International Association of Oil & Gas Producers

SPECIFICATION
S-619

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Specification for Unfired, Fusion Welded Pressure Vessels

Revision history

VERSION	DATE	AMENDMENTS
1.0	December 2018	Issued for Publication

Acknowledgements

This IOGP Specification was prepared by a Joint Industry Project 33 Standardization of Equipment Specifications for Procurement organized by IOGP with support by the World Economic Forum (WEF).

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Foreword

This specification was prepared under a Joint Industry Project 33 (JIP33) "Standardization of Equipment Specifications for Procurement" organized by the International Oil & Gas Producers Association (IOGP) with the support from the World Economic Forum (WEF). Ten key oil and gas companies from the IOGP membership participated in developing this specification under JIP33 Phase 2 with the objective to leverage and improve industry level standardization for projects globally in the oil and gas sector. The work has developed a minimized set of supplementary requirements for procurement, with life cycle cost in mind, based on the ten participating members' company specifications, resulting in a common and jointly approved specification, and building on recognized industry and international standards.

This specification has been developed in consultation with a broad user and supplier base to promote the opportunity to realize benefits from standardization and achieve significant cost reductions for upstream project costs. The JIP33 work groups performed their activities in accordance with IOGP's Competition Law Guidelines (November 2014).

Recent trends in oil and gas projects have demonstrated substantial budget and schedule overruns. The Oil and Gas Community within the World Economic Forum (WEF) has implemented a Capital Project Complexity (CPC) initiative which seeks to drive a structural reduction in upstream project costs with a focus on industry-wide, non-competitive collaboration and standardization. The vision from the CPC industry is to standardize specifications for global procurement for equipment and packages, facilitating improved standardization of major projects across the globe. While individual oil and gas companies have been improving standardization within their own businesses, this has limited value potential and the industry lags behind other industries and has eroded value by creating bespoke components in projects.

This specification aims to significantly reduce this waste, decrease project costs and improve schedule through pre-competitive collaboration on standardization.

Following agreement of the relevant JIP33 work group and approval by the JIP33 Steering Committee, the IOGP Management Committee has agreed to the publication of this specification by IOGP. Where adopted by the individual operating companies, this specification and associated documentation aims to supersede existing company documentation for the purpose of industry-harmonized standardization.

Table of Contents

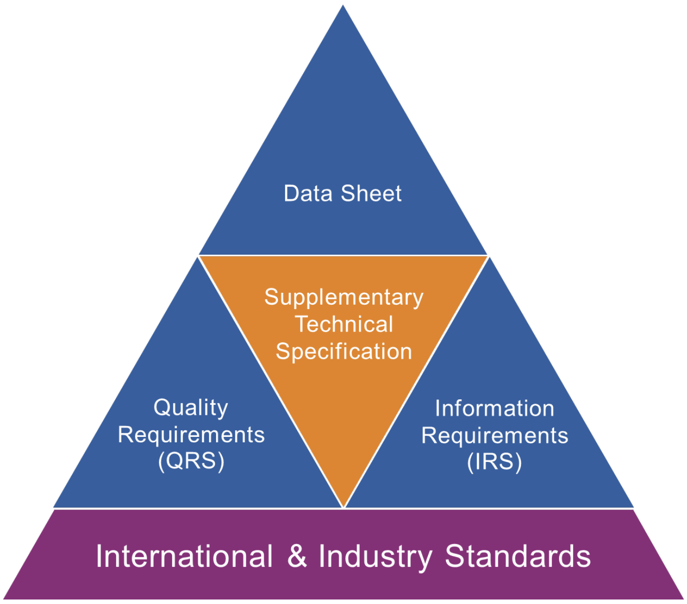
Tables

Figures

Introduction

The purpose of this specification is to define a minimum common set of specification requirements for the procurement of unfired, fusion welded pressure vessels for application in the petroleum and natural gas industries.

This JIP33 standardized procurement specification follows a common document structure comprising the four documents as shown below, which together with the purchase order define the overall technical specification for procurement.



JIP33 Specification for Procurement Documents
Supplementary Technical Specification

It is required to use all of these documents in conjunction with each other when applying this specification, as follows:

S-619: Specification for unfired, fusion welded pressure vessels

This specification is written as a set of minimum requirements for design, materials, fabrication, inspection, testing and preparation for shipment of unfired, fusion welded pressure vessels. The terminology used within this specification is in accordance with ISO/IEC Directives, Part 2.

S-619D: Datasheet for unfired, fusion welded pressure vessels

This document provides project specific requirements where this specification requires the purchaser to define an application specific requirement. It also includes information required by the purchaser for technical evaluation. Additional purchaser supplied documents are also listed in the datasheet, to define scope and technical requirements for enquiry and purchase of the equipment.

S-619L: Information requirements for unfired, fusion welded pressure vessels

This document defines the information requirements, including format, timing and purpose, for information to be provided by the vendor. It also defines the specific conditions which must be met for conditional information requirements to become mandatory. The information requirements listed in the IRS have references to the source of the requirement.

S-619Q: Quality requirements for unfired, fusion welded pressure vessels

This document includes a conformity assessment system (CAS) which specifies standardized user interventions against quality management activities at four different levels. The applicable CAS level is specified by the purchaser in the datasheet.

The datasheet and IRS are published as editable documents for the purchaser to specify application specific requirements. The supplementary specification and QRS are fixed documents.

Unless defined otherwise in the purchase order, the order of precedence (highest authority listed first) of the documents shall be:

a) regulatory requirements;

b) contract documentation (e.g. purchase order);

c) purchaser defined requirements (datasheet, IRS, QRS);

d) this specification.

1 Scope

1.1 General

This specification defines the minimum set of requirements for design, materials, fabrication, inspection, testing and preparation for shipment of unfired, fusion welded pressure vessels.

1.2 Materials

This specification includes requirements for the supply of vessels manufactured from:

a. carbon steel;

b. austenitic stainless steel;

c. 22 Cr Duplex, 25 Cr Super Duplex;

d. carbon steel base integrally clad or weld overlaid with austenitic stainless steel, alloy 276, alloy 625 and alloy 825.

2 Normative References

The following documents are referred to in this specification in such a way that some or all of their content constitutes requirements of this specification.

API RP 578	Guidelines for a Material Verification Program (MVP) for New and Existing Assets
API RP 582	Welding Guidelines for the Chemical, Oil and Gas Industries
API Std 660	Shell-and-tube Heat Exchangers
ASME BPVC Section VIII Div.2	Rules for Construction of Pressure Vessels — Alternative Rules
ASME BPVC Section IX	Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators
ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
ASTM A262	Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
ASTM A264	Specification for Stainless Chromium Steel-Nickel Steel-Clad Plate
ASTM A265	Specification for Nickel and Nickel base alloy clad steel plate
ASTM A578	Specification for straight-beam ultrasonic examination of rolled steel plates for special applications
AWS A4.2	Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal
EN 10160	Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm ($^1/_4$ in) (reflection method)
ISO 3834	Quality requirements for fusion welding of metallic materials

ISO 9712	Non-destructive testing — Qualification and certification of NDT personnel
ISO 14731	Welding Coordination — Tasks and Responsibilities
ISO 15156-1/ NACE MR0175-1	Petroleum and natural gas industries — Materials for use in H2S-containing environments in oil and gas production — Part 1: General principles for selection of cracking-resistant materials.
ISO 15156-2/ NACE MR0175-2	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/ NACE MR0175-3	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 17945/ NACE MR0103	Petroleum, petrochemical and natural gas industries — Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments
ISO 17781	Petroleum, petrochemical and natural gas industries — Test methods for quality control of microstructure of ferritic/austenitic (duplex) stainless steels
ISO 17782	Petroleum, petrochemical and natural gas industries — Scheme for conformity assessment of manufacturers of special materials
NACE TM 0284	Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking
NORSOK M-650	Qualification of manufacturers of special materials
TEMA	Standards of the Tubular Exchanger Manufacturers Association
WRC-297	Local Stresses in Cylindrical Shells Due to External Loading on Nozzles
WRC-452	Recommended practices for Local Heating of Welds in Pressure Vessels
WRC-537	Precision Equations and Enhanced Diagrams for Local Stresses in Spherical and Cylindrical Shells Due to External Loading for Implementation of WRC Bulletin 107

3 Terms and Definitions

3.1 Definitions

3.1.1 custom designed flange

flange, including girth flange, flanges in flanged heads, nozzle flanges, companion flanges, etc. designed as per the rules of the design code

3.1.2 effective diameter

insulated outside diameter of the vessel plus the additional diameter for any externally attached piping, ladders and platforms

3.1.3 fittings

fittings dimensioned and manufactured in conformance with ASME B16.9 or equivalent standard

3.1.4 standard flange

flanges dimensioned and manufactured in conformance with ASME B16.5, ASME B16.47 or equivalent standard

3.2 Abbreviations

Alphabetical list of abbreviations used in this document:

ACCP	ASNT Central Certification Program
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BPVC	boiler and pressure vessel code
CE	carbon equivalent (% C + % Mn / 6 + (% Cr + % Mo + % V) / 5 + (% Ni + % Cu) / 15)
DN	nominal diameter
EN	European Norm (standard)
FCAW	flux-cored arc welding
FN	ferrite number
GMAW-P	gas metal arc welding, pulsed arc
GTAW-P	gas tungsten arc welding, pulsed arc
HIC	hydrogen-induced cracking
HRC	Rockwell hardness, C scale
HV	Vickers hardness
ISO	International Organisation for Standardisation
MACA	maximum allowable corrosion allowance
NACE	National Association of Corrosion Engineers
NORSOK	Norsk Sokkels Konkuranseposisjon (the Norwegian shelf's competitive position)

NPS	nominal pipe size
NPT	national pipe thread
PMI	positive material identification
PWHT	post weld heat treatment
SAW	submerged arc welding
SMAW	shielded metal arc welding
WRC	Welding Research Council

3.3 Symbols

h	distance from the base of the support to the top tangent line of the vessel
d	average outside diameter of the top third of the vessel
d_i	inside diameter of shell or head

4 Vendor's data

4.1 Proposal information required

The vendor's proposal shall, as a minimum, include the following documents:

a. completed datasheet;

b. delivery schedule;

c. list of sub-vendors and sub-contractors;

d. concession requests.

4.2 Drawings and other information required

The vendor shall submit the following documentation to the purchaser:

a. non-conformance records;

b. concession requests;

c. completed datasheet;

d. quality plan;

e. inspection and test plan;

f. general arrangement drawing;

g. detail drawings;

h. design calculations;

i. welding book;

j. non-destructive examination procedures, if applicable;

k. forming procedure, if applicable;

l. positive material identification procedure, if applicable;

m. pickling and passivation procedure, if applicable;

n. heat treatment procedure, if applicable;

o. pressure test procedure;

p. lifting plan;

q. load testing certification of external lifting devices, if applicable;

r. surface preparation and coating procedure;

s. post welding heat treatment temperature chart;

t. non-destructive examination map;

u. material test certificates;

v. handling, shipping, storage and preservation procedure;

w. installation, operation and maintenance instructions;

x. spare part list;

y. manufacturing record book (MRB).

5 Design

5.1 General

5.1.1

The vessel shall be designed, fabricated and tested in accordance with the design code as specified in the datasheet.

5.1.2

Unless otherwise specified on the datasheet, the design life of the vessel shall be 20 years.

5.1.3

The minimum thickness *t* of the vessel wall shall satisfy all design load combinations specified in the design code and shall not be less than calculated by Equation (1).

$$t = \frac{d_i}{1000} + ca + x \qquad (1)$$

where

t	is the minimum thickness of the vessel wall
ca	is the corrosion allowance
x	is 2,5 mm (0,1 in)

For formed heads, the minimum thickness shall be after forming.

5.1.4

The use of ASME code cases is not permitted, except as allowed in 5.8.3.

5.1.5

The maximum allowable working pressure (MAWP), maximum allowable pressure – new and cold (MAP) or maximum allowable corrosion allowance (MACA) of the vessel shall not be limited by fittings, nozzle reinforcement, nozzle neck thickness, nozzle flange or flange bolting.

5.1.6

During the hydrotest, the general primary membrane stress in any pressure part shall not exceed 95 % of the material minimum specified yield strength, unless otherwise specified by the design code.

5.1.7

All components shall be designed for the most severe combination of pressure and temperature, which may include the effects of coincident vacuum in an adjacent chamber.

5.1.8

All butt welds on the primary pressure boundary shall be full penetration type. Partial penetration welds are not permitted.

5.1.9

Where the design code provides rules for the component thickness calculation using design by analysis, these shall not be used to justify a thinner thickness, unless approved by the purchaser.

5.2 Corrosion allowance

5.2.1

For internals, the corrosion allowance as specified on the datasheet shall be added to each face of the internals in contact with the process fluid (wetted surface).

5.2.2

The corrosion allowance for vessel supports made of carbon steel shall be 1,5 mm (0,06 in).

5.2.3

Corrosion allowance shall not be considered on gasket seating surface.

5.3 Wind, seismic and snow loads

5.3.1

Wind, seismic, and snow loads shall be calculated as per the applicable code and any additional data specified in the datasheet.

5.3.2

Vibration analysis for wind induced vortex-excited resonance shall be performed on:

a. vertical vessels with $5 \leq h/d \leq 15$ and natural frequency of vessel less than 2 Hz;

b. all vertical vessels with $h/d > 15$, irrespective of natural frequency.

5.3.3

Maximum allowable deflection at the top of vertical vessels shall not exceed 1:200 of height h, unless otherwise specified.

5.3.4

The effective diameter of the vessel shall be used in wind load calculations.

5.4 Design loads and load combinations

5.4.1

Design loads and load combinations shall be as per Table 1 and Table 2.

Table 1 – Design load combinations

Design load combination	Description
L2 + L10 + L12 + L14	Erected or (as installed) condition with full wind load and full snow load
L3 + L10 + L12 + L13 + L14 + L16	Operating condition (corroded), no pressure, with full wind load and full snow load
L3 + L11 + L12 + L13 + L14 + L16	Operating condition (corroded), no pressure, with full seismic load and full snow load
L3 + L6 + L10 + L12 + L13 + L14 + L16	Operating condition (corroded and uncorroded) with full pressure, full wind loads and full snow load
L3 + L6 + L11 + L12 + L13 + L14 + L16	Operating condition (corroded and un-corroded) with full pressure, full seismic loads and full snow load
L4 + L8 + (0,25)L10 + L12	Shop (or initial) hydrostatic test condition (uncorroded)
L4 + L9 + (0,25)L10 + L12	Field (or future) hydrostatic test condition (corroded)
L5 + L12 + L17	Transport condition
L3 + L7 + L12 + L13 + L14 + L15	Blast load Condition

Table 2 – Design load combination definitions

Design Load	Description
L1 – Fabricated Weight	Total weight of the vessel as fabricated in the shop
L2 – Empty weight	Total weight of the vessel sitting on the foundation, fully dressed, waiting for operating liquid
L3 – Operating weight	Empty weight plus any operating fluid weight
L4 – Hydrotest weight	Empty weight of the vessel under hydrostatic test condition including the weight of the test fluid
L5 – Shipping weight	Fabricated weight of the vessel plus any weight added for shipping purposes such as shipping saddle
L6	Internal (including static head) or external design pressure and internal or external design temperature
L7	Normal operating pressure and temperature
L8	Shop (or initial) hydro test pressure and temperature
L9	Field (or future) hydro test pressure and temperature
L10	Wind load (not wind speed)
L11	Seismic load
L12	Snow load
L13	Static reactions from the load of attached equipment, such as motors, machinery, other vessels and piping
L14 -- Motion induced Load	Hull/floating unit movement effect, towing out motion, etc. whenever applicable.
L15	Blast load
L16 – Thermal Load	Steady state or transient effect of fluid flow such as icing, chilling, thermal shock, etc.
L17	Transportation load (transportation acceleration forces)

5.5 Lifting loads

5.5.1

For vessels lifted in conditions expected to be stable, lifting attachments shall be designed using a factor of 1,5 on the weight of the vessel during lifting.

For vessels lifted in conditions expected to be dynamic (e.g. lifting from a barge subject to wave action), lifting attachments shall be designed using a factor of 2,0 on the weight of the vessel during lifting.

5.5.2

Unless otherwise specified in the datasheet, skirt supported vertical vessels with a total height of $h \geq 20$ m (65 ft), irrespective of the empty weight and empty weight ≥ 20 000 kg (44 000 lb), irrespective of height, shall be provided with tailing devices.

5.5.3

Vertical vessels along with lifting attachments shall be designed for erection from a horizontal to a vertical position. Design shall be verified at increments of no greater than 5°.

5.6 Local loads

5.6.1

Localized stresses caused by concentrated loads on nozzles or any external structural attachment due to piping reactions, supported equipment, lifting of vessel etc. shall be evaluated. The evaluation shall be performed in accordance with WRC 297, WRC 537 or by finite element analysis. Use of any other standard or numerical method is subject to the approval of the purchaser. All geometrical limits specified in methods (such as WRC, etc.) used for local load analysis shall be followed. Extrapolation beyond stated limits is not allowed.

5.6.2

Allowable nozzle loads at nozzle to shell or head junction shall be as per API Std 660. For nozzle sizes greater than DN 600 (24 in), maximum allowable nozzle loads shall be agreed with the purchaser.

5.6.3

Where the nozzle loads specified lead to an increase in local shell and head thickness, mutually acceptable loads shall be agreed with the purchaser.

5.7 Nozzles, manways and reinforcements

5.7.1

Except where set-in type nozzles are required by this specification (e.g. for sour service), set on type nozzles may be welded to the shell or head with a thickness greater than 50 mm (2 in) and nozzle thickness less than or equal to half of the shell or head thickness.

In this case, liquid penetrant or magnetic particle examination of the surface of the through wall cut (see Figure 1), and a lamination check by 100 % ultrasonic examination of the base plate to a distance of 100 mm (4 in) around the nozzle opening shall be performed prior to nozzle fit-up. The acceptance criteria shall be zero defects.

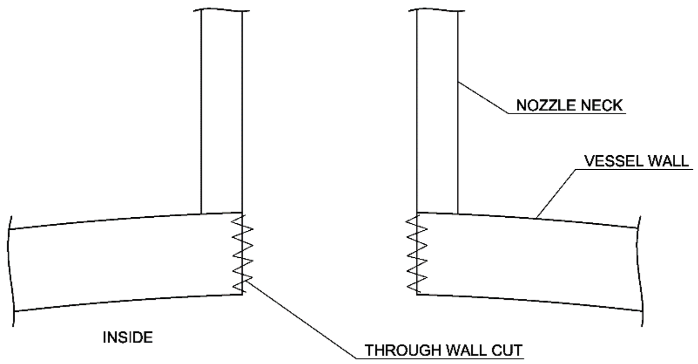


Figure 1 – Through-wall-cut

5.7.2

Minimum nozzle size shall be DN 40 (NPS $1^1/_2$).

5.7.3

All nozzle connections shall be either weld neck, long weld neck or stub-end (butt weld).

5.7.4

Flanged nozzles DN 40 (NPS 1 $^1/_2$) and DN 50 (NPS 2) shall be long weld neck flanges or fabricated from seamless pipe with nominal wall thickness per Table 3.

Table 3 – Fabricated flanged nozzles

Flanged nozzles size	Nominal wall thickness of seamless pipe
DN 40 (NPS 1 ½)	7,14 mm (0,281 in) or 10,15 mm (0,400 in)
DN 50 (NPS 2)	8,74 mm (0,344 in) or 11,07 mm (0,436 in)

5.7.5

Fittings shall not be directly welded to vessel wall.

5.7.6

No threaded connections shall be screwed directly into any pressure part of the vessel.

5.7.7

For vessels with removable internals, access shall be provided for maintenance or replacement.

5.7.8

For vessels with internal diameter less than 1 000 mm (40 in), bolted heads or body flanges may be used for access.

5.7.9

Inspection openings shall not be less than DN 100 (NPS 4).

5.7.10

Nozzle to vessel wall joints shall have full penetration welds.

5.7.11

Internal reinforcing pads shall not be used for nozzles.

5.7.12

Minimum manway inside diameter shall be 546 mm (21,5 in).

5.7.13

Minimum nozzle projections shall be as per Figure 2, Figure 3 and Table 4.

5.7.14

Set-in nozzles shall be ground to match the contour of the vessel inside diameter and inside edges of nozzle wall shall be rounded off.

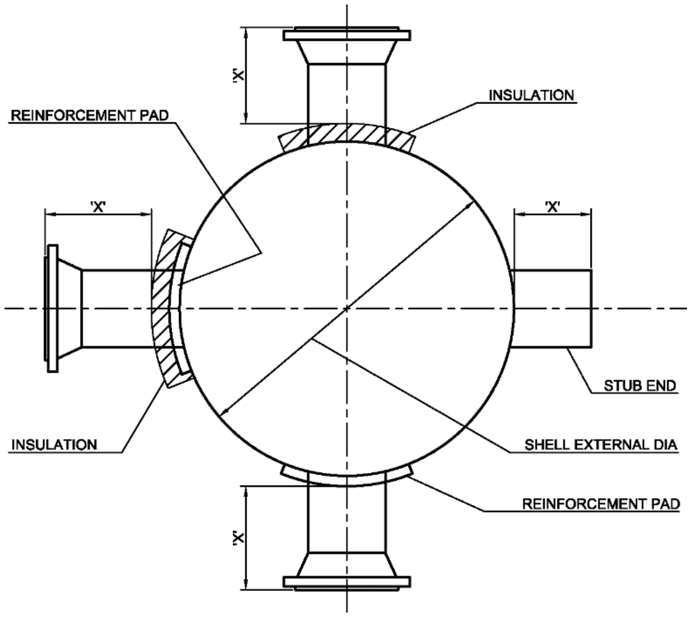


Figure 2 – Determining radial nozzle standout length "X"

SOURCE: Equinor TR1053, V.9.01, 2016, Fig.1

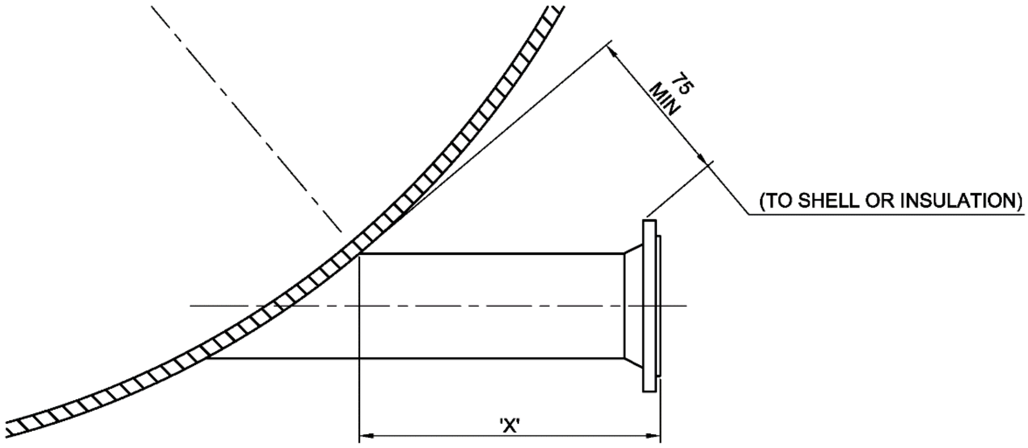


Figure 3 – Determining offset nozzle standout length "X"

SOURCE: Equinor TR1053, V.9.01, 2016, Fig.1

Table 4 – Minimum nozzle standout

Flange Class	Minimum nozzle standout length "X" Dimensions in millimetres (inches)											
	DN 50	DN 80	DN 100	DN 150	DN 200	DN 250	DN 300	DN 350	DN 400	DN 450	DN 500	DN 600
	NPS 2	NPS 3	NPS 4	NPS 6	NPS 8	NPS 10	NPS 12	NPS 14	NPS 16	NPS 18	NPS 20	NPS 24
Cl-150	200 (8)	200 (8)	200 (8)	200 (8)	200 (8)	200 (8)	220 (9)	220 (9)	220 (9)	220 (9)	220 (9)	320 (13)
Cl-300	200 (8)	200 (8)	200 (8)	200 (8)	220 (9)	220 (9)	220 (9)	220 (9)	220 (9)	220 (9)	220 (9)	320 (13)
Cl-600	200 (8)	200 (8)	200 (8)	220 (9)	220 (9)	220 (9)	260 (10,5)	260 (10,5)	260 (10,5)	260 (10,5)	260 (10,5)	320 (13)
Cl-900	200 (8)	200 (8)	220 (9)	220 (9)	260 (10,5)	260 (10,5)	260 (10,5)	260 (10,5)	260 (10,5)	260 (10,5)	260 (10,5)	320 (13)
Cl-1500	220 (9)	220 (9)	260 (10,5)	260 (10,5)	260 (10,5)	320 (13)	320 (13)	320 (13)	320 (13)	400 (16)	400 (16)	400 (16)
Cl-2500	260 (10,5)	260 (10,5)	320 (13)	320 (13)	320 (13)	400 (16)	400 (16)					

SOURCE: Equinor TR1053, V.9.01, 2016, Table 2

5.7.15

Unless otherwise specified, flanges on nozzles including manways and access opening shall be raised face.

5.7.16

Reinforcing pads for nozzles shall be limited to a maximum of two pieces.

5.7.17

The thickness of nozzle reinforcing pads shall be no thinner than the nominal vessel wall thickness minus the total corrosion allowance and shall not exceed 50 mm (2 in).

5.7.18

Removable internals shall be designed to pass through vessel manways.

5.8 Custom designed flanges

5.8.1

Minimum bolt spacing shall be in accordance with TEMA. If hydraulic bolt tensioning is required, sufficient spacing shall be provided between bolts to allow hydraulic bolt tensioning.

5.8.2

Nubbins are not permitted.

5.8.3

In addition to design pressure, flange design shall account for all other loadings (e.g. externally applied bending moment or axial thrust loadings), as applicable. ASME Code Case 2901 may be used for the evaluation of external loads.

5.8.4

Unless otherwise specified in the design code, the gasket seating surface finish and flatness tolerance for custom designed flanges shall be as per ASME PCC-1.

5.8.5

The flatness of all gasket surfaces for custom designed flanges shall be measured after heat treatment and final machining.

5.9 Flange bolting

5.9.1

Bolts shall be studs, threaded full length, with heavy hex nuts.

5.9.2

Stud lengths shall be such that they extend beyond the nut by at least three threads at each end.

5.9.3

When bolt tensioning is used, studs shall have additional threaded length equivalent to one stud diameter, extending from the nut at one end, to allow attachment of the bolt-tightening device. The exposed length shall be protected with an additional nut.

5.10 Skirt support

5.10.1

Skirts shall be no thinner than the lesser of 6 mm ($^{1}/_{4}$ in) inclusive of any skirt corrosion allowance or the nominal thickness of the vessel component to which it is attached.

5.10.2

Access openings shall be provided in skirts. No piping shall run through access openings.

5.10.3

No flanged connection shall be allowed inside the skirt.

5.10.4

Skirt openings shall be provided with rings or collars sized to ensure that the structural stability of the skirt is not compromised.

5.10.5

If specified in the datasheet, provision shall be made for venting and draining of the skirt. The location of the vent shall take into account any required insulation of the bottom head.

5.11 Legs

5.11.1

Small, cylindrical, vertical vessels [$d_i \leq 1\,000$ mm (40 in.)] may be supported by legs, if all of the following conditions are met:

a. the design temperature is not greater than 230 °C (450 °F);

b. the h/d_i ratio is no greater than 5.

5.12 Saddles

5.12.1

Horizontal vessels shall be supported on two saddles, one fixed and one sliding.

5.12.2

Vessels shall be evaluated for stresses imposed by all the applicable loading on the saddles.

6 Materials

6.1

Material specified in the datasheet shall not be substituted by the vendor without purchaser approval.

6.2

Castings shall not be used.

6.3

Unless specified in the datasheet, permanent attachments including vessel supports directly welded to pressure parts shall be of the same nominal chemistry as the pressure part. These permanent attachments shall be suitable for the minimum design metal temperature of the vessel.

6.4

For stainless steel vessels, the skirt support material shall be the same nominal chemistry as the vessel wall base material for a minimum length as calculated by Equation (2) or 300 mm (12 in) whichever is larger, below the vessel-to-skirt connection line.

Minimum length of skirt support = $1{,}8 \times \sqrt{D_S + T_S}$ (2)

where

D_s is the skirt outside diameter

T_s is the skirt nominal thickness

The remainder of the skirt may be code approved carbon steel provided it is suitable for the design minimum ambient temperature to avoid brittle fracture.

6.5

The minimum design metal temperature specified in the datasheet shall be used to evaluate the impact test requirements and exemptions as per the design code. Further reduction in the minimum design metal temperature (e.g. reduction for thickness ratio) for impact test exemption is not allowed.

6.6

Repair welding of forged or rolled base materials is not permitted, unless approved by the purchaser.

6.7

Positive material identification shall be carried out at vessel shop in accordance with API RP 578 or other equivalent standard to verify all pressure part components of alloy steel material including cladding and overlay welding.

6.8

Extent of PMI shall be as specified in the datasheet.

7 Fabrication

7.1 General

7.1.1

All continuously welded external reinforcing pads and similar attachments (e.g. wrapper plate for saddles, nozzle reinforcing plates, wear plates, etc.) shall be provided with one vent hole in each segment at the lowest practical point of the pad or attachment. Alternatively for continuously welded internal attachments, 25 mm (1 in) length at the low point may be left un-welded to create a vent.

7.1.2

The reinforcement pad vent hole shall be tapped DN 8 ($^1/_4$ NPT).

7.1.3

Non-circular attachment pads shall have a corner radius of at least five times the pad thickness or 50 mm (2 in), whichever is smaller.

7.1.4

Production test plates, if required per the design code or indicated in the datasheet, shall be fabricated using the same base material, of same heat and thickness, and shall be subjected to the same welding procedures and thermal treatment used for the longitudinal and circumferential weld joints in the shell and head.

7.1.5

The distance between main seam welds (longitudinal and circumferential joints) and nozzles, reinforcement or other welded attachments shall be at least 50 mm (2 in), measured weld toe to weld toe.

7.1.6

Where attachments will cover main seam welds, the length of the main seam weld covered by the attachment and projecting at least 50 mm (2 in) beyond each side of the attachment shall be ground flush and inspected with 100 % volumetric examination and magnetic particle or liquid penetrant examination.

7.1.7

All surfaces to be welded shall be clean and free from paint, oil, dirt, scale, oxides and other foreign material detrimental to weld integrity.

7.1.8

Arc strikes outside of the weld area shall be removed by light grinding and inspected with magnetic particle or liquid penetrant examination.

7.1.9

The thickness of all formed pressure parts shall be measured after forming and shall be recorded.

7.1.10

Permanent marking, if required on the pressure boundary, shall be done with low stress stamps on the outside of the vessel and before any post weld heat treatment is performed.

7.1.11

Local thin areas, as defined per the design code, that fall below the nominal thickness of the vessel wall less tolerance, shall be repaired or the component shall be replaced.

Fitness for service or an equivalent calculation shall not be used as a justification for not repairing defects such as local thin areas.

7.1.12

Longitudinal weld seams of horizontal vessels shall be located on or above the horizontal plane through the centreline of the vessel.

7.2 Welding

7.2.1

Welding and welder qualification shall be performed as per the requirements specified in the design code, datasheet and the requirements of this specification.

7.2.2

All welding and related activities shall comply with the requirements of ISO 3834 and ISO 14731 or ASME Section IX, if applicable.

7.2.3

FCAW self-shielded is not permitted. FCAW gas-shielded is acceptable for weld passes other than the root pass in single sided weld joints.

7.2.4

GTAW-P and GMAW-P shall be performed with the same make and model of equipment, and using the same program settings as those used in the qualification procedure.

7.2.5

Active flux shall not be used for submerged arc welding.

7.2.6

Any change in the following welding variables shall require requalification of the applicable welding procedure.

a. base materials:

   1. carbon steel material, an increase in CE of more than 0,03 than the value qualified in the procedure qualification record, when any of the following conditions apply:

      i. subject to sour service regardless of their wall thickness;

      ii. the wall thickness greater than 38mm (1,5 in), regardless of the service;

      iii. subject to PWHT due to service, regardless of their wall thickness;

      iv. subject to impact toughness requirements.

   2. carbon steel material other than covered in a.1, an increase in CE of more than 0,03 when the relevant value of the material tested during procedure qualification is greater than 0,43;

   3. from type 22Cr duplex to type 25Cr duplex.

b. welding consumables:

   1. consumable brand name when impact testing is required. This does not apply to solid wire provided with documentation confirming there is no change in origin, chemical composition and mechanical properties;

   2. for SMAW, any increase of size in consumable in the root run of single sided welds;

   3. for FCAW-gas shielded, any increase of size in consumable other than in the root run of single sided welds;

   4. for SAW, whenever the welding flux is changed from one consumable brand name to another.

c. welding position:

   1. from vertical uphill to vertical downhill welding;

   2. from vertical downhill to vertical uphill welding.

d. technique:

   1. from multi pass to single pass when impact testing is required.

e. joints:

   1. from double sided welding to single sided welding;

      NOTE Single sided welding with backing strip is equivalent to double sided welding.

   2. decrease in the included angle of more than 10° for included angles less than 60°;

   3. deviation from qualified angle or more than ± 2,5º if the qualified angle is less than 30° (except for portions of compound bevels).

7.2.7

Permanent backing strips are not permitted.

7.2.8

After the removal of temporary backing strips, the root of the weld shall be examined by either magnetic particle or liquid penetrant examination. When metallic backing strips are used, the root of the weld shall be ground smooth before examination.

7.2.9

All welds directly on to pressure parts shall be continuous except for insulation support ring welds. Insulation support ring welds may be discontinuous subject to approval of the purchaser.

7.2.10

Tack welds incorporated into the main weld shall have their ends ground and feathered, and shall be free of visible defects.

7.2.11

All welding consumables shall be individually marked as per the consumable specification.

7.2.12 Preheating

Preheating, if required, shall satisfy the following requirements.

7.2.12.1

The required preheat temperature shall be reached before commencement of welding and maintained until the welding has been completed.

7.2.12.2

The preheat temperature shall be measured at a distance of not less than 75 mm (3 in) on either side of the weld groove.

7.2.12.3

The interpass temperature measurements shall be taken from deposited weld metal. The minimum interpass temperature shall not be less than the specified preheat temperature.

7.2.13

Weld repair procedures shall be approved by the purchaser prior to the commencement of any repair.

8 Heat treatment

8.1

When post weld heat treatment is required, simulated post weld heat treatment of production test plates and weld procedure qualifications shall be subjected to a minimum of one additional post weld heat treatment cycle.

8.2

Complete weld procedure qualification mechanical testing shall be performed both after the initial heat treatment and a second simulated post weld heat treatment.

8.3

When post weld heat treatment is required, it shall be performed after completion of all welding including any weld repairs and all weld overlay and clad restoration, if applicable.

8.4

For quenched and tempered or normalized and tempered carbon steel materials, the post weld heat treatment holding temperature shall be at least 15 °C (25 °F) below the original tempering temperature of the base metal, unless the vendor demonstrates and the purchaser approves that mechanical properties can be achieved at a different post weld heat treatment temperature and holding time.

8.5

Thermocouples, in contact with both the internal and external surfaces of the vessel, shall be used to continuously and automatically record the post weld heat treatment temperature on a chart from the start of controlled heating until the end of the controlled cooldown. The thermocouples shall be insulated from the heat source.

8.6

When post weld heat treatment is required, the minimum soak time shall not be less than one hour.

8.7

Reduced post weld heat treatment temperatures for longer duration shall not be permitted.

8.8

Any heating method associated with post weld heat treatment, which implies direct flame impingement on any part of the vessel is not permitted.

8.9

Local post weld heat treatment shall not be permitted, unless approved by the purchaser. When permitted, local PWHT design shall be based on WRC 452.

9 Non-destructive examination

9.1 General

9.1.1

All required non-destructive examination for final acceptance of the vessel shall be performed after the completion of all welding, weld repairs and post weld heat treatment, if required, and prior to pressure testing.

9.1.2

The responsible person for the non-destructive examination shall be qualified to ISO 9712 level III, ASNT Central Certification Program (ACCP) level III or equivalent. All non-destructive examination operators shall be qualified to ISO 9712 level II, ACCP level II or equivalent if specified in the datasheet.

9.1.3

Acceptance criteria for all non-destructive examinations shall be as per the design code or as specified in the data sheet.

9.2 Radiographic and ultrasonic examination

9.2.1

The extent of examination shall be in accordance with the requirements of the design code and as specified in the datasheet.

9.2.2

Ultrasonic examination shall be acceptable in lieu of radiographic examination where allowed by the design code.

9.2.3

Where 100 % volumetric examination is specified, the complete length of all butt welds, nozzle to vessel wall joints, nozzle neck weld seams, nozzle to flange joints and skirt to forged ring (if applicable) shall be examined.

9.2.4

The welds of heads constructed from two or more pieces shall be examined by 100 % volumetric examination after forming.

9.2.5

When spot radiography is applicable, the purchaser or the purchaser's representative shall designate the locations at which the spot radiographs shall be taken.

9.3 Magnetic particle or liquid penetrant examination

9.3.1

Unless otherwise specified in the datasheet, the minimum extent shall be as per ASME BPVC.VIII.2:2017, Table 7.2.

9.3.2

All cold formed heads shall have the inside and outside surfaces of the knuckle region examined by magnetic particle or liquid penetrant examination after completion of all forming and material heat treatment.

10 Pressure testing

10.1

All vessels shall be hydrostatically tested at the hydrotest pressure as per the design code and the basis specified in the datasheet.

10.2

The minimum hold time at hydrotest pressure shall be one hour, unless otherwise specified on the datasheet.

10.3

Vertical vessels may be shop tested in a horizontal position with adequate support to prevent overstressing during testing.

10.4

Each reinforcing pad segment shall be tested at a gauge pressure of 100 kPa (15 psig) with dry air or nitrogen and a bubble forming solution.

10.5

Hydrostatic pressure testing shall be performed with gaskets and bolting identical to those required in service. These gaskets may be service gaskets if the bolted joint is not disassembled after completion of hydrostatic pressure testing.

10.6

No paint, primer or any other type of coating shall be applied to the vessel prior to hydrostatic testing.

11 Coating and painting

Requirement and extent of coating shall be as specified by the purchaser.

12 Preparation for shipment

12.1 General

12.1.1

All vent holes shall be plugged after testing. The plugging material used shall not be capable of sustaining pressure between the reinforcing plate and the vessel wall.

12.1.2

Unless otherwise specified, the vessel shall be shipped with service gaskets and bolting in place for all body flanges, custom designed flanges and permanently blinded connections.

12.1.3

Unless otherwise specified, steel shipping saddles shall be provided for vertical vessels.

12.1.4

A barrier material shall be provided between shipping saddles and the vessel to prevent damage to the surface of the vessel or contamination of the vessel material.

12.1.5

Baseplates, saddles or skirts may be welded to the deck of ships, barges, railcars, and trailers even if the vessel has been post weld heat treated.

12.2 Protection

12.2.1

All liquids used for cleaning or testing shall be drained from the vessel and any residues dried prior to shipment.

12.2.2

The vessel shall be free of any foreign matter prior to shipment.

12.2.3

Removable internal and external parts assembled with the vessel prior to shipment shall be tied or braced with temporary supports, as necessary, to prevent damage or dislodgement during shipment and installation.

12.2.4

Temporary supports shall be painted with a fluorescent colour paint.

12.2.5

All exposed machined and threaded surfaces on the vessel and parts to be shipped loose shall be suitably protected to prevent damage and corrosion.

12.2.6

Unless otherwise specified, flanges shall be blanked with oil resistant rubber gaskets or self-adhesive flange protectors and steel or water resistant plywood blanks with a minimum of four bolts sufficient to provide mechanical protection, and water and dust tight sealing.

12.2.7

Unless specified in the datasheet, the use of nitrogen or other means of creating an oxygen-deficient atmosphere shall not be used for vessel purging during transportation and storage.

12.2.7.1

When an inert gas purge is specified, pressure shall be maintained at no less than a gauge pressure of 35 kPa (5 psig) indicated by a pressure gauge during transportation and storage.

12.2.7.2

Gauges shall be suitably protected from damage during transportation.

12.2.7.3

When the vessel is purged with dry air and desiccant bags are placed in the vessel, the vendor shall record the quantity and location of the desiccant bags.

12.3 Identification

12.3.1

The exterior of the vessel shall be marked with the vessel tag number, shipping weight and purchase order number with a minimum of 75 mm (3 in) high letters of contrasting colour. For vessels less than 1 000 mm (40 in) inside diameter these markings may have 25 mm (1 in) high letters.

12.3.2

For all vessels, markings other than those required under 12.3.1 may have 25 mm (1 in) high letters.

12.3.3

The centre of gravity shall be marked on each side of the exterior of the vessel.

12.3.4

Vessels that have received post weld heat treatment shall be labelled or painted with the text “POST WELD HEAT TREATED – DO NOT BURN OR WELD”.

12.3.5

Any equipment protected by an inert gas fill shall have the warning "DANGER - NON-LIFE SUPPORTING ATMOSPHERE" displayed in the immediate vicinity of any manways or other points of access to the interior of the vessel.

Annex A
(normative)
Additional requirements for sour service vessels

A.1
The requirements specified by this annex are minimum requirements. If more stringent requirements such as butt-welded type nozzles, forged ring type skirt to head joints, full penetration groove welds for welded attachments, etc. are required based on severity of the service, these shall be agreed between the purchaser and the vendor.

A.2
All requirements of ISO 15156 / NACE MR0175 (all parts) or ISO 17945 / NACE MR0103 shall be satisfied.

A.3
All nozzles shall be set-in type, integrally reinforced and fitted flush with the shell or head.

A.4
All butt welds shall be subject to 100 % volumetric examination. Nozzle to vessel wall joints shall be 100 % ultrasonically tested.

A.5
All welds directly to the internal surfaces of the pressure part shall be subject to 100 % surface inspection by magnetic particle or liquid penetrant examination.

A.6
For carbon steel vessels, the preheat temperature reported during procedure qualification is an essential variable and shall be the minimum specified preheat temperature for production welding.

A.7
Welding procedures for the fabrication of vessels shall be qualified using supplementary hardness testing after the minimum anticipated heat treatment cycle (normally, the first heat treatment cycle).

A.8
Heat input values (per welding process) used for production welding shall not be less than the minimum heat input (per welding process) reported during procedure qualification.

A.9
The following dissimilar welds if in contact with process fluid (wetted surface) are not permitted unless approved by the purchaser:

a. ferritic steels and austenitic stainless steel;

b. ferritic steels and 22Cr duplex or 25Cr duplex;

c. ferritic steels and nickel base alloy steels.

A.10

When HIC testing is specified in the datasheet, one plate per lot shall be HIC tested in accordance with NACE TM0284, using test solution A and the following acceptance criteria shall apply.

a. crack length ratio (CLR) ≤ 15% per specimen;

b. crack thickness ratio (CTR) ≤ 5% per specimen;

c. crack sensitivity ratio (CSR) ≤ 2% per specimen;

d. 5 mm (0,2 in) maximum individual crack length.

e. ultrasonically tested as per ASTM A578 S1; S2.1 or EN 10160 quality classes S2 (plate) E3 (edge).

Annex B
(normative)
Additional requirements for integrally clad and weld overlay vessels

This annex covers requirements for integrally clad and weld overlaid carbon steel with austenitic stainless steel, alloy 276, alloy 625 or alloy 825.

B.1 General

B.1.1

Acceptable cladding methods are:

a. integral cladding achieved by hot rolling or explosion bonding;

b. weld overlay.

B.1.2

The base metal nominal thickness shall not be less than 10 mm ($^{3}/_{8}$ in).

B.1.3

The minimum thickness of cladding or overlay welding shall be 3 mm ($^{1}/_{8}$ in).

B.1.4

Design calculations shall be based on the base material thickness after clad restoration, excluding the thickness of the cladding.

B.1.5

When post weld heat treatment is required, weld procedure qualifications shall include corrosion testing according to ASTM A262 practice E for austenitic stainless steel.

Test coupons shall be heat treated prior to testing with at least twice the fabrication heat treatment soak time as specified for the equipment.

B.1.6

Surfaces contaminated with iron during fabrication shall be pickled and passivated.

B.1.7

The chloride content of the hydrostatic test water shall not exceed 50 mg/kg (50 parts per million by mass).

B.1.8 Nozzles

B.1.8.1

The minimum nozzle size for nozzles in cladded sections shall be DN 50 (NPS 2) unless otherwise specified by the purchaser in the datasheet.

B.1.8.2

Nozzles shall be clad, either integrally or by weld overlay. Nozzles DN 100 (NPS 4) and smaller and girth flanges may be of solid alloy subject to the purchaser’s approval.

If nozzles are rolled from integrally clad plate, the longitudinal and circumferential welds in the nozzle section shall be subject to 100 % volumetric examination.

B.1.8.3

Radius or profiling at nozzle connections shall not reduce any clad thickness below specified minimum value.

B.2 Integral cladding

B.2.1

Unless specified in the design code, integrally clad plate shall comply with the requirements of ASTM A264 or ASTM A265.

B.2.2

Plates shall be ultrasonically tested as per acceptance criteria agreed with the purchaser.

B.2.3

Formed heads or sections shall be ultrasonically tested after forming.

B.2.4

Cut areas shall be ultrasonically examined within 50 mm (2 in) from the edge of the opening.

B.2.5

Attachments may be welded directly to integrally clad plates if all of the following conditions are met.

a. the induced weld stress due to mechanical loads on the attachment do not exceed 25 % of the allowable stress for weld;

b. the temperature difference between the shell and the attachment is not expected to exceed 14 °C (25 °F).

All other attachments shall be welded directly to the base metal after stripping back the cladding locally. Cladding shall be restored by weld overlay.

B.2.6

When clad restoration is required, the clad layer shall be stripped back to a minimum distance of 5 mm (0,2 in) from the edge of the bevel. The edge of the cladding shall be rounded with a minimum radius of 1,5 mm (0,06 in) or tapered to a minimum angle of 30°. The stripped-back area shall be etched with either a nitric acid or copper sulfate solution to ensure complete removal of the clad.

B.3 Weld overlay

B.3.1

A minimum of two layers shall be applied for all overlay welding. Electroslag strip cladding may be performed with a single pass subject to the purchaser's approval.

B.3.2

The weld qualification procedure shall establish that the specified chemical composition of the filler metal is met at a depth of at least 1,5 mm (0,06 in) from the minimum specified thickness.

B.3.3

The maximum iron content for alloy 276 and alloy 625 overlay shall be 10 %.

B.3.4

Internal attachments shall be welded directly to the overlay.

B.3.5

For transition areas at nozzles and flanges, the vendor shall provide a fabrication procedure which shall as a minimum include:

a. detailed arrangement drawing showing:
   - functionality of the nozzle or flange;
   - set in or set on;
   - preparation of the nozzle or flange;
   - tapering;
   - line up and measurement prior to overlay welding.
b. details of overlay welding, including:
   - reference to the applicable welding procedure;
   - number of layers.
c. method of preparation after overlay welding;
d. examination after overlay welding, including:
   - thickness;
   - liquid penetrant.

B.3.6

The frequency and extent of thickness verification shall be agreed between the purchaser and the vendor.

B.3.7

Where there is change in geometry for highly stressed areas (such as nozzle or manway welds in shells or heads, internal beam support weld build-ups, etc.), the weld overlay shall have a smooth contour finish with a minimum radius of 6 mm (0,25 in).

B.3.8

All overlay welds, clad restoration welds and internal attachment welds shall be subject to 100 % liquid penetrant examination.

B.3.9

If overlay welding is to be machined, such as nozzles and flange facings, machined surfaces shall be subject to liquid penetrant examination. If the overlay is examined 100 % prior to any final post weld heat treatment, the overlay shall be re-examined after heat treatment and final hydrostatic testing.

B.3.10

The acceptance criteria for liquid penetrant examination shall be zero linear indications. All linear indications shall be repaired.

B.3.11

For liquid penetrant examination of austenitic stainless steel, neither the penetrant nor the developer shall contain any chlorides.

Annex C
(normative)
Additional requirements for carbon steel vessels

C.1

All plates having a nominal thickness greater than or equal to 50 mm (2 in) shall be subject to ultrasonic examination. The acceptance criteria shall be as specified in the datasheet.

C.2

All forgings (except standard flanges) having a nominal thickness greater than or equal to 50 mm (2 in) shall be subject to ultrasonic examination. The acceptance criteria shall be as specified in the datasheet.

C.3

The maximum allowable CE shall be in accordance with Table C.1.

Table C.1 – Maximum allowable CE

Nominal plate thickness	Maximum allowable CE
≤ 50 mm (2 in)	0,43
> 50 mm (2 in) ≤ 100 mm (4 in)	0,45
> 100 mm (4 in)	0,48

C.4

The maximum carbon content of carbon steel material shall not exceed 0,23 %.

C.5

Cold formed heads shall be normalised after forming. Hot formed heads not formed in the normalising range shall be normalised.

C.6

The maximum interpass temperature shall be 315 °C (600 °F).

C.7

When magnetic particle testing is applicable, internal welds shall be examined using the wet-fluorescent method. External welds shall be examined using either the wet-visible or wet-fluorescent method.

C.8

Minimum acceptable Charpy impact energy values, at minimum design metal temperature or impact testing temperature specified in design code whichever is lower, shall be average 27 J (20 ft-lb) and single 20 J (15 ft-lb) or as specified in the design code, whichever is higher. Testing shall include the base metal, weld metal and heat affected zone.

C.9

The chloride content of the hydrostatic test water shall not exceed 250 mg/kg (250 parts per million by mass).

Annex D
(normative)
Additional requirements for austenitic stainless steel, 22Cr and 25Cr duplex vessels

D.1 General

D.1.1

Material shall be supplied in solution annealed condition. Stainless steel grades 321 and 347 shall be stabilized after solution annealing heat treatment.

D.1.2

Cold formed heads and tori-conical transition sections shall be solution annealed after forming and before welding to the shell.

D.1.3

Hot formed heads shall be solution annealed followed by rapid cooling.

D.1.4

Arc-air or oxy-gas methods of cutting and bevelling are not permitted.

D.2 Contamination control

D.2.1

The vendor shall have in place measures to ensure no cross-contamination between ferritic and austenitic and duplex materials.

D.2.2

Only stainless steel brushes and clean, iron-free sand, ceramic or stainless steel grit shall be used for cleaning surfaces.

D.2.3

Cleaning tools or materials shall not have been previously used on carbon steel.

D.2.4

Exterior surfaces shall be protected from chloride exposure at all times.

D.2.5

Materials for marking, painting or inspection containing halides and heavy metals shall not be used. Aluminium and zinc based paints shall not be used for material identification.

D.2.6

The chloride content of the hydrostatic test water shall not exceed 50 mg/kg (50 parts per million by mass).

D.3 Ferrite control

D.3.1

Ferrite control shall be required for austenitic stainless steel weld metal if any of the following conditions are met.

a. the material is operating in high temperature service;

b. the weld will be post weld heat treated;

c. the welding procedure is qualified with impact testing.

D.3.2

The ferrite number (FN) shall be measured during procedure qualification and production welding prior to any post weld heat treatment using a ferritescope calibrated in accordance with ISO 8249 or AWS A4.2.

D.3.3

Ferrite number measurements of production welds shall as a minimum include all longitudinal and circumferential pressure retaining welds, and a minimum of three separate measurements shall be performed per weld.

D.3.4

The ferrite number for procedures qualification and production welds of austenitic stainless steel material requiring impact testing or in high temperature service shall not exceed 8FN.

D.3.5

When post weld heat treatment is specified, the acceptable ferrite number range shall be 3FN to 10FN, except for type 347 weld deposit which shall have a minimum of 5FN

D.4 Welding

D.4.1

The chemical composition of welding consumables and as-welded deposits during procedure qualification shall met the requirements of API RP 582.

D.4.2

The minimum preheat temperature shall be 10 °C (50 °F).

D.4.3

Unless otherwise qualified, the maximum interpass temperature shall not exceed the values listed in Table D.1.

Table D.1 – Interpass temperature limits

Material	Maximum interpass temperature
Austenitic stainless steel	175 °C (350 °F)
22Cr Duplex	150 °C (300 °F)
25Cr Duplex	120 °C (250 °F)

D.4.4

The maximum variation in heat input shall be ± 15 %.

D.5 Pickling and passivation

D.5.1

The internal surfaces of vessels with a wall thickness of less than 10 mm ($^3/_8$ in), shall be pickled and passivated after completion of all welding activities.

D.5.2

Surfaces contaminated with iron during fabrication shall be pickled and passivated.

D.5.3

All internal and external surfaces of welds shall be pickled and passivated.

D.6 Special requirements for 22Cr duplex and 25Cr duplex

D.6.1

All pressure retaining components shall be supplied by manufacturers qualified in accordance with the requirements of ISO 17782 or NORSOK M-650.

D.6.2 Welding procedure qualification

D.6.2.1

The weld hardness shall not exceed the values listed in Table D.2.

Table D.2 – Hardness limits

Material	Maximum weld hardness
22Cr Duplex	320 HV10 or 28 HRC
25Cr Duplex	350 HV10 or 32 HRC

D.6.2.2

For 25Cr duplex with thickness ≤ 7mm (0,276 in), the minimum thickness qualified shall be the thickness of the test piece.

D.6.3

Corrosion testing, impact testing, ferrite measurement and microstructure examination shall be carried out according to ISO 17781.

D.6.4

Ferrite measurement shall include the heat affected zone and shall comply with the ferrite content requirements of the weld metal.

D.6.5

The maximum number of repairs of the same defective area shall not exceed the values list in Table D.3.

Table D.3 – Repair limits

Material	Repairs allowed
22Cr Duplex	2
25Cr Duplex	1

D.6.6

22Cr duplex and 25Cr duplex shall not be post weld heat treated.

Annex E
(normative)
Vessel tolerances

E.1

Unless otherwise specified by the design code, tolerances shall be in accordance with Figure E.1 or Figure E.2.

E.2

Where tolerances for horizontal vessels are not shown, vertical vessel tolerances shall be applied.

E.3

Tangent lines, principal axis centre lines and orientation shall be punch marked externally.

E.4

Out of roundness tolerance for skirts shall be as per the design code for shell under external pressure.

E.5

Flatness tolerances for vessel support base plates e.g. skirts, legs, lugs and saddles shall be ± 6 mm ($^1/_4$ in).

E.6

For nozzles supplied with an agitator mounting the maximum out of plane, tolerance shall be ± 0,25°.

Figure E.1 – Vessel tolerances (SI units)

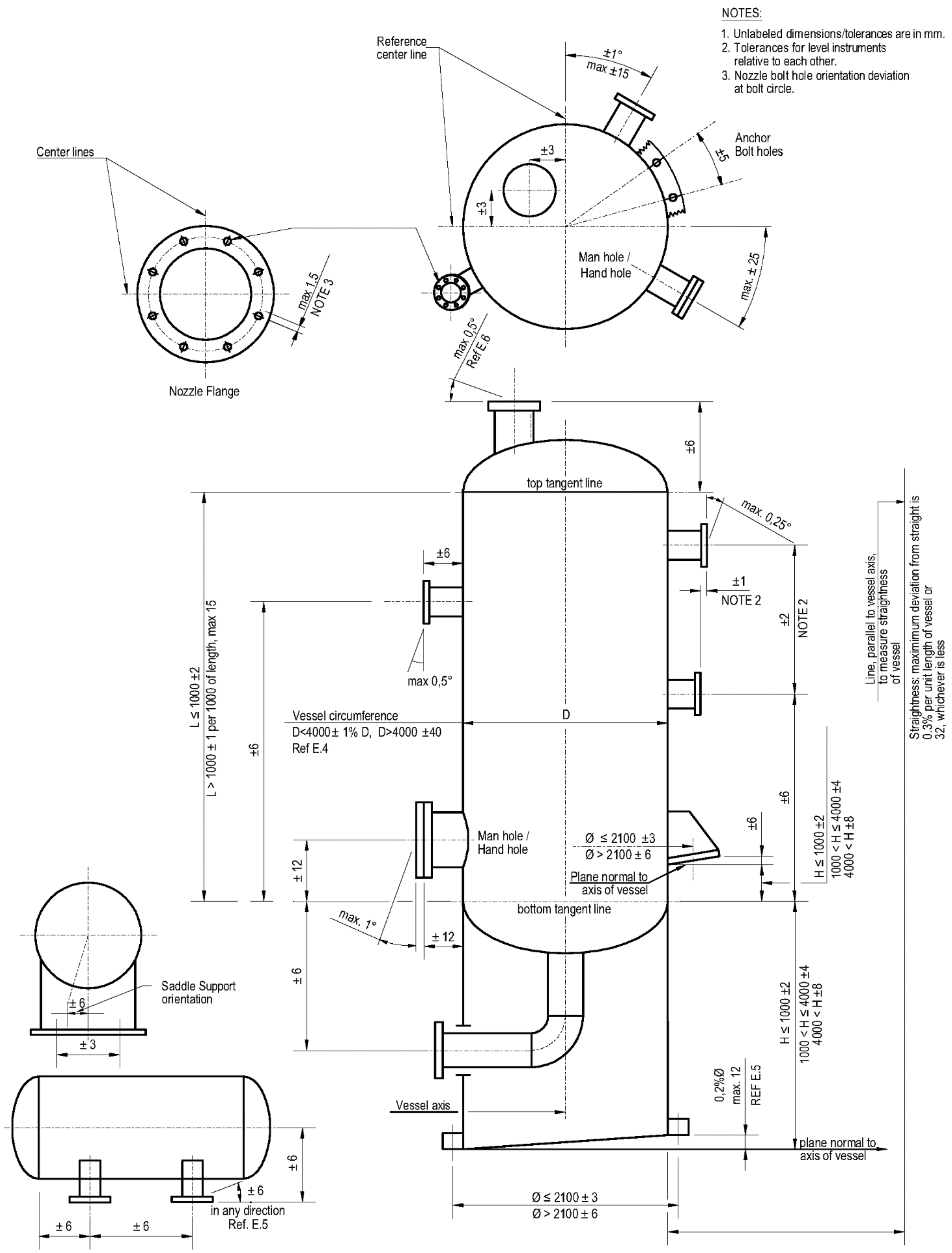
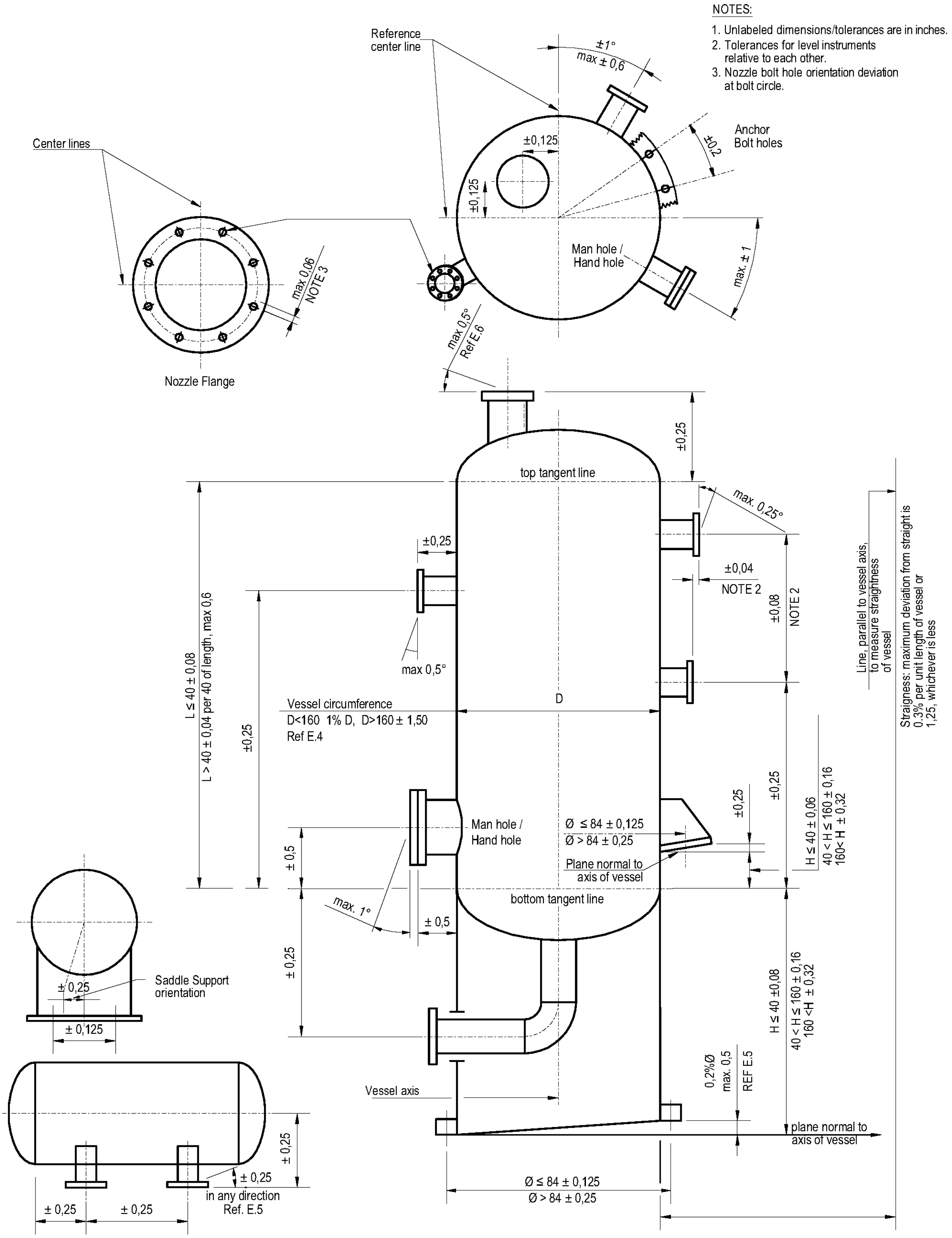


Figure E.2 – Vessel tolerances (US Customary units)



Annex F
(normative)
Requirements for maximum allowable corrosion allowance (MACA)

MACA for pressure components is the difference between the nominal thickness and the calculated required (retirement) thickness as per the design code. MACA is the design minimum corrosion allowance (internal, external or both) plus the rounded up thickness. These are added to obtain a commercially available nominal thickness.

F.1

When MACA methodology is specified in the datasheet, the following requirements shall be applied to optimize the design for corrosion allowance.

F.2

For formed components, nominal thickness shall be as measured after forming.

F.3

To calculate MACA, the maximum allowable working pressure of the vessel shall be equal to the design pressure.

F.4

Nozzle reinforcement calculations per the design code shall be performed using the area contributed by the vessel wall equal to zero. Additional thickness that is added to the vessel wall for the sole purpose of reinforcement may be used for the area contributed by vessel wall.

EXAMPLE

A vessel designed per ASME BPVC Sec. VIII based on an area replacement philosophy, the nozzle reinforcement calculations per ASME BPVC.VIII.1, UG-37 or ASME BPVC.VIII.2, Part 4.5 is performed using $A_1 = 0$. Additional thickness that is added to the component for the sole purpose of reinforcement may be used for A_1.

F.5

If the pressure area method is used for nozzle reinforcement calculation, plate thickened solely for nozzle reinforcement is not required to be counted towards MACA.

F.6

When attached to cylindrical shell components, the corrosion allowance of minor components (e.g. nozzle neck, nozzle flange, etc.) shall inherit the MACA of the cylindrical shell component.

F.7

When attached to a formed head or formed transition component, the corrosion allowance of minor components shall be 150 % of the vessel's design corrosion allowance.

F.8

MACA for each major component shall be, as a minimum, calculated to the nearest 0,2 mm (0,01 in).

F.9

MACA of the pressure component need not exceed twice the design corrosion allowance for that component.

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