DNV·GL

OFFSHORE STANDARDS

DNVGL-OS-B101 Edition July 2019

Metallic materials

DNV GL AS

FOREWORD

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

Any comments may be sent by e-mail to *rules@dnvgl.com*

CHANGES – CURRENT

This document supersedes the July 2018 edition of DNVGL-OS-B101.

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

Changes July 2019

Topic	*Reference*	*Description*
Certification requirements for materials.	Ch.2 Sec.1 [2.13]	Text is rearranged.
	Ch.3 Sec.1 [2.5.1] and Ch.3 Sec.1 [2.5.2]	Paragraphs are reworded and rearranged.
Carbon equivalent requirements.	Ch.2 Sec.1 [2.6.3] and Ch.2 Sec.1 [2.6.4]	Moved as new sub-notes to Ch.2 Sec.2 [4.3] Table 15.
CTOD test specimen size.	Ch.2 Sec.1 [3.12.1]	Wording changed to indicate that other CTOD test specimen dimensions are subject to agreement with the verifier (approval by the Society).
Fracture mechanics test evaluation criteria.	Ch.2 Sec.1 Figure 14	The figure has been updated to indicate correct distance d_f.
Test specimens for grey cast iron.	previous Ch.2 Sec.1 [3.4.11]	Paragraph *Grey cast iron i*s deleted.
Standards and acceptance criteria for automated NDT of hollow sections.	Ch.2 Sec.2 [1.9.9]	Applicable standards for automated NDT have been tabulated and acceptance criteria corrected.
Requirements for NDT after repair grinding of rolled steel plates.	Ch.2 Sec.2 [1.10.2]	Added that complete elimination of the defects shall be verified by NDT.
Higher carbon equivalent for extra high strength steels.	Ch.2 Sec.2 Table 16	Added sub-note to indicate that higher carbon equivalent may be approved.
Pipe fitting: extent of testing.	Ch.2 Sec.3 [6.6.7] and Ch.2 Sec.3 [6.6.8]	Extent of mechanical testing for pipe fittings is reduced from two to one tensile and impact tests to one per test unit.
Clean steel forgings.	Ch.2 Sec.4 [1.3.8]	Removed detailed requirements and made reference to relevant paragraph in DNVGL-RU-SHIP.
Mechanical properties for forgings subjected to excessive machining.	Ch.2 Sec.4 [1.6.6]	Added guidance indicating that for products machined to a depth exceeding the test specimen positions as specified in the Rules, the obtained mechanical properties may not be fully representative for the product. For such cases, the manufacturer may consider testing on prototype products.
Steel forgings: Condition of supply for rolled bars.	Ch.2 Sec.4 [2.3.1]	It is added that rolled bars may be delivered with the condition of supply normalised rolling (NR) or NR + tempering.
Alignment of requirements for steel forgings for low temperature application with IGC.	Ch.2 Sec.4 Table 4 and Ch.2 Sec.4 Table 5	Two new grades were implemented, and impact toughness requirements for nickel alloy grades were adjusted.

Topic	*Reference*	*Description*
Testing requirements and acceptance criteria for bolts.	Ch.2 Sec.4 [5]	Testing requirements and acceptance criteria aligned with the corresponding requirements for other forgings.
Bolts for pressure equipment with low design temperature.	Ch.2 Sec.4 [5.6.3]	Specified that the requirements are applicable for design temperature not lower than -10°C.
Clarification for welding workshop approval (WWA) and heat treatment workshop approval.	Ch.3 Sec.1 Table 2	It is now clarified that: — repair welding, subcontracted heat treatment and welding workshop may be covered by the material manufacturer approval — heat treatment workshop approval may cover welding workshop approval or vice versa.
Details of heat treatment on material certificate.	Ch.3 Sec.1 [2.5.4] and Ch.2 Sec.2 [1.12.1]	Added that material certificate shall give tempering temperature for QT steels, or recommended PWHT temperature.

Editorial corrections

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

CONTENTS

CHAPTER 1 INTRODUCTION

SECTION 1 GENERAL

1 Introduction

1.1 Objective

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 guidelines for designers, manufacturers, suppliers, purchasers and regulators
— provide the requirements for metallic materials to be used in offshore structures and facilities subject to DNV GL certification, verification and classification.

1.2 Scope

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

1.2.2 The standard provides principles, technical requirements and guidance for metallic materials to be used in the fabrication of offshore structures and equipment. Upon agreement, the scope may be extended to other applications.

1.2.3 The standard gives requirements for the following:

— 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
— steel for low temperature service
— clad steel plates
— bars for anchor chain cable (for offshore mooring chain, see DNVGL-OS-E302)
— iron castings
— copper alloy castings
— non-ferrous pipes

are given in DNVGL-RU-SHIP Pt.2 Ch.2.

1.2.4 Materials, manufacturing methods and procedures complying with proprietary specifications or recognised practices may be accepted provided such documents give reasonable equivalence to the requirements of this standard. See Ch.2 Sec.1 [2.5].

1.2.5 As well as representing DNV GL's recommendations on safe engineering practice for general use by the offshore industry, the offshore standards includes the technical basis for DNV GL classification, certification and verification services as given in Ch.3.

1.3 Application

1.3.1 The requirements in this standard apply to mobile offshore units, offshore installations and equipment.

1.3.2 The application of the materials used for construction of mobile offshore units and their equipment is limited to the use as specified in the relevant standards.

1.4 Structure of the standard

1.4.1 Technical standard

This chapter and Ch.2 give the requirements applicable for materials intended for offshore units, and are independent of the specific requirements of DNV GL for certification, verification or classification. The standard may therefore be referred by e.g. regulatory bodies, purchasers and builders without further involvement of DNV GL.

1.4.2 Specific requirements for DNV GL certification and classification

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

1.4.3 Relation to other applicable DNV GL documents

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

2 References

2.1 Normative references

2.1.1 The standards in Table 1 include provisions which, where referred in this document, constitute provisions of this 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 2 and Table 3.

2.1.3 Any deviations, exceptions and modifications to the design codes and standards shall be documented and agreed upon by the supplier, purchaser and verifier, as applicable. See Ch.2 Sec.1 [2.5].

2.2 Reference standards

Applicable reference standards are given in Table 1, Table 2 and Table 3.

Table 1 Offshore standards

Document code	*Title*
DNVGL-OS-C101	Design of offshore steel structures, general - LRFD method
DNVGL-OS-C102	Structural design of offshore ships
DNVGL-OS-C103	Structural design of column stabilised units - LRFD method
DNVGL-OS-C104	Structural design of self-elevating units - LRFD method
DNVGL-OS-C105	Structural design of TLPs - LRFD method
DNVGL-OS-C106	Structural design of deep draught floating units - LRFD method
DNVGL-OS-C201	Structural design of offshore units - WSD method
DNVGL-OS-C401	Fabrication and testing of offshore structures
DNVGL-OS-D101	Marine and machinery systems and equipment

Table 2 Class programmes

Document code	*Title*
DNVGL-CP-0351	Manufacture of heat treated products - heat treatment workshop
DNVGL-CP-0352	Manufacture of welded products - Welding workshop

Table 3 Other normative references

Document code	*Title*
ANSI H35.1	American National Standard Alloy and Temper Designation Systems for Aluminum
ANSI H35.2	American National Standard Dimensional Tolerances for Aluminum Mill Products
ASTM A53	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A106	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
ASTM A135	Standard Specification for Electric-Resistance-Welded Steel Pipe
ASTM A178	Standard Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes
ASTM A209	Standard Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes
ASTM A210	Standard Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes
ASTM A213	Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
ASTM A234	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A262	Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

Document code	*Title*
ASTM A275	Standard Practice for Magnetic Particle Examination of Steel Forgings
ASTM A312	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
ASTM A333	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness
ASTM A334	Standard Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service
ASTM A358	Standard Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications
ASTM A335	Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service
ASTM A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A388	Standard Practice for Ultrasonic Examination of Steel Forgings
ASTM A403	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM A420	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
ASTM A473	Standard Specification for Stainless Steel Forgings
ASTM A578	Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
ASTM A609	Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
ASTM A744	Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
ASTM A770	Standard Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications
ASTM A789	Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
ASTM A790	Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe
ASTM A815	Standard Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings
ASTM A928	Standard Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal
ASTM A960	Standard Specification for Common Requirements for Wrought Steel Piping Fittings
ASTM A961	Standard Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications
ASTM A965	Standard Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
ASTM A991	Standard Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
ASTM A1049	Standard Specification for Stainless Steel Forgings, Ferritic/Austenitic (Duplex), for Pressure Vessels and Related Components

Document code	*Title*
ASTM B928	Standard Specification for High Magnesium Aluminum-Alloy Products for Marine Service and Similar Environments
ASTM E23	Standard Test Methods for Notched Bar Impact Testing of Metallic Materials
ASTM E94	Standard Guide for Radiographic Examination
ASTM E112	Standard Test Methods for Determining Average Grain Size
ASTM E165	Standard Practice for Liquid Penetrant Examination for General Industry
ASTM E208	Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
ASTM E709	Standard Guide for Magnetic Particle Testing
ASTM G48	Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution
ASTM G66	Standard Test Method for Visual Assessment of Exfoliation Corrosion Susceptibility of 5XXX Series Aluminum Alloys (ASSET Test)
ASTM G67	Standard Test Method for Determining the Susceptibility to Intergranular Corrosion of 5XXX Series Aluminum Alloys by Mass Loss After Exposure to Nitric Acid (NAMLT Test)
EN 515	Aluminium and aluminium alloys - Wrought products - Temper designations
EN 755-1	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles - Part 1: Technical conditions for inspection and delivery
EN 1011-2	Welding - Recommendations for welding of metallic materials - Part 2: Arc welding of ferritic steels
EN 1369	Founding - Magnetic particle testing
EN 1371-1	Founding - Liquid penetrant testing - Part 1: Sand, gravity die and low pressure die castings
EN 1561	Founding - Grey cast irons
EN 10160	Ultrasonic Testing of Steel Flat Product of Thickness Equal or Greater than 6 mm (reflection method)
EN 10163	Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections
EN 10164	Steel products with improved deformation properties perpendicular to the surface of the product - Technical delivery conditions
EN 10204	Metallic Products - Types of inspection documents
EN 10216	Seamless steel tubes for pressure purposes - Technical delivery conditions
EN 10217	Welded steel tubes for pressure purposes
EN 10222 Series	Steel forgings for pressure purposes
EN 10225	Weldable structural steels for fixed offshore structures - Technical delivery conditions
EN 10228	Non-destructive testing of steel forgings
EN 10253 Series	Butt-welding pipe fittings
EN 10269	Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties

Document code	*Title*
ISO 148-1	Metallic materials - Charpy pendulum impact test - Part 1: Test method
ISO 148-2	Metallic materials - Charpy pendulum impact test - Part 2: Verification of testing machines
ISO 185	Grey cast irons - Classification
ISO 643	Steels - Micrographic determination of the apparent grain size
ISO 898	Mechanical properties of fasteners made of carbon steel and alloy steel
ISO 2566	Steel - Conversion of elongation values
ISO 3452-1	Non-destructive Testing – Penetrant inspection/testing
ISO 3506	Mechanical properties of corrosion-resistant stainless steel fasteners
ISO 4136	Destructive tests on welds in metallic materials - Transverse tensile test
ISO 4967	Steel -- Determination of content of non-metallic inclusions -- Micrographic method using standard diagrams
ISO 4992	Steel castings -- Ultrasonic examination
ISO 4993	Steel and iron castings -- Radiographic testing
ISO 5579	Non-destructive testing - Radiographic testing of metallic materials using film and X- or gamma rays - Basic rules
ISO 6362	Wrought aluminium and aluminium alloys -- Extruded rods/bars, tubes and profiles
ISO 6506	Metallic materials -- Brinell hardness test
ISO 6507	Metallic materials -- Vickers hardness test - Part 1: Test method
ISO 6508	Metallic materials - Rockwell hardness test
ISO 6892	Metallic materials - Tensile testing
ISO 7500-1	Metallic materials - Calibration and verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Calibration and verification of the force-measuring system
ISO 8492	Metallic materials -- Tube -- Flattening test
ISO 8493	Metallic materials -- Tube -- Drift-expanding test
ISO 8494	Metallic materials -- Tube -- Flanging test
ISO 8495	Metallic materials -- Tube -- Ring-expanding test
ISO 8496	Metallic materials -- Tube -- Ring tensile test
ISO 9017	Destructive tests on welds in metallic materials - Fracture test
ISO 9329	Seamless steel tubes for pressure purposes
ISO 9330	Welded steel tubes for pressure purposes
ISO 9712	Non-destructive testing – Qualification and certification of NDT personnel
ISO 10474	Steel and steel products — Inspection documents
ISO 10893	Non-destructive testing of steel tubes

Document code	Title
ISO 12135	Metallic materials -- Unified method of test for the determination of quasistatic fracture toughness
ISO 15614-1	Specification and qualification of welding procedures for metallic materials -- Welding procedure test - Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys
ISO 15653	Metallic materials -- Method of test for the determination of quasistatic fracture toughness of welds
ISO 17638	Non-destructive testing of welds - Magnetic particle testing
ISO 17640	Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels, and assessment
JIS B2312	Steel butt-welding pipe fittings
JIS B2313	Steel plate butt-welding pipe fittings
JIS B2316	Steel socket-welding pipe fittings
JIS G3214	Stainless steel forgings for pressure vessels
JIS G3454	Carbon steel pipes for pressure service
JIS G3455	Carbon steel pipes for high pressure service
JIS G3456	Carbon steel pipes for high temperature service
JIS G3458	Alloy steel pipes
JIS G3459	Stainless steel pipes
JIS G3460	Steel tubes for low temperature service
JIS G3461	Carbon steel boiler and heat exchanger tubes
JIS G3462	Alloy steel tubes for boiler and heat exchanger
JIS G3463	Stainless steel boiler and heat exchanger tubes

3 Abbreviations and definitions

3.1 Verbal forms

Verbal forms used are given in Table 4 and Table 5 .

Table 4 Definition of verbal forms

Term	Definition
shall	verbal form used to indicate requirements strictly to be followed in order to conform to the document
should	verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others
may	verbal form used to indicate a course of action permissible within the limits of the document

Table 5 Definition of specific verbal forms

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

3.2 Terms

Terms used are given in Table 6.

Table 6 Definition of terms

Term	*Definition*
inspection	an activity carried out by the contractor, subcontractor or manufacturer to verify compliance with the applicable rules and specifications
manufacturer	the party who is contracted to be responsible for planning, execution and documentation of manufacturing
mobile offshore unit	a buoyant construction engaged in offshore operations including drilling, production, storage or support functions, not intended for service at one particular offshore location and which can be relocated without major dismantling or modification
non-destructive testing	radiographic testing (RT), ultrasonic testing (UT), magnetic particle testing (MT), penetrant testing (PT) and other non-destructive methods for revealing defects and irregularities
offshore installation	a buoyant or non-buoyant construction engaged in offshore operations including drilling, production, storage or support functions and which is designed and intended for use at one particular location for an extended period
offshore unit	when the term offshore unit is used in this document, it shall be interpreted as mobile offshore unit or offshore installation
quality assurance	prevention of quality problems through planned and systematic activities
quality control	the activities or techniques used to identify defects after a product is developed and before it's released
purchaser	the owner or another party acting on his behalf, who is responsible for procuring materials, components or services intended for the design, construction or modification of a structure
test specimen	part of the sample, with specified dimensions, machined or un-machined, brought to a required condition for submission to a given test

Term	*Definition*
test unit	the quantity of products to be accepted or rejected, on the basis of the tests to be carried out on sample products. The term may be applied, for example, to a specific number of products of the same shape and dimensions originating from one cast, or to a length of rolled material (plate or strip) or to a single product (a large forging or casting).
sample	a sufficient quantity of material taken from the sample product for the purpose of producing one or more test specimens
sample product	a single forging, casting, plate, tube or other wrought product selected from a test unit
unit	a general term for an offshore installation such as ship shaped, column stabilised, self-elevating, tension leg or deep draught floater
verifier	an organization that is mandated to verify compliance. The owner or his representative may act as verifier unless the product or structure is subject to DNV GL certification, verification or classification, or unless otherwise required by applicable regulatory bodies, etc. The verifier shall be DNV GL where products or structures are subject to certification, verification or classification by DNV GL.

3.3 Abbreviations

Abbreviations used are given in Table 7.

Table 7 Abbreviations

Abbreviation	*Description*
AC	alternating current
AcC	accelerated cooling conditions
ACCP	ASNT central certification program
ALS	accidental limit state
ANSI	American National Standards Institute
AoM	approval of manufacturer
AP	approval
AR	as-rolled
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing of Materials
AWS	American Welding Society
BM	base material
C-Mn	carbon manganese
CTOD	crack tip opening displacement
DAC	distance amplitude curve
DAT(-X°C)	design ambient air temperature, see e.g. DNVGL-RU-SHIP Pt.5 Ch.6.
DC	direct current

Abbreviation	*Description*
DIN	Deutsches Institut für Normung (German Standards)
ECA	engineering critical assessment
EHS	extra high strength steel
EN	European standard
ET	eddy current testing
FCAW	flux cored arc welding
FI	for information
FL	fusion line
FM	fracture mechanics
GCHAZ	grain coarsened heat affected zone
GMAW	gas metal arc welding
GTAW	gas tungsten arc welding
HAZ	heat affected zone
HS	high strength steel
HV	Vickers hardness
IACS	International Association of Classification Societies
IACS UR	International Association of Classification Societies unified requirements
IIW	International Institute of Welding
IMO	International Maritime Organization
ISO	International Organisation for Standardisation
JIS	Japanese Industry Standard
MAG	metal active gas (welding)
MC	material certificate
MIG	metal inert gas (welding)
MPa	mega pascal
MSA	manufacturing survey arrangement
MSC	maritime safety committee
MT	magnetic particle testing
MTR	material test report
N	normalized
NACE	National Association of Corrosion Engineers
NDT	non-destructive testing
NDTT	nil-ductility test temperature

Abbreviation	*Description*
NR	normalising rolling
NS	normal strength steel
NSA	new building survey arrangement.
PAUT	phased array ultrasonic testing
PT	penetrant testing
PWHT	post-weld heat treatment
pWPS	preliminary welding procedure specification
Q	quenching
QA	quality assurance
QC	quality control
QT	quenched and tempered
R	on request
RP	recommended practice
RT	radiographic testing
SAW	submerged arc welding
SENB	single-edge notch bend
SM	specified microstructure
SMAW	shielded metal arc welding
SMYS	specified minimum yield strength
SOLAS	International Convention for the Safety of Life At Sea
TIG	tungsten inert gas (welding)
TOFD	time of flight diffraction
TM	thermo-mechanical rolling
TR	test report
UT	ultrasonic testing
VL	prefix for DNV GL material grades and for DNV GL certificates
VT	visual testing
W	works certificate
WM	weld metal or deposit
WPQR	welding procedure qualification records
WPQT	welding procedure qualification test
WPS	welding procedure specification
WPT	weld production test

Abbreviation	*Description*
WWA	welding workshop approval

3.4 Symbols

Symbols used are given in Table 8.

Table 8 Symbols

Symbol	*Definition*	*Unit*
a	Used for different measures: 1) thickness of tensile test specimens 2) width of abutting member for qualification of TKY welding 3) length related to qualification of welding of pipe branch connection 4) throat thickness of fillet welds	mm
A	Percentage elongation after fracture	%
A_0	Required non-proportional elongation	%
A_5	Elongation in % for test specimen with proportional gauge length	%
Ac1	The temperature at which austenite begins to be formed upon heating a steel	°C
Ac3	The temperature at which the transformation of ferrite to austenite is completed upon heating a steel	°C
Ar3	The temperature at which austenite begins to convert to ferrite upon cooling a steel	°C
α	Angle	Deg.
b	Width	mm
B	Width	mm
B_{min}	Minimum specimen width	mm
C	Outer diameter after expansion	mm
CET	Carbon equivalent CET	%
C_{eq}	Carbon equivalent C_{eq}	%
C_{max}	Maximum carbon content	%
d	Used for different measures: 1) test specimen diameter 2) journal diameter (forgings) 3) capital letters to give the delivery condition, e.g. N, NR, TM, QT. Optional for steels of normal and high strength, mandatory for steels of extra high strength	mm
d_f	Distance from the plane of the fatigue pre-crack to the fusion line (varies along the fatigue pre-crack)	mm
d_{max}	Maximum diameter	mm
d_{min}	Minimum diameter	mm

Symbol	*Definition*	*Unit*
D	Used for different measures: 1) external pipe diameter 2) diameter of toothed portion of gears	mm
e	Plastic deformation degree	%
e'	Strain rate	s^{-1}
F	Force	N
KV	Charpy V-notch impact toughness absorbed energy	J
KV_L	Impact tested in longitudinal direction	J
KV_T	Impact tested in transverse direction	J
l	Used for different measures: 1) longitudinal direction 2) length	- mm
l_{min}	Minimum length	mm
L	Used for different measures: 1) longitudinal direction 2) length of test sample 3) length of toothed portion of gears	mm
L_o	Gauge length	mm
L_c	Parallel test length	mm
L_{min}	Minimum length	mm
λ_i	Length of each area with acceptable location of the fatigue pre-crack (given as SM (λ) = specified microstructure in ISO 15653)	mm
N	Number	-
O	Letter included to designate an offshore grade of extra high strength steel where specified yield and tensile strength is independent of the product thickness	
P_{cm}	Cold cracking susceptibility	%
R	Transition radius	mm
R_C	Forming radius (inner radius of bends)	mm
R_m	Tensile strength	MPa
R_e	Yield strength (yield point)	MPa
R_{eL}	Lower yield strength (yield point)	MPa
R_{eH}	Upper yield strength (yield point)	MPa
R_p	Yield strength (proof stress)	MPa
$R_{p0.2}$	Yield strength at 0.2% non-proportional elongation	MPa
$R_{p1.0}$	Yield strength at 1.0% total elongation	MPa

Symbol	*Definition*	*Unit*
R_s	Transition radius	mm
R_t	Yield strength (proof stress), total elongation	MPa
S_u	Minimum cross section area of a tensile test specimen after fracture	mm^2
S_o	Cross-sectional area of a tensile test specimen	mm^2
Σ	Sum	-
t	Used for different measures: 1) thickness 2) transverse or tangential direction	 mm -
T	Used for different measures: 1) temperature 2) transverse or tangential direction	 -
v	Poisson's ratio	-
V	Notch opening displacement	mm
v_c	Tensile test machine crosshead separation rate	mm/s
VL	Designation of a steel grade according to DNV GL rules and standards	-
W	Letter included to designate a steel grade of improved weldability	
x	A capital letter corresponding to a specified impact toughness test temperature	
y	A figure designating the strength group according to the specified minimum yield stress	
Z	Percentage reduction of area	%

CHAPTER 2 TECHNICAL PROVISIONS

SECTION 1 MANUFACTURE, CERTIFICATION AND TESTING

1 General

1.1 Scope

This section specifies general requirements for materials used for construction of offshore units and their equipment related to:

— manufacture and manufacturer
— chemical composition
— heat treatment
— inspection and survey
— identification and certification
— testing and retesting
— testing machines
— test specimens and test methods.

1.2 Application

The requirements apply to:

— manufacturers
— testing laboratories and workshops
— contractors
— sub-contractors of manufactured, constructed and where relevant, repaired:
  — materials
  — offshore units and components.

1.3 Relation to other sections

Where specific or additional requirements are provided in Sec.2 to Sec.6, the specific or additional requirements are prevailing.

2 Manufacture, survey and certification

2.1 General

2.1.1 This subsection specifies general requirements for manufacture, survey and certification of metallic materials to be used in the fabrication of offshore structures and equipment. Appropriate specific requirements are given in Sec.2 to Sec.6.

2.1.2 Materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of Sec.2 to Sec.6 or are otherwise specially accepted, see [2.5].

2.1.3 The purchaser shall supply the manufacturer with all information necessary to ensure that survey and certification can be carried out in accordance with the standard. This applies particularly where optional

or additional conditions are specified in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.2 Pre-qualification of materials manufacturers

Pre-qualification of manufacturers and workshops 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.

Guidance note:

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

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2.3 Survey during manufacture

2.3.1 The verifier shall be given the opportunity to survey and check relevant plants and equipment used in the manufacture and testing. The manufacturer shall assist the verifier to enable him to verify that qualified processes are adhered to and to witness the selection and testing as required by the rules.

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

2.3.3 Where non-destructive tests are specified for the various products, these shall be performed under the manufacturer's responsibility. The testing operators shall be certified to a recognized scheme. The results together with details of the test method shall be documented by the manufacturer. When required, the verifier shall be given the possibility to be present during non-destructive tests. The requirements for test method and acceptance criteria are given in the relevant sections of this chapter.

2.3.4 All products shall be verified by the manufacturer for compliance with the specified dimensions and surface finish requirements. They shall also be inspected for possible defects. For this purpose, the products shall normally be in the prescribed delivery condition and shall have a clean surface, prepared for inspection, which is free from coatings or other protective media which impair the detection of defects.

Products that do not meet the required dimensions or show unacceptable defects shall be clearly marked accordingly and separated from the regular production process for clearance. The products, when this is called for, shall be presented to the verifier in the condition described above.

2.3.5 If there is reasonable doubt as to the quality of a product, the verifier may require additional tests to be performed.

2.3.6 The manufacturer shall ensure that delivered materials/products are within radioactive contamination limits permitted by regulatory bodies/agencies, as applicable for the place of manufacture. Specification of acceptance levels for radiation shall be documented in manufacturer's QA/QC procedures.

2.4 Material specification

2.4.1 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.

2.4.2 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.

2.4.3 The specification should include specific requirements in places where this standard gives options, e.g. chemical composition, testing, requirements subject to agreement, etc.

2.4.4 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.

2.5 Evaluation for acceptance of materials specified by other standards

Where indicated by the rules, materials specified to international, national or proprietary standards may be considered for acceptance. In order to be considered for acceptance, the suitability of these materials for the intended purpose shall first be evaluated and qualified by the manufacturer or builder.

As a minimum, the following particulars shall be specified for alternative materials:

- relevant standard/specification and grade
- manufacturing process
- chemical composition
- heat treatment/delivery condition
- sampling for mechanical properties testing, e.g. sampling process, sampling frequency, at what stage of manufacturing process, location of sample within the product, sizes, etc.
- mechanical properties (including thickness dependency)
- dimensional tolerances
- if relevant, non-destructive testing.

Further particulars may be required as relevant for the acceptance. Requirements for qualification of the manufacturer shall follow [2.2].

Guidance note:

In order for other materials to be considered for acceptance, a gap analysis report identifying the differences between the proposed material and the corresponding requirements of this standard should be submitted. Note that for all the rule requirements not addressed in the relevant standard, or not already accepted based on the manufacturer's evaluation and qualification, the requirements of this standard apply.

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2.6 Chemical composition

2.6.1 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 chapter.

2.6.2 When required, the carbon equivalent value (C_{eq}) shall be calculated using Equation (1):

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

2.6.3 The cold cracking susceptibility (P_{cm}) for evaluation of weldability shall be calculated using Equation (2):

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

2.6.4 If applicable, the carbon equivalent value *CET* is calculated using Equation (3):

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

Note:

The *CET* is included in the standard EN 1011-2 used as one of the parameters for preheating temperature determination.

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2.7 Heat treatment

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

2.7.2 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.

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

2.8 Selection of test material

2.8.1 Test material sufficient for the required tests shall be provided and preferably also for possible retest. The test material shall be representative of the test unit or sample product. It shall be securely attached to the sample product until all the specified heat treatments have been completed. If the test unit is reheat treated and the test material for retest was detached, it shall be reattached to the sample product before new heat treatment is commenced. Test materials or test specimens shall not be separately heat-treated.

2.8.2 Materials for testing shall be suitably marked in order to ensure traceability to the represented products.

2.9 Testing

2.9.1 The appropriate tests specified in Sec.2 to Sec.6 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 recognized testing laboratory.

2.9.2 Any material proving unsatisfactory during subsequent processing or fabrication shall be rejected, notwithstanding any previous certification. The verifier may require further tests of materials from affected test units.

2.10 Retesting

2.10.1 When the result of any test, other than impact test, fails 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.

2.10.2 When the results from a set of three impact test specimens fail to meet the requirements, the test unit is rejected, or alternatively, three additional test specimens from the same sample may be tested. The results are added to those previously obtained. The test unit may be accepted if:

— the average of all six specimens complies with the requirements, and
— 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.

2.10.3 If unsatisfactory results are obtained from retests representative of a test unit, see [2.11.1] and [2.11.2], the product from which the tests were made shall be rejected. The remaining material in the test unit may be accepted provided that two further products are tested with satisfactory result.

2.10.4 When a test unit is rejected, see [2.10.2] and [2.10.3], the remaining products in the test unit may be resubmitted individually for test and those which give satisfactory results may be accepted.

2.10.5 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.

Where the material is submitted to heat treatment or re-heat treatment, all the tests previously performed shall be repeated and the results shall meet the specified requirements.

2.10.6 If any test fails because of faulty specimen 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 specimen may be disregarded and replaced by an additional test specimen of the same type.

2.10.7 If a large proportion of the products fail the tests, e.g. because of constantly recurring manufacturing defects, the entire delivery may be rejected by the verifier.

The manufacturer shall determine any cause of recurring manufacture defect and establish countermeasures to prevent its recurrence. Investigation reports to this effect along with additional information required by the verifier shall be made available to the verifier on request. The frequency and extent of testing for subsequent products is at the discretion of the verifier.

Guidance note:

It is the manufacturer's responsibility to ensure that effective manufacture and process controls and where relevant, qualified and/or approved processes are implemented and adhered to in production. The qualified manufacturing processes may be revisited and the acceptance as qualified manufacturer may be reconsidered.

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2.11 Visual and non-destructive testing

2.11.1 Internal and surface defects

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 the subsequent sections.

2.11.2 Correction of defects

When defects are found, these shall be removed by appropriate methods and rectified in accordance with the applicable requirements of Sec.2 to Sec.6.

2.12 Identification of materials

2.12.1 The manufacturer shall adopt a system of identification which enables all finished material to be traced to the original cast, including the documentation of all important production steps. The verifier shall be given full facilities for tracing the materials when required.

2.12.2 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 the following particulars:

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

2.12.3 The marking is normally made by hard stamping, except where this may be detrimental to the material or production process, in which case stencilling, painting or electric etching may be used. Other marking systems providing durable identification and traceability may also be accepted, e.g. for products with wall thickness t < 6 mm.

2.12.4 A number of light materials such as shapes and bars weighing ≤ 25 kg per metre may be securely fastened together in bundles. For this case, the manufacturer may mark only the top piece of each bundle, or alternatively attach a durable label securely to each bundle. The content of the required marking is given in [2.13.2].

2.12.5 All marks shall be applied so that their legibility cannot be impaired by the transportation or storage of the products. Where the further processing of the products entails the removal of existing marks, the manufacturer concerned shall apply these to a different spot and shall arrange with the verifier for the transfer of the stamp, unless another solution is adopted.

2.13 Certification of materials

2.13.1 Materials and products shall be delivered with inspection documents as defined in ISO 10474, 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.

2.13.2 Certification of materials shall be based on compliance with all specified tests and inspections, as documented in a material certificate or inspection document. Unless otherwise agreed, certification shall take place at the manufacturer's works.

2.13.3 The manufacturer shall provide the type of inspection certificate required in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.13.4 The inspection certificate shall include the following particulars:

— 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 (including NDT) and mechanical tests
— condition of supply and where appropriate, details of heat treatment. For QT steels, tempering temperature or recommended post-weld heat treatment temperature.

Unless otherwise agreed, separate inspection certificates shall be issued for each casting and forging.

2.13.5 A product intended for certification may be made from semi-finished products not produced at the works where it will be finished by final rolling, forging or heat treatment. For this case, the semi-finished product shall be delivered with at least 3.1 inspection certificate stating process of manufacture and chemical composition and with traceable identification. The works at which the material was produced shall be considered for pre-qualification. Typical semi-finished products are indicated in Figure 1.

Note:

Where stricter certification requirements for semi-finished products are agreed or are given in the subsequent parts of the rules, the stricter requirements apply.

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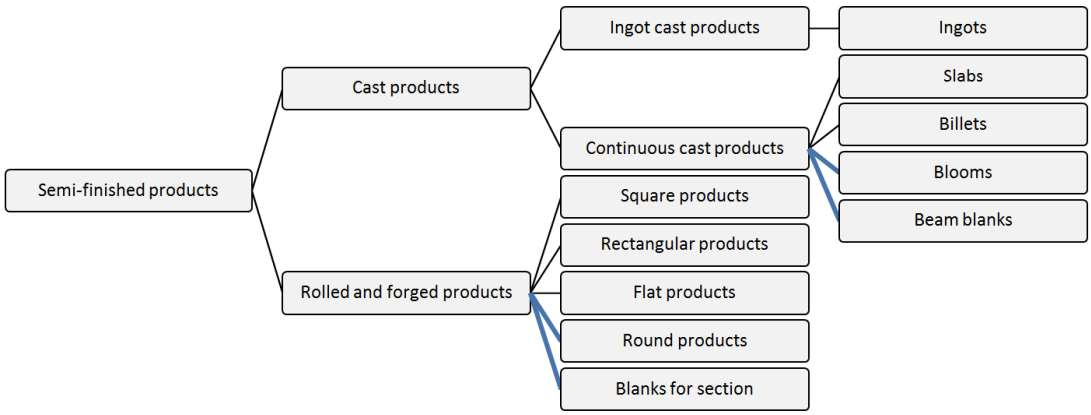

Figure 1 Overview of typical semi-finished products

2.14 Documentation

This topic is addressed in Ch.3.

3 Testing procedures

3.1 Scope

3.1.1 This subsection specifies the requirements for testing machines, test specimens and testing procedures when testing ferrous and nonferrous metals.

3.1.2 Alternative test specimens, such as those complying with recognized national and international standards may be accepted subject to agreement with the verifier and on condition that the test specimens will give comparable results. The same applies to the given testing procedures.

3.2 Testing machines type, maintenance and calibration

3.2.1 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 calibrated at approximately annual intervals by a testing authority. A record of such calibrations shall be kept available at the test laboratory.

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

3.2.3 Impact testing shall be carried out on Charpy V-notch machines calibrated to ISO 148-2, ASTM E23 or equivalent dependent on the testing machine type.

3.2.4 Stationary hardness testing equipment shall be calibrated at least yearly on calibrated test blocks. Portable hardness testers shall be calibrated on calibrated test blocks before and after use each day, or at 4 hours intervals, whichever is smaller. In case the manufacturer's specification indicates shorter intervals, the manufacturer's specification shall be followed. In case the calibration after use indicates values outside the calibration tolerances, the measurements performed after the previous calibration shall be repeated after a new calibration of the hardness tester. It shall be verified that the acceptable tolerances for the equipment parameters and the indicating accuracy are complied with in accordance with the appropriate standards.

Guidance note:

Examples of standards for calibration are ISO 6506-2 and ISO 6507-2.

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3.3 Preparation of test specimens

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

3.3.2 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.

Guidance note:

A margin of 10 mm may normally be considered sufficient. Smaller margins may be considered for acceptance subject to approval based on qualification by adequate testing. Qualification testing should at least comprise metallographic test, hardness test profile and comparative mechanical tests.

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3.3.3 Where possible, test specimens from rolled materials shall retain their rolled surface on both sides. The surface quality of the specimens shall be as prescribed in the appropriate standards, i.e. notches, grooves and burrs which occur during the preparation of test specimens and which may affect the test results shall be removed. The dimensional and geometrical tolerances of the specimens shall be as prescribed in the appropriate rules and standards.

3.3.4 If possible, the test specimens shall be taken in such a way that straightening is unnecessary. If test sections have to be straightened, e.g. in the case of transverse specimens from pipes, the straightening operation shall be performed in the cold state and shall not significantly affect the mechanical properties of the material. Tensile specimens taken from the pipe wall in the longitudinal direction shall not be pressed flat between the gauge marks.

3.3.5 Tolerances on tensile specimen dimensions shall be in accordance with ISO 6892 or another agreed recognised standard.

3.4 Tensile testing at ambient temperature

3.4.1 Yield and proof stress

Upper yield strength (R_{eH}) is the highest value of stress measured at the commencement of plastic deformation at yield. This value is often represented by a pronounced peak stress.

When no well-defined yield phenomena exist, the yield strength at 0.2% non-proportional elongation ($R_{p0.2}$) shall be determined unless otherwise stated in the applicable specification. If required by the relevant rules, the yield strength at 1% total elongation ($R_{p1.0}$) shall be determined for austenitic and duplex (ferritic/austenitic) stainless steels according to the applicable specification.

3.4.2 Tensile strength

Tensile strength (R_m) is the highest value of stress measured before fracture.

3.4.3 Stress and strain rates for tensile tests

For materials with a modulus of elasticity ≥ 150 GPa (typically steels including stainless steels) the test shall be carried out with an elastic stress rate between 6 and 60 MPa per second.

For materials with a modulus of elasticity < 150 GPa (typically copper, aluminium, titanium and their relevant alloys) the test shall be carried out with an elastic stress rate between 2 and 20 MPa per second.

After reaching the yield strength (R_e, R_p, R_t), the machine speed (v_c) for determination of the tensile strength (R_m), shall not exceed that corresponding to a strain rate (e') of $0.008s^{-1}$, where:

$$e' = (v_c / L_c) \leq 0.008\ s^{-1}$$

This corresponds to a crosshead separation rate of v_c (mm/s):

$$v_c \leq (L_c \times 0.008)$$

For cast iron the elastic stress rate shall not exceed 10 MPa per second.

3.4.4 Accuracy for yield and tensile strength

The test results shall be stated to an accuracy of 1 MPa (N/mm^2).

3.4.5 Elongation

If not otherwise stated, the elongation means elongation determined on a proportional gauge length $5.65\sqrt{S_0}$ or 5 d and has the designation A_5 (%).

The elongation may alternatively, after agreement with the verifier, be determined on a non-proportional gauge length L_o (i.e. a gauge length having a different ratio to the cross-section). In that case the required minimum elongation A is calculated from the formula given below. However, where stated otherwise in Sec.2 to Sec.6, the therein stated requirements apply.

$$A = 2A_5\left(\frac{\sqrt{S_0}}{L_0}\right)^{0.4} \qquad (4)$$

This conversion formula shall only be used for ferritic steels with tensile strength of ≤ 700 N/mm^2 which have not been cold formed, see also ISO 2566. When proportional specimens other than $L_0 = 5.65\ \sqrt{S_0}$, or 5 d, or non-proportional test specimens are used, the applied gauge length shall be stated in the certificate, e. g. A200 mm = elongation for initial gauge length L_0 = 200 mm. The test results shall be reported to an accuracy of a whole number, e.g. 20.51% is reported as 21%.

Requirements for position of fracture:

a) fracture within a specified range:
   - the elongation value is valid if the fracture occurs at least the following distance from the end marks of the gauge length (see Figure 2):
     - round test specimen: 1.25 d
     - flat test specimen: b + a.

b) fracture outside above specified range:
   - if the specified minimum elongation requirement is met, the test may be considered to be valid

— if the specified minimum elongation required is not met, the test is considered invalid and a new test shall be carried out.

3.4.6 Reduction of area (Z)

The reduction of area at fracture Z (%) shall be determined by the following formula where this is called for in this chapter:

$$Z = \left(\frac{S_0 - S_u}{S_0}\right) \times 100 \quad (\%) \qquad (5)$$

where S_u is the minimum cross section area after fracture. The test results shall be stated to an accuracy of 1%.

3.4.7 Tensile test specimen types and dimensions

For the purpose of determining the different designations related to tensile testing, two different types of test specimens are defined: round and flat, see Figure 2.

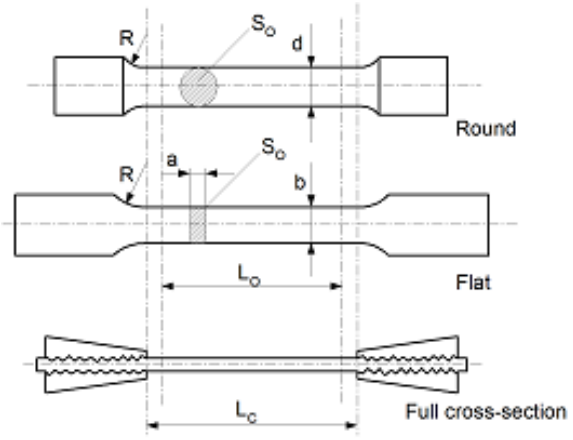


Figure 2 Tensile test specimens

Table 1 Dimensions of tensile test specimens

Alternative	*Dimension (mm)*					
	a	*b*	*d*	L_0 [1)]	L_C	*R*
A: proportional flat test specimen, Figure 2	t	25	-	$5.65\sqrt{S_0}$	$L_0 + 2\sqrt{S_0}$	25
B: non-proportional flat test specimen, Figure 2	t	25	-	200	≈ 225	25
C: proportional round test specimen, Figure 2	-	-	14 (or 10-20)	5 × d	≥ L_0 + d/2	10 [2)]
D: test specimen for sheet and strips with thickness less than 3 mm, Figure 2	t	12.5	-	50	≈ 75	25

Alternative	*Dimension (mm)*					
	a	*b*	*d*	L_0 1)	L_C	*R*
E: full cross-section test specimen with plugged ends, Figure 4	-	-	-	$5.65\sqrt{S_0}$	L_0 + D 3)	-
F: strip specimen 4), Figure 4	Tube wall thickness	12	-	$5.65\sqrt{S_0}$	L_0 + 2 b	-

1) the applied gauge length (L_o) may be rounded off to the nearest 5 mm, provided that the difference between the applied gauge length and the calculated gauge length (from [3.1.2]) is less than 10% of calculated gauge length
2) for nodular cast iron and materials with specified elongation less than 10%: R ≥ 1.5 d
3) L_c is the distance between the grips or the plugs, whichever is the smallest
4) the parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.

3.4.8 Plates, wide flats and sections

For plates, wide flats and sections with thickness 3 mm or more, flat test specimens of full product thickness according to alternatives A and B shall generally be used, see Table 1. When the capacity of the available testing machine is insufficient to allow the use of test specimens of full thickness, the test specimen may be reduced in thickness by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thickness, proportional round test specimen according to alternative C may be used. When round test specimen is used and unless otherwise specified, it shall be positioned with its axis at one-quarter of the thickness from a rolled surface (and for extra high strength steels, additionally at t/2 for thicknesses above 100 mm) or as near as possible to these positions.

3.4.9 Wrought aluminium alloys

Flat tensile test specimens shall be used for specified thicknesses up to and including 12.5 mm (alternative D, see Table 1) and may be used for thickness exceeding 12.5 mm. The test specimens shall be prepared so that both rolled/pressed/extruded surfaces are preserved. Round specimens may alternatively be used for product thicknesses exceeding 12.5 mm (alternative C, see Table 1). For product thicknesses up to and including 40 mm, the longitudinal axis of the round specimens shall be located at mid-thickness. For product thickness exceeding 40 mm, the longitudinal axis of round specimens shall be located at ¼ of the product thickness measured from one face.

3.4.10 Forgings, bars and castings (excluding grey cast iron)

Proportional round test specimen according to alternative C in Table 1 shall be used.

3.4.11 Bolts

For the tensile test, specimens may be machined from the sample material. Specimens of the type shown in Figure 3 may be used, or specimens in accordance with the standards in Sec.4 [5.2.2], unless specimen position as per Sec.4 [1.6] is required, e.g. for bolts with nominal thread diameter > M39.

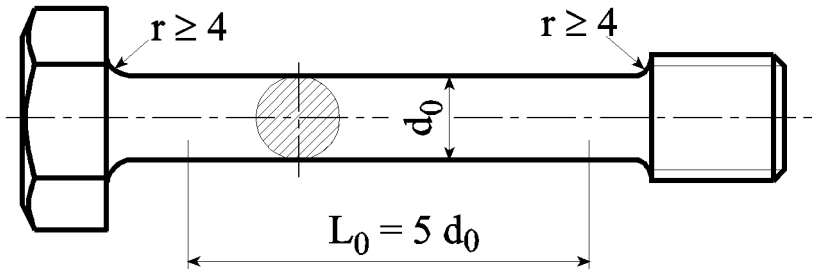


Figure 3 Machined specimen

3.4.12 Pipes and tubes

Test specimen according to alternative E or F shall be used, see Table 1 and Figure 4. Alternatively, provided sufficient wall thickness, round specimens according to alternative C as prescribed in Table 1 may also be used. Round specimens shall then be taken from the sample in such a way that their axis is located at the mid-point of the wall thickness.

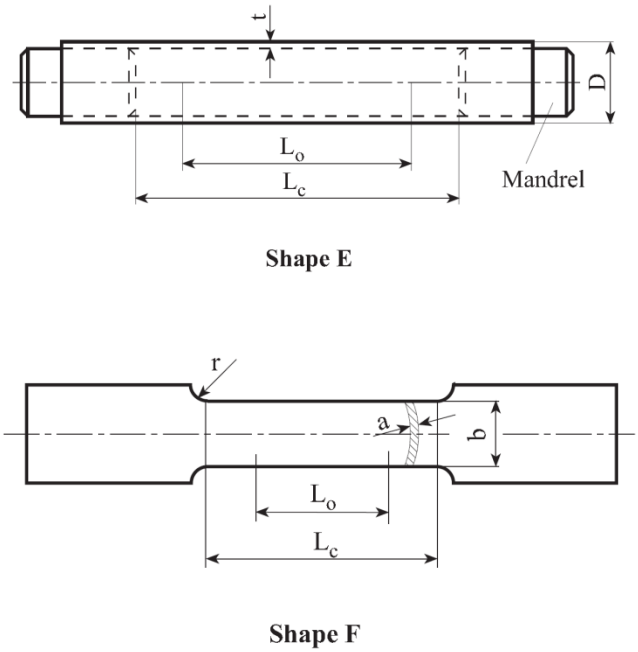


Figure 4 Alternatives E and F

3.4.13 Weldments

3.4.13.1 Deposited weld metal tensile test

Round specimen with the following dimensions shall be used, see Figure 2:

D = 10 mm

L_0 = 50 mm

L_C > 60 mm

R ≥ 10 mm

The tensile test specimens shall be taken so that the longitudinal axis coincides with the intersection between the mid-plane of the weld and the mid-plane of the plates.

For specially small or large dimensions other specimens may be used after agreement with the verifier, provided they conform to the geometrical relationship given in Table 1.

3.4.13.2 Butt weld tensile test, flat specimen

The weld shall be machined (or ground) flush with the surface of the plate, and the specimen prepared with the following dimensions, see Figure 2:

a = t

b = 12 mm for t ≤ 2 mm

b = 25 mm for t > 2 mm

L_0 = L_C = width of weld + 60 mm

R ≥ 25 mm

As an alternative, test specimens in accordance with ISO 4136 would be accepted.

3.5 Impact testing

3.5.1 Impact testing shall be carried out as Charpy V-notch test according to the specification in question. The average value of three test specimens 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 the specified minimum.

3.5.2 The Charpy V-notch impact toughness is the absorbed energy, expressed in joule (J), the symbol being KV. The test results shall be measured to an accuracy of 1 Joule.

3.5.3 The Charpy impact test machine shall be of a type acceptable to the verifier having a gap of 40 mm, a striking velocity between 5 and 5.5 m/sec (see Table 2) and an impact 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. The test arrangement is shown in Figure 5, with the tolerances given in Table 2.

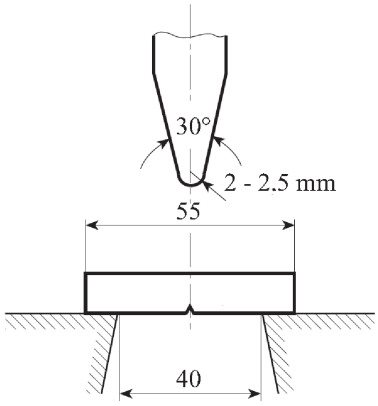


Figure 5 Charpy V-notch impact test setup

Table 2 Characteristic quantities of the testing machine

Dimension	*Requirement*
Clear spacing between supports	$40^{+0.2}_{-0} mm$
Radius of curvature of supports	$1^{+0.5}_{-0} mm$
Undercut of supports	11° ± 1°
Angle of peen wedge	30° ± 1°
Radius of curvature of peen cutter	$2^{+0.5}_{-0} mm$
Maximum thickness of pendulum face	18 mm
Striking velocity of pendulum	5 to 5.5 m/s[1)]
Angle between supports and bearing	90° ± 0.1°
Distance between centre of peen and centre of gap between supports	± 0.5 mm
1) For pendulum impact test machines built before 1983 a value of 4.5 to 7 m/s may be agreed.	

3.5.4 Samples may be flame-cut but the notch shall not to 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 safeguarding that cold working at the base is avoided as far as possible. The cutter shall be systematically checked at intervals not exceeding 100 test specimens.

The notch shall be cut in a face of the impact test specimens which was originally perpendicular to a rolled or forged surface, unless otherwise stated. For placing the notch in the appropriate microstructure, e.g. for qualification of welding procedures, the fusion boundary shall be identified by etching the specimens with a suitable reagent.

3.5.5 Dimensions and tolerances for standard Charpy V-notch test specimens shall be as given in Table 3.

Table 3 Charpy V-notch test specimens

Dimensions	*Nominal*	*Tolerances*
Length	55 mm	± 0.60 mm
- Width of standard test specimen - Width of sub-size test specimen - Width of sub-size test specimen	10 mm 7.5 mm 5 mm	± 0.11 mm ± 0.11 mm ± 0.06 mm
Height	10 mm	± 0.075 mm
Angle of notch	45°	± 2°
Height below notch	8 mm	± 0.075 mm
Root radius	0.25 mm	± 0.025 mm
Distance of notch from ends of test specimen	27.5 mm	± 0.42 mm

Dimensions	*Nominal*	*Tolerances*
Angle between plane of symmetry of notch and longitudinal axis of test specimen	90°	± 2°
Angle between adjacent longitudinal faces of test piece	90°	± 2°

3.5.6 Standard Charpy V-notch test specimens with a width of 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 sub-size test specimens 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. Except as specified for materials for low temperature service, impact tests are not required when the material thickness is less than 6 mm. For materials for low temperature service, the testing and requirements for specimens smaller than 5 mm in size shall be in accordance with recognized standards, e.g. ASTM E23.

3.5.7 The temperature shall be controlled sufficiently to ensure uniformity throughout the cross-section of the test specimen at breaking. Unless otherwise agreed, conditioning and specimen transfer shall comply with ISO 148-1 or an equivalent standard. Test temperature shall be stated in the certificate.

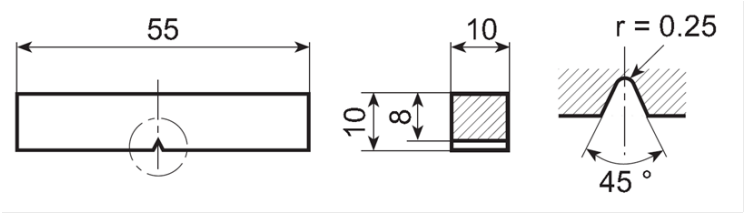


Figure 6 Charpy V-notch test specimen

3.5.8 When required, the crystalline proportion of the fracture surface and the lateral expansion at the point of fracture shall be determined. The crystalline proportion of the fracture surface shall then be estimated and expressed as a percentage of the total area of the fracture. The lateral expansion shall be measured to an accuracy of 0.01 mm on the side opposite the notch, see also ISO 148-1 and ASTM A370.

3.6 Bend testing

3.6.1 Flat bend test specimen as given in Figure 7 shall be used. Edges on tension side to be rounded to a radius of 1 to 2 mm. In addition to the method indicated in Figure 7, the wrap around method is accepted for materials of low strength, e.g. aluminium alloys.

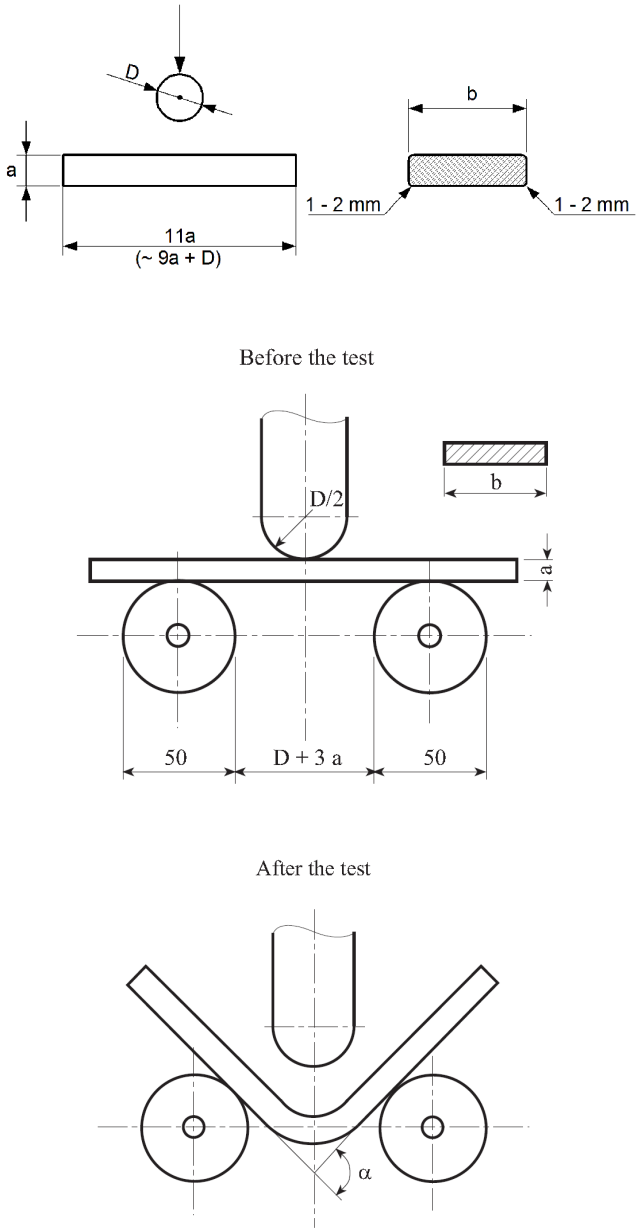


Figure 7 Bend test specimen

3.6.2 For plates, structural sections and sheets, test specimen with the following dimensions shall be used:

a = as rolled thickness of material

b = 30 mm or product width, whichever is smaller.

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

3.6.3 For forgings, castings and semi-finished products the specimen thickness shall be a = 20 mm and the specimen width b = 25 mm.

3.6.4 Face and root bend of butt welded joints. The test specimens shall be prepared perpendicular to the weld, with dimensions as follows:

a = as rolled thickness of the material

b = 30 mm

The weld shall be machined flush with the surface of the plate. If the as rolled thickness is greater than 25 mm, a may be reduced to 25 mm by machining on the compression side of the test specimen. When a longitudinal face-bend or root-bend weld test is required, a test specimen according to an appropriate standard will be accepted.

3.6.5 Side bend of butt welded joints. The test specimens shall be prepared perpendicular to the weld, with dimensions as follows:

a = 10 mm

b = as-rolled thickness of the material.

If the as rolled thickness is greater than 40 mm, the side bend test specimen may be subdivided, each part being at least 20 mm wide.

3.6.6 Unless otherwise detailed in the respective rules or standard, the mandrel diameter shall be 4 × a (four times specimen thickness) for materials with SMYS < 550 MPa and 5 × a for materials with SMYS ≥ 550 MPa.

For materials with specified elongation < 20% the mandrel diameter calculated in accordance with ISO 15614-1 is accepted as an alternative. The bending angle shall be 180°.

3.7 Drop-weight testing

3.7.1 For material with thickness t ≥ 16 mm, drop-weight test specimens for the determination of nil ductility transition temperature shall comply with specifications given in ASTM E208 or equivalent international or national standard and have one of the following sizes:

no.1: 25 by 90 by 360 mm

no.2: 19 by 50 by 130 mm

no.3: 16 by 50 by 130 mm.

The test specimen dimensions shall be based on the largest obtainable thickness. Where a test unit comprises more than one thickness, specimens shall be taken from the thickest product.

The correct specimen thickness shall be achieved by machining the compression side. The long sides of the test specimens shall be made with a saw cut or, in the case of specimens obtained by thermal cutting, shall be machined with a machining allowance of at least 25 mm.

When drop weight test is required for material thicknesses below 16 mm down to and including 12 mm, a test specimen machined down to 12 mm thickness shall be used. For material thicknesses below 12 mm down to and including 10 mm, the thickness of the test specimen shall be that of the material. Other dimensions and requirements for test specimen with thickness below 16 mm shall be as for test specimen no.3 above, except that a stop distance of 2.3 mm shall be used.

3.7.2 The test specimens may be cut with their axes either transverse or longitudinal to the final rolling direction of the material, but the orientation shall be the same for all test specimens.

3.7.3 Two test specimens shall be tested at the prescribed test temperature. Both test specimens shall exhibit a non-break performance, i.e. the nil ductility transition temperature shall be below the test temperature.

3.7.4 The drop-weight test shall be carried out and evaluated in accordance with ASTM E208.

Guidance note:

Note that one of the criteria for the test to be considered valid is that the striking tip of the weight shall strike within 2.5 mm of a line on the compression side of the specimen, normal to a long edge and directly opposite the notch in the crack-starter weld, see ASTM E208.

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

3.8 Ductility tests for pipes, tubes and nuts

3.8.1 Unless otherwise specified in an applicable standard referred in Sec.3, the following apply.

3.8.2 Pipe flattening test

A pipe section with length 1.5 times the pipe diameter, but not less than 10 mm and not more than 100 mm, shall be flattened between two plates to the prescribed distance or until fracture occurs, see Figure 8. In the case of welded pipes, the weld shall be located in the 3 or 9 o'clock position relative to the setup given in Figure 8.

After the test, the specimens shall be thoroughly examined for defects with normal visual acuity. The test shall be satisfactory if the specimen, having been flattened to the prescribed distance, is free from cracks and did not fracture.

The dimensions of the pipe section, the distance H between the flattening plates as well as the position of the welding joint shall be reported. Example of applicable standard is ISO 8492.

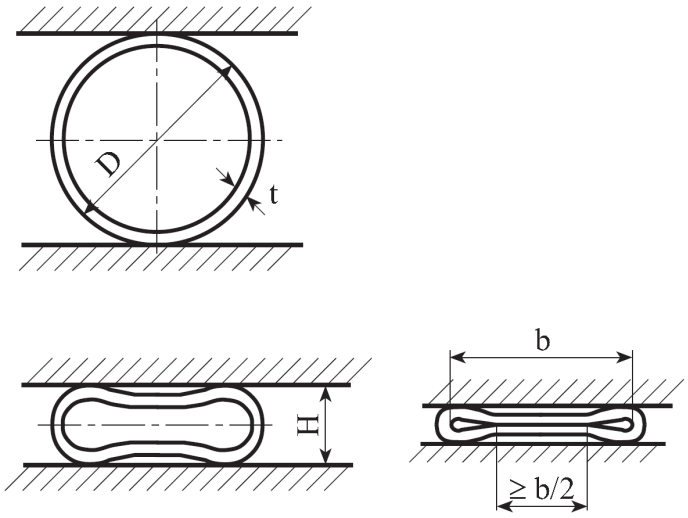


Figure 8 Pipe flattening test

3.8.3 Drift expanding test for pipes and tubes

To perform this test, a tapered drift is forced into the specimen until the outside diameter has increased to the prescribed value C for the product in question, see Figure 9. The length of the specimen and the taper angle β of the drift shall be as shown in Table 4.

The intrusion rate of the taper shall not exceed 50 mm/s. After the test, the specimens shall be thoroughly examined for defects with normal visual acuity. Unless otherwise specified in Sec.3, the test results are satisfactory if the prescribed expansion has been effectuated without cracks.

C = diameter after the prescribed expansion.

The dimensions of the pipe section, the outer diameter C of the expanded part of the pipe section or the relative expansion (%), as well as the taper angle shall be reported. Example of standard to be applied, see ISO 8493.

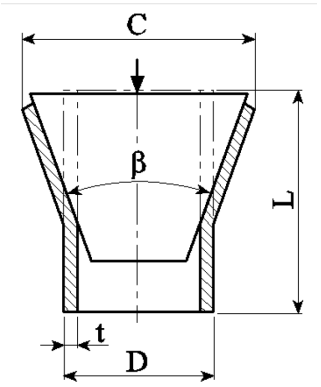


Figure 9 Drift expanding test

Table 4 Drift expanding test specimen dimensions

Material	*Length of specimen, L*	*Taper angle, β*
Steel	≤ 2 D ≤ 1.5 D Min. 50 mm	30° 45°, 60° or 120°
Copper and copper alloys	2 D	45°
Aluminium alloys	≥ 2 D Min. 50 mm	60°

3.8.4 Flanging test for pipes and tubes

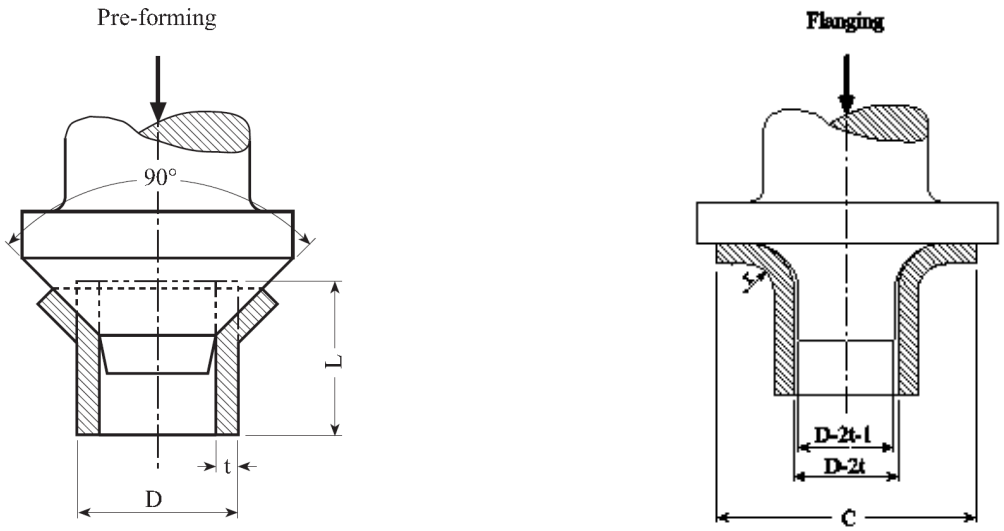
To perform this test, a sample of pipe with a length L = 1.5 D shall be worked into a flange in the device shown in Figure 10 until the outer diameter C of the flange attains the value prescribed for the product. The radius r shall match that prescribed for the product. The intrusion rate of the tool may not exceed 50 mm/ min.

Acceptance criteria: the test results are satisfactory if the flange has no apparent cracks. Minor defects on the edges may be disregarded. The dimensions of the pipe section, the outer diameter C of the expanded part of the pipe section or the relative expansion (%), as well as the edge radius of the forming tool shall be reported.

Guidance note:

Example of standard to be applied: ISO 8494.

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

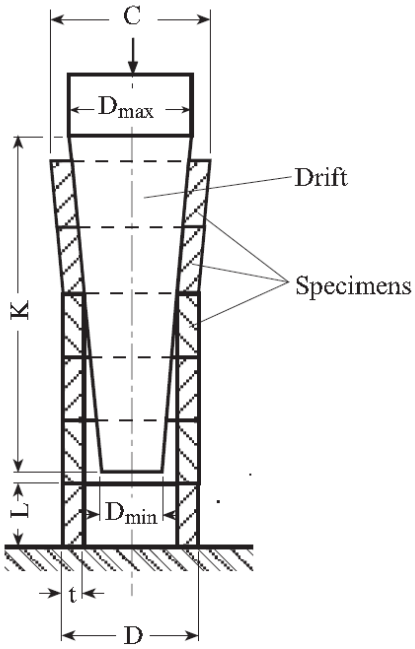


C = diameter after the prescribed expansion

Figure 10 Flanging test

3.8.5 Ring expanding test for pipes and tubes

To perform this test, sections of pipe measuring 10 to 16 mm in length L shall expanded to the prescribed diameter C or until fracture occurs using a drift with a taper of about 1:5. Where necessary, more than one test shall be performed with drifts of increasing diameter. The superimposition of several specimens of the same size and steel grade is permitted, see Figure 10. The intrusion rate of the mandrel shall not exceed 30 mm/s.



$$\frac{D_{max} - D_{min}}{K} = 1:5$$

Figure 11 Ring expanding test

The dimensions of the pipe sections, the outer diameter C of the expanded part of the pipe section or the relative expansion (%), as well as the ratio of the taper (if not 1:5) shall be reported. Example of standard to be applied is ISO 8495.

After the test, the specimens shall be thoroughly examined for defects with normal visual acuity and the ductility of the pipes shall be assessed by reference to the expansion achieved and, where applicable, to the appearance of cracks or fracture.

Acceptance criteria: The test results are satisfactory if the prescribed expansion has been reached without fracture and the specimen reveals no unacceptable defects such as scabs, laps, cracks, grooves or laminations.

3.8.6 Expansion test for nuts

A mandrel with a 1:100 taper shall be used, see Figure 11. Before testing, the nuts shall be drilled out to the thread outside diameter. Alternatively, testing in accordance with the referred standard is accepted, see Sec.4 [5.2].

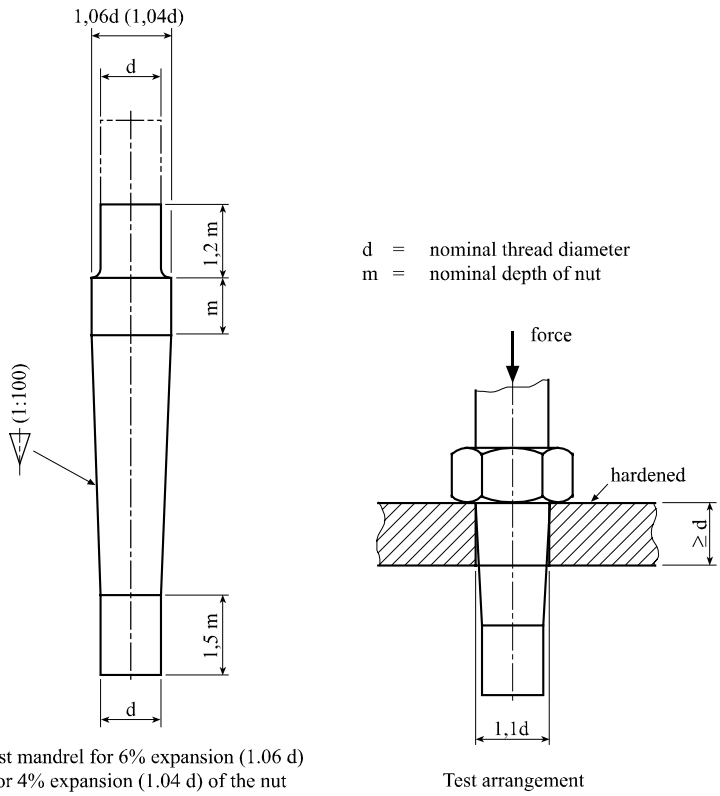


Figure 12 Expansion testing of nuts

3.8.7 Ring tensile test for pipes and tubes

The sections of pipe measuring about 15 mm in length shall have plane and smoothed ends and shall be at right angle to the pipe axis. To perform this test, the pipe sections are stretched in a tensile testing machine until fracture occur using two pins with a diameter equal to at least three times the wall thickness of the pipe, see Figure 13. In the case of welded pipes, the specimen shall be placed in the tensile testing device in such a way that the welded seam lies at 90° to the direction of the tensile load. The rate of the pins may not exceed 5 mm/s.

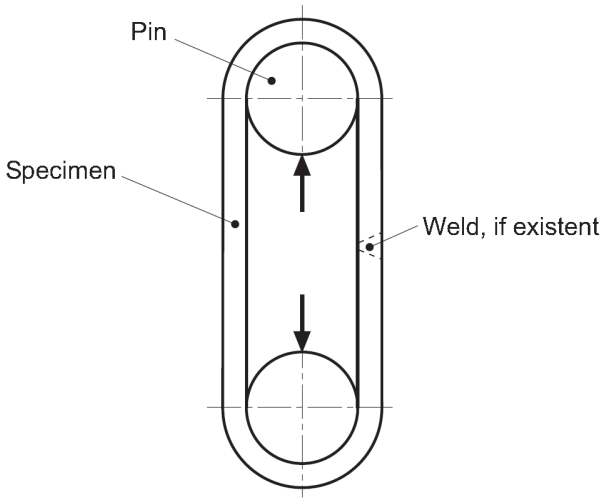


Figure 13 Ring tensile test

After the test, the specimens shall be thoroughly examined for defects with normal visual acuity. Acceptance criteria: the test is considered satisfactory if visible deformation has occurred at the point of fracture and if the specimen reveals no unacceptable defects such as scabs, laps, cracks, grooves or laminations. The dimensions of the pipe sections shall be reported. Example of standard to be applied, see ISO 8496.

3.9 Hardness test

3.9.1 Where hardness test is required, the tests shall be performed in accordance with a recognized standard, e.g. for brinell, vickers or rockwell hardness:

— ISO 6506 Brinell hardness test
— ISO 6507 Vickers hardness test
— ISO 6508 Rockwell hardness test.

3.9.2 Hardness test is in principle not considered to be a substitute for tensile test.

3.10 Determination of grain size

3.10.1 Where the austenitic grain size is specified, it shall be determined according to methods described in recognized 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.

3.11 Strain age test

3.11.1 The material shall first be strained using either an oversized tensile test specimen, or by the straining method applied in production, e.g. cold bending to representative bending angle or cold rolling to representative extent. Other methods may be accepted case by case.

3.11.2 The straining shall be carried out to a deformation rate corresponding to maximum deformation in production. Formulas for calculation of deformation are given in DNVGL-OS-C401 Ch.2 Sec.6. Unless otherwise agreed, the straining direction for simulated cold forming shall be parallel to the main rolling

direction, except for extra high strength steel where transverse tests are required, and specimen orientation shall be as specified for the original plate, see Sec.2.

3.11.3 The strained material shall then be aged in furnace at a specified temperature for a given time. Unless otherwise specified or agreed, the ageing shall be carried out at 250°C for one hour.

3.11.4 Unless otherwise agreed, the impact test specimens shall be located as close as possible to the surface. For bends, the test specimens shall be as close as possible to the outer radius of the bend (the extrados surface). The notch shall be in the through thickness direction.

3.11.5 The strain-aged material shall be impact tested and satisfy the requirements given for the base material.

3.11.6 Where specified or agreed, the material shall be tensile tested and the elongation shall satisfy a requirement which has been agreed with consideration of the relevant construction standards.

3.12 Fracture mechanics testing

3.12.1 When specified, fracture mechanics (FM) testing of materials and weldments shall be performed. The tests shall be carried out according to ISO 12135 (for base material) and ISO 15653 (for welded joints) using 3-point bend specimens (SENB), or another recognized standard as agreed with the verifier. Both B x 2B and B x B specimens may be used, although B × 2B specimens are recommended. The test is deemed to be valid provided post-test-data analysis meets all validity criteria of the standard. For further requirements concerning test equipment, fatigue (pre)cracking, test performance, evaluation and validity see ISO 12135.

The specimen width B shall be the full plate thickness unless otherwise agreed with the verifier or specified in an agreed/referred specification, i.e. when machining the specimens the width B shall be at least B_{min} = 0.9 t (where t = plate thickness).

The orientation of the specimen shall be perpendicular to the rolling direction, i.e. the notch is oriented parallel to the rolling direction. The notch shall be machined in through thickness direction of the plate. If test temperature is not otherwise specified, it shall be -10°C.

3.12.2 The test may be required for the base material or for a welded connection. For base metal at least three valid CTOD tests shall be obtained. For welded plates for each required crack tip position at least three valid CTOD tests shall be obtained. Unless otherwise specified in the referring standard, the acceptance criteria are given in DNVGL-OS-C401.

The test results report shall contain the information as given in ISO 12135 (paragraph 8 test report) and in ISO 15653 (paragraph 13 test report), the force (F) - notch opening displacement (V) records and photographs for the fractured surfaces on which the crack lengths are measured.

3.12.3 For welded connections, the test weld shall be made and tested for the actual combination of steel grade, manufacturer (steelmill), welding process and welding consumable (brand) used.

3.12.4 Requirements for FM testing of welds

The FM tests shall be carried out on a full penetration butt-weld with K- or single V-bevel preparation (single V-bevel with one edge with a given angle to the surface, the other edge perpendicular to the surface). The notch of the FM test specimen shall be perpendicular to the plate surface. Tests on either of these weld bevel preparations qualify for all types of bevels.

Depending on the requirements, the crack tip shall be positioned either in the weld metal (weld positional, WP), or in the specified microstructure (SM). The specified microstructure is the grain coarsened heat affected zone (GCHAZ) unless otherwise agreed. For SM specimens, the crack tip shall be located at the back

of the K or at the perpendicular side of the V. The fusion boundary shall be identified, e.g. by etching with a suitable reagent.

3.12.5 Unless otherwise detailed in the respective rules, the following apply:

— test weld shall be welded with a heat input representing the maximum heat input used in the fabrication
— test on a plate with thickness t qualifies the thickness range 0.5t to 1.1t.

3.12.6 On each test weld at least three FM test specimens shall be tested.

3.12.7 Metallographic sections to be tested according to ISO 15653 shall be prepared from each GCHAZ specimen. The metallographic section shall include weld metal and base metal. If necessary, in order to determine the exact location of the fatigue pre-crack, sections from both sides of the pre-crack shall be prepared. The faces of the metallographic sections shall not be taken deeper than the deepest point of the fatigue pre-crack and not more than 3 mm from the deepest point of the fatigue pre-crack. Figure 14 shows a cross-section through the weld of an un-fractured specimen.

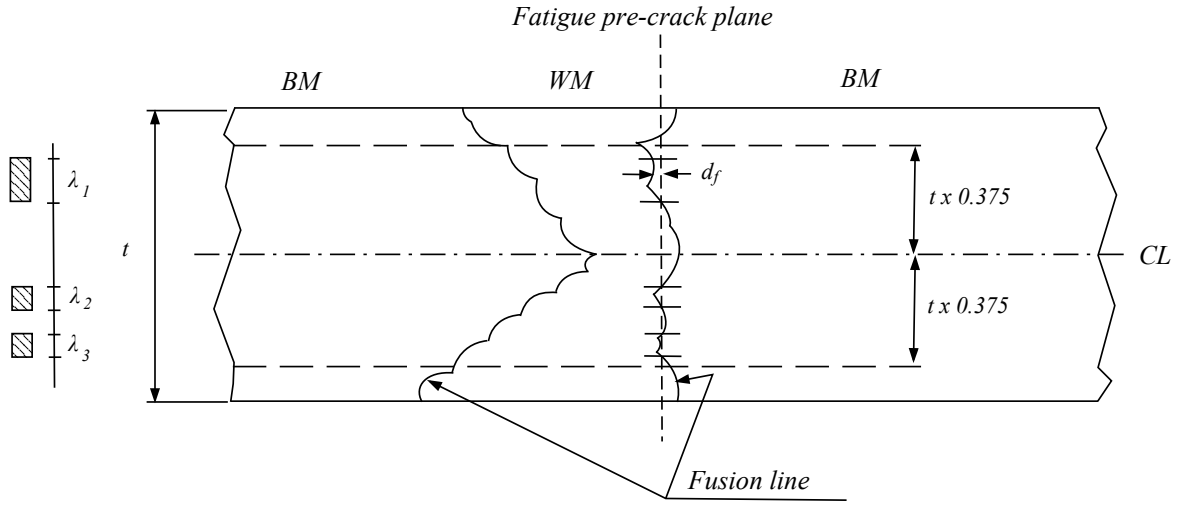


Figure 14 Cross-section through the weld

BM = base material
WM = weld metal or deposit
d_f = distance from the plane of the fatigue pre-crack to the fusion line (varies along the fatigue pre-crack)
λ_I = length (in mm) of each area with acceptable location of the fatigue pre-crack (given as SM (λ) = specified microstructure in ISO 15653)
t = plate thickness.

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

$\sum_{i=1}^{N} \lambda_i$ = ≥ 3 mm for t ≤ 20 mm
≥ 0.15 t for 20 < t ≤ 80 mm
≥ 12 mm for t > 80 mm

N = number of areas with $d_f \leq 0.5$ mm.

3.12.8 If the location of the fatigue pre-crack of the GCHAZ does not satisfy the specified requirement, the results from the testing are not valid. ISO 15653 shall be complied with for both GCHAZ (in addition to above requirements) and weld deposit specimens. Unless otherwise specified in the respective rules, three or more valid tests for each of weld deposit and GCHAZ shall be carried out.

SECTION 2 ROLLED STEEL FOR STRUCTURAL APPLICATION

1 General

1.1 Scope

1.1.1 This section specifies the general requirements for hot rolled steel products, i.e. plates/sheets, wide flats, strips, structural sections, structural hollow sections including structural pipes and bars, see Figure 1, for use in the construction of hulls and other marine structures.

For limitations to fabrication of welded hollow sections by hot or cold forming, see also DNVGL-OS-C401 Ch.2 Sec.6. Requirements for hot rolled round steel bars for non-structural application, e.g. intended for shafts, tie rods and bolts are given in Sec.3.

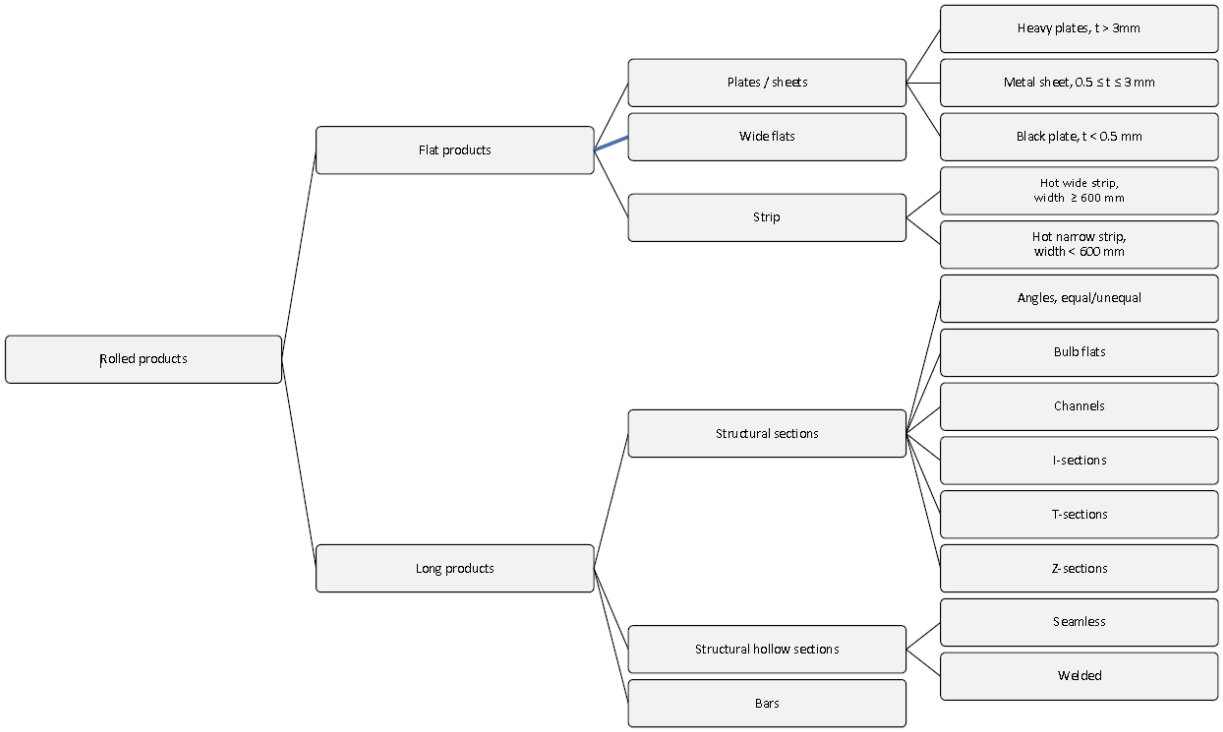


Figure 1 Overview of typical hot rolled steel products

1.1.2 For normal and high strength steels, the requirements apply to plates and wide flats not exceeding 150 mm in thickness and sections and bars not exceeding 50 mm in thickness, unless otherwise agreed. For greater thicknesses, variations in the requirements may be permitted for particular applications, i.e. based on case by case agreement.

For extra high strength steels, the requirements apply to plates, wide flats and bars not exceeding 250 mm in thickness, tubulars not exceeding 65 mm in thickness and sections not exceeding 50 mm in thickness, unless otherwise agreed.

For greater thicknesses, variations in the requirements may be permitted for particular applications, i.e. based on case by case agreement.

1.1.3 Austenitic and duplex (ferritic/austenitic) steels for structural application shall, unless otherwise agreed, follow the requirements of DNVGL-RU-SHIP Pt.2 Ch.2 Sec.3.

1.1.4 Steels differing from the specific requirements given in this section e.g. with respect to chemical composition, deoxidation practice, conditions of supply or mechanical properties may be accepted, subject to special agreement. Such steels shall have the letter S appended to the corresponding VL grade, e.g. VL A36S.

1.1.5 Subject to agreement and as an alternative to [1.1.4], materials which comply with other standards or proprietary specifications may be considered for acceptance provided such specifications give reasonable equivalence to the requirements of this section, or are agreed case by case for a specific application, see Sec.1 [2.5].

1.2 Grading system

1.2.1 The steels are classified by strength into three groups:

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

Each strength group is further subdivided into grades, as given in [2] to [5].

1.2.2 Supplementary requirements are given as follows:

— Z-grade steels (grades with specified through thickness properties), see [5].

For the steels intended for high heat input welding over 50 kJ/cm, the qualification of the manufacturer shall follow an agreed qualification scheme. The material designation will typically be indicated by using a high heat input welding notation, e.g. D32-W200, indicating a steel grade D32 qualified for welding by heat input ≤ 200 kJ/cm.

1.2.3 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 not more than 500 MPa.

1.2.4 The alphanumeric designation of the steel grade is:

— VL xyd for steels of normal weldability
— VL xWyd for steels of improved weldability
— VL xOyd for specific offshore grade extra high strength steels (with designation O), these are steels where the requirement for yield and tensile strength are independent of the product thickness.

VL = designation of a steel grade according to the DNV GL rules and 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

O = letter included to designate a specific offshore grade steel where the requirements for yield and tensile strength are independent of the product thickness

y = a figure designating the strength group according to the specified minimum yield stress. The figure y is omitted for NS steels.

d = capital letters to give the delivery condition, e.g. N, NR, TM, QT. Optional for steels of normal and high strength, mandatory for steels of extra high strength.

Guidance note:

Examples:

— VL D460TM, steel grade according to DNVGL-OS-B101 (VL), qualified for impact toughness at -20°C (D), with minimum specified yield stress 460 MPa for thickness ≤ 50 mm (460) and with delivery condition thermo-mechanical rolling (TM).

— VL DW460TM, same as above, for steel grade of improved weldability (W).

— VL DO460TM, same as first example, but offshore grade with same requirement for mechanical properties irrespective of product thickness (O).

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

1.2.5 Additional symbols following the alphanumeric designation given in [1.2.4] 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.

COD = steel grade where crack initiation resistance has been qualified by the manufacturer.

Table 1 Definitions of steel grades

Strength group	*Impact testing*				*Tensile properties*	
	Symbol x			*Test temperature °C*	*Symbol y*	*Minimum yield stress[1)2)] MPa*
	Normal weldability	*Improved weldability*	*Offshore grades*			
NS	A	-	-	-	Omitted	235
	B[3)]	BW		0		
	D	DW		–20		
	E	EW		–40		
HS	A	AW	-	0	27	265
	D	DW		–20	32	315
	E	EW		–40	36	355
	F	-		–60	40	390
EHS					420	420
					460	460
	A	-	AO	0	500	500
	D	DW	DO	–20	550	550
	E	EW	EO	–40	620	620
	F	-	FO	–60	690	690
					890	890
					960	960

1) for extra high strength steels of normal and improved weldability the indicated minimum yield stress is reduced for increasing product thickness. The indicated minimum yield stress is applicable for thickness up to 50 mm

2) for offshore grade steels, the indicated minimum yield stress is independent of the product thickness

3) Charpy V-notch tests are not required for grade B with thickness of 25 mm or less.

1.3 Manufacture

1.3.1 Steel shall be manufactured by an electric or one of the basic oxygen processes or any other process involving secondary refining accepted by the accepted by the verifier.

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. Unless otherwise agreed, the reduction ratio shall be at least 3 to 1. For slab to plate, reduction ratio applies for the thickness reduction. For other products, the reduction ratio requirement applies for the cross section reduction.

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 and where relevant, qualified or agreed processes are implemented and adhered to 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 along with additional information as the verifier may require shall be made available to the verifier on request. The frequency and extent of testing for subsequent products is at the discretion of the verifier.

1.4 Chemical composition

1.4.1 The chemical composition of each cast shall be determined on a sample taken preferably during the pouring of the cast and shall be within the specified limits in [2] to [5]. When multiple casts 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 in accordance with a qualified and agreed specification.

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 The manufacturer shall adopt adequate control in order to prevent accumulation of harmful elements in the product, e.g. tin, antimony and arsenic. This is particularly relevant for steelmaking where recycled scrap is used as raw material and where the ore may contain high levels of harmful elements.

1.4.5 When required, the carbon equivalent value (C_{eq}, P_{cm} or CET) shall be calculated using the formulas given in Sec.1.

1.4.6 The requirements for elements designated as fine grain elements (Al, Nb, V and Ti) are given in each subsection [2] to [5]. When two or more fine grain elements are used in combination, the minimum limit of each element of the applied combination is given as follows: Al: 0.015%, Nb: 0.010%, V: 0.030%, Ti: 0.007%, unless otherwise qualified. Each combination of fine grain elements is subject to qualification through the qualification of the manufacturer. The applicable combination of fine grain elements shall, unless otherwise agreed, follow the minimum and maximum limits given here and in subsections [2] to [5].

1.4.7 The manufacturer's declared analysis will be accepted subject to random checks on request by the verifier.

1.5 Condition of supply and heat treatment

1.5.1 Conditions of supply shall be in accordance with requirements given in [2] to [5] 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) steel refers to steel which is rolled without specific heat treatment and followed by cooling on air. The rolling finishing temperature and reduction are typically in the austenite recrystallization region and above the normalising temperature, but may not be accurately controlled resulting in variable grain sizes and, hence, variable mechanical properties.

1.5.3 Normalising rolling (NR), (or controlled rolling (CR)), is a rolling procedure where the final rolling temperature is controlled within the same temperature range as for conventional furnace normalizing. Normalizing rolling is typically followed by air cooling. The primary grain control and refining mechanism is the recrystallization of austenite following each rolling pass in the normalizing temperature range. The microstructure, grain size and mechanical properties are similar to those obtained by furnace normalizing.

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 (AcC) are controlled. It is characterized by high deformation ratios per rolling pass in the austenite non-recrystallization range close to the Ar3 temperature. It may also involve rolling in the austenite-ferrite dual phase temperature region below Ar3. After the final pass, either air cooling or accelerated cooling, excluding quenching, is used.

The primary grain size and microstructural control is the fine grained structure obtained when the highly deformed austenite is transformed into typically ferrite, pearlite, bainite, etc. during cooling.

Unlike steel produced by NR, the steel properties conferred by TM cannot be reproduced by subsequent furnace normalising.

Guidance note:

Where an NR (CR) process is followed by accelerated cooling (NR + AcC) the process will usually considered to be TM. However, where it is proven that the steel properties are reproduced by a subsequent furnace normalizing, it may be considered to be an NR process. This consideration will typically be done during the qualification of manufacturer process.

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1.5.5 Normalising (N) is a separate heat treatment after rolling involving heating above the critical temperature, Ac3, and in the lower end of the austenite recrystallization region for a specific period of time (austenitising), followed by air cooling, to produce a homogeneous, fine grained ferrite-pearlite microstructure.

1.5.6 Quenching and tempering

Quenching (Q) is a heat treatment process in which the steel is heated to an appropriate temperature above Ac3, held for a specific period of time, and followed by cooling at a rate sufficient for the formation of typically a martensite or bainite microstructure. Quenched steels are typically hard and brittle. Tempering (T) subsequent to quenching is reheating of the steel to a temperature below Ac1, and maintaining at that temperature for a specific period of time. Tempering improves the ductility and toughness of quenched materials through microstructural changes, but reduces the hardness and strength. Furthermore, the quenching process results in material residual stress which is to some extent released/reduced by the subsequent tempering.

The result of quenching followed by tempering is typically steels combining high strength with good toughness.

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

1.5.8 For normalizing and for quenching and tempering, the furnace temperature uniformity shall be calibrated at regular intervals and provided to the verifier on request.

1.5.9 Other delivery conditions than those listed above may be accepted based on special evaluation and acceptance. Extended qualification of manufacturer process will be considered for each relevant case.

1.6 Test material and test specimens for mechanical testing

1.6.1 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 specimens shall not be separately heat-treated in any way.

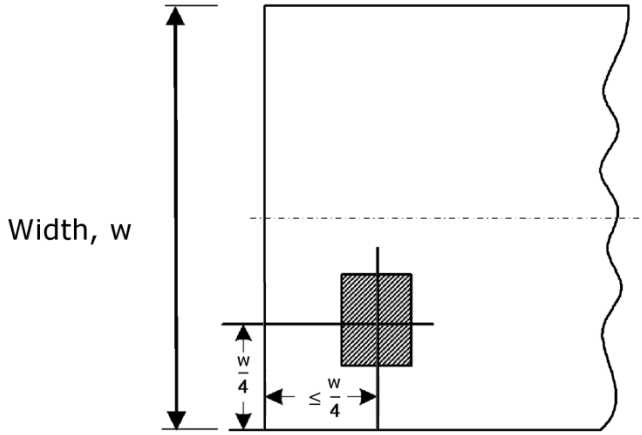
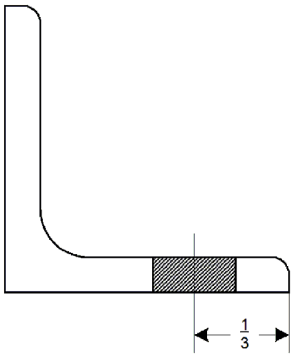
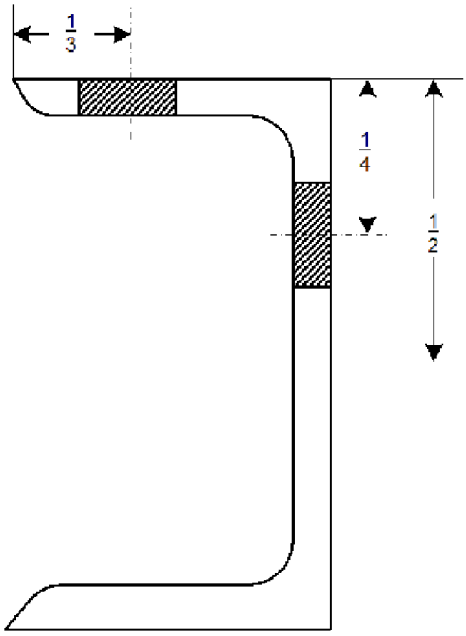
1.6.2 The size, thickness location and preparation of test specimens and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.1. See also [1.6.7].

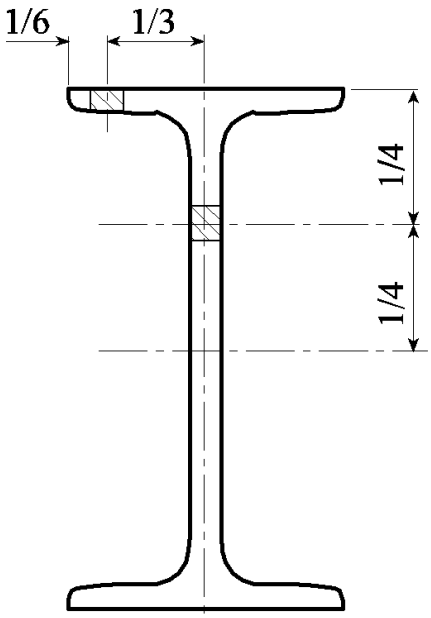
1.6.3 Test material shall be suitably marked to identify them with the products represented.

1.6.4 Test material shall be taken from the following positions:

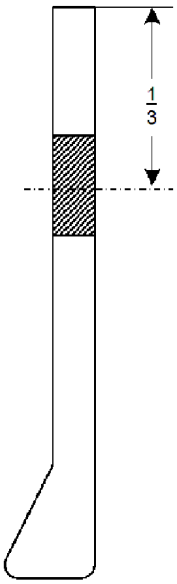
- plates and wide flats with a width ≥ 600 mm: the test material shall be taken at the square cut end of the piece approximately one-quarter width from a long edge and unless otherwise agreed, equal to or less than one-quarter width from a short edge, see Table 2
- flats with a width < 600 mm, channels, beams, bulb flats and other sections: the test material shall be taken at approximately 1/3 of the width from an edge, see Table 2. Where indicated, the test samples may alternatively be taken from a position approximately 1/4 of the width from the web centre line or axis
- 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 Table 2.

Table 2 Position of test material

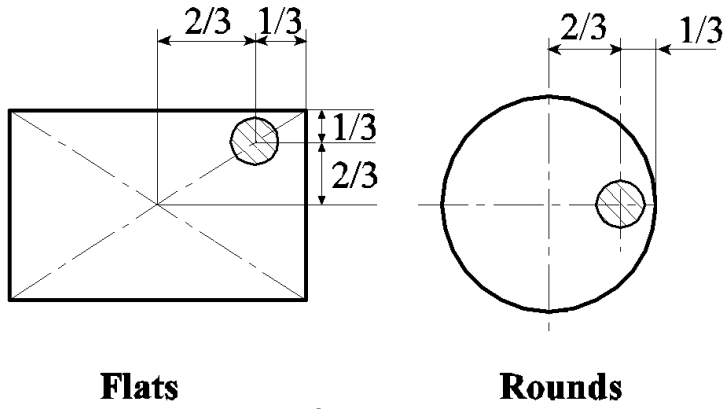
	
Plates and flats	Angles
	
Unequal angles	Channels and beams



Sections (joists)



Bulb flats



Flats and rounds (bars)

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

— longitudinal: longitudinal axis of test specimen parallel to the principal direction of rolling
— transverse: longitudinal axis of test specimen perpendicular to the principal direction of rolling.

1.6.6 Unless otherwise agreed, the test specimens shall be oriented as follows:

1) Plates and wide flats with a width ≥ 600 mm:
   — tensile test specimens shall be transverse

— impact test specimens shall be longitudinal, except that for extra high strength steel, transverse tests are required.

2) Flats with a width < 600 mm, bulb flats, sections, seamless hollow sections, bars and other similar products:
   — tensile and impact test specimens shall be longitudinal.
3) Welded hollow sections:
   — rectangular and square sections with circumference ≥ 600 mm:
      — tensile test specimen shall be transverse
      — impact test specimens shall be longitudinal.
   — circular sections and rectangular/square sections with circumference < 600 mm:
      — tensile test and impact test shall be longitudinal.

1.6.7 The size, thickness location and preparation of test specimens, and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.1 [3].

For impact testing, the following additional/specific requirements for sampling apply:

— for thickness up to 40 mm: test specimens shall be cut from a position within 2 mm of a rolled surface
— for thickness more than 40 mm: the axes of the test specimens shall be at one quarter of the thickness from a rolled surface
— for extra high strength steels with thickness more than 50 mm: additional impact test specimens shall be sampled at mid-thickness (t/2) of the product.

For tensile testing, the following additional/specific requirements for sampling apply:

— for t > 40 mm, round tensile test specimens from t/4 are accepted
— for extra high strength steels with thickness t > 100 mm, sampling is required at t/4 and t/2.

1.7 Test units and number of tests

1.7.1 Depending on product and grade, provision is made in [2] to [5] for testing of individual pieces or for batch testing. Where batch testing is permitted, a test unit shall consist of materials of the same product form, from the same cast, in the same condition of supply and with a total mass not exceeding limits given in [2] to [5].

1.7.2 For testing of individual pieces a piece shall be regarded as the rolled product from a single slab, billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.

1.7.3 Except as required in [1.7.4], one set of mechanical tests is required for each test unit. A set of tests shall consist of one tensile test specimen and, when required, three Charpy V-notch test specimens. See also [5] for testing of through thickness properties.

1.7.4 Additional sets of tests shall be made for every variation of 10 mm in the thickness or diameter of products from the same test unit.

1.8 Mechanical properties

1.8.1 The material shall meet the mechanical properties specified in [2] to [5].

1.8.2 If the results do not meet the specified requirements, the re-test procedures in Sec.1 may be adopted. Where the products are submitted to heat treatment or re-heat treatment, all the tests previously performed

shall be repeated and the results shall meet the specified requirements. For re-heat treatment, the products shall not be re-austenitized more than two times, unless otherwise agreed.

1.9 Inspection and tolerances

1.9.1 Surface inspection and verification of dimensions including shape and straightness are the responsibility of the manufacturer. Acceptance by the verifier of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.9.2 Products shall have a workmanlike finish consistent with the method of manufacture and shall be free from internal and surface defects prejudicial to the use of the material for the intended application. Cracks, injurious surface flaws, shells (over lapping material with non-metallic inclusion), sand patches, scabs, blisters, laminations and sharp edged seams (elongated defects) visually evident on surface and/or edge of plate are not accepted and require rejection or repair, irrespective of their size and number. Acceptance criteria for other imperfections such as pitting, rolled-in scale, indentations, and roll marks, scratches and grooves, which may occur under normal manufacturing conditions, shall be EN 10163-2 class A for plates/ wide flats, and minimum EN10163-3 class C for sections. A precondition is that the remaining thickness under the imperfections remains within the thickness tolerances for the product. Other recognized standards may be accepted by the verifier, provided equivalent or higher requirements are met. Total affected area with imperfection not exceeding the specified limits are not to exceed 15% of the total surface in question. For repair of defects, see [1.10].

If plates and wide flats are ordered with ultrasonic inspection, this shall be made in accordance with an accepted standard at the discretion of the verifier. Verification of internal soundness is the responsibility of the manufacturer. The acceptance of internal soundness by the verifier shall not absolve the manufacturer from this responsibility.

1.9.3 The responsibility for meeting the surface finish requirements rests with the manufacturer of the material, who is to take the necessary manufacturing precautions and is to inspect the products prior to delivery. At that stage, however, rolling or heat treatment scale may conceal surface discontinuities and defects. If, during the subsequent descaling or working operations, the material is found to be defective, the verifier may require materials to be repaired or rejected.

The surface quality inspection method shall be in accordance with recognized national or international standards agreed between purchaser and the manufacturer, accepted by the verifier.

If agreed by the manufacturer and purchaser, steel may be ordered with improved surface finish over and above these requirements.

Guidance note:

Cosmetic appearance is not considered. Purchaser should specify additional requirements to the surface quality where this is critical for the intended application.

Internal defects, e.g. inclusions/sand patches (see EN10163-1) making the steel prone to lamination, may to some extent be considered consistent with method of manufacture, unless Z-grade steels is specified, see subsection [5]. Purchasers should specify additional requirements to the internal quality (non-destructive test, e.g. ultrasonic testing) where this is critical for the intended application.

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1.9.4 For plates and wide flats, the minus tolerance on 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.

1.9.5 For sections, including tubulars, and bars, the surface quality and condition requirements, as well as the dimensional tolerances, shall comply with the requirements of a recognised standard or manufacturers' conformance standards, upon agreement with verifier.

1.9.6 The thickness of plates and wide flats shall be measured at locations whose distance from a longitudinal or transverse edge of the piece (see [1.7.2]) 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 pieces 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 based on sound statistical analyses.

1.9.7 The average thickness of plate and wide flat product or products shall be equal to or greater than nominal thickness.

Guidance note:

This requirement does not necessarily imply that the average thickness of each single plate shall be equal to or greater than nominal thickness. It may also be complied with when the average thickness of products produced e.g. within a certain time period, or for a given order or similar, meet this requirement.

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1.9.8 The manufacturer shall maintain records of inspections and dimensional measurements, and document compliance with the requirements. The records shall be presented to the verifier on request.

1.9.9 The seams of welded hollow sections shall be subjected to automated non-destructive testing over their entire length, unless otherwise agreed. Test standards and acceptance criteria are given in Table 3.

Table 3 Standards and acceptance criteria for automated NDT

NDT method	*Reference standard (acceptance criteria)*	*Comment*
ET	ISO 10893-2 (E4)	the technique of rotating pipes or with rotating saddle coils is not permitted
MT	ISO 10893-3 (F5)	-
UT	ISO 10893-11 (U5)	-
RT (analogue)	ISO 10893-6 (as specified therein)	-
RT (digital)	ISO 10893-7 (as specified therein)	-

Butt welds serving to connect strip or plate lengths by spiral submerged-arc welding shall be examined over their entire length according to the same test procedure and shall satisfy the same acceptance criteria as the main weld seam.

1.10 Repair

1.10.1 Surface defects may be removed by localized grinding provided that the remaining thickness is within the under thickness tolerances of the plates in question. Where necessary, the entire surface may be ground to a depth as given by the under thickness tolerances of the product.

1.10.2 Local grinding repairs where the remaining thickness of the repaired area is less than that given by the under thickness tolerance, are accepted 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 m^2

- 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
- ground areas lying opposite each other on both surfaces shall not decrease the product thickness by more than 7% or 3 mm, whichever is the less
- complete elimination of the defects shall be verified by NDT.

1.10.3 Surface defects which cannot be dealt with as in [1.10.1] or [1.10.2] may be repaired by chipping or grinding followed by welding, subject to the verifier's consent and under his supervision, provided that all of the following is complied with:

- after removal of defects and before welding, the thickness of the product is not to be reduced by more than 20% of the nominal thickness. For occasional defects with depths exceeding the 20% limit, special consideration by the verifier is necessary
- for repair of defects such as unacceptable imperfections, cracks, shells or seams, complete removal of the defect shall be confirmed by suitable MT or PT before welding
- welding is carried out by qualified and certified welders using qualified and accepted procedures with low hydrogen welding consumable for the appropriate steel grade
- the welding procedure is qualified using the requirements for butt welds according to DNVGL-OS-C401
- each single welded area does not exceed 0.125 m^2
- the total area of welded areas 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
- the repair shall be carried out by qualified welders using an approved procedure for the appropriate steel grade. The electrodes shall be of low hydrogen type and shall be dried in accordance with the electrode manufacturer's requirements and protected against rehumidification before and during welding.
- when deemed necessary, the repaired product is normalised or otherwise suitably post-weld heat treated
- the weld repairs are subjected to suitable non-destructive testingsuch as magnetic particle or by liquid penetrant testing
- if weld repair depth exceeds 3 mm, UT may be requested by the verifier. If required, UT shall be carried out in accordance with an approved procedure
- wherever possible, products which will be supplied in the normalized or quenched and tempered condition shall be repair welded prior to the heat treatment.

1.10.4 Products with delivery condition NR or TM shall, where appropriate further processing cannot be ensured, receive a stress-relieve heat treatment after welding according to the manufacturer's recommendation.

1.10.5 For every repair weld, the manufacturer shall prepare a report containing details of the size and location of the defects, the welding repair procedure and any heat treatment applied. The manufacturer shall present this report to the verifier. The verifier may require the repaired product to be presented for survey.

1.11 Identification

1.11.1 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 [5], the grade shall include the suffix Z25 or Z35, e.g. VL E36Z25

— a suffix indicating the delivery condition (N, NR, TM+AcC, TM+DQ or QT) shall be added for all extra high strength steels, e.g. VL 420TM
— 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.

Durable marking for unique identification and traceability of the product is required.

Guidance note:

Hard stamping is normally to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching may be used. Other marking systems giving durable identification and traceability may as well be accepted. Thin plates, stainless steel and non-ferrous plates are normally not marked by hard stamping but rather by paint or similar systems.

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1.11.2 The particulars in [1.11.1], but excluding the manufacturer's name or trade mark where this is embossed on finished products, shall be encircled with paint or otherwise marked to be easily recognisable.

1.11.3 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.

1.11.4 Where individually tested rolled lengths of plates (test piece/parent plate) are cut to more than one plate, each plate shall be marked in a manner identifying its relationship to the original length.

1.12 Certification

1.12.1 The manufacturer shall provide the type of inspection certificate required in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201) 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, cast identification and chemical composition
— condition of supply
— for QT steels; tempering temperature or recommended post-weld heat treatment temperature
— state if rimming steel has been supplied for grade A sections (applicable for max. thickness 12.5 mm)
— 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.

Additionally, for extra high strength steels the following shall be given:

— C_{eq}, CET or P_{cm} value
— surface quality and inspection results.

1.12.2 The manufacturer shall in writing confirm compliance with the requirements of the standard. Pending final certification, this applies for the shipping statement. The following form of declaration will be accepted if stamped or printed on each inspection certificate or shipping statement with the name of the manufacturer and signed by an authorized representative of the manufacturer:

We hereby certify that the material has been made by a qualified process and has been satisfactorily tested in accordance with DNVGL-OS-B101.

1.12.3 When products for certification are made from semi-finished products delivered by a sub-supplier, a certificate shall be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition.

2 Normal strength steel

2.1 Scope

These requirements are supplementary to [1] and apply to normal strength steel. Provision is made for four grades with specified minimum yield strength of 235 MPa and based on the specified impact toughness.

2.2 Chemical composition

The chemical composition and deoxidation practice shall comply with the limits given in Table 4 and Table 5. When fine grain practice is applied, the requirements of Table 9 for Al, Nb, V and Ti apply.

Table 4 Chemical composition limits[1)2)] and deoxidation practice for normal strength steel

Grade	*C*[3)]	*Si*	*Mn*[3)]	*P*	*S*	*Al*	*Deoxidation practice*
VL A	0.21[4)]	0.50	Min. 2.5 × C	0.035	0.035	-	For t ≤ 50 mm: any method except rimmed steel[5)]
							For t > 50 mm: killed steel
VL B	0.21	0.35	Min. 0.80[6)]	0.035	0.035	-	For t ≤ 50 mm: any method except rimmed steel
							For t > 50 mm: killed steel
VL D	0.21	0.10-0.35	Min. 0.60	0.035	0.035	-	For t ≤ 25 mm: killed steel
						Min. 0.020[7)]	For t > 25 mm: killed and fine grain treated steel
VL E	0.18	0.10-0.35	Min. 0.70	0.035	0.035	Min. 0.020[7)]	killed and fine grain treated

1) given value is maximum content (by weight) unless shown as a range or as a minimum

2) unless otherwise agreed, the following additional limits apply:
   - Cu Max. 0.35%
   - Cr Max. 0.20%
   - Ni Max. 0.40%
   - Mo Max. 0.08%

3) C + 1/6 Mn shall not exceed 0.40%

4) maximum 0.23% for sections

5) rimmed steel may be accepted for sections up to 12.5 mm thickness subject to special agreement

6) minimum 0.60% when the steel is impact tested

7) total content. Acid soluble content, if determined instead, shall be minimum 0.015%.

Table 5 Requirements for normal strength steel of improved weldability[1)]

Grade	*VL BW*	*VL DW*	*VL EW*
Deoxidation	*Killed and fine grain treated*		
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[5)]	0.0005		
P_{cm}	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, A_5 (%)	22 minimum		
Impact test, Charpy V-notch			
Test temperature (°C)	0	-20	-40
Minimum average energy (J)			
Transverse[6)]	40		
Minimum single value (J)			
Transverse[6)]	28		

Grade	*VL BW*	*VL DW*	*VL EW*
Deoxidation	*Killed and fine grain treated*		
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 cast, 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) this requirement is applicable to longitudinal test specimens for sections, bars and flats of width less than 600 mm, see [1.6.6].

2.3 Condition of supply and heat treatment

The condition of supply shall comply with the requirements given in Table 6.

Table 6 Conditions of supply for normal strength steel

Grade	*Thickness, t (mm)*	*Plates*	*Sections*
VL A, VL B	t ≤ 50	AR, NR, N, TM	AR, NR, N, TM
	50 < t ≤ 150	AR[1)], NR, N, TM	AR[1)], NR, N, TM
VL D	t ≤ 35	AR, NR, N, TM	AR, NR, N, TM
	35 < t ≤ 150	NR, N, TM	AR[1)], NR, N, TM
VL E	t ≤ 150	N, TM	AR[1)], NR[1)], N, TM

1) products may be supplied in this condition when especially agreed, e.g. through the manufacturer qualification.

2.4 Mechanical properties

2.4.1 The mechanical properties shall comply with the values specified in Table 5 and Table 7 for steel grades of improved weldability and normal weldability respectively.

Table 7 Mechanical properties for normal strength steel

Grade	*Yield strength R_{eH} minimum (MPa)*	*Tensile strength R_m (MPa)*	*Elongation A5 minimum (%)*	*Impact energy, average minimum (J)[1)]*					
				Test temperature (°C)	*t ≤ 50 (mm)*		*50 < t ≤ 70 (mm)*		*70 < t ≤ 150 (mm)*	
					L	*T*	*L*	*T*	*L*	*T*
VL A	235	400 to 520	22 [5)]	+20	-[2)]	-[2)]	34[4)]	24[4)]	41[4)]	27[4)]
VL B				0	27[3)]	20[3)]	34	24	41	27
VL D				-20	27	20	34	24	41	27
VL E				-40	27	20	34	24	41	27

1) test direction shall follow [1.6.6]
2) manufacturer shall ensure (e.g. through regular in-house tests) that material of grade VL A with thickness less than 50 mm meets an impact toughness energy of minimum 27 J at +20°C
3) testing of the impact toughness is not required for grade VL B steel with t ≤ 25 mm. Manufacturer shall ensure (e.g. through regular in-house tests) that material of grade VL B with thickness less than 25 mm meets an impact toughness energy of minimum 27 J at 0°C
4) testing of the impact toughness is not required for grade VL A over 50 mm thickness when the material is produced using fine grain practice and supplied in N condition. Manufacturer shall ensure (e.g. through regular in-house tests) that material of grade VL A with thickness more than 50 mm meets an impact toughness energy of minimum 27 J at +20°C.
5) for full thickness flat test specimens with width 25 mm and gauge length 200 mm, the minimum elongation (%) is required as follows:

Thickness (mm)	*t ≤ 5*	*5 < t ≤ 10*	*10 < t ≤ 15*	*15 < t ≤ 20*	*20 < t ≤ 25*	*25 < t ≤ 30*	*30 < t ≤ 40*	*40 < t ≤ 50*
All grades	14	16	17	18	19	20	21	22

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 8.

Table 8 Test units for impact testing of normal strength steel

Grade	*Thickness, t (mm)*	*Plates*	*Sections*
VL A	t ≤ 50	Not required	Not required
	50 < t ≤ 150	50 tonnes	Not required
VL B	25 < t ≤ 150	50 tonnes[1)2)]	50 tonnes[2)]
VL D	t ≤ 150	50 tonnes[1)2)]	50 tonnes[2)]
VL E	t ≤ 150	Each piece	25 tonnes[3)]

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 [1] and apply to high strength steel. Provision is made for four strength levels with specified minimum yield strength 265 MPa, 315 MPa, 355 MPa and 390 MPa. Each strength level is further subdivided into four grades based on the specified impact toughness.

3.2 Chemical composition

3.2.1 The chemical composition shall comply with the limits given in Table 9 and Table 10. Except for VL A27S with thickness less than 25 mm, the steel grades shall be killed and fine grain treated. VL A27S in thickness up to and including 25 mm may be semi-killed or killed and without fine grain treatment.

3.2.2 For TM steels, the carbon equivalent value (C_{eq}) shall comply with the limits given in Table 11.

Table 9 Chemical composition limits[1] for high strength steel

Grade	*C*	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*Ni*	*Cu*	*Al* 3)4)	*Nb* 4)	*V* 4)	*Ti* 4)5)	*N*
VL A27S, VL D27S, VL E27S	0.18	0.50	0.70 to 1.60	0.035	0.035	0.20	0.08	0.40	0.35	Min. 0.020	0.02 to 0.05	0.05 to 0.10	0.007 to 0.02	-
VL A32, VL D32, VL E32, VL A36, VL D36, VL E36, VL A40, VL D40, VL E40	0.18	0.50	0.90 to 1.60 2)	0.035	0.035	0.20	0.08	0.40	0.35	Min. 0.020	0.02 to 0.05	0.05 to 0.10	0.007 to 0.02	-
VL F27S, VL F32, VL F36, VL F40	0.16	0.50	0.90 to 1.60	0.025	0.025	0.20	0.08	0.80	0.35	Min. 0.020	0.02 to 0.05	0.05 to 0.10	0.007 to 0.02	0.009 6)

1) given value is maximum content (by weight) 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%. Al may be replaced by other fine grain elements, see 4)
4) the steel shall contain grain refining elements 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% (corresponding to acid soluble content of 0.010%)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% (corresponding to acid soluble content of 0.010%)and the minimum V content shall be 0.030%. Combinations with other amounts of grain refining elements may be agreed. See also [1.4.6]. The total content of Nb+V+Ti shall not exceed 0.12%
5) maximum 0.05% Ti for TM steels subjected to agreement
6) 0.012% if Al is present.

Table 10 Requirements for high strength steels of improved weldability[1]

Grade	*VL AW27* *VL DW27* *VL EW27*	*VL AW32* *VL DW32* *VL EW32*	*VL AW36* *VL DW36* *VL EW36*
Deoxidation	Killed and fine grain treated		
Chemical composition (ladle analysis, maximum weight % unless range stated)			
C	0.12		
Si	0.10 to 0.50		
Mn	1.65		
P	0.020		

Grade	*VL AW27* *VL DW27* *VL EW27*	*VL AW32* *VL DW32* *VL EW32*	*VL AW36* *VL DW36* *VL EW36*
S	0.008		
Cu	0.50		
Cr	0.25		
Ni	1.00		
Mo	0.25		
Al (total)[2)]	0.06		
Nb[3)4)]	0.04		
V[3)4)]	0.08		
Ti[4)]	0.05		
N	0.010		
B[5)]	0.0005		
P_{cm}	0.22		
Tensile test			
Tensile strength (MPa)	400 to 530	440 to 590	490 to 630
Yield stress (MPa)			
t ≤ 25 mm	265	315	355
25 mm < t ≤ 50 mm	245	295	335
50 mm < t ≤ 75 mm	230	280	320
75 mm < t ≤ 100 mm	220	270	310
Elongation, A_5 (%)	22	22	21
Impact test, Charpy V-notch			
Test temperature (°C)			
Grade VL AW	0		
Grade VL DW	– 20		
Grade VL EW	– 40		
Minimum average energy (J)			
Transverse[6)]	40	44	50
Minimum single value (J)			
Transverse[6)]	28	31	35
Minimum average through thickness ductility Z_z (%)	35		

Grade	VL AW27 VL DW27 VL EW27	VL AW32 VL DW32 VL EW32	VL AW36 VL DW36 VL EW36

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 cast, 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) this requirement is applicable to longitudinal test specimens for sections, bars and flats of width less than 600 mm, see [1.6.6].

Table 11 Maximum carbon equivalent values (C_{eq}) for high strength steel supplied in TM condition

Grade	t ≤ 50 mm	50 mm < t ≤ 100 mm	100 mm < t ≤ 150 mm
VL A27S, VL D27S, VL E27S, VL F27S	0.34	0.36	0.38
VL A32, VL D32, VL E32, VL F32	0.36	0.38	0.40
VL A36, VL D36, VL E36, VL F36	0.38	0.40	0.42
VL A40, VL D40, VL E40, VL F40	0.40	0.42	0.45

3.3 Condition of supply and heat treatment

The condition of supply shall comply with the requirements given in Table 12.

Table 12 Conditions of supply for high strength steel

Grade	Grain refining element	Thickness, t (mm)	Plates	Sections
VL A27S, VL A32, VL A36	Al or any combinations with Al	t ≤ 20	AR, NR, N, TM	AR, NR, N, TM
		20 < t ≤ 35	AR[1)], NR, N, TM	AR, NR, N, TM
		35 < t ≤ 150	NR, N, TM, QT	AR[1)], NR, N, TM, QT
	Any combination without Al	t ≤ 12.5	AR, NR, N, TM	AR, NR, N, TM
		12.5 < t ≤ 150	NR, N, TM, QT	AR[1)], NR, N, TM, QT
VL A40	Any	t ≤ 12.5	AR, NR, N, TM	AR, NR, N, TM
		12.5 < t ≤ 150	NR, N, TM, QT	NR, N, TM, QT
VL D27S, VL D32, VL D36	Al or any combinations with Al	t ≤ 20	AR, NR, N, TM	AR, NR, N, TM
		20 < t ≤ 25	AR[1)], NR, N, TM	AR, NR, N, TM
		25 < t ≤ 150	NR, N, TM, QT	AR[1)], NR, N, TM, QT
	Any combination without Al	t ≤ 12.5	AR, NR, N, TM	AR, NR, N, TM
		12.5 < t ≤ 150	NR, N, TM, QT	AR[1)], NR, N, TM, QT

Grade	Grain refining element	Thickness, t (mm)	Plates	Sections
VL D40	Any	t ≤ 150	NR, N, TM, QT	NR, N, TM, QT
VL E27S, VL E32, VL E36	Any	t ≤ 50	N, TM, QT	AR[1)], NR [1)], N, TM, QT
		50 < t ≤ 150	N, TM, QT	NR[1)], N, TM, QT
VL F27S, VL F32, VL F36	Any	t ≤ 150	N, TM, QT	NR[1)], N, TM, QT
VL E40, VL F40	Any	t ≤ 150	N, TM, QT	N, TM, QT
1) products may be supplied in this condition when agreed.				

3.4 Mechanical properties

3.4.1 The mechanical properties shall comply with the values given in Table 10 and Table 13 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 14.

3.4.3 Additional requirements concerning through thickness properties (Z-ductility) are given in [5].

Table 13 Mechanical properties for high strength steel

Grade	Yield strength R_{eH} minimum (MPa)	Tensile strength R_m (MPa)	Elongation A5 minimum (%)	Impact energy, average minimum (J)[1)]					
				Test temperature (°C)	t ≤ 50 (mm)		50 < t ≤ 70 (mm)		70 < t ≤ 150 (mm)	
					L	T	L	T	L	T
VL A27S VL D27S VL E27S VL F27S	265	400 to 530	22[2)]	0 -20 -40 -60	27	20	34	24	41	27
VL A32 VL D32 VL E32 VL F32	315	440 to 570	22[2)]	0 -20 -40 -60	31	22	38	26	46	31
VL A36 VL D36 VL E36 VL F36	355	490 to 630	21[2)]	0 -20 -40 -60	34	24	41	27	50	34

VL A40 VL D40 VL E40 VL F40	390	510 to 660	20[2)]	0 -20 -40 -60	39	26	46	31	55	37

1) test direction shall follow [1.6.6]
2) for full thickness flat test specimens with width 25 mm and gauge length 200 mm, the minimum elongation (%) is required as follows:

Thickness (mm)	*t ≤ 5*	*5 < t ≤ 10*	*10 < t ≤ 15*	*15 < t ≤ 20*	*20 < t ≤ 25*	*25 < t ≤ 30*	*30 < t ≤ 40*	*40 < t ≤ 50*
Strength levels 27S and 32	14	16	17	18	19	20	21	22
Strength level 36	13	15	16	17	18	19	20	21
Strength level 40	12	14	15	16	17	18	19	20

Table 14 Test units for impact testing of high strength steels

Grades	*Strength levels*	*Delivery condition*	*Thickness*	*Plates*	*Sections*
A and D	All	AR	All	25 tonnes	25 tonnes
		NR	≤ 50 mm	50 tonnes	50 tonnes
			> 50 mm	25 tonnes	
		N, TM	All	50 tonnes	50 tonnes
	27S, 32, 36	QT	All	50 tonnes	50 tonnes
	40	QT	All	Each piece	25 tonnes
E and F	All	AR, NR	All	Each piece	15 tonnes
		N, TM, QT	All	Each piece	25 tonnes

4 Extra high strength steel

4.1 Scope

These requirements are supplementary to [1] and apply to extra high strength steel. Provision is made for eight strength levels with specified minimum yield strength 420 MPa, 460 MPa, 500 MPa, 550 MPa, 620 MPa, 690 MPa, 890 MPa and 960 MPa. Each strength level is further subdivided into four grades based on the specified impact toughness, except for strength level of 890 MPa and 960 MPa for which grade F is not applicable. Three types of extra high strength steels are specified:

— normal weldability steels
— improved weldability steels (with designation W), for strength levels 420, 460 and 500 MPa, and toughness grades D and E
— specific offshore grade steels (with designation O), these are extra high strength steels where the requirement for yield, tensile and impact toughness are independent of the product thickness.

Guidance note:

The specific offshore grade steels (O) correspond to and replaces the former NV grade steels specified by this document and the corresponding VL grade steels specified by DNVGL-OS-B101 Edition 2015-07.

The normal weldability steels correspond to the extra high stength steels specified by IACS UR W16 of March 2016 and later versions.

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

4.2 Steel making process

Vacuum degassing shall be used for the following:

a) all steels with enhanced through thickness properties
b) all steels of grade VL 690, VL 890 and VL 960.

The steel shall be fully killed, fine grain treated and shall have fine grain structure. The fine grain practice shall be as detailed in the qualified and accepted manufacturing specification, see also [1.4.6].

Guidance note:

A fine grain structure has an equivalent index ≥ 6 determined by micrographic examination in accordance with ISO 643 or alternative test method.

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

The steels shall contain nitrogen binding elements as detailed in the qualified and accepted manufacturing specification. See also note 4 in Table 15.

4.3 Chemical composition

The chemical composition and deoxidation practice shall comply with the limits given in Table 15. The steel grades shall be killed and fine grain treated.

Steels of improved weldability (W) shall follow the chemical composition requirements of normal weldability steels, although an additional requirement is given as follows: $P_{cm} \leq 0.22$.

Maximum C_{eq}, CET and P_{cm} values for all the other extra high strength steel grades shall follow the values given in Table 16.

Table 15 Chemical composition

Delivery condition[1)]	*N/NR*		*TM*		*QT*	
VL grade	A420-A460 D420-D460 AO420-AO460 DO420-DO460	E420-E460 EO420-EO460	A420-A890 D420- D690 AO420-AO690 DO420-DO690	E420-E890 F420-F690 D890 EO420-EO690 FO420-FO690	A420-A960 D420-D690 AO420-AO690 DO420-DO690	E420-E960 F420-F690 D890-D960 EO420-EO690 FO420-FO690
Chemical composition (%)[2)]						
C	0.20	0.18	0.16	0.14	0.18	
Mn	1.0-1.70		1.0-1.70		1.70	
Si	0.60		0.60		0.80	
P[3)]	0.030	0.025	0.025	0.020	0.025	0.020
S[3)]	0.025	0.020	0.025	0.010	0.015	0.010
Al_{total} min [4)]	0.02		0.02		0.018	

Delivery condition[1)]	*N/NR*	*TM*		*QT*	
Nb	0.05[5)]	0.05[5)]		0.06[5)]	
V	0.20[5)]	0.12[5)]		0.12	
Ti	0.05[5)]	0.05[5)]		0.05	
Ni[6)]	0.80	2.00[6)]		2.0[6)]	
Cu	0.55	0.55		0.50	
Cr	0.30[5)]	0.50[5)]		1.50	
Mo	0.10[5)]	0.50[5)]		0.70	
N[4)]	0.025	0.025		0.015	
B	-	-		-	
Oxygen, ppm[7)]	-	-	50	-	30

1) see [1] for definition of delivery conditions
2) given values are maximum content (by weight) unless shown as a range or as minimum. The chemical composition shall be determined by ladle analysis and shall meet the qualified and accepted manufacturing specification at the time of qualification
3) for sections the P and S content can be 0.005% higher than the specified value
4) the total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N ratio do not apply
5) total Nb+V+Ti ≤ 0.26% and Mo+Cr ≤ 0.65%, not applicable for QT steels
6) higher Ni content may be qualified and accepted subject to qualification during manufacturer qualification testing
7) the requirement on maximum oxygen content is applicable to D890, E890, D960 and E960 only

Table 16 Maximum C_{eq}, CET and P_{cm} values

Steel grades[1)]	*Delivery condition*	*Carbon equivalent (%)* [2)]							
		C_{eq}						*CET* [3)]	*P_{cm}* [4)]
		Plates			*Sections*	*Bars*	*Tubulars*	*all*	*all*
		t≤50 mm	*50<t≤100 (mm)*	*100<t≤250 (mm)*	*t≤50 mm*	*t≤250 or d≤250 (mm)*	*t≤65 mm*	*all*	*all*
VL 420 VL O420	N/NR	0.46	0.48	0.52	0.47	0.53	0.47	-	-
	TM	0.43	0.45	0.47	0.44	-	-	-	
	QT	0.45	0.47	0.49	-	-	0.46	-	-
VL 460 VL O460	N/NR	0.50	0.52	0.54	0.51	0.55	0.51	0.25	-
	TM	0.45	0.47	0.48	0.46	-	-	0.30	0.23
	QT	0.47	0.48	0.50	-	-	0.48	0.32	0.24
VL 500 VL O500	TM	0.46	0.48	0.50	-	-	-	0.32	0.24
	QT	0.48	0.50	0.54	-	-	0.50	0.34	0.25

Steel grades[1]	*Delivery condition*	*Carbon equivalent (%)* [2]							
		C_{eq}						*CET* [3]	P_{cm} [4]
		Plates			*Sections*	*Bars*	*Tubulars*	*all*	*all*
		t≤50 mm	*50<t≤100 (mm)*	*100<t≤250 (mm)*	*t≤50 mm*	*t≤250 or d≤250 (mm)*	*t≤65 mm*	*all*	*all*
VL 550 VL O550	TM	0.48	0.50	0.54	-	-	-	0.34	0.25
	QT	0.56	0.60	0.64	-		0.56	0.36	0.28
VL 620 VL O620	TM	0.50	0.52	-	-	-	-	0.34	0.26
	QT	0.56	0.60	0.64	-	-	0.58	0.38	0.30
VL 690 VL O690	TM	0.56	-	-	-	-	-	0.36	0.30
	QT	0.64	0.66	0.70	-	-	0.68	0.40	0.33
VL 890	TM	0.60	-	-	-	-	-	0.38	0.28
	QT	0.68	0.75	-	-	-	-	0.40	-
VL 960	QT	0.75	-	-	-	-	-	0.40	-

1) steels of improved weldability (W) shall have $P_{cm} \leq 0.22$
2) higher carbon equivalents may be accepted subject to pre-qualification by the manufacturer, see also [1.1.4] and Sec.1 [2.2]
3) for steel grades VL 460 and higher, *CET* may be used instead of C_{eq} at the discretion of the manufacturer
4) for extra high strength steels in TM and QT condition and with carbon content not more than 0.12%, the specified values for P_{cm} may be used instead of C_{eq} or *CET* at the discretion of the manufacturer.

4.4 Condition of supply and heat treatment

Conditions of supply shall be in accordance with requirements given in Table 15, Table 16 and Table 17, and as defined in [1]. Where alternative conditions are permitted, the manufacturer shall supply materials only in those conditions for which he has been qualified and accepted.

Table 17 Condition of supply related to maximum thickness limits

Delivery condition	*Maximum thickness (mm)*[1]			
	Plates	*Sections*	*Bars*	*Tubulars*
N	250 [2]	50	250	65
NR	150	[3]		
TM	150	50	-	-
QT	150 [2]	50	-	50

1) maximum thickness for steels of improved weldability is 100 mm unless otherwise agreed
2) qualification for normalized (N) steels with thickness larger than 250 mm and QT steels with thickness larger than 150 mm is subject to the special consideration of the verifier
3) the maximum thickness limits of sections, bars and tubulars produced by NR process route are less than those manufactured by N route, and shall be at the discretion of verifier.

4.5 Mechanical properties

4.5.1 The mechanical properties shall comply with the values given in Table 18. Steel grades of improved weldability shall follow the requirements for steel grades of normal weldability.

The extent of tensile and impact testing shall be as given in [4.5.2] and [4.5.3]. Sampling and test direction of test specimens shall follow the requirements of [1.6].

Table 18 Mechanical properties for extra high strength steels

Mechanical properties	*Yield strength R_{eH}, minimum (MPa)*[1) 2) 3) 4)]			*Tensile strength R_m (MPa)*[2) 3) 4)]		*Elongation after fracture minimum (%) $L_0=5.65\sqrt{S}$*[2)]		*Charpy V-notch impact toughness test*			
	Nominal thickness (mm)[5)]			*Nominal thickness (mm)*[5)]		*Test direction*		*Tough-ness grade*	*Test temp (°C)*	*Min. impact energy (J), for test direction*[5) 6)]	
Steel grades[7)]	*3 ≤ t ≤ 50*	*50 < t ≤ 100*	*100 < t ≤ 250*	*3≤ t ≤ 100*	*100 < t ≤ 250*	*T*	*L*[8)]			*T*	*L*
VL 420	420	390	365	520-680	470-650	19	21	A D E F	0 -20 -40 -60	28	42
VL O420	420			530-680		19	21				
VL 460	460	430	390	540~720	500~710	17	19	A D E F	0 -20 -40 -60	31	46
VL O460	460			570-720		17	19				
VL 500	500	480	440	590~770	540~720	17	19	A D E F	0 -20 -40 -60	33	50
VL O500	500			610-770		17	19				
VL 550	550	530	490	640~820	590~770	16	18	A D E F	0 -20 -40 -60	37	55
VL O550	550			670-830		16	18				
VL 620	620	580	560	700~890	650~830	15	17	A D E F	0 -20 -40 -60	41	62
VL O620	620			720-890		15	17				
VL 690	690	650	630	770~940 [9)]	710~900 [9)]	14	16	A D E F	0 -20 -40 -60	46	69
VL O690	690			770-940 [9)]		14	16				

Mechanical properties	*Yield strength R_{eH}, minimum (MPa)*[1) 2) 3) 4)]			*Tensile strength R_m (MPa)*[2) 3) 4)]		*Elongation after fracture minimum (%) $L_0=5.65\sqrt{S}$*[2)]		*Charpy V-notch impact toughness test*			
	Nominal thickness (mm)[5)]			*Nominal thickness (mm)*[5)]		*Test direction*		*Tough-ness grade*	*Test temp (°C)*	*Min. impact energy (J), for test direction*[5) 6)]	
Steel grades[7)]	*3 ≤ t ≤ 50*	*50 < t ≤ 100*	*100 < t ≤ 250*	*3≤ t ≤ 100*	*100 < t ≤ 250*	*T*	*L*[8)]			*T*	*L*
VL 890	890	830	N/A	940~1100 9) 10)	N/A	11	13	A D E	0 -20 -40	46	69
VL 960	960	N/A	N/A	980~1150 9) 10)	N/A	10	12	A D E	0 -20 -40	46	69

1) for tensile test either the upper yield stress (R_{eH}) or where R_{eH} cannot be determined, the 0.2 percent proof stress ($R_{p0.2}$) shall be determined and the material is considered to comply with the requirement if either value meets or exceeds the specified minimum value of yield strength
2) for full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation shall comply with the minimum values shown in Table 19
3) for t > 40 mm, round tensile test specimens from t/4 are accepted. For t > 100 mm, sampling is required at t/4 and t/2, see also [1.6.7]
4) the ratio between yield strength to tensile strength shall not exceed 0.94, unless otherwise agreed.
5) for plates and sections for applications, where the design requires that tensile properties are maintained through the thickness, a decrease in the minimum specified tensile properties is not permitted with an increase in the thickness, i.e. grades denoted O shall be applied
6) for t > 50 mm, additional sampling is required at t/2, see also [1.6.7]
7) steel grades of improved weldability shall follow the requirements for steel grades of normal weldability
8) in the case that the tensile specimen is parallel to the final rolling direction, the test result shall comply with the requirement of elongation for longitudinal (L) direction
9) it is recommended that materials exposed to anaerobic environments or to cathodic protection is specified with a hardness equal to or less than 350 HV
10) applicable for thickness ≤ 50 mm.

Table 19 Elongation (%), minimum values for test specimens with 25 mm width and 200 mm gauge length

Thickness, t (mm)	*t ≤ 10*	*10 < t ≤ 15*	*15 < t ≤ 20*	*20 < t ≤ 25*	*25 < t ≤ 40*	*40 < t ≤ 50*	*50 < t ≤ 70*
Strength level 420	11	13	14	15	16	17	18
Strength level 460	11	12	13	14	15	16	17
Strength levels 500 and 550	10	11	12	13	14	15	16
Strength level 620	9	11	12	12	13	14	15
Strength level 690	9	10	11	11	12	13	14

1) the tabulated elongation minimum values are the requirements for testing specimen in transverse direction
2) for VL 690 plates with thickness ≤ 20 mm, round specimen in accordance with Sec.1 may be used instead of the flat tensile specimen. The minimum elongation for testing specimen in transverse direction is 14%.
3) for VL 890 and 960, specimens and specimens which are not included in this table shall be proportional specimens with a gauge length of $L_0=5.65\sqrt{S_0}$.

4.5.2 Test unit for tensile test

Tensile test sample shall be randomly selected from each batch that is less than or equal to 25 tonnes, and from the same cast, in the same delivery condition and of the same thickness.

4.5.3 Test unit for impact test

For impact testing, the following test units are applicable:

— for steel plates in N/NR or TM condition test sample shall be taken from each piece
— for steel plates in QT condition test sample is shall taken from each individually heat treated part thereof
— for sections, bars and tubulars, test sample is shall taken from each batch of 25 tonnes or fraction thereof.

Note:

If the mass of the finished material is greater than 25 tonnes, one set of tests from each 25 tonnes and fraction thereof is required. (e.g. for consignment of 60 tonnes would require 3 plates to be tested).

---e-n-d---o-f---n-o-t-e---

Guidance note:

For continuous heat treated products special consideration may be agreed to the number and location of test specimens.

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

4.5.4 Additional requirements for through thickness properties (Z-ductility) are given in [5].

5 Z-grade steels (plates with through thickness properties)

5.1 Scope

5.1.1 These requirements are supplementary to [1] to [5] and apply to plates and wide flats with thickness 15 mm and over with specified minimum through thickness Z direction properties, see Figure 2. The use of Z-grade steels is required for certain types of welded structures, as detailed in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201) or on the drawings. Common areas for Z-grade steels are areas where plates are subjected to significant tensile stress in the through thickness direction. Z-grade steels are typically used in order to minimise the possibility of lamellar tearing, e.g. during fabrication.

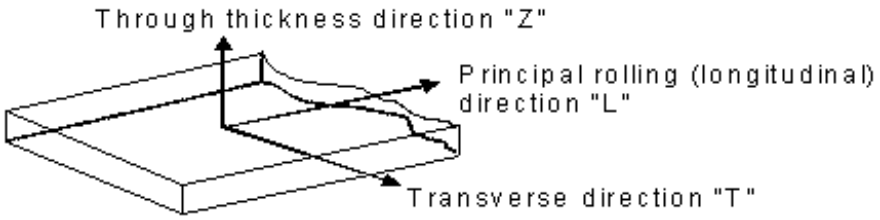

Figure 2 Through thickness tensile testing

5.1.2 Provision is made for the two quality classes Z25 and Z35 based on:

- specified minimum values for reduction of area in a through thickness tensile test, 25% and 35% respectively, see Table 20
- specified maximum values for sulphur content, see [5.2]
- ultrasonic testing, see [5.6].

Quality class Z25 is intended for normal vessel applications and Z35 for more severe applications.

5.2 Chemical composition

The steel grades shall be killed and fine grain treated. The ladle analysis sulphur content shall be ≤ 0.008% unless alternative methods of improving through thickness properties have been agreed. For sulphur content ≤ 0.005%, reduced test unit size is accepted, see Table 21.

5.3 Manufacture

All materials shall be manufactured at works accepted by the verifier for the grade of Z-quality steel being supplied.

Guidance note:

It is recommended that special steelmaking processes and techniques such as vacuum degassing, sulphide shape control or suitable low sulphur techniques are used.

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

5.4 Test material

5.4.1 Test material shall be taken close to the longitudinal centerline from one end of each rolled piece representing the test unit, see Figure 3. The longitudinal axes of the test specimens shall be perpendicular to the surface of the product.

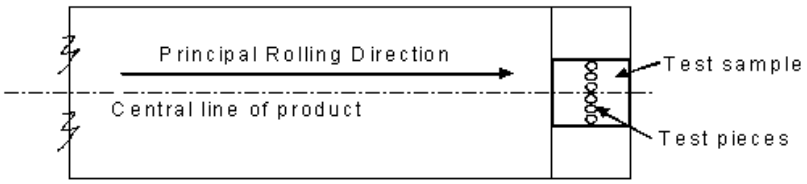

Figure 3 Plate and wide flat sampling position

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

5.4.3 Round test specimens shall be prepared in accordance with a recognised standard, e.g. EN 10164 or ASTM A770.

Table 20 Test unit (batch) maximum size dependent on product and sulphur content

Product	*Sulphur content*	
	0.005% < S ≤ 0.008%	*S ≤ 0.005%*
Plates	Each piece (parent plate)	50 tonnes
Wide flats of nominal thickness ≤ 25 mm	10 tonnes	
Wide flats of nominal thickness > 25 mm	20 tonnes	

5.5 Mechanical testing

5.5.1 The average reduction of area value of three test specimens shall be determined and meet the specified minimum average value given in Table 21. One individual value may be below the specified minimum average value, provided that it is not less than the specified minimum individual value.

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

— the average value of six test specimens 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.

5.5.3 Where batch testing is permitted and the conditions for acceptance after retest in [5.5.2] 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.

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

Table 21 Reduction of area acceptance values

Quality class	*Z25*	*Z35*
Minimum average	25%	35%
Minimum individual	15%	25%

5.6 Ultrasonic testing

Each product shall be subjected to ultrasonic testing in the delivery condition. Testing shall be performed in accordance with either EN 10160 and with acceptance criteria level S1/E1 or ASTM A578 with acceptance criteria level C. Details of the performance of testing including probe frequencies are described in the applied standard.

SECTION 3 STEEL PIPES AND FITTINGS

1 General requirements for pipes

1.1 Scope

1.1.1 This subsection 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.

1.1.2 Separate requirements for steel pipe fittings are given in [6]. Requirements for pipes and fittings of forgings and castings are given in Sec.3 and Sec.4 respectively.

1.1.3 Requirements for pipes and hollow sections intended for structural application are given in Sec.1.

1.2 Materials

1.2.1 Pipes shall be in accordance with recognised standards, as given in [2] to [5], provided that supplementary requirements contained herein and in [2] to [5] also are met. Recognition of other standards is subject to submission to the verifier for evaluation and agreement, see Sec.1 [2.5].

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

1.2.3 Where required by the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201), pipes shall comply with the requirements of Ch.1 and this section.

1.2.4 Where the use of material with differing requirements is proposed, particulars shall be submitted in connection with the acceptance of the design for which the material is proposed, see Sec.1 [2.5].

1.2.5 For carbon-manganese steel and other materials with definitive yield points, consideration shall be given to the limitation of the yield to tensile ratio.

1.3 Manufacture

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.

1.4 Chemical composition

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

1.4.2 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.

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

1.4.4 Unless stricter requirements are specified in the standard, carbon and carbon-manganese steel shall conform to a carbon equivalent C_{eq} of maximum 0.50% as determined by the formula 1 given in Sec.1.

1.5 Condition of supply

The pipes shall be supplied in a condition in accordance with the requirements of the relevant standard and the requirements in [2] to [5]. Unless otherwise required by the standard, hot finished or as-welded pipes need not be heat-treated.

1.6 Mechanical testing

1.6.1 Pipes shall be sampled and subjected to testing in accordance with the requirements of the relevant standard.

1.6.2 Unless stricter requirements are specified in the standard, the size of a test unit (batch) shall be restricted to maximum:

— 400 pipes for outside diameter < 100 mm
— 100 pipes for outside diameter ≤ 500 mm
— 50 pipes for outside diameter > 500 mm.

Further details are given in [1.6.3] and [1.6.4].

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

1.6.4 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.

1.6.5 Where pipes are designed for use at elevated temperatures on the basis of their high-temperature strength characteristics, a hot tensile test shall be performed on one test specimen per cast and per pipe size. The test is not required if the pipes are made according to a recognized standard where the high-temperature mechanical properties are regarded as proven.

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

Unless otherwise specified by the selected recognised standard for the grade in question, transverse Charpy V-notch specimens shall be used for outside diameter of D ≥ 200 mm. For outside diameter D < 200 mm, longitudinal specimens may be used.

If the dimensions of the pipe are such that transverse test specimens can be taken without straightening, an additional (transverse) set of specimens shall be taken from fusion-welded pipes so that the notch is located in the middle of the weld metal.

1.7 Leak tightness testing

1.7.1 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 [1.7.2].

1.7.2 The internal pressure test shall be performed at a standard hydraulic test pressure of 70 bars or at a test pressure calculated using the following equation, whichever is lower:

$$P = 20\frac{\sigma_r}{D}t$$

P = applicable test pressure [bar]
D = nominal outside diameter [mm]
t = nominal wall thickness [mm]
σ_r = stress [MPa], calculated to 70% of the specified minimum yield strength.

The test pressure shall be held for not less than 5 sec. for tubes with nominal outside diameter D less than or equal to 457 mm, and not less than 10 sec. for tubes with nominal outside diameter D greater than 457 mm.

Where pipes are intended for an operating pressure of ≤ 25 bars, the test pressure may be reduced to a standard value of 50 bars. Where, in exceptional cases, testing with water is not possible, another testing medium may be used in agreement with the verifier.

1.8 Inspection

1.8.1 Pipes shall be subjected to visual inspection and measurements of dimensions by the manufacturer 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.

1.8.2 All products shall satisfy the surface finish requirements of the applied pipe standard. Unless specified otherwise in the referred standard, the following apply:

— products shall have a finish appropriate to the manufacturing route
— products shall be free from laps, laminations, seams, visible cracks, tears, slivers, pits and other detrimental imperfections
— minor surface discontinuities which may occur under normal manufacturing conditions and within the thickness tolerances of the products are accepted.

1.8.3 For welded pipes, an automatic non-destructive testing of the whole length of the weld is required. Such pipes are considered equivalent to seamless pipes for design purpose.

1.8.4 Where required by the design principle, pipes shall be subjected to a non-destructive test over their whole length in accordance with a recognized standard, e.g. EN ISO 10893.

1.8.5 The test equipment used for the continuous inspection of pipes shall be regularly calibrated using pipes with artificial defects. The efficiency of the equipment shall be demonstrated to the verifier on request.

1.9 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. Defects removed by grinding shall be re-inspected by NDT. For pipes/fittings repaired by welding, both leak tightness test according to [1.7] and inspection according to [1.8] shall be repeated after repair.

1.10 Identification

Pipes shall be legibly marked for identification in accordance with the requirements of the relevant standard with the following minimum information:

— manufacturer's name or trade mark
— material designation

— where applicable, quality level in the case of boiler tubes
— cast number or production code.

1.11 Certification

The product shall be delivered with the type of inspection certificate required in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201) giving at least the following particulars for each test unit which has been accepted:

— purchaser's name, order number and offshore unit identification, where known
— manufacturer's name
— description of pipes/fittings and material quality
— identification marking of pipes/fittings
— cast 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 Pipes for pressure systems

2.1 Scope

These requirements are supplementary to [1] and apply to carbon and carbon-manganese and alloy steel pipes for use in pressure systems.

2.2 Materials

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

— ISO 9329 Pt.1 and Pt.2, ISO 9330 Pt.1 and Pt.2
— EN 10216 Pt.1 to Pt.3, EN 10217 Pt.1 to Pt.3, EN 10305 Part 1 and 2
— ASTM A53, ASTM A106, ASTM A135, ASTM A335
— JIS G3454, JIS G3455, JIS G3456, JIS G3458.

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

2.3 Manufacture

Pipes for class I and class 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
— cold finished electric resistance or induction welded
— electric fusion welded.

2.4 Mechanical testing

Pipes for class I and class II pressure vessels shall satisfy a Charpy V-notch impact toughness requirement of minimum 27 J, unless otherwise agreed.

3 Austenitic and ferritic-austenitic steel pipes

3.1 Scope

3.1.1 These requirements are supplementary to [1] and apply to austenitic stainless and ferritic-austenitic stainless steel pipes for corrosive service and to austenitic steel pipes for low-temperature service.

3.2 Materials

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

— ISO 9329 Pt.4, ISO 9330 Pt.6
— EN 10216 Pt.5, EN 10217 Pt.7
— ASTM A269, ASTM A312, ASTM A358, ASTM A789, ASTM A790, ASTM A928
— JIS G3459.

3.3 Manufacture

Pipes shall be manufactured by any of the following methods:

— hot finished seamless
— cold finished seamless
— electric resistance or induction welded
— cold finished electric resistance or induction welded
— electric fusion welded.

3.4 Condition of supply

The austenitic and duplex (ferritic/austenitic) stainless steel pipes shall be supplied in solution heat treated condition. Welded austenitic pipes may be delivered in the welded state provided that a test of the procedure has demonstrated that the characteristics of the material are satisfactory and that the strips or plates used for their manufacture are solution heat treated.

3.5 Mechanical testing

3.5.1 Where pipes are used at elevated temperatures, the required values for the 0.2% or 1% proof stress prescribed in the relevant standards or recognized specifications shall be met at the corresponding temperature level.

3.5.2 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 specimens shall be minimum 41 J.

3.6 Corrosion testing

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

3.6.2 Test specimen surfaces shall have a finish representative of the pipe's delivery condition. The test specimens shall be exposed to the solution at a constant temperature of be +22°C (±2°C) for type 22Cr duplex and +50°C (±2°C) for type 25Cr duplex for 24 hours. No pitting on specimen surfaces is allowed when viewed at 20 times magnification. The specimen mass loss shall be less than 4.0 g/m^2.

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. For pipes with thickness t > 25 mm special acceptance is required.

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

— ISO 9329 Pt.3, ISO 9330 Pt.3
— EN 10216 Pt.4, EN 10217 Pt.6
— ASTM A333, ASTM A334
— 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 followed by heat treatment
— electric resistance or induction welded
— cold finished electric resistance or induction welded followed by heat treatment
— electric fusion welded.

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

Steel type	*Heat treatment*	*Min. design temperature (°C)*	*Charpy V-notch impact test*	
			Test temperature (°C)	*Minimum average energy (J)*
C and C-Mn, fully killed fine grain	Normalized or as agreed	-55	[1)]	27
2 ¼ Ni	Normalized or normalized and tempered	-65	-70	34
3 ½ Ni	Normalized or normalized and tempered	-90	-95	34

Steel type	*Heat treatment*	*Min. design temperature (°C)*	*Charpy V-notch impact test*	
			Test temperature (°C)	*Minimum average energy (J)*
9 Ni	Double normalized and tempered or quenched and tempered	-165	-196	41
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 [2] 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 [3].

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

— ISO 9329 Pt.2, ISO 9330 Pt.2
— EN 10216 Pt.2, EN 10217 Pt.2
— ASTM A178, ASTM A209, ASTM A210, ASTM A213
— 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 followed by heat treatment
— electric resistance or induction welded
— cold finished electric resistance or induction welded followed by heat treatment.

6 Piping fittings

6.1 Scope

This subsection specifies the requirements for steel piping fittings such as elbows, bends, tees, reducers and caps for the applications covered in [2] to [5], made from plates, seamless pipes or welded pipes. Detachable pipe couplings and flanges are excluded from these requirements. Steel pipe fittings made by forging or casting are covered by Sec.4 and Sec.5, respectively.

6.2 Materials

6.2.1 Fittings shall be in accordance with recognised standards, as given in [6.2.2]. Recognition of other standards is subject to agreement.

6.2.2 Suitable fitting grades shall be selected from the following recognised standards:

— EN 10253
— ASTM A234, ASTM A403, ASTM A420, ASTM A744, ASTM A815, ASTM A960, ASTM A961
— JIS B2312, JIS B2313, JIS B2316.

6.2.3 Where required by the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201), fittings shall comply with the requirements of Ch.1 and this subsection.

6.2.4 Where the use of material with differing requirements is proposed, particulars shall be submitted in connection with the acceptance 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.

6.3 Manufacture

Fittings shall be manufactured by forming operations such as pressing, bending or fusion welding according to recognized standards.

6.4 Chemical composition

Chemical composition of the starting materials shall fulfil [1.4].

6.5 Condition of supply

All fittings shall be in the heat-treated or hot worked state specified for the material in the relevant standard or material specification.

6.6 Mechanical testing

6.6.1 Fittings shall be tested in accordance with the requirements of the relevant standard. For stainless steel fittings and fittings for low-temperature service, the supplementary requirements for testing given in [3] and [4] apply.

6.6.2 Unless stricter requirements are specified in the standard, the size of a test unit shall be restricted to the maximum size given in Table 2 and as given in [6.6.3] and [6.6.4].

Table 2 Test units for fittings

Size d_a (mm)[1)]	*No. of fittings per test unit*[2)]
< 100	≤ 200
100 ≤ d_a < 225	≤ 100
225 ≤ d_a < 350	≤ 50
d_a ≥ 350	≤ 25

1) d_a = outer diameter
2) for elbows: the test unit size apply to 90° elbows. The number of elbows in each test unit is halved in the case of 180° elbows and doubled in the case of 45° elbows.

6.6.3 Where heat treatment has been carried out, a test unit shall consist of fittings of the same size, made from the same grade of steel, the same heat treatment in a continuous furnace or heat-treated in the same furnace charge in a batch furnace, and in the case of alloy steel fittings with an outer diameter d_a > 100 mm, originating from the same cast.

6.6.4 Where no heat treatment has been carried out, a test unit shall consist of fittings of the same size, made by the same forming process, and from the same grade of steel.

Where the fittings are delivered without heat treatment, and have been subject to theoretical cold forming of less than 5% for ferritic steels and less than 10% for austenitic and ferritic-austenitic steels, testing of the starting material is sufficient. Theoretical cold forming may be calculated in accordance with DNVGL-OS-C401.

6.6.5 Testing shall be carried out on selected fitting from the unit to be covered. Provided the length of the fitting is not sufficient for testing, fittings of excess length shall be manufactured using the same or a similar process, and shall follow the test unit as described in [6.6.2] to [6.6.4]. The test samples shall be prepared from the hardest and softest fittings determined in the hardness test, see [6.6.6].

6.6.6 Hardness tests shall be carried out on 10% of the fittings per test unit, except for austenitic and austenitic-ferritic steels subject to tensile testing on the fitting. Where the number of fittings per test unit is less than 30 fittings a minimum of three fittings shall be tested. Hardness test shall be performed on each individual fitting for the following:

— outer diameter D ≥ 225 mm for unalloyed steel with tensile strength R_m ≥ 500 MPa
— outer diameter D ≥ 200 mm for alloyed steel, except for 0.3% Mo and Cr-Mo steel, which shall follow the requirement for unalloyed steel.

6.6.7 One tensile test shall be carried out for each test unit unless stricter requirements are specified in the applied standard. Sample product shall be selected as the softest fitting found in hardness tests according to [6.6.6]. Fittings having an outer diameter D < 100 mm may be tensile tested on the starting material.

6.6.8 Where Charpy V-notch impact testing is required, this is applicable for wall thickness 6 mm or greater, unless specified otherwise in the referring rule or standard.

Where the fittings are delivered without heat treatment and have been subject to theoretical cold forming of more than 5% for ferritic steels and more than 10% for austenitic and ferritic-austenitic steels, the area with the highest cold forming shall be tested. Where sampling of the representative area is not possible, testing of same material in artificially cold formed condition is accepted. For ferritic steels, the material shall additionally be tested in the strain-aged condition, see Sec.1.

6.7 Corrosion testing

6.7.1 Where fittings of austenitic stainless steels shall be used in systems where corrosion testing of the pipes is required, appropriate corrosion testing shall be carried out in accordance with an agreed standard, e.g. ASTM A262 *Practice E, Copper - Copper Sulphate - Sulphuric Acid Test* for intercrystalline corrosion testing, ASTM G48 for pitting or crevice corrosion testing, or to another recognised standard.

6.7.2 For duplex (ferritic/austenitic) stainless steel pipes fittings, corrosion testing in accordance with ASTM G48 method A or an equivalent standard is required.

6.7.3 Test specimen surfaces shall have a finish representative of the fitting's delivery condition. The test temperature shall be +22°C ±2°C for type 22Cr duplex and +50°C ±2°C for type 25Cr duplex for 24 hours .

No pitting on specimen surfaces is allowed when viewed at 20 times magnification. The specimen mass loss shall be less than 4.0 g/m^2.

6.8 Inspection

6.8.1 Fittings shall be subject to visual inspection and measurements of dimensions by the manufacturer. Surface quality and dimensions shall be in accordance with the requirements of the relevant standard.

The fittings 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.

6.8.2 Unless stricter requirements are specified in the standard, welded alloy steel fittings with nominal bores > 75 mm shall be subject to random radiographic inspection of the welds. These shall be selected in such a way that every size of fittings is included.

6.9 Identification

Fitting with outer diameter D ≥ 225 mm shall be marked in accordance with [1.10]. Smaller fittings may alternatively be marked with the manufacturer´s symbol and a unique identification number ensuring traceability to the test unit and certificate.

6.10 Certification

The manufacturer shall provide the type of inspection certificate required in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201) giving the following particulars for each test unit which has been accepted:

— purchaser's name, order number and offshore unit identification, where known
— manufacturer’s name
— description of fittings and material quality
— identification marking of fittings
— cast number and chemical composition
— results of mechanical tests and technological tests
— results of any supplementary and additional test requirements specified.

SECTION 4 STEEL FORGINGS

1 General requirements

1.1 Scope

1.1.1 This section specifies the general requirements for:

- steel forgings to be used in the construction of hulls, equipment, machinery, boilers, pressure vessels and piping systems, and forgings for low temperature service
- semi-finished rolled or forged products for forging stock and to forgings from which blanks for various components may be cut out
- rolled bars intended for machining into components of simple shape, e.g. shafts, bolts, studs and other components
- bolts and nuts.

1.1.2 Where required by the relevant parts of the DNV GL offshore rules and standards, steel forgings shall comply with the requirements of Ch.1, the general requirements of [1] and the appropriate specific requirements of [2] to [6]. 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 [1] or are especially agreed upon. See also Sec.1 [2.5].

1.1.4 This section contains requirements applicable to general certification of materials. However, for components that shall be certified according to other DNV GL standards, the requirements in these standards prevail.

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
- 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 shall be designated in accordance with a recognized standard.

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---o-f---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 verifier. 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.

1.3.4 Surface and skin defects, which may be detrimental during the subsequent working and forming operations, shall be removed.

1.3.5 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 in order to give reasonable machining allowance.

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. Preheating shall be employed when necessitated by the composition or thickness of the steel. Subsequent grinding or machining is required for certain components.

Excessive machining to give the forging its final shape may impair its characteristics e.g. by exposing the core zone. The core zone may have lower mechanical properties, as well as higher density of inclusions and other imperfections. The manufacturer is responsible for evaluation of the machining allowance suitable for their products. As a general advice, machining allowance should not exceed 20% of final dimension.

Necks of shafts, pinions and journals exceeding 1/10 of the outer diameter should be produced as far as possible by stepped forging.

The degree of deformation should be such that the core zone of the forging undergoes sufficient plastic deformation.

Surface hardening and surface carburizing caused by flame-scarfing or air-arc gouging will typically be removed if it is followed by grinding or machining to a depth of 1 mm or more.

1.3.6 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. However, the initial free upsetting operation of the ingot shall not be considered as part of the total forging reduction ratio.

Unless otherwise agreed the total reduction ratio, resp. the ratio for upsetting, shall be at least as stated in Table 1.

Table 1 Forging ratio and ratio for upsetting

Starting material	*Total forging ratio (cross section [1,2,3,4])*	
	Where L > D	*Where L ≤ D*
Ingots, continuous cast products (cut slabs, blooms, billets)	min. 3:1	min. 1.5:1
Rolled products	min. 4:1	min. 2:1
Rolled bars	min. 6:1, see [1.1.1]	

Starting material		*Total forging ratio (cross section [1,2,3,4])*	
		Where L > D	*Where L ≤ D*
Any of the above, or forging; for further forging by upsetting[5,6,7)]	In case of no initial forging, or initial forging less than 1.5:1	$L/L_1 \geq 3$	
	In the case of an initial forging reduction of at least 1.5:1 and up to 3:1	$L/L_1 \geq 1.5$	
	In the case of an initial forging reduction of at least 3:1	$L/L_1 \geq 1$	
	For alternating forging and upsetting	One of the above requirements shall be met at least once for the given starting material	

1) forging ratio for forgings not made by upsetting is calculated as cross section area before forging divided by cross section area after forging, or length before forging divided by length after forging, whichever is bigger
2) forging steps may be added to reach the total forging ratio requirement of 3:1, e.g. initial forging at steelmill plus forging at forge. The requirement is that the cross section of the final forging shall be ≤ 1/3 of the cross section of the listed starting materials.
3) L is the length and D is the diameter before the given forging operation
4) for complex shapes or special forging operations, other ratios may be agreed subject to special consideration by the verifier
5) bars with a rolling reduction ratio of at least 6:1 are excluded from this requirement
6) L_1 is height after upsetting
7) for forging by upsetting (for head, flange, bolts, coupling etc.), unsupported length (L_2) should be: $L_2 \leq 3 \times D$.

1.3.7 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 verifier. Welding procedure qualification tests may be required.

1.3.8 Where the referring rules specify steels with enhanced cleanliness, i.e. so called clean steel forgings, these are forgings with specified cleanliness. The requirements are further detailed in DNVGL-RU-SHIP Pt.2 Ch.2 Sec.6 [1.6.10].

1.4 Chemical composition

1.4.1 The chemical composition of each cast shall be determined by the manufacturer on a sample taken preferably during the pouring of the cast and shall be within the specified limits. When multiple casts 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 such as aluminium, niobium or vanadium 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 Condition of supply and heat treatment

1.5.1 All forgings shall be heat treated for mechanical properties as specified in subsequent subsections.

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

1.5.3 Sufficient thermocouples shall be connected to the furnace charge (minimum at lower part and thickest part of charge) to measure and record that its temperature is adequately uniform. This requirement does not apply when the temperature uniformity of the furnace is verified according to a recognized standard (e.g. ASTM A991) at regular intervals as agreed with the verifier.

1.5.4 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 verifier on request.

1.5.5 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.

1.5.6 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.

1.5.7 If a forging is locally re-heated or any straightening operation is performed after the final heat treatment, consideration shall be given to a subsequent stress relieving heat treatment. For machinery parts all straightening operations are subject to agreement.

1.6 Test material and test specimens for mechanical testing

1.6.1 Test material, from which test specimens are taken, shall be integral with the forging except as provided in [1.6.3], and shall not be detached from the forging until the heat treatment has been completed. 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 For closed die forgings, for components which shall be carburised, for hollow forgings where the ends shall be subsequently closed and for forgings submitted to re-heat treatment, the test material may be detached from the forging before heat treatment. For this case, the test material shall follow the forging represented through the entire heat treatment.

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. The test material shall follow the forgings represented through the entire heat treatment, unless otherwise agreed.

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 specimens apply:

— Longitudinal test: longitudinal axis of test specimen parallel to the principal direction of fibre deformation.
— Transverse test: longitudinal axis of test specimen perpendicular to the principal direction of fibre deformation.

1.6.6 The longitudinal axis of test specimens shall be positioned as follows:

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

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

Test specimens 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 specimen

The given positions are relative to the heat treated surface, not the surface after final machining. Other positions are subject to special agreement.

Guidance note:

For products machined to a depth exceeding the above test specimen positions, the obtained mechanical properties may not be fully representative of the product, see also [1.3.5]. For such cases the manufacturer may consider qualification tests on a prototype product to establish more representative mechanical properties.

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

1.6.8 Unless otherwise specified in the following paragraphs, the specified sampling position and test specimen orientation given in [1.6.5] and [1.6.6] apply.

1.6.9 The size, thickness location and preparation of test specimens, and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.1.

1.7 Test units and number of tests

1.7.1 Large forgings

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 Smaller forgings, normalized or solution heat-treated

Batch testing is accepted for normalised or solution heat treated forgings with mass up to 1 000 kg each. A test unit shall consist of forgings of similar shape and dimensions, made from the same cast of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes.

1.7.3 Smaller forgings, quenched and tempered

Batch testing is accepted for quenched and tempered forgings with mass up to 500 kg each. A test unit shall consist of forgings of similar shape and dimensions, made from the same cast of steel, heat treated in the same furnace charge and with a total mass not exceeding 3 tonnes.

1.7.4 Rolled bars

Batch testing of rolled bars, see [1.1.1], is accepted under the condition that the test unit consist of either:

a) 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
b) bars of the same diameter and cast, heat-treated in the same furnace charge and with a total mass not exceeding 2.5 tonnes.

1.7.5 Required tests

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 specimen and when required, three charpy V-notch test specimens.

1.7.6 Additional tests required for extra large forgings

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 Test requirements for multiple components made from one forging

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.1 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 shall 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. Unless otherwise agreed, the visual inspection and verification of dimensions is the responsibility of the manufacturer.

1.9.2 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. Forgings delivered in the unmachined condition shall have a proper surface condition consistent with the method of manufacture.

1.9.3 Forgings shall be presented to the verifier for visual survey. The verifier may require areas to be etched for the purpose of investigating weld repairs.

1.9.4 Forgings subject to non-destructive testing where specified in the subsequent subsections shall comply with the following requirements. In addition, the relevant DNV GL rules and standards shall be referred for non-destructive testing of finished machined components.

1.9.4.1 Personnel

All tests shall be carried out by personnel qualified and certified in accordance with recognised standards or schemes, e.g. ISO 9712, ASNT central certification program (ACCP). SNT-TC-1A may be accepted if the NDT company's written practice is reviewed and accepted by the verifier.

1.9.4.2 Methods

Non-destructive testing shall be performed in accordance with the general practice of recognised standards, e.g.:

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

d) as an alternative to a) to c), methods complying with national or proprietary standards or specifications may be agreed provided such standards or specifications give reasonable equivalence to the requirements of a) to c) or are especially agreed.

1.9.4.3 Extent and acceptance criteria

The extent of non-destructive testing and the acceptance criteria shall be agreed with the verifier:

a) for forgings, IACS recommendation no.68 is regarded as an example of an acceptable standard
b) as an alternative to a), acceptance criteria complying with national or proprietary standards or specifications may be agreed with the verifier provided such standards or specifications give reasonable equivalence to the requirements of a) or are especially agreed.

Guidance note:

The ordering specification with respect to NDT should be agreed between manufacturer and verifier and may typically give reference to recognised standards and/or specify:

— methods, areas, volume and extent of examination
— documentation requirements
— additional requirements as applicable.

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1.9.5 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.

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1.9.6 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. Scanning with both radial and axial sound wave direction, or with two perpendicular directions as relevant, shall be carried out when appropriate for the shape and dimensions of the forging being tested. When the configuration does not allow 100% volumetric examination, the report shall include a description of the areas not covered.

1.9.7 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.

1.9.8 The forging manufacturer shall maintain records of own inspections including dimensional measurements traceable to each forging. The records shall be presented to the verifier on request. The forging manufacturer shall provide the verifier 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.

1.9.9 Forgings proven defective during subsequent machining or testing shall be considered rejected notwithstanding any previous certification.

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 structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201). 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 (MT) or liquid penetrant testing (PT).

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 with the verifier. 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 verifier on request.

1.11 Identification

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

— identification number, cast 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 requirements

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

— purchaser's name, order number and offshore unit identification, where known
— manufacturer’s name
— description of forgings and steel quality
— identification marking of forgings
— steel making process, cast 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 Forgings for hull structures and equipment

2.1 Scope

These requirements are supplementary to [1] 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.

Table 2 Chemical composition limits[1] for steel forgings for hull structures and equipment[2]

Steel type	*C*	*Si*	*Mn*	*P*	*S*	*Cr*[3]	*Mo*[3]	*Ni*[3]	*Cu*[3]	*Total residuals*
C and C-Mn	0.23	0.45	0.30 to 1.50	0.035	0.035	0.30	0.15	0.40	0.30	0.85
Alloy	0.25	0.45	0.30 to 1.00	0.035	0.035	Min. 0.40[4]	Min. 0.15[4]	Min. 0.40[4]	0.30	-

1) given value is maximum content (by weight) unless shown as a range or as a minimum
2) forgings not intended for welding may be supplied to the composition limits given in DNVGL-RU-SHIP Pt.2 Ch.2 Sec.6 [3]
3) elements are considered as residual elements unless shown as a range or as a minimum
4) one or more of the elements shall comply with the minimum content.

2.3 Condition of supply and heat treatment

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

a) fully annealed
b) normalised
c) normalised and tempered at a temperature of not less than 550°C
d) quenched and tempered at a temperature of not less than 550°C.

Rolled bars: subject to qualification, e.g. through the manufacturer approval process, the specified normalizing or normalizing and tempering may be replaced by normalizing rolling (NR) or NR + tempering, respectively.

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 verifier.

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 3 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the agreed specification.

For materials manufactured to other specifications, the materials shall be grouped according to specified minimum tensile strength, and comply with the corresponding requirements of Table 3.

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 structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201). Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given in Table 3, corresponding minimum values for the other properties may be obtained by interpolation (relative to the specified minimum tensile strength).

Table 3 Mechanical properties for steel forgings for hull structures and equipment

Steel type	*VL Steel grade*	*Tensile strength R_m min. (N/mm^2)*	*Yield strength R_{eH} or $R_{p0.2}$ min. (N/mm^2)*	*Elongation A5 min. (%)*		*Reduction of area Z min. (%)*		*Charpy V-notch[1)2)]*		
								Test temperature[3)] (°C)	*Minimum average energy (J)*	
				L	*T*	*L*	*T*		*L*	*T*
C and C-Mn	F400UW	400	200	26	19	50	35	0	27	18
	F440UW	440	220	24	18	50	35	0	27	18
	F480UW	480	240	22	16	45	30	0	27	18
	F520UW	520	260	21	15	45	30	0	27	18
	F560UW	560	280	20	14	40	27	0	27	18
	F600UW	600	300	18	13	40	27	0	27	18
Alloy	F550AW	550	350	20	14	50	35	0	32	22
	F600AW	600	400	18	13	50	35	0	32	22
	F650AW	650	450	17	12	50	35	0	32	22

1) testing at +20°C may be accepted subject to compliance with a specified minimum average energy of 45 J longitudinal or 30 J transverse for all grades.
   L = longitudinal
   T = transverse/tangential
2) test direction shall follow the requirements of [1.6]
3) stricter test temperature requirements overruling above requirements are given in some of the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.5 Inspection

2.5.1 Magnetic particle (MT) or liquid penetrant testing (PT) of finished machined forgings shall be carried out as specified in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.5.2 Ultrasonic testing shall be carried out as specified in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

3 Ferritic steel forgings for low temperature service

3.1 Scope

These requirements are supplementary to [1] 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 max. 0.05% and Ti shall be max. 0.02%.

Table 4 Chemical composition limits[1] for ferritic steel forgings for low temperature service

Steel type	*Steel grade*	*C*	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*Ni*	*Cu*	*Al*[3]	*Total residuals*
C and C-Mn	VL F450L[4]	0.23	0.15 - 0.35	0.6 - 1.50	0.030	0.030	0.40	0.10	0.80	0.30	0.02 - 0.05	0.60
	VL F490L[4]											
	VL F450LI	0.16 [5]	0.1 - 0.5	0.7 - 1.6	0.025	0.025	0.25	0.08	0.8	0.35	0.02	-
	VL F490LI											
Nickel alloy	VL F3.5Ni	0.20	0.15 - 0.35	0.30 - 0.90	0.025	0.025	0.25	0.08	3.25 - 3.75	0.35	0.02 - 0.05	-
	VL F5Ni	0.12							4.70 - 5.30			
	VL F9Ni	0.10							8.50 - 10.0			

1) given value is maximum content (by weight) 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 DNVGL-RU-SHIP Pt.2 Ch.2 Sec.6 [7.2.2]
4) may be applied for low temperature service subject to by special agreement with the Society
5) by special agreement with the Society, the carbon content may be increased to 0.18% maximum, provided the design temperature is not lower than -40°C.

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.

Other delivery conditions may be accepted based on special agreement.

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. Other delivery conditions may be accepted based on special agreement.

3.4 Mechanical properties

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

3.4.2 For forgings which have been batch tested, hardness tests shall be made on each forging.

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

Steel type	VL steel grade	*Yield strength R_{eH} or $R_{p0.2}$ minimum (N/mm²)*	*Tensile strength R_m (N/mm^2)*	*Elongation A5 minimum (%)*	*Reduction of area Z minimum (%)*	*Charpy V-notch impact test*	
						Test temperature (°C)	*Minimum average energy (J)*
C and C-Mn	F450L [1)]	240	450 to 600	22	40	-60 [2)]	27
	F490L [1)]	275	490 to 640	20	40	-60 [2)]	27
	F450LI	240	450 to 600	22	40	-60 [2)]	41
	F450LI	275	490 to 640	20	40	-60 [2)]	41
Nickel alloy	F3.5Ni	275	490 to 640	20	35	-95	41 [3)]
	F5Ni	380	540 to 690	20	35	-110	41 [3)]
	F9Ni	480	640 to 790	18	35	-196	41 [3)]

1) may be applied for low temperature service subject to agreement with the verifier
2) applicable for design temperature -55°C or higher. For material thickness (t), test temperature may alternatively be:
   — t ≤ 25 mm: 5°C below the design temperature or –20°C, whichever is lower
   — 25 mm < t ≤ 30 mm; 10°C below design temperature or -20°C, whichever is lower
   — 30 mm < t ≤ 30 mm; 15°C below design temperature or -20°C, whichever is lower
   — 35 mm < t ≤ 40 mm; 20°C below design temperature
   — t > 40 mm, test temperature shall be agreed with the verifier
3) minimum average energy of 34 J may be accepted subject to agreement with the verifier.

3.5 Inspection

3.5.1 Quenched and tempered forgings are subject to magnetic particle testing (MT), see [1.9] and the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

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 (UT).

3.6 Pressure testing

Pressure retaining forgings shall be tested after machining to the test pressure required by the relevant design standard. No leaks are permitted.

4 Stainless steel forgings

4.1 Scope

4.1.1 These requirements are supplementary to [1] and apply to martensitic, martensitic-austenitic, precipitation hardened, ferritic, duplex (ferritic/austenitic) and austenitic stainless steel forgings, including austenitic steel forgings intended for use in the construction of cargo tanks and piping systems for liquefied gases and chemicals.

4.1.2 Stainless steel forgings shall be in accordance with recognised standards, e.g. EN 10222, ASTM A473, ASTM A965, ASTM A1049 and JIS G 3214, provided that supplementary requirements contained herein are also met. Recognition of other standards is subject to agreement. See also Sec.1 [2.5].

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 as specified in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201). Unless otherwise specified in the referring standard, testing shall be carried out at 5°C below the design temperature. Impact testing of austenitic stainless steel is required where the design temperature is below –105°C, and testing shall be carried out at –196°C. 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 Bolts and nuts

5.1 Scope

5.1.1 General

Where specifically required by the referring standard, bolts and nuts shall comply with the requirements of this subsection. This subsection specifies the requirements for bolts and nuts to be used in essential equipment e.g.:

— boilers, pressure vessels, equipment and pipelines
— diesel engines, gears, shafting and propellers
— rudder couplings
— other components for which proof of quality is required as specified in the rules.

Provision is made for carbon and carbon-manganese, alloy and stainless steels.

5.1.2 Reference to other DNV GL standards

Specific or additional requirements may be provided in the referring rules or standards. In case of conflicting requirements, the specific or additional requirements given by the referring rules or standards are prevailing.

The choice of bolts and nuts, together with the form of the requisite material test certificate is set out in the structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

Requirements for bolts and nuts not covered by this section, as well as for washers, shall comply with the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

5.1.3 Bolts and nuts with threads up to M39

For finished bolts and nuts with threads up to M39 all the requirements of one of the following standards are applicable and, with the additional requirements given in [5.5] and [5.6]:

— [2], [3] and [4]
— DNVGL-RU-SHIP Pt.2 Ch.2 Sec.6
— ISO 898-1 and ISO 898-2. Exempted thereof are bolts of strength categories for which the standard gives no data in respect of impact energy
— ISO 3506-1 and ISO 3506-2 for stainless steel fasteners.

Guidance note:

Bolts and nuts complying with other standards may be accepted provided proved suitable for the intended application.

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5.1.4 Bolts and nuts with threads exceeding M39

For finished bolts and nuts with threads exceeding M39 the relevant requirements of [5.2] to [5.8] are applicable.

5.2 Materials

5.2.1 Materials for bolts and nuts shall be in accordance with recognised standards, as given in [5.2.2]. Recognition of other standards is subject to agreement.

5.2.2 Recognized standards for materials for bolts and nuts

Materials for bolts and nuts shall be in accordance with one of the following, or a standard recognized by the verifier, see also guidance note and [5.2.3]:

— [2], [3] and [4]
— DNVGL-RU-SHIP Pt.2 Ch.2 Sec.6
— ISO 898-1 and ISO 898-2 up to and including M39 threads. Exempted thereof are bolts of strength categories for which the standard gives no data in respect of impact energy
— ISO 3506-1 and ISO 3506-2 for stainless steel fasteners
— steels conforming to EN 10269.

Guidance note:

Bolt and nut materials complying with other standards may be accepted provided the materials are proved suitable for the intended application. As an example, materials in accordance with DIN 267-13 may be accepted for general, low temperature and elevated temperature application.

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5.2.3 Where the use of material with differing requirements is proposed conforming to other standards or the manufacturer's material specifications, particulars shall be submitted in connection with the acceptance of the design for which the material is proposed. As a minimum, the following particulars shall be specified for alternative materials:

— relevant standard/specification and grade
— manufacturing process
— chemical composition
— heat treatment/delivery condition
— test units and number of tests
— mechanical properties, unless otherwise specified, the materials shall satisfy the requirements of [5.7]
— inspection including non-destructive testing.

Further particulars may be required as relevant for the acceptance.

5.3 Manufacture

5.3.1 Bolts and nuts shall be manufactured by hot or cold forming such as pressing, or rolled/forged bars with subsequent machining and/or rolling of threads according to a recognized standard.

Surface smoothing and rolling of the threads are not regarded as cold forming within the meaning of this section.

5.3.2 For the manufacture of nuts and bolts with threads up to and including M39 the requirements given in the standards in [5.2.2] are applicable.

5.3.3 For bolts and nuts with threads exceeding M39 forged semi-finished products shall be used.

5.3.4 Bolts and nuts shall be in the heat-treated condition specified for the material. The material shall not undergo unacceptable embrittlement up to the maximum temperature occurring in service. Bolts for sub-zero temperatures, shall exhibit adequate toughness. In the case of quenched and tempered steels, the tempering temperature shall be sufficiently higher than the maximum in-service temperature in order to avoid strength reduction.

5.3.5 Cold formed bolts shall be subjected to subsequent heat treatment. The same apply to hot formed bolts and nuts with the exception of those made of quenched and tempered steels, provided that the latter shall be used at normal ambient temperatures and the hot forming process results in a uniform structure.

5.4 Chemical composition

The chemical composition shall comply with the limits given in the referred standard, see [5.2.2].

5.5 Test units and number of tests

5.5.1 Test units and products to be tested

Bolts and nuts of the same type and strength category or made from the same material shall be grouped into test batches in accordance with Table 6 with the additional requirements as follows when relevant:

— if proof is furnished that the bolts or nuts in a delivery originate from one cast and have undergone the same heat treatment, testing of four sets of specimens is sufficient, regardless of the quantity supplied.

Where manufacture is followed by heat treatment, testing on the finished product is required.

Table 6 Batch sizes for the testing of mechanical properties

Quantity	*No. of sets of specimens for mechanical testing*
≤ 200	1
201 to 400	2
401 to 800	3
801 to 1200	4
1201 to 1600	5
1601 to 3500	6
> 3500	7

Where testing of the starting material is required, steel bars from the same cast and with the same diameter and heat treatment shall be grouped into test batches not exceeding 5000 kg each.

Testing of the starting material is applicable for:

— nuts with nominal thread diameters ≥ 39 mm
— where after manufacture, heat treatment is not required and the starting material is in the final heat treated condition.

5.5.2 Extent of testing

The tests required for each test batch are given in Table 7.

Table 7 Extent of testing

Test	*Bolts*		*Nuts*	
	Starting material	*Finished bolts*	*Starting material*	*Finished nuts*
Chemical composition	1)	-	1)	-
Tensile test	2), 3)	4)	2), 3)	-
Charpy V-notch test	2), 3)	5)	6)	-
Expansion test	-	-	-	4)
Hardness test	-	7)	-	7)

Test	Bolts		Nuts	
	Starting material	*Finished bolts*	*Starting material*	*Finished nuts*
1) each cast 2) in case testing of the starting material is required, steel bars from the same cast and with the same diameter and heat treatment shall be grouped into test batches not exceeding 5000 kg each 3) for elevated temperature application: the 0.2% or 1% proof stress shall be tested. The test may be dispensed with when the manufacturer has proven the elevated temperature mechanical properties within the manufacturer approval testing 4) each test batch as specified in [5.5.1]. For nuts, this requirement is applicable for d ≤ M39 5) required for d ≥ M16; each test batch as specified in [5.5.1] 6) not required unless specially specified 7) batch size ≤ 200: 10 pieces. Batch size > 200: 20 pieces.				

5.6 Mechanical properties

5.6.1 The procedures used for all mechanical tests including retests shall be in accordance with the appropriate requirements of Sec.1 [3]. For Charpy V-notch testing the specimen position shall be longitudinal direction.

5.6.2 Bolts and nuts conforming to the standards specified in [5.2.2] shall meet the mechanical properties set out in these standards, except bolts and nuts for pressure equipment which in addition shall meet the requirements given in [5.6.3]. Where other standards are accepted (see [5.2.2] and [5.2.3]), the mechanical properties shall satisfy the requirements of the applicable standard.

5.6.3 Steels for bolts and nuts for pressure equipment with design temperature not lower than -10°C shall have the characteristic values of the material and shall fulfil with longitudinal specimen direction:

— elongation A ≥ 14%
— impact energy ≥ 52 J for quenched and tempered steels
— impact energy ≥ 40 J for unalloyed steels.

Test temperature shall be 23°C ± 5°C unless otherwise specified in the rules.

5.6.4 Where during hardness testing, inspection or non-destructive testing one of the test specimens fails to meet the requirements, a further random sample of 20 specimens (or 10 specimens in the case of quantities ≤ 200) shall be taken, of which all the test specimens shall satisfy the requirements. Otherwise the entire test batch shall be regarded as unacceptable.

For the hardness test, the manufacturer may present this batch for retesting of all tests and inspections after a further heat treatment. If these test specimens still fail to satisfy the requirements, the entire batch shall be rejected.

5.7 Inspection

5.7.1 Surface finish and dimensions

The surface finish, dimensions and compliance with tolerances shall be verified by the manufacturer on at least 20 bolts or nuts of each batch, and on at least 10 bolts or nuts in the case of batch sizes of ≤ 200.

Guidance note:

Special consideration should be given to specifics which influence the effectiveness of the final bolted joint, due to e.g. insufficient contact surfaces, thus resulting in loss of friction. Such aspects are surface finish and quality, e.g. roughness, cleanliness (no rust) and, where applicable, coating. Other specifics concern the geometry, e.g. thread type, angularity and required parallelism between nut face and flange face.

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5.7.2 Non-destructive tests

Non-destructive testing of bolts and nuts shall be carried out as specified in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

5.8 Identification

5.8.1 Bolts and nuts with thread diameters < M52 shall be marked with the manufacturer's symbol and with the strength category or the steel grade shall be applied to the packing label.

Bolts and nuts with thread diameters ≥ M52 shall be marked in addition with the cast number.

5.8.2 Steel bars over 25 mm in diameter for the manufacture of bolts and nuts shall be marked at one end with the manufacturer's symbol and the steel grade. And alloy steel bars shall be additionally marked with the cast number. Where the diameter of the steel bars is 25 mm or less, it is sufficient to apply the corresponding markings to the label attached to the bundle of bars.

6 Other application areas

See DNVGL-RU-SHIP Pt.2 Ch.2 Sec.6 for requirements for forgings in other application areas such as machinery, gearing and pressure vessels.

SECTION 5 STEEL CASTINGS

1 General requirements

1.1 Scope

1.1.1 Requirements for steel castings to be used in the construction of hulls, equipment, machinery, boilers, pressure vessels and piping systems are specified.

1.1.2 Where required by the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201), steel castings shall comply with the requirements of Ch.1, the general requirements of [1] and the appropriate specific requirements of [2] to [5]. 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 this section or are agreed upon for each specific application, see also Sec.1 [2.5].

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
— 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.

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.

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1.3 Manufacture

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

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 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 welding procedure specification (WPS) shall be submitted for acceptance. Welding procedure qualification testing (WPQT) shall follow the requirements of DNVGL-OS-C401 Ch.2 Sec.5, unless otherwise agreed. The WPS shall comply with the corresponding requirements of the accepted drawing.

1.4 Chemical composition

1.4.1 The chemical composition of each cast shall be determined by the manufacturer and shall be within the specified limits. The sample for chemical composition shall preferably be taken during the pouring.

1) where one cast is tapped into one or more ladles before pouring into the moulds, the cast analysis shall be determined
2) where multiple casts are tapped and mixed in a ladle before pouring into the mould, the ladle analysis shall be determined
3) where multiple casts are poured into one mould, without first being mixed in one ladle, the chemical composition of each cast (a) or each ladle (b) shall be determined preferably during pouring.

1.4.2 Unless 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 be reported. Such elements shall not be intentionally added to the steel.

1.5 Heat treatment

1.5.1 All castings shall be heat treated as specified in [2] to [5].

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

1.5.3 Sufficient thermocouples shall be connected to the furnace charge (minimum at lower part and thickest part of charge) to measure and record that its temperature is adequately uniform. This requirement does not apply when the temperature uniformity of the furnace is verified according to a recognized standard (e.g. ASTM A991) at regular intervals.

1.5.4 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 verifier on request.

1.5.5 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.

Guidance note:

Holding time at normalizing, quenching and tempering temperature is typically one hour per 25.5 mm of the heaviest thickness of the casting, for castings with a thickness up to 127.5 mm. For castings with thickness more than 127.5 mm, at least one hour (or corresponding part thereof) is added for each addition of 102 mm.

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1.6 Test blocks and test specimens for mechanical testing

1.6.1 Test blocks, from which test specimens are taken, shall be cast integrally with the casting. When this is impracticable, the test blocks shall 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.

If the test block has to be removed from the casting before final heat treatment, e.g. for the purpose of machining, the verifier shall be invited for witnessing of the process of test block removal before machining and reattaching to the casting after machining but before final heat treatment.

1.6.2 In the case of small castings of about same size and less than 1000 kg in finished mass, the test blocks may alternatively be cast separately provided they are cast from the same cast 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 specimens shall be taken with their axis at least 14 mm from the cast surface. If the thickness of the test block is greater than 56 mm, the axis of the test specimen shall be at least one quarter thickness from the cast surface.

1.6.5 For castings where the method of manufacture has been specially agreed, the number and position of test samples shall be agreed.

1.6.6 The size, thickness location and preparation of test specimens, and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.1.

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 cast 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 casts, which are not mixed in a ladle prior to pouring, two or more sets of mechanical tests are required corresponding to the number of casts 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 [2] to [5] refer to test specimens 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.1 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 shall meet the specified requirements.

1.9 Inspection

1.9.1 All castings shall be visually inspected by the manufacturer on accessible surfaces for surface finish and compliance with the dimensional and geometrical tolerances. 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 When visually inspected, castings shall have a workmanlike finish and 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.

1.9.3 Castings shall be presented to the verifier for visual survey. The verifier may require areas to be etched for the purpose of investigating weld repairs.

1.9.4 Castings shall be subject to non-destructive testing as specified in [2] to [5] and shall fulfil the following requirements:

1.9.4.1 Personnel

All tests shall be carried out by personnel qualified and certified in accordance with recognised standards or schemes, e.g. ISO 9712 or ASNT central certification program (ACCP). SNT-TC-1A may be accepted if the NDT company's written practice is reviewed and accepted.

1.9.4.2 Methods

Non-destructive testing shall be performed in accordance with the general practice of recognised standards, e.g.:

a) magnetic particle testing (MT): ASTM E709, EN 1369, ISO 17638 (for welds), using wet continuous method
b) liquid penetrant testing (PT): ISO 3452-1, ASTM E165, EN 1371-1/2
c) ultrasonic testing (UT): ASTM A609, ISO 4992-1/2, ISO 17640 (for welds)
d) radiographic testing (RT): ISO 4993, ISO 5579 class B, ASTM E94
e) as an alternative to the methods described in 2), methods complying with national or proprietary standards or specifications may be agreed provided such standards or specifications give reasonable equivalence to the requirements of the listed standards or are especially agreed.

1.9.4.3 Extent and acceptance criteria

The extent of non-destructive testing and the acceptance criteria shall be agreed with the verifier

a) for MT, PT and UT of hull castings, IACS rec. no.69 is regarded as an example of an acceptable standard
b) for RT, ASME 16.34 App.I is regarded as an example of an acceptable standard
c) as an alternative to a) and b), acceptance criteria comply with national or proprietary standards or specifications may be agreed with the verifier provided such standards or specifications give reasonable equivalence to the requirements of a) or b) or are especially agreed.

In addition to this, the relevant DNV GL offshore rules and standards shall be referred for further non-destructive testing requirements.

Guidance note:

The ordering specification with respect to NDT may typically give reference to recognised standards, and/or specify:

— methods, areas, volume and extent of examination
— documentation requirements
— additional requirements as applicable.

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1.9.5 The following definitions relevant to MT or PT indications apply (see Figure 1):

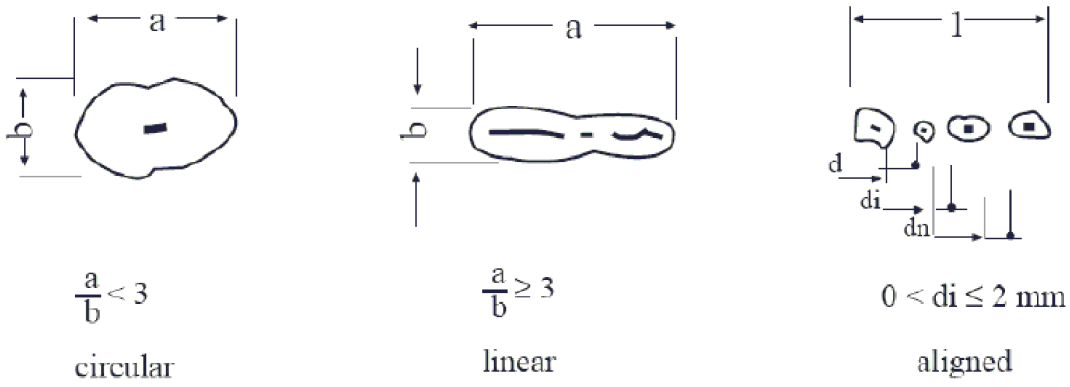

Figure 1 Shape of indications

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. 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.

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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 apply to castings with thickness less than 50 mm.

1.9.9 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 The foundry shall maintain records of own inspections including dimensional measurements traceable to each casting. The records shall be presented to the verifier on request. The foundry is also to provide the verifier 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 This paragraph gives general requirements for repair of steel castings. Higher requirements may be given for certain castings.

1.10.2 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, provided the remaining thickness is within the given tolerances (including minimum thickness). 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.

Guidance note:

Surface hardening and surface carburizing caused by flame-scarfing or air-arc gouging will typically be removed if it is followed by grinding to a depth of 1 mm or more.

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1.10.3 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 [1.10.2], 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 before and after welding.

1.10.4 Weld repairs are classified as major or minor. A weld repair is considered major when one of the following occurs:

- the depth of the groove prepared for welding exceeds 25% of the section thickness or 25 mm, whichever is smaller
- the area of the groove based on length times width exceeds 0.125 m^2
- castings have leaked on hydrostatic testing.

All other weld repairs are considered minor.

1.10.5 Major weld repairs require agreement by the verifier before the repair is commenced. Special attention should be paid to the high stress areas. A tailor-made procedure for each major weld repairs shall be prepared including 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 agreed.

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

Cosmetic repair by welding is considered minor weld repairs (unless it is major, as defined in [1.10.4]) and shall follow all the requirements for minor weld repairs.

1.10.7 All weld repairs (both minor and major welding repairs) shall be done by qualified welders using accepted welding procedures, see DNVGL-OS-C401.

Guidance note:

Alloy steel castings and crankshafts castings will typically need preheating prior to welding. Castings of carbon or carbon-manganese steels may also need preheating depending on chemical composition, dimensions and position of the weld repairs.

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1.10.8 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.

1.10.9 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, except for quenched and tempered steels. Quenched and tempered steels shall be stress relieved at least 30 °C lower than the final tempering temperature, but not below 550°C. The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs. 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.

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

1.10.11 The foundry shall maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. The records shall be presented to the verifier 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:

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

1.11.2 In case of castings of the same type but less than 230 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 structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201) giving the following particulars for each test unit of castings which has been accepted:

— purchaser's name, order number and offshore unit identification, where known
— manufacturer's name
— description of castings and steel quality
— identification marking of castings
— steel making process, cast number and chemical composition
— details of heat treatment, including temperatures and time at temperature
— 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 this paragraph are supplementary to [1] 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 verifier 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.

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

Steel type	*C*	*Si*	*Mn*	*P*	*S*	*Cr*[3]	*Mo*[3]	*Ni*[3]	*Cu*[3]	*V*[3]	*Total residuals*
C and C-Mn	0.23[4]	0.60	0.50 to 1.60	0.040	0.035	0.30	0.15	0.40	0.30	0.12	0.95
Alloy	0.25	0.60	0.50 to 1.70	0.035	0.030	Min. 0.40[5]	Min. 0.15[5]	Min. 0.40[5]	0.30	0.12	-

1) given value is maximum content (by weight) unless shown as a range or as a minimum
2) castings not intended for welding may be supplied to the composition limits given in DNVGL-RU-SHIP Pt.2 Ch.2 Sec.8 [3]
3) elements are considered as residual elements unless shown as a range or as a minimum
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.

2.3 Heat treatment

2.3.1 Carbon and carbon-manganese steel 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.

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 verifier.

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 (relative to the specified minimum tensile strength).

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

Steel type	*VL steel grade*	*Yield strength $R_{p0.2}$ minimum (N/mm^2)*	*Tensile strength R_m minimum (N/mm^2)*	*Elongation A5 minimum (%)*	*Reduction of area Z minimum (%)*	*Charpy V-notch impact toughness*	
						Test temperature (°C) 1)2)3)	*Minimum average energy (J)3)*
C and C-Mn	C400UW	200	400	25	40	0	27
	C440UW	220	440	22	30	0	27
	C480UW	240	480	20	27	0	27
	C520UW	260	520	18	25	0	27
	C560UW	300	560	15	20	0	27
	C600UW	320	600	13	20	0	27
Alloy	C550AW	355	550	18	30	0	32
	C620AW	430	620	16	30	0	32

1) alternatively, testing at +20 °C may be accepted subject to compliance with a specified minimum average energy of 45 J
2) steel castings in structural members subject to lower design temperatures than -10 ºC, shall be impact tested at 5 ºC below the design temperature
3) for some products, stricter test temperature requirements overruling above requirements are given in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.5 Inspection

The castings shall be subject to magnetic particle and ultrasonic testing, see [1.9], as specified in the relevant structural standard, see Ch.1 Sec.1 Table 1.

3 Ferritic steel castings for low temperature service

3.1 Scope

These requirements are supplementary to the requirements in [1] 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.

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

Steel type	*VL steel grade*	*C*	*Si*	*Mn*	*P*	*S*	*Cr*[2]	*Mo*[2]	*Ni*	*Cu*[2]	*V*[2]	*Total residuals*
C and C-Mn	C450L	0.25	0.60	1.60	0.035	0.035	0.40	0.15	0.80	0.30	0.03	0.60
	C490L											
Alloy	C2.25Ni	0.25	0.60	0.50-0.80	0.035	0.035	0.40	0.15	2.00-3.00	0.30	0.03	0.60
	C3.5Ni	0.15	0.60	0.50-0.80	0.035	0.035	0.40	0.15	3.00-4.00	0.30	0.03	0.60

1) given value is maximum content (by weight) 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.

3.3 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.

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

Steel type	*VL steel grade*	*Yield strength $R_{p0.2}$ minimum (N/mm^2)*	*Tensile strength R_m (N/mm^2)*	*Elongation A5 minimum (%)*	*Charpy V-notch*	
					Test temperature (°C)	*Minimum average energy (J)*
C and C-Mn	C450L	240	450 to 600	22	-60 [1]	27
	C490L	275	490 to 640	20	-60[1]	27
Alloy	C2.25Ni	275	490 to 640	20	-70	34

	C3.5Ni	275	490 to 640	20	-95	34

1) the test temperature may be 5 °C below the design temperature if the latter is above –55 °C, but test temperature shall not be higher than –20 °C.

3.5 Inspection

3.5.1 For each test unit, at least one casting shall be subjected to magnetic particle testing and ultrasonic or radiographic testing.

Subject to agreement, where a number of castings representing multiple test units are made from the same pattern, as an alternative, testing of the first three castings made from the pattern may be substituted for the testing of each test unit. In case the pattern is used for several years for various test units, at least once per year NDT shall be performed.

In addition, NDT shall be carried out as specified in the relevant construction standards.

3.5.2 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 structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201). No leaks are permitted.

4 Stainless steel castings

4.1 Scope

These requirements are supplementary to the requirements in [1] and apply to austenitic stainless steel castings for use in piping systems for chemicals and liquefied gases, and duplex (ferritic/austenitic) stainless steels for 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.

Table 5 Chemical composition limits[1)] for stainless steel castings

Steel type	*C*	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*Ni*
Austenitic stainless steels								
GX 2 CrNi 18 10 (304L)	0.03	2.0	1.5	0.040	0.030	17.0 to 21.0	-	8.0 to 12.0
GX 5 CrNi 19 9 (304)	0.08	2.0	1.5	0.040	0.030	18.0 to 21.0	-	8.0 to 11.0
GX 6 CrNiNb 19 10 (347) [2)]	0.08	2.0	1.5	0.040	0.030	18.0 to 21.0	-	9.0 to 12.0
GX 2 CrNiMo 19 11 2 (316L)	0.03	1.5	1.5	0.040	0.030	17.0 to 21.0	2.0 to 3.0	9.0 to 13.0
GX 5 CrNiMo19 11 2 (316)	0.08	1.5	1.5	0.040	0.030	17.0 to 21.0	2.0 to 3.0	9.0 to 12.0
GX 5 CrNiMo19 11 3 (317)	0.08	1.5	1.5	0.040	0.030	17.0 to 21.0	3.0 to 4.0	9.0 to 13.0

Duplex (ferritic/austenitic) stainless steels								
GX 2 CrNiMoN 22 5 3 [3]	0.030	1.00	2.00	0.035	0.025	21.0 to 23.0	2.5 to 3.5	4.5 to 6.5
GX 2 CrNiMoCuN 25 6 3 3 [4]	0.030	1.00	1.50	0.035	0.025	24.5 to 26.5	2.5 to 3.5	5.0 to 7.0
GX 2 CrNiMoN 26 7 4 [5]	0.030	1.00	1.00	0.035	0.025	25.0 to 27.0	3.0 to 5.0	6.0 to 8.0

1) given value is maximum content (by weight) unless shown as a range or as a minimum
2) niobium content shall be minimum 8 times the carbon content, and maximum 1.00%
3) N content: 0.12 to 0.20
4) Cu content: 2.75 to 3.50; N content: 0.12 to 0.22
5) Cu content: max. 1.30; N content: 0.12 to 0.22; for this grade a minimum value for the pitting resistance PREN = Cr+3.3Mo+16N equal or larger than 40 may be called for.

4.3 Heat treatment

All steel castings shall be supplied in a heat-treated condition appropriate to the grade of cast steel. 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.

Table 6 Mechanical properties for stainless steel castings

Steel type	*Proof stress $R_{p0,2}$ minimum [1] (N/mm²)*	*Tensile strength R_m minimum (N/mm²)*	*Elongation A_5 minimum (%)*	*Charpy V-notch*	
				Test temperature (°C)	*Minimum average energy (J)*
Austenitic stainless steels					
GX 2 CrNi 18 10 (304L)	180	440	30	-196 [2]	41
GX 5 CrNi 19 9 (304)	180	440	30		
GX 6 CrNiNb 19 10 (347)	180	440	25		
GX 2 CrNiMo 19 11 2 (316L)	180	440	30		
GX 5 CrNiMo19 11 2 (316)	180	440	30		
GX 5 CrNiMo19 11 3 (317)	180	440	30		
Duplex (ferritic/austenitic) stainless steels					
GX 2 CrNiMoN 22 5 3	395	600 - 800	20	RT [3]	30
GX 2 CrNiMoCuN 25 6 3 3	455	650 - 850	22	RT [3]	50
GX 2 CrNiMoN 26 7 4	455	650 - 850	22	RT [3]	50

1)	the minimum $R_{p1.0}$ value is 25 N/mm^2 higher
2)	unless otherwise specified in the referring standard, impact tests may be omitted if the design temperature is above −105 °C
3)	to be tested at minimum design temperature if this is equal to, or lower than 0°C.

4.5 Corrosion tests

4.5.1 Where required by the relevant structural standard, see Ch.1 Sec.1 Table 1 or specified for the order in question, the materials for piping systems for chemicals shall be subjected to corrosion test as specified in DNVGL-RU-SHIP Pt.2 Ch.2 Sec.3 [4.6].

4.6 Inspection

4.6.1 For each test unit, at least one casting shall be subject to liquid penetrant testing. (PT),as well as to ultrasonic or radiographic testing.

Subject to agreement, where a number of castings representing multiple test units are made from the same pattern, as an alternative, testing of the first three castings made from the pattern may be substituted for the testing of each test unit. In case the pattern is used for several years for various test units, at least once per year NDT shall be performed.

In addition, NDT shall be carried out as specified in the relevant construction standard.

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

5 Other application areas

See DNVGL-RU-SHIP Pt.2 Ch.2 Sec.8 for requirements for castings in other application areas such as machinery, propellers and pressure vessels.

SECTION 6 ALUMINIUM ALLOYS

1 Wrought aluminium alloys

1.1 Scope

1.1.1 This section 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 Plates and sections with thickness less than 3 mm or more than 50 mm may be manufactured and tested in accordance with the requirements of a recognised standard or specification.

1.2 Materials

1.2.1 Alloy grades suitable for marine environment 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 Where required by the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201), wrought aluminium alloys shall comply with the requirements of Ch.1 and the requirements of this subsection.

As an alternative to [1.2.1], 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 for each specific application. Generally, such materials shall evaluated as described in Sec.1 [2.5].

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.

1.3 Manufacture

The alloys shall 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 shall be formed by extrusion, rolling or drawing.

1.4 Chemical composition

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

Table 1 Chemical composition limits[1] for wrought aluminium alloys

Grade	*Si*	*Fe*	*Cu*	*Mn*	*Mg*	*Cr*	*Zn*	*Ti*	*Other elements*[2]	
									Each	*Total*
VL-5052	0.25	0.40	0.10	0.10	2.2 to 2.8	0.15 to 0.35	0.10	-	0.05	0.15
VL-5059	0.45	0.50	0.25	0.6 to 1.2	5.0 to 6.0	0.25	0.40 to 0.9	0.20	0.05[5]	0.15[5]

VL-5083	0.40	0.40	0.10	0.40 to 1.0	4.0 to 4.9	0.05 to 0.25	0.25	0.15	0.05	0.15
VL-5086	0.40	0.50	0.10	0.20 to 0.7	3.5 to 4.5	0.05 to 0.25	0.25	0.15	0.05	0.15
VL-5154A	0.50	0.50	0.10	0.50	3.1 to 3.9	0.25	0.20	0.20	0.05	0.15
VL-5383	0.25	0.25	0.20	0.7 to 1.0	4.0 to 5.2	0.25	0.40	0.15	0.05[4)]	0.15[4)]
VL-5454	0.25	0.40	0.10	0.50 to 1.0	2.4 to 3.0	0.05 to 0.20	0.25	0.20	0.05	0.15
VL-5456	0.25	0.40	0.10	0.50 to 1.0	4.7 to 5.5	0.05 to 0.20	0.25	0.20	0.05	0.15
VL-5754	0.40	0.40	0.10	0.50[3)]	2.6 to 3.6	0.30[3)]	0.20	0.15	0.05	0.15
VL-6005A	0.50 to 0.9	0.35	0.30	0.50[6)]	0.40 to 0.7	0.30[6)]	0.20	0.10	0.05	0.15
VL-6060	0.30 to 0.6	0.10 to 0.30	0.10	0.10	0.35 to 0.6	0.05	0.15	0.10	0.05	0.15
VL-6061	0.40 to 0.8	0.7	0.15 to 0.40	0.15	0.8 to 1.2	0.04 to 0.35	0.25	0.15	0.05	0.15
VL-6063	0.20 to 0.6	0.35	0.10	0.10	0.45 to 0.9	0.10	0.10	0.10	0.05	0.15
VL-6082	0.7 to 1.3	0.50	0.10	0.40 to 1.0	0.6 to 1.2	0.25	0.20	0.10	0.05	0.15

1) given value is maximum content (by weight) 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 to 0.60
4) Zr: maximum 0.20. The total for other elements does not include zirconium
5) Zr: 0.05 to 0.25. The total for other elements does not include zirconium
6) Mn + Cr: 0.12 to 0.50.

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 Temper conditions

1.5.1 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.

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

1.6 Mechanical testing

1.6.1 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.

Table 2 Mechanical properties for rolled aluminium alloys

Grade	*Temper*	*Thickness, t (mm)*	*Yield strength $R_{p0.2}$ min. or range[1)] (MPa)*	*Tensile strength R_m min. or range[1)] (MPa)*	*Elongation[2)]*	
					$A_{50\ mm}$ min. (%)	*A_{5d} min. (%)*
VL-5052	O	t ≤ 50	65	165 to 215	19	18
	H32	t ≤ 6	130	210 to 260	10	-
		6 < t ≤ 50	130	210 to 260	12	12
	H34	t ≤ 6	150	230 to 280	7	-
		6 < t ≤ 50	150	230 to 280	9	9
VL-5059	O	t ≤ 50	160	330	-	24
	H111	t ≤ 50	160	330	24	24
	H116	t ≤ 20	270	370	10	10
		20 < t ≤ 50	260	360	10	10
	H321	t ≤ 20	270	370	10	10
		20 < t ≤ 50	260	360	10	10
VL-5083	O	t ≤ 50	125	275 to 350	16	14
	H111	t ≤ 50	125	275 to 350	16	14
	H112	t ≤ 50	125	275	12	10
	H116	t ≤ 50	215	305	10	10
	H128	4 < t ≤ 8	215	305 to 385	10	-
	H321	t ≤ 50	215 to 295	305 to 385	12	10
VL-5086	O	t ≤ 50	95	240 to 305	16	14
	H111	t ≤ 50	95	240 to 305	16	14
	H112	t ≤ 12.5	125	250	8	-
		12.5 < t ≤ 50	105	240	-	9
	H116	t ≤ 6.3	195	275	8	-
		6.3 < t ≤ 50	195	275	10	9
VL-5154A	O	t ≤ 50	85	215 to 275	17	16
	H32	t ≤ 6	180	250 to 305	8	-
		6 < t ≤ 50	180	250 to 305	10	9

Grade	Temper	Thickness, t (mm)	Yield strength $R_{p0.2}$ min. or range[1] (MPa)	Tensile strength R_m min. or range[1] (MPa)	Elongation[2]	
					$A_{50\ mm}$ min. (%)	A_{5d} min. (%)
	H34	t ≤ 50	200	270 to 325	8	7
VL-5383	O	t ≤ 50	145	290	-	17
	H111	t ≤ 50	145	290	-	17
	H116	t ≤ 50	220	305	10	10
	H321	t ≤ 50	220	305	10	10
VL-5454	0	t ≤ 50	85	215 to 285	17	16
	H32	t ≤ 6	180	250 to 305	8	-
		6 < t ≤ 50	180	250 to 305	10	9
	H34	t ≤ 50	200	270 to 325	8	7
VL-5456	O	t ≤ 6.3	130 to 205	290 to 365	16	-
		6.3 < t ≤ 50	125 to 205	285 to 360	16	14
	H116	t ≤ 30	230	315	10	10
	H321	30 < t ≤ 40	215	305	-	10
		40 < t ≤ 50	200	285	-	10
		t ≤ 12.5	230 to 315	315 to 405	12	-
		12.5 < t ≤ 40	215 to 305	305 to 385	-	10
		40 < t ≤ 50	200 to 295	285 to 370	-	10
VL-5754	O	t ≤ 50	80	190 to 240	18	17
	H111	t ≤ 50	80	190 to 240	18	17
	H32	t ≤ 50	130	220 to 270	10	9
	H34	t ≤ 6	160	240 to 280	8	-
		6 < t ≤ 50	160	240 to 280	10	8

1) specified minimum where one value is given. Specified minimum to maximum value where a range is specified
2) 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

Grade	Temper	Thickness, t (mm)	Yield strength $R_{p0.2}$ min. (MPa)	Tensile strength R_m min. or range (MPa)	Elongation[1]	
					$A_{50\ mm}$ min. (%)	A_{5d} min. (%)
VL-5059	H112	t ≤ 50	200	330	10	10
VL-5083	O	t ≤ 50	110	270 to 350	14	12
	H111	t ≤ 50	165	275	12	10

Grade	Temper	Thickness, t (mm)	Yield strength $R_{p0.2}$ min. (MPa)	Tensile strength R_m min. or range (MPa)	Elongation[1]	
					$A_{50\ mm}$ min. (%)	A_{5d} min. (%)
	H112	t ≤ 50	110	270	12	10
VL-5086	O	t ≤ 50	95	240 to 315	14	12
	H111	t ≤ 50	145	250	12	10
	H112	t ≤ 50	95	240	12	10
VL-5383	O	t ≤ 50	145	290	17	17
	H111	t ≤ 50	145	290	17	17
	H112	t ≤ 50	190	310	13	13
VL-6005A	T4	t ≤ 50	90	180	15	13
	T5	t ≤ 50	215	260	9	8
	T6	t ≤ 10	215	260	8	6
		10 < t ≤ 50	200	250	8	6
VL-6060	T4	t ≤ 50	60	120	16	14
	T5	t ≤ 50	100	140	8	6
	T6	t ≤ 50	140	170	8	6
VL-6061	T4	t ≤ 50	110	180	15	13
	T5	t ≤ 50	205	240	6	7
	T6	t ≤ 50	240	260	10	8
VL-6063	T4	t ≤ 50	65	130	14	12
	T5	t ≤ 50	110	150	8	7
	T6	t ≤ 50	170	205	10	9
VL-6082	T4	t ≤ 50	110	205	14	12
	T5	t ≤ 50	230	270	8	6
	T6	t ≤ 5	250	290	6	-
		5 < t ≤ 50	260	310	10	8

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

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

1.6.3 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.

1.6.4 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.

1.6.5 For rolled products, the test material shall be taken at one third of the width from a longitudinal edge. The test specimens are normally to be cut with their longitudinal axis transverse to the final rolling direction. If the width is less than 300 mm, longitudinal tests will be permitted.

1.6.6 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 specimens are normally to be cut with their longitudinal axes parallel to the extruding direction.

1.6.7 The size, thickness location and preparation of test specimens and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.1.

1.7 Press weld testing of closed sections

1.7.1 Proper fusion of press welds for closed section extrusions shall be verified either by macrosection tests or by drift expansion tests. Other tests may be accepted after consideration.

For closed sections affecting the global strength of the offshore unit, every fifth section shall be sampled one section. Sections with lengths exceeding 6 m shall be sampled every section in the start of the production. The number of tests may be reduced to every fifth section if the results from the first three sections are found acceptable. Every sample section shall be tested at both ends.

For sections for structures not affecting the global strength of the offshore unit (e.g. helidecks), the extent of press weld testing structures may be reduced as agreed with the verifier, e.g. typical minimum extent of testing would be:

a) testing of the two first sections and of the last section of each cast and each production batch
b) one test from each heat treatment batch if this is less than that given by a).

1.7.2 Where verification is done by macrosection tests no indication of lack of fusion at the press welds is permitted.

1.7.3 Where verification is by drift expansion test, the test specimens shall be cut with the ends perpendicular to the axis of the section. The edges of the end may be rounded by filing. The minimum length of the test specimens shall be twice the external diameter of the section or 50 mm, whichever is greater. Testing shall be carried out at ambient temperature and shall consist of expanding the end of the section by means of a conical mandrel having an included angle of at least 60°. The end diameter and/or tested end circumference of the section shall be expanded by minimum 30% or until fracture. The test is considered to be unacceptable if it fails with a clean split along the weld line.

Guidance note:

For non-tubular closed sections, macro test will typically be more suitable. For further description of the drift expansion test method, see to ISO 8493 and IACS UR W25.

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

1.8 Corrosion testing

1.8.1 Rolled 5000 series alloys of grade 5083, 5383, 5059, 5086 and 5456 in the 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. Extent is one test from each test unit. Accepted test standards are ASTM G66 (ASSET) and G67 (NAMLT) or equivalent standards.

The indices for exfoliation corrosion shall be within the level EA and those for crevice corrosion rate shall be within PB according to ASTM G66. In case of testing in accordance with ASTM G67 the mass loss shall not exceed 15 mg/cm^2.

1.8.2 As an alternative the manufacturers may establish the relationship between microstructure and resistance to corrosion. A reference photomicrograph taken at 500×, under the conditions specified in ASTM B928-9.4.1 shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have undergone satisfactory testing according to [1.8.1].

1.8.3 Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the reference photomicrographs and the results of the corrosion tests shall be accepted by the verifier. Production practices shall not be changed after acceptance of the reference micrographs.

1.8.4 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 [1.8.1]. If the results from testing satisfy the acceptance criteria stated in [1.8.1] the test unit is accepted.

1.9 Inspections, dimensions and tolerances

1.9.1 Wrought aluminium products shall be subject to visual inspection and measurements of dimensions by the manufacturer, in accordance with the requirements of the relevant standard and as given in [1.9.2] and [1.9.3].

1.9.2 The materials shall have a smooth surface compatible with the method of manufacture and shall be free from defects liable to impair further manufacturing processes or the intended application of the product, e.g. cracks, laps, appreciable inclusions of extraneous substances and major mechanical damage.

1.9.3 Permissible under-thickness tolerances for rolled products are given in Table 4. The under-thickness tolerances for extruded products shall be in accordance with the requirements of recognized international or national standards, e.g. ISO 6362-5/6, EN755-3, ANSI H35.2.

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

Nominal thickness, t (mm)	*Width of plate, w (mm)*		
	w ≤ 1500	*1500 < w ≤ 2000*	*2000 < w ≤ 3500*
3.0 ≤ t < 4.0	0.10	0.15	0.15
4.0 ≤ t < 8.0	0.20	0.20	0.25
8.0 ≤ t < 12.0	0.25	0.25	0.25
12.0 ≤ t < 20.0	0.35	0.40	0.50
20.0 ≤ t < 50.0	0.45	0.50	0.65

1.9.4 Dimensional tolerances other than under-thickness tolerances shall comply with a recognized national or international standard.

1.9.5 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.

1.10 Repair

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

1.11 Identification

1.11.1 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, cast number or other marking which will enable the full history of the product to be traced.

1.11.2 Where a number of items are securely fastened together in bundles, marking of the top item of each bundle is sufficient. Alternatively, a durable label may be attached to each bundle.

1.12 Certification requirements

The product shall be delivered with the type of inspection certificate required in the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201) giving the following particulars for each test unit which has been accepted:

- purchaser's name, order number and offshore unit 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 see the standards in [1.2.1].

CHAPTER 3 CERTIFICATION AND CLASSIFICATION

SECTION 1 CERTIFICATION, VERIFICATION AND CLASSIFICATION

1 Introduction

1.1 Objective, scope and application

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

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

1.1.3 A complete description of principles, procedures, applicable class notations and technical basis for offshore classification is given by the DNV GL rules for classification: Offshore units (RU-OU) as listed in Table 1.

Table 1 DNV GL rules for classification: Offshore units

Document code	*Title*
DNVGL-RU-OU-0101	Offshore drilling and support units
DNVGL-RU-OU-0102	Floating production, storage and loading units
DNVGL-RU-OU-0103	Floating LNG/LPG production, storage and loading units
DNVGL-RU-OU-0104	Self elevating units
DNVGL-RU-OU-0503	Offshore fish farming units and installations

1.2 Basic requirements

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

1.2.2 This standard (Ch.1 and Ch.2) specify that certain aspects shall be specially considered, agreed upon, are subject to acceptance or may be accepted. These shall be subject to DNV GL approval when the standard is used for classification purposes, unless stated otherwise in this chapter.

1.2.3 Where Ch.2 of this standards refer to verifier, this word shall be replaced by DNV GL when the standard is used for classification purposes.

1.2.4 Where Ch.2 of this standard refers to type 3.1 or 3.2 certificate according to ISO 10474, this shall be replaced by DNV GL works (W) and VL certificates, respectively. For relation between ISO type certificates and DNV GL certificates see DNVGL-RU-SHIP Pt.2 Ch.1 Sec.2 [4.2].

Guidance note:

Some welding procedures require impact testing at different material thicknesses, e.g. centre of plate, see DNVGL-OS-C401. Certification of the base materials according to this document do not necessarily require impact toughness testing of all material thickness positions relevant for welding. Where relevant, the purchaser is recommended to order steel with adequate impact toughness at relevant plate thickness positions.

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

Guidance note:

A gap analysis and justification for the alternative solution should normally be prepared by the maker or designer accordingly, for evaluation and acceptance by DNV GL.

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

2 Procedural requirements

2.1 General

General certification, documentation and survey requirements are given by the rules in Table 1. The following additional requirements shall be applied in conjunction with the technical requirements given in Ch.2.

2.2 Information to be supplied by the purchaser

The purchaser shall supply the 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 structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.3 Identification of materials

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

2.3.2 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 Society.

2.3.3 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.

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

2.3.5 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.

2.4 Certification requirements for organizations and personnel

Organisations and personnel shall be certified as required by Table 2.

Table 2 Certification requirements for organizations and personnel

Object	*Certificate type*	*Issued by*	*Additional description*	*Certification standard**
Materials manufacturers	AoM[1)]	Society	Approval of manufacturer for materials delivered with VL certificate (MC, issued by DNV GL) or W certificate (MC, issued by manufacturer), see [1.2.4]. This includes additive manufacturers and manufacturers of semi-finished products (e.g. ingots, blooms, billets, pipes, round bars) for further processing by rolling, forging, drawing, extruding, making of pipe fittings, etc. Approved manufacturers are published on internet, see the approval finder. Detailed programmes for approval testing are given in the relevant class programmes for approval of manufacturers (AoM). For additive manufacturing the qualification for manufacturer approval shall be done case by case. When a manufacturer has more than one works, the approval is valid for the works which carried out the test programme.	*)
Welding workshops[2) 3)]	WWA[4)]	Society	Approval of welding workshop, see DNVGL-CP-0352.	*)
Heat-treatment workshops[2)]	AoM[1)]	Society	Approval of heat-treatment workshop, see DNVGL-CP-0351.	*)
NDT operators	-	Body recognized by the Society	— NDT operator certificate. — Certified according to standards or schemes recognized the Society, e.g. ISO 9712, ASNT central certification program (ACCP). SNT-TC-1A may be accepted if the NDT company's written practice is reviewed and accepted by the Society.	ISO 9712, ASNT (ACCP), SNT-TC-1A, see additional description

*) Unless otherwise specified the certification standard is the DNV GL rules.

1) AoM = approval of manufacturer

2) production or repair welding of materials, carried out by the approved material manufacturers do not require additional welding workshop approval if covered by the material manufacturer approval. Subcontracted heat treatment and welding workshops may be covered by the material manufacturer approval. WWA may also be included in the AoM certificate for heat treatment workshops and vice versa. For these cases the manufacturer or workshop holding the AoM or WWA certificate is fully responsible for the subcontracted work, and shall follow up accordingly to ensure that delivered products comply with relevant rules and standards.

3) WWA is recommended but not required for weld repairs during the operational phase of the unit

4) WWA = welding workshop approval.

2.5 Certification of materials

2.5.1 Certification of materials shall be based on compliance with all specified tests and inspections, as documented in a material certificate or inspection document. Unless otherwise agreed, certification shall take place at the manufacturer's works.

2.5.2 The manufacturer shall provide the type of inspection certificate required in the relevant rules, see Table 1, and applicable structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.5.3 As an alternative to [2.5.1], certification may be based on a manufacturing survey arrangement (MSA), subject to approval by DNV GL.

2.5.4 Rolled steel for structural application

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 and, where appropriate, the test specimen number
- steel making process, cast number and chemical composition, for extra high strength steel: Ceq, CET or Pcm value
- state if rimming steel has been supplied for grade A sections, up to 12.5 mm thick
- ladle analysis for specified elements
- results of all specified inspections and mechanical tests
- condition of supply and where appropriate, details of heat treatment, e.g, QT. For QT steels: tempering temperature or recommended post-weld heat treatment temperature.
- for extra high strength steels, surface quality and inspection results, where applicable: UT results.

2.5.5 Carbon and carbon-manganese steel pipes

- Unless otherwise required by the standard, suitable grain refining elements may be used at the discretion of the manufacturer. In this case, the content of such elements shall be reported.
- Carbon equivalent shall be reported.

2.5.6 Where applicable, the manufacturer shall provide the Society's surveyor with inspection certificates for all accepted materials giving at least the particulars detailed in Ch.2 Sec.1 [2.13.4]. Before the inspection certificates are signed by the Society's 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 DNVGL-OS-B101.

2.5.7 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 shall be approved.

2.6 Documentation requirements

2.6.1 Definitions

Four different documentation requirements are defined, these are:

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

For general definition of documentation types, see DNVGL-RU-SHIP Pt.1 Ch.3.

2.6.2 General qualification documentation for manufacturers

Manufacturers of materials subject to certification by DNV GL shall submit or make available documentation as required in Table 3. For testing that is carried out at independent laboratories or at contractor's laboratory, the requirements apply to the relevant testing laboratory.

Table 3 Qualification documentation for manufacturer

Item	*Documentation type*	*Additional description*
Materials and components, including ressure vessels	M010 - Material specification, metals	For VL material certification shall be provided to the Society's surveyor prior to testing and survey, including any conditions additional to the rule requirements
	Z251 - Test procedure	For testing at the builder. Including details for testing, retesting and non-destructive testing
	Z252 - Test procedures at manufacturer	For testing at the manufacturer. Manufacturer shall establish detailed procedures for testing, retesting and non-destructive testing
	Investigation report	Where deviations from approved process occurs and this could produce products of inferior quality
	Z270 - Records	Surface inspection and dimensions including shape and straightness: — the manufacturer shall maintain records of inspections and dimensional measurements — the records shall be presented to the Society's surveyor on request
		Heat treatment: — the manufacturer shall maintain records/logs of heat treatment identifying the furnace used, furnace charge, date, temperatures and time at temperatures — the records shall be presented to the Society's surveyor on request

Welders	Z270 - Records	Of welders certificates, all welders performing welding shall be certified. See also DNVGL-OS-C401 Ch.2 Sec.3. Applicable for welding on materials and products for VL or W certification.
NDT personnel	Z270 - Record	Of NDT operators certificates, all NDT shall be carried out by personnel qualified and certified to at least level II by a recognized body for the applicable NDT method. See further requirement in DNVGL-OS-C401 Ch.2 Sec.7.
Furnace	Z262 - Report from test at manufacturer	For calibration. For products subject to heat treatment, the furnace temperature uniformity shall be calibrated according to a recognized standard (e.g. ASTM A991) at regular intervals and the calibration report shall be provided to the Society's surveyor on request. Note that approval as heat treatment workshop may be required, see Ch.2 Sec.1 [2.7].

2.6.3 Qualification documentation for manufacturer of rolled steels

Additional manufacturer specific documentation requirements are given in Table 4.

Table 4 Qualification documentation for manufacturer of rolled steels

Item	*Documentation type*	*Additional description*
NR, TM and COD steels	Z270 - Records	For rolling schedule: — records providing start rolling temperature, start and stop finishing rolling temperatures, deformation ratios and where applicable, accelerated cooling start and stop temperatures, as well as heat treatment condition and significant parameters, such as holding temperature and holding time — the records shall be presented to the Society's surveyor on request.

2.6.4 Qualification documentation for manufacturer of forgings

Additional manufacturer specific documentation requirements are given in Table 5.

Table 5 Additional qualification documentation for manufacturer of forgings

Item	*Documentation type*	*Additional description*
CGF crankshaft	AoM certificate	Manufacturers producing forgings qualified as continuous grain flow crankshafts (CGF) shall be approved accordingly.
Clean steel forging	VL or W certificate or TR	For each clean steel forging, the cleanliness shall be reported. Additionally, the contents of the elements sulphur, phosphorus and oxygen shall be reported.

Hot formed pressed parts	Z270 - Records	For pressed parts supplied in the hot pressed condition, documenting: — that the whole forming operation was carried out within the specified normalizing temperature range — the method of cooling — the delivery condition of the starting material. The records shall be presented to the Society's surveyor on request.
Machinery forging	Z250 - Procedure	For straightening operations of machinery parts subject to approval by the Society.

2.6.5 Qualification documentation for manufacturer of castings

Additional manufacturer specific documentation requirements are given in Table 6.

Table 6 Additional qualification documentation manufacturer of castings

Item	*Documentation type*	*Additional description*
Castings	VL or W certificate or TR	— If applicable, the content of grain refining elements shall be reported. — Elements designated as residual elements in the individual specifications shall be reported.
Castings subject to major repair by welding	Z250 - Procedure	Proposals for major weld repairs shall be accompanied a tailor-made procedure including sketches or photographs showing the extent and positions of the repairs. Special attention should be paid to the high stress areas. A grain refining heat treatment shall be given to the whole casting prior to major repairs, unless otherwise approved. The procedure shall be approved case by case.
Castings subject to minor repair by welding and where local stress reliving is intended	Z250 - Procedure	Proposal and procedure for local stress relieving heat treatment. Subject to prior approval, local stress relieving heat treatment may be accepted for minor repairs. The proposal shall justify the need for local stress relieving rather than full stress relieving.
Castings subject to minor repair by welding and where omission of stress relieving is intended	Z250 - Procedure	Proposal for omission of stress relieving heat treatment. 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: — documentation of low operating stress — documentation showing that the combination of material and welding procedure gives minimized residual stress and hardness.

2.6.6 Qualification documentation for manufacturer of wrought aluminium alloys

Additional manufacturer specific documentation requirements are given in Table 7.

Table 7 Additional qualification documentation for manufacturer of wrought aluminium alloys

Item	*Documentation type*	*Additional description*
Wrought aluminium alloys	Reference micrographs	When metallographic examination is used as an alternative to corrosion test: — upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the reference photomicrographs and the results of the corrosion tests shall be approved by the Society.

2.6.7 Product specific documentation requirements

Product specific documentation requirements are given in Table 8.

Table 8 Documentation requirements – products required to be certified

Object	*Documentation type*	*Additional description*	*Info* [1)]
Materials for structure and components	C051 - Non-destructive testing (NDT) report	Including testing after repair	FI
	Z250 - Procedure	For repair by welding, when applicable. For content of procedure, M062 may be used as guidance	AP, L
	M060 – Welding procedure (WPS)	For materials and products joined or repaired by welding	AP, L
	M062 – Report from repair by welding	Each repair weld	FI
Steel material	M010 – Material specification, metals	Castings for crankshafts and connecting rods	FI
1) FI = for information, AP = for approval, L = by local station. For full definition of abbreviations, see Ch.1 Sec.1 Table 7.			

2.7 Survey, inspection and testing requirements

2.7.1 General survey, inspection and testing requirements

The requirements for survey, testing and inspection of materials and products manufactured by conventional methods is covered by Ch.2. The requirements for survey, testing and inspection of other manufacturing methods such as additive manufacturing shall be based on a case by case assessment. General survey, inspection and testing requirements are given in Table 9.

Table 9 General survey and testing requirements

Survey, inspection and testing item	*Description*
Approval of manufacturer	— the manufacturer shall carry out a test program and submit the results, as described in the relevant approval programme — the Society's surveyor shall be given the opportunity to witness and survey all relevant processes and tests.
Manufacturer plant, manufacturing process, materials and product testing	— the Society's surveyor shall be given the opportunity to survey and check at any time all plants and equipment used in the manufacture and testing — the manufacturer shall assist the Society's surveyor's surveyor to enable him to verify that approved processes are adhered to and to witness the selection and testing as required by the rules — Prior to the testing and inspection, the manufacturer shall provide the Society's surveyor with the technical specifications of the order and any conditions additional to the standard requirements.
Non-destructive testing	— where non-destructive tests are specified for the various products, these shall be performed under the manufacturer’s responsibility — all tests shall be carried out by personnel qualified and certified in accordance with recognised standards or schemes, see Table 1. When requested, the Society's surveyor shall be furnished with proof thereof — when requested, the Society's surveyor shall be given the possibility of being present during non-destructive tests.
Dimensions and visual inspection	— all products shall be checked by the manufacturer for compliance with the specified dimensions. The manufacturer shall inspect them for defects. For this purpose and unless otherwise approved, the products shall be in the prescribed delivery condition and shall have a clean surface, prepared for inspection, which is free from coatings or other protective media which impair the detection of defects — products that do not meet the required dimensions or show unacceptable defects shall be clearly marked accordingly — the products shall, when called for, be presented to the Society's surveyor in the condition described above.
Chemical composition	— the chemical composition of samples taken from each ladle cast shall be determined by the manufacturer in an adequately equipped and competently staffed laboratory and shall comply with the appropriate requirements of Ch.2 — when possible, the sample for chemical analysis shall be taken during pouring — the manufacturer's declared analysis will be accepted subject to occasional checks if required by the Society's surveyor.
Selection and marking of test material	Where the Society's certification is required, all the test material shall be selected and marked by the Society's surveyor before they are removed from the sample, unless otherwise agreed.

Survey, inspection and testing item	*Description*
Testing of materials	— the appropriate tests specified in Ch.2 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 testing laboratory recognized by the Society — where the Society's certification is required, all the testing (except for chemical composition analysis) shall be witnessed by the Society's surveyor, unless otherwise agreed — the Society's surveyor may require further tests when deemed necessary — all tests shall be carried out by competent personnel on machines of accepted type.
Retesting	Requirements for retesting are described in detail in this section.

2.7.2 Survey, inspection and testing requirements for rolled steels

Additional specific requirements are given in Table 10.

Table 10 Additional survey and testing requirements for rolled steels

Survey, inspection and testing item	*Description*
Chemical composition	Required for all materials. The Society's surveyor may require the content of impurity elements such as tin (Sn), antimony (Sb) and arsenic (As) to be determined when recycled scrap or contaminated ore is used.
Tensile test and impact toughness test	Required for all grades covered by this chapter unless otherwise specified. For steel grade VL BW with thickness t ≤ 25 mm, impact testing performed during AoM may replace the testing required in Ch.2 Sec.2.
Through thickness tensile test	Required for materials with specified through thickness properties.
Fracture mechanics test	Fracture mechanics testing (CTOD test) is required for all materials of grade with suffix COD. Fracture mechanics testing (CTOD test) is required in the course of manufacturer approval testing for all materials of grade with suffix COD. For production testing fracture mechanics testing is not required, unless otherwise stated.
Non-destructive testing	— seams of welded hollow sections, see specific requirements in Ch.2 Sec.2 — steels with through thickness properties, see specific requirements in Ch.2 Sec.2 [5].
Manufacturing parameters	It is in general the manufacturer's responsibility to ensure that the process and production controls qualified through the manufacturer approval testing, are adhered to in production. This is in particular emphasized for steels with delivery conditions NR and TM, as well as steels manufactured as COD grades.

2.7.3 Survey, inspection and testing requirements for steel pipes and fittings

Additional specific requirements are given in Table 11.

Table 11 Additional survey and testing requirements for steel pipes and fittings

Survey, inspection and testing item	*Description*
Chemical composition	Required for all materials.
Carbon equivalent	Unless stricter requirements are specified in the standard, carbon and carbon-manganese steel shall conform to a carbon equivalent of maximum 0.50%.
Mechanical testing	Required for all grades in accordance with the requirements of the relevant standard.
Hot tensile test	Where pipes are designed for use at elevated temperatures on the basis of their high-temperature strength characteristics, a hot tensile test shall be performed on one test specimen per cast and per pipe size.
Impact toughness test, all pipes	Where Charpy V-notch impact testing is required, this is applicable for wall thickness 6 mm or greater.
Impact toughness test of austenitic steel pipes	For austenitic stainless steel pipes, Charpy V-notch impact testing is required where the design temperature is below -105°C.
Hardness test on fittings	Hardness tests on fittings shall be carried out as specified in Ch.2 Sec.3 [6].
NDT of all pipes	Where required by the design principle, pipes shall be subjected to a non-destructive test over their whole length .
NDT of welded pipes	For welded pipes, an automatic non-destructive testing of the whole length of the weld is required.
Leak tightness test	Each pipe shall be subjected to a hydraulic test or an approved non-destructive test for leak tightness in accordance with the requirements of the relevant standard.
Test equipment used for the continuous inspection of pipes	The efficiency of the equipment shall be demonstrated to the Society's surveyor on request.
Corrosion test of pipes and fittings	Where pipes/fittings of austenitic stainless steels shall be used in systems where corrosion testing of the pipes is required, adequate corrosion testing shall be carried out in accordance with Ch.2 Sec.3.
Corrosion test for duplex (ferritic/austenitic) stainless steels	For duplex (ferritic/austenitic) stainless steel pipes, corrosion testing in accordance with ASTM G48 method A or an equivalent standard is required.
Repair by grinding	— 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.

NDT and Leak tightness test after repair	— defects removed by grinding shall be re-inspected by NDT — for pipes/fittings repaired by welding, both leak tightness test according to Ch.2 Sec.3 [1.7] and inspection according to Ch.2 Sec.3 [1.8] shall be repeated after repair.

2.7.4 Survey, inspection and testing requirements for steel forgings

Additional specific requirements are given in Table 12.

Table 12 Additional survey, inspection and testing requirements for steel forgings

Survey, inspection and testing item	*Description*
Chemical composition	Required for all materials. 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.
Clean steel forgings	For clean steel forgings the steels shall have a degree of cleanliness as given in Ch.2 Sec.4 [1.3.8]. Additionally, the contents of the elements sulphur, phosphorus and oxygen shall be restricted to maximum 0.005%, 0.015% and 25 ppm, respectively.
Mechanical testing	Required for all grades in accordance with the requirements of the relevant section.
Impact toughness test	Relevant for all grades where specified in the following sections.
Impact toughness test of austenitic steel forgings	Charpy V-notch impact testing is required where the design temperature is below −105°C.
Hardness test of crankshaft forgings	For forgings which have been batch tested, at least 10% of the forgings to be tested for hardness.
Hardness test of forgings for gears, forgings for boilers, pressure vessels and piping systems and forgings for low-temperature service (except austenitic stainless steels)	For forgings which have been batch tested, each forging to be tested.
Visual survey	Forgings for which certification by the Society is required shall be presented to the Society's surveyor for visual survey. The Society's surveyor may require areas to be etched for the purpose of investigating weld repairs.
NDT	Forgings shall be subject to non-destructive testing as specified in Ch.2 Sec.4 and shall comply with given requirements. In addition, the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201) shall be referred for non-destructive testing of finished machined components.
NDT after repair by grinding or chipping	Complete elimination of the defective material shall be verified by magnetic particle testing or liquid penetrant testing.
Pressure test	Pressure retaining forgings shall be tested after machining to the test pressure required by the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.7.5 Survey, inspection and testing requirements for steel castings

Additional specific requirements are given in Table 13.

Table 13 Additional survey and testing requirements for steel castings

Survey, inspection and testing item	*Description*
Chemical composition	Required for all materials.
Mechanical testing	Required for all grades in accordance with the requirements of the relevant section.
Impact toughness test	Relevant for all grades where specified in the following sections.
Impact toughness test of austenitic steel castings	Charpy V-notch impact testing may be omitted if the design temperature is above –105°C.
Test unit for large castings	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.
Test unit for castings made from two or more casts	Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more sets of mechanical tests are required corresponding to the number of casts involved. The test blocks shall be located as widely separated as possible.
Visual inspection	The manufacturer shall carry out visual inspection of all casting on accessible surfaces for surface finish and compliance with the dimensional and geometrical tolerances.
Visual survey	Castings for which certification by the Society is required shall be presented to the Society's surveyor for visual inspection. The Society's surveyor may require areas to be etched for the purpose of investigating weld repairs.
NDT	— castings shall be subject to non-destructive testing as specified in Ch.2 Sec.5 and shall comply with given requirements. In addition, the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201) shall be referred for non-destructive testing of finished machined components — 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 — 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 — where certification by the Society is required, the Society's surveyor may request to be present during NDT.

NDT of repairs	— complete elimination of the defective material shall be verified by MT or PT. This applies also for areas which will be subsequently repaired by welding — all repaired areas shall be subject to NDT as specified in Ch.2 Sec.5 [1.9].
NDT of propellers	The Society may require NDT such as RT or UT for verification of internal soundness. The extent, method and acceptance criteria shall be agreed between the manufacturer and the Society.
Pressure test	Pressure retaining castings shall be tested after machining to the test pressure required by the relevant structural design standard (e.g. DNVGL-OS-C101 to DNVGL-OS-C201).

2.7.6 Survey, inspection and testing requirements for wrought aluminium alloys

Additional specific requirements are given in Table 14.

Table 14 Additional survey and testing requirements for wrought aluminium alloys

Survey, inspection and testing item	*Description*
Chemical composition	Required for all materials.
Mechanical testing	Required for all grades in accordance with the requirements of the relevant paragraph.
Macrosection test, drift expansion test	Manufacturer shall verify and document proper fusion of press welds for closed profile extrusions by macrosection tests or drift expansion tests. Other tests may be accepted after consideration. The testing and test results shall be recorded. The Society's surveyor shall be given the opportunity to survey and check the sampling, testing, test laboratory, etc. at any time and the test records shall be presented to the Society's surveyor on request.
Corrosion test	Rolled 5000 series alloys of certain grades and 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.
Microstructure/metallographic evaluation	As an alternative to corrosion test, the manufacturers may establish the relationship between microstructure and resistance to corrosion and evaluate corrosion resistance based on photomicrographs.
Visual inspection	Wrought aluminium products shall be subject to visual inspection and measurements of dimensions by the manufacturer.

CHANGES – HISTORIC

July 2018 edition

Changes July 2018

Topic	*Reference*	*Description*
Surface finish requirements for pipes	Ch.2 Sec.3 [1.8.2)	Updated clause with more specific requirements for surface finish, giving consideration to manufacturing route, imperfections detrimental to the product as well as minor surface discontinuities.
Strain age testing	Ch.2 Sec.1 [3.11.2]	Wording amended such that specimen orientation in general shall be as specified for the original plate.
Re-structure of section on bolts and nuts	Ch.2 Sec.4 [5]	Re-structuring of this section for better overview of requirements for manufacture, test units, test scope and mechanical properties. Correction of room temperature for mechanical testing.
Frequency of NDT for steel castings	Ch.2 Sec.5 [2.5]	Clarified that for steel castings for hull structures and equipment NDT is specified in the relevant construction standard.
	Ch.2 Sec.5 [3.5]	Updated clause and alternative extent of NDT specified.
	Ch.2 Sec.5 [4.6.1]	Updated clause and alternative extent of NDT specified.
Corrosion testing for stainless steel castings	Ch.2 Sec.5 [4.5]	Updated clause making clear that corrosion testing shall be performed as required by the applicable structural standards.
Required details for certification	Ch.3 Sec.1 [2.5.4]	Information added on required details for the certificate, e.g for high strength steel the heat treatment temperatures and inspection results.

January 2018 edition

Main changes January 2018

Topic	*Reference*	*Description*
Alternatives to hard stamping	Ch.2 Sec.1 [2.12.3]	Information added to what extent and for which products painting/ sticker can be possibly permitted. Further information provided about requirements for marking methods alternative to hard stamping.
Updated IACS UR W11	Ch.2 Sec.2 [1.5]	Terminology for rolling procedures aligned with IACS UR W11.
	Ch.2 Sec.2 [1.9] and Ch.2 Sec.2 [1.10]	Updated clauses clarifying surface quality and NDT requirements.

Topic	Reference	Description
Impact test for VL A/VL B	Ch.2 Sec.2 [2.4.1]	Guidance note included, that requirement for notch bar impact test for grade VL A and VL B is by standard satisfied by testing within initial manufacturer approval.
Temperature for impact testing for VL B	Ch.2 Sec.2 Table 6	Temperature for impact test changed from +20°C to 0°C.
Acid soluble content	Ch.2 Sec.2 Table 8	Inserted clear specification of acid soluble aluminium content.
Pipe grades acc. to EN 10305	Ch.2 Sec.3 [2.2.]	EN 10305-1 and EN 10305-2 included.
Forging ratio and ratio for upsetting	Ch.2 Sec.4 Table 1	Table revised to precisely state requirements regarding forging ratio.
Additive manufacturing	Ch.3 Sec.1 [2.7.1]	Requirement added for the approval for additive manufacturing. New paragraph inserted indicating the requirements for testing and inspection for additive manufacturing.
	Ch.3 Sec.1 Table 2	Additive manufacturers added to description of material manufacturers.

July 2017 edition

Main changes July 2017

• General

The document has been restructured and aligned with DNVGL-RU-SHIP Pt.2 Ch.1 and DNVGL-RU-SHIP Pt.2 Ch.2.

• Ch.1 Sec.1 General

— Ch.1 Sec.1 Table 3: Added definition for verifier. The new term verifier replaces the former term purchaser where relevant.

• Ch.2 Sec.1 Manufacture, certification and testing

— Ch.2 Sec.1 [2.3]: More specific requirements for survey and manufacture, including requirements for radioactive contamination.
— Ch.2 Sec.1 [2.10.7]: The verifier may reject the entire delivery if a large proportion of the products fail.
— Ch.2 Sec.1 [2.13.4]: Certification requirements for semi-finished products applied as pre-material for products subject to certification.

• Ch.2 Sec.2 Rolled steel for structural application

— Ch.2 Sec.2 [1.2.4]: Added designation VL xOyd (e.g. VL EO690QT) where O indicates specific offshore grade extra high steels. The O grade steels correspond to former NV and VL grade extra high strength steels.
— Ch.2 Sec.2 [1.2.4]: Delivery condition shall be appended to the name of the grade for extra high strength steels (N, NR, TM, QT).
— Ch.2 Sec.2 [1.6.7]: Impact toughness test and requirements specified for extra high strength structural steels with thickness more than 50 mm.
— Ch.2 Sec.2 Table 3: Added max. limits for impurity elements for normal strength steels.

— Ch.2 Sec.2 Table 6: Added that manufacturer shall ensure the impact toughness where it is not required to be tested.
— Ch.2 Sec.2 [4.1]: Grades with minimum specified tensile strength 890 and 960 MPa are added.
— Ch.2 Sec.2 [4.1]: Added guidance note indicating that the new normal weldability VL grade extra high strength steels (without designation O) corresponds to the steels specified by IACS UR W16.
— Ch.2 Sec.2 [4.2]: New requirements for steel making process for extra high strength steels.
— Ch.2 Sec.2 [4.3] and Ch.2 Sec.2 Table 14: The required chemical composition for steels of improved weldability is changed and aligned with the requirements for steels of normal weldability, although the requirement of maximum P_{cm} of 0.22% is kept.
— Ch.2 Sec.2 [4.3] and Ch.2 Sec.2 Table 14: The required chemical composition of the former NV and VL grade extra high strength steels, that is, the new O grade steels is changed.
— Ch.2 Sec.2 [4.3]and Ch.2 Sec.2 Table 15: New requirements for carbon equivalent values for extra high strength steels.
— Ch.2 Sec.2 Table 16: New requirements for maximum thickness of different delivery conditions.
— Ch.2 Sec.2 Table 17: Introduced requirements for the mechanical properties of the new extra high strength steel VL grades (of normal weldability), changed requirements for the improved weldability steels and adjusted the elongation requirements for the former NV and VL grade steels, now VL O grades. Added recommendation for maximum hardness and requirement for yield to tensile strength ratio.
— Ch.2 Sec.2 [4.5.2]: Test unit size for tensile and impact tests of extra high strength steels are changed.
— Ch.2 Sec.2 [6]: Added subsection for the new COD grade steels, that is, steels with certain resistance to crack initiation.

• Ch.2 Sec.3 Steel pipes and fittings

— Ch.2 Sec.3 [1.6.3]: Test unit for pipes of alloy steel is limited to same heat.
— Ch.2 Sec.3 [1.6.6]: Impact test is required from the weld metal of longitudinally welded large pipes.
— Ch.2 Sec.3 [1.7.2]: A more specific requirement for the test pressure of hydraulic test is specified.
— Ch.2 Sec.3 [2.4]: A general requirement for impact test for pipes for class I and class II pressure vessels is introduced.

• Ch.2 Sec.4 Steel forgings

— Ch.2 Sec.4 [3.4.2]: Added that hardness test is required on each forging in case of batch testing.
— Ch.2 Sec.4 [4]: Added three ferritic-austenitic stainless steel grades.
— Ch.2 Sec.4 [5]: New subsection for bolts and nuts.

• Ch.2 Sec.5 Steel castings

— Ch.2 Sec.5 [1.6.1]: New requirement for witnessing of removal and re-attachment of test blocks in case test blocks are detached before final heat treatment.
— Ch.2 Sec.5 [1.10.5]: Added clarity with respect to repair procedures for major weld repairs.

• Ch.3 Sec.1 Certification, verification and classification

— Changed wording and tabulated certification, documentation and survey requirements according to the corresponding requirements in DNVGL-RU-SHIP Pt.2 Ch.1 and DNVGL-RU-SHIP Pt.2 Ch.2.

July 2015 edition

Main changes July 2015

• General

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

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

About DNV GL

DNV GL is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.

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