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An American National Standard

Process Specification and Operator Qualification for Laser Beam Welding

American Welding Society®

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Process Specification and Operator Qualification for Laser Beam Welding

2nd Edition

Revises AWS C7.4/C7.4M:2008

Prepared by the
American Welding Society (AWS) C7 Committee on High Energy Beam Welding and Cutting

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification on laser beam welding discusses applicable specifications, safety, requirements, fabrication, quality examination, equipment calibration and maintenance, approval of work, and delivery of work.

American Welding Society®

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Foreword

This foreword is not part of this standard but is included for informational purposes only.

In the year 2010 the laser industry celebrated the 50th Anniversary of the invention of the laser. Since its introduction, the output power of lasers has increased to the level where the use of lasers for material processing has become widespread worldwide. Lasers are accepted as industrial tools for various materials processing applications. The main subjects of this document are process specifications for laser welding and welding operator qualifications.

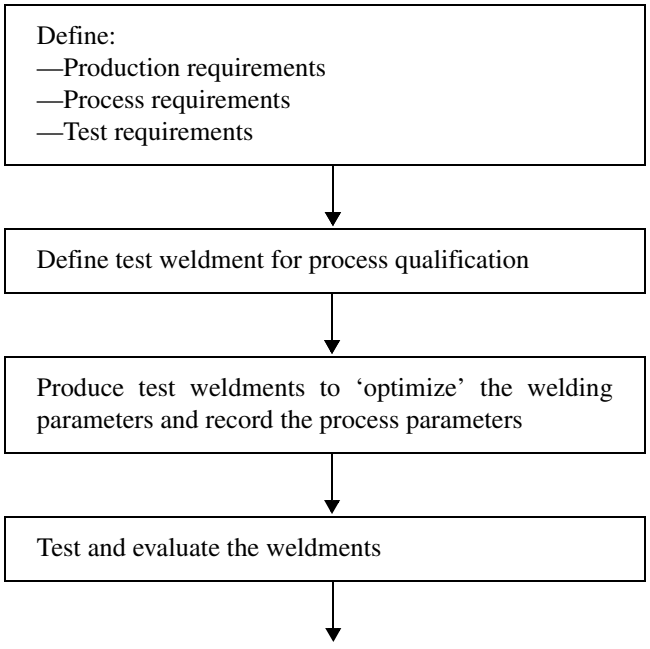
This is the second edition of the C7.4/C7.4M. This update was prepared recognizing the technological changes in lasers, beam delivery optics, laser beam diagnostic technology, and real time process monitoring. Furthermore, the Committee also recognized the need for formal training and qualification of the technical staff that is necessary to qualify the welding equipment and the laser welding process. With this document, the C7 Committee and the C7C Subcommittee hope to provide a working document for manufacturing professionals and educators involved in industrial laser welding.

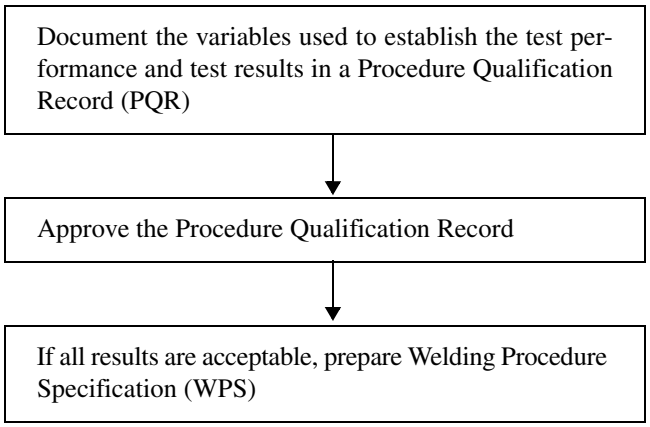
The information contained in this *Process Specification and Operator Qualification for Laser Beam Welding* has been compiled and reviewed by the C7C Laser Beam Welding and Cutting Subcommittee of the American Welding Society, which includes representatives from manufacturers and users of laser beam welding equipment.

Flow Diagrams below are provided as guidelines* to the reader.

Laser Weld Procedure Qualification

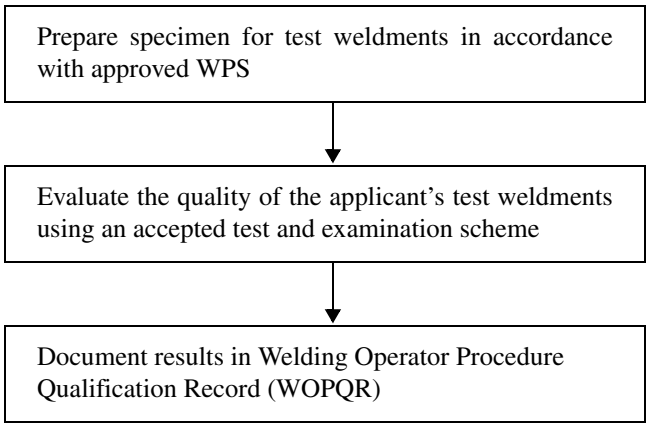
The 'Employer' or the 'Manufacturer' using Engineering and Production Resources should follow this suggested procedure for a laser welding program:





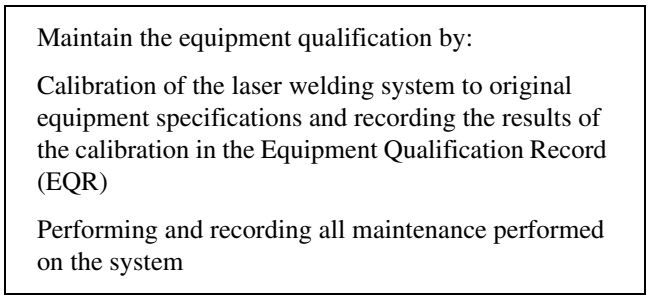
Laser Welding Operator Qualification

To qualify a person (Applicant) as a laser 'Welder' or the 'Welding Operator,' the Test Site Administrator (TSA) of the AWS Accredited Testing Facility (ATF), or a Certified Welding Inspector (CWI), should follow this suggested procedure:



Laser Welding Equipment Qualification

To qualify the laser welding equipment for engineering, production welds, or Welding Operator Qualification, the 'Employer,' the 'Manufacturer,' or the 'Test Site Administrator' should follow this suggested procedures and maintain the corresponding records:



*Reference: AWS B2.1/B2.1M:2009-ADD1, *Specifications for Welding Procedure and Performance Qualification*.

Amendment

The following amendment has been identified and is incorporated in this reprint.

AWS Standard: C7.4/C7.4M:2017-AMD1
Amendment Number: 1
Subject: Clause 6.5

Delete "shall" and replace with "should."

6.5 Equipment. The laser welding work stations ~~shall~~ should meet the Class 1 requirements as specified in the current version of ANSI Z136.1, *Safe Use of Lasers*. They should also conform to the basic equipment configurations listed in 6.5.1 or 6.5.2. Each facility may have one or both types of laser welding equipment configurations. Each type of laser welding equipment shall be able to produce the weld penetration required for the materials being used in the welding operator qualification tests.

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Process Specification and Operator Qualification for Laser Beam Welding

1. General Requirements

1.1 Scope. This specification covers the preparation, the process control, and quality control requirements for laser beam welding. Welding equipment includes Gas Lasers (CO_2) and Solid-State Lasers (Nd:YAG, Yb:YAG, Nd:Glass, Diode, Ruby, Disk and Fiber) in pulsed, continuous wave (CW), and quasi-continuous wave (QCW) output as defined in AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*.

Tutorial information regarding techniques of welding or details of equipment setup or operation is beyond the scope of this specification. For more information on this subject and recommended practices, refer to the latest published version of AWS C7.2, *Recommended Practices for Laser Welding, Cutting, and Allied Processes*.

1.1.1 Materials. This specification covers all major engineering alloys including:

(1) Ferrous Alloys (e.g., Carbon steels, stainless steels, etc.);

(2) Nonferrous Alloys (e.g., Alloys of Al, Ni, Ti, etc. and Super-alloys);

(3) Heat-Resisting and Refractory Metal Alloys (e.g., Alloys of Mo, Ta, W, etc.);

(4) Other Alloys (e.g., Be and Cu alloys, precious metals);

(5) Nonmetals (Plastics, polymers, etc.).

1.1.2 Qualification Categories. There are three categories to which welds may be qualified: Class A, B, or C. Classification levels are intended to delineate inspection level and process control. Examples of acceptance criteria, which may be applied to the classification levels, are presented in Annex D.

1.1.2.1 Class A—Critical Applications. Critical weldments include those where a failure of any portion of a weldment would cause loss of system, loss of major component, loss of control, unintentional release of critical stores, such as fuel or cargo, or endangerment of personnel.

1.1.2.2 Class B—Semicritical Applications. Semicritical weldments include those where a failure of any portion of a weldment would reduce the overall efficiency of the system, but loss of the system or endangerment of personnel would not be experienced.

1.1.2.3 Class C—Noncritical Applications. Noncritical weldments include those where a failure of any portion of a weldment would not affect the efficiency of the system or endanger personnel.

1.2 Units of Measure. This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets [ ] or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

1.3 Safety. Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein.

Safety and health information is available from the following sources:

American Welding Society:

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Laser Institute of America (LIA):

ANSI Z136.1, *Safe Use of Lasers*

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

American Welding Society (AWS) standards:

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*;

AWS A5.32M/A5.32 (ISO 14175:2008 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*;

AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*;

AWS B4.0, *Standard Methods for Mechanical Testing of Welds*; and

AWS C7.2M, *Recommended Practices for Laser Beam Welding, Cutting, and Drilling*.

American National Standards Institute (ANSI) standards:

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*;

ANSI Z87.1, *Practices for Occupational and Educational Eye and Face Protection*; and

ANSI Z136.1, *Practices for the Safe Use of Lasers*.

International Organization for Standardization (ISO) standards:

ISO 11146-1, *Laser and laser related equipment — Test methods for laser beam widths, divergence angles and beam propagation ratios*;

ISO 22826, *Destructive test on welds in metallic materials — Hardness testing of narrow joints welded by laser and electron beams*; and

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

American Society for Nondestructive Testing (ASNT) standard:

ASNT Recommended Practice No. SNT TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*.

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document. A list of acronyms used within the document can be found in Annex E.

AWS Accredited Testing Facility (ATF). An organization accredited by the American Welding Society in accordance with AWS B5.4, *Specification for the Qualification of Welder Test Facilities*, for the purpose of qualification of welding personnel.

beam cover tubes. Typically cylindrical hardware—hollow tubes—arranged to cover the path of the laser beam. They provide safety for personnel working around the laser, and also exclude airborne contamination that would interfere with the laser beam. Beam cover tubes are often interlocked with the laser system so that if there is an intrusion or interception of the laser beam, the system will shut down.

chiller. A device often attached to the laser power supply and the laser 'head' to provide controlled cooling of both.

correlation factor. Electronic laser beam diagnostic equipment often compares the spatial profile of the laser beam to a mathematically defined profile. The difference between the two is typically expressed as a 'correlation factor.' The Factor of 1.0 (=100%) represents a complete conformance of the computed and the actual spatial profile.

craters. A region of underfill, typically at the termination of a weld bead, susceptible to shrinkage stresses and cracking.

employer. The contractor or manufacturer that adopts this AWS C7.4/C7.4M:2017 *Process Specification and Operator Qualification for Laser Beam Welding* standard.

fiber. See **fiber optic cable**.

fiber laser. A solid-state laser design in which the active medium is a specially constructed optical fiber.

fiber optic cable. An optical fiber that is designed to transmit the laser beam with minimal loss of power. Sometimes called the 'process fiber.' An important characteristic of the fiber optic cable is the (core) diameter, since it ultimately affects the diameter of the focused laser beam.

focal distance. The distance between the focusing optics and the focal point of the optics. Focal distance needs to be identified as 'free air' or 'working' focal distance. Working focal distance is the actual focal distance during the laser welding operation.

focus shift. Unintended change in the axial position of the focal point of the final focus optics during laser processing, such as laser welding.

free air distance. The focal length of the focusing optics as measured when there are no changes in the optical properties of the air between the optical component and the focal point of the optic.

inclusions. Foreign material in the original metal or in the welded metal.

laser spot weld. A fusion weld between two or more pieces of material or upon overlapping members with coalescence initiating and occurring at faying surfaces or proceeding from the outer surface of one member. Depending upon the laser peak power density, the weld fusion zone may have a semi-circular cross section in the plane of the faying surfaces due to the limited effects of laser translation on the molten pool geometry. Typically, pulsed laser power is used for laser spot welding.

lens. A transparent optical element with curved surfaces that will converge or diverge (focus or defocus) light rays (laser beams) via refraction. Some lenses may be designed to change the spatial profile of the original laser beam.

M^2 (pronounced as 'm squared'). Defined as the beam quality parameter. M^2 is a measure of beam quality; a low M^2 value indicates a beam that may be focused to a tight spot. The value M^2 is equal to the ratio of the beam's angle of divergence to that of a Gaussian beam with the same waist width.

mirror. An optical element with flat or curved surfaces that will reflect, diverge or converge light rays (laser beams).

overlap. In pulsed power laser welding it may refer to the overlap of weld dots or nuggets in a defined path. In the case of seam welding with either pulsed power or CW power, it may refer to the overlap of the end of the weld path with the starting point of the weld path. Hence, 'overlap' must be explicitly defined.

plume. Vaporized metal and ionized gases that may exist above the molten pool, during laser welding.

power density. The power density is calculated by dividing the laser power by the area of the beam. The diameter of the beam used to define area is measured or computed using an appropriate procedure. It should be noted that the power distribution may or may not be uniform. Typical units for power density are watts per square inch or watts per square centimeter.

pulse sector. A section of the laser pulse. In typical laser welding applications a laser pulse may have one or more 'sectors.'

pulse shape. See **temporal profile**.

pulse width. The duration (time) of the optical pulse (ms).

ramp down. Refers to the progressive lowering of the laser power prior to the end of the weld path.

ramp setting. See **ramp up** and **ramp down**.

ramp up. Refers to the progressive increase of the laser power at the start of the weld path.

remote welding system (RWS). A welding system that manipulates the beam using a set of reflective optics mounted on the shafts of DC galvo-motors. As the shafts of the motors programmably rotate, the incoming laser beam is deflected by the reflective optics. If the incoming laser beam is 'focused' by another optic, then the reflective optics may be used to deflect the focus beam. Remote welding systems typically have a long focal distance that still maintains adequate power density regardless of beam position.

rise time. In pulsed laser operation, this is the time it takes for the power to rise from 10% of full power to 90% of full power.

root width. The width of the back side of the weld bead when the workpiece is fully penetrated.

shielding gas, auxiliary. This is the cover gas applied over the molten material and the heat-affected zone (HAZ) during welding. The gas is delivered by a gas delivery tube (nozzle) that is not coaxial with the laser beam.

shielding gas, coaxial. Shielding gas delivered coaxially with the focusing optics.

soot. The typically black colored residue found on the weld nugget or on the material near the weld nugget.

spatial profile (which relates to M^2). The distribution of laser power transversely across the laser beam. May be specified (and measured) for the unfocused laser beam or the focused laser beam at the focal point of the laser beam.

temporal behavior. Any changes in the characteristics of the laser beam over time. For example, changes in laser power, spatial profile, changes to direction of beam propagation, etc.

temporal profile. Typically refers to the 'pulse shape'; that is, the distribution of laser power over the time of the pulse (pulse width).

trajectory. Refers to the preprogrammed path scribed by a focused laser beam on a flat target. The trajectory would identify any misalignment in the motion system or the beam delivery optics.

weld monitoring system. This term is typically used to identify equipment that is used to monitor the laser welding process in real time. Weld monitoring systems may use one or more signals generated during laser welding to identify changes in the weld process parameters.

welding operator. An individual responsible for the setup of the laser welding equipment to perform a laser welding process. Once qualified in accordance with this AWS standard, this individual is also considered capable of performing initial evaluation of weld quality and making necessary adjustments to the laser welding process. In the previous version of this AWS Standard this person was called the 'operator.' Coverage of the formal Qualification of the Welding Operator may be found in Clause 6.

4. Safety

For authoritative information, see ANSI Z136.1, *Practices for the Safe Use of Lasers*.

The following are the major areas of concern:

(1) Electric shock;

(2) Laser radiation hazards;