
Welding — Recommendations for welding of metallic materials —

Part 6: Laser beam welding

*Soudage — Recommandations pour le soudage des matériaux
métalliques —
Partie 6: Soudage par faisceau laser*

ISO/TR 17671-6:2005

<https://standards.iteh.ai/catalog/standards/sist/099b7285-7c77-4b93-92d8-b475df6cf46/iso-tr-17671-6-2005>



PDF disclaimer

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

Adobe is a trademark of Adobe Systems Incorporated.

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

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO/TR 17671-6:2005](https://standards.iteh.ai/catalog/standards/sist/099b7285-7c77-4b93-92d8-b475df6cf46/iso-tr-17671-6-2005)

<https://standards.iteh.ai/catalog/standards/sist/099b7285-7c77-4b93-92d8-b475df6cf46/iso-tr-17671-6-2005>

© ISO 2005

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

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

Published in Switzerland

Contents

Page

Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	3
4 Health and safety and protection of the environment	3
5 Quality requirements	3
6 Equipment	4
6.1 General	4
6.2 Provisions for acceptance testing	4
6.3 Provisions for maintenance and calibration	4
7 Qualification of welding personnel	4
8 Welding procedure specification	5
9 Welding procedure test	5
10 Consumables	5
10.1 Filler metals	5
10.2 Gases	5
11 Design	6
11.1 Overall design of structure or product	6
11.2 Joint design	6
11.3 Joint preparation	6
12 Laser beam welding	7
12.1 Characteristics	7
12.2 Advantages and limitations	9
12.3 Assembling and fixtures	10
12.4 Process control	10
12.5 Inspection and testing	10
12.6 Imperfections	10
Annex A (informative) Equipment	11
A.1 Description of laser process	11
A.2 Laser beam sources	12
A.3 Guiding, shaping and focussing the beam	14
A.4 Devices used to create a relative movement between the laser beam and the work piece	18
A.5 Fixtures used to hold the work piece	18
A.6 Cooling system	19
A.7 Control systems	19
Annex B (informative) Laser beam properties	20
Annex C (informative) Information about weldability of metallic materials	22
C.1 General	22
C.2 Steels and iron alloys	22
C.3 Nickel alloys	24
C.4 Aluminium and magnesium alloys	24
C.5 Copper and its alloys	24
C.6 Refractory and reactive materials	24

C.7	Titanium and its alloys.....	25
C.8	Dissimilar metals	25
C.9	Non-metals	25
Annex D (informative) Information about causes of weld imperfections and their prevention.....		26
Annex E (informative) Beam control and monitoring.....		28
E.1	General	28
E.2	Focal point	28
E.3	Beam alignment and pilot beam coincidence	28
E.4	Beam power	29
E.5	Beam power distribution	29
E.6	Nozzle alignment	29
E.7	Pulsed beam power data	30
E.8	Manipulators, guides, etc.	30
Annex F (informative) Laser beam processing.....		31
F.1	Laser beam cutting.....	31
F.2	Laser beam drilling.....	33
F.3	Laser beam surface treatment	33
F.4	Laser beam cladding.....	34
F.5	Laser beam marking and engraving.....	35
Bibliography.....		36

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO/TR 17671-6:2005](https://standards.iteh.ai/catalog/standards/sist/099b7285-7c77-4b93-92d8-b475df6cf46/iso-tr-17671-6-2005)

<https://standards.iteh.ai/catalog/standards/sist/099b7285-7c77-4b93-92d8-b475df6cf46/iso-tr-17671-6-2005>

Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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 of all such patent rights.

ISO/TR 17671-6 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal welding*.

ISO/TR 17671 consists of the following parts, under the general title *Welding — Recommendations for welding of metallic materials*:

- *Part 1: General guidance for arc welding*
- *Part 2: Arc welding of ferritic steels*
- *Part 3: Arc welding of stainless steels*
- *Part 4: Arc welding of aluminium and aluminium alloys*
- *Part 5: Welding of clad steels*
- *Part 6: Laser beam welding*
- *Part 7: Electron beam welding*

Introduction

ISO/TR 17671 has been issued in several parts in order that it can be extended to cover the different types of metallic material that are produced in accordance with all International Standards for weldable metallic materials.

When ISO/TR 17671 is referenced for contractual purposes, the ordering authority or contracting parties should state the need for compliance with the relevant parts of ISO/TR 17671 and such of the annexes as are appropriate.

This part of ISO/TR 17671 gives general guidance for the satisfactory production and control of welding and associated processes and details of some of the possible detrimental phenomena that can occur, with advice on methods by which they can be avoided. It is generally applicable to laser beam processing of metallic materials and also to some extent for non-metallic materials. It is appropriate regardless of the type of fabrication involved, although the relevant product standard, structural code or design specification can have additional requirements. Permissible design stresses, methods of testing and inspection levels are not included because they depend on the service conditions of fabrication. These details should be obtained from the relevant application standard or established by agreement between the contracting parties.

It has been assumed in the drafting of this part of ISO/TR 17671 that the execution of its provisions is entrusted to appropriately qualified, experienced and trained personnel.

Requests for official interpretations of any aspect of this part of ISO/TR 17671 should be directed to the Secretariat of ISO/TC 44/SC 10 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

[ISO/TR 17671-6:2005](https://standards.iteh.ai/catalog/standards/sist/099b7285-7c77-4b93-92d8-b475df66cf46/iso-tr-17671-6-2005)

<https://standards.iteh.ai/catalog/standards/sist/099b7285-7c77-4b93-92d8-b475df66cf46/iso-tr-17671-6-2005>

Welding — Recommendations for welding of metallic materials —

Part 6: Laser beam welding

1 Scope

This document gives general guidance for laser beam welding of metallic materials in all forms (e.g. cast, wrought, extruded, forged), and associated processes.

NOTE Some guidance on laser beam cutting, drilling, surface treatment and cladding is given in Annex F.

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 referenced document (including any amendments) applies.

ISO 286-2, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*

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

ISO 3834-2, *Quality requirements for fusion welding of metallic materials — Part 2: Comprehensive quality requirements*

ISO 3834-5, *Quality requirements for fusion welding of metallic materials — Part 5: Normative references for the requirements of ISO 3834-2, ISO 3834-3 and ISO 3834-4*

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

ISO 9013, *Thermal cutting — Classification of thermal cuts — Geometrical product specification and quality tolerances*

ISO 10218, *Robots for industrial environments — Safety requirements*

ISO 11145, *Optics and optical instruments — Lasers and laser-related equipment — Vocabulary and symbols*

ISO 11553-1, *Safety of machinery — Laser processing machines — Part 1: General safety requirements*

ISO 13919-1, *Welding — Electron and laser-beam welded joints — Guidance on quality levels for imperfections — Part 1: Steel*

ISO 13919-2, *Welding — Electron and laser-beam welded joints — Guidance on quality levels for imperfections — Part 2: Aluminium and its weldable alloys*

ISO 13920, *Welding — General tolerances for welded constructions — Dimensions for lengths and angles — Shape and position*

ISO 14175, *Welding consumables — Shielding gases for arc welding and cutting*

ISO 14232, *Thermal spraying — Powders — Composition and technical supply conditions*

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

ISO 14343, *Welding consumables — Wire electrodes, wires and rods for arc welding of stainless and heat resisting steels — Classification*

ISO 14732, *Welding personnel — Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials*

ISO 14919, *Thermal spraying — Wires, rods and cords for flame and arc spraying — Classification — Technical supply conditions*

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

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

ISO 15614-7, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 7: Overlay welding*

ISO 15614-11, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 11: Electron and laser beam welding*

ISO 15616-1, *Acceptance tests for CO₂-laser beam machines for high quality welding and cutting — Part 1: General principles, acceptance conditions*

ISO 15616-2, *Acceptance tests for CO₂-laser beam machines for high quality welding and cutting — Part 2: Measurement of static and dynamic accuracy*

ISO 15616-3, *Acceptance tests for CO₂-laser beam machines for high quality welding and cutting — Part 3: Calibration of instruments for measurement of gas flow and pressure*

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

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

ISO 17633, *Welding consumables — Tubular cored electrodes and rods for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels — Classification*

ISO 17634, *Welding consumables — Tubular cored electrodes for gas shielded metal arc welding of creep-resisting steels — Classification*

ISO 17662, *Welding — Calibration, verification and validation of equipment used for welding, including ancillary activities*

ISO/TR 17671-1:2002, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*

ISO 18273, *Welding consumables — Wire electrodes, wires and rods for welding of aluminium and aluminium alloys — Classification*

ISO 18274, *Welding consumables — Wire and strip electrodes, wires and rods for arc welding of nickel and nickel alloys — Classification*

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

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

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

IEC 60825-1, *Safety of laser products — Part 1: Equipment classification, requirements and user's guide*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11145 apply.

4 Health and safety and protection of the environment

A general checklist on protection of the environment in welding and allied processes is in preparation by CEN/TC 121. It covers laser applications.

Laser beam processing introduces additional hazards over and above those normally experienced in arc welding. Specialist advice should be sought, see e.g. IEC 60825-1 and ISO 11553-1.

Guidance on safety aspects related to the application of industrial robots for manipulation of the focussing devices and/or the components to be welded can be found in ISO 10218.

5 Quality requirements

Laser beam welding is a complex process needing detailed process control. All processing is performed under numerical control, necessitating programming of each single operation. The application has to be controlled at a level compatible with ISO 3834-2 and ISO 3834-5.

NOTE This does *not* entail a requirement for certification, but the process control should operate in accordance with ISO 3834-2 and ISO 3834-5.

It is a condition for efficient process control that quality requirements for joint geometry and other relevant requirements have been specified prior to start of fabrication. A number of International Standards specify joint geometry and relevant quality criteria and can be used for reference, as appropriate (see Table 1).

Table 1 — Quality criteria

Requirements and tolerances	Standard No.
Quality requirements for beam welded joints	ISO 13919-1 ISO 13919-2
Quality requirements for cut surfaces	ISO 9013
General tolerances	ISO 13920
General requirements	ISO 3834-2 and ISO 3834-5 specify provisions for information and items to be agreed and specified prior to the start of fabrication. ISO/TR 17671-1:2002, Annex A, can be used as guidance if ISO 3834-2 and ISO 3834-5 are not called for.

6 Equipment

6.1 General

Information about particular equipment for laser beam processing has to be found in information from the supplier. A number of textbooks and a large number of articles provide background information. Annex A provides some very general information on principles and techniques. Annex B provides general information on the properties of laser beams.

6.2 Provisions for acceptance testing

Provisions for acceptance of laser beam equipment are found in the following standards (see Table 2).

ISO/TR 17671-6:2005
<https://standards.iteh.ai/catalog/standards/sist/099b7285-7c77-4b93-92d8-b475d166cf46/iso-tr-17671-6-2005>
 Table 2 — Provisions for acceptance testing

Type of equipment	Standard No.
CO ₂ laser beam equipment	ISO 15616-1, ISO 15616-2 and/or ISO 15616-3
Nd:YAG laser equipment	ISO 22827-1, ISO 22827-2

6.3 Provisions for maintenance and calibration

Provisions for maintenance are not standardized. The supplier's manuals have to be consulted. Principles for calibration, verification and validation and minimum requirements are specified in ISO 17662.

7 Qualification of welding personnel

The requirements for the qualification of personnel for fully mechanized and automatic welding and allied processes are laid down in ISO 14732. Among the different procedures specified in this standard, the functional test is particularly suitable as a basis for qualification of personnel responsible for the operation and set-up of laser beam processing. In a functional test, the operator or setter demonstrates his/her knowledge of working with a procedure specification and of setting, supervising and checking the laser beam processing machine.

8 Welding procedure specification

All details for the laser beam welding of components are to be recorded in a welding procedure specification (WPS) in accordance with ISO 15609-4. Procedure specifications for cutting, drilling, surface treatment and cladding are not standardized. ISO 15609-4 can, however, give some guidance.

9 Welding procedure test

Formal qualification of all procedures for laser processing is recommended for all applications and required for many applications. Qualification of procedures for laser beam welding (when required) can be performed by procedure testing (see ISO 15614-11). Qualification by pre-production testing can also be relevant, however (see ISO 15613). Qualification by pre-production testing is common practice for cutting, drilling and surface treatment. ISO 15613 can give some guidance.

Qualification of procedures for laser beam welding for cladding (when required) can be performed by procedure testing (see ISO 15614-7). Qualification by pre-production testing can also be relevant, however (see ISO 15613).

10 Consumables

10.1 Filler metals

Filler metals are used for laser beam cladding and sometimes for laser beam welding. The main problem as regards filler metals for laser applications is that the market for such filler metals is rather small and that dedicated standards for filler metals for laser applications do not exist. The usual form of delivery is solid cylindrical wires but powders can also be used, in particular for cladding. What is commercially available is the following:

- Wires marketed as consumables for gas shielded metal arc welding and tungsten inert gas welding. However, it should be noted that metal cored tubular wires might also be suitable. Small-scale (experimental) production of tubular wires can even be feasible for special applications. Relevant standards are ISO 636, ISO 14341, ISO 14343, ISO 17633, ISO 18273, ISO 18274, ISO 17632, ISO 17634, ISO 18276, ISO 16834.
- Wires marketed as consumables for thermal spraying. The usual form of delivery is solid cylindrical wires. Such wires are standardized in ISO 14919.
- Powders for thermal spraying. Such powders are standardized in ISO 14232.
- Powders for powder metallurgy.

10.2 Gases

Gases are used for shielding and plasma suppressing in laser beam welding, as cutting assist gases in laser beam cutting, and for shielding in laser beam cladding, drilling and marking. Further, CO₂ lasers may need a continuous supply of laser gas.

The only relevant standard is ISO 14175. This standard is, however, not adequate for all gases used for laser beam processing. Careful specification of composition, tolerances, etc., is necessary for all non-standardized gases when ordering.

11 Design

11.1 Overall design of structure or product

The main consideration is to ensure that all joints are accessible. It can be an advantage for the focussing head to be some distance from the surface of the joint. However, when shielding gas or plasma suppression jets are used, these nozzles have to be placed close to the surface. The use of sensors augments the requirements for accessibility.

11.2 Joint design

Joint design is, of course, relevant to laser beam welding. The default joint is a normal square butt weld in a butt joint. T-joints are welded similarly but full penetration may not be necessary. Overlap points are used for spot welding.

Laser beam welding can ensure welding of components to tight tolerances. It is a condition, however, that either the fixtures hold the parts very accurately or that the joints are “self-positioning”.

Laser beam welding with root backing can be employed if spatter and undercut are to be avoided.

For axial circular welds on components with narrow dimensional tolerances, a press fit like H7/r6 to H7/n6 (see ISO 286-2) is recommended. For circular welds with a clearance fit, tacking is essential.

11.3 Joint preparation

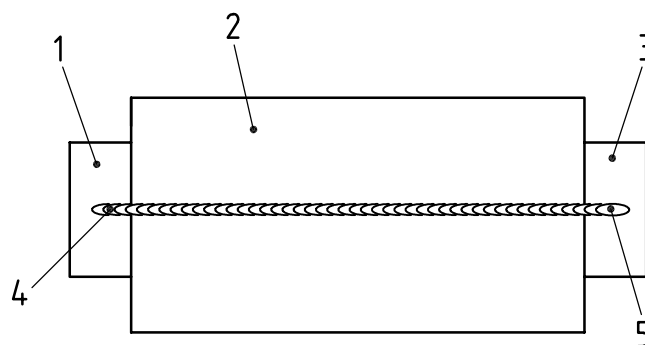
The quality of laser beam welding relies on the accuracy and cleanliness of joint preparation. Joints can be prepared by machining or cutting. Attention should be paid to the resulting surface condition. Cleaning of weld joint surfaces should be carried out if they are contaminated by oxides, oil, grease, coolant or paint.

The specific cleaning method used will be dependent on the material type, the component size and the quality requirements as well as the operational circumstances. The following treatments can be used:

- manual degreasing with a solvent;
- cleaning in a closed solvent vapour unit or in an ultrasonic bath;
- pre-treatment by steam cleaning with a slightly alkaline additive, following by drying;
- acid pickling neutralization, washing in distilled water, drying, short-term storage;
- mechanical cleaning by grinding, brushing, etc.;
- primers and similar layers on steel plates can be burnt away by de-focussing the laser beam and moving it along the joint prior to welding (very high speeds in excess of 100 mm/s can be used during this treatment).

Where components have surface layers produced by carburizing, anodizing, cadmium plating, nitriding, phosphating, galvanizing, etc., these layers usually have to be removed, preferentially by machining of the surface in the weld joint region.

If the component cannot be machined in the weld start and finish regions to remove the end crater, run-on or run-off plates should be used (see Figure 1). These run-on/run-off plates also suppress heat accumulation at the work piece ends. The run-on/run-off plates should be attached to the work piece by clamping or welding to achieve good thermal contact and are removed subsequently.



Key

- 1 run-on plate
- 2 work piece
- 3 run-off plate
- 4 start of weld
- 5 end of weld

Figure 1 — Work piece with run-on and run-off plate for separating the weld start and weld end

12 Laser beam welding

12.1 Characteristics

12.1.1 Modes

Laser beam welding is a fusion welding process and the joint is characterized by heat-affected zones in the parts joined by weld metal.

Laser beam welding is often performed as keyhole mode welding. Keyhole mode welding requires a beam with a high power density, able to vaporize the material at the point of interaction. The beam then is able to create (by the vapour pressure) a deep cavity, roughly cylindrical in shape. The walls of the cavity are covered by molten material. When the process is under control, the cavity is propagated with the beam along the joint. Heat and material propagation is essentially two-dimensional. The material melts at the front of the cavity and moves to the trailing edge, where it solidifies, creating the weld metal. A small proportion of the material evaporates or is ejected as spatter and this part of the material is transported in the direction along the axis of the beam. Keyhole mode welding is the usual mode for full and partial penetration butt welds in thick materials.

Another mode is conduction mode welding. In this mode, the intensity of the beam is insufficient to create a keyhole and the heat distribution becomes similar to the heat distribution in arc welding. Conduction mode welding occurs when the beam (of low intensity) is de-focussed or oscillated. Conduction mode welding can result in a three-dimensional heat distribution and the weld cross-section is then approximately circular with a width at the surface approximately two times the depth of penetration. However, the heat input can be spread over a wider area, resulting in a weld with a width larger than two times the depth of penetration. A similar technique is used for laser beam cladding where penetration usually is minimized.

In spot welding, the focussing head is kept stationary in relation to the parent material during welding. Welding time for each spot can be measured in milliseconds. Pulsed lasers are commonly used for this purpose. The resulting weld profile is usually intermediate between conduction and keyhole welds.