NORSOK STANDARD

M-601

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Welding and inspection of piping

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Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are as far as possible intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published supported by The Norwegian Oil Industry Association (OLF) and Federation of Norwegian Manufacturing Industries (TBL).

NORSOK standards are administered and published by Standards Norway.

Annex A is normative.

Introduction

The provision of the NORSOK standards are intended to comply with the requirements of the "Pressure Equipment Directive" (PED) and the Norwegian implementation regulation "Forskrift for trykkpåkjent utstyr" issued 9 June 1999. When this NORSOK standard refers to PED only, it is implicit that it also refers to the Norwegian implementation regulation. In those applications where PED is governing, it is therefore necessary to apply the PED and to involve a notified body to obtain the required approvals dependent of the selected conformity assessment module applicable to each specific project.

The revision 4 replaces revision 3 which was an update to include changes deemed necessary due to

- introduction of PED,
- changes made in the reference standard ASME B31.3, and
- experiences gained with revision 2 of this NORSOK standard.

Revision 4 of this NORSOK standard is an update based upon the hearing processes related to revision 3. Some of the changes made in revision 3 are found necessary to be modified due to reconsiderations.

No additional industrial hearing is carried out related to issue of revision 4, since these reconsiderations are all related to comments given in the industrial hearing related to revision 3.

All changes made after revision 2 are highlighted with revision marks.

1 Scope

This NORSOK standard covers additional and optional technical requirements to ASME B31.3 for welding and weld inspection of piping systems, selected according to NORSOK L-001, and applies to all piping fabrication including prefabrication, module assembly, package or skid mounted units, site and field installation.

NOTE An option to use EN ISO 15614 (all parts) for welding procedure qualifications, EN 287-1, and EN ISO 9606-3 to EN ISO 9606-5 for welder qualifications, and EN 473 for NDT inspectors, is given as an alternative to ASME Section V.

2 Normative and informative references

The following standards include provisions and guidelines, which through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements and guidelines of the standards referenced below.

2.1 Normative references

ASME Section II,	Materials Part C – Specifications for Welding Rods, Electrodes and Filler Metals.
ASME Section V,	Nondestructive Examination.
ASME Section VIII,	Rules for Construction of Pressure Vessels Division 1.
ASME Section IX,	Welding and Brazing Qualifications.
ASME B31.3,	Process Piping.
ASTM E562,	Practice for Determining Volume Fraction by Systematic Manual Point Count.
ASTM G48,	Standard Test Method for Pitting and Crevice Corrosion Resistance of Stainless Steel and Related Alloys by the use of Ferric Chloride Solution.
EN 287-1,	Qualification test of welders – Fusion welding – Part 1: Steels.
EN 288-2,	Specification and approval of welding procedures for metallic materials – Part 2: Welding procedure specification for arc welding.
EN 473,	Qualification and certification of personnel for non destructive examination.
EN 729-2,	Quality requirements for welding - Fusion welding of metallic materials – Part 2: Comprehensive quality requirements.
EN 970,	Non-destructive examination of fusion welds – Visual examination.
EN 1043-1,	Destructive tests on welds in metallic materials – Hardness testing – Part 1: Hardness test on arc welded joints.
EN 1418,	Welding personnel - Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanised and automatic welding of metallic materials.
EN 10204,	Metallic products - Types of inspection documents.
EN ISO 15156-2,	Petroleum, petrochemical and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons.
EN ISO 15156-3,	Petroleum, petrochemical and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys.
EN ISO 15614-1,	Specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys.
EN ISO 15614-5,	Specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 5: Arc welding of titanium, zirconium and their alloys.
EN ISO 3690,	Welding and allied processes - Determination of hydrogen content in ferritic arc weld metal.
EN ISO 9606-3,	Approval testing of welders – Fusion welding – Part 3: Copper and copper alloys.
EN ISO 9606-4,	Approval testing of welders – Fusion welding – Part 4: Nickel and nickel alloys.
EN ISO 9606-5,	Approval testing of welders – Fusion welding – Part 5: Titanium and titanium alloys, zirconium and zirconium alloys.
NORSOK M-001,	Materials selection.
NS 477,	Rules for approval of welding inspectors.
PED,	EC Pressure Equipment Directive, 97/23/EC,

2.2 Informative references

EN 288 (all parts),	Specification and approval of welding procedures for metallic materials
EN ISO 15607,	Specification and qualification of welding procedures for metallic materials – General rules.
ISO/TR 15608,	Welding – Guidelines for a metallic materials grouping system.
EN ISO 15609 (all parts),	Specification and qualification of welding procedures for metallic materials – (all parts).
EN ISO 15610,	Specification and qualification of welding procedures for metallic materials – Qualification based on tested welding consumables.
EN ISO 15611,	Specification and qualification of welding procedures for metallic materials – Qualification based on previous welding experience.
EN ISO 15612,	Specification and qualification of welding procedures for metallic materials – Qualification by adoption of a standard welding procedure.
EN ISO 15613,	Specification and qualification of welding procedures for metallic materials – Qualification based on pre-production welding test.
EN ISO 15614 (all parts),	Specification and qualification of welding procedures for metallic materials – (all parts).
NORSOK L-001,	Piping and valves.

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1.1
shall
verbal form used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.2
should
verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.1.3
may
verbal form used to indicate a course of action permissible within the limits of the standard

3.1.4
can
verbal form used for statements of possibility and capability, whether material, physical or casual.

3.1.5
carbon steel type 235
carbon steel with SMYS $\geq$ 220 MPa and not impact tested

3.1.6
carbon steel type 235LT
carbon steel with SMYS $\geq$ 220 MPa and impact tested at - 46 °C

3.1.7
carbon steel type 360LT
carbon steel with SMYS $\geq$ 350 MPa and impact tested at - 46 °C

3.1.8
3.5 Ni steel
low alloyed steel containing 3,5 % Ni

3.1.9
stainless steel type 316
alloys with approximately 2,5 % Mo of the type UNS S31600 or equivalent

3.1.10
stainless steel type 6Mo
alloys with 6 % Mo and PRE > 40, e.g. UNS S31254 UNS N08925, UNS N08367

3.1.11
stainless steel type 22Cr duplex
alloys with 22 % Cr according to UNS S31803, UNS 32205 or equivalent

3.1.12
stainless steel type 25Cr duplex
alloys with 25 % Cr and PRE > 40, e.g. UNS S32550, UNS S32750, NS S32760, UNS S39274

3.1.13
pitting resistance equivalent
PRE = % Cr + 3.3 x % Mo + 16 x % N

3.2 Abbreviations

DAC	distance amplitude curve
CE	carbon equivalent
EC	European Commission
FCAW	flux core arc welding
HAZ	heat affected zone
HV	hardness Vickers
NDT	non destructive testing
MAG	metal-arc active gas (135)
MIG	metal-arc inert gas (131)
MDT	minimum design temperature
MT	magnetic particle testing
PN	nominal pressure
PED	EC Pressure Equipment Directive
PMI	positive material identification
PRE	pitting resistance equivalent
PT	penetrant testing
RT	radiographic testing
PWHT	post weld heat treatment
SEP	sound engineering practice
SMAW	shielded metal arc welding
SMYS	specified minimum yield strength
UNS	unified numbering system
UT	ultrasonic testing
WPS	welding procedure specification

4 Welding qualification requirements

4.1 General

Welding procedures for steels, nickel and titanium based alloys shall be qualified according to ASME Section IX or EN ISO 15614-1 and EN ISO 15614-5 as applicable and to this NORSOK standard.

All welding or brazing of copper based alloys and clad materials shall be qualified according to ASME Section IX and this NORSOK standard.
All welding and brazing procedures applied to fabricate piping systems within the scope of the PED category II and III shall be approved by a third party organisation recognised by an EC member state.

The qualification is primarily valid for the workshop performing the welding tests, and other workshops under the same technical and quality management. It may also be transferred to and used by a subcontractor, provided the principles of EN 729-2 are implemented and documented.

NOTE The EN ISO series of standards EN ISO 15607 to EN ISO 15614 (including ISO/TR 15608) is partly issued and is intended to supersede EN 288 (all parts) in future. The use of these standards should be clarified and agreed between contracting parties.

4.2 Non-destructive testing of test welds

Non-destructive testing shall be according to EN ISO 15614-1 for all type of materials.

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

The acceptance criteria shall be as specified in Clause 7.

4.3 Mechanical testing

4.3.1 General

Mechanical testing shall be performed as specified in ASME Section IX or relevant part of EN ISO 15614 and the additional requirements in this NORSOK 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.

4.3.2 Impact tests

Impact testing of welds shall be according to Table 1. Full size specimens shall be applied where possible.

If two types of materials are welded together, each side of the weld shall be impact tested and fulfil the requirement for the actual material. The weld metal shall fulfil the requirement for the least stringent of the two.

4.3.3 Macro-sections

A macro-section shall be taken from all welds and shall be visually examined and meet the acceptance criteria according to EN ISO 15614-1 and EN ISO 15614-5.

4.3.4 Hardness tests

Hardness tests according to EN ISO 15614-1 are required for the materials listed in Table 2 and shall fulfil the stated requirements.

NOTE Hardness testing carried out according to EN ISO 15614-1 (and EN 1043-1) is evaluated to comply with the hardness test requirements of EN ISO 15156-2 and EN ISO 15156-3. For qualification of repair weld procedures hardness testing shall be carried out according to EN 15156-2, Figure 4.

4.3.5 Corrosion testing

Welds in stainless steels Type 6Mo, Type 25Cr duplex and nickel based alloys shall be corrosion tested according to ASTM G48, Method A.

The test specimen shall 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. Cut edges shall be prepared according to ASTM G48. The specimen shall be pickled (20 % HNO_3 + 5 % HF, 60 °C, 5 min). The exposure time shall be 24 h.

The test temperatures shall be 40 °C.

The acceptance criteria shall be as follows:

- no pitting at 20 X magnification;
- weight loss shall not exceed 4,0 g/m^2.

4.3.6 Micro-structural examination

Test samples for stainless steel Type 22Cr and 25Cr duplex shall comprise a cross section of the weld metal, heat affected zone and the base metal of the pipe. The micro-structure shall be suitably etched and

examined at 400 X magnification and shall have grain boundary with no continuous precipitations and the inter-metallic phases, nitrides and carbides shall not in total exceed 0,5 %.

For the stainless steel Type 22 and 25Cr duplex the ferrite content in the weld metal root and in the last bead of the weld cap shall be determined in accordance with ASTM E562 and shall be in the range of 30 % to 70 %.

Table 1 - Impact test requirements[a]

Material	Notch location [b c]	Tests temperature	Acceptance Criteria [d e]
Carbon steel Type 235 [f]	WM, FL, FL+2, FL+5	MDT or lower	27 J
Carbon 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
Carbon steel and low alloyed steel with SMYS > 360 MPa	WM, FL, FL+2, FL+5	MDT or lower	42 J
Type 3.5 Ni steel	WM, FL, FL+2, FL+5	÷ 101 °C	27 J
Type 316 and 6Mo and Ni-alloys	WM and FL	MDT or lower if MDT is below ÷101 °C [g]	Lateral expansion min. 0,38 mm
Type 22Cr duplex and Type 25Cr duplex	WM and FL	÷ 46 °C or at MDT.	27 J or lateral expansion min. 0,38 mm

[a] No impact test is required for wall thickness < 6 mm.
[b] WM means weld metal centre line and FL means fusion line.
[c] FL+2/FL+5 means that the centre of the notch shall be located in HAZ, at a distance of 2 mm or 5 mm from the fusion line.
[d] No single values shall be below 70 % of the average requirement.
[e] Reduction factors of energy requirements for sub-size specimens shall be 5/6 for 7,5 mm specimen and 2/3 for 5 mm specimen.
[f] Impact testing is required for welding of piping systems within the scope of PED category I - III. For piping systems classified to SEP impact test is not required.
[g] No impact is required if the design temperature is above ÷ 101 °C.

Table 2 - Hardness test requirements

Material type	Max. hardness HV10	Max. hardness sour service HV10
Carbon steels	350	250 (root side), 275 (cap side) [a]
3.5 Ni steel	320	Not accepted
Duplex stainless steels Type 22Cr Type 25Cr	 350 350	 310 (28 HRc) [a] 330 (32 HRc) [a]
Austenitic stainless steel and Ni based alloys	Not applicable.	According to EN ISO 15156-3.
Titanium Grade 2	The hardness of the weld metal and heat affected zone shall not exceed the base material by more than 50 HV10.	

[a] The stated hardness acceptance criteria are deemed to be in compliance with the requirements of EN ISO 15156-2 and EN ISO 15156-3. For duplex stainless steel grades use within the proposed service limitations stated by NORSOK M-001 is presupposed.

4.4 Essential variables

4.4.1 General

Re-qualification of a welding procedure is required upon any of the changes in the essential variables listed in EN ISO 15614-1, EN ISO 15614-5 or ASME Section IX and the additional essential variables listed in 4.4.2 to 4.4.8 are incurred.

4.4.2 Base materials

- a change of material thickness (t) outside the range in EN ISO 15614-1, Table 5 and Table 6;
- a change from Type 22Cr to Type 25Cr duplex and converse;
- a change from any other material to Type 6Mo;
- Type 25Cr duplex: a change of UNS number;
- for Type 25Cr duplex with wall thickness ≤ 7 mm: a separate welding procedure qualification test shall be carried out on the minimum wall thickness to be welded;
- for carbon steel where “sour” service requirements apply an increase in carbon equivalent (CE) of more than 0,03.

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

4.4.3 Consumables

- any change in consumable brand name when corrosion testing or impact testing is required;

NOTE This does not apply for solid wire provided documentation of no change in chemical composition, mechanical properties and source of origin.

- for SMAW and FCAW, any increase of size in consumable in the root run of single sided welds, except when welded against ceramic backing.

4.4.4 Heat input

- heat input requirements of EN ISO 15614-1 shall apply;
- for stainless steels the maximum variation in heat input shall be ± 15 %.

4.4.5 Welding position

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

4.4.6 Technique

- when impact testing is required: A change from multi pass to single pass.

4.4.7 Joints

- a change from double sided welding to single sided welding, but not converse;
- a decrease in bevel angle of more than 10° for bevel angles less than 60°.

4.4.8 Gas

- any change in shielding and back shielding gas beyond the requirements in ASME Section IX, also if welding is performed to EN ISO 15614-1 or -5.

5 Welding requirements

5.1 General

All welding and related activities shall satisfy the requirements of EN 729-2 and the additional requirements of this NORSOK standard.

WPSs 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, Type 25Cr duplex and Ni-alloys for seawater service shall be made with filler metal.

A non-slag producing 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 carbon steels piping systems with required cleanliness, e.g. gas compression systems.

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

No welding is permitted in cold work areas, e.g. cold bent pipe.

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.

Inspection of welds during production welding shall be carried out according to EN 970 by inspectors qualified according to NS 477 or equivalent.

Contamination of weld bevels and surrounding areas with low melting point metals such as copper, zinc, etc. are not acceptable.

For welding of high-alloyed austenitic stainless steels with PRE ≥ 40 (e.g. UNS S32654 and UNS S34565) the requirements given to stainless steel Type 6Mo herein shall apply.

5.2 Welder and welding operator qualification

All bracers, welders and welding operators shall be qualified in accordance with ASME Section IX, EN 287-1, EN ISO 9606-3 to EN ISO 9606-5 or EN 1418 as applicable or equivalent codes.

Welds in pressure equipments classified to PED category II and III shall be carried out by qualified welders approved by a third party organisation recognised by an EC member state.

5.3 Welding consumables

5.3.1 General

All welding consumables shall have individual marking.

All extra low hydrogen consumables for carbon steels and all consumables for welding of stainless steel Type 6Mo, Type 22Cr or 25Cr duplex, nickel and titanium alloys shall be delivered according to manufacturer data sheets and with certification according to EN 10204, Type 3.1B. Certificates should contain chemical analysis of weld metal including C, Si, Mn, P, S and any other intentionally 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. The data sheets should contain guaranteed values on mechanical and impact test results as long as the welding is carried out within the recommended range. If the consumables shall be used for welds in PWHT condition, then the properties shall also be documented in PWHT condition.

Batch testing of the welding consumables is also acceptable. The welding and testing shall be carried out as required for a welding procedure qualification record (WPQR) for the actual material.

Consumables for other materials and fluxes for submerged arc welding processes shall be delivered with certification according to EN 10204, Type 2.2.

5.3.2 Carbon and carbon manganese steels

For steels with specified minimum yield strength 420 MPa extra low hydrogen type consumable (H_{DM} 5 ml/100 g) shall be used. The hydrogen testing shall be carried out according to EN ISO 3690 or equivalent.

For all other welds 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 % to 1,0 % Ni,
- 0,4 % to 0,8 % Cu and 0,5 % to 1,0 % Ni.

For systems with sour service requirements welding consumables that produce a deposit containing more than 1 % Ni are acceptable after successful weld sulphide stress cracking qualification testing in accordance with ISO 15156-2, Annex B.

5.3.3 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 %;
- S ≤ 0,020 %.

5.3.4 Duplex stainless steels

A matching consumable with enhanced Ni content compared to the base material shall be used. The S content shall not exceed 0,020 %.

5.3.5 Titanium base alloys

Filler material for welding titanium grade 2 shall be according to ASME Section II, Part C, SFA 5.16 and classification ERTi - 1 or ERTi - 2 or equivalent.

5.3.6 Consumables for joining of dissimilar materials

The filler material used in buttering layer when welding carbon steels to stainless steel Type 316 should be to ASME Section II, Part C, SFA 5.4 E 309Mo, ASME section II, Part C, SFA 5.9 ER 309L or a nickel based alloy.

When welding higher alloyed stainless steel to carbon steels, the same or higher alloyed filler metal as used for welding the stainless steel to it self shall be used.

NOTE When welding stainless steel alloyed with nitrogen, e.g. Type 22/25Cr Duplex or Type 6Mo, to carbon or low-alloyed steels, it is recommended to use weld consumable without Nb-alloying. This is due to precipitation of Nb-nitrides, which may have a negatively effect to the ductility and corrosion properties, and the ferrite/austenite structure balance in the HAZ of the duplex alloys.

When PWHT is required after joining austenitic stainless steels to carbon steels the weld deposit shall be made using a nickel base consumable.

NOTE Careful considerations shall be made if PWHT of joints between dissimilar materials is required.

5.4 Interpass temperature

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 highest of maximum qualified or as stated below:

- 250 °C for carbon steels;
- 150 °C for stainless steels and nickel base alloys.

5.5 Backing and shielding gas

Back shielding gas shall be used for welding of all stainless steel and non-ferrous materials, and shall be maintained during welding of minimum the first three passes. The same requirement applies also for tack welding.

Shielding gas for welding of duplex stainless steels shall not contain hydrogen.

Shielding and back shielding gas for welding of titanium and its alloys shall be argon, helium or a mixture of the two, and shall be maintained until the weld and base material is below 400 °C.

5.6 Welding of clad materials

When welding clad materials from both sides, the carbon steel shall be completely welded prior to welding the cladding. Carbon steel or low-alloyed steel weld metal shall not be deposited onto a high alloy base material or weld metal.

5.7 Welding of O-lets

The weld bevel of O-lets shall be completely filled up to weld line on the O-lets. Smooth transition between the pipe and the O-lets is required. Notches below the weld line shall be avoided. Prior to welding, sufficient root gap shall be ensured.

5.8 Production test (optional)

Production tests shall be taken when specified. Each production test shall be tested and documented as for the relevant welding procedure qualification test unless otherwise agreed.

6 Inspection and non destructive testing (NDT)

6.1 General

All activities covered by this section covers final inspection of welded joints.

6.2 Qualification of inspectors and NDT-operators

Personnel responsible for all NDT activities shall be qualified according to EN 473, Level 3.

Personnel performing visual inspection of welded joints shall be qualified in accordance with NS 477, EN 473, VT level 2, or equivalent.

The NDT operator shall be qualified according to EN 473, level 2, or equivalent. All NDT personnel performing inspection of welds in piping systems classified to PED category III shall be approved by a third party organisation recognised by an EC member state. Operators simply producing radiographs and not performing evaluation, do not require level 2, but shall have sufficient training.

Ultrasonic operators performing inspection of welds in duplex stainless steel material shall be specially trained and qualified for the purpose according to EN 473.

6.3 Extent of visual inspection and non destructive testing

The NDT groups are defined in Table 3. The extent of visual inspection and NDT of welds in piping systems shall be in accordance with Table 4.

Table 3 - Definition of NDT groups

NDT group	System service	PED fluid group	Pressure rating	Design temp. °C
1 [a b]	Non-flammable and non-toxic fluids only	2	Class 150 (PN 20)	÷29 °C to 185 °C
2	All systems except those in NDT Group 1	1 and 2	Class 150 and 300 (PN 20 and PN 50)	All
3	All systems	1 and 2	Class 600 and above (≧ PN 100)	All

[a] Applicable to carbon steels and stainless steel Type 316 only.
[b] Applicable for all materials in open drain systems.

Table 4 - Extent of non destructive testing

NDT group	Piping category according to PED	Type of connection [a]	Visual inspection [b] %	Volumetric testing, RT [c f] %	Surface testing, MT/PT %
1	SEP	Buttweld	100	0	0
2	I, II and III	Buttweld	100	10 [d e]	10 [d e]
3	II and III	Buttweld	100	100	100

[a] 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.
[b] Visual inspection shall in addition to all welds in the piping system include all supports and attachments welded to the piping.
[c] When gas metal arc welding (131 MIG/135 MAG) without pulsed current is applied, ultrasonic testing shall be carried out to verify no sidewall lack of fusion in addition to radiographic testing.
[d] The specific percentage shall be calculated from the length of welds pr. WPS. The inspection shall be planned to represent each pipe size, welder, and fabrication location/shop. Minimum one off weld of each size shall be examined 100 % per WPS. Other practical definitions of the spot inspection may be agreed.
[e] Progressive examination shall be applied according to ASME B31.3 para. 341.3.4.
[f] For carbon and low alloyed steels UT may be used for T > 10 mm. UT is the preferred method for T > 40 mm.

6.4 Radiographic testing

The radiographic film sensitivity shall be as given in Table 5.

Table 5 - Radiographic film sensitivity

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

6.5 Ultrasonic testing

Ultrasonic testing shall not be used for thickness less than 10 mm and is not recommended used for pipes with OD ≤ 101,6 mm (4 in).

DAC reference curves shall be produced from reference block of thickness, and containing side-drilled holes with diameters, in accordance with Table 6. DAC curves shall be produced in accordance with ASME Section V, Article 4. The effective test range of a DAC curve shall be to the point at which the curve has fallen to 25 % of full screen height. In such cases it will be necessary to raise the curve using reflectors at increased depths. The actual refracted angle for each probe measured from the reference block or as measured on the actual object being tested shall be used when plotting indications. A transfer correction between the reference block and the test surface shall be performed.

Ultrasonic testing procedures shall be sufficiently detailed to ensure 100 % of the weld body and heat affected zones are examined for longitudinal defects in accordance with ASME Section V, T-542.7.2.3.

All indications exceeding 20 % DAC shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria. All indications exceeding acceptance criteria shall be reported. The examination report shall include the position, the echo height, length, depth and type of defect.

Ultrasonic testing of austenitic and duplex stainless steel requires a specific procedure and reference blocks to be prepared. The procedure used shall be qualified to demonstrate that relevant defects will be detected. Grinding of the weld cap should be considered dependent on the procedure qualification.

Table 6 - Calibration reference block requirements

Dimensions in millimetres

Thickness of material to be examined	Thickness of block	Diameter of hole	Distance of hole from one surface
$10 < t \leq 50$	40 or t	3 +/– 0,2	t/2 and t/4. Additional holes are allowed and recommended
$50 < t \leq 100$	75 or t		
$100 < t \leq 150$	125 or t	6 +/- 0,2	
$150 < t \leq 200$	175 or t		
$200 < t \leq 250$	225 or t		
$t > 250$	275 or t		

6.6 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 class 2500 psi, unless more severe requirements are specified on the piping class sheet. As an alternative, the acceptance criteria stated in Annex A may be used within the same limitations as stated above.

For ultrasonic testing the acceptance criteria shall be according to Table A.2.

For surface and testing (MT/PT) the acceptance criteria shall be in accordance with ASME Section VIII, Appendix 6 and Appendix 8, respectively.

Weld zones in stainless steels, nickel and titanium alloys shall be visually examined on the inside and outside and fulfil the following criteria:

a) the oxidation levels showing light brown to brown colour are acceptable;
b) oxidation levels showing a narrow band of dark brown colour and intermittent spots of blue colour are acceptable;
c) darker or more extensive oxidation colours are not acceptable, and shall be chemically or mechanically removed. For titanium the weld shall be cut out and rewelded.

7 Repair

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

8 Positive material identification (PMI)

If not otherwise agreed positive material identification shall be performed on ready installed piping systems in stainless steel materials and Ni-alloy based materials prior to any pressure testing or coating operation.

The PMI shall be carried out with equipment capable to identify the specified type of material in accordance with established procedure. The equipment shall not make burn marks to the pipe material.

In general, 10 % of the components (pipe, fittings and flanges) and welds shall be tested. The testing shall be uniformly distributed to cover the different type of components, manufacturer, pre-fabrication sites and installation sites.

For piping systems in stainless steel and Ni-base alloys carrying seawater and systems with MDT below ÷50 °C, the extent of PMI shall be increased to 100 %. The same extent applies to all piping systems in stainless steel and Ni-base alloys to be installed sub-sea.

If any non-conformance in material type is reported, the extent shall be increased to ensure that all mix of material is discovered.

Annex A
(Normative)
Alternative acceptance criteria

The defect acceptance criteria shall be in accordance with the tables and references given in this annex.

Radiographs shall be in accordance with Table A.1.

The acceptance criteria for ultrasonic testing shall be in accordance with Table A.2.

For visual examination, penetrant and magnetic particle testing the acceptance criteria shall be in accordance with Table A.3.

Weld zones in stainless steels, nickel and titanium alloys shall be visually examined on the inside and outside and fulfil the following criteria:

a) the oxidation levels showing light brown to brown colour are acceptable;
b) oxidation levels showing a narrow band of dark brown colour and intermittent spots of blue colour are acceptable;
c) darker or more extensive oxidation colours are not acceptable, and shall be chemically or mechanically removed. For titanium the weld shall be cut out and re-welded.

Table A.1 - Acceptance criteria for radiographic testing

Type of defect	NDT Group 2 and Group 3
Crack	Not acceptable
Lack of fusion	Not acceptable
Incomplete penetration	Maximum cumulative length 38 mm for each 150 mm weld length. The density of the defect shall not exceed the density of the base material.
Internal porosity	For t = 6 mm, the size and distribution shall be according to ASME Section VIII, Appendix 4. For t > 6 mm, the size and distribution shall be 1,5 times the values stated in ASME Section VIII, Appendix 4.
Slag inclusion, tungsten inclusion or elongated indications	Maximum length (individual) 2 x t Maximum width (individual) 3 mm or t/2 whichever is smaller. Cumulative length maximum 4 x t for each 150 mm weld length.
Undercutting	-
Concave root surface (suck up)	Remaining weld thickness including reinforcement shall exceed the wall thickness.
NOTE t is the wall thickness	

Table A.2 - Acceptance criteria for ultrasonic testing

Echo height [a]	Type of defect	Wall thickness (t)	Length
> 100 %	Slag or porosity	Up to 19 mm	> 6,4 mm - Not acceptable
	Slag or porosity	19 mm to 57 mm	> 1/3 x t - Not acceptable
	Slag or porosity	over 57 mm	> 19 mm - Not acceptable
	Crack	Not acceptable	
	Lack of fusion		
	Incomplete penetration		
> 20 %, but ≤ 100 %	Slag or porosity	Acceptable regardless of length	
	Crack	Not acceptable	
	Lack of fusion		
	Incomplete penetration		
[a] With UT performed from only one side of the weld with only one surface accessible, the acceptable echo heights are reduced by 50 %.			

Table A.3 - Acceptance criteria for visual inspection, magnetic particle and penetrant testing

Type of defect	NDT Group 1 and Group 2	NDT Group 3
Cracks	Not acceptable	Not acceptable
Lack of fusion	Not acceptable	Not acceptable
Incomplete penetration	Maximum depth 1 mm or 0,2 x t whichever is smaller. Maximum cumulative length 38 mm for each 150 mm weld length.	Not acceptable
Undercut	Maximum depth 1 mm or t/4, whichever is less. Maximum length of individual flaw is t/2. Maximum accumulated length in any 300 mm of weld is equal to t.	Maximum depth 0,3 mm. Maximum length of individual flaw is t/2. Maximum accumulated length in any 300 mm of weld is equal to t.
Surface porosity and/or cluster [a]	For t ≦ 5mm: Not acceptable For t > 5 mm: Maximum size of single pore t/4 and 2 mm, whichever is less. Accumulated pore diameters in any area of 10 x 150 mm shall not exceed 10 mm.	Not acceptable
Exposed slag	Not acceptable	Not acceptable
Concave root surface (suck-up)	The joint thickness including weld reinforcement to be greater than the wall thickness.	
Reinforcement or internal protrusion	For wall thickness ≤ 6 mm: 1,5 mm and smooth transition For wall thickness > 6 mm: 3 mm and smooth transition	
Misalignment of butt welds [b]	Maximum misalignment (M): 0,15 x t or maximum 4 mm, whichever is less.	
Symmetry of fillet welds (see Figure A.4)	"a" less or equal to 6 mm: Maximum difference, b - h = 3 mm "a" greater than 6 mm, up to 13 mm: Maximum difference, b - h = 5 mm "a" greater than 13 mm: Maximum difference, b - h = 8 mm	
Grinding arc strikes etc. and removal of temporary attachments [b]	Grinding of base material shall not exceed 7 % of the wall thickness or max. 3 mm. Repair welding and inspection shall be performed if removal of the base metal exceeds the specified requirements.	
Sharp edges [c]	Minimum 2 mm radius.	
Reinforcement of fillet/partial pen. Welds [a] (see Figure A.4)	"a" less or equal to 10 Maximum reinforcement "c" 2 mm "a" greater than 10, up to 15 Maximum reinforcement "c" 3 mm "a" greater than 15, up to 25 Maximum reinforcement "c" 4 mm "a" greater than 25 Maximum reinforcement "c" 5 mm	
Reinforcement of butt welds (see Figure A.3)	"t" less or equal to 10 Maximum reinforcement "c" 2 mm "t" greater than 10, up to 25 Maximum reinforcement "c" 3 mm "t" greater than 25, up to 50 Maximum reinforcement "c" 4 mm "t" greater than 50 Maximum reinforcement "c" 5 mm	
Roughness of weld (see Figure A.1)	"U" shall be less than 2,0 mm. Weld surface shall be smooth, without sharp transitions. The bottom of roughness in butt welds shall not be below the base material surface.	

[a] Surface porosity are ruled by the coating specification, if relevant.
[b] Temporary attachments shall be flame cut minimum 3 mm from the base metal and ground smooth. The ground area shall be visually inspected and MT or PT shall be performed in accordance with the inspection category in question.
[c] Only relevant for coated lines.

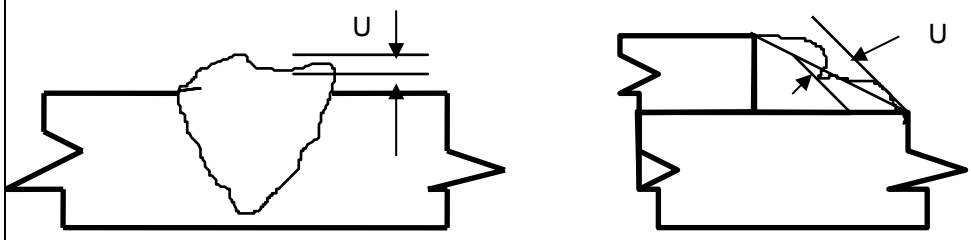

Figure A.1 Roughness of weld

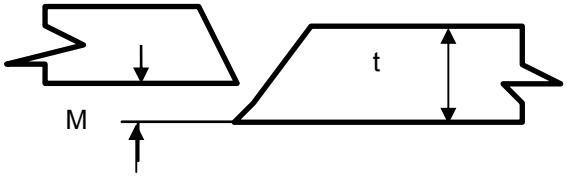

Fig. A.2 Misalignment of butt weld

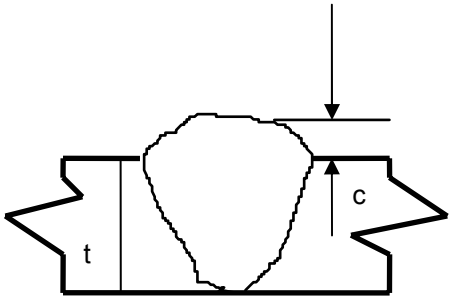

Fig. A.3 Reinforcement of butt weld

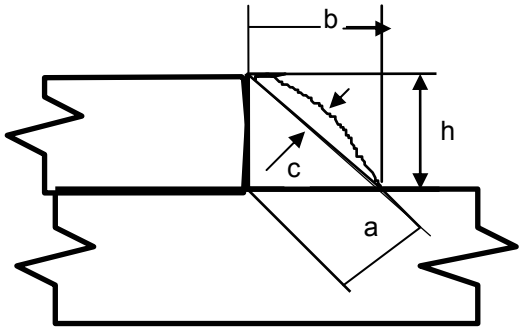

Fig. A.4 Symmetry of fillet