FOREWORD

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

DNV service documents consist of amongst other the following types of documents:

- Service Specifications. Procedural requirements.
- Standards. Technical requirements.

The Standards and Recommended Practices are offered within the following areas:

A) Qualification, Quality and Safety Methodology
B) Materials Technology
C) Structures
D) Systems
E) Special Facilities
F) Pipelines and Risers
G) Asset Operation
H) Marine Operations
J) Cleaner Energy
O) Subsea Systems

The electronic pdf version of this document found through http://www.dnv.com is the officially binding version
© Det Norske Veritas

Any comments may be sent by e-mail to rules@dnv.com
For subscription orders or information about subscription terms, please use distribution@dnv.com
Computer Typesetting (Adobe Frame Maker) by Det Norske Veritas

If any person suffers loss or damage which is proved to have been caused by any negligent act or omission of Det Norske Veritas, then Det Norske Veritas shall pay compensation to such person for his proved direct loss or damage. However, the compensation shall not exceed an amount equal to ten times the fee charged for the service in question, provided that the maximum compensation shall never exceed USD 2 million.

In this provision "Det Norske Veritas" shall mean the Foundation Det Norske Veritas as well as all its subsidiaries, directors, officers, employees, agents and any other acting on behalf of Det Norske Veritas.
CHANGES

• General
As of October 2010 all DNV service documents are primarily published electronically.
In order to ensure a practical transition from the “print” scheme to the “electronic” scheme, all documents having incorporated amendments and corrections more recent than the date of the latest printed issue, have been given the date October 2010.
An overview of DNV service documents, their update status and historical “amendments and corrections” may be found through http://www.dnv.com/resources/rules_standards/.

• Main changes
Since the previous edition (October 2009), this document has been amended, most recently in October 2010. All changes have been incorporated and a new date (October 2010) has been given as explained under “General”.

## CONTENTS

### CH. 1 INTRODUCTION

| Sec. 1 Introduction | 8 |

### Sec. 1 Introduction

| A. General | 8 |
| A 100 Introduction | 8 |
| A 200 Objective | 8 |
| A 300 Organisation of contents | 8 |

| B. Normative References | 8 |
| B 100 General | 8 |
| B 200 Offshore service specifications and rules | 8 |
| B 300 Offshore Standards | 8 |
| B 400 Other references | 9 |

| C. Informative References | 9 |
| C 100 General | 9 |

| D. Definitions | 9 |
| D 100 Verbal forms | 9 |
| D 200 Terms | 10 |
| D 300 Abbreviations | 11 |
| D 400 Latin symbols | 11 |
| D 500 Greek symbols | 12 |

### CH. 2 TECHNICAL PROVISIONS

| Sec. 1 Welding Procedures and Qualification of Welders | 14 |

| A. Introduction | 14 |
| A 100 General | 14 |
| A 200 Wide gap welding | 14 |
| A 300 Welding processes | 14 |

| B. Welding Procedures | 14 |
| B 100 General | 14 |
| B 200 Preliminary welding procedure specification, pWPS | 15 |
| B 300 Welding Procedure qualification test (WPQT) | 15 |
| B 400 Welding procedure qualification record (WPQR) | 15 |
| B 500 Welding procedure specifications (WPS) | 15 |

| C. Welding Procedure Tests, C-Mn Steel and Low Alloy Steel | 16 |
| C 100 General | 16 |
| C 200 Butt welds on plates | 16 |
| C 300 Butt welds in pipes | 20 |
| C 400 Full penetration T-, Y-, and K- joints | 21 |
| C 500 Tubular joints/ Branch connections | 22 |
| C 600 Fillet welds | 23 |
| C 700 Re-testing | 23 |
| C 800 Validity of a WPS | 23 |
| C 900 Fracture mechanic (FM) testing | 27 |

| D. Welding Procedure Tests, Aluminium | 29 |
| D 100 General | 29 |
| D 200 Butt welds | 29 |
| D 300 Fillet welds | 32 |
| D 400 Re-testing | 32 |

| E. Welding Procedure Tests, Stainless Steel | 33 |
| E 100 General | 33 |
| E 200 Supplementary requirements for austenitic stainless steel | 33 |
| E 300 Supplementary requirements for ferritic-austenitic stainless steel (duplex) | 33 |

| F. Qualification of Welders | 34 |
| F 100 General | 34 |
| F 200 Standards for qualification testing | 34 |

| G. Testing | 34 |
| G 100 General | 34 |
| G 200 Tensile testing at ambient temperature | 34 |
Sec. 2 Fabrication and Tolerances............................................................................................................ 37
A. General ........................................................................................................................................................ 37
A 100 Objective and scope ............................................................................................................................ 37
B. Fabrication Planning ................................................................................................................................... 37
B 100 General ................................................................................................................................................ 37
B 200 Quality system and workmanship ......................................................................................................... 37
C. Inspection .................................................................................................................................................. 37
C 100 General ................................................................................................................................................ 37
D. Material Identification, Cutting and Forming .............................................................................................. 38
D 100 Material identification ........................................................................................................................... 38
D 200 Cutting and forming .............................................................................................................................. 38
E. Tolerances .................................................................................................................................................. 39
E 100 Tolerances for alignment and straightness ............................................................................................ 39
F. Assembly, Welding, Heat Treatment and Repairs ....................................................................................... 43
F 100 Assembly and welding ............................................................................................................................ 43
F 200 Post weld heat treatment (PWHT) ........................................................................................................ 46
F 300 Repairs ................................................................................................................................................. 47
F 400 Flame straightening ............................................................................................................................... 48
Sec. 3 Non-Destructive Testing ...................................................................................................................... 49
A. General ........................................................................................................................................................ 49
A 100 Scope .................................................................................................................................................... 49
B. Non-Destructive Testing (NDT) ................................................................................................................... 49
B 100 General ................................................................................................................................................. 49
B 200 NDT procedures .................................................................................................................................. 49
B 300 Personnel qualification .......................................................................................................................... 49
B 400 Extent of NDT ..................................................................................................................................... 49
B 500 Acceptance criteria for NDT ................................................................................................................ 52
Sec. 4 Other Tests .............................................................................................................................................. 54
A. General ........................................................................................................................................................ 54
A 100 Scope .................................................................................................................................................... 54
B. Testing of Tightness .................................................................................................................................... 54
B 100 General ................................................................................................................................................. 54
C. Structural Tests ......................................................................................................................................... 54
C 100 General ................................................................................................................................................ 54
Sec. 5 Corrosion Protection Systems ............................................................................................................... 56
A. General ........................................................................................................................................................ 56
A 100 Scope .................................................................................................................................................... 56
A 200 General ................................................................................................................................................ 56
A 300 Application of coating ............................................................................................................................ 56
A 400 Fabrication and installation of sacrificial anodes .................................................................................... 56
A 500 Fabrication and installation of impressed current systems .................................................................... 57
Sec. 6 Miscellaneous ......................................................................................................................................... 58
A. Use General ................................................................................................................................................ 58
A 100 Scope .................................................................................................................................................... 58
B. Bolts .............................................................................................................................................................. 58
B 100 Bolts and nuts ..................................................................................................................................... 58
C. Mechanical Fastening ............................................................................................................................... 58
C 100 Contact surfaces in slip resistant connections ...................................................................................... 58
CH. 3 CERTIFICATION AND CLASSIFICATION .................................................................................. 59
Sec. 1 General .................................................................................................................................................. 60
A. General Requirements ............................................................................................................................... 60
A 100 Introduction ........................................................................................................................................ 60
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 200</td>
<td>Assumptions</td>
<td>60</td>
</tr>
<tr>
<td>B 100</td>
<td>General</td>
<td>60</td>
</tr>
<tr>
<td>B 200</td>
<td>Basic requirements</td>
<td>60</td>
</tr>
<tr>
<td>B 300</td>
<td>Contractors</td>
<td>60</td>
</tr>
<tr>
<td>B 400</td>
<td>Welding consumables</td>
<td>60</td>
</tr>
<tr>
<td>B 500</td>
<td>Welding procedures and qualification of welders</td>
<td>61</td>
</tr>
<tr>
<td>B 600</td>
<td>Corrosion protection systems</td>
<td>61</td>
</tr>
<tr>
<td>B 700</td>
<td>Non-destructive testing</td>
<td>61</td>
</tr>
<tr>
<td>C 100</td>
<td>General</td>
<td>61</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec. 1 Introduction</td>
<td>8</td>
</tr>
</tbody>
</table>
SECTION 1
INTRODUCTION

A. General

A 100 Introduction
101 This standard contains requirements for fabrication and testing of offshore structures involving units and installations described in DNV OSS-101 and DNV OSS-102.
102 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.

A 200 Objective
201 The objectives of this standard are to:
   — provide an internationally acceptable standard to ensure the quality of:
     1) all welding operations used in offshore fabrication, through identifying appropriate welding procedures, welder qualifications and test methods and
     2) application of coating and fabrication and installation of sacrificial anodes and impressed current systems
   — serve as a technical reference document in contractual matters between purchaser and contractor
   — serve as guideline for designer, purchaser and contractor
   — specify minimum requirements for welding operations subject to DNV certification and classification.

A 300 Organisation of contents
301 Ch.2 Sec.1 to Ch.2 Sec.6 give common requirements that are considered applicable to all types of offshore units and installations.

B. Normative References

B 100 General
101 The references given in Table B1, Table B2 and Table B3 include provisions, which through reference in this text constitute provisions for this standard.

B 200 Offshore service specifications and rules
201 The offshore service specifications and rules given in Table B1 are referred to in this standard.

<table>
<thead>
<tr>
<th>Table B1 DNV Offshore Service Specifications and rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
</tr>
<tr>
<td>DNV-OSS-101</td>
</tr>
<tr>
<td>DNV-OSS-102</td>
</tr>
<tr>
<td>DNV</td>
</tr>
</tbody>
</table>

B 300 Offshore Standards
301 The offshore standards given in Table B2 are referred to in this standard.

<table>
<thead>
<tr>
<th>Table B2 DNV Offshore Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
</tr>
<tr>
<td>DNV-OS-B101</td>
</tr>
<tr>
<td>DNV-OS-C101</td>
</tr>
<tr>
<td>DNV-OS-C201</td>
</tr>
</tbody>
</table>
B 400  Other references

401  The other references given in Table B3 are referred to in this standard.

<table>
<thead>
<tr>
<th>Table B3 Other references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference</strong></td>
</tr>
<tr>
<td>ANSI/AWS D1.1</td>
</tr>
<tr>
<td>ASME</td>
</tr>
<tr>
<td>ASTM G48</td>
</tr>
<tr>
<td>BS 7448-2</td>
</tr>
<tr>
<td>EN 287</td>
</tr>
<tr>
<td>EN 1418</td>
</tr>
<tr>
<td>ISO 148</td>
</tr>
<tr>
<td>ISO 898</td>
</tr>
<tr>
<td>ISO 5817</td>
</tr>
<tr>
<td>ISO 9001:2000</td>
</tr>
<tr>
<td>ISO 9606</td>
</tr>
<tr>
<td>ISO 10042</td>
</tr>
<tr>
<td>NACE MR0175</td>
</tr>
<tr>
<td>EN 473</td>
</tr>
<tr>
<td>ISO 9712</td>
</tr>
</tbody>
</table>

C. Informative References

C 100  General

101  The documents listed in Table C1 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>Table C1 DNV Recommended Practices and Classification Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference</strong></td>
</tr>
<tr>
<td>DNV-RP-C203</td>
</tr>
<tr>
<td>DNV Classification Note 30.1</td>
</tr>
<tr>
<td>DNV Classification Note No. 7</td>
</tr>
<tr>
<td>Standard for Certification No. 2.9 Approval Programme No. 402B</td>
</tr>
</tbody>
</table>

D. Definitions

D 100  Verbal forms

101  **Shall:** Indicates a mandatory requirement to be followed for fulfilment or compliance with the present standard. Deviations are not permitted unless formally and rigorously justified, and accepted by all relevant contracting parties.

102  **Should:** Indicates a recommendation that a certain course of action is preferred or particularly suitable. Alternative courses of action are allowable under the standard where agreed between contracting parties but
shall be justified and documented.

103 May: Indicates a permission, or an option, which is permitted as part of conformance with the standard.

104 Can: Can-requirements are conditional and indicate a possibility to the user of the standard.

105 Agreement, or by agreement: Unless otherwise indicated, agreed in writing between contractor and purchaser.

D 200 Terms

201 Purchaser: The owner or another party acting on his behalf, who is responsible for procuring materials, components or services intended for the design, construction or modification of a structure.

202 Contractor: A party contractually appointed by the purchaser to fulfil all, or any of, the activities associated with fabrication and testing.

203 Unit: A general term for an offshore installation such as ship shaped, column stabilised, self-elevating, tension leg or deep draught floater.

204 Installation: A collective term to cover any construction, buoyant or non-buoyant, designed and built for installation at a particular offshore location.

205 Welding procedure: A specified course of action to be followed in making a weld, including reference to materials, welding consumables, preparation, preheating (if necessary), method and control of welding and post-weld heat treatment (if relevant), and necessary equipment to be used.

206 Preliminary welding procedure specification (pWPS): A tentative welding procedure specification providing required welding variables, which is assumed to be adequate by the contractor, but which has not been qualified by the purchaser.

207 Welding procedure specification (WPS): A welding procedure specification, which has been qualified by the purchaser to conform with an agreed qualification scheme.

208 Welding procedure qualification test (WPQT): The process of accomplishing welding and testing of a standardised test piece, as indicated in the WPS.

209 Welding procedure qualification record (WPQR): A record comprising a summary of necessary data needed for the issue of a WPS.

210 Welding production test (WPT): A test carried out to demonstrate that actual production welding meets the specified requirements.

211 Non-destructive testing (NDT): Visual inspection, radiographic testing, ultrasonic testing, magnetic particle testing, penetrant testing and other non-destructive methods for revealing defects and irregularities.

212 Structural testing is a hydrostatic test, carried out in order to demonstrate the tightness of the tanks and the structural adequacy of the design. Where hydrostatic testing is not practically feasible, hydropneumatic testing may be carried out instead under provision that the test is simulating, as far as practicable, the actual loading of the tank.

213 Leak testing is an air or other medium test, carried out in order to demonstrate the tightness of the structure.

214 Hydropneumatic testing is a combination of hydrostatic and air testing, carried out in order to demonstrate the tightness of the tanks and the structural adequacy of the design.

215 Hose testing is a water test carried out to demonstrate tightness of structural items.

216 Shop primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.

217 Protective coating is a final coating protecting the structure from corrosion.

218 Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed.

219 Weathertight means that in any sea conditions water will not penetrate into the ship.
D 300  Abbreviations

301  The abbreviations given in Table D1 are used in this standard.

<table>
<thead>
<tr>
<th>Table D1 Abbreviations</th>
<th>Abbreviation</th>
<th>In full</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternating current</td>
<td></td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
<td></td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
<td></td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing of Materials</td>
<td></td>
</tr>
<tr>
<td>AWS</td>
<td>American Welding Society</td>
<td></td>
</tr>
<tr>
<td>BM</td>
<td>Base material</td>
<td></td>
</tr>
<tr>
<td>BS</td>
<td>British Standard (issued by British Standard Institution)</td>
<td></td>
</tr>
<tr>
<td>CE</td>
<td>Carbon equivalent</td>
<td></td>
</tr>
<tr>
<td>C-Mn</td>
<td>Carbon manganese</td>
<td></td>
</tr>
<tr>
<td>CTOD</td>
<td>Crack tip opening displacement</td>
<td></td>
</tr>
<tr>
<td>DAC</td>
<td>Distance amplitude curve</td>
<td></td>
</tr>
<tr>
<td>DC</td>
<td>Direct current</td>
<td></td>
</tr>
<tr>
<td>DNV</td>
<td>Det Norske Veritas</td>
<td></td>
</tr>
<tr>
<td>ECA</td>
<td>Engineering critical assessment</td>
<td></td>
</tr>
<tr>
<td>EN</td>
<td>European de Normalisation</td>
<td></td>
</tr>
<tr>
<td>FM</td>
<td>Fracture mechanics</td>
<td></td>
</tr>
<tr>
<td>HAZ</td>
<td>Heat affected zone</td>
<td></td>
</tr>
<tr>
<td>IACS</td>
<td>International Association of Classification Societies</td>
<td></td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation for Standardisation</td>
<td></td>
</tr>
<tr>
<td>MAG</td>
<td>Metal active gas (welding)</td>
<td></td>
</tr>
<tr>
<td>MIG</td>
<td>Metal inert gas (welding)</td>
<td></td>
</tr>
<tr>
<td>NACE</td>
<td>National Association of Corrosion Engineers</td>
<td></td>
</tr>
<tr>
<td>NDT</td>
<td>Non-destructive testing</td>
<td></td>
</tr>
<tr>
<td>PWHT</td>
<td>Post weld heat treatment</td>
<td></td>
</tr>
<tr>
<td>RP</td>
<td>Recommended practice</td>
<td></td>
</tr>
<tr>
<td>SMAW</td>
<td>Shielded metal arc welding</td>
<td></td>
</tr>
<tr>
<td>SMYS</td>
<td>Specified minimum yield stress</td>
<td></td>
</tr>
<tr>
<td>TIG</td>
<td>Tungsten inert gas (welding)</td>
<td></td>
</tr>
<tr>
<td>WM</td>
<td>Weld metal or Deposit</td>
<td></td>
</tr>
</tbody>
</table>

D 400  Latin symbols

401  The following Latin symbols are used:

- $a =$ size of test specimen
- $b =$ size of test specimen
- $d =$ diameter of round tensile test specimen
- $d_f =$ distance from the plane of the fatigue pre-crack to the fusion line
- $e =$ plastic deformation
- $h_T =$ test pressure height
- $h_{op1} =$ vertical distance from the load point to the position of maximum filling height
- $h_{a3} =$ vertical distance from the load point to the top of the tank
- $h_{p0} =$ height corresponding to valve opening pressure when exceeding the general value
- $h_{op2} =$ 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 $T_E$
- $h_{D2} =$ pressure head due to flow through pipes
- $l_e =$ equivalent parameter for conical shells
- $l_{min} =$ breadth of test assembly plates
- $l_r =$ length of template or rod
- $r =$ nominal radius of the shell
- $r_a =$ actual distance from the centre of the sphere to the shell wall
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

CONTENTS

Sec. 1 Welding Procedures and Qualification of Welders ........................................................... 14
Sec. 2 Fabrication and Tolerances ................................................................................................ 37
Sec. 3 Non-Destructive Testing ................................................................................................... 49
Sec. 4 Other Tests ......................................................................................................................... 54
Sec. 5 Corrosion Protection Systems ............................................................................................ 56
Sec. 6 Miscellaneous ...................................................................................................................... 58
SECTION 1
WELDING PROCEDURES AND QUALIFICATION OF WELDERS

A. Introduction

A 100 General

101 This section specifies requirements for welding procedures and welding procedure tests for C-Mn steel and low alloy steel, aluminium, austenitic stainless steels and ferritic-austenitic (duplex) stainless steels as well as qualification of welders.

102 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.

103 Qualification of welding procedures for overlay- / clad welding can be according to ISO 15614-7, AWS D1.1 or ASME IX. However, the requirements in DNV-OS-F101, App.C, E400 and F400 shall as a minimum apply.

A 200 Wide gap welding

201 Wide gap welding / buttering of the weld groove shall when the gap is above 10 mm, 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 than the essential variables for the process used for subsequent completion of the joint and/or the thickness of the buttering exceed 8 mm each side of the bevel.

No weaving is allowed.

The buttered area shall be 100% tested with MT/PT 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".

A 300 Welding processes

301 Welding may be performed with the following processes unless otherwise specified:

— 111 manual metal arc welding (metal arc welding with covered electrode)
— 114 self-shielded tubular-cored arc welding
— 121 submerged arc welding
— 121 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.

B. Welding Procedures

B 100 General

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

— material: standard, grade and modification
— identification of manufacturer
— identification of the WPS
— nominal thickness or diameter range (dimensions)
— reference to welding procedure qualification record
— 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, pulse welding details (machine settings and/or programme selection)
— heat input for each pass
— travel speed- and heat input ranges
— for automatic welding the specific make and model of welding equipment
— 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 FCAW/136 welding process:
— mode of metal transfer (short circuiting, spray or globular transfer).

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.

B 200 Preliminary welding procedure specification, pWPS

201 A tentative pWPS shall be agreed upon prior to starting up the welding procedure qualification test (WPQT).

A pWPS shall be prepared for each new welding procedure qualification. The pWPS shall contain the relevant information required for making a weld for the intended application when using the applicable welding processes, including tack welds, see B100.

B 300 Welding Procedure qualification test (WPQT)

301 A welding procedure specification (WPS) is required to be qualified by a WPQT, the welding process shall be performed based on the accepted WPS.

Qualification welding shall be performed based upon the pWPS, using the type of welding equipment to be used during production welding, and under conditions that are representative of the actual working environment for the work shop or site, where the production welding will be performed.

B 400 Welding procedure qualification record (WPQR)

401 A WPQR can be basis for the purchaser’s acceptance of a WPS. Prior to starting up production the WPQR shall be submitted to the purchaser for review including any corrosion test results, as applicable.

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 material certificates for the base and filler materials applied in the weld qualification test.

B 500 Welding procedure specifications (WPS)

501 A WPS is a specification based on one or more accepted WPQRs. One or more WPSs may be prepared based on the data of one or more 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.

The WPS shall be submitted together with the referenced supporting WPQR(s) for review and acceptance by the purchaser prior to start of production.
502 A WPS shall be valid under the provision that production welding is carried out with the same type of welding equipment on which the WPS has been established.

503 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.

Preheat for repair welding shall normally be minimum 50°C above minimum specified preheat for production welding. Refer Ch.2, Sec.2, F300.

504 The conditions on which the WPS has been established shall be representative of the working environment for the work shop or site where the production welding will be performed. (See C800).

The qualification is valid for the workshop performing the welding tests, and other workshops under the same technical and quality management.

C. Welding Procedure Tests, C-Mn Steel and Low Alloy Steel

C 100 General

101 All instruments for checking weld parameters (temperature, ampere, volt, when applicable the ppm measuring equipment, electrical post heating equipment) shall have valid calibration certificates and the adequacy of any control software (weld machine) shall be documented.

C 200 Butt welds on plates

201 The test assembly may consist of two plates welded together. For normal and high strength steel grades (ref. OS-B101 Ch.2 Sec.1 A200), impact tested in the longitudinal direction, 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, 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 can simulate the heat transfer during the production welding. For manual or semiautomatic welding, a test assembly according to Fig.1 shall be carried out with:
For automatic welding, the dimensions shall be:

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

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.

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 inspection
- 100% radiographic or ultrasonic testing
- 100% surface crack detection (dye penetrant or magnetic particle testing).

The acceptance criteria shall be according to ISO 5817 level B. Level B of ISO 5817 is considered equal to acceptance level 2 in EN 1712 for ultrasonic testing. (Ref. correlation given in EN 1712, EN 126062 and EN 17635).

The following mechanical tests are required from each assembly (see Fig.2):

- 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 \( t > 20 \text{ mm} \)
- 4 (6) sets of Charpy V-notch tests with the notch location as given in 207
- 1 macrosection test (metallographic examination + hardness measurements).

Specimens for transverse tensile testing shall be in accordance with G, type B. The tensile strength shall not be below the specified minimum tensile strength for the steel grade in question.
Transverse side bend, root bend and face bend specimens shall be machined to the dimensions shown in G300. 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 4t, where t is the thickness of the specimen, except for extra high strength steel grades NV 550, NV 620 and NV 690 where the diameter shall be 5t. 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. Defects appearing at the corners of a test specimen during testing shall be investigated case by case.

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. Cracks and lack of fusion are not accepted. The welded joints shall have a regular profile with smooth transitions to the base materials and without significant or excessive reinforcement.

The Charpy V-notch specimens shall be machined in accordance with the requirements given in DNV-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)

The V-notch shall be perpendicular to the material surface. For material thickness t > 50 mm two additional sets of specimens shall be taken from the root area: one with the notch in centre of weld and one with the notch in the fusion line. Where multiple welding processes are qualified in a single test piece, impact test specimens shall be taken from the weld metal and HAZ that include each process. 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. The Charpy V-notch test temperature and the average value for absorbed energy (KV) in WM, FL and HAZ shall be the same as required for the base material in transverse direction for extra high strength steels. For normal strength steels and high strength steels, 70% of the longitudinal value is to be used (see DNV-OS-B101).

The requirements given by the DNV Rules for Classification of Ships Pt.2 Ch.3 Sec.5 E401 can be applied as an alternative.

For grades of improved weldability (see DNV-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.

208 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 C1.

<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>

209 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.

210 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 average required value.

When the result of any test, other than impact test, fails to meet the requirements, two further tests may be made from the same welded joint. If both these additional tests are satisfactory, the test is acceptable.

211 The hardness testing shall be in accordance with ISO 6507-1 or equivalent. 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.

For material grades up to and including NV 420, a maximum hardness limit of 350 HV10 shall be met. For NV 460, NV 500, NV 550, NV 620 and NV 690 grades a maximum hardness limit shall be 420 HV10.

212 When a butt weld is made between two different material 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 Fig.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.
Butt welds in pipes

The test assembly shall be in accordance with Fig.4.

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 inspection
- 100% radiographic or ultrasonic testing
- 100% surface crack detection (dye penetrant, eddy current or magnetic particle testing).

The acceptance criteria shall be according to ISO 5817 level B.

The following mechanical tests are required from each assembly (see Fig.5):

- 2 tensile tests (flat specimen transverse to the weld)
- 1 root and 1 face bend tests when t ≤ 20 mm and 2 side bend tests when t > 20 mm
- 4 (6) sets of Charpy V-notch tests with the notch location as given in 207
- macrosection test (metallographic examination + hardness measurements).
The results of mechanical testing shall comply with the relevant requirements given in C200.

**C 400 Full penetration T-, Y-, and K-joints**

401 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 Fig.6).

402 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 inspection
- 100% ultrasonic testing
- 100% surface crack detection (dye penetrant, eddy current or magnetic particle testing).

The acceptance criteria shall be according to ISO 5817 level B.

The results of mechanical testing shall comply with the relevant requirements given in C200.

403 The following mechanical tests are required from each assembly (see Fig.7):

- 4 (6) sets of Charpy V-notch tests with the notch location as given in 207
- 1 macrosection test (metallographic examination + hardness measurements).

The results of mechanical testing shall comply with the relevant requirements given in C200.
C 500  Tubular joints/ Branch connections

501 The test assembly shall be in accordance with Fig.8.

502 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 inspection
— 100% ultrasonic testing
— 100% surface crack detection (dye penetrant or magnetic particle testing).

The acceptance criteria shall be according to ISO 5817 level B.

Figure 8  Test assembly for tubular joints/ branch connections

503 The following mechanical tests are required from each assembly (see Fig.9):

— 12 Charpy V-notch tests sampled at 9 o'clock and with the notch location as given in 207
— 2 macro section tests (metallographic examination + hardness measurements) at 12 and 6 o'clock.

504 The results of mechanical testing shall comply with the relevant requirements given in C200.
Restrictions and testing for joint configuration involving acute angles (less than 15°) should be specified. AWS D1.1 is a good reference for structural welds.

C 600 Fillet welds

601 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 fillet welds the test assembly shall be as defined in Fig.9.

![Figure 9](image_url)

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 and restart position shall 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.

602 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 inspection
- 100% surface crack detection (dye penetrant or magnetic particle testing).

The acceptance criteria shall be according to ISO 5817 level B.

If the stop and 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.

603 The following 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 and restart (for more details see 206).

For hardness testing, see 211.

C 700 Re-testing

701 If the welding procedure test fails to comply with any of the requirements for NDT one extra test shall be welded and subjected 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 welding procedure test.

C 800 Validity of a WPS

801 A qualified welding procedure of a particular manufacturer is valid for welding only in workshops or sites under the operational technical and quality control of that manufacturer.

802 A welding procedure remains valid provided the parameters are kept within the qualified ranges of essential variable during production welding. The essential variables and qualified ranges are given in 803.
When variations outside the qualification ranges of essential variables occur, the welding procedure qualification shall be considered invalid, and the WPS shall be re-specified and re-qualified.

803 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. The base material selected for the qualification testing shall be representative of the upper range of the specified chemical composition for C-Mn and low alloy steels. A change from wrought (rolled, forged) steel to cast steel or vice versa will require a new welding procedure qualification.

b) Structural steels of both normal and improved weldability are grouped in three strength groups:

i) Normal strength steel, grades A, B, D and E or equivalent structural steels with tensile strength 400 to 520 N/mm².

ii) High strength steel, grades A 27, D 27, E 27, A 32, D 32, E 32, F 32, A 36, D 36, E 36, F 36, A 40, D 40, E 40, F 40 or equivalent structural steels with minimum specified yield strength 265 to 390 N/mm².


The qualification on steel grades of higher toughness requirements will qualify the grades of lower toughness but not vice versa.

Thickness

Thickness, t, is defined as follows:

a) For a butt weld:
   The base metal thickness, which for welds between dissimilar thickness is that of the thinner material.

b) For a fillet weld:
   The base metal thickness, which for welds between dissimilar thickness is that of the thicker material.

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

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

e) For a T-butt joint in plate:
   The thickness of the prepared plate (abutting member).

The requirements for qualified thickness range for butt welds shall be as given in Table C2.

<table>
<thead>
<tr>
<th>Thickness in mm of test piece</th>
<th>Qualification range 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>for single run or single run from both sides</td>
</tr>
<tr>
<td>t &lt; 12</td>
<td>0.7 t to 1.1 t</td>
</tr>
<tr>
<td>12 ≤ t ≤ 100</td>
<td>0.7 t to 1.1 t</td>
</tr>
<tr>
<td>t &gt; 100</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

1) The qualification range for vertical downward position is 0.5 t to 1.1 t

Range of qualification for material thickness and throat thickness of fillet welds shall be as given in Table C3.
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 C4.

Table C4 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>$D \leq 25$</td>
<td>$0.5 D$ to $2 D$</td>
</tr>
<tr>
<td>$D &gt; 25$</td>
<td>$\geq 0.5 D$ 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 welding procedure test 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
— change of consumable brand when impact testing is required at temperatures below −20°C
— any significant change of mixture or composition (e.g. change from argon or mixed gas to CO2 gas), 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 Fig.10, Fig.11 and Fig.12) to another, unless complying with Table C5.
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
— addition or deletion of ceramic backing
— deletion of backing in cases where the backing material is equivalent to the base material
— 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 specified in the WPS and agreed with the purchaser, such as change of specified type of groove, root face and gap, which may affect penetration, fusion and dilution of the weld.

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
— stringer to weave ratio outside the tolerances specified in the agreed WPS
— 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 to short arc pulse, or vice versa
— any change beyond 25°C of the maximum interpass temperature
— change in heat input beyond ± 25% for steel up to 420 MPa in specified yield strength. For material with specified yield strength 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.
— 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.
Requirements to fracture mechanic testing are given in DNV-OS-C101 or DNV-OS-C201. 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.

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.

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.

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.)

Testing of the HAZ or the weld deposit can be omitted if tests with satisfactory results according to the

Table C5 Qualified principal positions for butt welds and fillet welds, steel

<table>
<thead>
<tr>
<th>Test weld Joint configuration 1)2)</th>
<th>Principal positions</th>
<th>Qualified positions 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plates</td>
<td>Pipes</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>1F</td>
</tr>
<tr>
<td></td>
<td>2F</td>
<td>1F, 2F, 4F</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 shall be qualified separately
3) The vertical downwards position shall be qualified separately

C 900 Fracture mechanic (FM) testing

901 Requirements to fracture mechanic testing are given in DNV-OS-C101 or DNV-OS-C201.

902 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.

903 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.

904 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.

905 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.)

906 Testing of the HAZ or the weld deposit can 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.

907 The FM tests shall be carried out according to BS 7448 Part 2 (with detailed requirements as given below) using 3-point bend specimens. The CTOD-technique with B × 2B specimens shall be used. For nominal plate thicknesses of the test weld equal to or exceeding 80 mm, B × B specimens may be used.

All specimens shall be tested with the fatigue pre-crack placed in the through-thickness direction. For tests of the weld deposit the fatigue pre-crack shall sample the central part of the deposit. For tests in the HAZ the required location of the fatigue crack depth is given in 908.

An evaluation of the relevant test temperature shall be made for all joints in question. Unless there is a high probability that the extreme loads on the joints will concur with lower temperatures the test temperature shall be:

For joints submerged at lowest waterline: ≤ 0°C
Other joints: ≤ design temperature.

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

A metallographic section according to BS 7448 Part 2 Section 11.2 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 Fig.13.

Figure 13
Cross-section through the weld

BM = Base material
WM = Weld metal or deposit
d_f = distance from the plane of the fatigue pre-crack to the fusion line (varies along the fatigue pre-crack)
l_i = length (in mm) of area with acceptable location of the fatigue pre-crack (see below)
t = Plate thickness

Measurements of the distance, d_f, between the plane of the fatigue pre-crack and the fusion line shall be taken. Within the central 75% of the plate thickness the areas where d_f ≤ 0.5 mm shall be identified. The length, l_i, of each of these areas shall be determined. The location of the fatigue pre-crack shall satisfy the following criteria:

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

N = number of areas with d_f ≤ 0.5 mm

909 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 BS 7448 Part 2 apply for both HAZ and weld deposit specimens.

Three valid tests for each of weld deposit and HAZ shall be carried out. 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 C5, shall be equal...
to or larger than 0.15 mm.

**Table C5 Characteristic value of CTOD**

<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.

910 If the characteristic value as specified in Table C5 is larger 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.

**D. Welding Procedure Tests, Aluminium**

**D 100 General**

101 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. Detailed Welding Procedure Specifications by testing shall be established and accepted by the purchaser for all welding. Qualified welding procedures by testing are required for all important structural joints. The procedure tests shall be representative of the following:

— each base material or alloy and temper used in production
— the thickness and diameter range in question (see Table C2 and Table C3)
— each type of consumable and welding process
— welding position (see Table D1)
— joint and groove design
— number of passes
— preheat (if any)
— volt-ampere characteristics
— shielding gas.

**Table D1 Qualified principal positions for butt welds and fillet welds, aluminium**

<table>
<thead>
<tr>
<th>Test weld</th>
<th>Joint configuration</th>
<th>Principal positions</th>
<th>Butt welds, plates</th>
<th>Butt welds, pipes</th>
<th>Fillet welds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1G</td>
<td>1G, 2G, 3G</td>
<td>1G</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1G</td>
<td>1G, 2G, 3G, 4G</td>
<td>1G, 2G, 3G, 4G</td>
<td>1F</td>
</tr>
<tr>
<td></td>
<td>Butt welds on plates</td>
<td></td>
<td></td>
<td></td>
<td>1F, 2F, 3F</td>
</tr>
<tr>
<td></td>
<td>2G</td>
<td>1G</td>
<td></td>
<td></td>
<td>1F, 2F, 3F</td>
</tr>
<tr>
<td></td>
<td>4G</td>
<td>All</td>
<td>1G, 2G, 3G, 4G</td>
<td>1G, 2G, 3G, 4G</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Butt welds in pipes</td>
<td></td>
<td></td>
<td></td>
<td>1F</td>
</tr>
<tr>
<td></td>
<td>1G</td>
<td>1G</td>
<td>1G, 2G, 3G, 4G</td>
<td>1G, 2G, 3G, 4G</td>
<td>1F, 2F, 3F</td>
</tr>
<tr>
<td></td>
<td>5G</td>
<td>All</td>
<td>1G, 2G, 3G, 4G</td>
<td>1G, 2G, 3G, 4G</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Fillet welds</td>
<td></td>
<td></td>
<td></td>
<td>1F</td>
</tr>
<tr>
<td></td>
<td>1F</td>
<td>1F</td>
<td>1F, 2F, 3F</td>
<td>1F, 2F, 3F</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>2F</td>
<td>1F, 2F, 3F</td>
<td>1F, 2F, 3F</td>
<td>1F, 2F, 3F</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>3F</td>
<td>1F, 2F, 3F</td>
<td>1F, 2F, 3F</td>
<td>1F, 2F, 3F</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>4F</td>
<td>1F, 2F, 3F</td>
<td>1F, 2F, 3F</td>
<td>1F, 2F, 3F</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>5F</td>
<td>All</td>
<td>1F, 2F, 3F</td>
<td>1F, 2F, 3F</td>
<td>All</td>
</tr>
</tbody>
</table>

1) The vertical downward position shall be qualified separately.

**D 200 Butt welds**

201 Each test assembly consists of 2 plates with dimensions 300 × 150 mm. The plates shall be joined with a longitudinal butt weld. For extruded sections and pipes the assembly shall consist of 2 sections each 150 mm long (see Fig.14 and Fig.15).

202 Weld and fit-up shall be as detailed in the pWPS. Welding consumables are those recommended in Table D2.

203 If back-sealing run is specified, this run shall be laid in the same position as for the respective weld.

204 The welds shall be subjected to visual inspection, dye penetrant testing and ultrasonic- or X-ray testing. The requirements for quality level for imperfections shall be as given in ISO 10042 level B. The correlation between the quality levels of ISO 10042 and the acceptance levels of the different NDT techniques are given in ISO 17635.
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.

For thickness below 10 mm one face bend and one root bend test specimens shall be taken. The width shall be 30 mm and the thickness equal to the plate thickness. The diameter of the bending mandrel shall be as given in Table D3.

Table D2 Selection of suitable consumables for combinations of aluminium alloys

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NV-5052, NV-5754 NV-5154, NV-5454 NV-5086</td>
<td>5356, 5556, 5183</td>
<td>5356, 5556, 5183</td>
<td>5356, 5556, 5183</td>
</tr>
<tr>
<td>NV-5083, NV-5383</td>
<td>5356, 5556, 5183</td>
<td>5183 1)</td>
<td>5356, 5556, 5183</td>
</tr>
<tr>
<td>NV-6060, NV-6061 NV-6063, NV-6005A NV-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.

Requirement
No cracks or open defects exceeding 3 mm measured on the convex surface after bending are accepted. Smaller cracks developing from the edges of the specimens should not be considered as significant, unless there is definite evidence that they result from inclusions or other defects. «Wrap around» bending as shown in Fig.16 is the preferred bending method.
Figure 15
Location of test specimens for a butt weld in pipe

Figure 16
Wrap around bending

208 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 Fig.17.

Figure 17
Tensile test specimen

209 The tensile strength of the test specimens shall not be less than specified for the parent alloy in Table D4.

210 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. The macrosection shall show a regular weld profile with a smooth transition to the base material without significant undercut or excessive reinforcement and show thorough fusion between adjacent layers of weld metal and base metal. There shall be no cracks, lack of fusion and incomplete penetration.
D 300 Fillet welds

301. 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 fillet welds the test assembly shall be as defined in Fig.9.

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

\[ l_{\text{min}} = 300 \text{ mm} \]
\[ L_{\text{min}} = 350 \text{ mm} \]

For automatic welding the length shall be:

\[ l_{\text{min}} = 400 \text{ mm} \]
\[ L_{\text{min}} = 1000 \text{ mm} \]

Weld and fit-up shall be as detailed in the pWPS.

The test assembly shall be welded on one side only. For manual and semi-automatic welding, the stop and restart position should 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.

302. 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 inspection
- 100% surface crack detection (dye penetrant).

The soundness of the weld shall comply with ISO 10042 level B.

If the stop and 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.

303. The following tests shall be performed:

- two macrosection tests (metallographic examination).

One of the macrosections shall be taken at the marked position of the stop and restart (for more details see C206).

D 400 Re-testing

401. If any of the tests do not satisfy the specified requirements, new procedure tests in duplicate may be carried out. The results of both re-tests shall meet the specified requirements, otherwise the test shall be rejected.

Guidance note:

HAZ softening adjacent to welds

The strength of a weldment is a function of the welding process, filler metal and the aluminium alloy in question. For design purposes it is assumed that the strength is reduced in HAZ. The extent of the HAZ is assumed to have the same width as the weldment plus the plate thickness in each direction of the weld as shown in Fig.18.

If the strength shall be measured for information, this shall be carried out on a gauge length \(2t + W\) of the weld (approximately 3 \(t\)).

---c-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---
E. Welding Procedure Tests, Stainless Steel

E 100 General

101 When welding procedure tests are required, the tests shall be performed in accordance with C and the supplementary requirements stated in E200 and E300 (if not otherwise specified herein). Prefabrication and welding of stainless steels, should be performed in a workshop, or parts thereof, which is reserved exclusively for these type of materials.

102 The welding procedure tests shall cover all relevant dimensions, positions and material combinations. Details regarding essential variables and validity of the procedure shall be as described in C. Mechanical testing shall be as described in C200, if not otherwise specified in E200 and E300.

E 200 Supplementary requirements for austenitic stainless steel

201 Impact testing is not required for design temperatures above –105°C. If used at below –105°C, the test temperature shall be at minimum design temperature.

202 If impact testing is required, the average impact value for the three specimens shall not be less than 34 J.

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

E 300 Supplementary requirements for ferritic-austenitic stainless steel (duplex)

301 Impact testing shall be 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.

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.

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

303 Butt welds and fillet welds 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 20°C for 24 hours for 22Cr steels and 40°C for 24 hours for 25Cr steels.
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 20 X magnification
— general weight loss shall be less than 4 g/m².

Guidance note:
Welds between ferritic-austenitic stainless steels and C- and C-Mn steels need not be subjected to corrosion test.

304 Type 22Cr and 25Cr duplex stainless steel shall be examined and the test samples shall comprise a cross section of the weld metal, HAZ and the base metal of the pipe. The micro-structure shall be suitably etched and examined at 400X magnification and shall have grain boundary with no continuous precipitations and the inter-metallic phases, nitrides and carbides shall not in total exceed 0.5%.

For the stainless steel Type 22 and 25Cr duplex the ferrite content in the weld metal root and in the last bead of the weld cap shall be determined in accordance with ASTM E 562 and shall be in the range of 30% to 70%.

F. Qualification of Welders

F 100 General

101 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.

F 200 Standards for qualification testing

201 Welders shall be tested according to a recognised standard, e.g. EN 287, ISO 9606, ASME Section IX or ANSI/AWS D1.1.

202 Welding operators using fully mechanised or fully automatic processes need generally not pass a qualification test. However, operators shall receive adequate training in setting or programming and operating the equipment. Appropriate records of training shall be maintained. Contractors may be required to furnish valid qualification test certificates. EN 1418 may be used as a reference.

G. Testing

G 100 General

101 Testing of welds shall be carried out as specified in 200 and 300.

G 200 Tensile testing at ambient temperature

201 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 Fig.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:

\[
\begin{align*}
a &= \text{thickness of plate, } t \\
b &= 25 \text{ mm}
\end{align*}
\]
Figure 19
Tensile test specimen

G 300  Bend testing

301  Flat bend test specimens, as given in Fig.20 shall be used. Edges on tension side shall be rounded to a radius of 1 to 2 mm.

302  When the wrap around bend test, exemplified Fig.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 Fig.20.

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

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

\[
\begin{align*}
L_0 &= L_C = 3 \ t \ or \ 2 \ t + \text{width of weld, (whichever is the greatest)} \\
R &= 25 \ mm \\
a &= \text{as rolled thickness } t \ of \ the \ plate \\
b &= 30 \ mm
\end{align*}
\]
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.

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

\[
\begin{align*}
    a & = 10 \text{ mm} \\
    b & = \text{as rolled thickness } t \text{ of the plate}
\end{align*}
\]

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

306 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

A. General

A 100 Objective and scope
101 This section gives requirements for fabrication and tolerances of offshore structures.
102 In order to determine the structural categorization, this section shall be read in conjunction with the following applicable standards:
DNV-OS-C101 Section 4 and relevant Object Standard, Section 2 “Selection of Material and Extent of Inspection” or DNV-OS-C201 Section 4.

B. Fabrication Planning

B 100 General
101 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 to the purchaser 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.
102 Relevant procedures, including information of pre-assembled items and the sequence of fabricating the parts into structure, shall be prepared.

B 200 Quality system and workmanship
201 Contractors involved in fabrication of structural members shall have a documented and implemented quality system according to ISO 9001 or equivalent. 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.
202 Workmanship shall be in accordance with written procedures accepted by the purchaser.
203 All work shall be executed with adequate control by the contractor. Repair work shall be carried out in accordance with written procedures accepted by the purchaser. Faults and deficiencies shall be corrected before painting or other means of permanent covers have been applied.
204 Prior to commencement of the work the contractor shall submit a plan for NDT, NDT procedures and documents for NDT inspectors’ certification for acceptance by the purchaser. The programme shall contain information and documents for planning, controlling, reporting etc. Acceptance criteria for NDT shall be accepted by the purchaser if they are not specified in relevant documents.

C. Inspection

C 100 General
101 Inspection shall be carried out by the contractor in accordance with accepted inspection and test plans to confirm that all project requirements are fulfilled to the satisfaction of the purchaser.
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.

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

103 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.

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

D. Material Identification, Cutting and Forming

D 100 Material identification

101 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.

D 200 Cutting and forming

201 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.

202 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.

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

204 The degree of cold deformation of special and primary structural elements shall be less than 5%. If the deformation exceeds 5%, either heat treatment or strain ageing tests shall be carried out according to an agreed procedure.

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:

\[
e = \frac{1}{D} \times 100\%
\]

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).

205 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.
E. Tolerances

E 100 Tolerances for alignment and straightness

101 Allowable fabrication tolerances shall be submitted to the purchaser for acceptance.

102 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.

103 The maximum fabrication tolerances may generally be taken in compliance with IACS Shipbuilding and Repair Quality Standard Part A Sec.6 and Sec.7.

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 Shipbuilding and Repair Standard.

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

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

105 Straightness of members which are based on buckling calculations according to DNV-RP-C201 and/or DNV-RP-C202 shall be within the tolerances given in Table E1.

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

107 Larger imperfections may be applied provided accounted for in the design calculations. See e.g. DNV-RP-C203 Sec.2.5.
Figure 1
Alignment of joints

Cruciform joints – Non-symmetrical

Misalignment

Tolerances for misalignment:
- Special: 0.15 t₁
- Primary: 0.30 t₁
- Secondary: 0.50 t₁
- t₁ is the smaller thickness of t₁, t₂, and t₃.

Misalignment

Cruciform joints – Symmetrical

Tolerances for misalignment:
- Special: 0.15 t₁
- Primary: 0.30 t₁
- Secondary: 0.50 t₁
- t₁ is the smaller thickness of t₁, t₂, and t₃.

Butt joints – Non-symmetrical

Misalignment

Tolerances for misalignment:
- Special: 0.10 t₁
- Primary: 0.15 t₁
- Secondary: 0.30 t₁
- t₁ is the smaller of the two thicknesses.
Maximum tolerance is 4 mm.

Butt joints – Symmetrical

Misalignment

Tolerances for misalignment:
- Special: 0.10 t₁
- Primary: 0.15 t₁
- Secondary: 0.30 t₁
- t₁ is the smaller of the two thicknesses.
Maximum tolerance is 4 mm.

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

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.

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.

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.

Transitions to be smoothened
Table E1 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="#" alt="Fig" /></td>
<td>$l = \text{unsupported length}$</td>
</tr>
<tr>
<td>Pillars, vertical columns</td>
<td>Max. inclination $\delta = 0.001 , l$</td>
<td><img src="#" alt="Fig" /></td>
<td>$l = \text{unsupported length}$</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="#" alt="Fig" /></td>
<td>$l = \text{Unsupported length of the stiffener or girder}$</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="#" alt="Fig" /></td>
<td>$l = \text{Unsupported length of the flange}$</td>
</tr>
<tr>
<td>Stiffened plane plates. Parallel stiffeners or girders</td>
<td>Max. misalignment $\delta = 0.02 , s$</td>
<td><img src="#" alt="Fig" /></td>
<td>$s = \text{distance between parallel stiffeners or girders}$</td>
</tr>
<tr>
<td>Stiffened plane plates. Plates between stiffeners or girders.</td>
<td>Max. out of plane displacement $\delta = 0.005 , s$</td>
<td><img src="#" alt="Fig" /></td>
<td>$s = \text{unsupported width of the plate panel}$</td>
</tr>
</tbody>
</table>
**Table E1 Tolerances for straightness (Continued)**

<table>
<thead>
<tr>
<th>Detail</th>
<th>Tolerance</th>
<th>Fig.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular cylindrical shells.</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="image1" 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>Circular cylindrical shells. Longitudinal stiffeners or girders.</td>
<td>Max out of straightness ( \delta = 0.0015 ) l</td>
<td><img src="image2" alt="Diagram" /></td>
<td>( l ) = Unsupported length of the stiffener or girder.</td>
</tr>
</tbody>
</table>
### Table E1 Tolerances for straightness (Continued)

<table>
<thead>
<tr>
<th>Detail</th>
<th>Tolerance</th>
<th>Fig.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular cylindrical shells. Flanges of longitudinal stiffeners or girder webs.</td>
<td>Max. out of straightness $\delta = 0.0015 l$</td>
<td><img src="image" alt="Diagram" /></td>
<td>$l = \text{Unsupported length of the flange}$</td>
</tr>
<tr>
<td>Circular cylindrical shells. Longitudinal stiffeners.</td>
<td>Max. misalignment $\delta = 0.02 s$</td>
<td><img src="image" alt="Diagram" /></td>
<td>$s = \text{stiffener spacing}$</td>
</tr>
<tr>
<td>Circular cylindrical shells. Local out of roundness. Local out of straightness.</td>
<td>Max. imperfection $\delta = \frac{0.01g}{1 + \frac{g}{r}}$</td>
<td><img src="image" alt="Diagram" /></td>
<td>A circular template or straight rod held anywhere on the shell. $g = \text{length of template or rod.}$ The length of the circular template shall be the smallest of: $s, 1.15 \sqrt{1.4rt}$ and $\frac{r}{2}$ $s = \text{stiffener spacing (of longitudinal stiffeners)}$ $l = \text{distance between rings or bulkhead.}$ The length of the straight rod shall be taken equal to the smallest of: $l$ and $4\sqrt{rt}$. The tolerance requirements given for cylindrical shells are applicable also for conical shells.</td>
</tr>
<tr>
<td>Conical shells</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### F. Assembly, Welding, Heat Treatment and Repairs

**F 100  Assembly and welding**

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

102 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.

103 Fit-up, preparation for welding and welding operations shall take place in accordance with procedures.
accepted by the purchaser.

When welding tubular any longitudinal welds shall be staggered at least 50 mm. Girth welds shall be separated at least 1.5 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.

104 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.

The weld area shall be heated to the minimum preheat temperature specified in the WPS. Pre-heating shall also be performed whenever moisture is present or may condense in the weld area and/or when the ambient temperature or material temperature is below 5°C.

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

105 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 Fig. 2.

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

106 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.

107 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 50-75 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.

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

109 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.

110 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.

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

112 For welds of structural category special, primary and butt-welds in secondary structural elements a WPS shall be established for acceptance by the purchaser.
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.

113 A WPS can be established by one of the following methods:
— performing of welding procedure test (WPQT) and subsequent review of the welding procedure qualification records (WPQR)
— review of previously qualified welding procedures tests (WPQT) which has been witnessed by a party recognised by the purchaser.

Use of a previously established WPS based on a combination of WPQTs is not acceptable.

114 Tack welding shall, when integrated in production welding, be qualified. For welds specified in 112 a WPS shall be submitted to the purchaser for acceptance.

115 All fabrication welding shall be performed within the limits of essential variables of the qualified welding procedure. This also includes tack welding, seal welding, welding of lifting lugs and attachment welds as well as repair welding.

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.

116 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.

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

118 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 DNV-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 DNV-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.

119 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.

120 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.

121 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.

122 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.

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 test.

123 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.

124 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.

125 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.

126 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).

F 200 Post weld heat treatment (PWHT)

201 Post weld heat treatment (PWHT) of C-Mn steels if required by DNV-OS-C101 or DNV-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---of---G-u-i-d-a-n-c-e---n-o-t-e---

202 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.

203 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.

204 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.

205 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.
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.

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

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

Guidance to repair work may be found in IACS Shipbuilding and repair Quality Standard, Part A Sec.9 and Part B. Ref. is also made to DNV-OSS-101 Ch.3 Sec.4 D207 regarding thickness gauge of existing material.

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.

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.

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

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.

Repair welding shall be performed using welding consumables satisfying the hydrogen test requirement given in 118. For heavy sections the preheating and working temperature shall when making shallow and local repairs in special and primary structural elements be raised 50°C above the level specified for production welding and be at least 100°C unless otherwise agreed. The working temperature shall be maintained until the repair has been completed. To ensure sound repair welds, the single repair length shall not be shorter than 50 mm.

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.

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

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.

All repairs shall be re-inspected with the same NDT methods to the same or increased extent as necessary.
F 400 Flame straightening

401 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.

402 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

A. General

A 100 Scope
101 This section gives requirements for non-destructive testing.

B. Non-Destructive Testing (NDT)

B 100 General
101 Prior to commencement of fabrication the contractor shall submit a plan for NDT, NDT procedures and documents for NDT inspectors’ certification for acceptance by the purchaser. The programme shall contain information and documents for planning, controlling and reporting (ref. Sec.2 B204).
102 The inspection categories shall be defined in accordance with DNV-OS-C101 Sec.4 or DNV-OS-C201 Sec.4 and shall be specified in relevant design drawings.
103 Welds shall be subject to NDT in progress with fabrication. The results of these activities shall be consecutively reported to the purchaser.
104 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.
105 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 NV 36 grades or lower and for NV 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.
106 When heat treatment is performed, the final NDT shall be carried out when all heat treatments have been completed.
107 All welds shall be 100% visually inspected and accepted prior to carrying out NDT.
108 All NDT shall be properly documented in such a way that the performed examination can 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.

B 200 NDT procedures
201 NDT shall be performed in accordance with agreed written procedures that, as a minimum are in accordance with DNV Classification Notes No.7 and 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 conditions for MT and PT
— calibration techniques and calibration references
— testing parameters and variables
— assessment of imperfections and the surfaces from which the examination has been performed
— reporting and documentation of results. The reporting system shall ensure that there is no doubt what is examined, where it is examined and give a clear and exact description of reportable defect location.
— reference to applicable welding procedure(s)
— personnel qualification
— acceptance criteria.

B 300 Personnel qualification
301 Personnel performing NDT and interpretation of examination results shall be certified according to a recognised certification scheme accepted by the Society, e.g. EN 473, ISO 9712. The certificate shall state the qualifications as to which examination method and within which category the operator is certified.

B 400 Extent of NDT
401 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 examination in-service.

402 Unless otherwise agreed, NDT shall normally be carried out to an extent not less than required in Table B1. 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.

403 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.

404 Radiographic examination may be replaced by ultrasonic examination and vice versa, when methodologically justifiable and in agreement with the purchaser. However, ultrasonic examination shall not be carried out on welds with thickness < 10 mm if not qualified and accepted down to 8 mm.

405 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 in agreement with the purchaser.

406 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 can 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.

407 NDT shall cover start and stop points of automatically welded seams, except in the case if run-on, run-off tabs are used.

408 Ultrasonic examination of welds shall include examination 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.

409 Plates which are subjected to significant tensile stresses in the thickness direction in way of cross joints, shall be ultrasonically tested after welding for the presence of lamellar tearing in the member subject to tensile stresses. The requirement to such ultrasonic examination 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.
410 Radiographic testing
Radiographic testing shall be performed by x-ray according to approved procedures. Gamma-ray sources may be used as outlined in Classification Notes No.7. The procedures shall be established in accordance with DNV Classification Notes No.7.

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

412 Processing and storage shall be such that the films maintain their quality throughout the agreed time of storage.

413 Ultrasonic testing
Ultrasonic testing shall be performed according to approved procedures. The procedures shall be established according to DNV Classification Notes No.7.

414 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°.

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

417 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 20% 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.

418 Reference blocks shall be made with thickness and side-drilled holes, as described in Table B2, 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 approved dimensions. The reference blocks shall be traceable to the material certificate. When ultrasonic testing is to be performed on steel produced by thermomechanical 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.

419 For ultrasonic examination 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 examination.

Table B1 Minimum extent (in %) 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></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></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) Liquid penetrant testing to be adopted for non ferro-magnetic materials
2) May be partly or wholly replaced by ultrasonic testing upon agreement
3) Ultrasonic examination shall be carried out for plate thicknesses of 10 mm and above
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%
The weld shall normally be examined 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.

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.

The indications shall be investigated by maximising the echoes with different angle probes and by rotating the probes. Imperfections, from which the reflected echo response is exceeding the evaluation level, 20% of DAC shall be investigated to the extent that the operator can determine the shape (planar/non-planar), identity and location of all such imperfections and evaluate them in terms of the acceptance criteria.

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>
<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>

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

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 leg spread applied. Field strength and lifting force shall be checked at regular intervals.

Use of permanent magnets is not permitted.

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.

De-magnetization should be considered in areas where residual magnetism could be detrimental.

Liquid penetrant testing shall be performed according to approved procedures. The procedures shall be established according to DNV Classification Notes 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.

All welds shall show evidence of good workmanship. For visual inspection and NDT the acceptance criteria level shall, for special structural welds, comply with ISO 5817 level B. Welds of category primary/secondary shall comply with ISO 5817 level C.

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

Level B and level C of ISO 5817 / ISO 10042 are equal to, respectively, acceptance level 2 and level 3 of EN 1712 "Non-destructive examination of welds. Ultrasonic examination of welded joints, acceptance levels."

Regarding ultrasonic examination EN 1712 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.

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.
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

A. General

A 100  Scope

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

B. Testing of Tightness

B 100  General

101  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), can 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 accepted by the purchaser.

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

102  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)

Tightness testing of continuous automatic and multipass semi-automatic weld processes in butt welds of plated boundaries may be omitted.

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

103  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. The method shall give clear indications even of small leaks.

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---

104  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.

105  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.

C. Structural Tests

C 100  General

101  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:

In agreement with the purchaser 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---

102  Bulkheads between tanks arranged to carry different liquids shall be hydraulically tested from at least one side.
103 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.

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

105 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.

106 If structural tests reveal weaknesses in the structure, further testing should be assessed.
SECTION 5
CORROSION PROTECTION SYSTEMS

A. General

A 100 Scope

101 This section lists requirements for application of coating and requirements for fabrication and installation of sacrificial anodes and impressed current systems.

A 200 General

201 Installation or application of corrosion protection systems shall be carried out in conformance with recognised standards of workmanship and specifications agreed upon.

A 300 Application of coating

301 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.

302 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.

303 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.

304 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 can be allowed.

305 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.

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

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

308 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.

A 400 Fabrication and installation of sacrificial anodes

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

402 Anode shapes and their fastening devices (studs, clamps, etc.) shall be subject to agreement with the purchaser.

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 procedures accepted by the purchaser and by qualified welders. Anodes shall if not otherwise agreed, be connected to the structure in way of local stiffening.

Any doubling plates to which anodes are welded, shall have a thickness normally not less than 10 mm, well rounded corners (r > 20 mm), and shall be continuously welded. Material grades of the doubling plates and anode studs or pads welded directly to main plating, shall be in accordance with the requirements given in DNV-OS-C101 Sec.4 or DNV-OS-C201 Sec.4. The doubling plates shall be of the material strength group as the main plate.
A 500  Fabrication and installation of impressed current systems

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

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

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

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

505  Final testing and acceptance of the system shall be performed after installation.
SECTION 6
MISCELLANEOUS

A. Use General

A 100 Scope

101 This section covers requirements for bolts and mechanical fastening.

B. Bolts

B 100 Bolts and nuts

101 Bolts and nuts considered as essential for structural and operational safety shall conform to a recognised standard, e.g. ISO 898.

102 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.

103 For general service, the specified tensile properties shall not exceed ISO 898 property Class 10.9 when the installation 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 8,8 class 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---

C. Mechanical Fastening

C 100 Contact surfaces in slip resistant connections

101 If required, contact surfaces in preloaded joints shall be prepared to produce the class of friction surface as required.

102 Details of surface treatments, which may be assumed to provide the stated classes of friction surface, are given in DNV-OS-C101 Sec.5.

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

104 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.

105 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.

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

107 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

CONTENTS

<table>
<thead>
<tr>
<th>Sec. 1</th>
<th>General</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>60</td>
</tr>
</tbody>
</table>
SECTION 1
GENERAL

A. General Requirements

A 100 Introduction

101 As well as representing DNV’s recommendations on safe engineering practice for general use by the offshore industry, the offshore standards also provide the technical basis for DNV classification, certification and verification services.

102 A complete description of principles, procedures, applicable class notations and technical basis for offshore classification is given by the DNV Offshore Service Specifications for classification, see Table A1.

| Table A1 DNV Offshore Service Specifications |
| No.  | Title                                      |
| DNV-OSS-101 | Rules for Classification of Offshore Drilling and Support Units |
| DNV-OSS-102 | Rules for Classification of Floating Production and Storage Units |

103 Classification procedures and requirements specifically applicable in relation to the technical provisions in Ch.2 are given in this chapter of the offshore standard.

A 200 Assumptions

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

202 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 approval when the standard is used for classification purposes.

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

B. Specific Certification and Classification Requirements

B 100 General

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

B 200 Basic requirements

201 Welding of special, primary and secondary structures for hull, welding of superstructure, and equipment shall be carried out by certified approved welders, with approved welding consumables and at contractors recognised by DNV.

B 300 Contractors

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

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

303 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.

304 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.

B 400 Welding consumables

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

402 Type approval of welding consumables will be considered subject to compliance with the requirements given in the Rules for Classification of Ships Pt.2 Ch.3 Sec.4 and Standard for Certification No.2.9 Type Approval Programme No.1-401.1 "Welding Consumables".

If, for some reason, the welding consumable is not approved, 1 extra tensile test (round specimen from the weld
metal) can be cut from the assembly. However, this result is project specific.

403 All brand names under which a tested and approved welding consumable is marketed, shall be registered by DNV. 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.

B 500 Welding procedures and qualification of welders

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

502 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 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.

B 600 Corrosion protection systems

601 Application of coating, steel surface preparation with respect to application of coating and fabrication and installation of sacrificial anodes and impressed current cathodic protection systems are not included in DNV’s scope of work unless upon special agreement.

B 700 Non-destructive testing

701 Subcontractors engaged in NDT services for newbuildings shall be approved in accordance with Standard for Certification No. 2.9 Approved Programme No. 402B.

C. Records and Documentation

C 100 General

101 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.