mm to 4 mm

c = 1 mm to 2 mm

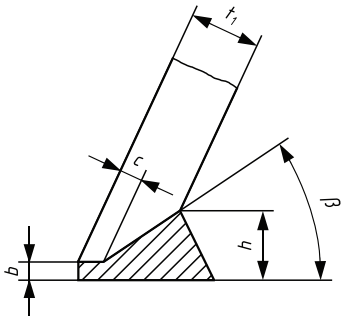
c) Detail at A or B



b = 2 mm to 4 mm

c = 1 mm to 2 mm

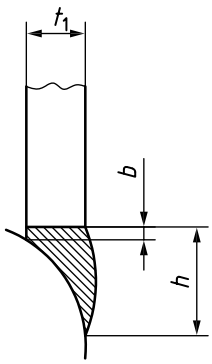
d) Detail at C



b = 2 mm to 4 mm

c = 1 mm to 2 mm

e) Detail at D:



For θ < 60°, a fillet weld detail (as Figure B.3) should be used at D in the heel area.

$d_1 = d_0$

b = max. 2 mm

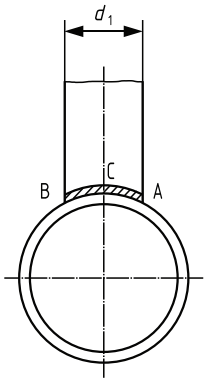
f) Detail at A or B for θ < 60°

Key

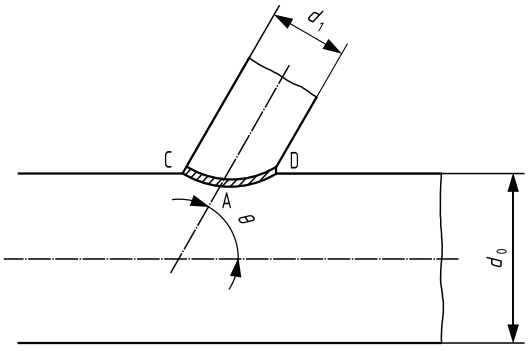
d_1	outside diameter of brace member	c	root face
d_0	outside diameter of chord member	t_1	thickness of brace member
θ	brace angle	h	weld height
b	root opening		

NOTE The figure presents the application of recommended joint preparation 1.4 as designated in ISO 9692-1 for circular hollow sections.

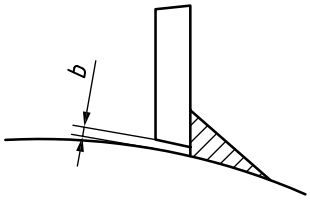
Figure B.2 — Weld preparation and fit-up — Butt welds in circular hollow sections brace to chord joints



a) End view

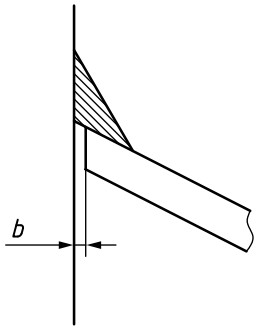


b) Side view



b = max. 2 mm

c) Detail at A or B:

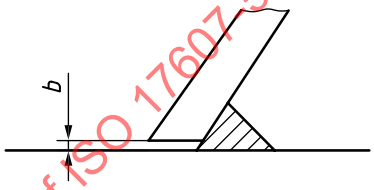


b = max. 2 mm

$60° \leq \theta < 90°$

d) Detail at C:

For $\theta < 60°$, a butt weld detail (as Figure B.2) should be used at C in the toe area

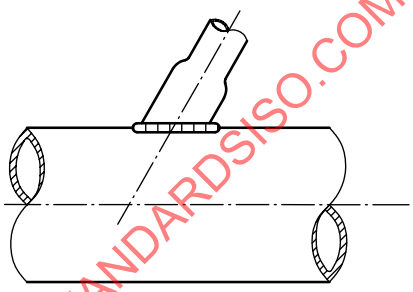


b = max. 2 mm

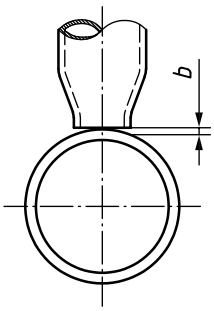
$30° \leq \theta < 90°$

e) Detail at D:

For the smaller angles, full penetration is not required provided there is adequate throat thickness



f) Side view



b = max. 2 mm, measured along the longitudinal axis of the larger pipe diameter

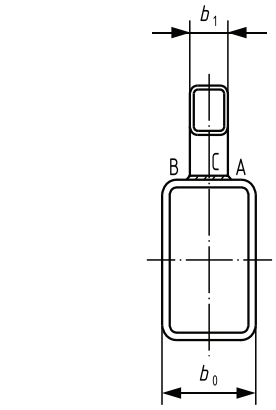
g) end view

Key

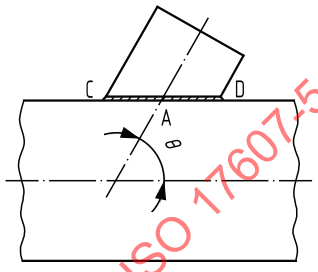
d_1	outside diameter of brace member	θ	brace angle
d_0	outside diameter of chord member	b	root opening

NOTE The figure presents the application of recommended joint preparation 3.1.1 as designated in ISO 9692-1 for circular hollow sections.

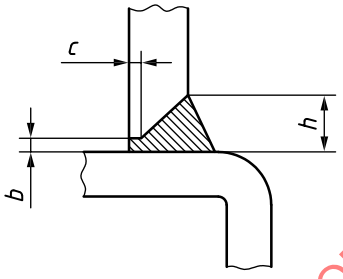
Figure B.3 — Weld preparation and fit-up — Fillet welds in circular hollow section brace to chord joints



a) End view



b) Side view

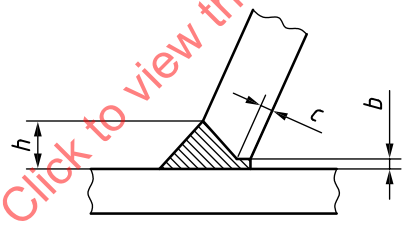


where $b_1 < b_0$

b = 2 mm to 4 mm

c = 1 mm to 2 mm

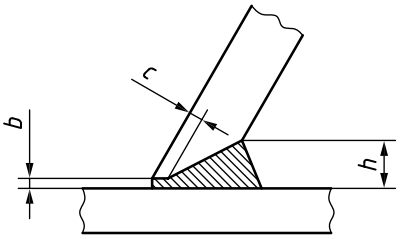
c) Detail at A or B:



b = 2 mm to 4 mm

c = 1 mm to 2 mm

d) Detail at C:



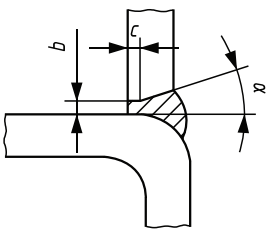
b = 2 mm to 4 mm

c = 1 mm to 2 mm

$60° \leq \theta < 90°$

e) Detail at D:

For $\theta < 60°$, a fillet weld detail (as Figure B.5) is preferred to the detail at D in the heel area – see also Tables B.1 and B.2 for z-loss allowances.



where $b_1 = b_0$

b = 2 mm max.

c = 1 mm to 2 mm

α = 20° to 25°

f) Detail at A or B where brace and chord of same width

Key

b_1	outside width of brace member	c	root face
b_0	outside width of chord member	h	weld height
θ	brace angle	α	chord bevel angle
b	root opening		

NOTE The figure presents the application of recommended joint preparation 1.4 as designated in ISO 9692-1 for circular hollow sections.

Figure B.4 — Weld preparation and fit-up — Butt welds in square or rectangular hollow section brace to chord joints

Table B.1 — Z loss dimension when determining minimum weld sizes in non-tubular connections

Dihedral angle, ψ	Welding position – PF/PG or PC/PD [b]		Welding position – PC/PD or PA [b]	
	Process [a]	Z mm	Process [a]	Z mm
60° >ψ ≥ 45 °	111	3	111	3
	114	3	114	0
	137	3	137	0
	131	N/A	131	0
45° >ψ ≥ 30 °	111	6	111	6
	114	6	114	3
	137	10	137	6
	131	N/A	131	6

[a] In accordance with ISO 4063.

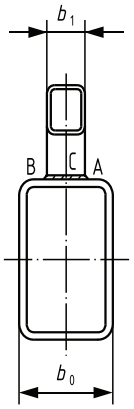
[b] In accordance with ISO 6947.

Table B.2 — Z loss dimension when determining minimum weld sizes in PJP T-, Y-, and K-tubular connections

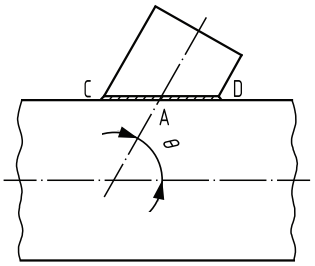
Joint included angle ϕ	Welding position – PF/PG or PE [b]		Welding position – PC or PA [b]	
	Process [a]	Z mm	Process [a]	Z mm
$\phi \geq 60°$	111	0	111	0
	114	0	114	0
	137	0	137	0
	131	N/A	131	0
	131-D	0	131-D	0
$60° > \phi \geq 45°$	111	3	111	3
	114	3	114	0
	137	3	137	0
	131	N/A	131	3
	131-D	3	131-D	6
$45° > \phi \geq 30°$	111	6	111	3
	114	6	114	6
	137	10	137	6
	131	N/A	131	6
	131-D	10	131-D	6

[a] In accordance with ISO 4063.

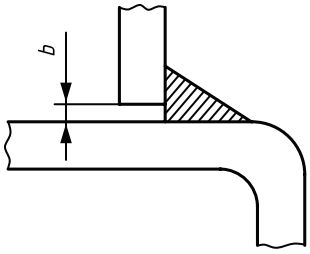
[b] In accordance with ISO 6947.



a) End view



b) Side view

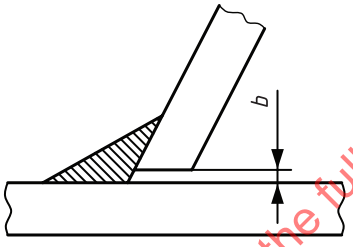


c) Detail A - B:

where $b_1 < b_0$

b = max. 2 mm

For $\theta < 60°$, a butt weld detail (as Figure B.4) should be used at C in the toe area.

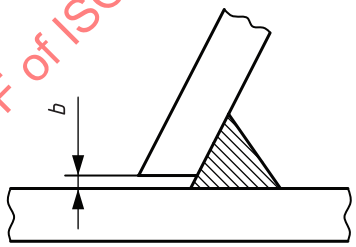


d) Detail at C:

$60° \leq \theta < 90°$

b = max. 2 mm

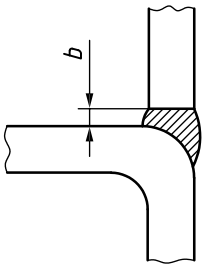
For the smallest angles, full penetration is not required provided there is adequate throat thickness



e) Detail at D:

$30° \leq \theta < 90°$

b = max. 2 mm



where $b_1 = b_0$

b = max. 2 mm

f) Detail at A or B where brace and chord of same width