INTERNATIONAL STANDARD

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Oil and gas industries including lower carbon energy — Piping systems on offshore production platforms and onshore plants —

Part 3: Fabrication

Industries du pétrole et du gaz, y compris les énergies à faible émission de carbone — Conception et installation des systèmes de tuyauterie sur les plates-formes de production en mer et les installations à terre —

Partie 3: Fabrication

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 6, *Process equipment, piping, systems, and related safety*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition of ISO 13703-3, together with ISO 13703-1 and ISO 13703-2, cancels and replaces ISO 13703:2000. It also incorporates the Technical Corrigendum ISO 13703:2000/Cor.1:2002.

The main changes compared to the previous edition are as follows:

— deletion of the installation and quality control requirements of Clause 10;

— deletion of previous Annex C as requirements are addressed in ASME B31.3.

A list of all parts in the ISO 13703 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The aim of this document is to establish common requirements for the fabrication, welding, inspection, examination and testing of new, metallic process piping systems designed in accordance with the requirements of ISO 13703-1, and using bulk piping materials in accordance with ISO 13703-2.

This document makes normative reference to ASME B31.3 as the base code for process piping. Alternative codes to ASME B31.3 exist for the fabrication, welding, inspection, examination and testing of process piping systems along with the potential need to comply with local or national regulatory/jurisdictional requirements. The user of this document is expected to assess the implications arising from local or national regulatory/jurisdictional requirements in implementing the requirements herein, including the need to specify additional requirements to those stated. ASME B31.3, Appendix N provides guidance on its use internationally, and specifically its use within the European Union for which additional requirements to those specified in ASME B31.3 will be necessary to meet the requirements of Directive 2014/68/EU on the harmonization of the laws of the Member States relating to the making available on the market of pressure equipment (PED).

This document is not intended to inhibit a user from accepting alternative fabrication, welding, examination or testing solutions for the individual application. This can be particularly appropriate where there is innovative or developing technology. Where an alternative to the requirements in this document is offered, the user is expected to review the implications in meeting the performance requirements within this document.

Oil and gas industries including lower carbon energy — Piping systems on offshore production platforms and onshore plants —

Part 3: Fabrication

1 Scope

This document specifies requirements for the fabrication, installation, welding, inspection, examination and testing of new, metallic piping systems , within temperature range limits for the materials meeting the requirements of ASME B31.3, on fixed and floating offshore production facilities and onshore production, processing and gas liquefaction plants. For piping systems above pressure class 2500, the requirements of chapter IX of ASME B31.3 shall be complied with, in addition to the requirements stated in this standard.

This document is applicable to all pressure retaining components and any non-pressure retaining component, such as a member of a pipe support, welded directly to a pressure retaining component.

This document is not applicable to the following:

— marine-related piping systems, e.g. ballasting piping systems, systems covered by classification societies;

— metallic tubing used for subsea umbilical systems;

NOTE 1 Reference can be made to ISO 13628-5 or API Spec 17E for welding and examination of these components.

— piping systems with corrosion resistant cladding (either integrally clad or mechanically lined) or weld overlay, including buttering and associated dissimilar welds;

NOTE 2 Reference can be made to DNV-RP-B204 for welding and examination of these systems.

— refractory alloys [with exception of CP titanium Grade 1 (UNS R50250) or Grade 2 (UNS R50400)];

— non-metallic piping assemblies;

— transportation pipeline systems, including flow-lines, designed in accordance with a recognized pipeline design code.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 8249, *Welding — Determination of Ferrite Number (FN) in austenitic and duplex ferritic-austenitic Cr-Ni stainless steel weld metals*

ISO 9015-1, *Destructive tests on welds in metallic materials — Hardness testing — Part 1: Hardness test on arc welded joints*

ISO 9606 (all parts), *Qualification testing of welders — Fusion welding*

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

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

ISO 11666:2018, *Non-destructive testing of welds — Ultrasonic testing — Acceptance levels*

ISO 11699-1, *Non-destructive testing — Industrial radiographic film — Part 1: Classification of film systems for industrial radiography*

ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes*

ISO 14344, *Welding consumables — Procurement of filler materials and fluxes*

ISO 14731, *Welding coordination — Tasks and responsibilities*

ISO 14732, *Welding personnel — Qualification testing of welding operators and 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/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 17636-2, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors*

ISO 17781:2017, *Petroleum, petrochemical and natural gas industries — Test methods for quality control of microstructure of ferritic/austenitic (duplex) stainless steels*

ISO 18265, *Metallic materials — Conversion of hardness values*

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

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

API RP 686, *Machinery Installation and Installation Design*

ASME B31.3, *Process Piping*

ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C:2019, Specifications for welding rods, electrodes, and filler metals

ASME Boiler and Pressure Vessel Code, Section V:2019, Non Destructive Testing

ASME Boiler and Pressure Vessel Code, Section IX:2019, Welding and Brazing Qualifications

ASNT CP-189, *Standard for Qualification and Certification of Nondestructive Testing Personnel*

ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*

ASTM A380/A380M, *Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems*

ASTM E140, *Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness*

ASTM E1815, *Standard Test Method for Classification of Film Systems for Industrial Radiography*

ASTM G48, *Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*

AWS A4.2M, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel*

AWS D10.10/D10.10M, *Recommended Practices for Local Heating of Welds in Piping and Tubing*

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

PFI ES-3, *Fabricating Tolerances*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
alkaline service
service environments containing alkaline compounds such as amines, caustic, carbonates

3.2
bolted connection
connections with bolts, to allow assembly and disassembly, that uses flanges or clamps as connectors.

3.3
carbon equivalent
C_E
numerical value for a steel's composition that represents the contribution of the relevant elements to the hydrogen cracking susceptibility of steel

Note 1 to entry: The carbon equivalent is based on:

$$C_E = \%C + \left(\frac{\%\,Mn}{6}\right) + \left(\frac{\%\,Cr + \%\,Mo + \%\,V}{5}\right) + \left(\frac{\%\,Ni + \%\,Cu}{15}\right)$$

where all mass fractions are expressed in percent.

3.4
closure weld
final weld connecting piping systems, assemblies or sub-assemblies that have been successfully leak tested, but that itself is not subject to leak testing

Note 1 to entry: Closure welds include any welds made after leak or tightness testing, such as seal welds to threaded connections, or repair welds made in the event of a leak that are not subject to further leak test.

Note 2 to entry: Closure welds are often also referred to as 'golden welds'.

3.5
computerized imaging technique
CIT
manual or encoded ultrasonic examination technique with capability for computer processed display or analysis and display of ultrasonic data to provide two or three dimensional surfaces

3.6
confined space
space that is substantially but not necessarily entirely enclosed, and where serious injury can occur from hazardous substances or conditions within the space or nearby (e.g. lack of oxygen)

Note 1 to entry: Confined space includes access into the internal bore of pipes to install, inspect and remove internal backing gas dams, and during cleaning, flushing, leak and tightness testing activities.

3.7
cryogenic service
service environments with a minimum design temperature lower than –104 °C

3.8
low-alloy steel
steel with significant alloy additions (e.g. Groups 4 to 6 according to ISO 15608, or P-No. 3 to P-No 5 and P-No. 15E according to ASME B31.3)

3.9
extrados
outer curved portion of a bend

3.10
fabricator
organization responsible for the fabrication, welding, examination and testing of piping systems including any externally provided products or services

Note 1 to entry: For the purposes of this document, "fabricator" is considered interchangeable with "manufacturer", "erector", "employer" or "purchaser" where these terms are used in referenced documents.

3.11
fibre elongation
elongation during bending or forming calculated as 100 r/R expressed as percentage

Note 1 to entry: Fibre elongation can be determined by physical measurement or calculation.

3.12
heat input
energy introduced into the weld region during welding per unit run length

Note 1 to entry: The reference for the calculation of heat input is ASME Boiler and Pressure Vessel Code, Section IX:2019 for the specific welding process.

3.13
high alloyed stainless steel
austenitic stainless steel typically having PREN ≥ 40 or [% Ni + 2 (% Mo)] > 30 where % Mo > 2, where all mass fractions are expressed as percent

EXAMPLE SS type 6Mo or SS type 565.

3.14
intrados
inner curved portion of a bend

3.15
leak testing
application of a pressure load greater than the design load to demonstrate the integrity of a piping assembly to safely withstand the design load

Note 1 to entry: Leak testing is also referred to as "hydrostatic leak testing" or "pneumatic leak testing", or combination thereof, as defined in ASME B31.3.

3.16
lot
totality of welds completed by all welders, and accepted by visual examination on any one day, unless otherwise defined in the engineering design

[SOURCE: PFI ES48:2015]

3.17
low sulfur oil
heating oil with maximum sulfur content of 1 000 ppm

3.18
nepheleometric turbidity units
NTU
measurement of water turbidity

3.19
owner
person, partnership, organization or business ultimately responsible for design, construction, operation, and maintenance of a facility

3.20
pitting resistance equivalent number
number indicating the resistance of stainless steels to pitting corrosion and related to chemical composition

Note 1 to entry: PREN is calculated from one of the following formulas:

PREN = % Cr + 3,3 % Mo + 16 % N

PREN = % Cr + 3,3 % (Mo + 0,5 W) + 16 % N

where all mass fractions are expressed as percent.

Note 2 to entry: All PREN limits are absolute limits based upon the heat analysis. The calculated value shall not be rounded.

3.21
sour service
service environments that contain sufficient H_2S to cause cracking of materials

Note 1 to entry: For the purpose of the document, the mechanisms that result in cracking are addressed in ISO 15156-2 or ISO 15156-3.

Note 2 to entry: For the purpose of this document, ANSI/NACE MR0175 is equivalent to ISO 15156-2 and ISO 15156-3, respectively.

3.22
stainless steel 300-series
SS 300-seriesaustenitic stainless steel with at least 16 % Cr (mass fraction) and 8 % Ni (mass fraction) possibly with other elements added to secure special properties

Note 1 to entry: Low carbon grades are typically used where welding is required.

EXAMPLE UNS S30400, UNS S30403, UNS S31600, UNS S31603.

3.23
stainless steel type 22Cr duplex
SS type 22Cr duplex
ferritic/austenitic stainless steel alloys with 30,0 < PREN < 40,0 and Cr ≥ 19 % (mass fraction)

EXAMPLE UNS S31803, UNS S32205.

3.24
stainless steel type 25Cr duplex
SS type 25Cr duplex
ferritic/austenitic stainless steel alloys with 40,0 ≤ PREN < 48,0

Note 1 to entry: This alloy is often referred to as “super duplex”.

EXAMPLE UNS S S32505, UNS S32550, UNS S32750, UNS S32760, UNS S39274, UNS S39277.

3.25
stainless steel type 6Mo
SS type 6Mo
austenitic stainless steel with PREN ≥ 40 and a nominal Mo alloying content of 6 % (mass fraction) and nickel alloys with Mo content in the range 6 % to 8 % (mass fraction)

EXAMPLE UNS S31254, UNS N08367, UNS N08926.

3.26
stainless steel type 565
SS type 565
manganese austenitic stainless steel with Mn content in the range 4 % to 12 % (mass fraction) and PREN ≥ 40

EXAMPLE UNS S34565.

3.27
tangent
straight section at the end of a bend

3.28
tightness testing
application of a pressure differential to a piping assembly to detect leakage paths or rates

Note 1 to entry: Tightness testing includes testing of mechanically completed piping systems as part of pre-commissioning activities, and sensitive leak tests as defined in ASME B31.3.

3.29
transition zone
areas of the start and stop points of induction heating, which include material that extends from the unheated mother pipe to the material that has been heated to the full bending temperature

3.30
weave bead
weld bead formed using weaving. See also stringer bead.

3.31
weaving
welding technique in which the energy source is oscillated transversely as it progresses along the weld path

3.32
weld zone
grouping of weld passes with similar parameters and function, e.g. root, fill and cap

3.33
stringer bead
weld bead formed without appreciable weaving

4 Abbreviated terms

4.1 Symbols

D	nominal pipe diameter, expressed in millimetres
H_{BW}	heated band width, expressed in millimetres
h	Maximum misalignment at a buttweld seam
L	length, expressed in millimetres
R	nominal bending radius to centreline of pipe, expressed in millimetres
r	nominal outside radius of the pipe, expressed in millimetres
t	nominal material thickness at the weld, expressed in millimetres
U_g	Geometric unsharpness

4.2 Abbreviated terms

AUT	Automatic Ultrasonic Testing
AWS	American Welding Society
aMDEA	activated MDEA
CMTR	certified material test report
CP	commercially pure (in relation to titanium materials)
CRA	corrosion resistant alloy
CSWIP	certification scheme for weldment inspection personnel
CWEng	certified welding engineer
DGA	di-glycol amine
DIPA	di-iso propyl amine
ECA	engineering critical assessment
EEA	European economic area

EWE	European welding engineer
EWF	European Welding Federation
FCAW-G	flux cored arc welding – gas shielded
FCAW-S	flux cored arc welding – self shielded
FMC/TFM	full matrix capture/total focussing method
FN	ferrite number
GMAW	gas metal arc welding
GMAW-S	gas metal arc welding – short circuiting mode of transfer
GTAW	gas tungsten arc welding
HAZ	heat affected zone
HBW	heated band width (of PWHT)
HIP	hot isostatic pressed
HRC	Rockwell C hardness number
HV	Vickers hardness number
IIW	International Institute of Welding
ITP	inspection and test plan
IWE	international welding engineer
MDEA	methyldiethanolamine
MDMT	minimum design metal temperature (synonymous with design minimum temperature as defined in ASME B31.3)
MEA	mono ethanolamine
MT	magnetic particle testing (for use on magnetic materials)
NDT	non-destructive testing
NTU	neophelemetric turbidity units
OES	optical emission spectrometry
PAUT	phased array ultrasonic testing technique
PCN	Personal Certification for Non-Destructive Testing
PED	Pressure Equipment Directive (European Directive 2014/68/EU) see Annex D
PMI	positive materials identification
PREN	pitting resistance equivalent number
PT	liquid penetrant testing (for use on non-magnetic materials)
PQR	procedure qualification record

PWHT	post weld heat treatment
QL	quality level
QMS	quality management system
RT	radiographic testing
SAW	submerged arc welding
SMAW	shielded metal arc welding
SMYS	specified minimum yield stress
SS	stainless steel
SSC	sulphide stress cracking
SWPS	standard welding procedure specification
TOFD	time of flight diffraction
WPS	welding procedure specification
UNS	unified numbering system
UT	ultrasonic testing

5 Health, safety and quality requirements

5.1 Health and safety requirements

5.1.1 The fabricator shall at least provide the following safety equipment and systems:

a) ventilation and extraction facilities for welding-related activities or work in a confined space;

b) personal protective equipment including eye, breathing and hearing protection;

c) access/scaffolding/working platforms and fall-arrest protective equipment for working at height;

d) access and secure, temporary formwork for working below-grade;

e) protective systems to prevent electric shock, build-up or discharge of static electricity, and earthing of welding current through susceptible components in the piping assembly;

f) 'whip checks' on test hoses for flushing, cleaning, leak testing/tightness testing.

5.1.2 All work undertaken in a confined space shall be managed using a permit-to-work system.

NOTE 1 ISO 45001 specifies requirements for an occupational health and safety management system, and gives guidance for its use, to enable organizations to provide safe and healthy workplaces by preventing work-related injury and ill health, as well as by proactively improving its occupational health and safety performance. IOGP Report 423 describes a process by which clients can select suitable contractors, set out expectations and requirements, award contracts, and manage all the phases of the contracting process with a view to improving client and contractor management of health, safety and environmental risks for contracted activities.

Note 2 ANSI Z49.1 and ISO/TR/18786 give specific requirements and guidance on safety in Welding fabrication activities.

5.2 Quality requirements

5.2.1 The fabricator shall operate in accordance with a QMS that meets an internationally recognized standard.

NOTE ISO 29001 and API Spec Q1 give sector-specific requirements and guidance on quality management systems.

5.2.2 The QMS of the fabricator shall include the following requirements related to the responsibilities for welding, inspection and testing personnel specified:

a) the organization shall meet the comprehensive welding quality requirements of ISO 3834-2;

b) welding coordination personnel shall demonstrate that they meet the requirements of ISO 14731 by either comprehensive level of competency or specific level of competency as appropriate for the relevant essential welding-related tasks described in ISO 3834-2;

NOTE 1 For the purposes of this provision, personnel with AWS CWEng certification in conformance to AWS B5.16 can be considered equivalent to personnel holding EWF European welding engineer (EWE) or IIW international welding engineer (IWE) certification as explained in EWF Publication EWF-663-19 and IIW publication IAB-362-19, respectively.

c) welding inspection personnel competencies shall be demonstrated in accordance with one of the following schemes:

— IIW international welding inspector – standard or IIW international welding inspector – comprehensive;

— AWS QC1 certified welding inspector or AWS QC1 senior certified welding inspector;

— CSWIP 3.1 welding inspector or CSWIP 3.2 senior welding inspector;

— PCN (British Institute of Non-Destructive Testing [BINDT], UK) - Weld inspection level 2.

NOTE 2 Welding inspection personnel with lower levels of certification can only be employed under the direct supervision of personnel having the required certification.

d) NDT personnel competencies shall be demonstrated in accordance with one of the following schemes:

— Personnel responsible for NDT activities, in accordance with ISO 9712, Level III, or equivalent.

— NDT operator, including visual inspection, in accordance with ISO 9712 level II, or equivalent. Operators simply producing radiographs and not performing evaluation, do not require level II, but shall have training comparable to ISO 9712 Level I for radiographic testing.

— UT operators performing inspection of welds in duplex and austenitic stainless steel material in accordance with ISO 9712.

— In addition, the use of AUT shall require training in operating the specific equipment and a procedure shall be established to demonstrate the ability of the operator to detect the relevant defects.

NOTE 3 Equivalent 3rd party certification scheme may for example be PCN or SNT-TC- 1A certified by ACCP.

e) Personnel responsible for undertaking PMI, hardness or ferrite testing, tightening of bolted connections, flushing/cleaning and subsequent leak testing/tightness testing activities shall demonstrate appropriate competency using industry-recognized or employer-based assurance schemes.

5.2.3 The QMS of the fabricator shall address the following activities:

a) traceability, storage and handling of piping system components, including bends, welding consumables, NDT and testing consumables to avoid damage or degradation

b) traceability and verification of each pressure retaining weld and direct attachment weld to the piping components, WPS(s) and welding consumables used, the responsible welder/welding operator, and the relevant PWHT, examination and production test records;

c) integrity management of bolted connections, including traceability and verification of bolted connections;

d) flushing, cleaning, leak testing/tightness testing and preservation, including division of piping systems into individual test packs;

e) development and implementation of an ITP for the systematic and sequential control of all fabrication, welding, examination, inspection and testing activities (including any sub-contractor activity, if applicable), and the level of fabricator and owner personnel involvement in each activity;

f) Workshop organization to prevent CRA contamination.

5.2.4 The welding consumable manufacturer shall operate in accordance with a QMS meeting an internationally recognized standard.

5.2.5 The test laboratory shall meet the requirements of ISO/IEC 17025 or another agreed internationally recognized standard, for the applicable test methods.

5.2.6 The fabricator shall maintain and retain the following documented information:

a) any documented information required by ASME B31.3;

b) all additional documented information to demonstrate that the requirements of this document have been met.

The fabricator shall hand over all relevant documented information to the owner as specified in ASME B31.3, the engineering design and this document.

5.2.7 All equipment and instruments used in support of the activities within the scope of this document shall have a valid and verified calibration certificate at time of use.

5.2.8 Heat treatment furnaces for post-bending heat treatment or PWHT shall be

a) configured to ensure that uniform heating, with or without forced circulation, is achieved, and

b) equipped with automatic temperature controlling and recording devices with an accuracy of ±1 % of their full-scale range.

NOTE Good practice for heat treatment is given in ISO 17663 and API RP 6HT.

6 Welding requirements

6.1 General requirements

6.1.1 WPSs shall include all information required by ASME Boiler and Pressure Vessel Code, Section IX or ISO 15609-1. Welding procedures shall be present at the welding station at all times and readable in a language understandable to the welder or welding operator and in English.

6.1.2 SWPSs or welding procedures that have not been qualified by the fabricator shall not be used.

6.1.3 Fabrication and welding of CRAs in a fabricator's shop shall be performed in an area reserved exclusively for these materials.

6.1.4 The fabricator shall protect CRA components or piping assembly from iron contamination, if it is impractical to segregate CRAs from carbon steels, such as during dissimilar welding at site construction.

6.1.5 Protection, such as windshields or temporary shelters, shall be provided if weather conditions can adversely affect the ability to meet the requirements of this document.

6.1.6 Pressure-retaining groove and fillet welds shall be welded with a minimum of two layers. Not applicable for mechanized orbital welding of tubing.

6.1.7 Arc strikes and stops/starts shall be confined to the weld groove. If arc strikes and stops/starts occur outside of the weld groove, they shall be removed by light grinding and the affected area shall be examined by MT or PT in accordance with 12.3 or 12.4.

6.1.8 All flux, slag and spatter shall be removed from welds and adjacent surfaces.

6.1.9 The application of peening on welds, either during or on completion of welding, shall be approved by the owner.

NOTE The use of needle guns to remove welding flux or slag is not considered to result in peening of the weld.

6.2 Welding processes

6.2.1 GTAW equipment shall be equipped with arc starting, crater eliminating and pre-gas/post-gas flow capabilities.

6.2.2 FCAW-S shall not be used for welding pressure retaining welds or direct attachment welds to pressure retaining components.

6.2.3 Controlled hydrogen welding consumable shall be used according to Table 1

Table 1 — Diffusible hydrogen limits for consumables

Base material	SMYS for the base material	Maximum diffusible hydrogen (ml/100 g)
carbon and low alloy steel	≤415 MPa (60 ksi)	8
carbon and low alloy steel	>415 MPa (60 ksi)	5
ferritic and martensitic stainless steel	all	5

6.2.5 Manually held SAW shall not be used.

6.2.6 For single-sided access welds, any slag on the internal surface of the root pass shall be removed completely. If slag removal is not feasible, a non-flux welding process shall be used.

6.3 Preparation for welding

Figure 1 stablishes the recommended distances between welds taking into consideration that:

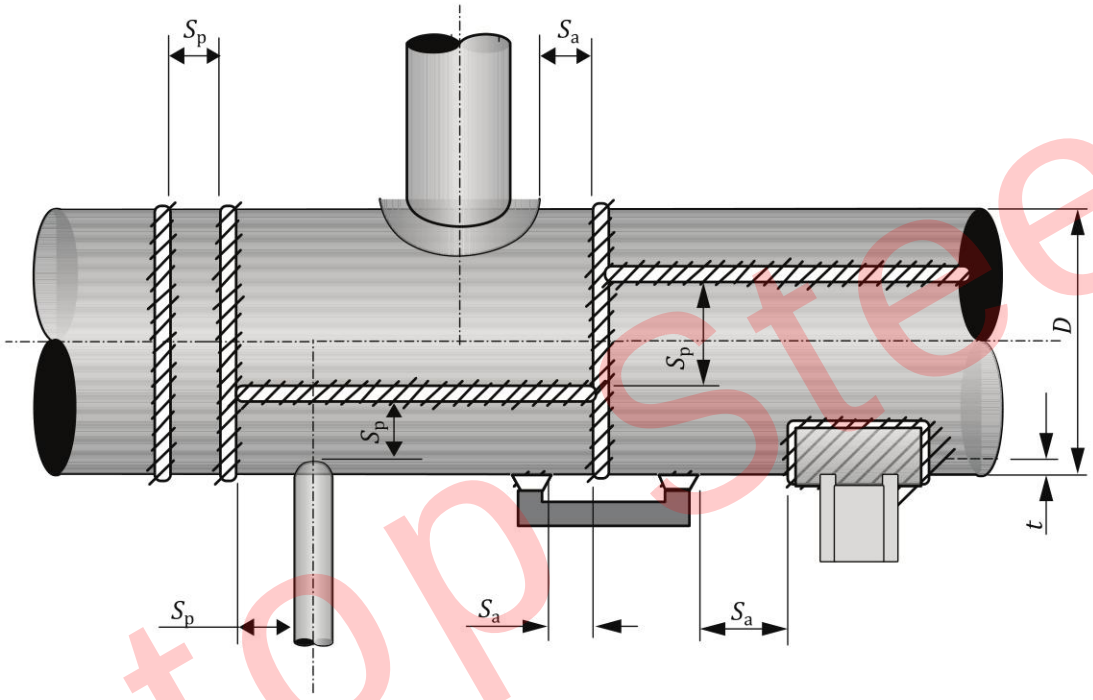
a) Separation between welds shall be arranged to eliminate or minimise the heat transfer from adjacent welds;

b) location and spacing of circumferential welds, longitudinal welds and welded branch connections shall allow for sufficient clearance to undertake any specified volumetric NDT of the weld;

c) for welded branch connections, including any reinforcing pads, and directly welded attachments shall avoid encroachment with any longitudinal seam weld or circumferential weld, except when the seam weld is fully heat treated;

d) Adjacent straight lengths of longitudinal welded pipe and/or fittings shall have the seam welds offset as indicated in Figure 1.

6.3.2 When longitudinally welded pipe and/or fittings has undergone a full heat treatment cycle subsequent to seam welding as part of the manufacturing process, offsetting may be omitted.



Key

S_p separation between any two pressure containing welds (see note) = $\sqrt{D \times t}$

S_a separation between an attachment weld an any other weld = the greater of 2 t or 50 mm

Figure 1 — Recommended distance between welds

6.3.3 In cases where meeting the weld proximity limits specified in 6.3.1 is unavoidable, the intersected longitudinal or circumferential weld shall be ground flush with the adjacent surface for a minimum distance of 50 mm or 2 t from the intersecting weld toe, and subject to MT or PT and RT or UT in accordance with 12.3 or 12.4 and 12.5 or 12.5.7, respectively.

6.3.4 Butt welds and welded branch connections, including integrally reinforced branch connections, shall be prepared as full penetration groove welds.

6.3.5 Permanent metallic backing rings shall not be used.

6.3.6 Permanent socket weld contraction rings shall only be used when approved by the owner.

6.3.7 Weld joint end preparation and root gap spacing shall conform to ASME B31.3 and the approved WPS.

6.3.8 Internal radial misalignment at butt welds shall

a) be distributed equally around the joint, and

b) not exceed the following values (see Figure 2):

— h = 1,6 mm for $t \leq 19$ mm or h = 2,5 mm for $t > 19$ mm for piping in hydrocarbon, alkaline or cyclic service; or

— $h \leq 0{,}25\ t$ with a maximum of 4 mm for all other services.

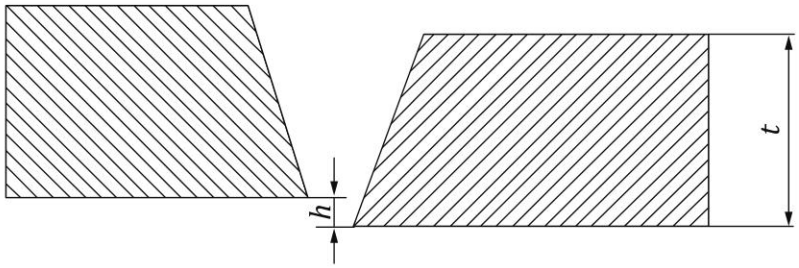


Figure 2 — Misalignment references

6.3.9 Where UT is specified for single-sided access welds joining components of unequal thickness, the thicker component shall be taper-bored on the internal surface to at least 1:4 slope. This may, in some cases, require removal of the weld reinforcement in order to apply alternative ultrasonic techniques (e.g half skip distance scanning) under agreement.

6.3.10 All piping components and sub-assemblies shall be examined before fit-up to verify freedom from contamination, loose materials and debris.

6.3.11 Temporary, fit-up attachments shall be of the same or equivalent material to the base material.

6.3.12 The weld preparation and adjacent surfaces within a minimum of 25,4 mm from the weld edge shall be cleaned to remove all visible contamination immediately prior to welding.

6.3.13 Only dedicated stainless steel wire brushes or tools shall be used to clean or prepare CRAs.

6.3.14 The weld area shall be at a minimum temperature of 3 °C above the ambient dew point temperature prior to welding, moisture on welding surface shall be removed by drying.

6.3.15 Indications or discontinuities identified on the weld bevel surface by visual examination shall be investigated by MT or PT in accordance with 12.3 or 12.4, respectively, prior to, and if applicable, after removal.

6.3.16 If carbon-arc or thermal cutting/gouging is used, the oxidation on the surface shall be completely removed to bright metal prior to welding. Carbon arc gouging shall not be used on CRA except for stainless steel 300-series with grinding after carbon arc gouging.

6.3.17 A backing gas shall be applied for CRA piping assemblies in accordance with 7.7 for:

— single sided access welds until at least 8 mm of weld metal has been deposited, unless the root is back gouged/ground to sound metal;

— tack welds in single sided access welds, unless the tack welds are completely removed;

— direct welded attachments where base material $t < 8$ mm;

— repair welds where the remaining ligament <8 mm.

6.3.18 Temporary attachments for welding alignment shall be removed by grinding prior to PWHT, if applicable, or leak testing, and the area examined by MT or PT in accordance with 12.3 or 12.4 respectively.

6.4 Welder and welding operator performance qualification

6.4.1 Welders and welding operators shall be qualified in accordance with the requirements of ASME B31.3 or ISO 9606 (all parts) and ISO 14732, respectively.

Note Endorsement of the qualification of welders and welding operators by a competent/recognized notified body or third-party organization can be required by the authorities.

6.4.2 A previous performance qualification of a welder or welding operator by others is permitted under the condition that the performance qualification has been verified by a competent notified body or third party organization.

6.4.3 Performance qualification of a welder or welding operator on production welds is not permitted.

6.4.4 Each welder or welding operator shall mark their unique identification number or symbol adjacent to each weld, or part thereof, to identify their work.

6.4.5 Welders and welding operators responsible for welding stainless steel type 22Cr duplex or stainless steel type 25Cr duplex shall be qualified using a WPS qualified in accordance with Clause 8, especially 8.3. As a minimum, the following requirements apply:

a) qualification on any UNS grade of SS type 25Cr duplex shall qualify for welding SS type 22Cr duplex, but not vice versa;

b) each completed test piece shall be subject to NDT (100 % RT and 100 % PT) and corrosion test in accordance with ISO 17781, in addition to testing described in 6.4.1.

6.4.6 Welders and welding operators responsible for welding CP titanium shall be qualified using a WPS qualified in accordance with Clause 8, specially 8.5 of this document. In addition, each completed test piece shall be subject to a bend test, and visual examination and radiography in accordance with 12.1.11 and 12.5, respectively, in addition to testing described 6.4.1.

7 Welding consumables

7.1 General requirements

7.1.1 The selection of welding consumables shall meet the requirements of ASME B31.3.

7.1.2 In cases where a welding consumable is selected that does not conform to the requirements of an ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C specification, this selected consumable shall be qualified as part of the welding procedure qualification in accordance with this document.

7.1.3 Welding consumables shall be specified on the WPS by reference to the relevant ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C specification and classification.

7.1.4 Welding consumables shall be procured in accordance with ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C:2019, SFA-5.01/SFA-5.01M or ISO 14344, and Table 2.

Table 2 — Welding filler material procurement requirements

Filler material	Lot class	Testing schedule	Inspection document
SMAW electrodes	C3	3 or H	CMTR according to — ASME Boiler and Pressure Vessel Code, Section II Materials, Part C, SFA-5.01/SFA-5.01M; or — ISO 10474 Type 3.1 for wire and Type 2.2 for flux; or — EN 10204 Type 3.1 for wire and Type 2.2 for flux
Solid metallic wires, rods and consumable inserts	S3	3 or H	
Tubular cored electrodes and rods	T2	3 or H	
SAW flux	F2	3 or H	

7.1.5 Only welding consumables certified with impact testing shall be used where impact testing of the base materials or weld metal is specified in ASME B31.3, the engineering design or this document.

7.1.6 Filler material shall be clearly identified in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C:2019, SFA-5.02/SFA-5.02M or the relevant individual SFA specification, with the identification retained until consumed.

7.1.7 Welding consumables shall be stored and handled in accordance with the manufacturer's recommendations. In addition, the following requirements apply:

a) SMAW electrodes and SAW fluxes shall be dried initially (if required). The number of re-drying cycles shall not exceed the manufacturer's recommendation;

b) storage and drying of SMAW electrodes and SAW fluxes shall be carried out in separate ovens with automatic temperature control and visible temperature indication;

c) re-dried SMAW electrodes shall be clearly identified to indicate the number of re-drying cycles;

d) any undamaged welding consumables remaining at the end of a specified task shall be returned to storage;

e) any damaged or unidentified welding consumables shall be rejected.

7.1.8 In case SAW flux is recovered and recycled, the following requirements apply:

a) the new-to-re-used recycling ratios and the number of times a flux can be recycled shall be:

   1) specified in accordance with the manufacturer's requirements;

   2) stated on the WPS;

b) the recovery process shall meet the flux manufacturer's requirements for protection from moisture and build-up of fines.

7.1.9 Welding consumables shall be used within the primary classification limits specified by the applicable AWS filler material specification and the manufacturer's recommendations.

7.1.10 Deliberate addition of principal elements through the SAW flux shall not be permitted, except to compensate for losses of alloying elements during welding.

7.1.11 Re-crushed SAW slag shall not be used.

7.1.12 Solid wire filler metals shall be dry and free from rust, oil or other foreign matter.

7.2 Additional requirements for carbon steel

7.2.1 Cellulosic covered electrodes (type EXX10-X or EXX11-X) shall not be used.

7.2.2 Welding consumables for the root and hot pass of single sided access welds, or back weld where applicable, shall be selected to avoid preferential weld corrosion, based on agreement between purchaser and fabricator.

NOTE 1 In carbon steel water injection systems, welding consumables and welding procedures that produce a deposit with either 0,8 % to 1,0 % (mass fraction) nickel or 0,4 % to 0,8 % (mass fraction) copper & 0,5 % to 1,0 % (mass fraction) nickel has been found to be effective in minimizing the likelihood of preferential weld corrosion.

NOTE 2 In sweet hydrocarbon service, the presence of corrosion inhibitors together with the filler material chemistry can influence the likelihood of preferential weld corrosion. Testing of the welding consumables in the process fluid with and without corrosion inhibitors can provide data to support the optimum filler metal chemistry.

7.3 Additional requirements for dissimilar welding

When welding SS type 22Cr duplex, SS type 25Cr duplex or high alloy stainless steels alloyed with nitrogen to carbon steels, welding consumables shall not contain deliberate additions of niobium.

7.4 Additional requirements for SS 300-series

Comparable low-carbon welding consumables shall be used for welding low-carbon grades of SS 300-series.

7.5 Additional requirements for SS type 22Cr duplex and SS type 25Cr duplex

7.5.1 Autogenous welding, including cosmetic repairs/'GTAW dressing' of the weld, shall not be applied.

7.5.2 Welding consumables shall be selected to meet the as-deposited minimum chemical composition in Table 3.

Table 3 — As-deposited chemical requirements for SS type 22Cr duplex and SS type 25Cr duplex

Element	Chemical composition limitations	
	SS type 22Cr duplex	SS type 25Cr duplex
Nitrogen	0,14 % (mass fraction) minimum	0,22 % (mass fraction) minimum
Nickel	8,0 % (mass fraction) minimum	9,0 % (mass fraction) minimum
Molybdenum	3,0 % (mass fraction) minimum	3,5 % (mass fraction) minimum
Sulphur	0,015 % (mass fraction) maximum	0,015 % (mass fraction) maximum
PREN	34,0 minimum	40,0 minimum

7.5.3 Welding consumables shall not contain deliberate additions of niobium.

7.6 Additional requirements for high alloy stainless steels

7.6.1 Autogenous welding, including cosmetic repairs/'GTAW dressing' of the weld, shall not be applied, except for autogenous mechanized GTAW orbital welding.

7.6.2 Welding consumables shall be selected with enhanced molybdenum and chromium compared to the base materials, and maximum sulphur content of 0,015 % (mass fraction).

7.7 Shielding, backing and secondary trailing gases

7.7.1 Shielding, backing and secondary trailing gases shall be procured in accordance with ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C:2019, SFA-5.32/SFA-5.32M or ISO 14175.

7.7.2 The WPS shall state the following:

a) the gas composition;

b) flow rate;

c) purity;

d) in case of backing gases, the acceptable oxygen content.

7.7.3 The maximum oxygen content of a backing gas prior to, and during, welding shall be the lesser of the value recorded during weld procedure qualification or 0,05 % (500 ppm) as measured in the back-purged volume during welding at the 12 o'clock pipe position. Where purging is directly through the root opening, an acceptable, higher maximum oxygen content to meet weld acceptance criteria in this document shall be demonstrated during the weld procedure qualification.

7.7.4 Gases for welding of SS type 22Cr duplex or SS type 25Cr duplex, and CP titanium shall not contain hydrogen.

7.7.5 For welding CP titanium, the shielding, backing and secondary trailing gases shall be maintained until the weld and HAZ metal temperature falls below 400 °C to meet the requirements in 12.2.1, unless the welding procedure qualification demonstrates that a lower temperature is required.

8 Welding procedure qualification

8.1 General requirements

8.1.1 Welding procedure qualification shall be performed in accordance with the requirements of ASME B31.3 or ISO 15614-1, ISO 15614-5 or ISO 15614-6.

8.1.2 Separate welding procedure qualification is required for the following:

— waveform-controlled welding processes;

— groove welds using consumable inserts;

8.1.3 Qualification on pipe shall qualify for plate, but not vice versa.

8.1.4 Heat input shall be calculated for the root and hot pass individually, and for typical fill and cap passes/zones. The average measured values for each pass/zone shall be used to calculate the allowable range of heat input:

a) where impact or hardness testing is specified by ASME B31.3, the engineering design or this document;

b) for welding of SS type 22Cr duplex and SS type 25Cr duplex, high alloyed stainless steels or CP titanium.

8.1.5 In addition to ASME B31.3 and ASME Boiler and Pressure Vessel Code, Section IX:2019, the following requirements apply:

a) specimens for impact and corrosion testing shall be taken from the location with the highest heat input;

b) specimens for metallographic microstructural examination and hardness testing shall be taken from the location with the lowest heat input;

c) for sub-size specimens, instead of temperature reduction as established in ASME B31.3, the following reduction factors of energy shall be applied: 5/6 for 7,5 mm specimen and 2/3 for 5 mm specimen.

8.1.6 If temper bead welding is employed, the relevant requirements in ASME Boiler and Pressure Vessel Code, Section IX:2019, shall apply.

8.1.7 For piping systems above pressure class 2500 the impact testing acceptance criteria shall be according to ASME B31.3 chapter IX, except for duplex material, described in 8.3.

8.2 Additional requirements for carbon steels

Except for high pressure service, as stated in 8.1.7, the acceptance criteria for impact testing, at specified temperature, shall be a minimum average of 27 J, based on three full-size specimens, with minimum of 20 J for any one specimen.

8.3 Additional requirements for SS type 22Cr duplex and SS type 25Cr duplex

8.3.1 Separate welding procedure qualifications are required for each UNS designated alloy, with exception of the following:

— UNS S31803 and UNS S32205 are interchangeable;

— UNS S32760, UNS S32750, UNS S32550 and UNS S32505 are interchangeable.

8.3.2 Welding procedure qualification test pieces shall be selected to meet the qualified thickness ranges specified in Table 4.

Table 4 — Qualified thickness range for SS type 22Cr duplex and SS type 25Cr duplex welding procedures

Wall thickness of test piece	Qualified wall thickness range
$t \leq 6{,}35$ mm	t to 2 t up to and including a maximum of 12,7 mm
$t > 12{,}7$ mm	0,5 t to t + 12,7 mm

8.3.3 Heat inputs shall be limited to the following:

— 0,5 kJ/mm to 2,5 kJ/mm for SS type 22Cr duplex;

— 0,5 kJ/mm to 1,5 kJ/mm for SS type 25Cr duplex;

8.3.4 Forced or accelerated cooling shall not be applied, unless qualified in the PQR and approved by owner

8.3.5 Welds shall

a) be subject to testing in accordance with ISO 17781:2017, 4.3,

b) meet the requirements in ISO 17781:2017, Clause 5, and

c) meet QL II with respect to minimum absorbed energy requirements per ISO 17781:2017, Table 3, unless otherwise specified in the engineering design. Lateral expansion values at the impact test temperature shall be documented, if required by ASME B31.3.

8.3.6 Weld repairs shall be qualified in accordance with 12.10.4.

8.4 Additional requirements for high alloyed austenitic stainless steels

8.4.1 Separate welding procedure qualifications are required for each UNS designated alloy with exception that stainless steel type 565 qualifies stainless steel type 6Mo, but not vice versa..

8.4.2 Welds shall be subject to corrosion testing to ASTM G48 Method A. In addition, the following requirements apply:

a) the test temperature shall be 40 °C with an exposure time of 24 h;

b) the test shall expose the external and internal surfaces and a cross-section surface in full wall thickness;

c) cut edges shall be prepared according to ASTM G48;

d) the internal and external surfaces shall not be ground/polished;

e) the complete specimen may be pickled in an acid solution in accordance with ASTM A380 before being weighed and tested;

f) the acceptance criteria shall be no pitting at ×20 magnification and weight loss shall not exceed than 4,0 g/m^2.

NOTE PT can be used to judge whether pitting is present or not.

8.5 Additional requirements for CP titanium

8.5.1 Welds shall be subject to visual examination and radiography in accordance with 12.2.1 and 12.5, respectively.

8.5.2 In case of dispute regarding the maximum oxidation levels in accordance with 12.2.1, additional hardness testing on a cross section of the base material, HAZs and weld metal shall be performed in accordance with the survey requirements in either ISO 9015-1 or ISO 15156-2, using HV10 methods.

8.5.3 In case additional hardness testing of the weld metal and HAZs is required, the average of the readings shall not exceed the average base material hardness by more than 40 HV10 with no individual reading greater than 50 HV10.

8.6 Additional requirements for materials in sour service

8.6.1 Where a maximum hardness value for welds and HAZs is specified in ISO 15156-2 or ISO 15156-3, hardness testing shall be performed on the PQR(s) for

a) pressure retaining butt welds,

b) pressure retaining fillet welds, and

c) partial or full penetration repair welds.

8.6.2 Carbon steel welding consumables and welding procedures that produce a deposit containing more than 1 % Ni (mass fraction) shall be subject to SSC qualification testing in accordance with Annex B of ISO 15156-2.

8.7 Welding procedure qualification essential variable

In addition to the essential and supplementary essential variables listed in ASME B31.3, ASME Boiler and Pressure Vessel Code, Section IX:2019 or the applicable parts of ISO 15614, a WPS shall be requalified when there is a change in the variable from that recorded on the PQR in accordance with Table 5.

Table 5 — Additional essential variables requiring re-qualification

Variable and specific application	Change in variable from that recorded on PQR
Joint design	
All welding processes	— Change from double-sided welding to single-sided welding; or — A decrease in groove angle of more than 10° for groove angles less than 60°; or — A decrease in groove angle when groove angle is less than 30°.
SS type 22Cr duplex and SS type 25Cr duplex High alloyed stainless steels	Root gap tolerance of ±1,0 mm
Base materials	
Carbon steel in the following applications: — in sour service; — subject to impact testing; — $t \geq 38$ mm; — base material, carbon equivalent, $C_E > 0{,}43$ %; — subject to PWHT in accordance with Table 7	Increase in C_E of more than 0,03 %
SS type 22Cr duplex and SS type 25Cr duplex	— Change in the UNS designation out with limits specified in 8.3.1; or — Thickness of test piece outside of qualified thickness range in 8.3.2
High alloy stainless steels	Change in the UNS designation with the exception that SS type 565 qualifies SS type 6Mo, but not vice versa
Welding consumables	
All welding consumables	Consumable chemistry not covered by an ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C, SFA classification
Carbon steel	— The nominal chemical composition of deposited weld metal, including change from ASME Boiler and Pressure Vessel Code, Section IX, A-No.1 to A-No.2 and vice versa; or — Wire chemistry from one ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C, SFA classification to another; or — Manufacturer or trade name designation for ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C, SFA "G" classification

Table 5 *(continued)*

Variable and specific application	Change in variable from that recorded on PQR
Where impact testing or hardness limit is specified High alloyed stainless steels CP titanium	Manufacturer or trade/brand name of welding consumable
SS type 22Cr and SS type 25Cr duplex	— Manufacturer or trade/brand name of welding consumable; or — Change from SS type 25Cr consumable to SS type 22Cr consumable for welding root pass and second pass of SS type 22Cr base materials and vice versa
Automated GTAW	Change from hot or cold wire addition and vice versa
Automated GTAW or GMAW process	Wire manufacturer and diameter
SAW	Wire-flux (including composite cored electrode) combination manufacturer and trade name designation
Consumable inserts	— Addition or deletion of consumable insert; or — Manufacturer and trade name designation; or — ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C, SFA classification, class and style; or — Base material not covered by an AWS classification
Secondary trailing gas	— Composition; or — Purity; or — Delivery system
Backing gas	— Addition or deletion; or — Composition; or — Purity; or — Specified flow rate range; or — Maximum measured oxygen content
FCAW-G cored or composite cored electrodes	— Wire chemistry from one ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C, SFA classification to another; or — Where impact testing is specified, position indicator from “1” to “0”, but not vice versa
Positions	
Automated or mechanised GTAW or GMAW processes	Pipe position
Preheat & interpass temperature	
Carbon steel in sour service	Reduction in preheat temperature
All materials	Increase in interpass temperature
PWHT	
Carbon steel in sour or alkaline service	Reduction in PWHT temperature or holding time
Electrical characteristics	
Automated or mechanised GTAW or GMAW processes	Programme schedule values of ±10 % (current, pulse times, voltage, travel speed, wire feed speed)

Table 5 *(continued)*

Variable and specific application	Change in variable from that recorded on PQR
Carbon steel (SMYS ≤ 400 MPa)	When impact or corrosion testing is required a change exceeding ±25 % of the average heat input for a weld zone measured in the PQR. In sour service, the minimum heat input shall not be lower than the minimum value from the PQR.
Carbon steel (SMYS > 400 MPa)	When impact or corrosion testing is required a change exceeding ±15 % of the average heat input for a weld zone measured in the PQR. In sour service, the minimum heat input shall not be lower than the minimum value from the PQR.
SS type 22Cr and SS type 25Cr duplex	— Change exceeding average heat input value of ±15 % for each weld pass/zone — For heat input calculation see 8.1.4
High alloyed stainless steels	Change exceeding average heat input value of ±15 % for each weld pass/zone
Technique	
Automated or mechanised GTAW or GMAW process	— Welding direction; or — Welding head, power source, control & programming unit; or — Software version
Waveform-controlled processes	— Equipment manufacturer or model; or — Software version
Weaving	When impact testing is required, any change from stringer bead to weaving technique or vice versa

9 Preheat and post weld heat treatment'

9.1 Preheating

9.1.1 Preheating shall meet the requirements of ASME B31.3 for all types of welding.

9.1.2 A minimum preheat temperature of 95 °C shall be applied for carbon steels, in case the base material $C_E \geq 0{,}46$ % and/or $t \geq 38$ mm.

9.1.3 The method of applying, checking and controlling preheat and inter-pass temperatures shall be stated on the WPS.

9.1.4 Where preheat is specified for welding, preheat shall also be applied prior to any thermal cutting or gouging.

9.1.5 Preheat shall be applied until the minimum temperature is achieved throughout the entire thickness of the weld and at least 75,0 mm on each side of the weld.

9.1.6 Where oil or natural gas is used as fuel, this fuel shall be of low sulfur grade. The fuel/air mixture shall produce a neutral flame.

9.1.7 For groove weld with $t > 19$ mm, preheat shall be applied by electric resistance or induction methods. Other gas preheating devices may be considered as acceptable provided a uniformity temperature test is agreed by parties to qualify the heaviest thickness to be used in production.

9.1.8 Once preheat is applied, welding shall not be interrupted or stopped until the greater of 30 % of the weld groove depth or 10,0 mm has been completed. In cases where this is unavoidable, MT or PT in accordance with 12.3 or 12.4 shall be performed before preheating and welding restarts. MT or PT is not necessary if preheating temperature is maintained.

9.1.9 For low-alloy steels, the preheat shall be maintained until PWHT is completed, unless a purchaser-approved dehydrogenation heat treatment (DHT) is applied immediately after welding is complete.

9.1.10 The interpass temperature shall neither exceed the maximum recorded on the PQR nor the limits in Table 6.

Table 6 — Maximum interpass temperatures

Material type	Maximum interpass temperature
Non-impact tested carbon steels	315 °C
Impact tested carbon steels	250 °C
SS 300-series	175 °C
SS type 22Cr duplex	150 °C
SS type 25Cr duplex	120 °C
High alloyed stainless steels	150 °C
Copper-nickel 90-10, aluminium bronze	175 °C
Nickel-base alloys	175 °C
CP titanium	150 °C

9.1.11 Preheat and interpass temperatures shall be measured using temperature indicating crayons (carbon steels only), thermocouples, contact or non-contact pyrometers. Regarding the non-contact pyrometers, the fabricator shall shall apply an agreed method with the user.

9.1.12 The preheat temperature and preheat maintenance temperatures shall be measured at a distance of not less than 1,5 in (38 mm) on either side of the weld groove.

9.1.13 Cutting torches shall not be used for pre-heating.

9.2 Post weld heat treatment

9.2.1 PWHT shall meet the requirements of ASME B31.3.

9.2.2 All PWHT operations shall be performed in accordance with a written procedure.

9.2.3 The method of applying, checking and controlling PWHT, including heating/cooling rates and hold time and temperatures, shall be stated on the WPS or by reference to the PWHT procedure.

9.2.4 PWHT shall be applied in a uniform manner throughout the entire thickness of the weld either in a furnace or for local PWHT, using electrical resistance or induction methods.

9.2.5 Direct flame impingement or an exothermic heat source on any part of the assembly shall not be applied.

9.2.6 PWHT of carbon steels shall be as specified in Table 7.

Table 7 — PWHT holding temperatures and holding times

Fluid service	Design temperature	Nominal material thickness	Minimum holding temperature [a]	Minimum time at holding temperature
All (except as modified below)	All	≤19 mm	None	Not required
		>19 mm [b]	595 °C [c]	1 h/25 mm, 1 h minimum
MEA, DIPA, Potassium carbonate	All	All	620 °C [d]	1 h/25 mm, 1 h minimum
DEA, MDEA, aMDEA	>60 °C			
DGA	>30 °C			
Sulfinol	>90 °C			
Caustic	>40 °C			

[a] The maximum PWHT temperature shall be at least 20 °C below the minimum tempering temperature for base materials subject to a tempering heat treatment during manufacture, unless acceptable properties at a different temperature and hold time are demonstrated during weld procedure qualification.

[b] Exemption from PWHT is not permitted, unless supported by a specific ECA, generic industry guidance or documented and relevant safe operating experience, and approved by owner. EEMUA 235 can be referenced as an example of generic industry guidance.

[c] Alternative lower PWHT temperatures of ASME B31.3 shall not be applied for welds exposed to sour environments.

[d] Alternative lower PWHT temperatures of ASME B31.3 shall not be permitted.

9.2.7 All machined surfaces shall be protected to prevent oxidation or damage.

9.2.8 Support shall be provided to prevent deformation during PWHT.

9.2.9 Thermocouples shall be insulated from the heat source.

9.2.10 For PWHT of piping assemblies undertaken in a furnace, the following requirements apply:

a) furnace shall be electrical or fired with low sulfur fuel;

b) the fuel/air mixture shall produce a neutral flame;

c) a heat treatment of a part of the piping assembly in a furnace may be applied, provided the length, L, of the overlap of the previously heat-treated section is the greater of 1 500 mm or the value as given in Formula (1):

$$L = 2{,}5\sqrt{(2D\text{-}4t)t} \tag{1}$$

d) thermocouples attached directly to the internal, as far as pratical, or external surfaces at the thickest and thinnest component section, per each furnace heating zone, shall be used to continuously and automatically monitor, control and record the temperature on a chart from the start of the controlled heating cycle to the completion of the controlled cool down cycle.

9.2.11 For welds subject to local PWHT, the following requirements apply:

a) the minimum heated band width, HBW, shall be the greater of the value as determined in accordance with AWS D10.10 or the value given in Formula (2):

$$H_{BW} = 2{,}5\sqrt{Rt} \tag{2}$$

b) the bore or ends of the pipe shall be plugged or closed to avoid through-draughts.

c) the minimum number and placement of thermocouples used to continuously and automatically monitor, control and record the temperature on a chart from the start to the completion of the controlled heating and cool down cycle shall be determined in accordance with AWS D10.10.

9.2.12 The results from all PWHT shall be documented.

10 Bending of pipe

10.1 General requirements

10.1.1 Pipe bending engineering design shall meet the requirements of ASME B31.3 and element data sheet provided in Annex B and Annex C.

NOTE Further good practice for pipe bending is given in PFI ES-24.

10.1.2 All bending operations shall be performed in accordance with a written procedure.

10.1.3 Pipe selected for bending shall not include circumferential groove welds or attachment welds in the bend area, transition zone or within the first 50,8 mm or 2 *t*, whichever is greater, of the tangent.

10.1.4 For single plane bends, pipe with a longitudinal seam weld shall have the weld axis orientated within ±40° in relation to the pipe neutral axis.

10.1.5 Direct flame impingement shall not be applied.

10.1.6 For bending of CRA pipe, any lubricant used shall have a maximum of 50 mg/l soluble halides. All lubricants used during bending operations shall be completely removed from the surface of the bend on completion.

10.1.7 A qualification bend shall be produced for any /cold formed and induction bends.

10.1.8 Essential variables for procedure qualification are specified in Table 8.

Table 8 — Essential variables for bend procedure qualification

Variable	Essential variable
Material	Change of MDS or type of material grade
Type of pipe	Welded pipe qualifies seamless pipe, but not vice-versa
Bend radius	One radius qualifies all larger radii, but not vice-versa
Diameter	+0 %, -50 %
Weld seam location	±15° from qualification bend location
Mother pipe $t \leq 19$ mm	+10 %, -25 %
Mother pipe $t > 19$ mm	+0 %, -25 %
Post bend heat treatment	Any change
Type of bending equipment	Any change
Induction bend forming speed	Greater of ±2,5 mm/min or ±10 %
Induction bend coolant	Any change
Induction bend coolant flow rate/pressure	±10 %
Induction bend coolant temperature	±15 °C
Induction bend power	±5 % in steady conditions

Table 8 *(continued)*

Variable	Essential variable
Induction bend frequency	±20 %
Hot forming temperature	±25 °C

10.1.9 For hot induction bending, all testing of qualification bends shall be according to Table 9.

Table 9 — MPS qualification test for bend in carbon and stainless steels, nickel alloys and clad pipe[a,g]

Type of tests	Carbon and low alloy steel	Duplex SS	Austenitic SS and Nickel alloys	CS Clad[g]	Test conditions and acceptance criteria
Tensile	T	T	T	T	According to the mother pipe specification.
Tensile transverse weld	T	T	T	T	
Charpy V-notch (CVN)	T[b]	T[b]	N	T	
Through thickness hardness (Including HAZ if applicable)	T	N	N	T[c e]	
Microstructure	N	T	T	T[d]	
Corrosion	N	T	T	N	
Bend test	T	N	N	T[g]	ISO 15614-1/ASME IX
Surface NDT[f]	T and P	T and P	T and P	T and P[g]	
Bend body (UT) laminations	N	N	N	P	
Residual magnetism ends	P	N	N	P	<2 mT (20 Gauss)

[a] Definition of N, O, T and P shall be as follows:

N – Not required.

O – Performance of the test or inspection on a production induction bend may be required by agreement.

P – Required for each production bend.

T – Required for each test bend.

[b] For bends with wall thickness greater than 20 mm, additional Charpy V-notch testing shall be performed during MPS qualification testing. In addition to the test pieces sampled 2 mm below the outer surface, the same number of specimens shall be sampled 2 mm below inner surface position in the following locations:

— transition zones base metal (if applicable)

— bend extrados base metal

— bend intrados base metal

— bend weld metal (if applicable)

[c] The clad layer and interface to carbon or low-alloyed steel shall be tested in accordance with ASME IX.

[d] The cladding thickness shall be verified by destructive testing at the extrados location. The cladding thickness shall be minimum 3 mm after bending.

[e] For clad pipe bends the MPS qualification shall repeat the mechanical testing from the clad WPQR, i.e. side bend and hardness tests, ref. ISO 10423 PSL 3.

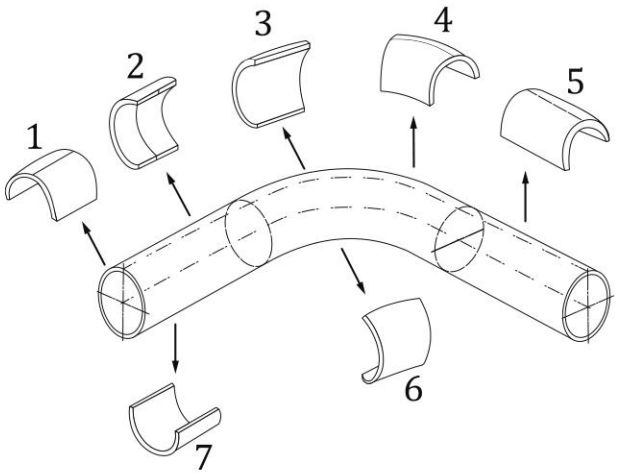
[f] For all bends, independent of material type, the bend body shall be visual and surface inspected according to ISO 15590-1.

[g] The cladding of carbon or low-alloyed steel shall be 100 % inspected with LP and bond line integrity with UT per API 6A/ISO 10423 PSL 3.

10.1.10 For hot induction bending, the tests shall be located as specified in Table 10 and Figure 3.

Table 10 — Location of test specimens and type of destructive testing of qualification test bend dependent of type of material, see Table 9

Location, ref. Figure 3	Type of test
Tangent base metal (7) Testing after bending is not necessary if test results are available for mother pipe and the tangent is not heat-treated during induction bending or subsequent heat treatment.	— Tensile — Charpy V-notch — Microstructure — Corrosion test — Through-thickness hardness
Tangent weld (1) Testing after bending is not necessary if test results are available for mother pipe and the tangent is not heat-treated during induction bending or subsequent heat treatment.	— Tensile transverse, ISO 15614-1/ASME IX — Microstructure — Charpy V-notch — Corrosion test — Through-thickness hardness — Guided bend, ISO 15614-1/ASME IX
Transition zones base metal extrados, start and stop (2) Testing in stop transition zone is not required provided quenching of heated zone is carried out continuously. (No release of pipe clamp needed.)	— Tensile — Charpy V-notch — Microstructure — Corrosion test — Through-thickness hardness
Transition zones weld (start and stop) (5) Testing in stop transition zone is not required provided quenching of heated zone is carried out continuously. (No release of pipe clamp needed.)	— Microstructure — Charpy V-notch — Corrosion test
Bend extrados base metal (3)	— Through-thickness hardness
Bend intrados base metal (6)	— Tensile — Charpy V-notch — Microstructure — Corrosion test — Through-thickness hardness
Bend weld (4)	— Tensile transverse, ISO 15614-1/ASME IX — Microstructure — Charpy V-notch — Corrosion test — Through-thickness hardness — Guided bend, ISO 15614-1/ASME IX



Key

1 tangent weld
2 transition zone base metal (both stop and start transitions)
3 bend extrados base metal
4 bend weld
5 transition zone weld (both stop and start transitions)
6 bend intrados base metal
7 tangent base metal

Figure 3 — Location for extraction of test samples

10.2 Heat treatment of bends

10.2.1 Cold formed bends shall be heat treated in accordance with

a) when required by ASME B31.3, and

b) the requirements in Table 11.

Table 11 — Additional criteria for heat treatment after cold bending

Material	Service	Additional criteria for heat treatment
P-No 1 through P-No 6	Non-Impact tested	According to cold bending and forming requirements of ASME B31.3
Carbon steels	Impact tested [a]	Fibre elongation exceeds 5 %
	Alkaline service	
	Sour service	Hardness value or fibre elongation after bending exceeds the maximum value specified in ISO 15156-2
SS 300-series	Impact tested [a]	Fibre elongation exceeds 5 %
	Sour service	Hardness value after bending exceeds the maximum value in ISO 15156-3
SS type 22Cr duplex SS type 25Cr duplex	Impact tested [a]	Fibre elongation exceeds 5 %
	Sour service	Required unless cold formed bend is qualified in accordance with ISO 15156-3
	Subsea (non-sour)	Hardness value after bending exceeds 35 HRC

[a] Only required when impact testing is specified in ASME B31.3.

Table 11 *(continued)*

Material	Service	Additional criteria for heat treatment
High alloy stainless steel	Impact tested [a]	Fibre elongation exceeds 5 %
	Sour service	Hardness value after bending exceeds 35 HRC
Other CRA materials	Sour service	Hardness values after bending exceed maximum values in ISO 15156-3

[a] Only required when impact testing is specified in ASME B31.3.

10.2.2 Hot formed bends shall be heat-treated in accordance with 10.2.3 as a separate operation to the forming operation.

NOTE Separate heat treatment of induction bends can be omitted, if satisfactory results are obtained from the induction bending process itself.

10.2.3 Heat treatment after bending shall be performed in accordance with one of the following methods as appropriate to the material grade:

— using the original heat treatment methodology, hold temperature and time, and heating/cooling rate as specified in the relevant inspection document;

— as a stress relief heat treatment at a temperature at least 20 °C below any minimum specified tempering temperature, unless acceptable properties at a different temperature and hold time are demonstrated during bend procedure qualification; or

— during the final furnace PWHT of the piping assembly or sub-assembly in accordance with 9.2.

10.3 Examination of bends

10.3.1 Each qualification and production bend, including any longitudinal seam weld, shall be

a) cleaned of scale, and

b) subject to the examination and testing requirements in Table 12.

Table 12 — Examination and testing of bends

Test	Qualification bend	Production bend
Visual examination	All bends shall be free from cracks, buckling, gouges, flattening, wrinkling, die marks or other surface imperfection out with the requirements of ASME B31.3 or the engineering design	
Physical inspection	The minimum and maximum thickness, finished dimensions, angularity, profile, flattening, peaking and ovality measurements shall meet the requirements of ASME B31.3 and the engineering design	
NDT	For each bend, the intrados and extrados, including the greater of 50,8 mm or 2.t of the tangent area (and including the start/stop transition zone of induction bends), shall be examined by MT or PT in accordance with the requirements of 12.3 or 12.4, and RT or UT in accordance with 12.5 or 12.5.7 of the longitudinal seam weld (if present)	
Mechanical and corrosion testing	Properties from samples taken from the extrados, and the extrados start/stop transition zone for induction bends, shall meet the requirements of the product material specification and engineering design	N/A
Hardness testing	In accordance with the product material specification or engineering design	All bends shall be tested in accordance with 12.8

10.3.2 Rejected bends shall be either re-worked and re-heat treated, if applicable, once or replaced in their entirety.

10.3.3 The results of any heat treatment and all examination and testing shall be documented.

11 Installation

11.1 General requirements

11.1.1 Assembly and erection shall meet the requirements of ASME B31.3, the engineering design and this document.

11.1.2 All piping assemblies, sub-assemblies, components and in-line equipment or instruments shall be examined before assembly and erection to verify freedom from contamination, loose materials and debris.

11.1.3 Open ends shall be blanked until ready for connection.

11.1.4 Fabricated pipe spool alignment tolerances shall meet the requirements of ASME B31.3 and PFI ES-3, unless specified otherwise in the engineering design.

11.1.5 Heating of piping to correct misalignment is prohibited.

11.2 Threaded connections

11.2.1 For non-seal welded threaded connections, only liquid thread joint sealant/compound, applied to the male end, shall be used.

11.2.2 For seal welded threaded connections, a maximum of three threads shall be visible prior to welding.

11.3 Bolted connections

11.3.1 Bolted connections shall meet the requirements in ASME B31.3 for flanged joints, the engineering design.

11.3.2 The integrity of bolted connections shall be managed to ensure they meet the requirements in 13.3 and 13.4.

NOTE ISO 27509, ASME PCC-1 and Energy Institute guidelines[24] can be referenced in developing integrity management processes and procedures for bolted connections.

11.3.3 Bolted connections to static equipment and rotating/reciprocating machinery shall be offered-up 'strain-free' and both mating flanges/hubs checked for misalignment, within the specified tolerances, prior to connecting to the equipment.

11.3.4 All torqueing and tensioning equipment shall be calibrated and have a valid calibration certificate. Maximum validity for calibration certificate is 12 months.

11.3.5 All bolted connection shall be tagged (whether temporary or permanent) with its unique identification number and the means to document the status of the connection and the personnel responsible for assembling, tightening and inspecting it.

NOTE Tags can be permanent (e.g. if a life-cycle record is required) or temporary (e.g. if its purpose is only to show status during construction/commissioning).

11.3.6 All bolted flange and clamp connections shall have controlled tightening by means of manual torque wrench or hydraulic bolt tightening equipment. For bolts with diameter larger than 1 inch, hydraulic equipment (tensioning or torque) shall be used.

11.3.7 The method selected for tightening bolted connections shall be qualified by tightening joints under controlled conditions using the same flange size and rating, bolting and flange/clamp materials, lubricant and equipment as proposed for production tightening.

11.3.8 Each completed bolted connection shall be inspected to verify that

a) its alignment, correct gasket and fasteners are installed,

b) there are no loose bolts/nuts, and

c) for bolted connections, the tag documentation is complete and represents its specified status.

11.3.9 Unacceptable bolted connections shall be re-worked and re-inspected. For bolted connections, the tag shall be updated to document the rework status.

11.3.10 Where a bolted connection is released ('broken') either prior to, or after, leak testing or tightness testing, the following requirements apply:

a) the same methodology as used for the original tightening process shall be followed for re-tightening the connection;

b) the alignment, gasket/seal and condition of gasket seating surface/metal sealing face shall be assessed for cleanliness or damage;

c) gaskets/seals shall be replaced with new ones;

NOTE Metallic ring joint gaskets and metallic seals can be re-used, if recommended by the gasket/seal manufacturer and if they do not show signs of damage.

d) for bolted connections, the tag shall be updated to document the rework status.

11.3.11 The results from tightening of bolted connections shall be documented in accordance with 5.2.6.

12 Inspection, examination and testing

12.1 General requirements

12.1.1 Inspection, examination and testing shall be performed in accordance with the requirements of ASME B31.3, Chapter VI.

12.1.2 All examination activities shall be performed in accordance with a written procedure in accordance with ASME Boiler and Pressure Vessel Code, Section V:2019, T-150.

12.1.3 The results of all inspection, examination and testing shall be included in the final handover documentation in accordance with 5.2.6, unless otherwise specified in this document.

12.1.4 The examination category for specific fluid services, pressures and temperatures, and construction materials is defined in Table 13.

Table 13 — Definition of examination category

NDT Category[a]	System service	Pressure class	Design temperature °C
1[b c]	Category D fluid service non-flammable and non-toxic fluids	150	-29 to 185
2	Normal fluid service	150 and 300	Below creep range
3	Normal fluid service	600 and above	All
	Severe cyclic service	All	All
	Category M fluid service	All	All
	High temperature service	All	Above creep range

[a] For NDT category definition, if criteria is valid for more than one category, the higher NDT category prevails.

[b] Applicable to carbon steels and stainless steel type 316 only.

[c] Applicable for all materials in open drain systems.

12.1.5 The type and extent of NDT per examination category shall be in accordance with the additional requirements in Table 14.

Table 14 — Examination category, type and extent of NDT

Examination category	Weld type	Type & extent of NDT		
		Visual[a]	RT or UT[b,c]	MT or PT
1	Circumferential groove weld Contour/extruded outlet fitting groove weld	100 % [a]	5 % random spot	5 % random spot
	Other branch connection grove welds, including integrally reinforced branch connections	100 % [a]	Not required	5 % random spot
	Socket weld Pressure retaining fillet weld	100 %	Not required	5 % random spot
	Non-pressure retaining fillet weld Removal of temporary attachment welds	100 %	Not required	Not required
2	Circumferential groove weld Contour/extruded outlet fitting groove weld	100 % [a]	5 % random	5 % random
	Other branch connection groove welds, including integrally reinforced branch connections	100 % [a]	5 % random	5 % random
	Socket weld	100 %	5 % random pipe-socket gap	5 % random
	Pressure retaining fillet weld Non-pressure retaining fillet weld Removal of temporary attachment welds	100 %	Not required	5 % random

[a] The internal surface of the root pass of welded branch connections shall be visually examined to verify conformance with the acceptance criteria in ASME B31.3, Table 341.3.2 or as specified in this document.

[b] In-process examination shall not be substituted for all or part of the specified RT or UT examination.

[c] UT may be used to examine the root area in partially completed welds in thicker-section components to mitigate the need for through-wall repairs after the weld is completed.

Table 14 *(continued)*

Examination category	Weld type	Type & extent of NDT		
		Visual[a]	RT or UT[b,c]	MT or PT
3	Circumferential groove weld Contour/extruded outlet fitting groove weld	100 % [a]	100 %	100 %
	Other branch connection groove welds, including integrally reinforced branch connections	100 % [a]	100 %	100 %
	Socket weld	100 %	5 % random pipe-socket gap	100 %
	Pressure retaining fillet weld Non-pressure retaining fillet weld Removal of temporary attachment welds	100 %	Not required	100 %

[a] The internal surface of the root pass of welded branch connections shall be visually examined to verify conformance with the acceptance criteria in ASME B31.3, Table 341.3.2 or as specified in this document.

[b] In-process examination shall not be substituted for all or part of the specified RT or UT examination.

[c] UT may be used to examine the root area in partially completed welds in thicker-section components to mitigate the need for through-wall repairs after the weld is completed.

12.1.6 Where 5 % random or 5 % random spot examination is specified, the following requirements apply:

a) the welds selected as part of the 5 % sample shall include each welder's or welding operator's work for each WPS used;

b) each welder or welding operator shall have their first two production welds (or their part if the weld is made by more than one welder/welding operator) in the lot examined as part of the 5 % sample;

c) examination shall be undertaken immediately upon completion of the designated lot;

d) results shall not be applied to incomplete welds at the time of examination;

e) progressive sampling for examination shall be performed immediately after a defective weld is found;

f) progressive sampling shall not be accepted as part of the minimum random or random spot examination requirements;

g) for 5 % random spot examination, the lesser of 150,0 mm or 25 % of the weld length shall be examined.

12.1.7 Welders or welding operators shall be re-tested and, if necessary, re-trained, when their repair rate exceeds criteria specified in the engineering design.

12.1.8 Each welder or welding operator subject to re-testing shall, on recommencing work, have their first five production welds completely examined.

12.1.9 Use of ultrasonic examination in-lieu of radiographic examination for welds between 5,5 mm and 9,5 mm thickness or where an acceptable radiographic exposure technique is not capable of meeting the requirements of ASME B31.3 and this document, may be applied subject to meeting the requirements of 12.6.3. Recordable automated or semiautomated (e.g.TOFD and /or Phased Array) ultrasonic examination shall be used when replacing radiographic examination, providing that recordable UT.

12.1.10 Closure welds shall be subject to additional examination as follows:

a) examination of all weld preparations by MT or PT in accordance with 12.3 or 12.4;

b) in-process examination;

c) examination of completed groove welds by MT or PT in accordance with 12.3 or 12.4, and RT or UT in accordance with 12.5 or 12.6;

d) examination of completed socket welds or seal welded threaded joints by MT or PT in accordance with 12.3 or 12.4;

e) production tests as specified in 12.7, 12.8 or 12.9 as applicable.

12.1.11 Documentation of all examinations shall be prepared in accordance with ASME Boiler and Pressure Vessel Code, Section V:2019, T-190.

12.2 Visual examination

12.2.1 The discolouration ('heat tint') of weld metal and HAZ of CRA materials shall be visually examined before cleaning, both during and after completion of welding, to verify acceptable gas shielding or back purging is in accordance with Table 15. Annex A provides guidance on acceptable and unacceptable oxidation levels.

Table 15 — Maximum oxidation levels for CRAs

[a] Welds shall not be ground or brushed before visual examination.		

Material	Weld colour	Remedial action
All CRAs (with exception of CP titanium)	Weld colour of light straw/brown to brown	No action
	Narrow band of dark brown and intermittent spots of blue	No action
	Darker blue or more extensive oxidation	Remove oxidation by mechanical means or by chemical cleaning and re-examine weld
CP titanium [a]	Silver	No action
	Light straw	No action
	Blue, grey or powdery white	Completely remove weld and oxidised area, prepare, re-weld and re-examine
[a] Welds shall not be ground or brushed before visual examination.		

12.2.2 When internal root bead requires to be smooth and flush, a visual examination shall be performed to guarantee that weld surface is aligned to internal diameter of the pipe.

12.2.3 For carbon steels in sour service, the height of the root pass internal reinforcement or protrusion shall not exceed 3,0 mm for $t > 6{,}0$ mm. This shall be included in the weld qualification procedure and submitted to visual inspection according to 12.2.4(d).

12.2.4 The results of the following visual examinations shall be reported and recorded in accordance with the requirements in ASME Boiler and Pressure Vessel Code, Section V:2019, T-990 or ISO 5817 quality level B:

a) when specified on the ITP;

b) when in-process examination is specified in ASME B31.3 and this document;

c) internal root pass bead profile at welds as per item 12.2.2;

d) internal root bead profile at accessible welds categorised in sour service or severe cyclic service.

12.3 Magnetic particle examination

12.3.1 Magnetic particle examination shall be performed with wet particles and colour contrast using an electromagnetic yoke technique.

12.3.2 A minimum of 25,4 mm of base material either side of the weld centreline shall be included in the examination.

12.3.3 The essential variables in ASME Boiler and Pressure Vessel Code, Section V:2019, Article 7 shall be applied.

12.3.4 The results of MT examinations shall be documented in accordance with the requirements in ASME Boiler and Pressure Vessel Code, Section V:2019, T-790.

12.4 Liquid penetrant examination

12.4.1 A minimum of 25,4 mm of base material either side of the weld centreline shall be included in the examination.

12.4.2 The essential variables in ASME Boiler and Pressure Vessel Code, Section V:2019 Article 6, shall be applied.

12.4.3 The results of PT examinations shall be documented in accordance with the requirements in ASME Boiler and Pressure Vessel Code, Section V:2019, T-690.

12.5 Radiographic examination

12.5.1 Fluorescent or fluoro-metallic intensifying screens shall not be used.

12.5.2 Geometric un-sharpness values for penetrated material thickness $t \leq 50{,}8$ mm shall not exceed the limits in ASME Boiler and Pressure Vessel Code, Section V:2019, T-274.2 and Table 16.

Table 16 — Geometric un-sharpness limits

Penetrated material thickness t	Geometric un-sharpness U_g
$t \leq 12{,}7$ mm	0,30 mm
12,7 mm < $t \leq 25{,}4$ mm	0,35 mm
25,4 mm < $t \leq 50{,}8$ mm	0,51 mm

12.5.3 Radiographic film class shall be selected to meet the applicable quality requirements (e.g. IQI sensitivity, density, contrast, geometric un-sharpness) of ASME Boiler and Pressure Vessel Code, Section V:2019. As a reference, the minimum classification should be in accordance with Table 17.

Table 17 — Radiographic film classification

Application		Film classification per ISO 11699-1	Film classification per ASTM E1815
X-ray techniques	Impact tested carbon steels; Carbon steels in sour service	C3 or C4	Type I
	All other materials and service environments	C4 or C5	Type I or Type II
Gamma-ray techniques	Impact tested carbon steels; Carbon steels in sour service	C2 or C3	Type I
	All other materials and service environments	C3 or C4	Type I

12.5.4 Computed or digital radiography shall be performed in accordance with the requirements in ASME Boiler and Pressure Vessel Code, Section V or ISO 17636-2 Class A.

12.5.5 Film-side IQI sensitivity shall be at least as good as that for source-side IQIs.

12.5.6 Acceptance criteria for weld examination shall conform to ASME B31.3, Table 341.3.2 and the additional requirements in Table 18.

Table 18 — Additional RT acceptance criteria for welds

Application	Rejectable weld imperfections
Carbon steels in sour service	Incomplete penetration Internal undercut

12.5.7 The results of RT examinations shall be documented in accordance with the requirements in ASME Boiler and Pressure Vessel Code, Section V:2019, T-290.

12.6 Ultrasonic examination

12.6.1 Ultrasonic computerized imaging technique (CITs) shall be qualified and applied in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section V and all non-mandatory appendices applicable to the selected technique.

12.6.2 Ultrasonic examination techniques for CRAs and dissimilar metal welds shall be qualified and applied in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section V and ISO 22825.

12.6.3 Ultrasonic examination techniques for $t \leq 9{,}53$ mm shall be qualified using a demonstration block with a thickness between 75 % and 100 % of the actual production thickness under examination.

12.6.4 Grouping of discontinuities shall be assessed in accordance with

a) the rules in ISO 11666:2018, 6.4, for amplitude-based UT techniques, and

b) the rules for multiple flaws in ASME B31.3, Appendix R, where ECA/fracture mechanics acceptance criteria are specified.

12.6.5 Acceptance criteria for weld examination shall conform to ASME B31.3 and the additional requirements in Table 19.

Table 19 — Additional UT acceptance criteria for welds

Application		Rejectable weld imperfection
Carbon steel	Sour service	Cracks Lack of fusion Incomplete penetration Internal undercut
Carbon steel and CRAs	Severe cyclic service	
Carbon steel and CRAs	All other service environments	Cracks
All	ECA/fracture mechanic-based design	ASME B31.3, Appendix R or as specified in the engineering design

12.6.6 The results of UT examinations shall be documented in accordance with the requirements in ASME Boiler and Pressure Vessel Code, Section V:2019, T-490.

12.7 Positive materials identification

12.7.1 PMI shall be performed on completed piping for all materials except carbon steels as follows:

a) weld metal and base piping materials on either side of the weld, prior to leak testing or tightness testing;

b) CRA bolts and nuts shall also be tested, if it is not possible to verify the material quality by its grade marking.

12.7.2 Each test shall comprise one set of three measurements in close proximity at any location around the weld circumference.

12.7.3 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. Arc emission instruments shall not be used if arc strikes cannot be made good.

Note OES technique is better suited to identify carbon content.

12.7.4 The extent of elements analysed shall be sufficient to verify nominal composition of the component or weld metal.

12.7.5 Surfaces to be examined shall be prepared by light grinding or by abrasive paper, (60 to 35) microns, and solvent cleaned to remove any surface films.

12.7.6 Acceptance criteria shall be in accordance with Table 20, unless otherwise specified in the engineering design.

Table 20 — PMI acceptance criteria

Component	Acceptance criteria
Base materials and deposited weld metal	The relevant element concentration is within the stated tolerance range for the PMI instrument
Base material	Not less than 10 % of the minimum specified element concentration value or greater than 10 % of maximum specified element concentration value in the base material specification
Deposited weld metal between similar base materials using matching filler material(s)	Not less than 10 % of the minimum specified element concentration value or greater than 10 % of maximum specified element concentration value in the welding filler material specification
Deposited weld metal between dissimilar base materials	Not less than 10 % of the minimum value or greater than 10 % of maximum value recorded on the PQR

12.7.7 If a valid measurement at one location gives a value outside the acceptance criteria, two additional locations shall be measured in the vicinity of the first measuring point.

NOTE Subject to owner approval, a more accurate chemical analytical method can be used to validate the measurement and whether it is within the acceptance criteria.

12.7.8 All materials shall be made good after examination.

12.7.9 All acceptable components and welds shall be clearly marked. This identification shall be retained, until all examination, inspection and testing are complete.

12.7.10 The results from each test shall be documented and made available for owner inspection, but are not required to be submitted in accordance with 5.2.6 unless otherwise specified in the engineering design.

12.7.11 Rejected components and welds shall be repaired or replaced in accordance with 12.10.

12.8 Production testing

12.8.1 Production tests shall be performed as defined in the Material Data Sheets of ISO 13703 Part 2 or Owner Specifications.

12.8.2 In the following items requirements for production hardness testing are specified, when hardness control is required in the owner specifications. Those items are not applicable for duplex and austenitic stainless steels.

12.8.3 Production hardness testing shall be performed on butt welds in completed piping assemblies, or readily identifiable sub-assemblies, in sour service as follows:

a) one test prior to leak testing or tightness testing on each groove weld in Examination Category 3;

b) one test on not less than a 5 % random spot selection of groove welds per welder/welding operator per WPS used in Examination Category 2.

12.8.4 Each hardness test shall comprise one set of three measurements in close proximity, at the 12 o'clock position and either the 9 o'clock or 3 o'clock position.

12.8.5 Hardness testing shall be performed in accordance with a written procedure by portable hardness testing instruments, within the limits recommended by the instrument supplier. and the hardness testing instruments shall be calibrated prior to the start of each set of tests.

NOTE The accuracy, precision and reliability of measurements from portable testers depends strongly on the surface preparation and thickness of the component or weld being measured. Reference can be made to ASTM A833, ASTM A956, ASTM A1038 and ASTM E110 in developing appropriate testing procedures.

12.8.6 Conversion of hardness values shall conform to the methods specified in either ASTM E140 or ISO 18265. A specific conversion table for cases not covered in the previous standards shall be agreed with the owner. In case of conversion, the measured values shall also be recorded in the documentation in addition to the converted values.

12.8.7 Acceptance criteria for butt welds in sour service shall be in accordance with ISO 15156-2 or ISO 15156-3.

12.8.8 If a valid measurement at one location gives a value out with the acceptance criteria, two additional locations shall be measured in the vicinity of the first measuring point.

12.8.9 The results from each test shall be documented and made available for owner inspection, but are not required to be submitted in accordance with 5.2.6 unless otherwise specified in the engineering design.

12.8.10 Rejected welds shall either be heat treated in accordance with 9.2, and verified by hardness testing on completion, or replaced in accordance with 12.10.

12.9 Weld metal ferrite testing

12.9.1 Ferrite control shall be required for austenitic stainless steel weld metal, where the service application exceeds 662 °F (350 °C) or if below -150 °F (-101 °C), or where the weld will be subject to PWHT.

Note when required for SS type 22Cr duplex and SS type 25Cr duplex, guidance for ferrite control can be found in ISO 17781.

12.9.2 Weld metal ferrite testing shall be performed on completed piping assemblies, or readily identifiable sub-assemblies, as follows:

a) one test prior to leak testing or tightness testing on each groove weld in Examination Category 3;

b) one test prior to leak testing or tightness testing on not less than a 5 % random spot selection of groove welds per welder/welding operator per WPS used in Examination Category 2.

12.9.3 Each test shall comprise one set of three measurements in close proximity, at either the 12 o'clock, 3 o'clock or 9 o'clock position.

12.9.4 Ferrite testing shall be performed in accordance with a written procedure by instruments using direct magnetic force or magnetic induction in accordance with AWS A4.2M or ISO 8249.

12.9.5 The following calibrations requirements apply:

a) calibration blocks shall be traceable to the IIW secondary calibration standards;

b) calibration blocks shall cover the FN range under examination;

c) instrument readings during calibration shall be within the maximum deviation from the FN value assigned to the relevant secondary standard.

d) correction for thickness and curvature shall be applied as appropriate, per instrument manufacturer's recommendation.

12.9.6 Surfaces to be examined shall be prepared in accordance with AWS A4.2M or ISO 8249.

12.9.7 Only sequential measurements that are stable (within ±3 % of the measured values) shall be used.

12.9.8 Acceptance criteria shall be in accordance with Table 21.

Table 21 — Production weld metal ferrite testing acceptance criteria

Weld metal	Acceptance criteria
All	The reading is within the stated tolerance range for the instrument
SS 300-series in cryogenic service – type E/ER 3XXL	Average reading falls within 3 FN to 10 FN and no individual value falls outside these values by 1 FN
SS 300-series in cryogenic service – type E/ER 16-8-2	Average reading falls within 1 FN to 5 FN and no individual value exceeds 6 FN

12.9.9 If a valid measurement at one location gives a value outside the acceptance criteria, two additional locations shall be measured in the vicinity of the first measuring point.

12.9.10 The results from each test shall be documented and made available for owner inspection, but are not required to be submitted in accordance with 5.2.6 unless otherwise specified in the engineering design.

12.9.11 Rejected welds shall be replaced in accordance with 12.10.

12.10 Repairs and replacement

12.10.1 Where random or random spot weld examination, PMI, hardness or ferrite testing is specified, progressive sampling in accordance with ASME B31.3, 341.3.4 shall be performed if any result is outside the specified acceptance criteria.

12.10.2 For a local weld repair, the area shall be contoured by machining, grinding or thermal gouging in accordance with 6.3, to permit access for visual examination and NDT.

12.10.3 The complete surface of the repair area shall be subject to visual examination followed by MT or PT in accordance with 12.3 or 12.4 to verify complete removal of the defect.

12.10.4 Weld repairs shall be performed in accordance with either

a) the original WPS providing there is no change in the requirements specified in Clause 8,

b) a separate weld repair WPS qualified for the specific repair scenario, including any additional requirements specified by ASME B31.3 or this document, or

c) for SS type 22Cr duplex and SS type 25Cr duplex, weld repairs qualified in accordance with Table 22.

Table 22 — Weld repair qualification for SS type 22Cr duplex and SS type 25Cr duplex welds

Weld repair type	Weld qualification requirements
— Cap repair; or — Partial penetration repair where the maximum excavation depth is no closer than 6,0 mm from the inner surface (i.e. remaining ligament beneath the excavation is a minimum of 6,0 mm)	Use original qualified WPS subject to minimum of two passes for cap repairs
Partial penetration repair where the maximum excavation depth lies between 3,0 mm and 6,0 mm from the inner surface (i.e. remaining ligament beneath the excavation is between 3,0 mm and 6,0 mm)	— Test piece thickness shall conform with Table 4 — The test piece shall have a section of the existing weld excavated to a depth that leaves between 3,0 mm and 6,0 mm remaining ligament and for a length sufficient to undertake metallography, ferrite determination and corrosion testing in accordance with 8.3.5
Partial penetration repair with maximum excavation cavity depth within 3,0 mm of the inner surface (i.e. less than 3,0 mm remaining ligament) or through-wall repair	Not permitted – weld shall be completely removed

12.10.5 For 25Cr duplex, 6Mo and titanium, only one repair attempt shall be allowed in the same area.

12.10.6 Materials not covered by 12.10.5, only two repair attempts shall be allowed in the same area.

12.10.7 The completed weld repair shall be subject to visual examination, NDT and production testing using the same technique(s) and procedures used initially to detect the defect.

12.10.8 Where a complete weld is to be replaced, the weld metal and at least 6,0 mm of the adjacent base materials shall be removed. The weld shall be prepared in accordance with 6.3.

12.10.9 Weld repairs made to carbon steels after completion of PWHT without subsequent PWHT shall be subject to the limitations in Table 7.

12.10.10 The results from examination and testing of repairs shall be documented in accordance with 5.2.6.

13 Cleaning, leak testing and preservation

13.1 General requirements

13.1.1 The sequencing and methods for flushing, cleaning, leak testing or tightness testing, and applicable acceptance criteria for cleanliness and leakage rates, together with requirements for preservation after mechanical completion shall be specified in the engineering design for each piping assembly.

13.1.2 Flushing, cleaning, leak testing and tightness testing shall be performed in accordance with a written procedure.

13.1.3 All piping assemblies shall be examined before flushing, cleaning or leak testing/tightness testing to verify freedom from debris and contamination including removal of any temporary internal protective coatings, paint or varnish.

13.1.4 Flushing and cleaning operations shall be managed to avoid damage to piping assemblies, sensitive in-line equipment, such as soft-seat/control/relief valves, instruments, and sensitive electrical/electronic equipment or instruments in the vicinity, including but not limited to the following:

a) isolation or removal of sensitive equipment/components;

b) installation of all necessary supports/anchors, including supports for temporary spools to replace isolated or removed equipment/components;

c) installation of additional valves for flushing and cleaning;

d) temporary restraint of spring hangers;

e) provision of suitable vents and drains in accordance with the applicable piping class at high/low points;

f) provision of suitable temporary filters, including appropriate controls to verify their removal;

g) provision of suitable baskets/target plates for trapping/recording debris.

13.1.5 Water used for flushing, cleaning or leak testing shall

a) be near-neutral pH (pH = 6,5 to pH = 7,5),

b) contain a maximum of 50 mg/l chloride for use with SS 300-series or 250 mg/l chlorides for use with all other materials, and

c) have low turbidity (less than 4 NTU).

13.1.6 Air used for shock blowing, flushing, drying or leak testing/tightness testing shall be oil-free and dry.

13.1.7 The metal temperature at any point in a system during flushing, cleaning leak testing/tightness testing or air-drying operations shall not exceed 50 °C.

13.1.8 Oil used for flushing/cleaning shall be the same grade as that used in operation.

13.1.9 Once started, flushing/cleaning and leak testing/tightness testing activities shall be carried on to completion and supervised at all times.

13.1.10 All cleaning agents and effluents used or produced during the flushing/cleaning, leak testing and subsequent preservation operations shall be safely recovered and disposed taking into account local and statutory legislation.

13.1.11 The results from all flushing/cleaning activities and leak testing/tightness testing shall be documented in accordance with 5.2.6.

13.2 Flushing and cleaning

13.2.1 Specified flushing/cleaning velocities shall be monitored to verify they are met at all points in the system.

13.2.2 On completion of flushing/cleaning with water, the water shall be drained immediately and the system shall be air-dried to remove all traces of water, unless hydrostatic leak testing is performed as a continuous operation.

13.2.3 If draining of water after flushing/cleaning is not possible and hydrostatic leak testing is not performed contiguously afterwards, alternative fluids such as methanol or inhibited water shall be used.

13.2.4 Flushing/cleaning of machinery lubrication systems shall be performed in accordance with the requirements of API RP 686.

13.2.5 Where mechanical cleaning is selected, all dust and debris shall be removed by air blowing and vacuum cleaning.

13.2.6 Where chemical cleaning is selected, the following requirements apply:

a) a leak test shall be conducted with water at 1,5 times the intended circulation pressure before introduction of cleaning agents into the system;

b) cleaning agents shall not be introduced into a circuit, unless high-point vents and low-point drains are available in order to ensure proper filling and complete removal of effluents and venting of any gas generated;

c) cleaning agents shall not stand undisturbed in any part of the system at any time;

d) samples shall be taken during cleaning operations to verify ferric iron, total iron and acid strength (acid cleaning agents only) are in accordance with levels specified in the procedure;

e) samples shall be taken during passivation and/or flushing operations to verify the effluent is between 7 pH and 8 pH .

13.2.7 The system shall be inspected to verify that the specified level of cleanliness has been met.

13.2.8 If direct visual examination of pipe surfaces, baskets or target plates is not feasible, alternative arrangements, such as the use of a borescope or removing pipe sections, shall be used to verify cleanliness.

13.2.9 All low point drains and high point vents shall be opened to verify the system is free from liquids and gases.

13.3 Leak testing

13.3.1 Closure welds and bolted or screwed connections that are not leak tested shall be tightness tested in accordance with 13.4.

13.3.2 The metal temperature during leak testing shall be maintained at 5 °C minimum and at least 7 °C above the specified MDMT for the duration of the test.

13.3.3 If it is impractical, as agreed with owner, to prevent ice formation test fluid with water or ambient temperature air, alternative hydrostatic test fluids such as methanol or water with approved anti-freeze, or warm air shall be used.

13.3.4 The ambient temperature during leak testing shall be 0 °C and above. If practical, the metal temperature, pressure and time shall be:

a) monitored continuously throughout testing, and

b) documented once the test pressure is reached until the completion of the test.

13.3.6 Where hydrostatic testing is specified, the following requirements apply:

a) pressure shall be applied gradually in stages up to the specified test pressure with each stage held for a sufficient time to allow all parts of the piping assembly to stabilize.

b) at each stage, the piping assembly shall be examined to verify there are no gross leaks;

c) once the test pressure is reached, it shall be held for a minimum period of 10 minutes or for a sufficient time to undertake a complete examination of the pipe assembly under test; alternatively, once the test pressure is reached, it shall be held for a minimum period of 30 minutes and then the pressure reduced to the design pressure prior to examination;

d) on completion of the test, the water shall be drained immediately, and the system shall be dried to remove all traces of water;

e) if it is impractical, as agreed with owner, to immediately drain the water, alternative fluids such as methanol or water with an approved corrosion inhibitor shall be used.

f) a preliminary air test at no more than 500 kPa may be performed to identify any gross leaks prior to the introduction of water.

13.3.7 Where pneumatic testing is specified, the following requirements apply:

a) pressure shall be applied gradually up to the lesser of 170 kPa or 50 % of the specified test pressure;

b) thereafter, pressure shall be applied in stages no greater than 25 % of the test pressure, up to the specified test pressure with each stage held for a sufficient time to allow all parts of the piping assembly to stabilise;

c) at each stage, the piping assembly shall be examined to verify there are no gross leaks;

d) once the test pressure is reached, it shall be held for a minimum period of 10 minutes;

e) once the end of hold period is reached, the pressure shall be reduced to the design pressure prior to examination.

13.3.8 For piping assemblies subject to an initial service leak test, a preliminary air test at no more than 170 kPa shall be performed prior to introduction of the service fluid.

13.3.9 For piping systems subject to sensitive leak test, the test medium shall be either air in accordance with 13.1.6 or test media in accordance with 13.4.1.

13.3.10 De-pressuring of the system shall be performed in a controlled manner to prevent collapse from vacuum or auto-refrigeration.

13.3.11 If any leaks are detected, the system shall be de-pressured, and the cause investigated and remedied prior to re-testing.

13.3.12 Any welding performed after leak testing, such as seal welds to threaded connections or a weld repair that is not re-leak tested, shall be treated as a closure weld.

13.4 Tightness testing

13.4.1 The tightness test, if applicable, is to be performed after final assembly. In such a case, the following requirements apply.

13.4.2 The test media for tightness testing shall be specified in the engineering design selected from either

a) air in accordance with 13.1.6,

b) helium or helium/N_2 mixture, or

c) N_2.

13.4.3 The test shall be performed in accordance with ASME Boiler and Pressure Vessel Code, Section V:2019, Article 10 and the requirements in 13.3.7 up to the specified tightness test pressure and held for sufficient time to permit examination of all parts under test.

13.4.4 For tightness testing with air or N_2, leakage shall be detected by means of proprietary bubble forming solutions that produce films that do not break away from the surface under test and the bubbles produced do not break rapidly due to air drying or low surface tension.

13.4.5 For tightness testing with helium or helium/N_2 mixture, the detector probe shall be calibrated in accordance with the manufacturer's instructions prior to performing the leak test and thereafter every four hours until testing is complete.

13.4.6 Acceptable leak rates shall be specified in the engineering design.

13.5 Preservation

13.5.1 Desiccant or vapour phase inhibitor shall not be injurious to any construction materials present in the preserved system.

13.5.2 Inert gas blanketing shall be used for systems in cryogenic service.

13.5.3 Systems under an inert gas blanket shall:

a) have gauges installed to verify the integrity of the preservation, and

b) be labelled with an appropriate notice warning of the dangers from inert gases.

Annex A
(informative)

Reference images for oxidation of weldments

A.1 General

The following figures show examples of acceptable and unacceptable oxidation of stainlees steel and titanium weldments.

A.2 Stainless steel colour acceptance examples

Images on Figure A.1 are considered acceptable, while images on Figure A.2 are considered not acceptable.

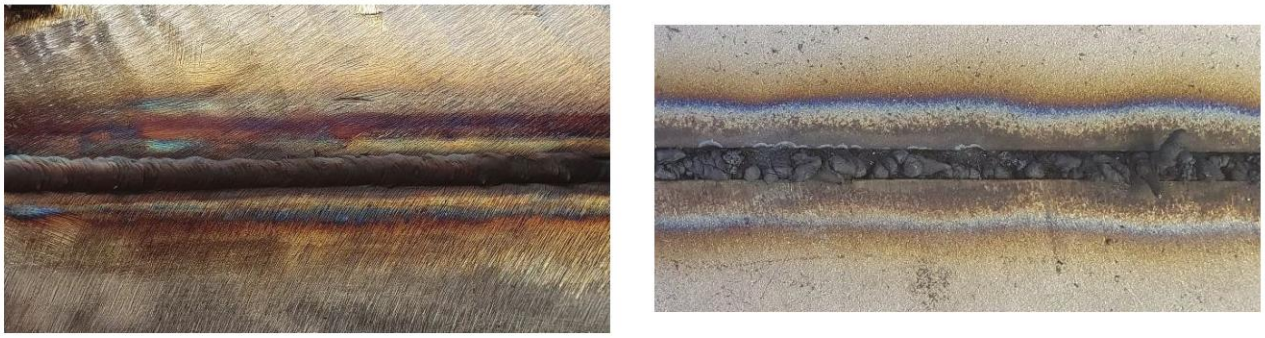
a) Accepted

b) Light brown and brown colours are acceptable

c) A narrow band or dark brown and intermittent spots of blue color are acceptable

d) Acceptable provided the blue colours are intermittent

Figure A.1 — Reference for acceptable stainless steel weldments oxidation images



a) Not acceptable

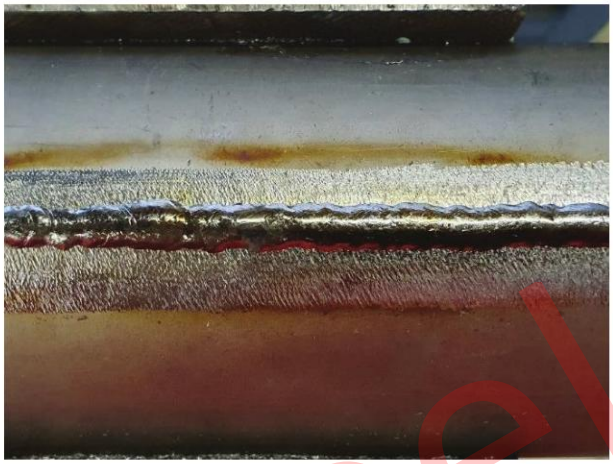
b) Not acceptable

Figure A.2 — Reference for not acceptable stainless steel weldments oxidation images

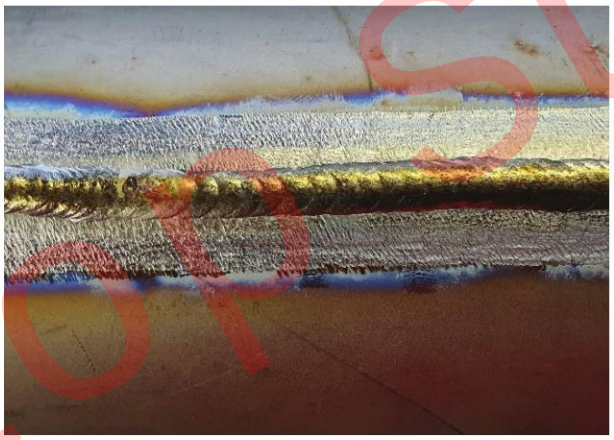
A.3 Titanium steel colour acceptance examples

Images on Figure A.3 are considered acceptable, while images on Figure A.4 are considered not acceptable.

a) Accepted

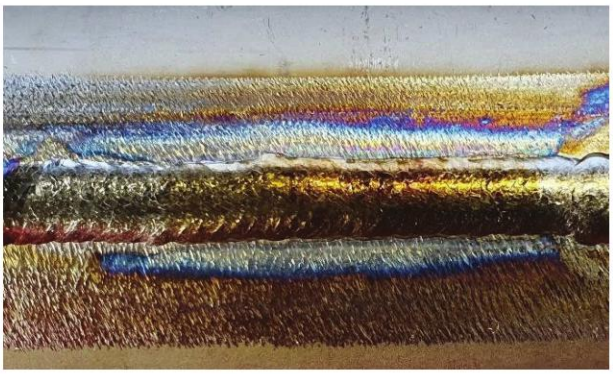


b) Acceptable colours are silver and pale straw

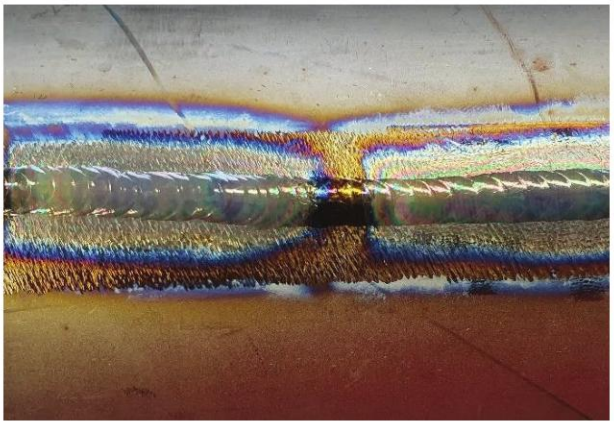


c) Acceptable provided the narrow band of intensive colours are close to the limits of the shielding gas

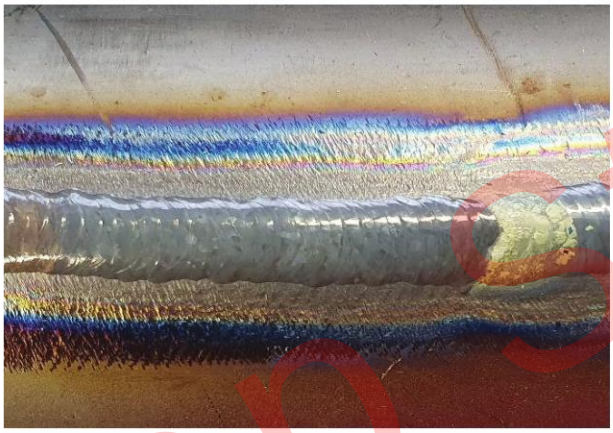
Figure A.3 — Reference for acceptable titanium weldments oxidation images



a) Darker brown, purple and blue colours are not acceptable



b) Grey or white colours are not acceptable



c) Flaky white colours are not acceptable

Figure A.4 — Reference for non-acceptable titanium weldments oxidation images

Annex B
(normative)

Requirements for cold bending of pipes

1. SCOPE	This document specifies requirements that shall apply when pipes and tubes are cold bent for use within a pressure containing piping system. NOTE Instrument and hydraulic tubing is not within scope of this document.	
2. MATERIAL	All base material shall comply with the specified material data sheet of ISO 13703-2.	
3. APPLICATION	The pressure design shall be in compliance with ASME B31.3 paragraph 304.7.2. Flexibility and stress intensification factor shall be documented with maximum allowed thinning of the outside wall for the actual bending radius. The service limitations for use in marine atmosphere and subsea installation, and/or additional testing for the different material types related to cold bending are given in below.	
Material data sheet	**Service**	**Limitations and special requirements for cold bent pipes**
CMn-steel MDS C001/C001S, C002/C002S, C003/C003S C004/C004S, C005/C005S, C006/C006S, C007/C007S	Utility service and non-sour hydro-carbon service	When the hardness exceeds this limit a post bend heat treatment according to ASME B31.3 shall be applied. The maximum hardness shall not exceed 350 Hv10 or 35 HRC.
	H_2S containing service defined sour in accordance with ISO 15156-2.	Not acceptable to use without post bend heat treatment unless qualification testing in compliance with ISO 15156-2 is successfully qualified and documented, ref. item 5.
Type 316 MDS S101, S102, S103, S104, S105, S106 and S108	Utility service and non-sour hydro-carbon service	
	H_2S containing service within the limitations of ISO 15156-3.	The maximum hardness requirements shall be 22 HRC and SSC testing to ISO 15156-3 is required.
Type 22Cr and 25Cr duplex, MDS D141, D142, D143, D144, D145, D146 and D148 MDS D251, D252, D253, D254, D255, D256 and D258.	Utility service and non-sour hydro-carbon service	
	H_2S-containing service within the limitations of ISO 15156-3.	Not acceptable to use without post bend heat treatment unless qualification testing in compliance with ISO 15156-3 is successfully qualified and documented, ref. item 5.
	Subsea	The maximum hardness of any cold bend part shall not exceed 350 Hv10 or 35 HRC
SS Type 6Mo MDS R111, R112, R113, R114, R115, R116 and R117	Utility service and non-sour hydro-carbon service	
	H_2S containing service within the limitations of ISO 15156-3.	The maximum hardness shall be 328 HB or 35 HRC and SSC testing to ISO 15156-3 is required.

Titanium Grade 2 MDS T101, T102, T103, T104, T105, T106 and T108	Utility service H_2S containing service within the limitations of ISO 15156-3.	 Not acceptable unless specifically qualified according to ISO 15156-3, ref. Item 5.
4. BENDING PROCEDURE	All cold forming shall be performed in accordance with a written procedure detailing: — material; — diameter; — wall thickness; — type of forming equipment; — relevant forming parameters; — post forming heat treatment if applicable; — visual inspection and NDT of bends and flares, including acceptance criteria; — dimensional control, including acceptance criteria. The longitudinal weld of welded pipes should be located in a sector ±40 ° from the neutral plan. No welding shall be performed in the plastically deformed zone nor closer than 2 times wall thickness, minimum 30 mm, to this zone.	
5. QUALIFICATION	The equipment and processes shall be qualified and maintained to ensure that the material properties fulfil the requirements for piping fabrication. The qualification bend shall be 90°. Specimens for destructive testing shall be sampled from the extrados area. For bends made from welded pipes both the weld and base material shall be tested. The material properties of the qualification bend shall be verified by testing after bending. All tests specified in the applicable MDS for the pipe and Table 1 shall be performed, except cross weld tensile testing. Carbon steel intended used for service containing H_2S shall be in heat treated condition and without any post cold forming. Stainless steel may be used in solution annealed and post cold formed condition provided hardness are within the requirement of ISO 15156-2 or ISO 15156-3 and qualification tested to ISO 15156-2 or ISO 15156-3. Acceptance criteria shall be according to the applicable MDS with the following exceptions: — Elongation shall be ≥ 14 %. — The minimum absorbed impact energy shall be 27 J average and 20 J single. — The hardness of any cold-formed material shall not exceed the limits specified in Table 8. — For items exposed to H_2S-containing service, testing shall comply with ISO 15156-2 or ISO 15156-3. NOTE For guidance how to comply with specified elongation, reference is made to EN 13480-4 or by physical testing as follows: — Specimens shall be straightened by mechanical means, e.g. counter bending, pressing, or pulling, according to a documented procedure. — Gauge length (L_0) marking shall be made along internal curvature and marked prior to the straightening operation.	

	If any of these requirements are not met, heat treatment is required with temperatures and duration as given in ASME B31.3. The qualification bend shall be subjected to 100 % visual inspection and 100 % MT/PT as applicable. For bends made from welded pipes the weld area shall be subjected to 100 % RT after bending. NDT methods and acceptance criteria shall be as per the pipe MDS. The dimensional tolerances of the qualification bend shall be controlled (before and after bending) as per Item 9 of this document. The qualification dossier shall contain: — record of bending method and parameters; — record of bending radius and angle; — test reports; — NDT reports; — material certificate for pipe material. The bending procedure essential variables and changes requiring requalification are defined in Table 8.
6. PRODUCTION TESTING	Production testing shall be performed to demonstrate that the requirements listed under Item 5 above are fulfilled. The testing frequency shall be agreed.
7. NON-DESTRUCTIVE TESTING	The extent of NDT for cold formed parts shall be 100 % visual inspection and 10 % surface testing by the MT or PT methods for carbon steel and stainless steel grades, respectively. For MT and PT the acceptance criteria shall be in accordance with ASME VIII, Div. 1, Appendix 6 and 8 respectively. If defect indications are revealed the NDT extent shall be increased to 100 % until the reasons for the defect indications are concluded and necessary corrections in the forming process are made. NDT operators shall be certified in accordance with ISO 9712 or equivalent and shall be approved by a 3rd party organization recognized by an EEA member state.
8. POST BEND HEAT TREATMENT TESTING	If a stress relieving heat treatment is carried out in accordance with the specified temperatures of ASME B31.3 no additional testing is required except for surface hardness measurements. If the cold formed bends have to be given a full new heat treatment, e.g. normalising, quench and temper or solution anneal, the material properties shall be documented by testing in accordance with the applicable MDS, ref. ISO 13703 Part 2 Table A.1. The heat treatment procedure shall be qualified to M-650/ISO 17782 when specified by the MDS. The lot definition, extent of testing, test location, acceptance criteria, etc. shall be in accordance with the relevant MDS for wrought fittings.
9. DIMENSIONAL CONTROL	The out-of-roundness, waves at bends, wall thickness and other dimensional requirements of the bend shall be checked before and after bending. The pipe wall thickness requirements shall comply with ASME B31.3. The out-of-roundness and waves at bends tolerances shall comply with EN 13480-4. The angle and straightness tolerances shall comply with NORSOK Standard L-004.

Annex C
(normative)

Requirements for hot induction bending of pipes

1. SCOPE	This annex specifies the technical delivery conditions for bends made by the induction bending process for use within a pressure containing piping system. This annex use ISO 15590-1 as the reference standard and specifies supplementary requirements that shall amend or supersede requirements specified by ISO 15590-1.
2. STARTING MATERIAL	Mother pipes shall comply with ISO 13702-2 and the applicable material data sheet (MDS) or as agreed. Mother pipes clad with a corrosion resistant internal layer shall comply with an agreed specification.
3. POST BEND HEAT TREATMENT	Hot forming by induction heating, bending and quenching down to room temperature by water spray does not require a new quality heat treatment provided the process is successfully qualified and tested as required by this EDS. If full heat treatment, involving an austenitization and tempering or solution annealing process, is applied after the induction bending operation, the bend shall be destructively tested in compliance with the mother pipe specification. If the mother pipe is delivered in as welded condition the extent of destructive testing of the weld shall include the same tests as specified for the weld procedure qualification by the mother pipe specification. For manufacture of bends in stainless steel type 22Cr duplex, 25Cr duplex, 6Mo or 565 where solution heat treatment is carried out the heat treatment procedure shall be qualified in accordance with ISO 17782.
4. BENDING PROCEDURE	The induction bending process of pipe shall be performed according to requirements given by ISO 15590-1 and this EDS. All induction bending shall be performed in accordance with a written procedure. The longitudinal weld of welded pipes should be located in a sector ±40° from the neutral plan. At no time, prior to or during bending, shall the pipe contact low melting temperature materials such as zinc, copper, brass or aluminium.
5. ESSENTIAL VARIABLES	For all steels and Nickel based alloys the essential variables of the MPS qualification shall be in accordance with ISO 15990-1 except that the modifications specified in Table 8 shall apply, additionally, any change of the clad welding procedure shall be an essential variable.

6.	MPS QUALIFICATION BEND TESTING	Each bend group, as defined by the essential variables referenced above shall be qualified in accordance with ISO 15590-1 and this section before commencement of production bending. All testing of the qualification bends shall be to Table 9. The tests shall be located as specified in Table 10 and Figure 3. NOTE Where the entire length of the mother pipe, including tangents, is subject to the same continuous induction heating, cooling and speed parameters as the bent portion during the induction bending process then, unless specified otherwise by the purchaser, these induction bends are not considered to have transitions for testing purposes. All testing shall be carried out in accordance with test methods specified for the mother pipe specification and the test acceptance criteria shall be to the same standard. Transverse tensile test and bend test of weld shall be carried out in accordance with ISO 15614-1 or ASME IX and the acceptance criteria shall be accordingly. Transverse tensile testing is only applicable for pipes with OD 168 mm or greater. For tensile test transverse weld only the tensile strength, RM, shall be required. Dimensional control and tolerances shall be in accordance with ISO 15590-1 for all type of materials.
7.	NON-DESTRUCTIVE TESTING	NDT operators shall be certified in accordance with ISO 9712 or equivalent and shall be approved by a 3rd party organization recognized by an EEA member state.
8.	DELIVERY CONDITION	The surface condition of bends in carbon and low alloyed steel shall be as agreed. All bends in stainless steel, nickel base alloys and the internal clad layer of clad carbon steel/low alloyed steel shall be delivered in white pickled and passivated condition.
9.	DOCUMENTATION	A material certificate shall be issued in accordance with EN 10204 Type 3.1 including all inspection test reports. The documentation dossier shall include the following test reports: — material certificate; — MPS qualification test report; — NDT test report; — starting pipe material certificate; — dimensional test report.

Annex D
(informative)

Guidance to European Pressure Equipment Directive

This document was not written to comply specifically with European Pressure Equipment Directive 2014/68/EU.

In applications where PED is governing, it is necessary to apply the PED and involve a notified body to obtain the required approvals dependent of the selected conformity assessment module applicable to each specific project. Reference is made to ASME B31.3 on how to comply with PED.

The PED specific requirements for materials to be used for pressure parts are:

— no less than 14 % elongation and no less than 27 J absorbed energy measured on Charpy V-notch at the lowest scheduled operating temperature;

— approval of welders and welding procedures by a third-party organization recognized by an EEA member state;

— approval of NDT operators by a third-party organization recognized by an EEA member state for NDT of permanent joints;

— certification of specific product control;

— the material manufacturer having an appropriate quality assurance system, certified by a competent body recognized within the EEA and having undergone a specific assessment for materials.

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