

OFFSHORE STANDARDS

DNVGL-OS-C401

Edition January 2018

Fabrication and testing of offshore structures

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FOREWORD

DNV GL offshore standards contain technical requirements, principles and acceptance criteria related to classification of offshore units.

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CHANGES – CURRENT

This document supersedes the July 2017 edition of DNVGL-OS-C401.

Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Main changes January 2018, entering into force July 2018

<i>Topic</i>	<i>Reference</i>	<i>Description</i>
Hardness testing value for extra high strength steel for CP application	Ch.2 Sec.5 [3.3.5.2]	Change of guidance note to requirement.
Wording with respect to CTOD test of BM	Ch.2 Sec.5 [3.3.7.1]	Deletion of FM testing for base material (BM).
Number and location of hardness measurements for fillet weld	Ch.2 Sec.5 [4.6.1] and Ch.2 Sec.5 [4.6.3.2]	Definition of stop/restart position for single run fillet weld. Hardness measurement for one macrosection taken from the weld start of the test assembly only.
WPQT heat input range coverage for high heat input welding	Ch.2 Sec.5 [4.7.2.10]	Qualified range for high heat input welding changed to +10/-25%.
Wide gap welding	Ch.2 Sec.6 [8.2.3]	Change of guidance note to requirement in line with rules for classification of ship.
NDT procedures to be approved	Ch.2 Sec.7 [2.1.3]	NDT procedures changed from agreed to approved.
	Ch.3 Sec.1 Table 4, Ch.3 Sec.1 Table 5 and Ch.3 Sec.1 Table 6	NDT procedures to be changed from agreed to approved. New documentation type 'H135 – Non-destructive testing (NDT) procedure added.
Minor corrections	Ch.2 Sec.4 Table 3	Subnote 2 is valid for group M11 to M33 for the Ar column only
	Ch.2 Sec.5	Deleted previous subsection [5] and [6] covering requirements to COD grade and additional welding procedure qualification test requirements for liquified gas systems as these are covered by requirements in rules for classification of ship (DNVGL-RU-SHIP).
	Ch.2 Sec.5 [1.1.1]	Reference inserted to rules for classification of ship (DNVGL-RU-SHIP).
	Ch.2 Sec.5 [3.3.6.1]	Deleted COD grades and steel for liquified systems as these are covered by rules for classification of ship.
	Ch.2 Sec.6 [9.7.5]	Deleted welding requirement to COD material.
Requirements for qualification of welding repair procedure reinstated	Ch.2 Sec.6 [9.8.5]	Requirement that was deleted in July 2017 edition has been reinserted, limited to extra high strength steel.

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.

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CHAPTER 1 INTRODUCTION

SECTION 1 GENERAL

1 Introduction

1.1 Objective

The objectives of this standard are to:

- Provide an internationally acceptable standard giving the minimum requirements for fabrication of offshore units, installations and equipment by welding, including requirements for mechanical fastening, testing and corrosion protection systems.
- Serve as a contractual reference document between manufacturers, suppliers and purchasers.
- Serve as guideline for designers, manufacturers, suppliers, purchasers and regulators.
- Provide the DNV GL specific requirements for certification, verification and classification of offshore units and installations.

1.2 Scope

1.2.1 The standard has been written for general world-wide application. Governmental regulations may include requirements in excess of the provisions by this standard depending on the size, type, location and intended service of an offshore unit.

1.2.2 The standard provides requirements for fabrication and testing of offshore units, see [2.2].

1.2.3 The standard gives requirements for the following:

- contractors, see [Ch.2 Sec.2](#)
- qualification of welders, see [Ch.2 Sec.3](#)
- welding consumables, see [Ch.2 Sec.4](#)
- qualification of welding procedures, see [Ch.2 Sec.5](#)
- fabrication and tolerances, see [Ch.2 Sec.6](#)
- non-destructive testing, see [Ch.2 Sec.7](#)
- structural and tightness testing, see [Ch.2 Sec.8](#)
- corrosion protection systems, see [Ch.2 Sec.9](#)
- bolts and mechanical fastening, see [Ch.2 Sec.10](#)
- specific requirements for DNV GL certification and classification, see [Ch.3](#).

1.2.4 As well as representing DNV GL's recommendations on safe engineering practice for general use by the offshore industry, the offshore standards includes the technical basis for DNV GL classification, certification and verification services as given in a separate chapter, [Ch.3](#).

1.3 Application

1.3.1 The requirements in this standard apply to offshore units, installations and equipment fabricated by welding.

1.3.2 Upon agreement, the scope may be extended to other applications.

1.3.3 The requirements are applicable to fabrication of important structures and equipment like, but not limited to:

- Hull and structure taking part in the overall strength, including superstructure, crane pedestals (pedestal below slewing ring), attachment of helideck support structure, foundation and support for heavy equipment.
- Hull equipment.
- Machinery and systems including bedplates, frames, housings, piston crowns, cylinder covers, piping, pressure systems.

1.4 Structure of the standard

1.4.1 Technical standard

Ch.1 and Ch.2 of this standard gives the requirements applicable for fabrication and testing of offshore units and installations, and are independent of the specific requirements of DNV GL for certification, verification or classification. The standard may therefore be referred by e.g. regulatory bodies, purchasers and builders without further involvement of DNV GL.

1.4.2 Specific requirements for DNV GL certification and classification

Ch.3 of this standard gives the additional specific requirement for fabrication and testing of offshore units and installations applicable for DNV GL certification and classification.

1.4.3 Relation to other applicable DNV GL documents

Where this standard is referred by other relevant DNV GL rules or standards and unless otherwise agreed, the specific or additional requirements of the referring standard are prevailing.

2 References

2.1 Normative references

The references given in Table 1, Table 2 and Table 3 include provisions, which through reference in this text constitute provisions for this standard.

2.2 Offshore standards

The offshore standards given in Table 1 are referred to in this standard.

Table 1 DNV GL offshore standards

<i>Document code</i>	<i>Title</i>
DNVGL-OS-B101	Metallic materials
DNVGL-OS-C101	Design of offshore steel structures, general - LRFD method
DNVGL-OS-C102	Structural design of offshore ships
DNVGL-OS-C103	Structural design of column stabilised units - LRFD method
DNVGL-OS-C104	Structural design of self-elevating units - LRFD method
DNVGL-OS-C105	Structural design of TLPs - LRFD method
DNVGL-OS-C106	Structural design of deep draught floating units - LRFD method
DNVGL-OS-C201	Structural design of offshore units - WSD method

2.3 Offshore rules

The rules for classification: Offshore units given in [Table 2](#) are referred to in this standard.

Table 2 DNV GL rules for classification - offshore units

<i>Document code</i>	<i>Title</i>
DNVGL-RU-OU-0101	Offshore drilling and support units
DNVGL-RU-OU-0102	Floating production, storage and loading units
DNVGL-RU-OU-0103	Floating LNG/LPG production, storage and loading units
DNVGL-RU-OU-0104	Self elevating units, including wind turbine installation units and liftboats
DNVGL-RU-OU-0503	Offshore fish farming units and installation

2.4 Informative references

The documents listed in [Table 3](#) include acceptable methods for fulfilling the requirements in the standard and may be used as a source of supplementary information. Other recognised documents as listed below may be used provided it is shown that they meet or exceed the level of safety of the actual standards.

Table 3 DNV GL and DNV recommended practices and classification notes

<i>Document code</i>	<i>Title</i>
DNV-RP-C201	Buckling strength of plated structures
DNVGL-RP-C202	Buckling strength of shells
DNVGL-RP-C203	Fatigue design of offshore steel structures
DNVGL-CG-0051	Non-destructive testing
DNVGL-CG-0128	Buckling
DNVGL-CP-0484 App.B	DNV GL approval of service supplier scheme
DNVGL-CP-0069	Welding consumables

2.5 Reference standards

Applicable reference standards are given in [Table 4](#). Latest issue of the standards shall be used unless otherwise agreed. Where the requirements of [Ch.2](#) of this standard gives conflicting or higher requirements than the referred standard, the requirements of [Ch.2](#) applies, unless otherwise specified or agreed with the verifier.

Table 4 Normative reference standards

<i>Document code</i>	<i>Title</i>
ANSI/AWS D1.1	Structural Welding Code - Steel
ASME Sec.IX	Boiler and pressure vessel code, IX - welding and brazing qualifications
ASTM E165	Standard test method for liquid penetrant examination
ASTM E562	Standard test method for determining volume fraction by systematic manual point count
ASTM G48	Standard test methods for pitting and crevice corrosion resistance of stainless steels and related alloys by use of ferric chloride solution
IACS Rec.47	Shipbuilding and repair quality standard
ISO 148	Steel - Charpy impact test (V-notch)
ISO 898	Mechanical properties of fasteners made of carbon and alloy steel
ISO 1011-1	Recommendations for welding of metallic materials - Part 1: General guidance for arc welding
ISO 3452	Non-destructive testing – Penetrant testing
ISO 3690	Welding and allied processes -- Determination of hydrogen content in arc weld metal
ISO 3834- 2	Quality requirements for fusion welding of metallic materials – Comprehensive quality requirements
ISO 4063	Welding and allied processes – Nomenclature of processes and reference numbers
ISO 5817	Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for imperfections
ISO 6507-1	Metallic materials - Vickers hardness test - Part 1: Test method
ISO 6520-1	Welding and allied processes – Classification of geometric imperfections in metallic materials – Fusion welding
ISO 8501	Preparation of steel substrates before application of paints and related products -- Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
ISO 8502	Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness
ISO 8503	Preparation of steel substrates before application of paints and related products -- Surface roughness characteristics of blast-cleaned steel substrates
ISO 9001	Quality management systems - Requirements
ISO 9015-1	Destructive tests on welds in metallic materials – Hardness test on arc welded joints
ISO 9017	Destructive tests on welds in metallic materials - Fracture test
ISO 9606	Approval testing of welders - Fusion welding
ISO 9712	Non-destructive testing - Qualification and certification of NDT personnel
ISO 10042	Arc-welded joints in aluminium and its weldable alloys - Guidance on quality levels for imperfections
ISO 10675	Non-destructive testing of welds – Acceptance levels for radiographic testing

<i>Document code</i>	<i>Title</i>
ISO 11666	Non-destructive testing of welds -- Ultrasonic testing -- Acceptance levels
ISO 12135	Metallic materials -- Unified method of test for the determination of quasistatic fracture toughness
ISO 14175	Welding consumables – Gases and gas mixtures for fusion welding and allied processes
ISO 14341	Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels - Classification (ISO 14341:2010)
ISO 14731	Welding coordination – Tasks and responsibilities
ISO 14732	Welding personnel – Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials
ISO 15614-6	Specification and qualification of welding procedures for metallic materials - Welding procedure test - Arc and gas welding of copper and its alloys
ISO 15614-7	Specification and qualification of welding procedures for metallic materials -- Welding procedure test -- Part 7: Overlay welding
ISO 15653	Metallic materials - Method of test for the determination of quasistatic fracture toughness of welds
ISO 17635	Non-destructive testing of welds - General rules for metallic materials
ISO 17662	Welding -- Calibration, verification and validation of equipment used for welding including ancillary activities
ISO 23277	Non-destructive testing of welds – Penetrant testing of welds - Acceptance levels
ISO 23278	Non-destructive testing of welds – Magnetic particle testing of welds – Acceptance levels
ISO/IEC 17020	Conformity assessment - Requirements for the operation of various types of bodies performing inspection
ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories
NACE MR0175	Petroleum and natural gas industries - Materials for use in H ₂ S-containing environments in oil and gas production - Parts 1, 2, and 3 (Identical to ISO 15156-1:2009, 15156-2:2009, and 15156-3:2009)

3 Abbreviations and definitions

3.1 Definitions

Verbal forms used are given in [Table 6](#) and [Table 7](#).

Table 5 Verbal forms

<i>Term</i>	<i>Definition</i>
shall	verbal form used to indicate requirements strictly to be followed in order to conform to the document
should	verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required
may	verbal form used to indicate a course of action permissible within the limits of the document

Table 6 Specific verbal forms

<i>Term</i>	<i>Definition</i>
accepted, acceptance, agreed, agreement, or by agreement	unless otherwise indicated, accepted/agreed in writing between manufacturer/contractor and purchaser or verifier. When the standard is applied as basis for certification or classification by DNV GL, the terms shall mean approved upfront in writing by DNV GL.
recognised, required	unless otherwise indicated, recognised/required by the purchaser or verifier. When the standard is applied as basis for certification or classification, the terms shall mean recognised/required by DNV GL.
submitted	unless otherwise indicated, submitted to the purchaser or verifier. When the standard is applied as basis for certification or classification, the term shall mean submitted to DNV GL.

3.2 Terms

Table 7 Terms

<i>Term</i>	<i>Definition</i>
automatic welding	covers fully automatic processes where all operations are mechanized, and fully mechanized welding where all main operations (excluding the handling of the work piece) are mechanized
contractor	a party contractually appointed by the purchaser to fulfil all, or any of, the activities associated with fabrication and testing
essential variables/parameters	welding parameters essential for the range of validity of a welding procedure, see Sec.5 [4.7]
failure rate	failure rate, e.g. for NDT is calculated as follows: Total length of non-acceptable defects divided by tested weld length (multiplied by 100%) The maximum length of each defect shall be applied, e.g. for a transverse crack it is the length of the crack in the transverse direction. For a group of transverse cracks with distance less than 50 mm, the length between first and last crack shall be used.
heat input	energy introduced into the weld region during welding. Heat input is calculated as follows: $\text{Heat input (kJ/cm)} = \frac{\text{Volt} \times \text{Ampere} \times 6}{\text{Travel speed (cm/min)} \times 100}$ In case the heat input is corrected for thermal efficiency in accordance with ISO 1011-1, the thermal efficiency coefficient shall be stated. For multi-wire welding, the heat input is calculated as the sum of the heat inputs calculated separately for each wire. This do not apply if the interpass temperature between each wire is 250°C or lower. For the waveform controlled welding power supply, the heat input calculation equations given in ASME Sec.IX QW-409.1 may be used.
hold point	a point where the product shall be present for supervision or survey Advance notification to the verifier shall be given in writing or any other agreed system of notification. Work shall not proceed beyond a hold point without verifier being present or, in exceptional cases where presence is waived, without first obtaining written authorisation from the verifier.
hose testing	is a water test carried out to demonstrate tightness of structural items

<i>Term</i>	<i>Definition</i>
hydro pneumatic testing	is a combination of hydrostatic and air testing, carried out in order to demonstrate the tightness of the tanks and the structural adequacy of the design
inspection	an activity carried out by the contractor or subcontractor to verify compliance with the applicable rules and specifications
inspection body	an impartial body having the organisation, staffing, competence and integrity to perform to specified criteria functions such as assessing, recommending for acceptance and subsequent audit of manufacturers' quality control operations, and selection and evaluation of products on site or in factories or elsewhere as directed, to specified criteria
leak testing	is an air or other medium test, carried out in order to demonstrate the tightness of the structure
manual welding	welding where the electrode holder, welding hand gun, torch or blowpipe is manipulated by hand
manufacturer	the party who is contracted to be responsible for planning, execution and documentation of planning, execution, testing and documentation of manufacturing of materials and components
monitoring	intermittent monitoring or surveillance of any stage of the work in progress including, but not limited to, checking compliance with procedures/instructions for manufacture, testing and inspection, observing workmanship, traceability, etc.
non-destructive testing (NDT)	visual testing (VT), radiographic testing (RT), ultrasonic testing (UT), magnetic particle testing (MT), penetrant testing (PT) and other non-destructive methods for revealing defects and irregularities
partly mechanized welding	manual welding where the wire feed is mechanized
preliminary welding procedure specification (pWPS)	a tentative welding procedure specification providing required welding variables, which is assumed to be adequate by the contractor, but which has not been qualified
protective coating	is a final coating protecting the structure from corrosion
purchaser	the owner or another party acting on his behalf, who is responsible for procuring materials, components or services intended for the design, construction or modification of a structure
quality management system	quality management system worked out in accordance with a reputable quality standard, such as ISO 9001 or equivalent The quality management system may be required to be certified by an accredited certification body.
quality survey plan (QSP)	a project specific document The QSP (sometimes called ITP) is a plan containing verification activities such as document reviews, monitoring, witness and hold points of manufacturing and testing. The plan contains activity descriptions, acceptance criteria and verifying documents. The purpose is to provide information concerning the planned verification activities performed by manufacturer, contractor, purchaser, verifier and third party.
review	examination of records of activities performed or results achieved
semi-automatic welding	same as partly mechanized welding: manual welding where the wire feed is mechanized
shop primer	is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication

<i>Term</i>	<i>Definition</i>
structural testing	is a hydrostatic test, carried out in order to demonstrate the tightness of the tanks and the structural adequacy of the design. Where hydrostatic testing is not practically feasible, hydro pneumatic testing may be carried out instead under provision that the test is simulating, as far as practicable, the actual loading of the tank.
supervisor	responsible person who provides specific knowledge/expertise and who coordinates, monitors and regulates employees and their performance of assigned or delegated tasks, e.g. for welding and NDT
subcontractor	independent unit performing work under supervision by the contractor
unit	a general term for an offshore installation such as ship shaped, column stabilised, self-elevating, tension leg or deep draught floater
verifier	an organization that is mandated to verify compliance The owner or his representative may act as verifier unless the product or structure is subject to DNV GL certification, verification or classification, or unless otherwise required by applicable regulatory bodies, etc. The verifier shall be DNV GL where products or structures are subject to certification, verification or classification by DNV GL.
watertight	means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed
weathertight	means that in any sea conditions water will not penetrate into the ship
welding, brazing, spraying	the term welding, used in these rules also cover all other special thermal and/or mechanized joining processes such as brazing, spraying, etc. which require pre-qualification for the personnel like brazer/sprayer tests or the procedures like brazing/spraying procedures This standard shall be applied in an analogous manner to these special processes. Where no special provisions are made in this standard, the nature and scope of the pre-qualification tests and quality assurance measures required will be agreed with the verifier on a case-by-case basis.
welding procedure	a specified course of action to be followed in making a weld, including reference to materials, welding consumables, preparation, preheating (if necessary), method and control of welding and post-weld heat treatment (if relevant), and necessary equipment to be used
welding procedure specification (WPS)	a welding procedure specification, which has been qualified to conform with an agreed qualification scheme
welding procedure qualification test (WPQT)	the process of accomplishing welding and testing of a standardised test piece, as reported in a WPQR
welding procedure qualification record (WPQR)	a record comprising a summary of necessary data needed for the issue of a WPS
welding production test (WPT)	a test carried out to demonstrate that actual production welding meets the specified requirements
witness point	a point where the verifier may be present for supervision or survey, at their discretion Advance notification to the verifier shall be given in writing or any other agreed system of notification. Work may proceed beyond a witness point with or without the verifier being present.

3.3 Abbreviations

The abbreviations given in [Table 8](#) are used in this standard.

Table 8 Abbreviations

<i>Term</i>	<i>Definition</i>
A.C.	alternating current
ACCP	ASNT central certification program
ALS	accidental limit state
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing of Materials
AWS	American Welding Society
BM	base material
CE	carbon equivalent
CET	carbon equivalent
Ceq	carbon equivalent
C-Mn	carbon manganese
CTOD	crack tip opening displacement
DAC	distance amplitude curve
D.C.	direct current
ECA	engineering critical assessment
EN	European Standard (European de Normalisation)
FCAW	flux cored arc welding
FL	fusion line
FM	fracture mechanics
FRP	fibre reinforced plastic
GMAW	gas metal arc welding
GTAW	gas tungsten arc welding
HAZ	heat affected zone
HRC	Rockwell hardness
HV	Vickers hardness
IACS	International Association of Classification Societies
ISO	International Organisation for Standardisation
ITP	inspection and test plan

<i>Term</i>	<i>Definition</i>
MAG	metal active gas (welding)
MIG	metal inert gas (welding)
MT	magnetic particle testing
NACE	National Association of Corrosion Engineers
NDT	non-destructive testing
PAUT	phased array ultrasonic testing
PT	penetrant testing
PWHT	post weld heat treatment
pWPS	preliminary welding procedure specification
QSP	quality and survey plan
QT	quenched and tempered
RP	recommended practice
RT	radiographic testing
SAW	submerged arc welding
SMAW	shielded metal arc welding
SMYS	specified minimum yield stress
TIG	tungsten inert gas (welding)
TM	thermo-mechanical rolling
TOFD	time of flight diffraction
UT	ultrasonic testing
VI	Visual inspection
VT	visual testing
W	DNV GL work certificate
WM	weld metal or deposit
WPQR	welding procedure qualification records
WPQT	welding procedure qualification test
WPS	welding procedure specification
WPT	weld production test
WWA	welding workshop approval

3.4 Latin symbols

The following latin symbols are used:

a	size of test specimen
A	diameter used in wrap around bending test
b	size of test specimen
C	diameter of roller in bend test
d	diameter of round tensile test specimen
d_f	distance from the plane of the fatigue pre-crack to the fusion line
D	outside diameter
$D1$	outside diameter of the greater tube (can)
$D2$	outside diameter of the smaller tube (brace)
e	plastic deformation
h_{D2}	pressure head due to flow through pipes
h_{op1}	vertical distance from the load point to the position of maximum filling height
h_{op2}	vertical distance from the load point to the position of maximum filling height. For tanks adjacent to the sea that are situated below the extreme operational draught (T_E), h_{op2} is not normally to be taken as being less than T_E
h_{p0}	height corresponding to valve opening pressure when exceeding the general value
h_{s3}	vertical distance from the load point to the top of the tank
h_T	test pressure height
KV	impact energy requirement
l_e	equivalent parameter for conical shells
l_{min}	breadth of test assembly plates
l_r	length of template or rod
L_{min}	length of test assembly plates
L_o	length of test area in test specimens
N	number of
r	nominal radius of the shell
r_a	actual distance from the centre of the sphere to the shell wall
r_a	actual distance from the cylinder axis to the shell wall
r_e	equivalent parameter for conical shells
R	radius
R_c	forming radius
s	distance between stiffeners or girders
t	thickness

t_1	wall thickness of the greater tube (can)
t_2	wall thickness of the smaller tube (brace)
T	thickness of plate in bend test
W	width of weld

3.5 Greek symbols

The following greek symbols are used:

α	tubular joint angle
δ	measure of deformation compared to theoretical geometry
λ_i	length of area with acceptable location of the fatigue pre-crack
ν	Poisson's ratio
σ_1	largest compressive principal membrane stress
σ_2	principal membrane stress normal to σ_1
ψ	ratio between principal stresses

CHAPTER 2 TECHNICAL PROVISIONS

SECTION 1 GENERAL REQUIREMENTS

1 Introduction

General requirements for fabrication and survey, and for calculation of carbon equivalents (CE) are specified. Specific requirements are further detailed in the relevant sections and paragraphs of this chapter.

2 Fabrication and survey

2.1 Pre-qualification of workshops

Requirements for the pre-qualification of workshops shall be considered in each case. The consideration shall take into account the complexity and criticality of the product to be supplied, the workshop's previous experience and the requirements of this standard.

Guidance note:

DNV GL's approval of manufacturer schemes indicates typical practice for pre-qualification.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.2 Heat treatment

2.2.1 Furnace heat treatment shall be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions shall be such as to allow the material to be uniformly heated to the specified temperature.

2.2.2 The need for pre-qualification of heat treatment workshops shall be considered, see [2.2].

2.2.3 Specific requirements for localized heat treatments like preheating and post-weld heat treatment (PWHT) are specified in the relevant subsections, e.g. [Sec.6 \[9.3\]](#) and [Sec.6 \[9.6\]](#), respectively.

2.3 Survey, testing, inspection and certification

2.3.1 The purchaser shall supply the manufacturer with all information necessary to ensure that fabrication, survey and certification can be carried out in accordance with the standard. This applies particularly where optional or additional conditions are specified in the relevant construction rules.

2.3.2 Where non-destructive tests are specified for the various products, these shall be performed under the manufacturer's responsibility. The testing operators shall be certified to a recognized scheme. The results together with details of the test method shall be documented by the manufacturer. The requirements for test method and acceptance criteria are given in the relevant sections of [Ch.2](#).

2.3.3 All products shall be verified by the manufacturer for compliance with the specified dimensions and surface finish. They shall also be inspected by him for possible defects. For this purpose, the products shall have a clean surface prepared for inspection.

Products that do not meet the required dimensions or show unacceptable defects shall be clearly marked accordingly and separated from the regular production process for repair/clearance.

3 Base material weldability

3.1 Carbon equivalents

3.1.1 When required, the carbon equivalent value (C_{eq}) shall be calculated using the formula:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (\%) \quad (1)$$

3.1.2 For thermo-mechanical rolling (TM) and quenched and tempered (QT) steels with carbon content not more than 0.12%, the cold cracking susceptibility (P_{cm}) for evaluation of weldability may be used instead of carbon equivalent C_{eq} or CET at the manufacturer's discretion and shall be calculated using the formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cu + Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B \quad (\%) \quad (2)$$

3.1.3 For steel grades VL 460 and higher, CET may be used instead of C_{eq} at the discretion of the manufacturer, and shall be calculated according to the following formula:

$$CET = C + \frac{(Mn + Mo)}{10} + \frac{1(Cr + Cu)}{20} + \frac{Ni}{40} \quad (3)$$

Note:

The CET is included in the standard EN 1011-2:2001 used as one of the parameters for pre-heating temperature determination which is necessary for avoiding cold cracking.

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SECTION 2 REQUIREMENTS FOR CONTRACTORS

1 General

1.1 Scope

This section gives requirements for contractors involved in building activities of structures and components intended for offshore units. This section shall also apply to subcontractors of contractors.

1.2 Capability

Prior to commencement, contractors unknown to the verifier shall demonstrate their capability to carry out fabrication in line with the overall requirements of this section.

2 Quality management system

2.1 General

Contractors involved in fabrication of structural members shall possess a documented and implemented quality system according to ISO 9001 or equivalent. Quality requirements for welding may be based on International Organisation for Standardisation (ISO) 3834-series. If not, the verifier may consider an extended survey scheme. The extent of the quality management system shall be dependent on the size and type of the organisation, complexity and interaction of the processes and personnel competence.

2.2 Specific procedures

2.2.1 A prerequisite for fabrication is that procedures, inspection and test plans (ITP) and work instructions for execution and control of fabrication activities shall be established. The purpose of the procedures and work instruction shall be:

- to provide instructions and information regarding the requirements for and the principles of the work execution
- to identify and document the responsibilities and plans for the work execution in accordance with the project requirements
- to provide information on how the work is executed and controlled
- to identify applicable procedures, test plans, work instructions, acceptance criteria, hold points and documents to be generated
- to serve as basis for quality audits.

2.2.2 Relevant procedures, including information of pre-assembled items and the sequence of fabricating the parts into structure, shall be prepared.

3 Workmanship

3.1 General

3.1.1 The contractor shall ensure that the work is executed in accordance with established fabrication procedures and work instructions, ITP.

3.1.2 The contractor shall ensure that the work is effectively and systematically controlled at all stages.

3.1.3 The contractor shall prove and document his abilities to carry out the welding operations in question. Further:

- the contractor shall inspect welding operations by the use of necessary equipment in order to assure compliance with the welding procedures
- the contractor shall present the results of own and subcontractors inspections before surveys by the verifier
- important welding operations shall be carried out under daily supervision of a nominated qualified and experienced welding supervisor/inspector. The work of each welder shall be regularly examined.

3.1.4 The contractor shall be in control of work performed at the location of subcontractors and of subcontractors performing work at the contractor's premises.

3.1.5 Repair work shall be carried out in accordance with written and agreed procedures. Faults and deficiencies shall be corrected before painting or other means of permanent covers have been applied.

SECTION 3 QUALIFICATION OF WELDERS

1 General

1.1 Scope

1.1.1 These requirements apply to the qualification of welders and welding operators for fusion welding of steel and non-ferrous metals.

1.1.2

This section specifies requirements for welder and operator qualifications for:

- hull structures
- other applications than hull structures.

1.1.3

The training of welders, control of their qualification and maintenance of their skills are the responsibility of the contractors and subcontractors. When requested, this shall be documented and demonstrated to the satisfaction of the verifier.

1.1.4

Builders and subcontractors shall keep a register of all certified welders. The register shall give information on welders training, and date and results of qualification tests. Information about the base metal, type of welding consumable, welding process, type of welded joint, material thickness and welding position shall be stated in the event of re-qualification tests.

2 Welding operators

2.1 Scope

This subsection gives the qualification and certification requirements for welding operators setting up using fully mechanized or fully automatic welding equipment. Requirements for welders are given in [3].

2.2 Records of proficiency

The welding operator responsible for setting up and/or adjustment of fully mechanized and automatic equipment, such as submerged arc welding, gravity welding, electro-gas welding and metal active gas welding with auto-carriage, etc., shall be qualified whether he operates the equipment or not. For this, records of proficiency, which gives evidence that he is receiving adequate regularly training in setting, programming and operation functions of the equipment (in accordance with applicable WPS's) are required.

For a welding operator who solely operates the equipment without responsibility for setting up or adjusting it, the builder shall ensure that he has adequate experience and that he produces welds of required quality. For this, records of proficiency, which gives evidence that he is receiving regularly adequate training in operation functions of the equipment (in accordance with applicable WPS's) are required.

2.3 Training

In addition to the requirements of [2.2], the training of welding operators shall include training in evaluation of:

- groove dimensions according to WPS
- groove cleanliness requirements
- weather and wind requirements

— handling of welding consumables.

Appropriate records of training shall be maintained.

Guidance note:

Alternatively to training records, welding operators certificates according to a recognized standard may be accepted, e.g. ISO 14732, ASME Section IX or ANSI/AWS D1.1.

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3 Welders

3.1 Scope

This subsection gives the qualification and certification requirements for welders of manual and semi-automatic welding processes.

3.2 Qualification

The contractor is responsible for the qualification of welders.

3.3 Certification

3.3.1 Welders shall be certified to [DNVGL-RU-SHIP Pt.2 Ch.4 Sec.3](#) or a recognized standard, e.g. IACS UR W32, ISO 9606, ASME Sec.IX or ANSI/AWS D1.1.

3.3.2 Recognition of other standards is subject to agreement with the verifier.

3.3.3 A welder's certificate shall be validated every 6 months and in accordance with the certification standard. Records thereof are required.

3.3.4 The verifier shall be allowed to examine the register at any time and the records/evidence shall be provided according to the relevant standards.

SECTION 4 WELDING CONSUMABLES

1 General

1.1 Scope

This section specifies basic groups and grades for welding consumables, application of the various grades, and grouping of the shielding gases.

1.2 Basic groups and grades

Welding consumables are divided into groups, depending on the strength of the filler metal, corresponding to the strength of the steel grade to be welded. The groups correspond to the steel types and grades defined in [DNVGL-OS-B101](#). The applicable groups are:

- normal strength steels (C/C-Mn steels with specified minimum yield stress (SMYS) ≤ 235 MPa, e.g. see [DNVGL-OS-B101 Ch.2 Sec.2 \[2\]](#))
- high strength steels (C/C-Mn steels with $235 < \text{SMYS} \leq 400$ MPa, e.g. see [DNVGL-OS-B101 Ch.2 Sec.2 \[3\]](#))
- extra high strength steels (C/C-Mn steels with $400 < \text{SMYS} \leq 960$ MPa, e.g. see [DNVGL-OS-B101 Ch.2 Sec.2 \[4\]](#))
- boiler and pressure vessel steels (C/C-Mn steels designed for boilers and pressure vessels, e.g. see [DNVGL-RU-SHIP-Pt.2 Ch.2 Sec.3 \[2\]](#))
- steels for low temperature service (steels designed for low temperature application, e.g. see [DNVGL-RU-SHIP-Pt.2 Ch.2 Sec.3 \[3\]](#))
- austenitic stainless steels and austenitic high manganese steels (e.g. see [DNVGL-RU-SHIP-Pt.2 Ch.2 Sec.3 \[4\]](#))
- ferritic-austenitic (duplex) steels (e.g. see [DNVGL-RU-SHIP-Pt.2 Ch.2 Sec.3 \[4\]](#))
- other stainless steels
- aluminium alloys (e.g. see [DNVGL-OS-B101 Ch.2 Sec.6](#))
- other non-ferrous metals (e.g. see [DNVGL-RU-SHIP-Pt.2 Ch.2](#)).

The groups are further divided into grades depending on the impact test temperature and the chemical composition of the filler metal, see e.g. details given in the referred rules and standards.

2 Selection of welding consumables

2.1 General

2.1.1 Welding consumables shall be qualified in accordance with a scheme or standard recognized by the verifier.

2.1.2 Welding consumables shall be classified with respect to strength, application area and hydrogen level according to recognised scheme. All welding consumables shall have identifiable marking.

2.2 Carbon, carbon-manganese and alloy steel

2.2.1 The following general limitations apply:

- Unless as specified in [\[2.1.2\]](#), consumables of a higher toughness grade may be applied for steels of same or lower toughness grades.
- Unless otherwise agreed, consumables shall have minimum specified yield and tensile strength equal to or higher than the steel to be welded.

- When two different steel grades shall be joined, the welding consumable shall have yield strength not below that of the lower strength steel.

2.2.2 For recommended steels for structural application see [Table 1](#).

Table 1 Recommended welding consumables for different steel grades

Steel grade specification				Welding consumable specification					
SMYS	TS	Temp B	CVN	SMYS	TS	A5	Temp W	CVN	Hydrogen ¹⁾
<i>Normal strength steels</i>									
235	400-520	$B \geq 0$ (0, +20)	20-41	²⁾	400 ²⁾ -660 ³⁾	22	$\leq B$	47 ⁴⁾	-
235	400-520	$-20 < B < 0$ (-10)	20-41	²⁾	400 ²⁾ -660 ³⁾	22	0	47 ⁴⁾	-
235	400-520	$B \leq -20$ (-20, -40, -60)	20-41	²⁾	400 ²⁾ -660 ³⁾	22	$\leq (B+20)$	47 ⁴⁾	-
<i>High strength steels</i>									
315-390 ⁵⁾	440-660	$B \geq -20$ ⁵⁾ (-20, 0, +20)	22-55	²⁾	440 ²⁾ -660 ³⁾	22	≤ 0	47 ⁴⁾	H10 ⁸⁾
315-390 ⁶⁾	440-660	$B \geq -20$ ⁶⁾ (-20, 0, +20)	22-55	²⁾	440 ²⁾ -660 ³⁾	22	≤ -20	47 ⁴⁾	H10 ⁸⁾
315-390 ⁵⁾	440-660	$B < -20$ ⁵⁾ (-40, -60)	22-55	²⁾	440 ²⁾ -660 ³⁾	22	$\leq (B+20)$	47 ⁴⁾	H10 ⁸⁾
315-390 ⁶⁾	440-660	$B < -20$ ⁶⁾ (-40, -60)	22-55	²⁾	440 ²⁾ -660 ³⁾	22	$\leq B$	47 ⁴⁾	H10 ⁸⁾
<i>Extra high strength steels</i>									
420-549	530-830	B	28-55	²⁾	530 ²⁾ -830 ⁷⁾	²⁾	$\leq B$	²⁾	H10 (H5 ⁸⁾)
550-689	670-940	B	55-69	²⁾	670 ²⁾ -940 ⁷⁾	²⁾	$\leq B$	²⁾	H5
690-960	940-1150	B	69	⁹⁾	940 ⁹⁾ -1150 ⁹⁾	²⁾	$\leq B$	²⁾	H5
<i>Boiler and pressure vessel steels</i>									
≥ 175	360-650	B	27-48	²⁾	360 ²⁾ -650 ⁷⁾	22	$\leq B$	47 ⁴⁾	H15 ¹⁰⁾
<i>Steels for low temperature service</i>									
≥ 215	360-610	B	27-41	²⁾	360 ²⁾ -610 ⁷⁾	22	$\leq B$	47 ⁴⁾	H15

<i>Steel grade specification</i>	<i>Welding consumable specification</i>
<p>SMYS = specified minimum yield strength (MPa) for the base material (BM).</p> <p>TS = specified tensile strength (MPa) for the BM.</p> <p>Temp B = specified impact toughness test temperature (°C) for the BM. Temperatures in brackets are given as examples.</p> <p>Temp W = specified impact toughness test temperature (°C) for the welding consumables (weld deposit)</p> <p>CVN = specified minimum Charpy V-notch impact toughness value (J).</p> <p>A5 = specified minimum elongation for the welding consumables (weld deposit).</p> <p>B = specified impact toughness test temperature (°C) for the BM.</p> <ol style="list-style-type: none"> 1) See DNVGL-CP-0069 for definition. 2) Equal to or more than the minimum specified value for the steel grade. 3) Up to 690 MPa subject to agreement. 4) Same value as for the steel grade to be welded may be agreed. 5) For thickness equal to or less than 50 mm. 6) For thickness more than 50 mm. 7) Not more than the maximum specified value for the steel grade. 8) Applicable for covered electrodes. 9) Subject to agreement. 10) Not required for Temp B \geq 20°C. 	

2.2.3 For selection of shielding gas see [3].

2.3 Stainless steel and high-manganese austenitic steel

2.3.1 Welding consumables for stainless steels shall be selected in accordance with the consumable manufacturer's recommendations for the applicable grade of steel, taking the corrosion resistance, strength requirements, toughness requirements and the welding metallurgy (including resistance to hot cracking) into account.

2.3.2 Welding consumables for welding of high-manganese austenitic steel shall be selected in accordance with the steel plate manufacturer's recommendation.

2.3.3 Welding consumables which have satisfied the requirements for a higher toughness grade are considered to comply with the toughness requirements for a lower toughness grade of the same type of stainless or high-manganese austenitic steel.

2.3.4 For selection of shielding gas see [3].

2.4 Aluminium alloys

Welding consumables for hull structural aluminium shall be one of those specified in [Table 2](#).

Table 2 Selection of consumables for aluminium alloys

<i>Base metal alloy</i>	<i>VL 5052, VL 5754 VL 5154, VL 5454 VL 5086</i>	<i>VL 5083 VL 5383 VL 5059</i>	<i>VL 6060, VL 6061 VL 6063, VL 6005A VL 6082</i>
VL 5052, VL 5754 VL 5154, VL 5454 VL 5086	5356, 5556, 5183	5356, 5556, 5183	5356, 5556, 5183
VL 5083, VL 5383 VL 5059	5356, 5556, 5183	5183 ¹⁾ , 5556	5356, 5556, 5183
VL 6060, VL 6061 VL 6063, VL 6005A VL 6082	5356, 5556, 5183	5356, 5556, 5183	5356, 5556, 5183

Note: all consumables are covered by the AWS specification. The prefix ER is omitted.

1) Other consumables may be used if allowable stresses are reduced, see [Sec.5 Table 8](#).

2.5 Other non-ferritic metallic materials like copper alloys and titanium alloys

2.5.1 Recommendations for welding consumables for repair of copper alloy propellers are given in [Sec.5 \[10.2\]](#).

2.5.2 Welding consumables for other non-ferritic materials shall be selected in accordance with manufacturer's recommendations for the applicable materials, taking the corrosion resistance, strength

requirements, toughness requirements and the welding metallurgy (including resistance to hot cracking) into account.

3 Shielding gas

Where applicable, the composition of the shielding gas shall be reported.

For welding of steel, the acceptance of a wire/gas combination with any particular gas can be applied to or transferred to, any combination of the same wire and any gas in the same numbered group as defined in Table 3.

Table 3 Grouping of shielding gases¹⁾

Group	Gas composition (Vol. %)				
	CO ₂	O ₂	H ₂	He	Ar ²⁾
I 1	-	-	-	-	100
I 2	-	-	-	100	-
I 3	-	-	-	0 to 95	Rest
M 11	0 to 5	-	0 to 5	-	Rest ²⁾
M 12	0 to 5	-	-	-	Rest ²⁾
M 13	-	0 to 3	-	-	Rest ²⁾
M 14	0 to 5	0 to 3	-	-	Rest ²⁾
M 21	5 to 25	-	-	-	Rest ²⁾
M 22	-	3 to 10	-	-	Rest ²⁾
M 23	5 to 25	0 to 8	-	-	Rest ²⁾
M 31	25 to 50	-	-	-	Rest ²⁾
M 32	-	10 to 15	-	-	Rest ²⁾
M 33	5 to 50	8 to 15	-	-	Rest ²⁾
C 1	100	-	-	-	-
C 2	Rest	0 to 30	-	-	-

1) The compositions of shielding gases in group I are in accordance with International Organization for Standardization (ISO) 14175, while group M and C gases are in accordance with IACS UR W17.

2) Argon may be partly substituted by helium up to 95% of the argon content.

SECTION 5 WELDING PROCEDURES

1 General

1.1 Scope and application

1.1.1 Materials

This section specifies requirements for WPS and welding procedure qualification tests (WPQT) for:

- carbon-manganese steels (C-Mn) and low alloy steels (referred to as steels)
- austenitic stainless steels
- ferritic-austenitic (duplex) stainless steels
- aluminium alloys
- copper alloys.

Requirements for COD grade steels, materials for liquefied gas systems and repair welding of steel castings are given in [DNVGL-RU-SHIP Pt.2](#).

WPS for materials not covered by this section shall be qualified in accordance with a recognized standard or a recognized practice.

1.1.2 Welding methods

1.1.2.1 General

This section is applicable for the welding methods listed in [\[1.2.1\]](#). Other welding methods requires special consideration.

1.1.2.2 Clad welding

WPS for overlay/clad welding shall be qualified according to ISO 15614-7, ASME IX or another recognized standard.

1.1.2.3 Wide gap welding

Wide gap welding for butt joints shall be qualified by a separate WPQT when the gap is more than 16 mm and up to maximum $1.5 \times t$ (max. 25 mm), where t is the plate thickness. The largest gap in production (for remedial welding) shall be used. Gap more than 25 mm shall, unless specially agreed, be repaired by insert.

Buttering of the weld groove shall be qualified by a separate WPQT for the following cases:

- the buttering process essential variables are different from the essential variables of the process used for subsequent completion of the joint
- the thickness of the buttering exceeds 8 mm.

For the WPQT to be qualified the buttered area shall be 100% tested with magnetic particle testing (MT) (ferromagnetic materials) or PT (non-magnetic materials) before the filling of the groove starts. No surface linear indications are accepted.

Guidance note:

For typical butt and fillet weld plate edge preparation repairs, see e.g. [IACS Rec. No.47 Shipbuilding and Repair Quality Standard Part A](#).

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1.2 Welding processes

1.2.1 Welding shall be performed with the following processes unless otherwise specified (methods numbering system in accordance with ISO 4063):

111	Manual metal arc welding (metal arc welding with covered electrode, SMAW)
114	Self-shielded tubular-cored arc welding (FCAW-S)
121	Submerged arc welding (SAW) with solid wire electrode
122	Submerged arc welding (SAW) with strip electrode
124	Submerged arc welding (SAW) with metal powder addition
125	Submerged arc welding (SAW) with tubular cored electrode
131	Metal inert gas welding,(MIG, GMAW) with solid wire electrode
132	Metal inert gas welding (MIG, FCAW-G) with flux cored electrode
135	Metal active gas welding (MAG, GMAW) with solid wire electrode
136	Metal active gas welding (MAG, FCAW-G) with flux cored electrode
138	Metal active gas welding (MAG) with metal cored electrode
141	Gas tungsten arc welding (TIG, GTAW) with solid filler material (wire/rod)
15	Plasma arc welding

1.2.2 For other processes and for high heat input welding (> 50 kJ/cm), the requirements for qualification testing and validity range require special consideration.

2 Welding procedures

2.1 Preliminary welding procedure specification

A preliminary welding procedure specification (pWPS) shall be prepared and accepted by verifier for each new WPQT. The pWPS shall contain the relevant information required for the WPS, see [2.4]. The pWPS may be modified and amended during the procedure welding. In case the test pieces welded according to the pWPS show unacceptable results, the pWPS shall be adjusted by the contractor or subcontractor. The new pWPS shall be prepared and the test pieces welded in accordance with the new pWPS.

2.2 Welding procedure qualification test

2.2.1 The pWPS (see [2.1]) shall be qualified by WPQT in order to prove that it is suitable for a WPS. The test results shall meet the acceptance criteria given in this standard in order to be valid for qualification of a WPS.

2.2.2 The general WPQT requirements are further specified in [3], and the specific WPQT requirements for different joints and materials are further detailed in [4] to [12].

2.2.3 Qualification welding shall be performed under general conditions representative of the actual working environment for the work shop or site, where the production welding will be performed (see also [4.7.1.1] and Sec.6 [4] and Sec.6 [9]).

2.2.4 During qualification test welding, all welding parameters relevant for the final acceptance of the WPS (including the weld bead width) shall be recorded for each welding pass. A report summarizing the records from the welding and the test results, i.e. a welding procedure qualification record (WPQR), shall be prepared (see [2.3]). The WPQR shall give the material certificate of the base and filler materials applied in the WPQT.

2.2.5 The base materials (BM) used for welding procedures shall be identified by means of material marking and certificates. The material shall be certified with a type 3.1 or 3.2 certificate according to ISO 10474.

2.2.6 All relevant instruments for checking of welding parameters (e.g. temperature, ampere, volt) applied for the WPQT shall have valid calibration certificates and the adequacy of any control software (weld machine) shall be documented.

Guidance note:

Calibration and validation in accordance with ISO 17662 is recommended.

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2.3 Welding procedure qualification record

2.3.1 The WPQR shall be a record of the materials, consumables, parameters and any heat treatment used during qualification welding, and records of the subsequent non-destructive, destructive and corrosion test results. All essential variables used during qualification welding that are relevant for the final application of the WPQR shall be documented, and the actual welding parameters recorded in relevant positions for each welding pass. The weld bead width range shall be recorded for each welding pass.

2.3.2 The WPQR documentation shall include the manufacturer certificates for the base and filler materials applied in the weld qualification test.

2.4 Welding procedure specification

2.4.1 A WPS shall as a minimum contain the following information as relevant for the welding operation:

- Identification of contractor or subcontractor performing the qualification testing (name, address).
- Identification of the WPS and reference to the WPQR.
- Welding process(es), including the order of processes if more than one process is used.
- Number and configuration of electrodes for multi-wire welding.
- Welding position(s) and direction of progression.
- Joint type.
- Backing and backing material.
- Preheating and interpass temperatures.
- PWHT parameters.
- Method of preparation including cleaning process.
- Material: standard, grade, delivery condition (AR, N, NR, TM, QT) and modification, carbon equivalent (when relevant).
- Nominal plate/pipe thickness or diameter range (dimensions).
- Welding consumables: trade name, electrode or wire diameter, shielding gas, flux and recognised classification.
- Joint or groove design with tolerances of angles, root face, root gap (sketch). Throat thickness range for fillet welds.
- Welding sequence: number and order of passes or layers (sketch).
- Electrical parameters: voltage range, current range, polarity direct current (D.C.+), (D.C.-) or alternating current (A.C.), pulse welding details (machine settings and/or programme selection).

- Shielding gas flow rate.
- Travel speed ranges.
- Heat input ranges for at least root, fill and cap passes.
- Number of passes to be completed before cooling to below preheat temperature.
- Details on cleaning processes employed and restrictions if any.
- Minimum length of tack welds, when relevant.
- Type and coating thickness of overweldable shop primer for fillet welding if automatic welding is applied.

Specific/additional for the submerged arc welding (SAW)/121 welding process:

- flux, designation, manufacturer and trade name
- contact tip, work piece distance.

Specific/additional for the gas metal arc welding (GMAW)/135 welding process:

- contact tip, work piece distance.

Specific/additional for the GTAW/141 welding process:

- nozzle diameter
- diameter and codification of tungsten electrode
- hot or cold wire
- type of weld head and gas lens.

2.4.2 The WPS shall be submitted together with the referenced supporting WPQR(s) for review and acceptance.

2.4.3 A WPS shall be established by one of the following methods:

- a) Review of a welding procedure qualification test record (WPQR) corresponding to the WPS in question. The WPQT on which the WPQR is based shall be witnessed by a recognised party. Unless otherwise agreed, the WPQT and test results, the content of the WPQR and the content and validity range of the WPS shall comply with the requirements of this standard.
- b) The WPS is compiled on basis of other agreed welding procedure specifications.

2.4.4 One or more WPSs may be prepared based on the data of one or more accepted WPQRs provided the essential variables are kept within the acceptable limits. All limits and ranges for the applicable essential variables for the welding to be performed shall be stated in the WPS.

Guidance note:

The number of WPQRs (alternative a) used for the preparation of a new WPS should not exceed 6. The number of WPSs (alternative b) used for the preparation of a new WPS should not exceed 3. When a new WPS is based on several WPQRs or WPSs the contractor should prepare an overview indicating the overlap of each essential variable specified in this standard.

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2.4.5 For multi-process procedures the WPS shall be qualified by either:

- separate WPQTs for each welding process
- a multi-process procedure test. The qualification of a multi-process procedure test is only valid for the process sequence carried out for the qualification test.

3 General welding procedure qualification test requirements and acceptance criteria

3.1 Introduction

This subsection gives the general requirements applicable for all joint configurations, unless otherwise specified. Additional requirements each specific joint configuration and material type is further specified in [4] to [11].

3.2 Non-destructive testing

3.2.1 Butt welds and full penetration welds

3.2.1.1 Extent of testing

Unless otherwise specified, the extent of non-destructive testing (NDT) shall be as follows:

- 100% visual inspection (VI)
- 100% radiographic testing (RT) or ultrasonic testing (UT)
- 100% surface crack detection (MT for ferromagnetic materials or penetrant testing (PT) for non-ferromagnetic materials).

3.2.1.2 Acceptance criteria

The soundness of the weld shall comply, unless otherwise specified, with EN ISO 5817 quality level B. Regarding use of EN ISO 5817 and EN ISO 10042 for RT, UT, MT and PT, EN ISO 17635 shall be followed.

Guidance note:

For UT level 2 of ISO 11666 is considered equal to level B of EN ISO 5817.

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3.2.2 Fillet welds and partial penetration welds

3.2.2.1 Extent of testing

Unless otherwise specified, the extent of NDT shall be as follows:

- 100% visual inspection (VI)
- 100% surface crack detection (MT for ferromagnetic materials or PT for non-ferromagnetic materials).

3.2.2.2 Acceptance criteria

The soundness of the weld shall comply, unless otherwise specified, with EN ISO 5817 quality level B. Regarding use of EN ISO 5817 and EN ISO 10042 for RT, UT, MT and PT, EN ISO 17635 shall be followed.

Where the stop/restart spot is included in the test length, special attention shall be paid to this position with respect to profile, proper fusion and absence of crater defects.

3.2.3 Failure to meet the non-destructive test requirements - retest

If the WPQT fails to comply with any of the requirements for the NDT, one extra WPQT may be welded and subject to the same testing. If this additional test does not meet the relevant requirements, the actual pWPS shall be considered as not qualified and a re-specification of the pWPS shall be made prior to a new qualification test.

3.3 Destructive testing

3.3.1 Introduction

3.3.1.1 General

Method and general requirements for mechanical testing shall follow [DNVGL-OS-B101 Ch.2 Sec.1](#).

3.3.1.2 Dissimilar materials

For dissimilar material grades and joints between cast or forged and rolled materials see [\[12\]](#).

3.3.2 Cross-weld tensile test

3.3.2.1 Test requirements

Location of fracture, weld metal or deposit (WM) or base material (BM), and tensile strength shall be reported.

When round tensile test specimen is required, care shall be taken so that the longitudinal axis coincides with the intersection between the mid-plane of the weld, and the mid-plane of the plates. If the section area of the weld metal is too small to allow sampling of the round specimen, an all-weld-metal tensile test shall be carried out.

3.3.2.2 Acceptance criteria

The tensile strength shall not be below the specified minimum tensile strength for the base material grade in question. Location of fracture (WM or BM), and tensile strength shall be reported.

3.3.3 Bend test

3.3.3.1 Test requirements

For a mixed or heterogeneous butt joint, transverse bend test specimens may be replaced by longitudinal bend test specimens.

For normal and high strength steels, the test specimens shall be bent on a mandrel with diameter $4 \times t$ where t is the thickness of the specimen. For extra high strength steels with SMYS 420, 460, 500 MPa the mandrel diameter shall be $5 \times t$ and for SMYS 550, 620 and 690 MPa the mandrel diameter shall be $6 \times t$. For SMYS > 690 MPa, the mandrel diameter shall be agreed.

Unless otherwise specified, the bending angle shall be 180° .

3.3.3.2 Acceptance criteria

After bending, the test specimens shall not reveal any one single open defect in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing shall be investigated case by case.

3.3.4 Macro-section test

3.3.4.1 Test requirements

The macro-section shall include about 10 mm of unaffected BM and shall be prepared and etched on one side to clearly reveal the fusion line (FL) and the heat affected zone (HAZ).

3.3.4.2 Acceptance criteria

Cracks and lack of fusion are not accepted. Other defects shall follow level B of EN ISO 5817. The welded joints shall have a regular profile with smooth transitions to the BMs and without significant or excessive reinforcement. Acceptance criteria for weld profile shall follow [IACS Rec. No.47](#).

3.3.5 Hardness test

3.3.5.1 Test requirements

The hardness testing shall be in accordance with ISO 6507-1 and ISO 9015-1 or equivalent. Hardness test is required for grades with SMYS 265 MPa and higher.

Unless otherwise agreed, the Vickers method (HV10) shall be used. Indentations shall be made along traverses in the weld, HAZ and the parent metal, maximum 2 mm below the surface. For each traverse, a minimum of 3 indentations shall be made in the weld, HAZ (both sides) and parent metal (both sides). See Figure 1 to Figure 4.

For HAZ the first indentation shall be placed as close to the FL as possible. For double sided welds, for fillet and T-butt welds, one additional row of indentations shall be made through the root area.

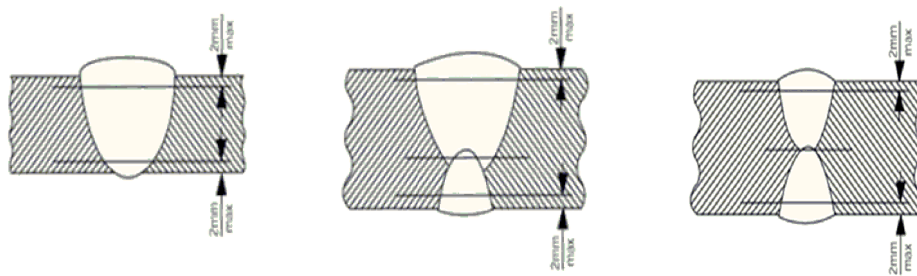


Figure 1 Examples of hardness test with rows of indentations in butt welds

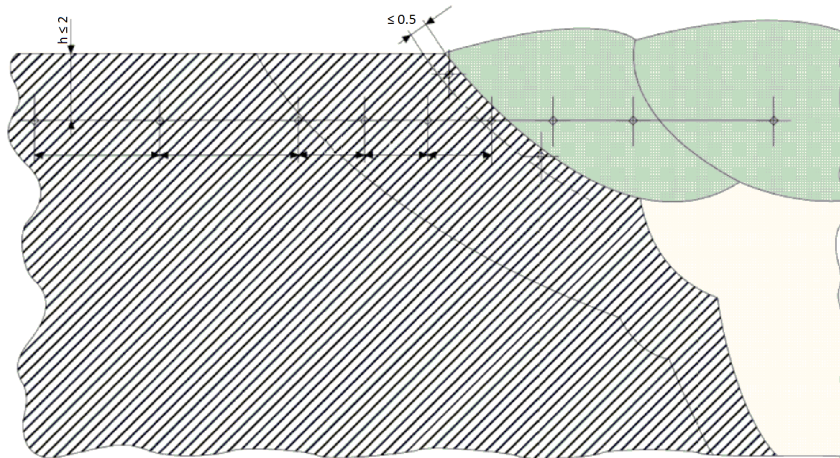


Figure 2 Example of hardness indentations in butt welds

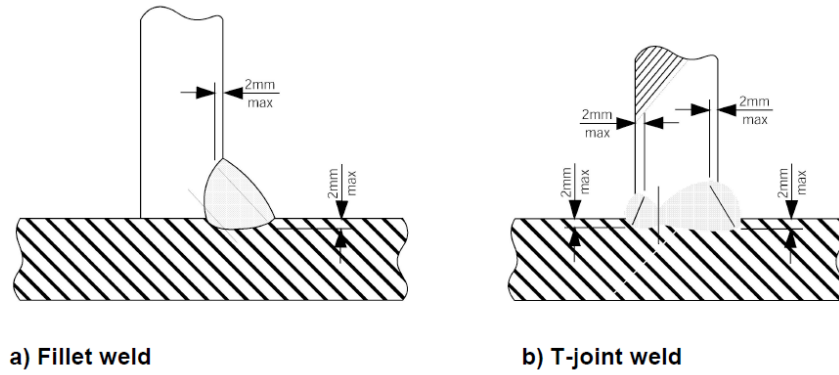


Figure 3 Examples of hardness test with row indentation (R) in fillet welds and in T-joint welds

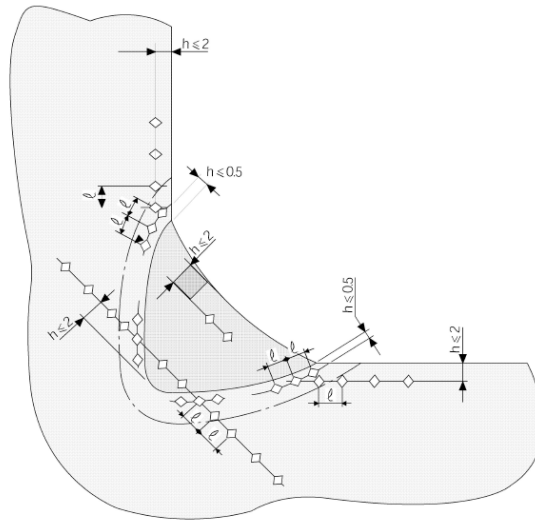


Figure 4 Example showing the position of the indentations for hardness test in the weld metal, the heat affected zone and the base metal of a fillet weld (dimensions in mm)

3.3.5.2 Acceptance criteria

The following general acceptance criteria are given for C-Mn and low alloy steels, and applies unless other requirements are specified in the following paragraphs or specially agreed. Grades denoted VL are specified by [DNVGL-OS-B101 Ch.2 Sec.2](#):

- For steel grades up to and including VL 420 and corresponding grades, a maximum hardness limit of 350 HV10 shall be met, except for single run fillet welds where the maximum hardness limit shall be 380 HV10.
- For VL460 VL 500, VL 550, VL 620 and VL 690 and corresponding grades, the maximum hardness limit shall be 420 HV10.
- For VL 890 and VL 960 and corresponding grades, the maximum hardness limit shall be 450 HV10.

For other grades and materials, the acceptance criteria shall be agreed.

Materials exposed to anaerobic environments or to cathodic protection shall have a hardness equal to or less than 350 HV.

3.3.6 Charpy V-notch impact toughness test

3.3.6.1 Test requirements

For a single- or double bevel groove preparation the location of the impact test specimens shall be taken from the vertical side of the groove (without the bevel).

For material thicknesses below 6 mm impact testing is not required unless specifically agreed.

For ferritic type steels (including martensitic, bainitic, etc.), and unless otherwise agreed, three sets of three charpy V-notch specimens each shall be sampled 1 - 2 mm below the surface of the parent material and transverse to the weld. The V-notch shall be perpendicular to the plate surface. Unless otherwise specified in the following paragraphs, at least nine charpy V-notch specimens shall be localized in the welded joint as follows (see [Figure 8](#)):

- three specimens with the notch along the weld metal centerline (WM)
- three specimens with the notch in the FL
- three specimens with the notch in the HAZ, 2 mm from the fusion line (FL+2).

Additional or alternative charpy V-notch specimens shall be tested as indicated in the following paragraphs, e.g. for thick plates, for high heat input welding, steels for low temperature service, etc.

Where multiple welding processes are qualified in a single test piece, separate impact test specimens shall be taken from the weld metal, FL and HAZ, representative of each welding process. This does not apply to the process and consumables used to make the first weld run or root deposit of a multipass weld.

For dissimilar material grade and joints between cast or forged and rolled materials, impact tests shall be carried out on test specimens with notch in FL and 2 mm from FL in each parent material. See also [\[12\]](#).

Test temperature: the impact test temperature for hull structural steels of normal and high strength (see [DNVGL-OS-B101](#)), shall be as given in [Table 1](#) with the acceptance criteria as given in [\[3.3.6.2\]](#). The test temperature may alternatively follow the requirements of the BM (e.g. see [DNVGL-OS-B101](#)) with the corresponding acceptance criteria required for the relevant BM.

Table 1 Impact test temperature

<i>Impact test temperatures</i>	<i>For VL grades¹⁾</i>
+20°C	A, A27S, A32, A36 and A40
0°C	B, D, D27S, D32, D36 and D40
-20°C	E, E27S, E32, E36 and E40
-40°C	F27S, F32, F36 and F40
1) See DNVGL-OS-B101 .	

For the following listed steel grades, materials and applications, the charpy V-notch test temperature shall be the same as required for the BM.

- steel grades of improved weldability (see [DNVGL-OS-B101](#))
- extra high strength structural steels (SMYS > 390 MPa)
- boiler and pressure vessel steels
- weldable C- and C-Mn hull steel castings and forgings
- production/drilling plants related equipment, structures and systems.

For the following materials and applications, specific requirements are given in the referred paragraphs.

- austenitic stainless steels, see [7]
- austenitic-ferritic (duplex) steels, see [8]
- aluminium, see [9]
- copper alloys, see [10]
- repair of steel castings, see [11].

3.3.6.2 Acceptance criteria

The acceptance criteria for the charpy V-notch impact toughness of hull structural steels of normal and high strength (the steel grades are defined in [DNVGL-OS-B101](#)), shall be as follows:

- For grades VL A and VL B and corresponding grades, all welding methods and positions: minimum 27 J.
- For all other VL grades (and corresponding non-VL grades), different requirements apply for different welding process and welding positions as follows:
 - manual and semi-automatic welding in all welding positions except vertical: minimum 47 J
 - manual and semi-automatic welding in vertical position: 34 J (for VL 40 grades: 39 J)
 - automatic welding and fully mechanised welding: 34 J (for VL 40 grades: 39 J).

As indicated in [\[3.6.2.1\]](#) the test temperature and acceptance criteria may alternatively follow the requirements of the BM, except for grades corresponding to VL A and VL B which shall meet an impact toughness requirement of 27 J tested at +20°C and 0°C respectively.

For the other materials and applications listed in [\[3.3.6.1\]](#), and unless otherwise specified in the referred paragraphs, the required impact toughness shall be the same as that required for the BM.

The general impact toughness requirements for the BM grades with designation VL are given in [DNVGL-OS-B101](#). Other hull structural steel grades may be accepted subject to agreement. In such cases, the requirements apply to the non-VL grade corresponding to the listed VL grade, unless otherwise agreed.

Guidance note:

Some welding procedures require impact testing at different material thicknesses, e.g. centre of plate. Qualification of the BMs according to a given standard, e.g. [DNVGL-OS-B101](#) do not necessarily require impact toughness testing of all material thickness positions relevant for the WPQT. Where relevant, the purchaser is recommended to order steel with adequate impact toughness at relevant plate thickness positions.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

The average impact requirements shall be satisfied for each notch location, but one single value of three values from specimens from the same notch location may be below the average requirements, but not below 70% of minimum average.

In case of sub-size Charpy V-notch test specimens, see acceptance criteria given in [DNVGL-OS-B101 Ch.2 Sec.1](#).

3.3.7 Fracture mechanics test

3.3.7.1 Test requirements

Where fracture mechanics (FM) testing (e.g. crack tip opening displacement (CTOD) test) is required by the relevant standard or specification, it shall be carried out in accordance with [DNVGL-OS-B101 Ch.2 Sec.1](#).

Guidance note:

[DNVGL-OS-C101](#) and [DNVGL-OS-C201](#) gives requirements to FM testing.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

The test weld shall be made and tested for the actual combination of steel grade, manufacturer, welding process and welding consumable (brand) used. FM testing is, however, not required for consumables used for root passes only in two-sided welds.

FM testing of the weld deposit or HAZ may be omitted based on a case-by-case acceptance. In this case, tests with satisfactory results shall have been carried out previously, by either the steel manufacturer or the welding consumable manufacturer. This provided that the tested weld deposit or HAZ (welding parameters) is representative.

The test temperature shall be equal to or lower than the service temperature as defined in [DNVGL-OS-C101](#) and/or [DNVGL-OS-C201](#).

3.3.7.2 Acceptance criteria

The critical CTOD for all of the valid specimens shall be equal to or larger than 0.15 mm unless otherwise specified in the following paragraphs (e.g. [\[5\]](#)) and by the relevant rules.

If, for HAZ or weld deposit, one or more of the three specimens have a critical CTOD lower than 0.15 mm additional tests may be carried out. In such a case the characteristic value, as defined in [Table 2](#), shall be equal to or larger than 0.15 mm.

Table 2 Characteristic value of crack tip opening displacement

<i>Number of valid tests¹⁾</i>	<i>Characteristic value</i>
3 to 5	Lowest result
6 to 10	Second lowest result
11 to 15	Third lowest result

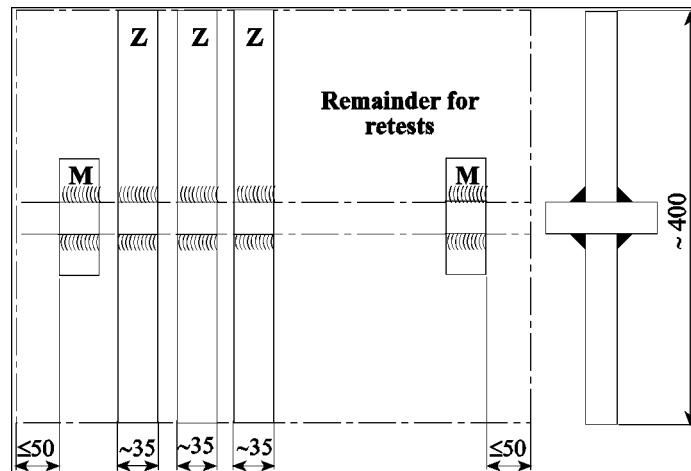
1) All valid tests that have been carried out shall be included in the evaluation. It is not permissible to discard any valid test result.

If the characteristic value as specified in [Table 2](#) is lower than 0.15 mm an engineering critical assessment (ECA) may be carried out with the purpose of demonstrating that extra capacity is available in the structure. Acceptance based on ECA shall be specially agreed.

3.3.8 Cruciform joint tensile shear test

3.3.8.1 Test requirements

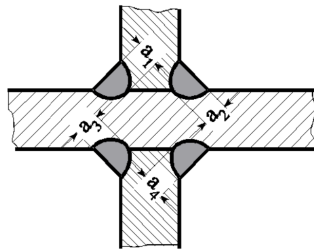
Where cruciform joint tensile shear test is required in the following, the test requirements are given as follows: for the set of double-T (cruciform) test specimens see Figure 5 and for the calculation of the shear tensile strength see Figure 6.



M = macro section
 Z = cruciform tensile test specimen

Figure 5 Set of double-T (cruciform) test specimens

The cruciform tensile test specimens shall be evaluated in order to determine the tensile-shear strength of the weld metal according to Figure 6. Before the testing, the fillet weld throat thicknesses and the width of the specimens shall be measured. The width of the specimen should be about 35 mm.



$a_1 + a_2$ = fracture section $S_{1/2}$
 $a_3 + a_4$ = fracture section $S_{3/4}$

$$\text{Tensile-shear strength} = \frac{\text{Breaking load } F}{S_B \cdot \text{width of specimen}} \quad [\text{N/mm}^2]$$

$S_B = S_{1/2}$ or $S_{3/4}$ according to position of fracture

Figure 6 Cruciform tensile test specimen (weld cross section)

3.3.8.2 Acceptance criteria

For the tensile-shear strength requirements applicable to cruciform tensile specimens, see [Table 3](#).

Table 3 Requirements applicable to cruciform tensile test specimens

<i>Grades¹⁾</i>	<i>Tensile-shear strength (N/mm²)</i>
VL A – VL E, VL A27S - VL F27S	350
VL A32 – VL F36	430
VL A40 – VL F40	450
1) See DNVGL-OS-B101 Ch.2 Sec.2	

3.3.9 Retesting

3.3.9.1 Destructive tests except for impact test

If the result of any destructive test, except for impact toughness test, fails to meet the requirements, two further tests may be made from the same welded joint if there is sufficient material available. If not, a new assembly may be welded using the same pWPS. If either of these additional test specimens does not comply with the relevant requirements, the pWPS shall be regarded as not capable of complying with the requirements without modification.

3.3.9.2 Impact toughness test

For retesting of impact toughness test, where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be taken. The results obtained shall be combined with the original results to form a new average which, for acceptance, shall be not less than the required value. Additionally, for these combined results not more than two individual values shall be less than the required average value. Of these two, not more than one shall be less than 70% of the required average value.

4 Carbon manganese steel and low alloy steel

4.1 Full penetration butt welds in plates

4.1.1 Test assembly

The test assembly shall consist of two plates welded together. For rolled plates impact tested in the longitudinal direction (KV_L -tested, see [Figure 7](#)), the butt weld of the test assembly is perpendicular to the rolling direction of the two plates. For extra high strength steel grades impact tested in the transverse direction (KV_T -tested, see [Figure 7](#)), the butt weld of the assembly is parallel to the rolling direction of the two plates. As far as possible the plates shall have a size which can simulate the heat transfer during the production welding. For manual or semiautomatic welding, a test assembly according to [Figure 7](#) shall be carried out with:

$$l_{\min} = 300 \text{ mm}$$

$$L_{\min} = 350 \text{ mm}$$

For automatic welding, the dimensions shall be:

$$l_{\min} = 400 \text{ mm}$$

$$L_{\min} = 1000 \text{ mm.}$$

Guidance note:

An increase of the minimum test piece length (l_{\min}) may be needed if additional specimens like the round tensile test from the weld metal are included.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Edge preparation and fit-up shall be as detailed in the pWPS. The plates shall be joined and held by tack welds to provide the correct gap for the edge preparation used. 50 mm at each end of the test piece shall be discarded.

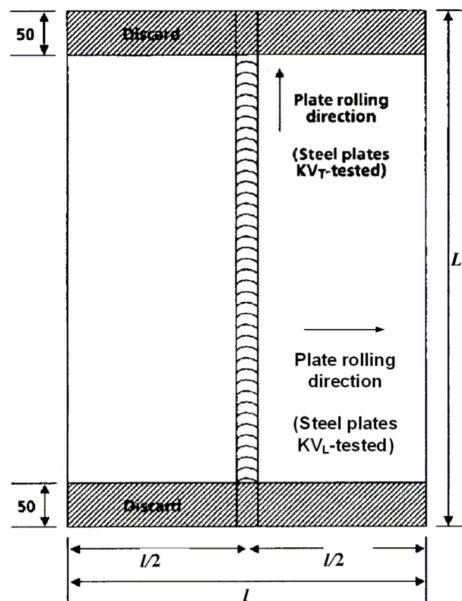


Figure 7 Test assembly for butt welds on plates

4.1.2 Non-destructive testing

NDT shall be carried out in accordance with the specification given for the production welding in question. The extent of the testing and acceptance criteria shall be as given in [3.2.1].

4.1.3 Destructive testing

4.1.3.1 General

The general test requirements and the acceptance criteria for destructive testing are given in [3.3].

4.1.3.2 Specific/additional test requirements

The following specific mechanical tests are required from each assembly, see [Figure 8](#):

- Two cross-weld tensile tests (flat specimen transverse to the weld), see [\[3.3.2\]](#).
- Two root and two face bend specimens shall be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested.
- Three sets of three Charpy V-notch specimens with the notch location as given in [Figure 8](#). Depending on the type of joint (one side or both side), the heat input and the plate thickness, more than nine specimens are required, see [Figure 9](#) and [Figure 10](#).
- One macro-section test (metallographic examination + hardness measurements), see [\[3.3.4\]](#) and [\[3.3.5\]](#).

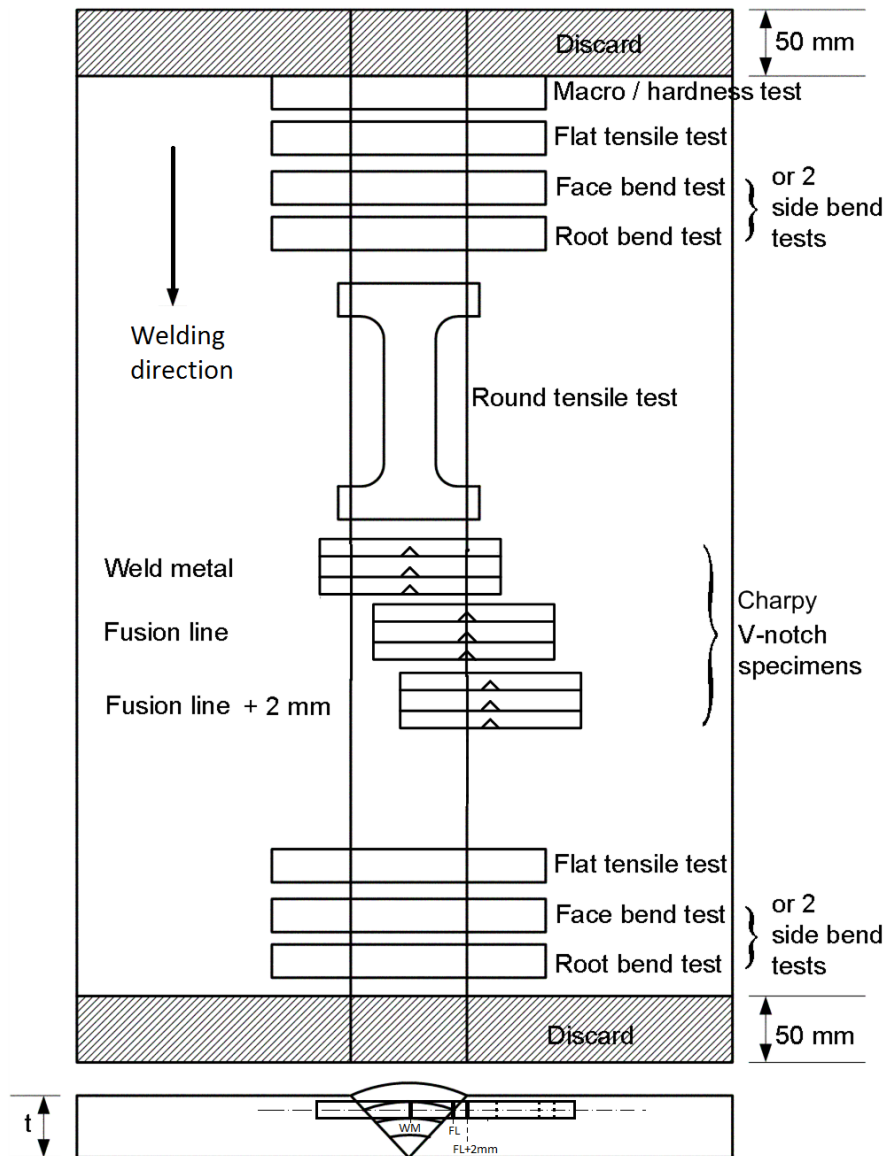


Figure 8 Sampling of test specimens in plates

Impact testing:

The general requirements for impact toughness testing are given above and in [3.3.6]. Specific/additional requirements for Charpy V-notch testing for one side welding on thick plates and welding with high heat input are given in Figure 9, Figure 10 and Table 4.

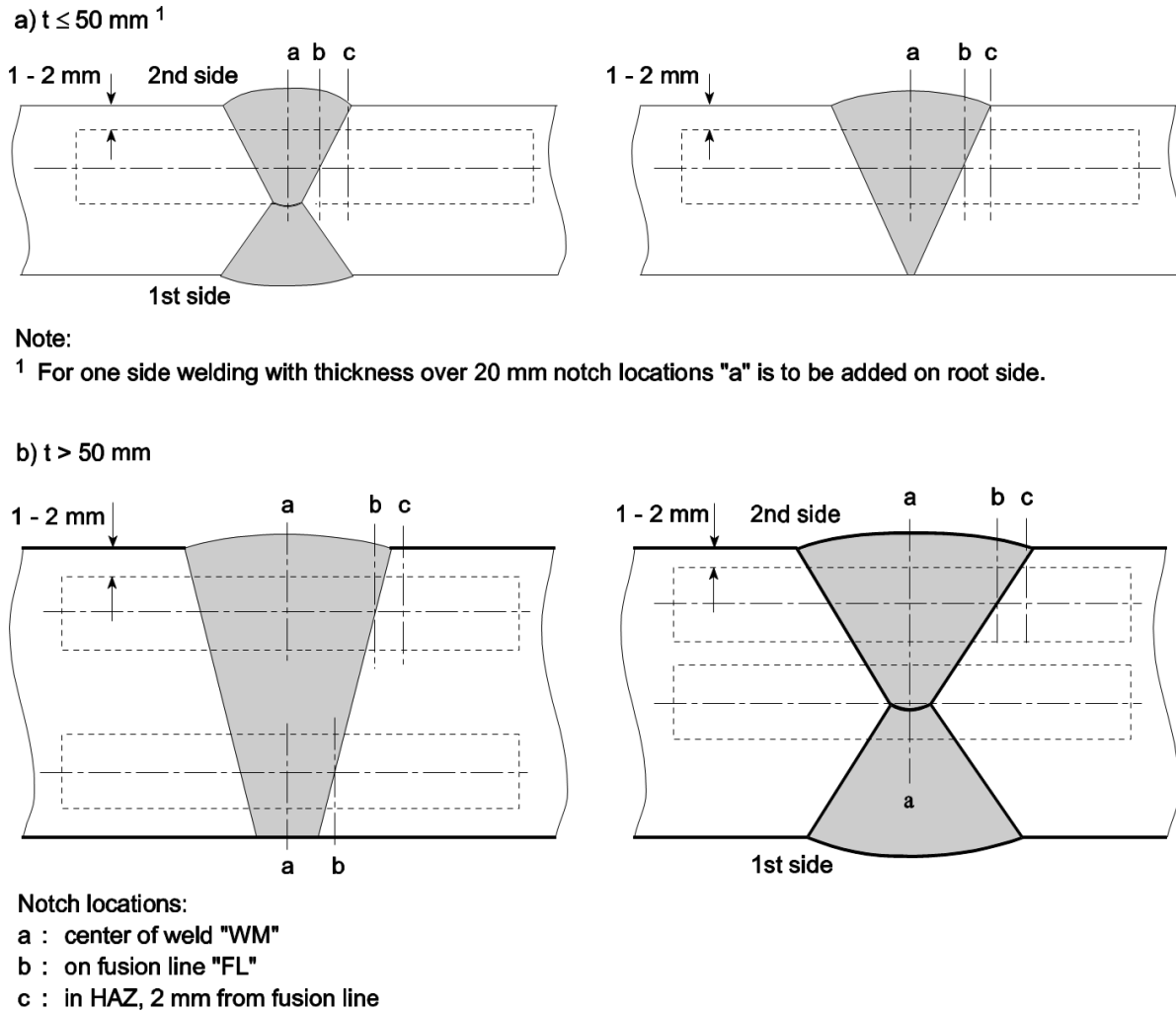
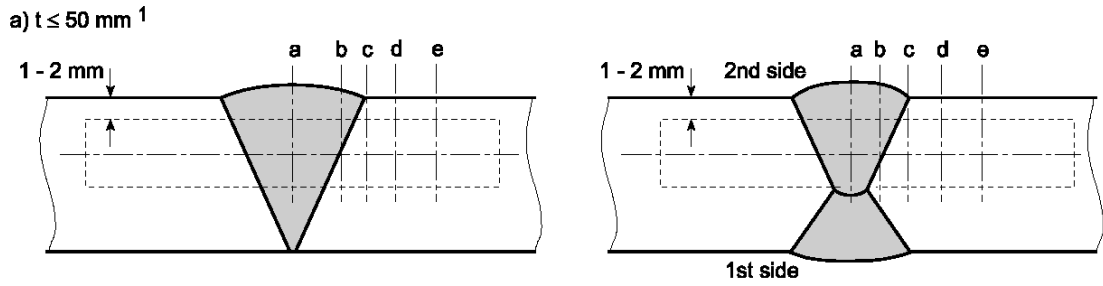
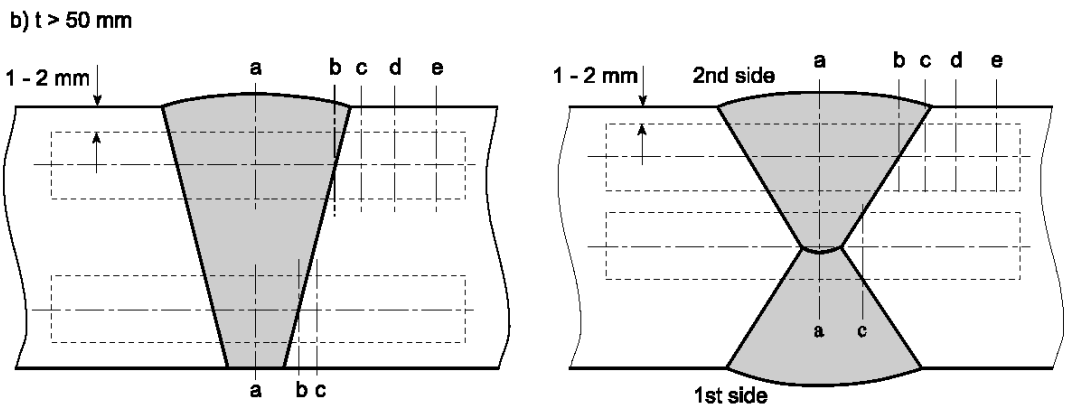


Figure 9 Locations of V-notch for butt weld of normal heat input (heat input $\leq 50 \text{ kJ/cm}$)



Note:
¹ For one side welding with thickness over 20 mm notch locations "a", "b" and "c" are to be added on root side.



- Notch locations:**
- a : center of weld "WM"
 - b : on fusion line "FL"
 - c : in HAZ, 2 mm from fusion line
 - d : in HAZ, 5 mm from fusion line
 - e : in HAZ, 10 mm fusion line in case of the heat input > 200 kJ/cm

Figure 10 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)

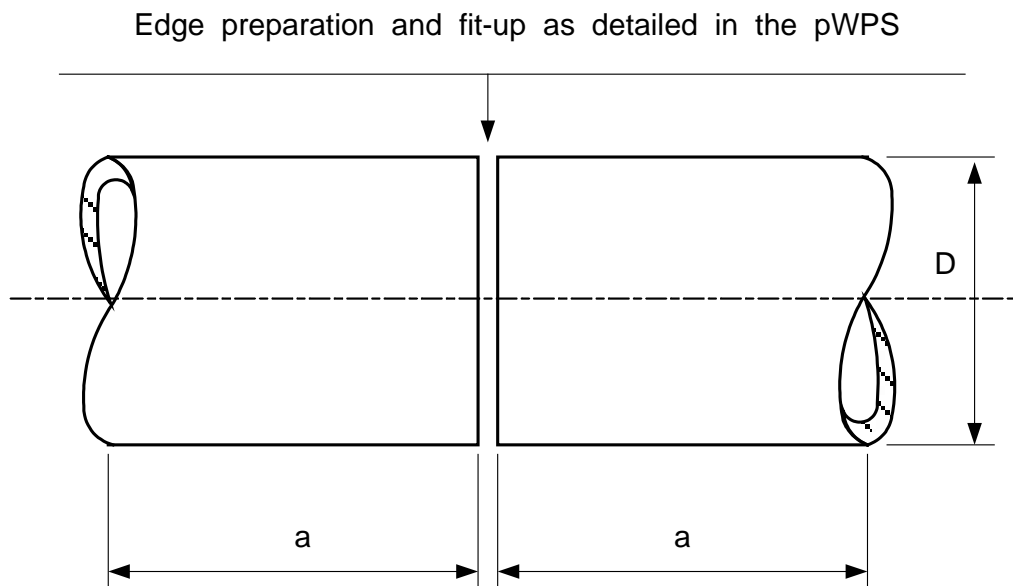
Table 4 Notch location of charpy V-notch impact test

Type of butt weld joint	Heat input (kJ/cm)	Plate thickness, t (mm)	Notch location	
			Cap	Root
One side	≤ 50	≤ 20	WM, FL, FL+2	-
		20 < t ≤ 50	WM, FL, FL+2	WM
		> 50	WM, FL, FL+2	WM, FL
	50 < E ≤ 200	≤ 20	WM, FL, FL+2, FL+5	-
		> 20	WM, FL, FL+2, FL+5	WM, FL, FL+2
	> 200	≤ 20	WM, FL, FL+2, FL+5, FL+10	-
> 20		WM, FL, FL+2, FL+5, FL+10	WM, FL, FL+2	
Both sides	≤ 50	≤ 50	WM, FL, FL+2	-
		> 50	WM, FL, FL+2	WM
	50 < E ≤ 200	≤ 50	WM, FL, FL+2, FL+5	-
		> 50	WM, FL, FL+2, FL+5	WM, FL
	> 200	≤ 50	WM, FL, FL+2, FL+5, FL+10	-
		> 50	WM, FL, FL+2, FL+5, FL+10	WM, FL

4.2 Full penetration butt welds in pipes

4.2.1 Test assembly

The test assembly shall be in accordance with [Figure 11](#).



a = minimum value 150 mm

D = outside diameter

Figure 11 Test assembly for butt welds in pipes

4.2.2 Non-destructive testing

NDT shall be carried out in accordance with the specification given for the production welding in question. The extent of the testing and acceptance criteria shall be as given in [3.2.1].

4.2.3 Destructive testing

4.2.3.1 General

The general test requirements and the acceptance criteria for destructive testing are given in [3.3].

4.2.3.2 Specific/additional requirements

The following specific mechanical tests are required from each assembly, see Figure 12:

- Two cross-weld tensile tests (flat specimen transverse to the weld), see [3.3.2].
- Two root and two face bend tests when $t < 12$ mm and four side bend tests when $t \geq 12$ mm, see [3.3.3].
- Three sets of three charpy V-notch specimens with the notch location as given in Figure 8.
- For pipe thickness > 20 mm with one side welding, one additional set of specimens shall be taken from the root area as given in Figure 10.
- One macro section test (metallographic examination + hardness measurements), see [3.3.4] and [3.3.5].

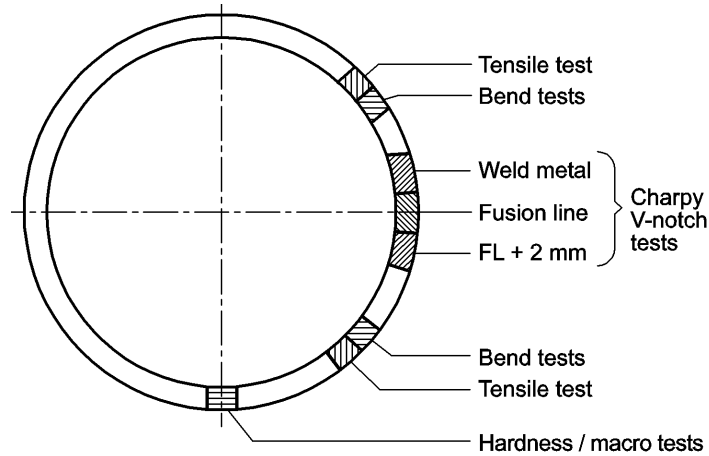
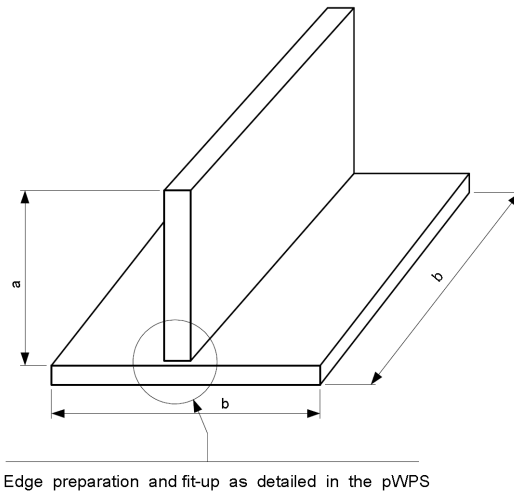


Figure 12 Sampling of test specimens in pipes

4.3 Full penetration T-, Y-, and K- joints

4.3.1 Test assembly

WPQTs for full penetration groove welds between plates at right angles or inclined, i.e. T- or Y- and K- configurations, shall cover a weld length of minimum 350 mm (see Figure 13). The test assembly shall consider the rolling direction, as for the butt welds, see [4.1.1].



$$a = 3t, \text{ minimum value } 150 \text{ mm}$$

$$b = 6t, \text{ minimum value } 350 \text{ mm}$$

Figure 13 Test assembly for full penetration T-joints

4.3.2 Non-destructive testing

NDT shall be carried out in accordance with the specification given for the production welding in question. The extent of the testing and acceptance criteria shall be as given in [3.2.1] (UT is required, not RT).

4.3.3 Destructive testing

4.3.3.1 General

The general test requirements and the acceptance criteria for destructive testing are given in [3.3].

4.3.3.2 Specific/additional requirements

The following mechanical tests are required from each assembly, see Figure 14:

- Three sets of three charpy V-notch tests with the notch location as given in [4.1.3.2], see also guidance note.
- For web plate thickness > 20 mm with one side welding, one additional set of specimens shall be taken from the root area as given in [4.1.3.2], see guidance note.
- One macro section test (metallographic examination + hardness measurements), see [3.3.4] and [3.3.5].

Guidance note:

If the flange thickness is < 30 mm and therefore charpy V-notch specimens can't be machined, qualification tests on butt welds may be performed as an alternative. In this case, with comparable welding parameters as for the full penetration T-joint.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Tests as detailed do not provide information on the tensile strength of the joint. Where the tensile strength properties are relevant for the application, two cross weld tensile tests (see [3.3.2]) shall be carried out. If the size of the sample does not allow for cross weld tensile test, an additional butt weld qualification shall be performed using the same welding parameters.

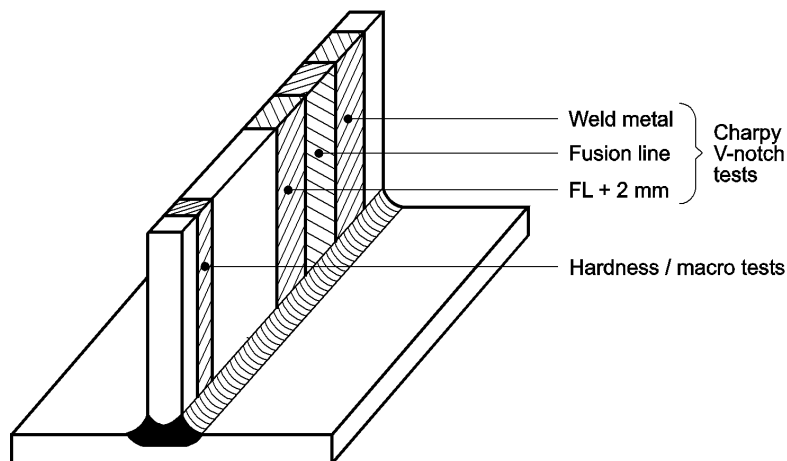
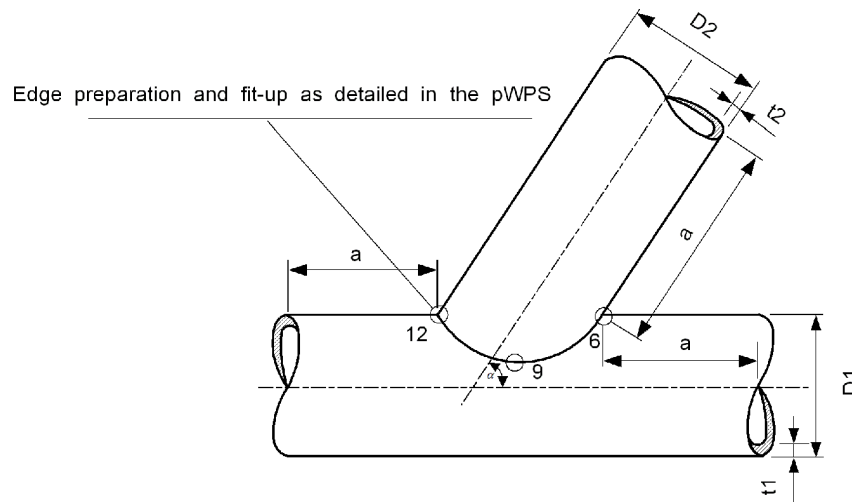


Figure 14 Sampling of test specimens on full penetration T-joints

4.4 Full penetration tubular joint/branch connection

4.4.1 Test assembly

The test assembly shall be in accordance with Figure 15.



- a = minimum value 150 mm
 $D1$ = outside diameter of the main pipe
 $t1$ = wall thickness of the main pipe
 $D2$ = outside diameter of the branch pipe
 $t2$ = wall thickness of the branch pipe
 α = branch connection angle

Figure 15 Test assembly for branch connections

4.4.2 Non-destructive testing

NDT shall be carried out in accordance with the specification given for the production welding in question. The extent of the testing and acceptance criteria shall be as given in [3.2.1] (UT, not RT).

4.4.3 Destructive testing

4.4.3.1 General

The general test requirements and the acceptance criteria for destructive testing are given in [3.3]. Restrictions and testing for joint configuration involving acute angles (less than 15°) should be specified.

4.4.3.2 Specific/additional requirements

The following mechanical tests are required from each assembly (see Figure 15):

- Three sets of three charpy V-notch tests sampled at nine o'clock position in the branch pipe and with the notch location as given in [4.1.3.2]. Alternatively, the tests may be carried out on test specimens from a representative butt weld assembly.
- For pipe thickness > 20 mm with one side welding, one additional set of specimens shall be taken from the root area as given in [4.1.3.2]. Alternatively, the tests may be carried out on test specimens from a representative butt weld assembly.
- Two (2) macro section tests (metallographic examination + hardness measurements), one at twelve o'clock position and one at six o'clock position, see [3.3.4] and [3.3.5].

Tests as detailed do not provide information on the tensile strength of the joint. Where the tensile strength properties are relevant for the application an additional cross weld tensile test (see [3.3.2]), or a butt weld qualification, shall be performed using the same welding parameters.

4.5 Partial penetration welds

For WPQT of partial penetration welds, including partial penetration butt welds, the test conditions including all essential variables, test specimens and acceptance criteria shall be agreed on a case by case basis.

4.6 Fillet welds

4.6.1 Test assembly

For fillet welds, the two plates are assembled and positioned edgewise so as to constitute a tee-assembly with no clearance. For plate fillet welds, the test assembly shall be as defined in Figure 16, except for vertical-down fillet welds on structural steel grades VL A to VL F40 (the grades are defined in DNVGL-OS-B101 Ch.2 Sec.2). For vertical-down fillet welds on structural steel grades VL A to VL F40 the test assembly (cruciform test) shall be as defined in Figure 17 or Figure 18. For pipe fillet welds the test assembly shall be as defined in Figure 19.

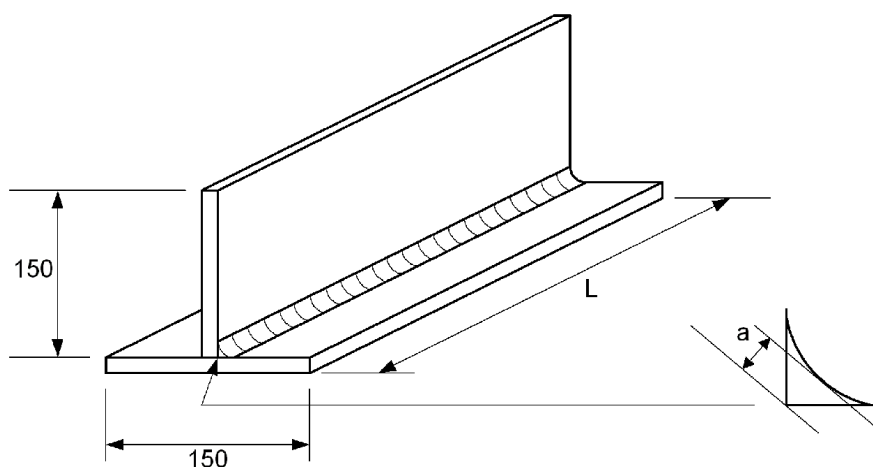


Figure 16 Test assembly for plate fillet welds

For manual and semi-automatic welding the length of the test piece shall be:

$$L_{min} = 350 \text{ mm}$$

For automatic welding the length shall be:

$$L_{min} = 1000 \text{ mm.}$$

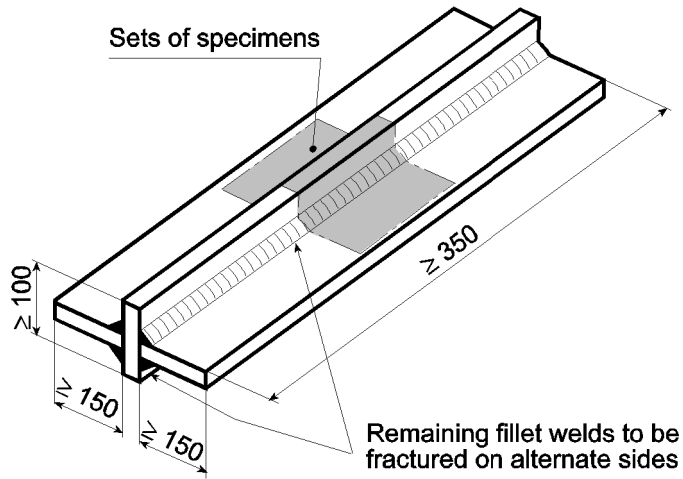


Figure 17 Double T- joint (cruciform) plate test piece for manual and semi-automatic welding procedures

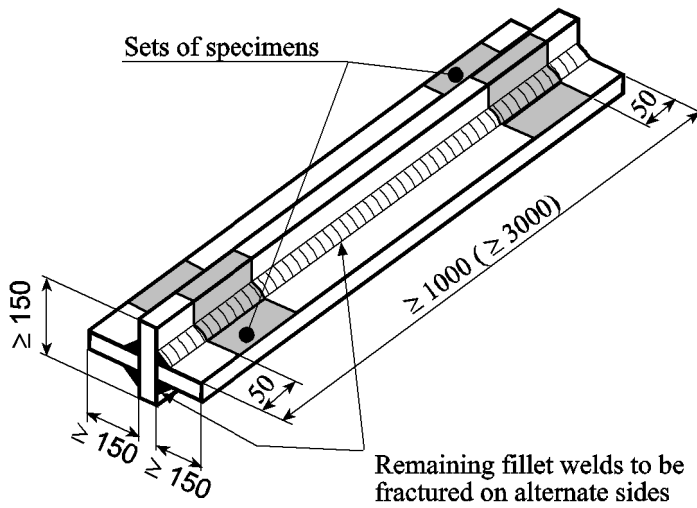


Figure 18 Double T- joint (cruciform) plate test piece for automatic welding procedures

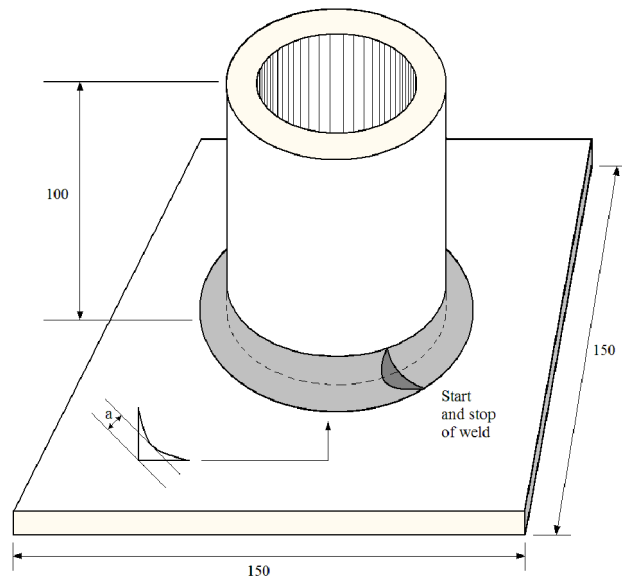


Figure 19 Test assembly for pipe fillet welds

Weld and fit-up shall be as detailed in the pWPS. The test assembly shall be welded on one side only. However, for automatic two side fillet welding (tandem technique), welding from two sides is acceptable. For single run manual and semi-automatic welding, the stop/restart position is normally to be included in the test length and shall be clearly marked for subsequent examination.

The ends of the specimen are exempted from examination over a length of 50 mm. When the automatic fillet welding procedure is intended for plates and sections coated with overweldable shop primer, similarly coated plates shall be used for the qualification. The type of the shop primer and the dry film thickness shall be recorded in the WPQR.

For cruciform test piece, the throat thickness of the fillet weld shall correspond to those used in production, but shall not exceed 0.5 times the plate thickness of the test piece.

4.6.2 Non-destructive testing

NDT shall be carried out in accordance with the specification given for the production welding in question. The extent of the testing and acceptance criteria shall be as given in [3.2.2].

4.6.3 Destructive testing

4.6.3.1 General

The general test requirements and the acceptance criteria for destructive testing are given in [3.3].

4.6.3.2 Specific/additional test requirements

The following destructive tests shall be performed:

- Two macro section tests (metallographic examination, hardness measurements on one macrosection taken from the weld start of the test assembly), see [3.3.4] and [3.3.5]. One of the macro sections shall be taken at the marked position of the stop/restart.
- For plate fillet welds: one fracture test shall be performed by folding the upright plate onto the through plate, e.g. according to ISO 9017. Evaluation shall be concentrated on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration. Imperfections that are detected shall be assessed in accordance with EN ISO 5817 quality level B.

- For qualification of vertical down fillet welding on structural steel grades VL A to VL F40 (see [DNVGL-OS-B101 Ch.2 Sec.2](#)): three cruciform tensile tests.

Unless cruciform tensile tests are carried out, the tests as detailed do not provide information on the mechanical properties of the joint. Where these properties are relevant for the application, an additional butt weld qualification shall be performed using the same welding parameters.

4.7 Validity of welding procedure specification

4.7.1 General

4.7.1.1 Contractor holding the welding procedure specification

The validity of an accepted WPS is restricted to the contractor or subcontractor performing the qualification, including contractor and subcontractor workshops under the same technical management and working in accordance with the same QA system and procedures.

The contractor's WPSs may be transferred to and used by subcontractors provided the principles of ISO 3834-2 and ISO 14731 are implemented. This shall be documented by the contractor/subcontractor. For this case, additional welding production tests (WPT) and/or extended NDT may be required as found necessary.

4.7.1.2 Range of qualification

Qualification of a welding procedure remains valid provided the essential parameters are kept within the qualified ranges during production welding. The qualified ranges shall be given on the WPS and shall not exceed the limitations specified in [\[4.7.2\]](#).

4.7.2 Essential parameters

4.7.2.1 General

A qualified welding procedure shall be used within the ranges of the parameters of essential variables listed below.

4.7.2.2 Base material

The following changes and considerations shall lead to a new qualification:

- a) Significant change of material properties which obviously will affect the weldability and mechanical properties, such as:
 - Change from wrought (rolled, forged) steel to cast steel or vice versa (applicable also for stainless steels).
 - Change from delivery condition QT to any other delivery condition or vice versa, applicable for forgings, castings, and steel plates of grade VL D40, VL E40, VL F32, VL F36, VL F40 and extra high strength steels (the grades are defined in [DNVGL-OS-B101 Ch.2 Sec.2](#)).
 - Change from delivery condition TM to any other delivery conditions, but not vice versa. Change from delivery condition TM to other delivery conditions will be accepted provided the carbon equivalent of the qualified TM-steel is same or higher than the steel to be covered.

- A change from steel with improved weldability (see [DNVGL-OS-B101](#)) to steels without improved weldability. This change may, however, be accepted provided the carbon equivalent of the qualified improved weldability steel is same or higher than the steel to be covered.

Guidance note:

For steels with $C \geq 0.22$ or $C_{eq} \geq 0.45$ the WPQT on which the WPS is based, should be qualified on a BM having a C_{eq} not less than 0.03 of the material to be welded. Example: A material with actual $C_{eq} = 0.50$ requires a WPQT qualified on a material with $C_{eq} \geq 0.47$.

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- b) Additional considerations for strength levels and toughness grades for rolled steel plates:
- For normal and high strength steels (see [DNVGL-OS-B101](#), WPQTs are considered applicable to the same and two lower strength levels as that tested (the special grade VL 27S is not counted, e.g. qualification of VL A36 may also qualify welding of grades VL A, VL A27S and VL A32). The grades are defined in [DNVGL-OS-B101 Ch.2 Sec.2](#).
 - The qualification of steel grades of higher toughness requirements will qualify the grades of lower toughness but not vice versa, e.g. qualification of grade VL E will also qualify VL grades A, B and D. The grades are defined in [DNVGL-OS-B101 Ch.2 Sec.2](#).
 - For extra high strength steels, WPQTs are considered applicable to the same and one lower strength level as that tested, e.g. qualification of grade VL A500 will qualify grade VL A460. The grades are defined in [DNVGL-OS-B101 Ch.2 Sec.2](#).
 - For high heat input welding processes (> 50 kJ/cm), the WPQT is applicable to the toughness grade tested and one strength level below, e.g. qualification of grade VL E40-W200 will qualify grades VL E40-W200 and VL E36-W200. The grades are defined in [DNVGL-OS-B101 Ch.2 Sec.2](#).
- c) Additional considerations for strength levels and toughness grades for castings and forgings:
- Change to a grade of higher specified strength.
 - Change to higher specified toughness requirements. That is lower impact toughness temperature requirements or higher impact toughness value requirements.
- d) Additional consideration for welding with heat input more than 50 kJ/cm:
- For TM steels not pre-qualified for high heat input welding, change of material manufacturer requires either new qualification, or special case by case acceptance. For case by case acceptance, the following information shall be submitted for the TM steels in question:
 - grade
 - thickness range
 - deoxidation practice
 - fine grain practice
 - aim range of chemical composition
 - aim maximum C_{eq} and P_{cm}
 - welding production test results, etc.
- e) For dissimilar material grade and joints between cast or forged and rolled materials, see [\[12\]](#).

4.7.2.3 Thickness

Thickness (t) is defined as follows:

- a) Butt welds:
 - the base metal thickness, which for welds between dissimilar thicknesses is that of the thinner material.
- b) T-butt joints in plate:
 - the thickness of the plate with bevelling (abutting member).
- c) Fillet welds:
 - the thickness of both BMs.
- d) Set-on branch connections:
 - the thickness of the branch pipe.
- e) Set-in or set-through branch connections:
 - the thickness of the main pipe.
- f) Partial penetration welds:
 - same as for butt weld or T-butt joint, respectively.

The requirements for qualified thickness range for butt welds shall be as given in [Table 5](#). This table is applicable to full penetration welds in plates, pipes and T, Y, K-joints, fillet welds and partial penetration welds.

Table 5 Qualified thickness range

Thickness of test piece, t (mm)	Qualification range ^{1) 2) 3) 4)}	
	Single run, or single run from both sides	Multi-run and all fillet welds ^{5) 6)}
t ≤ 3	0.7 × t to 1.3 × t	0.7 × t to 2 × t
3 < t ≤ 12	0.7 × t to 1.1 × t	3 mm to 2 × t
12 < t ≤ 100	0.7 × t to 1.1 × t	0.5 × t to 2 × t (max. 150 mm)
t > 100	Not applicable	0.5 × t to 2 × t

- 1) The maximum thickness qualified for vertical downward welding is 1.0 × t.
- 2) For high heat input processes > 50 kJ/cm, the upper limit of range of validity is 1.0 × t.
- 3) For multi process procedures, the recorded thickness contribution of each process shall be used as basis for the range of validity for the individual welding process.
- 4) The validity of maximum thickness of base metal for any technique shall be restricted to the thickness of test assembly if three of the hardness values in the HAZ are found to be within 25 HV of the maximum permitted, as stated in [\[3.3.5\]](#).
- 5) Where a fillet weld is qualified by a butt weld qualification, the throat thickness range qualified shall be the same as the qualified plate thickness range.
- 6) For fillet welds between materials of dissimilar thickness, the qualified thickness range shall be applied to both parent materials independently. Example: multi-run fillet weld. Thickness of abutting member is 15 mm, thickness of base plate is 25 mm and throat thickness is 15mm by multi-run. Qualified range for abutting member is then 7.5 mm to 30 mm, qualified range for base plate is 12.5 mm to 50 mm. Qualified throat thickness a range is 7.5 mm to 30 mm.

4.7.2.4 Throat thickness

In addition to the requirements of [Table 5](#), the range of validity of throat thickness a for fillet welds shall be as follows:

- single run: $0.75 \times a$ to $1.5 \times a$
- multi-run: same qualification range as for thickness (t) of multi-run butt welds, i.e. $t = a$, see [Table 5](#).

4.7.2.5 Diameter of pipes and tubular joints/branch connections

The qualification of a WPQT on diameter (D) shall include qualification for diameters in the following ranges as given in [Table 6](#).

Table 6 Qualified range for pipe and branch connection diameters

<i>Diameter of the test piece, D (mm)^{1) 2)}</i>	<i>Qualification range</i>
$D \leq 25$	$0.5 \times D$ to $2 \times D$
$D > 25$	$> 0.5 \times D$ and plates

1) D is the outside diameter of the pipe or outside diameter of the branch pipe.
2) Qualification given for plates also covers pipes when the outside diameter is greater than 500 mm.

4.7.2.6 Angle of tubular joints/branch connection

A WPQT carried out on a branch connection with angle α shall qualify all branch connection angles in the range of α to 90° .

4.7.2.7 Welding consumables

The following changes shall lead to a new qualification:

- Any change in consumable classifications: mechanical properties, type of covering core or flux (e.g. basic, rutile), nominal chemical composition and increase in hydrogen content.
- Change of consumable brand when impact testing for WPQT is required at temperatures below -20°C .
- Any significant change of mixture or composition, flow rate, filling time and filling volume for shielding and purging gases (see also [Sec.4 \[3\]](#)).

4.7.2.8 Welding positions

A change from one principal welding position to another shall lead to a new qualification, unless complying with [Table 7](#). Welding positions are indicated in [Figure 20](#), [Figure 21](#) and [Figure 22](#).

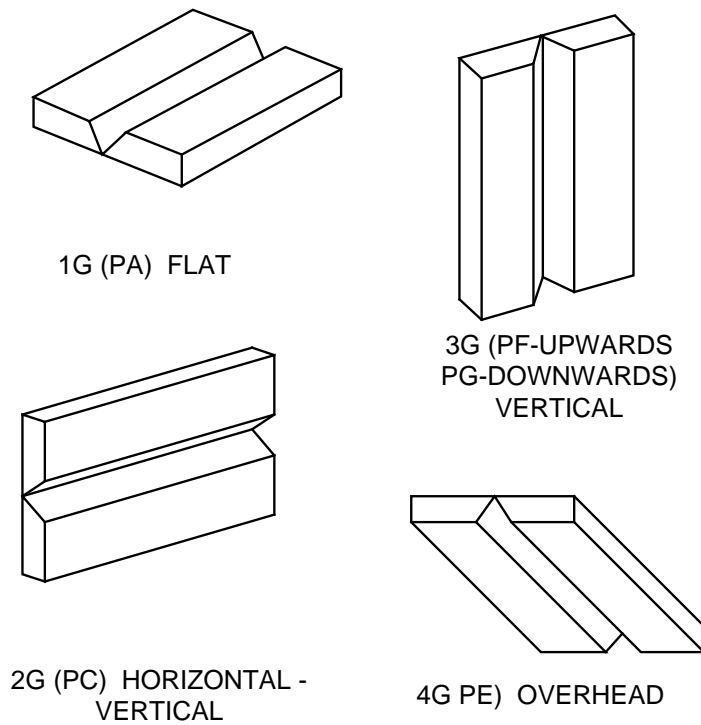


Figure 20 Plate test positions

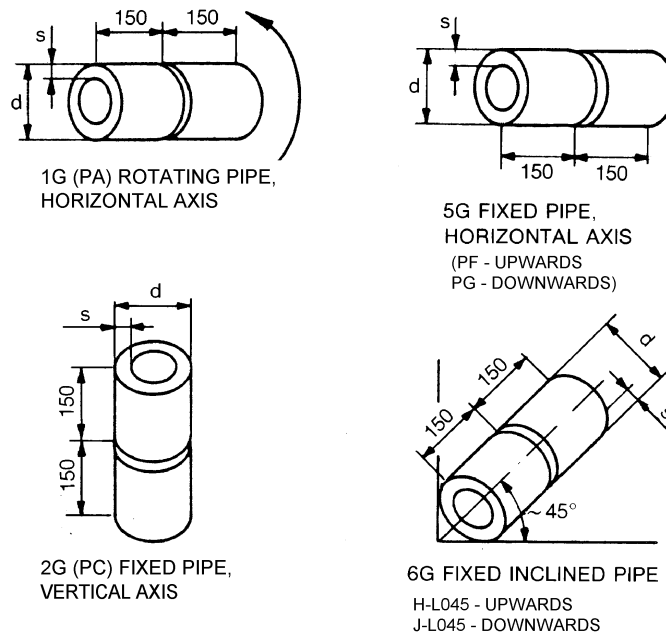


Figure 21 Pipe test positions

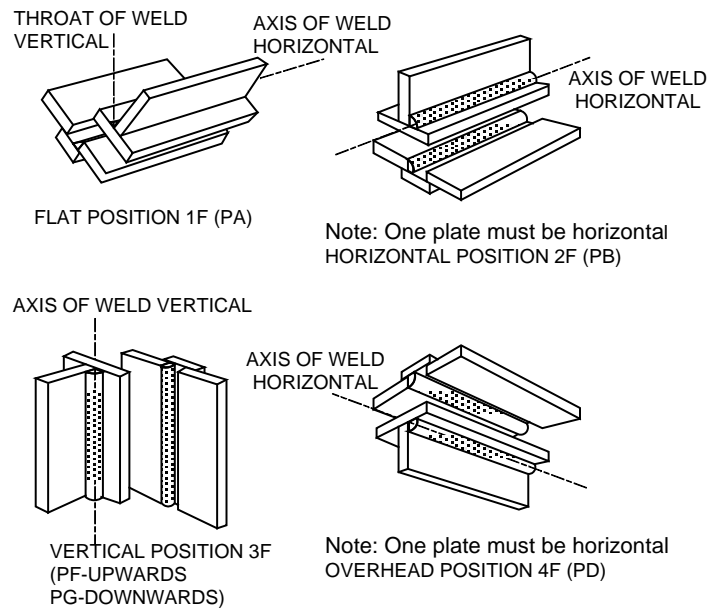


Figure 22 Positions of test plate for fillet welds

Table 7 Qualified principal positions for butt welds and fillet welds, steel

Test weld joint configuration ^{1) 2)}	Principle positions	Qualified positions ³⁾			
		Butt welds		Fillet welds	
		Plates	Pipes	Plates	Pipes
Butt welds in plates	2G + 3G	All	-	All	All
	1G	1G	-	1F	1F
	2G	2G	-	2F	1F, 2F, 4F
	3G	3G	-	3F	3F
	4G	4G	-	4F	1F, 4F
Butt welds in pipes	2G + 5G = 6G	All	All	All	All
	1G	1G	1G	1F	1F
	2G	2G	1G, 2G	2F	1F, 2F, 4F
	5G	All	1G, 5G	All	All
Fillet welds	2F + 3F	-	-	All	All
	1F	-	-	1F	1F
	2F	-	-	2F	1F, 2F, 4F
	3F	-	-	3F	3F
	4F	-	-	4F	1F, 2F, 4F
	5F	-	-	All	All

1) Pipes with D > 500 mm are considered equivalent to plates (apply only to the main pipe in branch connections).
2) Branch connections shall be qualified separately.
3) The vertical downwards position shall be qualified separately.

4.7.2.9 Type of joint

The following changes shall lead to a new qualification:

- change from fillet weld to butt weld
- change from butt weld to fillet weld in case of automatic welding of fillet joint with shop primer
- change from T-, K- or Y-joint to butt weld but not vice versa
- change from butt joint in plates to butt joints in pipes with outside diameter less than 500 mm
- any changes outside the qualified range given as follows:

Type of welded joint for test assembly			Range of validity	
Butt welding	One side	With backing	A	A, C
		Without backing	B	A, B, C, D
	Both side	With gouging	C	C
		Without gouging	D	C, D

- f) any change of groove angle outside the following limits, unless otherwise accepted:

Groove angle β from WPQT	Qualified tolerances β (°)
$\beta < 35^\circ$	-0, +20
$35^\circ \leq \beta < 40^\circ$	Min. 35° , +20
$\beta \geq 40^\circ$	-5, +20

- g) any change of root gap outside the following limits. Different gaps and tolerances may be accepted based on adequate qualification:

Backing	Welding method	Root gap (mm)		
		Standard	Max.	Tolerances
With backing	All	3-10	16 ¹⁾	-2, +6
Without backing	Manual, semi-automatic	3	5	± 2
	Automatic	0.8	2	-0.8, +1.2

1) Welding of root gap more than 16 mm is considered remedial welding. See also [1.1.2.3].

4.7.2.10 Welding conditions

The following changes shall lead to a new qualification:

- any change of welding process
- any decrease in preheat temperature
- higher interpass temperature than that used in the qualification test
- change of PWHT parameters used in the qualification test. Holding time may be adjusted as a function of thickness
- change from multi-pass welding to one-pass welding
- change in welding current from A.C. to D.C. or vice versa, or change in polarity. If recommended by the welding consumable manufacturer a case by case exemption may be given for shielded metal arc welding (SMAW) in change from A.C. to D.C.
- change in metal powder or wire addition beyond $\pm 10\%$
- change from manual (or semi-automatic) to fully mechanized (or fully automatic welding processes), and vice versa
- change in heat input beyond $\pm 25\%$ or 55 kJ/cm maximum heat input, whichever is smaller. For high heat input welding (> 50 kJ/cm) and/or for material with SMYS equal to or above 420 MPa the change shall not be more than +10/-25%. The heat input range shall be established at least for (1) root pass and (2) filling and cap passes.

Guidance note:

Average heat input for the relevant welding passes (root, fill, cap) is calculated based on the recorded values from the WPQT. The qualified range (+25% or +10/-25% as relevant) is based on the calculated average value.

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5 Austenitic stainless steel - additional welding procedure qualification test requirements

5.1 Welds in plates and pipes

5.1.1 When WPQT are required, the tests shall be performed in accordance with [4] and the supplementary requirements given below. The WPQT shall cover all relevant dimensions, positions and material combinations. Details regarding essential variables and validity of the procedure shall be as given in [4.7]. General testing and acceptance criteria shall be as given in [3], unless otherwise specified below.

5.1.2 Impact testing is required for design temperatures below -105°C . When design temperature is below -105°C , impact testing is required for the weld metal only (not FL and HAZ). The testing shall be conducted at -196°C meeting an average impact energy value of minimum 27 J.

5.1.3 Hardness testing is not required.

5.1.4 Depending on the field of application or if required for the BM, additional corrosion tests shall be performed within the scope of welding procedure tests, e.g. testing of resistance against intergranular corrosion.

5.2 Range of validity

The requirements of [4.7] apply. In addition, a change to a grade of higher specified strength or higher impact toughness requirements shall lead to a new qualification.

6 Ferritic-austenitic stainless steel (duplex) - additional welding procedure qualification test requirements

6.1 Test requirements

6.1.1 Welding consumables: unless otherwise agreed, welding consumables with enhanced nickel and nitrogen content shall be used. Backing and shielding gases shall not contain hydrogen and shall have a dew point not higher than -30°C .

6.1.2 Impact testing shall be as described in [4] using an impact test temperature of -20°C , or -5°C below the design temperature whichever is lower. The average value for absorbed energy shall not be less than 27 J. Other test requirement can be agreed for individual cases.

6.1.3 When a butt weld is made between dissimilar material grades, see [12].

6.1.4 The hardness of the HAZ after welding shall, unless otherwise agreed, not exceed the maximum hardness specified for the BM, and the hardness of the weld metal shall not exceed the maximum hardness specified for the weld deposit of the applied welding consumable.

Unless other requirements are specified for the applicable BMs and welding consumables, the following requirements applies:

- for 22 Cr duplex: max. 290 HV10 or 28 HRC
- for 25 Cr duplex: max. 330 HV10 or 32 HRC.

6.1.5 Duplex stainless steels shall be micro structurally examined and the test samples shall comprise the weld metal, HAZ and base metal. The microstructures shall be suitably etched and examined at 400X to 500X magnification and shall be free from grain boundary carbides and precipitates. The ferrite content in the weld metal root and un-reheated weld cap shall be determined in accordance with ASTM E562 and be in the range of 30-70%.

6.1.6 Type 25Cr duplex shall be corrosion tested according to ASTM G48 method A. The test specimen shall be in the as welded state after normal weld cleaning operation. The test specimens shall be exposed to the solution at a constant temperature of 40°C for 24 hours. The test specimens shall have a dimension of full wall thickness by 25 mm along the weld and 50 mm across the weld. The test shall expose the external and internal surface and a cross section surface including the weld zone in full wall thickness. Cut edges shall be prepared according to ASTM G48. The whole specimen shall be pickled before being weighed and tested. Pickling may be performed for 5 min. at 60°C in a solution of 20% HNO₃ + 5% HF.

The following test requirements shall be fulfilled:

- there shall be no visible pitting at 20X magnification
- general weight loss shall be less than 4.0 g/m².

Guidance note:

Welds between ferritic-austenitic steels and other grades of stainless, C/Mn steels or for welds in non-corrosive area may not need to be corrosion tested.

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6.2 Validity of a qualified welding procedure

See [4.7] and any change in the following additional essential variable which shall lead to a new qualification:

- variation in the heat input greater than ±15%.

7 Aluminium - welding procedure qualification test requirements

7.1 General

7.1.1 Basic requirements are given in [1], [2] and [3].

7.1.2 Welding consumables shall be one of those as specified in Sec.4.

7.2 Butt welds in plates

7.2.1 Test assembly shall be as described in [4.1.1].

7.2.2 The following mechanical tests are required from each assembly:

- two cross-weld tensile test specimen, see [3.3.2]
- two root and two face or four side bend specimens
- one macro test specimen, see [3.3.4].

For the location of test specimens, see Figure 23.

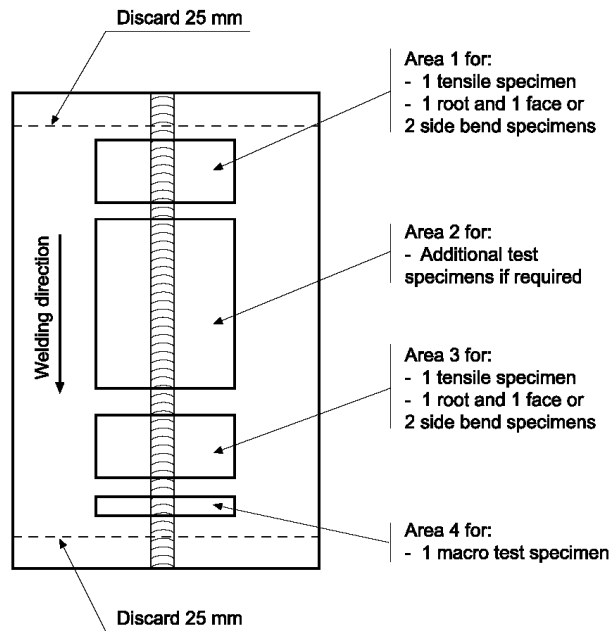


Figure 23 Location of test specimens for a butt weld on plate

7.2.3 Two cross-weld tensile specimens shall be taken from each of the welded assemblies. The test specimen dimensions are given in [DNVGL-OS-B101 Ch.2 Sec.1](#).

7.2.4 Side bend tests shall be carried out for thickness equal to and above 12 mm (see [\[3.3.3\]](#)). Four bend specimens shall be taken from each of the welded assemblies. The bend test specimens shall be machined to the dimensions given in [DNVGL-OS-B101 Ch.2 Sec.1](#).

7.2.5 For thickness below 12 mm two face bend and two root bend test specimens shall be taken (see [\[3.3.3\]](#)). The diameter of the bending mandrel shall be as given in [\[9.7.2\]](#).

7.2.6 One macro section shall be prepared from the test assembly to reveal the weldment macro structure, see [\[3.3.4\]](#). The macro section shall be visually inspected using a magnification of 5 to 10X.

7.3 Butt welds in pipes

7.3.1 Test assembly shall be as described in [\[4.2.1\]](#).

7.3.2 The following mechanical tests are required from each assembly, see [Figure 24](#):

- two cross-weld tensile test specimen, see [\[3.3.2\]](#)
- two root and two face or four side bend specimens
- one macro test specimen, see [\[3.3.4\]](#).

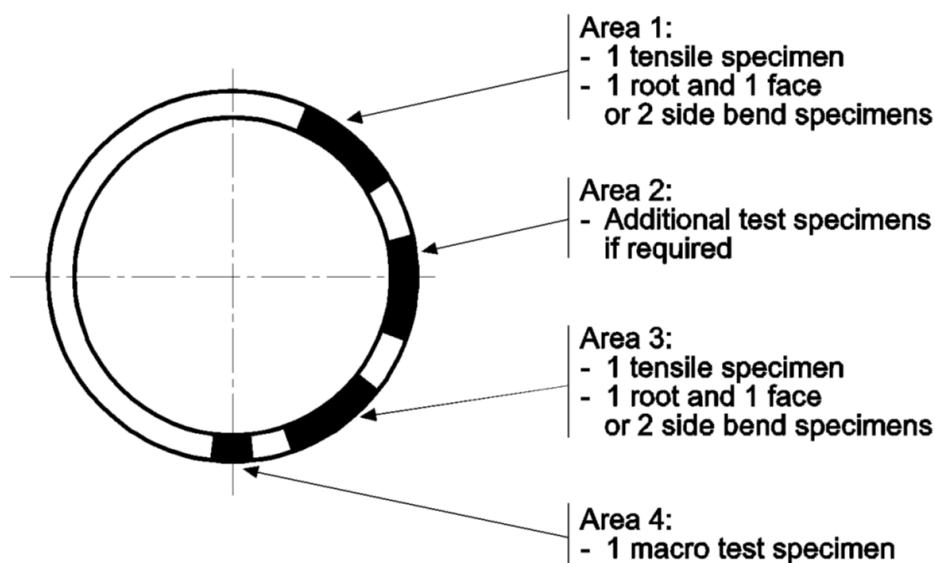


Figure 24 Location of test specimens for a butt weld in pipe

7.3.3 Two cross-weld tensile specimens shall be taken from each of the welded assemblies. The test specimen dimensions are given in [DNVGL-OS-B101 Ch.2 Sec.1](#).

7.3.4 Side bend tests (see [\[3.3.3\]](#)) shall be carried out for thickness equal to and above 12 mm. Four bend specimens shall be taken from each of the welded assemblies. The bend test specimens shall be machined to the dimensions given in [DNVGL-OS-B101 Ch.2 Sec.1](#).

7.3.5 For thickness below 12 mm two face bend and two root bend test specimens shall be taken, see [\[3.3.3\]](#). The diameter of the bending mandrel shall be as given in [\[9.7.2\]](#).

7.3.6 One macro section shall be prepared from the test assembly to reveal the weldment macro structure, see [\[3.3.4\]](#). The macro section shall be visually inspected using a magnification of 5X to 10X.

7.4 Branch connections

The following mechanical tests are required from each assembly (see [Figure 15](#)):

- two macro section tests at twelve position o'clock and six position o'clock, see [\[3.3.4\]](#).

7.5 Fillet welds

7.5.1 Test assembly shall be as described in [\[4.6\]](#).

7.5.2 The following tests shall be performed:

- Two macro-section tests, see [\[3.3.4\]](#). One of the macro-sections shall be taken at the marked position of the stop/restart, see [\[3.3.4\]](#). The macro-section shall include about 10 mm of unaffected BM and shall be prepared and etched on one side to clearly reveal the FL and the HAZ.

- One fracture test shall be performed by folding the upright plate onto the through plate. Evaluation shall concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration.

7.6 Non-destructive testing of test assemblies

7.6.1 NDT shall be carried out in accordance with the specification given for the production welding in question. The extent of the testing shall be as given in [3.2]. The soundness of the weld shall comply, unless otherwise specified, with ISO 10042 level B. If the stop/restart spot is included in the test length, special attention shall be paid to this position with respect to profile, proper fusion and absence of crater defects.

7.7 Mechanical testing

7.7.1 The tensile strength of the test specimens shall not be less than specified in Table 8. The referred VL grades are defined in DNVGL-OS-B101 Ch.2 Sec.6.

Table 8 Mechanical properties in the welded condition

<i>Alloy</i>	<i>Temper</i>	<i>Filler</i>	<i>Tensile strength R_m minimum (N/mm²)</i>
VL 5052	0, H111, H32, H34	5356, 5556	170
VL 5754	0, H111, H24	5356, 5183, 5556	190
VL 5154A	0, H111, H32, H34	5356, 5183, 5556	215
VL 5454	0, H111, H32, H34	5356, 5183, 5556	215
VL 5086	0, H111, H112, H116, H321, H34	5356, 5183, 5556	240
VL 5083	0, H111, H112; t ≤ 6 mm	5183	270
	0, H111, H112; t > 6 mm	5356, 5183	270
	H116, H321	5356, 5183	270
VL 5383	0, H111, H116, H321	5183, 5556	290
VL 5059	0, H111, H116, H321	5183	330
VL 6060	T4, T5, T6	5356, 5183, 5556	95
VL 6061	T4, T5, T6	5356, 5183, 5556	165
VL 6063	T4, T5, T6	5356, 5183, 5556	100
VL 6005A	T4, T5, T6	5356, 5183, 5556	165
VL 6082	T4, T5, T6	5356, 5183, 5556	170

7.7.2 The bend test specimens shall be bent on a mandrel with maximum diameter as given in the formula below. The bending angle shall be minimum 180°. After bending, the test specimens shall not reveal any open defects greater than 3 mm in any direction. Smaller cracks developing from the edges of the specimens shall not normally be considered as significant, unless there is definite evidence that they result from inclusions or other defects. Wrap around bending is the preferred bending method.

$$d = \frac{100t_s}{A} - t_s$$

Where:

- D = maximum former diameter
 t_s = thickness of the bend test specimen (this includes side bends)
 A = minimum tensile elongation required by the material specification (for combination between different alloys, the lowest individual value shall be used).

7.7.3 The macro sections shall show a regular weld profile with smooth transitions to the BMs and without significant or excessive reinforcement. Cracks and lack of fusion are not acceptable. The fillet weld fracture test as well as the macro examination shall satisfy the acceptance level in EN ISO 10042 quality level B except for excess weld metal or convexity, excess throat thickness and excess of penetration for which the level C applies.

7.7.4 When a butt weld is made between two plates of different alloys the tensile strength to be obtained on the welded assembly shall satisfy the requirements of the alloy with the lower strength.

7.7.5 If the WPQT fails to comply with any of the requirements for NDT, one extra WPQT shall be welded and subjected to the same testing. If this additional test does not meet the relevant requirements, the actual WPS shall be considered as not qualified and a re-specification of the WPS shall be made prior to a new WPQT.

7.8 Range of qualification

7.8.1 General

In addition to the requirements given in this subsection, the qualification is limited as specified in [\[4.7.1\]](#).

7.8.2 Base material

The following shall be considered:

- a) In general, significant change of material properties which will obviously affect the weldability and mechanical properties shall lead to a new qualification.
- b) For each of the following groups, the qualification made on one alloy qualifies the procedure also for the other alloys within the same group, i.e. alloys with equal or lower specified tensile strength after welding. The referred VL grades are defined in [DNVGL-OS-B101 Ch.2 Sec.6](#):
 - 1) VL 5052, VL 5754, VL 5154, VL 5454
 - 2) VL 5086, VL 5083, VL 5383, VL 5059
 - 3) VL 6060, VL 6061, VL 6063, VL 6005A, VL 6082.
- c) The qualification made on group 2) alloy, qualifies the procedure also for group 1) alloys.
- d) A dissimilar metal joint shall be qualified by the same dissimilar combination.

7.8.3 Thickness

Thickness (t) is defined as follows:

- a) For a butt weld: the base metal thickness, which for welds between dissimilar thicknesses is that of the thinner material.
- b) For a fillet weld: the base metal thickness, which for welds between dissimilar thicknesses is that of the thicker material. However, for each thickness range qualified, as given in [Table 9](#) and [Table 10](#) there is an associated range of qualified throat thickness.
- c) For a set-on branch connection: the thickness of the branch pipe.
- d) For a set-in or set-through branch connection: the thickness of the main pipe.
- e) For a T-butt joint in plate: the thickness of the prepared plate.

The requirements for qualified thickness range for butt welds shall be as given in [Table 9](#).

Table 9 Qualified thickness range

<i>Thickness of test piece, t (mm)</i>	<i>Qualification range (mm)</i>
$t < 3$	$0.5 \times t$ to $2 \times t$
$3 \leq t \leq 20$	3 to $2 \times t$
$t > 20$	$\geq 0.8 \times t$

In addition to the requirements of Table 9, the range of qualification of the throat thickness a of fillet welds is given in Table 10.

Table 10 Range of qualification for the throat thickness for plates and pipes

<i>Throat thickness of the test piece, a (mm)</i>	<i>Range of qualification (mm)</i>
$a < 10$	$0.75 \times a$ to $1.5 \times a$
$a \geq 10$	≥ 7.5

Where a fillet weld is qualified by means of a butt weld test, the throat thickness range qualified shall be based on the thickness of the deposited weld metal.

7.8.4 Diameter of pipes and branch connection diameters

The qualification of a welding procedure test on diameter (D) qualifies diameters in the ranges given in Table 11.

Table 11 Qualified range for pipe and branch connection diameters

<i>Diameter of the test piece, D (mm)¹⁾</i>	<i>Qualification range (mm)</i>
$D \leq 25$	$0.5 \times D$ to $2 \times D$
$D > 25$	$\geq 0.5 \times D$ and plates

1) D is the outside diameter of the pipe or outside diameter of the branch pipe.

7.8.5 Angle of branch connection

A WPQT carried out on a branch connection with angle α shall qualify all branch connection angles in the range of α to 90° .

7.8.6 Welding consumables

The following changes shall lead to a new qualification:

- any change in consumable classification
- any significant change of shielding gas mixture.

7.8.7 Welding positions

The following change shall lead to a new qualification:

- change from one principal welding position to another, see figures in [4.7.2.8], unless complying with Table 12.

7.8.8 Type of joint

The following changes shall lead to a new qualification:

- change from fillet weld to butt weld
- change from two sided welding to one side, but not vice versa
- deletion of back gouging
- deletion of backing
- change from butt joint in plates to butt joints in pipes with outside diameter less than 500 mm
- any change of groove dimensions specified in the WPS.

7.8.9 Welding condition

The following changes shall lead to a new qualification:

- any change of welding process
- change from spray arc to short arc or pulsed arc or vice versa
- change in heat input beyond $\pm 25\%$
- any increase in preheat temperature for heat-treatable alloys when the specified preheat is above 50°C
- any decrease in preheat temperature
- higher interpass temperature than that used in the WPQT
- change of heat treatment used in the WPQT. Holding time may be adjusted as a function of thickness
- change from weaving to stringer bead technique or vice versa
- change from multi-pass welding to one-pass welding
- change in type of cleaning method (chemical or mechanical)
- change in welding current from A.C. to D.C. or vice versa, or change in polarity.

Table 12 Qualified principal positions for butt welds and fillet welds, aluminium

Test weld joint configuration ^{1) 2)}	Principal positions	Qualified positions ³⁾		
		Butt welds		Fillet welds plates or pipes
		Plates	Pipes	
Butt welds in plates	1G	1G	1G	1F
	2G	1G, 2G, 3G	-	1F, 2F, 3F
	3G	1G, 2G, 3G	-	1F, 2F, 3F
	4G	All	-	All
Butt welds in pipes	1G	1G	1G	1F
	2G	1G, 2G, 3G	2G	1F, 2F, 4F
	5G	All	1G, 5G	All
Fillet welds	1F	-	-	1F
	2F	-	-	1F, 2F, 3F
	3F	-	-	1F, 2F, 3F
	4F	-	-	All
	5F	-	-	All

1) Pipes with D > 500 mm are considered equivalent to plates (apply only to the main pipe in branch connections).
2) Branch connections shall be qualified separately.
3) The vertical downwards position shall be qualified separately.

8 Copper alloys - welding procedure qualification test requirements

8.1 Pipes, plates, castings and other product forms, not including propeller castings

Welding procedures for pipes and plates shall be qualified in accordance with ISO 15614-6 unless otherwise agreed.

8.2 Copper alloy castings for propellers

8.2.1 General recommendations for filler metal and pre- and post-weld heat treatment of copper alloy propeller castings are given in [Table 13](#).

Table 13 Recommendations for welding of copper alloy propeller castings

<i>Alloy type</i>	<i>Description</i>
Mn-bronze, Cu1	Use Al-bronze ¹⁾ or Mn-bronze filler metal. Preheat to 150°C and interpass temperature not to exceed 300°C. Stress relief at 350°C to 500°C.
Mn-Ni-bronze, Cu2	Use Al-bronze or Mn-Ni-bronze filler metal. Preheat to 150°C and interpass temperature not to exceed 300°C. Stress relief at 350°C to 550°C.
Ni-Al-bronze, Cu3	Use Al-bronze, Ni-Al-bronze ²⁾ or Mn-Al-bronze filler metal. Preheat to 100°C and interpass temperature not to exceed 250°C. Stress relief at 450°C to 500°C.
Mn-Al-Bronze, Cu4	Use Mn-Al-bronze filler metal. Preheat to 100°C and interpass temperature not to exceed 300°C. Stress relief at 450°C to 600°C.
1) Ni-Al-Bronze and Mn-Al-Bronze acceptable.	
2) If Ni-Al-Bronze is used, stress relief is not required.	

8.2.2 For qualification of WPS, a test assembly of minimum 30 mm thickness shall be welded. See [Figure 25](#).

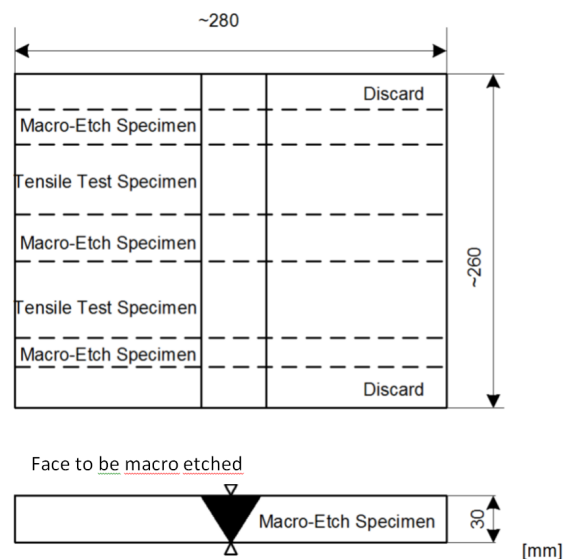


Figure 25 Weld test assembly

8.2.3 Prior to sectioning, the test assembly shall be visually inspected and penetrant tested in accordance with a recognized standard, e.g ISO 3452, ASTM E165. Imperfections shall be assessed in accordance with [Table 14](#).

Table 14 Allowable number and size of indications depending on severity zones

Severity zone	Maximum total number of indications	Indication type	Maximum number for each type ^{1) 2)}	Maximum dimension of indications (mm)
A	7	Non-linear	5	4
		Linear or aligned	2	3
B	14	Non-linear	10	6
		Linear or aligned	4	6
C	20	Non-linear	14	8
		Linear or aligned	6	6

1) Single non-linear indications less than 2 mm in zone A and less than 3 mm in other zones may be disregarded.
2) The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

8.2.4 Three macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the FL and the HAZ. The sections shall be visually inspected for any imperfections present in the weld metal and HAZ. Inclusions or pores greater than 3 mm and cracks or lack of fusion are not permitted.

Guidance note:

An etching medium with the following constituents is suitable for this purpose:

- 5 g ferric (III) chloride
- 30 ml hydrochloric acid
- 100 ml distilled water.

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8.2.5 Two tensile test pieces shall be prepared as shown in [Figure 26](#). The tensile strength for copper alloy propeller castings shall meet the specified minimum values given in [Table 15](#). The tensile strength for other copper alloy castings shall meet the requirements for the BM. The location of fracture shall be reported, i.e. weld metal, HAZ or BM.

8.2.6 For welding procedures qualified according to this chapter, all thicknesses are qualified. Range of validity for other parameters shall follow ISO 15614-6 unless otherwise agreed.

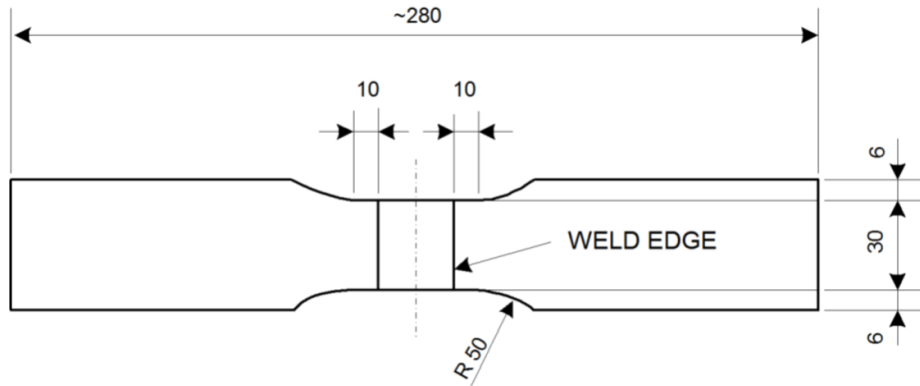


Figure 26 Tensile test specimen for weld test assembly

Table 15 Tensile strength requirements for WPQT

<i>Alloy type</i>	<i>Tensile strength (N/mm²)</i>
Mn-Bronze, Cu1 (brass)	370
Mn-Ni-Bronze, Cu2 (brass)	410
Ni-Al-Bronze, Cu3 (bronze)	500
Mn-Al-Bronze, Cu4 (bronze)	550

9 Repair welding of steel castings - welding procedure qualification test requirements

9.1 General

The requirements in this subsection are applicable to welding procedure qualification for repair welding of steel castings, including stainless steel propeller castings.

Note:

This subsection is limited to the qualification of a WPS. The requirements for repair of steel castings are given in [DNVGL-OS-B101 Ch.2 Sec.5](#).

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9.2 Welding procedure qualification test

9.2.1 For qualification of procedures, a test assembly of minimum 30 mm thickness shall be welded.

9.2.2 Prior to sectioning, the test assembly shall be visually inspected and penetrant tested.

Imperfections shall be assessed in accordance with the requirements given for steel castings in [DNVGL-OS-B101](#).

9.2.3 Two macro-sections (see [\[3.3.4\]](#)) shall be prepared and etched on one side to clearly reveal the weld metal, the FL, and the HAZ. The sections shall be examined by eye for any imperfections present in the weld

metal and HAZ. Cracks or lack of fusion are not permitted. Inclusions or pores greater than 3 mm are not permitted.

9.2.4 Two flat transverse tensile test pieces shall be prepared. The tensile strength shall meet the specified minimum value of the BM. The location of fracture shall be reported, i.e. weld metal, HAZ or BM.

9.2.5 Two transverse side bend test pieces shall be prepared, see [3.3.3]. The former diameter shall be 4 times the thickness except for austenitic steels, in which case the mandrel diameter shall be 3 times the thickness. The test piece, when visually inspected after bending, shall have no surface imperfections greater than 2 mm in length.

9.2.6 Where impact test is required for the BM, Charpy V-notch impact toughness test is required in accordance with [4]. For stainless steel propeller castings, two sets would suffice, one set with the notch positioned in the centre of the weld and one set with the notch positioned in the FL. The test temperature and absorbed energies shall comply with the requirements for the BM.

9.2.7 One of the macro-sections shall be used for HV5 hardness testing. Indentations shall traverse 2 mm below the surface. Minimum three individual indentations shall be made in the weld metal, the HAZ (both sides) and in the BM (both sides). The values shall be reported for information.

Guidance note:

Materials exposed to anaerobic environments or to cathodic protection should have a hardness equal to or less than 350 HV.

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9.2.8 The chemical composition of the deposited metal shall be analysed and the result shall be within the same category as the parent metal.

9.3 Range of validity

The qualification is valid for repair welding on all thicknesses and bevel configurations.

For limitations to range of validity for material grades, heat input and welding consumables, see [4.7].

10 Welds between different material grades

10.1 Test requirements

HAZ and FL of both BMs shall be tested where testing of HAZ is required, e.g. impact toughness tests and hardness test.

10.2 Acceptance criteria

The test temperature and achieved impact energy for impact toughness test shall comply with the minimum specified requirements for the lower grade. The hardness shall, unless otherwise agreed, follow the requirements for each grade, respectively.

10.3 Validity

The cross-weld tensile strength shall meet the requirements of the material having the lower strength.

The validity of the corresponding WPS shall be limited to the range qualified by the lower grade welded to a material limited by the range qualified by the higher grade.

Guidance note:

As an example the test temperature, impact energy and tensile strength for the butt welded joints given in Figure 27 are those required for the plate of grade VL D in the left assembly and for the plate of grade VL E in the right assembly. The grades are defined in DNVGL-OS-B101 Ch.2 Sec.2.

As an example for the qualified range of steels, the left assembly qualifies welding of VL grade steels A - D welded to steel grades A - E. Welding of VL grades E to E is not covered. For the right assembly welding of VL grade steels A - E welded to VL grade steels A - EH is covered. Welding of VL grade steels AH - EH welded to VL grade steels AH - EH is not covered.

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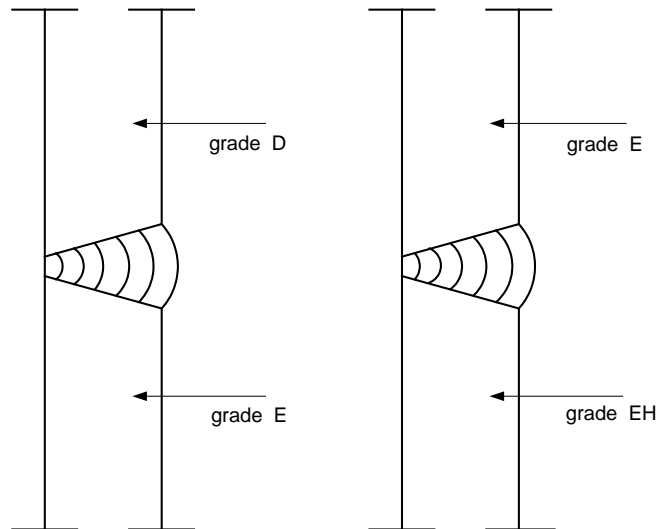


Figure 27 Butt welded plate joints of different grades

SECTION 6 FABRICATION AND TOLERANCES

1 General

1.1 Objective and scope

1.1.1 This section gives requirements for fabrication and tolerances of offshore structures. Specific requirements for the designing and dimensioning of welded joints in the various ranges of application are additionally governed by the referring offshore standards.

1.1.2 In order to determine the structural categorization, this section shall be read in conjunction with the [DNVGL-OS-C101 Ch.2 Sec.3](#) and relevant DNVGL offshore standards (i.e. [DNVGL-OS-C102 Ch.2 Sec.1](#), [DNVGL-OS-C103](#), [DNVGL-OS-C104](#), [DNVGL-OS-C105](#), [DNVGL-OS-C106](#) or [DNVGL-OS-C201 Ch.2 Sec.3](#)).

2 Identification and weldability of materials

2.1 Identification

A material identification system which ensures and is documenting correct installation and traceability of the material grades shall be established. Proper care shall be exercised during handling and storage to preserve identification.

2.2 Weldability

Welded structures shall be fabricated using BMs of proven weldability, see [DNVGL-OS-B101](#). Special attention shall be paid to the approval of hull structural steels intended for welding with heat input more than 50 kJ/cm. In case of doubt, the weldability of the materials shall be verified before welding commences.

3 Shop primers

3.1 General

Shop primer applied over areas which will subsequently be welded shall be of a suitable quality demonstrated to have acceptably low detrimental effect on the finished weld.

Fully mechanized fillet welding over shop primer shall be qualified for each type of shop primer by a WPQT, see [Sec.5](#).

4 Welding environment

4.1 General

4.1.1 Welding work shall not be carried out in environmental conditions that have a detrimental effect such as wind, damp, draught and low temperatures.

Guidance note:

If preheating at temperature above ambient is not already required or recommended, see [\[9.3\]](#), recommendations for preheating for welding at low temperatures are given in [IACS Rec. No.47](#) Table 6.12.

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4.1.2 Surfaces to be welded shall be free from mill scale, slag, rust, paint or other contaminating substances. The grooves shall be clean and dry at all time of welding.

4.1.3 During the entire construction period, suitable measures shall be taken in transport, storage and fabrication to keep the surface of stainless steels free from impurities and extraneous metallic inclusions.

Guidance note:

Prefabrication and welding of stainless steels, should be performed in a workshop, or parts thereof, which is reserved exclusively for these types of materials.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

5 Cutting

5.1 General

5.1.1 Cut edges shall be accurate and uniform in order to provide a shape compatible with the weld joint design.

5.1.2 Deviation of cut edges shall generally be within the standard specified by [IACS Rec. No.47](#) Part A.

5.1.3 Attention shall be paid to avoid excessive local hardening and carbon contaminations by thermal cutting.

5.1.4 The effect of work hardening and risk of cracked edges shall be considered if shearing is used for cutting of material.

Guidance note:

Extra high strength material with thickness more than 50 mm should be preheated before flame cutting, with a preheating temperature according to the recommendations given by the manufacturer (steel mill). The flame cut surface should be examined 100% by MT.

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5.1.5 Correction by welding as compensation for improper cutting shall be in accordance with procedures for repairs.

6 Forming

6.1 General

Forming and straightening of materials shall be performed according to procedures which outline the succession of the controlled steps. Such work shall be controlled by the contractor.

6.2 Cold forming of ferritic steels

6.2.1 The degree of cold deformation of special and primary structural elements shall be less than 5%, unless otherwise agreed and qualified. The contractor shall prepare a procedure for cold forming before the production starts, and the procedure shall be agreed.

6.2.2 Cold forming with theoretical deformation exceeding 5% and up to a maximum deformation of 12% may be accepted subject to additional testing of representatively cold formed material, e.g. strain age testing. The strain age test method is described in [DNVGL-RU-SHIP Pt.2 Ch.1 Sec.3 \[3.8\]](#). The average impact energy after strain ageing shall meet the impact requirements specified for the grade of steel used. Unless otherwise agreed, each heat represented shall be tested.

Guidance note:

Strain age test is applicable to C-Mn-steels and low alloy steels. In addition to representative cold forming, representative cold formed material means at least same material grade, with similar chemical composition and mechanical properties, and from one steel manufacturer. For destructive testing, the following should be tested as a minimum: impact toughness tests of representatively strained material and strain aged material. Test temperature should be the same as required for the BM.

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6.2.3 Cold deformation exceeding 12% and up to maximum 20% and followed by heat treatment may, subject to agreement, be considered for acceptance case by case based on qualification.

Guidance note:

The contractor should prepare a procedure for qualification, and the procedure should be agreed before the production starts. The qualification procedure should at least include non-destructive, destructive and weldability testing of representative cold formed material. For destructive testing, at least full scope of testing as for qualification of the BM should be required, although additional testing will typically be required, e.g. testing at different thickness locations, drop weight testing, etc. The testing should include strain age testing.

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6.2.4 Cold forming exceeding 20% shall in no case be carried out.

6.2.5 If welding is applied in cold formed areas, special consideration shall be taken with respect to material properties and subsequent cracking.

6.2.6 All cold formed (more than 5%) and heat treated areas shall be tested 100% by MT (or PT for stainless steels) after final forming, heat treatment and welding.

6.2.7 The theoretical plastic deformation ϵ (%) shall be calculated by the following simplified formulas:

6.2.7.1 Single-curvature deformation

Cold rolling or pressing of plates to cylindrical forms:

$$\epsilon = \frac{t}{2R_c + t} \times 100 \quad (1)$$

Cold bending of straight pipes to bends:

$$\epsilon = \frac{D}{2R_c} \times 100 \quad (2)$$

6.2.7.2 Double curvature deformation

Forming of plates to spheres:

$$\epsilon = \frac{t(1+\nu)}{2R_c} \times 100 \quad (3)$$

- D = outside diameter of pipe or vessel, mm
- ϵ = theoretical plastic deformation, %
- R_c = forming radius (inner radius of bend), mm
- t = material thickness, mm
- ν = Poisson's ratio (0.5 for plastic condition).

6.3 Hot forming of ferritic steels

Forming of steels at high temperatures shall be effectuated with due regard to adverse effects of the material properties. Forming of steels above 650°C shall be subject to agreement.

7 Fabrication planning

7.1 General

7.1.1 As a prerequisite for fabrication, procedures, ITP and work instructions for execution and control of fabrication activities, including information of pre-assembled items and the sequence of fabricating shall be established, see also [Sec.2](#).

7.1.2 Prior to commencement of the work the contractor shall submit a plan for NDT, NDT procedures and documentation for NDT operators certification for acceptance. The programme shall contain information and documents for planning, controlling, reporting etc. Acceptance criteria for NDT shall be agreed if they are not specified in relevant documents. See further details in [Sec.7](#).

7.2 Workmanship

7.2.1 Workmanship shall be in accordance with written and agreed procedures.

7.2.2 All work shall be executed with adequate control by the contractor. Repair work shall be carried out in accordance with written and agreed procedures. Faults and deficiencies shall be corrected before painting or permanent covers have been applied.

8 Assembly

8.1 General

8.1.1 Assembly and welding operations shall be carried out by qualified personnel and under supervision of qualified supervisors.

8.1.2 A fabrication sequence shall be established to ensure that the structure can be assembled in a manner which allows for effective control at all stages of work.

8.1.3 Structures or components shall not be subjected to any appreciable movements or vibration during welding.

Parts to be assembled while suspended from cranes or floating shall be clamped prior to tack-welding of the joints, in such a way that no relative movement of the parts is possible.

8.1.4 Components which have not been fully welded and which shall be handled or turned shall have welded joints of adequate strength.

8.2 Fit-up

8.2.1 Fit-up, preparation for welding and welding operations shall take place in accordance with agreed procedures.

8.2.2 Members to be welded shall be brought into correct alignment and held in position by clamps, tack welds, or other suitable devices.

Clamping plates, temporary ties and aligning pins shall be made from a material of similar composition and should not be used more than necessary. Any damage caused during removal shall be repaired.

8.2.3 Fit-up shall be checked for dimensional accuracy before welding, in order to ensure compliance with the weld shapes and root openings (air gaps) according to the manufacturing documents and approved WPS. The root opening shall not exceed twice the specified gap as given in the approved WPS.

Root opening for fabrication should not exceed the limits given by [IACS Rec. No.47](#) Part A (standard range).

If the permitted size of the gap is exceeded locally over a limited area, remedial work shall be carried out within the limitations specified in [IACS Rec. No.47](#) Part A for remedial work.

Special attention shall be paid to the alignment of structural members where visual inspection is not possible.

8.2.4 Edges for welding shall have a smooth and uniform surface.

Guidance note:

Internal defects, e.g. inclusions making the steel plate prone to lamination, may to some extent be considered consistent with method of manufacture, unless Z-grade steels are specified. Purchasers should specify additional requirements for the internal quality (e.g. Z-grade steel or additional UT) where through thickness properties are critical for the intended application.

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Grooves produced by gouging shall be followed by grinding removing carbonised material and the groove shall be dressed to a shape consistent with agreed tolerances.

8.2.5 Where the difference in plate thickness of butt welds exceeds 4 mm the thicker plate shall be tapered not steeper than 1 : 3. Butt joints prone to fatigue loading shall be tapered not steeper than 1 : 4.

See [Figure 1](#).

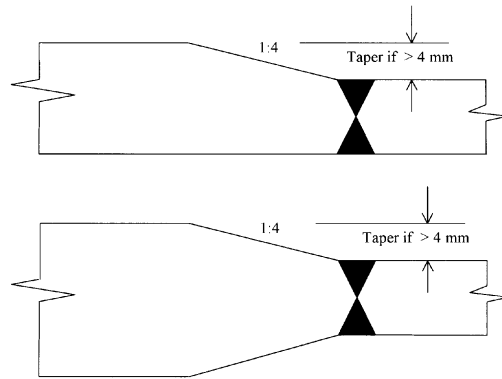


Figure 1 Tapering of butt joints

8.2.6 Tubular members framing into joints shall be carefully contoured to obtain accurate alignment. The bevel shall be formed providing a continuous transition from maximum to minimum bevel angle around the circumference. The fabrication shall be planned in such a manner that back welding can be performed to the largest extent possible.

8.2.7 Corners of cut-outs shall be given appropriate radii minimising local stress concentrations. Where temporary cut-outs are made, such cut-outs shall be made of sufficient size to allow sound replacement.

8.3 Tack welds

8.3.1 Tack welding shall, when integrated in production weld, be carried out by qualified welder (or qualified tack welder), and in accordance with agreed WPS specifying the applied minimum welding length. For welds specified in [9.2.2] a WPS shall be submitted for acceptance.

Guidance note:

Tack welds should have a length of minimum 50 mm and number of tacks sufficient to avoid cracking.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

8.3.2 Tack welds, if retained as part of the final weld, shall be free from defects and provide adequate conditions for pass welding. Cracked tack welds shall not be welded over.

8.3.3 Temporary tack welds using bridging or bullets shall only be performed using materials equivalent to the BM and using a WPS based on a qualified welding procedure. All such tack welds and any spacer wedges shall be removed from the final weldment.

9 Welding and fabrication

9.1 General

9.1.1 Qualification welding shall be performed under general conditions representative of the actual working environment for the work shop site where the production welding will be performed, see also Sec.5 [4.7.1.1].

9.1.2 All instruments for checking of welding parameters (e.g. temperature, ampere, volt, welding speed) shall have valid calibration certificates and the adequacy of any control software (weld machine) shall be documented.

9.2 Planning

9.2.1 The welding sequence shall be such that the amount of shrinkage, distortions and residual stresses are minimised.

Guidance note:

Welding should be performed in the optimum welding position. Positional welding (e.g. in the overhead positions) should be limited to the indispensable minimum.

Vertical down fillet welding should not be used:

- for joining together continuous primary supporting members interrupted by transverse members (e.g. the longitudinal members of the upper and lower girder), the same applies where transverse loads predominate
- for mainly dynamically loaded welded joints (e.g. in the area of engine base plates, shaft, brackets and rudders)
- on crane components and other lifting gear including their substructures (e.g. crane pillars)
- at intersections of main girders and in the area of the supports or stoppers of hatchway covers.

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9.2.2 For welds of the following listed categories, a WPS shall be established according to [Sec.5 \[2.4.3\]](#) alternative a). The WPS shall be submitted together with the referenced supporting WPQR(s) for review and acceptance prior to start of production.

- structural category special and primary
- butt-welds in secondary structural elements
- all welds in aluminium
- welded connections between castings/forgings and rolled material.

Guidance note:

The weld connection between two components will normally be assigned the structural category area equal to the higher category of the joined components, see relevant design standard. For stiffened plates not classified as structural category special, the weld connection between stiffener and stringer and girder web to plate may normally be assigned structural category secondary.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

9.2.3 Tack-welds alone may in certain cases not sufficiently maintain the integrity of the structure during fabrication. The builder shall assess the need for and implement additional means to ensure that the integrity of the structure is maintained during fabrication.

9.2.4 When welding tubular any longitudinal welds shall be staggered at least 50 mm. Unless otherwise agreed, girth welds shall be separated at least one tubular diameter or 300 mm, whichever is larger.

9.3 Pre-heating

9.3.1 The need and the degree of preheating necessary for welding are governed by a series of factors (see guidance note). If preheating is necessary for welding it shall be applied in accordance with agreed preheating procedures. Special attention shall be paid to temperature control during the welding process such that the preheat temperature is kept uniformly in affected part of the welded object.

Guidance note:

Normal strength steels may require preheating depending on the plate thicknesses and the degree of joint restraint. Preheating is normally required for welding of high and extra high strength steels depending on:

- plate thickness
- the chemical composition of the parent material and weld metal
- the hydrogen content of the weld metal
- heat input during welding
- the temperature of the welded object
- the stress level (incl. the joint restraint condition)
- post heating may additionally be required for extra high strength steels.

Several recommendations gives detailed guidance for preheating, e.g. IACS Rec.47 part B table 5.1, ISO/TR 17671, EN 1011, etc.

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9.3.2 Preheating temperature, whenever required, shall in any case be within the limit of the WPS.

9.3.3 When resuming welding on partially filled joints in special areas, preheating shall be performed and the temperature within the specified tolerances, shall if not otherwise agreed, be equal to the interpass temperature for the welding pass in question.

9.3.4 Preheating shall preferably be performed with electric heating elements. Gas burners may be used under controlled conditions. Cutting torches should not be used.

9.4 Welding consumables

9.4.1 The welding shop's supervisors shall ensure that only welding consumables which have been accepted are being used. Proof thereof shall be furnished on request. Welding consumables specified in an accepted welding procedure can only be replaced by equivalent consumables of appropriate quality grade. Further details are given in [Sec.5 \[4.7.2.7\]](#).

9.4.2 The welding consumables (including flux, backing, welding gas, etc.) shall enable a welded joint to be made which is suited to the BM and the operating conditions. For selection of welding consumables, see [Sec.4](#).

9.4.3 Welding consumables shall be classified with respect to strength, application area and hydrogen level according to recognised scheme. All welding consumables shall have identifiable marking.

9.4.4 Covered electrodes for welding of high strength steels (see [DNVGL-OS-B101](#)) shall satisfy a hydrogen test requirement for at least suffix H10, i.e. $H_{DM} \leq 10$ ml/100 g in weld metal.

Covered electrodes for welding of extra high strength steel (see [DNVGL-OS-B101](#)) shall satisfy a hydrogen test requirement for the suffix H5, i.e. $H_{DM} \leq 5$ ml/100 g in weld metal.

Hydrogen testing shall be according to ISO 3690 or equivalent.

9.4.5 Storage and handling of welding consumables shall be in accordance with the manufacturer's recommendations, and in accordance with procedures giving details regarding conditions in storage rooms, temperature in storage ovens and quivers, length of exposure and conditions.

9.4.6 Recycling of fluxes for SAW shall be performed in a manner that ensures a mixture of new and used flux with continually homogenous properties.

9.4.7 Consumables that have been contaminated by moisture, rust, oil, grease, dirt or other deleterious matter, shall be discarded unless properly reconditioned.

9.5 Welding

9.5.1 All welding shall be based on welding processes, welding techniques and using welding consumables proven to be suitable for the type of material and type of fabrication in question.

9.5.2 All fabrication welding referred in [9.2.2] shall be performed within the limits of essential variables of the qualified welding procedure (qualified for the structure to which they are attached). This also includes tack welding (see [8.3]), seal welding, welding of lifting lugs and attachment welds as well as repair welding (see [9.9]).

9.5.3 When one or more variations outside the qualification ranges variables occur, the welding procedure qualification shall be considered invalid, and the WPS shall be re-specified and re-qualified.

9.5.4 The welding interpass temperature shall not drop below the minimum required preheating temperature and shall not exceed the maximum qualified interpass temperature.

9.5.5 The use of permanent steel backing strips may be accepted after thorough corrosion evaluation and when accounted for in the design analysis with respect to fatigue.

Guidance note:

Fatigue of welds with permanent backing strips may be determined on basis of DNVGL-RP-C203 App. A Table A-6.

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9.5.6 Unless otherwise accounted for in the design analysis, the permanent backing strip material shall be of same strength group as the bonded plates. The welding procedures shall be qualified accordingly, see Sec.5.

9.5.7 Welds shall be terminated in a manner that will ensure sound welds without end-craters. Extension bars and run-off plates shall be removed upon completion and cooling of the weld. The end of the weld shall be made smooth and flush with the edges of abutting parts.

Start and stop points shall be distributed over a length of the weld and not stacked in the same area.

9.6 Post weld heat treatment

9.6.1 PWHT of C-Mn steels shall, when applied, be performed in accordance with a procedure specification giving at least the following:

- heating and cooling rates
- temperature gradients
- soaking temperature range and minimum holding time

- heating facilities
- insulation
- control devices
- recording equipment
- configuration of structure to be post-weld heat treated or details if local PWHT shall be carried out.

Heat treatment records shall be kept throughout the heat treatment process.

Guidance note:

PWHT is e.g. required as per [DNVGL-OS-C101](#) or [DNVGL-OS-C201](#). The procedure specification may be worked out on basis of combined material thicknesses as shown in [Figure 2](#).

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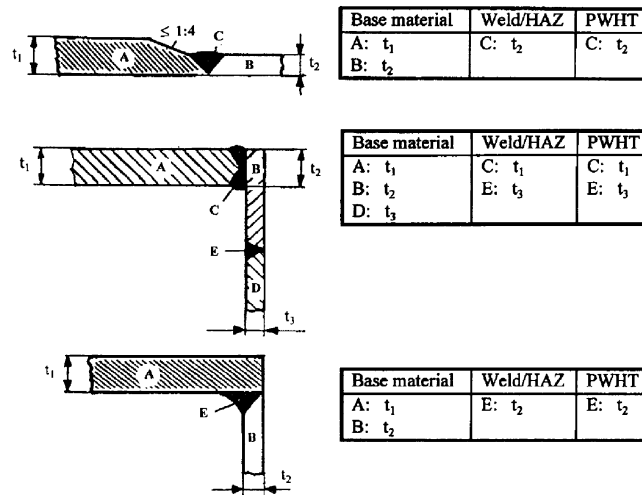


Figure 2 Guidance on material thickness for post weld heat treatment

9.6.2 Heat treatment shall be performed at a soaking temperature in the range 550 to 620°C, for a time of at least two minutes per mm thickness. Soaking temperature and time shall be selected considering recommendations for the welding consumables and steel grade in question. Soaking temperature for QT steels shall be decided in each case.

The maximum PWHT temperature for QT low alloy steels shall be 30°C less than the tempering temperature of the material as stated in the material certificate. If the PWHT temperature exceeds this limit, the effect on the mechanical properties shall be demonstrated. PWHT shall, unless otherwise agreed, be qualified through the WPQT, see [Sec.5](#).

9.6.3 The temperature difference between the outside and the inside surface during soaking shall if practically possible to measure, not exceed 30°C within the heated area. Double-sided heating shall be applied as far as possible.

9.6.4 Heating, soaking and cooling shall be carried out in a controlled manner that prevents cracking or distortions outside the dimensional tolerances. The temperature difference along lines or planes of symmetry shall normally not exceed 30°C when the material temperature is above 300°C.

9.6.5 The heat-treatment cycle and the actual metal temperature shall be recorded using thermocouples equally spaced externally, and whenever possible internally, throughout the heated region. The heat treatment temperature cycle charts shall be available for verification if requested.

9.6.6 Heat treatment, wherever possible, shall be carried out in an enclosing furnace according to written procedures agreed upon. The temperature distribution throughout heating furnaces shall be controlled within $\pm 15^\circ\text{C}$.

Where it is impractical to heat-treat the whole item in a closed furnace, local heat treatment may be adopted.

9.6.7 Only welding consumables recommended for PWHT by the manufacturer shall be used for joints to be post weld heat treated.

9.7 Additional requirements for duplex steel

9.7.1 Stringer beads shall be used to ensure a constant heat input, and any weaving of the weld bead shall be limited to maximum 3x filler wire/electrode diameter. The heat input shall be kept within the range 0.5-1.8 kJ/mm, avoiding higher heat input.

9.7.2 For the root pass the heat input shall be higher than for second pass.

9.7.3 Excavation of repair grooves shall be by chipping, grinding or machining. Entire welds shall be removed by plasma cutting or machining.

9.7.4 Welding consumables shall be segregated from consumables for C-Mn steel.

9.7.5 Backing gas shall be used for welding of root pass and for sufficient succeeding passes to avoid back side oxidising.

9.8 Remedial

9.8.1 General guidance to repair work is given in [IACS Rec.47](#) Part A for new construction and Part B for existing ships. See [DNVGL-RU-OU-0101 Ch.3 Sec.3 \[4.2\]](#), [DNVGL-RU-OU-0102](#) and [DNVGL-RU-OU-0103](#) respectively, and [DNVGL-RU-OU-0104 Pt. 7 Ch.4 Sec.3](#) regarding thickness gauge of existing material.

9.8.2 Members distorted by welding may be straightened by mechanical means or by carefully supervised application of a limited amount of localised heat, see [\[9.10\]](#). The application of heat or mechanical force shall be in accordance with a written procedure.

9.8.3 Defects in welds may be rectified by grinding or machining, and/or followed by welding. In order to verify complete removal of defects after grinding or machining, affected areas shall be examined with suitable NDT methods. Welds of insufficient strength, ductility or notch toughness shall be completely removed prior to repair. The mechanical properties of repair weld shall satisfy the minimum specified properties of the steel in question.

9.8.4 Minor discontinuities may be removed by grinding or machining, making a smooth transition to the surrounding material. The thickness shall not be reduced to less than 93% of the nominal thickness but in no case by more than 3 mm. The extent of such repair shall be agreed upon.

9.8.5 Repair procedure

Repairs by welding shall be carried out in accordance with qualified repair procedures. The repair procedures shall be agreed.

For extra high strength steel repair welding shall be qualified by a separate weld repair qualification test if the repair depth is beyond $\frac{1}{4}$ of the parent material thickness

For planar defects the repair length on either side of the defect shall be 50 mm longer than the size of the defect as confirmed by NDT.

Long defects may be required repaired in several steps to avoid overloading or cracking. Each repair step shall be controlled so as not to cause plastic deformation of the remaining material when removing the defect.

9.8.6 WPS for repair welding

Repairs by welding shall be carried out in accordance with agreed WPS. Mechanical properties shall satisfy the minimum specified properties of the material in question.

9.8.7 Repair welding shall be performed using welding consumables satisfying the hydrogen test requirement given in [Sec.4](#) and in [\[9.4.4\]](#).

9.8.8 Defects shall be completely removed before repairs by welding. Repairs with arc-air gouging shall be followed by grinding. Whenever a defect is removed, the gouged and ground area shall be examined by MT, PT, UT or other suitable methods to verify complete removal before welding.

9.8.9 For heavy sections (e.g. for thickness of 50 mm or more) the preheating and working temperature shall when making shallow and local repairs in special and primary structural elements be raised 50°C above the level specified for production welding and be at least 100°C unless otherwise agreed. The working temperature shall be maintained until the repair has been completed.

9.8.10 To ensure sound repair welds, the length of single repair welds shall satisfy the requirements of [IACS Rec.47](#) Table 9.14.

9.8.11 Repair welding of post-weld heat-treated joints shall unless otherwise agreed initiate a new heat treatment.

9.8.12 All repairs shall be re-inspected with the same NDT methods to the same or increased extent as necessary.

9.8.13 Repair welding in the same area may be carried out twice. Further repairs shall be subject to agreement.

9.9 Fairing by line or point heating

9.9.1 Members distorted by welding may be straightened by mechanical means or by a limited amount of localised heat. Fairing by line or point heating shall be done in accordance with an agreed procedure.

9.9.2 Corrective measures relating to flame straightening shall be carried out with due regard to possible degradation of the material properties. See [IACS Rec.47](#) Part A Table 6.5 regarding maximum heating temperature.

9.10 Welding production test

9.10.1 The first fabrication welds shall be included as part of the welding procedure tests if:

- the test coupon for approval of WPS for fully mechanized or automatic welding process is not welded in the comparable environment as the production condition or
- if the manufacturer has no or limited experience with the process and equipment.

For both cases the first fabrication welds shall be included as part of the welding procedure tests and be subjected to non-destructive testing.

9.10.2 Welding production tests (WPT) shall be made during fabrication of welds in special areas and in primary structural elements to verify that the produced welds are of acceptable quality. Minimum one test coupon is required from each applied welding process. For sister units built by the same contractor, the extent may be reduced by agreement.

Guidance note:

Requirements for WPT are also given for specific applications, e.g. for pressure vessels and for some low temperature applications.

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9.10.3 Additionally, when deemed necessary by the verifier, WPT shall be made during fabrication of welds to verify that the produced welds are of acceptable quality.

9.10.4 The welding parameters for the WPT shall be as for the actual weld and the environmental conditions shall be kept as realistic as possible. The requirements for a WPT are in general the same as for the relevant WPQT.

9.10.5 If one or more tests fail to give satisfactory results, see [Sec.5 \[3.3.9\]](#) for retest.

Should the retest according to [Sec.5 \[3.3.9\]](#) fail, two more production tests may be carried out. Should one or more of the new production tests fail, the total production welding performed with the welding procedure in question shall be evaluated based on testing of welds and BM cut-out from the actual structure fabricated.

9.10.6 In all cases the failure of a production test shall lead to a review of the welding performed to establish the reason for the failure, and appropriate corrective action shall be carried out.

9.11 Other fabrication requirements

9.11.1 After weld completion, all spatter, scales, slag, porosity, irregularities and extraneous matter on the weld and the adjacent area shall be removed. The cleaned area shall be adequate for the subsequent NDT. Peening is not permitted.

9.11.2 Arc strikes shall be repaired by mechanical removal of affected BM. For high strength and extra high strength steel, the removal shall be followed by NDT to verify absence of cracks.

9.11.3 All welding of attachments shall comply with the requirements (e.g. welder, WPS) for the structure to which they are attached.

Temporary attachments shall be cut minimum 3 mm from the base metal and ground. The ground area shall be visually examined and MT/PT tested (as relevant).

9.11.4 Where applicable, grinding of welds with the intention of increasing the fatigue life and/or reducing the probability of brittle fracture shall be carried out according to agreed procedures and specifications.

10 Inspection

10.1 General

10.1.1 Inspection shall be carried out in accordance with an agreed quality and survey plan (QSP), to confirm that work is carried out in accordance with established project procedures and plans, such that all project requirements are complied with.

10.1.2 The inspection categories shall be defined in accordance with [DNVGL-OS-C101 Ch.2 Sec.3](#) or [DNVGL-OS-C201 Ch.2 Sec.3](#) and shall be specified in relevant design drawings.

10.1.3 The inspection shall cover items such as:

- correct identification and documentation and use of materials
- qualification and acceptance of fabrication procedures and personnel
- inspection of preparatory work (assembly, fit-up form work, reinforcement etc.)
- welding inspection
- inspection of fabrication work for compliance with specifications and procedures
- witnessing NDT, control and testing
- inspection of repairs
- inspection of corrosion protection systems
- ensure functionality of examination or testing equipment and of recording and/or measuring devices vital for correct functioning of equipment and machinery used in fabrication.

10.1.4 Welds shall be subject to NDT in progress with fabrication, see further details in [Sec.7](#).

10.1.5 Due consideration shall be given to the access and the time required for adequate inspection during fabrication.

10.1.6 High non-conformance rates in execution of the work or in the product itself shall call for special considerations in agreement with the verifier. Such special considerations may include increased inspection by the contractor, increased surveys by the verifier, re-qualification of personnel and other agreed remedial actions.

10.1.7 The contractor's inspectors shall be qualified and shall be able to provide documentation of proficiency.

11 Tolerances

11.1 Tolerances for alignment and straightness

11.1.1 Allowable fabrication tolerances shall be submitted for acceptance.

11.1.2 Special considerations shall be given in providing proper alignment of structural members. Allowable fabrication tolerances shall be established on basis of due consideration to the criticality of the design.

11.1.3 Unless otherwise agreed, the maximum fabrication tolerances shall be in compliance with [IACS Rec.47](#).

Guidance note:

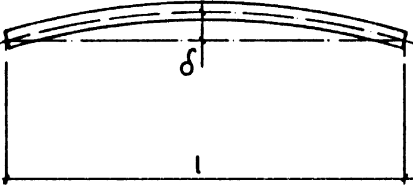
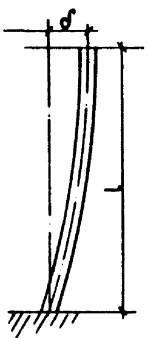
Special and primary category areas are regarded as strength members and secondary category area are regarded as other in the IACS Rec.47 *Shipbuilding and Repair Standard*.

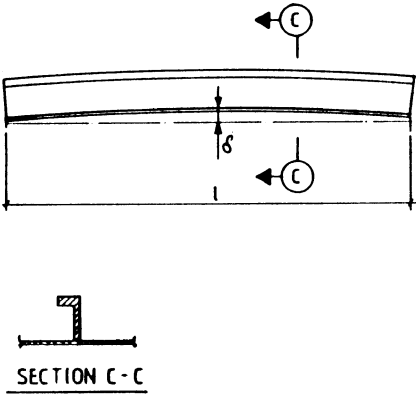
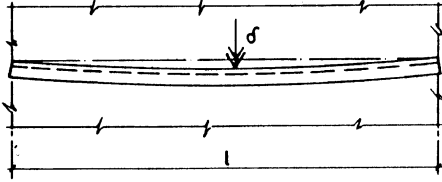
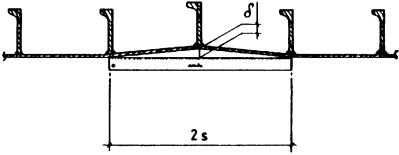
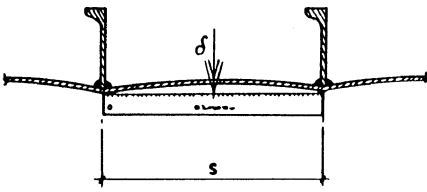
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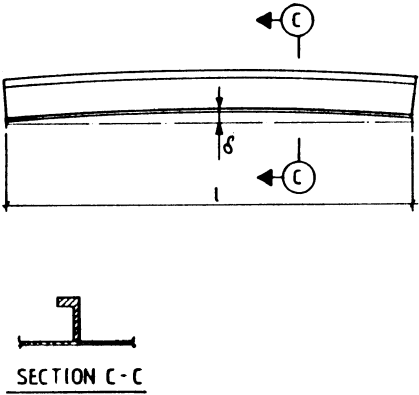
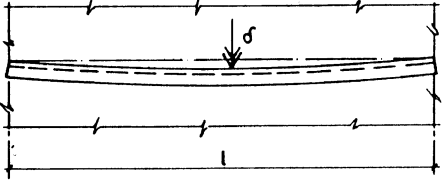
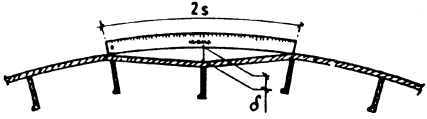
11.1.4 Straightness of members shall be within the tolerances given by the buckling code.

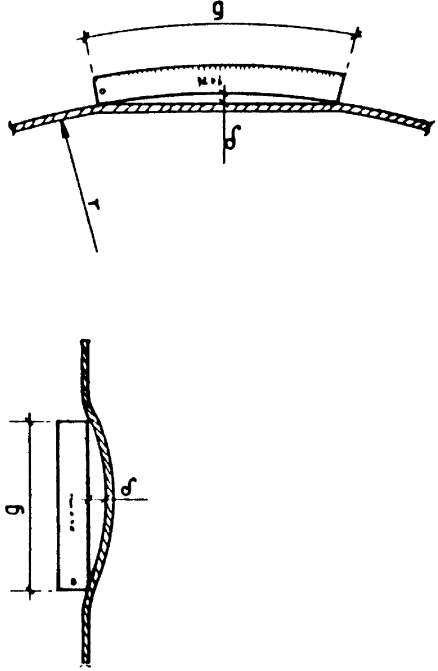
11.1.5 Straightness of members which are based on buckling calculations according to DNV-RP-C201 and DNV-RP-C202 shall be within the tolerances given in [Table 1](#).

Table 1 Tolerances for straightness

<i>Detail</i>	<i>Tolerance</i>	<i>Fig.</i>	<i>Comments</i>
Bars and frames	Max. out of straightness $\delta = 0.0015 l$		$l =$ unsupported length
Pillars, vertical columns	Max. inclination $\delta = 0.001 l$		$l =$ unsupported length

Detail	Tolerance	Fig.	Comments
Stiffened plane plates. Stiffener or girder webs relative to the plate plane.	Max. out of straightness $\delta = 0.0015 l$		l = unsupported length of the stiffener or girder
Stiffened plane plates. Stiffener or girder flanges relative to the web plate	Max. out of straightness $\delta = 0.0015 l$		l = unsupported length of the flange
Stiffened plane plates. Parallel stiffeners or girders	Max. misalignment $\delta = 0.02 s$		s = distance between parallel stiffeners or girders
Stiffened plane plates. Plates between stiffeners or girders.	Max. out of plane displacement $\delta = 0.005 s$		s = unsupported width of the plate panel
Circular cylindrical shells.	Max. deviation from the nominal radius measured at ring stiffener or bulkhead $\delta = (r_a - r) = 0.005 r$		r_a = actual distance from the cylinder axis to the shell wall. r = nominal radius of the shell

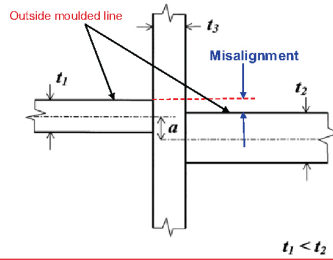
Detail	Tolerance	Fig.	Comments
Circular cylindrical shells. Longitudinal stiffeners or girders.	Max out of straightness $\delta = 0.0015 l$		l = unsupported length of the stiffener or girder.
Circular cylindrical shells. Flanges of longitudinal stiffeners or girder webs.	Max. out of straightness $\delta = 0.0015 l$		l = unsupported length of the flange
Circular cylindrical shells. Longitudinal stiffeners.	Max. misalignment $\delta = 0.02 s$		s = stiffener spacing

Detail	Tolerance	Fig.	Comments
<p>Circular cylindrical shells. Local out of roundness. Local out of straightness.</p>	<p>Max. imperfection</p> $\delta = \frac{0.01g}{1 + g/r}$		<p>A circular template or straight rod held anywhere on the shell.</p> <p>g = length of template or rod.</p> <p>The length of the circular template shall be the smallest of:</p> $s, 1.15 \sqrt{l\sqrt{rt}}$ <p>and $\pi \frac{r}{2}$</p> <p>s = stiffener spacing (of longitudinal stiffeners) l = distance between rings or bulkhead.</p> <p>The length of the straight rod shall be taken equal to the smallest of:</p> $l \text{ and } 4\sqrt{rt}.$
<p>Conical shells</p>			<p>The tolerance requirements given for cylindrical shells are applicable also for conical shells.</p>

11.1.6 Alignments of the non-continuous plates in cruciform joints and butt welds shall be within the tolerances given in [Figure 3](#).

11.1.7 Larger imperfections may be applied provided accounted for in the design calculations. See e.g. [DNVGL-RP-C203 \[2.6\]](#).

Cruciform joints – Non-symmetrical

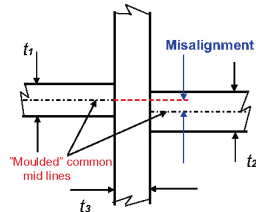


Tolerances for misalignment:

- Special: $0.15 t_1$
- Primary: $0.30 t_1$
- Secondary: $0.50 t_1$
- t_1 is the smaller thickness of t_1 , t_2 and t_3 .

For cruciform joints **not** designed to be symmetrical, the alignment to be measured from the common outside moulded line. The limiting tolerances to be based on the smaller thickness.

Cruciform joints – Symmetrical

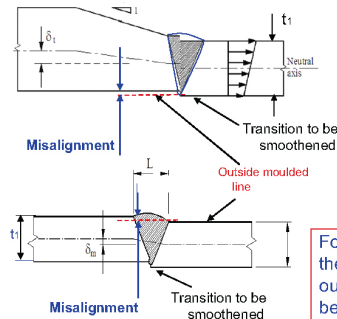


Tolerances for misalignment:

- Special: $0.15 t_1$
- Primary: $0.30 t_1$
- Secondary: $0.50 t_1$
- t_1 is the smaller thickness of t_1 , t_2 and t_3 .

For cruciform joints designed to be **symmetrical**, the alignment to be determined on basis of the "moulded" common mid line of the plates. The limiting tolerances to be based on the smaller thickness.

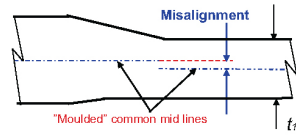
Butt joints - Non-symmetrical



Tolerances for misalignment:

- Special: $0.10 t_1$
- Primary: $0.15 t_1$
- Secondary: $0.30 t_1$
- t_1 is the smaller of the two thicknesses.
- Maximum tolerance is 4 mm.

For butt joints **not** specified to be symmetrical, the alignment to be measured from the common outside moulded line. The limiting tolerances to be based on the smaller thickness.

Butt joints - Symmetrical**Tolerances for misalignment:**

- Special: $0.10 t_1$
- Primary: $0.15 t_1$
- Secondary: $0.30 t_1$
- t_1 is the smaller of the two thicknesses.

Maximum tolerance is 4 mm.

For butt joints designed to be **symmetrical** (both sides tapered), the alignment to be determined on basis of the "moulded" common mid line of the plates. The limiting tolerances to be based on the smaller thickness.

Figure 3 Alignment of joints

SECTION 7 NON-DESTRUCTIVE TESTING OF WELDS

1 General

1.1 Scope

1.1.1 The section contains requirements for the application of NDT, methods, extent of testing and acceptance criteria.

1.1.2 Additional requirements for extent of testing and acceptance criteria are given in [DNVGL-OS-C101](#) to [DNVGL-OS-C201](#), see [Ch.1 Sec.1 Table 1](#).

1.1.3 This offshore standard is based on the following conditions:

1.1.3.1 Weld joint types

The following main weld joints are covered, see the figures in [Sec.5](#):

- butt joints
- T-joints (with and without full penetration)
- fillet welds.

1.1.3.2 Types of imperfections

The main types of imperfections in fusion welding are given in EN ISO 6520-1 *Welding and Allied Processes – Classification of Geometric Imperfections in Metallic materials, Part 1: Fusion Welding*.

1.1.3.3 Testing methods

For detection of surface imperfections the following methods applies:

- visual testing (VT)
- MT
- PT.

For detection of sub-surface imperfections the following methods applies:

- UT
- RT.

For the choice of applicable test methods, see [DNVGL-CG-0051](#).

1.2 Basic requirements

1.2.1 For NDT the contractor or its sub-supplier shall set up a qualified inspection body.

Guidance note:

The inspection body should be independent of the manufacturing departments. It should be a part of the manufacturing site, and either approved according to [DNVGL-CP-0484 App.B](#) or complying with ISO/IEC 17025 or ISO/IEC 17020 Type A or B, or complying with a similar scheme.

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1.2.2 Unless otherwise agreed, the surface to be tested shall be presented clean and smooth, i.e. free from dirt, scale, rust, welding spatter, etc., which may influence the results of the testing.

1.2.3 Due consideration shall be given to the access and the time required for adequate inspection during fabrication.

1.2.4 Final NDT of high strength and extra high strength structural steel welds (see definition in [DNVGL-OS-B101 Ch.2 Sec.2 \[4\]](#)) shall not be carried out before 48 hours after completion, except where PWHT is required.

The time delay may upon agreement be reduced to 24 hours for VL 36 grades or lower for all plate thicknesses, and for VL 420 grades or lower for plate thicknesses less than 40 mm, if one of the following conditions are complied with (the grades are defined in [DNVGL-OS-B101 Ch.2 Sec.2](#)):

- 1) Consistent low failure rate of delayed cracking has been documented for the materials and welding consumables in question (including shielding gas), adequate handling of welding consumables are strictly controlled and documented, and the welding environments are controlled (weather, wind, temperature, etc.).
- 2) Adequate post heating for hydrogen removal has been carried out (contractor shall document that selected post heating parameters will ensure sufficient hydrogen removal).

1.2.5 When heat treatment is performed, the final NDT shall be carried out when all heat treatments have been completed.

1.2.6 High non-conformance rates in execution of the work or in the product itself shall call for special considerations in agreement with the verifier. Such special considerations may include increased inspection by the contractor, increased surveys by the verifier, re-qualification of personnel and other agreed remedial actions.

2 Documentation, procedures and reports

2.1 General

2.1.1 Prior to commencement of fabrication the contractor shall submit a plan for NDT, procedures for NDT and documentation of NDT inspectors' certification for acceptance. The programme shall include information and documents for planning, controlling and reporting (see [Sec.2 \[2.2\]](#)).

2.1.2 The locations and areas to be examined shall be described in an NDT plan. The NDT plan shall clearly identify the critical areas, see [\[5\]](#).

2.1.3 NDT shall be performed in accordance with approved written procedures. The procedures shall be in accordance with [DNVGL-CG-0051](#). Other recognised standards may be accepted based on case by case consideration.

2.1.4 All NDT shall be properly documented in such a way that the performed testing may be duplicated. The reports shall identify all defects exceeding the acceptance criteria and all imperfections exceeding the reporting level given, unless more stringent reporting requirements have been agreed. All weld repair work shall be documented.

2.1.5 Unless otherwise agreed, NDT reports shall be signed by the NDT operator performing the testing.

3 Personnel qualifications

3.1 General

Except for VT, all testing shall be carried out by qualified and certified personnel. The NDT operators and supervisors shall be certified according to a 3rd party certification scheme based on ISO 9712 or ASNT central certification program (ACCP). SNT-TC-1A may be accepted if the NDT company's written practice is reviewed and accepted. The certificate shall clearly state the qualifications as to which testing method, level and within which industrial sector the operator and supervisor is certified.

VT shall be carried out by qualified personnel. The qualifications shall be documented by the contractor.

3.2 Non-destructive testing operators

NDT operators (except for VT inspectors) shall be certified level 2 in the testing method and industrial sector concerned, see further details in [DNVGL-CG-0051](#).

3.3 Non-destructive testing supervisors

The supervisor shall be available for scheduling and monitoring the performed NDT. The supervisor shall be available for developing, verifying and/or approving the NDT procedures in use and make sure these procedures are in compliance with the applicable rules and standards. NDT supervisors shall, unless otherwise agreed, be certified level 3 in the testing method and industrial sector concerned.

4 Non-destructive testing methods

4.1 Magnetic particle testing

4.1.1 MT shall be performed according to procedures subject to agreement. The procedures shall be established according to [DNVGL-CG-0051](#).

4.1.2 Where possible, both sides of the welds shall be tested. MT shall be applied for welds in ferro-magnetic materials if not otherwise agreed.

4.2 Penetrant testing

4.2.1 Liquid PT shall be performed according to agreed procedures. The procedures shall be established according to [DNVGL-CG-0051](#).

4.2.2 Where possible, both sides of the welds shall be tested. PT shall only be applied for welds in non-ferromagnetic materials if not otherwise agreed.

4.2.3 The penetrant products (penetrant, developer and cleaner) shall be traceable to a batch certificate or data sheet documenting compliance with ISO 3452-2 (other standards may be accepted upon agreement).

4.3 Radiographic testing

4.3.1 X-ray source shall be used whenever possible. Gamma-ray sources may be used as outlined in [DNVGL-CG-0051](#). The procedures shall be established in accordance with [DNVGL-CG-0051](#).

Guidance note:

RT may be replaced by UT and vice versa, when methodologically justifiable and agreed upon.

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4.3.2 Indications suspected to be planar and discovered by RT shall be type determined, located and sized by UT.

4.3.3 Processing and storage shall be such that the films maintain their quality throughout the agreed time of storage. The radiographs shall be free from imperfections due to processing.

4.4 Ultrasonic testing

4.4.1 UT, including time of flight diffraction (TOFD) and phased array ultrasonic testing (PAUT) techniques, shall be performed in accordance with agreed procedures. The procedures shall be established in accordance with [DNVGL-CG-0051](#).

4.4.2 UT shall not be carried out on welds with thickness < 10 mm unless qualified and accepted down to 8 mm.

4.4.3 UT procedure giving the testing/scanning technique for testing of austenitic stainless and ferritic-austenitic (duplex) steel welds shall be developed for each applicable joint configuration and qualified using samples made of WPS to be used in production.

5 Extent of non-destructive testing

5.1 General

5.1.1 All welds shall be subjected to 100% VT by the contractor's qualified personnel and accepted prior to carrying out NDT. See also [Sec.6 \[10\]](#).

5.1.2 The extent, locations and areas to be examined shall be defined in an NDT plan.

5.1.3 Welds shall be subjected to NDT as given in [Table 1](#).

Methods of NDT shall be chosen with due regard to the sensitivity of the method and the method's ability to detect defects likely to occur as a consequence of the chosen welding process. The test method selected shall in a reliable way be capable of detecting external and/or internal defects present. Where necessary, this shall be achieved by using two or more test methods in combination. The particular test method(s) to be used shall be stated in the NDT plan.

Table 1 Minimum extent of non-destructive testing for structural welds

Structural category	Inspection category	Type of connection	Visual testing	Test method		
				Magnetic ¹⁾	Radiography ²⁾	Ultrasonic ³⁾
Special/essential	I	Butt weld	100%	100%	100%	-
		Cross- and T-joints, full penetration welds	100%	100%	-	100%
		Cross- and T-joints, partly penetration and fillet welds	100%	100%	-	-
Primary	II	Butt weld	100%	20% ⁴⁾	10%	-
		Cross- and T-joints, full penetration welds	100%	20%	-	20%
		Cross- and T-joints, partly penetration and fillet welds	100%	20%	-	-
Secondary	III	Butt weld	100%	Spot ⁵⁾	Spot ⁵⁾	-
		Cross- and T-joints, full penetration welds	100%	Spot ⁵⁾	-	Spot ⁵⁾
		Cross- and T-joints, partly penetration and fillet welds	100%	Spot ⁵⁾	-	-

1) PT to be adopted for non ferro-magnetic materials.
2) May be partly or wholly replaced by UT upon agreement.
3) UT shall be carried out for plate thicknesses of 10 mm and above. Testing of thicknesses $8 \leq t < 10$ mm may be agreed if special qualification is carried out.
4) For weld connections on hull shell not subjected to high residual stress, spot check will be accepted as sufficient.
5) Approximately 2% to 5%.

5.1.4 For welds that are examined for only a given percentage, the importance to the integrity of the structure shall be considered when selecting the welds to be examined. A representative sampling of welds, with due regard to fabrication assembly and welding methodologies, shall be performed.

5.1.5 The inspection categories shall be defined in accordance with [DNVGL-OS-C101 Ch.2 Sec.3](#) or [DNVGL-OS-C201 Ch.2 Sec.3](#) and shall be specified in relevant design drawings.

5.1.6 The welds shall be assigned inspection categories equal to the highest structural category of the two components. The inspection structural categories shall be applied to the drawings (IC-1, IC-II, IC-III). Aspects that shall be considered in determining the extent of NDT are:

- stress level and stress direction
- cyclic loading
- material toughness
- redundancy of the member
- overall integrity of the structure
- accessibility for testing in-service.

Guidance note:

For stiffened plates, which are not assigned inspection category I (special), the weld connection between stiffener and stringer and girder web to the plate may normally be inspected according to inspection category III (secondary).

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5.1.7 Plates which are subjected to significant tensile stresses in the thickness direction in way of full penetration cross joints, shall undergo UT after welding for the presence of lamellar tearing in the member subject to tensile stresses. The requirement to such UT shall be included as NDT notes in the actual drawings.

If steel with improved through thickness properties has been adopted, this test may be reduced to spot-checks only.

5.1.8 NDT shall cover start and stop points of automatically welded seams, except for internal members where the extent of testing should be agreed. UT of welds shall include testing of the area adjacent to the weld (the scanning area for angle probes) for laminations and scanning for transverse defects in the weld and BM.

5.1.9 The verifier may alter the test positions and/or extend the scope of NDT against the NDT plan in case of doubts about proper workmanship.

5.1.10 NDT failure rate shall be submitted regularly e.g. weekly basis.

5.1.11 If a high NDT failure rate is observed, the extent of NDT inspection required shall be increased, see [7].

5.1.12 If a consistently low NDT failure rate is documented, the extent of NDT inspection required for elements within structural category primary may, subject to agreement, be reduced but shall not be less than for inspection category III.

6 Acceptance criteria

6.1 General

6.1.1 All welds shall show evidence of good workmanship. The acceptance criteria are applicable for VT and NDT.

6.1.2 The soundness of welds shall comply with the acceptance criteria for each of the NDT methods used. Defects exceeding the limits shall be repaired and after repair welding has been performed, the complete weld, (i.e. the repaired area plus at least 100 mm on each side) shall be subjected to at least the same NDT method(s) as specified for the original weld.

6.1.3 Where acceptance criteria for NDT are not specified below or in the applicable standard or referred documents, e.g. [DNVGL-OS-B101](#), the acceptance criteria shall be specially agreed.

6.1.4 Acceptance of defects exceeding the given limits may be agreed based on FM testing and appropriate calculations. If this approach is considered, the inherent inaccuracy of the NDT methods shall be considered when the critical defect size is determined.

6.2 Welds of category special

Welds of category special shall comply with EN ISO 5817 level B. See correlation to relevant standards in [\[6.5\]](#).

6.3 Welds of category primary and secondary

Welds of category primary/secondary shall comply with EN ISO 5817 quality level C. See correlation to relevant standards in [\[6.5\]](#)

6.4 Welds in aluminium

Welds in aluminium shall comply with ISO 10042 level B (applies for category special) or level C (applies for category primary/secondary).

6.5 Relevant standards for non-destructive testing acceptance criteria

6.5.1 Relevant standard for MT and PT is ISO 23278 and ISO 23277, respectively (see correlation in ISO 17635 and [DNVGL-CG-0051](#)).

6.5.2 Relevant standard for RT is ISO 10675, level 1 and level 2 (see correlation in ISO 17635 and [DNVGL-CG-0051](#)).

6.5.3 Relevant standard for UT is EN ISO 11666. Level B and level C of EN ISO 5817 are equal to, respectively, acceptance level 2 and level 3 of ISO 11666 (see correlation given in ISO 17635 and [DNVGL-CG-0051](#)).

Regarding UT EN ISO 11666 level 2 or level 3 applies with the following amendment: all imperfections from which the reflected echo amplitude exceeds the evaluation level shall be characterised, and all that are characterised as planar e.g. cracks, lack of fusion, incomplete penetration shall be rejected.

7 Non-conforming welds

7.1 General

7.1.1 For non-conforming discontinuities detected during testing at spot basis, the scope of testing shall be extended. For each section of weld to be repaired, two more sections of same length shall be tested. If systematically repeated non-conforming discontinuities are revealed, the extent of testing shall be increased for welds manufactured under same conditions and where similar defects may be expected.

7.1.2 When non-conforming discontinuities are found to occur regularly, the reason for the non-conforming discontinuities shall be investigated. The WPS shall be reassessed before continuation of the welding. Necessary actions shall be taken to bring the production to the required quality level.

Guidance note:

Frequent occurrence of excessive porosity may be indicative of inadequate handling of welding consumables. If inadequate handling is confirmed, the welds made during the period in question should be investigated by adequate methods for hydrogen induced cracking.

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7.1.3 If severe defects (i.e. cracks and other planar defects or excessive slag lines) occur repeatedly, all welds made with the same welding procedure during the period in question, shall be examined full length. If the defects are found to be from the work of the same welders, spot check of other welds by the same welders shall be carried out, see also [7.1.5].

7.1.4 Detected non-conforming discontinuities shall be repaired unless they are agreed to be acceptable. Removal of weld discontinuities and repair shall be performed in accordance with an agreed procedure.

7.1.5 Frequent repairs/high NDT failure rate shall result in increased extent of NDT. The extent of NDT shall be increased in a manner such that all relevant defects are discovered in the areas of concern and that representative sampling is carried out on all welds. When the weld quality level has been restored, the extent of examination may be reduced when agreed upon.

Guidance note:

The NDT failure rate level where increased extent of NDT will apply, including how much to extend is typically given in the builders fabrication specification, and agreed with the verifier. E.g. a level of 5% or more (per week) as per NORSOK M101 is typically considered the level where extent of NDT shall be increased. For primary structure, the increase may typically be from 20% to 50%, etc. For calculation of failure rate, see definition of failure rate in [Ch.1 Sec.1 Table 7](#).

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7.1.6 After repair welding has been performed, the complete weld, (i.e. the repaired area plus minimum 100 mm on each side) shall be subjected to at least the same NDT method(s) as specified for the original weld.

SECTION 8 STRUCTURAL AND TIGHTNESS TESTING

1 General

1.1 Scope

1.1.1 This section covers requirements for structural and tightness testing of tanks of offshore units.

1.1.2 Requirements for structural and tank testing of tanks and holds of ship-shaped offshore structures shall be carried out according to ship rules [DNVGL-RU-SHIP Pt.2 Ch.4 Sec.8](#).

1.2 Definitions

1.2.1 The following terms are used:

- Structural testing is a hydrostatic test, carried out in order to demonstrate the structural adequacy of the design, and may be combined with tightness test of the tanks, provided the premises for testing the tightness of welds as stated by this section are met. Where hydrostatic testing is not practically feasible, hydro pneumatic testing may be carried out instead under provision that the test is simulating, as far as practicable, the actual loading of the tank.
- Leak testing is an air or other medium test, carried out in order to demonstrate the tightness of the structure.
- Shop primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.
- Protective coating is a coating protecting the structure from corrosion.
- Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed.
- Weathertight means that in any sea conditions water will not penetrate into the vessel.
- Fibre reinforced plastic (FRP).

1.2.2 Definition and requirements of test types are given in [Table 1](#).

Table 1 Test types (IACS UR S14)

Hydrostatic test (leak and structural)	A test by filling the space with a liquid to a specified head
Hydro pneumatic test (leak and structural)	A test wherein the space is partially filled with liquid and air pressure applied on top of the liquid surface
Hose test (leak)	A test to verify the tightness of the joint by a jet of water. The hose pressure shall be minimum 200 kN/m ² and applied at a maximum distance of 1.5 m. The nozzle inside diameter shall be minimum 12.0 mm.
Air tests (leak)	A test to verify the tightness by means of air pressure differential and leak detection solution. It includes tank air tests and joint air tests, such as a compressed air test and vacuum box test. An efficient indicating liquid shall be applied, when air is used as the test medium. The air test pressure shall be stabilized and kept not less than 15 kN/m ² above atmospheric pressure during inspection. In addition to an effective means of reading the air pressure, a safety valve, or a reliable equivalent alternative, shall be connected to the compartment being tested. The pressure holding time shall be sufficient to detect smaller leaks, which may take time to appear.
Compressed air fillet weld test (leak)	An air test of a fillet welded T-joint with a leak indicating solution applied on the fillet welds. Pressure gauges shall be arranged so that an air pressure of minimum 15 kN/m ² can be verified at each end of all passages within the portion being tested.
Vacuum box test (leak)	A box over a joint with leak indicating solution applied on the fillet or butt welds. A vacuum (20 to 26 kN/m ²) is created inside the box to detect any leaks.
Ultrasonic test (leak)	A test to verify the tightness of a sealing by means of ultrasound
Penetration test (leak)	A test to verify that no visual dye penetrant indications of potential continuous leakages exist in the boundaries of a compartment by means of low surface tension liquids (i.e. dye penetrant test)

Other test methods are subject to agreement between the contractor and the verifier.

2 Tightness testing

2.1 General

2.1.1 All tanks shall be tested for tightness. The test may be performed as a hydrostatic test using water. Alternatively, tightness may be confirmed by use of compressed air and an efficient indicating liquid.

Guidance note:

Void spaces not part of the structural integrity in the accidental limit state (ALS), may normally be omitted from this tightness test. A void space is defined as a confined space typically not intended to carry liquid cargo, ballast or fuel. Gas tightness of e.g. boundaries between cofferdams/pump room and adjacent non-hazardous area, may be subject to appropriate methods when especially agreed upon.

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2.1.2 Tightness testing shall be carried out before protective coating is applied to the welds. Shop primer may be applied prior to tightness testing.

Guidance note:

Silicate based shop primer may be applied to welds before leak testing. The layer of the primer should be maximum 50 microns. Other primers of uncertain chemical composition shall be maximum 30 microns.

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2.1.3 Leak testing shall be carried out on all weld connections of:

- tank boundaries
- boundaries to sea
- pipe penetrations
- erection joints on tank boundaries.

2.1.4 Tightness testing of continuous automatic (SAW) and multipass semi-automatic, flux cored arc welding (FCAW), weld processes in butt welds of plated boundaries may be omitted provided that visual inspections show continuous weld profile shape, free from repairs and the results of NDT show no significant defects.

2.1.5 If water is applied, the pressure shall not be less than 25 kN/m² at the top of the tank. The outside of the tank shall be dry and clean.

3 Structural testing

3.1 General

3.1.1 When structural testing is carried out at the building berth, it shall be ensured that the tank structure can resist the tank testing load.

3.1.2 When the structural testing is carried out afloat, examination of bottom and lower side structures adjacent to sea shall be made in empty tanks at the maximum practical attainable draught.

3.2 Specific requirements for structural testing of tanks

3.2.1 At least one of identical tanks shall undergo a structural test. The test shall normally be carried out by applying seawater.

Guidance note:

When agreed the structural test may be omitted for a series of sister units, or for the twin hull (e.g. the twin pontoon of column-stabilized unit) of similar arrangement, design and scantlings.

Protective coating may be applied before a structural test is carried out.

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3.2.2 Bulkheads between tanks arranged to carry different liquids shall be hydraulically tested from at least one side.

3.2.3 The tank testing pressure heights shall be taken as the nominal design pressure height (h_{op}) given in the relevant offshore object standard, and shall be tested as described in [Table 2](#).

3.2.4 The principle for how to apply the tank testing pressures is shown in [Figure 1](#) and [Figure 2](#).

Alternative 1: for tanks with maximum filling height to the top of the air pipe. Alternative 2: for tanks with maximum filling height less than to the top of the air pipe:

- a) filling with pumps with tank level alarms and automatic pump shut-off systems according to [DNVGL-OS-D101](#)
- b) filling by free flooding.

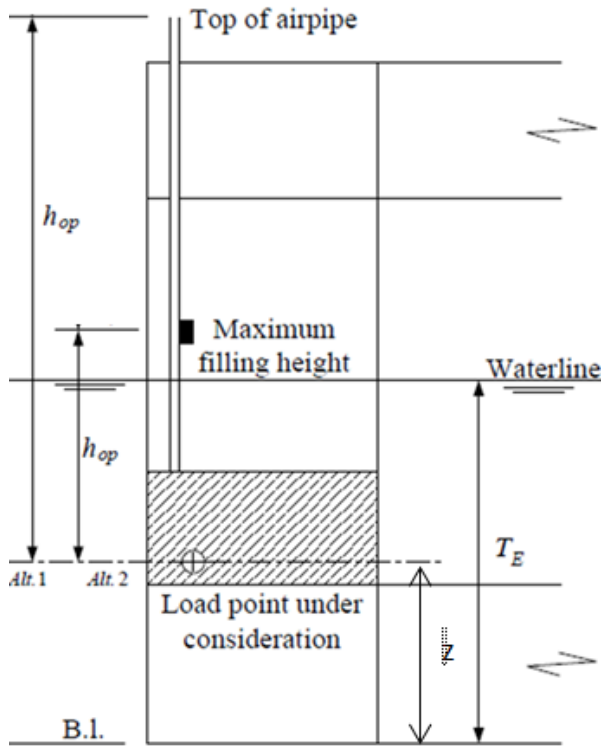


Figure 1 Description of tank testing pressure heights (1)

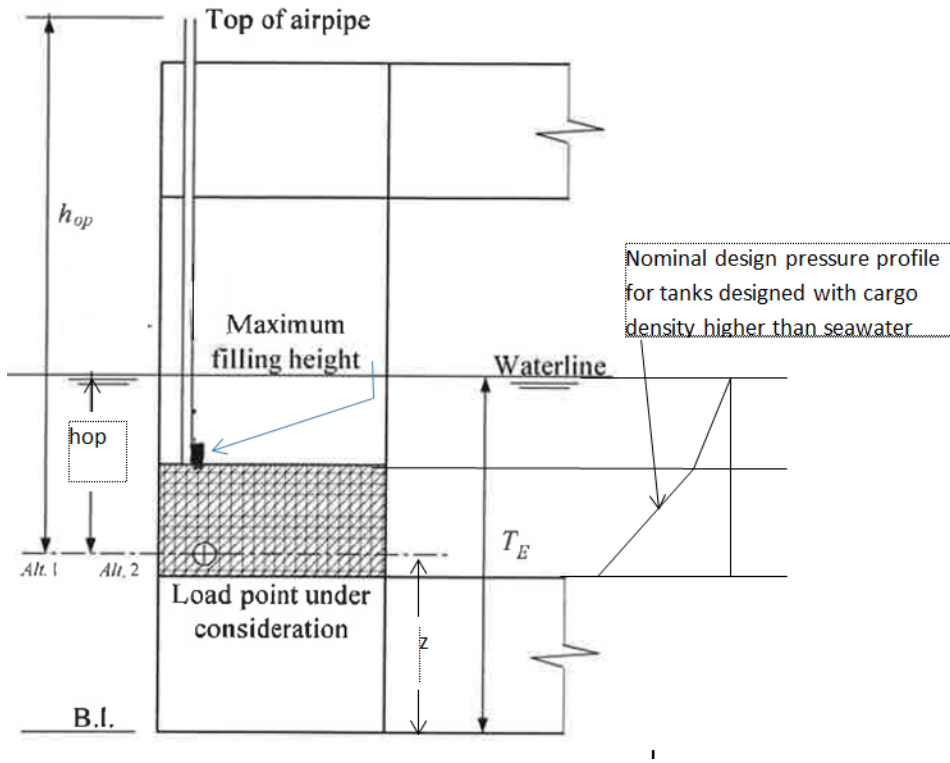


Figure 2 Description of tank testing pressure heights (2)

Table 2 Tank testing

<i>Location of tank</i>	<i>Description</i>	<i>Structural test pressure head with sea water¹⁾</i>
Tanks below the maximum design operational draught (T_E)	Alternative 1: tanks with maximum filling height to the top of the air pipe:	h_{op} : vertical distance (m) from the load point to the top of air pipe (minimum 2.4 m test pressure water head at the top of tank)
	Alternative 2 a) ²⁾ : tanks with maximum filling height less than to the top of the air pipe (tank level alarms)	h_{op} (minimum 2.4 m test pressure water head at the top of tank, but h_{op} not to be taken less than $(T_E - z)$, see Figure 1 and Figure 2)
	Alternative 2 b): tanks with maximum filling height to the top of the air pipe (free flooding)	$(T_E - z)$ (minimum 2.4 m test pressure water head at the top of tank)
Tanks above the maximum design operational draught (T_E)	Alternative 1: tanks with maximum filling height to the top of the air pipe	h_{op} : vertical distance (m) from the load point to the position of maximum filling height. (minimum 2.4 m test pressure water head at the top of tank)
	Alternative 2 a) ²⁾ : tanks with maximum filling height less than to the top of the air pipe (tank level alarms)	h_{op} : vertical distance (m) from the load point to the position of maximum filling height. (minimum 2.4 m test pressure water head at the top of tank) ³⁾
<p>1) Tanks carrying liquid cargo of density higher than sea water shall be tested as far as practicable with the nominal design pressure profile applied in the structural analysis (see examples in Figure 2). However, where un-practicable, and in agreement with the verifier, the tank may be tested applying seawater upon special consideration of e.g. the tank configuration, testing scheme of adjacent tanks, structural design analysis and workmanship. Unless accounted for in the design, the tanks shall not be tested at any load point above the nominal design pressure.</p> <p>Similarly, open tanks (e.g. open mud pits) may be structurally tested to the maximum possible filling height applying seawater.</p> <p>2) Tanks provided with alarms and automatic pump shut-off systems according to DNVGL-OS-D101.</p> <p>3) When the automatic pump shut-off level device is located below the top of tank, the minimum test pressure at top of tank shall be excluded, if not taken into account in the design, see DNVGL-RP-C103 [3.8]).</p>		

3.2.5 The pressure shall be maintained for at least 20 minutes. The filling rate shall be restricted to avoid excessive dynamic design pressure.

3.2.6 The structural test is considered successful if no significant deformations or other damages have developed during the test.

3.2.7 Closing appliances for access openings etc. in decks, bulkheads etc. which shall be watertight, shall be separately tested before installation. Structural testing of other parts outside tanks may be required.

3.2.8 If structural tests reveal weaknesses in the structure, further testing should be assessed.

SECTION 9 CORROSION PROTECTION SYSTEMS

1 Scope

This section lists requirements for surface preparation, coating application and requirements for fabrication and installation of sacrificial anodes and impressed current cathodic protection systems.

2 Requirements

2.1 General

2.1.1 Fabrication, installation and/or application of corrosion protection systems shall be carried out in conformance with recognised standards of workmanship and specifications agreed upon.

Guidance note:

For further details see [DNVGL-RP-B101](#) (for floating offshore production and storage units) or [DNV-RP-B401](#) (for permanently installed offshore units).

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2.1.2 All dedicated seawater ballast tanks shall be coated during construction in accordance with MSC.215(82): IMO PSPC.

2.2 Surface preparation and coating application

2.2.1 Procedures for in-service maintenance and repair of coating system shall be included in the overall unit's maintenance scheme.

2.2.2 Coating inspection shall be carried out by qualified coating inspectors certified to National Association of Corrosion Engineers (NACE) or FROSIO or equivalent qualification schemes.

2.2.3 The area to be coated shall be defined and if necessary limited by masking. Components and areas, which may be damaged by the pre-treatment and/or by the coating, such as anodes, shall be shielded.

2.2.4 Steel preparation

Sharp edges, fillets, corners and welds shall be rounded or smoothed by grinding (minimum radius 2 mm). Hard surface layers (e.g. resulting from flame cutting) shall be removed by grinding prior to blast cleaning to comply with ISO 8501-3 P3 grade.

2.2.5 The surfaces to be coated shall be clean and dry. Oil, grease or dirt shall be removed by washing with a suitable detergent. Soluble impurities such as salts shall be removed by washing with fresh water.

The maximum content of soluble impurities on the blasted surface as sampled using ISO 8502-6 and distilled water, shall not exceed a conductivity measured in accordance with ISO 8502-9 corresponding to a NaCl content of 50 mg/m² or lower as appropriate.

Dust, blast abrasives etc. shall be removed from the surface after blast cleaning so the particle quantity and particle size do not exceed rating 2 of ISO 8502-3.

2.2.6 Preparation of steel substrates before application of coating shall comply with ISO 8501-3, Imperfection and preparation grade P3. The minimum requirements for steel surface quality for primer coating application is ISO 8501-1 Sa 2 1/2 or equivalent for external surfaces and internal zones exposed to sea-water or otherwise intended for coating.

Roughness shall be in accordance with the recommendations from the coating manufacturer. Typical values for surface roughness is in the range 50 - 85 μm measured according to ISO 8503.

2.2.7 Final blast-cleaning and coating application shall be carried out only when the steel temperature is 3°C above the dew point and the relative humidity < 85% in order to prevent condensation of moisture on the surface.

If applying products needing moisture for curing, such as inorganic zinc silicate, higher humidity may be allowed.

2.2.8 Coating systems shall be applied in the number of coats and within the thickness ranges as stated in the agreed specification and in accordance with the manufacturer's recommendations.

Note:

Maximum thickness shall not exceed the manufacturers recommendation.

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2.2.9 Inspection, repair and touch-up shall be performed according to specifications agreed upon.

2.2.10 Primer-coated surfaces shall be inspected and be adequately cleaned and prepared before applying the next coating layer.

2.2.11 Adequate curing times in relation to temperature and humidity conditions, overcoating intervals, dry-film thickness of individual coats and total dry-film thickness, shall be within tolerances stated in the coating specification.

2.3 Fabrication and installation of sacrificial anodes

2.3.1 Fabrication and installation of anodes shall be carried out according to drawings and specifications.

2.3.2 Anode shapes and their fastening devices (studs, clamps, etc.) shall be subject to special agreement. For anodes fastened by other means than welding, attention should be paid to the establishing of good electrical contact. Resistance measurements may be required.

Welding of connections shall be carried out to agreed procedures and by qualified welders. Anodes shall if not otherwise agreed, be connected to the structure in way of local stiffening.

Any doubling plates to which anodes are welded, shall have a thickness normally not less than 10 mm, well rounded corners ($r > 20$ mm), and shall be continuously welded. Material grades of the doubling plates and anode studs or pads welded directly to main plating, shall be in accordance with the requirements given in [DNVGL-OS-C101 Ch.2 Sec.3](#) or [DNVGL-OS-C201 Ch.2 Sec.3](#). The doubling plates shall be of the material strength group as the main plate.

Guidance note:

For further details see [DNVGL-RP-B101](#) (for floating offshore production and storage units) or [DNV-RP-B401](#) (for permanently installed offshore units).

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2.4 Fabrication and installation of impressed current cathodic protection systems

2.4.1 The anodes, the cables and the signal receivers shall be furnished with relevant material certificates and be properly marked for identification.

2.4.2 The installation of the system shall be carried out according to an agreed specification.

2.4.3 All equipment, cables etc. shall be accepted for use in the respective hazardous zones, if applicable.

2.4.4 Testing of the proper functioning of the systems shall be carried out. The test method and results shall be reported.

2.4.5 Final testing and acceptance of the system shall be performed after installation.

Guidance note:

For further details see [DNVGL-RP-B101](#) (for floating offshore production and storage units).

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SECTION 10 BOLTS AND MECHANICAL FASTENING

1 Scope

This section covers requirements for bolts and mechanical fastening.

2 Bolts

2.1 Bolts and nuts

2.1.1 Bolts and nuts considered as essential for structural and operational safety shall, unless otherwise agreed, conform to [DNVGL-OS-B101 Ch.2 Sec.4 \[5\]](#) or to a recognised standard, e.g. ISO 898.

2.1.2 Major pressure retaining or structural bolts and nuts with specified min. yield stress above 490 N/mm² shall be made of alloy steel, i.e. (% Cr + % Mo + % Ni) ≥ 0.50 and supplied in the QT condition.

2.1.3 For general service, the specified tensile properties shall not exceed ISO 898 property class 10.9 when the equipment is in atmospheric environment. For equipment submerged in seawater, the tensile properties shall not exceed property class 8.8 or equivalent.

Guidance note:

For bolted joints to be part of equipment designed for sulphide stress cracking service, lower tensile properties than for property class 8.8 may be necessary in order to comply with NACE MR0175.

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3 Mechanical fastening

3.1 Contact surfaces in slip resistant connections

3.1.1 If required, contact surfaces in pre-loaded joints shall be prepared to produce the class of friction surface as required.

3.1.2 Details of surface treatments, which may be assumed to provide the stated classes of friction surface, are given in [DNVGL-OS-C101 Ch.2 Sec.11](#).

3.1.3 The class of friction surface produced by other treatment may be determined according to other international recognised standards.

3.1.4 Contact surfaces shall be cleaned and roughened by blasting with an appropriate material to produce a surface confirming the required quality. In case of coated surfaces, this treatment shall be followed immediately by the application of the appropriate coating.

3.1.5 At the time of assembly, the contact surfaces shall be free from all contaminants, such as oil, dirt or paint, except for a slip resistant coating. Burr that would prevent solid seating of the connecting parts shall be removed.

3.1.6 Oil shall be removed from the surface by using chemical cleaners, not by flame-cleaning.

3.1.7 If un-coated surfaces cannot be assembled directly after preparation of the contact surfaces, they should be freed from all thin films of rust and other loose material by brushing with a steel brush. Care should be taken not to damage or smooth the roughened surface.

CHAPTER 3 CERTIFICATION AND CLASSIFICATION

SECTION 1 CERTIFICATION, VERIFICATION AND CLASSIFICATION

1 Introduction

1.1 Objective

1.1.1 This chapter gives the additional specific requirement for fabrication and testing of offshore units and installations applicable for DNV GL classification, certification and verification services.

1.1.2 A complete description of principles, procedures, applicable class notations and technical basis for offshore classification is given by the DNV GL Rules for classification of offshore units as listed in [Table 1](#).

Table 1 DNV GL Rules for classification - Offshore units

<i>Document code</i>	<i>Title</i>
DNVGL-RU-OU-0101	Offshore drilling and support units
DNVGL-RU-OU-0102	Floating production, storage and loading units
DNVGL-RU-OU-0103	Floating LNG/LPG production, storage and loading units
DNVGL-RU-OU-0104	Self elevating units

1.2 Scope

1.2.1 The requirements are applicable for fabrication and testing of special, primary and secondary structures on the structural design scope as defined in the rules listed in [Table 1](#).

1.2.2 Upon agreement, the requirements may be applied for certification or verification of other products.

1.2.3 The scope of DNV GL classification work does not include verification of steel surface preparation and verification of coating application.

1.2.4 The scope of DNV GL classification work does not include involvement during fabrication and installation of sacrificial anodes and impressed current cathodic protection systems unless upon special agreement.

1.3 Basic requirements

1.3.1 Any deviations, exceptions and modifications to this standard and to the design codes and standards given as recognised reference codes shall be documented by the contractor and approved by DNV GL.

1.3.2 The requirements of [Ch.2](#) in this standard specify that certain aspects shall be specially considered, agreed upon, are subject to acceptance or shall be accepted, etc. These shall be subject to DNV GL approval when the standard is used for classification purposes.

1.3.3 Where [Ch.2](#) of this standards refer to verifier, this word shall be replaced by DNV GL when the standard is used for classification purposes.

1.3.4 Where [Ch.2](#) of this standard refers to type 3.1 or 3.2 certificate according to ISO 10474, this shall be replaced by DNV GL works (W) and VL certificates, respectively. However, for the BMs applied for WPQT, type 3.1 or 3.2 certificates according to ISO 10474, or material certificates issued by other recognized class societies may be accepted.

Guidance note:

Requirements for impact toughness testing of BMs are given in [DNVGL-OS-B101](#). Some welding procedures require impact testing at different material thicknesses, e.g. centre of plate. Certification of the BMs according to [DNVGL-OS-B101](#) do not necessarily require impact toughness testing of all material thickness positions relevant for welding. Where relevant, the purchaser is recommended to order steel with adequate impact toughness at relevant plate thickness positions.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.3.5 DNV GL may accept alternative solutions found to represent an overall safety level equivalent to that stated in the requirements of this standard.

2 Procedural requirements

2.1 General

General certification, documentation and survey requirements are given by the rules referred in [\[1.1.2\]](#). The following additional requirements shall be applied in conjunction with the technical requirements given in [Ch.2](#).

2.2 Information to be supplied by the purchaser

The purchaser shall supply the contractor with all information necessary to ensure that survey and verification/certification can be carried out in accordance with the appropriate requirements. This applies particularly where optional or additional conditions are specified in the relevant structural design standard (e.g. [DNVGL-OS-C101](#) to [DNVGL-OS-C106](#)).

2.3 Certification requirements

2.3.1 Organisations and personnel

The additional certification requirements for organisations and personnel are given in [Table 2](#).

Table 2 Certification requirements for organisations and personnel

<i>Object</i>	<i>Certificate type</i>	<i>Issued by</i>	<i>Certification standard*</i>	<i>Additional description</i>
Welding workshops	WWA	Society	DNVGL-CP-0352	<ul style="list-style-type: none"> – The welding workshop (including subcontractors workshops) shall be approved for the relevant fields of application e.g. for welding of hull structures/ equipment, machinery components, pressure equipment and piping systems. – Welding workshops approved by either of the former companies DNV AS or GL SE will be accepted provided the validity is maintained. For welding workshops not already approved by either of the legacies, a reasonable grace period for establishing such approval will be given. – Applies also to welding workshops of subcontractors. – Welding workshop approval (WWA) certificate is not required if welding is carried out by an approved manufacturer qualified for welding.
Welders	Welders certificates	Society	See Ch.2 Sec.3	<ul style="list-style-type: none"> – To be certified, see Ch.2 Sec.3. – For welding of hull steel structures subject to DNV GL classification, the welders shall be certified in accordance with DNVGL DNVGL-RU-SHIP Pt.2 Ch.4 Sec.3 or a standard complying with IACS UR W32. – Where certification is performed by other IACS members or independent organisations, e.g. accredited or nationally approved certification bodies, recognition of such certification will be evaluated on a case by case basis. DNV GL reserves the right, however, to require verification of welders' qualifications when deemed necessary. Such verification may include testing prior to production, extra NDT and/or welding production tests. <p>Guidance note:</p> <p>An independent organisation may be an accredited or nationally approved certification body.</p> <p style="text-align: center;">---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---</p>
Tack welders	Welders certificates	Society	See Ch.2 Sec.3	If the tack weld is not removed prior to production welding
Welding operators	-	-	See Ch.2 Sec.3	Welding operators shall be qualified but, not necessarily certified
NDT operators	NDT operator certificate	-	See Ch.2 Sec.7	Level II according to a scheme recognized by the Society, see Ch.2 Sec.7 (not required for VT operators). Operators for ultrasonic testing (UT) of austenitic steels and duplex steels shall be specially qualified/certified accordingly.
NDT supervisors	-	-	See Ch.2 Sec.7	Level III according to a scheme recognized by the Society, unless otherwise agreed

Object	Certificate type	Issued by	Certification standard*	Additional description
NDT subcontractors	AoSS	Society	DNVGL-CP-0484	Subcontractors engaged in NDT services for newbuildings shall be approved in accordance with DNVGL-CP-0484 App.B
*) Unless otherwise specified the certification standard is DNV GL rules and standards.				

2.3.2 Materials

Welding related materials shall be certified as required by [Table 3](#).

Table 3 Certification requirements for welding related materials

Object	Certificate type	Issued by	Certification standard*	Additional description
Welding consumables	TA	Society	See Sec.4	<ul style="list-style-type: none"> – Welding consumables shall be type approved by the Society. See type approval programme DNVGL-CP 0069. – If the welding consumable is not approved, a welding production test (WPT) or a welding procedure qualification test (WPQT) with one extra all-weld-metal tensile test (round specimen from the weld metal) is required from each batch of consumables, for a project specific qualification of the consumable in question.
Base materials for weld tests	MC	Society or manufacturer	See Ch.1 and Ch.2	Base materials applied for WPQT
Shop primers	TA	Society	*)	<p>Shop primer applied over areas which will subsequently be welded shall be type approved in accordance with DNVGL-CP 0109.</p> <p>Guidance note:</p> <p>Type approved shop primers are listed in the Society register of approved products and manufacturers, the approvalfinder.</p> <p>---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---</p>
*) Unless otherwise specified the certification standard is DNV GL rules.				

2.4 Documentation requirements

2.4.1 Introduction

Adequate records related to the fabrication of the structure shall be prepared to document that the structure meets the specified requirements. Such records shall be compiled in parallel with the fabrication process. Compiled records shall be systematic and fully traceable. Such records shall reflect all relevant testing, alterations, additions, corrections and revisions made during the fabrication period in order to provide information required during the in-service life of the structure.

2.4.2 Definitions

Four different documentation requirements are defined, these are:

- Qualification documentation for manufacturer (manufacturer specific): documentation to be prepared, made available, submitted when required, and stored by the manufacturer.
- Qualification documentation for contractor (contractor specific): documentation to be prepared, made available, submitted when required, and stored by the contractor.
- Product specific: documentation prepared for a defined material/product subjected to certification in accordance with the DNV GL rules and standards. The documentation shall be submitted to the Society for information or approval as specified.
- Vessel specific: documentation prepared for a defined vessel subjected to classification by the Society. The documentation shall be submitted for information or approval as specified.

For general definition of documentation types, see [DNVGL-RU-SHIP Pt.1 Ch.3 Sec.3](#).

2.4.3 Vessel specific documentation requirements

In addition to the requirement specified above, the following shall be submitted or available as required by [Table 4](#).

Table 4 Documentation requirements – vessel

<i>Object</i>	<i>Documentation type</i>	<i>Additional description</i>	<i>Info¹⁾</i>
Structural fabrication	H130 - fabrication specification	For contractors unknown to the Society	FI, L, R
	H131 - non-destructive testing (NDT) plan		AP, L
	H135 - Non-destructive testing (NDT) procedure		AP
Ship hull structure	H041 - structural inspection plan		FI, L, R
	H132 - tank testing plan		AP, L
	H133 - erection and inspection plan		FI, L
	H134 - hole and penetration plan		FI, L, R
	H140 - welding tables		FI, L, R
Structural materials	M010 - material specification, metals		FI, L, R
Welding	M060 - welding procedures (WPS)	Applicable for Vessel specific WPS not already approved. With reference to guidance note in Sec.5 [4.7.1.1] : the contractor's WPS may be transferred to and used by other subcontractors provided the welding workshop is approved by the Society and the principles of ISO 3834-2 and ISO 14731 are implemented. This shall be documented by the yard/subcontractor and accepted by the Society. For this case WPT or extended NDT may be required by the Society.	AP, L

	M061 - welding procedure qualification record (WPQR)	<p>Applicable for vessel specific WPQR not already approved.</p> <p>During qualification test welding, all welding parameters, see Sec.5 [2.2] shall be recorded for each welding pass. The report summarizing the records from the welding and the test results, i.e. a welding procedure qualification record (WPQR), shall be prepared. The WPQR shall also give the material certificate of the base and filler materials applied in the WPQR.</p> <p>When approved by the Society, all the testing (except for chemical composition analysis) shall be witnessed by the surveyor, unless otherwise agreed</p> <p>When the shop primer is not approved, see Sec.6 [3], extra testing according to DNVGL-CP-0109 is required.</p>	AP, L ²⁾ FI, L ³⁾
<p>1) FI = for information AP = for approval L = by local station R = on request. For full definition of abbreviations, see DNVGL-RU-SHIP Pt.1 Ch.3 Sec.2 Table 1.</p> <p>2) When witnessed by the Society.</p> <p>3) When approved by a recognized party.</p>			

2.4.4 Qualification documentation for contractor

In addition to the requirement specified above, the following shall be submitted or available as required by [Table 5](#).

Table 5 Qualification documentation for contractor

<i>Item</i>	<i>Documentation type</i>	<i>Additional description</i>
Hull survey for new construction according to IACS UR Z23	Records	<ul style="list-style-type: none"> — The contractor shall maintain the records according to IACS UR Z23. — The records shall be presented to the surveyor.
Quality manual	Q010	To be submitted for information
Document control procedure	Q020	To be submitted for information
pWPS	Preliminary welding procedure specification	The contractor or subcontractor shall submit to the Society a preliminary welding procedure specification (pWPS) for review prior to the WPQT. The pWPS shall give all relevant parameters as required in Ch.2 Sec.5 .
Instruments for checking welding parameters	Calibration records	All relevant instruments for checking of welding parameters e.g. temperature, ampere, volt, applied for the WPQT shall have valid calibration certificates and the adequacy of any control software shall be documented to the satisfaction of the surveyor.
Welding consumables	Welding consumables list	List of all project relevant welding consumables and auxiliaries, e.g. wire-gas combination and wire-flux combinations, the DNV GL type approved grade and the base materials for which the consumable shall be applied
	Procedure for storage and handling	The consumable manufacturer's recommendations shall be observed and procedures giving details regarding conditions in storage rooms, temperature in storage ovens and quivers, length of exposure and conditions, as applicable shall be made available to the surveyor on request
WPS	M060 - welding procedures (WPS)	<p>WPS shall be approved.</p> <p>See guidance note in Sec.5 [4.7.1.1]: The contractor's WPS may be transferred to and used by other subcontractors provided the welding workshop is approved by the Society and the principles of ISO 3834-2 and ISO 14731 are implemented. This shall be documented by the yard/subcontractor and accepted by the Society. For this case WPT or extended NDT may be required by the Society.</p> <p>Welding procedures (WPS) qualified in accordance with DNV GL rules for ships DNVGL-RU-SHIP Pt.2 Ch.4 Sec.5 is accepted for offshore construction, unless otherwise specified by the applied rules/standards or by the Society.</p>

<i>Item</i>	<i>Documentation type</i>	<i>Additional description</i>
WPQR	M061 - welding procedure qualification record (WPQR)	During qualification test welding, all welding parameters, see Sec.5 [2.2] shall be recorded for each welding pass. The report summarizing the records from the welding and the test results, i.e. a welding procedure qualification record (WPQR), shall be prepared. The WPQR shall also give the material certificate of the base and filler materials applied in the WPQT. When approved by the Society, all the testing (except for chemical composition analysis) shall be witnessed by the surveyor, unless otherwise agreed. When the shop primer is not approved, see Sec.6 [3] , extra testing according to DNVGL-CP-0109 is required.
Cold forming	Document of manufacturer recommendation for cold forming or procedure for qualification of cold forming	Unless qualified and recommended by the manufacturer, procedures for cold forming to a deformation ratio of more than 5% shall be approved. See also Ch.2 Sec.6 .
NDT procedure	H135	

2.5 Survey, inspection and testing requirements

General survey, inspection and testing requirements are given in [Ch.2](#). Specific requirements are given in [Table 6](#).

Table 6 Survey, inspection and testing requirements

<i>Survey, inspection and testing item</i>	<i>Description</i>
Contractors and QSP	Prior to commencement, contractors unknown to the Society shall demonstrate their capability to carry out fabrication and welding in line with the overall requirements of this standard.
Mechanical testing	Mechanical testing shall, unless otherwise specified or agreed, be witnessed by the surveyor
Non-destructive testing	<ul style="list-style-type: none"> – The surveyor shall be furnished with proof of the NDT operators certification on requests. – When required, the surveyor shall be given the possibility to be present during non-destructive tests. See DNVGL-CG-0051. – If deemed necessary by the Society, welds tested and accepted by the contractor shall be verified. – The Society may require verification/audit of the contractor's NDT department, NDT facilities, NDT procedures and NDT performance at any time. – The Society shall be provided with access to all relevant parts of the works, and shall be provided with necessary facilities and information to verify that NDT has been carried out in accordance with approved procedures.

<i>Survey, inspection and testing item</i>	<i>Description</i>
Welding consumables	<ul style="list-style-type: none"> — Selection of welding consumables shall follow the requirements given in DNVGL-RU-SHIP Pt.2 Ch.4 Sec.4, unless otherwise approved. — The appropriate type approval tests shall be carried out before the welding consumables are dispatched from the manufacturer. — If the necessary facilities are not available at the manufacturer's works, the testing shall be carried out at a recognized testing laboratory. — Where the Society's certification is required, all the testing (except for chemical composition analysis) shall be witnessed by the surveyor, unless otherwise agreed. — The surveyor may require further tests when deemed necessary. — All tests shall be carried out by competent personnel on machines of accepted type. See DNVGL-CP-0069 — The consumables used for WPQT should preferably be approved by the Society. Non-approved consumables may, however, be accepted for the WPQT. — The welding shop's supervisors shall ensure that only welding consumables which have been approved by the Society are being used and shall furnish proof thereof to the surveyor on request.
Testing of shop primer	Where the Society's certification is required, all testing shall be witnessed by the surveyor, unless otherwise agreed. See DNVGL-CP-0109 .
Welder tests	Welding and testing of weld assemblies for welder certification by the Society shall be performed in the presence of the Society's representative. Upon successful completion, and on client's request, the Society will certify that the welder has passed the approval testing.
Welders' list	The surveyor shall be allowed to examine the register at any time
WPQT	where WPQR shall be approved by the Society, welding and testing of weld assemblies for welding procedure qualification shall be performed in the presence of the Society's representative
WPT	As verification of the quality of produced welds WPT may be required by the surveyor
Fit-up inspections	Fit-up shall be checked for dimensional accuracy before welding by the contractor, in order to ensure compliance with the weld shapes and root openings (air gaps) according to the manufacturing documents and approved WPS. The surveyor may request to attend on a case by case basis.
Structural and tightness testing	The particular test method(s) to be used shall meet the requirements given in Ch.2 Sec.8 . Tests shall be carried out in the presence of the surveyor

CHANGES – HISTORIC

July 2017 edition

Main changes July 2017

- General

The document has been restructured and aligned with DNVGL-RU-SHIP Pt.2 Ch.4 and DNVGL-OS-B101.

- Ch.1 Sec.1 General

- Ch.1 Sec.1 [1]: Aligned with DNVGL-OS-B101 and with new style manual.
- Ch.1 Sec.1 Table 7: Added definition for verifier. Verifier replaces the term purchaser in the standard.

- Ch.2 Sec.1 General requirements

- Ch.2 Sec.1 [2.1]: Requirements for the pre-qualification of workshops shall be considered.
- Ch.2 Sec.1 [2.2]: Added requirements for heat treatment furnaces.

- Ch.2 Sec.2 Requirements for contractors

- Ch.2 Sec.2 [1.2]: Added requirements for contractors to demonstrate their capabilities.
- Ch.2 Sec.2 [3.1.3]: Added requirements for control of welding operations.

- Ch.2 Sec.3 Qualification of welders

- Ch.2 Sec.3 [3.3]: Added requirements for register of welders, validation every six months, verifiers right to examine the register.
- Ch.2 Sec.3 [3.3]: Added DNVGL RU-SHIP Pt.2 Ch.3 as recognised standard for certification of welders.

- Ch.2 Sec.4 Welding consumables

- Ch.2 Sec.4 [2.2]: New table added giving recommendations for selection of welding consumables.

- Ch.2 Sec.5 Welding procedures

- Ch.2 Sec.5 [1.2.1]: Added welding processes 122, 124, 125, 132, 138 and removed 137. Adjusted description of each method.
- Ch.2 Sec.5 [2.4.1]: List is aligned with DNVGL-RU-SHIP, removed stringer/weave.
- Ch.2 Sec.5 [2.4.1]: Added joint type, carbon equivalent, throat thickness range for fillet welds, minimum length of tack welds, type and thickness of overweldable coating.
- Ch.2 Sec.5 [3.3.2.1]: Added requirements related to cross-weld test using round specimen.
- Ch.2 Sec.5 [3.3.3.1]: Bend test mandrel diameter requirement aligned with ship rules.
- Ch.2 Sec.5 [3.3.6.1]: Impact test temperature aligned with DNVGL-RU-SHIP.
- Ch.2 Sec.5 [3.3.6.2]: Impact test acceptance criteria aligned with DNVGL-RU-SHIP.
- Ch.2 Sec.5 [3.3.7.1]: Added possibility to omit FM test in case representative testing is carried out by the steel manufacturer or the welding consumable manufacturer.
- Ch.2 Sec.5 [3.3.8]: Added test requirements for cruciform joint tensile shear test.
- Ch.2 Sec.5 [4.1.3.2]: Removed general impact test requirements at FL+5. Added requirements for impact test of one side welding, welding on thick plates and welding with high heat input.
- Ch.2 Sec.5 [4.2.3.2]: Increased number of bend tests from two to four. Reduced number of impact tests from twelve to nine.

- Ch.2 Sec.5 [4.3.3.2]: Reduced number of impact tests. Added requirement for impact test from root side for one side welding of thickness more than 20 mm. Added requirement for butt weld qualification where tensile strength is relevant for the application.
 - Ch.2 Sec.5 [4.4.3.2]: Reduced number of impact tests. Added requirement for impact test from root side for one side welding of thickness more than 20 mm. Added requirement for butt weld qualification where tensile strength is relevant for the application.
 - Ch.2 Sec.5 [4.6.1]: Added special requirements (cruciform test) for qualification of vertical-down fillet welds. Specified requirements related to overlaid shop primer.
 - Ch.2 Sec.5 [4.6.2]: Added special requirements (cruciform test) for qualification of vertical-down fillet welds.
 - Ch.2 Sec.5 [4.6.3.2]: Added requirement for butt weld qualification where tensile strength is relevant for the application.
 - Ch.2 Sec.5 [4.7.2.2]: Adjusted validity range for high heat input welding. Added validity range for high heat input welding of TM steels.
 - Ch.2 Sec.5 [4.7.2.8]: Adjusted table for validity range of welding positions, 2G will no longer cover 1G and 4G.
 - Ch.2 Sec.5 [4.7.2.9]: Added limitation, change from butt weld to fillet weld in case of automatic welding of fillet joint with shop primer.
 - Ch.2 Sec.5 [4.7.2.10]: Removed limitation, change from weaving to stringer. Removed limitation, change from spray arc or globular arc to short arc pulse, or vice versa.
 - Ch.2 Sec.5 [5]: New subsection for COD steels.
 - Ch.2 Sec.5 [6]: New subsection for steels for liquefied gas systems. Ch.2 Sec.5 [7.1.4]: Added requirements for corrosion test when required for the base material.
 - Ch.2 Sec.5 [8.1.2]: Required impact test temperature changed to -5°C below design temperature.
 - Ch.2 Sec.5 [9.2.2]: Increased the number of tensile tests from one to two, and the number of bend tests from two to four.
 - Ch.2 Sec.5 [9.3.2]: Increased the number of tensile tests from one to two, and the number of bend tests from two to four.
 - Ch.2 Sec.5 [9.5.2]: Added fracture test.
 - Ch.2 Sec.5 [9.8.2]: Text is aligned with ship rules. Group three alloys will no longer qualify group two and one alloys.
 - Ch.2 Sec.5 [9.8.9]: Added any increase in preheat temperature for heat-treatable alloys when the specified preheat is above 50°C, and change in type of cleaning method (chemical or mechanical).
- **Ch.2 Sec.6 Fabrication and tolerances**
 - Ch.2 Sec.6 [6.2.4]: Specified maximum cold forming of 20%, aligned with DNVGL-RU-SHIP minimum bending radius $2 \times t$.
 - Ch.2 Sec.6 [9.9.6]: Deleted the requirements for separate WPQT for qualification of repair welding.
 - Ch.2 Sec.6 [9.9.10]: Replaced 50 mm with IACS Rec.47.
 - Ch.2 Sec.6 [9.11.1]: Additional testing for some fabrication.
 - Ch.2 Sec.6 [9.11.3]: Verifier may require WPT when deemed necessary.
 - **Ch.2 Sec.7 Non-destructive testing of welds**
 - Ch.2 Sec.7 [3]: New requirements for NDT supervisors.
 - Ch.2 Sec.7 [7]: More specific requirements for extension of NDT.
 - **Ch.2 Sec.8 Structural and tightness testing**
 - Ch.2 Sec.8 [2]: New text, more clear requirements.
 - Ch.2 Sec.8 [3]: New text, more clear requirements.

- Ch.3 Sec.1 Certification, verification and classification
 - Ch.3 Sec.1 [2]: Procedural requirements rewritten and aligned to a large extent with DNVGL-RU-SHIP.
 - Ch.3 Sec.1 [2.3.1]: VT operators excluded from the requirements for level II.
 - Ch.3 Sec.1 [2.4]: Welders for welding of steel hull structures to DNV GL classification shall be certified to [DNVGL RU-SHIP Pt.2 Ch.4 Sec.3](#) or IACS UR W32.

July 2015 edition

Main changes July 2015

- General

The revision of this document is part of the DNV GL merger, updating the previous DNV standard into a DNV GL format including updated nomenclature and document reference numbering, e.g.:

- Main class identification **1A1** becomes **1A**.
- DNV replaced by DNV GL.
- DNV-RP-A201 to DNVGL-CG-0168. A complete listing with updated reference numbers can be found on DNV GL's homepage on internet.

To complete your understanding, observe that the entire DNV GL update process will be implemented sequentially. Hence, for some of the references, still the legacy DNV documents apply and are explicitly indicated as such, e.g.: Rules for Ships has become DNV Rules for Ships.

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping our customers make the world safer, smarter and greener.

SAFER, SMARTER, GREENER