

NORSOK STANDARD

COMMON REQUIREMENTS
WELDING AND INSPECTION OF PIPING

M-CR-601
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1 FOREWORD

This standard has been developed by the NORSOK Standardisation Work Group for the widest possible national and international application. This standard will be used as input to the development of ISO 13703, "Platform Piping Systems", which will replace API 14E.

2 SCOPE

This standard covers technical requirements for welding and weld inspection of piping systems, for which NORSOK L-CR-001, «Piping and Valves» is the governing design standard .

This standard is based on ASME B31.3 in general and as an option to use EN 288 for welding procedure qualifications and EN 287 for welder qualifications in particular. The ASME B31.3 shall apply with addition of the requirements given in this standard.

This standard applies to all piping fabrication including prefabrication, module assembly, package or skid mounted units, site and field installation and shall be considered together with applicable drawings.

3 NORMATIVE REFERENCES

ASME	Boiler and Pressure Vessel Code, Section II, Part C - Welding Rods, Electrodes, and Filler Metals Section V - Nondestructive testing. Section VIII - Rules for Construction of Pressure Vessels Div. 1. Section IX - Welding and Brazing Qualification.
ASME B31.3	Code for Pressure Piping - Chemical Plant and Petroleum Refinery Piping.
ASTM E 562	Practice for Determining Volume Fraction by Systematic Manual Point Count.
ASTM G 48	Standard Test Method for Pitting and Crevice Corrosion Resistance of Stainless Steel and Related Alloys by the use of Ferric Chloride Solution.
ASTM A 370	Mechanical Testing of Steel Products.
DnV	Classification Note No. 7, Ultrasonic Inspection of Weld Connections.
EN 287	Approval testing of welders - Fusion welding.
EN 288	Specification and approval of welding procedures for metallic materials.

EN 473	Qualification and certification of personnel for non destructive examination.
EN 719	Welding coordination - Task and responsibilities.
EN 729	Quality requirements for welding - Fusion welding of metallic materials.
EN 1011	Recommendation for arc welding of ferritic steels.
EN 10204	Metallic products - Types of inspection documents.
ISO 148	Beam Impact Test V-notch for steel.
ISO 3690	Welding - Determination of hydrogen in deposited weld metal arising from the use of covered electrodes for welding mild and low alloy steels.
ISO 4136	Fusion-welded butt joints in steel - Transverse tensile tests.
ISO 5173	Fusion welded butt joints in steel - Transverse root and face bend test.
ISO 5177	Fusion welded butt joints in steel - Transverse side bend test.
NS 477	Rules for approval of welding inspectors.
NACE MR0175	Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment.
NORSOK L-CR-001	Piping and valves.

4 DEFINITIONS AND ABBREVIATIONS

4.1 Abbreviations

CE	Carbon Equivalent
NACE	National Association of Corrosion Engineers
NDT	Non Destructive Testing
NPS	Nominal Pipe Size
PN	Nominal Pressure
PRE	Pitting Resistance Equivalent, $PRE = \% Cr + 3.3 \% Mo + 16 x \% N$
SMYS	Specified Minimum Yield Strength
UNS	Unified Numbering System
WPS	Welding Procedure Specification

4.2 Definitions

Carbon Steel Type 235:	Carbon steel with SMYS \geq 220 MPa and not impact tested.
Carbon Steel Type 235LT:	Carbon steel with SMYS \geq 220 MPa and impact tested at - 46°C.
Carbon Steel Type 360LT:	Carbon steel with SMYS \geq 350 MPa and impact tested at - 46°C.
Stainless Steel Type 316:	Alloys with approx. 2.5 % Mo of the type UNS S31600 or equivalent.
Stainless Steel Type 6Mo:	Alloys with 6 % Mo and PRE > 40, e.g. UNS S31254 UNS N 08925, UNS N 08367.
Stainless Steel Type 22Cr duplex:	Alloys with 22 % Cr according to UNS S31803 or equivalent.
Stainless Steel Type 25Cr duplex:	Alloys with 25 % Cr and PRE > 40, e.g. UNS S32550, UNS S32750, UNS S32760.

5 WELDING QUALIFICATION REQUIREMENTS

5.1 General

Welding procedures for steels shall be qualified according to ASME IX or EN 288-3 as applicable and to this standard.

All welding or brazing of Copper, Nickel and Titanium based alloys and clad materials shall be qualified according to ASME IX and this standard.

The limitations of essential variables according to 5.4 shall apply in addition to those of ASME IX or EN 288-3.

5.2 Non Destructive Testing of Test Welds

Non destructive testing shall be according to EN 288-3 for all type of materials.

All required post weld heat treatment shall be complete before final non destructive testing.

The acceptance criteria shall be as specified in clause 7.

5.3 Mechanical Testing

5.3.1 General

Mechanical testing shall be performed as specified in ASME IX or EN 288 and the additional requirements in this standard.

If a specimen fails to meet the test requirements, two sets of retests, for that particular type of test, may be performed with specimens cut from the same procedure qualification test coupon. The results of both retest specimens shall meet the specified requirements.

5.3.2 Cross Weld Tensile Tests

Specimens and testing shall be in accordance with ISO 4136 or ASME IX and the acceptance criteria shall be according to ASME IX and EN 288, respectively.

5.3.3 Bend Tests

Bend test specimens shall be prepared and tested in accordance with ISO 5173/5177 or ASME IX and the acceptance criteria shall be according to ASME IX or EN 288-3, respectively.

5.3.4 Impact Tests

Impact testing of welds shall be performed when required and according to requirements in table 5.1.

The testing and dimensions of all impact test specimens shall be in accordance with ISO 148 or ASTM A 370. Full size specimens shall be applied where possible.

Table 5.1 Impact Test Requirements¹⁾

Material	Notch location²⁾	Tests temperature	Acceptance Criteria^{3),5)}
CMn steel Type 235	WM, FL, FL+2, FL+5	Not applicable	Not applicable
CMn steel Type 235LT and 360LT	WM, FL, FL+2, FL+5	- 46 °C	27 J for Type 235 LT 36 J for Type 360 LT
CMn steel with SMYS > 420 MPa	WM, FL, FL+2, FL+5	Min. design temp.	42 J
Type 316 and 6Mo	WM and FL	Min. design temp. if used at temperatures below -105 °C ⁴⁾	Lateral expansion min. 0,38 mm.
Type 22Cr duplex	WM and FL	- 46 °C or at min. design temperature.	27 J
Type 25Cr duplex	WM and FL	- 46 °C or at min. design temperature.	27 J or lateral expansion min. 0,38 mm.
<p>NOTES</p> <ol style="list-style-type: none"> No impact test is required for wall thickness < 6 mm. WM means weld metal centre line and FL means fusion line. No single values shall be below 75 % of the average requirement. If Type 316 and Type 6Mo is welded with Nb-alloyed consumables above 0.5 %, and the min. design temperature is below - 29 °C, impact testing shall be carried out at -105 °C or at minimum design temperature. Reduction factors of energy requirements for subsize specimens shall be: 7,5 mm - 5/6 and 5 mm - 2/3. 			

5.3.5 Macrosections

A macrosection shall be taken from all welds and shall be visually examined and meet the acceptance criteria according to EN 288-3.

5.3.6 Hardness Tests

Hardness tests are required for the materials listed in table 5.2 and shall fulfill the stated requirements.

Table 5.2 - Hardness Test Requirements

Material type	Max. hardness HV10	Max. hardness, HV10 Sour service
C and CMn steels	350	250 (root side), 275 (cap side)
Duplex stainless steels, Type 22Cr Type 25Cr	350 350	290 (28 HRc) 290 (28 HRc)
Other stainless steels and non-ferrous materials		Acc. to NACE MR 0175
Titanium Grade 2	The hardness of the weld metal and heat affected zone shall not exceed the base material by more than 50 HV10.	

5.3.7 Corrosion Testing

Welds in stainless steels Type 6Mo, Type 25Cr duplex and Nickel based alloys used in seawater service shall be corrosion tested according to ASTM G 48 Method A.

The test specimen shall be in the as welded state after normal weld cleaning operation and have a dimension of full wall thickness by 25 mm along the weld and 50 mm across the weld. The test shall expose the external and internal surface and a cross section surface including the weld zone in full wall thickness. The exposure time shall be 24 hours.

The test temperatures shall be:

- 40°C for Type 6Mo
- 35°C for Type 25Cr duplex

The acceptance criteria shall be:

- No pitting on the internal nor external surface is acceptable at 20 X magnification.
- Weight loss shall not exceed 4,0 g/m².

5.3.8 Microstructural Examination

Test samples for stainless steel Type 22 and 25Cr duplex shall comprise the weld metal, heat affected zone and the base metal from surface to surface of the pipe. The microstructure shall be suitably etched and examined at 400 X magnification and shall be free from grain boundary carbides and precipitates.

For the stainless steel Type 22 and 25 Cr duplex the ferrite content in the weld metal root and unreheated weld cap shall be determined in accordance with ASTM E 562 and shall be in the range of 25-65 %.

5.4 Essential Variables

Requalification of a welding procedure is required upon any of the changes in the essential variables listed in EN 288-3 or ASME IX and the additional essential variables listed below are incurred:

Base Materials - General:

- A change of material thickness (t) outside the range in EN 288-3, table 5.
- A change from Type 22Cr to Type 25Cr duplex.
- A change from any other material to Type 6Mo.

Base Materials - Carbon and Carbon Manganese Steels:

For steels where “sour” service requirement apply:

- An increase in carbon equivalent (CE) of more than 0.03.

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad \text{or}$$

When the residual elements are not reported: $CE = C + \frac{Mn}{6} + 0.04$

Consumables:

- Any change of consumable classification.
- Any change in consumable brand name when corrosion testing or impact testing is required.
- Any increase of size in consumable in the root run of single sided welds.

Heat Input:

- Heat input requirements of EN 288-3 shall apply.
- For stainless steels and non ferrous materials the maximum variation in heat input shall be $\pm 15\%$.

Welding Position:

- A change from vertical upwards to vertical downward or converse.

Gas:

- Any change in shielding and purging gas beyond the requirements in ASME IX, also if welding is performed to EN 288-3

6 WELDING REQUIREMENTS

6.1 General

All welding and related activities shall satisfy the requirements of EN 719, EN 729-2, ASME B31.3 and the additional requirements of this standard.

WPS's shall be established for all welding which will be used in the fabrication of piping systems. The WPS shall contain the information listed in EN 288-2.

The root pass of welds in stainless steels Type 6Mo and Type 25Cr duplex for seawater service shall be made with filler metal.

A non slagging welding process shall be used for the root pass on all single sided welds in all stainless steels, Nickel based and Titanium based alloys. The same applies to single sided welds in C and CMn steels piping systems with required cleanliness e.g. gas compression systems.

All fillet welds directly welded to pressure containing pipework shall be continuous.

Prefabrication of stainless steels, Copper, Titanium and Nickel based alloys should be performed in a workshop, or parts thereof, which is reserved exclusively for those types of materials.

Contamination of weld bevels and surrounding areas with low melting point metals such as Copper, Zinc, Bronze, are not acceptable.

6.2 Welder and Welding Operator Qualification

All bracers, welders and welding operators shall be qualified in accordance with ASME IX, EN 287 as applicable or equivalent codes.

6.3 Welding Consumables

6.3.1 General

All welding consumables shall have individual marking.

All extra low hydrogen consumables for C and CMn steels and all consumables for welding of stainless steel Type 6Mo, Type 22Cr or 25Cr duplex should be delivered according to manufacturer data sheets and with certification according to EN 10 204 Type 3.1B. Certificates should contain chemical analysis of weld metal including C, Si, Mn, P, S and any other intentional added element stated in the data sheet. Level of impurities maximised in the data sheet or classification code should be stated, but may be given as guaranteed maximum. Mechanical and impact testing should be performed according to ASME II, Part C, SFA 5.01 Schedule I or equivalent.

Consumables for other materials and fluxes for submerged arc welding processes shall be delivered with certification according to EN 10 204 Type 2.2.

6.3.2 Carbon and Carbon Manganese Steels

For steels with specified minimum yield strength ³ 420 MPa extra low hydrogen type consumable, H_{DM} £ 5 ml/100g weld metal measured according to ISO 3690, shall be used.

For all other weldments where impact testing is required low Hydrogen type consumables, H_{DM} £ 10 ml/100 g weld metal, shall be used.

For water injection systems, the root and hot pass shall be made using low alloy consumables containing:

- 0.8 - 1.0 % Ni
- 0.4-0.8 % Cu and 0.5-1.0 % Ni

For systems with sour service requirements the Ni content shall be < 2.2 %.

6.3.3 Austenitic Stainless Steels Type 6Mo and Nickel Base Alloys

Consumables for welding austenitic stainless steel Type 6Mo shall contain a minimum of 8 % Mo, 15 % Cr and 28 % (Mo + Cr). The following limitations shall also apply: C £ 0.03 % and S £ 0.020 %.

6.3.4 Duplex Stainless Steels

A consumable with enhanced Ni content compared to the base material shall be used. The S content shall not exceed 0.020 % .

6.3.5 Titanium Base Alloys

Titanium Grade 2 filler material shall be according to ASME II, Part C, SFA 5.16 and classification ERTi-1 or ERTi-2 or equivalent.

6.4 Preheat and Interpass Temperature

The minimum preheat for C and CMn steel shall be based on prEN 1011.

The interpass temperature shall be measured within the joint bevel. The minimum interpass temperature shall not be less than the specified preheat temperature. The maximum interpass temperature shall not exceed the maximum qualified or as stated below:

- 250 °C for C and CMn steels
- 150 °C for stainless steels and Nickel base alloys

6.5 Backing and Shielding Gas

The inside surface of all steel pipes with Chromium content equal to or above 12 % and all non ferrous materials shall be purged in sufficient amounts with an inert gas during welding of minimum the first three passes.

For welding stainless steels Type 22 and 25 Cr duplex shielding gasses shall not contain Hydrogen.

For welding of Titanium base alloys, the shielding and purging gas shall be Argon, Helium or a mixture of the two and shall be maintained until the metal temperature is less than 250 °C.

7 INSPECTION AND NON DESTRUCTIVE TESTING (NDT)

7.1 Personnel Qualification

The NDT operators shall be qualified according to EN 473 level II or to an equivalent scheme. Visual inspectors shall be qualified in accordance with NS 477 or equivalent. The responsible person for the NDT system shall be qualified to EN 473 level III or equivalent.

7.2 Acceptance Criteria

The defect acceptance level shall be in accordance with ASME B31.3, Chapter VI, Normal Fluid Service and Chapter IX, High Pressure Service, for pipe classes with rating above 2500psi.

If radiographic testing is replaced by ultrasonic the acceptance criteria for ultrasonic shall be in accordance with ASME VIII, Div. 1, Appendix 12.

For dye penetrant and magnetic particle testing the acceptance criteria shall be in accordance with ASME VIII, Div. 1, Appendix 6 and 7, respectively.

Weld zones in stainless steels, Nickel and Titanium alloys shall be examined on the inside and outside and fulfill the criteria stated below.

- a) The oxidation levels showing light brown to brown colour are acceptable.
- b) Oxidation levels showing a narrow band of darkbrown colour and intermittent spots of blue colour are acceptable.

7.3 Radiographic Testing

The radiographic film sensitivity shall be as given in table 7.1.

Table 7.1 - Radiographic Film Sensitivity

Technique	Nominal wall thickness	Sensitivity
X-ray	> 3 mm	2,0 %
	£ 3 mm	3,0 %
Gamma ray	> 5 mm	2,0 %
	£ 5 mm	3,0 %

7.4 Ultrasonic Testing

Ultrasonic testing shall, if used, be performed according to ASME V, Article 5 or DnV Classification Note No. 7.

Ultrasonic testing shall not be used for thicknesses less than 10mm.

Ultrasonic testing of austenitic and ferritic/austenitic stainless steel require specific qualifications.

7.5 Extent of Non Destructive Testing

The extent of NDT of piping systems shall be in accordance with table 7.3. The NDT groups are defined in table 7.2.

Table 7.2 - Definition of NDT Groups

NDT Group	System service	Pressure rating	Design temp. (°C)
1 1)	Non-flammable and non-toxic fluids only	≤ 150 psi (£ PN 20)	- 29 to 185
2	All other systems	≤ 300 psi (£ PN 50)	All
3	All other systems	≥ 600 psi (≥ PN 100)	All
Note			
1) Applicable to C and CMn steels and stainless steel Type 316 only.			

Table 7.3 - Extent of Non Destructive Testing

NDT Group	Type of connection ¹⁾	Visual inspection	Radiographic or ultrasonic testing ²⁾	Magnetic particle or liquid penetrant testing
1	Buttweld	100	0	0
2	Buttweld	100	5 ^{3,4)}	5 ^{3,4)}
3	Buttweld	100	100	100
NOTES				
1) Angular branch welds shall be examined to the same extent as butt welds. All socket, branch connections, "o"-lets and attachment welds shall be surface examined to the same extent as stated for butt welds.				
2) When gas metal arc welding process is employed ultrasonic examination or other relevant NDT method shall be applied to verify no lack of fusion.				
3) The specified percentage or minimum one weld whichever is the greater.				
4) Progressive examination shall be applied according to ASME B31.3 para. 341.3.4.				

8 REPAIR

The same area on a weld shall not be repaired more than twice. For welds in stainless steel Type 6Mo, 25Cr Duplex and Titanium base alloys only one local attempt of repair is acceptable in the same area.

