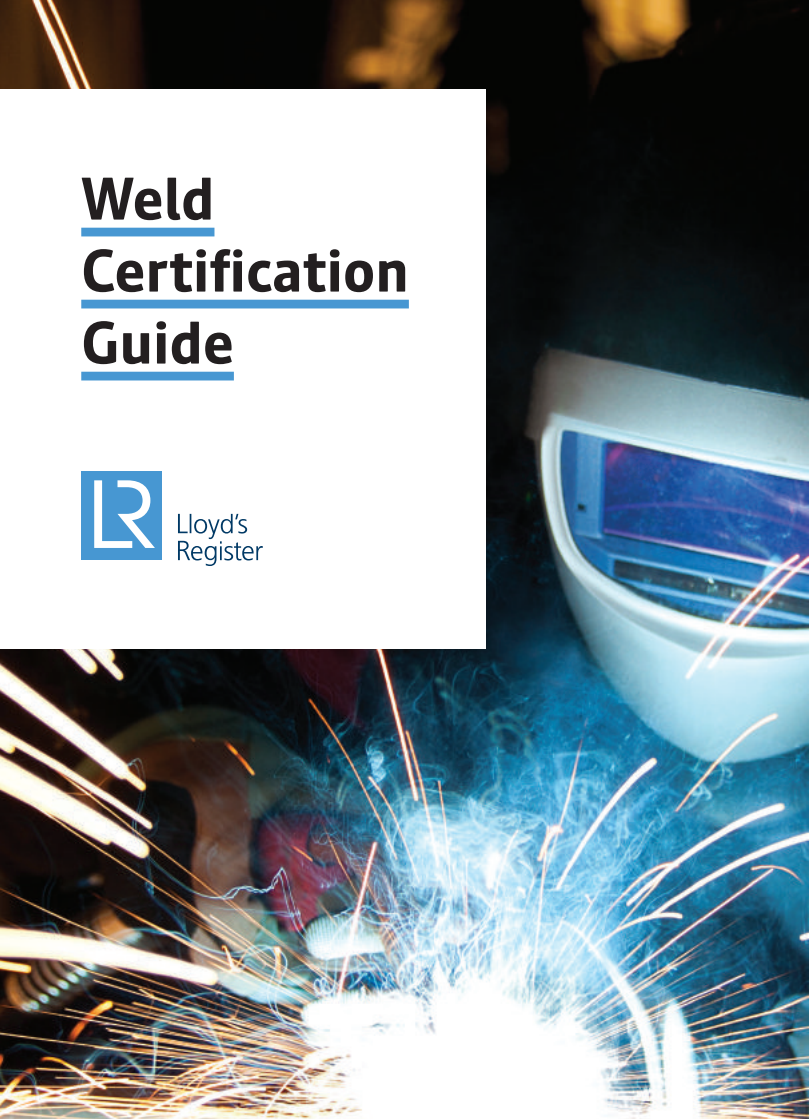
Weld Certification Guide

Lloyd's Register



Contents

Introduction

Weld certification is a critical element in the provision of assurance of the structural and pressure integrity of fabricated components and systems. This guide not only provides an overview of the route to weld certification but also provides a comparative review of the requirements of the principal welding codes:

- ASME IX
- EN ISO 15614 series
- AWS D1 series
- EN ISO 9606 series

– as applied to both weld procedure and weld performance qualifications.

The guide also identifies the applicability of the welding standards to codes of construction and provides examples of where welding standards are modified by such construction codes.

Code compliant welding procedures help ensure consistent and safe welding practices for a company's welders. Independent witness and review helps refine the procedures to make sure safety-critical assets are welded safely and achieve the desired quality level the code of construction requires.

Many codes, such as EN 1090-2, EN 13445 and EN 13480 now require compliance with EN ISO 3834 Quality Requirements in Fusion Welding. Lloyd's Register can help with training and certification to these standards.

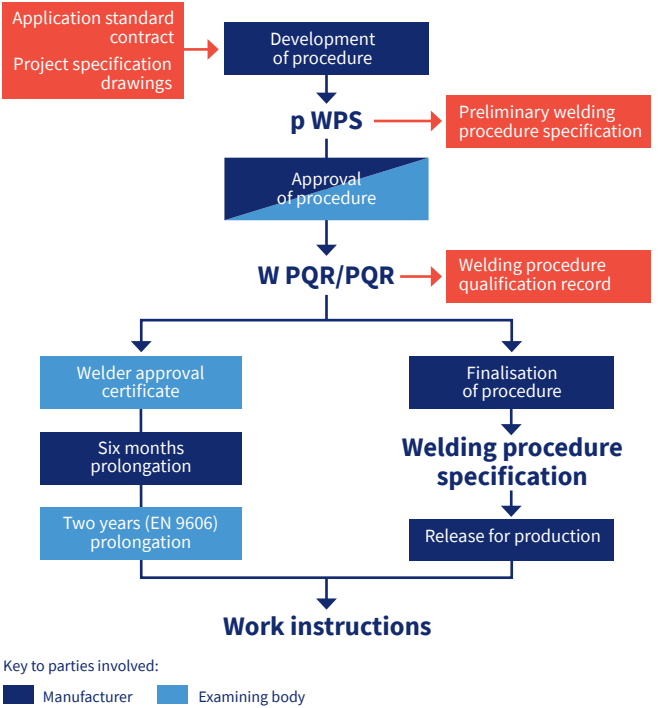
A note about welding and classed assets

Welding qualifications used for the construction, conversion, modification or repair of ships, other marine structures, offshore units and associated machinery which are classed or are intended for classification by Lloyd's Register are to be manufactured, tested and inspected in accordance with the appropriate Lloyd's Register Rules. These Rules can modify and add to the basic requirements of National and International welding codes.

These Rules originate from the minimum requirements which have been agreed and adopted by the members of the International Association of Classification Societies (IACS). LR Rules can be downloaded from the Rules and Regulations section of LR's website at www.lr.org/en/RulesandRegulations and the welding qualification requirements are located in the Rules for the Manufacture, Testing and Certification of Materials.

LR Rules are supplemented by procedures for application for approval of manufacturers and products, covering the details of information to be supplied by the manufacturer, and the test programme to be conducted on the products are given in the appropriate book of LR's Materials and Qualification Procedures for Ships (MQPS), which are published in the Class Direct section of LR's web site at www.lr.org

Welding procedure and approval stages



Terminology

Term	Definition
WPS – Weld Procedure Specification	Qualified instructions on how to complete the weld
PQR – Procedure Qualification Record (ASME) & WPQR – Weld Procedure Qualification Record	Record of the welding parameters and test results
Welders Qualification Test Certificate & Welders Performance Qualification (ASME)	Record of welder test results and ranges of approval
Essential Variable	A parameter that when changed outside its permitted range requires requalification
Supplementary Essential Variable (ASME)	When impact testing is required, treat as an essential variable
Non-essential Variable	A parameter that when changed does not require requalification

Ranges of approval

Component	Element
Weld Procedures	Weld Procedure range of approval is limited to materials with similar chemical composition and mechanical properties to that used in the PQR. Welding is within a strict range of parameters for the essential variables recorded during the PQR test.
Welder Qualifications	Range of approval is not as restrictive as procedure testing with fewer essential variables. One welder performance qualification can cover many WPS's.

Components of welding procedure

Weld certification – type	Ranges of approval
Parent Material	Parent Material Type (Grouping) Thickness Diameter (Pipes) Surface condition
Welding Process	Type of process (MMA, MAG, TIG, SAW, etc.) Equipment parameters Amps, Volts, Travel speed Polarity, Heat input
Welding Consumables	Type of consumable/diameter of consumable Brand/classification Heat treatments/storage
Joint Design	Edge preparation Root gap, root face Jigging and tacking Type of backing
Welding Position	Location, shop or site Welding position (e.g. 1G, 2G, 3G etc.) Any weather precaution
Thermal Heat Treatments	Preheat, interpass, temps Post weld heat treatments (e.g. stress relieving)

Mechanical properties

Mechanical properties	Definition
Malleability	Ability of a material to undergo plastic deformation under static tensile loading without rupture.
Ductility	Ability of a material to undergo plastic deformation under static tensile loading without rupture. Measurable elongation and reduction in cross section area.
Toughness	Ability of a material to withstand bending or the application of shear stresses by impact loading without fracture.
Hardness	Measurement of a materials surface resistance to indentation from another material by static load.
Tensile strength	Measurement of the maximum force required to fracture a materials bar of unit cross-sectional area in tension.

Weld test plate tests

Tests for required properties	Tests for weld quality
Tensile tests (Transverse Welded Joint, All Weld Metal)	Macro testing
Toughness testing (Charpy, Izod)	Fillet weld fracture testing
Hardness tests (Brinell, Rockwell, Vickers)	Butt weld nick-break testing
Bend testing	NDE (VT, PT, MT, RT, UT)
CTOD (Crack Tip Opening Displacement)	
Corrosion tests, HIC & SOHIC Tests	

Welding standards

The welding standards give the minimum requirements for compliance.

Welding standards such as EN ISO 15614, EN ISO 15613, EN ISO 9606 series and ASME IX are supporting standards and they are only used when specified in a code of construction (e.g. PD 5500, EN 13445, ASME VIII Division 1, ASME B31.3, examples of which are detailed in Table 1).

These codes of construction specify when the welding standards apply and may modify the requirements and approval ranges of the welding standards.

EN ISO standards for fusion welding

	Steel	Aluminium
Grouping of materials	CEN ISO/TR 15608, 20172 (European), 20173 (US), 20174 (Japan)	
Welder qualification	EN ISO 9606-1	EN ISO 9606-2
Welding operator qualification	EN ISO 14732	
Weld procedure qualification	EN ISO 15614-1	EN ISO 15614-2 & 4
	EN ISO 15607, 15610, 15611, 15612, 15613	
WPS	EN ISO 15609-1	
NDT personnel	EN ISO 9712	
Welding coordination	EN ISO 14731	

	Copper	Nickel	Titanium & Zirconium
Welder qualification	EN ISO 9606-3	EN ISO 9606-4	EN ISO 9606-5
Weld procedure qualification	EN ISO 15614-6	EN ISO 15614-1	EN ISO 15614-5

	Cast Iron	Over Lay Welding	Tube to Tube Plate
Weld procedure qualification	EN ISO 15614-3	EN ISO 15614-7	EN ISO 15614-8
Quality management for welding	EN ISO 3834 Series		

Table 1. Supporting welding standards

Applications	Application code	Weld procedure approval	Welder approval
Pressure vessels	PD 5500 ASME Sec. III NB (Nuclear) ASME Sec. VIII	EN ISO 15614 ASME Sec. IX	EN ISO 9606 ASME Sec. IX
Process pipework	BS 2633 BS 4677 BS 2971 ANSI/ASME B31.1 ANSI/ASME B31.3	EN ISO 15614 EN ISO 15614 EN ISO 15614-1 (if required) ASME Sec. IX ASME Sec. IX EN ISO 15614-1 (if required)	EN ISO 9606 ASME Sec. IX
Structural fabrication	AWS D1.1 AWS D1.2 AWS D1.6 EN 1011 BS 8118	AWS D1.1 AWS D1.2 AWS D1.6 EN ISO 15614-1 EN ISO 15614-2	AWS D1.1 AWS D1.2 AWS D1.6 EN ISO 9606 BS 4872
Storage tanks	EN 14015 EN 12285 API 620/650	EN ISO 15614-1, -2 EN ISO 15614-1, -2 ASME Sec. IX	EN ISO 9606-2 BS 4872 ASME Sec. IX

Examples of how welding standards are modified by construction codes and regulatory or contractual requirements

Welding standards can be modified by the requirements of both regulations, end users, and classification societies. As we see it, there are four levels of such requirements, and each can build on and/or include the specifications of the previous levels.

e.g. EN ISO15614, ISO9606, ASME IX , AWSD1.1

Code requirements to be met as a minimum

Level 2: Regulatory Requirements

e.g. EC Directives (PED,SPV, TPED etc), ASME Authorisation, Indian Boiler Regulations, Marine Classification Society Rules (LR, DNV-GL, BV , ABS, etc.)

Can have specific requirements for Examiners, Authorisations, additional testing, specific consumables, etc.

Level 3: Construction Codes

e.g. PD 5500, EN13445, EN12952, EN12953, ASME I,IV, VIII

References National & International Welding Codes and details specific requirements

Level 4: Contractual Requirements

e.g. NORSOK, EEMUA, NACE, purchaser/end user specifications

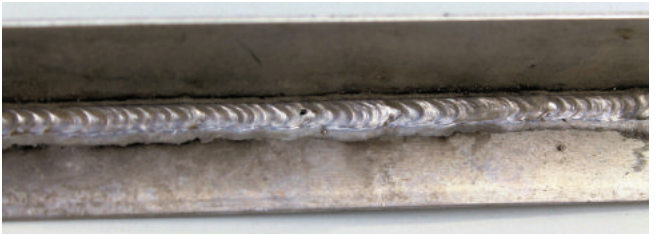
Can have more onerous requirements than other levels for limits on acceptance criteria, approval ranges, additional or modified essential variables, special testing requirements, repair procedures etc.

Choice of a weld test piece

All the listed welding standards utilise a set of standard test specimens to represent production applications. There is often a desire to produce samples which replicate the production joint and try to use this to qualify weld procedures and operators. Great caution must be used before undertaking this approach as in many instances the configuration selected does not meet the requirements of the welding standard and it will not be possible to use this test piece to qualify in accordance with the standard.

Choice of welding test piece

The choice of welding test piece has even greater significance, where the intention is to qualify to two or more standards, as all the requirements of each standard must be satisfied. This includes the types of test samples required and the position within the test piece from where they must be cut. It is not always possible to select a test piece that can be used to satisfy multiple codes.



Weld Procedure Qualifications

Weld Procedure Qualifications demonstrate that the welds produced to a specific set of parameters produce the required mechanical properties in the weld joint to satisfy the design requirements of production items. Each qualification normally provides a range of approval for parameters like materials, thickness, heat inputs and joint configurations.

Each of the welding standards has its own method of grouping materials and welding consumables to reduce the number of tests required. However they all have different systems and rules which can greatly change the range of approval for the same parameter from one standard to another.

Weld Performance Qualifications

Welder Performance Qualifications follow a similar logic to weld procedure qualifications with ranges of approval based on materials, consumables, process and welding positions. Welder performance tests are aimed at demonstrating the welders skill in being able to produce a sound weld. Therefore the range of approval and parameters for approval of specific ranges can be significantly different from the range in the procedure qualification for the same parameter.

Again each standard has its own criteria and this can result in significant differences between the ranges of two standards for the same test specimen.

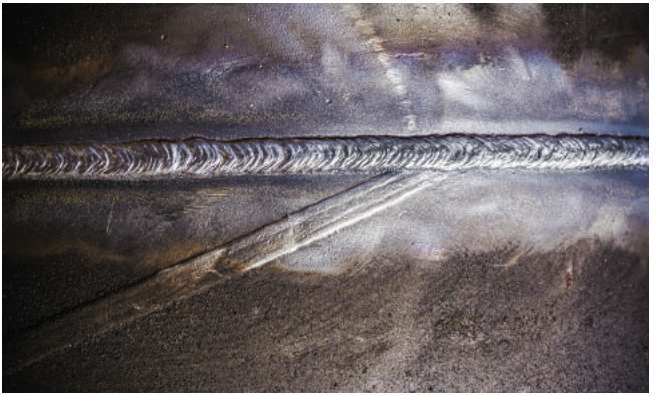


Table 2a. Comparison of basic requirements of EN ISO 15614-1, ASME Sec. IX and AWS D1.1 for Weld Procedure Qualification

Welding Test Pieces for Procedure Qualification			
Test piece – type	**EN ISO 15614-1**	**ASME Sec. IX**	**AWS D1.1**
Plate butt weld full penetration	Yes - equal thickness	Acceptable	Acceptable
Plate butt weld partial penetration	Not acceptable	Acceptable	Not acceptable
Pipe butt weld full penetration	Yes - equal thickness	Acceptable	Acceptable*
Pipe butt weld partial penetration	Not acceptable	Acceptable	Not acceptable
Plate fillet weld	Acceptable	Non-pressure retaining plate and pipe	Yes + butt for weld consumable
Pipe fillet weld	Acceptable	Non-pressure retaining plate and pipe	Yes + butt for weld consumable
Full penetration tee butt weld	Acceptable	Not accepted	Groove weld
	EN ISO 15614-1 Level 2	**EN ISO 15614-1 Level 1**	

*additional special requirements apply for T-, Y-, K- connections.

Table 2b - part 1. Comparison of basic requirements of EN ISO 15614-1, ASME Sec. IX and AWS D1.1 for Weld Procedure Qualification

Welding Test Pieces for Procedure Qualification			
Butt welds in plate and pipe			
Qualification tests – type	**EN ISO 15614-1**	**ASME Sec. IX**	**AWS D1.1**
Visual inspection	Mandatory	Not specified	Mandatory
Surface NDE (DPI, MPI)	Mandatory	Not required	Not required
Volumetric NDE (Radiography/UT)	Mandatory	Not required	Mandatory
Bend tests	Mandatory	Mandatory	Mandatory
Tensile tests - cross weld	Mandatory	Mandatory	Mandatory
Tensile test - all weld	Not required	Not required	ESW and ESG only
Macro etch	Mandatory	Not required	Not required
Hardness survey	Mandatory (for listed groups)	Not required	Not required
Impact tests - weld metal	Mandatory for >= 12 base metal tested	When required by other section	When required by contract docs
Impact tests - HAZ metal	Mandatory for >= 12 base metal tested	When required by other section	FL+1 & FL+5 when required by contract docs
	EN ISO 15614-1 Level 2	**EN ISO 15614-1 Level 1**	

Table 2b - part 2. Comparison of basic requirements of EN ISO 15614-1, ASME Sec. IX and AWS D1.1 for Weld Procedure Qualification

Welding Test Pieces for Procedure Qualification			
Fillet Welds			
Qualification tests – type	**EN ISO 15614-1**	**ASME Sec. IX**	**AWS D1.1**
Visual inspection	Mandatory	Not specified	Mandatory
Surface NDE (DPI, MPI)	Mandatory	Not required	Not required
Macro etch	Mandatory	Mandatory	Mandatory
Hardness survey	Mandatory (for listed groups)	Not required	Not required
	EN ISO 15614-1 Level 2	**EN ISO 15614-1 Level 1**	

Table 3 - part 1. Comparison of basic requirements of EN ISO 9606-1, ASME Sec. IX and AWS D1.1 for Weld Performance Qualification

Testing requirements for performance qualification			
Butt welds in plate and pipe			
Qualification tests – type	**EN ISO 9606-1**	**ASME Sec. IX**	**AWS D1.1**
Visual inspection	Mandatory	Mandatory	Mandatory
Surface NDE (DPI, MPI)	Not required	Not required	Not required
Volumetric NDE (Radiography/UT)	Mandatory (a)(b)	Option for some processes	Option except for GMAW-S
Bend tests	Mandatory (a)(b)	Mandatory or replaced by radiography	Mandatory or replaced by radiography
Fracture test	Mandatory (a)(b)	Not required	Mandatory for T-, Y-, K-connections on box tubing

(a) Either radiography or bend or fracture tests shall be used

(b) When radiographic testing is used, then additional bend or fracture tests are mandatory for welding processes 131, 135, 138 and 311

Table 3 - part 2. Comparison of basic requirements of EN ISO 9606-1, ASME Sec. IX and AWS D1.1 for Weld Performance Qualification

Testing requirements for performance qualification			
Fillet welds in plate or pipe			
Qualification tests – type	**EN ISO 9606-1**	**ASME Sec. IX**	**AWS D1.1**
Visual inspection	Mandatory	Mandatory	Yes
Surface NDE (DPI, MPI)	Not required	Not required	No
Bend test	Not applicable		
Fracture test	Mandatory/ replace with macro	Mandatory plus additional macro	Mandatory for some
Macro test	Option	Mandatory + additional option	Mandatory for some

EN ISO 3834 quality requirements for fusion welding of metallic material

Compliance with EN ISO 3834 is now mandatory for welding quality management in harmonised European standards for construction products, pressure vessels, pipework and boilers. One of the key elements of EN ISO 3834 is that it requires the manufacturer to demonstrate the competence of their welding coordinators.

Lloyd's Register offers accreditation to Part 2, 3 and 4 of the EN ISO 3834 standard:

- Part 2 – Comprehensive Quality Requirements
- Part 3 – Standard Quality Requirements
- Part 4 – Elementary Quality Requirements

For further information visit us at www.lr.org/weld-certification, email inspection@lr.org

Lloyd's Register started out in 1760 as a marine classification society. Today, we're one of the world's leading providers of professional services for engineering and technology – improving safety and increasing the performance of critical infrastructures for clients in over 75 countries worldwide. The profits we generate fund the Lloyd's Register Foundation, a charity which supports science and engineering-related research, education and public engagement around everything we do. All of this helps us stand by the purpose that drives us every single day: Working together for a safer world.

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