Fabrication and testing of offshore structures
FOREWORD

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

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Any comments may be sent by e-mail to rules@dnvgl.com
CHANGES – CURRENT

General
This document supersedes DNV-OS-C401, October 2014.

Text affected by the main changes in this edition is 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.

On 12 September 2013, DNV and GL merged to form DNV GL Group. On 25 November 2013 Det Norske Veritas AS became the 100% shareholder of Germanischer Lloyd SE, the parent company of the GL Group, and on 27 November 2013 Det Norske Veritas AS, company registration number 945 748 931, changed its name to DNV GL AS. For further information, see www.dnvgl.com. Any reference in this document to "Det Norske Veritas AS", “Det Norske Veritas”, “DNV”, “GL”, “Germanischer Lloyd SE”, “GL Group” or any other legal entity name or trading name presently owned by the DNV GL Group shall therefore also be considered a reference to “DNV GL AS”.

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.

Editorial corrections
In addition to the above stated main changes, editorial corrections may have been made.
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CHAPTER 1 INTRODUCTION

SECTION 1 INTRODUCTION

1 General

1.1 Introduction

1.1.1 This standard contains requirements for fabrication and testing of offshore units described in the DNV GL rules for classification of offshore units.

1.1.2 This 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 Objective

The objectives of this standard are to:

— provide an internationally acceptable standard to ensure the minimum quality of:

1) all welding operations used in offshore fabrication, through identifying appropriate welding procedures, welder qualifications and test methods and
2) surface preparation, coating application and fabrication and installation of sacrificial anodes and impressed current systems

— specify requirements for offshore units and installations subject to DNV GL certification and classification.

1.3 Organisation of content

Ch.2 Sec.1 to Ch.2 Sec.6 give common requirements that are considered applicable to all types of offshore units.

2 Normative references

2.1 General

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 rules

The Rules for classification of offshore units given in Table 1 are referred to in this standard.

Table 1 DNV GL Rules for classification - Offshore units

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNVGL-RU-OU-0101</td>
<td>Offshore drilling and support units</td>
</tr>
<tr>
<td>DNVGL-RU-OU-0102</td>
<td>Floating production, storage and loading units</td>
</tr>
<tr>
<td>DNVGL-RU-OU-0103</td>
<td>Floating LNG/LPG production, storage and loading units</td>
</tr>
<tr>
<td>DNVGL-RU-OU-0104</td>
<td>Self elevating units</td>
</tr>
</tbody>
</table>
2.3 Offshore standards

The offshore standards given in Table 2 are referred to in this standard.

Table 2 DNV GL Offshore standards

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNVGL-OS-B101</td>
<td>Metallic materials</td>
</tr>
<tr>
<td>DNVGL-OS-C101</td>
<td>Design of offshore steel structures, general - LRFD method</td>
</tr>
<tr>
<td>DNVGL-OS-C201</td>
<td>Structural design of offshore units - WSD method</td>
</tr>
</tbody>
</table>

2.4 Other references

The other references given in Table 3 are referred to in this standard.

Table 3 Other references

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI/AWS D1.1</td>
<td>Structural Welding Code - Steel</td>
</tr>
<tr>
<td>ASME Section IX</td>
<td>ASME Boiler and Pressure Vessel Code, IX - Welding and Brazing Qualifications</td>
</tr>
<tr>
<td>ASTM G48</td>
<td>Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution</td>
</tr>
<tr>
<td>EN 287</td>
<td>Qualification test of welders - Fusion welding</td>
</tr>
<tr>
<td>EN ISO 9712</td>
<td>Non-destructive testing. Qualification and certification of NDT personnel</td>
</tr>
<tr>
<td>EN 1011</td>
<td>Welding - Recommendations for welding of metallic materials</td>
</tr>
<tr>
<td>ISO 148</td>
<td>Steel - Charpy impact test (V-notch)</td>
</tr>
<tr>
<td>ISO 898</td>
<td>Mechanical properties of fasteners made of carbon and alloy steel</td>
</tr>
<tr>
<td>ISO 3690</td>
<td>Welding and allied processes -- Determination of hydrogen content in arc weld metal</td>
</tr>
<tr>
<td>ISO 3834- series</td>
<td>Quality requirements for fusion welding of metallic materials</td>
</tr>
<tr>
<td>ISO 4063</td>
<td>Welding and allied processes -- Nomenclature of processes and reference numbers</td>
</tr>
<tr>
<td>ISO 5817</td>
<td>Welding - Fusion-welded joints in steel, nickel, and their alloys (beam welding excluded) - Quality levels for imperfections</td>
</tr>
<tr>
<td>ISO 8502</td>
<td>Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness</td>
</tr>
<tr>
<td>ISO 8503</td>
<td>Preparation of steel substrates before application of paints and related products -- Surface roughness characteristics of blast-cleaned steel substrates</td>
</tr>
<tr>
<td>ISO 9001</td>
<td>Quality management systems - Requirements</td>
</tr>
<tr>
<td>ISO 9606</td>
<td>Approval testing of welders - Fusion welding</td>
</tr>
<tr>
<td>ISO 9712</td>
<td>Non-destructive testing - Qualification and certification of NDT personnel</td>
</tr>
<tr>
<td>ISO 10042</td>
<td>Arc-welded joints in aluminium and its weldable alloys - Guidance on quality levels for imperfections</td>
</tr>
<tr>
<td>ISO 11666</td>
<td>Non-destructive testing of welds -- Ultrasonic testing -- Acceptance levels</td>
</tr>
<tr>
<td>ISO 12135</td>
<td>Metallic materials -- Unified method of test for the determination of quasistatic fracture toughness</td>
</tr>
<tr>
<td>ISO 14341</td>
<td>Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels - Classification (ISO 14341:2010)</td>
</tr>
<tr>
<td>ISO 14732</td>
<td>Welding personnel – Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials</td>
</tr>
<tr>
<td>ISO 15614-7</td>
<td>Specification and qualification of welding procedures for metallic materials -- Welding procedure test -- Part 7: Overlay welding</td>
</tr>
</tbody>
</table>
3 Informative references
The documents listed in Table 4 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>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 15653</td>
<td>Metallic materials - Method of test for the determination of quasistatic fracture toughness of welds</td>
</tr>
<tr>
<td>ISO 17635</td>
<td>Non-destructive testing of welds - General rules for metallic materials</td>
</tr>
<tr>
<td>ISO 17662</td>
<td>Welding -- Calibration, verification and validation of equipment used for welding including ancillary activities.</td>
</tr>
</tbody>
</table>

4 Definitions

4.1 Verbal forms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>shall</td>
<td>verbal form used to indicate requirements strictly to be followed in order to conform to the document</td>
</tr>
<tr>
<td>should</td>
<td>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</td>
</tr>
<tr>
<td>may</td>
<td>verbal form used to indicate a course of action permissible within the limits of the document</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accepted, acceptance, agreed, agreement, or by agreement</td>
<td>Unless otherwise indicated, accepted/agreed in writing between manufacturer/contractor and purchaser. 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.</td>
</tr>
<tr>
<td>Recognised, required, qualified</td>
<td>Unless otherwise indicated, recognised/required/qualified by the purchaser. When the standard is applied as basis for certification or classification, the terms shall mean recognised/qualified by DNV GL.</td>
</tr>
<tr>
<td>Submitted</td>
<td>Unless otherwise indicated, submitted to the purchaser. When the standard is applied as basis for certification or classification, the term shall mean submitted to DNV GL.</td>
</tr>
</tbody>
</table>
### 4.2 Terms

#### Table 7 Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>purchaser</td>
<td>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.</td>
</tr>
<tr>
<td>manufacturer</td>
<td>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</td>
</tr>
<tr>
<td>contractor</td>
<td>a party contractually appointed by the purchaser to fulfil all, or any of, the activities associated with fabrication and testing</td>
</tr>
<tr>
<td>unit</td>
<td>a general term for an offshore installation such as ship shaped, column stabilised, self-elevating, tension leg or deep draught floater</td>
</tr>
<tr>
<td>welding procedure</td>
<td>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</td>
</tr>
<tr>
<td>preliminary welding procedure specification (pWPS)</td>
<td>a tentative welding procedure specification providing required welding variables, which is assumed to be adequate by the contractor, but which has not been qualified</td>
</tr>
<tr>
<td>welding procedure specification (WPS)</td>
<td>a welding procedure specification, which has been qualified to conform with an agreed qualification scheme</td>
</tr>
<tr>
<td>welding procedure qualification test (WPQT)</td>
<td>the process of accomplishing welding and testing of a standardised test piece, as indicated in the WPS</td>
</tr>
<tr>
<td>welding procedure qualification record (WPQR)</td>
<td>a record comprising a summary of necessary data needed for the issue of a WPS</td>
</tr>
<tr>
<td>welding production test (WPT)</td>
<td>a test carried out to demonstrate that actual production welding meets the specified requirements</td>
</tr>
<tr>
<td>non-destructive testing (NDT)</td>
<td>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</td>
</tr>
<tr>
<td>sub-contractor</td>
<td>independent unit performing work under supervision by the contractor</td>
</tr>
<tr>
<td>structural testing</td>
<td>is a hydrostatic test, carried out in order to demonstrate the tightness of the tanks and the structural adequacy of the design</td>
</tr>
<tr>
<td></td>
<td>Where hydrostatic testing is not practically feasible, hydropneumatic testing may be carried out instead under provision that the test is simulating, as far as practicable, the actual loading of the tank.</td>
</tr>
<tr>
<td>leak testing</td>
<td>is an air or other medium test, carried out in order to demonstrate the tightness of the structure</td>
</tr>
<tr>
<td>hydro pneumatic testing</td>
<td>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</td>
</tr>
<tr>
<td>hose testing</td>
<td>is a water test carried out to demonstrate tightness of structural items</td>
</tr>
<tr>
<td>shop primer</td>
<td>is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication</td>
</tr>
<tr>
<td>protective coating</td>
<td>is a final coating protecting the structure from corrosion</td>
</tr>
<tr>
<td>watertight</td>
<td>means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed</td>
</tr>
<tr>
<td>weathertight</td>
<td>means that in any sea conditions water will not penetrate into the ship</td>
</tr>
</tbody>
</table>
4.3 Abbreviations

The abbreviations given in Table 8 are used in this standard.

Table 8 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>In full</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.C.</td>
<td>alternating current</td>
</tr>
<tr>
<td>ALS</td>
<td>accidental limit state</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing of Materials</td>
</tr>
<tr>
<td>AWS</td>
<td>American Welding Society</td>
</tr>
<tr>
<td>BM</td>
<td>base material</td>
</tr>
<tr>
<td>CE</td>
<td>carbon equivalent</td>
</tr>
<tr>
<td>C-Mn</td>
<td>carbon manganese</td>
</tr>
<tr>
<td>CTOD</td>
<td>crack tip opening displacement</td>
</tr>
<tr>
<td>DAC</td>
<td>distance amplitude curve</td>
</tr>
<tr>
<td>D.C.</td>
<td>direct current</td>
</tr>
<tr>
<td>ECA</td>
<td>engineering critical assessment</td>
</tr>
<tr>
<td>EN</td>
<td>European de Normalisation</td>
</tr>
<tr>
<td>FCAW</td>
<td>flux cored arc welding</td>
</tr>
<tr>
<td>FL</td>
<td>fusion line</td>
</tr>
<tr>
<td>FM</td>
<td>fracture mechanics</td>
</tr>
<tr>
<td>GMAW</td>
<td>gas metal arc welding</td>
</tr>
<tr>
<td>GTAW</td>
<td>gas tungsten arc welding</td>
</tr>
<tr>
<td>HAZ</td>
<td>heat affected zone</td>
</tr>
<tr>
<td>IACS</td>
<td>International Association of Classification Societies</td>
</tr>
<tr>
<td>IIW</td>
<td>International Institute of Welding</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation for Standardisation</td>
</tr>
<tr>
<td>MAG</td>
<td>metal active gas (welding)</td>
</tr>
<tr>
<td>MIG</td>
<td>metal inert gas (welding)</td>
</tr>
<tr>
<td>MT</td>
<td>magnetic particle testing</td>
</tr>
<tr>
<td>NACE</td>
<td>National Association of Corrosion Engineers</td>
</tr>
<tr>
<td>NDT</td>
<td>non-destructive testing</td>
</tr>
<tr>
<td>PT</td>
<td>penetrant testing</td>
</tr>
<tr>
<td>PWHT</td>
<td>post weld heat treatment</td>
</tr>
<tr>
<td>pWPS</td>
<td>preliminary welding procedure specification</td>
</tr>
<tr>
<td>RP</td>
<td>recommended practice</td>
</tr>
<tr>
<td>RT</td>
<td>radiographic testing</td>
</tr>
<tr>
<td>SAW</td>
<td>submerged arc welding</td>
</tr>
<tr>
<td>SMAW</td>
<td>shielded metal arc welding</td>
</tr>
<tr>
<td>SMYS</td>
<td>specified minimum yield stress</td>
</tr>
<tr>
<td>TIG</td>
<td>tungsten inert gas (welding)</td>
</tr>
<tr>
<td>UT</td>
<td>ultrasonic testing</td>
</tr>
<tr>
<td>WM</td>
<td>weld metal or deposit</td>
</tr>
<tr>
<td>WPQR</td>
<td>welding procedure qualification records</td>
</tr>
<tr>
<td>WPQT</td>
<td>welding procedure qualification test</td>
</tr>
<tr>
<td>WPS</td>
<td>welding procedure specification</td>
</tr>
</tbody>
</table>
4.4 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
- \( D_1 \) = outside diameter of the greater tube (can)
- \( D_2 \) = 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
- \( L_0 \) = 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
- \( r_s \) = 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

4.5 Greek symbols

The following Greek symbols are used:

- \( \alpha \) = tubular joint angle
- \( \delta \) = measure of deformation compared to theoretical geometry
- \( \lambda_i \) = length of area with acceptable location of the fatigue pre-crack
- \( \nu \) = Poisson's ratio
- \( \sigma_1 \) = largest compressive principal membrane stress
- \( \sigma_2 \) = principal membrane stress normal to \( \sigma_1 \)
- \( \psi \) = ratio between principal stresses.
CHAPTER 2 TECHNICAL PROVISIONS

SECTION 1 WELDING PROCEDURES AND QUALIFICATION OF WELDERS

1 Introduction

1.1 General

1.1.1 This section specifies requirements for welding procedure specifications (WPS) and welding procedure qualification tests (WPQT) for C-Mn steel and low alloy steel, aluminium, austenitic stainless steels, ferritic-austenitic (duplex) stainless steels and copper alloys as well as qualification of welders.

1.1.2 Welding procedures for overlay- / clad welding shall, unless otherwise agreed be qualified according to ISO 15614-7, AWS D1.1 or ASME IX.

1.1.3 Welding procedures for materials not covered by this section shall be qualified in accordance with an agreed recognized standard and/or a recognized practice.

1.2 Wide gap welding

When the gap is more than 10 mm, wide gap welding / buttering of the weld groove shall be qualified by a separate WPQT. In the WPQT the largest gap in production shall be used. This applies when the essential variables for the buttering process are different from the essential variables for the process used for subsequent completion of the joint and/or the thickness of the buttering exceed 8 mm.

The buttered area shall be 100% tested with MT (ferromagnetic materials) or PT (non-magnetic materials) before the filling of the groove starts. No surface linear indications are accepted. For typical butt- and fillet weld plate edge preparation repairs, reference is made to IACS Rec. No.47 “Shipbuilding and Repair Quality Standard, part A”.

1.3 Welding processes

Welding may 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)
- 114 self-shielded tubular-cored arc welding
- 121 submerged arc welding
- 122 submerged arc welding with strip electrode
- 131 metal inert gas welding, (MIG) welding
- 135 metal active gas welding, (MAG) welding
- 136 tubular-cored metal arc welding with active gas shield
- 137 tubular-cored metal arc welding with inert gas shield
- 141 gas tungsten arc welding, (GTAW)
- 15 plasma arc welding.

Other processes shall be specially agreed.

2 Welding procedures

2.1 General

A welding procedure specification shall as a minimum contain the following information as relevant for the welding operation:

- identification of contractor or subcontractor performing the qualification welding
— material: standard, grade, delivery condition (AR, N, NR, TM, QT) and modification
— identification of the WPS
— nominal thickness or diameter range (dimensions)
— reference to welding procedure qualification record (WPQR)
— welding process and for multiple processes; the order of processes used manual, partly-mechanised, mechanised and automatic welding, weld thickness for each process, wire feed speed
— joint or groove design with tolerances of angles, root face, root gap. Backing and backing material and weld run sequence
— shielding gas flow rate and nozzle diameter
— welding position(s) and direction of progression
— purging gas type and flow rate
— welding consumables: trade name, electrode or wire diameter, shielding gas, flux and recognised classification
— tungsten electrode diameter and designation
— welding sequence: number and order of passes or layers
— electrical parameters: voltage range, current range, polarity (D.C.+, D.C.-), or (A.C.), pulse welding details (machine settings and/or programme selection)
— travel speed ranges
— heat input ranges for at least root, fill and cap passes
— method and min. preheat and maximum interpass temperature
— stringer/weave beads. Sequence of deposition of different consumables. Number of passes to be completed before cooling to below preheat temperature
— post weld heat treatment parameters
— arc characteristics: spray arc, globular arc, pulsating arc or short circuiting transfer (dip)
— details on cleaning processes employed and restrictions if any.

Specific for the SAW/121 welding process:
— number and configuration of wire electrodes
— flux, designation, manufacturer and trade name
— contact tip - work piece distance.

Specific for the GMAW/135 welding process:
— shielding and backing gas flow rate
— contact tip - work piece distance.

Specific for the GTAW/141 welding process:
— shielding and backing gas flow rate
— nozzle diameter
— diameter and codification of tungsten electrode
— hot or cold wire.
— type of weld head and gas lens.

2.2 Preliminary welding procedure specification
A preliminary welding procedure specification (pWPS) shall be prepared and agreed upon for each new welding procedure qualification test (WPQT). The pWPS shall contain the relevant information required for the WPS, see [2.1]. 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.
2.3 Welding procedure qualification test

2.3.1 All relevant instruments for checking of welding parameters (e.g. temperature, ampere, volt, gas flow) shall have valid calibration certificates and the adequacy of any control software (weld machine) shall be documented. All welding equipment used at the qualification test shall be calibrated and validated in accordance with ISO 17662.

2.3.2 Qualification welding shall be performed under general conditions representative of the actual working environment for the workshop or site, where the production welding will be performed (see also [3.6]).

2.3.3 The test results shall meet the specified minimum requirements given in this standard in order to be valid for qualification of a WPS.

2.3.4 If the Welding Procedure qualification test (WPQT) fails to comply with any of the requirements for NDT, one extra WPQT shall 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.

2.3.5 If the results of any destructive test, other than impact 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 shall be welded using the same pWPS. If either of these additional tests does not comply with the relevant requirements, the pWPS shall be regarded as not capable of complying with the requirements without modification.

2.4 Welding procedure qualification record (WPQR)

The WPQR shall be a record of the materials, consumables, parameters and any heat treatment used during qualification welding and 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 welding parameters recorded in relevant positions for each pass.

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

2.5 Welding procedure specifications (WPS)

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

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

a) Review of a welding procedure qualification test record (WPQR) corresponding to the welding procedure specification in question. The welding procedure test (WPQT) on which the WPQR is based shall be witnessed by a recognised party.

b) The welding procedure specification is compiled on basis of other agreed welding procedure specifications

2.5.3 One or more WPSs may be prepared based on the data of one or more agreed 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.

2.5.4 For multi-process procedures the welding procedure qualification test may be carried out with separate tests for each welding process. It is also possible to make the test as a multi-process procedure test. The qualification of such a test is only valid for the process sequence carried out during the multi-process procedure test.
3 Welding procedure qualification, C-Mn steel and low alloy steel

3.1 Butt welds on plates

3.1.1 The test assembly may consist of two plates welded together. For steel plates impact tested in the longitudinal direction (KVL-tested, see Figure 1), 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 (KVT-tested, see Figure 1), 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 that simulates the heat transfer during the production welding. For manual or semi-automatic welding, a test assembly according to Figure 1 shall be carried out with:

![Figure 1 Test assembly for butt welds on plates](image)

For automatic welding, the dimensions shall be:

\[
\begin{align*}
I_{\text{min}} &= 400 \text{ mm} \\
L_{\text{min}} &= 1000 \text{ mm}
\end{align*}
\]

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.

3.1.2 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 follows:

- 100% Visual testing (VT)
- 100% Radiographic testing (RT) or Ultrasonic testing (UT)
- 100% Surface crack detection (Penetrant testing (PT) or Magnetic particle testing (MT)).

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

For ultrasonic testing, Level 2 of ISO 11666 is considered equal to Level B of ISO 5817.

3.1.3 The following mechanical tests are required from each assembly (see [6.3.2]):

— 2 tensile tests (flat specimen transverse to the weld)
— 2 root and 2 face bend specimens shall be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested
— 12 Charpy V-notch tests with the notch location as given in [3.1.6]
— 1 macro-section test (metallographic examination + hardness measurements).

3.1.4 Specimens for transverse tensile testing shall be in accordance with [8.2], type B. Location of fracture (WM or BM), and tensile strength shall be reported.

Acceptance criteria: The obtained tensile strength shall not be below the specified minimum tensile strength for the steel grade in question.

Figure 2  Sampling of test specimens in plates
Transverse side bend, root bend and face bend specimens shall be machined to the dimensions shown in [8.3].

For a mixed or heterogeneous butt joint longitudinal bend test specimens may replace transverse bend test specimens.

The test specimens shall be bent on a mandrel with diameter $4 \times t$, where $t$ is the thickness of the specimen, except for extra high strength steel grades VL 550, VL 620 and VL 690 where the diameter shall be $5 \times t$.

The bending angle shall be at least $180^\circ$.

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

The macro-section shall include about 10 mm of unaffected base material and shall be prepared and etched on one side to clearly reveal the fusion line and the HAZ. The macro-section shall be cut at the weld start of the test piece.

Acceptance criteria: Cracks and lack of fusion are not accepted. Other defects shall follow Level B of ISO 5817. The welded joints shall have a regular profile with smooth transitions to the base materials and without significant or excessive reinforcement. Acceptance criteria for weld profile according to IACS Rec. No. 47.

The hardness testing shall be in accordance with ISO 6507-1 or equivalent, and is only required for grades with specified minimum yield stress 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 approximately 1 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). For HAZ the first indentation shall be placed as close to the fusion line as possible. For double sided welds, for fillet and T-butt welds one additional row of indentations shall be made through the root area.

Acceptance criteria:

For material grades up to and including VL 420, a maximum hardness limit of 350 HV10 shall be met. For VL 460, VL 500, VL 550, VL 620 and VL 690 grades a maximum hardness limit shall be 420 HV10. For single run fillet welds a maximum hardness limit of 380 HV10 shall be met.

The Charpy V-notch specimens shall be machined in accordance with the requirements given in DNVGL-OS-B101. Four sets of three specimens each shall be sampled 2 mm below the surface of the parent material and transverse to the weld. 12 Charpy V-notch specimens shall be localised in the welded joint as follows:

- 3 specimens with the notch along the weld metal centreline (WM)
- 3 specimens with the notch in the fusion line (FL)
- 3 specimens with the notch in the HAZ, 2 mm from the fusion line (FL+2)
- 3 specimens with the notch in the HAZ, 5 mm from the fusion line (FL+5)

HAZ impact test specimens are normally not required for aluminium and for austenitic stainless steels with service temperature above -105°C.

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

The V-notch shall be perpendicular to the plate surface. For plate thickness $t > 50$ mm two additional sets of specimens shall be taken from the root area: one with the notch in the centre of the weld and one with the notch in the fusion line.

Where multi-process welding is qualified in a single test piece, impact test specimens shall be taken from the weld metal and HAZ that include each 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 metal joints and/or joints between cast or forged and rolled materials, impact tests shall be carried out on test specimens with notch in fusion line, 2 mm from fusion line and 5 mm from fusion line in each parent material.
**Acceptance criteria:**

Unless otherwise specified below, the Charpy V-notch test temperature shall be the same as required for qualification of the base material (ref. DNVGL-OS-B101). The obtained minimum and average value for absorbed energy in WM, FL and HAZ shall meet the transverse direction requirements for the base material.

For weldable C- and C-Mn hull steel castings and forgings, the Charpy V-notch test temperature and the average value for absorbed energy in WM FL and HAZ shall be the same as required for the base material. Grade VL A and VL B shall meet an impact toughness requirement of 27J tested at +20°C and 0°C respectively.

The requirements given by the DNV Rules for ships Pt.2 Ch.3 Sec.5 may be applied as an alternative.

For pressure vessels and production/drilling plants related equipment, structures and systems, the Charpy V-notch test temperature and the obtained values for absorbed energy in weld metal, fusion line and HAZ shall be the same as required for the base material.

For grades of improved weldability (see DNVGL-OS-B101), the Charpy V-notch test temperature and the average value for absorbed energy in weld metal, fusion line and HAZ shall be the same as required for the base material of the comparable normal weldability grade in transverse direction.

**3.1.9** In the case of reduced Charpy V-notch test specimens (10 mm × 7.5 mm and 10 mm × 5 mm), the impact energy values to be obtained shall satisfy the requirements in Table 1.

### Table 1 Impact energy requirement for sub-size specimens

<table>
<thead>
<tr>
<th>Dimensions of Charpy V-notch test specimen</th>
<th>Impact energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 × 10 mm</td>
<td>KV</td>
</tr>
<tr>
<td>10 × 7.5 mm</td>
<td>5/6 KV</td>
</tr>
<tr>
<td>10 × 5 mm</td>
<td>2/3 KV</td>
</tr>
</tbody>
</table>

**3.1.10** 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.

**3.1.11** 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, and of these, not more than one shall be less than 70% of the required average value.

**3.1.12** When a butt weld is made between two plates of different grades, the test temperature and achieved impact energy shall comply with the minimum specified requirements for the lower steel grade.

In the same way, the tensile strength to be obtained on the welded assembly shall be in agreement with the requirements relating to the plate steel having the lower strength.

As an example the test temperature, impact energy and tensile strength for the butt welded joints given in Figure 3 are those required for the plate of grade D in the left assembly and for the plate of grade E in the right assembly.
3.2 Butt welds in pipes

3.2.1 The test assembly shall be in accordance with Figure 4.

```
Figure 4 Test assembly for butt welds in pipes
```

\[ a = \text{minimum value 150 mm} \]
\[ D = \text{outside diameter} \]

3.2.2 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 follows:

- 100% Visual testing (VT)
- 100% Radiographic testing (RT) or Ultrasonic testing (UT)
- 100% Surface imperfection detection (Penetrant testing (PT) or Magnetic particle testing (MT)).

Acceptance criteria: The soundness of the weld shall comply, unless otherwise specified, with EN ISO 5817 quality level B for ferrous materials. Regarding use of EN ISO 5817 for RT, UT, MT and PT, EN ISO 17635 shall be followed.
3.2.3 The following mechanical tests are required from each assembly (see Figure 5):

— 2 tensile tests (flat specimen transverse to the weld)
— 1 root and 1 face bend tests when \( t \leq 20 \text{ mm} \) and 2 side bend tests when \( t > 20 \text{ mm} \)
— 12 Charpy V-notch tests with the notch location as given in [3.1.8]
— macrosection test (metallographic examination + hardness measurements).

![Figure 5 Sampling of test specimens in pipes](image)

3.2.4 The results of mechanical testing shall comply with the relevant requirements given in [3.1].

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

3.3.1 WPQT’s 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 6).

3.3.2 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 follows:

100% Visual testing (VT)
100% Ultrasonic testing (UT)
100% Surface imperfection detection (Penetrant test (PT) or Magnetic particle testing (MT)).

Acceptance criteria: The soundness of the weld shall comply, unless otherwise specified, with EN ISO 5817 quality level B for ferrous materials. Regarding use of EN ISO 5817 for RT, UT, MT and PT, EN ISO 17635 shall be followed.
3.3.3 The following mechanical tests are required from each assembly (see Figure 7):

— 12 Charpy V-notch tests with the notch location as given in [3.1.8]
— 1 macrosection test (metallographic examination + hardness measurements).

The results of mechanical testing shall comply with the relevant requirements given in [3.1].

Figure 6 Test assembly for full penetration T-joints

Figure 7 Sampling of test specimens on full penetration T-joints

3.4 Tubular joints/ Branch connections

3.4.1 The test assembly shall be in accordance with Figure 8.

3.4.2 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 follows:

100% Visual testing (VT)
100% Ultrasonic testing (UT)
100% surface Imperfection detection (Penetrant testing (PT) or Magnetic particle testing (MT)).

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

![Figure 8 Test assembly for tubular joints/branch connections](image)

3.4.3 The following mechanical tests are required from each assembly (see Figure 8):

- 12 Charpy V-notch tests sampled at 9 o’clock in the branch pipe and with the notch location as given in [3.1.8]
- 2 macro section tests (metallographic examination + hardness measurements) at 12 and 6 o’clock.

3.4.4 The results of mechanical testing shall comply with the relevant requirements given in [3.1].

3.4.5 Restrictions and testing for joint configuration involving acute angles (less than 15°) should be specified.

Guidance note:
AWS D1.1 is a good reference for structural welds.

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

3.5 Fillet welds

3.5.1 For plate fillet welds, the two plates are assembled and positioned edgewise so as to constitute a tee-assembly with no clearance. As far as possible the plates shall be of a sufficient size to ensure a reasonable heat distribution.

For plate fillet welds the test assembly shall be as defined in Figure 9.
Figure 9  Test assembly for fillet welds

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

\[ L_{\text{min}} = 350 \text{ mm} \]

For automatic welding the length shall be:

\[ L_{\text{min}} = 1000 \text{ mm} \]

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 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.

3.5.2 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 follows:

100% Visual testing (VT)
100% Surface imperfection detection (Penetrant testing (PT) or magnetic particle testing (MT)).

Acceptance criteria: The soundness of the weld shall comply, unless otherwise specified, with EN ISO 5817 quality level B for ferrous materials. Regarding use of EN ISO 5817 for MT and PT, EN ISO 17635 shall be followed.

3.5.3 The following destructive tests shall be performed:

— 2 macro section tests (metallographic examination, hardness measurements). One of the macrosections shall be taken at the marked position of the stop/restart. For hardness testing, see [3.1]
— One fracture test. Shall be performed by folding the upright plate onto the through plate. Evaluation is to concentrate on cracks, porosities and pores, inclusions, lack of fusion and incomplete penetration. Imperfections that are detected shall be assessed in accordance with ISO 5817 quality level B.

3.6 Validity of a WPS

3.6.1 The validity of an approved WPS shall be restricted to the contractor or subcontractor performing the qualification or receiving the approval. It is a prerequisite that the workshops/yards belonging to the contractor and/or subcontractor are under the same technical management and working in accordance with the same QA – program and – procedures.
Guidance note:
Contractors WPS’es may be transferred to and used by subcontractors provided the principles of ISO 3834-2 and ISO 14731 are implemented and documented. For this case, additional Welding Production Tests (WPT) and/or extended NDT may be required as found necessary.

---end-of-guidance-note---

3.6.2 Qualification of a welding procedure remains valid provided the parameters are kept within the qualified ranges during production welding. The qualified ranges are given in [3.6.1]. 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.

Guidance note:
Note that a qualified procedure is always based on a welding procedure test (WPQT) and that acceptance of a WPS based on a welding procedure test is only required for the type of services listed in [6.1].

---end-of-guidance-note---

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

Base material
The following changes shall lead to a new qualification:

a) In general, significant change of material properties which will obviously affect the weldability and mechanical properties.

Guidance note:
For materials with C ≥ 0.22 and/or CE ≥ 0.45 the weld procedure qualification test on which the WPS is based, is to be qualified on a base material having a CE not less than 0.03 of the material to be welded.

---end-of-guidance-note---

i) A change from wrought (rolled, forged) steel to cast steel or vice versa
ii) A change from delivery condition quenched and tempered (QT) to any other delivery condition or vice versa; applicable for forgings, castings, and steel plates of grade D40, E40, F32, F40 and extra high strength steels.
iii) A change from delivery condition thermo-mechanical rolling (TM) to any other delivery conditions, but not vice versa. Change from delivery condition TM to other delivery conditions may, however, be accepted provided the carbon equivalent of the qualified TM-steel is same or higher than the steel to be covered.
iv) A change from "steel with improved weldability" (ref. 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.

b) Additional considerations for strength levels and toughness grades for rolled steel plates:

i) For normal and high strength steels (ref. DNVGL-OS-B101), welding procedures are considered applicable to the same and two lower strength levels as that tested (the DNV GL special grade 27S is not counted, e.g. qualification of A36 may qualify welding of grades A, A27S and A32).
ii) For extra high strength steels, welding procedures are considered applicable to the same and one lower strength level as that tested (e.g. qualification of A500 will also qualify grade A460).
iii) For high heat input welding processes (> 5 kJ/mm), the qualification is applicable to the same and one lower strength level as that tested.
iv) 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 E will also qualify grades A, B and D).

c) Additional considerations for strength levels and toughness grades for castings and forgings:

i) A change to a grade of higher specified strength.
ii) A change to higher specified toughness requirements (that is; lower impact toughness temperature requirements or higher impact toughness value requirements).
**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 T-butt joint in plate:
   The thickness of the prepared plate (abutting member).

c) For a fillet weld:
   The thickness of both plates independently.

d) For a set-on tubular joint/branch connection:
   The thickness of the brace/branch pipe.

e) For a set-in or set-through tubular joint/branch connection:
   The thickness of the main pipe.

The requirements for qualified thickness range for butt welds and full penetration T, Y and K-joints shall be as given in Table 2.

**Table 2 Qualified thickness range**

<table>
<thead>
<tr>
<th>Thickness t in mm of test piece</th>
<th>Qualification range for single run or single run from both sides for multi-run welding and all fillet(^{5,6}) welds</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 &lt; t \leq 12</td>
<td>0.7 \times t to 1.1 \times t 3 mm to 2 \times t</td>
</tr>
<tr>
<td>12 &lt; t \leq 100(^{7})</td>
<td>0.7 \times t to 1.1 \times t 0.5 \times t to 2 \times t (max. 150 mm)</td>
</tr>
<tr>
<td>t &gt; 100</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

1) The maximum thickness qualified for vertical downward welding is 1.0 \times t
2) For high heat input processes over 5 kJ/mm, the upper limit of range of acceptance is 1.0 \times t
3) For multiprocess procedures, the recorded thickness contribution of each process shall be used as a basis for the range of acceptance for the individual welding process
4) The acceptance 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 heat affected zone are found to be within 25 HV of the maximum permitted, as stated in [3.1.7].
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 welds between materials of dissimilar thickness, the qualified 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. Qualified range for abutting member is 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.
7) WPQT on plates of thickness 25 mm to 50 mm will qualify WPS for max. 50 mm, unless Charpy V-notch impact test is carried out for the root in line with [3.1.8]. Alternatively, the WPS may be qualified up to 2 \times t by WPT with Charpy V-notch tests from the root on a plate of thickness >50 mm.

In addition to the requirements of Table 2, the range of acceptance 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 welds (i.e. a = t, see Table 2).

**Diameter of pipes and tubular joints/branch connections**

The qualification of a welding procedure test on diameter D shall include qualification for diameters in the following ranges as given in Table 3.

**Table 3 Qualified range for pipe and branch connection diameters**

<table>
<thead>
<tr>
<th>Diameter of the test piece D (mm)(^{1,2})</th>
<th>Qualification range</th>
</tr>
</thead>
<tbody>
<tr>
<td>D \leq 25</td>
<td>0.5 \times D to 2 \times D</td>
</tr>
<tr>
<td>D &gt; 25</td>
<td>\geq 0.5 \times D and plates</td>
</tr>
</tbody>
</table>

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.
Angle of tubular joints/branch connection

A WPQT carried out on a tubular joint/branch connection with angle $\alpha$ shall qualify all tubular joint/branch connection angles in the range of $\alpha$ to 90°.

Welding consumables

The following changes shall lead to a new qualification:

- any change in consumable classification e.g. AWS Classification ER 70S-X, ISO classification ISO 14341-A-G 3Si1.
- change of consumable brand when impact testing for WPQT is required at temperatures below −20°C
- any significant change of mixture or composition (see DNV Rules for ships, Pt. 2 Ch. 3 Sec. 4 Table A8), flow rate, filling time and filling volume for shielding and purging gases.

Welding positions

The following changes shall lead to a new qualification.

- Change from one principal welding position (see Figure 10, Figure 11 and Figure 12) to another, unless complying with Table 4.

---

Figure 10  Plate test positions
Figure 11  Pipe test positions

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 T-, Y- or K-joint to butt joint but not vice versa
— change from butt joint in plates to butt joints in pipes with outside diameter less than 500 mm
— any change of groove dimensions outside the following limits, unless otherwise agreed:
  — butt welds, groove angle $\geq 40^\circ$; $-5^\circ$ and $+10^\circ$
  — butt welds, groove angle $35^\circ$ to $40^\circ$; minimum $35^\circ$ and $+10^\circ$
  — butt welds, groove angle $<35^\circ$; $-0^\circ$ and $+10^\circ$
  — butt welds, root gap, manual or semi-automatic welding without backing; $\pm 2$ mm, standard 3 mm, maximum 5 mm
  — butt welds, root gap, automatic welding without backing; $-0.8$ mm and $+1.2$ mm, standard 0.8 mm, maximum 2 mm.
  — butt welds, root gap, with backing; $-2$ mm, $+6$ mm, standard 3-9 mm, maximum 16 mm (see also [1.2]).
  — fillet welds and remedial welding, see IACS Recommendation No. 47.

Welding condition
The following changes shall lead to a new qualification:

— any change of welding process
— change from weaving to stringer bead technique or vice versa (weaving of less than three times electrode diameter is considered stringer)
— change from multi-pass welding to one-pass welding
— change in welding current from A.C. to D.C., or vice versa, or change of polarity. If recommended by the consumable manufacturer particular exemption may be given for SMAW in change from A.C. to D.C..
— change in metal powder or wire addition beyond ±10%.
— change from spray arc or globular arc to short arc pulse, or vice versa
— any increase in interpass temperature above maximum recorded for WPQT
— change in heat input beyond ±25%. For high heat input welding (>5 kJ/mm) and/or for material with specified yield stress equal to or above 420 MPa the change shall not be more than ±10%. 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 welding procedure qualification test. The qualified range (±25% or ±10% as relevant) is based on the calculated average value.

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

— any decrease in preheating temperature
— change of post weld heat treatment parameters except for holding time, which may be adjusted as a function of thickness.

Figure 12 Positions of test plate for fillet welds

Table 4 Qualified principal positions for butt welds and fillet welds, steel

<table>
<thead>
<tr>
<th>Test weld Joint configuration 1)2)</th>
<th>Principal positions 3)</th>
<th>Qualifed positions 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Butt welds Plates</td>
<td>Fillet welds Plates or Pipes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butt welds in plates</td>
<td>2G + 3G</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>1G</td>
<td>1G</td>
</tr>
<tr>
<td></td>
<td>2G</td>
<td>1G, 2G, 4G</td>
</tr>
<tr>
<td></td>
<td>3G</td>
<td>3G</td>
</tr>
<tr>
<td></td>
<td>4G</td>
<td>1G, 4G</td>
</tr>
<tr>
<td>Butt welds in pipes</td>
<td>2G + 5G = 6G</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>1G</td>
<td>1G</td>
</tr>
<tr>
<td></td>
<td>2G</td>
<td>1G, 2G, 4G</td>
</tr>
<tr>
<td></td>
<td>5G</td>
<td>All</td>
</tr>
<tr>
<td>Fillet welds</td>
<td>2F + 3F</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>1F</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>2F</td>
<td>1F</td>
</tr>
<tr>
<td></td>
<td>3F</td>
<td>1F, 2F, 4F</td>
</tr>
<tr>
<td></td>
<td>4F</td>
<td>1F, 2F, 4F</td>
</tr>
<tr>
<td></td>
<td>5F</td>
<td>1F, 2F, 4F</td>
</tr>
</tbody>
</table>

1) Pipes with D > 500 mm are considered equivalent to plates (apply only to the can in tubular joints)
2) Tubular joints/branch connections shall be qualified separately
3) The vertical downwards position shall be qualified separately
3.7 Fracture mechanics (FM) testing

3.7.1 Requirements to FM testing are given in DNVGL-OS-C101 or DNVGL-OS-C201.

3.7.2 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.

3.7.3 The FM tests shall be carried out on a full penetration butt-weld with K- or single V-preparation. The back of the K and one of the legs of the single V (on which the FM test shall be carried out) shall be perpendicular to the plane of the plate. Tests on either of these weld bevel preparations qualify for all types of bevel preparations.

3.7.4 The test weld shall be welded with a heat input representing the maximum heat input used in the fabrication. The test weld shall be made on a plate with a thickness not smaller than 90% of the maximum plate or wall thickness for which the welding procedure shall apply. The test weld also qualifies for plate thicknesses down to 50% of the test weld plate thickness.

3.7.5 On each test weld at least three FM test specimens shall be tested in each of the weld deposit and the heat affected zone (HAZ). (Details regarding the required number of test specimens and the location of fatigue pre-cracks are given further below.)

3.7.6 Testing of the HAZ or the weld deposit may be omitted if tests with satisfactory results according to the requirements in this standard have been carried out previously by either the steel manufacturer or the welding consumable manufacturer.

3.7.7 The FM tests shall be carried out according to ISO 15653 and ISO 12135 using 3-point bend specimens, or another recognized standard as agreed. CTOD-technique with B × 2B specimens is recommended. The test is deemed to be valid provided post-test-data analysis meets all validity criteria of the standard. The test temperature shall be equal to or lower than the service temperature as defined in DNVGL-OS-C101 and/or DNVGL-OS-C201.

3.7.8 Subsequent to the CTOD-test the specimens in the HAZ shall be sectioned and examined as described below.

Metallographic sections according to ISO 15653 shall be prepared from each HAZ specimen. The metallographic section shall include weld metal and base metal. If necessary, in order to determine the exact location of the fatigue pre-crack, sections from both sides of the pre-crack shall be prepared. The faces of the metallographic sections shall not be taken deeper than the deepest point of the fatigue pre-crack and not more than 3 mm from the deepest point of the fatigue pre-crack.

A figure of a cross-section through the weld (of an un-fractured specimen) is shown in Figure 13.

![Figure 13 Cross-section through the weld](image)

| BM | = | Base Material |
| WM | = | Weld Metal or deposit |
\( df \) = distance from the plane of the fatigue pre-crack to the fusion line (varies along the fatigue pre-crack)

\( \lambda_i \) = length (in mm) of each area with acceptable location of the fatigue pre-crack (given as SM \( \lambda \) = Specified Micro-structure in ISO 15653)

\( t \) = plate thickness

Within the central 75% of the plate thickness the areas where \( df \leq 0.5 \) mm shall be identified. The length, \( \lambda_i \), of each of these areas shall be determined. The location of the fatigue pre-crack shall satisfy the following criteria:

\[
\sum N \lambda_i = \begin{cases} 
3 \text{ mm for } t \leq 20 \text{ mm} \\
0.15 t \text{ for } 20 < t \leq 80 \text{ mm} \\
12 \text{ mm for } t > 80 \text{ mm}
\end{cases}
\]

\( N \) = number of areas with \( df \leq 0.5 \) mm

3.7.9 Results from HAZ specimens on which the location of the fatigue pre-crack does not satisfy the requirement above, are not valid. In addition to these requirements given for HAZ specimens, all the requirements specified in ISO 15653 apply for both HAZ and weld deposit specimens.

Three valid tests for each of weld deposit and HAZ shall be carried out.

Acceptance criteria:

The critical CTOD for all of the specimens shall be equal to or larger than 0.15 mm.

If (for HAZ or weld deposit) one or more of the three specimens has 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 5, shall be equal to or larger than 0.15 mm.

<table>
<thead>
<tr>
<th>Number of valid tests</th>
<th>Characteristic value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 5</td>
<td>Lowest result</td>
</tr>
<tr>
<td>6 to 10</td>
<td>Second lowest result</td>
</tr>
<tr>
<td>11 to 15</td>
<td>Third lowest result</td>
</tr>
</tbody>
</table>

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.

3.7.10 If the characteristic value as specified in Table 5 is lower than 0.15 mm an ECA (Engineering Critical Assessment) may be carried out with the purpose of demonstrating that extra capacity may be available in the structure. Acceptance based on ECA shall be specially agreed.

4 Welding procedure qualification, aluminium

4.1 General

Basic requirements are given in [1] and [2].

— Welding consumables shall be one of those as recommended in Table 6.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VL-5052, VL-5754, VL-5154, VL-5454, VL-5086</td>
<td>5356, 5556, 5183</td>
<td>5356, 5556, 5183</td>
<td>5356, 5556, 5183</td>
</tr>
<tr>
<td>VL-5083, VL-5383, VL-5059</td>
<td>5356, 5556, 5183</td>
<td>5183 1), 5556</td>
<td>5356, 5556, 5183</td>
</tr>
<tr>
<td>VL-6060, VL-6061, VL-6063, VL-6064A, VL-6082</td>
<td>5356, 5556, 5183</td>
<td>5356, 5556, 5183</td>
<td>5356, 5556, 5183</td>
</tr>
</tbody>
</table>

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 Table 7
4.2 Butt welds in plates

4.2.1 Test assembly shall be as described in [3.1].

4.2.2 The following mechanical tests are required from each assembly (see Figure 14):
- 1 tensile test
- 1 root and 1 face or 2 side bend tests
- 1 macro test specimen.

![Figure 14 Location of test specimens for a butt weld on plate](diagram)

4.2.3 One tensile specimen shall be taken from each of the welded assemblies. The test specimen, 25 mm wide and with full plate thickness and orientated transverse to the weld, is shown in Figure 15.

![Figure 15 Tensile test specimen](diagram)

4.2.4 Side-bend tests shall be carried out for thickness equal to and above 10 mm. Two bend specimens shall be taken from each of the welded assemblies. The bend test specimens shall be machined to the dimensions given in [8.3].

4.2.5 For thickness below 10 mm one face bend and one root bend test specimens shall be taken. The diameter of the bending mandrel shall be as given in [4.7.2].

4.2.6 One macrosection shall be prepared from the test assembly to reveal the weldment macro structure. The macrosection shall be visually inspected using a magnification of 5 to 10X.

4.3 Butt welds in pipes

4.3.1 Test assembly shall be as described in [3.2.1].
4.3.2 The following mechanical tests are required from each assembly:

- 1 tensile test specimen
- 1 root and 1 face or 2 side bend specimens
- 1 macro test specimen.

![Figure 16 Location of test specimens for a butt weld in pipe](image)

4.3.3 One tensile specimen shall be taken from each of the welded assemblies. The test specimen, 25 mm wide and with full plate thickness and orientated transverse to the weld, is shown in Figure 15.

4.3.4 Side-bend tests shall be carried out for thickness equal to and above 10 mm. Two bend specimens shall be taken from each of the welded assemblies. The bend test specimens shall be machined to the dimensions given in [8.3].

4.3.5 One macrosection shall be prepared from the test assembly to reveal the weldment macro structure. The macrosection shall be visually inspected using a magnification of 5 to 10X.

4.4 Branch connections

The following mechanical tests are required from each assembly (see Figure 8):

- two macrosection tests at 12 and 6 o'clock.

4.5 Fillet welds

4.5.1 Test assembly shall be as described in [3.5.1].

4.5.2 The following tests shall be performed:

- two macrosection tests. One of the macrosections shall be taken at the marked position of the stop/restart. The macrosection shall include about 10 mm of unaffected base material and shall be prepared and etched on one side to clearly reveal the fusion line and the HAZ.

4.6 Non-destructive testing of test assemblies

4.6.1 Butt welds and full penetration T, K, Y-joints

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 follows:

100% Visual testing (VT)
100% Radiographic testing (RT) or Ultrasonic testing (UT)
100% Surface crack detection (Penetrant testing (PT)).

The soundness of the weld shall comply, unless otherwise specified, with ISO 10042 level B.

### 4.6.2 Fillet welds and partial penetration welds

The extent of the testing shall be as follows:

— 100% visual inspection
— 100% surface crack detection (PT).

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.

### 4.7 Destructive testing

#### 4.7.1

The tensile strength of the test specimens shall not be less than specified for the parent alloy in Table 7.

**Table 7 Mechanical properties in the welded condition**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Temper</th>
<th>Filler</th>
<th>Tensile strength $R_{m\text{y}}$ minimum (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL-5052</td>
<td>0, H111, H32, H34</td>
<td>5356</td>
<td>170</td>
</tr>
<tr>
<td>VL-5754</td>
<td>0, H111, H24</td>
<td>5356, 5183</td>
<td>190</td>
</tr>
<tr>
<td>VL-5154A</td>
<td>0, H111, H32, H34</td>
<td>5356, 5183</td>
<td>215</td>
</tr>
<tr>
<td>VL-5454</td>
<td>0, H111, H32, H34</td>
<td>5356, 5183</td>
<td>215</td>
</tr>
<tr>
<td>VL-5086</td>
<td>0, H111, H112, H116, H321, H34</td>
<td>5356, 5183</td>
<td>240</td>
</tr>
<tr>
<td>VL-5083</td>
<td>0, H111, H112; $t \leq 6$ mm</td>
<td>5183</td>
<td>270</td>
</tr>
<tr>
<td></td>
<td>0, H111, H112; $t &gt; 6$ mm</td>
<td>5356, 5183</td>
<td>270</td>
</tr>
<tr>
<td></td>
<td>H116, H321</td>
<td>5356, 5183</td>
<td>270</td>
</tr>
<tr>
<td>VL-5383</td>
<td>0, H111, H116, H321</td>
<td>5183</td>
<td>290</td>
</tr>
<tr>
<td>VL-5059</td>
<td>0, H111, H116, H321</td>
<td>5183</td>
<td>330</td>
</tr>
<tr>
<td>VL-6060</td>
<td>T4, T5, T6</td>
<td>5356, 5183</td>
<td>95</td>
</tr>
<tr>
<td>VL-6061</td>
<td>T4, T5, T6</td>
<td>5356, 5183</td>
<td>165</td>
</tr>
<tr>
<td>VL-6063</td>
<td>T4, T5, T6</td>
<td>5356, 5183</td>
<td>100</td>
</tr>
<tr>
<td>VL-6005A</td>
<td>T4, T5, T6</td>
<td>5356, 5183</td>
<td>165</td>
</tr>
<tr>
<td>VL-6082</td>
<td>T4, T5, T6</td>
<td>5356, 5183</td>
<td>170</td>
</tr>
</tbody>
</table>

#### 4.7.2

The bend test specimens shall be bent on a mandrel with maximum diameter as given in the formula below. The bending angle shall be at least 180°. After bending, the test specimens shall not reveal any open defects in any direction greater than 3 mm. 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 as shown in [8.3] is the preferred bending method.

\[
d = \frac{100 t_s}{A} - t_s
\]

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).

#### 4.7.3

The macrosections shall show a regular weld profile with smooth transitions to the base materials and without significant or excessive reinforcement. Cracks and lack of fusion are not acceptable.
4.7.4 When a butt weld is made between two plates of different alloys the tensile strength to be obtained on the welded assembly shall be in agreement with the requirements relating to the alloy having the lower strength.

4.7.5 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 qualification test.

4.8 Range of qualification

4.8.1 The validity of acceptance for the welding procedure shall be as given in [3.6].

4.8.2 A qualified welding procedure shall be used within the ranges of the parameters below.

**Base material**

The following changes shall lead to a new qualification:

a) In general, significant change of material properties which will obviously affect the weldability and mechanical properties.

b) More specifically, aluminium alloys are grouped in the following categories:

i) VL-5052, VL-5754A, VL-5154, VL-5454

ii) VL-5086, VL-5083, VL-5383, VL-5059


The qualification on aluminium alloys in category iii) will qualify for the alloys in category ii) and category i) but not vice versa. The qualification on aluminium alloys in category ii) will qualify for the alloys in category i) but not vice versa.

Any other combination and dissimilar metal joints, shall lead to a specific test with no range of qualification for other base materials.

**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 in Table 8 there is an associated range of qualified throat thickness as given below.

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 to qualified thickness range for butt welds shall be as given in Table 8.

<table>
<thead>
<tr>
<th>Thickness, ( t ) (mm) of test piece</th>
<th>Qualification range</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t &lt; 3 )</td>
<td>( 0.5 \times t ) to ( 2 \times t )</td>
</tr>
<tr>
<td>( 3 \leq t \leq 20 )</td>
<td>( 3 \times t ) to ( 2 \times t )</td>
</tr>
<tr>
<td>( t &gt; 20 )</td>
<td>( \geq 0.8 \times t )</td>
</tr>
</tbody>
</table>

In addition to the requirements of Table 8, the ranges of qualification of the throat thickness “a” of fillet welds are given in Table 9.
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.

### Diameter of pipes and branch connections

The qualification of a welding procedure test on diameter D shall cover qualification for diameters in the following ranges as given in Table 10.

#### Table 10 Qualified range for pipe and branch connection diameters

<table>
<thead>
<tr>
<th>Diameter of the test piece, D (mm)</th>
<th>Qualification range</th>
</tr>
</thead>
<tbody>
<tr>
<td>D ≤ 25</td>
<td>0.5 D to 2 D</td>
</tr>
<tr>
<td>D &gt; 25</td>
<td>≥ 0.5 D and plates</td>
</tr>
</tbody>
</table>

Table 9 Range of qualification for the throat thickness for plates and pipes

<table>
<thead>
<tr>
<th>Throat thickness of the test piece (mm)</th>
<th>Range of qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>a &lt; 10</td>
<td>0.75 a to 1.5 a</td>
</tr>
<tr>
<td>a ≥ 10</td>
<td>≥ 7.5 mm</td>
</tr>
</tbody>
</table>

Angle of branch connections

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

Welding consumables

The following changes shall lead to a new qualification:

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

Welding positions

The following changes shall lead to a new qualification:

- change from one principal welding position (see figures in [3.2]) to another, unless complying with Table 11.

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 500mm.
- any change of groove dimensions specified in the WPS.

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 ±25%
- any decrease in preheat temperature
- higher interpass temperature than that used in the qualification test
- change of heat treatment used in the qualification test. 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 welding current from A.C. to D.C. or vice versa, or change in polarity. If recommended by the consumable manufacturer particular exemption may be given for SMAW in change from A.C. to D.C.

### Table 11 Qualified principal positions for butt welds and fillet welds, aluminium

<table>
<thead>
<tr>
<th>Test weld Joint configuration 1,2)</th>
<th>Principal positions</th>
<th>Qualified positions 3)</th>
<th>Butt welds</th>
<th>Plates</th>
<th>Pipes</th>
<th>Fillet welds plates or pipes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Pipes with D &gt; 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.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butt welds in plates</td>
<td>1G</td>
<td>1G, 2G, 3G</td>
<td>1G</td>
<td>1G, 2G, 3G</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2G</td>
<td>1G, 2G, 3G</td>
<td>1G</td>
<td>1F, 2G, 3F</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3G</td>
<td>1G, 2G, 3G</td>
<td>1G</td>
<td>1F, 2G, 3F</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4G</td>
<td>All</td>
<td>1G</td>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butt welds in pipes</td>
<td>1G</td>
<td>1G, 2G, 3G</td>
<td>1G</td>
<td>1F, 2G, 4F</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2G</td>
<td>1G, 2G, 3G</td>
<td>2G</td>
<td>1F, 2G, 4F</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5G</td>
<td>All</td>
<td>1G, 5G</td>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fillet welds</td>
<td>1F</td>
<td>1F, 2G, 3F</td>
<td>1F</td>
<td>1F, 2G, 3F</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2F</td>
<td>1F, 2G, 3F</td>
<td>2F</td>
<td>1F, 2G, 3F</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3F</td>
<td>All</td>
<td>3F</td>
<td>All</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>4F</td>
<td>All</td>
<td>4F</td>
<td>All</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>5F</td>
<td>All</td>
<td>5F</td>
<td>All</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.9 Retesting

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 qualification test.

If the result of any destructive 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 shall be welded using the same WPS. If either of these additional test specimens does not comply with the relevant requirements, the WPS shall be regarded as not capable of complying with the requirements without modification.

5 Welding procedure qualification, stainless steel

5.1 General

5.1.1 When welding procedure qualification tests are required, the tests shall be performed in accordance with C and the supplementary requirements stated in [5.2] and [5.3] (if not otherwise specified herein).

5.1.2 The welding procedure qualification tests shall cover all relevant dimensions, positions and material combinations. Details regarding essential variables and validity of the procedure shall be as described in [3]. Mechanical testing shall be as described in [3.1], if not otherwise specified in [5.2] and [5.3].

5.2 Additional requirements WPQT for austenitic stainless steel

5.2.1 Welds in plates and pipes

— Test assembly shall be as described in 1.3.
— Impact testing is not required for design temperatures above – 105°C.

5.2.2 Test requirements

If impact testing is required, the testing shall be conducted at -196°C meeting an average impact energy level of minimum 27J.
5.2.3 Range of validity

The requirements of [3.6] applies. In addition; a change to a grade of higher specified strength or higher impact toughness requirements shall lead to a new qualification.

5.3 Additional requirements WPQT for ferritic-austenitic stainless steel (Duplex)

5.3.1 Welding consumables with enhanced nickel and nitrogen content shall be used. Welding consumables shall be segregated from consumables for C-Mn steel. Backing and shielding gases shall not contain hydrogen and shall have a dew point not higher than -30°C. Backing gas shall be used for welding of root pass and succeeding passes.

5.3.2 Impact testing shall be as described in [3.1.3] carried out at design temperature or -20°C, whichever is the lower. The average impact value for the three specimens shall not be less than 27 J.

5.3.3 When a butt weld is made between dissimilar material grades, both sides of the weld shall be impact tested.

5.3.4 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 specimen shall have a dimension of full wall thickness by 25 mm along the weld and 50 mm across the weld. The test shall expose the external and internal surface and a cross section surface including the weld zone in full wall thickness. Cut edges shall be prepared according to ASTM G48. The 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 pitting at 20X magnification
— general weight loss shall be less than 4.0 g/m².

Guidance note:
Welds between Ferritic-Austenitic stainless steels and other grades of stainless, C-Mn steels or for welds in "non-corrosive" area may not need to be corrosion tested.

5.3.5 Duplex stainless steel types shall be micro-structurally examined and the test samples shall comprise the weld metal, HAZ and the base metal. The micro-structure shall be suitably etched and examined at 400X magnification and shall be free from grain boundary carbides and precipitates. The ferrite content in the weld metal root and in the un-reheated weld cap shall be determined in accordance with ASTM E 562 and shall be in the range of 30% to 70%.

5.3.6 Validity of a qualified welding procedure

Reference is made to [3.6]. Additionally, variation in heat input greater than ±15% shall lead to a new qualification.

6 Welding procedure qualification, copper alloys

6.1 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.

6.2 Copper alloy castings for propellers

6.2.1 General recommendations for filler metal and pre- and post-weld heat treatment of copper alloy propeller castings are given in Table 12.
6.2.2 For qualification of procedures, a test assembly of minimum 30 mm thickness shall be welded. See Figure 17.

6.2.3 Prior to sectioning, the test assembly shall be visually inspected and liquid penetrant tested in accordance with a recognized standard, e.g ISO 3452, ASTM E165. Imperfections shall be assessed in accordance with Table 13.

6.2.4 Three macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. 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.

6.2.5 Two tensile test pieces shall be prepared as shown in Figure 18. The tensile strength for copper alloy propeller castings shall meet the specified minimum values given in Table 14. The tensile strength for other copper alloy castings shall meet the requirements of the base material. The location of fracture shall be reported, i.e. weld metal, HAZ or base material.

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

---

**Figure 17  Weld test assembly**

**Figure 18  Tensile test specimen for weld test assembly**
Chapter 2  Section 1

7 Qualification of welders

7.1 General

7.1.1 The welding processes for which qualifications are required include those which are designated as manual or partly mechanised welding. Welders shall pass a qualification test in accordance with 200. The contractor shall be responsible for the qualification of welders and are required to keep records of the welders' qualifications and, when required, furnish copies of valid welders' certificates.

7.1.2 Welding operators using fully mechanized or fully automatic processes shall be required to have records of proficiency, which provide evidence that the operators are receiving adequate regularly training in setting, programming and operating the equipment in accordance with the WPS. Training shall also include evaluation of groove dimensions according to WPS, groove cleanliness requirements, weather and wind requirements, and handling of welding consumables. Appropriate records of training shall be maintained. When specially agreed, welding operators certificates according to a recognized standard may be required, e.g. ISO 14732, ASME Section IX or ANSI/AWS D1.1.

7.2 Standards for qualification testing

7.2.1 Welders shall be qualified to a recognised standard, e.g. EN 287, ISO 9606, ASME Section IX or
ANSI/AWS D1.1. Appropriate validation of welders certificates (in line with the referred standards) every 6 months, and records thereof is required.

7.2.2 Certification of welding operators is not required provided [7.1.2] is complied with. However, if specially agreed, qualification certificates according to a recognized standard may be required for welding operators, e.g. ISO 14732, ASME Section IX or ANSI/AWS D1.1.

8 Testing

8.1 General
Testing of welds shall be carried out as specified in [8.2] and [8.3]. With respect to requirements not stated herein e.g. personnel qualifications, testing machines, preparation of test specimens, testing methods, etc., the relevant requirements of DNVGL-OS-B101 apply.

8.2 Tensile testing at ambient temperature
For tensile testing of all-weld-metal and butt welds two different types of test specimens may be used, round test specimens or flat test specimens (see Figure 19) as described below:

A - Deposited metal tensile test
Normally, round test specimens with the following dimensions shall be used:

\[
\begin{align*}
&d = 10 \text{ mm} \\
&L_o = 50 \text{ mm} \\
&L_c = 60 \text{ mm} \\
&R \geq 5 \text{ mm}
\end{align*}
\]

B - Butt weld tensile test for testing of the weld as a whole
Flat test specimens with the weld machined flush with the surface of the plate, shall be used. The dimensions shall be as follows:

\[
\begin{align*}
&a = \text{ thickness of plate, } t \\
&b = 25 \text{ mm} \\
&L_o = L_c = 3t \text{ or } 2t + \text{ width of weld, (whichever is the greatest)} \\
&R = 25 \text{ mm}
\end{align*}
\]

Figure 19  Tensile test specimen

8.3 Bend testing

8.3.1 Flat bend test specimens, as given in Figure 20 shall be used. Edges on tension side shall be rounded to a radius of 1 to 2 mm.
8.3.2 When the wrap around bend test, exemplified Figure 21 is used, e.g. for the side bend test of a weld, the length of the test specimen shall be greater than the length 11a shown in Figure 20.

8.3.3 For butt weld bend test specimens, the weld shall be machined flush with the surface of the plate.

8.3.4 For transverse face-bend and root-bend test specimens for butt weld test the dimensions shall be as follows:

\[ a = \text{as rolled thickness } t \text{ of the plate} \]
\[ b = 30 \text{ mm} \]

If the as rolled thickness \( t \) is greater than 25 mm, it may be reduced to 25 mm by machining on the compression side of the test specimen.

8.3.5 For transverse side-bend test specimens for butt weld test the dimensions shall be as follows:

\[ a = 10 \text{ mm} \]
\[ b = \text{as rolled thickness } t \text{ of the plate} \]

If \( t \geq 40 \text{ mm} \), the side-bend test specimen may be subdivided, each part being at least 20 mm wide.

8.3.6 When a longitudinal face-bend or root-bend weld test is required, a test specimen according to an appropriate standard will be accepted.
SECTION 2 FABRICATION AND TOLERANCES

1 General

1.1 Objective and scope

1.1.1 This section gives requirements for fabrication and tolerances of offshore structures.

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 Object Standard’s (i.e. DNVGL-OS-C102/103/104/105/106) Ch.2 Sec.1 Selection of Material and Extent of Inspection or DNVGL-OS-C201 Ch.2 Sec.3.

2 Fabrication planning

2.1 General

2.1.1 As a prerequisite for fabrication, procedures, inspection and test plans 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.

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

2.2 Quality system and workmanship

2.2.1 Contractors involved in fabrication of structural members shall have a documented and implemented quality system according to ISO 9001 or equivalent. Quality requirements for welding may be based on ISO 3834-series. 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 competence of personnel.

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

2.2.3 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 other means of permanent covers have been applied.

2.2.4 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 specially agreed if they are not specified in relevant documents.

3 Inspection

3.1 General

3.1.1 Inspection shall be carried out by the contractor in accordance with agreed inspection and test plans to confirm that all project requirements are fulfilled.

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.

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

3.1.3 High non-conformance rates in execution of the work or in the product itself shall call for special considerations. Such special considerations may include, but not be limited to, increased inspection, re-qualification of personnel or other agreed remedial actions.

3.1.4 Inspectors shall be qualified according to a recognised scheme and shall be able to provide documentation of proficiency.

4 Material identification, cutting and forming

4.1 Material identification
A traceability system that ensures correct installation and documentation of the material grades or strength classes shall be established by the contractor throughout the prefabrication and installation process. Proper care shall be exercised during handling and storage to preserve identification of such material.

4.2 Cutting and forming

4.2.1 The effect of work hardening shall be considered if shearing is used for cutting of material. Special attention shall be paid to the risk of cracked edges.

4.2.2 Attention shall be paid to excessive local hardening and carbon contaminations by thermal cutting. This may be reduced by suitable heat treatment or removed by mechanical means.

4.2.3 Forming and straightening of materials shall be performed according to agreed procedures. Such work shall be controlled by the contractor.

4.2.4 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.

If the deformation exceeds 5% and up to a maximum deformation of 12%, subject to agreement, the cold forming shall be qualified. The qualification procedure shall at least include destructive testing of representatively cold formed material.

In addition to representative cold forming, in this context “representative material” means at least same material grade, with similar chemical composition and mechanical properties, and from one steel manufacturer. For destructive testing, the following shall be tested as a minimum; impact toughness tests of representatively strained material and strain aged material. Test temperature shall be the same as required for the base material.

Cold deformation exceeding 12% followed by heat treatment may, subject to agreement, be considered for acceptance case by case based on qualification. The contractor shall prepare a procedure for qualification, and the procedure shall be agreed before the production starts. The qualification procedure shall 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 base material is required.

All cold formed and heat treated areas shall be tested 100% by MT (or PT for stainless steels) after final forming, heat treatment and welding.
Guidance note:
The plastic deformation $e$ may be calculated by the following, simplified formulae:

Single-curvature deformation
Cold rolling or pressing of plates to cylindrical forms:
$$e = \frac{t}{2R_c + t} \times 100\%$$

Cold bending of straight pipes to bends:
$$e = \frac{D}{2R_c} \times 100\%$$

Double curvature deformation
Forming of plates to spheres:
$$e = \frac{t(1 + \nu)}{2R_c} \times 100\%$$

$t$ = material thickness
$D$ = outside diameter of pipe or vessel
$R_c$ = forming radius
$\nu$ = Poisson’s ratio (0.5 for plastic condition).

Guidance note:
Strain age test is applicable to C-Mn-steels and low alloy steels. Normally, a sample is to be plastically strained at the actual deformation and then artificially aged at 250°C for one hour. The material is then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

4.2.5 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.

5 Tolerances

5.1 Tolerances for alignment and straightness

5.1.1 Allowable fabrication tolerances shall be submitted for acceptance.

5.1.2 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.

5.1.3 The maximum fabrication tolerances may generally be taken in compliance with IACS Recommendation No. 47 Shipbuilding and Repair Quality Standard Part A.

Guidance note:
Special and primary category areas shall be regarded as “strength” members and secondary category area shall be regarded as “other” in the IACS Rec.47 Shipbuilding and Repair Standard.

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

5.1.5 Straightness of members which are based on buckling calculations according to DNVGL-RP-0004 and/or DNV-RP-C202 shall be within the tolerances given in Table 1.

5.1.6 Alignments of the non-continuous plates in cruciform joints and butt welds shall be within the tolerances given in Figure 1.

5.1.7 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 \(t_3\)
- Primary: 0.30 \(t_3\)
- Secondary: 0.50 \(t_3\)
- \(t_3\) 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 \(t_3\)
- Primary: 0.30 \(t_3\)
- Secondary: 0.50 \(t_3\)
- \(t_3\) 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 \(t_3\)
- Primary: 0.15 \(t_3\)
- Secondary: 0.30 \(t_3\)
- \(t_3\) is the smaller thickness 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 \(t_3\)
- Primary: 0.15 \(t_3\)
- Secondary: 0.30 \(t_3\)
- \(t_3\) is the smaller thickness 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 1 Alignment of joints**
### Table 1  Tolerances for straightness

<table>
<thead>
<tr>
<th>Detail</th>
<th>Tolerance</th>
<th>Fig.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bars and frames</td>
<td>Max. out of straightness ( \delta = 0.0015 \ l )</td>
<td><img src="image1.png" alt="image" /></td>
<td>( l ) = unsupported length</td>
</tr>
<tr>
<td>Pillars, vertical columns</td>
<td>Max. inclination ( \delta = 0.001 \ l )</td>
<td><img src="image2.png" alt="image" /></td>
<td>( l ) = unsupported length</td>
</tr>
<tr>
<td>Stiffened plane plates. Stiffener or girder webs relative to the plate plane.</td>
<td>Max. out of straightness ( \delta = 0.0015 \ l )</td>
<td><img src="image3.png" alt="image" /></td>
<td>( l ) = Unsupported length of the stiffener or girder</td>
</tr>
<tr>
<td>Stiffened plane plates. Stiffener or girder flanges relative to the web plate</td>
<td>Max. out of straightness ( \delta = 0.0015 \ l )</td>
<td><img src="image4.png" alt="image" /></td>
<td>( l ) = Unsupported length of the flange</td>
</tr>
<tr>
<td>Stiffened plane plates. Parallel stiffeners or girders</td>
<td>Max. misalignment ( \delta = 0.02 \ s )</td>
<td><img src="image5.png" alt="image" /></td>
<td>( s ) = distance between parallel stiffeners or girders</td>
</tr>
</tbody>
</table>
### Table 1 Tolerances for straightness (Continued)

<table>
<thead>
<tr>
<th>Detail</th>
<th>Tolerance</th>
<th>Fig.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stiffened plane plates. Plates between stiffeners or girders.</strong></td>
<td>Max. out of plane displacement  ( \delta = 0.005 , s )</td>
<td><img src="image" alt="Diagram" /></td>
<td>( s = ) unsupported width of the plate panel</td>
</tr>
<tr>
<td><strong>Circular cylindrical shells.</strong></td>
<td>Max. deviation from the nominal radius measured at ring stiffener or bulkhead  ( \delta = (r_a - r) = 0.005 , r )</td>
<td><img src="image" alt="Diagram" /></td>
<td>( r_a = ) actual distance from the cylinder axis to the shell wall. ( r = ) nominal radius of the shell</td>
</tr>
<tr>
<td><strong>Circular cylindrical shells.</strong></td>
<td>Max out of straightness  ( \delta = 0.0015 , l )</td>
<td><img src="image" alt="Diagram" /></td>
<td>( l = ) Unsupported length of the stiffener or girder.</td>
</tr>
<tr>
<td><strong>Circular cylindrical shells.</strong></td>
<td>Max. out of straightness  ( \delta = 0.0015 , l )</td>
<td><img src="image" alt="Diagram" /></td>
<td>( l = ) Unsupported length of the flange</td>
</tr>
<tr>
<td><strong>Circular cylindrical shells.</strong></td>
<td>Max. misalignment  ( \delta = 0.02 , s )</td>
<td><img src="image" alt="Diagram" /></td>
<td>( s = ) stiffener spacing</td>
</tr>
</tbody>
</table>
6 Assembly, welding, heat treatment and repairs

6.1 Assembly and welding

6.1.1 Assembly and welding operations shall be carried out by qualified personnel and supervision.

6.1.2 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.

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

When welding tubular any longitudinal welds shall be staggered at least 50 mm. Girth welds shall be separated at least one tubular diameter or 300 mm, whichever is larger.

If applicable pre-heating shall be applied prior to any welding, including tack welding. The pre-heating temperature shall be measured at a distance of minimum 75 mm from the edges of the groove at the opposite side of the heating source when practically possible.

6.1.4 The welding sequence shall be such that the amount of shrinkage, distortions and residual stresses are minimised.
All welding shall be performed under controlled conditions with adequate protection from detrimental environmental influence such as humidity, dust, draught and large temperature variations.

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

The weld area shall be heated to the minimum preheat temperature specified in the WPS. Pre-heating shall be performed to remove condense in the weld area when the material temperature is below dew point or 0°C whichever is lower.

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

6.1.5 Difference in plate thickness of butt welds exceeding 4 mm the thicker plate shall be tapered not steeper than 1 : 3 generally. Butt joints, which are prone to fatigue loading shall be tapered not steeper than 1 : 4. See Figure 2.

![Figure 2 Tapering of butt joints](image)

6.1.6 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. Generally, the fabrication shall be planned in such a manner that back welding can be performed to the largest extent possible.

6.1.7 Members to be welded shall be brought into correct alignment and held in position by clamps, other suitable devices or by tack welds until welding has been completed or progressed to a stage where the holding devices or tack welds can be removed without danger of distortion, shrinkage or cracking. Suitable allowances shall be made for distortion and shrinkage where appropriate.

Tack welds shall have a min. length of 50 to 75 mm and no.of tacks are to be sufficient to avoid cracking. Temporary tack welds using bridging or bullets shall only be performed using materials equivalent to the base material 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.

Tack welds to be fused into the weld shall be made in the weld groove only and the ends of the tack welds shall have their ends ground.

6.1.8 The use of permanent steel backing strips may be permitted after thorough corrosion evaluation and when properly accounted for in the design analysis.

6.1.9 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.

6.1.10 The fit-up shall be checked for dimensional accuracy before welding. Surfaces to be welded shall be free from mill scale, slag, rust, grease, paint etc. Edges are to have a smooth and uniform surface. No welding shall be performed when the surfaces are damp. Suitable protection shall be arranged when welding is performed during inclement weather conditions. The groove shall be dry at the time of welding.

6.1.11 Preheating shall preferably be performed with electric heating elements. Gas burners may be used under controlled conditions. Cutting torches should not be used.
6.1.12 All welding shall be based on welding consumables, welding processes and welding techniques proven to be suitable for the type of material and type of fabrication in question.

6.1.13 For welds of the following listed categories, a WPS shall be established according to [2.5.2] 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, primary and 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 shall be assigned the structural category area equal to the higher category of the joined components. 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---of---g-u-i-d-a-n-c-e---n-o-t-e---

6.1.14 All fabrication welding referred in [6.1.13] shall be performed within the limits of essential variables of the qualified welding procedure. This also includes tack welding (see [6.1.15]), seal welding, welding of lifting lugs and attachment welds as well as repair welding (see [6.3.2]).

6.1.15 Tack welding shall, when integrated in production welding, be qualified. For welds specified in [6.1.13] a WPS shall be submitted for acceptance.

**Additional requirements for welding of duplex steel:**
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 and avoiding the higher heat input.

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

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

6.1.16 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.

6.1.17 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. Arc strikes shall be repaired by mechanical removal of affected base material followed by NDT to verify absence of cracks.

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 sufficient for the subsequent NDT. Peening is not permitted.

6.1.18 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.

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. $H_{DM} \leq 10 \text{ ml/100 g in weld metal}$.

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. $H_{DM} \leq 5 \text{ ml/100 g in weld metal}$.

Hydrogen testing shall be according to ISO 3690 or equivalent.

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

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, as applicable.

Recycling of fluxes for submerged-arc welding shall be performed in a manner that ensures a mixture of new and used flux with continually homogenous properties.
6.1.20 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.

6.1.21 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.

6.1.22 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.

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 welding procedure qualification test.

6.1.23 If one or more production tests fail to give satisfactory results, two more shall be made, both of which shall give acceptable results.

Should one or both of the additional tests fail, the total production welding performed with the welding procedure in question shall be evaluated based on testing of welds and base material cut-out from the actual structure fabricated.

6.1.24 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.

6.1.25 Shop primers 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.

6.1.26 All welding of attachments shall comply with the requirements 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).

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

6.2 Post weld heat treatment (PWHT)

6.2.1 Post weld heat treatment (PWHT) of C-Mn steels if required by DNVGL-OS-C101 or DNVGL-OS-C201, shall be performed in accordance with a procedure specification including:

- 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:
The procedure specification may be worked out on basis of combined material thicknesses as shown in Figure 3.

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

6.2.2 Heat treatment shall be performed at a soaking temperature in the range 550 to 620°C, for a time of at least 2 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 quenched and tempered steels shall be decided in each case.

The maximum PWHT temperature for quenched and tempered 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.

6.2.3 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.

6.2.4 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.

6.2.5 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.

Figure 3 Guidance on material thickness for PWHT

6.2.6 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 ± 15°C.

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

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

6.3 Repairs

6.3.1 Repairs shall be carried out in accordance with qualified repair procedures subject to agreement.

6.3.2 Repair welding procedure specifications shall be prepared, based on WPQRs for the type of weld repair to be applied.

Repair welding shall be qualified by a separate weld repair qualification test if the repair depth is beyond ¼ of the parent material thickness.

Qualification of repair welding procedures shall be made by excavating a repair groove in an original weld welded in accordance with a qualified welding procedure. The excavated groove shall be of sufficient length to obtain the required number of test specimens + 50 mm at each end.

Guidance note:
Scope and extent of testing is as described for butt welds, ref. Ch.2 Sec.1 Charpy V-notch impact test specimens for FL and HAZ shall be located to the fusion line (FL) between the repair weld and weld metal of pre-existing weld, and the corresponding HAZ.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
6.3.3 Guidance to repair work may be found in IACS Rec. 47 Shipbuilding and repair Quality Standard, Part A Sec.9 and Part B. Ref. is also made to OSS-101, 102 and 103 Ch.3 Sec.3 [4.2] respectively OSS-104 Pt. 7 Ch.4 Sec.3 regarding thickness gauge of existing material.

6.3.4 Members distorted by welding may be straightened by mechanical means or by carefully supervised application of a limited amount of localised heat. The application of heat or mechanical force shall be in accordance with a written procedure.

6.3.5 Defects in welds may be rectified by grinding, machining or welding. 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.

6.3.6 Repair welding in the same area may be carried out twice. Further repairs shall be evaluated in each individual case.

6.3.7 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.

6.3.8 Repair welding shall be performed using welding consumables satisfying the hydrogen test requirement given in [6.1.18]. 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 50ºC above the level specified for production welding and be at least 100ºC unless otherwise agreed. The working temperature shall be maintained until the repair has been completed. To ensure sound repair welds, the single repair length shall not be shorter than 50 mm.

6.3.9 Repair of welded joints shall be carried out by removing the unacceptable portion of the weld without substantial removal of base material. 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.

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

6.3.11 Minor discontinuities may be removed by grinding or machining, making a smooth transition into 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.

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

6.4 Flame straightening

6.4.1 Members distorted by welding may be straightened by mechanical means or by a limited amount of localised heat. Flame straightening shall be done in accordance with an agreed procedure.

6.4.2 Corrective measures relating to flame straightening shall be carried out with due regard to possible degradation of the material properties. Reference is made to IACS Rec. No.47 part A Table 6.5 regarding max. heating temperature on the surface.
SECTION 3 NON-DESTRUCTIVE TESTING

1 Scope
This section gives requirements for non-destructive testing.

2 Non-destructive testing (NDT)

2.1 General

2.1.1 Prior to commencement of fabrication the contractor shall submit a plan for NDT, NDT procedures and documents for NDT inspectors’ certification for acceptance. The programme shall contain information and documents for planning, controlling and reporting (ref. [2.2.4]).

2.1.2 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.

2.1.3 Welds shall be subject to NDT in progress with fabrication. The results of these activities shall be consecutively submitted.

2.1.4 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.

2.1.5 Final inspection and NDT of structural steel welds shall not be carried out before 48 hours after completion, except where PWHT is required.

The time delay may upon agreement be reduced for VL 36 grades or lower and for VL 420 grades or lower for plate thicknesses less than 40 mm, if consistent low failure rate of delayed cracking has been documented for the materials and welding consumables in question.

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

2.1.7 All welds shall be 100% visually inspected and accepted prior to carrying out NDT.

2.1.8 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 unless more stringent reporting requirements have been agreed. All weld repair work shall be documented.

2.2 NDT procedures

NDT shall be performed in accordance with agreed written procedures. The procedures shall be in accordance with DNV Classification note No.7. Other recognised standards may be agreed based on a case by case consideration. The agreed procedures shall as a minimum give detailed information on the following aspects:

— applicable code or standard
— materials, dimensions and temperature of tested material
— periodically verification of equipment requirements
— joint configuration and dimensions
— technique (sketches/ figures to be referenced in the NDT report)
— equipment and consumables
— sensitivity, and light/viewing conditions for MT and PT
— calibration techniques and calibration references
— testing parameters and variables
— assessment of imperfections and the surfaces from which the testing has been performed reporting and documentation of results. The reporting system shall ensure that there is no doubt what is testing where it is testing and give a clear and exact description of reportable defect location.
— reference to applicable welding procedure(s)
— personnel qualification
— acceptance criteria.

2.3 Personnel qualification
Personnel performing NDT and interpretation of examination results shall be certified according to a
recognised certification scheme, e.g. with a grade equivalent to level II qualification of EN ISO 9712, SNT-
TC-1A or ASNT Central Certification Program (ACCP). The certificate shall state the qualifications as to which
examination method, level and within which industrial sector the operator is certified.

2.4 Extent of NDT

2.4.1 The extent of NDT shall be based on type and level of design stresses and on the importance of the
connection in question. The welds shall be assigned inspection categories equal to the highest structural
category of the two components.

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).

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.

2.4.2 Unless otherwise agreed, NDT shall normally be carried out to an extent not less than required in
Table 1. 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.

2.4.3 If a consistently low NDT failure rate is documented, the extent of NDT inspection required for
elements within structural category primary may be reduced, but shall not be less than for Inspection
category III. Repair rate shall be submitted regularly e.g. weekly basis.

2.4.4 Radiographic testing may be replaced by ultrasonic testing and vice versa, when methodologically
justifiable and agreed upon. However, ultrasonic examination shall not be carried out on welds with
thickness < 10 mm if not qualified and agreed down to 8 mm.

2.4.5 Frequent repairs 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.

2.4.6 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.

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 shall be
investigated by adequate methods for hydrogen induced cracking.

2.4.7 NDT shall cover start and stop points of automatically welded seams. Except for internal members
where the extent of testing should be agreed. Ultrasonic testing 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 base material.
2.4.8 Plates which are subjected to significant tensile stresses in the thickness direction in way of full penetration cross joints, shall undergo ultrasonic testing after welding for the presence of lamellar tearing in the member subject to tensile stresses. The requirement to such ultrasonic testing 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.

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

<table>
<thead>
<tr>
<th>Structural category</th>
<th>Inspection category</th>
<th>Type of connection</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Visual</td>
</tr>
<tr>
<td>Special / Essential</td>
<td>I</td>
<td>Butt weld</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross- and T-joints, full penetration welds</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross- and T-joints, partly penetration and fillet welds</td>
<td>100%</td>
</tr>
<tr>
<td>Primary</td>
<td>II</td>
<td>Butt weld</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross- and T-joints, full penetration welds</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross- and T-joints, partly penetration and fillet welds</td>
<td>100%</td>
</tr>
<tr>
<td>Secondary</td>
<td>III</td>
<td>Butt weld</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross- and T-joints, full penetration welds</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross- and T-joints, partly penetration and fillet welds</td>
<td>100%</td>
</tr>
</tbody>
</table>

1) Penetrant testing to be adopted for non ferro-magnetic materials.
2) May be partly or wholly replaced by ultrasonic testing upon agreement.
3) Ultrasonic testing shall be carried out for plate thicknesses of 10 mm and above. Testing of thicknesses 10 ≤ 8 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%.

2.4.9 Radiographic testing

Radiographic testing shall be performed by x-ray according to agreed procedures. Gamma-ray sources may be used as outlined in DNV Classification note No.7. The procedures shall be established in accordance with DNV Classification note No.7.

2.4.10 Suspect planar indications discovered by radiographic testing shall be type determined, located and sized by ultrasonic testing.

2.4.11 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.

2.4.12 Ultrasonic testing

Ultrasonic testing shall be performed according to agreed procedures. The procedures shall be established according to DNV Classification note No.7.

2.4.13 Ultrasonic examination equipment is to:

— be applicable for the pulse echo technique and for the double-probe technique
— cover as a minimum the frequency range from 1 to 6 MHz
— have a calibrated gain regulator with minimum 2 dB per step over a range of at least 60 dB
— have a flat screen accessible from the front for direct plotting of reference curves or equipped with automatic calibration or DAC (Distance Amplitude Curve)
— display presentation echoes with amplitudes of 5% of full screen height shall be clearly detectable under test conditions
— include straight beam transducers and angle beam transducers of 45°, 60° and 70°.

2.4.14 Periodically check of equipment shall be in accordance with DNV Classification note No.7.
2.4.15 The IIW or ISO calibration block shall be used for calibration of range and for angle determination.

2.4.16 For evaluation of flaw indications a reference curve shall be established. The curve shall be plotted on the instrument screen. Imperfections, which produce a response greater than 33% of the reference level shall be investigated to the extent that the operator can determine the shape, identity and location of all such imperfections and evaluate them in terms of the acceptance criteria. All defects exceeding the acceptance criteria shall be reported unless more stringent requirements are agreed.

2.4.17 Reference blocks shall be made with thickness and side-drilled holes, as described in Table 2, and shall be used for gain calibration and construction of reference curves. The reference block shall normally be manufactured from the actual material examined and have agreed dimensions. The reference blocks shall be traceable to the material certificate. When ultrasonic testing is to be performed on steel produced by thermo-mechanical rolling (TM materials), reference blocks shall be produced both perpendicular to, and parallel to, the direction of rolling. The rolling direction shall be clearly identified and action shall be taken to determine possible difference in angle of reflection and echo height/ amplitude.

2.4.18 For ultrasonic testing the scanning surfaces shall be clean and smooth, i.e. free from dirt, scale, rust, welding spatter, etc. which may influence the results of the testing.

2.4.19 The weld shall normally be tested from both sides and the testing shall include the area adjacent to the weld for laminations and scanning for transverse indications in the weld and base material. Use of multiple angle probes scanning in addition to normal probe scanning is required.

UT procedure of austenitic stainless and ferritic-austenitic (duplex) steel welds shall be qualified using samples made of WPS to be used in production.

2.4.20 For flaw detection the corrected primary gain shall be increased by at least 6 dB. Defect size evaluation shall not be performed at this increased gain level.

2.4.21 The indications shall be investigated by maximising the echoes with different angle probes and by rotating the probes. The length of the imperfection shall be determined by measuring the distance between the points where the echo amplitude exceeds the evaluation level. Final evaluation against the acceptance criteria shall be based on the echo amplitude and length measured with the probe angle giving the maximum response.

Table 2 Calibration reference block requirements

<table>
<thead>
<tr>
<th>Thickness of material to be examined (mm)</th>
<th>Thickness of block (mm)</th>
<th>Diameter of hole (mm)</th>
<th>Distance of hole from one surface (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 &lt; t ≤ 50</td>
<td>40 or t</td>
<td>Ø 3 ± 0.2</td>
<td>t/2 and t/4. Additional holes are allowed and recommended</td>
</tr>
<tr>
<td>50 &lt; t ≤ 100</td>
<td>75 or t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 &lt; t ≤ 150</td>
<td>125 or t</td>
<td>Ø 6 ± 0.2</td>
<td></td>
</tr>
<tr>
<td>150 &lt; t ≤ 200</td>
<td>175 or t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 &lt; t ≤ 250</td>
<td>225 or t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t &gt; 250</td>
<td>275 or t</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.4.22 Magnetic particle testing

Magnetic particle testing shall be performed according to procedures subject to agreement. The procedures shall be established according to DNV Classification note No.7.

2.4.23 The equipment shall establish a field strength between 2.4 kA/m and 4.0 kA/m for prods. Prods shall be soft tipped with lead or similar. Use of prods soft tipped with copper is not permitted. Sparks between the prods and the material tested shall be avoided. Electromagnetic A.C. yokes shall develop a minimum lifting force of 4.5 kg at maximum pole spacing applied. Field strength and lifting force shall be checked at regular intervals.

2.4.24 Use of permanent magnets is not permitted.

2.4.25 Non-fluorescent wet or dry particles shall provide adequate contrast with the background or the surface being tested. The Fe-powder shall be traceable to a batch certificate or data sheet documenting compliance with a recognized standard.
2.4.26  De-magnetization should be considered in areas where residual magnetism could be detrimental.

2.4.27  Liquid penetrant testing

Liquid penetrant testing shall be performed according to agreed procedures. The procedures shall be established according to DNV Classification note No.7.

The penetrant products (penetrant, developer and cleaner) shall be traceable to a batch certificate or data sheet documenting compliance with a recognized standard.

Penetrant testing shall only be applied for welds in non-ferro magnetic materials if not otherwise agreed.

2.5  Acceptance criteria for NDT

2.5.1  All welds shall show evidence of good workmanship. For visual testing and NDT the acceptance criteria shall, for special structural steel welds, comply with EN ISO 5817 level B. Welds of category primary/secondary shall comply with EN ISO 5817 quality level C. Regarding use of EN ISO 5817 for RT, UT, MT and PT, correlation is given in EN ISO 17635.

Relevant standard for Magnetic particle testing and penetrant testing (MT/PT) is EN ISO 23278 (see correlation in ISO 17635).

Relevant standard for Ultrasonic testing (UT) is EN ISO 11666. Level B and level C of EN ISO 5817 are equal to, respectively, acceptance level 2 and 3 of ISO 11666 (ref. correlation given in ISO 17635). Regarding ultrasonic testing 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.

Relevant standard for Radiographic testing (RT) is ISO 10675, Level 1 and 2 (see correlation in ISO 17635)

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

2.5.2  Acceptance of defects exceeding the given limits may be granted based on fracture mechanics 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.

2.5.3  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.
SECTION 4 OTHER TESTS

1 Scope
This section covers requirements for testing of tightness and structural tests.

2 Testing of tightness

2.1 General

2.1.1 All tanks shall be tested for tightness. The test may be performed as a hydraulic 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 test by compressed air and an effective indicating liquid shall be carried out before protective coating has been applied.

Guidance note:
A thin layer (< 50 μm) of primer with documented chemical composition may be applied prior to testing. Tightness may also be confirmed by the following methods:
- vacuum testing of individual welds
- injection of air into root gap of fillet welds (fillet air test).

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

2.1.3 If compressed air compressed air and an efficient indicating liquid are used, the air pressure shall not exceed 0.2 bar, and shall be reduced to a smaller value, but not less than 0.15 bar before inspection.

Guidance note:
Care should be taken so that the pressure in the tank does not exceed 0.2 bar above atmospheric pressure because of unexpected raise in ambient temperature, falling atmospheric pressure or otherwise. The pressure shall be measured by an accurate method, such as a U-shaped tube with water. Means should be provided to release pressure in emergency case.

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

2.1.4 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.

2.1.5 For hose testing, the hose pressure shall be at least 200 kN/m² and applied at a maximum distance of 1.5 m. The nozzle inside diameter shall be at least 12.0 mm.

3 Structural tests

3.1 General

3.1.1 At least one of several identical tanks shall undergo a structural test. The test shall by agreement be carried out by applying water.

Guidance note:
When agreed the structural test may be omitted for a series of sister vessels. Protective coating may be applied before a structural test is carried out.

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

3.1.2 Bulkheads between tanks arranged to carry different liquids shall be hydraulically tested from at least one side.
3.1.3 The test pressure height shall be taken as the design pressure height for load case a) as defined in the relevant offshore object standard. The pressure shall be maintained for at least 20 minutes. The filling rate shall be restricted to avoid excessive dynamic design pressure.

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

3.1.5 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.

3.1.6 If structural tests reveal weaknesses in the structure, further testing should be assessed.
SECTION 5  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, DNVGL-RP-0171 (for floating offshore production and storage units) or DNV-RP-B401 (for permanently installed offshore units) may be used.

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 NACE or FROSIO.

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  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.

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.

2.2.5  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 50 - 85 μm measured according to ISO 8503.

2.2.6  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.

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

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

2.2.9  Primer-coated surfaces shall be inspected and be adequately cleaned and prepared before applying the next coating layer.
2.2.10 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 \((r > 20 \text{ mm})\), 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, DNVGL-RP-0171 (for floating offshore production and storage units) or DNV-RP-B401 (for permanently installed offshore units) may be used.

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

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, DNVGL-RP-0171 (for floating offshore production and storage units) may be used.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
SECTION 6 MISCELLANEOUS

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 conform 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 quenched and tempered 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.

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

3 Mechanical fastening

3.1 Contact surfaces in slip resistant connections

3.1.1 If required, contact surfaces in preloaded 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.4.

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  GENERAL

1  General requirements

1.1  Introduction

1.1.1 As well as representing DNV GL’s recommendations on safe engineering practice for general use by the offshore industry, the offshore standards also provide the technical basis 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 see Table 1.

Table 1  DNV GL Rules for classification - Offshore units

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNVGL-OU-0101</td>
<td>Offshore drilling and support units</td>
</tr>
<tr>
<td>DNVGL-OU-0102</td>
<td>Floating production, storage and loading units</td>
</tr>
<tr>
<td>DNVGL-OU-0103</td>
<td>Floating LNG/LPG production, storage and loading units</td>
</tr>
<tr>
<td>DNVGL-OU-0104</td>
<td>Self elevating units</td>
</tr>
</tbody>
</table>

1.1.3 Classification procedures and requirements specifically applicable in relation to the technical provisions in Ch.2 are given in this chapter.

1.2  Assumptions

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

1.2.2 Aspects of the design and construction provisions of this standard (Ch.2) which shall be specially considered, agreed upon, or may be accepted are subject to DNV GL approval when the standard is used for classification purposes.

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

2  Specific certification and classification requirements

2.1  General

The following requirements shall be applied in conjunction with the technical requirements given in Ch.2 and when used for certification or classification purposes.

2.2  Basic requirements

Welding of special, primary and secondary structures for hull, welding of superstructure, and equipment shall be carried out by certified approved welders, with DNV GL approved welding consumables, with DNV GL approved welding procedure specifications (WPS'’es) and at contractors recognised by DNV GL.

2.3  Contractors

2.3.1 Contractors will have to prove their qualifications for the welding operations in question.

2.3.2 It is assumed that the contractors make use of the necessary equipment for carrying out inspection of the welding operations in a satisfactory manner.

2.3.3 Important welding operations shall be carried out under daily supervision of an inspector, who has the experience and qualifications, which enable him to judge this type of work. The work of each welder shall be regularly examined.
2.3.4 The contractors shall keep a card index or register of all approved welders. The register shall give information on training of the welders and date and results of qualification tests. Information about the base metal, type of welding consumable, joint design and welding positions shall be stated in the event of re-qualification tests. The surveyor shall be allowed to examine the register at any time.

2.4 Welding consumables

2.4.1 Consumables for welding of offshore structures intended for classification shall be approved by DNV GL.

2.4.2 Type approval of welding consumables will be considered subject to compliance with the requirements given in the DNV Rules for ships Pt.2 Ch.3 Sec.4 and DNV Type Approval Programme No.1-401.1 "Welding Consumables".

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 for a project specific qualification of the consumable in question.

2.4.3 All brand names under which a tested and approved welding consumable is marketed, shall be registered by DNV GL. In order to avoid duplication of tests, the manufacturer shall certify that the welding consumables marketed under alternative brand names are identical with the consumables tested for approval.

2.4.4 Selection of welding consumables shall follow the requirements given in DNV Rules for ships Pt.2 Ch.3 Sec.4, unless otherwise approved.

2.4.5 The welding voltage, current and polarity shall follow the DNV GL Type Approval Certificate for the welding consumables.

2.5 Welding procedures and qualification of welders

2.5.1 The contractor shall inform the surveyor about the welding/testing schedule. The surveyor shall be allowed to witness welding /testing at any time.

2.5.2 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.

2.6 Corrosion protection systems

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

2.6.2 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.

2.7 Non-destructive testing

Subcontractors engaged in NDT services for newbuildings shall be approved in accordance with DNV Approval of Service Suppliers Programme No. 402B.

3 Records and documentation

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.
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 and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.