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Welding and inspection of piping

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Content

Foreword

NORSOK M-601:2016 was adopted as NORSOK Standard in April 2016.

NORSOK M-601:2016 supersedes NORSOK M-601 Rev. 5, April 2008.

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, added value 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 recognized 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 Subject to development and publication of international standards, the relevant NORSOK standards will be withdrawn.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-001N.

The NORSOK standards are prepared and published with support by the Norwegian Oil and Gas Association, the Federation of Norwegian Industries, Norwegian Shipowners' Association and The Petroleum Safety Authority (PSA) Norway.

NORSOK standards are administered and published by Standards Norway.

Annex B is normative. Annex A, C, D and E are informative.

Introduction

The intention of this NORSOK standard is to provide additional requirements regarding welding and inspection of piping systems designed to ASME B31.3 for hydrocarbon production and process systems and supporting utility systems.

In this edition the following main changes are introduced:

- the scope of the standard has been amended;
- definition of carbon steel is added;
- references to EN 473 is replaced with ISO 9712;
- references to EN 287 is replaced with ISO 9606-1;
- a new informative Clause for use of this standard is added;
- new sections for weld qualification with respect to welding position and range of heat input/arc energy are added;
- requirements related to low alloy steel and nickel base alloys are deleted;
- weld qualification requirements for austenitic stainless steel type 565 is added;
- recommendation for minimum distance between girth welds is added;
- requirement for documentation of compliance with ISO 3834-2 is added;
- requirement for organization chart and responsibility for responsible weld co-ordinator are added;
- requirements for measurement and recording of weld parameters during qualification test weld are added;
- requirements to the documentation dossier of WPQR/PQR is added;
- references to EN 1418 are replaced with ISO 14732;
- the corrosion test temperature of type 25Cr duplex is reduced to 35 °C;
- essential variable for change in groove angle is modified;
- the maximum interpass temperature of type 25Cr duplex is reduced to 100 °C for manual welding;
- requirements for measurement and maximum content of oxygen content in backing gas for welding of SS and titanium alloy is added;
- requirement for purging of gas when welding attachments to pipes is added;
- requirements to welds with buttering is added;
- requirement for PWHT procedure is added;
- requirements to removal of temporary attachments are added;
- visual testing of internal root run during welding o-lets to header is added;
- new section for visual testing is added;
- option to replace radiographic testing with ultrasonic testing is added for all materials;
- requirements for reporting level of UT is added;
- requirements for alternative NDT methods are added;
- acceptance criteria for oxidation of welds in titanium is modified;
- requirements to weld repair is modified;
- extent of PMI is modified.

In addition minor changes and modifications in wording are made.

1 Scope

This NORSOK standard covers additional and optional technical requirements to ASME B31.3 for welding and weld inspection of piping systems in material types carbon steel with SMYS ≤ 360 MPa, SS type 316, type 6Mo, type 565, type 22Cr duplex and type 25Cr duplex, titanium grade 2 and copper-nickel alloys. The materials shall be selected and specified in accordance with piping class sheets included in NORSOK L-001. That means that this standard covers piping systems with nominal outside diameter greater than 20 mm and wall thickness ranging from 2,5 mm and above.

The standard applies to all welding and weld inspection of piping fabrication at all stages from prefabrication, through module or skid mounted unit assembly, site and field installation and modification work during operation.

2 Normative references

The following standards include provisions and guidelines, which through reference in this text, constitute provisions and guidelines of this NORSOK standard.

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*

ASME PCC-2, *Repair of Pressure Equipment and Piping*

ASTM E 29, *Standard Practice for Using Significant. Digits in Test Data to Determine Conformance with Specifications*

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*

AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*

EN 1011-1, *Welding – Recommendations for welding of metallic materials – Part 1: General guidance for arc welding*

EN 10204, *Metallic products – Types of inspection documents*

ISO 22825, *Non-destructive testing of welds – Ultrasonic testing – Testing of welds in austenitic steels and nickel-based alloys*

ISO 2553, *Welding and allied processes – Symbolic representation on drawings – Welded joints*

ISO 3059, *Non-destructive testing – Penetration testing and magnetic particle testing – Viewing conditions*

ISO 3452, *Non-destructive testing – Penetrant testing*

ISO 3690, *Welding and allied processes – Determination of hydrogen content in arc weld metal*

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

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

ISO 9001, *Quality management systems – Requirements*

ISO 9606-1, *Qualification testing of welders – Fusion welding – Part 1: Steels*

ISO 9606-3, *Approval testing of welders – Fusion welding – Part 3: Copper and copper alloys*

ISO 9606-4, *Approval testing of welders – Fusion welding – Part 4: Nickel and nickel alloys*

ISO 9606-5, *Approval testing of welders – Fusion welding – Part 5: Titanium and titanium alloys, zirconium and zirconium alloys*

ISO 9712, *Non-destructive testing – Qualification and certification of NDT personnel*

ISO 10474, *Steel and steel products – Inspection documents*

ISO 14731, *Welding coordination – Tasks and responsibility*

ISO 14732, *Welding personnel – Qualification testing of welding operators weld setters for mechanized and automatic welding of metallic materials*

ISO 15156-2, *Petroleum and natural gas industries – Materials for use in H2S-containing environments in oil and gas production – Part 2: Cracking-resistant carbon and low-alloy steels, and the use of cast irons*

ISO 15156-3, *Petroleum and natural gas industries – Materials for use in H2S-containing environments in oil and gas production – Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*

ISO 15609-1, *Specification and qualification of welding procedures for metallic materials – Welding procedure specification. Part 1: Arc welding*

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*

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*

ISO 15614-6, *Specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 6: Arc and gas welding of copper and its alloys*

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 17020, *Conformity assessment – Requirements for the operation of various types of bodies performing inspection*

ISO 17637, *Non-destructive testing of welds – Visual testing of fusion-welded joint*

ISO 17638, *Non-destructive testing of welds – Magnetic particle testing*

NORSOK L-001, *Piping and Valves*

NORSOK M-630, *Material data sheets and element data sheets for piping*

NS 477, *Welding inspectors – Tasks, education and certification*

3 Terms and definitions

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

3.1
can
verbal form used for statements of possibility and capability, whether material, physical or casual

3.2
carbon equivalent CE_{IIW}
equivalent carbon content is used to understand how the different alloying elements affect hardness of the steel being welded. The formula CEIIW=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15 has been adopted by IIW and found suitable for predicting hardenability in plain carbon and carbon-manganese steels.

3.3
carbon steel
alloy of carbon and iron containing up to 2 % (mass fraction) carbon, up to 1,65 % (mass fraction) manganese and residual quantities of other elements, except those intentionally added in specific quantities for deoxidation (usually silicon and/or aluminium)

3.4
carbon steel type 235
carbon steel with SMYS ≤ 275 MPa and not impact tested

Note 1 to entry ISO/TR 15608 Material group 1.1

3.5
carbon steel type 235LT
carbon steel with SMYS ≤ 275 MPa and impact tested at - 46 °C

Note 1 to entry ISO/TR 15608 Material group 1.1

3.6
carbon steel type 360LT
carbon steel with 275 MPa < SMYS ≤ 360 MPa and impact tested at - 46 °C

Note 1 to entry ISO/TR 15608 Material group 1.2

3.7
may
verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.8
shall
verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted

3.9
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

3.10
stainless steel type 316
austenitic SS certified to both Grade 316 and 316L with SMYS ≥ 205 MPa and carbon content ≤ 0,035 %

Note 1 to entry ISO/TR 15608 Material group 8.1

3.11
stainless steel type 6Mo
austenitic stainless steel alloys with PREN ≥ 40,0 and a nominal Mo alloying content of 6 % mass fraction, and nickel alloys with Mo content in the range 6 % to 8 % mass fraction, e.g. UNS S31254; UNS N08367; UNS N08926.

Note 1 to entry ISO/TR 15608 Material group 8.2

3.12
stainless steel type 22Cr duplex
ferritic/austenitic stainless steel alloys with 30 ≤ PREN < 40,0 and Mo ≥ 2,0 % mass fraction e.g. UNS S31803 and UNS 32205

Note 1 to entry ISO/TR 15608 Material group 10.1

3.13
stainless steel type 25Cr duplex
ferritic/austenitic stainless steel alloys with 40,0 ≤ PREN < 45, e.g. UNS S32550, UNS S32750, UNS S32760, UNS S39274, UNS S39277

Note 1 to entry ISO/TR 15608 Material group 10.2

3.14
stainless steel type 565
austenitic stainless steel alloys SMYS ≥ 450 MPa and PRE ≥ 40,0

Note 1 to entry ISO/TR 15608 Material group 8.3

4 Abbreviations

For the purposes of this NORSOK standard, the following abbreviations apply:

AWS	American Welding Society
DAC	distance amplitude curve
EC	European Commission
EDS	element data sheet
EN	European Standard
EWF	European Welding Federation
FCAW	flux cored arc welding (114, 136)
FL	fusion line
HAZ	heat affected zone
HV	hardness Vickers
IIW	International Institute of Welding
IWE	international welding engineer
IWT	international welding technologist
MAG	metal-arc active gas (135, 138)
MDS	material data sheet
MDT	minimum design temperature
MIG	metal-arc inert gas (131)
MT	magnetic particle testing
NDT	non-destructive testing
PED	pressure equipment directive
PN	nominal pressure
PMI	positive material identification
PQR	procedure qualification record
PRE_N	pitting resistance equivalent with nitrogen = Cr + 3,3Mo +16N
PT	penetrant testing
RAL	Reichsausschuß für Lieferbedingungen (colour space system)
RT	radiographic testing
PWHT	post weld heat treatment
SMAW	shielded metal arc welding (111)
SMYS	specified minimum yield strength
SS	stainless steel
TIG	tungsten inert gas (141)
UNS	unified numbering system
UT	ultrasonic testing

VT visual testing

WM weld metal

WPQR welding procedure qualification record

WPS welding procedure specification

5 Information for use of this standard (Informative)

5.1 General

This standard is written as an amendment to ASME B31.3, which is a design code for Process Piping Systems, and shall be read and implemented as such. Therefore the general requirement is that all welding and NDT activities and requirements shall be in compliance with ASME B31.3 and the referenced standards such as ASME V and IX unless specified otherwise herein. When this standard has requirements that supersedes the requirements of ASME B31.3 inclusive ASME V and IX these requirements shall apply.

If this standard is used outside the scope defined in Clause 1 it is the user's responsibility to assess the suitability towards the applicable equipment design code and/or process design conditions and to amend the standard as found relevant.

5.2 Deviations to ASME B31.3

This standard is prepared to cover welding and NDT for piping systems specified by NORSOK L-001. The specified material requirements to the same piping systems are specified by NORSOK M-630. The use of the piping materials according to NORSOK L-001, NORSOK M-630 and this standard will result in the following deviations from ASME B31.3. All deviations have been considered, and they are in line with the PED harmonized standards. The deviations are as follows:

- the wall thickness for requiring impact testing is limited to ≥ 6 mm;
- if sub-size Charpy V-notch impact test specimens are used the test temperature is not reduced.

5.3 Listed alternatives to ASME V and IX

ASME V and IX are both American codes and when this standard is applied outside the United States of America, it allows use of alternative ISO standards. This is applicable to welding and NDT activities and operator performance and the specified ISO standards are considered as equivalent standards to ASME V and IX when used as specified herein and summarized below:

- WPS qualified to relevant parts of ISO 15614 is acceptable alternative to ASME IX;
- welders qualified to the relevant part of ISO 9606 or ISO 14732, as applicable, are acceptable alternative to ASME IX;
- performance of NDT activities to ISO standards specified herein are acceptable alternatives to ASME V;
- NDT operators qualified to ISO 9712 are acceptable alternative to ASME V.

5.4 European Pressure Equipment Directive

The provision of the NORSOK standards are intended to comply with the requirements of the EC Pressure Equipment Directive and the Norwegian implementation regulation "Forskrift for trykkpåkjent utstyr" issued 9th of 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 in the responsibility of the equipment manufacturer to implement the PED and to involve a notified body to obtain the required approvals dependent of the selected conformity assessment module applicable to specific project.

For piping systems classified to be within category II and III it is necessary to obtain approval from a 3rd party organization recognized by an EC member state for the following procedures and certificates related to the fabrication welds:

- welding procedures;
- welder/welding operator certification;
- NDT operator certification.

5.5 Tolerances and significant digits

This standard does not fully address tolerances. When dimensions, sizes, or other parameters relevant to weld procedure qualifications are not specified with tolerances, the values of these parameters are considered nominal, and allowable tolerances or local variances may be considered acceptable when based on engineering judgement and standard practices as determined by the designer.

For the purpose of determining conformance with the acceptance criteria of Clause 8 and 10 in this standard all limits shall be considered absolute limits as defined in ASTM E 29. With the absolute method, an observed value or a calculated value is not to be rounded, but is to be compared directly with the specified limiting value. Conformance or non-conformance with the specification is based on this comparison.

6 Quality assurance

6.1 General

The fabricator shall operate under a quality system certified to ISO 9001.

6.2 Welding and NDT quality system

All welding and related activities shall comply with the requirements of ISO 3834-2 and the additional requirements of this NORSOK standard. All procedures and qualifications shall represent the organization and actual site where the welding activity shall take place. Welding workshops that are not certified shall document compliance to ISO 3834-2 by presenting an overview of standard requirements and how these are implemented in their internal quality system.

Companies performing NDT activities shall have a quality system in compliance with ISO 17020. NDT companies that are not accredited shall document compliance to ISO 17020.

The inspection frequency shall be sufficient to report weekly quality status during fabrication based on welding inspection reports.

Causes for non-conformance shall be immediately investigated and corrective action shall be taken to prevent further occurrence. Non-conformance shall require documented investigation/action by the responsible welding coordinator.

6.3 Welding coordination

All welding coordination shall be according to ISO 14731. The fabricator shall appoint a responsible welding coordinator for the welding activities carried out by the contract/project/fabrication site. This position shall be identified in the organization chart for the actual project and site. If welding activities are carried out at different sites the responsible welding coordinator at each site and the organizational links between the different sites shall be identified.

The responsible welding coordinator shall be qualified as an IWE or as otherwise accepted in ISO 14731 Annex A. Depending of the scope of work an IWT qualification may be accepted.

All personnel who are carrying out one or more welding activities according to ISO 14731 Annex B are welding coordinators. The level of technical knowledge, tasks, responsibility and authority shall be identified for each person/function in a job description, for information and guidance see Annex D.

The fabricator is regarded as the responsible welding organization in cases where fabrication is sub-contracted. The fabricator’s responsible welding coordinator shall ensure that subcontractor’s weld related quality procedures are in compliance to fabricator’s system, and that all contractual requirements are met.

6.4 Welder and welding operator qualification

All welders and welding operators shall be certified in accordance with ASME Section IX, ISO 9606-1/-3/-4/-5 or ISO 14732 as applicable.

For personnel performing temporary tack welding, an internal test according with ISO 9606 without use of 3rd party is acceptable.

6.5 Welding inspection

Welding inspector tasks and responsibilities is to be familiar with all standards, rules and specifications, and continuously verify that all requirements and adequate parts in ISO 3834-2 are implemented and followed.

Welding inspection shall be performed before, during and after welding according to typical check points listed in Annex C. All inspections shall be reported to the responsible welding coordinator.

Welding inspectors shall be certified according with NS 477 or qualified to the EWF/IIW-rules for approval of international welding inspector IWI-SI.

6.6 Qualification of inspectors and non-destructive testing operators

Personnel responsible for all NDT activities shall be certified according to ISO 9712, Level 3.

Personnel performing visual inspection of welded joints shall be certified in accordance with ISO 9712 VT level 2 or NS 477 Edition 2005 or later.

The NDT operator shall be certified according to ISO 9712 level 2, or equivalent 3rd party certification scheme. Operators simply producing radiographs and not performing evaluation, do not require level 2, but shall have training comparable to ISO 9712 Level 1 for radiographic testing.

Ultrasonic operators performing inspection of welds in duplex and austenitic stainless steel material shall be specially trained and certified for the purpose according to ISO 9712.

6.7 Quality system for test laboratories

Test laboratories shall have a quality system in compliance with ISO 17025 or equivalent. Test laboratories that are not certified shall document compliance to ISO 17025 by presenting an overview how requirements in the standard are implemented in their internal quality system.

7 Drawings for fabrication

Symbolic presentation of welds shall be according to ISO 2553 or AWS A2.4.

All pressure retaining welds shall be identified with a unique number or another unique traceable identification.

The shop drawings shall contain enough information to enable correct selection of WPS. Minimum information needed is:

- material type/grade and grouping number (ISO/TR 15608);
- dimension (outside diameter and wall thickness);
- sour service, if relevant;
- PWHT requirement, if relevant.

8 Welding qualification requirements

8.1 General

Welding procedures for steels, titanium and copper based alloys shall be qualified according to ASME Section IX or ISO 15614-1, ISO 15614-5 and ISO 15614-6 as applicable and to this NORSOK Standard.

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 ISO 3834-2 and ISO 14731 are implemented and documented.

Weld procedure qualification for manual welding is also acceptable for partly mechanized welding, but not vice versa.

8.2 Welding position

When corrosion, impact or hardness test requirements are not specified, welding of the test piece (pipe or plate) in any position qualifies for welding in all positions.

When both hardness and impact/corrosion test requirements are specified, two test pieces in different welding positions (low and high heat input) are required for qualification of all positions. The following requirements shall be fulfilled:

- specimens for corrosion and impact test as applicable shall be taken from the weld in the highest heat input position;
- specimens for hardness test shall be taken from the weld in the lowest heat input position.

For type 22 and 25Cr duplex, the lowest and highest heat input positions shall be subjected to impact testing to qualify for all positions.

8.3 Heat input

The heat input shall be calculated for the root and 2nd pass (hot/cold pass), and typical fill and cap passes. The average measured values for each pass/area shall be the basis for calculation of the allowable range of heat input.

When welding of carbon steel with requirement of impact testing or all types of stainless steel and non-ferrous materials, the qualified heat input shall be limited as follows:

- the maximum heat input used when welding the test piece; or
- heat input shall be within the limits of the average value of the heat input ± 25 % used when welding the test piece for carbon steel and SS type 316;
- heat input shall be within the limits of the average value of the heat input ± 15 % used when welding the test piece for SS type 22/25Cr, type 6Mo, type 565 and titanium alloys.

NOTE For SS type 25Cr duplex the 2nd pass should be welded with a heat input less than the heat input of the root pass.

For covered electrode the average heat input shall be calculated for each used diameter in order to define the maximum qualified heat input.

It shall be clearly stated whether arc energy or heat input is used as term at the WPS.

NOTE Heat input = ηArc energy, where “η” is the weld process efficiency factor, ref. EN 1011-1.

8.4 Measuring and recording of test welds

The manufacturer shall prepare detailed procedure/steering documentation for how to plan, perform, measure and apply welding qualifications, from pWPS, WPQR to final WPS for fabrication welding.

The procedure shall detail how and which parameters to be measured and recorded for each pass of the test weld.

The WPQR/PQR shall include information and documentation of all essential welding parameters required according to qualification standard and any other parameters which are essential in order to achieve required final weld quality condition.

The WPQR/PQR documentation shall include:

- WPQR/PQR front page;
- weld parameter log;
- material certificates for the base and filler materials applied in the weld qualification test;
- PWHT report and chart if applicable,
- NDT reports,
- reports from mechanical, metallurgical and corrosion testing as applicable.

8.5 Non-destructive testing of test welds

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

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

The NDT acceptance criteria shall be as specified in Clause 10.8.

8.6 Mechanical testing

8.6.1 General

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

8.6.2 Impact tests

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

For piping systems designed to ASME B31.3 Chapter IX, high pressure piping, the testing and acceptance specified in Chapter IX shall apply.

Table 1 – Impact test requirements

Material	Notch location	Tests temperature	Minimum average absorbed energy
Carbon steel type 235	Not applicable		
Carbon steel type 235LT and 360LT	WM and HAZ	- 46 °C	27 J for type 235LT 36 J for type 360LT
Austenitic stainless steel grades	Reference is made to ASME B31.3		
SS type 22Cr duplex and type 25Cr duplex	WM and HAZ	The lowest of - 46 °C and MDT	27 J or lateral expansion min. 0,38 mm

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.

Impact testing is required for nominal wall thickness ≥ 6 mm.

Location of test specimens in HAZ shall be made in compliance with ISO 15614-1.

No single Charpy V-notch value shall be below 70 % of the average requirement.

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.

8.6.3 Macro-sections

A macro-section shall be taken from test welds in accordance with ISO 15614 and shall be visually examined and meet the acceptance criteria specified by the applicable part of ISO 15614. This shall apply also when WPQR is qualified according to ASME IX.

8.6.4 Hardness tests

Hardness testing of all carbon steel grades and titanium grades is required in accordance with ISO 15614-1 as follows:

- for carbon steels the maximum hardness shall not exceed 350 HV10;
- when service is defined sour in accordance with ISO 15156-2 the maximum hardness shall be in compliance with ISO 15156-2 as applicable;
- for Titanium Grade 2 the hardness of the weld metal and HAZ shall not exceed the base material by more than 50 HV10.

For qualification of repair weld procedures in carbon steels with sour service requirements, hardness testing shall be carried out according to ISO 15156-2, Figure 4.

NOTE Hardness testing carried out according to ISO 15614-1 (and EN 1043-1) is evaluated to comply with specified hardness test requirement of ISO 15156-2.

Hardness testing of welds in other type of materials than identified above when exposed to sour service shall be in compliance with ISO 15156-1/-2/-3.

8.6.5 Corrosion testing

Welds in SS type 6Mo, type 565 and type 25Cr duplex shall be corrosion tested according to ASTM G 48, 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.

Cut edges are to be ground wet by 120-grit abrasive paper to remove deformed material, and sharp edges should be rounded by same grit paper. The internal/external surfaces shall not be ground. The whole specimen shall be pickled before being weighed and tested. Pickling should be performed for 5 minutes at 60 °C in a solution of 20 % HNO3 + 5 % HF.

The test temperature shall be:

- 40 ºC for SS type 6Mo and type 565;
- 35 ºC for SS type 25Cr duplex.

The exposure time shall be minimum 24 hours.

The acceptance criteria shall be:

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

8.6.6 Micro-structural examination

SS type 22 and 25Cr duplex shall be examined and the test samples shall comprise a cross section of the weld metal, HAZ and the base metal.

The micro-structure shall be etched in a 20/40 % NaOH/KOH solution and examined at 400 or 500 X magnification and the total content of inter-metallic phases shall not exceed 0,5 %. Any presence of intermetallic phases and/or precipitates shall be reported.

For the SS 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 E 562 and shall be in the range of 30 % to 70 %.

8.7 Essential variables

8.7.1 General

Re-qualification of a welding procedure is required upon any of the changes in the essential variables listed in ISO 15614-1/-5/-6/-7 or ASME Section IX and the additional essential variables listed in Clause 8.7.2 to 8.7.5.

If special precautions are taken under WPQR welding to obtain test requirements these precautions shall be included in WPS for production.

8.7.2 Base materials

The following essential variables to base material shall apply in addition to those specified in ASME IX/ISO 15614-1:

- a change from any other material to SS type 6Mo or type 565;
- a change from SS type 6Mo to type 565, but not converse;
- a change from SS type 22Cr to type 25Cr duplex, but not converse;
- for SS 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 steels type 360 without PWHT: An increase in carbon equivalent CEIIW of more than 0,03;
- for carbon steels for use in sour service: An increase in carbon equivalent CEIIW of more than 0,03.

8.7.3 Consumables

The following essential variables to weld consumables shall apply in addition to those specified in ASME IX/ISO 15614-1:

- any change in consumable brand name, except for solid wire, when corrosion or impact testing is required;

  NOTE This does not apply for solid wire provided documentation of no change in AWS or EN grouping and nominal chemical composition.

- for SMAW (111) and FCAW (114, 136), any increase of size in consumable in the root run of single sided welds, except when welded against ceramic backing.

8.7.4 Joints

The following essential variables to weld joints shall apply in addition to those specified in ASME IX/ISO 15614-1:

- a decrease in groove angle of more than 10° for groove angles less than 60°;
- a decrease in groove angle when groove angle is less than 30°.

8.7.5 Gas

The following essential variable to weld gas shall apply in addition to those specified in ISO 15614-1:

- any change in shielding and back shielding gas beyond the requirements in ASME Section IX, also if welding is performed to ISO 15614-1/-5/-6/-7.

9 Welding requirements

9.1 General

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 ISO 15609-1 or ASME Section IX including voltage range, tolerances for root gap and face, and maximum mismatch of butting weld ends.

WPSs shall state compliance with the contracted welding specification including revision number and the WPSs shall be signed by responsible weld coordinator.

The applicable WPS shall be given directly to the welder and shall be available at the site of welding at all times.

NOTE A collection of WPSs on walls or boards are only for general information and not accepted used for welding.

The distance between girth welds should be minimum one outside diameter of the pipe. If this for practical reasons is not possible the minimum distance between welds may be reduced to 2 times wall thickness or 50 mm (between the weld toes) whichever is the greatest, but not for standard pipe fittings. Fillet welds, welds between support and piping with throat thickness less than 5 mm do not require minimum distance between welds.

The root pass of welds in SS type 6Mo, type 565 and type 25Cr duplex 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 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 shall be continuous.

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

Prefabrication of stainless steels, copper and titanium based alloys shall be performed in a workshop, or parts thereof, which is reserved exclusively for those types of materials.

All type of inspection/examination shall be performed by personnel other than those performing and responsible for the fabrication work.

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 SS with PREN ≥ 40,0 (e.g. UNS S31254 and UNS S34565) the requirements given to stainless steel type 6Mo herein shall apply.

9.2 Colour coding of materials and welding consumables

If colour coding of pipes, fittings and welding consumables is done the coding should be according to Annex E.

9.3 Welding consumables

9.3.1 General

All welding consumables shall have individual marking.

All consumables for welding shall be delivered in accordance with product data sheet with certification of chemical analysis according to ISO 10474/EN 10204, type 3.1.

Flux for submerged arc welding processes shall be delivered with certification according to ISO 10474/EN 10204, type 2.2.

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 with addition of weld metal chemical analysis.

Handling and storage of consumables shall follow manufacturer recommendations.

9.3.2 Carbon steels

For all welds where impact testing is required low hydrogen type consumables (HDM ≤ 10 ml/100 g weld metal) shall be used.

For water injection systems, the root and hot pass shall be made using consumables containing such as

- 0,8 % to 1,0 % Ni, or
- 0,4 % to 0,8 % Cu and 0,5 % to 1,0 % Ni.

For systems defined for sour service the requirements to weld metal chemical composition of ISO 15156-2 shall apply.

9.3.3 Austenitic stainless steels type 6Mo and type 565

A consumable with enhanced Mo and Cr content compared to the base material shall be used.

The sulphur content shall not exceed 0,015 %.

9.3.4 Duplex stainless steels

A matching consumable with enhanced Ni content compared to the base material shall be used.

The sulphur content shall not exceed 0,015 %.

9.3.5 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-2.

9.3.6 Consumables for joining of dissimilar materials

The filler material used in buttering layer when welding carbon steels to stainless steel type 316 should be according 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 shall be used.

NOTE 1 When welding stainless steel alloyed with nitrogen, e.g. SS 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 2 Careful considerations shall be made if PWHT of joints between dissimilar materials is required.

9.4 Preheat and interpass temperature

The material to be welded shall be at a temperature above ambient dew point temperature.

Cutting torches shall not be used for preheating.

The maximum interpass temperature shall realistically reflect the conditions under WPQR test welding and shall not be boosted for one run out length only.

The interpass temperature shall be measured at the edge of the groove.

The minimum interpass temperature shall not be less than the specified preheat temperature.

The maximum interpass temperature shall not exceed the maximum temperature recorded during the weld qualification test, but in no case above temperatures stated below:

- 250 °C for carbon steels;
- 150 °C for all SS and non-ferrous materials;
- 150 °C for SS type 25Cr duplex for mechanized welding methods;
- 100 °C for SS type 25Cr duplex for manual welding methods.

9.5 Backing and shielding gas

Backing gas shall be used for welding of all stainless steel and non-ferrous materials, and shall be maintained during welding of minimum 8 mm thickness. The same requirement applies also for tack welding.

When welding all types of stainless steel and non-ferrous materials the back shielding gas shall be tested with an oxygen meter. The maximum oxygen content shall be set to fulfil the oxidation colours, ref. Clause 10.7 and Annex B.

NOTE Based upon experience from site welding the oxygen content should be quite low (<100 ppm) to ensure compliance with the oxidation colours specified.

Shielding and back 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.

When welding supports or attachments to stainless steel pipes with nominal thickness less than 8 mm, the pipe shall be purged with inert gas to avoid unacceptable internal oxidation.

9.6 Welds with buttering

Buttering due to dimensional modification between members in same material group shall be made to a specific WPS qualified to Clause 8.

Buttering of members due to dissimilar material, heat treatment or different essential variables shall be carried out to in accordance with WPS qualified to ASME Section IX QW 283, and shall be inspected as the respective butt weld. All buttering to be included in a butt weld shall be tested as applicable to the butt weld.

9.7 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 are not allowed. Prior to welding, sufficient root gap shall be ensured.

9.8 Cutting, grinding, brushing and weld cleaning

To avoid contamination and material particles transferred from one type of material to others, it is important to use tools designed for the material to be worked and not to use tools used for carbon steel on stainless steel or non-ferrous material.

For cleaning welds in carbon steels both power-driven and hand brushes can be used.

For stainless steels and non-ferrous materials, not subjected to subsequent painting, use of power-driven stainless steel brush is not permitted for weld cleaning.

9.9 Post weld heat treatment

Post weld heat treatment shall be performed when required by the ASME B31.3 unless alternative requirements are specified, see ASME B31.3.

For quenched and tempered materials PWHT shall be carried out minimum 20 °C below the tempering temperature of products involved.

PWHT shall be carried out in accordance with a procedure which shall include:

- heating rate;
- cooling rate;
- soaking temperature and time;
- heating facilities;
- insulation;
- control devices;
- recording equipment;
- configuration of structure to be PWHT or details if local PWHT shall be carried out;
- number and location of thermocouples to be used during PWHT.

The temperatures shall be continuously recorded on a chart.

9.10 Production test

A production test program shall be established for the contracted scope of work. Verification of previously qualified WPS and weldability of actual material used shall be considered when establishing the program.

Each production test shall be tested and documented as for the relevant welding procedure qualification test unless otherwise agreed.

9.11 Temporary attachments

All welding of attachments shall comply with the requirements for the equipment to which they are attached.

Temporary attachments shall be 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.

10 Inspection and non-destructive testing

10.1 General

All activities specified within this Clause 10 are related to final inspection of welded joints.

Prior to fabrication start-up, contractor shall implement a system for recording of weld defect rates. The defect rates shall be recorded on a weekly basis for VT, MT, PT, UT, RT and PMI for each production area (geographically split in production areas at the same yard) and shall be reported together with the accumulated defect rate. The defect rate statistics shall be used as a tool in weld quality control. Causes for defects shall be immediately investigated and corrective action shall be taken to prevent further occurrence.

Cracks detected with any NDT method shall require documented investigation/action by the responsible welding coordinator.

The defects shall be reported with reference to the numbering system according with ISO 6520-1.

NOTE The defect rate is defined as (Defect length x 100%) / (Length of weld seam tested).

10.2 Extent of non-destructive testing

The NDT groups are defined in Table 2. The extent of NDT of welds in piping systems shall be in accordance with Table 3.

When performing spot/percentage NDT control the NDT shall represent completed work (not representing future welds). Progressive examination shall be applied according to ASME B31.3. NDT shall be performed at regular intervals through the complete fabrication phase.

The specific percentage shall be calculated from the length of welds per 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.

Table 2 – 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 to 185
2	All systems except those in NDT Group 1	1 and 2	Class 150 and class 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 3 – Extent of NDT

NDT group	Type of connection	Visual inspection, (%)	Volumetric testing, RT/UT, (%)	Surface testing, MT/PT, (%)
1	Butt weld	100	0	0
2	Butt weld	100	10	10
3	Butt weld	100	100	100

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.

Welds of O-lets towards the main header in NDT Group 3 shall be 100 % visually inspected from the root side.

Visual inspection shall in addition to all welds in the piping system include all supports and attachments welded to the piping.

When gas metal arc welding (131 MIG/135/138 MAG) without pulsed current is applied, ultrasonic testing shall be carried out to verify no sidewall lack of fusion in addition to radiographic testing.

UT may be used to replace radiographic testing for t > 10 mm. UT is the preferred method for t > 40 mm.

Welds in titanium systems shall not be ground or brushed before visual inspection.

10.3 Visual testing

The visual testing shall be carried out in accordance with ISO 17637. Light intensity shall be minimum 1000 lux.

10.4 Surface testing

Surface testing shall be carried out by magnetic particle or penetrant testing methods in accordance with ASME V, alternatively ISO 17638 and ISO 3452 may be used, respectively. Viewing conditions shall be according to ISO 3059 and the light intensity shall be minimum 1000 lux.

10.5 Radiographic testing

Radiographic testing shall be in accordance with ASME V Article 2 and relevant parts of Article 22.

10.6 Ultrasonic testing

Ultrasonic testing shall not be used for thickness less than 10 mm and is not recommended used for pipes with outside diameter ≤ 114,3 mm (4,0 in).

The UT procedures shall be established in accordance with ASME Section V, Article 4. DAC reference curves shall be produced from reference block according to Article 4 or Table 4. 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 HAZs are examined for longitudinal defects.

All indications exceeding 50 % of DAC shall be reported. The examination report shall include the position, the echo height, length, depth and type of defect.

Ultrasonic testing of welds between components in austenitic and duplex stainless steel or carbon steel with internal clad shall only be performed if permitted by Company. Specific procedure and reference blocks shall be prepared in accordance with ISO 22825. 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 4 – Calibration reference block requirements

Dimensions in millimeters

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

10.7 Alternative non-destructive testing methods

Phased array may replace conventional ultrasonic testing and radiographic testing provided the following criteria are fulfilled and agreed by all involved parties for each purpose before being implemented. Time of flight diffraction may be used to size defects in combination with phased array or conventional ultrasonic testing:

- the testing shall be based on ASME V, Article 4;
- the procedure for these techniques shall be qualified and documented to demonstrate that all relevant defects and defect orientations will be detected;
- the acceptance criteria for phased array in combination with or without time of flight diffraction shall be demonstrated to be equivalent to the corresponding acceptance criteria for ultrasonic pulse echo technique;
- ultrasonic operators performing phased array and/or time of flight diffraction of welds shall, in addition to being certified to ordinary ultrasonic testing Level 2, be specially trained and certified in phased array and/or time of flight diffraction as stipulated in ISO 9712.

Eddy current array may replace magnetic particle and penetrant testing provided the following criteria are fulfilled:

- the testing shall be based on relevant parts of ASME V, Article 8;
- the procedure shall be qualified and documented to demonstrate that all relevant defects will be detected;
- the acceptance criteria for eddy current array are agreed before testing starts and are equivalent to the corresponding acceptance criteria for magnetic particle and penetrant testing;
- operators performing eddy current array of welds shall, in addition to being certified to ordinary eddy current testing Level 2 for welds, be specially trained and qualified in eddy current array as stipulated in ISO 9712.

10.8 Acceptance criteria

Unless more severe requirements are specified on the piping class sheet the defect acceptance level shall be in accordance with ASME B31.3, Chapter VI and applicable service. As an alternative, the acceptance criteria stated in Annex A may be used for Normal Service.

For pipe classes with design to Chapter IX, High Pressure Piping, the test and defect acceptance criteria specified in Chapter IX shall apply.

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

Surface oxidation of weld zones in stainless steels and titanium alloys shall be visually tested on the outside and the inside, if accessible, and fulfil the criteria specified below:

Stainless steels:

- the oxidation levels showing light brown to brown colour are acceptable;
- oxidation levels showing a narrow band of dark brown colour and intermittent spots of blue colour are acceptable;
- darker or more extensive oxidation colours are not acceptable, and shall be chemically or mechanically removed.

Alternatively, acceptance can be evaluated using the pictures included in Annex B.

Titanium grade 1 and 2 (equivalent to ISO 15614-5):

- acceptable colours are silver and pale straw;
- a narrow band of intensive colours close to the limits of the gas shielding is acceptable;
- darker brown, purple and blue colours and grey or flaky white are not acceptable.

11 Repair

11.1 General

Before repair welding, the defect shall be completely removed.

The excavated area shall have smooth transitions to the metal surface and allow good access for both NDT after excavation and subsequent repair welding. After excavation, complete removal of the defect shall be confirmed by MT or PT. PWHT shall be performed after repair if specified for the original weld.

Re-welding, i.e. when a weld repair takes the form of a weld cut-out, shall include complete removal of the original weld and HAZ.

Arc strikes shall be removed with subsequent MT or PT.

Weld repair of piping systems in operation shall be carried out in accordance with ASME PCC-2

11.2 Repair in carbon steel

The excavated groove shall be minimum 50 mm long, measured at defect depth even if the defect itself is smaller.

Defects spaced less than 100 mm shall be repaired as one continuous defect.

The preheat temperature shall be 50 °C above preheat of the original weld and minimum 100 °C.

Repair welding shall be performed using the same WPS as for the original weld, or a separately qualified procedure. Weld procedure qualification of weld repairs shall include tests as applicable for the relevant material as specified in Clause 8.

Repair welding may only be carried out twice in the same area.

11.3 Repair in stainless steel and titanium

After repair welding the full weld, i.e. the repaired length plus at least 100 mm on each side, shall be subjected to at least the same NDT as specified for the original weld.

For welds in SS type 6Mo, type 565, type 25Cr duplex and titanium base alloys only one attempt of repair is acceptable in the same area.

All oxidation on weld zones in stainless steel with unacceptable colours shall be chemically or mechanically removed, and for welds in titanium alloys the welds with unacceptable oxidation shall be cut out and rewelded.

12 Positive material identification

PMI shall be performed on ready installed piping systems in stainless steel materials prior to any pressure testing or coating operation.

A written PMI procedure shall be established giving materials, product forms and systems to be tested. The test procedure shall include the method to be used, equipment calibration, qualification requirements for PMI personnel, acceptance criteria and documentation requirements.

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 tested material.

PMI shall be performed of piping systems on base material components and welds to the following extent:

1) 100 % for systems in SS type 6Mo, type 565 and type 22/25Cr duplex;
2) 100 % for systems in austenitic steel and design temperature below -50 °C;
3) 10 % for systems in SS type 316.

The testing shall be uniformly distributed to cover the different type of components, manufacturer, pre-fabrication sites and installation sites.

If any non-conformance in material type is found, the extent shall be increased to 100 % for the material quality/product form involved to ensure that all mix of material is discovered.

All PMI testing shall be recorded, but only negative reporting is required.

Annex A
(Informative)
Alternative acceptance criteria for normal service

ASME B31.3 differentiates between several types of services including severe cyclic conditions. The defect acceptance criteria specified within this annex are based on the criteria specified for girth welds in Table 341.3.2 for normal service. More stringent criteria may be specified in the engineering design.

The reference numbers related to type of defects are according to ISO 6520-1.

Acceptance criteria for radiographs are given in Table A.1.

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

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

Table A.1 – Acceptance criteria for radiographic testing

Type of defect	Acceptable value limits
100 Crack	Not acceptable
401 Lack of fusion	Not acceptable
402 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. Tightly butted unfused root faces are unacceptable.
201 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.
301 Slag inclusion 301 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.
501 Undercutting	See Table A.3
515 Concave root surface (suck up)	Remaining weld thickness including reinforcement shall exceed the wall thickness.
Definition: t = nominal wall thickness	

Table A.2 – Acceptance criteria for ultrasonic testing

Echo height	Type of defect	Wall thickness t (mm)	Length (mm)
> 100 % [a]	301/201 Slag or porosity	≤ 19	> 6: Not acceptable
		19 < t ≤ 57	> t/3: Not acceptable
		> 57	> 19: Not acceptable
	Linear indication	All	Not acceptable

[a] When UT is 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 testing, magnetic particle testing and penetrant testing

Type of defect	Acceptable value limits	
100 Cracks	Not acceptable	
401 Lack of fusion	Not acceptable	
402 Incomplete penetration	Maximum depth 1 mm or 0,2 x t, whichever is less. Maximum cumulative length, 38 mm for each 150 mm weld length.	
501 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.	
2017 Surface porosity and/or cluster[a]	For t ≤ 5 mm: 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.	
301/302 Exposed slag	Not acceptable	
517 Poor restart	Acceptable if smooth transition	
515 Concave root surface (suck-up)	Total remaining joint thickness including weld reinforcement shall not be less than the nominal wall thickness.	
502 Reinforcement or internal protrusion, Fig. A.3	For wall thickness ≤ 6 mm > 6 mm ≤ 13 mm > 13 mm ≤ 25 mm > 25 mm Weld metal shall merge smoothly with the component surface.	 = 1,5 mm = 3 mm = 4 mm = 5 mm
507 Misalignment of butt weld, see Fig. A.2	Maximum misalignment (h):	0,15 x t or maximum 4 mm, whichever is less.
512 Symmetry of fillet welds (see Fig. A.4)	"a" less or equal to 6 mm	Maximum difference, z2 – z1 = 3 mm
	"a" greater than 6 mm, up to 13 mm	Maximum difference, z2 – z1 = 5 mm
	"a" greater than 13 mm	Maximum difference, z2 – z1 = 8 mm
Sharp edges [c]	Minimum 2 mm radius.	
503 Reinforcement of fillet/partial penetration welds [a] (see Fig. A.4)	"a" less or equal to 10 mm	Maximum reinforcement h = 2 mm
	"a" greater than 10 mm, up to 15 mm	Maximum reinforcement h = 3 mm
	"a" greater than 15 mm, up to 25 mm	Maximum reinforcement h = 4 mm
	"a" greater than 25 mm	Maximum reinforcement h = 5 mm
514 Roughness of weld (see Fig. A.1)	Roughness (u) shall be less than 2 mm. Weld surface shall be smooth without sharp transitions. The bottom of roughness in butt welds shall not be below the base material surface.	
606 Grinding 601 Arc strikes etc. and removal of 605/607 temporary attachments [b]	Grinding of base material shall not exceed the lesser of 7 % of the wall thickness or maximum 3 mm. Repair welding and inspection shall be performed if removal of the base metal exceeds the specified requirements.	

Notification: "a" is fillet weld throat thickness, and “t” is nominal thickness of butting members.

[a] Surface porosity is governed by the coating specification, if relevant.

[b] Temporary attachments shall be cut minimum 3 mm from the base metal and ground smooth. The ground area shall be VT and MT/PT shall be performed in accordance with the inspection category in question.

[c] Only relevant for coated lines.

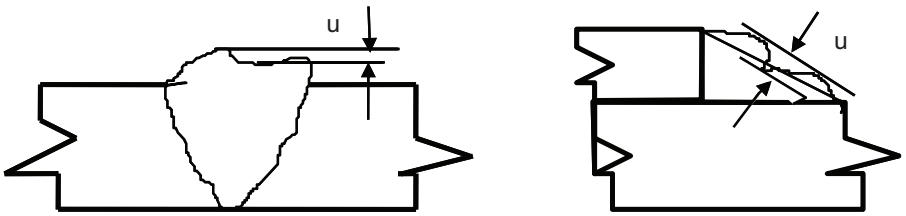


Figure A.1 – Roughness of weld

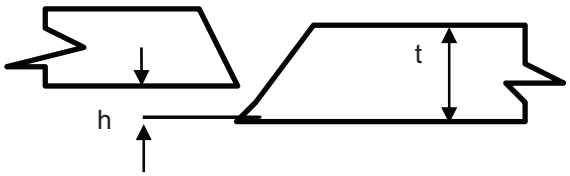


Figure A.2 – Misalignment of butt weld

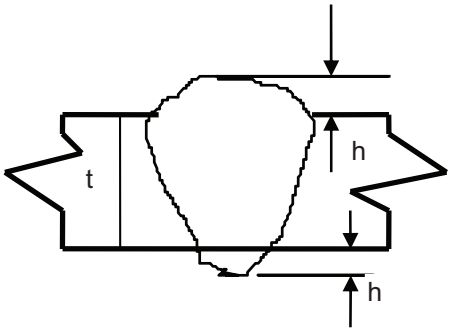


Figure A.3 – Reinforcement or internal protrusion of butt weld

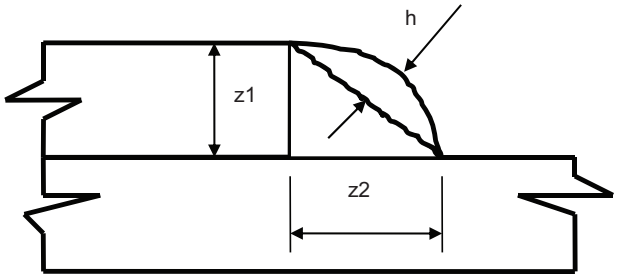
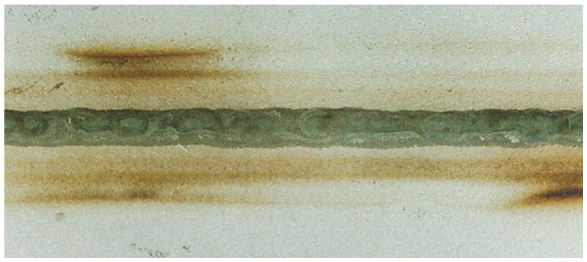


Figure A.4 – Symmetry of fillet

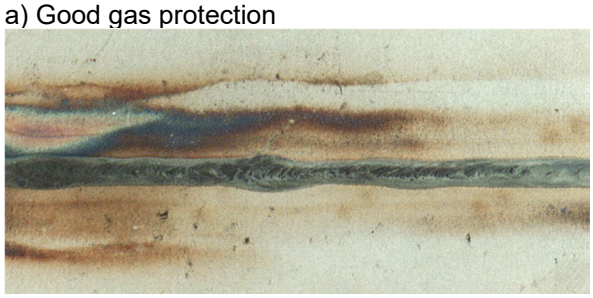
Annex B
(Normative)
Acceptable oxidations of welds in stainless steels

All pictures figure B.1 show root side of welding process 141 TIG weld with Argon shielding gas. Picture a) to d) shows examples of acceptable oxidation, while picture e) to g) shows examples of unacceptable oxidation.

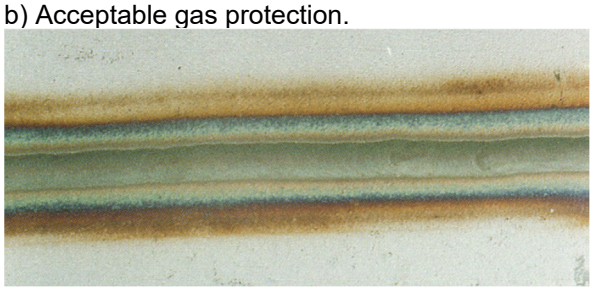
a) Good gas protection



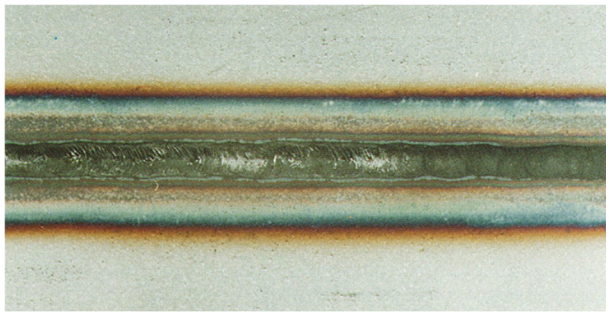
b) Acceptable gas protection.



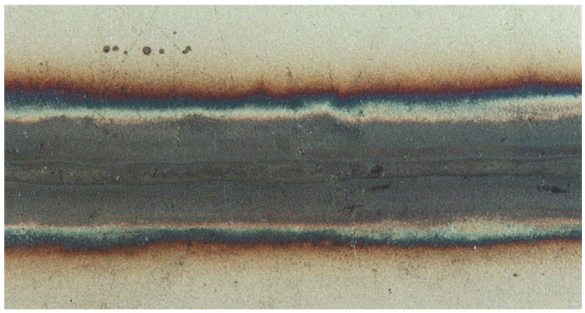
c) Acceptable provided the blue areas are intermittent.



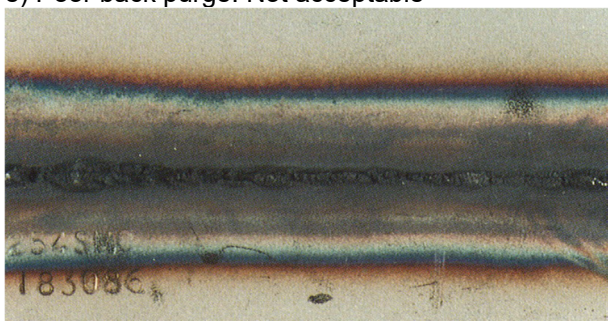
d) Acceptable provided the brown coloured zone close to the weld is as shown, narrow and light coloured.



e) Poor back purge. Not acceptable



f) Poor back purge. Not acceptable.



g) Extremely bad result. Not acceptable.

Figure B.1 – Acceptable oxidations of welds in stainless steels

Annex C
(Informative)
Weld inspection

The following check points should be considered in connection with weld inspection:

General

- workshop/worksite in general;
- storage and handling of material and welding consumables;
- traceability;
- equipment: use, registration, maintenance, calibration and documentation;
- routines for certification, registration, confirmation of validity and prolongation of welders qualifications, approval by a third party organization recognised by an EC member (as relevant);
- registration, confirmation of validity and prolongation of NDT personnel certificates and approved by a third party organization recognised by an EC member (as relevant);
- job-package: Only approved drawings, latest revision and specifications are used. Welding symbols according to ISO 2553. Welding numbering system and identification/traceability;
- check that all welding coordinators are working according their job-descriptions, instructions and routines.

Checkpoints before welding

- drawing;
- material, marking/coding/traceability and handling;
- bevelling/cutting, groove preparation, fit up and staggering of adjacent longitudinal welds;
- welding equipment and use: tools, welding machine, etc. (check of calibration/maintenance);
- preheating and protection against wind, rain, etc., if necessary;
- purging gas and check of oxygen content, if necessary (type and flow-rate);
- procedure for tack-welding. Tack-welding (parameter control) and tack welders qualification;
- treatment of welding consumables;
- equipment/tools accommodated the type of material;
- renovation/cleaning, ready for welding.

Checkpoints during welding

- drawing available;
- treatment of material and welding consumables;
- groove geometry;
- welding equipment and use: tools, welding machine etc. (check of calibration/maintenance);
- preheating, method and temperature;
- interpass temperature and protection against wind, rain etc., if necessary;
- purging gas and check of oxygen content, if necessary (type and flow-rate);
- welder’s approval for the welding work;
- welding performance (placing of run layer, welding direction and sequence, staggering of stop/start, cleaning between layers);
- WPS on work place available for the welder and check of various parameters listed in WPS and measuring/calculating heat input (arc energy);
- visual checking during welding (self-control) done by the welder.

Checkpoints after welding

- marking/traceability;
- are welder identification and WPS number marked closed to weld?
- is the used WPS and welder qualification (welding certificate) relevant for the welded joint?
- check of “self-inspection” done by the welder;
- check of weld geometry/size welding symbol on drawing/WPS;
- check of weld surface, transition area and area close to the weld;
- oxidation levels (colour);
- performing and documentation of PWHT, if necessary;
- extent of NDT, NDT operator qualifications, reporting and documentation;
- marking, cleaning, flushing, preservation, protection of flange/fittings, etc;
- documentation review (weld summary list).

Annex D
(Informative)
Welding coordination/inspection functions

An example to visualise competence levels of different welding coordinator/inspection functions are shown in table D.1:

Table D.1 – Welding coordination/inspection functions

Function (task)	IWE	IWT	IWS	IWI-C	IWI-S
Company`s authorized coordinator (Lead welding engineer)	X	(X)			
Responsible welding engineer in project	X	(X)			
Welding engineer	X	(X)			
Welding engineer assistant		X	(X)		
Welding technician		X	(X)		
Welding certificate coordinator (site-testing)		X	(X)		
Fabrication/installation lead		X	(X)		
Construction supervisor		X	(X)		
Shop master (welding fabrication)		X	(X)		
Foremen for welders and fitters		(X)	X		
Material engineer (design engineering)	X	(X)			
Material engineer (purchasing)	X	(X)			
Test laboratory	X	(X)			
NDT coordinator			X		
Senior welding inspector				X	
Welding inspector					X
Notification: (X) means an acceptable alternative competence that should require acceptance by Client.					

Annex E
(Informative)
Colour coding systems for piping material and solid wire consumables

Colour code	Type of material	Pipes		Forged components (flange, etc.)		Butt weld fittings		Solid wire consumables [a]	
		MDS	Material standard	MDS	Material standard	MDS	Material standard	Type/designation	Colour code
-	Carbon steel type 235	C01	A 106 Grade B API 5L Grade B	C01	A 105	C01	A 234 WPB	-	-
Grey RAL-7001	Carbon steel type 235LT	C11	A 671 CC70 A 333 Grade 6	C11	A 350 LF2	C11	A 420 WPL6	ER 80S-Ni1 [b]	Grey
Red RAL-3000	Carbon steel type 360LT	C22	API 5L X52	C21	A 694 F52	C23	A 860 WPHY52	ER 80S-Ni1 [b]	Grey
								ER 80S-Ni2 [b]	White
Orange RAL-2004	Carbon steel	X01	AISI 4130	X04	A 788 AISI 4130	X01	A 234 AISI 4130	ER 100S-G	Combined green/yellow
Yellow RAL-1018	Ferritic/austenitic stainless steel type 22Cr duplex	D41 D42	A 790 S31803 A 928 S31803	D44	A 182 F51	D43	A 815 UNS S31803	ER 2209	Yellow
Green RAL-6032	Ferritic/austenitic stainless steel type 25Cr duplex	D51 D52	A 790 S32750/32760 A 928 S32750/32760	D54	A 182 F53/F55/F61	D53	A 815 UNS S32750/32760	ER 2509	Green
Black RAL-9005	Austenitic stainless steel type 6Mo	R11 R12	A 312 S31254 A 358 S31254	R14	A 182 F44 (UNS S31254)	R13	A 403 UNS S31254	ER NiCrMo-3	Black
								ER NiCrMo-13	Violet
Blue RAL-5015	Austenitic stainless steel type 316	S01	A 312 TP316 A 358 Grade 316	S01	A 182 F316	S01	A 403 WP316	ER 316LSior ER 316L	Blue
								ER 309LMo [c]	Orange
Brown RAL-8024	Titanium Grade 2	T01	B 861 Grade 2 B 862 Grade 2	T01	B 381 Grade F2	T01	B 363 Grade WPT2	ERTi-2	Brown

[a] Solid wire consumables to be marked by flag or paint.
[b] Same weld consumable may be used for welding all type of carbon steel with SMYS ≤ 360 MPa.
[c] Solid wire consumables for joining stainless steel type 316L and carbon steels.

Bibliography

1. EN 1043-1, *Destructive tests on welds in metallic materials – Hardness testing – Part 1: Hardness test on arc welded joints*
2. ISO/TR 15608, *Welding – Guidelines for a metallic materials grouping system*