BS EN 4678:2011

BSI Standards Publication

Aerospace series — Weldments and brazements for aerospace structures — Joints of metallic materials by laser beam welding — Quality of weldments

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National foreword

This British Standard is the UK implementation of EN 4678:2011.

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A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Série aérospatiale - Assemblages soudés et brasés pour constructions aérospatiales - Assemblages de matériaux métalliques soudés par faisceaux laser - Qualité des assemblages soudés

Luft- und Raumfahrt - Schweiß- und Lötverbindungen für die Luft- und Raumfahrt - Laserstrahlschweißen - Qualität der Schweißverbindungen

This European Standard was approved by CEN on 9 July 2010.

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Foreword

This document (EN 4678:2011) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2012, and conflicting national standards shall be withdrawn at the latest by January 2012.

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After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

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1 Scope

This European Standard defines the rules to be observed to ensure the quality of aerospace structures in metallic materials by (solid reference number **521** and gas reference number **522** and diode laser Semi-conductor **523** according to EN ISO 4063) laser beam welding, implemented automatically, semi-automatically or manually.

It is applicable without any restriction for the manufacturing of new parts or repair parts, these operations being under the responsibility of an approved design authority or repairer.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the reference document (including any amendments) applies.

EN 1011-6, *Welding — Recommendation for welding of metallic materials — Part 6: Laser beam weld*

EN 1435, *Non-destructive examination of welds — Radiographic examination of welded joints*

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

EN 4632-001, *Aerospace series — Welded and brazed assemblies for aerospace constructions — Weldability and brazeability of materials — Part 001: General requirements*

EN 4632-002, *Aerospace series — Welded and brazed assemblies for aerospace constructions — Weldability and brazeability of materials — Part 002: Homogeneous assemblies aluminium and aluminium alloys*

EN 4632-003, *Aerospace series — Weldability and brazeability of materials in aerospace constructions — Part 003: Welding and brazing of homogeneous assemblies of unalloyed and low alloy steels*[1)]

EN 4632-004, *Aerospace series — Welded and brazed assemblies for aerospace constructions - Weldability and brazeability of materials — Part 004: Homogeneous assemblies highly alloyed steels* **Error! Bookmark not defined.**)

EN 4632-005, *Aerospace series — Weldability and brazeability of materials in aerospace constructions — Part 005: Homogeneous assemblies of heat resisting Ni or Co base alloys* **Error! Bookmark not defined.**)

EN 4632-006, *Aerospace series — Weldability and brazeability of materials in aerospace constructions — Part 006: Homogeneous assemblies of titanium alloys* **Error! Bookmark not defined.**)

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

EN ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers (ISO 4063:2009, Corrected version 2010-03-01)*

EN ISO 4136, *Destructive tests on welds in metallic materials - Transverse tensile test (ISO 4136:2001)*

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

EN ISO 5173, *Destructive tests on welds in metallic materials - Bend tests (ISO 5173:2009)*

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1) Published as ASD-STAN Prestandard at the date of publication of this standard by Aerospace and Defense Industries Association of Europe-Standardization (ASD-STAN), (www.asd-stan.org).

EN ISO 6520-1, Welding *and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding (ISO 6520-1:2007)*

EN ISO 6947, *Welding and allied processes - Welding positions (ISO 6947:2011)*

EN ISO 9015-2, *Destructive tests on welds in metallic materials - Hardness testing - Part 2: Microhardness testing of welded joints (ISO 9015-2:2003)*

EN ISO 9016, *Destructive tests on welds in metallic materials - Impact tests - Test specimen location, notch orientation and examination (ISO 9016:2001)*

EN ISO 11145, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols (ISO 11145:2006)*

EN ISO 14731, *Welding coordination — Tasks and responsibilities (ISO 14731:2006)*

EN ISO 15609-4, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 4: Laser beam welding (ISO 15609-4:2009)*

EN ISO 15616-1, *Acceptance tests for CO_2-laser beam machines for high quality welding and cutting — Part 1: General principles, acceptance conditions (ISO 15616-1:2003)*

EN ISO 15616-2, *Acceptance tests for CO_2-laser beam machines for high quality welding and cutting — Part 2: Measurement of static and dynamic accuracy (ISO 15616-2:2003)*

EN ISO 15616-3, *Acceptance tests for CO_2-laser beam machines for high quality welding and cutting — Part* 3: *Calibration of instruments for measurement of gas flow and pressure (ISO 15616-3:2003)*

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

ISO 17639, *Destructive tests on welds in metallic materials — Macroscopic and microscopic examination of welds*

EN ISO 17640:2, Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels, and assessment (ISO 17640:2010)

ISO 22826, *Destructive tests on welds in metallic materials — Hardness testing of narrow joints welded by laser and electron beam (Vickers and Knoop hardness tests)*

EN ISO 22827-1, *Acceptance tests for Nd:YAG laser beam welding machines — Machines with optical fibre delivery — Part 1: Laser assembly (ISO 22827-1:2005)*

EN ISO 22827-2, *Acceptance tests for Nd:YAG laser beam welding machines — Machines with optical fibre delivery — Part* 2: *Moving mechanism (ISO 22827-2:2005)*

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

ISO/TR 25901, *Welding and related processes — Vocabulary*

NAS 410, *Certification and qualification of non-destructive test personnel* [2)]

2) Published by: National Standards Association, Inc., 1200 Quince Orchard Blvd, Gaithersburg, MD 20878, United States.

3 Terms and definitions

For the purposes of this document, the following terms and definitions given in ISO 857-1 and EN ISO 11145 standards apply.

3.1 General

3.1.1 Laser beam welding

Fusion welding process (using radiation) in which the heat required for the fusion is provided by the coherent and monochromatic light emitted by a laser focused by an optical system either:

— solid (FLS or 521 according to EN ISO 4063);

— Example: YAG: (Yttrium Aluminium Garnet) doped with neodymium. The wavelength λ of corresponding radiation is 1,06 µm; or

— gas (FLG or 522 according to EN ISO 4063);

— Example: CO_2 wavelength λ of corresponding radiation is 10,6 µm;

— Diode laser welding (Semi-conductor laser welding or 523 according to EN ISO 4063).

The word laser is the acronym for "**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation".

3.2 Technical terms

3.2.1 Welding parameters

3.2.1.1 Run-on or run-off plates

See ISO/TR 25901.

NOTE This interval is measured on the detail parts, positioned in their welding setup, and is used as a reference to determine the minimum width of the weld zone.

3.2.1.2 Beam shift

Deviation of beam position compared with the effective position of joint plane in certain heterogeneous welds (materials and/or dissimilar thicknesses).

3.2.1.3 Firing distance

Distance between the impact point of the beam on detail parts and a reference surface linked to the machine

EXAMPLE End of nozzle.

3.2.1.4 Specific welding energy

Ratio between the beam power over the welding speed, multiplied by 60. P_{average} (W) is measured at nozzle exit side.

$$E_{\text{average}} = \frac{P_{\text{average}}\ (W) \times 60}{1000 \times V\ (\text{cm/min})}\ (\text{kJ/cm})$$

3.2.1.5 Slope (or ramp) down

Operating conditions for which the depth of penetration differs in a decreasing manner according to a slope, a series of ramps or steps.

NOTE Slope down occurs either according to time or distance, see Figure 1.

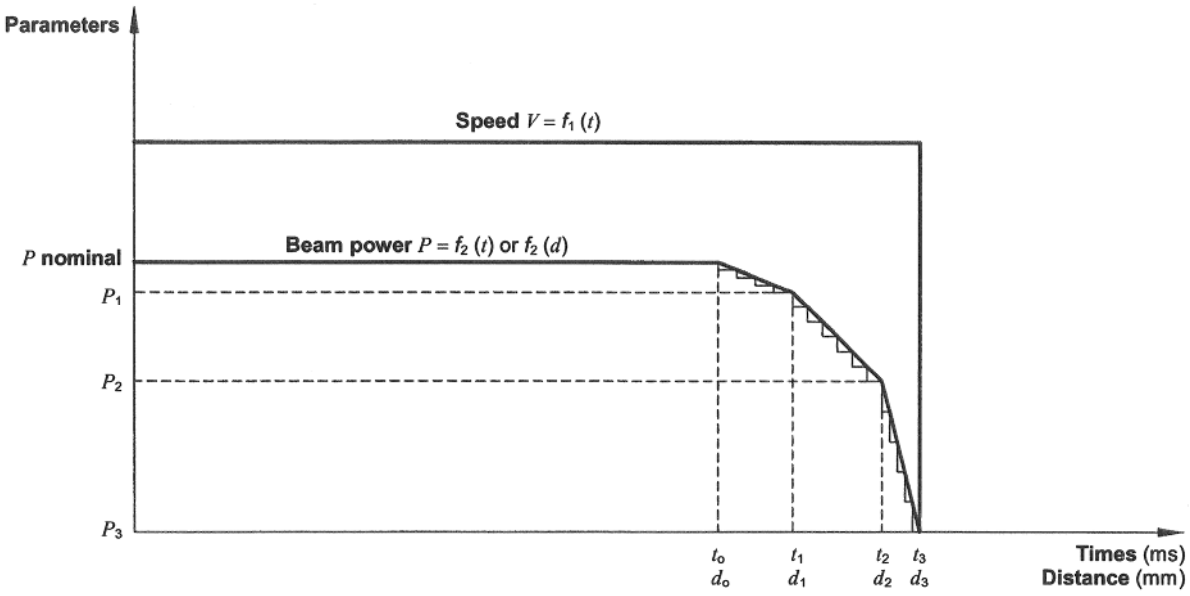


Figure 1

3.2.1.6 Slope (or ramp) up

Controlled increase of the beam power at the beginning of the welding

3.2.1.7 Clearance before welding

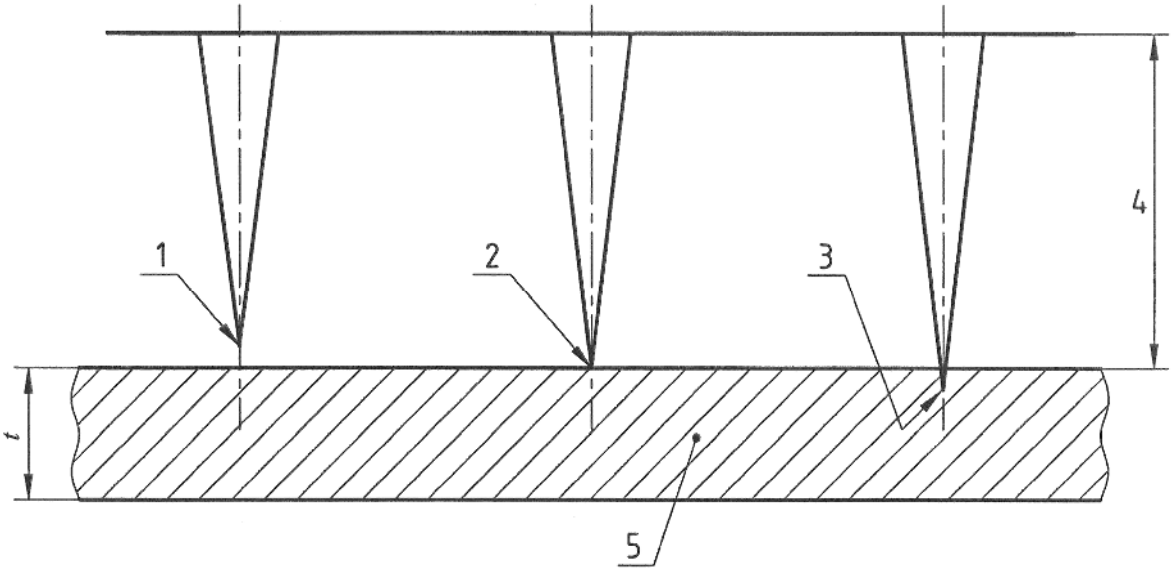
Distance measured on a straight section of the joint between the sides to weld.

NOTE The clearance depends on the design of the welded joint (for circular axial welds or circular welds see EN 1011-6).

3.2.1.8 Focusing level

Distance between the beam impact point on the detail parts and the focusing point.

NOTE Conventionally, this distance is negative when the focusing point is within the detail parts, see Figure 2.



Key

1 Positive focusing level (+ 1 mm)
2 Focusing level 0
3 Negative focusing level (– 1 mm)
4 Firing distance
5 Detail part

Figure 2

3.2.1.9 Beam power

The laser beam power is measured with a calorimeter which absorbs all or part of the beam

3.2.1.10 Welding speed

Length of the weld on beam impact side produced per time unit.

3.2.2 Other technical terms

3.2.2.1 Welding campaign

Series of welding operations on identical parts, executed on the same machine, without any changes to adjustments, without performing other welds on the machine, without interrupting manufacturing for more than a week (working days).

3.2.2.2 Tacking pass

Pre-assembling of elementary detail parts using the same process as the one used for welding, consisting of making slightly penetrating, narrow weld, continuous or discontinuous along the joint plane. The purpose is to maintain detail parts in position.

3.2.2.3 Adjustment verification specimen

A flat or round test specimen of the same material, subjected to the same heat treatments as the detail parts, on which a melt run will be made in the middle using the parameters identical to those used for parts, and for which the relation between the micrographic shape of the cross section cut of the bead and that obtained on test specimens or real parts has been previously defined.

3.2.2.4 Structural state

State of the crystalline metal structure

3.2.2.5 Manufacturing

Execution of welding operations on new parts or parts being repaired

3.2.2.6 Stabilized manufacturing

Manufacturing for which the reliability can be established without doubt over several welding campaigns, of which the number is previously defined by the design authority.

3.2.2.7 Smoothing pass or cosmetic pass

Surface new fusion of the welded zone

3.2.2.8 Batch of parts

Set of parts with the same reference from:

— the same welding campaign;

— the same heat treatment batch;

— traceable material (processing, chemical analysis, etc).

3.2.2.9 Parent material

Material or metal used to make the detail parts.

3.2.2.10 Filler material

Additional alloy or metal used to make a weld of an assembly or a deposit.

3.2.2.11 Tooling

Equipment required to hold and position parts before and during welding.

3.2.2.12 Detail part

Individual element to be assembled with other elements to make up a complete part.

3.2.2.13 Part

Assembly comprising several assembled detail parts.

3.2.2.14 Tack welding

Pre-assembly of detail parts by welding consisting of a set of tacks (by laser or an alternative process, for example TIG) along the joint plane, intended to hold the detail parts in position.

3.2.2.15 Pre-heating

Heating of detail parts before welding without fusion.

NOTE This operation may be carried out with an defocused beam or any other process.

3.2.2.16 Blind weld

Case where the beam only crosses part of the thickness of the parts to be welded.

3.2.2.17 Qualification test specimen – Manufacturing test specimen

— Test specimen representing manufactured parts to be welded under the same conditions as these parts;
— Test specimen made from the same material grade, in the same structural state, with the same dimensions as the manufactured part.

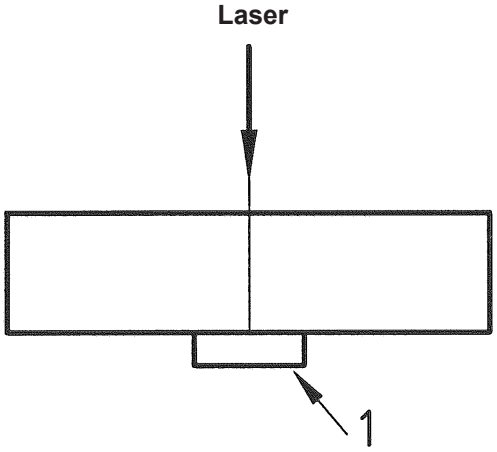
NOTE Manufacturing test specimens may be real parts.

3.2.2.18 Pool support

Element positioned on detail parts to prevent the fused metal from overflowing.

NOTE The material making up the pool support shall be of the same base alloy as the detail parts, to prevent any weld contamination.

The pool support may be positioned as shown in Figure 3.



Key

1 Pool support

Figure 3

3.2.2.19 Heat treatment

Treatment intended to provide the base material and the welded zone with the required characteristics and structural state

3.3 General terms

3.3.1 Customer

Individual or company placing a contract or order and who may or may not be the design authority.

3.3.2 Manufacturer

Person who makes, or manufactures and assembles the elements or subassemblies into assemblies.

3.3.3 Supplier

Individual or company holding a contract or order that it has accepted, binding to the design authority of one company or to the final customer to perform the services defined therein.

3.3.4 Design authority

The organisation responsible for the design of the welded assembly and for defining the performance and inspection requirements.

3.3.5 Welding coordinator

Person responsible and competent to perform welding coordination according to EN ISO 14731.

3.3.6 Welder

Person who is able to manipulate by hand the laser system and to manage the filler metal in the fusion pool and to develop the welding parameters.

3.3.7 Reinforced visual inspection

Visual inspection of a surface with a magnifying glass, endoscope or other tests (dye penetrant or magnetoscopy, etc.).

3.3.8 Operator

Person who operates adaptive control, automatic, mechanized, or robotic welding equipment.

3.3.9 Qualification

Action recognizing that a welder, product, etc. is capable of fulfilling the role for which they are intended.

3.3.10 Repair

Act consisting in making acceptable a part that was felt to be beyond the acceptance criteria after its normal manufacturing and inspection cycle

NOTE Bringing into conformity of a part which had been damaged during operation

3.3.11 Setter

Person in charge of the complete programming of the machine, beam analysis and finalization of welding procedure parameters and, if necessary, of performing welding operations using a mechanized or automated process.

3.3.12 Repairer

Supplier in the repair activity domain.

3.3.13 Competent department

Specialist service within a company with specific tasks.

EXAMPLE Design office, quality service, laboratory, methods office.

3.3.14 Official supervisory body

Approved government authorities or organizations responsible for checking the conformity of materials and welds with the definition file.

3.3.15 Welding procedure

welding schedule specified course of action to be followed in making a weld, including the welding process(es), reference to materials, welding consumables, preparation, preheating (if necessary), method and control of welding and postweld heat treatment (if relevant), and necessary equipment to be used Redraft this definition.

[ISO/TR 25901]

3.3.16 Welding procedure specification WPS

document that has been qualified and provides the required variables of the welding procedure to ensure repeatability during production welding

[ISO/TR 25901]

3.3.17 Non-destructive testing

act of determining the suitability of some material or component for its intended purpose, using techniques that to do not affect its serviceability

[ISO/TR 25901]

NOTE Personnel shall be qualified in accordance with EN 4179/NAS 410.

4 Symbols and abbreviations

GLW	Gas Laser Welding
SLW	Solid state laser welding
P	Welding power
E	Welding energy
V	Welding speed
WPS	Welding Procedure Specification

5 Weldability

5.1 Concept of weldability

It is considered that a metallic material is weldable to a given degree, by a given process or for a given application type when, it can be used to produce a weld provided that precautions corresponding to this degree are taken, and if the characteristics and the consequences of the presence of the weld satisfy the required properties chosen as the basis for a judgement.

5.2 Weldability degrees

Weldability of materials is assessed according to the following four degrees (see EN 4632-001):

— degree 1: material with very good weldability, for which no special precautions are necessary. To be used in preference.

— degree 2: material with good weldability but which may require special welding precautions (for example, preheating, low welding speed).

— degree 3: material with poor weldability, requiring specific development for each part type and which may involve manufacturing uncertainties. Not to be recommended.

— degree 4: material with very poor weldability. To be avoided.

6 General requirements

6.1 Weld classification

Weld classification is the responsibility of the design authority.

6.1.1 Manufacturing new parts

The design authority, at the time of part design, shall allocate a weld class to each joint: 1, 2 or 3 according to a decremental functional severity order.

The requirements are listed in Table 1. A higher severity weld class may be allocated to meet specific problems such as manufacturing complexity or interpretation of inspection operations, etc.

Table 1 — Weld class allocation requirements

Part with function	Assembly weld rupture	
	can alter normal operation of the part	without significant consequences
Safety critical	1	2
Other	2	3

A given part may have several different weld classes.

Each weld class is associated with one of the following conditions:

— implementation before manufacturing;

— follow up during manufacturing;

— inspection on welded assembly;

— acceptance criteria.

For weld classes 1 and 2, the design authority verifies with the quality department that the inspection operation makes it possible to guarantee compliance of the welds to the requirements of these classes.

For class 1 welds, designs of lap welds, on raised edge or square-edged joint plane are not recommended (see sketch in Table 4).

For classes 2 and 3 welds, overlapping welds on raised edges, on square-edged joint plane and with partial penetration joint are to be addressed in particular specifications.

6.1.2 Salvage

The repairer shall comply with the recommendations of the design authority.

However, if the acceptance criteria of this standard are selected due to the requirements of Clause 6, the repairer may propose a weld class. He shall then ask for the approval from the design authority or from the official supervisory body involved.

6.2 Welding machines

The machines used for welding shall comply with EN ISO 15616-1, EN ISO 15616-2, EN ISO 15616-3, EN ISO 22827-1 and EN ISO 22827-2.

In particular, machines shall have undergone specific qualification tests according to EN ISO 15616-1, EN ISO 15616-2 and EN ISO 22827-1 when they were acquired or renovated.

6.3 Operators, welders and setters

6.3.1 Training

6.3.1.1 Operator training

For any manufacturing or repair operation, the laser beam-welding operator shall have followed a training course given by the competent department of the manufacturer (part manufacturer), or an external training organization, with regard to:

— technical training on the process;

— operation of the machine used (electrical power supply, etc.);

— safety related to this machine and the welding operation;

— equipment, instruments and tooling required for correct operation of the machine, and performance of the welding operation;

— display and verification of welding procedures;

— positioning of the focal point in relation to the part surface;

— alignment check of the beam in relation to the joint plane;

— appearance and geometrical check of welded assemblies.

The operator shall weld beads and/or melt runs on standard parts and/or test specimens and/or manufacturing test specimens according to the validated welding procedure corresponding to his training.

6.3.1.2 Welder training

Welders implementing the laser process by hand shall be able to manage the filler metal in a fusion bath and to develop the welding parameters.

For any manufacturing or repair operation, the laser beam-welding operator shall have followed a training course given by the competent department of the manufacturer (part manufacturer), or an external training organization, with regard to:

— technical training on the process;

— operation of the machine used (electrical power supply, etc.);

— safety related to this machine and the welding operation;

— equipment, instruments and tooling required for correct operation of the machine, and performance of the welding operation;

— display and verification of welding procedures;

— positioning of the focal point in relation to the part surface;

— alignment check of the beam in relation to the joint plane;

— visual and geometrical inspection of welded assembly parts

— finalization of parameters and production of the necessary documents.

The welder shall weld beads and/or melt runs on standard parts and/or test specimens and/or manufacturing test specimens according to the validated welding procedure corresponding to his training.

6.3.1.3 Setter training

For any manufacturing or repair operation, the laser welding setter shall have followed the operator and welder training course, as well as a theoretical and technical training course given by the competent department of the manufacturer (part manufacturer), and/or an external training organization.

The training concerns:

— complete programming of the machine;

— analysis of beam quality according to EN ISO 15616-1. For instance, use of a beam analysis device which enables to obtain the position, diameter of focal point and space distribution of energy;

— finalization of parameters and production of the necessary documents;

The setter shall prepare a welding procedure in order to validate his training.

6.3.2 Qualification

6.3.2.1 Operator and welder qualification

The examination on physical fitness (eyesight) of the operator and the welder will be realized in accordance with the test and requirements of the Table 2 hereafter or a test judged equivalent by the design authority.

Table 2 — Operator and welder qualification requirements

Test	Requirement
Near vision	Visual acuity (eyesight) shall be examined for near vision. Welder and Welding operators shall have vision acuity of 20/30 or better in each eye, and shall be able to read the Jaeger No. 2 eye chart at 400 mm or to pass an equivalent test as specified by an optometrist. Corrective vision may be used to fulfil eye test requirements
Colour perception	Be capable of distinguishing and differentiating colours used in the process involved. Where it is not possible to devise a suitable test, Ishihara test may be used.

Vision shall be tested to these requirements at least every two years.

Operator and welder qualification shall comprise technical training on the process and production of a manufacturing test specimen, according to a given parameter welding procedure and have correctly produced at least one welded part.

Guidance on operator and welder qualification is given in ISO 24394.

Production of the manufacturing test specimen according to a given parameter welding procedure shall be renewed each time the operator has not welded for more than six months.

Technical training on the process shall be repeated at least once every two years according to ISO 24394.

Operator and welder qualification shall be the subject of a welding work quality follow up made by quality audit, based on conformance and periodic inspection operations carried out on standard production welds.

Operator and welder qualification shall be awarded by the competent department of the manufacturer, who will justify the training given and the results from test specimen manufacturing.

The manufacturer shall verify the qualification of the operator and the welder, in accordance with the requirements of this standard or an equivalent standard acceptable to the design authority. Documented records shall be maintained.

The supplier or repairer, if sub-contracting is involved, shall verify the qualification of operators and welders. Depending on the company, application of the following may be demanded:

— this document;

— a national document considered equivalent to the contents of this document;

— an internal qualification procedure considered equivalent to the one described in this document.

In case of a discrepancy or imperfections fully found, the responsibility of the operator and the welder, the supplier or the repairer is engaged; the qualification procedure applied shall be justified.

This qualification shall be officially recorded in an internal document.

Furthermore, operators and welders shall pass the following tests:

— operational maintenance of optic systems (mirrors, lenses);

— inspection of focusing point on part to weld (distance measured between a reference point of the welding head and the parts to weld);

— performance of a weld according to welding procedure specification and visual inspection of the obtained quality of weld.

6.3.2.2 Welder qualification supplement

Welders implementing the laser process by hand shall be able to manage filler metal in a fusion bath and to develop welding parameters.

6.3.2.3 Setter qualification

The procedure defined during training 6.3.2.1. shall involve the production of welded parts by the setter or an operator and assessed as being in compliance by the competent department.

Setter qualification shall be awarded by the competent department of the manufacturer which shall justify the training course followed.

If the setter performs production operations, he shall be qualified according to 6.3.2.1.

This qualification shall be officially recorded in an internal document.

6.4 Responsibilities

The choice and the execution of "non-destructive" control, which would not be required by this standard, are under the responsibility of the competent department of manufacturer or supplier with prior agreement of the design authority.

Machine acceptance and qualification is under the responsibility of the manufacturer who shall, in addition, designate a competent person in charge of the application of this standard in each workshop.

If the requirements of this standard are not observed, the competent departments of the manufacturer, supplier or repairer may request the manufacturer to stop production.

Only the design authority is entitled to give the final decision regarding the compliance of welded parts and the acceptability of non-conformed parts.

7 Technical requirements for manufacturing new parts

7.1 Materials

Each time a weldment is envisaged, the weldabilty of the material(s) comprising the joint and, where dissimilar materials are involved, their compatibility should be known (see EN 4632-001 to EN 4632-006) or determined by representative trials.

Otherwise, the design authority shall carry out the development tests to define:

— degree of weldability of concerned materials;

— heat treatment before or after welding;

— requirements to satisfy before welding: geometry of parts, joint configuration, physico-chemical preparation, surface condition.

7.2 Preparation and qualification of welding procedures

7.2.1 Purpose

All welding operation parameters shall be determined in a welding procedure and qualified:

— launching the manufacture of new products on a given machine;

— after any work on the automated welding machine likely to affect the parameters of the procedures, for example:

  — machine location change;

  — modification of the electrical circuit of the machine;

  — power supply or source change;

  — optical fiber change;

  — change of focusing head (focal length of mirror or lens);

  — modification of optical head position and movement tooling;

  — change of fixture (mounting of multiple station system, change of optical path, etc.);

  — in any case, the machine shall be in accordance with EN ISO 15616-1, EN ISO 15616-2 and EN ISO 15616-3 standards or a document agreed by the user and the machine manufacturer;

  — etc.

In all these cases, qualification of welding operation parameters shall be repeated if the qualification tests of the machine provide different results from those obtained before the machine was modified:

— before any modification to the manufacturing procedure of a product already being manufactured, and likely to affect the assembly quality, for example:

  — surface preparation;

  — weld thickness;

  — heat treatment before and after welding;

- change of grip tooling for weld parts;
- etc.

- transfer to a higher severity class;

- variation to manufacturing random problem rates according to the procedures in 7.3 and 7.4.

However, the manufacturing launch of a new product may not require the preparation and qualification of a new welding procedure, if one exists for an assembly that satisfies al of the following:

- same or higher severity class;
- same material in the same structural state;
- identical geometry of the assembly;
- same type of tooling.

Qualification is decided by the competent department of the manufacturer or the supplier.

The design authority may undertake, or request the undertaking of, an additional qualification operation, at their discretion.

7.2.2 Assembly characterization

The characterization of assemblies may be done by a document indicating the welding procedure.

For example, this comprises:

- the reference of this document;
- parts: reference of the welded assembly, reference of the manufacturing procedure;
- machine: reference, location;
- process: gas laser welding (CO_2) or solid laser welding (YAG) processes or diode laser welding (Semi-conductor laser welding);
- weld class;
- detail part characteristics:
  - materials: grade, type of product (rolled, forged, molded, etc.), thicknesses of parts to assemble and the diameter, if applicable;
  - structural state defined by:
    - heat treatments before welding or;
    - characteristics such as resistance, hardness, etc.
  - geometrical characteristics of edges to weld and support and grip zones:
    - schema defining the above (for assemblies other than butt welds, the geometrical characteristics and the preparation of edges to be indicated in the requested description are those of the assembly to qualify).
  - surface conditions to weld, preparation conditions:
    - mechanical or chemical preparation;
    - cleaning (type and method of use of cleaning products, including any time limitations prior welding).
  - reference of positioning and welding tooling to use;

— operating parameters:
  - pre-heating conditions, where applicable;
  - grip and clamping conditions of detail part;
  - use of run-on and run-off plates for the linear welds;
  - clearance before welding, level difference of the edges to weld and beam misalignment compared with the joint plane;
  - welding parameters (firing distance, laser power, beam impulse, focal distance, welding speed, focusing intensity, number of runs, hot spot positioning, slope (or ramp) up, slope (or ramp) down, beam shift, nozzle diameter, nozzle/part distance, nature and flow rate of protective gas, face and root side of weld);
  - welding position(s) see EN ISO 6947;
  - filler metal (grade, shape (wire or listel), wire diameter, speed);
  - breakdown of scheduled runs (tacking pass and/or welding and smoothing run) and the welding process used for tack welding if not laser beam.

— details of post-weld heat-treatment, including any time limitations after welding;

— permissible deformation at the grip zone;

— definition of the adjustment verification specimen and the macro-graphic shape of the bead to observe.

Moreover, certain conditions may be specified, such as:

— beam alignment specimens made (recommended practice): the identification shall be on the face and root sides so as to detect junction shortages;

— verifications or inspection operations to perform during manufacturing;

— required recording of welding parameters and referencing of numerical control program(s);

— verification after assembly;

— etc.

The weld procedure shall include a reference, the date of qualification and be endorsed by a competent person, employed by the manufacturer

A template for a weld procedure is included within EN ISO 15609-4 with additional information:

— machining of the part;

— surface treatment before welding;

— clearance before welding;

— machine program difference;

— height difference;

— type of beam: mono or bi spot;

— spot diameter;

— distance between spots;

— focusing position (distance between the focal spot and the surface of the part);

— trailing gas shield;

— gaseous protection weld under bead;

— energy of welding (kJ/cm);

— peak power for pulsed mode solid laser.

7.2.3 Qualification tests

7.2.3.1 Requirements

Tests and inspection operations to carry out for welding parameter qualification of the welding procedures depend on the weld class.

The minimum requirements are given in Table 3 hereafter.

Table 3 — Qualification specimen tests and inspections

	Weld class	1		2			3		
	Degree of weldability	1.2	3	1.2	3	4	1.2	3	4
	Number of specimens to bewelded	2	4	1	2	4	1	2	3
After welding before or without heat treatment	"Non-destructive testing" of surfaces	■	■	■	■	■	■	■	■
	"Non-destructive testing" of internal soundness	■	■	■	■	■	no	■	■
	Dimensional check	■	■	■	■	■	no	no	no
	Metallography on cross-section on welding requiring no heat treatment	■	■	■	■	■	no	■	■
	Hardness profile or mapping on one cross-section if welding requiring no heat treatment [a]	■	■	■	■	■	no	no	no
[b] After welding after heat treatment	"Non-destructive testing" of surfaces after machining [c]	■	■	■	■	■	■	■	■
	"Non-destructive testing" of internal soundness after machining [c]	■	■	■	■	■	no	■	■
	Metallography on cross-section [d]	■	■	■	■	■	■	■	■
	Hardness profile or mapping on one cross-section [e]	■	■	■	■	■	no	no	no
	Mechanical characterization of the joint [f]	■	■	■	■	■	no	■	■

■ On all specimens except [a]

[a] One cross-section for hardness profile or mapping.

[b] See 7.3.2.4.

[c] Machining re-work is only necessary if requested on real parts. It will be carried out under the conditions of the real parts (same thickness removed, same machining conditions).

[d] According to ISO 4969 and ISO 17639:
- cross section sampled in single melt run zone: beginning, middle and end of bead,
- length section sample: slope down and overlap zone bead axis.

[e] According to EN ISO 9015-2 and ISO 22826.

[f] Test conditions if required, reference standards:
- weld cross traction according to EN ISO 4136,
- bending according to EN ISO 5173,
- resilience according to EN ISO 9016,
- fatigue, stress corrosion, etc.

The competent department of the design authority or supplier or manufacturer may require further tests in addition to those listed in Table 3.

Mechanical characterization tests shall be adapted to the effective stress conditions of the assembly involved. They are to be defined by the design authority.

Inspection operations before heat treatment are not required when heat treatment is carried out immediately after welding.

The competent department of the manufacturer or the supplier shall determine the position of the test specimens to undergo destructive testing.

7.2.3.2 Test methods

7.2.3.2.1 Test specimens

Qualification tests and process optimisation shall be undertaken on test specimens that are fully representative of the actual parts, in respect of material composition, condition and prior treatments and with geometry in the assembly zone that simulates the actual parts. The use of actual parts and tooling is recommended where feasible.

If manufacturing incorporates specific features (for example, difficult access), it is necessary to take them into account so that the test performance conditions are as similar as possible to the actual welding conditions.

7.2.3.2.2 Surface preparation

Prior machining methods shall be defined and validated, including reproducibility where applicable. A surface roughness finish may be defined.

Fusion faces and the adjacent surfaces shall be free from oxide (including anodic films), oil, grease, paint, moisture, coatings or any other substances which might affect the quality of the weld or impede the progress of welding. A maximum time delay between pre-cleaning and welding may be imposed in the welding procedure, where applicable.

The surface preparation procedure shall be included in the welding procedure.

The use of chemical solutions shall be confirmed by preparing a procedure and performing tests to see if rinse operations ensure the metallurgical quality of weld pieces and weldments (in the case of lap or socket joints designs).

7.2.3.2.3 Welding

Test specimens shall be numbered chronologically in the sequence of welding. All operating parameters defined by the applicable welding procedure shall be transcribed. The records will be used as a reference during subsequent studies and/or audits.

If it is not possible to make satisfactory welds within the limits of the parameter data sheet, qualification shall be stopped to verify the machine, installation and process; a new parameter data sheet shall be prepared and provided for the drawing up of qualification.

7.2.3.2.4 Machining after welding

The machining conditions shall be identical to those used during production with regard to:

— the machining method;

— the surface state obtained (roughness).

7.2.3.2.5 Heat treatment after welding

If heat treatment is carried out immediately after welding, the inspection operations before heat treatment scheduled in Table 3 will be replaced by:

— non-destructive testing of surfaces and internal soundness after heat treatment;

— dimensional check after heat treatment.

7.2.3.2.6 Acceptance criteria

The non-destructive testing procedure shall be fully documented and endorsed by a Level three practitioner in the relevant non-destructive testing in accordance with EN 4179/NAS 410 or an equivalent standard acceptable to the design authority.

7.2.3.2.7 "Non-destructive testing" of external surfaces

By visual inspection and other methods, as defined in the welding procedure (e.g. dye penetrant, magnetic particle etc.).

Unless otherwise defined by the design authority and recorded in the applicable weld procedure, cracks are not permitted and the acceptance criteria for other flaws are as detailed in Table 4.

For joint configurations other than butt welds, the acceptance criteria shall be defined by the design authority and recorded in the weld procedure/schedule

Laser welds undertaken on titanium alloys shall exhibit in the as-welded state a silver glossy metallical grey appearance: no white, purplish, blue colour shall appear in the fused zone. For single run welding, a light yellow colour in the fused zone or a light blue colour in the heat affected zone is permitted.

It may be necessary to clarify features identified during visual inspection by the preparation and examination of metallographic sections

The bulk defects identified on the surface by non-destructive testing are accepted if they comply with the criteria if Table 4.

For certain lap welds, the quality department of the supplier with the prior agreement of the design authority may decide to substitute the dye penetrant inspection for a binocular inspection with a magnification x 30.

7.2.3.2.8 "Non-destructive testing" for internal flaws

Weld bead integrity is verified by radiography (X or γ) according to EN 1435 or ISO 17636. Unless otherwise defined by the design authority and recorded in the applicable weld procedure, the acceptance criteria for internal flaws are as detailed below and in Table 4:

— Linear imperfections (cracks, lack of fusion, incomplete penetration): Not accepted;

— More or less dense inclusions ℓ_o shall comply with the requirements of Table 5. Those inclusions less than 0,2 mm shall be discounted.

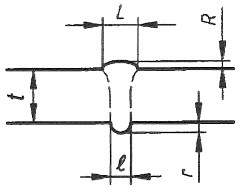
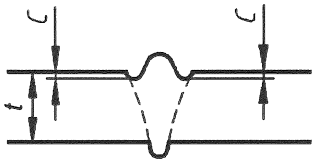
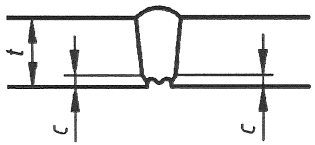
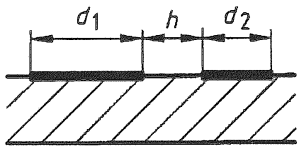
Linear imperfections may also be verified by ultrasound according to EN ISO 17640 or ultrasonic inspection procedure agreed by Level three practitioner.

In general: An array of isolated imperfections may be considered to be a single discrete imperfection, if they are separated by a distance less than or equal to three times the length of the smallest imperfection in the array;

For the slope up or down (ramp in or out) zones, however, this distance shall be equal to the length of the smallest imperfection.

Table 4 — Acceptance criteria for geometry and external imperfections of butt welds

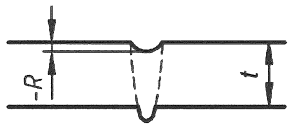
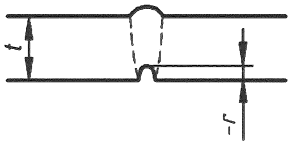
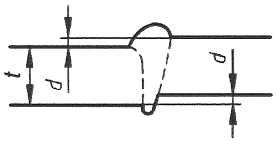
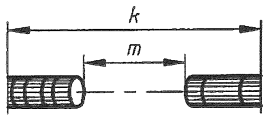
Dimensions in millimetres

Bead	Characteristics	Imperfection reference number according to EN ISO 6520-1	Aluminium, magnesium and their alloys	Steel and nickel alloys	Titanium and titanium alloys
	Face width: L	–	$L \leq t + 1$	up to $t = 10$: $L \leq 3 + 0{,}1 \times t$	up to $t = 8$: $L \leq 3 + 0{,}1\ t$
	Root width: ℓ	–	$\ell \leq 1 + 0{,}5 \times t$	$1 \leq \ell \leq L$	$1 \leq \ell \leq L$
	Face reinforcement: R	502	$R \leq 0{,}2 \times t + 0{,}1$	$R \leq 0{,}15 \times t + 0{,}1$	$R \leq 0{,}15 \times t + 0{,}1$
	Root reinforcement: r	504	$r \leq 0{,}3 \times t + 0{,}1$	$r \leq 0{,}15 \times t + 0{,}1$	$r \leq 0{,}15 \times t + 0{,}1$
	Face undercut: C	5011 and 5012	for $t \leq 3$: $C \leq 0{,}15$ for $3 < t \leq 5$: $C \leq 0{,}05 \times t$ for $t > 5$: $C \leq 0{,}5$	for $t \leq 5$: $C \leq 0{,}1 \times t$ for $t > 5$: $C \leq 0{,}5$	for $t \leq 5$: $C \leq 0{,}05 \times t$ for $t > 5$: $C \leq 0{,}5$
	Shrinkage groove: c	5013	0,1 t or 0,5 mm, the lower of the two values is applicable	0,1 t or 0,5 mm, the lower of the two values is applicable	0,1 t or 0,5 mm, the lower of the two values is applicable
	Maximum length of isolated imperfection: f [a] for undercut $\Sigma f = d_1 + d_2$	–	$f \leq 10$ mm Interval between two imperfections [a] $\Sigma f \leq k/20$	$f \leq 10$ mm Interval between two imperfections [a] $\Sigma f \leq k/20$	$f \leq 10$ mm Interval between two imperfections [a] $\Sigma f \leq k/20$

continued

Table 4 — Acceptance criteria for geometry and external imperfections of butt welds *(concluded)*

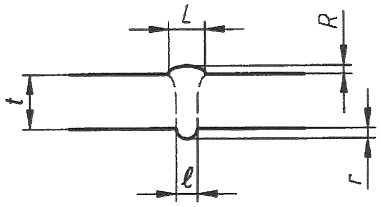
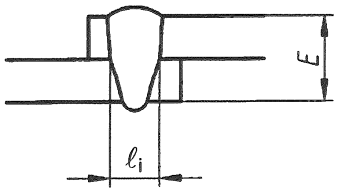
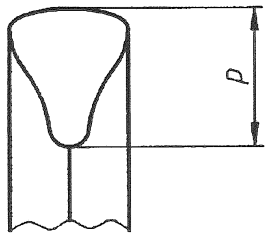
Dimensions in millimetres

Bead	Characteristics	Imperfection reference number according to EN ISO 6520-1	Aluminium, magnesium and their alloys	Steel and nickel alloys	Titanium and titanium alloys
	Incompletely filled groove: $-R$	511	0,1 t or 0,5 mm, the lower of the two values is applicable	0,1 t or 0,5 mm, the lower of the two values is applicable	0,1 t or 0,5 mm, the lower of the two values is applicable
	Root concavity: $-r$	515	0,1 t or 0,5 mm, the lower of the two values is applicable	0,1 t or 0,5 mm, the lower of the two values is applicable	0,1 t or 0,5 mm, the lower of the two values is applicable
	Linear misalignment: d	507	$d \leq 0{,}1\ t$ or 1,0 mm whichever is the smaller	$d \leq 0{,}1\ t$ or 1,0 mm whichever is the smaller	$d \leq 0{,}1\ t$ or 1,0 mm whichever is the smaller
—	Lack of fusion	401	Not permitted		
	m: length of incomplete penetration k: total length of weld bead	402	Not permitted	Not permitted	Not permitted

[a] An alignment of small imperfections is considered as a continuous and isolated imperfection if the interval separating them is less than three times the length of the smallest adjacent imperfection (if $h < 3 \times d_2$, then continuous imperfection $f = d_1 + h + d_2$).

Table 5 — Density imperfection acceptance criteria

Dimensions in millimetres

Bead	Characteristics	Maximum tolerances	
		Steel and nickel alloys, Titanium and titanium alloys	**Aluminium, magnesium and their alloys**
	Butt welds [a]	In general: $0{,}2 \le \ell_o \le 0{,}2 \times t$ $\Sigma\ \ell_o \le 2 \times t$ over a length of $20 \times t$ and t: thickness of the thinnest part of the assembly	In general: $0{,}2 \le \ell_o \le 0{,}3 \times t$ $\Sigma\ \ell_o \le 4 \times t$ over a length of $20 \times t$ and t: thickness of the thinnest part of the assembly
		Slope down zone: $0{,}2 \le \ell_o \le 0{,}5 \times t$	Slope down zone: $0{,}2 \le \ell_o \le 0{,}6 \times t$
	Lap welds in through mode [a]	In general: $0{,}2 \le \ell_o \le 0{,}3 \times E$ $\Sigma\ \ell_o \le 2 \times E$ over a length of $20 \times E$ and E: total thickness of 2 sheets ℓ_i: lap width	In general: $0{,}2 \le \ell_o \le 0{,}4 \times E$ $\Sigma\ \ell_o \le 2 \times E$ over a length of $20 \times E$ and E: total thickness of 2 sheets
		Slope (or ramp) down zone: $0{,}2 \le \ell_o \le 0{,}4 \times E$	Slope (ramp) down zone: $0{,}2 \le \ell_o \le 0{,}6 \times t$
	Welds obtained by assembling square-edged sheets at joint plane [a]	$0{,}2 \le \ell_o \le 0{,}3 \times p$ $\Sigma\ \ell_o \le 2 \times p$ over a length of $20 \times p$	—

ℓ_o = diameter of a density imperfection.

[a] The acceptance criteria for density imperfection concerning slope down, overlap and slope up zones are defined in particular specifications.

7.2.3.2.9 Dimensional inspection

This inspection shall be carried out after welding and before heat treatment.

Such inspections, which shall not highlight any dimensions non compliant with the design definition, shall include the entire length of the weld including the slope up or down (ramp in or out) zones.

In case of interpretation problems, methods such as patterns, profile projector, needle profile meter, etc. may be used.

7.2.3.2.10 Metallography

Unless otherwise defined by the design authority and recorded in the welding procedure, the acceptance criteria for external and internal flaws revealed by macro- or micro-section, shall be as defined in 7.2.3.2.7 and 7.2.3.2.8 and Tables 3 and 4. There shall not be any detrimental metallurgical compounds or phases present in the weld zone. The nail head imperfection shall only be accepted with the approval of a competent department of the design authority. A decrease in weld bead thickness due the presence of imperfections is not acceptable if the cumulative depth of these imperfections exceeds the maximum permitted value for an imperfection in Table 4. The minimum width of the fusion zone (see Table 4) is determined by microsection. Hardness profiles or mapping may be used to confirmed effective post-weld heat-treatment, with the absence of hard or soft zones"

For circular welds, it is recommended to make at least three macro-graphic and micro-graphic examination of cross sections, one of which is in the slope (or ramp) down zone.

7.2.3.2.11 Hardness profile and mapping

Hardness profiling or mapping may be undertaken on metallographic sections, when required by the design authority or at the discretion of the manufacturer, in order to characterise the weld fusion and heat-affected zones. Such examinations would also confirm an acceptable response to heat-treatment, without non-compliant hard or soft regions.

These tests can be carried out according to the recommendations in Table 3.

Hardness profiling or mapping may also be undertaken to ensure that welds undertaken on metals susceptible to reactions with gases such as oxygen, nitrogen, hydrogen etc., remain of good integrity. For example, welds in titanium alloys exhibiting yellow or blue discolouration of the "heat-affected zone", may be considered to be acceptable of the hardness of these zones does not exceed that of the parent metal plus 80 HV.

7.2.3.2.12 Joint mechanical characterization

The results from tests carried out on test specimens (for example: tensile test, fatigue, stress-corrosion, etc.) shall comply with the requirements of the design authority.

7.2.3.2.13 Parameter verification

Melt runs are made on flat or circular test specimens with the welding parameters defined on the parameter data sheet (same firing distance, power, welding speed, etc.).

Melt runs may undertaken using a blind weld to simulate a butt weld, providing that similar welding conditions and parameters are employed.

Cross sections are made across the bead and the macro-graphic shape is determined (penetration depth, width on beam input side, mid-penetration width) by tolerance values indicated on the parameter data sheet.

7.2.4 Approval

Qualification of the welding procedure shall be confirmed by the competent department of the manufacturer, providing that the results of all inspections and tests undertaken are compliant with the requirements of this standard and/or the design definition. The qualified welding procedure shall be fully documented and identified by a reference number.

7.3 Process monitoring and inspection in manufacture

7.3.1 General

For classes 1 and 2 welded joints, the manufacturer shall prepare a documented welding procedure/ schedule, detailing the pre-treatments, welding equipment and tooling, weld parameters, quality and inspection requirements etc. This procedure is also recommended for class 3 welded joints.

For classes 2 and 3 welds, the manufacturing test specimen may be replaced by a parameter verification specimen when agreed by the design authority.

7.3.2 Checking before manufacturing

7.3.2.1 Document(s)

Manufacture shall be monitored during the production phase by the documented examination of test specimens and welded assemblies.

A properly justified relaxation in the inspection requirements may be possible during the production phase, with the prior agreement of the design authority.

7.3.2.2 Verification of welding equipments

Welding machines shall be subject to regular, documented, routine preventative maintenance and calibration procedures, undertaken by suitably accredited organisations

7.3.2.3 Production condition for manufacturing test specimens and parameters verification specimen

The surface condition of manufacturing test specimens shall comply with 7.2.3.2.2, the dimensional tolerances of joints to weld shall correspond to those of the qualification test specimens.

Parts shall be handled in a manner not to alter the cleanliness of surfaces. Use of clean gloves is recommended.

Production welding shall be undertaken in accordance with the validated welding procedure.

For any new welding campaign, the welding technique shall be verified by the assessment of sample weld test specimens, at the following intervals, unless otherwise specified by the design authority:

a) At the start of the production run.

b) At the start of each shift.

c) After any adjustment to the welding parameters or repair to the welding machine.

d) At the completion of the production run if "non-destructive testing" for internal flaws is not applied.

For all stabilized manufacturing processes, and for each batch of parts, at least one parameter verification specimen or one manufacturing test specimen will be welded at the beginning of the production run.

When visual inspection of both the upper and root sides of the welded joint is possible and when the welds are subject to 100 % inspection of internal quality then, with the agreement of the design authority, a relaxation in the number of batch related weld test specimens may be considered

The competent department of the manufacturer or the supplier may decide to carry out inspection operations and tests not previously imposed.

7.3.2.4 Inspection operations to carry out on manufacturing test specimens

The inspection operations to carry out on manufacturing test specimens are indicated in Table 6.

Table 6 — Tests and inspections on manufacturing test specimens

Tests and inspections		After welding					
		without or before heat treatment			after heat treatment		
		weld class [a]			weld class [a]		
		1	2	3	1	2	3
"Non-destructive testing" of surfaces	visual	yes	yes	yes	yes	yes	yes
	reinforced visual	yes	yes	no	yes [b]	yes [b]	no
"Non-destructive testing" of internal soundness		yes	yes	no	yes	yes	no
Metallography on cross-section		yes	yes	no	yes	yes	no

[a] It is reminded that for classes 2 and 3 welds, the manufacturing test specimens can be replaced by the adjustment verification specimen.

[b] The test shall be carried out after machining if the part undergoes this operation.

Adjustment verification specimens are inspected visually.

A macro-graphic inspection across the section is carried out in as-welded state.

7.3.2.5 Requirements

Manufacturing test specimens shall comply with the inspection and quality requirements defined for the finished assembly in the relevant welding procedure

The macro-graphic shape obtained on the parameter adjustment verification specimen shall be that indicated on the welding procedure.

7.3.2.6 Parameter tolerances

Production welding shall be undertaken using the parameters defined in the relevant validated welding procedure, although some adjustments within the following tolerances are permitted:

— Power: ± 10 % of the qualified value;

— welding speed: ± 5 % of the qualified value;

— focal distance: ± 10 % of the thickness in mm;

— firing distance: ± 5 % of the qualified value.

Only two parameters may be modified simultaneously and then the maximum tolerance for each parameter shall be divided by 2.

If deviations in welding parameters are necessary outside of the tolerances defined above, then manufacturing shall cease and the causes established. If necessary, a revised welding procedure shall be defined and qualified.

7.3.3 Part welding

7.3.3.1 Preparation of detail parts

The surface condition shall comply with 7.2.3.2.2. The dimensional tolerances in the welding configuration of joints to weld shall correspond to those specified in reference document.

Parts shall be handled in a manner not to alter the cleanliness of surfaces close to the zone to weld.

7.3.3.2 Welding

Welding shall be carried out within the time frame indicated in the manufacturing procedure specification including the assembly parameters after preparation of parts.

Parts shall be welded according to the qualified parameters.

7.3.3.3 Part examinations

If during welding, the operator visually detects imperfections not conforming to the criteria defined in 7.2.3.2.7, manufacturing shall cease.

The manufacturer shall establish the reason for the defects and take the necessary corrective steps.

7.3.3.4 Heat treatment

Heat treatment after welding shall be carried out within the time frame indicated on the adjustment data sheet.

7.4 Acceptance of welded assemblies

7.4.1 Requirements

7.4.1.1 General

Unless otherwise defined by the design authority and recorded in the applicable weld procedure, all welded assemblies shall be subject to the necessary inspection operations, to demonstrate compliance with the acceptance criteria defined in Table 4.

7.4.1.2 Visual inspection

See 7.2.3.2.7.

Unless otherwise defined by the design authority and recorded in the applicable weld procedure, all welded assemblies shall be subject to visual inspection to demonstrate compliance with the acceptance criteria defined in Table 4.

The root and face side of the weld bead shall have an even appearance. If the root side of the weld incorporates irregular solidified droplets, special care shall be paid to the inspection of the weld integrity (risk of formation of cavities in the fused zone).

The visual inspection of the face side of the weld bead shall also concern the overlap zone and slope (ramp) down zone (risk of weld bead settling at end of overlap).

Unless otherwise defined by the design authority and recorded in the applicable weld procedure, all class 1 and 2 welded joints shall also be subjected to surface dye penetrant or magnetic particle flaw detection, as appropriate, to demonstrate compliance with the acceptance criteria defined in Table 4. This requirement may be waived for class 3 welds, with the prior agreement of the design authority

7.4.1.3 Radiographic inspection

Unless otherwise defined by the design authority and recorded in the applicable weld procedure, all class 1 welded joints shall be subject to radiographic inspection to demonstrate compliance with the acceptance criteria defined in Table 6. The requirements for classes 2 and 3 welds shall be defined by the design authority and recorded in the applicable weld procedure for limiting the inspection to a delicate zone of the bead (overlap, slope down, etc.).

On request and indicated on definition documents, this inspection may be applied to classes 2 and 3 welds. In this case, and for manufacturing runs of which the reliability is confirmed, the competent department of the supplier may decide to reduce the frequency of the radiographic inspection

7.4.1.4 Other internal integrity assessment tests

Other non-destructive test or inspection requirements (ultrasound test) may be required by the design authority and recorded in the applicable weld procedure.

7.4.1.5 Dimensional check

See 7.2.3.2.9.

7.4.1.6 Special requirements

Other characteristics for example, sealing, shall be verified by the appropriate means, if requested by the design authority.

Small mechanically-welded assemblies for which quality requirements do not allow the use of dye penetrant inspection, and if the configuration of assembled parts does not allow the use of a "non-destructive" internal soundness inspection method, the competent department of the supplier with the prior agreement of the design authority may decide to assess the quality of a batch of welded parts by making metallographic cross sections of the first and last parts. Sampling of one part per batch for a metallographic cross section is sufficient for stabilized production runs.

7.4.2 Acceptance criteria

The criteria to be obtained on manufacturing test specimens are those defined in Tables 4 and 5 unless otherwise defined by the design authority and recorded in the applicable weld procedure

7.4.3 Sentencing of assemblies

Welded parts shall be rejected if one or more of the results from the inspection and test activities fails to comply with the quality requirements of Table 4, or other criteria defined by the design authority and recorded in the applicable weld procedure. In such cases, the parts shall then be subject to the manufacturer or supplier non-conformance procedure.

The decision is then:

— either repair (refer to 7.4.4);

— or rejection.

7.4.4 Repair of Non-Conforming Welded Joints

7.4.4.1 General conditions

Repair solutions shall take into account:

— the effects on the mechanical and metallurgical characteristics of the welded assembly;

— the strength of the repaired welded joints and the mechanical and dimensional requirements of the design authority;

— Repairs shall only be undertaken once without the prior agreement of the design authority;

Repairs shall be formally documented and underwritten by the design authority.

7.4.4.2 Potential repair solution

The following list of repair solutions include but are not limited to:

— acceptance as is on concession;

— mechanical re-work;

— smoothing pass or cosmetic pass with or without filler metal;

— remelt by laser;

— re-work by another welding process (e.g. electron beam welding or TIG welding).

Any re-work involving remelt on even a partial part of the welded zone shall be followed up by inspection in order to guarantee that the quality of the re-work part is equivalent to that of the parts accepted without re-work.

Inspection operations are defined by the competent department of the manufacturer, who may decide on the need to qualify the re-work parameters according to the procedure defined in 7.2.

8 Technical repair requirements

The repair shall be fully documented. The repairer is bound to comply with the technical requirements of the welded assembly, as defined by the design authority. Any deviations shall be subject to a concessionary procedure, agreed by the design authority.

9 Special case

In the case of isolated parts or non repeated operations, for example:

— the manufacture of prototypes,

— test or development hardware,

— repair.

With the prior agreement of the design authority, the manufacturer may waive the preparation and qualification of weld parameters and/or supervision during manufacture. In which cases, enhanced inspection shall be undertaken during the acceptance of the welded parts.

Inspection requirements shall be underwritten by the design authority.

In all cases, unless otherwise agreed in advance by the design authority, welded assemblies shall comply with the requirements of 7.4.

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