INTERNATIONAL STANDARD

**ISO 17927-1**

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# Welding for aerospace applications — Fusion welding of metallic components —

## Part 1: Process specification

*Soudage pour applications aérospatiales — Soudage par fusion des composants métalliques —*

*Partie 1: Spécification de processus*



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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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 44, *Welding and allied processes*, Subcommittee SC 14, *Welding and brazing in aerospace*.

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. Official interpretations of ISO/TC 44 documents, where they exist, are available from this page: https://committee.iso.org/sites/tc44/home/interpretation.html.

A list of all parts in the ISO 17297 series can be found on the ISO website.

# Welding for aerospace applications — Fusion welding of metallic components —

# Part 1: Process specification

## 1 Scope

This document specifies the requirements for fusion welding of aerospace hardware. It is to be used in conjunction with the design/engineering authority's design documents or their accepted data.

This document covers the processes given in Table 1 and material groups given in Table 2.

**Table 1 — Fusion welding processes covered by this document**

| Process | Process number (ISO 4063) |
|---|---|
| Oxyfuel welding | 31 |
| Gas-shielded arc welding with non-consumable tungsten electrode, Gas tungsten arc welding | 14 |
| Plasma arc welding | 15 |
| Electron beam welding | 51 |
| Laser welding, Laser beam welding | 52 |

**Table 2 — Material groups covered by this document (see ISO 24394:2018, 4.5)**

| Material group | Description |
|---|---|
| A | Unalloyed steel, low-alloyed steels, high-alloyed ferritic steels |
| B | Austenitic, martensitic and precipitation hardening steels |
| C | Titanium and titanium alloys, niobium, zirconium and other reactive metals |
| D | Aluminium and magnesium alloys |
| E | Materials that do not conform to other material groups (e.g. molybdenum, tungsten, copper alloys) |
| F | Nickel alloys, cobalt alloys. |



## 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 3452 (all parts), *Non-destructive testing — Penetrant testing*

ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers*

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

ISO 5173, *Destructive tests on welds in metallic materials — Bend tests*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

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

ISO 6508 (all parts), *Metallic materials — Rockwell hardness test*

ISO 6892 (all parts), *Metallic materials — Tensile testing*

ISO 9015-1, *Destructive tests on welds in metallic materials — Hardness testing — Part 1: Hardness test on arc welded joints*

ISO 10863, *Non-destructive testing of welds — Ultrasonic testing — Use of time-of-flight diffraction technique (TOFD)*

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

ISO 17636 (all parts), *Non-destructive testing of welds — Radiographic testing*

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 17927-2[1)], *Welding for aerospace applications — Fusion welding of metallic components — Part 2: Acceptance criteria*

ISO 19828, *Welding for aerospace applications — Visual inspection of welds*

ISO 24394, *Welding for aerospace applications — Qualification test for welders and welding operators — Fusion welding of metallic components*

ISO/TR 25901-1, *Welding and allied processes — Vocabulary — Part 1: General terms*

EN 4179, *Aerospace series — Qualification and approval of personnel for non-destructive testing*

ASTM E8/E8M, *Test Methods for Tension Testing of Metallic Materials*

ASTM E18, *Test Methods for Rockwell Hardness of Metallic Materials*

ASTM E21, *Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials*

ASTM E384, *Standard Test Method for Microindentation Hardness of Materials*

ASTM E1417/E1417M, *Standard Practice for Liquid Penetrant Testing*

ASTM E1742/E1742M, *Standard Practice for Radiographic Examination*

ASTM E1444/E1444M, *Standard Practice for Magnetic Particle Testing*

SAE AMS 2644, *Inspection Material, Penetrant*

SAE AMS-STD-2154, *Inspection, Ultrasonic, Wrought Metals, Process for*



## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 25901-1 and the following apply.

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

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

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

1) Under preparation. (Stage at the time of publication: ISO/FDIS 17927-2:2019.)

**3.1**
**backgouging**
removal of weld metal and base metal from the weld root side of a welded joint to facilitate complete fusion and complete joint penetration upon subsequent welding from that side

**3.2**
**design/engineering authority**
organization having the responsibility for the structural integrity or maintenance of airworthiness of the hardware and compliance with all relevant documents

[SOURCE: ISO 24394:2018, 3.8]

**3.3**
**welding procedure specification**
**WPS**
document providing in detail the required variables of the welding procedure to ensure repeatability

**3.4**
**welding procedure qualification record**
**WPQR**
record comprising all necessary data needed for qualification of a preliminary welding procedure specification

**3.5**
**autogenous weld**
fusion weld without filler material

## 4 Conformance

When conformance to this document is claimed, all provisions of this document are to be complied with, except those for provisions that the design/engineering authority specifically exempts.

## 5 Classification and inspection requirements of joints

For the purposes of this document, three classes of welds are defined. This classification shall be stated in the design documents. If there are no other testing requirements defined by the design/engineering authority, the minimum amount of testing shall be as follows.

— Class I: A welded joint whose failure under operating conditions causes the loss of the aircraft/spacecraft or one of its main components, or constitutes a direct hazard to people.

  Visual and dimensional inspection: 100 % of all welds; penetrant or and magnetic particle testing or any other surface test method: 100 % of all welds; testing of the sub-surface characteristics: 100 % of all welds.

— Class II: A welded joint whose failure causes malfunctions without compromising continued safe flight until the end of the mission.

  Visual and dimensional inspection, 100 % of all welds and penetrant or and magnetic particle testing or any other adequate test method, 100 % of all welds.

— Class III: A welded joint whose failure does not affect the safety and the transport function of the aircraft/spacecraft.

  Visual and dimensional inspection, 100 % of all welds.

For the purpose of series preparation/pre-production or in the case of critical welding operations, it can be necessary, also for classes II and III, to increase the scope of testing beyond that specified here. Likewise, in the course of series production, the scope of testing may be reduced if sufficient evidence of process reliability can be provided.

Refer to design/engineering authority for design documents not specifying a classification and/or inspection requirements.

## 6 Quality levels

Quality level A weld: Weld with high quality acceptance requirements.

Quality level B weld: Weld with moderate quality acceptance requirements.

Quality level C weld: Weld with typical quality acceptance requirements.

The quality levels are as defined by the engineering/drawing and/or specified by the design/engineering authority.

## 7 Weldment design

The design/engineering authority is responsible for the design of the weldment and defines the requirements to ensure compliance with all mission and systems requirements. The engineering documentation shall clearly define special requirements, such as fracture critical, durability critical, mission critical, or safety critical, imposed over and above the general requirements. Also, the design/engineering authority shall define process controls to ensure that all design requirements can be met by welds produced in accordance with specified procedure, fabrication, and inspection requirements.

For fillet welds, the weld size specified on the drawing is the minimum.

## 8 Welding procedure specification (WPS)

### 8.1 General

A welding procedure specification is required for each weld. For an example of a WPS, see Annex B.

The welding procedure specification (WPS) shall include the information as given in Table 3.

**Table 3 — Welding procedure specification (WPS) data**

| Essential variable | | Electron beam welding | TIG welding (GTAW[a]) | Laser beam welding | Oxyfuel welding | Plasma arc welding |
|---|---|---|---|---|---|---|
| **Joint design** | | | | | | |
| * | Joint type and dimensions | X | X | X | X | X |
| * | Treatment of backside, method of gouging/preparation | O | O | O | O | O |
| * | Backing | O | O | O | O | O |
| **Base metal(s)** | | | | | | |
| * | Base metal(s) designation(s) | X | X | X | X | X |
| * | Heat treatment condition | X | X | X | X | X |
| * | Base metal form (sheet, tube etc.) | X | X | X | X | X |
| * | Thickness | X | X | X | X | X |
| | Diameter (tubular only) | X | X | X | X | X |

X Data that shall be included in a WPS.

O Data that only need to be included in a WPS if used for that particular welding procedure.

[a] Gas tungsten arc welding.

**Table 3** *(continued)*

| Essential variable | | Electron beam welding | TIG welding (GTAW[a]) | Laser beam welding | Oxyfuel welding | Plasma arc welding |
|---|---|---|---|---|---|---|
| * | Coating description or type | O | O | O | O | O |
| | Material group number according to Table 2 | X | X | X | X | X |
| **Filler material** | | | | | | |
| * | Specification, alloy designation, or the nominal composition | O | O | O | O | O |
| * | Filler material size or diameter | O | O | O | O | O |
| * | Flux | | O | | O | |
| * | Filler material feed rate | O | O | O | | O |
| * | Consumable insert and type | | O | | | O |
| * | Hot wire | | O | O | | O |
| **Position** | | | | | | |
| * | Welding position(s) | X | X | X | X | X |
| **Preheat and interpass temperature** | | | | | | |
| | Preheat method | O | O | O | O | O |
| * | Preheat minimum and/or maximum temperature | O | O | O | O | O |
| * | Interpass temperature minimum and/or maximum | O | O | O | O | O |
| **Shielding gas** | | | | | | |
| * | Torch shielding gas and flow rate range | | X | X | | X |
| * | Root shielding gas and flow rate range | | X | X | | X |
| * | Environmental shielding and vacuum pressure | X | O | O | | |
| * | Shielding gas devices and flow rate ranges | | O | O | | O |
| * | Gas cup design/size or gas lens | | O | | | O |
| **Energy characteristics** | | | | | | |
| * | Current type and polarity | | X | | | X |
| * | Current range | X | X | | | X |
| * | Voltage range | X | O | | | X |
| * | Beam power; focus, current; pulse frequency range; filament type, shape, size | X | | X | | |
| * | Specification, classification, and diameter of tungsten electrode | | X | | | X |
| * | Electrode geometry | | X | | | X |
| * | Control of electrode to work piece distance (mechanized welding) | | X | | | X |
| * | Pulsed current parameters | | O | | | O |

X Data that shall be included in a WPS.

O Data that only need to be included in a WPS if used for that particular welding procedure.

[a] Gas tungsten arc welding.

**Table 3** *(continued)*

| Essential variable | | Electron beam welding | TIG welding (GTAW[a]) | Laser beam welding | Oxyfuel welding | Plasma arc welding |
|---|---|---|---|---|---|---|
| | Torch model number | | O | | | O |
| **Other welding process variables** | | | | | | |
| * | Welding process (designation and process number according to ISO 4063) | X | X | X | X | X |
| | Type of mechanization (manual, semiautomatic, mechanized, or automatic) | | X | | | X |
| * | Machine type for mechanized or automatic welding | X | X | X | | X |
| * | Multiple electrodes/energy sources and spacing | O | O | O | | O |
| * | Single or multipass | X | X | X | X | X |
| * | Cleaning method, tools, and/or agents | X | X | X | | X |
| | Post weld mechanical treatment (e.g. peening) | | O | | | O |
| * | Conventional or keyhole technique | X | | X | | X |
| * | Stringer bead or weave bead | | X | | | X |
| * | Travel-speed range for mechanized or automatic welding and manual applications requiring heat input calculations | X | X | X | | X |
| * | Fuel gas and flame type (oxidizing, neutral, carburizing) | | | | X | |

X Data that shall be included in a WPS.

O Data that only need to be included in a WPS if used for that particular welding procedure.

[a] Gas tungsten arc welding.



## 8.2 WPS qualification/welding procedure qualification record (WPQR)

WPS shall be qualified to the requirements given by the design/engineering authority.

The documentation shall be made by using a WPQR form (for an example, see Annex A) or as defined by the design/engineering authority.

If representative test pieces are used to replicate production parts, the correlation shall be based on the minimum essential variables as given in 8.1.

The standard welding procedure test shall be based on the design/engineering authority requirements. If no standard weld test pieces are specified, the standard weld test pieces specified in ISO 24394 may be used.

See Figure 1.

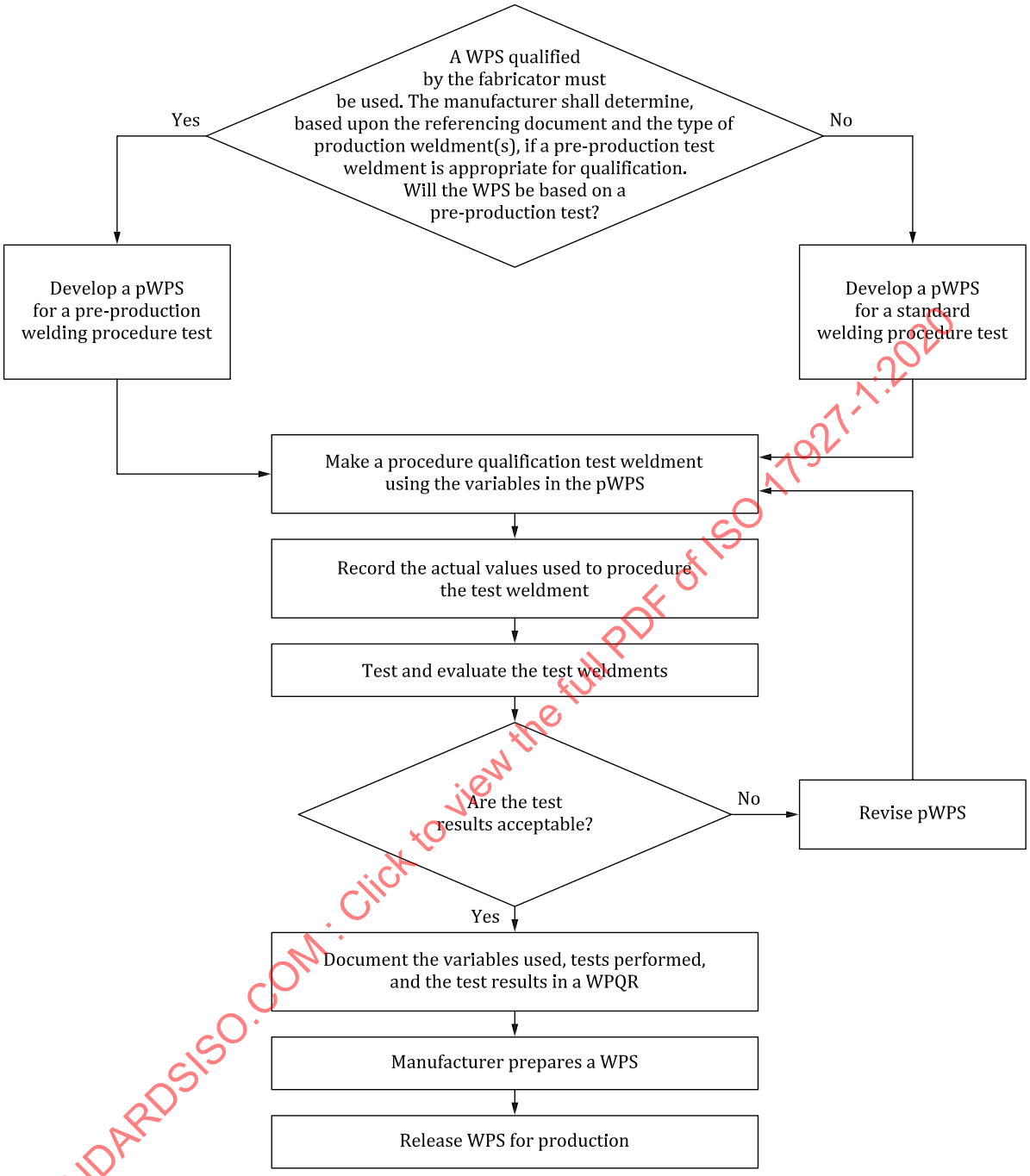





**Figure 1 — WPS qualification flowchart**

# 9 Fabrication

## 9.1 General

This clause establishes requirements for the fabrication of weldments. All welding shall be performed according to an approved WPS. All welding shall be performed by qualified personnel according to Clause 10.

## 9.2 Identification and traceability of welding consumables

Welding consumables shall be identified using a standard or specification agreed by the design/engineering authority. If the identification is destroyed or missing, the welding consumable shall not be used.

Identification should include:

a) the manufacturer;

b) the lot number (heat lot);

c) the standard/specification;

d) the certificate.

Traceability of welding consumables to heat/lot number to the component is not required unless specified by the design/engineering authority. If traceability is required, it shall be maintained throughout the welding process and documented.

## 9.3 Storage and use

### 9.3.1 Filler material

Filler material shall be stored in a clean and dry environment. During storage and use, filler materials with different identification shall not be mixed. Heating may be employed as necessary to prevent moisture accumulation.

### 9.3.2 Welding fluxes

Fluxes shall be stored in a clean and dry environment. During storage and use, fluxes with different identification shall not be mixed.

### 9.3.3 Gases

Gas containers shall be clearly marked (for example, see ISO 14175).

NOTE National requirements can exist regarding gas storage and use.

The gas quality (such as purity and/or dew point of gases) shall meet the specified requirements.

The fabricator is responsible for the gas quality at the point of use as relevant for the welding process. The fabricator shall address gas quality checks at suitable intervals.

## 9.4 Welding equipment

### 9.4.1 General

Welding equipment (such as welding machines, welding torches, regulators, filler material feeders, etc.) shall be capable of and maintained in a way that consistently produces welds that meet the specified acceptance criteria.

### 9.4.2 Calibration

#### 9.4.2.1 Meters, gauges and dials

In general, meters, gauges, and dials installed on automatic, mechanized, or robotic welding apparatus shall be calibrated using an established procedure. Manual adjusted float-type gas flow meters do not need to be calibrated.



For manual welding, the calibration of meters, gauges and dials is not mandatory according to this document. However, a functional check should be performed at regular intervals.

#### 9.4.2.2 Calibration period

Calibrations shall be performed at specified intervals as defined by the calibration procedure. The calibration interval shall not exceed two years.

Calibrations shall also be performed when meters, gauges and dials have been affected by maintenance or repair.

## 9.5 Weld joint preparation

### 9.5.1 Pre-weld joint configuration

#### 9.5.1.1 Joint preparation

The weld joint shall be prepared as indicated specified by the weld symbols (see ISO 2553) on the engineering drawing.

NOTE The ISO 9692 series provides guidelines for joint preparation.

#### 9.5.1.2 Fit-up

Fit-up tolerances shall be in accordance with the WPS.

### 9.5.2 Butt joint members of unequal thickness

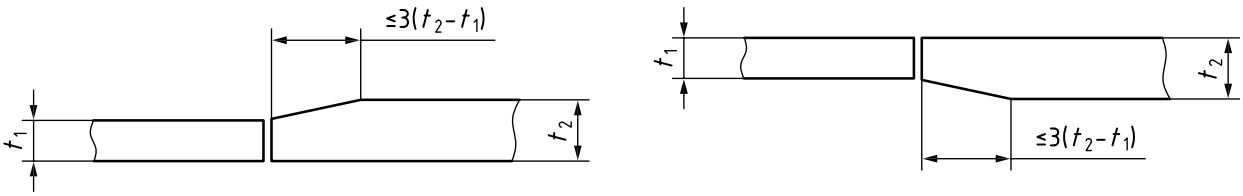
#### 9.5.2.1 Butt joint member preparation

Unless otherwise specified in the design documents, joint members shall be prepared as shown in Figure 2 when all of the following conditions exist:

a) a full penetration weld is specified on the engineering drawing;

b) both joint members exceed 3,2 mm in thickness;

c) the thickness ratio between joint members meets or exceeds: 1,5:1.




**Key**

$t_1$ thickness of the thinner member

$t_2$ thickness of the thicker member

**Figure 2 — Preparation of members of unequal thickness**

## 9.6 Pre-weld cleaning and other preparation

### 9.6.1 Surface cleaning

All surfaces to be welded and surfaces that can affect quality of the resulting weld (e.g. welding filler materials and fixtures) shall be free from slag, surface oxides, scale, protective finishes, oils, grease, dirt, or any other contaminants.

Mechanical methods (e.g. wire brushing, scraping or machining) and/or chemical methods (e.g. alkaline cleaning, solvent wipe, or etching) shall be used before assembly for welding, as needed, to assure compliance to these requirements.

Unless otherwise specified by the design/engineering authority, chlorinated solvents or methyl alcohol shall not be used for cleaning titanium or titanium alloys.

Austenitic stainless steel wire brushes or carbon steel wire brushes may be used on carbon or low alloy steels. Only austenitic stainless steel wire brushes shall be used on all other materials being welded. Once an individual wire brush is used on a certain material type (e.g. titanium, aluminium, nickel alloys, cobalt), it shall be suitably identified and used only on that material type, with the exception that the same wire brush may be used on corrosion resistant steels, cobalt alloys and nickel alloys.

NOTE The intent is to avoid cross-contamination between material types.

### 9.6.2 Protection and recleaning of cleaned surfaces before fit-up

Previously cleaned surfaces shall be protected from contamination. If contamination does occur, the surfaces shall be cleaned by the methods specified in 9.6.1 before welding, unless otherwise specified by the design/engineering authority.

## 9.7 Preheating and interpass temperature control

Preheating and interpass temperature shall be established for materials susceptible to cracking during or after welding and shall be documented in the WPS.

NOTE Annex C provides recommended preheat and interpass temperatures for some materials.

## 9.8 Tack welds

Filler material specification used for tack welds shall be the same as that used for subsequent welding unless otherwise specified on the engineering drawing or approved by the design/engineering authority.

Tack welds shall be fully consumed during subsequent welding processes or be fully removed by subsequent processes, unless otherwise defined by the engineering documents.

The requirements of 9.6 and 9.7 shall be considered during the tack welding operations.

If cleaning of tack welds is needed, the method shall be described in the manufacturing documents, e.g. the WPS.

NOTE For tack weld cleaning, it is essential not to contaminate the weld joint.

Tack welds shall meet the discolouration requirements of the design/engineering authority. If such requirements do not exist, refer to ISO 17927-2.

If post tack weld cleaning of material group C is necessary, it can only be performed if approved by the design/engineering authority and the post tack weld cleaning method is specified by the design/engineering authority.

## 9.9 Run-on, run-off tabs and beam stopper

When used, run-on, run-off tabs and beam stopper, attached to the part, shall be of the same material composition as the joint members. They shall be welded with the same filler material specification as defined on the engineering drawing or as approved by the design/engineering authority.

## 9.10 Weld shielding

The material shall be protected against contamination by atmospheric gases by suitable weld shielding.

Both the weld face and weld root of gas tungsten arc (GTAW), plasma arc (PAW) and laser beam (LBW) welds shall be protected from oxidation during welding. However, it is possible that weld root shielding is not required for material group D. The shielding shall include the weld and the heat-affected zones.

The shielding shall be suitable for the materials and welding process and shall be defined in the WPS. The requirements from the design/engineering authority shall be met.

Shielding methods:

— gases (see ISO 14175): Gas type and quality shall be defined. Gas quality at the point of use shall comply with the defined requirements;

— flux: If used, flux shall be as specified on the engineering documents;

— vacuum: For electron beam processes, the working chamber vacuum level shall be suitable for the material to be welded and be defined on the WPS.

## 9.11 Spatter protection

When spatter protection is used it shall be approved and as specified by the WPS.

EXAMPLE

— Masking (e.g. by use of sheet metal, foil, tape).

— Surface treatment (e.g. by the use of paint, wax, spray, ceramic slurry).

## 9.12 Filler materials

If filler material is used, it shall be specified on the WPS and the same as required by the engineering documentation.

If filler material is needed and not specified by the design/engineering authority, welding shall not be performed until pertinent filler material information is available and the appropriate WPS is qualified.

If required by the design/engineering authority, the part shall be traceable to the filler material batch or lot.

## 9.13 Interpass cleaning

If interpass cleaning is needed, the method shall be described in the manufacturing documents, e.g. the WPS.

All weld passes shall meet the discolouration requirements of the design/engineering authority. If such requirements do not exist, refer to ISO 17927-2.

If interpass cleaning of material group C is necessary, it can only be performed if approved by the design/engineering authority and the interpass cleaning is performed using a qualified method.

## 9.14 Welding and weldments

### 9.14.1 General

The welding of joint members and the resulting weldment shall comply with the requirements specified in 9.14.2 to 9.14.5.

### 9.14.2 Weld settings

Before starting a welding cycle, the settings on the welding equipment shall be set to those listed in the qualified WPS.

### 9.14.3 Arc strike

The welding arc shall not be started on any portion of the base metal away from the surfaces to be joined.

### 9.14.4 In-process correction

#### 9.14.4.1 General

Any correction of a weld made by the welder before submitting the weldment for acceptance inspection in accordance with Clause 11 is an in-process correction. The correction shall occur before subjecting the weld to any heat treat operations.

Before initiating in-process correction by welding, parts shall be free of oxides and contamination. If a re-cleaning is needed, it shall be performed according to the approved WPS.

Any material removal shall be followed by welding. If material is removed mechanically, the weld shall encompass the area of material removal.

#### 9.14.4.2 In-process correction by welding

When allowed, all in-process correction by welding shall be performed according to a WPS. Any other processes or parameters are only allowed when the engineering document allows such correction.

An undercut, underfill or crater (without crack) shall be considered as a surface depression and can be corrected by depositing filler material (the same as used in making the original weld) that fairs smoothly into the weld and the base metal. In the case of correcting autogenous welds, the filler material shall be defined by the responsible design/engineering authority.

When there is reason to suspect tungsten inclusion for GTAW or PAW, make a best effort to remove the inclusion and continue welding. Verification of inclusion removal shall be by radiographic methods after completion of the weld.

All other weld corrections are considered to be rework as per 9.16 or repair as per 9.17.

#### 9.14.4.3 Allowed number of in-process correction attempts performed by welding

One in-process correction attempt performed by welding is allowed in each individual location. If more than one in-process correction attempt performed by welding is needed, it shall be considered as rework as per 9.16.

#### 9.14.4.4 Documentation of in-process correction

The in-process correction history shall be documented. At a minimum, the size and location of the in-process correction shall be documented.

### 9.14.5 Post-weld processing

#### 9.14.5.1 General

Post-weld processing of the weldment shall be as specified on the engineering documents or the qualified WPS.

Any post-weld processing shall be carried out after visual weld inspection. If penetrant inspection is requested, this shall be performed before post-weld processing.

#### 9.14.5.2 Removal of weld reinforcement

Weld reinforcement removal shall be performed by a qualified method and shall not reduce the thickness of the base metal below that specified. This removal shall result in a smoothly blended surface that meets the requirements on surface finish.

Weld reinforcement shall only be removed in post-weld processing for one or more of the following reasons:

a) when specified by the engineering drawing notes or weld symbol. (The removal shall not exceed limits specified on the engineering drawing or any other contractual document);

b) for material group D reinforcement may be removed to aid inspection. Remaining reinforcement shall be visually evident above the surface plane of the adjacent joint member and extend throughout the weld bead width. If reinforcement is not visually evident, then the material thickness shall be measured in the processed area. The weld toe area shall comply with the requirements of ISO 17927-2.

#### 9.14.5.3 Post-weld finishing

The completed weldment shall be free of spatter, flux, scale, slag, or other foreign matter. Removal of such material during the post-weld finishing operation shall be by a qualified method and approved by the design engineering authority.

## 9.15 Weld identification requirements

### 9.15.1 Weld traceability

Each weld shall be traceable to the welder/welding operator.

### 9.15.2 Acceptance inspection

The completed weldment shall be submitted to the fabricator's quality assurance organization or its designee for an acceptance inspection. The acceptance inspection shall be performed in accordance with Clause 11.

### 9.15.3 Acceptance criteria

ISO 17927-2 shall be applied for acceptance criteria provided it is referenced or approved by the responsible design/engineering authority.

When the responsible design/engineering authority has referenced a different specification for acceptance criteria, these criteria shall take precedence.

## 9.16 Rework

### 9.16.1 General

Rework is any corrective action made to a weldment before any heat treatment following acceptance inspection. The corrective action shall bring the weldment into full conformance with the engineering drawing and the requirements of this specification. Except as specified in this subclause, every requirement of 9.14 applies for rework.

In case of a mechanical weld zone rework (dressing) or re-welding, the weld zone shall be re-inspected after rework or re-welding.

NOTE See penetrant inspection specifications for requirements regarding the necessity of etching after material removal.

### 9.16.2 Allowed number of rework attempts

The number of rework attempts performed by welding shall be specified by the design/engineering authority or in a qualified WPS. If the number of allowed rework attempts is exceeded, it shall be considered as repair according to 9.17.

### 9.16.3 Root area rework

A butt weld with inadequate penetration or incomplete fusion at the root may be corrected by welding from the root side with the agreement of the design/engineering authority.

### 9.16.4 Inspection of the rework

All rework shall be submitted for acceptance inspection in accordance with Clause 11.

### 9.16.5 Documentation of rework

All operations involved in rework shall be documented using a method approved by the design/engineering authority.

## 9.17 Repair

### 9.17.1 General

Repair is any corrective action on a part directed by the design/engineering authority.

### 9.17.2 Repair instructions

Repairs shall be approved by the design/engineering authority. Repair instructions shall be detailed and shall include the following information as a minimum:

a) allowed number of weld corrections during the repair;

b) required documentation;

c) details for each operation (including acceptance inspection) involved in the repair.



### 9.18 Record requirements

Records shall be maintained of consumables, calibration, in-process correction, rework, and repair according to the requirements specified herein or by the design/engineering authority.

The records shall be kept for a time period as specified by the design/engineering authority. The written records shall be made available to the design/engineering authority upon request.

### 9.19 Welding parameters

All welding shall be carried out according to an approved WPS. Welding parameters shall be within the limits specified in the approved WPS.

### 9.20 Reproducibility tests for qualified machine welding settings

#### 9.20.1 Applicability of requirements

These requirements are applicable to automatic, mechanized, and robotic equipment only. The reproducibility test shall be performed according to 9.20.2 when either of the following is encountered:

a) the equipment fails to produce acceptable weld quality using the settings of a qualified WPS;

b) a major component of the equipment is either repaired or replaced (as determined by the fabricator).

#### 9.20.2 Test requirements

The reproducibility test shall be performed according to a written procedure. The written procedure shall establish welding parameters, test specimen configuration, and acceptance criteria for the welded test specimen(s).

## 10 Personnel

### 10.1 Welding coordination personnel

The manufacturer shall have at his disposal appropriate welding coordination personnel. Such persons having responsibility for quality activities shall have sufficient authority to enable any necessary action to be taken. The tasks and responsibilities of such persons shall be clearly defined. For example, see ISO 14731.

### 10.2 Qualification of welders and welding operators

Personnel performing fusion welding shall be trained and certified according to ISO 24394, unless specified otherwise by the design/engineering authority.

### 10.3 Qualification of inspection personnel

#### 10.3.1 Qualification of non-destructive testing (NDT) personnel

Non-destructive testing personnel shall be qualified in accordance with NDT standards as specified by the design/engineering authority, e.g. EN 4179 or equivalent standard.

Unless otherwise specified by NANDTB, eyesight requirements shall be according to EN 4179 or equivalent standard.

NOTE The NANDTB (National Aerospace NDT Board) is an independent aerospace organization representing a nation's aerospace industry that is chartered by the participating prime contractors and recognized by the nation's regulatory agencies to provide or support NDT qualification and/or examination services.

#### 10.3.2 Visual weld inspectors

Personnel performing visual weld inspections shall be trained and certified according to ISO 19828 or CWI/SCWI with an AWS D17.1 endorsement according to AWS QC1, unless specified otherwise by the design/engineering authority.

## 11 Inspection methods

### 11.1 Visual weld inspection

All visual inspections shall be performed in accordance with ISO 19828, unless otherwise specified by the design/engineering authority. All welds shall be subjected to visual inspection over the complete weld length (face and root side). Both face and root side shall be inspected (for limitations see ISO 19828).

Unless otherwise specified, weld zones shall be inspected in the as-welded condition.

In case of a mechanical weld zone rework (dressing) or re-welding, the weld zone shall be re-inspected after rework or re-welding.

Welds shall be inspected according to a written instruction/inspection plan for conformance to engineering requirements.

### 11.2 Non-destructive testing

#### 11.2.1 General

Non-destructive testing shall be carried out at the relevant stage of manufacturing to ensure that the parts do not contain imperfections beyond the acceptance criteria defined by the applicable engineering requirements. The sequence of non-destructive testing operations within the manufacturing process shall be defined by the responsible Level III. Consideration shall be given to:

a) manufacturing processes with the potential to introduce imperfections;

b) manufacturing processes with the potential to impair the performance of non-destructive testing methods;

c) defining the appropriate stage in the manufacturing sequence to perform non-destructive testing methods;

d) determining the appropriate non-destructive testing method.

#### 11.2.2 Penetrant testing (PT)

Penetrant testing shall be according to the ISO 3452 series, ASTM E1417 or SAE AMS 2644, unless otherwise specified by the design/engineering authority.

Non-ferromagnetic Class I and Class II welds shall be penetrant tested.

Ferromagnetic Class I and Class II welds can be penetrant tested as an alternative to magnetic particle testing when specified by the responsible Level III or as designated on the drawing or in the contract.

Non-ferromagnetic and ferromagnetic Class III welds shall be penetrant tested when specified on the drawing or in the contract.

#### 11.2.3 Magnetic particle testing (MT)

Magnetic particle testing shall be according to ISO 17638 or ASTM E1444, unless otherwise specified by the design/engineering authority.

Ferromagnetic Class I and Class II welds shall be magnetic particle tested, where practicable. At the discretion of the responsible Level III, penetrant testing may be used as an alternative to magnetic particle testing.

Ferromagnetic Class III welds shall be magnetic particle tested when specified on the drawing or in the contract.

#### 11.2.4 Radiographic testing (RT)

Radiographic testing shall be according to the ISO 17636 series or ASTM E1742, using film or non-film techniques, unless otherwise specified by the design/engineering authority.

Class I butt welds shall be radiographically tested over the full length of the weld.

When radiographic inspection of fillet welds or partial penetration butt welds is defined, the acceptance criteria of the root side shall be specified by the design/engineering authority.

Class II and Class III welds shall be radiographically tested when specified on the drawing or in the contract.

#### 11.2.5 Ultrasonic testing (UT)

Ultrasonic testing shall be according to ISO 17640, ISO 10863, ISO 13588 or SAE AMS-STD-2154, unless otherwise specified by the design/engineering authority. The responsible Level III shall determine the suitable method for the application.

Ultrasonic inspection may be used in lieu of radiographic inspection when specified by the drawing, in the contract, or by the design/engineering authority.

#### 11.2.6 Other non-destructive test methods

Non-destructive tests, procedures, techniques, equipment, or materials (e.g., acoustic emission, electromagnetic or eddy current, leak, neutron radiographic, etc.) not specifically addressed in this document may be used in conjunction with those stated in 10.1 to 10.2.5. When these test methods are indicated, they shall be specified by the design/engineering authority.

### 11.3 Destructive testing

#### 11.3.1 General

Destructive testing may be used for qualification purposes and accompanying specimen, when indicated by the design/engineering authority.

#### 11.3.2 Tensile testing

Tensile testing shall be according to ISO 6892 (all parts), as applicable, ISO 4136, ASTM E8/E8M and/or ASTM E21, unless otherwise specified by the design/engineering authority.

#### 11.3.3 Bend testing

Bend testing shall be according to ISO 5173, unless otherwise specified by the design/engineering authority.

#### 11.3.4 Hardness testing

Hardness testing shall be according to ISO 9015-1, ISO 6507-1, ISO 6506-1, the ISO 6508 series, ASTM E18 or ASTM E384, unless otherwise specified by the design/engineering authority.

### 11.3.5 Metallographic examination

Metallographic examination can be used to investigate the weld geometry, fillet weld root penetration, heat affect zone, grain sizes, etc.

## 12 Requirements specific to TIG and plasma welding processes

Tungsten electrodes shall be defined in the WPS. It is recommended to use standardized tungsten electrodes, e.g. ISO 6848. Electrode diameter and tip geometry shall be defined in the WPS.

# Annex A
(informative)

# Welding procedure qualification record (WPQR)

Example of a WPQR:

| Company, Name | WPQR No. | Rev. No. | Date |
|---|---|---|---|
| | | | |

| Base metals | Product form | Base metal(s) designation(s) | Heat treatment condition | Material group | Thickness | Diameter |
|---|---|---|---|---|---|---|
| Part 1 | | | | | | |
| Part 2 | | | | | | |
| Other | | | | | | |

| **Joint details** | |
|---|---|
| Joint type | |
| Groove angle | |
| Root opening | |
| Root face | |
| Backing material | |
| Backgouging method | |
| Consumable insert and type | |
| **Post-weld heat treatment** | |
| Temperature | |
| Time at temperature | |
| Other | |

Joint details (sketch)

Sketches, welding symbols, or written description should show the actual arrangement of the tested weldment. Where applicable, the root details of the weld groove may be specified.

| **Procedure** | | | | | |
|---|---|---|---|---|---|
| Weld pass | | | | | |
| Welding process (designation and process number according to ISO 4063) | | | | | |
| Type of mechanization (manual, semiautomatic, mechanized, or automatic) | | | | | |
| Preheat temperature/Interpass temperature | | | | | |
| Machine type for mechanized or automatic welding | | | | | |
| **Filler material (specification)** | | | | | |
| Specification, alloy designation, or the nominal composition | | | | | |
| Manufacturer/trade name | | | | | |
| Filler material size or diameter | | | | | |
| Filler material feed rate | | | | | |
| Welding position | | | | | |
| **Torch shielding gas** | | | | | |