Metallic materials
FOREWORD

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

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

General
This document supersedes DNV-OS-B101, April 2009.

Text affected by the main changes in this edition is highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

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

Main changes July 2015

- General
The revision of this document is part of the DNV GL merger, updating the previous DNV standard into a DNV GL format including updated nomenclature and document reference numbering, e.g.:
   - Main class identification 1A1 becomes 1A.
   - DNV replaced by DNV GL.
   - DNV-RP-A201 to DNVGL-CG-0168. A complete listing with updated reference numbers can be found on DNV GL's homepage on internet.

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

As a part of the reformatting, the structure of this document has furthermore been converted to decimal numbering. Older references to this document may normally be interpreted by analogy to the following example:
   - "Ch.2 Sec. 3 D506" is now “Ch.2 Sec. 3 [4.5.6]“ etc.

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

SECTION 1 INTRODUCTION

1 General

1.1 Introduction

1.1.1 This standard provides principles, technical requirements and guidance for metallic materials to be used in the fabrication of offshore structures and equipment.

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

1.1.3 The objectives of this standard are to:

— provide an internationally acceptable standard for quality of metallic materials used for offshore construction and fabrication, by defining minimum requirements for material specifications, treatment processes and testing
— serve as a contractual reference document between manufacturers, suppliers and purchasers
— serve as guideline for designers, manufacturers, suppliers, purchasers and regulators
— specify procedures and requirements to metallic materials to be used in offshore structures and facilities subject to DNV GL certification and classification.

1.2 Scope and application

1.2.1 The requirements are applicable to:

— rolled steel for structural applications
— steel pipes
— forgings and castings
— wrought aluminium alloys.

Unless otherwise agreed, requirements for

— rolled steels for boilers, pressure vessels and special applications
— clad steel plates
— iron castings
— copper alloy castings
— non-ferrous pipes

are given in DNV Rules for ships, Pt.2 Ch.2.

1.2.2 Materials, manufacturing methods and procedures complying with proprietary specifications or recognised practises may be accepted provided such documents give reasonable equivalence to the requirements of this standard.

1.3 Material specification

1.3.1 A material specification shall be prepared referring to the relevant section of this standard and stating possible additional requirements and/or modifications to materials, manufacture and testing.

1.3.2 The specified properties shall be consistent with the specific application and operational requirements of the structure or equipment. Suitable allowances shall be included for possible degradation of the mechanical properties resulting from subsequent fabrication and installation activities.

1.3.3 The specification should include specific requirements in places where this standard gives options, e.g. chemical composition, testing, requirements subject to agreement, etc.
1.4 Pre-qualification of materials and manufacturers

1.4.1 Pre-qualification of materials based on loads, temperatures and service conditions, shall be considered in order to verify that the materials will fulfil functional requirements.

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

1.5 Marking

1.5.1 All marking shall be easily identifiable and in such a condition that it is legible during the subsequent activities.

1.5.2 The type of marking shall be subject to agreement.

1.5.3 Each product shall be marked with a unique number. The marking shall reflect the correlation between the product and the respective inspection document.

1.6 Certification

Materials and products shall be delivered with inspection documents as defined in EN 10204 or agreed equivalent. The level of documentation i.e. test report, type of inspection certificate, etc. will depend on the application and shall be subject to agreement in each case.

2 Normative references

2.1 General

2.1.1 The standards in Table 1 include provisions which, through reference in this text, constitute provisions of this offshore standard. Latest issue of the standards shall be used unless otherwise agreed.

2.1.2 Other recognised standards may be used provided it can be demonstrated that these meet or exceed the requirements of the standards in Table 1.

2.1.3 Any deviations, exceptions and modifications to the design codes and standards shall be documented and agreed between the supplier, purchaser and verifier, as applicable.

2.2 Reference documents

Applicable reference documents are given in Table 1.

Table 1 Normative references

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A 275</td>
<td>Standard Test Method for Magnetic Particle Examination of Steel Forgings</td>
</tr>
<tr>
<td>ASTM A 388</td>
<td>Standard Practice for Ultrasonic Examination of Heavy Steel Forgings</td>
</tr>
<tr>
<td>ASTM E 165</td>
<td>Standard Test Method for Liquid Penetrant Examination</td>
</tr>
<tr>
<td>ASTM E 709</td>
<td>Standard Guide for Magnetic Particle Examination</td>
</tr>
<tr>
<td>ISO 3452</td>
<td>Non-destructive Testing – Penetrant inspection/testing</td>
</tr>
<tr>
<td>ISO 9712</td>
<td>Non-destructive Testing – Qualification and certification of personnel</td>
</tr>
<tr>
<td>EN 10204</td>
<td>Metallic Products - Types of inspection documents</td>
</tr>
<tr>
<td>EN 473</td>
<td>Qualification and Certification of NDT personnel</td>
</tr>
<tr>
<td>EN 10160</td>
<td>Ultrasonic Testing of Steel Flat Product of Thickness Equal or Greater than 6 mm (reflection method)</td>
</tr>
<tr>
<td>EN 10228-1/2/3/4</td>
<td>Non-destructive Testing of Steel Forgings</td>
</tr>
<tr>
<td>DNVGL-OS-D101</td>
<td>Marine and Machinery Systems and Equipment</td>
</tr>
</tbody>
</table>
3 Definitions

3.1 Verbal forms

Table 2 Verbal forms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>shall</td>
<td>verbal form used to indicate requirements strictly to be followed in order to conform to the document</td>
</tr>
<tr>
<td>should</td>
<td>verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.</td>
</tr>
<tr>
<td>may</td>
<td>verbal form used to indicate a course of action permissible within the limits of the document.</td>
</tr>
<tr>
<td>Agreement, agreed or by agreement</td>
<td>unless otherwise indicated, agreed in writing between manufacturer and purchaser</td>
</tr>
</tbody>
</table>

3.2 Terms

Table 3 Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>purchaser</td>
<td>the owner or another party acting on his behalf, who is responsible for procuring materials, components or services intended for the design, fabrication or modification of a unit or installation</td>
</tr>
<tr>
<td>manufacturer</td>
<td>the party who is contracted to be responsible for planning, execution and documentation of manufacturing</td>
</tr>
<tr>
<td>non-destructive testing</td>
<td>Visual inspection, radiographic testing, ultrasonic testing, magnetic particle testing, penetrant testing and other non-destructive methods for revealing defects and irregularities</td>
</tr>
</tbody>
</table>

4 Abbreviations and symbols

4.1 Abbreviations

Abbreviations used are given in Table 4.

Table 4 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full text</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR</td>
<td>as rolled</td>
</tr>
<tr>
<td>EHS</td>
<td>extra high strength steel</td>
</tr>
<tr>
<td>EN</td>
<td>European norm</td>
</tr>
<tr>
<td>HS</td>
<td>high strength steel</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization</td>
</tr>
<tr>
<td>N</td>
<td>normalised</td>
</tr>
<tr>
<td>NDT</td>
<td>non-destructive testing</td>
</tr>
<tr>
<td>NR</td>
<td>normalising rolling</td>
</tr>
<tr>
<td>NS</td>
<td>normal strength steel</td>
</tr>
<tr>
<td>QT</td>
<td>quenched and tempered</td>
</tr>
<tr>
<td>TM</td>
<td>thermo-mechanical rolling</td>
</tr>
</tbody>
</table>
4.2 Symbols
Symbols used are given in Table 5.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL</td>
<td>designation of a steel grade according to DNV GL offshore standards</td>
</tr>
<tr>
<td>X</td>
<td>a capital letter corresponding to a specified impact toughness test temperature</td>
</tr>
<tr>
<td>Y</td>
<td>a figure designating the strength group according to the specified minimum yield stress</td>
</tr>
<tr>
<td>W</td>
<td>letter included to designate a steel grade of improved weldability</td>
</tr>
<tr>
<td>Z</td>
<td>steel grade of improved through-thickness properties</td>
</tr>
<tr>
<td>S</td>
<td>specially accepted steel</td>
</tr>
<tr>
<td>R_{tm}</td>
<td>tensile strength</td>
</tr>
<tr>
<td>R_{y}</td>
<td>yield stress (yield point)</td>
</tr>
<tr>
<td>R_{p}</td>
<td>yield strength (proof stress)</td>
</tr>
<tr>
<td>R_{e}</td>
<td>yield strength (proof stress), total elongation</td>
</tr>
</tbody>
</table>
CHAPTER 2 TECHNICAL PROVISIONS

SECTION 1  ROLLED STEEL FOR STRUCTURAL APPLICATION

1  General

1.1  Scope

1.1.1 This section specifies the requirements for weldable normal strength, high strength and extra high strength hot rolled structural steel plates and sections. These requirements are also applicable to seamless steel pipes intended for structural application.

1.1.2 The requirements are applicable to steel products with a thickness not exceeding 150 mm. For thickness greater than 150 mm, deviations from these requirements may be applied as necessary after special consideration and agreement in each case.

1.1.3 Steels differing from these requirements in chemical composition, deoxidation practice, condition of supply and mechanical properties may be acceptable, provided that they are specially considered and demonstrated to be suitable (e.g. seamless and welded steel pipes produced according to recognised standards).

1.2  Designation of steel grades

1.2.1 The steel grades referred to in this section are divided into three strength groups:

— normal strength steels (NS)
— high strength steels (HS)
— extra high strength steels (EHS).

1.2.2 Each group consists of two parallel series of steel grades:

— steels of normal weldability
— steels of improved weldability.

The two series are intended for the same applications. However, in addition to leaner chemistry and better weldability the improved weldability grades have extra margins to account for reduced toughness after welding. These grades are also limited to a specified minimum yield stress of 500 MPa.

1.2.3 The alphanumeric designation of the steel grade is:

— VL xy for steels of normal weldability
— VL xWy for steels of improved weldability.

VL = designation of a steel grade according to the DNV GL offshore standards
x = a capital letter corresponding to a specified impact toughness test temperature, see Table 1
W = letter included to designate a steel grade of improved weldability
y = a figure designating the strength group according to the specified minimum yield stress. The figure y is omitted for NS steels.

1.2.4 Additional symbols following the alphanumeric designation given in [1.2.3] may be:

Z = steel grade of improved through-thickness properties. This symbol is omitted for steels of improved weldability although improved through-thickness properties are required.
1.3 Manufacture

1.3.1 Steel shall be manufactured by the open-hearth, an electric or one of the basic oxygen processes or any other process involving secondary refining accepted by the purchaser.

1.3.2 Steel shall be cast in metal ingot moulds or by continuous casting. Sufficient discard shall be made to ensure soundness in the finished product. The size of the ingot, billet or slab shall be proportional to the dimensions of the final product such that the cross section reduction ratio or, in the case of slab to plate, thickness reduction ratio shall normally be at least 3 to 1.

1.3.3 Conditions of supply shall be in accordance with [1.5].

1.3.4 It is the manufacturer’s responsibility to ensure that effective manufacture and process controls are implemented in production. Where deviation from the controls occurs and this could produce products of inferior quality, the manufacturer shall investigate to determine the cause and establish countermeasures to prevent its recurrence. Investigation reports to this effect shall be made available to the purchaser on request.

1.4 Chemical composition

1.4.1 The chemical composition of each heat shall be determined on a sample taken preferably during the pouring of the heat and shall be within the specified limits in [2] to [5]. When multiple heats are tapped into a common ladle, the ladle analysis shall apply and be within the specified limits. Variations from the chemical compositions given may be allowed for grades supplied in the thermo-mechanical rolled condition or when thicknesses exceed 50 mm provided that these variations are agreed upon.

1.4.2 The composition shall be determined after all alloying additions have been made and sufficient time allowed for such an addition to homogenize.

1.4.3 Elements designated as residual elements in the individual specifications shall not be intentionally added to the steel. The content of such elements shall be reported.

1.4.4 When recycled scrap is used in steelmaking, adequate controls shall be in place to prevent accumulation of harmful elements in the final product. The content of impurity elements such as tin, antimony and arsenic may be required determined.

1.4.5 When required, the carbon equivalent value shall be calculated from the heat analysis using the formula:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \ (%)$$
Subject to agreement, the weldability may alternatively be evaluated by calculating the cold cracking susceptibility using the formula:

\[ P_{cm} = \frac{C + \frac{Si}{30} + \frac{Mn + Cu + Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B}{100} \]

1.5 Condition of supply and heat treatment

1.5.1 Conditions of supply shall be in accordance with requirements given in subsections [2] to [4] and as defined in [1.5.2] to [1.5.6]. Where alternative conditions are permitted, the manufacturer shall supply materials only in the conditions agreed.

1.5.2 As-rolled (AR) refers to conventional rolling at high temperature followed by air cooling. The rolling temperature and reduction may not be accurately controlled resulting in variable grain sizes and, hence, variable mechanical properties.

1.5.3 Normalising rolling (NR) is a rolling procedure in which the final rolling temperature is controlled within a certain range above the Ar3 temperature so that the austenite completely re-crystallises. After the final pass, air cooling produces a fine grained ferrite-pearlite microstructure comparable to that obtained after normalising heat treatment.

1.5.4 Thermo-mechanical rolling (TM) is a rolling procedure in which both the rolling temperatures and reductions and, when used, accelerated cooling conditions are controlled. Generally, a high proportion of the rolling reduction is carried out close to the Ar3 temperature and may involve the rolling in the austenite-ferrite dual phase temperature region. After the final pass, either air cooling or accelerated cooling, excluding quenching, is used. Final rolling in the same temperature range as used for NR followed by accelerated cooling is considered to be a TM procedure. Unlike NR the properties conferred by TM cannot be reproduced by subsequent normalising heat treatment.

1.5.5 Normalising (N) is a separate heat treatment after rolling involving austenitising and air cooling to produce a fine grained ferrite-pearlite microstructure.

1.5.6 Quenching and Tempering (QT) is a separate heat treatment after rolling involving austenitising, rapid cooling for hardening and subsequent reheating to produce a tempered martensite microstructure.

1.5.7 It is the manufacturer’s responsibility to ensure that the programmed rolling schedules for NR and TM are adhered to. Production records to this effect shall be made available to the surveyor on request. Where deviation from the programmed rolling schedules occurs, the manufacturer must ensure that each affected rolled piece is tested and that an investigation is carried out according to [1.3.4].

1.6 Inspection and tolerances

1.6.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer. Acceptance by the purchaser of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.6.2 Products shall have a workmanlike finish consistent with the method of manufacture and shall be free from cracks, shells and seams. Acceptance criteria for other imperfections such as rolled-in scale, indentations and roll marks, which may occur under normal manufacturing conditions, shall be EN 10163 Class A for plates and Class D for sections or equivalent standard.

1.6.3 For plates and wide flats, the minus tolerance on ordered nominal thickness shall not exceed 0.3 mm. The plus tolerance on nominal thickness and other dimensional tolerances shall comply with the requirements of a recognised standard. The tolerances on nominal thickness are not applicable to areas repaired by grinding.

1.6.4 For sections and bars, the dimensional tolerances shall comply with the requirements of a recognised standard.

1.6.5 The thickness of plates and wide flats shall be measured at locations whose distance from a longitudinal or transverse edge of the product shall be at least 10 mm. At least 3 measuring points along a
line at each side shall be made. Measurements shall be made by on-line automated methods or off-line manual methods. The number of products to be measured, number of measurement readings to be recorded, and spacing between any two consecutive measured readings shall be decided and implemented by the manufacturer and shall be generally based on sound statistical analysis requirements.

1.6.6 Thickness measurement data for plates and wide flats shall be analysed to assess that the readings are within permissible tolerance limits and the computed mean value shall be equal to or greater than ordered nominal thickness.

1.6.7 The manufacturer shall maintain records of inspections and dimensional measurements. The records shall be presented to the purchaser on request.

1.7 Repair

1.7.1 Surface defects may be removed by local grinding provided that:

— the thickness is in no place reduced by more than 7% of the nominal thickness, but in no case by more than 3 mm
— each single ground area does not exceed 0.25 m²
— the total area of local grinding does not exceed 2% of the total surface area
— the ground areas have smooth transitions to the surrounding surface.

Ground areas lying in a distance less than their average width to each other shall be regarded as one single area.

1.7.2 Surface defects which cannot be dealt with as in [1.7.1] may be repaired by chipping or grinding followed by welding, subject to the purchaser’s consent and under his supervision, provided that:

— after removal of defects and before welding, the thickness of the product is in no place reduced by more than 20% of the nominal thickness
— welding is carried out by qualified welders using qualified procedures
— the welding procedure is qualified using the requirements for butt welds according to DNVGL-OS-C401
— each single weld does not exceed 0.125 m²
— the total area of welding does not exceed 2% of the surface area of the side involved
— the distance between any two welds is not less than their average width
— the welds are made with an excess layer of beads and then ground flush with the product surface
— when deemed necessary, the repaired product is normalised or otherwise suitably post-weld heat treated
— the weld repairs are subjected to suitable non-destructive testing.

1.7.3 The manufacturer shall maintain records of repairs and subsequent inspections traceable to each product repaired. The records shall be presented to the purchaser on request.

1.8 Identification

1.8.1 Every finished product shall be clearly marked by the manufacturer in at least one place with the following particulars:

— manufacturer’s name or trade mark
— steel grade, e.g. VL E36. When products comply with the requirements of E, the grade shall include the suffix Z25 or Z35, e.g. VL E36Z25
— identification number, heat number or other marking which will enable the full history of the product to be traced
— if required by the purchaser, his order number or other identification mark.

1.8.2 The particulars in [1.8.1], but excluding the manufacturer’s name or trade mark where this is embossed on finished products, shall be encircled with paint or otherwise marked so as to be easily recognisable.
1.8.3 Where a number of products are securely fastened together in bundles, the manufacturer may brand only the top product of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

1.9 Certification

1.9.1 The manufacturer shall provide the type of inspection certificate required in the relevant construction rules giving the following particulars for each test unit which has been accepted:

— purchaser’s name, order number and, if known, the unit identification
— manufacturer’s name
— description of products and steel grade
— identification marking of products
— steel making process, heat number and chemical composition
— condition of supply
— results of mechanical tests
— when products comply with the requirements of [5], the results of through thickness tensile tests and ultrasonic tests
— results of any supplementary and additional test requirements specified.

1.9.2 When steel is not produced at the works at which it is rolled, a certificate shall be supplied by the steelmaker stating the process of manufacture, the heat number and the chemical composition.

2 Normal strength steel

2.1 Scope
These requirements are supplementary to A and apply to normal strength steel, which is defined as steel with specified minimum yield stress of 235 MPa.

2.2 Chemical composition
Requirements for chemical composition and deoxidation practice for normal strength steel are given in Table 2 and Table 3.

2.3 Heat treatment, condition of supply
Normal strength steel shall be delivered in a condition complying with the requirements given in Table 4.

2.4 Mechanical properties

2.4.1 Normal strength steel shall comply with the mechanical properties specified in Table 2 and Table 5 for steel grades of improved weldability and normal weldability respectively.

2.4.2 For tensile testing the total mass of products in a test unit shall be maximum 50 tonnes. For impact testing the maximum size of a test unit shall be as given in Table 6.

2.4.3 Additional requirements concerning through thickness properties (Z-ductility), are given in [5.4] for steel grades of improved weldability and, where specified, for grades of normal weldability.
### Table 2  Chemical composition limits 1) and deoxidation practice for normal strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>C 2)</th>
<th>Si</th>
<th>Mn 2)</th>
<th>P</th>
<th>S</th>
<th>Al</th>
<th>Deoxidation practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A</td>
<td>0.21 3)</td>
<td>0.50</td>
<td>Min. 2.5 × C</td>
<td>0.035</td>
<td>0.035</td>
<td>-</td>
<td>For t ≤ 50 mm: Any method except rimmed steel 4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>For t &gt; 50 mm: Killed</td>
</tr>
<tr>
<td>VL B</td>
<td>0.21</td>
<td>0.35</td>
<td>Min. 0.80 5)</td>
<td>0.035</td>
<td>0.035</td>
<td>-</td>
<td>For t ≤ 50 mm: Any method except rimmed steel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>For t &gt; 50 mm: Killed</td>
</tr>
<tr>
<td>VL D</td>
<td>0.21</td>
<td>0.10 to 0.35</td>
<td>Min. 0.60</td>
<td>0.035</td>
<td>0.035</td>
<td>-</td>
<td>For t ≤ 25 mm: Killed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min. 0.020 6) For t &gt; 25 mm: Killed and fine grain treated</td>
</tr>
<tr>
<td>VL E</td>
<td>0.18</td>
<td>0.10 to 0.35</td>
<td>Min. 0.70</td>
<td>0.035</td>
<td>0.035</td>
<td>Min. 0.020 6)</td>
<td>Killed and fine grain treated</td>
</tr>
</tbody>
</table>

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) C + 1/6 Mn shall not exceed 0.40%.
3) Maximum 0.23% for sections.
4) Rimmed steel may be accepted for sections up to 12.5 mm thickness.
5) Minimum 0.60% when the steel is impact tested.
6) Total content. Acid soluble content, if determined instead, shall be minimum 0.015%.

### Table 3  Requirements for normal strength steel of improved weldability 1)

<table>
<thead>
<tr>
<th>Grade</th>
<th>VL BW</th>
<th>VL DW</th>
<th>VL EW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deoxidation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killed and fine grain treated</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Chemical composition  
(ladle analysis, maximum weight % unless range stated) |   |   |   |
| C | 0.12 |       |       |
| Si | 0.10 to 0.50 |       |       |
| Mn | 0.60 to 1.40 |       |       |
| P | 0.020 |       |       |
| S | 0.008 |       |       |
| Cu | 0.35 |       |       |
| Cr | 0.20 |       |       |
| Ni | 0.40 |       |       |
| Mb | 0.08 |       |       |
| Al (total) 2) | 0.06 |       |       |
| Nb 3) 4) | 0.04 |       |       |
| V 3) 4) | 0.06 |       |       |
| Ti 4) | 0.05 |       |       |
| N | 0.010 |       |       |
| B 3) | 0.0005 |       |       |
| Pcm | 0.22 |       |       |
| Tensile test |   |   |   |
| Tensile strength (MPa) | 400 to 520 |       |       |
| Yield stress (MPa)  
t ≤ 25 mm | 235 minimum |       |       |
| 25 mm < t ≤ 50 mm | 215 minimum |       |       |
| 50 mm < t ≤ 75 mm | 200 minimum |       |       |
| 75 mm < t ≤ 100 mm | 190 minimum |       |       |
| Elongation, A5 (%) | 22 minimum |       |       |
| Impact test, Charpy V-notch 5) 7) |   |   |   |
| Test temperature (°C) | 0 | -20 | -40 |
| Minimum average energy (J) | Transverse | 40 |       |
### Metallic materials

#### Chapter 2  Section 1

**Minimum single value (J)**

- Transverse: 28

**Minimum average through thickness ductility $Z_z$ (%)**

- 35

1) The amount of the following residual elements shall not exceed: 0.03% As, 0.01% Sb, 0.02% Sn, 0.01% Pb, 0.01% Bi and 0.005% Ca. Unless tested for each heat, the frequency of testing shall be agreed (e.g. each 5000 tons).

2) $\text{Al:Na} \geq 2:1$ (not applicable for titanium killed steel)

3) $(\text{Nb} + \text{V})_{\text{max}} : 0.06\%$

4) $(\text{Nb} + \text{V} + \text{Ti})_{\text{max}} : 0.10\%$

5) Boron (maximum 30 ppm) may be added subject to agreement.

6) Test direction shall follow [5.3] of this section.

7) This requirement is applicable to longitudinal test pieces for sections, bars and flats of width less than 600 mm, ref. [5.1.5].

### Table 4  Conditions of supply for normal strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Thickness, $t$ (mm)</th>
<th>Plates</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A, VL B</td>
<td>$t \leq 50$</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td>$50 &lt; t \leq 150$</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td>VL D</td>
<td>$t \leq 35$</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td>$35 &lt; t \leq 150$</td>
<td>NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td>VL E</td>
<td>$t \leq 150$</td>
<td>N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
</tbody>
</table>

1) Products may be supplied in this condition when especially agreed.

### Table 5  Mechanical properties for normal strength steel

(Entries are to be aligned with steel grade)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield stress $R_{yH}$ minimum (MPa)</th>
<th>Tensile strength $R_m$ (MPa)</th>
<th>Elongation $A_{5}$ minimum (%)</th>
<th>Impact energy, average minimum (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$t \leq 50$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(mm)</td>
</tr>
<tr>
<td>VL A</td>
<td>235</td>
<td>400 to 520</td>
<td>22</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
</tr>
<tr>
<td>VL B</td>
<td></td>
<td></td>
<td></td>
<td>271)</td>
</tr>
<tr>
<td>VL D</td>
<td></td>
<td></td>
<td></td>
<td>271)</td>
</tr>
<tr>
<td>VL E</td>
<td></td>
<td></td>
<td></td>
<td>271)</td>
</tr>
</tbody>
</table>

1) Impact tests are not required for grade B steel with thickness of 25 mm or less.

2) Impact tests for grade A over 50 mm thickness are not required when the material is produced using fine grain practice and supplied in either N or TM conditions.

3) For full thickness flat test pieces with width 25 mm and gauge length 200 mm, the minimum elongation (%) is reduced to the following values:

<table>
<thead>
<tr>
<th>Thickness, $t$ (mm)</th>
<th>$t \leq 50$</th>
<th>$5 &lt; t \leq 10$</th>
<th>$10 &lt; t \leq 15$</th>
<th>$15 &lt; t \leq 20$</th>
<th>$20 &lt; t \leq 25$</th>
<th>$25 &lt; t \leq 30$</th>
<th>$30 &lt; t \leq 40$</th>
<th>$t &gt; 40$</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
</tr>
</tbody>
</table>

### Table 6  Test units for impact testing of normal strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Thickness, $t$ (mm)</th>
<th>Plates</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A</td>
<td>$t \leq 50$</td>
<td>Not required</td>
<td>Not required</td>
</tr>
<tr>
<td></td>
<td>$50 &lt; t \leq 150$</td>
<td>50 tonnes</td>
<td>Not required</td>
</tr>
<tr>
<td>VL B</td>
<td>$t \leq 25$</td>
<td>Not required</td>
<td>Not required</td>
</tr>
<tr>
<td></td>
<td>$25 &lt; t \leq 150$</td>
<td>50 tonnes 1)</td>
<td>50 tonnes 4)</td>
</tr>
<tr>
<td>VL D</td>
<td>$t \leq 150$</td>
<td>50 tonnes 1) 2)</td>
<td>50 tonnes 4)</td>
</tr>
<tr>
<td>VL E</td>
<td>$t \leq 150$</td>
<td>Each piece</td>
<td>25 tonnes 3)</td>
</tr>
</tbody>
</table>

1) Maximum 25 tonnes for plates over 50 mm in thickness supplied in the normalising rolled (NR) condition.

2) Maximum 25 tonnes for plates and sections supplied in the as rolled (AR) condition.

3) Maximum 15 tonnes for sections supplied in the as rolled (AR) or normalising rolled (NR) condition.
3 High strength steel

3.1 Scope
These requirements are supplementary to A and apply to high strength steel, which is defined as steel with specified minimum yield stress of 265 MPa and up to and including 390 MPa.

3.2 Chemical composition

3.2.1 For steel grades of normal weldability and improved weldability, the chemical composition, shall comply with the requirements in Table 7 and Table 8 respectively. The steel grades shall be killed and fine grain treated except for VL A27S in thickness up to and including 25 mm which may be semi-killed or killed without fine grain treatment.

3.2.2 For TM steels the carbon equivalent calculated from above formula shall comply with the requirements given in Table 9.

3.3 Condition of supply
High strength steel shall be delivered in a condition complying with the requirements given in Table 10.

3.4 Mechanical properties

3.4.1 High strength steel shall comply with the mechanical properties specified in Table 8 and Table 11 for steel grades of improved weldability and normal weldability respectively.

3.4.2 For tensile testing the total mass of products in a test unit shall be maximum 50 tonnes. For impact testing the maximum size of a test unit shall be as given in Table 12.

3.4.3 Additional requirements concerning through thickness properties (Z-ductility) are given in [5.4] for steel grades of improved weldability and, where specified, for grades of normal weldability.

Table 7 Chemical composition limits 1) for high strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>C  1)</th>
<th>Si 1)</th>
<th>Mn 1)</th>
<th>P  1)</th>
<th>S  1)</th>
<th>Cr  1)</th>
<th>Mo  1)</th>
<th>Ni 1)</th>
<th>Cu 1)</th>
<th>Al 3) 4)</th>
<th>Nb 4)</th>
<th>V  4)</th>
<th>Ti  4)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A27S, VL D27S, VL E27S</td>
<td>0.18</td>
<td>0.50</td>
<td>0.70 to 1.60</td>
<td>0.035</td>
<td>0.035</td>
<td>0.20</td>
<td>0.08</td>
<td>0.40</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.05</td>
<td>-</td>
</tr>
<tr>
<td>VL A32, VL D32, VL E32, VL A40, VL D40, VL E40</td>
<td>0.18</td>
<td>0.50</td>
<td>0.90 to 1.60 2)</td>
<td>0.035</td>
<td>0.035</td>
<td>0.20</td>
<td>0.08</td>
<td>0.40</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.05</td>
<td>-</td>
</tr>
<tr>
<td>VL F27S, VL F32, VL F36, VL F40</td>
<td>0.16</td>
<td>0.50</td>
<td>0.90 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>0.20</td>
<td>0.08</td>
<td>0.80</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.05</td>
<td>0.0095</td>
</tr>
</tbody>
</table>

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Minimum 0.70% for thicknesses up to and including 12.5 mm.
3) Total content. Acid soluble content, if determined instead, shall be minimum 0.015%.
4) The steel shall contain Al, Nb, V or Ti, either singly or in any combination. When used singly, the steel shall contain the specified minimum content of the element. When Al and Nb are used in combination, the minimum total Al content shall be 0.015% and the minimum Nb content shall be 0.010%. When Al and V are used in combination, the minimum total Al content shall be 0.015% and the minimum V content shall be 0.030%. The total content of Nb+V+Ti shall not exceed 0.12%.
5) 0.012% if Al is present.
Table 8 Requirements for high strength steels of improved weldability 1)

<table>
<thead>
<tr>
<th>Grade</th>
<th>VL AW27</th>
<th>VL AW32</th>
<th>VL AW36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VL DW27</td>
<td>VL DW32</td>
<td>VL DW36</td>
</tr>
<tr>
<td></td>
<td>VL EW27</td>
<td>VL EW32</td>
<td>VL EW36</td>
</tr>
</tbody>
</table>

Deoxidation: Killed and fine grain treated

### Chemical composition

<table>
<thead>
<tr>
<th>Element</th>
<th>VL AW27</th>
<th>VL AW32</th>
<th>VL AW36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VL DW27</td>
<td>VL DW32</td>
<td>VL DW36</td>
</tr>
<tr>
<td></td>
<td>VL EW27</td>
<td>VL EW32</td>
<td>VL EW36</td>
</tr>
</tbody>
</table>

(ladle analysis, maximum weight % unless range stated)

- C: 0.12
- Si: 0.10 to 0.50
- Mn: 0.90 to 1.60
- P: 0.020
- S: 0.008
- Cu: 0.35
- Cr: 0.20
- Ni: 0.70
- Mo: 0.08
- Al (total): 0.06
- Nb: 0.04
- V: 0.06
- Ti: 0.05
- N: 0.010
- B: 0.0005
- Pcm: 0.22

### Tensile test

<table>
<thead>
<tr>
<th>Test condition</th>
<th>400 to 530</th>
<th>440 to 590</th>
<th>490 to 630</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength (MPa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t ≤ 25 mm</td>
<td>265</td>
<td>315</td>
<td>355</td>
</tr>
<tr>
<td>25 mm &lt; t ≤ 50 mm</td>
<td>245</td>
<td>295</td>
<td>335</td>
</tr>
<tr>
<td>50 mm &lt; t ≤ 75 mm</td>
<td>230</td>
<td>280</td>
<td>320</td>
</tr>
<tr>
<td>75 mm &lt; t ≤ 100 mm</td>
<td>220</td>
<td>270</td>
<td>310</td>
</tr>
<tr>
<td>Elongation, A5 (%)</td>
<td>22</td>
<td>22</td>
<td>21</td>
</tr>
</tbody>
</table>

### Impact test, Charpy V-notch 6)7)

<table>
<thead>
<tr>
<th>Test temperature (°C)</th>
<th>Grade VL AW</th>
<th>Grade VL DW</th>
<th>Grade VL EW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum average energy (J)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse</td>
<td>40</td>
<td>44</td>
<td>50</td>
</tr>
<tr>
<td>Minimum single value (J)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Minimum average through thickness ductility Zz (%) 35

1) The amount of the following residual elements shall not exceed: 0.03% As, 0.01% Sb, 0.02% Sn, 0.01% Pb, 0.01% Bi and 0.005% Ca. Unless tested for each heat, the frequency of testing shall be agreed (e.g. each 5000 tons).

2) Al:N ≥ 2:1 (not applicable for titanium killed steel)

3) (Nb+V) max : 0.06%

4) (Nb+V+Ti) max : 0.10%

5) Boron (maximum 30 ppm) may be added subject to agreement.

6) Test direction shall follow E300 of this section.

7) This requirement is applicable to longitudinal test pieces for sections, bars and flats of width less than 600mm, ref. [5.1.5].
### Table 9  Maximum carbon equivalent values for high strength steel supplied in TM condition

<table>
<thead>
<tr>
<th>Grade</th>
<th>t ≤ 50 mm</th>
<th>50 mm &lt; t ≤ 100 mm</th>
<th>100 mm &lt; t ≤ 150 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A27S, VL D27S, VL E27S, VL F27S</td>
<td>0.34</td>
<td>0.36</td>
<td>0.38</td>
</tr>
<tr>
<td>VL A32, VL D32, VL E32, VL F32</td>
<td>0.36</td>
<td>0.38</td>
<td>0.40</td>
</tr>
<tr>
<td>VL A36, VL D36, VL E36, VL F36</td>
<td>0.38</td>
<td>0.40</td>
<td>0.42</td>
</tr>
<tr>
<td>VL A40, VL D40, VL E40, VL F40</td>
<td>0.40</td>
<td>0.42</td>
<td>0.45</td>
</tr>
</tbody>
</table>

### Table 10  Conditions of supply for high strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Grain refining element</th>
<th>Thickness, t (mm)</th>
<th>Plates</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A27S, VL A32, VL A36</td>
<td>Al or any combinations with A1</td>
<td>t ≤ 20</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 &lt; t ≤ 35</td>
<td>AR&lt;sup&gt;1)&lt;/sup&gt;, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35 &lt; t ≤ 150</td>
<td>NR, N, TM, QT</td>
<td>AR&lt;sup&gt;1)&lt;/sup&gt;, NR, N, TM, QT</td>
</tr>
<tr>
<td></td>
<td>Any combination without Al</td>
<td>t ≤ 12.5</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5 &lt; t ≤ 150</td>
<td>NR, N, TM, QT</td>
<td>AR&lt;sup&gt;1)&lt;/sup&gt;, NR, N, TM, QT</td>
</tr>
<tr>
<td>VL A40</td>
<td>Any</td>
<td>t ≤ 12.5</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5 &lt; t ≤ 150</td>
<td>NR, N, TM, QT</td>
<td>AR&lt;sup&gt;1)&lt;/sup&gt;, NR, N, TM, QT</td>
</tr>
<tr>
<td>VL D27S, VL D32, VL D36</td>
<td>Al or any combinations with Al</td>
<td>t ≤ 20</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 &lt; t ≤ 25</td>
<td>AR&lt;sup&gt;1)&lt;/sup&gt;, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 &lt; t ≤ 150</td>
<td>NR, N, TM, QT</td>
<td>AR&lt;sup&gt;1)&lt;/sup&gt;, NR, N, TM, QT</td>
</tr>
<tr>
<td></td>
<td>Any combination without Al</td>
<td>t ≤ 12.5</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5 &lt; t ≤ 150</td>
<td>NR, N, TM, QT</td>
<td>AR&lt;sup&gt;1)&lt;/sup&gt;, NR, N, TM, QT</td>
</tr>
<tr>
<td>VL D40</td>
<td>Any</td>
<td>t ≤ 150</td>
<td>NR, N, TM, QT</td>
<td>NR, N, TM, QT</td>
</tr>
<tr>
<td>VL E27S, VL E32, VL E36</td>
<td>Any</td>
<td>t ≤ 50</td>
<td>N, TM, QT</td>
<td>AR&lt;sup&gt;1)&lt;/sup&gt;, NR&lt;sup&gt;1)&lt;/sup&gt;, N, TM, QT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 &lt; t ≤ 150</td>
<td>N, TM, QT</td>
<td>NR&lt;sup&gt;1)&lt;/sup&gt;, N, TM, QT</td>
</tr>
<tr>
<td>VL F27S, VL F32, VL F36</td>
<td>Any</td>
<td>t ≤ 150</td>
<td>N, TM, QT</td>
<td>NR&lt;sup&gt;1)&lt;/sup&gt;, N, TM, QT</td>
</tr>
<tr>
<td>VL E40, VL F40</td>
<td>Any</td>
<td>t ≤ 150</td>
<td>N, TM, QT</td>
<td>N, TM, QT</td>
</tr>
</tbody>
</table>

<sup>1)</sup> Products may be supplied in this condition when agreed.

### Table 11  Mechanical properties for high strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yeld stress $R_{y, min}$ (MPa)</th>
<th>Tensile strength $R_m$ (MPa)</th>
<th>Elongation $A_5$ (%)</th>
<th>Impact energy, average minimum (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td>VL A27S, VL D27S, VL E27S, VL F27S</td>
<td>265</td>
<td>400 to 530</td>
<td>22&lt;sup&gt;1)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0 -20 -40 -60</td>
</tr>
<tr>
<td>VL A32, VL D32, VL E32, VL F32</td>
<td>315</td>
<td>440 to 570</td>
<td>22&lt;sup&gt;1)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>VL A36, VL D36, VL E36, VL F36</td>
<td>355</td>
<td>490 to 630</td>
<td>21&lt;sup&gt;1)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>VL A40, VL D40, VL E40, VL F40</td>
<td>390</td>
<td>510 to 660</td>
<td>20&lt;sup&gt;1)&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1)</sup> For full thickness flat test pieces with width 25 mm and gauge length 200 mm, the minimum elongation (%) is reduced to the following values.
4 Extra high strength steel

4.1 Scope

These requirements are supplementary to A and apply to extra high strength steels, which is defined as steel with specified minimum yield stress of 420 MPa and up to and including 690 MPa.

The steel grades shall be killed and fine grain treated.

4.2 Chemical composition

The chemical composition shall satisfy the requirements in Table 13 and Table 14 for steel grades of normal weldability and improved weldability respectively.

4.3 Heat treatment, condition of supply

Steel grades of strength levels up to and including 500 MPa may be supplied in N, TM or QT condition. Steel grades of strength levels above 500 MPa shall be supplied in TM or QT condition.

4.4 Mechanical properties

4.4.1 Extra high strength steel shall comply with the mechanical properties specified in Table 14 and Table 15 for steel grades of improved weldability and normal weldability respectively.

The extent of tensile and impact testing shall be each piece.

4.4.2 Additional requirements for through thickness properties (Z-ductility) are given in [5.4] for steel grades of improved weldability and, where specified, for grades of normal weldability.
Table 13 Chemical composition limits 1) for extra high strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr  2)</th>
<th>Mo 3)</th>
<th>Ni 4)</th>
<th>Cu 4)</th>
<th>Al 4)</th>
<th>Nb 5)</th>
<th>V 4)</th>
<th>Ti 4)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade A of all strength levels</td>
<td>0.21</td>
<td>0.10 to 0.55</td>
<td>1.70</td>
<td>0.035</td>
<td>0.035</td>
<td>0.20</td>
<td>0.08</td>
<td>0.40</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.05</td>
<td>-</td>
</tr>
<tr>
<td>Grades D and E of all strength levels</td>
<td>0.20</td>
<td>0.10 to 0.55</td>
<td>1.70</td>
<td>0.030</td>
<td>0.030</td>
<td>0.20</td>
<td>0.08</td>
<td>0.40</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.05</td>
<td>-</td>
</tr>
<tr>
<td>Grade F of all strength levels</td>
<td>0.18</td>
<td>0.10 to 0.55</td>
<td>1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>0.20</td>
<td>0.08</td>
<td>0.80</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.05</td>
<td>0.009 5)</td>
</tr>
</tbody>
</table>

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) The limits given do not apply when elements are intentionally added.
3) Total content. Acid soluble content, if determined instead, shall be minimum 0.015%.
4) The steel shall contain Al, Nb, V or Ti, either singly or in any combination. When used singly, the steel shall contain the specified minimum content of the element. When Al and Nb are used in combination, the minimum total Al content shall be 0.015% and the minimum Nb content shall be 0.010%. When Al and V are used in combination, the minimum total Al content shall be 0.015% and the minimum V content shall be 0.030%. The total content of Nb+V+Ti shall not exceed 0.12%.
5) 0.012% if Al is present.

Table 14 Requirements for extra high strength steels of improved weldability 1)

<table>
<thead>
<tr>
<th>Grade</th>
<th>VL DW420</th>
<th>VL DW460</th>
<th>VL DW500</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VL EW 420</td>
<td>VL EW460</td>
<td>VL EW500</td>
</tr>
</tbody>
</table>

Deoxidation: Killed and fine grain treated

<table>
<thead>
<tr>
<th>Chemical composition (ladle analysis, maximum weight % unless range stated)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.12</td>
</tr>
<tr>
<td>Si</td>
<td>0.10 to 0.50</td>
</tr>
<tr>
<td>Mn</td>
<td>1.65</td>
</tr>
<tr>
<td>P</td>
<td>0.020</td>
</tr>
<tr>
<td>S</td>
<td>0.008</td>
</tr>
<tr>
<td>Cu</td>
<td>0.50</td>
</tr>
<tr>
<td>Cr</td>
<td>0.25</td>
</tr>
<tr>
<td>Ni</td>
<td>1.00</td>
</tr>
<tr>
<td>Mo</td>
<td>0.25</td>
</tr>
<tr>
<td>Al (total)2)</td>
<td>0.06</td>
</tr>
<tr>
<td>Nb 3)4)</td>
<td>0.04</td>
</tr>
<tr>
<td>V 3)4)</td>
<td>0.08</td>
</tr>
<tr>
<td>Ti 4)</td>
<td>0.05</td>
</tr>
<tr>
<td>N</td>
<td>0.010</td>
</tr>
<tr>
<td>B 5)</td>
<td>0.0005</td>
</tr>
<tr>
<td>Pcm</td>
<td>0.22</td>
</tr>
</tbody>
</table>

**Tensile test**

<table>
<thead>
<tr>
<th>Tensile strength (MPa)</th>
<th>530 to 680</th>
<th>570 to 720</th>
<th>610 to 770</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield stress (MPa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t ≤ 50 mm</td>
<td>420</td>
<td>460</td>
<td>500</td>
</tr>
<tr>
<td>50 mm &lt; t ≤ 75 mm</td>
<td>400</td>
<td>440</td>
<td>480</td>
</tr>
<tr>
<td>75 mm &lt; t ≤ 100 mm</td>
<td>380</td>
<td>420</td>
<td>460</td>
</tr>
<tr>
<td>Elongation, A5 (%)</td>
<td>20</td>
<td>19</td>
<td>18</td>
</tr>
</tbody>
</table>

**Impact test, Charpy V-notch6)7)**

<table>
<thead>
<tr>
<th>Test temperature (°C)</th>
<th>Grade DW</th>
<th>Grade EW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum average energy (J)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Metallic materials

Chapter 2  Section 1

Transverse 60
Minimum single value (J)
Transverse 42
Minimum average through thickness ductility Zz (%)

1) The amount of the following residual elements shall not exceed: 0.03% As, 0.01% Sb, 0.02% Sn, 0.01% Pb, 0.01% Bi and 0.005% Ca. Unless tested for each heat, the frequency of testing shall be agreed (e.g. each 5000 tons).

2) Al:N \geq 2:1 (not applicable for titanium killed steel).

3) (Nb+V)_{\text{max}} : 0.09%.

4) (Nb+V+Ti)_{\text{max}} : 0.13%.

5) Boron (maximum 30 ppm) may be added subject to agreement.

6) Test direction shall follow [5.3] of this section.

7) This requirement is applicable to longitudinal test pieces for sections, bars and flats of width less than 600mm, ref. [5.1.5].

Table 15  Mechanical properties for extra high strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield stress ReH minimum (MPa)</th>
<th>Tensile strength Rm minimum (MPa)</th>
<th>Elongation AS minimum (%)</th>
<th>Impact energy, average minimum (J)1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L \hspace{1cm} T</td>
</tr>
<tr>
<td>VL A420</td>
<td>420</td>
<td>530 to 680</td>
<td>18 2)</td>
<td>0 \hspace{1cm} -20 \hspace{1cm} -40 \hspace{1cm} -60</td>
</tr>
<tr>
<td>VL D420</td>
<td>VL E420</td>
<td>VL F420</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL A460</td>
<td>460</td>
<td>570 to 720</td>
<td>17 2)</td>
<td>0 \hspace{1cm} -20 \hspace{1cm} -40 \hspace{1cm} -60</td>
</tr>
<tr>
<td>VL D460</td>
<td>VL E460</td>
<td>VL F460</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL A500</td>
<td>500</td>
<td>610 to 770</td>
<td>16 2)</td>
<td>0 \hspace{1cm} -20 \hspace{1cm} -40 \hspace{1cm} -60</td>
</tr>
<tr>
<td>VL D500</td>
<td>VL E500</td>
<td>VL F500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL A550</td>
<td>550</td>
<td>670 to 830</td>
<td>16 2)</td>
<td>0 \hspace{1cm} -20 \hspace{1cm} -40 \hspace{1cm} -60</td>
</tr>
<tr>
<td>VL D550</td>
<td>VL E550</td>
<td>VL F550</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL A620</td>
<td>620</td>
<td>720 to 890</td>
<td>15 2)</td>
<td>0 \hspace{1cm} -20 \hspace{1cm} -40 \hspace{1cm} -60</td>
</tr>
<tr>
<td>VL D620</td>
<td>VL E620</td>
<td>VL F620</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL A690</td>
<td>690</td>
<td>770 to 940</td>
<td>14 2)</td>
<td>0 \hspace{1cm} -20 \hspace{1cm} -40 \hspace{1cm} -60</td>
</tr>
<tr>
<td>VL D690</td>
<td>VL E690</td>
<td>VL F690</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Test direction shall follow [5.3] of this section
2) For full thickness flat test pieces with width 25 mm and gauge length 200 mm, the minimum elongation (%) is reduced to the following values.

<table>
<thead>
<tr>
<th>Thickness, mm</th>
<th>t \leq 10</th>
<th>10 &lt; t \leq 15</th>
<th>15 &lt; t \leq 20</th>
<th>20 &lt; t \leq 25</th>
<th>25 &lt; t \leq 40</th>
<th>40 &lt; t \leq 50</th>
<th>t &gt; 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength level 420</td>
<td>11</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Strength level 460</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Strength levels 500 and 550</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Strength level 620</td>
<td>9</td>
<td>11</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Strength level 690</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
</tbody>
</table>
5 Testing

5.1 Test material and test pieces for mechanical testing

5.1.1 Test material shall be fully representative of the sample product and, where appropriate, shall not be cut from the sample product until heat treatment has been completed. Test material or test pieces shall not be separately heat treated in any way.

5.1.2 Test material shall be suitably marked to identify them with the products represented.

5.1.3 Test material shall be taken from the following positions:

— *Plates and wide flats with a width $\geq 600$ mm*
  The test material shall be taken at the square cut end approximately one-quarter width from an edge, see Figure 1 a.

— *Flats with a width $< 600$ mm, bulb flats and other sections*
  The test material shall be taken at approximately one-third of the width from an edge, see Figure 1 b, Figure 1 c, Figure 1 d and Figure 1 e. For channels and beams, the test material shall be taken either at position A or at position B, ref. Figure 1 d.

— *Bars and other similar products*
  The test material shall be taken at a depth one-third of the radius below the surface or, in the case of non-cylindrical sections, at a depth one-third of the half-diagonal from the surface, see Figure 1 f.
5.1.4 The following definitions relevant to orientation of test pieces apply:

- **Longitudinal**: longitudinal axis of test piece parallel to the principal direction of rolling.
- **Transverse**: longitudinal axis of test piece perpendicular to the principal direction of rolling.

5.1.5 Unless otherwise agreed, the test pieces shall be oriented as follows:

- **Plates and wide flats with a width ≥ 600 mm**
  Tensile test pieces shall be transverse. Impact test pieces shall be longitudinal, except that for extra high strength steel, transverse tests are required.

- **Flats with a width < 600 mm, bulb flats and other sections**
  Tensile and impact test pieces shall be longitudinal.

- **Bars and other similar products**
  Tensile and impact test pieces shall be longitudinal.

5.1.6 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.6.
5.2 Tensile testing

5.2.1 The dimensions of the tensile test pieces shall be in accordance with Sec.6. Generally and unless otherwise agreed, flat test pieces of full product thickness shall be used. Round test pieces may be used for bars and other similar products. Alternatively for small sizes of bars, and so forth, test pieces may consist of a suitable length of the full cross section of the product.

5.2.2 Unless otherwise agreed, for each test unit presented, one tensile test shall be made from one sample product unless the weight of finished material is greater than 50 tonnes, in which case one extra test shall be made from a different sample product from each 50 tonnes or fraction thereof. Additional tests shall be made for every variation of 10 mm in the thickness or diameter of products from the same test unit. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests.

5.2.3 For extra high strength steels each tensile test shall only represent material from the same heat treatment batch.

5.2.4 When no distinct yield is observed during tensile testing, $R_{p0.2}$ shall be considered as yield stress.

5.3 Impact testing

5.3.1 The impact test pieces shall be of the Charpy V-notch type cut with their longitudinal axes either parallel or transverse to the final direction of rolling of the material. Generally, only longitudinal test pieces need be prepared and tested, except for extra high strength steels and steel grades of improved weldability in which case the pieces shall be taken with their axes transverse to the main rolling direction. However, the steel works shall guarantee that the impact values in both directions satisfy the requirements of this section.

The notch shall be cut in a face of the test pieces which was originally perpendicular to the rolled surface. The position of the notch shall not be nearer than 25 mm to a flame cut or sheared edge.

5.3.2 Impact test pieces for plates and sections shall be cut from a position within 2 mm of a rolled surface except that for plates and sections over 40 mm thick, the axes of the test pieces shall be at one-quarter of the thickness from a rolled surface.

5.3.3 Where it is impossible to use a standard impact test piece of 10 mm $\times$ 10 mm, the largest possible of the following pieces shall be used: 10 mm $\times$ 7.5 mm or 10 mm $\times$ 5 mm. The required impact values are then reduced to respectively 5/6 and 2/3 of the required values of the standard test piece.

5.3.4 The average energy value from each set of three impact tests and the single values shall comply with the appropriate requirements of Table 5, Table 11, and Table 15 for steel grades of normal weldability. For steel grades of improved weldability, requirements are given in Table 3, Table 8 and Table 14 as appropriate. Further, only one individual value within each set may be below the specified minimum average value, but not lower than 70% of this value.

5.4 Testing of through thickness properties

Scope

5.4.1 These requirements are supplementary to A to D and apply to plates and wide flats with thickness 15 mm and over with improved through thickness or ‘Z’ direction properties, see Figure 2. The use of ‘Z’ grade steels is recommended for certain types of welded structures where plates are subjected to significant strains in the through thickness direction in order to minimise the possibility of lamellar tearing during fabrication.

5.4.2 Provision is made for two quality classes Z25 and Z35 based on specified minimum values for reduction of area in a through thickness tensile test.
5.4.3 It is recommended that special steelmaking processes and techniques such as vacuum degassing, sulphide shape control or suitable low sulphur techniques are used.

Chemical composition

5.4.4 The steel grades shall be killed and fine grain treated. The maximum sulphur content shall be 0.008% unless alternative methods of improving through thickness properties have been agreed to.

Test material

5.4.5 Test material shall be taken close to the longitudinal centreline from one end of each rolled piece representing the test unit, see Figure 3 and Table 16.

5.4.6 The test material must be large enough to accommodate the preparation of six test pieces. Three test pieces shall be prepared while the rest of the sample remains for possible retest.

5.4.7 Round test pieces shall be prepared in accordance with recognised standards, e.g. EN 10164 and ASTM A770.

<table>
<thead>
<tr>
<th>Product</th>
<th>$S &gt; 0.005%$</th>
<th>$S \leq 0.005%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plates</td>
<td>Each piece (parent plate)</td>
<td>Maximum 50 t of products of the same heat, thickness and condition of supply</td>
</tr>
<tr>
<td>Wide flats of nominal thickness $\leq 25$ mm</td>
<td>Maximum 10 t of products of the same heat, thickness and condition of supply</td>
<td>Maximum 50 t of products of the same heat, thickness and condition of supply</td>
</tr>
<tr>
<td>Wide flats of nominal thickness $&gt; 25$ mm</td>
<td>Maximum 20 t of products of the same heat, thickness and condition of supply</td>
<td>Maximum 50 t of products of the same heat, thickness and condition of supply</td>
</tr>
</tbody>
</table>

Mechanical testing

5.4.8 The average reduction of area value of three test pieces shall be determined and meet the specified minimum average value given in Table 17. One individual value may be below the specified minimum average value, provided that it is not less than the specified minimum individual value.

5.4.9 If the results do not meet the specified requirements, three additional test pieces from the same sample may be tested. The test unit will then be accepted provided that the following conditions are met:

- the average value of six test pieces meets the specified minimum average value
- not more than two of six individual values are lower than the specified minimum average value
- not more than one of six individual values is lower than the specified minimum individual value.

5.4.10 Where batch testing is permitted and the conditions for acceptance after retest in [5.4.9] are not
met, the tested product shall be rejected. The remaining products in the test unit may be resubmitted individually for test and accepted provided satisfactory results.

5.4.11 If the fracture of a test piece occurs in the weld or in the heat affected zone the test is regarded as invalid and shall be repeated on a new test piece.

Table 17 Reduction of area acceptance values

<table>
<thead>
<tr>
<th>Quality class</th>
<th>Z25</th>
<th>Z35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum average</td>
<td>25%</td>
<td>35%</td>
</tr>
<tr>
<td>Minimum individual</td>
<td>15%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Ultrasonic testing

5.4.12 All products shall be submitted to ultrasonic testing in the condition of supply with a probe frequency of 3-5 MHz. Testing shall be performed in accordance with EN 10160 Level S1/E1 or ASTM A578 Level C.
SECTION 2 STEEL PIPES

1 General requirements

1.1 Scope

1.1.1 This sub-section specifies the general requirements for steel pipes to be used in the construction of piping for pressure, cargo, and process systems. Provision is made for carbon and carbon-manganese, alloy, and stainless steels. Separate requirements for steel piping fittings are given in [6]. Requirements for pipes intended for hull structural application are given in Sec.1 [1.2].

1.1.2 Pipes shall be in accordance with recognised standards, as given in [2] to [5], provided that additionally supplementary requirements equivalent to specific requirements in [2] to [5] are also met. Recognition of other standards is subject to agreement.

1.1.3 Pipe grades selected from recognised standards shall be suitable for bending, flanging, and similar forming operations, and for welding.

1.1.4 Where required by the relevant design and construction parts of the DNV GL Offshore Standards, pipes shall comply with the requirements of Ch.1 Sec.1 and Sec.6.

1.1.5 Where the use of material with differing requirements is proposed, particulars shall be submitted in connection with the approval of the design for which the material is proposed. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties, leak tightness testing and non-destructive testing.

1.2 Manufacture

1.2.1 Pipes shall be manufactured as specified in [2] to [5]. The terms “hot finished” and “cold finished” apply to the condition of the pipe before it is heat treated.

1.2.2 When welded, an automatic non-destructive testing of the whole length of the weld is required. Such pipes are considered equivalent to seamless pipes.

1.3 Chemical composition

1.3.1 The chemical composition of each heat shall be determined by the steel manufacturer on a sample taken preferably during the pouring of the heat and shall be in accordance with the requirements of the relevant standard. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

1.3.2 Unless otherwise required by the standard, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements shall be reported.

1.3.3 Elements designated as residual elements in the standard shall not be intentionally added to the steel. The content of such elements shall be reported.

1.3.4 Unless stricter requirements are specified in the standard, carbon and carbon-manganese steel shall conform to a carbon equivalent of 0.50% maximum as determined by the following formula:

\[ C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}\%

1.4 Heat treatment

The pipes shall be supplied in a condition in accordance with the requirements of the relevant standard. Unless otherwise required by the standard, hot finished or as-welded pipes need not be heat treated.

1.5 Mechanical testing

1.5.1 Pipes shall be sampled and subjected to testing in accordance with the requirements of the relevant

\[ C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}\%\]
standard. Unless stricter requirements are specified in the standard, the size of a test unit (batch) shall be restricted to maximum 400 pipes and as given in [1.5.2] and [1.5.3].

1.5.2 Where heat treatment has been carried out, a test unit shall consist of pipes of the same size, made from the same grade of steel, and the same heat treatment in a continuous furnace or heat treated in the same furnace charge in a batch furnace.

1.5.3 Where no heat treatment has been carried out, a test unit shall consist of pipes of the same size, made by the same method, and from the same grade of steel.

1.5.4 Where Charpy V-notch impact testing is required, this is applicable for wall thickness 6 mm or greater.

1.6 Leak tightness testing

1.6.1 Each pipe shall be subjected to a hydraulic test or an agreed non-destructive test for leak tightness in accordance with the requirements of the relevant standard. Unless stricter requirements are specified in the standard, the testing shall be as given in [1.6.2].

1.6.2 Where hydraulic testing is carried out, the maximum test pressure need not exceed 70 bar.

1.7 Inspection

1.7.1 Pipes shall be subjected to visual inspection and measurements of dimensions in accordance with the requirements of the relevant standard. Unless stricter requirements are specified in the standard, the pipes shall be inspected at the same frequency as that required for mechanical testing.

1.7.2 The pipes shall have a workmanlike finish consistent with the method of manufacture and shall be free from external and internal defects that can be detected by visual inspection.

1.8 Repair

Defects may be removed by grinding provided that the dimensional tolerances are not exceeded. Repair by welding is not permitted except for repair to the weld seam of electric fusion welded pipe.

1.9 Identification

Pipes shall be legibly marked for identification in accordance with the requirements of the relevant standard.

1.10 Certification

The manufacturer shall provide the type of inspection certificate required in the relevant design and construction rules giving the following particulars for each test unit which has been accepted:

— purchaser’s name, order number and vessel identification, where known
— manufacturer’s name
— description of pipes and material quality
— identification marking of pipes
— heat number and chemical composition
— results of mechanical tests and technological tests
— results of leak tightness testing
— results of any supplementary and additional test requirements specified.

2 Pressure pipes

2.1 Scope

2.1.1 These requirements are supplementary to A and apply to carbon and carbon-manganese and alloy steel pipes for use in pressure systems.
2.1.2 Suitable pipe grades shall be selected from the following recognised standards:

- ISO 9329 Parts 1 and 2, ISO 9330 Parts 1 and 2
- EN 10216 Parts 1 to 3, EN 10217 Parts 1 to 3
- ASTM A53, ASTM A106, ASTM A135, ASTM A335
- DIN 1626, DIN 1628, DIN 1629, DIN 1630, DIN 17178, DIN 17179
- JIS G3454, JIS G3455, JIS G3456, JIS G3458.

In addition, those standards given in [4] and [5] may be used.

2.2 Manufacture

Pipes for class I and II pressure systems, as defined in DNVGL-OS-D101, shall be manufactured by any of the following methods:

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see [1.2.2]
- cold finished electric resistance or induction welded, see [1.2.2]
- electric fusion welded, see [1.2.2].

3 Stainless steel pipes

3.1 Scope

3.1.1 These requirements are supplementary to A and apply to austenitic and ferritic-austenitic stainless steel pipes for corrosive service and to austenitic stainless steel pipes for low-temperature service.

3.1.2 Suitable pipe grades shall be selected from the following recognised standards:

- ISO 9329 Part 4, ISO 9330 Part 6
- EN 10216 Part 5, EN 10217 Part 7
- ASTM A269, A312, A358, A789, A790, A928
- DIN 17455, DIN 17456, DIN 17457, DIN 17458, DIN 17459
- JIS G3459.

3.2 Manufacture

Pipes shall be manufactured by any of the following methods:

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see [1.2.2]
- cold finished electric resistance or induction welded, see [1.2.2]
- electric fusion welded, see [1.2.2].

3.3 Mechanical testing

For austenitic stainless steel pipes, Charpy V-notch impact testing is required where the design temperature is below -105°C. Testing shall be carried out at -196°C and the average energy value for standard 10 mm wide test pieces shall be minimum 41 J.

3.4 Corrosion testing

3.4.1 For ferritic-austenitic (duplex) stainless steel pipes, corrosion testing in accordance with ASTM G48 Method A or an equivalent standard is required.

3.4.2 Test specimen surfaces shall have a finish representative of the pipe’s delivery condition. The test
temperature shall be +20°C for type 22Cr duplex and +50°C for type 25Cr duplex, respectively. No pitting on specimen surfaces is allowed when viewed at 20 times magnification. The specimen mass loss shall be less than 4.0 g/m².

4  Pipes for low-temperature service

4.1  Scope

4.1.1  These requirements are supplementary to [1] and apply to carbon and carbon-manganese and alloy steel pipes for use in piping systems for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.1.2  Suitable pipe grades shall be selected from the following recognised standards:

— ISO 9329 Part 3, ISO 9330 Part 3
— EN 10216 Part 4, EN 10217 Part 6
— ASTM A333, A334
— DIN 17173, DIN 17174
— JIS G3460.

4.2  Manufacture

4.2.1  Carbon and carbon-manganese steel pipes shall be manufactured by any of the following methods:

— hot finished seamless
— cold finished seamless
— electric resistance or induction welded, see [1.2.2]
— cold finished electric resistance or induction welded, see [1.2.2]
— electric fusion welded, see [1.2.2].

4.2.2  Nickel alloy steel pipes shall be manufactured by a seamless process.

4.3  Mechanical testing

Requirements for Charpy V-notch impact testing dependent of steel type and minimum design temperature are given in Table 1.

Table 1  Charpy V-notch impact properties

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Min. design temperature (°C)</th>
<th>Charpy V-notch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test temperature (°C)</td>
<td>Average energy (J)</td>
</tr>
<tr>
<td>C and C-Mn</td>
<td>-55</td>
<td>1) 27</td>
</tr>
<tr>
<td>2 ¼ Ni</td>
<td>-65</td>
<td>-70 34</td>
</tr>
<tr>
<td>3 ½ Ni</td>
<td>-90</td>
<td>-95 34</td>
</tr>
<tr>
<td>9 Ni</td>
<td>-165</td>
<td>-196 41</td>
</tr>
</tbody>
</table>

1) The test temperature shall be 5°C below the design temperature or -20°C whichever is lower.

5  Boiler and superheater tubes

5.1  Scope

5.1.1  These requirements are supplementary to [1] and apply to carbon and carbon-manganese and alloy steel tubes for use in boilers, superheaters and heat exchangers.

5.1.2  Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, see [1.1.5].
5.1.3 Suitable pipe grades shall be selected from the following recognised standards:
— ISO 9329 Part 2, ISO 9330 Part 2
— EN 10216 Part 2, EN 10217 Part 2
— ASTM A178, A209, A210, A213
— DIN 17175, DIN 17177
— JIS G3461, JIS G3462, JIS G3463.

5.2 Manufacture
Pipes shall be manufactured by any of the following methods:
— hot finished seamless
— cold finished seamless
— electric resistance or induction welded, see [1.2.2]
— cold finished electric resistance or induction welded, see [1.2.2].

6 Piping fittings

6.1 Scope
6.1.1 This sub-section specifies the requirements for steel piping fittings such as elbows, bends, tees, reducers and caps - for the applications covered in [2] to [5]. Detachable pipe couplings and flanges are excluded from these requirements.
6.1.2 Fittings shall be in accordance with recognised standards, as given in [6.1.3]. Recognition of other standards is subject to agreement.
6.1.3 Suitable fitting grades shall be selected from the following recognised standards:
— EN 10253
— ASTM A234, A403, A420, A744, A815, A960, A961
— DIN 2605, DIN 2609, DIN 2615, DIN 2616, DIN 2617
— JIS B2312, JIS B2313, JIS B2316.
6.1.4 Where required by the relevant design and construction parts of the rules, fittings shall comply with the requirements of Ch.1 Sec.1 and Sec.6 and this sub-section.
6.1.5 Where the use of material with differing requirements is proposed, particulars shall be submitted in connection with the approval of the design for which the material is proposed. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment and mechanical properties.

6.2 Materials and manufacture
6.2.1 Materials for fittings shall consist of plates, seamless or welded pipes.
6.2.2 Fittings shall be manufactured by forming operations such as pressing, bending or fusion welding.

6.3 Testing and inspection
Fittings shall be tested and inspected in accordance with the requirements of the relevant standard. For stainless steel fittings and fittings for low-temperature service, supplementary requirements for testing in C and D also apply.

6.4 Certification
The manufacturer shall provide the type of inspection certificate required in the relevant design and construction rules giving the following particulars for each test unit which has been accepted:
— purchaser's name, order number and vessel identification, where known
— manufacturer’s name
— description of fittings and material quality
— identification marking of fittings
— heat number and chemical composition
— results of mechanical tests and technological tests
— results of any supplementary and additional test requirements specified.
SECTION 3 STEEL FORGINGS

1 General requirements

1.1 Scope

1.1.1 This subsection specifies the general requirements for steel forgings to be used in the construction of hull structures, and equipment. These requirements are also applicable to semi-finished rolled or forged products for forging stock and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape, as well as forgings from which blanks for various components may be cut out.

1.1.2 Where required by the relevant design and construction parts of the DNV GL standards, steel forgings shall comply with the requirements of Ch.1 Sec.1 and Sec.6, the general requirements of A and the appropriate specific requirements of B to D. If the specific requirements differ from these general requirements, the specific requirements shall prevail.

1.1.3 As an alternative to [1.1.2], materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of A or are especially agreed upon. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties and non-destructive testing.

1.2 Grading system

1.2.1 The forgings concerned are classified by chemical composition into three steel types: carbon and carbon-manganese (C and C-Mn) steel, alloy steel and stainless steel.

1.2.2 Where applicable, C and C-Mn steels and alloy steels are covered by several grades designated by their specified minimum tensile strength. Stainless steels are designated by chemical composition only.

Guidance note:
For the purpose of this grading system, C and C-Mn steels are classified as one type and considered to be those steels in which carbon and manganese are the principal alloying elements.

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

1.3 Manufacture

1.3.1 The steel used in the manufacture of forgings shall be made by a process in agreement with the purchaser. All forgings shall be made from killed steel.

1.3.2 For forgings with specified minimum ultimate tensile strength 800 MPa or above, the molten steel shall be vacuum treated prior to or during pouring of the ingot in order to remove objectionable gases, particularly hydrogen and oxygen, and improve steel cleanliness. Other processes may be accepted provided adequate cleanliness is documented.

1.3.3 Ingots for forgings shall be cast in chill moulds with the larger cross-section up, and with efficient feeder heads. Adequate top and bottom discards shall be made to ensure freedom from piping and harmful segregation in the finished forgings. Surface and skin defects, which may be detrimental during the subsequent working and forming operations, shall be removed.

1.3.4 The material shall be progressively hot worked by hammer or press, and shall be forged as close as practical to the finished shape and size, see also [1.5.4]. Shaping of forgings by flame cutting, scarfing or arc-air gouging shall be undertaken in accordance with recognised good practice and, unless otherwise agreed, shall be carried out before the final heat treatment.

1.3.5 The reduction ratio shall be calculated with reference to the average cross-sectional area of the cast material. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation. Unless otherwise agreed the total reduction ratio shall be at least:

— for forgings made from ingots or from forged blooms or billets, 3:1 where \( L > D \) and 1.5:1 where \( L < D \)
— for forgings made from rolled products, 4:1 where \( L > D \) and 2:1 where \( L < D \)
— for forgings made by upsetting, the length after upsetting shall be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting
— for rolled bars (see [1.1.1]), 6:1.

L and D are the length and diameter respectively of the part of the forging under consideration.

1.3.6 Where two or more forgings are joined by welding to form a composite item, the proposed welding procedure specification shall be submitted for acceptance by the purchaser. Welding procedure qualification tests may be required.

1.3.7 For clean steel forgings, the steels shall have a degree of cleanliness as given in Table 1 when tested according to ISO 4967 method A. Samples shall be obtained from forged or rolled product representative of each heat. Additionally, the contents of the elements sulphur, phosphorus, and oxygen shall be restricted to maximum 0.005%, 0.015%, and 25 ppm, respectively.

### Table 1 Cleanliness requirements

<table>
<thead>
<tr>
<th>Inclusion group</th>
<th>Series</th>
<th>Limiting value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type B</td>
<td>Fine</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type C</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type D</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type DS</td>
<td>N.A.</td>
<td>1</td>
</tr>
</tbody>
</table>

1.4 Chemical composition

1.4.1 The chemical composition of each heat shall be determined by the manufacturer on a sample taken preferably during the pouring of the heat and shall be within the specified limits. When multiple heats are tapped into a common ladle, the ladle analysis shall apply and be within the specified limits.

1.4.2 Except where otherwise specified, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements shall be reported.

1.4.3 Elements designated as residual elements in the individual specifications shall not be intentionally added to the steel. The content of such elements shall be reported.

1.5 Heat treatment

1.5.1 All forgings shall be heat treated for mechanical properties as specified in subsequent subsections. Heat treatment shall be carried out in a properly constructed furnace which is efficiently maintained and has adequate means for temperature control and is fitted with recording-type pyrometers. The furnace dimensions shall be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature.

1.5.2 Sufficient thermocouples shall be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

1.5.3 The forge shall maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records shall be presented to the purchaser on request.

1.5.4 Where forgings shall be quenched and tempered and cannot be hot worked close to shape, they shall be suitably rough machined or flame cut prior to being subjected to this treatment.

1.5.5 All hot forming operations shall be conducted prior to the final heat treatment. If for any reasons a forging is subsequently heated for further hot forming, the forging shall be re-heat treated.
1.5.6 If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration shall be given to a subsequent stress relieving heat treatment.

1.6 Test material and test pieces for mechanical testing

1.6.1 Test material, from which test pieces are taken, shall be integral with the forging except as provided in [1.6.3]. Test material shall be provided by prolongation or extensions with a cross-sectional area of not less than that part of the forging which it represents. For ring or disk-like forgings, test material shall be provided by increasing the diameter, thickness, or length of the forging.

1.6.2 Except for closed die forgings or for components which shall be carburised or for hollow forgings where the ends shall be subsequently closed or for forgings submitted to re-heat treatment, the test material shall not be detached from the forging until the heat treatment has been completed.

1.6.3 Where batch testing is permitted according to [1.7], the test material may alternatively be a production part or separately forged. Separately forged test material shall have a cross-section and a reduction ratio similar to that used for the forgings represented.

1.6.4 All test material shall be suitably marked to identify them with the forgings represented.

1.6.5 The following definitions relevant to orientation of test pieces apply:

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- **Longitudinal test**: longitudinal axis of test piece parallel to the principal direction of fibre deformation.
- **Transverse test**: longitudinal axis of test piece perpendicular to the principal direction of fibre deformation.
- **Tangential test**: longitudinal axis of test piece perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a centre.

1.6.6 Unless otherwise agreed, the longitudinal axis of test pieces shall be positioned as follows:

a) For thickness or diameter up to maximum 50 mm, the axis shall be at the mid-thickness or the centre of the cross section.

b) For thickness or diameter greater than 50 mm, the axis shall be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface.

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12.5 mm to any heat treated surface. For impact testing, this requirement shall apply to the complete test piece.

1.6.7 Longitudinal tests are normally to be made except that rings, hollow forgings which are expanded, and disks are subject to tangential tests.

1.6.8 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.6.

1.7 Test units and number of tests

1.7.1 Normalised or solution heat treated forgings with mass 1 000 kg or more and quenched and tempered forgings with mass 500 kg or more shall be individually tested. The limits refer to the as forged or rough machined mass at time of heat treatment but exclude the test material.

1.7.2 Normalised or solution heat treated forgings with mass up to 1 000 kg each may be batch tested. A test unit shall consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes.

1.7.3 Quenched and tempered forgings with mass up to 500 kg each may be batch tested. A test unit shall consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 3 tonnes.

1.7.4 Rolled bars (see [1.1.1]) may be batch tested and the test unit shall consist of either:

---

- material from the same rolled ingot or bloom provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge
— bars of the same diameter and heat, heat treated in the same furnace charge and with a total mass not exceeding 2.5 tonnes.

1.7.5 Unless otherwise specified in the subsequent subsections, one set of mechanical tests is required for each test unit. A set of tests shall consist of one tensile test piece and, when required, three Charpy V-notch test pieces.

1.7.6 Where a forging exceeds both 4 tonnes in mass and 3 m in length, tests shall be taken from each end. These limits refer to the ‘as forged’ mass and length but exclude the test material.

1.7.7 When a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required shall be related to the total length and mass of the original multiple forging.

1.8 Mechanical properties

1.8.1 The material shall meet the mechanical properties specified in the subsequent subsections.

1.8.2 If the results do not meet the specified requirements, the re-test procedures in Sec.6 may be adopted. Where the forgings and test material are submitted to re-heat treatment, they may not be re-austenitised or solution treated more than twice. All the tests previously performed shall be repeated after re-heat treatment and the results must meet the specified requirements.

1.9 Inspection

1.9.1 All forgings shall be visually inspected on accessible surfaces. Where applicable, this shall include the inspection of internal surfaces and bores. The surfaces shall be adequately prepared for inspection. Black forgings shall be suitably descaled by either shot blasting or flame descaling methods.

1.9.2 Forgings shall be presented to the purchaser for visual inspection.

1.9.3 When visually inspected, forgings shall be free from injurious pipe, cracks, seams, laps or other imperfections which, due to their nature, degree or extent, will interfere with the use of the forgings.

1.9.4 Forgings are subject to non-destructive testing where specified in the subsequent subsections. For non-destructive testing of finished machined components, see the relevant construction rules. All tests shall be carried out by personnel qualified and certified to at least Level II in accordance with recognised standards or schemes, e.g. ISO 9712, EN 473 or ASNT. Non-destructive testing shall be performed in accordance with the general practice of recognised standards, e.g.:

— magnetic particle testing (MT): EN 10228-1, ASTM A275, using wet continuous method
— liquid penetrant testing (PT): ISO 3452, EN 10228-2, ASTM E165
— ultrasonic testing (UT): EN 10228-3/4, ASTM A388.

1.9.5 The following definitions relevant to MT or PT indications apply:

— **Linear indication**: an indication in which the length is at least three times the width.
— **Non-linear indication**: an indication of circular or elliptical shape with a length less than three times the width.
— **Aligned indication**: three or more indications in a line, separated by 2 mm or less edge-to-edge.
— **Open indication**: an indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
— **Non-open indication**: an indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
— **Relevant indication**: an indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5 mm shall be considered relevant.

1.9.6 Where MT or PT is specified, the tests shall be carried out after the final heat treatment when the surface is in the final condition, but before any peening. Machined forgings shall be tested after final
machining. PT may only be applied where MT is not possible or suitable and for interpretation of open indications detected by MT.

**Guidance note:**
Where a forging is delivered in the as-forged or rough machined condition for subsequent processing and final MT or PT by the purchaser, there will always be a risk of subsurface defects appearing on the surface after final machining. The manufacturer should consider this risk and should e.g. perform suitable intermediate inspections taking into consideration the quality level required in finished condition. The responsibility of the internal quality of the material lies with the manufacturer. Repair of defects discovered after final machining is the responsibility of the manufacturer.

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

1.9.7 Where UT is specified, the tests shall be carried out after the final heat treatment when the forgings have been machined to a condition suitable for UT, but prior to drilling of bores and prior to surface hardening. Both radial and axial scanning shall be carried out when appropriate for the shape and dimensions of the forging being tested.

1.9.8 Where a forging is delivered in the as-forged condition for subsequent machining, the forging manufacturer shall ensure that a suitable ultrasonic test is carried out to verify the internal quality.

1.9.9 The extent of non-destructive testing and acceptance criteria shall be agreed with the purchaser. For forgings, IACS Recommendation No. 68 is regarded as an example of an acceptable standard.

1.9.10 The forging manufacturer shall maintain records of own inspections including dimensional measurements traceable to each forging. The records shall be presented to the purchaser on request. The forging manufacturer shall provide the purchaser with a statement confirming that non destructive tests have been carried out with satisfactory results including information on the test standard and the extent of testing.

1.10 Repair

1.10.1 Defects may be removed by grinding or by chipping and grinding provided the component dimensions are acceptable and the repair is made in accordance with any applicable requirements of the relevant construction rules. See also [1.10.2]. The resulting grooves shall have a bottom radius of approximately three times the groove depth and shall be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material shall be verified by magnetic particle testing or liquid penetrant testing.

1.10.2 Unless otherwise agreed for hull forgings, the permissible depth of grinding shall be in accordance with IACS Recommendation No. 68.

1.10.3 Repair welding of forgings may be permitted subject to prior agreement of the purchaser. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures shall be submitted for the acceptance.

1.10.4 The forging manufacturer shall maintain records of repairs and subsequent inspections traceable to each forging repaired. The records shall be presented to the purchaser on request.

1.11 Identification

1.11.1 Each forging which has been tested and inspected with satisfactory results shall be suitably identified by the manufacturer with the following:

---
identification number, heat number or other marking which will enable the full history of the forging to be traced
---
---
---
test pressure, where applicable.

1.11.2 In the case of forgings of the same type less than 115 kg in mass, modified arrangements for identification may be agreed upon.

1.12 Certification

The manufacturer shall provide the type of inspection certificate required in the relevant construction rules giving the following particulars for each test unit which has been accepted:

---
purchaser's name, order number and vessel identification, where known

---
2 Forgings for hull structures and equipment

2.1 Scope
These requirements are supplementary to A and apply to steel forgings intended for hull structures and equipment. Provision is made for carbon and carbon-manganese and alloy steel grades suitable for assembly by welding or for clad welding.

2.2 Chemical composition
The chemical composition shall comply with the overall limits given in Table 2 or, where applicable, the requirements of the agreed specification.

2.3 Heat treatment
2.3.1 Carbon and carbon-manganese steel forgings shall be supplied in one of the following conditions:
- normalised
- normalised and tempered at a temperature of not less than 550°C
- quenched and tempered at a temperature of not less than 550°C.

2.3.2 Alloy steel forgings shall be quenched and tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalised and tempered condition, in which case the specified mechanical properties shall be agreed with the purchaser.

2.4 Mechanical testing
2.4.1 Longitudinal tests shall be made but, at the discretion of the manufacturer, transverse tests may be used.

2.4.2 The mechanical properties shall comply with the values given in Table 2 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the agreed specification.

2.4.3 Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 2 but subject to any restrictions of the relevant construction rules. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given in Table 2, corresponding minimum values for the other properties may be obtained by interpolation.

2.5 Inspection
2.5.1 Magnetic particle or liquid penetrant testing shall be carried out on forgings intended for rudder stocks and pintles with diameter larger than 100 mm, see [1.9.6].

2.5.2 Ultrasonic testing shall be carried out on forgings intended for rudder stocks and pintles with diameter larger than 200 mm.
Chapter 2  Section 3

3  Ferritic steel forgings for low temperature service

3.1  Scope
These requirements are supplementary to A and apply to ferritic steel forgings intended for use in the construction of cargo tanks and process pressure vessels for liquefied gases, including forgings for the piping systems where the design temperature is below 0°C. Provision is made for carbon and carbon-manganese steels and alloy steels with specified impact properties at temperatures down to –196°C.

3.2  Chemical composition

3.2.1  The chemical composition shall comply with the overall limits given in Table 4 or, where applicable, the requirements of the agreed specification.

3.2.2  Where carbon and carbon-manganese steel is fine grain treated with niobium, vanadium or titanium, either singly or in any combination, the content of Nb shall be within 0.01 to 0.05%, V shall be 0.05% maximum and Ti shall be 0.02% maximum.

3.3  Heat treatment

3.3.1  Carbon and carbon-manganese steel forgings shall be supplied in one of the following conditions:
   – normalised
   – normalised and tempered at a temperature of not less than 550°C
   – quenched and tempered at a temperature of not less than 550°C.
3.3.2 Alloy steel forgings shall be normalised and tempered, double normalised and tempered, or quenched and tempered at a temperature of not less than 550°C.

3.4 Mechanical properties
The mechanical properties shall comply with the values given in Table 5 or, where applicable, the requirements of the agreed specification.

3.5 Inspection
3.5.1 Quenched and tempered forgings are subject to magnetic particle testing, see [1.9.6] and the relevant construction rules.

3.5.2 Normalised forgings with mass 1 000 kg or more and quenched and tempered forgings with mass 500 kg or more are subject to ultrasonic testing.

3.6 Pressure testing
Pressure retaining forgings shall be tested after machining to the test pressure required by the relevant design and construction parts of the rules. No leaks are permitted.

**Table 4 Chemical composition limits 1) for ferritic steel forgings for low temperature service**

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si 1)</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr 2)</th>
<th>Mo 2)</th>
<th>Ni</th>
<th>Cu 2)</th>
<th>Al 3)</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>0.23</td>
<td>0.15 to 0.35</td>
<td>0.60 to 1.50</td>
<td>0.030</td>
<td>0.030</td>
<td>0.40</td>
<td>0.10</td>
<td>0.80</td>
<td>0.30</td>
<td>0.02 to 0.05</td>
<td>0.60</td>
</tr>
<tr>
<td>3 ½ Ni</td>
<td>0.20</td>
<td>0.30 to 0.90</td>
<td>0.025</td>
<td>0.025</td>
<td>0.25</td>
<td>0.08</td>
<td>3.25 to 3.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Ni</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.70 to 5.30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Ni</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.50 to 10.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Composition in percentage by mass maximum unless shown as a range or as a minimum.
2) Elements are considered as residual elements unless shown as a range or as a minimum.
3) Aluminium total content. Other grain refining elements may be used for carbon and carbon-manganese steel, see [3.2].

**Table 5 Mechanical properties for ferritic steel forgings for low temperature service**

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Grade</th>
<th>Yield stress R_{p0.2} or R_{0.2} minimum (MPa)</th>
<th>Tensile strength R_m (MPa)</th>
<th>Elongation A5 minimum(%)</th>
<th>Reduction of area Z minimum(%)</th>
<th>Charpy V-notch</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>450L</td>
<td>240</td>
<td>450 to 600</td>
<td>22</td>
<td>40</td>
<td>-60 1) 27</td>
</tr>
<tr>
<td></td>
<td>490L</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>40</td>
<td>-60 1) 27</td>
</tr>
<tr>
<td>3 ½ Ni</td>
<td>-</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>35</td>
<td>-95 34</td>
</tr>
<tr>
<td>5 Ni</td>
<td>-</td>
<td>380</td>
<td>540 to 690</td>
<td>20</td>
<td>35</td>
<td>-110 34</td>
</tr>
<tr>
<td>9 Ni</td>
<td>-</td>
<td>480</td>
<td>640 to 790</td>
<td>18</td>
<td>35</td>
<td>-196 34</td>
</tr>
</tbody>
</table>

1) The test temperature may be 5°C below the design temperature if the latter is above –55°C, or –20°C whichever is lower.

4 Stainless steel forgings

4.1 Scope
4.1.1 These requirements are supplementary to [1] and apply to austenitic stainless steel forgings intended for use in the construction of cargo tanks and piping systems for liquefied gases and chemicals.

4.1.2 Steel forgings shall be in accordance with recognised standards, e.g. EN 10222, ASTM A 336 and JIS G 3214 provided that supplementary requirements contained herein are also met. Recognition of other standards is subject to agreement.
4.2 Manufacture
Steel shall be manufactured by an electric or one of the basic oxygen processes or any other process involving secondary refining subject to agreement.

4.3 Mechanical properties
Charpy V-notch impact testing is required where the design temperature is below −105°C. Testing shall be carried out at −196°C and the average energy value shall be minimum 41 J for longitudinal tests and 34 J for tangential tests, respectively.

4.4 Inspection
Forgings with mass 1 000 kg or more are subject to ultrasonic testing.

5 Other application areas
Reference is made to Rules for Classification of ships, Pt.2 Ch.2 Sec.5 for requirements for forgings in other application areas such as machinery, gearing and pressure vessels.
SECTION 4  STEEL CASTINGS

1  General requirements

1.1  Scope

1.1.1  This subsection specifies the general requirements for steel castings to be used in the construction of hull and equipment.

1.1.2  Where required by the relevant design and construction parts of the DNV GL Offshore Standards, steel castings shall comply with the requirements of Ch.1 Sec.1 and Sec.6, the general requirements of A and the appropriate specific requirements of B to D. If the specific requirements differ from the general requirements, the specific requirements shall prevail.

1.1.3  As an alternative to [1.1.2], materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of Sec.4 or are agreed upon for each specific application. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties and non-destructive testing.

1.2  Grading system

1.2.1  The castings concerned are classified by chemical composition into three steel types: carbon and carbon-manganese (C and C-Mn) steel, alloy steel and stainless steel.

1.2.2  Where applicable, C and C-Mn steels and alloy steels are covered by several grades designated by their specified minimum tensile strength. Stainless steels are designated by chemical composition only.

Guidance note:
For the purpose of this grading system, C and C-Mn steels are classified as one type and considered to be those steels in which carbon and manganese are the principal alloying elements.

1.3  Manufacture

1.3.1  Steel shall be manufactured by the open-hearth, an electric or one of the basic oxygen processes or any other process involving secondary refining agreed by the purchaser. All castings shall be made from killed steel.

1.3.2  All flame cutting, scarfing or arc-air gouging to remove surplus metal shall be undertaken in accordance with recognised good practice and, unless otherwise agreed, be carried out before the final heat treatment. Preheating shall be employed when necessitated by the chemical composition and/or thickness of the castings. The affected areas shall be either machined or ground smooth.

1.3.3  Where two or more castings are joined by welding to form a composite item, the proposed welding procedure specification shall be submitted for approval. Welding procedure qualification tests may be required.

1.4  Chemical composition

1.4.1  The chemical composition of each heat shall be determined by the manufacturer on a sample taken preferably during the pouring of the heat and shall be within the specified limits. When multiple heats are tapped into a common ladle, the ladle analysis shall apply and be within the specified limits.

1.4.2  Except where otherwise agreed, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements shall be reported.

1.4.3  Elements designated as residual elements in the individual specifications shall not be intentionally added to the steel. The content of such elements shall be reported.
1.5 Heat treatment

1.5.1 All castings shall be heat treated as specified in the subsequent subsections. Heat treatment shall be carried out in a properly constructed furnace, which is efficiently maintained and has adequate means for temperature control and is fitted with recording-type pyrometers. The furnace dimensions shall be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature.

1.5.2 Sufficient thermocouples shall be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

1.5.3 The foundry shall maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records shall be presented to the purchaser on request.

1.5.4 If a casting is locally reheated or any straightening operation is performed after the finishing heat treatment, a subsequent stress relieving heat treatment is required unless otherwise agreed.

1.5.5 Soaking time at normalising, quenching and tempering temperature shall unless otherwise agreed, not be less than one hour per 25.5 mm of the heaviest thickness of the casting for castings up to 127.5 mm. For castings with thickness more than 127.5 mm, at least one hour (or corresponding part thereof) shall be added for each addition of 102 mm.

1.6 Test blocks and test pieces for mechanical testing

1.6.1 Test blocks, from which test pieces are taken, shall be cast integrally with the casting. When this is impracticable, the test blocks may be cast with and gated to the casting. In either case these test blocks shall not be detached from the casting until the heat treatment has been completed.

1.6.2 In the case of small castings of about same size under 1000 kg in finished mass, the test blocks may alternatively be cast separately provided they are cast from the same heat of steel as the production castings represented and heat treated with the castings. Separately cast test blocks shall receive substantially the same casting practices as the castings represented.

1.6.3 All test blocks shall be suitably marked to identify them with the castings represented.

1.6.4 The dimensions of test blocks (integrally cast and separately cast) shall be in accordance with recognised standards but in all cases shall have a thickness of not less than 30 mm. The test pieces shall be taken with their axis at least 14 mm from the cast surface.

1.6.5 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.6.

1.7 Test units and number of tests

1.7.1 For castings with finished mass 1000 kg or more, each casting shall be regarded as the test unit.

1.7.2 For small castings of about same size, where each casting is less than 1000 kg in mass, batch testing is permitted and each heat in each heat treatment charge shall be regarded as the test unit.

1.7.3 At least one set of mechanical tests is required for each test unit, except as specified in [1.7.4] and [1.7.5].

1.7.4 For castings with mass 10 tonnes or more, two sets of mechanical tests are required for each test unit. The test blocks shall be located as widely separated as possible.

1.7.5 Where large castings are made from two or more heats, which are not mixed in a ladle prior to pouring, two or more sets of mechanical tests are required corresponding to the number of heats involved. The test blocks shall be located as widely separated as possible.

1.8 Mechanical properties

1.8.1 The mechanical properties specified in the subsequent subsections refer to test pieces machined from integrally cast or separately cast test blocks and not to the castings themselves.
1.8.2 If the results do not meet the specified requirements, the re-test procedures of Sec.6 may be adopted. Where the castings and test blocks are submitted to re-heat treatment, they may not be solution treated or re-austenitised more than twice. All the tests previously performed shall be repeated after re-heat treatment and the results must meet the specified requirements.

1.9 Inspection

1.9.1 All castings shall be visually inspected on accessible surfaces. Where applicable, this shall include the inspection of internal surfaces and bores. The surfaces shall be adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surfaces shall not be hammered, peened or treated in any way which may obscure discontinuities.

1.9.2 Castings shall be presented to the purchaser for visual inspection. The surveyor may require areas to be etched for the purpose of investigating weld repairs.

1.9.3 When visually inspected, castings shall be free from adhering sand, scale, cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings.

1.9.4 Castings are subject to non-destructive testing where specified in the subsequent subsections. All tests shall be carried out by personnel qualified and certified in accordance with recognised standards or schemes, e.g. ISO 9712, EN 473 or ASNT. Non-destructive testing shall be performed in accordance with the general practice of recognised standards, e.g.:

- magnetic particle testing (MT): ASTM E709, using wet continuous method
- liquid penetrant testing (PT): ISO 3452, ASTM E165
- ultrasonic testing (UT): ASTM A609
- radiographic testing (RT): ISO 5579, ASTM E94.

1.9.5 The following definitions relevant to MT or PT indications apply:

*Linear indication:* an indication in which the length is at least three times the width.

*Non-linear indication:* an indication of circular or elliptical shape with a length less than three times the width.

*Aligned indication:* three or more indications in a line, separated by 2 mm or less edge-to-edge.

*Open indication:* an indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.

*Non-open indication:* an indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.

*Relevant indication:* an indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5 mm shall be considered relevant.

1.9.6 Where MT or PT is specified, the tests shall be carried out after the final heat treatment when the surface is in the final condition, but before any cold working. Machined castings shall be tested after final machining. PT may only be applied where MT is not possible or suitable and for interpretation of open indications detected by MT.

*Guidance note:* Where a casting is delivered in the as-cast or rough condition for subsequent processing and final MT or PT by the purchaser, there will always be a risk of subsurface defects appearing on the surface after final machining. The manufacturer should consider this risk and e.g. perform suitable intermediate inspections taking into consideration the quality level required in finished condition. The responsibility of the internal quality of the material lies with the manufacturer.

1.9.7 The castings are subject to MT or PT in the following areas:

- at fabrication weld preparations and over a band width of 30 mm from welding edges
- at positions where repair welds are made
- at all accessible fillets and abrupt changes of section
- at positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
1.9.8 Where UT is specified, the tests shall be carried out after the final heat treatment when the casting surface has been brought to a condition suitable for UT. RT may also be accepted and generally applies to castings with thickness less than 50 mm.

1.9.9 Unless otherwise agreed the castings are subject to UT or RT in the following areas:

— in way of fabrication weld preparations for a distance of 50 mm from the edge
— at positions where major repair welds are made
— at any repair welds where the original defect was detected by UT or RT
— at all areas to be subsequently machined, e.g. bores of stern boss castings
— at positions where gates and feeders have been removed.

1.9.10 Acceptance criteria for non-destructive testing shall be agreed with the purchaser. For hull castings, IACS Recommendation No. 69 is regarded as an example of an acceptable standard.

1.9.11 The foundry shall maintain records of own inspections including dimensional measurements traceable to each casting. The records shall be presented to the purchaser on request. The foundry is also to provide the purchaser with a statement confirming that non-destructive tests have been carried out with satisfactory results including information on the test standard and the extent of testing.

1.10 Repair

1.10.1 Defects may be removed by grinding or by chipping and grinding to a depth of 10% of the section thickness or 15 mm, whichever is smaller. The resulting grooves shall have a bottom radius of approximately three times the groove depth and shall be blended into the surrounding surface so as to avoid any sharp contours. Flame-scarfing or arc-air gouging may also be used provided that the surfaces of the resulting grooves are subsequently ground smooth. Complete elimination of the defective material shall be verified by MT or PT.

1.10.2 Where the repair entails removal of more than 10% of the thickness or 15 mm, whichever is smaller, the defective area shall be repaired by welding. Shallow defective areas (see [1.10.1]) may also be repaired by welding. The excavations shall be suitably shaped to allow good access for welding. The resulting grooves shall be subsequently ground smooth and complete elimination of the defective material shall be verified by MT or PT.

1.10.3 Weld repairs are classified as major or minor. A weld repair is considered major when:

— the depth of the groove prepared for welding exceeds 25% of the section thickness or 25 mm, whichever is smaller, or
— the area of the groove based on length times width exceeds 0.125 m², or
— castings have leaked on hydrostatic testing.

All other weld repairs are considered minor.

1.10.4 Major weld repairs require agreement by the purchaser before the repair is commenced. Proposals for major weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs. A grain refining heat treatment shall be given to the whole casting prior to major repairs, unless otherwise approved.

1.10.5 Minor weld repairs do not require the approval of the purchaser before the repair is commenced but must be recorded on sketches showing the extent and positions of the repairs. The records shall be presented to the purchaser on request.

1.10.6 All weld repairs shall be done by qualified welders using approved welding procedures, ref. DNVGL-OS-C401.

1.10.7 The welding consumables used shall be of a suitable composition giving a weld deposit with mechanical properties at least similar to those of the parent castings. Only low hydrogen consumables shall be used. Welding consumables shall be stored and handled so as to maintain the hydrogen classification and in accordance with the manufacturers recommendations.
1.10.8 When repair welding is done after the casting has been heat treated for mechanical properties, the repaired casting shall be given a furnace stress relieving heat treatment. Unless otherwise agreed, stress relieving heat treatment shall be carried out at a temperature in the range 550 to 620°C and shall be 30°C less than the final tempering temperature for quenched and tempered steels. Subject to agreement, local stress relieving heat treatment may be accepted for minor repairs. Special consideration may be given to the omission of stress relieving heat treatment for minor repairs in areas of low operating stress and provided that the combination of material and welding procedure is such that tensile residual stresses and hardness are minimised.

1.10.9 On completion of heat treatment the weld repairs and adjacent material shall be ground smooth. All weld repairs are subject to non-destructive testing as required by [1.9].

1.10.10 The foundry shall maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. The records shall be presented to the surveyor on request.

1.11 Identification

1.11.1 Each casting which has been tested and inspected with satisfactory results shall be suitably identified by the manufacturer with the following:

— heat number or other marking which will enable the full history of the casting to be traced
— test pressure, where applicable.

1.11.2 In the case of castings of the same type less than 230 kg in mass, modified arrangements for identification may be agreed upon.

1.12 Certification

1.12.1 The manufacturer shall provide the type of inspection certificate required in the relevant construction rules giving the following particulars for each test unit of castings which has been accepted:

— purchaser’s name, order number and vessel identification, where known
— manufacturer’s name
— description of castings and steel quality
— identification marking of castings
— steel making process, heat number and chemical composition
— details of heat treatment, including temperatures and holding times
— results of mechanical tests
— results of non-destructive tests, where applicable
— test pressure, where applicable
— results of any supplementary and additional test requirements specified.

2 Castings for hull structures and equipment

2.1 Scope

2.1.1 The requirements in B are supplementary to A and apply to steel castings for hull structures and equipment. Provision is made for carbon and carbon-manganese steel and alloy steel grades suitable for assembly by welding.

2.1.2 Where the use of steel with differing requirements is proposed, particulars of chemical composition, mechanical properties and heat treatment shall be submitted to the purchaser in connection with the acceptance of the design for which the material is proposed.

2.2 Chemical composition

The chemical composition shall comply with the overall limits given in Table 1 or, where applicable, the requirements of the agreed specification.
2.3 Heat treatment

2.3.1 Carbon and carbon-manganese steel castings shall be supplied in one of the following conditions:

— fully annealed
— normalised
— normalised and tempered at a temperature of not less than 550°C
— quenched and tempered at a temperature of not less than 550°C.

2.3.2 Alloy steel castings shall be quenched and tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalised and tempered condition, in which case the specified mechanical properties shall be agreed with the purchaser.

2.4 Mechanical properties

2.4.1 The mechanical properties shall comply with the values given in Table 2 or, where applicable, the requirements of the agreed specification.

2.4.2 Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given in Table 2, corresponding minimum values for the other properties may be obtained by interpolation.

2.5 Inspection

The castings are subject to magnetic particle (see [1.9.6]) and ultrasonic testing.

Table 1 Chemical composition limits 1) for steel castings for hull structures and equipment 2)

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr 3)</th>
<th>Mo 3)</th>
<th>Ni 3)</th>
<th>Cu 3)</th>
<th>V 3)</th>
<th>Total residuals 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>0.23 1)</td>
<td>0.60</td>
<td>0.50 to 1.60</td>
<td>0.040</td>
<td>0.035</td>
<td>0.30</td>
<td>0.15</td>
<td>0.40</td>
<td>0.30</td>
<td>0.12</td>
<td>0.95</td>
</tr>
<tr>
<td>Alloy</td>
<td>0.25</td>
<td>0.60</td>
<td>0.50 to 1.70</td>
<td>0.035</td>
<td>0.030</td>
<td>Minimum 0.40 5)</td>
<td>Minimum 0.15 5)</td>
<td>Minimum 0.40 5)</td>
<td>0.30</td>
<td>0.12</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Composition in percentage by mass maximum unless shown as a range or as a minimum.
2) Castings not intended for welding may be supplied to the composition limits given in DNV Rules for ships Pt.2 Ch.2 Sec.7 Table C1.
3) Elements are considered as residual elements unless shown as a range or as a minimum. For low temperature service castings (DAT(-X°)), Ni content is permitted up to maximum 0.8%.
4) An increase is permitted up to maximum 0.30% provided that the Manganese content is reduced to maximum 1.20%.
5) One or more of the elements shall comply with the minimum content.
6) Al can be used for grain refining but the content to be less than 0.08%.

Table 2 Mechanical properties for steel castings for hull structures and equipment

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Steel grade</th>
<th>Yield stress $R_y$ minimum (MPa)</th>
<th>Tensile strength $R_m$ minimum (MPa)</th>
<th>Elongation $A_5$ minimum (%)</th>
<th>Reduction of area $Z$ minimum (%)</th>
<th>Charpy V-notch 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>410 W</td>
<td>235</td>
<td>410</td>
<td>24</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>450 W</td>
<td>255</td>
<td>450</td>
<td>22</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>480 W</td>
<td>275</td>
<td>480</td>
<td>20</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Alloy</td>
<td>550 W</td>
<td>355</td>
<td>550</td>
<td>18</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>620 W</td>
<td>430</td>
<td>620</td>
<td>16</td>
<td>30</td>
<td>0</td>
</tr>
</tbody>
</table>

1) Steel castings in structural members subject to lower design temperatures than -10°C, shall be impact tested at 5°C below the design temperature.

3 Ferritic steel castings for low temperature service

3.1 Scope

These requirements are supplementary to the requirements in A and apply to ferritic steel castings for liquefied gas cargo and process piping where the design temperature is below 0°C. Provision is made for
carbon and carbon-manganese steels and alloy steels with specified impact properties at temperatures down to –95°C.

3.2 Chemical composition
The chemical composition shall comply with the limits given in Table 3 or, where applicable, the requirements of the agreed specification.

3.3 Heat treatment
Castings shall be supplied in one of the following conditions:

— normalised
— normalised and tempered at a temperature of not less than 550°C
— quenched and tempered at a temperature of not less than 550°C.

3.4 Mechanical properties
The mechanical properties shall comply with the values given in Table 4 or, where applicable, the requirements of the agreed specification.

3.5 Inspection

3.5.1 For each test unit, at least one casting is subject to magnetic particle testing. As an alternative, where a number of castings representing multiple test units is made from the same pattern, testing of the first three castings made from the pattern may be substituted for the testing of each test unit.

3.5.2 The first casting made from the same pattern is subject to ultrasonic or radiographic testing. This casting may represent one or more test units.

3.5.3 All castings repaired by welding shall be non-destructive tested.

3.6 Pressure testing
Pressure retaining castings shall be tested after machining to the test pressure required by the relevant design and construction parts of the rules. No leaks are permitted.

Table 3 Chemical composition limits 1) for ferritic steel castings for low temperature service

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr  2)</th>
<th>Mo  2)</th>
<th>Ni</th>
<th>Cu  2)</th>
<th>V</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>0.25</td>
<td>0.60</td>
<td>1.60</td>
<td>0.035</td>
<td>0.035</td>
<td>0.40</td>
<td>0.15</td>
<td>0.80</td>
<td>0.30</td>
<td>0.03</td>
<td>0.60</td>
</tr>
<tr>
<td>2 ½ Ni</td>
<td>0.25</td>
<td>0.60</td>
<td>0.50 to 0.80</td>
<td>0.035</td>
<td>0.035</td>
<td>0.40</td>
<td>0.15</td>
<td>2.00 to 3.00</td>
<td>0.30</td>
<td>0.03</td>
<td>0.60</td>
</tr>
<tr>
<td>3 ½ Ni</td>
<td>0.15</td>
<td>0.60</td>
<td>0.50 to 0.80</td>
<td>0.035</td>
<td>0.035</td>
<td>0.40</td>
<td>0.15</td>
<td>3.00 to 4.00</td>
<td>0.30</td>
<td>0.03</td>
<td>0.60</td>
</tr>
</tbody>
</table>

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Elements are considered as residual elements unless shown as a range or as a minimum.

Table 4 Mechanical properties for ferritic steel castings for low temperature service

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Grade</th>
<th>Yield stress R_y or R_y0.2 minimum (MPa)</th>
<th>Tensile strength R_m (MPa)</th>
<th>Elongation A_5 minimum (%)</th>
<th>Charpy V-notch Temperature (°C)</th>
<th>Charpy V-notch Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>450L</td>
<td>240</td>
<td>450 to 600</td>
<td>22</td>
<td>-60 1)</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>490L</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>-60 1)</td>
<td>27</td>
</tr>
<tr>
<td>2 ½ Ni</td>
<td>-</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>-70</td>
<td>34</td>
</tr>
<tr>
<td>3 ½ Ni</td>
<td>-</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>-95</td>
<td>34</td>
</tr>
</tbody>
</table>

1) The test temperature may be 5°C below the design temperature if the latter is above –55°C or –20°C whichever is lower.
4 Stainless steel castings

4.1 Scope
These requirements are supplementary to the requirements in [1] and apply to stainless steel castings for use in piping systems for liquefied gases and chemicals.

4.2 Chemical composition
The chemical composition shall comply with the overall limits given in Table 5 or, where applicable, the requirements of the agreed specification.

4.3 Heat treatment
Austenitic stainless steel castings shall be supplied in the solution treated condition.

4.4 Mechanical properties
The mechanical properties shall comply with the values given in Table 6 or, where applicable, the requirements of the agreed specification.

4.5 Inspection

4.5.1 For each test unit, at least one casting is subject to liquid penetrant testing. As an alternative, where a number of castings representing multiple test units is made from the same pattern, testing of three castings made from the pattern may be substituted for the testing of each test unit.

4.5.2 The first casting made from the same pattern is subject to ultrasonic or radiographic testing. This casting may represent one or more test units.

4.5.3 All castings repaired by welding shall be non-destructive tested.

Table 5 Chemical composition limits 1) for stainless steel castings

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>GX 2 CrNi 18 10 (304L)</td>
<td>0.03</td>
<td>2.0</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>-</td>
<td>8.0 to 12.0</td>
</tr>
<tr>
<td>GX 5 CrNi 19 9 (304)</td>
<td>0.08</td>
<td>2.0</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>18.0 to 21.0</td>
<td>-</td>
<td>8.0 to 11.0</td>
</tr>
<tr>
<td>GX 6 CrNiMo 19 11 2 (316L)</td>
<td>0.03</td>
<td>1.5</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>2.0 to 3.0</td>
<td>9.0 to 13.0</td>
</tr>
<tr>
<td>GX 5 CrNiMo19 11 2 (316)</td>
<td>0.08</td>
<td>1.5</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>2.0 to 3.0</td>
<td>9.0 to 12.0</td>
</tr>
<tr>
<td>GX 5 CrNiMo19 11 3 (317)</td>
<td>0.08</td>
<td>1.5</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>3.0 to 4.0</td>
<td>9.0 to 13.0</td>
</tr>
</tbody>
</table>

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Niobium content shall be minimum 8 times the Carbon content and maximum 1.00%.

Table 6 Mechanical properties for stainless steel castings

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Proof stress $R_{p0.2}$ minimum 1) (MPa)</th>
<th>Tensile strength $R_m$ minimum (MPa)</th>
<th>Elongation $A_S$ minimum (%)</th>
<th>Charpy V-notch Temperature (°C)</th>
<th>Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GX 2 CrNi 18 10 (304L)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td>-196 2)</td>
<td>41</td>
</tr>
<tr>
<td>GX 5 CrNi 19 9 (304)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GX 6 CrNiMo 19 10 (347)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GX 2 CrNiMo 19 11 2 (316L)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GX 5 CrNiMo19 11 2 (316)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GX 5 CrNiMo19 11 3 (317)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) The minimum $R_{p0.2}$ value is 25 N/mm² higher.
2) Impact tests may be omitted if the design temperature is above -105°C.

5 Other application areas
Reference is made to Rules for Classification of ships, Pt.2 Ch.2 Sec.7 for requirements for castings in other application areas such as machinery, propellers and pressure vessels.
SECTION 5  ALUMINIUM ALLOYS

1  Wrought aluminium alloys

1.1  Scope

1.1.1  This subsection specifies the requirements for aluminium alloy plates, sections, pipes and bars to be used in the construction of hulls and other marine structures and for cryogenic applications. These requirements are applicable to wrought aluminium products within the thickness range of 3 mm to 50 mm.

1.1.2  Where required by the relevant design and construction parts of the DNV GL Offshore Standards, wrought aluminium alloys shall comply with the requirements of Ch.1 Sec.1 and Sec.6 and the requirements of this subsection.

1.1.3  As an alternative to [1.1.2], materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of this section or are agreed upon for each specific application. Generally, such materials shall comply with the appropriate requirements of Ch.1 Sec.1 and Ch.2 Sec.6. Plates and sections less than 3.0 mm thick or above 50.0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

1.2  Aluminium grades and temper conditions

1.2.1  The alloy grades are listed in Table 1. The numerical designation (grade) of aluminium alloys are based on those of the Aluminium Association. Temper conditions (delivery heat treatment) are defined in EN 515 or ANSI H35.1.

1.2.2  5000 series alloys shall be supplied in any of the temper conditions given in Table 2 and Table 3, as applicable. 6000 series alloys shall be supplied in any of the temper conditions given in Table 3.

1.2.3  The use of 6000 series aluminium alloys in direct contact with sea water may be restricted depending on application and corrosion protection system. The use of these alloys shall be subject to agreement.

1.2.4  Unless otherwise agreed, aluminium for cryogenic applications shall be of the 5000 series alloys and supplied in the annealed condition.

1.3  Manufacture

1.3.1  The alloys may be cast either in ingot moulds or by a continuous casting process. Plates shall be formed by rolling and may be hot or cold finished. Sections, bars and tubes may be formed by extrusion, rolling or drawing.

1.3.2  The materials shall have a finish consistent with the method of manufacture and shall be free from imperfections which, due to their nature, degree or extent, will interfere with the use of the materials.

1.4  Chemical composition

1.4.1  The chemical composition of each heat shall be determined by the manufacturer on a sample taken preferably during the pouring of the heat. The chemical composition shall comply with the limits given in Table 1.

1.4.2  Other alloys or alloys which do not fully comply with Table 1, may be accepted after consideration in each particular case. Special tests and/or other relevant information, e.g. which confirm satisfactory corrosion resistance and weldability, may be required.

1.5  Test material and test pieces for mechanical testing

1.5.1  For rolled products, the test material shall be taken at one third of the width from a longitudinal edge. The test pieces are normally to be cut with their longitudinal axis transverse to the final rolling direction. If the width is insufficient to obtain transverse tests, longitudinal tests will be permitted.
1.5.2 For extruded products, the test material shall be taken in the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of the section. The test pieces are normally to be cut with their longitudinal axes parallel to the extruding direction.

1.5.3 Flat tensile test piece of width 12.5 mm shall be used for thicknesses up to and including 12.5 mm. The test piece shall be prepared so that both rolled surfaces are maintained. Round tensile test piece shall be used for thicknesses over 12.5 mm. For thicknesses up to and including 40 mm, the longitudinal axis of the round tensile test piece shall be positioned at the mid-thickness. For thicknesses over 40 mm, the longitudinal axis shall be positioned at one quarter thickness below the surface.

1.6 Test units and number of tests

1.6.1 All materials in a test unit (lot) shall be of the same alloy grade, temper, heat, product form (plates, sections etc.) and thickness. Artificially aged grades are in addition to be from the same furnace charge.

1.6.2 For rolled products, one tensile test is required for each 2000 kg, or fraction thereof, in each test unit. For single plates or for coils weighing more than 2000 kg, only one tensile test per plate or coil is required.

1.6.3 For extruded products with a nominal mass of less than 1 kg/m, one tensile test is required for each 1000 kg, or fraction thereof, in each test unit. For nominal masses between 1 and 5 kg/m, one tensile test is required for each 2000 kg, or fraction thereof, in each test unit. Where the nominal mass exceeds 5 kg/m, one tensile test is required for each 3000 kg, or fraction thereof, in each test unit.

1.7 Mechanical properties

The mechanical properties shall comply with the values given in Table 2 and Table 3, as applicable. Other temper conditions with related mechanical properties may be accepted by agreement.

1.8 Press weld testing

1.8.1 Proper fusion of press welds for closed profile extrusions shall be verified by macro section tests or drift expansion tests. Other tests may be accepted after consideration. Every fifth profile shall be sampled after final heat treatment. Test units of five profiles or less shall be sampled one profile. Profiles with lengths exceeding 6 m shall be sampled every profile in the start of the production. The number of tests may be reduced to every fifth profile if the results from the first three profiles are found acceptable. Every sample profile shall be tested at both ends.

1.8.2 Where verification is by macro section tests, no indication of lack of fusion at the press welds is permitted.

1.8.3 Where verification is by drift expansion test, the test pieces shall be cut with the ends perpendicular to the axis of the profile. The edges of the end may be rounded by filing. The minimum length of the test piece shall be twice the external diameter of the profile or 50 mm, whichever is greater. Testing shall be carried out at ambient temperature and shall consist of expanding the end of the profile by means of a conical mandrel having an included angle of at least 60°. The test is considered to be unacceptable if it fails with a clean split along the weld line.

1.9 Corrosion testing

1.9.1 Rolled 5000 series alloys of grade 5083, 5383, 5059, 5086 and 5456 in the H111, H112, H116 and H321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected shall be tested with respect to exfoliation and inter-granular corrosion resistance.

1.9.2 The manufacturers shall establish the relationship between microstructure and resistance to corrosion. A reference photomicrograph taken at 500 × under the conditions specified in ASTM B928 Section 9.4.1, shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET). The samples shall also have exhibited resistance to inter-granular corrosion at a mass loss no greater than 15 mg/cm², when subjected to the test described in ASTM G67.
1.9.3 Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the reference photomicrographs and the results of the corrosion tests shall be by agreement with the purchaser. Production practices shall not be changed after approval of the reference micrographs.

1.9.4 For test unit acceptance, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate shall be carried out. A longitudinal section perpendicular to the rolled surface shall be prepared. The microstructure shall be compared to the reference photomicrograph of acceptable material. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitates in excess of the reference photomicrographs, the test unit shall either be rejected or tested for exfoliation-corrosion resistance and inter-granular corrosion resistance. The corrosion tests shall be in accordance with ASTM G66 and G67 or equivalent standards. If the results from testing satisfy the acceptance criteria stated in [1.9.2] the test unit is accepted, else it is rejected.

1.9.5 As an alternative to metallographic examination, each test unit may be tested for exfoliation-corrosion resistance and inter-granular corrosion resistance in accordance with ASTM G66 and G67 or equivalent standards.

1.10 Inspection and tolerances

1.10.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer.

1.10.2 Permissible under-thickness tolerances for rolled and extruded products are given in Table 4 and Table 5, respectively. Dimensional tolerances other than those given shall comply with a recognised standard.

1.10.3 The under-thickness tolerance acceptable for classification shall be considered as the lower limit of a "plus-minus" range of thickness tolerances which could be found in the normal production of a plant producing rolled or extruded products, on average, to the nominal thickness.

1.11 Repair

Surface imperfections may be removed by machining or grinding provided the final dimensions are within the tolerances. Repair by welding is not permitted.

1.12 Identification

1.12.1 Each item which has been tested and inspected with satisfactory results shall be suitably identified by the manufacturer with the following:

— manufacturer’s name or trade mark
— alloy grade and temper condition
— identification number, heat number or other marking which will enable the full history of the product to be traced.

1.12.2 Where a number of items are securely fastened together in bundles, only the top item of each bundle need to be branded. Alternatively, a durable label may be attached to each bundle.

1.13 Certification

The manufacturer shall provide the type of inspection certificate required in the relevant construction rules giving the following particulars for each test unit which has been accepted:

— purchaser’s name, order number and vessel identification, where known
— manufacturer’s name
— number, dimensions and mass of the product
— alloy grade and temper condition
— identification marking
— chemical composition
— results of mechanical tests
results of any supplementary and additional test requirements specified.

For Temper descriptions reference is made to the standards in [1.2.1].

Table 1 Chemical composition limits 1) for wrought aluminium alloys

<table>
<thead>
<tr>
<th>Grade</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Ti</th>
<th>Other elements 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL-5052</td>
<td>0.25</td>
<td>0.40</td>
<td>0.10</td>
<td>0.10</td>
<td>2.2</td>
<td>0.15</td>
<td>0.10</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5059</td>
<td>0.45</td>
<td>0.50</td>
<td>0.25</td>
<td>0.10</td>
<td>5.0</td>
<td>0.25</td>
<td>0.20</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>VL-5083</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>0.40</td>
<td>4.0</td>
<td>0.05</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5086</td>
<td>0.40</td>
<td>0.50</td>
<td>0.10</td>
<td>0.20</td>
<td>3.5</td>
<td>0.05</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5154A</td>
<td>0.50</td>
<td>0.50</td>
<td>0.10</td>
<td>0.50</td>
<td>3.1</td>
<td>0.25</td>
<td>0.20</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5383</td>
<td>0.25</td>
<td>0.25</td>
<td>0.20</td>
<td>0.10</td>
<td>4.0</td>
<td>0.25</td>
<td>0.40</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5454</td>
<td>0.25</td>
<td>0.40</td>
<td>0.10</td>
<td>0.50</td>
<td>2.4</td>
<td>0.05</td>
<td>0.25</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>VL-5456</td>
<td>0.25</td>
<td>0.40</td>
<td>0.10</td>
<td>0.50</td>
<td>4.7</td>
<td>0.05</td>
<td>0.25</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>VL-5754</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>0.50</td>
<td>2.6</td>
<td>0.30</td>
<td>0.20</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>VL-6005A</td>
<td>0.50</td>
<td>0.35</td>
<td>0.30</td>
<td>0.50</td>
<td>0.40</td>
<td>0.30</td>
<td>0.20</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-6060</td>
<td>0.30</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.35</td>
<td>0.05</td>
<td>0.15</td>
<td>0.10</td>
<td>0.15</td>
</tr>
<tr>
<td>VL-6061</td>
<td>0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.15</td>
<td>0.8</td>
<td>0.04</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-6063</td>
<td>0.20</td>
<td>0.35</td>
<td>0.10</td>
<td>0.10</td>
<td>0.45</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-6082</td>
<td>0.7</td>
<td>0.50</td>
<td>0.10</td>
<td>0.40</td>
<td>0.6</td>
<td>0.25</td>
<td>0.20</td>
<td>0.10</td>
<td>0.15</td>
</tr>
</tbody>
</table>

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Includes Ni, Ga, V and listed elements for which no specific limit is shown. Regular analysis need not be made.
3) Mn + Cr: 0.10-0.60.
4) Zr: maximum 0.20. The total for other elements does not include Zirconium.
5) Zr: 0.05-0.25. The total for other elements does not include Zirconium.
6) Mn + Cr: 0.12-0.50.

Table 2 Mechanical properties for rolled aluminium alloys DNVGL-OS-B101.fm

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper</th>
<th>Thickness, t (mm)</th>
<th>Yield strength Rp0.2 min. or range (MPa)</th>
<th>Tensile strength Rm min. or range (MPa)</th>
<th>Elongation 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A50 mm min. (%)</td>
</tr>
<tr>
<td>VL-5052</td>
<td>O</td>
<td>t ≤ 50</td>
<td>65</td>
<td>165 to 215</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>t ≤ 6</td>
<td>130</td>
<td>210 to 260</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 &lt; t ≤ 50</td>
<td>130</td>
<td>210 to 260</td>
<td>12</td>
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<tr>
<td></td>
<td>H32</td>
<td>t ≤ 6</td>
<td>150</td>
<td>230 to 280</td>
<td>7</td>
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<tr>
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<td>6 &lt; t ≤ 50</td>
<td>150</td>
<td>230 to 280</td>
<td>9</td>
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</table>
Table 2 Mechanical properties for rolled aluminium alloys DNVGL-OS-B101.fm (Continued)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper</th>
<th>Thickness, ( t )(mm)</th>
<th>Yield strength ( R_{p0.2} ) min. or range (MPa)</th>
<th>Tensile strength ( R_m ) min. or range (MPa)</th>
<th>Elongation 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>( A_{50 \text{ mm}} ) min. (%)</td>
<td>( A_{5d} ) min. (%)</td>
<td></td>
</tr>
<tr>
<td>VL-5059</td>
<td>O</td>
<td>( t \leq 50 )</td>
<td>160</td>
<td>330</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>( t \leq 50 )</td>
<td>160</td>
<td>330</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>( t \leq 20 )</td>
<td>270</td>
<td>370</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 20 &lt; t \leq 50 )</td>
<td>260</td>
<td>360</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>( t \leq 20 )</td>
<td>270</td>
<td>370</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 20 &lt; t \leq 50 )</td>
<td>260</td>
<td>360</td>
<td>10</td>
</tr>
<tr>
<td>VL-5083</td>
<td>O</td>
<td>( t \leq 50 )</td>
<td>125</td>
<td>275 to 350</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>( t \leq 50 )</td>
<td>125</td>
<td>275 to 350</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>( t \leq 50 )</td>
<td>125</td>
<td>275</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>( t \leq 50 )</td>
<td>215</td>
<td>305</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>( t \leq 50 )</td>
<td>215 to 295</td>
<td>305 to 385</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( t \leq 50 )</td>
<td>215 to 295</td>
<td>305 to 385</td>
<td>12</td>
</tr>
<tr>
<td>VL-5086</td>
<td>O</td>
<td>( t \leq 50 )</td>
<td>125</td>
<td>250</td>
<td>8</td>
</tr>
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<td></td>
<td>H111</td>
<td>( t \leq 50 )</td>
<td>125</td>
<td>250</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>( t \leq 12.5 )</td>
<td>125</td>
<td>250</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 12.5 &lt; t \leq 50 )</td>
<td>105</td>
<td>240</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>( t \leq 6.3 )</td>
<td>195</td>
<td>275</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 6.3 &lt; t \leq 50 )</td>
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<td>275</td>
<td>8</td>
</tr>
<tr>
<td>VL-5154A</td>
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<td>85</td>
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<td>17</td>
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<tr>
<td></td>
<td>H32</td>
<td>( t \leq 6 )</td>
<td>180</td>
<td>250 to 305</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 6 &lt; t \leq 50 )</td>
<td>180</td>
<td>250 to 305</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H34</td>
<td>( t \leq 50 )</td>
<td>200</td>
<td>270 to 325</td>
<td>8</td>
</tr>
<tr>
<td>VL-5383</td>
<td>O</td>
<td>( t \leq 50 )</td>
<td>145</td>
<td>290</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>( t \leq 50 )</td>
<td>145</td>
<td>290</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>( t \leq 50 )</td>
<td>220</td>
<td>305</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>( t \leq 50 )</td>
<td>220</td>
<td>305</td>
<td>10</td>
</tr>
<tr>
<td>VL-5454</td>
<td>O</td>
<td>( t \leq 50 )</td>
<td>85</td>
<td>215 to 285</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>H32</td>
<td>( t \leq 6 )</td>
<td>180</td>
<td>250 to 305</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 6 &lt; t \leq 50 )</td>
<td>180</td>
<td>250 to 305</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H34</td>
<td>( t \leq 50 )</td>
<td>200</td>
<td>270 to 325</td>
<td>8</td>
</tr>
<tr>
<td>VL-5456</td>
<td>O</td>
<td>( t \leq 6.3 )</td>
<td>130 to 205</td>
<td>290 to 365</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>( t \leq 30 )</td>
<td>125</td>
<td>285 to 360</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>( 30 &lt; t \leq 40 )</td>
<td>215</td>
<td>305</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 40 &lt; t \leq 50 )</td>
<td>200</td>
<td>285</td>
<td>10</td>
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<tr>
<td></td>
<td></td>
<td>( t \leq 12.5 )</td>
<td>230 to 315</td>
<td>315 to 405</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 12.5 &lt; t \leq 40 )</td>
<td>215 to 305</td>
<td>305 to 385</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 40 &lt; t \leq 50 )</td>
<td>200 to 295</td>
<td>285 to 370</td>
<td>10</td>
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<tr>
<td>VL-5754</td>
<td>O</td>
<td>( t \leq 50 )</td>
<td>80</td>
<td>190 to 240</td>
<td>18</td>
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<tr>
<td></td>
<td>H111</td>
<td>( t \leq 50 )</td>
<td>80</td>
<td>190 to 240</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>H32</td>
<td>( t \leq 50 )</td>
<td>130</td>
<td>220 to 270</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H34</td>
<td>( t \leq 6 )</td>
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<td>240 to 280</td>
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<tr>
<td></td>
<td></td>
<td>( 6 &lt; t \leq 50 )</td>
<td>160</td>
<td>240 to 280</td>
<td>10</td>
</tr>
</tbody>
</table>

1) Elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.
### Table 3  Mechanical properties for extruded aluminium alloys

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper</th>
<th>Thickness, t (mm)</th>
<th>Yield strength $R_{p0.2}$ min. (MPa)</th>
<th>Tensile strength $R_m$ min. or range (MPa)</th>
<th>Elongation 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL-5059</td>
<td>H112</td>
<td>$t \leq 50$</td>
<td>200</td>
<td>330</td>
<td>10</td>
</tr>
<tr>
<td>VL-5083</td>
<td>O</td>
<td>$t \leq 50$</td>
<td>110</td>
<td>240 to 350</td>
<td>14</td>
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<tr>
<td></td>
<td>H111</td>
<td>$t \leq 50$</td>
<td>165</td>
<td>275</td>
<td>12</td>
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<tr>
<td></td>
<td>H112</td>
<td>$t \leq 50$</td>
<td>110</td>
<td>270</td>
<td>12</td>
</tr>
<tr>
<td>VL-5086</td>
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<td>$t \leq 50$</td>
<td>95</td>
<td>240</td>
<td>14</td>
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<td></td>
<td>H111</td>
<td>$t \leq 50$</td>
<td>145</td>
<td>250</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>$t \leq 50$</td>
<td>95</td>
<td>240</td>
<td>12</td>
</tr>
<tr>
<td>VL-5383</td>
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<td>$t \leq 50$</td>
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<td>290</td>
<td>17</td>
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<tr>
<td></td>
<td>H111</td>
<td>$t \leq 50$</td>
<td>145</td>
<td>290</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>H112</td>
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<td>T5</td>
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<td>260</td>
<td>9</td>
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<tr>
<td></td>
<td>T6</td>
<td>$t \leq 10$</td>
<td>215</td>
<td>260</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10 &lt; t \leq 50$</td>
<td>200</td>
<td>250</td>
<td>8</td>
</tr>
<tr>
<td>VL-6060</td>
<td>T4</td>
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<td>60</td>
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<tr>
<td></td>
<td>T5</td>
<td>$t \leq 50$</td>
<td>100</td>
<td>140</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>$t \leq 50$</td>
<td>140</td>
<td>170</td>
<td>8</td>
</tr>
<tr>
<td>VL-6061</td>
<td>T4</td>
<td>$t \leq 50$</td>
<td>110</td>
<td>180</td>
<td>15</td>
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<tr>
<td></td>
<td>T5</td>
<td>$t \leq 50$</td>
<td>205</td>
<td>240</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>$t \leq 50$</td>
<td>240</td>
<td>260</td>
<td>10</td>
</tr>
<tr>
<td>VL-6063</td>
<td>T4</td>
<td>$t \leq 50$</td>
<td>65</td>
<td>130</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>$t \leq 50$</td>
<td>110</td>
<td>150</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>$t \leq 50$</td>
<td>170</td>
<td>205</td>
<td>10</td>
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<tr>
<td>VL-6082</td>
<td>T4</td>
<td>$t \leq 50$</td>
<td>110</td>
<td>205</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>$t \leq 50$</td>
<td>230</td>
<td>270</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>$t \leq 5$</td>
<td>250</td>
<td>290</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$5 &lt; t \leq 50$</td>
<td>260</td>
<td>310</td>
<td>10</td>
</tr>
</tbody>
</table>

1) Elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.

### Table 4  Under-thickness tolerances for rolled products (mm)

<table>
<thead>
<tr>
<th>Nominal thickness, t (mm)</th>
<th>Width of plate (w) (mm)</th>
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<tbody>
<tr>
<td></td>
<td>$w \leq 1500$</td>
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<tr>
<td>3.0 $\leq t &lt; 4.0$</td>
<td>0.10</td>
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<tr>
<td>4.0 $\leq t &lt; 8.0$</td>
<td>0.20</td>
</tr>
<tr>
<td>8.0 $\leq t &lt; 12.0$</td>
<td>0.25</td>
</tr>
<tr>
<td>12.0 $\leq t &lt; 20.0$</td>
<td>0.35</td>
</tr>
<tr>
<td>20.0 $\leq t &lt; 50.0$</td>
<td>0.45</td>
</tr>
</tbody>
</table>

### Table 5  Under-thickness tolerances for extrusions (mm)

<table>
<thead>
<tr>
<th>Nominal thickness range, t (mm)</th>
<th>Open profiles, sections circumscribed by a circle of diameter, d (mm)</th>
<th>Closed profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$d \leq 250$</td>
<td>$250 &lt; d \leq 400$</td>
</tr>
<tr>
<td>3.0 $\leq t &lt; 6.0$</td>
<td>0.25</td>
<td>0.35</td>
</tr>
<tr>
<td>6.0 $\leq t &lt; 50.0$</td>
<td>0.30</td>
<td>0.40</td>
</tr>
</tbody>
</table>
SECTION 6 TESTING PROCEDURES

1 General

1.1 Scope

1.1.1 This section specifies the requirements for testing machines and testing procedures when testing ferrous and non-ferrous metals.

1.1.2 Alternative test pieces, such as those complying with recognized national and international standards, may be accepted subject to agreement. The same applies to the given test procedures.

1.2 Definitions relevant to testing

1.2.1 Test unit: The number of pieces or the tonnage of products to be accepted or rejected together, on the basis of the tests to be carried out on sample products.

1.2.2 Sample product: A single forging, casting, plate, pipe or other wrought product selected from a test unit.

1.2.3 Sample: A sufficient quantity of material taken from the sample product for the purpose of producing one or more test pieces.

1.2.4 Test piece: Part of the sample, with specified dimensions, machined or unmachined, brought to a required condition for submission to a given test.

1.3 Testing machines

1.3.1 All tests shall be carried out by competent personnel on machines of accepted type. The machines shall be maintained in satisfactory and accurate condition and shall be recalibrated at approximately annual intervals by a qualified organisation. A record of such calibrations shall be kept available in the test laboratory.

1.3.2 Tensile testing machine load cells shall be calibrated ±1% in accordance with ISO 7500-1 or another recognised standard.

1.3.3 Impact testing shall be carried out on Charpy V-notch machines calibrated to ISO 148, EN 10045 or ASTM E23 dependent on the testing machine type.

1.4 Selection of test material

Test material sufficient for the required tests and preferably also for possible retest purposes shall be provided. The test material shall be representative of the test unit or sample product and shall not be separated until all the specified heat treatment has been completed, unless otherwise agreed.

1.5 Preparation of test pieces

1.5.1 The preparation of test pieces shall be done in such a manner that test pieces are not subjected to any significant cold straining or heating.

1.5.2 If samples are cut from material by flame cutting or shearing, a reasonable margin is required to enable sufficient material to be removed from the cut edges during final machining.

1.5.3 Where possible, test pieces from rolled materials shall retain their rolled surface on both sides.

1.5.4 Tolerances on tensile specimen dimensions shall be in accordance with ISO 6892-98 or another recognised standard.

1.6 Testing

1.6.1 The appropriate tests specified in this section shall be carried out at the place of manufacture before materials are dispatched. If the necessary facilities are not available at the manufacturer's works, the testing shall be carried out at a recognised testing laboratory.
1.6.2 In the event of any material proving unsatisfactory during subsequent processing or fabrication, such material shall be rejected, notwithstanding any previous certification. The purchaser may require further tests of materials from affected test units.

1.7 Retesting

1.7.1 When the result of any test, other than impact test and Z-testing, fail to meet the requirements, two further tests may be made from the same sample. If both of these additional tests are satisfactory, the test unit may be accepted.

1.7.2 When the results from a set of three impact test pieces fail to meet the requirements, three additional test pieces from the same sample may be tested and the results added to those previously obtained to form a new average. If this new average complies with the requirements and if not more than two individual results are lower than the required average and, of these, not more than one result is below 70% of the specified average value, the test unit may be accepted.

1.7.3 If unsatisfactory results are obtained from retests representative of a test unit, the sample product from which the tests were made shall be rejected. The remaining material in the test unit may be accepted provided that two further sample products are tested with satisfactory result.

1.7.4 When a test unit is rejected, the remaining sample products in the test unit may be resubmitted individually for test, and those which give satisfactory results may be accepted.

1.7.5 At the option of the manufacturer, rejected material may be resubmitted after heat treatment or reheat treatment, or may be resubmitted as another grade and may then be accepted provided the required tests are satisfactory.

1.7.6 If any test piece fails because of faulty preparation, visible defects or (in the case of tensile test) because of fracturing outside the range permitted for the appropriate gauge length, the defective test piece may be disregarded and replaced by an additional test piece of the same type.

2 Test methods

2.1 Tensile testing at ambient temperature

2.1.1 Symbols related to tensile testing.

- \( R_m \) = tensile strength
- \( R_y \) = yield stress (yield point)
- \( R_p \) = yield strength (proof stress)
- \( R_t \) = yield strength (proof stress), total elongation
- \( A \) = percentage elongation after fracture
- \( Z \) = percentage reduction of area.

2.1.2 Upper yield stress \( (R_{ey}) \) is the highest value of stress measured at the commencement of plastic deformation at yield; often this value is represented by a pronounced peak stress. For steels and copper the test shall be carried out with an elastic stress rate between 6 and 60 MPa per sec. and between 2 and 20 MPa per second for aluminium.

2.1.3 When no well-defined yield phenomena exists, either the yield strength at 0.2% non-proportional elongation \( (R_{0.2}) \) or the yield strength at 0.5% total elongation \( (R_{0.5}) \) shall be determined according to the applicable specification.

2.1.4 After reaching the yield stress or yield strength, the machine speed for determination of the tensile strength, is not to exceed that corresponding to a strain rate of 0.008s\(^{-1}\). For cast iron the elastic stress rate shall not exceed 10 MPa per sec.

2.1.5 The elongation generally means elongation determined on a proportional gauge length \( 5.65 \sqrt{S_d} \), or 5\( d \) and has the designation \( A_5 \).

If the material is a ferritic steel of low or medium strength and not cold worked, the elongation may also be
measured on a non-proportional gauge length $L_0$ after agreement. In that case the required elongation $A_0$ is calculated from the following formula:

$$A_0 = 2A_5 \left( \frac{\sqrt{S_0}}{L_0} \right)^{0.40}$$

$A_5$ = the required elongation in % for test piece with gauge length $5.65 \sqrt{S_0}$

$S_0$ = the cross-sectional area of the test piece in question

$L_0$ = the gauge length in question

The elongation value is valid if the fracture occurs at least the following distance from the end marks of the gauge length:

- round test piece: $1.25 \; d$
- flat test piece: $b + a$

2.1.6 For the purpose of determining the different designations related to tensile testing, three different types of test pieces may be used: Round, flat and full cross-section test pieces, see Figure 1.

The following symbols are used:

- $d$ = diameter
- $a$ = thickness
- $b$ = width
- $L_0$ = gauge length
- $L_c$ = parallel test length
- $S_0$ = cross-section
- $R$ = transition radius
- $D$ = external pipe diameter
- $t$ = plate thickness

![Figure 1 Tensile test pieces.](image)

2.1.7 The gauge length $L_0$ may be rounded off to the nearest 5 mm, provided that the difference between this length and $L_0$ is less than 10% of $L_c$.

The parallel test length shall be parallel within acceptable tolerances.

2.1.8 For plates, wide flats and sections with thickness 3 mm or more, flat test pieces of full product thickness according to alternatives A and B shall generally be used. When the capacity of the available testing machine is insufficient to allow the use of test piece of full thickness, this may be reduced in thickness by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thickness,
proportional round test piece according to alternative C may be used. When round test piece is used it shall be positioned with its axis at one-quarter of the thickness from a rolled surface.

*Alternative A, proportional flat test piece:*

\[ a = t \]
\[ b = 25 \text{ mm} \]
\[ L_0 = 5.65 S_0 \]
\[ L_c = L_0 + 2 S_0 \]
\[ R = 25 \text{ mm} \]

*Alternative B, non-proportional flat test piece:*

\[ a = t \]
\[ b = 25 \text{ mm} \]
\[ L_0 = 200 \text{ mm} \]
\[ L_c = 225 \text{ mm} \]
\[ R = 25 \text{ mm} \]

*Alternative C, proportional round test piece:*

\[ d = 10 \text{ mm to } 20 \text{ mm, preferably } 14 \text{ mm} \]
\[ L_0 = 5d \]
\[ L_c \geq L_0 + d/2 \]
\[ R = 10 \text{ mm} \]

2.1.9 For sheet and strips with thickness \( t \) less than 3 mm, flat test piece with the following dimensions shall be used:

\[ a = t \]
\[ b = 12.5 \text{ mm} \]
\[ L_0 = 50 \text{ mm} \]
\[ L_c = 75 \text{ mm} \]
\[ R = 25 \text{ mm} \]

2.1.10 For forgings, bars, cast steel and nodular cast iron, proportional round test piece according to alternative C in 108 shall be used. The test piece for materials with a specified minimum elongation \( A_5 \leq 10\% \) shall have transition radius \( R \geq 1.5d \).

2.1.11 For propeller casting the diameter shall not be less than 14 mm.

2.1.12 For bars of small dimensions a full cross-section test piece may be used.

2.1.13 For grey cast iron the test piece shall have dimensions as stipulated in Figure 2.

![Figure 2 Grey cast iron test piece.](image)

2.1.14 For pipes, test piece according to alternative A or B below shall be used.

*Alternative A:*

Full cross-section test pieces with plugged ends.
\[ L_o = 5.65 \sqrt{S_0} \]
\[ L_c \equiv L_o + D \]

L_c is the distance between the grips or the plugs, whichever is the smallest.

**Alternative B:**

Strip

\[ a = \text{wall thickness of the pipe} \]
\[ b = 12 \text{ mm} \]

\[ L_o = 5.65 \sqrt{S_0} \]
\[ L_c \equiv L_o + 2b \]

### 2.2 Bend testing

#### 2.2.1
Flat bend test piece as given in Figure 3 shall be used. Edges on tension side to be rounded to a radius of 1 to 2 mm.

![Figure 3 Bend test piece](image)

#### 2.2.2
For plates, structural sections and sheets, test piece with the following dimensions shall be used:

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

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

#### 2.2.3
For forgings, castings and semi-finished products, test piece with the following dimensions shall be used:

\[ a = 20 \text{ mm} \]
\[ b = 25 \text{ mm} \]

### 2.3 Impact testing

#### 2.3.1
Impact testing shall be carried out as Charpy V-notch test according to the specification in question. The average value of three test pieces shall be determined and meet the specified minimum requirement. One individual value may be below the specified value, provided that it is not less than 70% of that value.

#### 2.3.2
The Charpy V-notch impact toughness is the absorbed energy, expressed in Joule (J), the symbol being KV.

#### 2.3.3
The Charpy impact test machine shall be of a type having a gap of 40 mm, a striking velocity between 4.5 and 7 m/sec. and a striking energy of not less than 150 J. The angle between the striking edges of the pendulum shall be 30° with the edge rounded to a radius 2 to 2.5 mm. (Pendulum according to ASTM E 23 will also be accepted.)

The point of impact of the hammer shall be in the centre line of the notch.

#### 2.3.4
Samples may be flame-cut but the notch shall not be closer to a flame-cut edge than 25 mm. The
notch shall be made in a single cut by a special milling cutter. The cutter shall be kept sharp so that the shape of the notch is correct and cold working at the base is avoided as far as possible. The cutter shall be systematically checked at intervals not exceeding 100 test pieces.

2.3.5 Dimensions and tolerances for Charpy V-notch test pieces shall be as given in Table 1.

Table 1 Charpy V-notch test pieces.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Nominal</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>55 mm</td>
<td>± 0.60 mm</td>
</tr>
<tr>
<td>Width</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- standard test piece</td>
<td>10 mm</td>
<td>± 0.11 mm</td>
</tr>
<tr>
<td>- subsize test piece</td>
<td>7.5 mm</td>
<td>± 0.11 mm</td>
</tr>
<tr>
<td>- subsize test piece</td>
<td>5 mm</td>
<td>± 0.06 mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>10 mm</td>
<td>± 0.06 mm</td>
</tr>
<tr>
<td>Angle of notch</td>
<td>45°</td>
<td>± 2°</td>
</tr>
<tr>
<td>Depth below notch</td>
<td>8 mm</td>
<td>± 0.05 mm</td>
</tr>
<tr>
<td>Root radius</td>
<td>0.25 mm</td>
<td>± 0.025 mm</td>
</tr>
<tr>
<td>Distance of notch from ends of test piece</td>
<td>27.5 mm</td>
<td>± 0.42 mm</td>
</tr>
<tr>
<td>Angle between plane of symmetry of notch and longitudinal axis of test piece</td>
<td>90°</td>
<td>± 2°</td>
</tr>
</tbody>
</table>

2.3.6 Standard Charpy V-notch test pieces with width 10 mm shall be used, except when the thickness of the material does not permit this size. In such cases the largest obtainable of the subsize test pieces with width 7.5 mm or 5 mm shall be used. The required energy values are then reduced to 5/6 and 2/3 of tabulated values, respectively. Impact tests are generally not required when the material thickness is less than 6 mm.

2.3.7 The temperature of the test piece at the moment of breaking shall be the specified temperature within ±2°C. The temperature shall be controlled for sufficient time to ensure uniformity throughout the cross-section of the test piece.

Test temperature shall be stated in the certificate.

**Guidance note:**
The required temperature tolerance is usually obtainable by immersing the test piece for at least 2 minutes in an agitated liquid bath having the specified test temperature, and have the test piece broken within 5 seconds after withdrawal from the bath.

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

Figure 4 Charpy V-notch test piece

2.4 Determination of grain size

Where the austenitic grain size is specified, it shall be determined according to methods described in recognised standards. At least one sample shall be taken from finished material from each ladle. For rolled products the sample is preferably to be taken from the thickest piece rolled. The grain size numbers refer to the ASTM scale described in ASTM E112.

2.5 Fracture mechanics (FM) testing

When specified, FM testing of materials and weldments shall be performed. The tests shall be carried out according to ISO 12135 and ISO 15653 using 3-point bend specimens, or another recognised standard. The CTOD-technique with 8 × 2B specimens is recommended. The test is deemed to be valid provided post-test-data analysis meets all validity criteria of the standard.
3 Miscellaneous

3.1 Chemical composition

3.1.1 The chemical composition of samples taken from each ladle of each cast shall be determined by the manufacturer in an adequately equipped and competently staffed laboratory and shall comply with the appropriate requirements of this standard.

3.1.2 The manufacturer’s declared analysis will be accepted subject to occasional checks if required by the purchaser.

3.2 Heat treatment

3.2.1 All materials shall be supplied in a condition complying with the appropriate requirements of this standard.

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

Provided sufficient thermocouples connected to the furnace charge (e.g. as required in Sec.3 [1.5.2] and Sec.4 [1.5.2]), is replaced by temperature uniformity test, then the temperature uniformity of the heat treatment furnace shall be verified according to a recognised standard at regular intervals as agreed with the purchaser.

3.2.3 In the case of very large castings or forgings alternative methods for heat treatment will be specially considered.

3.3 Non-destructive testing

All finished material shall have a workmanlike finish and shall be free from internal and surface defects prejudicial to the use of the material for the intended application. Otherwise the material shall comply with the appropriate specific requirements of this standard.

3.4 Correction of defects

When unacceptable defects are found, these shall be removed by appropriate methods and rectified in accordance with the applicable requirements of this standard.
CHAPTER 3 CERTIFICATION AND CLASSIFICATION

SECTION 1 CERTIFICATION AND CLASSIFICATION

1 General

1.1 Introduction

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

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

Table 1 DNV GL Rules for classification - Offshore units

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNVGL-RU-OU-0101</td>
<td>Offshore drilling and support units</td>
</tr>
<tr>
<td>DNVGL-RU-OU-0102</td>
<td>Floating production, storage and loading units</td>
</tr>
<tr>
<td>DNVGL-RU-OU-0103</td>
<td>Floating LNG/LPG production, storage and loading units</td>
</tr>
<tr>
<td>DNVGL-RU-OU-0104</td>
<td>Self elevating units</td>
</tr>
</tbody>
</table>

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

1.2 Assumptions

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

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

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

2 Specific requirements

2.1 General

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

2.2 Information to be supplied by the purchaser

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

2.3 Approval of manufacturers

2.3.1 All steel materials delivered with VL or works certificate shall be made at works approved by DNV GL.

All wrought aluminium products shall be manufactured at works approved by DNV GL.

Approved manufacturers are published on the Internet.

2.3.2 In order to be approved, the manufacturer shall demonstrate and submit documentation to the effect that the necessary manufacturing, testing and inspection facilities are available and are supervised by qualified personnel. The manufacturer shall also carry out a test programme and submit the results.
2.3.3 Detailed programmes for approval testing are given in Standards for Certification No.2.9.

For steel grade NVBW and t ≤ 25 mm, impact testing performed during AoM may replace the testing required in Ch.2 Sec.1 Table 1

When a manufacturer has more than one works, the approval is only valid for the works which carried out the test programme.

2.4 Survey during manufacture

2.4.1 The surveyor shall be given the opportunity to inspect and check at any time all plants and equipment used in the manufacture and testing. The manufacturer shall assist the surveyor to enable him to verify that approved processes are adhered to and to witness the selection and testing as required by the standards.

2.4.2 Prior to the testing and inspection, the manufacturer shall provide the surveyor with the technical specifications of the order and any conditions additional to the standard requirements.

2.5 Selection of test material and testing

2.5.1 All test material shall be selected and marked by the surveyor, unless otherwise agreed.

2.5.2 All testing shall be witnessed by the surveyor, unless otherwise agreed.

2.6 Identification of materials

2.6.1 The manufacturer shall adopt a system of identification which enable all finished material to be traced to the original cast. The surveyor shall be given full facilities for so tracing the materials when required.

2.6.2 Before acceptance, all materials which have been tested and inspected with satisfactory results shall be clearly marked by the manufacturer in at least one place with DNV GL brand, as furnished by the surveyor, and the following particulars:

— manufacturer's name or trade mark
— material grade
— identification number, cast number or other marking which will enable the full history of the product to be traced
— if required by the purchaser, his order number or other identification mark.

2.6.3 Where a number of light materials are securely fastened together in bundles the manufacturer may brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

2.6.4 The marking is normally made by hard stamping, however, other methods may be accepted.

2.6.5 In the event of any material bearing DNV GL brand failing to comply with the test requirements, the brand shall be unmistakably defaced by the manufacturer.

2.7 Certification of materials

2.7.1 Certification of materials will be based on compliance with all specified tests and inspection. Unless otherwise specially approved, certification shall take place at the manufacturer's works and the surveyor shall attend and witness testing and inspection in accordance with the appropriate requirements of Ch.1 and Ch.2.

Certification of materials shall be documented as given in the applicable Rules Ch.1 Sec.6.

2.7.2 As an alternative to [2.7.1], certification may be based on a Manufacturing Survey Arrangement (MSA), subject to approval by DNV GL.
2.7.3 Normally, separate inspection certificates are issued for each grade of material and each product form. The inspection certificate shall include the following particulars:

- purchaser’s name and order number and if known the unit identification for which the material is intended
- manufacturer’s name
- description of the product, dimensions, weight, etc.
- identification of specification or grade of material
- identification of the cast and product
- ladle analysis for specified elements
- results of all specified inspections and mechanical tests
- condition of supply and where appropriate, details of heat treatment.

2.7.4 Where applicable, the manufacturer shall provide the surveyor with inspection certificates for all accepted materials giving at least the particulars detailed in [2.7.3]. Before the inspection certificates are signed by the surveyor, the manufacturer shall furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the required tests. The following form of declaration will be accepted if stamped or printed on each inspection certificate with the name of the works and signed by an authorised representative of the manufacturer: "We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with DNV GL Offshore Standards".

2.7.5 When a material is not produced at the works at which it is rolled or forged, a certificate shall be supplied by the maker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the material was produced must be approved.
Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.